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Seyhan Fırat
John Kinuthia
Abid Abu-Tair *Editors*

Proceedings of 3rd International Sustainable Buildings Symposium (ISBS 2017)

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Foreword

With the UEA having announced its vision 2030 to become an environmentally, socially and economically sustainable community and with Dubai's Sustainable City aiming to be the star tourist attraction for Expo 2020, it was an exciting time to be involved with the 3rd International Sustainable Buildings Symposium—ISBS 2017 held on 15–17th March 2017. This conference with its broad range of research topics and many excellent papers will be a sound basis for establishing sustainable cites, especially those in hot climates. I learned a lot at this conference, and others will find the papers a useful reference.

Geoff Levermore
Emeritus Professor
MACE
University of Manchester, UK

Preface

The first "International Sustainable Buildings Symposium" conferences (ISBS 2010) took place on 26–28th May 2010, at Gazi University, Ankara, Turkey. The plan was to hold the ISBS conference series at different cities every two years. The sequel to ISBS 2010 (ISBS 2015), however, also took place at Gazi University on 26–28th May 2015, but at a much improved scale. The decision to hold it here was partly contributed by the development of an efficient conference organizing team within the Department of Civil Engineering in the Technology Faculty of Gazi University. The other reason is that Ankara has plenty to offer, and this also contributed to hosting the ISBS conference two years in a row. Ankara is the capital of Turkey since the establishment of the Republic of Turkey in 1923 and the country's second largest city, İstanbul, being the largest. The city of Ankara had a population of 5.150.072 as of 2014. Centrally located in Anatolia, the city is an important commercial and industrial centre of attraction.

Against the background explained, the "3rd International Sustainable Buildings Symposium" (ISBS 2017) was held on 15–17th March 2017, far away from Ankara, in Dubai, UAE. Dubai is the most populous city in the UAE. It is located on the south-east coast of the Arabian Gulf and is one of the seven emirates that make up the country. Dubai has emerged as a global city and business hub of the Middle East. It is also a major transport hub for passengers and cargo. Dubai is a beautiful city and a major tourist destination. It is famous for sightseeing attractions such as the Burj Khalifa (the world's tallest building) and shopping malls that come complete with mammoth aquariums and indoor ski slopes. Moreover, the city has many cultural highlights as well as all the glamourous modern add-ons. It is in this city that ISBS 2017 was successfully held.

Organizing ISBS 2017 aimed at bringing together researchers and experts from UAE, Turkey and the rest of the world in dialogue with researchers and authorities of implementing and consulting firms and institutions. Researchers with significant reputation on an international scale were invited to the symposium as keynote speakers. In this context, the symposium facilitated researchers, academic institutions, municipalities, government bodies, non-governmental organizations, other official and private establishments that are active in construction sector and environmental technologies, to discuss the current issues in construction and environmental technology areas. In addition, both national and international companies found the opportunity to introduce their products and services. The effective interaction between local and foreign experts, authorities from private and government agencies, as well as between key players in academic, research and administrative circles in higher education institutions, is a prerequisite to the holistic achievement of the aspirations of the ISBS series of conference on sustainable buildings.

The conference proceedings are split into two separate volumes: Volume 1 (the current book) contains the sections "Sustainable Buildings and Smart Cities" and "Sustainable Planning—Infrastructure and Resilience", and Volume 2 (ISBN 978-3-319-64348-9) contains the sections "Energy and Environment—Emerging Climate Change and Impact on the Built Environment", "Environmental Policies and Practices" and "Strengthening and Rehabilitation of Structures".

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Great gratitude also goes to our sponsors, the Emirates National Oil Company, our Main sponsor and Al Maktoum Foundation, our Gold sponsor, Gazi University in Ankara, the British University in Dubai and the Turkish Civil Engineering Council.

The symposium was enriched by the participation of the keynote speakers from the UK, the USA and the UAE, and we thank them all wholeheartedly.

The success of 3rd International Symposium of Sustainable Buildings is owed to the authors and delegates who wrote and presented the papers, and we are especially indebted to them all. I also want to thank proceedings co-editors Prof. John Kinuthia and Prof. Seyhan Fırat.

Dubai, United Arab Emirates — Prof. Abid Abu-Tair
June 2017

Contents

Part I
Sustainable Buildings and Smart Cities

Using Waste Concretes as Recycling Aggregate in Concrete Production and Sustainability

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Abstract. Protecting natural sources is an important responsibility for the whole world. Concrete is the most widespread construction material, as a result of its production, natural sources are running out, and also natural environment is being disturbed. In addition, building wastes brought about by the renovation activities for the structures that have expired. In order to maintain the ecological balance, using the available sources wisely and efficiently is crucial. In this study, known class and age of waste concrete is used as coarse and fine aggregates as production of concrete. There are two types of aggregates are used in concrete production as 0–4 and 4–22.4 sizes. These aggregates groups are replaced with normal aggregates as 0, 10, 20, 30, 40, 50 and 100% ratios in concrete. Compressive strength of concrete specimens are determined as 28 and 90 days coring regime. According to the experimental results, it has been seen that recycled aggregates may be used in concrete production and that they may shed light in the production of sustainable concrete.

Keywords: Sustainable concrete · Waste concrete · Recycled aggregate Compressive strength

1 Introduction

European Concrete Platform (ECP) and Architects' Council of Europe (ACE) and also European Economic and Social Committee (EESC) published a new, multilingual glossary called Sustainable (Concrete) Construction Glossary. The purpose of this glossary is to provide comprehension of the terminology used within the scope of sustainable construction concurringly, to be used by the policy makers at the national and European level and to be used with the purposes of communication, education and teaching at the related sectors. [1].

The most important recycling source is the aggregates obtained from the wastes of construction ruins. When we look at the European countries, they are used at high levels in England, Holland and Belgium. Turkey does not appear having a considerable rank at recycling in Europe [2].

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Construction and ruin wastes appearing when the construction completes its service life and is demolished constitute the large part of the solid wastes. Today, control and management of the solid wastes have become one of the biggest problems of the developed societies. Recycling rate of the construction materials and the effects of the wastes on the environment is also a topic to be studied during this process [3, 4].

Nowadays, recycling of concrete material have become a topic started to be mentioned most often. Many applications were performed in recent years on using concrete or reinforced concrete element wastes arising from ruined buildings as concrete aggregate again after they were crushed, broken into pieces and separated. Using crushed concretes on building pavements, drainage system, installing sewer pipes, as infrastructure packing material on open parking lots or airports or as surface cover on filled pebble roads turn the concrete into a recycling material. Furthermore, today, it may also partly be possible to utilise concrete wastes on producing new (unused) concrete by crushing them [5].

It is stated in the studies made by recycling aggregate (RCA) obtained from waste concretes that the quality of the aggregate depends on the quality of the waste concrete it is obtained. Besides, it is underlined that it provides a good adherence with the cement paste in the mixture, has a lower density, and also its Los Angeles abrasion loss and water absorption percentage are higher than normal weight aggregate. Furthermore, it has been stated that compressive strength and elasticity module values of the concrete obtained by RCA depend on the water/cement (w/c) rate, cement amount, aggregate quality, concrete vacancy and cement paste aggregate adherence of the old concrete [6–8].

In their studies, Demirel and Şimşek studied density, compressive strength and elasticity properties of the concrete produced by RCA whose ages and classes are definite. Consequently, they observed that the properties of the concrete produced by them approximated to the concrete properties of the one-down class concrete [6]. It has been determined in several studies that when the amount of the RCA increases, strength and specific bulk density of the concrete decreases [6, 9, 10].

In this study, primarily, seven-day C35 class concrete samples were broken, sifted and their 0–4 and 4–22.4 sized RCA were produced. A lower class C30 concrete production was aimed by decreasing the crushed aggregate (CAG) groups on definite rates and adding RCA instead of them. In the mixtures, RCA coarse aggregate (CAG), fine aggregate (FAG) were substituted by weight on 0, 10, 20, 30, 40, 50% rates. In the research, fly ash (FA) at the rate of 20% of the cement weight and super plasticizer chemical admixtures (PCA) at the rate of 1.2% of the weight of the cement amount were used. Slump experiments were made on the fresh concretes; and 28 and 90-day compressive strengths were determined on the hardened concretes.

2 Material and Method

2.1 Material

Recycling aggregate (RCA) was produced by using limestone-based crushed aggregate (LA) and 7-day C35 waste concrete. 0–4 and 4–22.4 aggregate groups were used on both types of aggregates.

In the concrete mixtures, CEM I 42.5 R type cement and Çayırhan Thermal Power Plant fly ash were used. Their chemical and physical properties were determined and shown at Table 1.

Table 1. Chemical properties of CEM I 42.5 R and FA

Chemical composition	Cement (%)	Fly ash (%)
SiO_2	20.35	50.88
Al_2O_3	5.98	13.34
Fe_2O_3	3.06	10.09
CaO	63.35	13.09
MgO	1.89	5.50
SO_3	2.71	3.32
Na_2O	0.58	2.59
K_2O	0.88	2.72

In the study, as mixing water, Ankara province city water supply and POLYCAR-100 named F type super plasticizer (SP) additive suitable in compliance with ASTM C 494 were used.

2.2 Method

Determination of particle size distribution was made in accordance with TS EN 933–1 standard [11], determination of particle density and water absorption rate in accordance with TS EN 1097–6 standard [12], abrasion experiment in accordance with TS EN 1097–2 standard [13], flatness index in accordance with TS 9582 EN 933-3 standard [14].

In the concrete design, based on TS 802 [15] and TS EN 206-1 [16], the following values; 0–4 and 4–22.4 aggregate groups, 212 lts mixing water, 0.53 w/s rate and 7 cm slump amounts were determined to produce C 30 concrete.

In the mixtures, the amount of the cement was decreased 20% and instead, it was substituted by FA. As for SA, it was added into the mixing water at the rate of 1.2% of the cement weight. The amounts of the materials used in the production of the concrete were given at Table 2. Six each cylinder concrete samples 100 × 200 mm sized from each mixture rate given at Table 2 were prepared.

Fresh concrete slump values were made in accordance with the values of TS EN 12350–2 standard [17].

Table 2. Mixing ratios

Mixture code	RCCA substitution rate (%)	RCCA (kg)		Crushed aggregate (kg)		S/Ç	Cement (kg)	FA (kg)	SPCA (kg)	Slump (cm)
		0–4	4–22.4	0–4	4–22.4					
RCA	100	660	950	–	–	0.46	460	–	5.5	8
CRUSHED AG I	–	–	–	660	950	0.46	460	–	5.5	10
RCA + FA	100	660	950	–	–	0.46	368	92	5.5	7
CRUSHED AG II + FA	–	–	–	660	950	0.46	368	92	5.5	9
RCA CAG50	50	–	475	660	475	0.46	368	92	5.5	8
RCA CAG40	40	–	380	660	570	0.46	368	92	5.5	8
RCA CAG30	30	–	285	660	615	0.46	368	92	5.5	8.5
RCA CAG20	20	–	190	660	760	0.46	368	92	5.5	9
RCA CAG10	10	–	95	660	855	0.46	368	92	5.5	9.5
RCA FAG50	50	330	–	330	950	0.46	368	92	5.5	7
RCA FAG40	40	264	–	396	950	0.46	368	92	5.5	8
RCA FAG30	30	198	–	462	950	0.46	368	92	5.5	8
RCA FAG20	20	132	–	528	950	0.46	368	92	5.5	10.5
RCA FAG10	10	66	–	594	950	0.46	368	92	5.5	11

Table 3. Technical properties of crushed and coarse RCA

Sieves	RCA		Crushed aggregate		Literature limit values [18, 19]			
	0–4	4–22.4	0–4	4–22.4	Perfect	Fine	Middle	Weak (low)
Density (g/cm^3)	2.53	2.63	2.7	2.7	>2.9	2.6–2.9	2.5–2.6	<2.5
Water absorption (%)	11.7	5.9	11.0	4.6	<0.5	0.5–2.0	2.0–6.0	>6.0
Abrasion (%)	–	35.6	–	23.9	<15	15–25	25–35	>35
Flatness index	–	6.3	–	3.0	–	–	–	–

3 Findings and Discussion

Densities of RCA aggregates used in the research are between 2.53 and 2.63 g/cm^3. On the other hand, it is seen that densities of Crushed aggregates are about 2.70 g/cm^3. When the values at Table 3 are compared with the literature limit values, it is seen that RCA values are at middle-class. As for KA, it is at fine-class. When the other properties are also examined respectively, it will be seen that RCA is at weak (low) classification. It is due to the structure of the RCA. It can be said that the reason for this is the cement residues adherent on it. Therefore, water absorption percentage of it was found high. Water absorption percentage of crushed aggregate is at fine-class on 0–4 aggregate, whereas, it is at middle-class on 4–22.4 aggregate.

In the determination of resistance to fragmentation of aggregate, it is recommended that the highest abrasion loss amount should be 50% after 500 cycle [20, 21]. In the experiments made by taking three each samples from each aggregate group, abrasion loss of the crushed aggregates was 24%, meanwhile, RCA was 36%.

Slump values of the concretes produced in the study were planned to be 12 ± 1 cm by super plasticizer. Slump values of the concrete types are seen at Table 2. When Table 2 is examined, it is seen that slump values of all the mixtures produced by coarse RCA are between 8 and 9.5 cm. Slump values of all the mixtures produced by fine RCA are between 7 and 11 cm. While slump value of the fresh concrete mixtures produced by 100% limestone aggregate is 10 cm, slump value of the concrete produced by 100% RCA is 8 cm. It is seen at all mixtures that slump decreases, that is to say, water need increases when RCA rate increases. When RCA rate increases, workability is affected negatively. It is possible to say that it is due to the surface of the RCA is rough, sharp-edged and porous.

When 28-day compressive strengths of the concretes produced by coarse RCA are examined, it is seen that strength decreases when RCArate increases. While compressive strength of the concrete produced by RCA CAG10 mixture has the highest strength in this group by 36 MPa, RCA CAG50 strength has the lowest strength by 31 MPa. When 90-day compressive strengths of the same concretes were looked, it was seen that RCA CAG10 mixtures gave the highest strength (in Table 4).

When the compressive strengths of the concretes produced by fine RCA were examined, it was seen that, RCA FAG20 concrete had the highest strength by 34 MPa, and the concrete produced by RCA FAG50 had the lowest strength by 28 MPa. 6 MPa difference is mentioned between the lowest and the highest compressive strength. When 28-day and 90-day compressive strengths of the concrete produced by RCA FAG compared, there is a definite increase according to age, and this is quite normal. At 90-day concretes, the difference between the lowest and the highest compressive strength is 4 MPa (in Table 4).

The difference between FA-additive and FA-additive-free shows the effect of FA on 90-day concrete compressive strength. While RCA + FA compressive strength is 34 MPa FAG 28 days, it reaches 44 MPa in 90 days. When it is compared with RCA, the effect of FA arises. Besides, when Crushed Ag II + FA and Crushed Ag I are compared, it is seen that the difference between 90-day compressive strength is 5 MPa (in Table 4).

It is seen that target strength was reached at all concretes used in different rates.

Table 4. Compressive strengths of the concretes produced by RCA

Mixture code	Sample number	28-day compressive strength (MPa)				90-day compressive strength (MPa)			
		Min	Max	Average	Standard error	Min	Max	Average	Standard error
RCA CAG50	6	30	33	31	0.819	40	40	40	0.163
RCA CAG40	6	29	34	32	0.993	41	43	42	0.552
RCA CAG30	6	31	34	33	0.679	42	43	43	0.187
RCA CAG20	6	30	36	34	1.312	44	46	45	0.481

(*continued*)

Table 4. (*continued*)

Mixture code	Sample number	28-day compressive strength (MPa)				90-day compressive strength (MPa)			
		Min	Max	Average	Standard error	Min	Max	Average	Standard error
RCA CAG10	6	34	37	36	0.571	45	48	47	0.567
RCA FAG50	6	27	29	28	0.408	36	39	38	0.628
RCA FAG40	6	28	31	30	0.641	39	42	40	0.633
RCA FAG30	6	29	34	32	1.080	40	42	41	0.430
RCA FAG20	6	32	36	34	0.982	41	42	42	0.756
RCA FAG10	6	31	34	33	0.571	37	40	39	0.575
RCA + FA	6	32	37	34	1.098	42	45	44	0.815
Crushed Ag II + FA	6	39	40	38	0.694	49	51	50	0.496
RCA	6	32	35	33	0.552	39	41	40	0.501
Crushed Ag I	6	35	37	36	0.637	44	46	45	0.481

4 Conclusions

The results obtained in this research can be summarized as those below:

- ➢ Densities of RCA conform with the literature, however, the result of the water absorption gave higher values than the literature. It can be said that this situation was arisen from the cement particles adhered to the aggregate particles. Particularly, cement particles within the fine aggregate increase water absorbing capacity of the aggregate. It can be said that adherent cement particles strengthen the adherence.
- ➢ Since the concrete age is 7 days, it can be said that coarse aggregates can leave the concrete more easily than the other ages.
- ➢ In case of using FA in the production of concrete by crushed and RCA in accordance with standards, plasticizer chemical additive must be used for workability.
- ➢ If a decrease is able to be provided with cement consumption used as binding material within the cement, a decrease will be provided with the consumption of natural sources such as limestone, clay, etc. used at cement production.
- ➢ Even though abrasion loss of coarse RCA is more than abrasion loss of crushed aggregate, it is less than the limit value.
- ➢ Since water absorbing capacity of RCA was high, it increased mixing water of fresh concretes.
- ➢ When we compared the concretes with CA, FAG mix in terms of compressive strength, it was seen that the concretes produced with CA had higher compressive strength.

➢ The concretes broken at an early age can be utilised as RCA in circumstances that pouring concrete is not in accordance with the project or earthquake regulations, and so building audit firms demand being ruined and rebuilded.
➢ Using the wastes of other sectors such as fly ash, granulated blast furnace slag, silica fume in the production of cement will both decrease the cement production and increase useful life, durability for environmental conditions of concrete.
➢ It is vital that not only producers but also consumers must demand sustainable yields (products), administrations must invest on waste collection, storage and process more, must be decisive on encouraging sustainable production at every phase.
➢ Waste concretes can be used in the production of new (unused) concrete as recycling aggregate. The methods which will provide decrease of energy used in the phase of concrete production must be found and new design and construction methods making recycling easier must be developed.

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A Study on the Using of Game Theory in Sustainable Construction

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Abstract. In recent years, population growth, consumption of natural resources as a result of industrialization and urbanization, environmental issues have increased rapidly and this increase has reached dangerous proportions. Therefore, Environmental concept has influenced the structure of the planning discipline, ecological approach to planning and sustainability has gained importance. In this area, using different methods have been made in the quest to produce fast and effective solutions. Game theory approach, which can be given as an example of such methods, is seen planning and structure design in the content of sustainability. In this paper, studies on the sustainability and game theory concepts in the literature have been investigated and evaluated, as a whole.

Keywords: Sustainability · Sustainable construction · Sustainable architecture · Game theory · Nash equilibrium · Shapley value

1 Introduction

The term sustainable development can be described as enhancing quality of life and thus allowing people to live in a healthy environment and improve social, economic and environmental conditions for present and future generations [1].

Sustainability has been enshrined as a goal of society to ensure that the satisfaction of present needs does not compromise the ability of future generations to meet their own needs [2].

Sustainability as a recent idea arose in response to two big problems and a host of particular ones. The two big worries—the spreading gulf between rich and poor and the continued degradation of biospheric systems—are entwined in a vicious spiral that increasingly threatens the enormous achievements made in other fields. The numerous particular concerns have centered on the common and sometimes catastrophic failures of decision-making efforts that failed to take key linked factors into account [3]. A building project can be regarded as sustainable only when all the various dimensions

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of sustainability (environmental, economic, social, and cultural) are dealt with. The various sustainability issues are interwoven, and the interaction of a building with its surroundings is also important. The environmental issues share, in common, concerns which involve the reduction of the use of non-renewable materials and water, and the reduction of emissions, wastes, and pollutants. The following goals can be found in several building sustainability assessment methods: optimization of site potential, preservation of regional and cultural identity, minimization of energy consumption, protection and conservation of water resources, use of environmentally friendly materials and products, a healthy and convenient indoor climate, and optimized operational and maintenance practices [4–6].

Sustainability assessment is a procedure used to evaluate whether environmental and societal changes arising from man's activities and use of resources are decreasing or increasing our ability to maintain long-run sustainability [7]. It is used as a means to evaluate the impacts of policies, plans and projects in order to ascertain the extent to which they affect sustainable development [8, 9].

2 Game Theory

Game Theory (GT) usually analyses decision-making processes in various fields. It mainly studies on how the decision makers decide their actions when there is the interaction between the actions of each decision maker and the equilibrium based on their decisions [10, 11]. Depending on the player's knowledge about each other's strategies, payoffs, and past histories; games can be subdivided into different categories. Depending upon the number of players, a game can be classified as 2-player game or n-players where $n > 2$.

In non-cooperative games, each participant player acts in his own interest and the unit of analysis is always the individual player instead of group of players. In these types of games, the players are always selfish—i.e., they always try to increase their own individual payoffs without taking care of other player's payoffs in the game. So, non-cooperative game theory studies the competitive nature of individual players where players come into contact with the sole aim to increase their own benefits from the strategic situation [12, 13].

In cooperative games, the groups of players are the unit of analysis and the players tend to increase their group payoffs as well as their own. A cooperative game can be considered as a competition among the groups in a game rather than individual players. The applications of cooperative game theoretical models are in the situations where players form groups, called coalitions, and the individual or group of player's contribution towards the game depends on the actions of other agents in the game [12, 13].

In this review, GT in different research fields (Fig. 1) is presented in its development as two basic fields: in Sustainable Buildings, Smart Cities and Sustainable Planning.

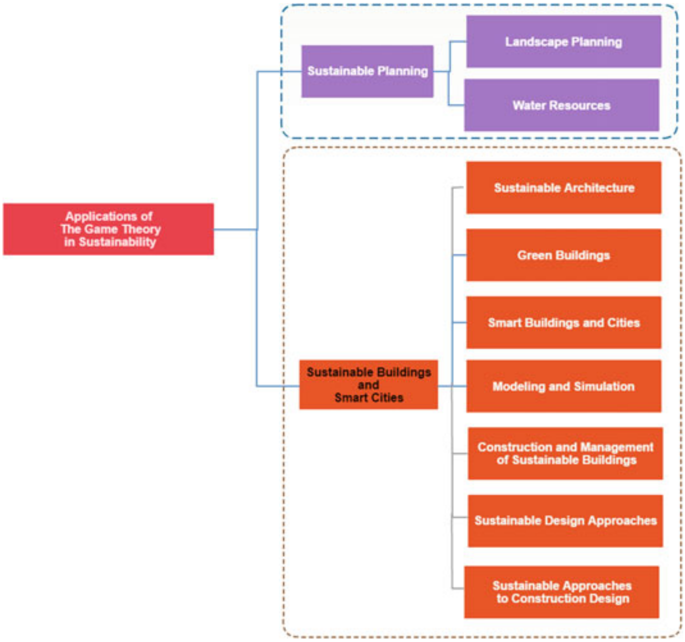

Fig. 1. Applications of the game theory in sustainability

3 Literature Review

Game theory is widely used in research related to sustainable buildings and smart cities in the topics that can be seen from Fig. 1.

Let us examine the studies under the related topics.

3.1 Sustainable Architecture

Sustainable architecture is the design of sustainable buildings. Sustainable architecture attempts to reduce the collective environmental impacts during the production of building components, during the construction process, as well as during the lifecycle of the building handled this topic in education field [14]. Information about sustainable building design is provided and the visualized evaluation is fed back, as a way to encourage sustainable building design. In addition, to maximize the effect of the interaction between competition and cooperation among students they have applied a game theory approach called 'prisoner's dilemma' to enhance sustainable building design in an educational environment.

3.2 Green Buildings

Green building has now become a pilot of sustainable development in this century that takes the responsibility for balancing long-term economic, environmental and social health [15].

Green design does not only make a positive impact on public health and the environment, it also reduces operating costs, enhances building and organizational marketability, increases occupant productivity, and helps create a sustainable community [16].

Since buildings have considerable impacts on the environment, it has become necessary to pay more attention to environmental performance in building design. Green building is a recent design philosophy which requires the consideration of resources depletion and waste emissions during its whole life cycle. A green building is designed with strategies that conserve resources, reduce waste, minimize the life cycle costs, and create healthy environment for people to live and work. The successful design of green buildings requires that special attention be paid to the conceptual stage when many potential design alternatives are generated and roughly evaluated in order to obtain the most promising solution. Decisions made in the conceptual stage have considerable impacts on the building performance. For example, simply making buildings the right shape and the correct orientation can reduce energy consumption by 30–40% with no extra cost [17].

In recent years building assessment systems have begun to focus on neighborhood and community issues rather than solely on building technology and design. However, there is no consensus about which sustainability indicators are appropriate to single buildings or single development projects [18].

In [19], three static game models for green engineering between the government and construction units are established based on hypotheses, and equilibrium strategies are deduced respectively. According to the equilibrium strategies, the government couldn't promote construction units to take green engineering only with direct rewards. But if the government gives the public an incentive to supervise construction units, and strengthen the punishment dynamics, the green engineering can be promoted effectively.

The economic compensation mechanism principle is used to solve problems of green building promotion is solved in [20]. They used non-cooperative game model between the government and investors. The backward induction method is used to solve the sub-game perfect Nash equilibrium in this study. By analyzing the results of game model they presented, investment income is the core factors of investors in choosing green building.

Liang et al. [21] aims to reveal the underlying logic by analyzing the behaviors of the building owners and occupiers, who are the direct decision makers in initiating green retrofit at the initial intention phase. Three occupancy scenarios, namely, owner-occupied (baseline scenario), single occupied, and multi-occupied buildings, are used for the game analysis. The Nash Equilibrium of the game is used to analyze the probable decisions of the owners and occupiers under the last two occupancy scenarios. Results demonstrate that both owners and occupiers are reluctant to retrofit under both scenarios.

The study [22] presents a conceptual model in simulating the risk behaviors of decision makers in influencing the decision making of selecting green building designs by using 3 difference processes including benefit-cost analysis, multi-criteria decision-making, and Nash equilibrium game. The proposed approach allows the project owner and the consultant to assess the green building cost and effectiveness of performance for different design alternatives during the early design stage. A two-person nonzero sum game is considered in this paper to model the interactions between both players with respect their different utilities and different risk behaviors. The results of the case study show the consultant plays an important role in influencing the developer's choice of selecting a desirable green building design alternative.

3.3 Smart Buildings and Cities

The city plays a pivotal role in the perspective of sustainable development: it consists of the accumulation of previous generations' actions accomplished to transform the territory and to improve the living conditions [23].

The concept of "smart city" is evolving as a new approach to mitigate and remedy current urban problems and make urban development more sustainable [24].

With the rise in urban populations, we are required to manage an escalating number of technical, social, physical, and organizational issues arising from complex congregations of people in spatially limited areas. A smart city should envision smart economy, smart governance, smart mobility, smart environment, smart people, and smart living. There are many recent studies which have conceptualized and defined a smart city in various contexts and meanings [25, 26].

Hurtado et al. [27] proposes a decentralized method for flexibility allocation among a set of buildings and use concepts from non-cooperative game theory in their paper. Two case of study (2-player and 5-player games) are used to evaluate the performance of the decentralized algorithm, and compare it against a centralized option. It is shown that flexibility requests from the grid operator can be met without deteriorating the comfort levels. Based on their model, a n-player non-cooperative game is set up, with the objective of meeting the flexibility request while ensuring that comfort is not deteriorated below a certain minimum threshold.

Energy saving in smart buildings is addressed through an innovative approach based on GT. Starting from the measurement of the users' consumptions performed with wireless smart meters interconnected to the appliances; the collected data are processed by a control unit to evaluate the optimal load profiles and to suggest to the users the most convenient schedule of appliances [27]. The objective is that of reaching the Nash equilibrium in which all the players are not interested in changing their situation/status as every deviation would be suboptimal. Results from numerical simulations are reported to assess the performance of the proposed GT-based method, while preliminary experimental tests are performed to show the potentialities of the system in real conditions. A centralized decision support system (DSS) is proposed to optimize the energy usage from both the end user's viewpoint and the overall power grid. More in detail, the proposed solution exploits GT-based approach to optimize the user's load profiles for minimizing the peak loads and, consequently, reducing the costs of the energy.

3.4 Modeling and Simulation

In [28], the authors are interested in examining whether dependency can create an economic reason to avoid such long-term commitments. They integrate an agent-based simulation model with game theory to examine whether pre-contract partner selection strategies that do not consider subcontractor selection as a repeated game may lead to a version of the holdup problem. GT is used to model the bidding process. They model the price in our game theoretic approach to evaluate sub-contractor selection strategies as a first-price, sealed-bid auction. The implicit assumption is that the contract is lump sum. The Nash equilibrium is found to determine the bids that subcontractors will submit in each period.

An analytical model, the Claims Decision Model based on GT is developed to study opportunistic bidding and construction claims in [29]. The results of this study indicate that the equilibrium solution of a construction claim is to negotiate and settle, which concurs with most of the claim cases in the industry. GT is used as an analytical framework to derive an economic model. They found the conditions where opportunistic bidding is encouraged, showed that to "negotiate" was the Nash equilibrium in a construction claim, and derived the possible range of a negotiation settlement. Decision rules and strategies for the owner and builder are proposed according to the model.

3.5 Construction and Management of Sustainable Buildings

More than ever, the construction industry is concerned with improving the social, economic and environmental indicators of sustainability. In order to overcome the increasing concern of today's resource depletion and to address environmental considerations in both developed and developing countries, life cycle assessment (LCA) can be applied to decision making in order to improve sustainability in the construction industry [1].

In [30], building energy efficiency services market government cultivation behavior model was set up based on the cultural construction. The disadvantages of single government cultivation behavior were analyzed and the mechanisms of cultural construction behavior of the government were researched by using game theories. The model explained that how to use culture to impact the market by the government, forming the interaction among the market, users and government, which could achieve the management aims of government, and proved that it could be one of effective government cultivation behaviors in this market.

The aim of the paper [31] is to select rational renewal variants of derelict buildings from the viewpoint of sustainable development by applying the Game Theory. The study analyses modeling renewal of construction objects applying methods of the GT. Sustainable development always involves great uncertainty; accordingly, the methods of the GT are used for a particular problem. Bayes's and Laplace's rules are applied for searching rational renewal variants of derelict buildings in Lithuanian rural areas. The case study proved that the methods of the GT are effective in a real life situation and can be successfully applied to solving similar problems.

Meng and Kunhui [32] aims to recognize the stakeholders involved and analyze the interaction between various stakeholders of Angola Mode projects from the perspective of business processes and cash flow. The relationships between different stakeholders are detected in line with the theory of game theory and the game path relation chain is concluded as the result. The Angola Mode-based project consists of many stakeholders. There are secondary stakeholders including Angolan citizens and Chinese citizens, who are just affected by the project rather than participant in it. Other stakeholders may include Angolan government, Chinese government, the Export-Import Bank of China, Owners of Angola, Chinese contractors, Chinese Oil Company and so forth, and who are called the primary stakeholders. They are the game agents and a close cooperation between them can guarantee the success of project construction.

From the scientific distribution of affordable housing and the use of game theory, [33] sorts out the existing process of indemnificatory housing assignment problem, puts forward the strict qualification examination, improves the allocation standard, puts forward the improvement measures to increase supervision, and strive to affordable housing allocation fairness and justice. The use of the GT puts forward the corresponding measures so as to guarantee the realization of housing allocation fairness and justice.

3.6 Sustainable Approaches to Construction Design

The term ‘sustainable construction’ was originally proposed to describe the responsibility of the construction industry in attaining ‘sustainability’. November 1994 saw the holding of the First International Conference on Sustainable Construction in Tampa, Florida, United States of America [34].

The term ‘sustainable construction’ is generally used to describe a process which starts well before construction per se (in the planning and design stages) and continues after the construction team have left the site. Sustainable construction includes managing the vice ability of a building during its lifetime and eventual deconstruction and recycling of resources to reduce the waste stream usually associated with demolition [35].

Peldschus et al. [36] presents the theory of the two-person zero-sum games with a practical example. This research shows that the applications to construction site selections can be provided and the game theory can be applied for the supporting decision in a competitive environment. Calculation of the equilibrium point for construction site assessment problem is handled as a case study.

Gu et al. [37] analyses the differences between the two basic paradigms to solve the current housing problem: top-down (provider paradigm) or bottom-up (support paradigm), especially from an energy efficiency perspective. Housing development is a gaming process between diverse stakeholders. All the stakeholders try to choose different actions in an attempt to maximize their returns.

3.7 Landscape Planning

The concept of sustainable development has emerged over the past decades as a new requirement for urban and metropolitan level public action, which involves conceptual principles and practices as applied to land use and urban planning [38].

Sustainable development assumes that human uses of the environment will continue and without maintaining the productive capacity of the earth, cannot been sustained communities. Herewith, the sustainability of communities requires planners to focus on sustaining landscape structure and function [23–40].

Purnomo and Irawati [41] describes the development of the landscape game, which takes on a realism of the virtual world. The game was developed based on the issues of competing use of land; maximize benefits for each set of actors and sustainability of forest landscape. As defined as a normal game, the developed game elements comprises players, set of possible strategies in forest landscape and pay offs. The game aims at providing lessons for its players and observers and shows what can occur to the landscape and players' income when the players apply various strategies after a specific time period. It includes how Nash Equilibrium, in which all players apply optimal strategy, is approached. These lessons are expected to contribute to the development of appropriate strategies and institutions of multi-stakeholders for forest landscape management.

Moretti et al. [42] introduce an application of cooperative game theory to a cost allocation problem arising from a complex water project in Egypt, taking into account differences in the regional landscape of land sectors (sectors) of the project area that affect the benefits that can be accrued by water users in each of the project land sectors. They demonstrate the challenges faced during the application of cooperative game theory concepts and how they are addressed. The analysis produces a differential two-part tariff that differs by the project land sectors, in contrast to the unified tariff that was recommended by the traditional methods used by the planners.

Lawson [43] argues that a gaming approach for adult social play can help higher-education students of landscape architecture acquire key knowledge and skills for land-use decision making. It has proposed a repertoire of game designs that aims to support conceptual change for adult learners in ecological landscape planning.

Lin and Liu [44] uses cooperative game theory to better understand the choices and tradeoffs made by Indigenous Taiwanese villagers who were in a "competitive" situation with regard to Indigenous autonomy and government-led protected areas. The aim was to understand how interactions among different groups of local people could affect community-based natural resource management (CBNRM) processes that aim to balance environmental sustainability with Indigenous autonomy. Results show that the knowledge and rights of Indigenous people could be part of a compromising collaboration with legislation-supported protected areas, if this collaboration benefits Indigenous autonomy as well as sustainability of the local environment and livelihoods.

Zhang et al. [45] seeks to rectify this by using game theory to optimize landscape space allocation within World Heritage Landscapes (WHLs) by analyzing the conflicts involved and the means by which they can be resolved. The game they used involves two sets of players, the WHL managers and the WHL tourists, which are both assumed to comprise rational economic beings. The goal of the managers is to maximize the economic benefits to pay for operating and maintenance costs and future sustainable development, while the goal of the tourists is to maximize their net benefit of enjoying the WHL. They apply the game model to identifying the optimal solution to the ticket prices and proportion of this packaged high-rental space.

Using game theory, [46] identifies three potential outcomes ranked by the extent of restoration of ecosystem services and processes: nonstrategic, non-cooperative strategic equilibrium, and cooperative bargaining solution. They identify conditions under which additional restoration can decrease the overall flow of ecosystem services and processes. To analyze the feedback effects on restoration by farmer responses, they start with the simplest game, one restorations and one farmer in a static game (both decide simultaneously) of two choices each and complete information. The best response function for the restorations is to restore the piece of land if the ecological function gains from restoration outweigh the cost of restoration plus, if the farmer defends in the face of restoration, the ecological function lost by the farmers' defense. This pair of responses is the Nash Equilibrium (NE), the point where all players choose the move that provides them the highest payoff in light of the moves played or expected to be played by the other players.

3.8 Water Resources

Sustainable water resources management is a concept that emphasizes the need to consider the long-term future as well as the present. Water resource systems that are managed to satisfy the changing demands placed on them, now and on into the future, without system degradation can be called sustainable [47].

Madani [48] reviews applicability of game theory to water resources management and conflict resolution through a series of non-cooperative water resource games in detail. The paper illustrates the dynamic structure of water resource problems and the importance of considering the game's evolution path while studying such problems. [Dinar] also review the main contributions of GT in water resources over the past 70 years. It will compare the set of issues faced by water resources and those which the sector is most likely to face in the coming future.

Kahil et al. [49] develops a cooperative game theory framework in order to analyze water management policies that could address scarcity and drought in a typical arid and semiarid basin in Southeastern Spain. The results provide clear evidence that achieving cooperation reduces drought damage costs. They construct the games in non-cooperative game and in cooperative game. Nash-Harsanyi Equilibrium, the Shapley value and the nucleolus solution concepts are used. The cooperative game theory solutions and stability indexes examined in this paper demonstrate the importance of incorporating the strategic behavior of water stakeholders in the design of acceptable and stable basin-wide drought mitigation policies.

Ramirez-Jaime et al. [50] proposes a control methodology based on differential game theory that aims to efficiently use the existing network elements in order to minimize overflows and properly manage the water resource. The proposed controller is tested on a typical UDS and is compared with a centralized MPC achieving similar results in terms of flooding minimization and network usage, but only using local information on distributed controllers. For this work, only the Nash equilibrium is studied.

The methodological approach for the allocation of scarce resources in a complex supply system by using the Bankruptcy Games techniques described in [51] is linked to Cooperative Games Theory and allows the evaluation of a sharing rule for goods that are not sufficient to satisfy the total requests of the users in the system. Moreover, a new criterion is developed that, in resource allocation, privileges those users with higher priority. Users' willingness to pay is considered to define priority; the methodology can be considered innovative in this field of research. This approach has been applied in water resource systems using critical scarcity scenarios: initially, a simplified water system is used; then, the complex and multi-purpose Tirso-Flumendosa-Campidano water system in southern Sardinia, Italy, is examined. The proportional rule (PROP), the constrained equal award rule (CEA), the constrained equal loss rule (CEL), the Talmudic rule (TAL), and the adjusted proportional rule (APROP) are considered in this study.

A cooperative game theoretic approach is proposed to solve water allocation problems in two steps: (1) initial allocation of water rights to water users or stake-holders based on existing water rights systems or agreements, and (2) reallocation of water to achieve efficient use of water through water transfers in [52]. The core, the Nucleolus, the weak nucleolus, the proportional nucleolus, the normalized nucleolus (variation solution concepts of nucleolus) and the Shapley value are used.

4 Discussion

There exist several main terminologies in GT (Table 1). The Nash Equilibrium for non-cooperative games, The Shapley value and the Core for cooperative games. They can be found as solution concept in the literature. Some papers use both of solutions in cooperative and non-cooperative games.

Table 1. Common terminologies in typical GT in sustainability

Terminology	Typical GT methods in NR		
	Cooperative	Non-cooperative	Cooperative, non-cooperative
The Nash equilibrium		[20–22, 27–29, 36, 41, 46, 48, 50]	[49]
Shapley value	[52]		[49]
The core	[52]		
The others	[32, 33, 42, 44, 45, 51]	[19, 27, 30, 31, 37, 43]	

5 Outlook

This paper has summarized the recent developments in Game Theory for Sustainability. Game Theory has the capability to examine a larger amount of possible scenarios before performing the action. Game Theory can make a decision process more sophisticated in sustainable building. The potential of applying Cooperative Game Theory to Sustainability is prospective. Some researchers have already explored the game-theoretic approach to non-cooperative game theory. However, studies towards cooperation have not become widespread as non-cooperative games. We see that the cooperative game theory approaches mostly used in sustainable planning literature. When the studies examines in the framework of sustainable buildings and smart cities, the non-cooperative game theory approaches more common. Representative contributions are listed to give a general overview. This paper appears to be a promising avenue for future development in the sustainable building.

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Production of Insulations and Construction Materials from Expanded Perlite

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Abstract. Today, importance of sustainable development increases the importance of studies on energy efficiency. Residential and industrial fields consume 70% of total energy consumption and constitute the largest portion of it. There is an energy saving potential of 30% in industry and 70% in homes by insulation. The production of low thermal conductivity lightweight insulation materials from domestic resources and diversification of these materials has gained importance. Expanded perlite aggregates which have different particle size were used as a main raw material. Perlite is a lightweight material due to their high open and closed micro pores. Expanded perlite aggregate has porous structure and has hygroscopic properties. In order to prevent these properties, hydrophobic polymer, and organic or mineral acids additives were used to coat the surface by spraying method. Perlite surfaces were coated and become hydrophobic after this process. In the second part of the study, perlite aggregates mixed with certain amount of sodium silicate solution (water glass) and shaped in the mold. The main objective of this study is to production of highly heat isolative construction materials from expanded perlite which is very abundant in Turkey. According to the study, productions of insulation products which have thermal conductivity constant lower than 0.060 W/mK were obtained by using coated expanded perlite.

Keywords: Building materials · Thermal insulation materials
Heat insulation · Perlite

1 Introduction

The European Union has aimed to reduce the amount of energy used for heating in buildings by 20% until 2020 and by 50% until 2050. In order to reach this target, it will be necessary to increase the insulation thickness of the building envelope [1]. 40% of the total energy is consumed in the houses in USA and EU countries. This rate is 30% in Turkey.

Energy efficiency can be defined as achieving more energy performance without sacrificing comfort conditions with minimal energy consumption. The advantages of energy efficiency can be listed as follows:

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- Increased energy safety: especially for political risks, reduced dependence on high fossil fuels,
- Conservation of the environment through lower or zero emission,
- Decrease in energy cost and improvement in financial balance,
- Contribution to production and employment.

The advantages and profits of the insulation incentives in buildings can be summarized below.

It is expected that the number of un-insulated housing, which is still around 16 million, will decrease to low levels in Turkey until 2023. An average annual loss of 10 billion TL will be avoided. Depending on the number of facilities producing heat insulation materials and the production process, 10–25 new plants will need to be commissioned each year. Ten thousand new employments will be achieved and significant contributions will be made to Turkey commitments to the KYOTO protocol. Greenhouse gas emissions will be reduced and significant positive contributions will be made against global warming and climate change [2].

The heat conduction can be divided in three parts; conduction through solid, conduction through gas phase and radiation through pores (1).

$$\lambda_{tot} = \lambda_{gas} + \lambda_{solid} + \lambda_{rad}\ (\mathrm{W/mK}) \tag{1}$$

New and high performance thermal insulation materials will provide significant and feasible solutions to reduce the thickness of building envelope whilst maintaining thermal resistance on the one hand [1]. These materials will provide new opportunities for architects and engineers to design energy efficient buildings [3]. The geopolymer includes silicate and aluminate by-products for the treatment of the geopolymerization process. It is environmentally friendly and requires moderate energy in its production. Geopolymerization is also known as a geosynthesis (an integrated reaction of chemical minerals) containing naturally occurring aluminosilicates [4–6].

The aqueous solutions of sodium and potassium silicates are well suited for coating applications in terms of physical and chemical properties and bonding between the granules. Silicates; they are widely used in many areas because they are low price, incombustibility, durability, odorless and non-toxic structure, metal, particles, combined with fiber materials, glass and ceramics. Due to the low prices and versatile properties of these compounds, a wide area is used especially as a coating and binder [7, 8].

Silicates are converted into solid films or bonds by two methods. Evaporation (dehydration) of the water from this body, and the other is the mechanism of chemical adjustment. These events may be brought separately or together. The chemical setting is usually used to increase the moisture resistance of the film and to strengthen the bond strength when necessary.

Liquid sodium silicates are reacted with various acids to produce stable bonds and films. During the neutralization of the alkali silicates with acids polymerization occurs in the form of silica and gel. These are mainly mineral and organic acids, carbon dioxide, acid salts.

SiO_2/Na_2O (Si/Na) ratio is very important in water-soluble silicates. Those with low silicate ratios are preferred where flexibility is desired. The main reason for this is that the water content in the environment adds to the internal consolidation properties. The resulting body has a less fragile structure.

It is possible to bond the powder and granular materials to a particle of each particle with a thin silicate film. This binding varies depending on the size and density of the particulate matter. In order to allow the particles to agglomerate, 2–5% sodium silicate solutes are more suitable for the amount of solids. Examples of such coatings are perlite, chipboard or acoustical coating granules [9].

Silicones have self-wetting properties and this improves film-forming properties, and shows that they have good surface coating properties. The high thermal and oxidative strengths, high UV stability, low surface tension, dielectric resistance and glassy transition temperature (Tg), superior physical properties in a wide temperature range, good optics, excellent flame retardant properties, hydrophobic behavior, permeability, flexibility in the polymer chain polysiloxanes are interesting and important properties [10–13].

The main objective of this study was to investigate the coating of the surfaces of the expanded perlite by sodium silicate. Pore structure over the expanded perlite surface was investigated by stereo and SEM microscopy techniques. Compacted test samples were produced from coated and uncoated expanded perlite and their thermal conductivities were compared. This study showed the possibility of production of heat insulation panels which have heat conductivity constants of 0.050–0.070 W/mK by using expanded perlite and geopolymer technology together. Experimental samples were mineral based and fireproof, therefore they can be alternatives to the petroleum based (EPS, XPS etc.) materials.

2 Materials and Methods

The characteristics of the materials used in the study and the methods applied are presented in this section. Expanded perlite aggregate with different grain sizes was used as the main material in the study. Due to the number of open and closed micropores, it is a fairly lightweight. These pores give extraordinary heat insulation properties to the perlite. Perlite, a neutral material, does not enter the chemical reaction due to its stable chemical structure. It is sterile and doesn't contain bacteria and germs. Depending on particle size distribution and expansion ratio, the expanded perlite unit volume weights can be quite different. The thermal conductivity values of dry perlite at 24 °C, 32 and 180 kg/m^3 where unit weights are 0.040 and 0.055 W/mK, respectively [14–17]. In the study, expanded perlite supplied from a private firm (Genper A.S. Kütahya, Turkey) was used. The chemical structure of expanded perlite used in the study mainly consists of SiO_2 and Al_2O_3 compounds (Table 1). Perlite particle size used in the study was chosen as max 2.5 mm (Table 2).

Table 1. Chemical structure of perlite

SiO_2	Al_2O_3	Na_2O	K_2O	CaO	Fe_2O_3	MgO	LOI
73.16	12.87	2.35	4.79	0.85	0.83	–	2.58

Table 2. Grain size distribution of the perlite

Size (μm)	1000–2500	800–1000	500–800	160–250	–160
% Pas.	25	12	10	18	10

Liquid sodium silicate, known as “water glass”, consisting of Na_2O and SiO_2 in different proportions, has wide physical and chemical properties and has wide application as industrial binder. Low cost, inorganic structure, ease of use, high strength, chemical stability and insolubility is important features. Sodium silicate is widely used as a binder because of its properties. Silicate bonded perlite can be transformed into a completely non-flammable insulation material by acquiring refractory properties. The water glass used in this study was diluted with water by 50%.

Two different processes have been studied in the studies. First, the cracks and pores on the surface of perlite grains were coated to make them more impermeable and the pores were reduced. 50 μm to 2.5 mm expanded perlite grain surfaces were coated in a laboratory-type pellet machine (Fig. 1). In this process, the coating of the grain surfaces were provided, on the expanded perlite placed in the pellet machine by spraying citric acid, sodium silicate and citric acid, respectively (Fig. 2). After spraying, the expanded perlite was placed in an oven and subjected to heat treatment at 300 °C and then at 250 °C for 10 min. After heat treatment, the coated surfaces of the perlite grains were examined by polarizing microscope and SEM. Stereographic microscope images of the coated and uncoated perlite grains were given on the Fig. 3. According to pictures, the pores on the uncoated grain surfaces can be seen clearly. It can be seen that the pores were reduced or completely closed on the coated surface of the grain. SEM images clearly show that the pores on the surface of the coated grains were closed or reduced and the pores on the untreated surface of the particle can be distinguished (Fig. 4).

Fig. 1. Coating of expanded perlite surface with acid/silicate treatment in pellet machine

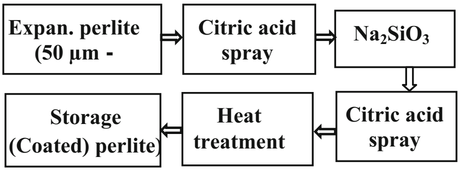

Fig. 2. Surface coating process of expanded perlite grains

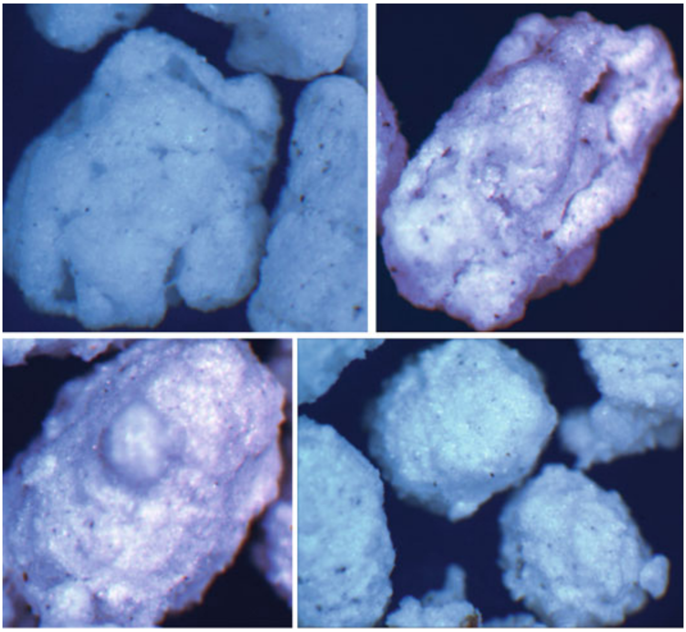

Fig. 3. Untreated perlite grains (top) and coated grains (bottom)

Test specimens were produced in two different batches using coated and uncoated granular perlite. The specimens were shaped in 40 × 40 × 160 mm steel mould and with a diameter 50 mm cylinder mould. When the coated perlite grains were poured into the mould, granular perlite at 2.5 times the volume of the mould was sufficient. In the case of uncoated perlites which have the same grain size distribution, about 3.5 times of the mould volume were required. As a result of this coating, the grains have become tighter, stronger and have a closed-pore structure. Due to the surface cracks, open pores and fissures in uncoated grains were caused more compression. The samples taken from the mold were heat treated at 200 °C for 4 h to gain strength (Fig. 5).

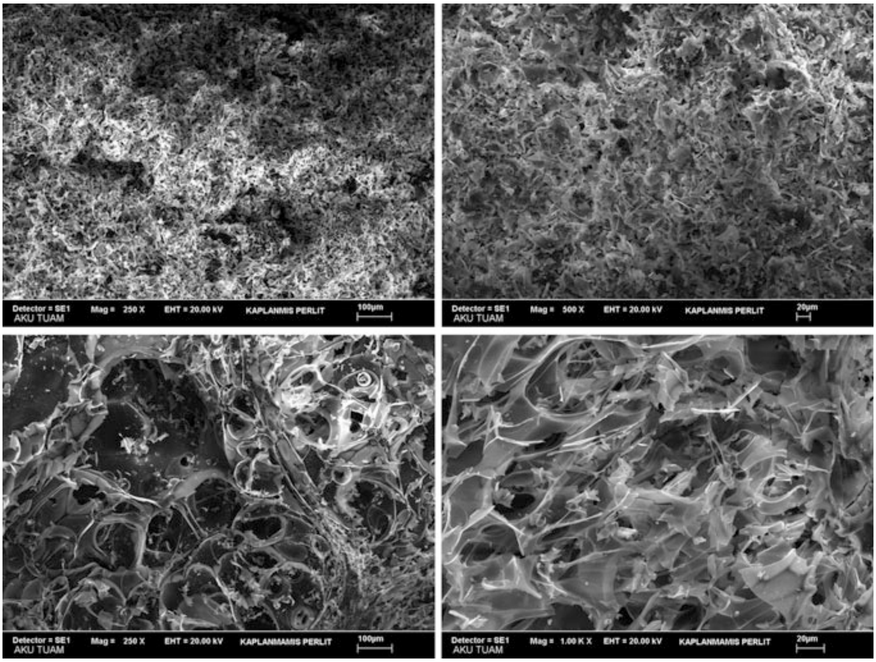

Fig. 4. SEM images of the coated (top) and uncoated (bottom) perlite grains

Fig. 5. The produced test specimens (40 × 40 × 160) mm prisms (top), and 50 mm diameter cylinders (bottom)

The thermal conductivity values of the prism samples were measured in the C-THERM thermal conductivity meter (Fig. 6).

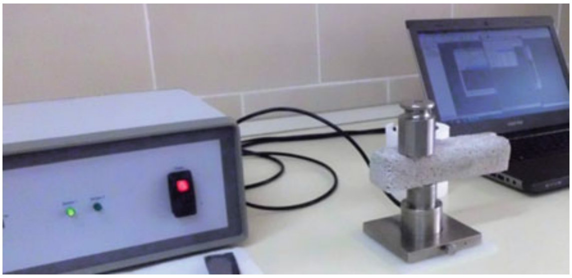

Fig. 6. Determination of λ values of samples (C-THERM device)

3 Results and Discussion

The unit volume weights of the test samples were 130 kg/m^3 for coated perlite. The unit weights of test samples which were produced from uncoated perlites were determined as 180 kg/m^3. It is believed that more material is needed in the production of uncoated perlite. Uncoated perlite surfaces are more porous and cracked which in case more materials needed to produce test samples. Therefore, the unit weights of the samples have also increased for samples which are produced from uncoated perlite.

The increase in unit weight negatively affects the insulation property, especially by conduction. The average thermal conductivity values of untreated perlite produced samples (180 kg/m^3) were determined as λ: 0.070 W/mK while the thermal conductivity values of the surface treated samples (130 kg/m^3) were λ: 0.050 W/mK. This is thought that, because the pores are mostly closed by surface coating which resulted in the perlite grains having closed pores and/or smaller surface cracks. Convection in the closed-pore environment is also minimized. Furthermore, since the unit weight values of the untreated perlite-produced samples much more, heat transfer by conduction is considered to be increased [1, 18].

4 Discussion

Based on the experimental investigation reported in this paper, the following conclusions are drawn.

The surface of perlite grains was coated. Physical and mechanical properties have been improved by this way. Experimental samples were produced by geopolymeric binding method from perlite grains of the both coated and uncoated. The samples produced from the coated perlite grains were lighter than samples produced with uncoated perlite grains. It is considered that, less perlite is needed to produce with the same volume of the sample.

Lower thermal insulation values were obtained in coated specimens compared to those uncoated samples. This is thought to be due to lower unit weight and closed-pore structure.

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An Investigation of the Effect of PVA and Boric Acid on Concrete Mixtures

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Abstract. In this study, we investigate the effect of the addition of poly vinyl alcohol (PVA), a polymer filler, which is known to promote the strength of unit mass, corrosion strength and the flexibility of the final product together with boric acid as a cross linking agent to concrete polymer composites by viscosity, setting time, compressive and bending strength tests in accordance with Turkish standards. The addition of PVA and boric acid caused 4% increase in 28 days' compressive strength results. The bending strength on the other hand, the bending strength decreased by 45%. The samples were also investigated by scanning electron microscope (SEM) and X-ray diffraction (XRD) methods. The experiments repeated with higher filler concentrations showed that porosity of the final concrete was significantly decreased resulting a much higher quality end product.

Keywords: Cement · Polyvinyl alcohol · Boric acid · Strength SEM · XRD

1 Introduction

The studies related to the improving of the properties of the concrete polymer composites by the addition of certain supporting materials have shown a rapid increase in last 30 years [1–3]. Polymers have a big advantage against the traditional supporting materials as regards to strength per unit mass, corrosion strength and binding power of the resulting concrete. The addition of boron as a cross linking agent with PVA produces great improvement in the binding capacity and strength of the final concrete to various effects [4, 5]. Alhozaimy et al. reported that there is a significant improvement in the collision strength of the concrete as a result of addition poly

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propylene [6]. Bindiganavile and Banthia [7] reported that there was a considerable increase in the strength to the expansion after the addition of the polymer supporting material. Manolis et al. proved that the polypropylene supporting material generate a substantial increase in the flexibility strength of the concrete without having any adverse effect upon the bending strength [8]. Peled and Mobasher [9] report that the PVA addition has a very positive effect upon the static and collision test values. They also reported that the micro fiber supporting material such as PVA has a very positive effect upon the prevention of micro-cracks after shrinkage [10]. The ductility, tensile strength, collision and expansion strength of the concrete can be greatly improved by the addition of micro-fibrous materials [11].

2 Material and Method

2.1 Material

The material used in this study were, CEM I 42.5 N cement, boric acid, polyvinyl alcohol and distilled water.

2.2 Method

The physical (spreading and setting time) tests were carried out in accordance with the BS 1881-105 [12] and TS EN 196-3 [13]. The preparation of the concrete samples and the bending and compressive strength tests were carried out in accordance with TS EN 196-1 and TS EN 196-1 [14]. The samples were also subjected to SEM and XRD analyses.

Preparation of the cement samples

The cement samples were prepared according to the ratios listed in Table 1.

Table 1. The ratios of PVA and oric in cement samples

Mixture no.	%	
	PVA	H_3BO_3
1	0	0
2	1	0
3	1	0.25
4	1	0.50
5	2	0
6	2	0.25
7	2	0.50
8	3	0
9	3	0.25
10	3	0.50

The appropriate amounts of PVA corresponding to 80 g water were mixed in a beaker for an hour by constant stirring. Then the appropriate amount of boric acid was added to it and the total mixture was stirred for further 60 min. This procedure was repeated for ten different samples. The mixtures prepared were placed in separate beakers.

Each solution prepared as described above was mixed with cement with gradually increasing the stirring rate in 30 s intervals. The whole process was finalized in 90 s. The mixtures were coded and placed in triple steel molds. The samples were cured in a curing pool at 20 ± 2 °C and the relative humidity of 100% for 3, 7 and 28 days. The samples were taken out of the molds 15 min prior to the experiments and wiped with a damped cloth and they were ready for the 3, 7 and 28 days' pressure and bending strength tests.

3 Result and Discussion

3.1 The Physical Values of the Cement Samples Used in the Experiment

3.1.1 Spreading Test Data

The spreading test values carried out with the freshly prepared samples are listed in Table 2 and plotted in Fig. 1.

Table 2. The spreading test results

Mixture no.	Spread (cm)
1	19.1
2	18.2
3	14.1
4	12.5
5	15
6	13.3
7	12
8	17.8
9	13
10	11.7

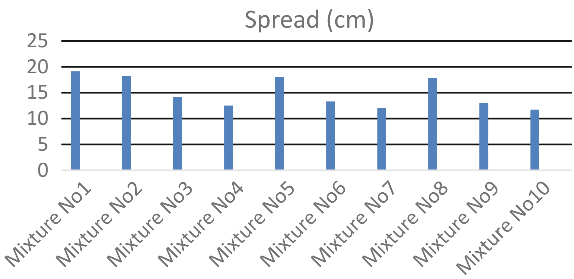

Fig. 1. The spreading values of the samples

The experimental results reveal that the spreading values of the experimental sample 1 and samples 2, 5 and 8 containing only PVA are higher than the rest. The addition of boric acid decreases the spreading problem as seen in samples 3, 6 and 9. The increase in the boric acid content causes a large decrease in the spreading value. It is obvious that the use of PVA together with boric acid decreases the spreading of the samples (4, 7 and 10) and decreases the losses due to consistency of the samples. These results are in good accordance with the literature [3].

3.1.2 The Determination of the Setting Time

The literature shows that the addition of boric acid or borax prolongs the hydration time of the concrete similar to carboxylic acid, lignin, sugars and some phosphate compounds [15]. The results of the hydration time of our samples and the relations between them are shown Table 3 and Fig. 2.

Table 3. The results of the hydration (setting) time of the samples

Mixture no.	Setting times (min)	
	First setting	Last setting
1	155	205
2	198	238
3	240	282
4	260	302
5	210	242
6	253	294
7	275	308
8	218	248
9	261	303
10	281	314

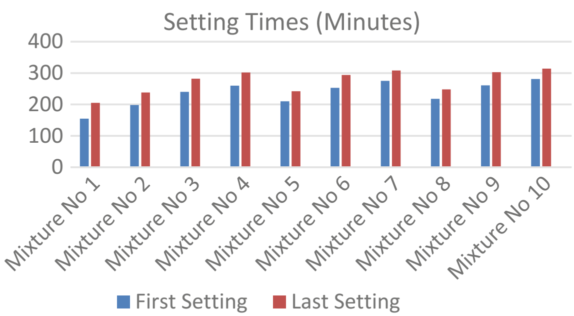

Fig. 2. The starting and finishing times of setting of the samples used in this study

The times for the initiation and completion of the setting of the samples used in his study were observed to be between 155 and 205 min. The samples 2, 5 and 8 containing only PVA the setting time shows a slight increase. However, comparing sample 1 (reference sample) with the ones which contain boric acid (samples 2, 4, 6, 7, 9 and 10) the addition of boric increased the starting and finishing time of setting from 155 and 205 min to 240 and 282 min. This increase was higher in sample 4 in which the amount of boric acid was doubled. The setting time was also prolonged in samples 6 and 9 which contain twice the amount PVA than the previous sample. However, the increase was much higher in sample 4 which contains twice more boron than the sample 3.

The corresponding increase in the amount of boric acid caused a much more dramatic increase in setting times (samples 4, 7 and 10). This was attributed to the formation of calcium di boride (CBH_6) as a result of the reaction of Ca^{2+} cations with $B(OH)_4$ which covers the surface of the samples delaying or completely inhibiting the hydration reaction.

It is obvious that the increase in the amounts of PVA and boric acid prolong the setting starting times in samples 2, 5 and 9 which contain one (taken as the reference) two and three parts of the PVA as 198, 210 and 218 min respectively. The completion times also followed a similar trend as 238, 242 and 248 min. When we compare the changes induced by the addition of boric acid the increase resulted by the cross linking the polymer chains are very limited.

3.2 The Mechanical Test Applied to Cement Mixtures

3.2.1 Compressive Strength Test

The 3, 7 and 28 days compressive strength data are tabulated in Table 4 and the relations between different samples are displayed in Fig. 3.

Table 4. 3 day, 7 day and 28 day pressure strength data of the samples

Mixture no.	Compressive strength (MPa) 4 × 4 × 16 cm		
	3 days	7 days	28 days
1	35.4	38.7	50.63
2	36.69	41.47	51.75
3	41.33	45.48	53.73
4	43.2	47.22	54.41
5	37.38	42.46	53.87
6	43.52	48.37	56.24
7	45.28	51.56	58.14
8	40.49	44.35	55.33
9	49.71	52.68	59.83
10	49.1	51.41	57.41

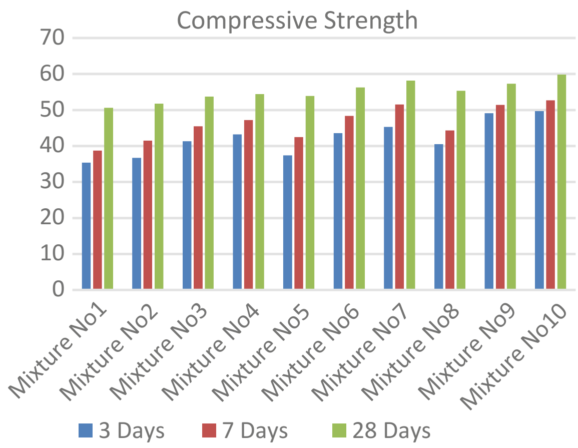

Fig. 3. The change of 3, 7 and 28 days' compressive strength of the samples

The addition of boric acid to the cement mixtures resulted in a modest increase in their 7 and 28 days' compressive strength. The addition of PVA also resulted in an insignificant increase in compressive strength values just as the case for the setting times. For instance, the compressive strength values showed a very insignificant change in 3 days' tests such as 36.69, 37.38 and 40.49 for the reference sample 2 with unit PVA content, for sample 5 containing twice and for sample 8 containing three times more PVA content of sample 2 taken as the reference respectively. The addition of boric acid has been much more effective then the addition of PVA. Addition of PVA has a much more distinctive effect on 3 and 7 days' pressure values than the results obtained in more prolonged times. Therefore, the data obtained after 28 days is not very reliable.

3.2.2 Bending Strength Test

The bending strength data of the cement mixtures used in this study are tabulated in Table 5, plotted in Fig. 4.

Table 5. The 28 days bending strength of the samples

Mixture no.	Bending strength (MPa) 4 × 4 × 16 cm
1	7.79
2	6.38
3	6.11
4	5.19
5	5.62
6	5.52
7	4.78
8	4.88
9	4.14
10	4.06

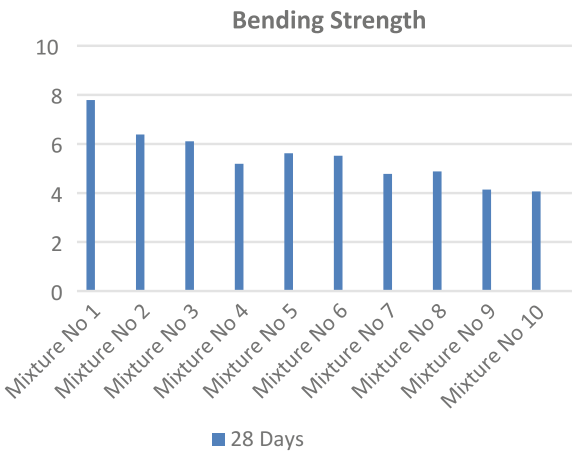

Fig. 4. 28 days bending strength of the samples

The bending strength shows a slight decrease with the addition of PVA. However, the use of boric acid resulted in a much marked decrease in 28 days bending strength tests. There was a marked decrease in the bending strength as the boric acid content was increased (21 and 33% for the samples 3 used as a reference and 4 which include twice of the boric acid compared with the reference). Similarly, the decrease in bending strength in samples 6 and 7 which include twice of the PVA compared with the reference sample were 29 and 38% and this decrease was culminated in samples and 10 which were supported with the three times of the amount of PVA. In spite of the promoting effect of boron on setting time and compressive strength the calcium di borate (CBH_6) formed by the reaction of CA^{2+} ions $B(OH)_4$ causes a drastic loss of bending strength. These data are quite compatible with the literature values [16].

3.3 The Surface Techniques Applied to the Samples

3.3.1 Scanning Electron Microcopy (SEM)

The (SEM) micrographs of the samples are shown in Figs. 5, 6, 7, 8 and 9.

When the micrographs in Fig. 5a displaying the sample which contain PVA or boric acid is examined, one sees a non-crystalline surface replete with micro cracks. The micrograph B which contains only PVA there appeared to have big holes with occasional needle shaped crystals. The quality of the concrete material is not good due to this porous structure formed by holes at 3–5 micron dimensions. The decrease in bending also shows that the quality of the cement is very low.

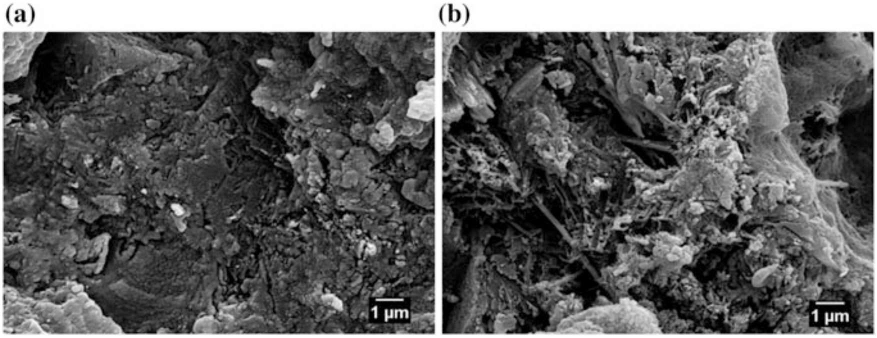

Fig. 5. SEM micrographs of **a** sample 1 and **b** sample 2

Figure 6a shows that the addition of boric acid resulted in a granulated surface by the location of boron atoms on the pores and the crack sizes show a marked decrease and the bore diameter also became smaller (below 1 micron) and the structure assumes almost a crack free form. After the increase of the boron content almost twice (Fig. 6b) there occurs a formation of long and very narrow cracks (with a width of 50–100 nm). The biggest reason for that is the addition of excessive boron required for the cross linking of the polymer chains and the reaction of this excessive boron with the cations such as Ca^{2+}, Mg^{2+} present in the structure and decrease of the flexibility of the final concrete making it much more ductile. The bending test results also verify this fact.

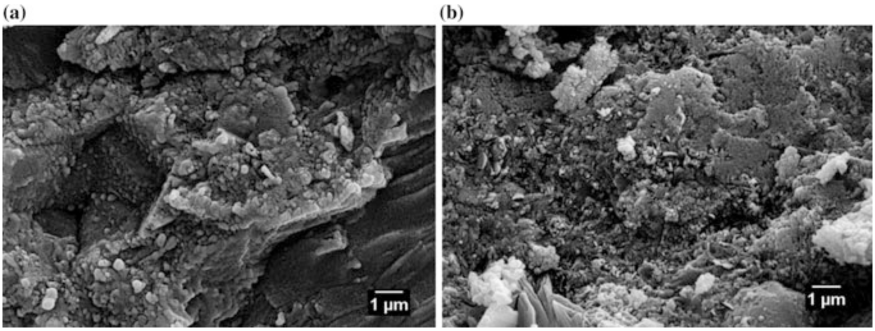

Fig. 6. SEM micrographs of **a** sample 3 **b** sample 4

Figure 7 shows the effect of doubling the amount of PVA in the concrete samples in Fig. 7a which corresponds to doubling the PVA content without the addition of any boric acid. Although the 600–700 nm long cracks are apparent, the quality of the concrete containing the two twice more PVA compared with Fig. 5 which contains only one part of PVA is much superior. The compressive strength data also verifies this situation. SEM macrographs reveal the fact that although the micro cracks are not completely eliminated, the particles assume more spherical shapes.

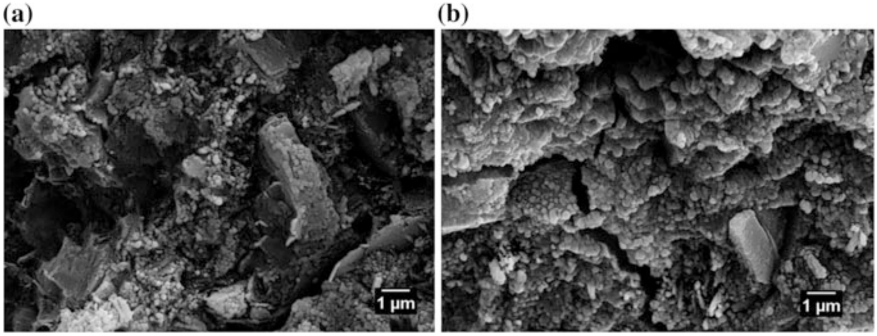

Fig. 7. SEM micrographs of **a** sample 4 **b** sample 6

Doubling the amounts of boric acid and PVA results in a significant decrease of the porosity of the final concrete and gives a much quality end product (Fig. 8a).

However, tripling the amount of PVA without the addition of boric acid results in a much inferior product with a non-crystalline structure. This clearly shows the fact that one should refrain from excessive use of PVA without boric acid.

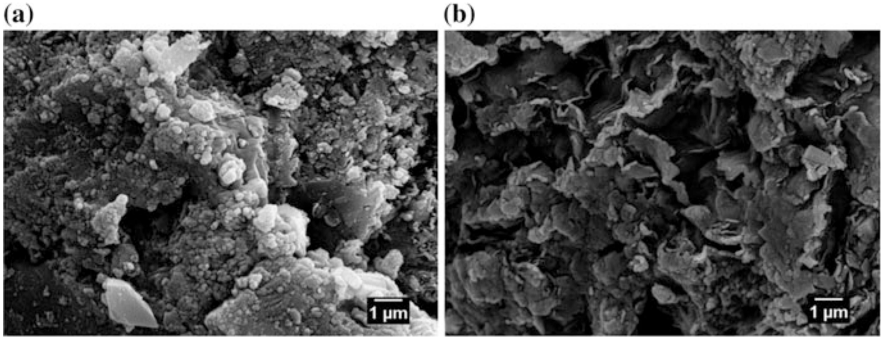

Fig. 8. SEM micrographs of **a** sample 7 and **b** sample 8

Figure 9a (sample 7) shows the fact that the porous structure and micro fractures are minimized and an almost poreless compact structure formed by a 500 nm grains appears in the sample containing the three parts of both PVA and boric acid. This is much superior to the best material (Fig. 8a, sample 7) seen up to now. The 3 days compressive strength of sample 9 (Fig. 9a) is 8.4% more than sample 7 (Fig. 8a) However, the properties of the sample which contains excessive boric acid deteriorates due to reaction of boric acid with Ca^{2+} cations present in the medium making the concrete much more ductile.

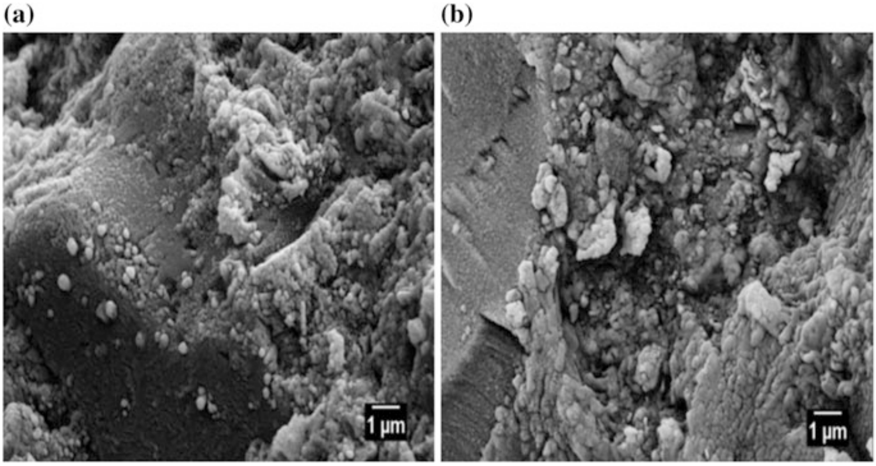

Fig. 9. SEM micrographs of **a** sample 9 and **b** sample 10

3.3.2 X-Ray Diffraction (XRD)

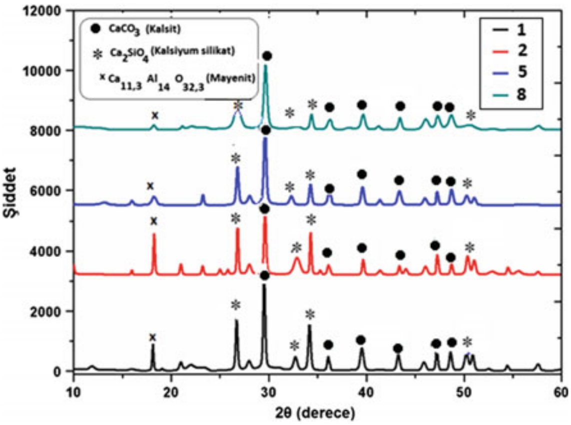

Fig. 10. The XRD graphs of the mixtures with different amounts of PVA

The peaks located at 2θ values of 29.48°, 36.07°, 39.52°, 43.25°, 47.26° and 48.56° is due to calcite ($CaCO_3$) (JCPDS Pattern No: 2-623). There are also other compounds formed in addition to calcite: the 2θ peaks located at 2θ values of 26.71°, 32.73°, 34.16° and 50.60° are due to the formation of calcium silicate (Ca_2SiO_4) (JCPDS Pattern No: 1-1029) and the peak located at 18.11° originates by the formation of magnetite ($Ca_{11.3}Al_{14}O_{32.3}$) (JCPDS Pattern No: 78-910). These peaks are indicated by •, * and x. The peak at 2θ value 32.73° belonging to calcium silicate gradually diminishes by the increase of PVA content and completely disappear at the 3% PVA content. This peak is thought to be due to interaction between the atoms adsorbed upon the surface. The peak at 28° disappears at.%3 PVA without showing any form of relation to the PVA concentration. This could not be explained by the experimental data. However, it is obvious that 3% PVA appears to be optimum value. The PVA content increases from sample 1 to sample 8 and the crystallinity decreases in the same order. Also the increase in the PVA content oppresses the peak belonging to boric acid at 29.63° appears. The peak at 37.73° splits into two at and the peak at 56.60° diminishes. All these were attributed to the formation of an amorphous structure. That is why the sample 8 gave the worst results (Figs. 10 and 11).

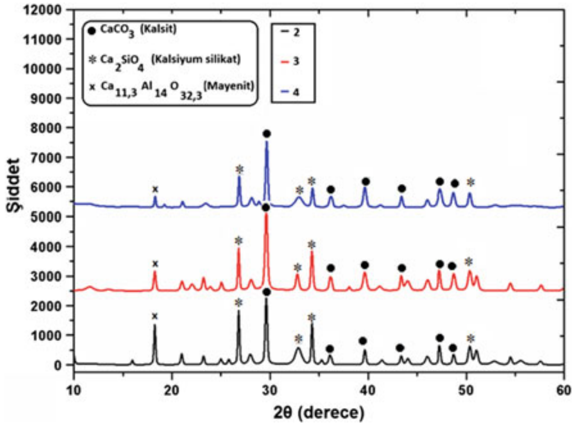

Fig. 11. The XRD data of boric effect acid content at fixed PVA concentration

The effect of boron on all the peaks we considered above are also valid here. However, the changes are not as clear as those.

The only difference is that boric acid causes shifts in those peaks. Therefore, if we keep the boric acid content at.%1, there is no deleterious effect on the resulting structure.

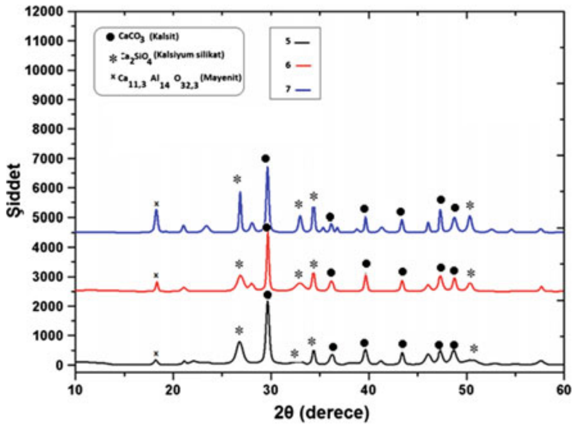

Fig. 12. XRD data of samples 5, 6 and 7

The effect of boric acid by doubling the PVA content resulted in the increase of the peaks belonging to calcium silicate located at 32.73° and 50.60° proving the interaction between boric acid and calcium silicate. Also, there was another peak which occurs by the increase of boric acid content at 28°. These shifts are also present in Fig. 12 for samples 6 and 7. The major peak here is located at 29.62° and shifts by the effect of boric acid concentration. The decrease in peak dimensions are interpreted as the conversion from the crystalline structure to amorphous structure. This fact is also verified by the SEM micrographs (Fig. 13).

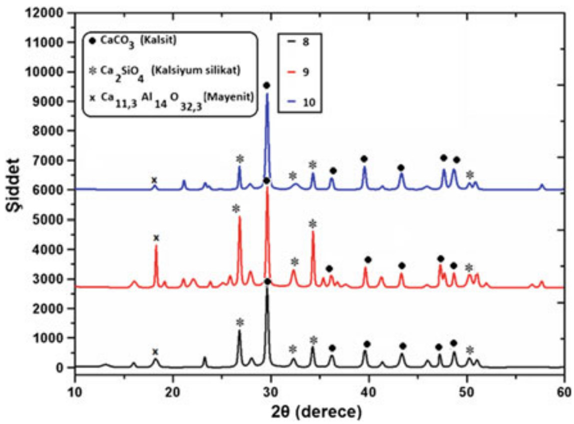

Fig. 13. XRD data of samples 8, 9 and 10

The relation between the increasing PVA concentrations with constant boric acid content showed that there was an optimum PVA concentration of 3% and the amount exceeding this value do not cause any significant change in the structure. The optimum concentration of boric acid which can be added into the concrete polymer composite was 0.5% which cross links the polymer chains and increases the crystallinity.

4 Results

✓ The increase in the amounts of PVA contents decreases the spreading and increases the consistency losses.

✓ In the literature there are numerous reports that addition of boron compound such as boric acid or borax increases the hydration or setting times. It was proven in this study that the increase of the PVA and boric acid in concrete samples prolongs the initiation and completion of the setting time.

✓ The addition of excess boric acid alone causes much more drastic effect compared with the effect of cross linking of PVA chains by the boric acid.

✓ The addition of boric acid to the concrete polymer composites improves the compressive strength values more than PVA.

✓ The 3 and 7 days' compressive strength tests give much more realistic values than 28 days' strength tests. Therefore, one should be tactful when using 28 days' compressive strength test results.
✓ The 26 days bending strength tests results showed a slight decrease with PVA. The decrease with boric acid were much more drastic.
✓ Although the increase in the boric acid content have a very positive effect upon the compressive strength and setting time, it has a very serious adverse effect upon the bending strength of the final concrete due to calcium di borate formed with the reaction of Ca^{2+} with $B(OH)_2$.
✓ The cross linking effect of boric acid with PVA increases the ductility and decreases the bending strength of the final product.
✓ The decrease in the bending strength was much more drastic when using three parts of boric acid content keeping the PVA content constant. The result is in good accordance with the literature.
✓ If we investigate the SEM micrographs, we see that the samples without PVA and H_3BO_3 are in highly fractured non-crystalline form.
✓ The samples containing solely PVA display the formation of large holes with needle shaped PVA formations in SEM micrographs.
✓ The SEM micrographs also displayed that the additional boric acid causes the structure to assume a nearly homogeneous particulate form. The location of the small dimensional particles upon the holes greatly reduces the porous structure.
✓ The addition of two parts of excess boric acid causes the formation of narrow cracks and fractures. This is due to the reaction of the excess boric acid with the cations such as Ca^{2+} and Mg^{2+} present in the structure decreasing the flexibility and increasing the ductility of the final concrete polymer composite. This situation was also observed in micrographs and verified by the bending strength results.
✓ In the samples with two parts of PVA content without the presence of any boric acid resulted in 600–700 nm long cracks. However, the quality of final concrete is better than the one containing one part of PVA. This was verified with the higher compressive strength of the sample with higher PVA content.
✓ The SEM micrographs show that the particles turn into more spherical form as the PVA content is increased.
✓ The SEM micrographs clearly indicate that the fractured structure continued when the boric acid content at the fixed PVA content is not enough to eliminate the fractured structure.
✓ However, the porous structure was minimized when both the PVA and boric acid content are doubled. The result is a high quality concrete polymer composite with a very little porosity.
✓ Doubling the amount of PVA without boric acid has a very deleterious effect upon the final concrete resulting in a badly crystalline structure with 1 micron long cracks. The results of the three times increase in the boric acid content is even worse yielding a structure replete with almost micrometer long and wide cracks. These results are highly compatible with the literature.
✓ Therefore, there was an optimum concentration of PVA to be used without the boric acid.

- ✓ The cracks showed a marked decrease in porous where thre parts of both the PVA and boric acid yielding a nearly poreless structure with 500 nm diameter particles.
- ✓ In samples which have two parts PVA and three parts, boric acid has a negative effect upon the quality of the final concrete. This is due to the reaction of the excess boric acid with Ca^{2+} anions making the structure of the final concrete polymer composite highly ductile.
- ✓ The 2θ values in xrd analyses show the formation of calcite ($CaCO_3$), calcium silicate (Ca_2SiO_4) and magnetite ($Ca_{11.3}Al_{14}O_{32.3}$).
- ✓ The decrease of the peak densities in XRD graphs with increasing PVA content is the indication of the decreased crystallinity and formation of an amorphous structure which was verified by the SEM micrographs and decrease in the peak densities as the PVA content is increased.
- ✓ There are shifts in the xrd peaks of the boric acid containing samples. There is not seen in the PVA containing samples.
- ✓ The major peak of the boric acid was located at 29.53° in sample 1, 29.57° in sample 3, 29.67° in sample 4, 29.62° in samples 6 and 7 finally 29.62° in samples 9 and 10.

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Problems Encountered in the Life Cycle Assessment (LCA) of Recycled Materials in Construction

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Abstract. The establishment of sustainability credentials of emergent construction materials is very subjective, and most available tools such as BREEAM, CEQUAL, ARUP SpeAR among others are not fully quipped or equipped at all to deal with individual material systems. The main problem emanates from the challenges of the audit of each aspect of the material processing, and especially the quantification of the relevant transport, energy, environmental and other inputs into the composite product. Incorporation of materials with long and complex recycling processes further exacerbate the challenge. This paper reports on a simplified approach towards full Life Cycle Assessment (LCA) of seven clay-based brick products developed in UK and in Spain, based on known material data and estimated energy inputs in the manufacturing processes. In order to test the robustness of the proposed approach, results on UK-based bricks are compared with a parallel LCA on clay-based product developed in Spain. Finally, the clay-based products are compared with a typical Portland cement-based concrete block and fired clay brick. In the LCA, boundary conditions include fixed transport, thus attempting to factor only the (i) material ingredients, (ii) their known atmospheric emissions, and (iii) estimated energy inputs during processing. Results suggest that the most challenging aspect in the undertaking of LCA is the availability of reliable input data. Results also show that there are numerous parameters that can reliably and corroboratively facilitate the comparison of performance, besides carbon dioxide emissions.

Keywords: Clay · Life cycle analysis · Stabilisation · Soil · Cementation Sustainability

1 Introduction

Sustainability is a complex term to define in a sufficiently or practical way so as to make it operative and there are wide-ranging insights into sustainability and its practices [1]. It is a holistic, ambiguous, forward-thinking, global and normative concept. There have been attempts to achieve complex meshed tools for the assessment of

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sustainability, by using the many constituent characteristics of sustainability. For example, cross-border considerations have been meshed with local considerations, and these have been further meshed with qualitative and abstract approaches. Other additional layers include quantitative and specific aspects, future and present considerations, as well as individual meshed with conceptual aspects [2].

With these difficulties in definition and differences in perception, the Kyoto Protocol (1995) has resulted in pressure on societies, through respective governments, to have enhanced concern for the environment. This has resulted in a large number of initiatives and programs aimed at reducing the effects of human activities on the environment. The construction industry is one of the socio-economic sectors with the highest impact on the environment. With concrete being the third most used substance in the world after air and water, attention has quickly turned to soil-based materials for applications that do not necessarily warrant excessively strong binding. Soil stabilisation involves the utilisation of chemical binders such as lime and/or Portland cement, whose manufacture consumes large quantities of precious natural raw material resources and energy, and has other negative impact. The manufacture of modern Portland cement for example produces 600–1000 kg of atmospheric CO_2 per tonne of cement produced, depending on production process, accounting for at least 5% of man-made CO_2 emission in the atmosphere

Life Cycle Assessment (LCA) is one of the most used methods for evaluating a product's impact on the environment over its entire lifespan. The LCA method was developed to analyse the resources extracted and quantify the emissions related to a product over its entire life cycle [3]. The main characteristics of a LCA approach are that it includes a wide range of different environmental problems such as climate change, toxic effects, material and land resource depletion, and it has a holistic character which prevents the transfer of the environmental problem, and also prevents the solution of a particular problem deteriorating elsewhere in the lifecycle.

LCA provides valuable information that allows managers to make decisions aimed at improving the environmental performance of their products and/or services. In addition, it provides comparative and competitive advantages of different situations [4].

Although LCA is not aimed at individual material products, it still remains useful as a tool for environmental management, since it facilitates the identification of the source of a potential problem or concern, optimize resource use and manage waste produced, thus contributing to the decision making process between different sustainable materials [5].

When performing LCA, it is important and helpful to follow the international standard ISO 14040-series [6], especially when a company uses an LCA externally. Based on these standards, The International Reference Life Cycle Data System (ILCD) Handbook [3] provides recommendations on models and characterization factors that should be used for impact assessment in applications such as LCA.

In LCA methodology applied to products that include recycling materials, the most important decision is how to consider the environmental output of these materials. According to the new EU directive [7], some waste should be now considered as by-products and thus be affected by an allocation coefficient [5, 8]. There is an open discussion about the allocation process and new methods based on the market price of products and by-products are arising [8, 9]. However, when developing new sustainable materials, the origin of these inputs are not usually known, and for that reason one approach is set boundary conditions, enabling the consideration of only the processes that are needed to transform the inputs [5].

A big effort is being made in the search for new environmental-friendly materials through research and development activities in different areas such as (i) raw material substitution, (ii) clinker substitution, (iii) low carbon concrete production and (iv) recycling concrete among others, in order to meet target CO_2 emissions [9, 10]. There is potential inherent in industrial waste and by-product materials with embodied energy, such as Pulverised Fuel Ash (PFA or of fly ash) from the burning of coal, and ground granulated blastfurnace slag (GGBS) from steel manufacture, for exploitation in order to reduce consumption of Portland cement, and hence reduce the emissions [11–13]. In addition, the preference of clay-based materials for sustainable construction has increased.

In the search for more sustainable materials in order to meet global emission targets, numerous tools for the establishment and assessment of sustainability credentials of emergent construction materials have mushroomed. The advocacy for each tool has resulted in very subjective tools being available tools such BREEAM, CEQUAL, SpeAR among others. These tools are not equipped to deal with individual material systems, such as individual composite cement- or lime-based cementitious systems, including clay-based blocks and bricks. Mainly used for the rating of the environment credentials of master plans, the world leading tool developed in UK—BREEAM (Building Research Establishment Environmental Assessment Methodology) does not assess individual building units for buildings and infrastructure. CEEQUAL (Civil Engineering Environmental Quality) is another UK-developed award scheme that breaks down the three pillars of sustainability—social, economic and environment—to rate entire projects in a 10-step process to arrive at a pass, good, very good or excellent rating. In-house tools are not necessarily any easier. For example, ARUP's SPeAR (Sustainable Project Appraisal Routine) uses about 23 steps. Other more laborious tools include ENVISION, developed in the US and uses about 60 sustainability criteria. There is therefore very little research devoted to approaches for rating or assessing individual materials systems.

In the detailed assessment of individual materials systems or products, the main challenge results from the accurate audit of each aspect of the material processing, and especially the quantification of the relevant transport, energy, environmental (emissions) and the many other inputs into the sustainable product. There are however pockets of information, especially on embodied carbon, available depending on individual awareness of its availability. In the UK, Jacobs Ltd. have detailed data on embodied carbon of different materials for pipework. At the University of Bath, there is an inventory of embodied energy of about 200 different civil engineering materials.

Not all the available data is in agreement. Also, the variability in material ingredients, poses a significant challenge, together with the lack of key data for each material ingredients, especially for the emergent wide range of recycled materials. Key data such as on energy consumption and tally of emissions during production, creates major challenges. Incorporation of materials with a long history of processing during recycling further exacerbates the challenge. For example, the variable sourcing and complex recycling processes involved in the recycling of waste from plastics, tyres, glass, among other recyclables, sometimes creates unsurmountable challenges. These concerns for generally agreed end of life assessment pose further challenges and create bottlenecks to the confidence in the uptake of these emergent materials.

As overall sustainably eventually depends on consideration, and the uptake, of individual materials systems, a more focussed address of individual systems and products is needed. There is need to start developing widespread and more accurate or agreed material trails and data for input for pragmatic and robust whole life cycle analyses (LCAs) of individual products. This is more critical for composite materials that incorporate non-traditional constituents such as recycled wastes and by-products. Such emergent LCA approaches could help to facilitate the comparison of different alternatives for individual materials and products, for a global rating or point of view. These new LCA analyses could be devolved or simplified into generically agreed steps (LCA(I), LCA(II) etc.). For example, LCA(I) could be made, and generally agreed, to only refer to materials development from cradle to gate approach (see Fig. 1).

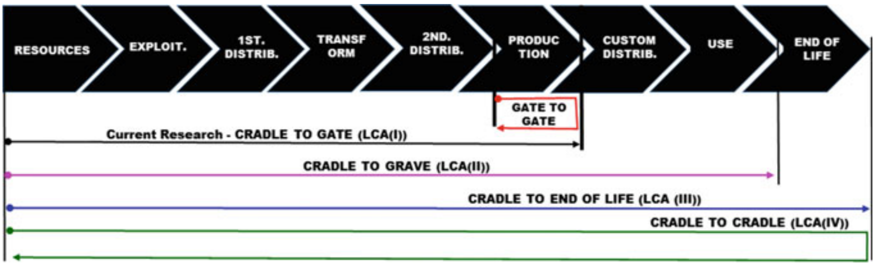

Fig. 1. LCA boundary conditions (based on ISO 14040 [6])

The results of LCA(I) could be used as input in further LCAs if necessary. Extension of data would lead to the next phases such as uptake for building construction and exploitation (cradle to grave) (LCA(II)) and even to the end of life phase (LCA(III)) and materials recycling phase (cradle to cradle) (LCA(IV)).

A few researchers have indirectly recognised the benefits of simple or devolved assessment tools as in enabling practitioners to obtain better selection criteria between different materials [14]. This paper reports on such a devolved approach towards LCA. The approach analyses three clay-based brick products developed in Pamplona, Navarre, Spain, based on known material data and estimated energy inputs in the manufacturing process. In order to test the robustness of the proposed approach, results are compared with four other clay-based products developed in the United Kingdom. Results suggest that it is possible to adopt and/or aim for a multi-pronged result in the undertaking of a holistic and meaningful LCA, rather than adopting a single parameter approach or consensus.

2 Materials

Seven clay-based products were selected for LCA, based on the authors' knowledge of not only their exact compositions but also of the basic information regarding their constituent ingredients. This knowledge is critical for a meaningful LCA. In addition, the awareness of the performance in terms of mechanical or other properties is essential, for the assessment of the likelihood and degree of success of their application, as well as for normalization of comparisons.

The three Spanish brick products all comprised of a marl target soil. This is a soft gray-colored fine clay soil where XRD analysis showed a mineralogical composition of 51% calcite, 20% illite, 15% quartz, 5% kaolinite, 5% attapulgite and 4% ankerite [15]. The soil was stabilised using three alternative cementitious additives, (i) Portland cement, (ii) a blended binder comprising of hydrated lime (CL-90-S) and GGBS, and (iii) Magnesium Oxide combined with GGBS. The magnesium oxide was obtained as a commercial industrial by-product (PC-8), produced as a waste from the industrial calcination of natural magnesite at 1100 °C [15]. The properties of the binders in the various clay products from Spain are shown in Table 1, while the mix designs for both Spain- and UK-based products are summarized in Table 2.

Table 1. Oxide composition of PC, PC-8, lime and GGBS (Spain)

Oxides (%)	Portland cement	PC-8	Lime (CL-90-S)	GGBS
$Ca(OH)_2$	–	–	>95	–
CaO	65	7.0		37
MgO	1	61.85		10
SO_3	4	5.51		0.23
Fe_2O_3	0.5	2.42		0.5
Al_2O_3	3	0.56		12
SiO_2	25	3.41		38

Table 2. Compositions of different products used in the LCA

Country	Product	Composition						Compressive strength (MPa)
		Target soil	%	Binder material[a]	%	Binder material[b]	%	
Spain[a]	1	Marl	90	PC	10	GGBS	0	11.1
	2		90	Lime	2	GGBS	8	11.7
	3		90	Magnesium oxide	2	GGBS	8	13.7
UK[b]	4		92	Lime	8	–	–	4.3
	5	LOC	90	Lime	3	GGBS	7	7.6
	6		90	PC	10	–	–	5.2
	7		90	PC	3	GGBS	7	5.7

[a]Seco et al. [15]
[b]Oti et al. [16, 17]

The four clay-based products developed in the United Kingdom (see Table 1) all targeted Lower Oxford Clay (LOC). It was supplied by Hanson Brick Company Ltd., from their Stewartby fired brick plant in Bedfordshire, UK. The composition of the LOC includes 23% illite, 10% kaolinite, 7% Chlorite, 10% Calcite, 29% Quartz, 2% Gypsum, 4% Pyrite, 8% Feldspar and 7% Organic material (Oti et al. [16, 17]). The LOC was stabilised using (i) Hydrated lime, (ii) Lime-GGBS blend, and (iii) Portland cement, and (iv) Portland cement-GGBS blend. The lime used was quicklime (calcium oxide), and was manufactured and supplied by Ty-Mawr Lime Ltd, Llangasty, Brecon, UK. Portland Cement (PC), manufactured in accordance with BS EN 197-1, 2000 [18], and supplied by Lafarge Cement UK, was used throughout this work. The GGBS used was in compliance with BS EN, 15167-1, 2006 [19] and was supplied by Civil and Marine Ltd, Llanwern, Newport, UK. For LOC and all these additives, Table 3 shows their oxide compositions.

Table 3. The oxide composition and other available data for LOC, lime, GGBS and PC (UK)

Oxide	LOC	Lime	GGBS	PC
CaO	6.15	89.2	41.99	63.00
SiO_2	46.73	3.25	35.35	20.00
Al_2O_3	18.51	0.19	11.59	6.00
MgO	1.13	0.45	8.04	4.21
Fe_2O_3	6.21	0.16	0.35	3.00
MnO	0.07	0.05	0.45	0.03–1.11
S^{2-}	–	<0.01	1.18	–
SO_3	–	2.05	0.23	2.30
SO_4	–	2.46	–	–
TiO_2	1.13	–	–	–
K_2O	4.06	0.01	–	–
N_2O	–	0.02	–	–
FeO	0.8	–	–	–
P_2O_5	0.17	–	–	–
Na_2O	0.52	–	–	–
CO_3	–	4.00	–	–
Soluble silica	–	1.10	–	–
Free lime	–	51.10	–	–

For the concrete block used as control, data available in ELCD data base [20] shows its main ingredients as being quartz sand (60–70%), cement (type CEMI) (20–30%), quick lime (10–20%), and gypsum (2–5%). The mineral residue is considered to be about 3.5%, and for LCA purposes may be handled as inert waste, reusable in the building industry. As an additional reference point, a fired brick has been included, and base data on energy production obtained in the authors' previous publications [21].

3 Methodology

The environmental impact evaluation of the Spain-based and UK-based clay bricks was carried out by a LCA approach using an Open access software 'Open LCA' using the European reference Life Cycle Database [20] that provides Life Cycle Inventory (LCI) data from EU-level business associations and other sources for key materials, energy carriers, transport, and waste management. The environmental impacts were evaluated according to the baseline method of CML01 [22] that analyses 10 environmental impacts (abiotic depletion, global warming, ozone layer depletion, fresh and marine water ecotoxicity, terrestrial ecotoxicity, human toxicity, eutrophication, acidification and photochemical oxidation). Among these categories, four of them have the greatest environmental impact: (i) Global warming (due to the CO_2, CO, CH_4 emissions), (ii) Acidification and (iii) Eutrophication (due to SO_2, NH_3, and NOx emissions), and (iv) Human toxicity (due to dust and SO_2 emissions). Using these impacts, four phases of assessment adopted in ISO framework [6] were used (goal and scope definition, inventory assessment, impact assessment and results interpretation).

3.1 Goal and Scope

The main goal of this study was to quantify the environmental impact of different clay-based construction materials, and to compare them with one clay-based and one non-clay based material. In order to avoid the complications of recycling a multi-ingredient product, with some of the ingredient being recycled themselves, cradle-to-gate LCA approach (that ends with production) was be applied. This simplified approach involves the journey from resources to the product stage, and avoids distribution, use and end of life issues in two different countries (UK and Spain). In addition, the following assumptions were taken into account:

1. A baseline target processing of 1 tonne of final product.
2. As this study includes materials from different countries (UK and Spain), no transport-based emissions were considered.
3. As all the products do not have equivalent mechanical performance and durability, a baseline performance rating based on the impact per unit strength gained (normalisation) was adopted.

Normalisation is a procedure that is an optional step in LCA [6]. This was made in the current analysis, so that different impact parameters could be standardised and a near global evaluation for each product could achieved. This normalisation allowed the comparison of the different materials. The normalization was based on the relationship between the emissions of the materials and the impact from all activities of a European citizen during one year.

- For energy, the data set represents the average specific electricity consumption during production. Main technologies for combustion, flue gas cleaning and electricity generation are considered according to the national or region specific situation.

- For Portland cement Data are based on cement plants which are representative for CEMBUREAU member countries [23].
- The brick production process includes the crushing of the clay, the mixing of all components and the compression to make the bricks. Power data are based on a mobile machinery from the Belgian company APPRO-TECHNO, S.A., so as to achieve commonality and an analysis that is independent of brick making facilities.

3.2 Inventory Analysis

The LCI for the materials are based on CEMBUREAU [23]; Habert et al. [12]; and on Oti and Kinuthia [21] and data extracted from the European Life Cycle Database (ELCD) [20] accessed on 26/09/2016. When no detailed data about materials input are known, the input considered has been the energy needed for its production. The inventory data on energy needed for production is shown in Table 4.

Table 4. Estimated energy used in obtaining the different materials

Binder	Energy (MJ/tonne)	Data source
Lower Oxford Clay (LOC)	525	Oti and Kinuthia [21]
Lime	4000	
Fired brick	4187	
Brick production	13	
Marl	400	ELDC (European Life Cycle Data Base) [20]
Concrete block	10,000	
PC	5000	CEMBUREAU [23]
GGBS	1300	Habert et al. [12]

3.3 Impact Assessment

The environmental impact evaluation of the Spain-based and UK-based clay products was carried out by a LCA approach using an Open access software 'Open LCA' using the European reference Life Cycle Database [18] that provides Life Cycle Inventory (LCI) data from EU-level business associations and other sources for key materials, energy carriers, transport, and waste management. The environmental impacts were evaluated according to the baseline method of CML01 [22] that analyses 10 environmental impacts (abiotic depletion, global warming, ozone layer depletion, fresh and marine water ecotoxicity, terrestrial ecotoxicity, human toxicity, eutrophication, acidification and photochemical oxidation). Among these categories, four of them have the greatest environmental impact: Global warming (due to the CO_2, CO, CH_4 emissions), Acidification and eutrophication (due to SO_2, NH_3, and NOx emissions) and ozone layer depletion.

4 Results and Discussion

4.1 Compressive Strength

Figure 2 shows the raw compressive strength data of the various brick or block products under investigation. The three marl-based bricks made in Spain had superior compressive strength within 10–14 MPa. In contrast, the four UK-based products based on LOC were within 4–8 MPa. In both UK and Spanish products, the highest strength values were recorded with the GGBS-containing products. The UK team set its target compressive strength based on the strength of the minimum design compressive strength values mentioned in the British Standard for concrete masonry units—2.8 N/mm^2 for blocks and 7 N/mm^2 for bricks (BS 6073-2:2008) [24]. The equivalent strength referred to for fired clay units is far higher, being a minimum of 75 N/mm^2 for clay engineering bricks Class B, and 125 N/mm^2 for Class A (BS EN 771-1:2011) [25]. The Spanish team did not work to any known target strength, and aimed at maximal strength achievable using the target materials and what they considered reasonable binder content range. The current work therefore selected mix formulations that are of comparable binder content levels of 8–10% replacement level for both lime- and PC-based formulations. It is because of the resultant strength differences that all impact parameters were normalised, so as to evaluate impact per unit strength gain.

Based on the various compressive strength values, the raw LCA data was normalised in order to show impact per unit strength. Six parameters that were considered representative of typical impact were selected to facilitate the comparison between Spain- and UK-based products, relative to two common materials controls, (i) a typical high density concrete block (CB) and (ii) a typical fired clay brick (FCB). The selected parameters are acidification potential (SO_2), climate change (CO_2), depletion of fossil fuels (MJ), eutrophication (PO_4), depletion of the ozone layer depletion (CFC), and terrestrial ecotoxicity (equivalent 1, 4 dichlorobenzene).

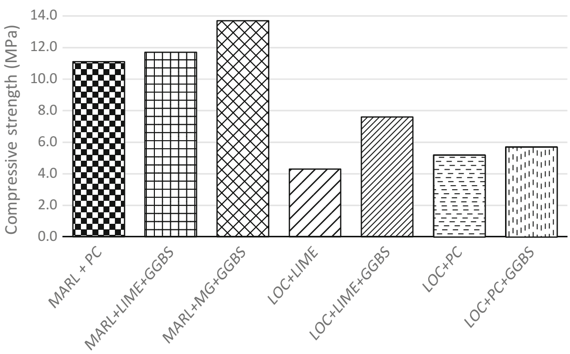

Fig. 2. Unconfined compressive strength (MPa) of the various brick/block products from Spain and UK (CB and FCB are controls)

4.2 Acidification Potential (SO_2 eq.)

Acidification is associated with the increase of heavy metals in solid, and surface waters, and hence in plants, and is associated with pollutant components. It is assessed with reference to SO_2. The known acidification potential of a selected sample of substances is illustrated in Table 5. For the materials under investigation, Fig. 3 shows acidification impacts (kg SO_2 eq.) values per unit strength respectively, for the different products.

Table 5. Acidification potential of selected substances

Substance	Acidification potential (kg SO_2-equiv./kg)
SO_2	1.00
NO	1.07
N_2O	0.70
NO_x	0.70
NH_3	1.88
HCl	0.88
HF	1.6

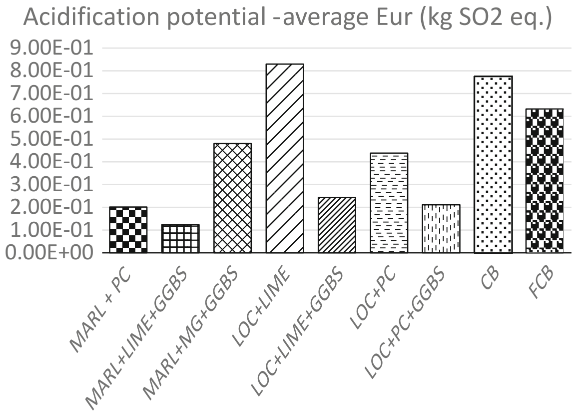

Fig. 3. Acidification potential (SO_2 eq.)

Absolute acidification emanating from the concrete block (CB) is the most significant, followed by the Mg-containing product from the Spanish products range. However, when the strength results are factored (as presented in Fig. 3), the high strength of the Mg-based product favours the outcome, and the most concerning product is the UK-product made using clay and lime (without GGBS). Although the absolute acidification of this product (LOC-Lime) is moderate, it shows worse outcome relative to the two controls (CB and FCB) due to the superior strength performance of the latter. It is therefore preferable to replace some of the lime using GGBS during soil-stabilisation (as suggested by test results or both marl and LOC), for all-round good performance and environmental friendliness.

4.3 Climate Change (CO_2 eq.)

Figure 4 shows the effects of climate change based on equivalent CO_2 from the manufacture of the various Spanish and UK-based cementitious products. From both the normalised CO_2 emission values presented, the researched products in both countries performed far better than the concrete block and fired clay brick product. In the researched products, the highest emission level was from the PC-based products—Marl-PC from Spain, and LOC-PC from UK. Once again, the GGBS-containing products demonstrated superior environmental benefits. By combining GGBS with the MgO industrial waste, one of the best all-round performances was observed. Overall, GGBS appeared to impart better improvement on lime-based formulation than on PC-based formulations.

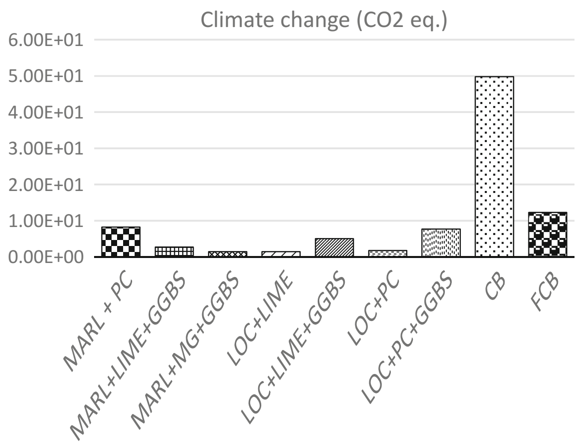

Fig. 4. Climate change (CO_2 eq.)

4.4 Depletion of Fossil Fuels (MJ)

The consumption of precious natural raw materials resources is a major concern and consideration in the realisation of economic development. Figure 5 gives an indication of the depletion of fossil fuels in the manufacture of 1 tonne of the cementitious products developed in both Spain and UK in the current research study. It is reassuring to note that the control traditional products (concrete block and the energy intensive fired clay brick both show highest depletion levels. Of the researched products, highest depletion was shown by the use of LOC with lime (LOC-Lime). This was mitigated by replacing some of the lime with GGBS in LOC-Lime-GGBS, which performed better than LOC-PC per unit strength achieved. All the Spanish products performed very well per unit strength achieved. The differences between the well-performing Spanish and UK products is thought to be due to minor differences in processing stage. For this reason, the data presented should be aimed and interpreted to as showing the most obvious differences, and minor differences between trends/products should either be ignored and/or interpreted with caution.

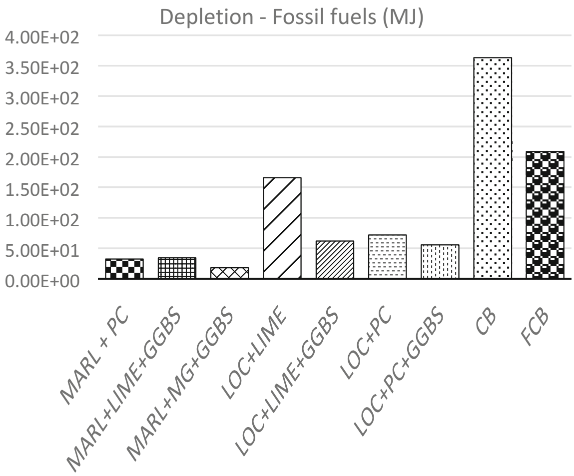

Fig. 5. Depletion of fossil fuels (MJ)

4.5 Eutrophication (PO_4 eq.)

Eutrophication is a measure of the depletion of oxygen in water masses. This can be caused by unwanted growth in water masses due to provision nutrients. The decay of biomass consumes dissolved oxygen, and thus negatively impacting on aquatic life-forms. Excess nutrients can be produced from sources of excess phosphates, and thus eutrophication is commonly assessed by monitoring the levels of residual equivalent phosphate (PO_4 eq.). Industrial run-off can be a contributor to eutrophication, and thus monitoring PO_4 levels can provide a tool for the assessment of whole life cycle environmental impact of industrial activities such as material manufacture as in the current research study. Figure 6 shows the eutrophication levels resulting from the assessment of the Spain- and UK-researched products, relative to the two control products of concrete block and fired clay brick.

The UK-based products made using the traditional binders of lime and Portland

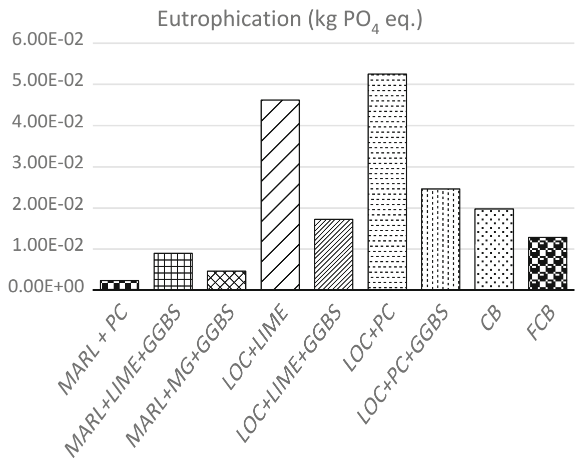

Fig. 6. Eutrophication (PO_4 eq.)

cement were observed to show highest levels of eutrophication per unit strength. Incorporation of GGBS mitigated this negative effect. The concrete block and fired clay brick showed low eutrophication levels, due to their higher strength development and hence superior binding of phosphates.

4.6 Ozone Layer Depletion (CFC eq.)

Depletion of the ozone layer is associated with global warming, due to the accumulation of greenhouse gas (GHG) effect. The GHG gases are established relative to the much more polluting, but less prevalent, chloro-fluoro carbons (CFCs). Figure 7 shows the indicative effects of the researched products on the ozone layer depletion, relative to the damage by the concrete block and fired clay bricks. Once again products incorporating GGBS showed best performance, which was further enhanced by addition of the MgO industrial waste. Use of lime or PC on their own as binder materials showed worst performance. This confirms the now well-establish fact that traditional binders, particularly Portland cement, is very damaging to the atmosphere.

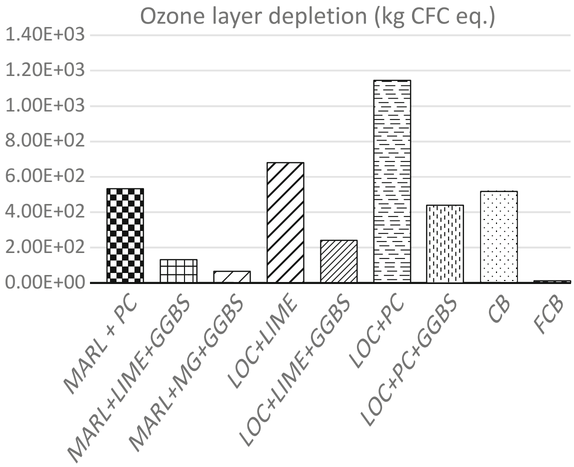

Fig. 7. Ozone layer depletion (CFC)

4.7 Terrestrial Ecotoxicity (kg 1, 4, Dichlorobenzene eq.)

Toxins are formed as unintentional by-products of many industrial processes. The more harmful toxins (dioxins) mainly emanate from industrial processes involving the production of chlorine, although natural process such as volcanoes and forest fires, among other processes are also known to produce dioxins. 2,3,7,8-Tetrachlorodibenzodioxin (2, 3, 7, 8-TCDD) is one of the most potent poisons in the dioxin family, classified by the World Health Organisation (WHO) as class one carcinogen. Apart from cancer, even at levels many times lower than those associated with cancer, dioxins are suspected to cause severe human developmental problems including lower sperm count, behavioural problems, immune system damage, among other negative impact. In the current LCA, 1, 4 dichlorobenzene equivalent is used in assessing the processes for the manufacture of 1 tonne of the Spanish and UK products. Results on terrestrial ecotoxicity presented in graphical form in Fig. 8 show that the use of the traditional binder materials to stabilise both the Spanish soil (marl) and the UK clay (LOC) was observed to show the highest ecotoxicity (Marl + PC; LOC + Lime; LOC + PC). Their poor performance is however lower than the ecotoxicity levels of the concrete block. It is therefore significant to note that both the extraction of aggregates, and binding them with the material sapping, energy-intensive Portland cement, results with highest potential ecotoxicity for the materials considered in the study. The high ecotoxicity can be exacerbated by use of waste in the manufacture process (waste tyres, municipal waste among others), as incineration is also well-known for its share contribution in ecotoxicity.

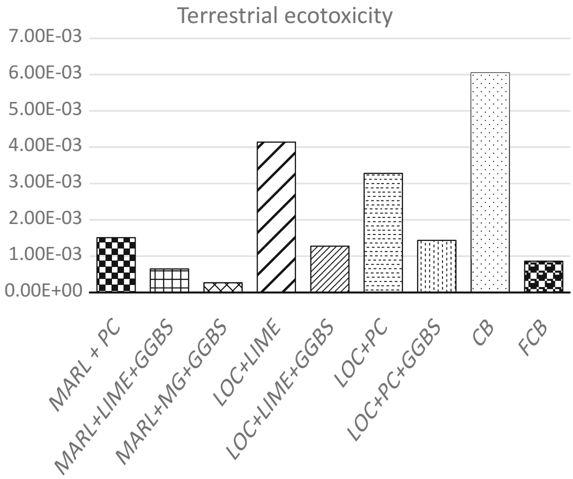

Fig. 8. Terrestrial ecotoxicity (kg 1, 4 dichlorobenzene eq.)

5 Conclusions

The results presented in the current study have confirmed that the establishment of sustainability credentials of emergent construction materials is very subjective. For this reason, most available tools such as BREEAM, CEQUAL, ARUP SpeAR among others may not necessarily be fully quipped or equipped at all to deal with individual material systems, such as composite cement- or lime-based cementitious systems, including clay-based blocks and bricks. From the work reported in the current study, the following conclusions may be drawn:

1. The preference of clay-based materials for sustainable construction is justifiable. All the parameters used in the current study have shown that the clay-based materials performed better, per unit strength achieved, than the concrete block. The extraction of aggregates, followed by their binding using the materials sapping and energy-intensive Portland cement is perhaps the worst combination in terms for sustainability.
2. Unfired clay systems are further justified, compared with fired clay bricks. While recognising that the unfired systems have much lower performance compared to the fired counterparts, the far higher environmental credentials of the unfired system suggest that more work is needed to identify scope of applicability and limitations of the use of the unfired systems, so as to adopt complementary and synergistic action between the two systems rather than in antagonistic or competing operation.
3. The use of natural, industrial and agricultural waste and by-product materials for partial or whole replacement of the traditional binder materials of lime and/or Portland cement is of significant impact. The impact of this endeavour should not be underestimated. All the parameters used in the current study show over-whelming evidence in favour of this development, despite all the work being a modest replacement level of only 10%. The potential benefits with higher replacement

levels of the order of 40% and above can cumulatively be a game changer for future socio-economic development.

4. The most challenging aspect in the undertaking of LCA is the availability of reliable input data. The main problems emanate from the audit of each aspect of the material sourcing and processing, and especially the quantification of the relevant transport, energy, environmental (emissions) and other inputs into the composite product. The variability in material ingredients, and lack of base data (emission, energy etc.) for each aspect of the processes involved creates major challenges. Incorporation of materials with long and complex recycling processes further exacerbate the challenge.
5. There is agreement by all the parameters plotted, unanimously suggesting that researchers have many options in parameters for establishing environmental performance depending on capacity, capability, and individual discipline and expertise. Despite all the problems associated with the availability or reliable input data, results show that numerous parameters can reliably be used to assess and to compare different products with/without overemphasis on atmospheric carbon dioxide emissions. The different parameters can be fine-tuned to corroborate different aspects of products manufactured under different conditions, as a way round variable sourcing and complex recycling processes involved in recycling.

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Sustainable Architecture and Energy Efficiency a University Campus Project in Fez City, Morocco

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Abstract. The building sector happens to be a major player in climate change through energy consumption and greenhouse gas emissions. At the same time, the climate change impacts negatively buildings by reducing thermal comfort. To reach this comfort buildings need energy. This situation makes building sector among the most energy consuming sectors. Thus, the challenge is how to adapt buildings to climate change by being energy efficient, and by producing their own electricity. Environmental and energy issues have been a topic of growing concern in Morocco which is endowed with high potential for renewable energy resources, but not yet very well exploited in the building sector. Today the country realizes that and takes its first steps toward sustainable development through several initiatives and measures developed by the government. However, increasing environmental awareness among citizens can be crucial to adapting and reducing climate change, by encouraging people to change their perceptions and behavior. Therefore the educational system and its environment can be the most effective way to promote lasting ecological citizenship among college students. The present paper analyses the impact of the human and social dimensions of sustainable development and proposes a university campus architectural project. The main objective of the paper is to provide favorable conditions for studying and to encourage universities and educational systems to integrate sustainability into their teaching and especially into their functioning. This project aims to introduce construction techniques that ensure better thermal comfort and help lowering building energy consumption.

Keywords: Sustainable architecture · Energy efficiency · Student housing Architecture project

1 Introduction

Nowadays, with the rapid growth of the world population, the pressures on the environment are steadily increasing. Moreover, the depletion of natural resources of the planet and the effects of increased greenhouse gas emissions that include global warming and the loss of biodiversity are constantly growing.

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In its 5th report of 2014 [1], the Intergovernmental Panel on Climate Change (IPCC) reports that the greenhouse gas emissions are resulting from human activities, mostly energy consumption and production that result in global warming. The buildings sector is the largest energy-consuming sector, accounting for over one-third of final energy consumption globally; The supply of energy to buildings alone accounts for about 33% of global carbon dioxide emissions, the buildings also consume approximately 60% of the world's electricity according to the United Nations Environment Program.

The effects of climate change vary considerably across regions. The most vulnerable regions of the world would be the least developed, either because of their exposure to climate change risks or because of their very limited capacity to cope with climate variability. According to a study on climate change and energy in the Mediterranean carried out by the European Investment Bank, countries bordering the Mediterranean are particularly affected by climate change more than most regions of the world during the 21st century. As a part of it, Morocco is a country poorly endowed with fossil energy resources that depends on 97% from abroad for its energy supply [2].

Paradoxically, Morocco is potentially endowed with sustainable energy resources and today the country is becoming aware of it and wants to take a lead in adapting and reducing climate change since its participation in The Rio Conference in 1992 and recently during November 2016, Morocco hosted in Marrakech the 22nd session of the Conference of the Parties (COP 22) of the UNFCCC (UN Framework Convention on Climate Change). It has set a target to reduce its energy expenditure by reducing energy use especially in buildings sector which is one of the most energy consuming sectors in the country. In 2014, Morocco has adopted the thermal regulation on the energy performance requirements for buildings [3].

2 General Statements

Morocco has recently faced many problems related to the scarcity of natural resources and environmental pollution: Primary energy consumption increased considerably between 2004 and 2010 for all final consumer sectors [4] (transport, industry, residential and tertiary buildings) according to the report on energy efficiency indicators in the Mediterranean countries.

2.1 The Reality of Climate Change in Morocco

Morocco is heavily impacted by climate change. It is experiencing increasingly frequent and severe weather events, including high and low temperatures: Rainfall anomalies especially the regression on annual rainfall and erratic precipitation; low rainfall and recurrent drought accompanied by an increasing demand for water and constantly increasing temperature.

As a reminder, Morocco is facing numerous vulnerabilities to climate change because of its geographical location in one of the driest places on Earth. Its vulnerability is also due to the fact that the country's economy is heavily dependent on natural resources and sectors that are highly sensitive to the adverse impacts of climate change, such as agriculture, coastal resources, water resources and forest resources. The country has therefore put in place strategies for mitigation and adaptation to climate change that are compatible with its sustainable development policy.

According to the second national communication to the United Nations Framework Convention on Climate Change elaborated in 2010, the projected climatic conditions throughout the 21st century (Fig. 1), an average reduction in precipitation could reach 60% compared to the period 1961–1990. Climatic projections for Morocco also concern the continued worsening situation (Fig. 2), with temperatures rising from 0.6 to 5 °C compared to the period 1961–1990.

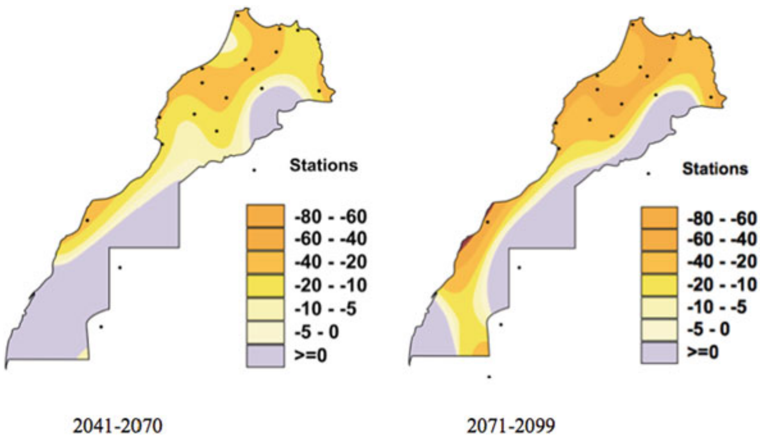

Fig. 1. Expected reduction in precipitation for Morocco

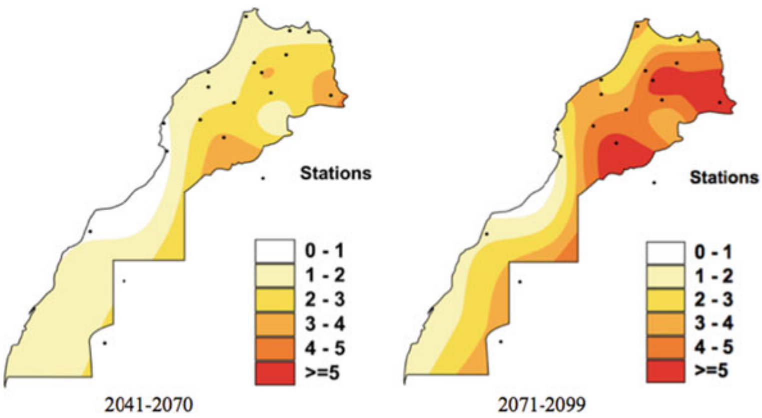

Fig. 2. Expected temperatures increase

2.2 The Impact of Climate Change on the Built Environments

Because of population growth contributing to the strong demand for housing, Morocco is currently experiencing rapid urbanization that has a dramatic effect on the increased demand for energy and on environmental degradation. Indeed, the building sector in Morocco does not take any measures to reduce the effect of climate change on the indoor climate of buildings, which result in higher energy consumption during building use related to heating, air conditioning, lighting, cooking, ventilation, etc.

Nevertheless, the built environment must play a crucial role in the fight against climate change as it is responsible for CO_2 emissions. Reducing energy use in the buildings can increase energy security and reduce dependence on imported fuels, while also reducing or eliminating greenhouse gas emissions.

The buildings are facing multiple effects of climate change, including increased heat, more frequent strong winds, floods and forest fires that accompany other extreme weather events. The buildings have already undergone several damages in the last decades.

Regarding the rising temperatures and heat waves during the summer months, the phenomenon of global warming is exacerbated by the heat energy generated by the urban metabolism and human activities, it results in the phenomenon of urban heat island. This requires the use of different approaches for new constructions.

2.3 The Building Energy Consumption

Morocco is experiencing an increase in energy prices that causes an increase in the Moroccan household expenditure. According to a survey of Moroccan households presented in 2012 by the National Observatory of Human Development, the average expenditure per person increased by 50% in ten years. Monthly housing and energy costs engage one-quarter of the household budget on average.

On the basis of this observation, the housing sector has a great potential for further energy efficiency improvements, through the adoption of the new General Building Regulations setting the rules for energy performance. The purpose of this regulation is to ensure thermal comfort and enhance energy performance in buildings. For this reason, it becomes necessary to increase general awareness of environmental choices that could give economic benefits. The success of environmental projects depends on people's ability to take control over their energy consumption and change their behavior in order to support effective policies. There are many ways of raising awareness for the environment, such as the media, brochures, television films and posters. However, the education sector remains one of the most effective ways, because not only does it raise awareness, but it provides tools and methods to translate principles and concepts to good practices.

3 Paper Objectives

Energy efficiency in buildings or thermal comfort are still far from being achieved since people's habits and constructive modes don't follow any innovative ecological approach. Moreover, thermal comfort is an old subject that goes back a long time, our ancestors considered the climatic environment of a building as an asset to be valued rather than as a constraint to be overcome. They considered the building as a dynamic object interacting with its surrounding environment. Thus, their bioclimatism was based on the understanding of thermal phenomena and led to simple solutions for self-sufficient buildings that rely solely on themselves for heating cooling.

The most important thing to learn from our ancestors bioclimatic architecture is the case-by-case study of each building's environment before implementing any bioclimatic solutions. That is, the situation may vary depending on the external environment. The situation can sometimes induce double glazing as it can be completely not recommended at other times for instance. Taking into consideration all other aspects of inertia, solar radiation management and ventilation can be a great solution to thermal comfort in buildings.

Since 2014, Morocco sets a thermal regulation for buildings in order to optimize their needs for heating and air conditioning while improving their thermal comfort. Some of the strongest points in this regulation are taking into consideration the building envelope and its thermal losses, in addition to the geographical location and the outdoor temperature according to the climate zone. The design of the building envelope should also take into account the opportunities that can be created for the efficient operation of lighting, cooling and heating systems through design of the building skin for daylighting, natural ventilation and solar control.

After presenting the specific context on Morocco in relation to climate change and the concept analysis of sustainable architectural design, the paper is focusing on the design of an architectural project according to the results of the analysis.

4 Project's Concept and Context

4.1 Project's Main Vision

Education is critical for achieving environmental and ethical awareness, values and attitudes, skills and behavior consistent with sustainable development and for effective public participation in decision-making. Therefore, educational institutions must embody, through their design and practices, the world they wish to contribute to create. Hence the idea of the project includes an institution of higher education: A project that will use Moroccan thermal regulation and environmental impact to propose an educational, ecological and sustainable space of living.

The higher education sector in Morocco is suffering from lacks cultural, commercial, residential and sports Generally, each university ensures only a minimum of equipment for students. Consequently, as soon as the students leave their institution, they become disoriented in a world that doesn't gather open and communicating universities to offer the necessary services related to student life.

Creating a sustainable campus that reduces our impact on the environment will build a live learning place for staff and students and will also help to overcome the crisis of student housing. This project with a double ecological and pedagogical vocation will help to introduce new methods and ways of lifestyle and decision-making, because it is through higher education that we can actually train eco-citizens, the decision-makers of tomorrow.

4.2 Project's Site

The choice of Fez city (Fig. 3) was made because of its mainly temperate and varied climate: Very hot and dry in summer and relatively cold and humid in winter. And also because the city has a rich and varied urban fabric represented on one side by the Medina and on the other by the modern city.

The proposed site is located in the urban expansion zone to the southeast of the city, at the crossroads of a number of universities in the Sais cluster area, in order to meet the challenges facing the students regarding housing, catering and proximity services.

The university campus in this site aims to break the isolation of higher education institutions, by creating a student space open to the city that will revitalize the Sais cluster, strengthen the restructuring of higher education in Fez and provide training Necessary for ecological transition through its integration of climate resilience.

Fig. 3. Morocco map showing the location of Fez city

The project is located in a peripheral zone (extension of the urban area), where agricultural areas and the forest domain are under tremendous pressure (Fig. 4). Therefore, the project aims to be an ecological model and serve as a showcase for quality urban expansion, where existing plantations should be maintained. This project is in this site to make known construction techniques that guarantee a better thermal comfort without resorting to energy intensive air conditioning.

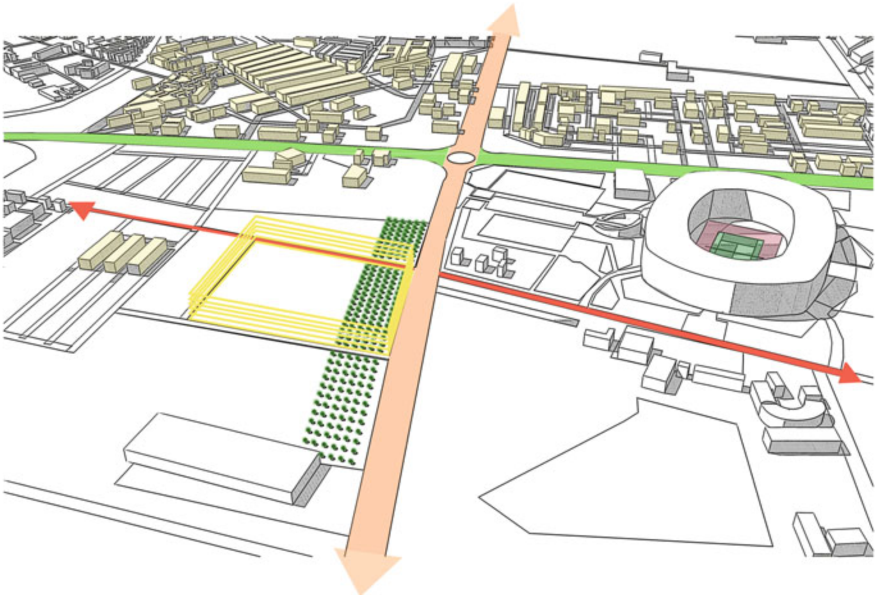

Fig. 4. Location of the chosen site

4.3 Design Process

The project [5] aims to design and build a university campus in a particular physical and natural environment, it plans to maintain forest continuity on the entrance to the site, in order to ensure a perfect integration of the project into the existing natural landscape units. The project intends to present a strong functional mix, notably through the creation of a multifunctional building and through the development of public spaces with waterpoints, gardens and spaces for animation.

Regarding the parking, the project incorporates a parking facility covered with an entirely green roof terrace to help solve the increasing parking problems in the area and to limit the impact on the environment and landscape through compensating for green areas lost to this development.

The architectural design of the buildings in this project is shaped according to the climatic conditions and the building function. The building's primary function (student housing) takes form through several rooms juxtaposed in the shape of bars.

The buildings features two symmetrical bars built around an inner courtyard to form compact blocks.

The dimensions of this internal void are proportional to the height of the building (the height of the building is equal to or greater than the width of this void) to obtain moderate microclimate from the buildings and their geometry. The rounded shape of the building, the orientation to the south, and a suitable H/L ratio will maximize solar heat gains and reduce heat losses in winter (Fig. 5).

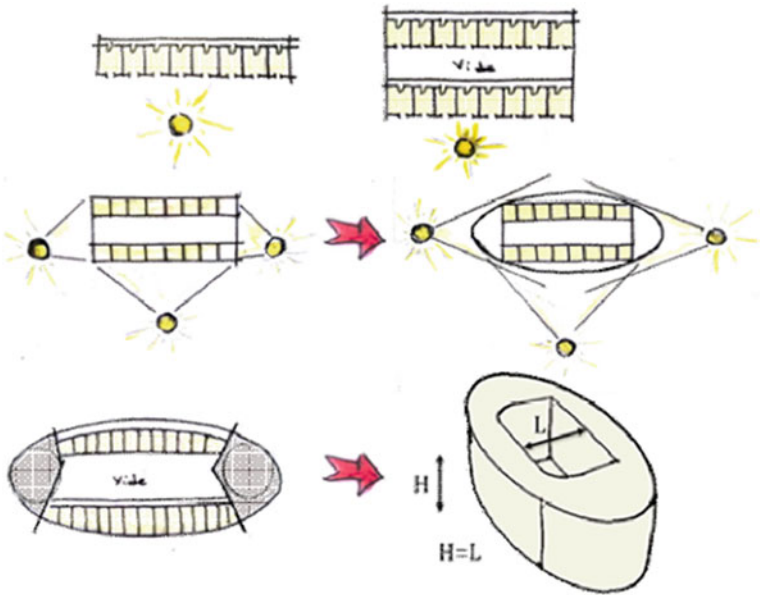

Fig. 5. The building design process

4.4 Project's Program

The large plot of 8 ha devoted to the operation is to be developed into four student housing buildings featuring five-storey residential component, and a mixed-use building (Fig. 6).

The mixed-use building is located at the entrance of the campus with an ambitious program mixing uses in an elliptical floor plan. The building offers a number of leisure activities, catering, cultural and thematic activities to students. A design concept with all the activities arranged around a central space of an open patio dedicated to vertical and horizontal circulations.

The building will consist of four stories and will include, among other cultural equipment, an administration at the entrance to the ground floor, an exhibition hall, an amphitheater, a library, a university restaurant, an indoor swimming pool and a gymnasium, in addition to a hotel with an affordable price for families coming from afar to visit students.

Fig. 6. The project master plan

The project includes 664 student accommodation units, with two types of rooms (double and single for people with disability), with a total capacity of 1320 students. Each building has a central courtyard that allows natural ventilation.

Illuminated corridors on the north façade give direct access to the dwellings. Both sides of the block are irrigated by a vertical cage and a common space for studies, while all the dwellings benefit from orientations of the same quality (Figs. 7 and 8).

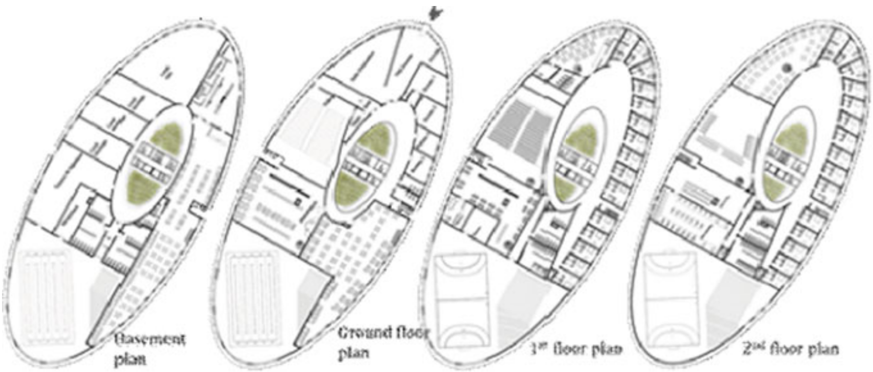

Fig. 7. The mixed-use building floor plans

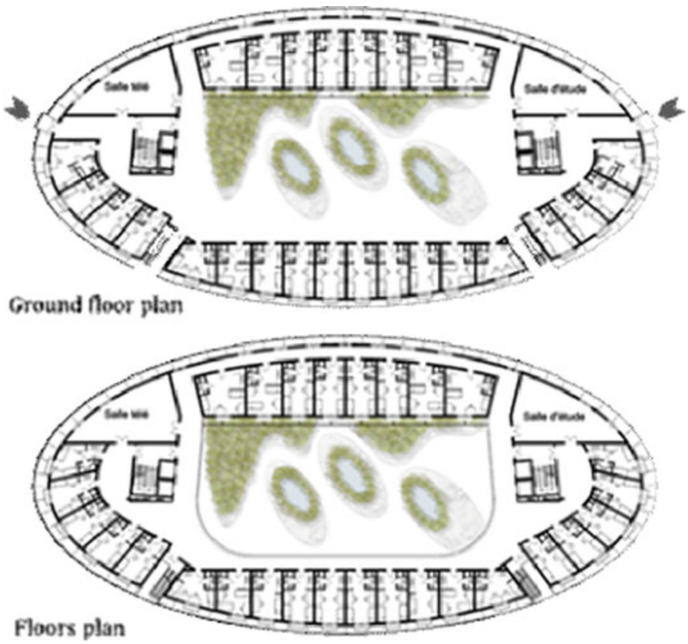

Fig. 8. Student accommodation floor plans

The external fittings in this project want to compose at the same time a place of relaxation and walk, a playground, a picnic area and an outdoor reading room (Fig. 9).

Fig. 9. Exterior view showing relaxation space

5 Bioclimatic Concept

5.1 Sunlight and Orientation

Reflections on the solar insolation at the site, angle and orientation of buildings, and shading led to an arrangement that adapts to the daily sun path (Fig. 10).

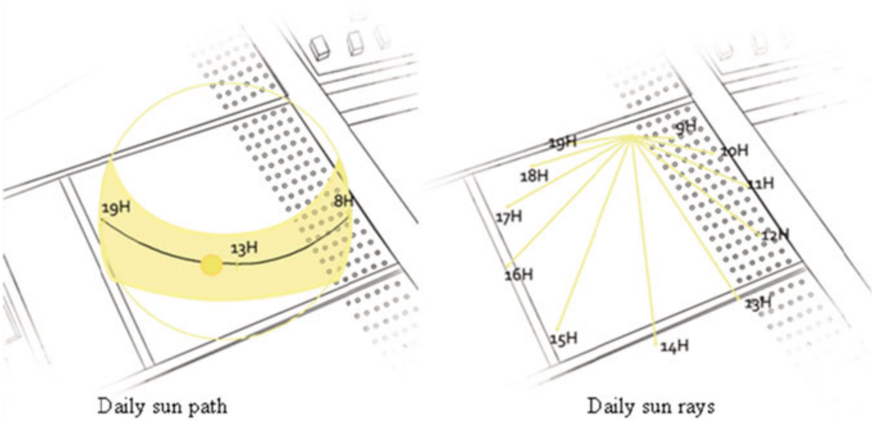

Fig. 10. Daily sun path and sun rays

The project involves four student housing buildings with a north-south orientation, in order to maximize solar heat gains in winter. While other fixed solar protection will be installed to reduce solar heat gain in summer, taking account of the height of the sun in the sky during the year.

5.2 Project Implementation

In this distinguished setting, the project wants to make a difference in the student's daily life and sustainable development through the integration of environmental protection and improvement requirements, and intend to capitalize on the site's resources by maintaining the existing plantations. These will act as a buffer zone to fulfill several functions: improving the visual and aesthetic quality of the landscape; reducing noise and pollution caused by traffic on highway, and increasing natural areas that create shade, reflect heat and reduce urban heat-island effects.

5.3 Thermal Comfort

In the winter, it draws heat from outside and brings it into the house and in the summer it does the opposite in order to achieve the human comfort objective. For this purpose, simple solutions have been implemented, inspired by the traditional know-how among building craftsmen and the ancient bioclimatic techniques.

Firstly, the patio, which is an inner courtyard and a solution for natural lighting and ventilation, is well suited to the warm and semi-arid climate and acts as a thermal “buffer” between the living space and outside air. Secondly, the modern moucharabieh which serves as a second skin of the building. This device often used in traditional Arab architecture serves to condition the air naturally by the reduced surface of its mesh which accelerates the air flow and refreshes it, creating drafts that act positively on comfort. Horizontal fixed shading devices are also installed to reduce direct solar gain in summer.

The double skin facade is a system that gives an effect of pointillistic light, whose shape is inspired by the organic form of buildings (Fig. 11).

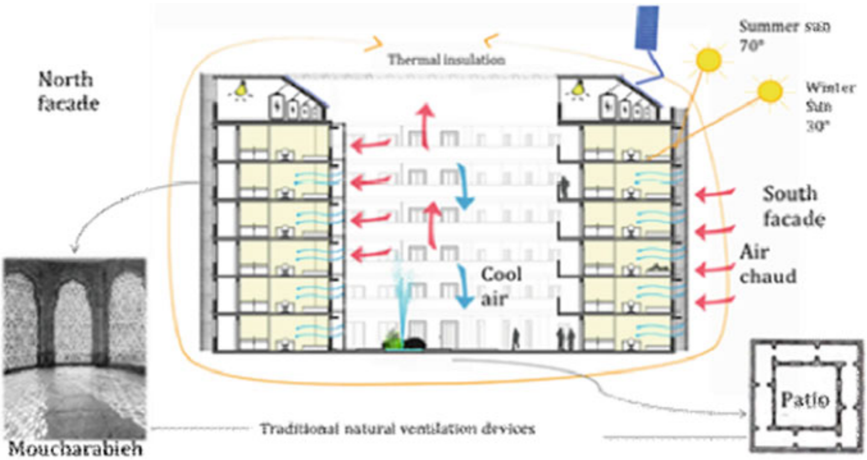

Fig. 11. Section showing bioclimatic design principles

This skin acts as a solution for privacy and sun protection and contributes to coherent facades. A reinterpretation of oriental moucharabiehs, it lets the light enter by forming delicate shadows on the ground. Aesthetic, game of shadows and modernization of the building, this lace wants also to provide thermal comfort and improved air quality for the occupants.

5.4 Energy Efficiency Evaluation

With an overall bay windows rate of less than 45% in both types of buildings, we have the possibility to respect the Moroccan thermal regulation in buildings according to the prescriptive approach [3], which is a very simplified method using the following coefficients: the U value and the overall rate of the bay windows (TGBV).

The thermal regulation for buildings in Morocco is focusing on the building envelope. Technical specifications will help choose adequate equipment according to the maximum values not to be exceeded in the climatic zone 3 represented by Fez region.

Maximum values for TGBV 25% and TGBV 32%:

Uwall = 0.8 W/m^2 K and Uwall = 0.7 W/m^2 K
Uroof = 0.65 W/m^2 K and Uroof = 0.55 W/m^2 K
Ubaywindow = 3.3 W/m^2 K and Ubay window = 2.6 W/m^2 K

The exterior walls consist of two skins allowing to have a thermal insulation and a filter of air and light each. The first wall is a wall double partition consisting of an external plaster + brick 8 holes of 7 cm + an air space of 10 cm with 4 cm of an insulation material + brick 8 holes 7 cm + an internal plaster. The project U value is 0.51 W/m^2 K less than Uwall.

Regarding the roof, the first type used is an ordinary joist slab with insulation. The second type of roof is a green roof made up of a concrete slab of 20 cm + thermal insulation + a waterproof layer and a draining layer + a layer of culture of 10 cm. The project U value for this case is 0.38 W/m^2 K less than Uroof. The green roof reduces significantly the heat transfer coefficient and is therefore more efficient than a simple roof (Fig. 12).

Concerning the bay windows, we opted for a double glazing 4/10/4 with thermal transmission U = 3 W/m^2 K and 70% for the solar factor (Fig. 13).

Fixed solar protections are also installed, sized according to the different solar heights. Thus, the building adapts to the seasons, in the summer, horizontal sun protection reduces the entering sunlight, while in winter the size of the openings and their orientation allow the maximum amount of light to penetrate inside the building.

The diagnosis of energy performance in the two buildings was carried providing technical sheets of compliance with the building thermal regulations in Morocco and according to the recommendations obtained by the use of Mahoney tables and Szokolay bioclimatic diagram.

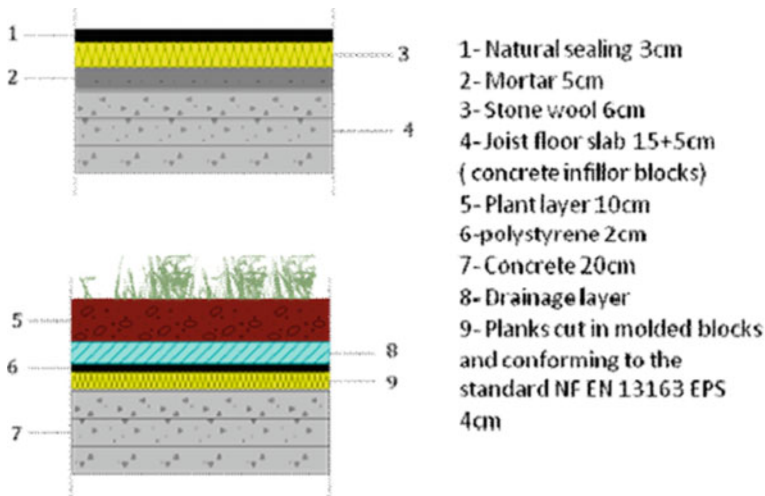

Fig. 12. Composition of roof assemblies

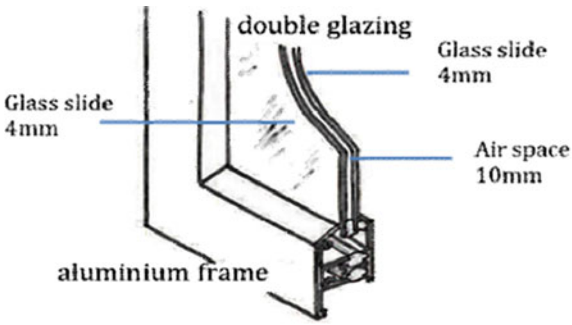

Fig. 13. Double glazed window

5.5 Solar Electric Self-production and Energy Control

In this project, electricity production is provided by roof-mounted photovoltaic solar panels, the main use of which would be to supply general services such as lighting, hot water and elevators etc. While surplus production could be resold to benefit the nearby social housing. The project also wants to find a way to encourage students to collectively control their energy consumption by visualizing collective consumption in the hall of entrance to the building and by using other methods such as reducing their energy bill in exchange for collective control of energy expenditure.

The surplus photovoltaic electricity produced after consumption can also be used poetically in luminous installations and luminous trees on site, in order to enhance the collective energy control and promote the production of electricity on a small scale using renewable energy sources.

6 Conclusions

Since temperate climates in Morocco do not offer sufficient climatic conditions to ensure thermal comfort throughout the year, it becomes necessary to improve the climatic ambiance by heating or cooling buildings. The problem of thermal comfort is often neglected in urban areas, while a bad urban climate directly and negatively influences the use of urban spaces and indirectly the thermal comfort inside buildings. The urban climate may be influenced by some factors including geometry of buildings, orientation, vegetation, pollution, thermal properties of materials and activities producing heat.

It is possible to obtain a better match between the climate, the building and the behavior of the occupant, if an energy-conscious approach to the design of the building is used. Energy saving, thermal comfort of users and respect for the environment are now factors to consider as well as the costs of buildings and their robustness. These new concerns should avoid energy crises and be an important driver in the building sector.

Generally, it remains difficult to define a perfect sustainable architecture suitable for a hot and dry climate. However, it is possible to improve the thermal comfort from an architectural design adapted as much as possible to the climate, and the use of insulation materials.

The urban and architectural concepts adapted to the climate are part of the strategy of sustainable development and respect the environment and aim to limit the climatic constraints to which the inhabitants are exposed in an urban environment. This climate adaptation needs to be studied both at the level of the urban plan and the plans of construction since the typology and the urban morphology are closely linked.

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Examination of Biophilia Phenomenon in the Context of Sustainable Architecture

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Abstract. World's population today, most of them living in cities, have been isolated from the natural environment, combat with the physical and mental health problems like the loss of productivity, chronic fatigue, depression etc. due to stress-related disorders. Moving from the estimation that 70% of the world's population will be living in the cities in the coming years, re-establishing the human-nature relationship and presentation of the experience possibilities of nature as a therapy tool for urbanists can be expected to be significant. The concept of biophilia defined by social psychologist Erich Fromm in 1964 for the first time defends that there is an instinctive connection need between human and other living systems. In the case of rupture of this connection, occurrence of various physical and psychological drawbacks in human health has been proven by several scientific investigations. Biophilic architecture arising from the implementation of a psychological originated concept to the architecture, took place as an intense-studied area in the literature especially in 2000 and beyond. Biophilic design draws attention to the emotional aspect of the interaction need with the natural environment while sustainable design approaches physical and material-oriented to the natural processes required by people. Sustainable architecture focuses on reducing the environmental impact of the buildings and remains insufficient to re-establish the human-nature relationship. Biophilic design aims to fill his gap becoming the architectural design of life. In this study, biophilia phenomenon is examined approaching sustainability by putting the protection of the human and humans' physical/psychological health in center. Main design principles of the biophilic architecture are discussed through current scientific studies and architectural projects.

Keywords: Biophilia · Biophilic architecture · Sustainable architecture
Human-nature relationship

1 Introduction

The biophilia concept is formed by the combination of the words "bio" and "philia". "Bio" means "live, alive". Unlike the phobia, which means deep fears that people feel about objects in the natural world, "philias" are "the attraction and positive emotions people feel for certain living spaces, actions, and beings in the natural environment. Social psychologist Erich Fromm used the term for the first time in 1964. Fromm says, "Biophilia is the psychological obsession of being attracted by things that are live and

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vital." It was used to describe the psychological orientation of "attraction to everything that is alive" [1].

The term, popularized by E. O. Wilson, known as academician and entomologist, is defined as "innate tendency to focus on life and lifelike processes" [2], "innate emotional affiliation of human beings to other living organisms" [3] or, "inborn affinity human beings have for other forms of life, an affiliation evoked, according to circumstances, by pleasure, or a sense of security, or awe, or even fascination blended with revulsion" [4]. In his book, "Biophilia," Wilson suggests that the deep familiarity of humans to nature and their biology originate from biological production. Wilson argues that the value of human nature or the acceptance of nature comes to a great extent from birth. "If Wilson speaks about an innate tendency, he means by that the structure of our brains at least partially at the time of birth contains certain basic mental facilities that develop with contact with the external environment in a somewhat predictable fashion" [5].

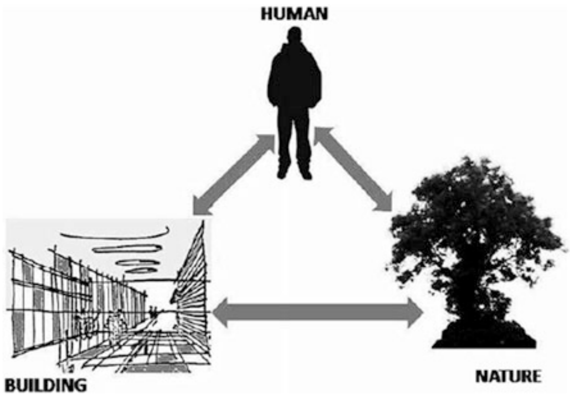

Fig. 1. The components of human settlement (building-human-nature) [6]

Contact with nature is essential to human health and well-being. Based on this theory, a framework has been developed that will reconnect humans and nature within the built environment. According to the framework, when the direct relationship breaks with other forms of life, psychological needs and problems arise in the human mind. People need to be in connection with natural environment and habitats. The hypothesis reveals both this need and suggests the recognition of the psychological and ethical heritage resulting from the evolution that all species in the biosphere have done together. Architecture must be an element that supports and strengthens this relationship (Fig. 1).

2 Design Principles of Biophilic Architecture

The relationship between biophilia—which is a concept belonging to the field of evolutionary/developmental psychology and related to various disciplines such as philosophy—and the built environment—mainly to accomodate human health/welfare, has been revealed by Kellert's studies [7, 8, 16, 23, 28]. Biophilic design carries the concept of biophilia to architecture. While green/ecological design approaches physical and material-focused to the natural processes that people need, biophilic design draws attention to the emotional direction of the need for interaction with natural elements. A few definitions belonging to scientists studying on biophilic design are as follows:

"Biophilic design is the deliberate attempt to translate an understanding of the inherent human affinity to affiliate with natural systems and processes—known as biophilia" [2, 3]—into the design of the built environment [8].

"To explore and affiliate with life is a deep and complicated process in mental development. To an extent still undervalue our existence depends on this propensity, our spirit is woven from it, hope rises on its currents" [2].

"Biophilic design is expression of the inherent human need to affiliate with nature in the design of the built environment. The basic premise of biophilic design is that the positive experience of natural systems and processes in our buildings and constructed landscapes remains critical to human performance and well-being" [8].

Biophilic design balances human needs with the value and considerations of natural environments and processes, and incorporates aspects and qualities of those elements into architectural design. This serves to reinforce man's instinctual connection and relationship with those systems [9].

The importance of the biophilic design can be summarized as follows:

- It has been proven by numerous scientific researches that biophilic principles provide real, measurable benefits in terms of human performance criteria such as productivity, emotional well-being, stress-reduction, learning and healing.
- From an environmental point of view, because biophilic properties take nature to its focal point, it can lead to the highest level of preservation of the natural environment, the reduction of pollution and the creation of a clean natural environment.

It has also been proven in various researches that the places with strong connection with the natural environment have positive effects on user psychology (increase of concentration, stimulant and soothing effect etc.). Table 1: Biophilic design patterns & Biological Responses illustrates the functions of each of the patterns in supporting stress reduction, cognitive performance, emotion and mood enhancement and the human body. Patterns that are supported by more rigorous empirical data are marked with up to three asterisks (***), indicating that the quantity and quality of available peer-reviewed evidence is robust and the potential for impact is great, and no asterisk indicates that there is minimal research to support the biological relationship between health and design, but the anecdotal information is compelling and adequate for hypothesizing its potential impact and importance as a unique pattern [10].

Table 1. Biophilic design patterns & biological responses [10]

14 Patterns		•	Stress reduction	Cognitive performance	Emotion, mood & preference
Nature in the space	Visual connection with nature	• • •	**Lowered blood pressure and heart rate** (Brown et al. 2013; van den Berg et al. 2007; Tsunetsugu and Miyazaki 2005)	**Improved mental engagement/attentiveness** (Biederman and Vessel 2006)	**Positively impacted attitude and overall happiness** (Barton and Pretty 2010)
	Non-visual connection with nature	• •	**Reduced systolic blood pressure and stress hormones** (Park et al. 2009; Hartig et al. 2003; Orsega Smith et al. 2004; Ulrich et al. 1991)	**Positively impacted on cognitive performance** (Mehta et al. 2012; Ljungberg et al. 2004)	**Perceived improvements in mental health and tranquility** (Li et al. 2012; Jahncke et al. 2011; Tsunetsugu et al. 2010; Kim et al. 2007; Stigsdotter and Grahn 2003)
	Non-rhythmic sensory stimuli	• •	**Positively impacted on heart rate, systolic blood pressure and sympathetic nervous system activity** (Li 2009; Park et al. 2008; Kahn et al. 2008; Beauchamp et al. 2003; Ulrich et al. 1991)	**Observed and quantified behavioral measures of attention and exploration** (Windhager et al. 2011)	
	Thermal & airflow variability	• •	**Positively impacted comfort, well-being and productivity** (Heerwagen 2005; Tham and Wilem 2005; Wigo 2005)	**Positively impacted concentration** (Hartig et al. 2003; Hartig et al. 1991; R. Kaplan and Kaplan 1989)	**Improved perception of temporal and spatial pleasure (alliesthesia)** (Parkinson et al. 2012; Zhang et al. 2010; Arens et al. 2005; Zhang 2003; de Dear and Brager 2002; Heschong 1979)
	Presence of water	• •	**Reduced stress, increased feelings of tranquility, lower heart rate and blood pressure**	**Improved concentration and memory restoration** (Alvarsson et al. 2010; Biederman and Vessel 2006)	**Observed preferences and positive emotional responses** (Windhager 2011; Barton and Pretty 2010; White et al. 2010; Karmanov and Hamel 2008; Biederman and Vessel 2006; Heerwagen and

(*continued*)

Table 1. (*continued*)

14 Patterns		•	Stress reduction	Cognitive performance	Emotion, mood & preference
			(Alvarsson et al. 2010; Pheasant et al. 2010; Biederman and Vessel 2006)	**Enhanced perception and psychological responsiveness** (Alvarsson et al. 2010; Hunter et al. 2010)	Orians 1993; Ruso and Atzwanger 2003; Ulrich 1983)
	Dynamic & diffuse light	• •	**Positively impacted circadian system functioning** (Figueiro et al. 2011; Beckett and Roden 2009) **Increased visual comfort** (Elyezadi 2012; Kim and Kim 2007)		
	Connection with natural systems				**Enhanced positive health responses; Shifted perception of environment** (Kellert et al. 2008)
Natural analogues	Biomorphic forms & patterns	•			**Observed view preference** (Vessel 2012; Jaye 2007)
	Material connection with nature			**Decreased diastolic blood pressure** (Tsunetsugu et al. 2007) **Improved creative performance** (Lichtenfeld et al. 2012)	**Improved comfort** (Tsunetsugu et al. 2007)
	Complexity & order	• •	**Positively impacted perceptual and physiological stress responses** (Salingaros 2012; Joye 2007; Taylor 2006; Kaplan 1988)		**Observed view preference** (Salingaros 2012; Hagerhall et al. 2008; Hagerhall et al. 2004; Taylor 2006)

(*continued*)

Table 1. (*continued*)

14 Patterns		•	Stress reduction	Cognitive performance	Emotion, mood & preference
Nature of the space	Prospect	• • •	**Reduced stress** (Grahn and Stigsdotter 2010)	**Reduced boredom, irritation, fatigue** (Clearwater and Coss 1991)	**Improved comfort and perceived safety** (Herzog and Bryce 2007; Wang and Taylor 2006; Petherick 2000)
	Refuge	• • •		**Improved concentration, attention and perception of safety** (Grahn and Stigsdotter 2010; Wang and Taylor 2006; Wang and Taylor 2006; Petherick 2000; Ulrich et al. 1993)	
	Mystery	• •			**Induced strong pleasure response** (Biederman 2011; Salimpoor et al. 2011; Kemi 2005; Blood and Zatorre 2001)
	Risk/Peril	•			**Resulted in strong dopamine or pleasure responses** (Kohno et al. 2013; Wang and Tsien 2011; Zald et al. 2008)

In the studies conducted on visual preferences and reactions, reduced stress levels, more positive emotional functioning, increased speed of concentration and healing of the users have been observed in places where the visual connection is established with the natural environment. The decision to increase natural lighting and ventilation can profoundly affect the residents' well-being/wellness including health, motivation, morale, physical and mental well-being and satisfaction.

"The last decade has seen a steady growth in work around and the intersections of neuroscience and architecture, both in research and in practice; even green building standards have begun to incorporate biophilia, predominantly for its contribution to indoor environmental quality and connection to place. Popular texts, such as "Last Child in the Woods" [11], "Healing Spaces" [12], "The Shape of Green" [13], "Your Brain on Nature" [14] and "The Economics of Biophilia" [15] are bringing the conversation mainstream, helping the public grapple with modern society's dependency on technology and persistent disconnect with nature. Most recently, biophilic design is being championed as a complementary strategy for addressing workplace stress, student performance, patient recovery, community cohesiveness and other familiar challenges to health and overall well-being" [10].

Three kinds of experience of nature represent the basic categories of Kellert and Calabrese's biophilic design framework. However, it should be kept in mind that the listed principles are not independent of one another and are in the same network as the one in the nature [16] (Fig. 2).

Fig. 2. Experiences and attributes of biophilic design [16]

All these biophilic design qualities are experienced through a variety of human senses including sight, sound, touch, smell, taste, and movement. The visual sense is by far the dominant way people perceive and respond to the natural world. When we see plants, animals, water, landscapes, and other natural features, a variety of physical, emotional and cognitive responses are triggered. People also react to indirect visual contact with nature, especially the sight of striking pictures, natural materials, organic shapes and forms, and more. Aesthetically attractive nature particularly arouses our interest, curiosity, imagination, and creativity. By contrast, when we lack visual contact with the natural world, such as a windowless and featureless space, we frequently experience boredom, fatigue, and in extreme cases physical and psychological abnormality [16].

On the other hand, Terrapin (William Browning and Jenifer Seal-Cramer) outlined three classifications of user experience (Fig. 3):

Fig. 3. 14 patterns of biophilic design [10]

It is seen that in two most prominent classifications on this subject have grouped highly similar principles in different headings but in fact the headings have close meaning to each other. For example; "direct experience of nature" can be seen as "nature in the space". Same situation is valid for the other two headings; "indirect experience of nature" and "natural analogues", "experience of space and place" and "nature of the space". At this point in the study, the principles of biophilic design will be explained using Kellert's classification.

2.1 Direct Experience of Nature

The direct experience of nature refers to actual contact with environmental features in the built environment including natural light, air, plants, animals, water, landscapes etc. Direct experience is to connect with the broad self-sustaining features of the natural world such as a wooded green area, a natural river or unfiltered weather and light. Natural lighting and ventilation experience qualities with the conscious design decisions such as large sliding windows, light shelves, consideration of the sun path and prevailing wind, plant types and quantities and the relationship between interior/exterior spaces of buildings are common expressions of biophilic design. Plants, soil, water, geological forms and even other natural features including fire or animal life, can be designed in buildings and built landscape areas.

A current example of the direct experience of nature and a strongly designed natural/built environment integration is Herzog & de Meuron and Vilhelm Lauritzen's hospital design at Denmark. The hospital organically reaches out into the wide landscape. Simultaneously its soft, flowing form binds the many components of the hospital. It is a low building that fosters exchange between staff and patients, and it has a human scale despite its very large size. The building is scheduled to open in 2020, but could also facilitate an expansion in 2050 [17] (Fig. 4).

Fig. 4. New North Zealand Hospital, Hillerød, Denmark, Arch.: Herzog & de Meuron, Vilhelm Lauritzen (Competition 2013–2014, project 2014) [17]

The hospital is surrounded by nature and contains a garden in its center. The horizontality of the building and its undulating form responds to the location of the hospital in the midst of the wide Danish landscape. A horizontal building is an appropriate building typology for a hospital, because this fosters exchange: across the various departments, the employees work on a shared goal: the healing of the ailing human being [18].

2.2 Indirect Experience of Nature

The indirect experience of nature refers to contact with the representation or image of nature, the transformation of nature from its original condition, or exposure to particular patterns and processes characteristic of the natural world. These include pictures and artwork, natural materials such as wood furnishings and woolen fabrics, ornamentation inspired by shapes and forms occurring in nature, or environmental processes that have been important in human evolution such as aging and the passage of time, information richness, natural geometries, and others [16].

Examples of such manipulated contact with the natural environment include planters decorating an interior lobby, fish in an aquarium tank, or formally designed fountains. Greatly transformed from their natural state, these features typically depend on continual human management and control to exist. But if these indirect expressions of nature are well designed, they can be deeply satisfying and beneficial. Designing the indirect experience of nature often involves manipulating environmental elements [7].

Another example; the Royal Children's Hospital project; provided an opportunity for deliver new models of care, incorporating innovative international health care concepts including:

- evidence based design principles
- family-centered design approach
- environmentally sustainable design
- introduction of daylight and nature into work and healthcare settings
- co-location of clinical, research and education facilities [19] (Fig. 5).

Fig. 5. The royal children's hospital, Melbourne, Australia, Designer: Bates Smart [36]

Building and landscape designs that involve contact with nature are frequently revealed through representation, allusion and metaphorical expression. Moreover, such experience occurs far more often than generally recognized and significantly affects people's responses to and satisfaction derived from the built environment. Nature is represented symbolically through various guises—including decoration, ornamentation, pictorial expression, and shapes and forms that simulate and mimic nature—and in a wide diversity of building features—such as walls, doors, entryways, columns, trim, casement, fireplaces, furnishings, carpets, fabrics, art, and sometimes even an entire façade [7].

According to Browning, Ryan and Clancy's classification about natural analogues are as follows:

- Biomorphic Forms & Patterns: Symbolic references to contoured, patterned, textured or numerical arrangements that persist in nature.

- Material Connection with Nature: Material and elements from nature that, through minimal processing, reflect the local ecology or geology to create a distinct sense of place.
- Complexity & Order: Rich sensory information that adheres to a spatial hierarchy similar to those encountered in nature [10].

Another example is the five-thousand square meter kinetic façade for the car park of Brisbane's domestic terminal. Viewed from the exterior, the buildings entire exterior face will appear to ripple fluidly as the wind activates 118,000 suspended aluminum panels as it responds to the ever-changing patterns of the wind. The elevation will create a direct interface between the installation and its natural environment [20] (Fig. 6).

Fig. 6. Brisbane airport kinetic parking garage facade by ned kahn + UAP [20]

The sculptural façade, poignantly named May–September, appears to shift in topography and hues, from a brilliant, bold yellow to a cool, deep blue, for passersby traveling east to west. The effect is mesmerizingly complex even though the installation itself—approximately 6500 bent aluminum panels with an articulated east-to-west color strategy—is relatively simple, with no moving parts. Completed in May 2014, the 13,000-square-foot installation spans the seven-story garage's prominent south elevation [21] (Fig. 7).

Fig. 7. Urbana studio designed an interactive aluminum facade for an existing parking structure at Eskenazi Hospital in Indianapolis. (Serge Hoeltschi) [22]

Symbolic representations of nature can be seen at many modern buildings' facades and structures. Ito's hotel design at Barcelona and Calatrava's Allen Lambert Galleria and Atrium at Toronto are good examples regarding on the symbolic representations of nature (Fig. 8).

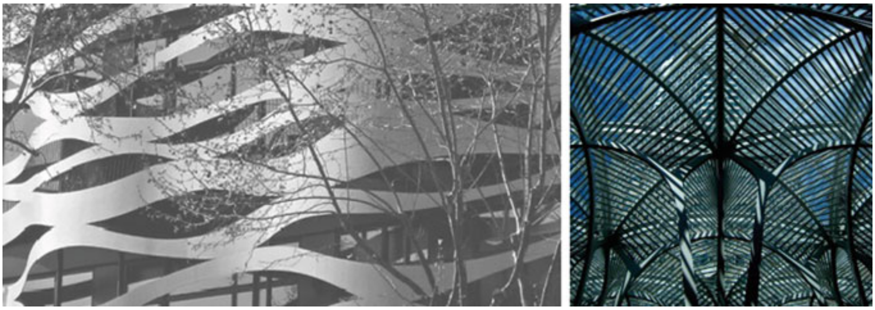

Fig. 8. Facade renovation of Suites Avenue Aparthotel by Toyo Ito, Barcelona, Spain—the engaging ceiling structure of the Allen Lambert Galleria and Atrium at Brookfield Place by Santiago Calatrava in Toronto [10]

2.3 Experience of Space and Place

The experience of space and place refers to spatial features characteristic of the natural environment that have helped to advance human health and wellbeing. Biophilic design attributes described in this category focus on fundamental aspects of the inherent human relationship to nature:

- Prospect and refuge—Prospect refers to long views of surrounding settings that allow people to perceive both opportunities and dangers, while refuge provides sites of safety and security. This biophilic outcome can be achieved through such design strategies as vistas to the outside, visual connections between interior spaces, and the occurrence of secure and sheltered settings.
- Organized complexity—People covet complexity in both natural and human settings, which signify places rich in options and opportunities. Complex spaces tend to be variable and diverse, while organized ones possess attributes of connection and coherence.
- Integration of parts to wholes—People covet settings where disparate parts comprise an integrated whole. This satisfying integration of space can be enhanced by a central focal point that occurs either functionally or thematically.
- Transitional spaces—Successfully navigating an environment often depends on clearly understood connections between spaces facilitated by clear and discernible transitions.
- Mobility and wayfinding—People's comfort and wellbeing often relies on freely moving between diverse and often complicated spaces. Clearly understood pathways and points of entry and egress are especially critical to fostering mobility and

feelings of security, while the absence of these features often breeds confusion and anxiety.

– Cultural and ecological attachment to place—Culturally relevant designs promotes a connection to place and the sense that a setting has a distinct human identity. Ecological connections to place can similarly foster an emotional attachment to an area, particularly an awareness of local landscapes, indigenous flora and fauna, and characteristic meteorological conditions. Cultural and ecological attachments to place often motivate people to conserve and sustain both natural and human built environments [8, 16, 23] (Fig. 9).

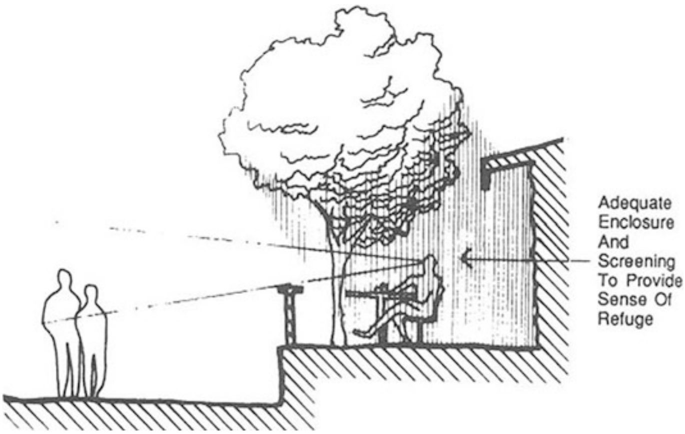

Fig. 9. Schematic representation of the refuge concept. Drawing: Motloch, introduction to landscape architecture [24]

"Refuge" and "prospect" is the concept that we psychologically feel safest in scenarios where we "have our back in a corner" per se, (knowing there isn't anything or anyone behind us) and have an unobstructed and welcoming view of the "beyond", the social landscape beyond, with a clear understanding and safe vantage point of what's happening "out there" [25] (Fig. 10).

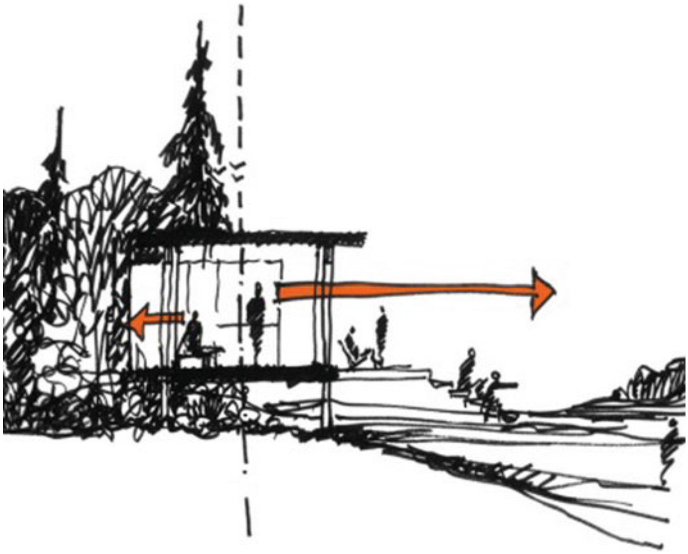

Fig. 10. Prospect and refuge—ability to observe but not have to participate, Sketch by Alan Maskin at olsonkundig.com [25]

3 Sustainable Architecture from the Point of View of Biophilic Design

Sustainable architecture can be briefly defined as the contemporary architectural understanding compatible with environmental systems, based on conscious and responsible use of energies and scarce resources, realized by integrating a working system of technical intelligence and interdisciplines. It is also known that it stipulates including the balanced integration of the economic, environmental and social dimensions in the design process. However, when studies and practices related to sustainable architecture are examined, it is observed that the focused dimensions differ. While some researchers and practitioners take the foreground on environmental and economic contexts like the conservation of natural resources and energy, selection of sustainable materials, reduction of waste, and so on, the others focus on social and cultural issues. Sustainability studies are usually focuses on the physical dimension of the problem, since the inverse proportion between changing consumption patterns and lifestyles and natural resources is considered a major threat to sustainability at global and local scale. In this context, the first ideas that come to mind about sustainable architecture are mainly environmental issues such as conservation of the environment and conscious consumption of energy.

The main idea of improving the environmental conditions of sustainable architectural design is a design conception that focuses on the future of the earth, not on human comfort. Although the arguments that Wilson uses are primarily scientific, the actual motive for forming the biophilia hypothesis is for its use in nature conservation. One of Wilson's main research questions has a purely environmental subtext—how to ensure more friendly human behavior towards and thinking about other species. Wilson interprets the environmental movement information obtained from research on human ecological relationships in biological basis and evolutionary history, and advocates the need for rebirth of environmental movement [5]. The idea of biophilic design arises from the increasing recognition that the human mind and body evolved in a sensorial rich world, one that continues to be critical to people's health, productivity, emotional, intellectual, and even spiritual well-being [8]. "… The biophilia hypothesis proclaims a human dependence on nature that extends far beyond the simple issues of material and physical sustenance to encompass as well the human caving for aesthetic, intellectual, cognitive, and even spiritual meaning and satisfaction" [26].

While sustainable design and biophilia may seem closely related, there are many areas in which they don't overlap or may even be contradictive. Sustainability as we know it was first defined by the United Nation's Brundtland Commission as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" [27]. While this is a noble and laudable goal, it is most commonly addressed in terms of the conservation and management of resources, materials and energy. Sustainable architecture does not specifically address the emotional and psychological needs which are a part of biophilia. The definition also came about as a result of a compromise between economic pressures and environmental interests and does not address damage already done to the environment [9]. Although green/ecological/sustainable architecture focuses on reducing environmental impacts of buildings, it is insufficient to reconstruct the human-nature relationship. The biophilic design that aims to be the architect of life aims to cover this inadequacy.

The basic deficiency of current sustainable design is a narrow focus on avoiding harmful environmental impacts, or so called low environmental impact design. Low environmental impact design, while fundamental and essential, fails to address the equally critical needs of diminishing human separation from nature, enhancing positive contact with environmental processes, and building within a culturally and ecologically relevant context; all basic to human health, productivity, and well-being. These latter objectives are the essence of biophilic design. Biophilic design has been until now the largely missing link in current sustainable design [8].

Kellert exemplifies this inadequacy in an interview. "Imagine a condominium made entirely of solar panels. Such a structure might have a small ecological footprint, but it will fail to tap into a resident's aesthetic tendencies, much less his "love of life." Worse, it will ultimately be unsustainable. If it's a place that doesn't breed satisfaction, enhance morale or motivate people (and in fact alienates them), when the cutting-edge technology that made it energy efficient is no longer cutting edge, and people don't want to be there, they won't sustain that environment" [28].

The Zuidkas, an experimental project commissioned by the Government Building Agency, challenges architects with an imaginary office building of over 11,000 m^2 in Amsterdam that demands innovative solutions. The main objective of the Zuidkas project is to achieve the highest possible score with regard to the fulfillment of environmental objectives [29]. This is an extraordinary example of a horizontal farm—The Zuidkas, by Architectenbureau Paul de Ruiter from the Netherlands. The post makes the case for horizontal versus vertical farming as perhaps a more realistic opportunity for integrated urban agriculture. Using rooftop greenhouses, along with captured waste heat from buildings, shortening the distance from food to fork and incorporating mixed use into the buildings [30] (Fig. 11).

Fig. 11. Images of the Zuidkas project/Paul de Ruiter, Integrated Urban Agriculture in a Multi-Use Structure (office building, Amsterdam/Holland) [31]

De Ruiter's model creates an opportunity to develop a more balanced response to the demand for energy. Depending on the program, the demand for energy will be different throughout the course of the day. For instance, in residential units, the energy demand spikes in the mornings and evenings while, in the case of offices, the energy demand reaches its highest point at the middle of the day. By placing these two programmatic components in the same building, energy can cycle from where it is needed presently to where it will be needed later. It is a logical and yet innovative approach to addressing an energy solution [29]. Besides the sustainable design principles that it has successfully implemented, this project is also a positive example for the integration of the green with the building (Fig. 12).

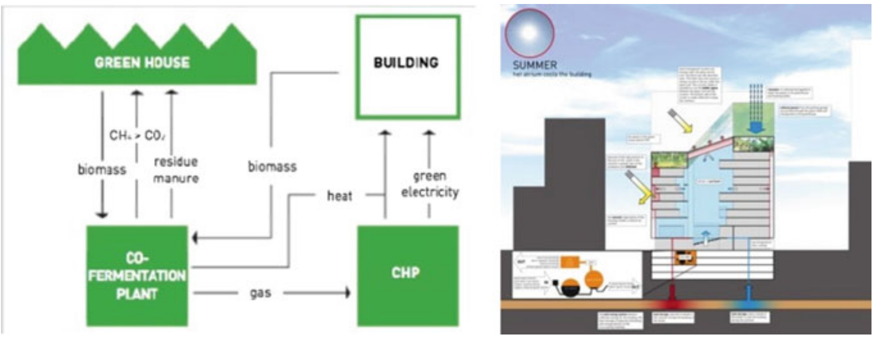

Fig. 12. Building systems scheme and the section of the Zuidkas project/Paul de Ruiter, Integrated Urban Agriculture in a Multi-Use Structure (office building, Amsterdam/Holland) [31]

"Biophilic design seeks to create a positive connection between people and the environment as well as promoting health and well-being. "…Yet until the biophilia hypothesis is more fully absorbed in the science and culture of our times—and becomes a tenet animating our everyday lives—the human prospect will wane as the rich biological exuberance of this water planet is quashed, impoverished, cut, polluted, and pillaged. The biological terrain must be better mapped, so that government and business leaders have better information on which to base decisions to shape sustainable development" [32].

With its green façades and roof, Sportplaza Mercator marks the start and end of the Rembrandtpark. From a distance, it seems like an overgrown fortress flanking and protecting the entryway to the 19th-century city. Glimpsed through the glass façade, a modern spa-style complex glistens, complete with swimming pools, fitness space, and restaurant and party facilities. The entrance seems like a departure hall from which the various visitors can reach their destination. The building was designed as a city—a society in miniature—inside a cave. The building is full of lines of sight and keyholes that offer perspectives on the various visitors, activities and cultures in the building. Sunlight penetrates deep into the building's interior through all sorts of openings in the roof. Low windows frame the view of the street and the sun terrace (Figs. 13 and 14).

Fig. 13. The concept of vertical gardens at Sportplaza Mercator. As every wall has its own climate, over 50 different kinds of shrubs, bushes and trees have been planted in the roofs and facades of this sports centre [31]

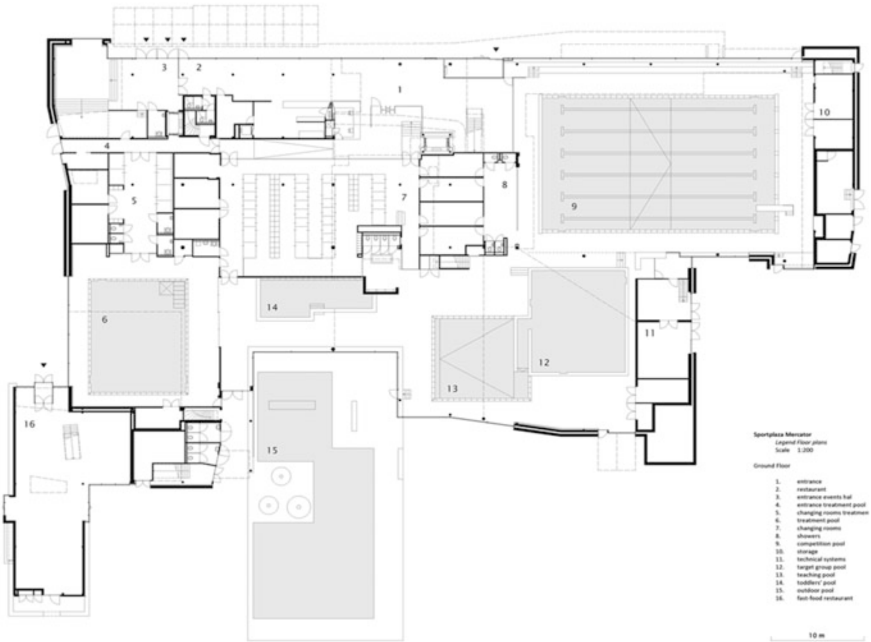

Fig. 14. Ground floor plan [33]

SportPlaza Mercator is positioned at the entrance to a park in the De Baarsjes neighborhood. The architects wanted it to fit in with its surroundings, so they added a camouflaging facade of bushy plants and flowers. Behind the planted walls, the three-storey building contains swimming pools, a sauna and fitness studios, as well as an events hall, a fast-food restaurant, a cafe and a nursery. An outdoor pool is also included at the rear. Windows nestle in amongst the planted exterior but feature tinted glass to reduce visibility into the swimming-pool halls. Skylights were also added to bring in more natural light. The building was completed in 2006 [31, 33].

"For workplaces, schools, hospitals, and neighborhoods biophilic design has emerged as a promising way to add value to the energy-centric concept of sustainable or green design. As a word and concept, sustainability is surely important, but it suggests static, bringing our environment up to par, as if we know what constitutes par. Many of us, particularly the young, hunger for a more powerful frame, one that suggests creativity …Sustainable or green design is essentially about conserving energy and leaving a small footprint on the earth; biophilic design is about conserving energy and producing human energy" [11].

4 Conclusion

In the modern world, as the number of scientific studies increases of people living in metropolitan areas with regards to the parameters affecting the health and productivity of users and the speed of healing of the patients the negative effects created due to living detached from the natural elements are more prominent.

Biophilic architecture as a design approach which emphasizes this theme is a missing -an important but often overlooked—part of sustainability. It is a fact that only a physical and material focused sustainable architecture can't be sufficient, emotional and psychological factors must be included in the process. Biophilic architecture aims to bridge the disconnection between the human-natural-built environments and to create strong links, which requires a design process involving social scientists as well as architects and technical professionals. In this respect, communication between architects and social scientists studying on biophilia should be developed and design teams should be created as interdisciplinary.

It is important that certificate systems which are updating periodically and are used widely today include biophilic design principles in their criteria. Biophilic design, focused on the emotional and psychological needs and health of people, will enrich the generally weak social sustainability criteria of certification systems which are focused more on resource conservation.

Motivating building users to improve the attachment and the sense of belonging to the building is as important as reducing energy consumption in terms of sustainability goal. Biophilic buildings which are felt with natural elements and have rich sensory stimulants in, support the feeling of belonging and satisfaction of users. When architectural projects, that have entered into the literature of architecture today are examined, it is noticed that many of them have powerful examples in terms of integrating natural elements and buildings, even though the concept of biophilia is not mentioned in the descriptions. Examples given in the scope of this study also carry such features. This shows that such a need and tendency has already been formed.

It is known that the success of sustainable architecture is related more to conscious user behaviors rather than the intelligent systems the building has. Of course, realization of the user's behavior in the desired direction is possible with the users' sense of belief, acceptance and satisfaction. In this context, the biophilia phenomenon in architecture presents a space that designers nowadays have to think thoroughly.

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The Limitations of LCA Methodology Towards Sustainable Construction Materials

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Abstract. Life Cycle Assessment (LCA) is an internationally accepted methodology for assessing the environmental impacts caused by the construction materials. The methodology described in the ISO 14040 standard series consists of goal and scope definition, Inventory Analysis (LCI), Impact Assessment (LCIA) and interpretation phases. While LCI is a phase where the inputs and outputs are calculated, LCIA aims at understanding and evaluating the magnitude and significance of the environmental impacts for a product system throughout the life cycle of the product. The LCA of the construction materials is different from other products because of a wide variety of materials, life cycle phases and the long service life. While the lack of environmental data and the implementation period of LCA restrict the use of the methodology; different goal and scopes, different limitations make difficult the comparisons of the studies. In this study, it was aimed to the promotion of the use of LCA. Brick is one of the common construction materials that cause several environmental impacts. Therefore, the recent studies on LCA of brick production were evaluated. The problems in the use of LCA for the construction materials were identified under the sub-headings;

- The problems encountered in the goal and scope definition
- The problems encountered in LCI
- The problems encountered in LCIA

Finally, it was shown which gaps need to be filled for the methodology in the upcoming years. It is thought that LCA should continue to be improved as an analysis methodology which is still in development.

Keywords: Brick · Construction materials · LCA · Limitations · Sustainability

1 Introduction

LCA is an internationally accepted and innovative methodology which improves sustainability in the construction sector considering all phases of the building life cycle [1]. It has been used in the building sector since 1990 and is an important tool for assessing buildings [2, 3].

LCA consists of four main phases according to International standards of series ISO 14040/2006 [4]. Firstly, goal and scope definition involves objectives and the system boundary of the study such as the product system to be studied, the functional unit, the

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life cycle phases, assumptions, limitations, selection of impact assessment method and environmental impact categories. Secondly, LCI involves data collection and calculation procedures for the compilation and quantification of inputs and outputs of a product system throughout its life cycle. Thirdly, LCIA aims at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system. It has mandatory and optional elements. Selection of impact categories (global warming, acidification, eutrophication, waste, etc.); selection of category indicators (global warming potential, resource depletion potential, etc.) and selection of characterization models (characterization model of Intergovernmental Panel on Climate Change (IPCC) for global warming category) are mandatory elements; while normalization, grouping and weighting are optional elements. In the characterization phase, category indicator results are calculated. Category indicator that is quantifiable representation of an impact category is selected in accordance with the characterization model. A characterization model reflects the environmental mechanism, that is a system of physical, chemical and biological processes for a given impact category, by describing the relationship between LCI results and the category indicators and calculates characterization factors. Characterization factors are applied to convert an assigned LCI result to the common unit of the category indicator. In the classification, the emissions and resources in the LCI are assigned to the selected impact categories [4] (Fig. 1). The volume editors, usually the program chairs, will be your main points of contact for the preparation of the volume.

In the normalization as an optional element in LCIA, the results of each impact category are divided by a reference value. Thus, all impact categories are made dimensionless. In the weighting, importance degrees of the environmental impact categories are specified according to the region or the country in which the methodology is developed. In the grouping, the impact categories are sorted and possibly ranked in each hierarchy like high, medium and low priority. Finally, the interpretation phase evaluates findings to reach conclusions and formulate recommendations [4] (Fig. 1).

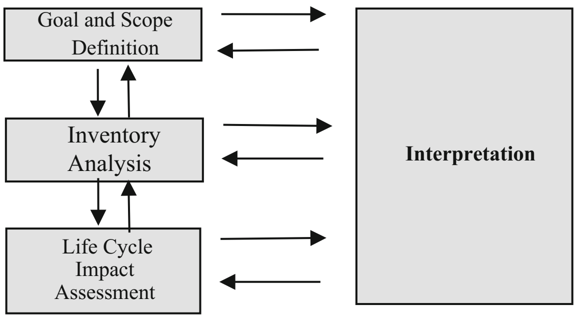

Fig. 1. LCA methodology based on ISO 14040. *Source* ISO 14040

LCA of the construction materials requires too much environmental data because of a wide variety of materials, long life span of materials, many unit processes in life cycles. And it is a complex and time consuming process. Therefore, LCA studies are mostly carried out in developed countries. According to Cabeza et al. [5] there is no case about LCA in Africa, only one case was found from South America, several papers from Asia; while a lot of cases from North America and Europe were available. LCA studies also have lack of consensus for each phase of products. According to Rashid and Yusoff [6], there is a need to standardized LCA methodology for building in order to create a robust database.

In this study, it was aimed to the promotion of the use of LCA methodology. Therefore, the major problems in the use of LCA for the construction materials are evaluated by phase. And nine studies on brick as a common used construction material were evaluated in terms of the problems in LCA. Differences in the studies about the same material that make difficult the comparison of LCA studies were highlighted.

2 Goal and Scope Problems

Problems have occurred in terms of two decisions in goal and scope definition. The first of these is the functional unit definition. The functional unit is a quantified performance for a construction material as a reference unit in LCA study. There is no agreement on the functional unit to be considered.

Nine LCA studies evaluated in the scope used different functional units. Almeida et al. [7] studied LCA methodology for ceramic bricks and the functional unit used was 1 m^2 of a single layer brick wall with brick dimensions of 30 × 20 × 11 cm and a total equivalent weight of 71.6 kg; Bribian et al. [8] evaluated LCA of 1 kg of different brick types; Koroneos and Dompros [9] evaluated LCA of 1 tone of a specific type of brick; Sunil Kumar et al. [10] evaluated LCA of a clay brick with dimensions of 6.8 × 10.3 × 22 cm; Lopez Aguilar et al. [11] evaluated a brick manufactured with natural igneous rock, standard size 7 × 14 × 28 cm; Talang and Sirivithayapakorn [12] studied LCA for 1 m^2 of brick wall, comprising 121 bricks with the standard size of 14 × 6.5 × 4 cm; Ali and Negm [13] studied LCA for 1 kg of different brick types; Christoforou et al. [14] evaluated LCA of 1 kg of an adobe brick; Kulkarni and Rao [15] evaluated LCA of unit mass of fired brick (Table 1).

The second of two decisions in goal and scope definition is the boundary selection that defines the unit processes to be included in the system. The studies consider different approaches about life cycle phases in the scope. "Cradle to grave" (open loop material flow) approach includes a material's life cycles from raw material acquisition (cradle) through production, transportations, use, end-of-life treatment, recycling and final disposal (grave). "Cradle to gate" approach includes life cycle phases from raw material acquisition to the factory gate, before it is transported to the consumer. "Gate to gate approach" includes only construction process analysis. Finally, "cradle to cradle" approach (closed loop material flow) evaluates materials that are recycled into a new product at the end of their life, so that ultimately there is no waste (Fig. 2). In addition to these approaches, some studies evaluate specific parts of the life cycle such as construction, waste management, use phase etc.

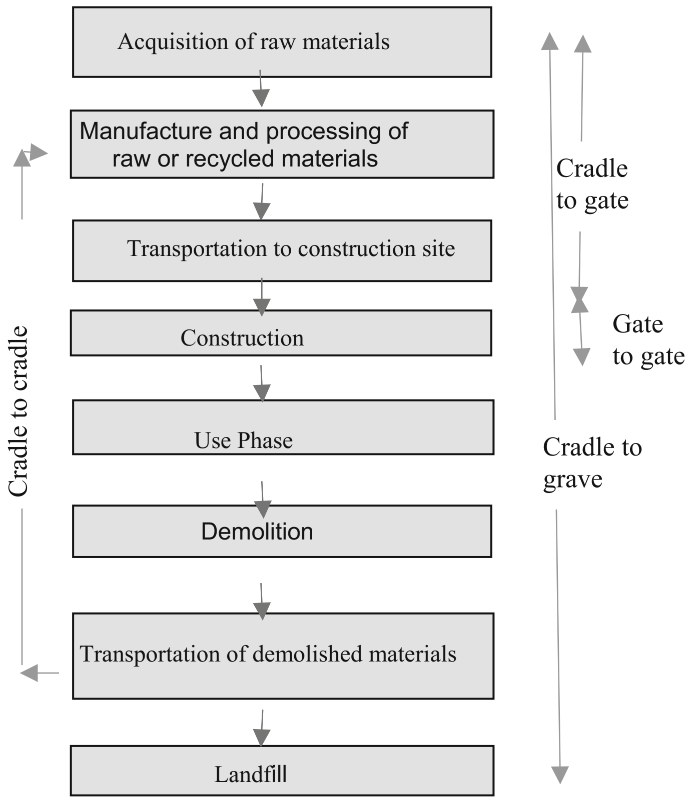

Fig. 2. LCA phases of the construction materials. *Source* ISO 14040

Alternative scenarios about fuel types, materials types transportation distances, transportation vehicles, service life etc. are assumed in scope of LCA studies. In the study of Almeida et al. [7] three scenarios were developed considering natural gas, biomass and petroleum coke as the fuel types used in the brick production. For the transportation of the brick to the building site, a scenario of 100 km by trucks weighing 25 tons was assumed. In the study of Talang and Sirivithayapakorn [12], nine scenarios were investigated in fired bricks produced using cane leaves, rice straw and rice husk. In the study of Christoforou et al. [14] scenarios about brick production in a factory or building site, brick production with locally available soil or transported soil and brick production with saw dust or straw were investigated. In the study of Sumil, average life of the brick was assumed to be 25 years. For the studies about brick production, system boundaries for life cycle phases were given in Table 1.

Table 1. Different scopes in LCA of the brick studies

	Year	Country	Functional unit	System boundary
Almeida et al. [7]	2015	Portugal	1 m^2	Cradle to grave
Bribian et al. [8]	2011	Spain	1 kg	Material manufacture, transport, construction, demolition, final disposal
Koroneos and Dompros [9]	2007	Greece	1 tone	Cradle to grave
Sunil et al. [10]	2016	India	1 brick (6.8 × 10 × 22 cm)	Production, transport, use and disposal
Lopez et al. [11]	2016	Mexico	1 brick (7 × 14 × 28 cm)	Cradle to gate
Talang and Sirivithayapakorn [12]	2016	Thailand	1 m^2	Cradle to grave
Ali and Negm [13]	2014	Egypt	1 kg	Cradle to gate
Christoforou et al. [14]	2016	Cyprus	1 kg	Cradle to gate
Kulkarni and Rao [15]	2016	India	1 unit mass	Cradle to gate

3 Inventory Analysis Problems

The lack of inventory data is a big problem for LCA studies especially for developing countries. Process specific information for inventory require time and labor intensity. Although there are many LCI databases, no existing database can be completed due to the variety of materials, construction techniques, locations, energy sources and manufacturing differences [1].

There are two data systems for inventory analysis. The foreground system (primary data) is defined as the processes of the system that are under control of the decision maker involved in the study [16]. It includes various sources such as literature, industry survey, industry-based data and European average data. Background system (secondary data) is defined as the processes that are not specific to the studied system such as extraction of raw materials, production of the construction materials or electricity. The background system comprises the processes that are operated as part of the system but that are not under direct control of decisions analyzed in the study [17]. It includes data such as Ecoinvent database [18].

Lack of systematic approaches for determining data quality is another problem in LCI. According to EN 14025 standard [19], data quality requirements include coverage, precision, completeness, data sources and uncertainty, representativeness, consistency, reproducibility.

The nine studies are investigated in terms of data sources (Table 2). It is seen that the data were obtained from both of foreground and background data in the studies. Local factors have an effect that can influence the results of LCI and should be considered when using the background data of the construction materials. Because, there might be mistakes in the inventory analysis results as there are differences between the real system and the system used as a source. Technology, energy mix for the energy production and distances can vary with location. Ignoring these differences affects the accuracy of the inventory.

Table 2. Data sources in LCA of the brick studies

	Data sources
Almeida et al. [7]	Primary data on Portuguese extraction industry (eight Portuguese manufacturers) Secondary data from ecoinvent database [18]
Bribian et al. [8]	Ecoinventv2.0 database [20]
Koroneos and Dompros [9]	Raw data from the brick production plant in Greece, measured data on site Calculated data based on bibliographical information
Sunil et al. [10]	A database in SimaPro
Lopez et al. [11]	Local brick producer Ecoinventv2.2 database İnformation from the plant provides electricity
Talang and Sirivithayapakorn [12]	Primary data on production of four brick plants in Thailand
Ali and Negm [13]	12 Egyptian brick plants, 3 sand brick factories, 4 clay brick factories, five cement brick factories Literature review, international papers Assumptions, ecoinvent database
Christoforou et al. [14]	Local adobe producers Literature
Kulkarni and Rao [15]	Field data Data from Ministry of Environment and Forests, Government of India Central Electricity Authority, Ministry of Power, Government of India Kirloskar Oil Engines Ltd

Technology of extraction, production and end of life for the construction materials is an important factor that has effects of the results of LCI in terms of locality. For brick production; brick kilns can be classified according to the burning process: continuous, as in fixed chimney bulls trench kiln, natural draught zigzag kiln, high draught zigzag kiln, vertical shaft brick kiln (VSBK), Hoffman kiln, and tunnel kiln, or intermittent, as in clamps kiln and down draught kilns [21]. The environmental impacts of fired bricks depend on the type of kiln and fuel types. In the study of Talang and Sirivithayapakorn [12] and the study of Kulkarni and Rao [15], the clamp kilns were used. In the study of Lopez Aguilar et al. [11], intermittent traditional kiln was used; in the study of Almeida et al. [7], tunnel kiln was used.

The methods used for LCI also have been questioned [22, 23]. There are different methods for LCI such as process based analysis, input-output (I-O) based analysis and hybrid analysis. Environmental inputs and outputs are modeled by utilizing a process flow diagram in the process based LCI. Software and tools such as SimaPro, Gabi have been developed to support process based LCAs. Input-output (I-O) based method combines national sector-by-sector economic interaction data which quantify the dependencies between sectors, with sector level environmental effects and resource use data. Hybrid method combines the strengths of both methods [22]. Process based LCI is used because it provides detailed analysis of specific processes, product comparisons and identifies process improvements for the construction materials. It has disadvantages because of lack of comprehensive data in many cases, time and labor intensive. All the studies about brick production evaluated in this study used process based analysis.

4 Impact Assessment Problems

There are several problems in terms of the selection of the impact assessment method, environmental impact categories, category indicators, characterization models; local environmental uniqueness; weighting; data availability and quality for LCIA phase.

LCIA methods have been developed with three approaches as midpoint approach, endpoint approach and approach which combine midpoint and endpoint. Midpoints are considered the links in the environmental mechanism of an impact category, prior to the endpoints, at which characterization factors or indicators can be derived to reflect the relative importance of emissions or extractions. This approach is referred as a problem-oriented approach. Endpoints are the terminals of the impact chains which the environmental impacts are quantified. This approach is referred as a damage-oriented approach. There have been many discussions assessing the benefits and shortcomings of each approach [24]. According to Bare, the endpoint approach considers environmental impacts to a greater extent such as ecosystem, resources, climate change and human health. Therefore, the endpoint approach can lead to high modeling and parameter uncertainties compared with midpoint approach. Midpoint impact assessment continues to support more scientifically based decision analysis [25].

Different LCIA methods, environmental impact categories, category indicators and characterization models do not allow comparative studies to improve the environmental properties of the construction materials. The studies about brick production investigate different impact categories for the same material (Table 3).

Table 3. LCIA methods and selection of the environmental impact categories in LCA of the brick studies

	LCIA methods	Impact categories
Almeida et al. [7]	CML [26], Impact 2000+ [27], CED method [28], Water demand Emission of particles to air was tested. Midpoint approach	Global warming, ozone layer dep., photochemical oxidation, acidification, eutrophication, depletion of abiotic resources, respiratory inorganics, energy and water consumption
Bribian et al. [8]	CED method [28], IPCC [29] Midpoint approach	Primary energy demand, GWP, water demand
Koroneos and Dompros [9]	Eco Indicator 95 [30] Midpoint approach	Global warming, acidification, eutrophication, winter and smog formation, solid wastes
Sunil et al. [10]	Eco Indicator 99 [31] Endpoint approach	Human health, ecosystem quality, resources
Lopez et al. [11]	Eco Indicator 99 [32] Endpoint approach	Human health, ecosystem quality, resources
Talang and Sirivithayapakorn [12]	CML [26] Midpoint approach	Abiotic depletion (fossil fuels), global warming, photochemical oxidation, acidification, eutrophication
Ali and Negm [13]	Impact 2002+ [32], method which combine midpoint and endpoint approaches	Endpoints: human health, ecosystem quality, climate change, resources Midpoints: carcinogens, non-carcinogens, respiratory inorganics, ionizing radiation, ozone layer dep, respiratory organics, aquatic and terrestrial eco toxicity, land occupation, aquatic acidification, aquatic eutrophication, global warming, non-renewable energy, mineral extraction
Christoforou et al. [14]	CML (2001) Midpoint approach	Global warming potential, acidification, eutrophication, ozone layer depletion, abiotic depletion, freshwater aquatic ecotoxicity, marine aquatic ecotoxicity, terrestrial eco toxicity, human toxicity, photochemical ozone creation
Kulkarni and Rao [15]	IPCC [29]	Carbon footprint

EcoIndicator99, methods were used in the nine studies. Impact 2002+ [32] is a combination of four methods; Impact2002, Eco Indicator99, CML, IPCC. Therefore, in these studies, characterization models and category indicators for each impact category are not different because of the selected LCIA methods.

Weighting is one of the important elements of LCIA in terms of locality, although it is an optional according to ISO 14040/2006 [1]. The calculation of weighting factors has different approaches such as panel method, monetization method and distance to target method [33]. A group of experts are asked to determine the importance of environmental impact categories in the panel method. Weighting factors are expressed in monetary costs according to the estimated economic damage incurred in an impact category or to what is necessary to prevent the damage itself in the monetization method. Weighting factors are calculated as a function of some type of target values, which are often based on political decisions in the distance to target method [34].

Table 4. Weighting factors for different countries

		BEES(EPA) [35]	BRE [36]	BPIC-ICIP [37]	LCIA-TR [38]
	Country	USA	England	Australia	Turkey
	Weighting factors	Panel M.	Panel M.	Panel M.	Panel M.
Impact categories	Global warming	16	21.6	19	15
	Acidification	5	0.05	3	3
	Eutrophication	5	3	3	5
	Mineral consumption	5	9.8	4	7
	Indoor air quality	11			8
	Land use	16		17	10
	Water consumption	3	11.7	6	15
	Air particulates	6	–		–
	Smog for.	6	0.2	3	3
	Ecological toxicity	11	–	–	–
	Ozone depletion	5	9.1	4	3
	Human health	11	–	3	–
	Human toxicity		8.6	3	–
	Nuclear waste		8.2		–
	Eco toxicity—water		8.6	10	–
	Eco toxicity—land		8	6	–
	Eco toxicity—fresh water			10	–
	Waste		7.7		12
	Fossil fuel depletion		3.3	4	19
	Ion radiation			2	–
	Total	100	100	100	100

For LCIA of the construction materials, it is necessary to determine the importance degree of environmental impact categories for a region or a country, because the impact of the environmental category with a high weighting coefficient will be more important for a country or region, while two environmental impact categories have the same impact score. Table 4 shows different weighting factors over 100 points according to the countries. BEES [35], BRE [36], BPIC-ICIP [37] are the LCA methodologies for the construction materials. LCIA-TR is a LCIA model developed for Turkey [38]. All the methodologies used panel method to calculate weighting factors for the construction materials (Table 4).

From the studies about the brick production, Koroneos and Dompros [9], Sunil Kumar et al. [10] considered weighting for three impact categories by using Eco-Indicator.

5 Conclusions

There is still need to improve LCA methodology for the construction materials. From the results of this study, conclusions are given below.

ISO standard doesn't include all rules about LCA. Definition of functional units and system boundaries has been adopted according to different scopes and researchers' preferences in the LCA studies. Therefore, there is need to develop an internationally acceptable guidance on the establishment of LCA methodology for the construction materials.

In developing countries, national or regional databases should be developed because of the importance of local factors. The awareness of the environmental issues for the construction materials sector should be raised. And it should be urged the manufacturers of the construction materials to use of LCA.

For LCIA phase, simplified LCIA method by using all impact categories according to EN 15804 standard [39] about the construction materials may be selected in developing countries firstly. Then, complementary impact categories such as indoor air quality, waste and land use should be considered.

Weighting factors should be calculated to determine the importance of environmental impact categories for the countries or regions.

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Properties of High Content Ground Granulated Blast Furnace Slag Concrete

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Abstract. "Ground Granulated Blast-Furnace Slag" (GGBFS) is produced by the process for grinding "Granulated Blast Furnace Slag" (GBFS) that is a kind of by-product produced via blast furnace operated in steel works. Ground granulated blast furnace slag (GGBFS) has been used in the construction industry for years as a replacement for Ordinary Portland Cement (OPC). Ground granulated blast furnace slag also has a lower heat of hydration and, hence, generates less heat during concrete production and curing. GGBFS cement can be added to concrete in the concrete manufacturer's batching plant, along with Portland cement, aggregates and water. The normal ratios of aggregates and water to cementitious material in the mix remain unchanged. GGBS is used as a direct replacement for Portland cement, on a one-to-one basis by weight. Replacement levels for GGBS vary from 30% to up to 85%. Typically, 40 to 50% is used in most instances. This study is the result of using 70% GGBFS instead of cement even if it is allowed to use maximum 25% of GGBFS instead of it. The use of GGBFS, which has an amorph structure and shows pozzolan characteristics when finely granulated, as a replacement material within the systems of cement or concrete positively effects the properties of fresh and hardening concrete.

Keywords: Concrete · By-product · Ground granulated blast-furnace slag
Strength · Durability

1 Introduction

Ground granulated blast furnace slag (GGBFS) has been used in the construction industry for years as a replacement for Ordinary Portland Cement (OPC). Ground granulated blast furnace slag also has a lower heat of hydration and, hence, generates less heat during concrete production and curing. GGBFS is a desirable material to utilize in mass concrete placements where control of temperatures is an issue. GGBFS can be used instead of cement with the ratios from 10 to 90%. However, because of its low heat generating characteristics, GGBFS was approved for use at a 70% replacement even if it is allowed to use maximum 25% instead of cement [1].

The general GGBFS literature indicates that the replacement of OPC by GGBFS typically results in lower early strengths (7–28 days), greater long term strengths, lower chloride ion permeability, less creep, greater sulfate attack resistance, greater alkali

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silica reactivity (ASR) durability, enhanced workability, less bleeding, lower heat of hydration, and increased steel corrosion resistance. Results for drying shrinkage and freeze-thaw durability are somewhat mixed, although in general, the use of slag appears to be no detrimental. Besides lower early strength, the downsides to the use of GGBFS include extended curing times, increased salt scaling, increased plastic shrinkage cracking, and increased air entrainment dosage required. When Grade 120 (highest activity) slag is used, at least a 70% replacement may be needed to meet specification requirements. Most ready-mix concrete producers use 50% replacement with highly reactive slag during warm weather [1].

2 Significance of Using High Volume GGBFS

Most of the cement plants consume great amounts of energy and have a negative role in the environmental pollution with the destructive greenhouse gasses they emit to atmosphere during the production process of the cement. Therefore, cement producers benefit from various mineral additives so as to reduce the CO_2 emission and increase the production rate by decreasing the energy consumption.

One of those mineral additives is granulated blast furnace slag which occurs during the production of pig iron in the iron and steel factories and major part of which is ready to be used as an alternative binding material. The use of industrial by-products containing high percentage of silica and alumina as an additive in cement or concrete, an area convenient for the utilization of large volumes of waste materials, will remedy the environmental problems to some extent. By preventing the rapid consumption of limited natural resources, the production of more qualified and more economic materials instead of the traditional ones will also be possible.

The use of GGBFS, which has an amorph structure and shows pozzolan characteristics when finely granulated, as a replacement material within the systems of cement or concrete positively effects the properties of fresh and hardening concrete. The slag use provides advantage especially in avoiding the thermal cracks in mass concrete and solving the durability problems such as corrosion resistance, sulphate attack and ASR (Alkali Silica Reactivity). On the other hand, when the slag is used in the concrete structures which will be exposed to hard conditions, there are some points, especially for cold climates, to be taken into consideration such as, preference of low rate of water/binder in the mixture and due to the fact that the slag has a low speed of hydration, the need of longer cure process compared to concrete with OPC.

3 Hardened Concrete Properties with High Volume GGBFS

Unit weight, compressive strength and strength development, tensile strength, splitting-tensile strength, modulus of elasticity, creep, shrinkage, permeability and chemical stability and capillary water absorption are examined in high volume GGBFS.

3.1 Unit Weight

The unit weight of hardened concrete with GGBFS is less than of control concrete. Regarding the concrete age, the unit weight of the concrete with GGBFS is increasing more than normal concrete. While the unit weight in normal concrete does not importantly change by years, generally, it noticeably increases in concrete with GGBFS. The most significant reason of this is that the slag in the concrete with GGBFS produces new C–S–H, by combining with CH in the first times of hydration.

As it is known, even if the concrete gets older, the hydration slowly continues. As a result of this the new C–S–H production goes on until the silicates finish deriving from slag and the unit weight value slightly increases. For further ages, however, due to the fact that the density of the slag is less than of the cement, the unit weight of the concrete with high volume GGBFS is smaller than the control concrete. For instance, the dry unit weight of the 28-days old concrete with 10, 20, 30% GGBFS are 5, 10 and 14% less than the control concrete. The unit weight of the same concretes after 90 days are 2, 5 and 6% less than the control concrete as well [2].

3.2 Compressive Strength and Strength Development

When the equal amount of cement and w/b rate is concerned, the slag concrete has less compressive strength at early ages, more compressive strength at late ages than the concrete with OPC has. Because of the fact that the GGBFS hydrates slower than OPC, the rate of strength development is lower at early ages for slag concrete.

High volume slag replacement instead results in a lower rate of strength development. However, when a suitable humidity condition is provided, the long-term strength of the slag concrete will probably be higher. This higher strength in late terms stems from the partial long-term strength of the slag and the micro structure which is intensively hydrated due to the slower hydration reaction. When the temperature is increased, the rate of strength development of the slag concrete is also more than of the concrete with OPC [3].

It is informed that on 28th day the performance of the concrete with GGBFS is similar to of control concrete; however, on 56th day the concrete with GGBFS has a superior performance comparatively to the concrete with OPC. According to the researchers, all of the concretes with up to 55% slag showed a lower compressive strength than the control concrete within 7 days. The results of the tests demonstrated that the hidden binding property of GGBFS, together with the increasing rate of slag replacement slow down the strength development at early ages. But at ages such as 28, 56 and 91 days, the strength development of the concrete with GGBFS is similar or more compared to of the slag-free control concrete with OPC [4].

It is studied on the features of slag concrete which they produced mixing blast furnace slag of four different fineness such as 300, 400, 500 and 600 m^2/kg into 300 m^2/kg cement with a replacement rate from 50 to 80%, informed that the finer the slag, the higher the compressive strength according to the results of the experiments [5].

In a research performed, for the compounds at 100 MPa pressure level, with slag of 70% when compared to the compounds with OPC, the strength percentage for 7th, 28th, 56th and 91st days were respectively found as 46, 71, 85 and 96%. The strength percentage on 91st day, for the compounds with 50% slag at 40 MPa is found 97% [6].

Another study includes 0, 50, 60, 70 and 80% replacement rates of GGBFS at concretes and shows that the changes of compressive strengths in accordance with the concretes age and curing conditions. The compressive strength values of the control concretes are between 50.6 and 63.1 MPa and compressive strength values of the GGBFS concretes are between 27.9 and 66.2 MPa as shown in Fig. 1 [7].

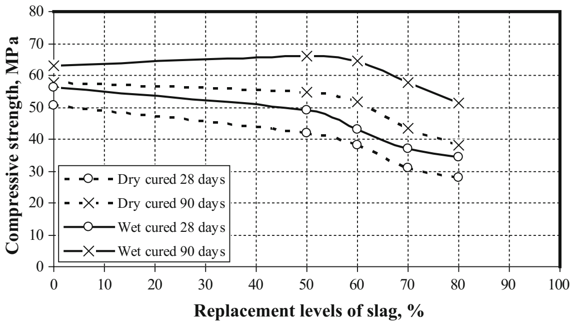

Fig. 1. Effects of slag replacement and curing conditions on 28 and 90-day compressive strength of concretes [7]

3.3 Flexural Strength

The slag concrete, under a determined compressive strength, has a higher tensile strength than the concrete with OPC [8]. It is obtained nearly 8 MPa of strength in 14-day [9].

3.4 Splitting-Tensile Strength

The results of splitting experiment are similar to of compressive. By increasing slag amount, the splitting strength decreases. It is mentioned that it is not valid for the samples having 50 and 60% slag and cured in water for 90 days [7]. Furthermore, as shown on Fig. 2, the decrease in splitting strength is less than the decrease in compressive strength. The results of splitting and compressive strength for the samples with 80% are lower.

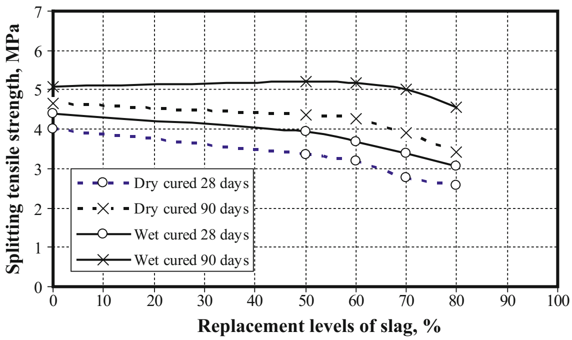

Fig. 2. Effects of slag replacement and curing conditions on 28 and 90-day splitting tensile strength of concretes [7]

3.5 The Capillary Water Absorption

The capillary water absorption values of the concrete formed by partial replacement of OPC with GGBFS decreases to an important extent, this is especially crucial for concretes which are exposed to getting wet and dry.

Capillary water absorption value decreases by increasing compressive strength, also reports that the capillary water absorption value is so vulnerable against the cure conditions [10], and the lowest coefficient of capillary water absorption is obtained from the samples which are kept under 20 °C in lime-saturated water cures during 28-day [3].

Figure 3 shows the variation in water absorption rates with concrete age and curing condition for the control and slag concretes. It is clear that rate of water absorption decreases systematically with an increase in curing period (from 28 to 90-day), and the gradients of the water absorption tends to decrease with increase in the replacement level of slag.

Generally, slag concrete performed better than the control concrete and marked improvements in terms of lower rate of water penetration through capillary suction were apparent, particularly under wet curing condition.

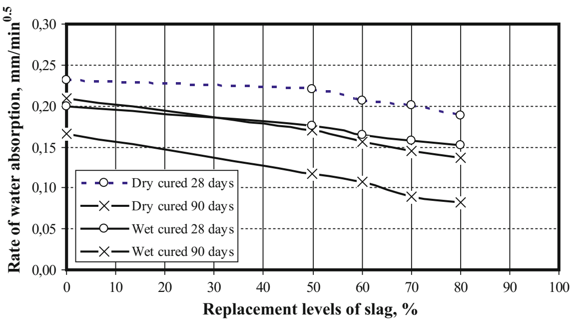

Fig. 3. Effects of slag replacement and curing conditions on 28 and 90-day water absorption rate of concretes [7]

Furthermore, the reduction in the water absorption with increasing test age was about 12 and 15% for air and wet cured conventional concretes, respectively, while it was about 18–22% and 30–35% for air and wet cured slag concretes, respectively. This reduction in the water absorption with age indicates better performance of slag blended cement concretes over conventional concrete. The improvement in the performance of the air cured samples might be explained due to the surface carbonation of the air-cured concrete resulted in enhanced reduction in sorptivity.

The correlation between water absorption with the curing conditions and the age of the concrete is given in Fig. 4 [7]. Similar to the rate of water absorption test results, water absorption characteristics of the concrete specimens decreased with increasing slag content, irrespective of curing condition and testing age. However, the differences at water absorptions are more characteristic after 28 days of curing, water absorption of the GGBFS concretes are less than control concretes.

At the age of 90-day, water absorption decreases with the ratio of between 12 and 15% at wet and dry cured control concretes. Decreasing ratio of water absorption at dry cured GGBFS concretes are between 18 and 22% and at wet cured GGBFS concretes are between 30 and 35%.

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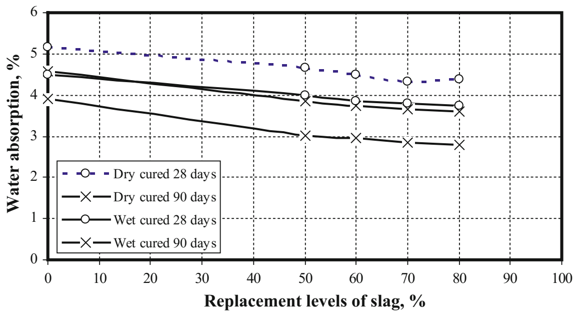

Fig. 4. Effects of slag replacement and curing conditions on 28 and 90-day water absorption of concretes [7]

4 Durability of Concretes with High Volume GGBFS

4.1 Sulfate Resistance

In a study in which Hooton and Emery (1990) used solutions of $MgSO_4$, $CaSO_4$ and Na_2SO_4, 130 different cement were used and proportionally to the amount of GGBFS, even though the concrete obtained by respectively 45 and 72% GGBFS replacement by sulphate OPC, did not show a deterioration inside 3000 mg/lt SO_4 solution for 10.5 years, the concrete with C_3A of a ratio from 3.5 to 12.3% with OPC was badly affected [11].

The sulphate resistance of the concrete is affected from GGBFS content rather than water/cement content [12]. The reason of it is related to the decrease in permeability caused by GGBFS. Furthermore, it is known that the increase in sulphate resistance, caused by GGBFS is due to the decrease in C_3A content. Additionally, slag decreases $Ca(OH)_2$, increases the gels of C–S–H and improves the strength, weakens the permeability of the concrete [1].

4.2 Resistance to Chloride-Ion Penetration and Reinforcement Corrosion

Resistance to the effects of chloride: the effects of different cure conditions such as autoclave (175 °C, 0.5 MPa), steam cure (80 °C) and normal cure (20 °C, 100% RH) on the properties of concrete produced by four different slag replacement (0, 25, 50 and 75%) reported that the cure at room conditions is the best to improve durability, to prefer steam cure instead of autoclave cure when early strength development is desired [2], and finally a reduction in chloride permeability occurs by increasing slag replacement rate, depending on also application, the use of different slag rates is possible to increase the strength and to decrease the chloride permeability [3].

Chloride permeability: The slag cement or slag concrete is more resistant to penetration of chloride ions into the concrete than OPC. This positive effect stems from the chemical combination of chloride ions and slag hydration products which have reducing feature of chloride stream and at the same time the decreasing permeability of slag cement. Moreover, this increased strength has a potential to decrease the corrosion risk of steel in concrete structures.

The important point in chloride permeability is the chloride binding capacity of the cement. Through studies, it is known that C_3A binds chloride. Even though OPC is supposed to bind more chloride ions and to decrease chloride penetration due to having C_3A more than slag cement, the studies proved the contrary. In the analysis done by cement with GGBFS, it is observed that the penetration of chloride ions in OPC is less. This is because the gels of C–S–H bind more chloride. Owing to the fact that the C–S–H occurred after the hydration of slag cement is more than OPC, due to binding chloride ions, the chloride permeability of slag concrete mainly decreases.

Fernandez and Malhotra [13] examined the effects of different cure conditions, (natural environment cure and wet cure) on chloride permeability of concrete with 70% GGBFS. At the end of their study, they observed that the use of GGBFS at a rate of 70% decreases the chloride ion permeability [13]. The chloride permeability decreases considerable at the concretes include more than 50% of GGBFS shown in Fig. 5. For example, permeability value of 70 and 80% of GGBFS concretes at the age of 90-day is 1000 Coulombs and this value is qualified as wonderful in accordance with the ASTM 1202 [7].

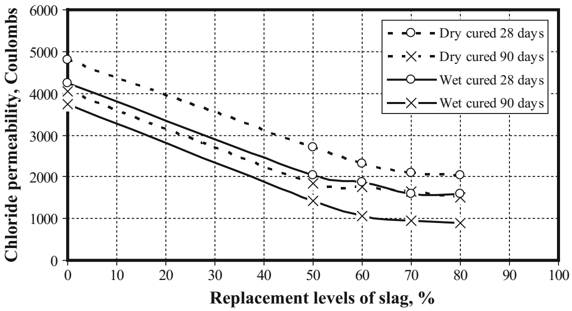

Fig. 5. Effects of slag replacement and curing conditions on 28 and 90-day chloride permeability of concretes [7]

Corrosion resistance: Free chloride permeability of the concrete with GGBFS and they saw that the higher the amount of GGBFS, the lower the values of free chloride permeability. Additionally, they found out that the free chloride permeability of the concrete with 70% GGBFS is 43.8% less than of the control concrete [14].

Corrosion resistance of the concrete with GGBFS and they discovered that the steel corrosion potential of the concrete with GGBFS is smaller than 250 mV. This corrosion value is a very small value. In addition to that, they studied the surface of the steel exposed to corrosion according to the percentage of GGBFS and they found out that the surface under corrosion decreases while the amount of GGBFS increases [4].

4.3 Durability to Sea Water

In his experimental study in which he worked with mortar samples completely sunk in sea water, it is examined the effect of the slag amount against sea water attack and pointed that by increasing GGBFS amount in cement the expansion decreases [15]. It is made a research on the performance of the concrete with slag and OPC of different C_3A content and sea water, reported that the strength development of the concrete with 70% slag and completely sunk in sea water better improves and it is exposed to less chemical attacks with a mediocre chloride permeability [16].

4.4 Resistance to Carbonation

Carbonation occurs when CO_2 penetrates into the concrete. Both the porosity and the permeability of the concrete have an important role in the mechanism of carbonation. The carbonation of the concrete depends on the cure conditions, water/binding rate, the temperature at which the concrete exposed to carbonation and relative humidity, and the properties of the mineral additives used. The decreased permeability delays the CO_2 penetration deeply through the concrete [3]. The examination of the carbonation depth of the concrete with 0, 30, 50 and 70% of GGBFS showed that the more the slag rate, the less the carbonation depth [17].

It is found that for low Blaine fineness slag (4500 cm^2/g), although the slag concretes were denser, the carbonation rate increased with increasing amounts of slag. This was thought to be attributable to less CH being available due to the pozzolanic reaction, so the carbonation must progress deeper to get at the available CH. There is less material available prone to carbonation per unit area to react with CO_2. Initially the pozzolanic reaction is slow, thus porosity is higher and CO_2 diffusion is rapid [18].

However, they found that for higher fineness slags (6000–8000 cm^2/g), carbonation rates were lower than that for OPC, thus pore modification was more dominant than the change in CH content. So, slag mixes tend to have greater depths of carbonation and are more permeable (although not necessarily more porous) and therefore would tend to scale more, especially under severe environmental conditions [1].

4.5 Freeze-Thaw Durability (Resistance)

In the study, it is obtained perfect results in the study with the samples of 60% GGBFS and OPC. However, for all experiments, better results are gained for the mixtures with

GGBFS rather than for with OPC. The highest resistance factor was obtained in the sample with 50% GGBFS [19]. The mixtures with OPC and 66% slag compared. For both group of samples, length changes, massive loss and changes in dynamic modulus of elasticity and compressive strength, air-gap systems, air-gap conditions are similarly obtained [20].

4.6 Acid Resistance

In their study where they study the long and short term performance of the concrete with GGBS and FA, prepared concretes are prepared with 40% FA and OPC. After 3 days of wet cure, among the samples left in 2% H_2SO_4 solution, under room temperature by a time of 4, 8, 16 and 50 weeks, it is observed that the concrete with 15% GGBFS and 25% FA are more superior against acid attack than both concrete with OPC and 40% FA are. They informed that the change in weight at the end of 50th week is approximately 8%. According to them, the weak resistance of concrete with OPC against H_2SO_4 attack is due to the presence of large pores and frees $Ca(OH)_2$ in the concrete [21].

The concrete with 40% FA is also poor against H_2SO_4 attack at the early age. The reason is that there are numerous un-hydrated FA particles in the concrete, and the matrix is significantly porous at the early age. Furthermore, the amount of C–S–H gel in the concrete with 40% FA formed by cement hydration, is less than the amount of C–S–H in concretes with OPC or with FA and slag [3].

4.7 Durability of High and Low Temperature Effect

By use of GGBFS in concrete, the resistance of the concrete under high temperatures increases as a result of pozzolanic activity of the slag. High strength concretes including SF, FA and GGBFS were exposed to different temperature conditions maximally to 800 °C. According to experiment results, the concrete with FA and GGBFS, especially under 600 °C showed the best performance compared to control concrete. In previous studies, it stated that the resistance of the concrete with 40% GGBFS and exposed to 200 °C high temperature increased at a rate of 15% in comparison to those tested under room conditions. While the remaining resistance of the concrete with 40% under 400, 600 and 800 °C is 100%, 61 and 29%, the resistance of the controlled concrete is 89, 58 and 24% [22].

An earlier work on the performance of slag cement at elevated temperatures was done [15]. Four cement pastes containing 0, 50, 70, and 90% replacement of slag were tested by weight with OPC. The maximum tested temperature was 500 °C with an interval of 100 °C. All slag-cement paste specimens experienced an increase in strength between 100 and 250 °C. The 70% slag replacement showed the best results with a residual compressive strength of 190% of the original strength at 110 °C.

Moreover, the residual strength of this paste was higher at all temperatures as compared to the original strength. The other two slag-cement paste specimens also showed better residual strengths as compared to the pure cement paste specimen. Cement paste and concrete specimens incorporating 65% slag were prepared by weight of cement and firebrick aggregates. The results were compared with pure OPC cement paste/concrete and 30% PFA cement paste. The maximum temperature was 700 °C, while the residual properties were measured at every 100 °C interval. They found that the slag-cement paste and concrete gave the best results among all the specimens tested. The residual compressive strengths of slag concrete were 102 and 80% of the initial cold strength at 450 and 600 °C [23].

4.8 Abrasion Durability (Resistance)

The abrasion durability of concrete with GGBFS increases by applying the suitable and sufficient cure. While the insufficient cure conditions decrease the abrasion durability to a large extent, slag concrete is affected from that more than concrete with OPC. In their study on abrasion durability and its mechanical features, it is reported that the strength development of slag concrete indicates the partial usage of GGBFS instead of cement in concrete; however, the abrasion durability of slag concrete is lower than of control concrete without slag [13]. In condition that suitable and sufficient cure is applied, the use of GGBFS in concrete provides some advantage in abrasion durability [8].

5 Future Trends on Concretes High Volume GGBFS

In the concrete production applications of today and future, the expected concrete types with GGBFS and the result of the studies done about this is tried to be listed below.

Self-Compacting Concrete: The self-compacting concrete (SCC), which is developed especially to be used in structures with dense reinforcement at the end of 80s in Japan, has a perfect workability and high resistance to segregation. SCC can easily furnish itself to the dense reinforced areas without using any vibration. The fresh SSC can be defined as a concrete which has ability to fill the molding and hold the reinforcement by means of its own weight, while keeping necessary homogeneity. Regarding the positive effects of GGBFS used instead of cement on cost and hydration will be better for the strength feature of the concrete [24].

Roller Compacted Concrete: Roller compacted concrete (RCC) is a low-viscosity concrete which is laid in plates and before hardening which is able to carry at least 5 tons of roller in order to be compacted. The reason which renders RCC economic is its very little content of cement. This small amount of cement in RCC brings about a decrease in hydration heat. Hence, RCC is used in mass concrete such as barrage constructions.

The effects of interval between mixing and compacting in RCC including high volume GGBFS were examined. For the mixture having 0, 25, 50 and 75% of GGBFS, he observed that the interval between mixing and compacting mainly influences the compressive strength by increasing rate of GGBFS. He pointed out the increased distance between cement granules by increased amount of GGBFS as the reason of this. For RCC, concrete without sedimentation is produced [21].

Non-Slump Concrete: It is noted that GGBFS used instead of fine aggregate up to 30% is useful for the compacting and compressive strength of RCC, the surface area of the GGBFS effects the development of strength. Larger surface area at early ages, smaller surface area at late ages show higher strength. They also mentioned that the GGBFS with small surface area is more effective in reducing the temperature of concrete [25].

Reactive Powder Concrete: It is mentioned that for reactive powder concretes with 20, 40 and 60% GGBFS even at 40 and 60%, they obtained compressive strength over 200 MPa, among concrete with 20, 40 and 60% GGBFS and applied standard, steam and autoclave cure, obtained compressive strength over 250 MPa in concrete that had autoclave cure with 20% GGBFS addition. In the presence of external pressure, they observed that this value paramount up to 400 MPa with addition of 40 and 60% GGBFS they reached strength of 210 and 254 MPa by standard cure in 90 days, they attained 33.2 MPa of flexural strength, 6161 N/m of fractural energy and 17,210 Nmm of toughness value and they obtained approximately the same results with autoclave cure [26].

Lightweight Concrete: It is observed that compressive strength in aerated concrete with GGBFS addition increases at a rate of 8–63% depending on the cure conditions, adding high volume of GGBFS improves compressive strength in aerated concretes and it contributes to a better microstructure formation [4].

Ungrounded BFS: It is mentioned that, for concretes in which they use 10, 20, 30, 40, 50% of GBFS and BA (Bottom Ash) as aggregate, by increasing replacement rates, the resistance of the concrete decreases.

BA gives rise to reduction in resistance more than GGBFS does and replacement over 40% is more effective. The resistance of concrete prepared by industrial waste such as polypropylene fiber, GBFS and BA as fine aggregate towards 800 °C high temperatures, showed how it is possible to use these wastes with a ratio of 50% of aggregate which covers 30% volume of the concrete [27].

The study on shrinkage done by GBFS as fine aggregate, determined that by increasing GBFS rate, there is a decrease in shrinkage cracks. They also mentioned that the reason of this is the gap form related to GBFS structure and linked with the same reason flexural strength, compressive strength and modulus of elasticity decreases [28].

Alkali Activated Slags: By means of the activation of GGBFS with alkalis such as NaOH, $NaCO_3$ and $NaSiO_3$ super qualified concrete can be produced. It is informed that the alkali activated mortar with GGBFS exceeds the potential danger limit in ASR but does not exceed the danger limit [29].

6 Conclusion and Recommendations

For 28 days and older ages, to add 50–60% GGBFS to concrete results in higher resistance, whereas to add GGBFS over 80% results in lower resistance. It is understood that to obtain the maximum resistance, the optimum GGBFS rate is 40–60%. The more vitreous content, fineness and alkali content of GGBFS and greater fineness and alkali content of OPC was used together with it improve the strength development.

Using GGBFS up to 80% can increase the resistance to 28 MPa. Therefore, it will be useful to prepare specifications for mixture design and regulations concentrated on the factory operating requirements for high volume GGBFS and the real expectations from the concrete. Hence, more qualified concrete will be obtained regarding workability, resistance and strength, as well as more economic concrete by waste reduction. At the same time air pollution could be reduced.

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Investigation on Foster's High Buildings with Sustainability Criteria and Load-Bearing Systems Interaction

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Abstract. Tall buildings, the indispensable elements of the cities evolved in order to respond to rapidly increasing population and urbanization from the beginning of the 20th century, are quickly emerging to the foreground with their unique designs in both load-bearing systems and energy and resource management. Their sensitivity to lateral loads due to wind and earthquakes has inadvertedly made an important contribution to the development of advanced construction technologies in tall structures. The main aim of the study is to discuss the load-bearing systems, which has an effect on the shaping of the function in architectural design, combined with the concept of sustainability, which holds a significant place in the discourse of modern day. In this context, the buildings of Norman Foster, who successfully combines his engineering and architectural identities in his work and synthesizing advanced load-bearing systems within sustainable design principles, have been examined. These buildings, examined via criteria such as construction system, material, structural form, lateral load resistance, the utility core, innovation, energy efficiency and effective use of water, are prime examples of 21st century tall building construction, safe and respectful to environment via the meeting between form and function. As a result, it is believed that this study will be an archival feature in discussing architectural design and structural design criteria together. It has been emphasized to develop architectural design solutions integrating technological, aesthetic and environmental sensitivities.

Keywords: High-rise buildings · Sustainability · Load-bearing system Energy efficiency · Construction technology

1 Introduction

Tall buildings were built in various geographies as a symbol of power and prestige throughout history. They have evolved into being indispensable elements of the cities in order to respond to rapidly increasing population and urbanization since the beginning of the 20th century. Containing unique design solutions resultant from their high altitude in terms of both load-bearing systems and energy-resource usage, tall buildings stand out from other types of constructions with their combination of load-bearing systems and sustainability designs. Scientific developments and technical

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advancements in building materials and construction technology have created a wide range of possibilities for tall building development. Their sensitivity to lateral loads caused by wind and earthquakes has led to significant advancements in the development of advanced construction technologies. In addition, the fact that they are status symbols in the race between countries/cities/companies affords expanded budgets to the construction of tall buildings, which in turn affords them a more advantageous position in the context of implementing sustainable design solutions. During tall building designing, architectural design and structural design phases constitute an integral part of the sustainable design process. Choosing the type and application of structural systems, making crucial decisions on building materials and taking necessary steps so that the buildings can adapt to changes throughout their life cycle; these two design processes are carried out together in order to achieve successful results [1]. In this study, the buildings of Norman Foster, who effectively uses both architectural designs and structural designs, resultant in synthesizing advanced load-bearing systems within sustainable design principles, have been examined.

2 Tall Buildings

It is possible to say that the examples of the first tall buildings were made in the direction of religious beliefs in order to exist closer to God. In medieval times, castles were structures that emphasized the superiority of the aristocratic class. Clock towers, fire towers and lighthouses were built tall to serve the purpose of keeping watch and observation [2]. The overall characteristics of buildings began to change with the production of the steel, the creation of the steel frames and the transition from the loadbearing wall construction system to the skeleton construction system, resultant of the development of the required technical and material technology. Since the concept of height is subjective in context, it is quite challenging to name structures as tall buildings. Tall buildings are defined in different ways according to the country, period, environment, structural criteria and many regulations that they are built in.

Certain definitions about tall buildings are given below;

- It is a building which constitutes a higher structure, height and feature a different design, construction and usage conditions from its surrounding buildings [3]
- It is a tube where the flooring is stacked vertically on top of the floor and where holes are drilled in its side in order to create indoor spaces [4, 5].

When the concept of tall buildings are examined in context of legal legislations; German standards define buildings exceeding 22 m at their highest points [6], whereas the Istanbul zoning regulation considers structures with a height of at least 60.50 m as a tall building [7]. According to the Council on Tall Buildings and Urban Habitat (CTBUH) established in the U.S., there is not an absolute definition of tall buildings and it is suggested that the altitude concept can be defined according to the following criteria [8]:

a. Height Relative to Environment: Height is not just a quantifiable value, it is also a relative estimation in context with the environment the building exists within.
b. Proportion: As the ratio of height to width increases, the frailty of the building also increases. Many buildings exist around the world that cannot be classified as very tall, yet presenting a very frail image.
c. Tall Building Technologies: If a building contains technologies which may be attributed as being a product of specific vertical transport technologies, lateral rigidity systems or structural wind bracing as a product of height, then this building can be classed as a tall building (Fig. 1).

The increasingly reduced number of areas to conduct construction, the need to place condense constructions in these limited areas, the increase in land prices due to demand, the desire to build prestigious constructions, the development of materials and construction technologies are all factors contributing to the need of building tall buildings that is sustainable in ecological and ecological terms.

Fig. 1. **a** Relative context in environment, **b** Proportionality, **c** Utilized advanced technologies. *Source* http://www.ctbuh.org/TallBuildings/HeightStatistics/Criteria/tabid/446/language/en-US/Default.aspx

3 Load-Bearing Systems in Tall Buildings

The load-bearing system is a natural or artificial conveying element to transfer the forces and loads acting on it to the ground and provide the predicted static balance. In tall buildings, the design of the load-bearing system is greatly affected by the cargo and the function of the structure it is exposed to [5–9]. For this reason, it is important to pay attention to these dynamic loads in determining the bearing system as the lateral loads increase as elevation increases.

3.1 Lateral Loads in Tall Buildings

Tall buildings are subject to many loads throughout their lifetimes. Many of these loads result from themselves or design preferences. The affecting loads must be assigned prior to building design. Since it is not possible to outline a standard load-bearing system that may be applicable to all settlement areas, each building is designed and applied to its own and its region according to special conditions. The most important loads that affect the design of the load-bearing systems of tall buildings are the horizontal loads (wind, earthquake) and they have an influence on the structural behavior. Shaping modes of load-bearing systems under lateral loads in multi-story structures are tilting, turning, bending and sliding. In line with these behaviors, a multi-level building effected by pressure forces generated by vertical loads can be likened to a console [10]. The composition of the total lateral and vertical forces acting on the structure must remain within the building area in this console. Otherwise, it will bring about a tipping event. The more sloping the composite features, the higher the probability of tipping over it represents. One of the most important loads to be considered in tall buildings is the wind loads increasing parabolically in relation to the height. This load, which, after a certain height, affects the building without any relation to any factors stemming from field, has an important influence on the structural design, especially in structures over 40 storeys. Another important lateral force, earthquakes cause rapid stress changes in structural elements. During the earthquake, the structural loads are proportional to the weight of the structure. The excess vertical loads to be added to the structure create large moments during the earthquake. Rigidity of the building reduces by an increasing the height/weight ratio. Vertical loads should be observed closely especially near the fault lines [11].

3.2 Load-Bearing System Classifications in Tall Buildings

Variations in spans due to the influences within planning and the differences required by construction technologies, the increase of all loads with increasing building height in multi storey buildings, the relation of wind loads and dead loads on height, the increase of earthquake load with increasing building weight and increasing importance of lateral shifts in multi storey buildings have significantly impacted the building structures. Load-bearing system classifications have changed with evolving technology and experience.

In 1969 Fazlur Khan classified structural systems for tall buildings relating to their heights with considerations for efficiency in the form of "Heights for Structural Systems" diagrams [12]. This marked the beginning of a new era of skyscraper revolution in terms of multiple structural systems. Later, he upgraded these diagrams by way of modifications [13, 14]. He developed these schemes for both steel and concrete as can be seen from Fig. 2 [15–17]. Khan argued that the rigid frame that had dominated tall building design and construction so long was not the only system fitting for tall buildings. Because of a better understanding of the mechanics an exterior structure. It should be noted, however, that any interior structure is likely to have some minor components of the lateral load-resisting system at the building perimeter, and any exterior structure may have some minor components within the interior of the building [18].

Based on their morphological properties, tall buildings' structural systems can be grouped into four basic classifications; rigid and semi-rigid frames, shear wall or braced frames structures, shear wall or truss-frame interactive structures, and tube structures. Tube structures can be further categorized into frames tube systems and high efficiency tube systems. High efficiency tube systems have evolved from the basic frame tube. Figure 2 shows a comparison of tall building systems versus number of stories [19].

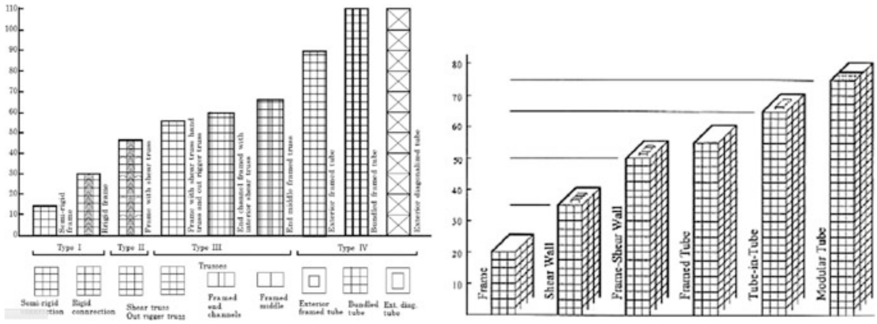


Fig. 2. Comparisons of structural systems (*Source* Paulino [19]) and classification of tall building structural systems by Fazlur Khan (*Source* Schueller [15], Ali [16], Ali and Armstrong [17])

4 Sustainability of Tall Buildings

Nature has been regarded as an unlimited resource well for centuries. In the 18th century, in response to the developing society and increasing needs of the industrial revolution, natural resources were used callously, resulting in the rapid increase in environmental pollution and the emergence of various environmental problems. In the 1970s, many countries began to seek environmental consciousness and solutions in the face of emerging energy crisis. Parallel to those efforts, the concept of "sustainability" started to become a topic of discussion in global conferences and reports.

The opening basis of the concept of sustainability is focused on avoiding environmental problems that arise in parallel with economic and technological developments and protecting the ecosystem in the wake of those developments. The concept of sustainability also has many definitions. According to Erengezgin, sustainability is an effort to maintain life not "in spite of everything", but "considering everything" [20].

In addition to the indispensability of today's tall buildings for many reasons, the fact that their negative effects on the natural environment is more dire compared to the medium and low-rise buildings have placed a greater importance on the sustainability of tall buildings [5]. The concept of sustainability of tall buildings calls for a more economical use of these buildings without damaging the environment.

Sustainable design of tall buildings consists of design ideas that reduce the energy and resource usage down to the lowest possible level that keeps the building operational. In this context, a building is directly concerned with the design of consumption of energy and resources. The decisions made in the early stages of building design play an important role in increasing energy efficiency [2]. Many subjects such as the location of the structure, the climate of the region, the position of the structure, its harmony with its surroundings, air conditioning and lighting systems, the weight of the structure, the structural system, the materials used in the construction phase, the construction methods can be considered as sustainability-related design criterion within the construction of a tall building.

5 Norman Foster and Design Approaches in Tall Buildings

When Norman Foster designs and implementations from the past to the present day are observed, it is easy to assess the advanced technology and ecological features they all carry. The buildings all exhibit the continuous usage of architectural design and structural principles together with an emphasis on ecological studies from the beginning of the 21st century. It can be said that Foster can not give up on both advanced technological systems and ecological architecture because of his dependency on technology and sensitivity to the environment.

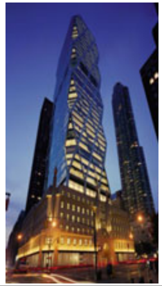
Foster's most overt tendency is to choose the rational option for material handling, detailing and using industrial modular components in all of his works. The reinterpretation of old and traditional materials brought with it the previously untested, non-drawn and unapplied details. New developments around the world have also made him more sensitive to environmental values, resource consumption and technology use. The fact that he expenditures only as much material and energy is needed have been a staple in all his buildings. The interesting result of these is that he enabled the ecological architecture to work in tandem with tall building designs as he utilized technology for that purpose [21].

According to Foster, the best architecture relates not only to the structure of the street or its relation to the skyline, the structure that keeps it upright, the mechanical system that allows it to work, the ecology of the building, the materials used, the personality of the spaces, the use of light and the shadow, the symbolic meaning of its shape and how it represents itself in town, but also from the synthesis of all these parts that bring it together.

6 Structural and Sustainable Assessment

In order to be able to discuss the concepts of structure and sustainability, which are mentioned for their importance in the previous sections, at the tall building scale, architect Norman Foster's three different buildings which have the same function and constructed in different years are selected, and the general characteristics of selected buildings are given in Table 1. This building, which has become an important milestone in the tall building design process moving forward, has been examined in detail in terms of the structural system and sustainable design. General criteria in sustainable design review are; land and orientation, materials, innovation, energy efficiency and efficient use of water, while the criteria in the study of the load-bearing system are; construction material, construction form, lateral load resistance and utility core location-geometry.

Table 1. Tall buildings in which concepts of structure and sustainability are discussed (*Source* www.fosterandpartners.com)

Name	Commerzbank		Swiss Re		Hearst Tower	
Location	Frankfurt		Londra		New York	
Construction year	1997		2004		2006	
Building function	Office		Office		Office	
Architect	Foster and Partners		Foster and Partners		Foster, Gens	
Height	298 m		180 m		182 m	
Total area	120.736 m^2		64.469 m^2		79.500 m^2	

6.1 Commerzbank

This building, which has a contrarian scale to its surrounding area, has successfully implemented both the load-bearing system and sustainability in its structural design based on the year it was built in. Steel has been used as frame material. Steel is the most economically recoverable material in the world. Since steel structures use thermal insulation solutions, the energy losses are considerably reduced. Steel constructions can be reused, disassembled and installed. In the light of all this, the use of steel materials seems to have contributed greatly to structural ecological and economic sustainability. The criteria of the building related to the structural system and sustainable design are briefly summarized in Table 2.

The triangular form of the structure is intended to reduce the effect of the wind which will affect the tall building and to avoid the direct striking effect that might affect the design based on the natural ventilation (Fig. 3). The form resulting from the measures taken against the wind load also affected the sustainability function. The climate in Germany, where the building is located in, is modest. The position of the utility core can help prevent heat from entering the building by providing indoor shading or in the preservation of building's interior heat. There are 3 cores in the building and all 3 are located in the corners and the exterior of the building (Fig. 3).

The core at the corners of the building's north-facing corner reduces the cold effect of the wind coming in from the north. As the edge of the triangular building form is located on the south side of the land, the cores positioned on the corners do not prevent the sunlight gain. Although the central core systems are usually used to reduce the moment effects of lateral forces in tall buildings, the cores are separated in the Commerzbank Building and placed symmetrically to the corners so that the lateral load component passes through the center of rigidity and the torsion effect is prevented.

Table 2. Commerzbank office building's load-bearing system and sustainable design related criteria

Commerzbank	
Load-bearing system related criteria	**Sustainable system related criteria**
Material: Composite material is used. Column beams and flooring are all steel. Each component of the steel column assembly was sprayed with a cement-based component against corrosion	**Material**: The outer shell consists of a low-e glass layer with spacing in between. The outer surface is a fixed cladding system consisting of opaque and transparent components
Construction System: Curtain wall frame system was used. Beams with an 8-storey height and hollow structure were used in the building	**Field-Orientation**: The structure is positioned in such a way that one of the edges are aligned with north, while the one of the facades of the building face directly south

(*continued*)

Table 2. (*continued*)

Commerzbank	
Building Plan Form: The building plan is in the form of a rounded triangle. In correlation to that, it exhibits a rigid structure in terms of static	**Energy Efficiency**: In the building center, natural ventilation and lighting are provided thanks to the atrium and double façade system from the ground floor to the top. The entry and exit details of air and controlled rainwater are solved in the curtain wall
Lateral Load Resistance: The building form being a triangle reduces the effect of wind, an important lateral load	**Efficient Use of Water**: The wastewater from the air conditioning plants is reused as reservoir water to clean the WCs. There is also a treatment system for the reuse of wastewater throughout the building
Utility Core: There is a core in each of the three arc-shaped corners of the arc-corners of the triangular form	**Innovation**: It's been noted to be the world's first ecological tall building that uses new design ideas and technological system at the time of its construction

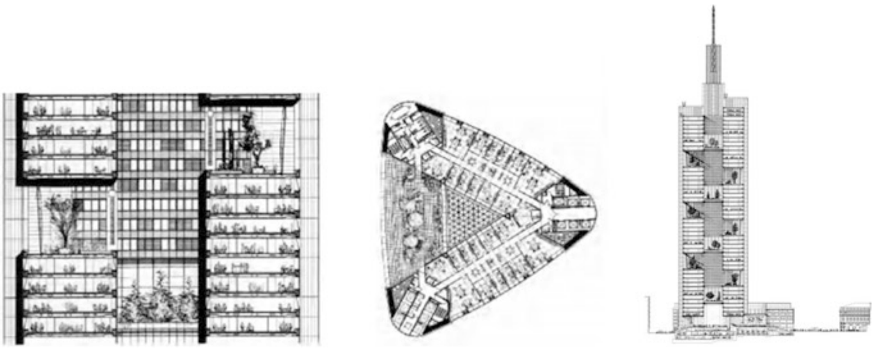


Fig. 3. Commerzbank's plan, cross-section and courtyard design

When the plans are examined, it can be seen that the north facade has only one of the corners facing it, while the south facade corresponds directly with one side of the building. While this positioning is based on the fact that the building is placed according to the plot it belongs to, the placement of courtyards at south side and the transparent shell surface placed on this same side also enables the utilization of natural lighting and daylight effectively. However, the higher floor, which is required to form the courtyard, causes soft floor problems in the face of seismic loads. This irregularity created on the vertical axis causes rigidity fluctuations. Increasing the number of columns or adding the diagonal elements reduces these loads which will occur in the earthquake when placed in floors and especially on ground level where high storeys are to be built on.

6.2 Hearst Tower

It is a tower built by emptying the interior of an existing Art Deco structure, preserving the stone shell and constructed in this new space. Recyclable materials are used in the exterior and load-bearing system elements of the tower [5]. The criteria of the building related to the structural system and sustainable design are briefly summarized in Table 3.

The load-bearing system of the tower is surrounded by steel cores, reinforced concrete columns up to 10th floor, and steel crossings applied on the every 4th floor after 10th floor. This load-bearing system, which is called Diagrid systems, has become especially popular worldwide after this design. The diagrid load-bearing system, which is a tall building load-bearing system formed by placing oblique columns and beams on the outer surface in the outer shell of the structure in such a way as to form triangular units, consists of repeating modules. In addition to their structural effectivity, they are also visually preferred systems. The construction of the diagrid load-bearing system is more difficult in tall buildings compared to conventional systems. However, the need for reinforced concrete walls with crossed frames on the exterior wall has been greatly reduced and the resistance against lateral loads has been increased.

The implementation of the diagrid load-bearing system allowed the usage of 20% less steel than the conventional frame system in comparison [15]. In this context, the effective use of material with efficient load-bearing system design has contributed to the economic sustainable design.

The rectangular shaped core block (Fig. 4), starting from the west side and extending to the middle of the structure, functions partly as a solar and wind buffer on the west side. In terms of load-bearing system assessment, its irregular placement both on vertical and lateral planes affects the structural rigidity negatively. However, in the context of diagrid systems, the utility core is not required carry any load other than the gravitational force.

Table 3. Hearst Tower's load-bearing system and sustainable design related criteria

Hearst Tower	
Load-bearing system related criteria	**Sustainable system related criteria**
Material: Composite material was used. Composite flooring with steel columns and beams available	**Material**: 90% of the steel used in construction was recycled. Double-layer façade system with low-e glass panels is used in the outer layer in triangular form
Construction System: Steel, diagrid structure system is used. The part of the entrance floor which is housed within the old building are supported via mega columns	**Field-Orientation**: It is a building designed and built on an existing older structure
Building Plan Form: The building plan form is rectangular, close to a square	**Energy Efficiency**: During the majority of the year, 75% of the building is ventilated and cooled using HVAC system utilizing outside air. Natural lighting is also available

(*continued*)

Table 3. (*continued*)

Hearst Tower	
Lateral Load Resistance: Diagrid system was utilized in construction	**Efficient Use of Water**: Rain water is collected and reused. There is a rainwater collection tank on the roof
Utility Core: It has a rectangular-shaped core block starting from the west side and extending almost to the middle of the structure	**Innovation**: Its most distinctive feature is the external facade with a sloped form in diamond shape

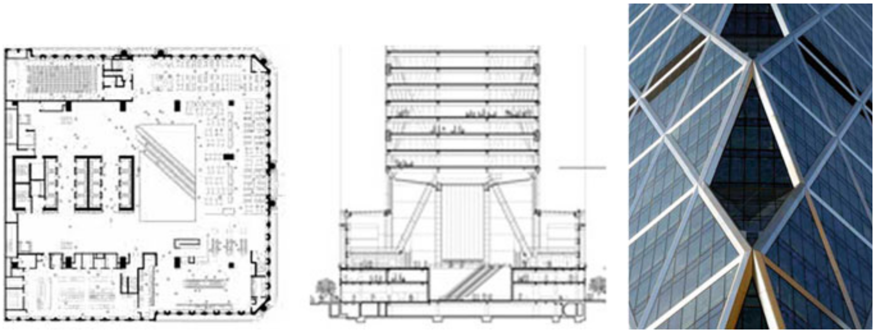


Fig. 4. Hearst Tower type floor plan, cross-section and diagrid system view

A transparent side was formed as an energy-efficient advantage of the Diagrid system. Since the interior does not contain any columns, the building receives plenty of daylight. This side consists of high performance, low emission glass that blocks the heat and takes up natural light into the interior spaces. Heat loss is prevented and comfortable interiors are created. In addition, the floorings of the tower have the feature of storing heat in the summer and spreading heat in the winter. The roof is designed to collect rainwater during the rainy season, allowing 30% less rain water to mix in with the city's drainage system.

6.3 Swiss Re

The curvilinear form of the building has been designed and constructed via utilizing digital technologies in the field of architecture, which is designed with environmental texture in mind and an approach sensitive to the existing city structure. Due to the circular shape of the building plan form and the 5° of rotation, the interior of the building can receive sunlight from all angles. Since the utility core is centralized and the office units with the gaps are located on the structure surface, a flexible design was obtained and the sunlight has been utilized effectively as a result (Table 4).

Table 4. Swiss Re Office Building's load-bearing system and sustainable design related criteria

Swiss Re Building	
Load-bearing system related criteria	**Sustainable system related criteria**
Material: Composite material was used. Composite flooring with steel columns and beams available	**Material**: Double shell facade system was used. There are double glazed panels in triangle and rhombic form on the outer layer and single glazed doors in the inner layer. There is solar radiation reduction glass built in the spiral parts
Construction System: The steel diagrid system was used	**Field-Orientation**: The structure is circular in shape. It ascends by turning 5°
Building Plan Form: The building plan is circular. It has a diameter of 50 m on ground floor, 57 m in the broadest floor and 25 m in the top floor	**Energy Efficiency**: There are 6 spiral atriums for ventilation in the building. These atriums also have an effect on lighting. There is a sky garden covered with glass on the top floor
Lateral Load Resistance: The structure features a curvilinear aerodynamic form to reduce wind loads	**Efficient Use of Water**: There is no ecologically efficient water reuse system such as waste water recycling for reuse
Utility Core: It features a centralized utility core	**Innovation**: Spiral-shaped atriums were built. The structure is overall in cylindrical form

Similar to the Hearst Building, the building load-bearing system is constructed with factory-built diagonal grid-shaped steel carriers (Fig. 5). The flooring holds on the centralized core and rotates around it to form the spiral atrium. The Diagrid system provides resistance against lateral loads while the core is designed to withstand only vertical loads [22]. The intensive use of steel as building material is a positive factor in terms of economic sustainability. The diagrid system constructed to counteract the lateral load effect allows for the formation of a transparent structure shell, thus enabling the use of energy efficient approaches. It also improves the visual comfort conditions for the residents of the building. These atriums, formed due to the structure plan form and service core, allows for hot air to be directed upwards by chimney effect in the summer months and provide natural ventilation; while in winter, it contributes to the reduction of heating costs by creating greenhouse effect. The structure form and atriums are strikingly innovative approaches in design. Simultaneously, the upwards-tapering cylindrical form provides more resistance against the wind than the classical prismatic tall buildings.

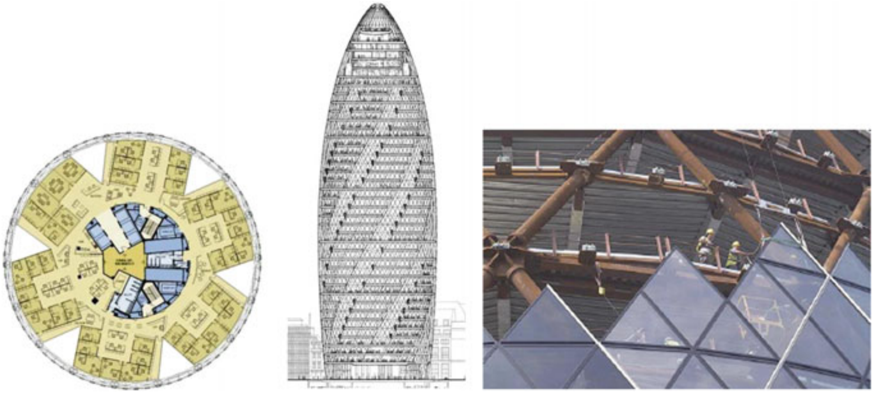


Fig. 5. Swiss Re Building ground floor and sky garden floor, assembly of the form

The criteria of the building related to the structural system and sustainable design are summarized briefly in Table 4. The architectural, technical, technologically and spatially radical approach aims to meet the ecological and technological requirements of future generations. The central positioning of the building core (Fig. 4) inhibited the torsional effect, while the non-symmetrical positioning of the cores at the center have damaged the rigidity of irregular placement between layers and floor.

7 Assessment and Conclusion

Tall buildings have been evaluated over Norman Foster's 3 structures in the context of the load-bearing system and sustainable architectural design principles. The primary factor to consider in the design of the load-bearing system is life safety. Secondly, it is the continuation of human life in a stable structure and healthy environment. This raises the notion that the load-bearing system and sustainability as two concepts that must be in harmony with each other in the design of the building. It can be seen from the assessed structures that the architects in the 21st century are now aware that the structural form and ecological reconciliation must be ensured. Providing safe and healthy environments for users via developing architectural design solutions that integrate technological, aesthetic and environmental sensitivities in the design of high structures that are designed with advanced technologies by way of strengthening architect-engineer communication should be the most important building design principle. The most important criterion in the direction of these principles is cost. It is clear to see that cost-effective, structurally robust and environmentally-sensitive building design principles will soon become the most important factors for many architects and engineers. In this context, the design principles discussed in this article must be internalized and implemented in all building applications.

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Daylighting in Educational Buildings: Its Effects on Students and How to Maximize Its Performance in the Architectural Engineering Department of the University of Sharjah

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Abstract. The aim of this paper is to study the impact of daylighting in educational buildings and consequently, maximize the daylighting performance in the Architectural Engineering Department, (M8 Building), of the University of Sharjah. The academic, psychological, and physiological effects of daylighting on students in addition to the effects of decreasing the artificial light consumption on the environment and economy were intensively researched. Then, for a practical implementation, classrooms in AE Department were studied in terms of daylighting. To maximize the daylight intake in the best possible way, four scenarios were prepared for simulation using Revit and Ecotect, which propose different possible ways to bring in natural light. Accordingly, the four scenarios in Ecotect were analyzed and the best one was chosen in terms of daylight intake. After that, the authors calculated and compared the energy consumed (due to artificial light) in each case and chose the one with the least energy consumption.

Keywords: Classroom · Energy · Glare · Daylight · Ecotect · Revit

1 Introduction

1.1 Literature Review

Daylighting is one of the critical factors that contribute to both the indoor quality of space and the energy savings of the building. The indoor quality plays a crucial role in the health of the building occupants (in our case, students and teachers). After food and water, light is the most significant environmental factor that affects different bodily functions such as pulse, blood pressure and brain activity [1]

The Heschong Mahone Group, an energy efficiency consulting firm, performed a study on the behalf of the California Board for Energy Efficiency (1999) on over 21,000 students to study the effects of natural light on student performance. They grouped classrooms to mainly 4 groups (Figs. 1, 2, 3 and 4).

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Fig. 1. Classroom with maximum daylight (Group 1). *Source* Heschong Mahone Group (1999)

Fig. 2. Classroom with minimum daylight (Group 2). *Source* Heschong Mahone Group (1999)

Fig. 3. Classroom with type A skylight (Group 3). *Source* Heschong Mahone Group (1999)

Fig. 4. Classroom with type B skylight (Group 4). *Source* Heschong Mahone Group (1999)

The first two groups were classified according to the amount of daylight entering the classroom, while the second two were grouped according to the type of skylight used (but not all classrooms had skylights). Type A skylight had a diffusing lens which, from its name, diffuses and spreads daylight equally across the classroom. It also had manual louvers for the teacher to control the amount of daylight entering the room. On the other hand, Type B skylight had patches of sunlight entering the classroom (no diffusing lens) with no louvers or any option to dim the light.

According to the Heschong Mahone Group [2], students in the classrooms that had the most daylighting improved 20% faster in mathematics and 26% faster in reading tests (during a year) than those in the classrooms with the minimum daylighting. In addition, students in classrooms with Type A skylights improved 19% faster in reading tests and 20% faster in mathematics than students in classrooms that did not have any skylight. However, students in classrooms with Type B skylights had a decrease of 21% on reading tests and almost no change in mathematics, when comparing them to students in classrooms with no skylights.

The reason for this drop in the last case was due to the glare entering the classrooms since the skylights brought in patches of sunlight without diffusing it, as well as they lacked any kind of louvers to dim the light. This demonstrates how important it is to consider glare while designing an opening and not just bring in light.

Because students in classrooms with most daylighting were progressing the fastest, researchers at the Heschong Mahone Group calculated how much time they need to finish learning what other students require the whole year to finish. They estimated that those students (who were exposed to the most daylighting) "could save up to one month of instruction time in the reading and math curriculum that could be used for other areas of learning" [2].

Effects of natural light also extend to the health of students. Dr. Charles Kenneth Tanner (a professor and researcher in this field) wrote in his book, *Educational Facilities Planning*: "Poorly lit and windowless classrooms can cause students to experience a daily form of jet lag; furthermore, forms of florescent lighting may affect some students and teachers negatively by causing mild seizures".

In addition, students exposed to more natural light were less prone to dental decay. They also had improved eyesight, increased growth, and an overall better immune system [3]. More sunlight exposure means more vitamin D intake, which increases calcium levels in the students' bodies and hence improve their dental health. Vitamin D and calcium are also associated with better growth in general, especially for children. Furthermore, daylight has the richest spectral content (when compared to other forms of light) which means that it provides more usable light to the eye. This decreases the amount of stress on the students' eyes while they are reading [3]. Besides, having more windows to get in daylight also provides a view to the outside which serves as both a means for students to rest their eyes (which requires at least 50 feet of view), as well as a necessary relief for them to have as a 'soft distraction' [1].

Having sufficient daylight in classrooms would save the energy spent on artificial light. According to Yu and Su [4], "generating one unit of electricity needs three units of fossil fuels consumption, with other two units being wasted as heat". So, saving one unit of electricity means saving three units of fossil fuel consumption and reducing pollution by three times. Other than that, daylight has a high luminous flux to power ratio (high luminous efficacy), which means that daylight will release less heat than artificial light for the same amount of light emitted [4]. Thus, the cooling load is decreased and so is the size of the HVAC units and therefore less energy is spent on cooling. Saving all that energy from both electricity and HVAC would save money and is less harmful to the environment.

1.2 Climate and Location

The M8 Building (Architectural Engineering Department) is located in Sharjah, United Arab Emirates, which is an arid land in summer and has a slightly mild winter. Summer months are between April and October, but we are more interested in the winter months since, most of the academic year is in the winter season. The following graph (Fig. 5) shows the weather extremes and averages recorded for this region.

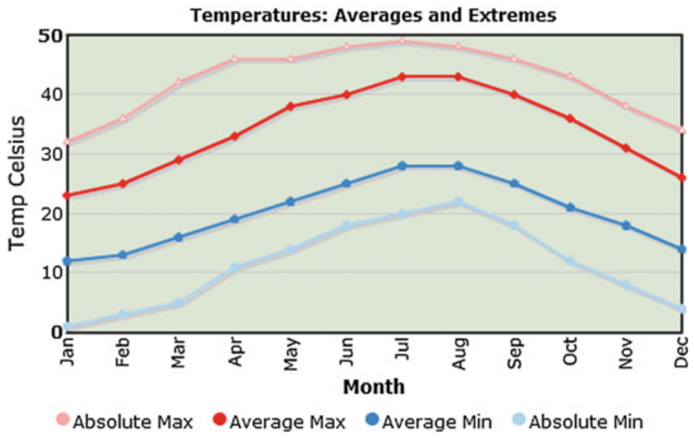

Fig. 5. Graph showing temperature averages and extremes of the region. *Source* Weather2 (website)

1.3 Objectives

This study aims to:

– Maximize daylight intake in M8 classrooms, this provides economic benefits for the university, as well as physiological and psychological benefits for the students.
– Achieve visual comfort by minimizing the glare entering the M8 classrooms.

1.4 Methodology

We created four different scenarios for the M8 classrooms and modeled them using Autodesk Revit software. To analyze the scenarios, we exported the Revit file to Ecotect to obtain the amount of lux in each scenario (and from that we would know which scenario provides the most daylight intake). After having the amount of lux for every scenario, we can convert it to energy units (Kilowatt-hours) to calculate the amount of energy saved by the best scenario. For simulations (3D interior shots), we will use Autodesk Revit rendering in cloud.

To get results that are as realistic as possible, we made sure to include the orientation of the classrooms as well as the latitude and longitude values of the UAE. Figure 6 shows the plan of the first floor of the M8 building and the three classrooms that we are studying:

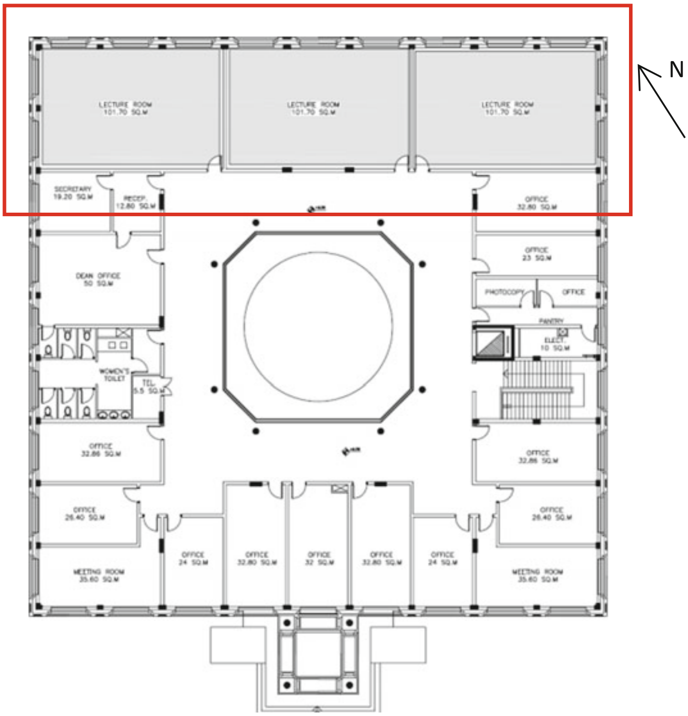

Fig. 6. M8 first floor plan

2 Simulation Scenarios

As mentioned earlier, we modeled four different scenarios which will be analyzed using Ecotect. The first scenario is the already existing one. This scenario is essential to see how much our proposed solutions have improved the existing case. It will tell us whether we have achieved significant improvements or only marginal ones. Of course, it will also assure us that we are actually making the daylight intake better, not worse.

The second scenario was basically increasing the window sizes of the classrooms. This solution is probably the simplest and most straightforward approach to our problem but not necessarily the most effective (in terms of glare and heat transmission).

In the third scenario, we added light shelves, which have two advantages. (1) They reflect light to the interior of the space, thus allowing light to travel more inward than it originally would. (2) They also act as shading elements to the window below it to decrease the amount of glare entering the space. Figure 7 shows how a light shelf works.

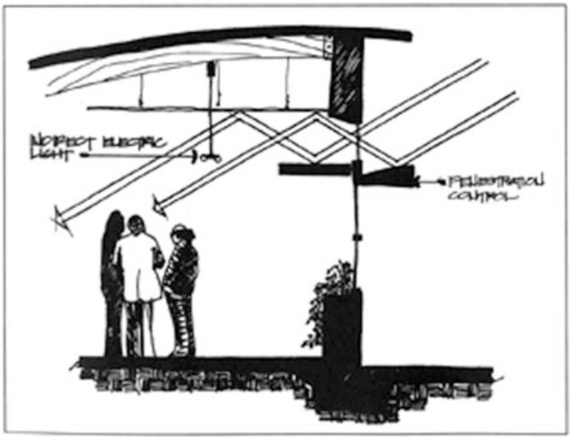

Fig. 7. Wall section through light shelf. *Source* Illuminating Engineering Society (website)

The fourth and last scenario included placing vertical light tubes in the ceiling of the classrooms. We used the VELUX TGR 014 (Tubular—Daylighting—Rigid) light tubes and spread six of them evenly across each room. The advantages of these vertical light tubes are (1) they spread light the most efficiently since light is coming through the ceiling. (2) The shape of the tube allows only diffused light to pass through which eliminates the problem of glare entering the rooms. (3) Using light tubes eliminates the need of enlarging the windows since through these small openings, light spreads across the whole room. Without them, windows need to increase in size to ensure that light reaches the innermost part of the room. And increasing the size of the window means increasing the heat and glare transmission into the interior (Fig. 8).

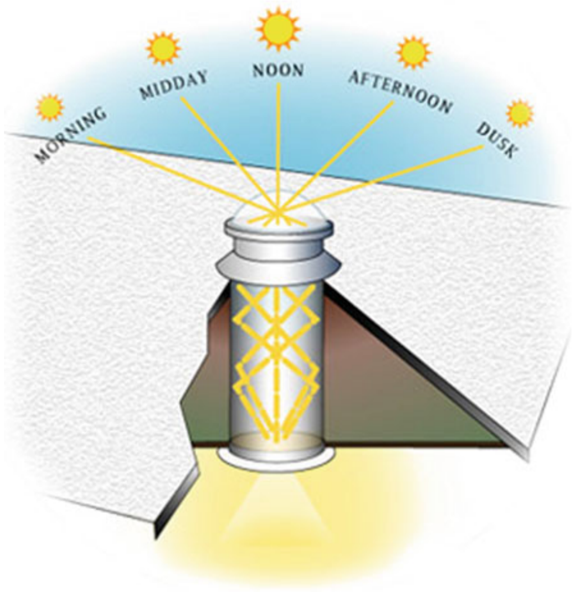

Fig. 8. Vertical light tube diagram. *Source* Barefoot Floor Blog (2010) (website)

3 Results and Analysis

3.1 Existing Scenario

Average lux for the three classrooms: 286 lx (Figs. 9a–c, 10, 11, and 12).

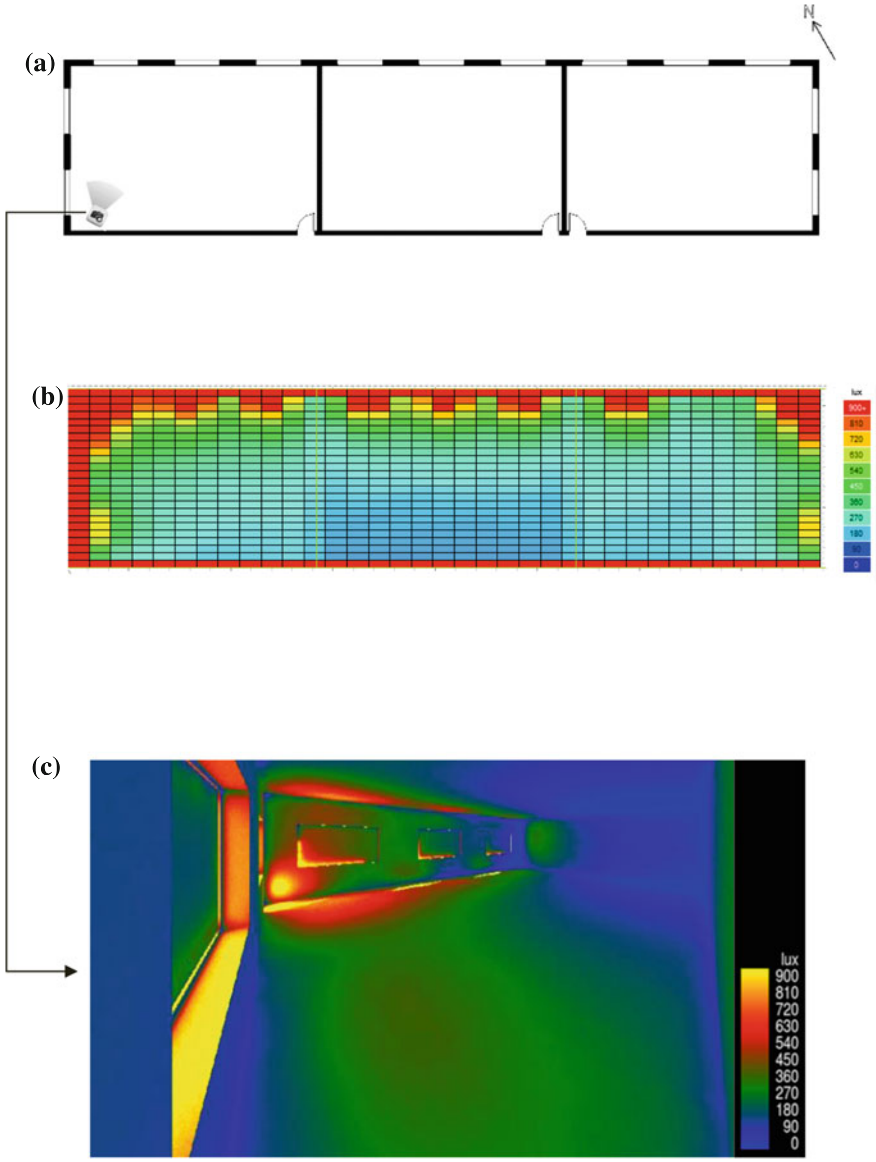

Fig. 9. **a** Plan of the 3 classrooms (Existing Scenario), **b** Plan of the 3 classrooms daylight analysis using Ecotect (Existing Scenario), **c** 3D interior shot of one of the classrooms rendered in Revit (Existing Scenario)

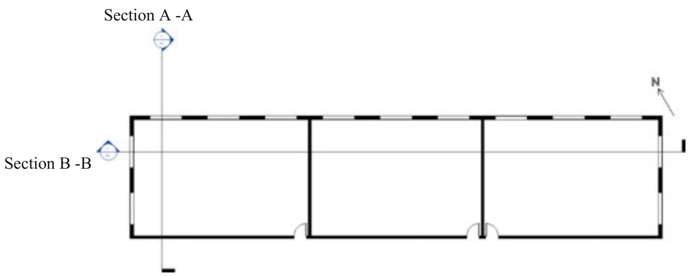

Fig. 10. Plan of the 3 classrooms with section lines (Existing Scenario)

Fig. 11. Section A-A (Existing Scenario)

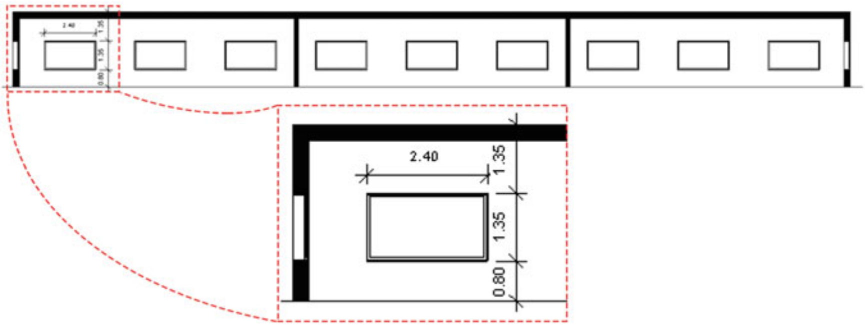

Fig. 12. Section B-B with callout (Existing Scenario)

3.2 Larger Windows Scenario

Average lux for the three classrooms: 357 lx (Figs. 13a–c, 14, 15, and 16).

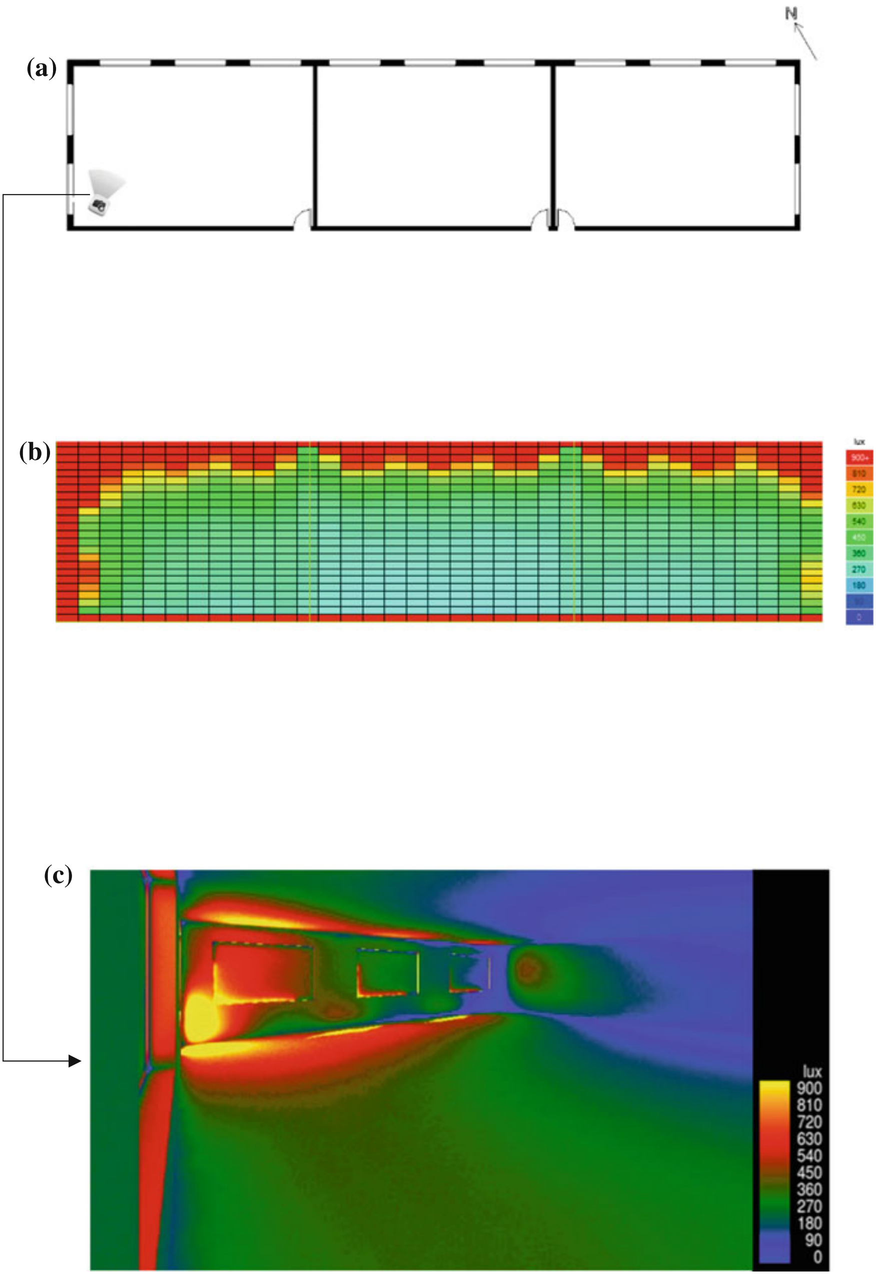

Fig. 13. **a** Plan of the 3 classrooms (Larger Windows Scenario), **b** Plan of the 3 classrooms daylight analysis using Ecotect (Larger Windows Scenario), **c** 3D interior shot of one of the classrooms rendered in Revit (Larger Windows Scenario)

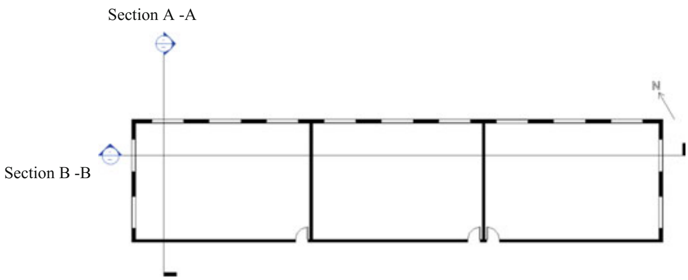

Fig. 14. Plan of the 3 classrooms with section lines (Larger Windows Scenario)

Fig. 15. Section A-A (Larger Windows Scenario)

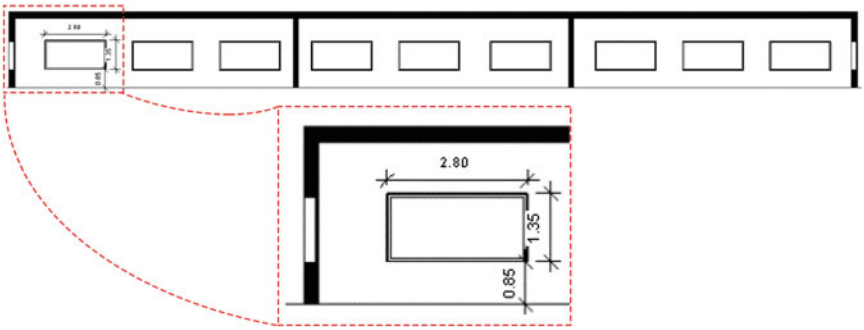

Fig. 16. Section B-B with callout (Larger Windows Scenario)

3.3 Light Shelves Scenario

Average lux for the three classrooms: 418 lx (Figs. 17a–c, 18, 19, and 20).

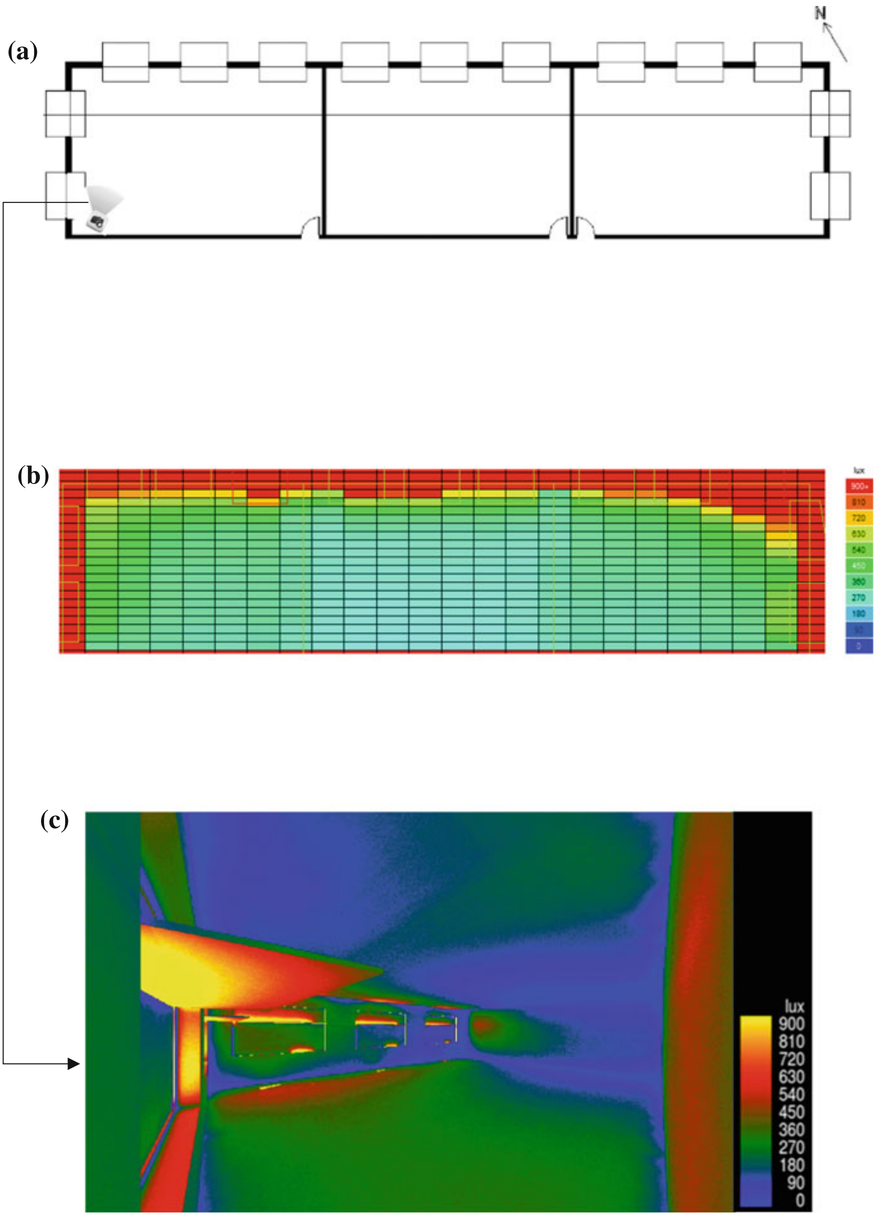

Fig. 17. **a** Plan of the 3 classrooms (Light Shelves Scenario), **b** Plan of the 3 classrooms daylight analysis using Ecotect (Light Shelves Scenario), **c** 3D interior shot of one of the classrooms rendered in Revit (Light Shelves Scenario)

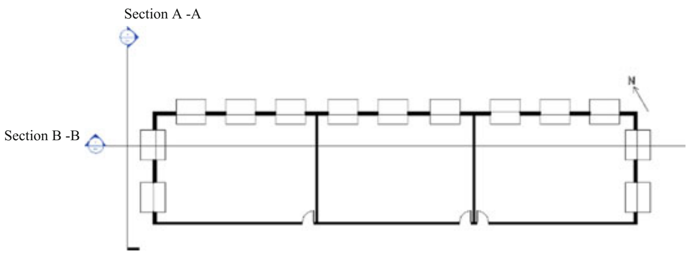

Fig. 18. Plan of the 3 classrooms with section lines (Light Shelves Scenario)

Fig. 19. Section A-A (Light Shelves Scenario)

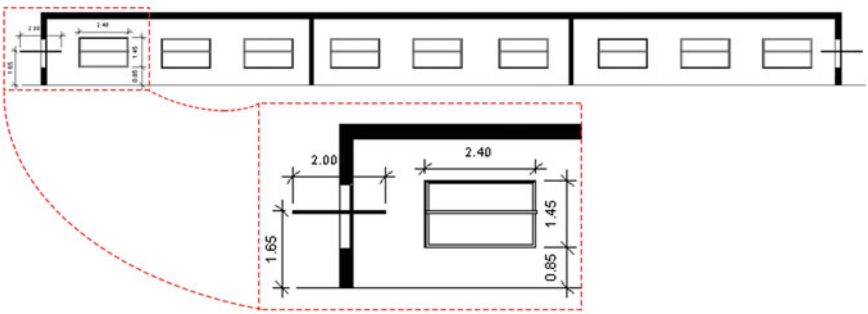

Fig. 20. Section B-B with callout (Light Shelves Scenario)

3.4 Light Tube Scenario

Average lux for the three classrooms: 497 lx (Figs. 21a–c, 22, 23, 24, and 25).

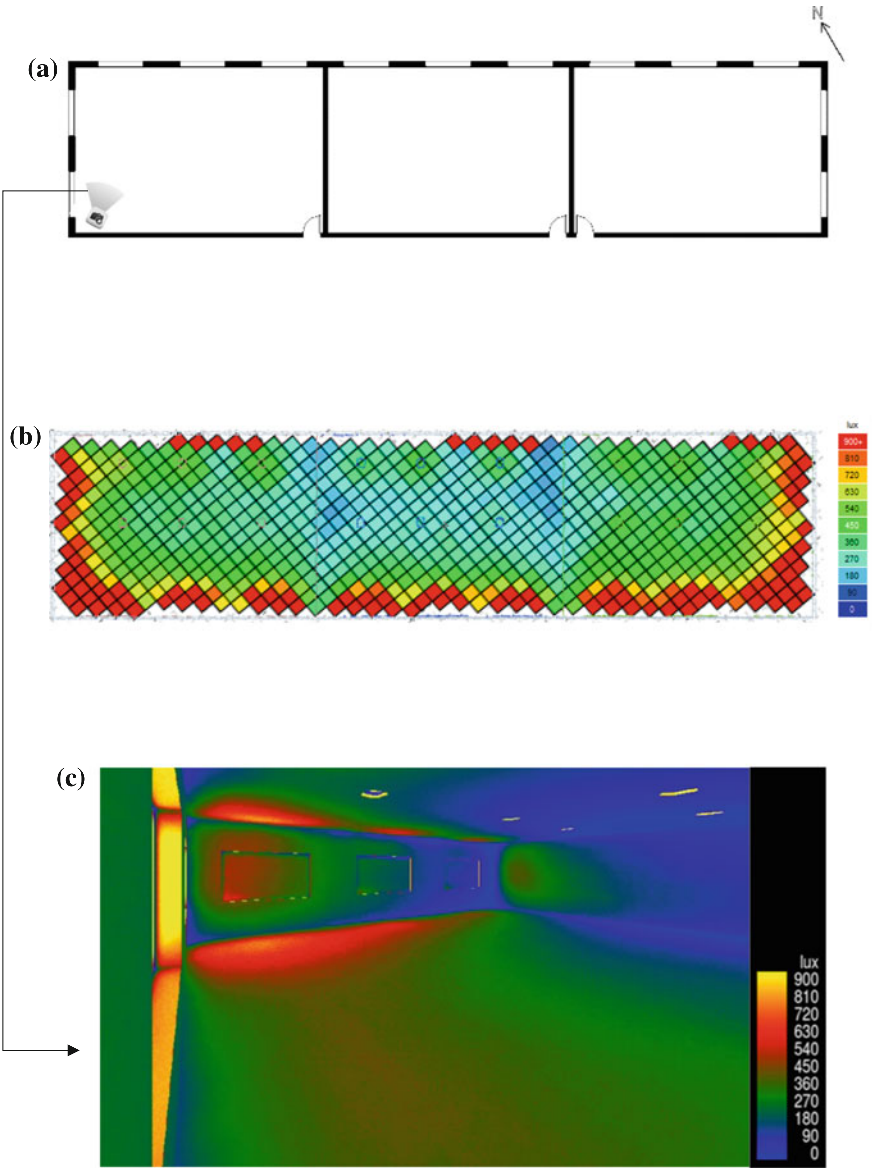

Fig. 21. **a** Plan of the 3 classrooms (Light Tube Scenario), **b** Plan of the 3 classrooms daylight analysis using Ecotect (Light Tube Scenario), **c** 3D interior shot of one of the classrooms rendered in Revit (Light Tube Scenario)

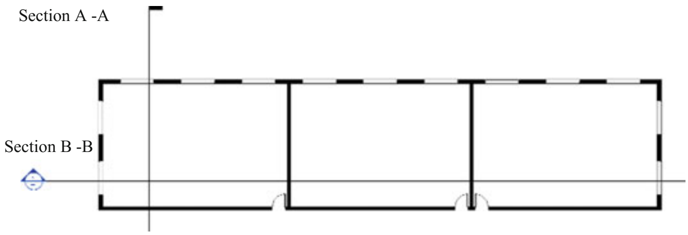

Fig. 22. Plan of the 3 classrooms with section lines (Light Tube Scenario)

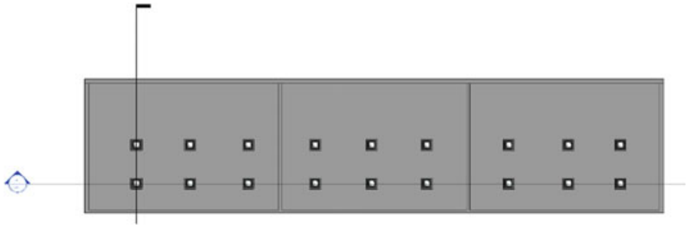

Fig. 23. Reflected ceiling plan of the 3 classrooms showing the locations of the light tubes (Light Tube Scenario)

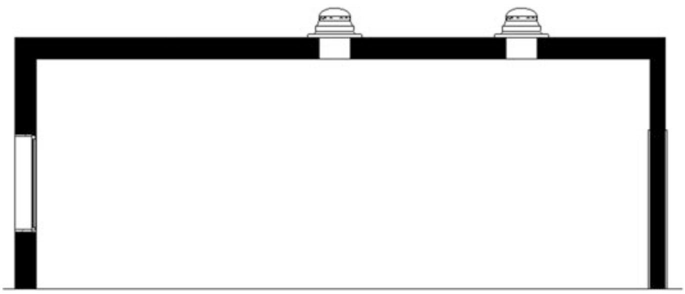

Fig. 24. Section A-A (Light Tube Scenario)

Fig. 25. Section B-B (Light Tube Scenario)

4 Energy Analysis

See Figs. 26, and 27, Table 1

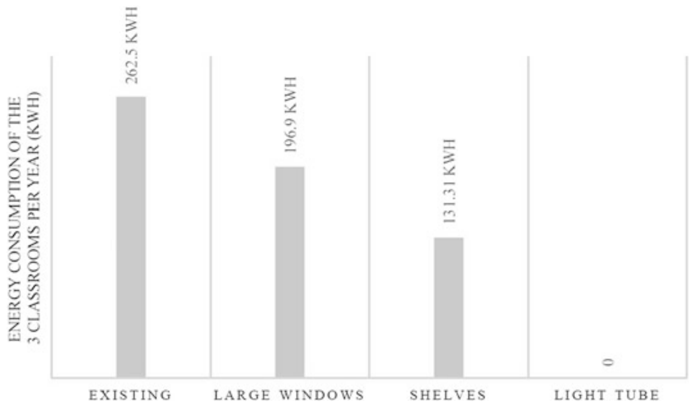

Fig. 26. Energy consumption per year for each scenario graph

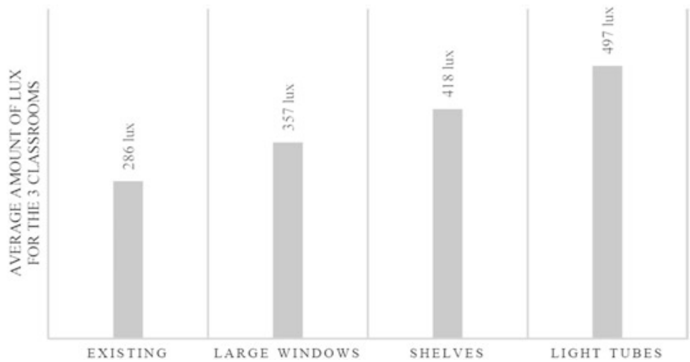

Fig. 27. Daylight intake for each scenario graph

Table 1. Calculation's table

Senarios	Amount of lux existing (lux)	Amount of lux needed to achieve required lux (lux)	Amount of light bulbs needed to meet standards	Amount of energy spent by bulb (Kwh/day)
1. Existing	286	214	4	0.875
2. Large windows	357	143	3	0.656
3. Light shelves	412	88	2	0.437
4. Light tube	497	3	0	0

The required lux for a "teaching space with detailed work" such as a studio classroom, which is the case in M8, is 500 lx according to the "CIBSE Code for Interior Lighting 1994, 'Sect. 2.6.4.4 Public and education buildings'" [5]

The best-Case scenario in terms of daylight intake was the one with the vertical light tubes since it was the only scenario that provided the standard amount of lux required for a classroom "with detailed work" (which is 500 lx) [5]. In addition, the light tubes provided diffused light (no glare) due to its cylindrical shape. On the contrary, the worst case scenario in terms of daylight intake was the existing one as it provided the least amount of lux. As a result, it required the most amount of artificial light which wasted energy.

Specifications of the products used in our simulations:

See Figs. 28, and 29, Tables 2, and 3.

Table 2. Tubular fluorescent lamp specifications

Tubular fluorescent lamp (CFL) (2500 lm)	
Typical luminous efficacy	80 lm/w
Wattage range	31.25 W

Table 3. VELUX TGR 014 specifications.

Source Velux Company (website)

Skylight—VELUX TGR 014—Tubular—Daylighting—Rigid	
Country	United States
Diameter	10″, 14″
Dome material	Acrylic, high-impact polycarbonate
Installation slope	15° (3:12)–60° (20:12)
Region	North America
Tunnel length	20′

Fig. 28. Tubular fluorescent lamp with different diameters. *Source* Electrical and Mechanical Services Department, HKSARG (website)

Fig. 29. VELUX TGR 014 (Section view). *Source* Velux Company (website)

5 Summary and Recommendations

The aim of this research was to investigate the daylighting in educational buildings in general, and to maximize the daylighting performance in the M8 building in specific. The research and its outcomes and recommendations are summarized in the following points:

- According to all of the sources and experiments mentioned earlier, daylighting proved to be very crucial for the students' academic performance and health. Besides, it increased the overall energy performance of buildings when done correctly (without extra glare).
- To increase the daylighting performance in the M8 building (Architectural Engineering Department at the UOS), we analyzed the already existing case of the classrooms and proposed three alternative scenarios for comparison and analysis.

- Among the four scenarios (existing, increasing window sizes, adding light shelves, and adding light tubes), the addition of light tubes proved to be the best solution as it provided the standard amount of lux for a classroom without the need of increasing the original window sizes. It is important to note however, that the addition of light tubes was possible in our case due to the fact that our classrooms were located at the highest floor of the building.
- For similar future attempts to increase the daylighting level of any existing building, we recommend studying the possibility of adding light tubes, since in our case study, they were the most efficient at spreading light evenly across the space using smaller openings. But of course, this is not a fixed rule since it differs from one case to another (all possibilities must be simulated and studied).

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A Study on the Acoustic Comfort Evaluation of Construction Elements in Architectural Design Studio and Classes

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Abstract. A sustainable education building prepares young people for a sustainable life during education with its day-to-day practices. Sustainable education buildings that add value to the students and the environment provide success in students' exam results, increase in their attendance, decrease in operating costs, increase in educator performance and satisfaction, increase in building life, reduction in environmental impacts and change in habits. Therefore, a sustainable educational buildings should be planned, which shows students and society the effects of people on world, and encourages students to take part in a more sustainable way of life. In this context, the current situation was evaluated through in situ measurements and sound transmission loss value affecting the acoustic comfort conditions were calculated and evaluated for the acoustic comfort conditions of the architectural design studio and building elements between classroom and corridor at the Faculty of Engineering and Architecture.

Keywords: Educational buildings · Classrooms · Acoustic comfort Bozok university · Sound transmission loss

1 Introduction

Sufficiency of the classes in terms of acoustics is directly related to the "intelligibility" parameter in the education buildings built in order to educate pupils. The factors that play a role in understanding a speech are; background noise level, sufficient loudness, reverberation time and sound insulation [1].

In architecture education, architectural design studios are the places where students and instructors spend most of their times and discuss about design methods and teachings. The impact of auditory comfort is great in architectural education, in which talking and discussion is essential. Hence, it is an important parameter to provide the understandability of speech in acoustic arrangements in architectural design studios and classes [2].

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https://doi.org/10.1007/978-3-319-63709-9_12

2 Evaluation of Current Situation

Necessary measurements [3] for building elements and buildings in accordance with the standard of TS EN ISO 16283-1 in the design studio and classroom of Bozok University, Faculty of Engineering and Architecture, Department of Architecture were made at source and receiver points determined according to space/area size, spatial arrangement and the relation of the space with adjacent spaces. The measurements were made between the design studio and the adjacent place (studio-corridor) and between the class and the adjacent place (class-corridor) for interior wall (Figs. 1, 2, 3, and 4).

The microphones were calibrated before measurements. The measurements were then repeated three times, giving 16 s of white noise from the source for every receiver point depending on frequencies and mean sound pressure level (Leq).

As a result of the measurements in the class and the design studio of Bozok University, Department of Architecture, the averages of the values obtained were calculated and the performance of building elements against propagation of sound through air was estimated by the "Sound Reduction Index" formula given below:

$$\mathrm{Rw} = \mathrm{L1} - \mathrm{L2} + 10 \log \mathrm{S}/\mathrm{A}[4, 5, 6, 7]. \tag{1}$$

Here;

Rw: stands for sound reduction index (dB),
L1: for mean sound pressure level in source room (dB),
L2: for mean sound pressure level in receiving room (dB),
S: for party wall/floor area (m^2),
A: for equivalent sound absorption area of the receiving room (Sabin, m^2).

Equivalent sound absorption area was calculated by the formula below:

$$\mathrm{A} = \frac{0.16\,V}{T} \tag{2}$$

Here;

A: Equivalent sound absorption area in receiving room (sound absorption surface area) in m^2
V: Volume of receiving room in m^3
T: Reverberation time in receiving room in second [4–7].

2.1 The Wall Between the Classroom and the Corridor

K1 sound source is fixed, and measurements are taken at three points, A1, A3 and A7 for the wall between the classroom and the corridor. K1 sound source is located at a distance of 2.00 m, A1 of 1.00 m and A3 of 4.00 m from the reflector wall on the middle axis, and A7 is located at a distance of 2.00 m from reflector wall and K1 source (Fig. 1, Table 1).

Table 1. Measurement and calculation results of sound transmission loss for the composite wall between the class and the corridor

Frequency (Hz)	L_1 (dB)	L_2 (dB)		$R_w = L_1 - L_2 + 10 \log S/A$ (dB)
	A7	A1	A3	
100	89.0	78.9	79.0	15.7
125	94.8	78.8	77.4	21.6
160	91.2	82.0	79.8	14.7
200	95.5	79.1	78.7	21.6
250	94.8	72.6	73.5	27.2
315	94.4	73.3	71.6	26.9
400	91.1	70.3	71.0	25.1
500	90.5	69.0	67.9	26.3
630	90.0	66.2	65.9	28
800	88.1	63.8	63.0	28.7
1000	86.2	62.7	62.8	27.3
1250	88.0	63.6	62.1	28.8
1600	87.7	65.0	63.7	26.8
2000	86.1	64.9	64.0	24.8
2500	89.1	67.4	66.1	25.1
3150	87.0	66.1	65.1	23.7

The evaluation of the sound transmission loss value for the class-corridor wall according to the reference curves given in TS EN ISO 717-1 [8] is given in Fig. 2.

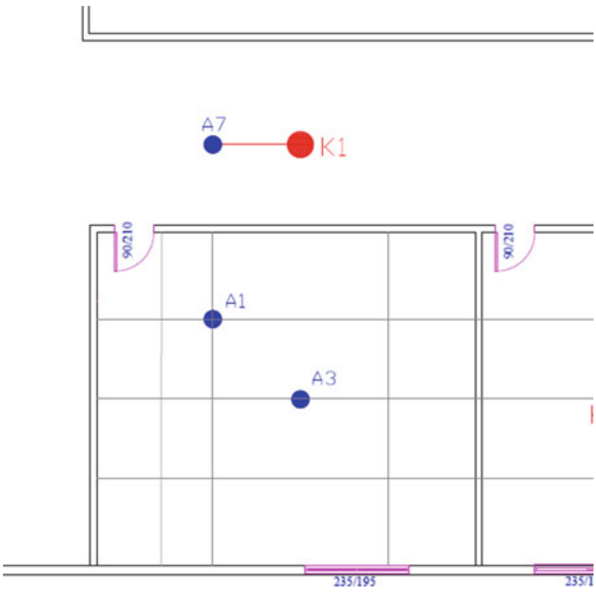


Fig. 1. Source and receiver points (classroom)

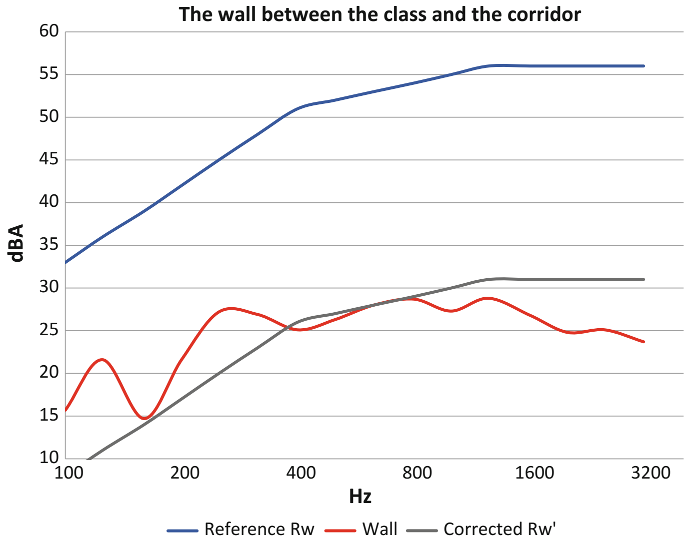


Fig. 2. As a result of measurements, sound transmission loss graphic of the wall between the class and the corridor

Fig. 3. Photos from the measurements at wall between class-corridor

2.2 The Wall Between the Design Studio and the Corridor

For the wall between the design studio and the corridor, K2 sound source is fixed and measurements are taken at three receiver points A3, A5 and A9.

K2 sound source is located at a distance of 2.00 m, A5 of 5.00 m and A3 of 5.40 m from the reflector wall on the middle axis, and A9 is located at a distance of 2.00 m from reflector wall and K1 source. The reverberation time was also measured in receiver room with a fixed sound source (Figs. 4, 5 and 6, Table 2).

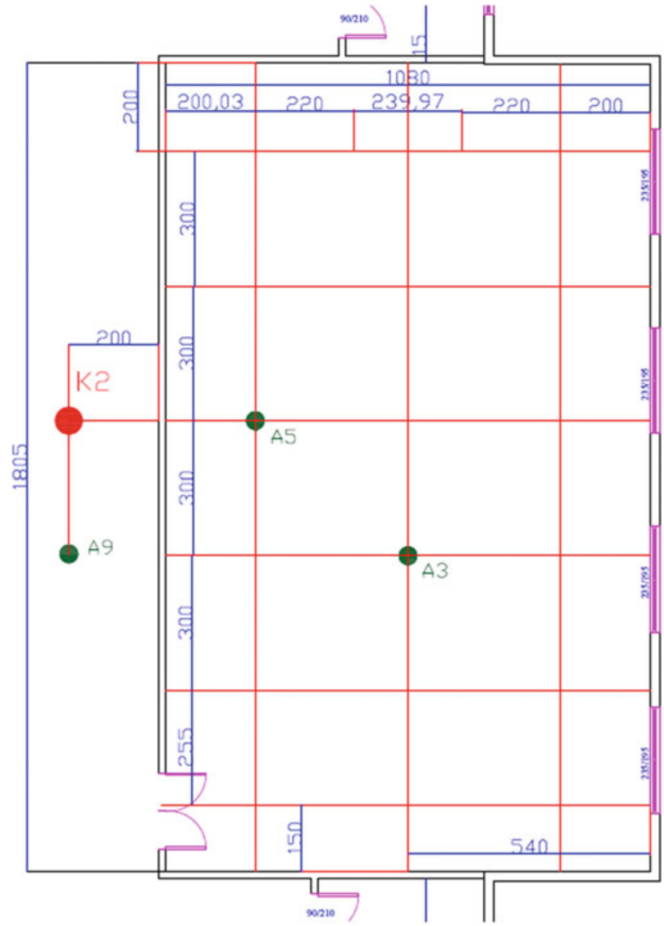


Fig. 4. Source and receiver points (desing studio)

Fig. 5. Photos from the measurements at wall between the design studio-corridor

Table 2. Measurement and calculation results of sound transmission loss for the wall between the design studio and the corridor

Frequency (Hz)	L_1 (dB)	L_2 (dB)		$R_w = L_1 - L_2 + 10 \log S/A$ (dB)
	A9	A3	A5	
100	95.3	69.0	70.1	30.4
125	100.4	70.6	73.5	32.7
160	97.1	71.6	70.4	30.2
200	98.4	73.6	71.3	29.2
250	94.3	68.7	69.2	29.0
315	93.1	68.4	67.9	28.5
400	92.6	65.5	65.5	30.3
500	92.0	61.6	63.0	32.5
630	90.2	60.3	59.1	33.0
800	89.1	57.4	56.4	34.4
1000	86.7	56.0	54.8	33.1
1250	89.1	57.2	56.0	33.9
1600	89.4	58.4	56.5	33.1
2000	86.5	56.6	55.5	31.3
2500	90.1	58.4	56.8	33.1
3150	88.5	57.7	56.0	31.9

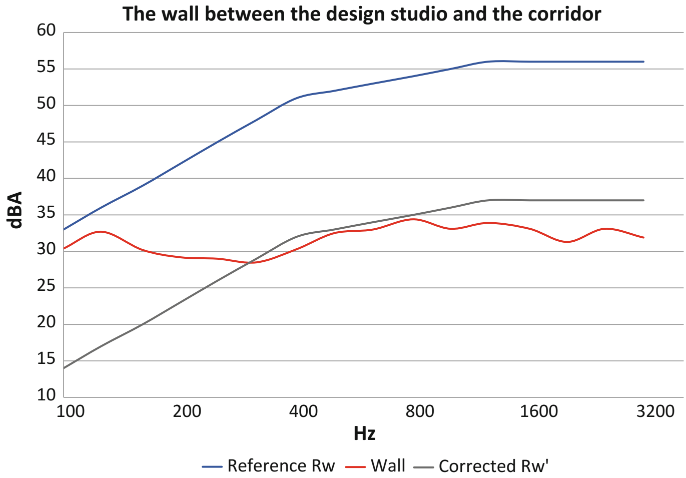


Fig. 6. As a result of measurements, sound transmission loss graph of the wall between the design studio and the corridor

Table 3. Evaluation of current situation (Wall between classroom—corridor)

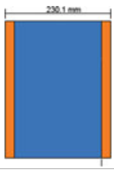
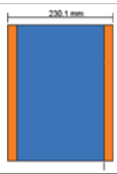
Material information of the building element	**20 mm plaster + 190 mm brick wall + 20 mm plaster**
Detail of the building element	
Optimum values to be provided in accordance with regulations R_w (dB)	**$R_w \geq 55$ [4–7, 9]**
The sound transmission loss value calculated measurement result R_w (C; C_{tr}) (dB)	**$R_w = 27$ (−1; −2)**
Evaluation	**Not Suitable**

Table 4. Evaluation of current situation (Wall between studio—corridor)

Material information of the building element	**20 mm plaster + 190 mm brick wall + 20 mm plaster**
Detail of the building element	
Optimum values to be provided in accordance with regulations R_w (dB)	**$R_w \geq 55$ [4–7, 9]**
The sound transmission loss value calculated measurement result R_w (C; C_{tr}) (dB)	**$R_w = 33$ (−1; −1)**
Evaluation	**Not Suitable**

3 Result and Evaluation

Sustainability is an important concept not only for today, but also for future generations. Sustainable education programs developed in this direction will enable future generations to live in a healthier and more qualified environment.

In this context, the current situation has been evaluated in terms of acoustic comfort conditions in the classroom and the design studio of Faculty of Engineering and Architecture (new Faculty of Communication) of Bozok University. According to in situ measurements and analysis made in the current building components located between the class and the corridor, and between the design studio and the corridor in Faculty of Engineering and Architecture of Bozok University, it has been determined that R_w = 27 (−1; −2) dB for the class-corridor wall, R_w = 33 (−1; −1) dB for the design studio-corridor wall and thus the insulation performance against sound propagating through air does not satisfy the values recommended in the legislation (Tables 3 and 4). This is due to the acoustic inadequacy of the materials used in the walls. Furthermore, low sound insulation performance of the door located between the classroom-corridor and the design studio-corridor (due to the spaces in the joints and the frames of the door) causes reduction in sound transmission loss value of the composite wall. If sound insulation performance of the gates are improved, the sound transmission loss values of the walls will also increase. That is why, it is necessary to exchange the current gates for those with high sound insulation performance and remove gaps in door-joint by using seal. Acoustic insulation should also be done on the walls.

The composite wall between the design studio and the corridor is greater than the composite wall between the class and the corridor in terms of area. This indicates that the door with low sound insulation performance has less effect on sound insulation performance of the composite wall, since the area of the wall between the design studio and the corridor is much.

Tables 3 and 4 show the evaluation of current situation of the composite wall between design studio-corridor and class-corridor.

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Acoustic Comfort Evaluation with the Simulation Program Specific to the Educational Buildings of Bozok University Classrooms

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Abstract. Spaces that possess the acoustic comfort, which people require, can be provided by building structures that are suitable for work and living by solving acoustic problems, which will influence the performance of work by affecting the health and the comfort of the peoples in a negative way. Although it has been known for many years that the acoustic comfort conditions play an important role in the success of the students, this fact in general has been disregarded. Within this context, in this paper as of specific to educational buildings, an acoustic analysis study is conducted through Odeon (v 10.02) simulation program aimed for the acoustic comfort conditions of the classrooms located in the Faculty of Engineering and Architecture of Bozok University.

Keywords: Educational buildings · Classrooms · Acoustic comfort Odeon

1 Introduction

The effect of the acoustic design, which will be created in the classes and classrooms, to the intelligibility of the speech should not be ignored. A classroom that contains artfully thought out acoustics and is designed in an appropriate way signifies an increase in productivity by making it easier for the students to receive the information. Researches which were conducted in the UK have paved the way for the preparation of rather effective legislations (BB93) [1]. These standards have brought up the

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imperativeness of the design by taking into consideration of the factors, which fulfill its intended purpose and appropriate acoustic conditions of all the rooms and other spaces found in the buildings for educational purposes.

With regard to solving the education problem of our country, decreasing the quality and the quantity of the educationalists as well as the importance of building decent schools should not be overlooked. To obtain the schools in which the education and training will be actualized with an utmost effectiveness, the architectural design principles along with the acoustic parameters of the schools should be approached meticulously and elaborately [2].

2 The Acoustic Comfort Conditions in the Educational Buildings

It is an undeniable fact that the comprehension of a subject which is verbalized in the classrooms is directly proportional with the intelligibility of speech of the educator. The acoustic factors that are essential for the educator to be intelligible consist of these parameters: background noise, the intelligibility of speech and the reverberation time [2].

3 The Performance Evaluation of the Classrooms with the Simulation Program

In this paper, a performance analysis has been carried out with the Odeon simulation program in the classrooms, which are located in the Department of Architecture of Bozok University. In a classroom taking an approximately 55 m^2 space, 6 receiver and 1 source point was specified (Fig. 1). According to these specifications, the analysis of the following parameters were carried out: reverberation time with the Odeon simulation program (T_{30}), early delay time (EDT), speech transmission index (STI), definition (D50) and sound pressure level (SPLA).

The sound absorption coefficients of the materials which are used in the analysis study executed with the Odeon program are given in the Table 1 (Fig. 2).

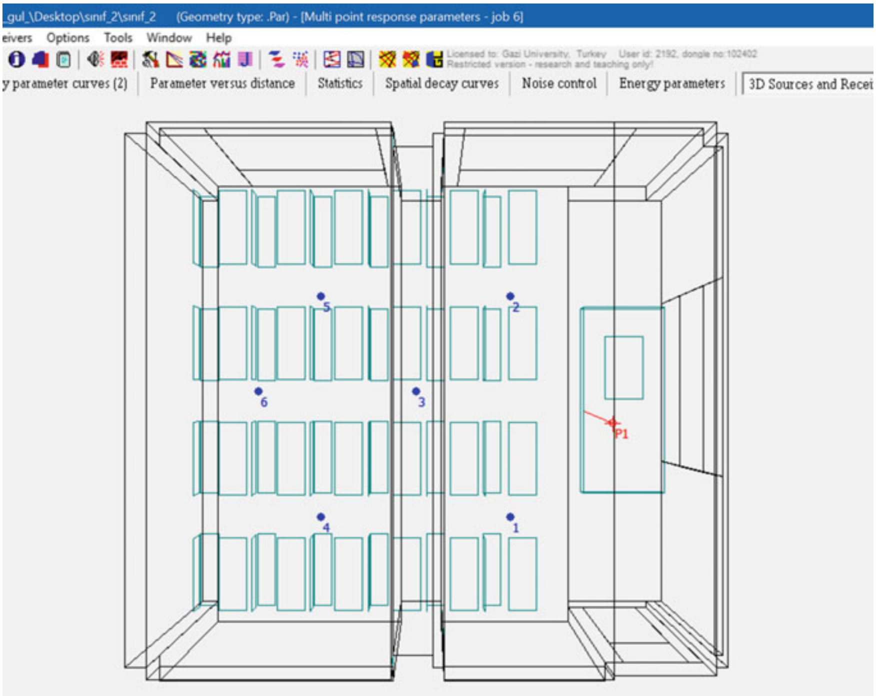


Fig. 1. Source and receiver points

Table 1. Sound absorption coefficients of used materials

Wall	Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03
Ceiling	Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Floor	Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Door	Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
	0.14	0.14	0.10	0.06	0.08	0.10	0.10	0.10
Windows	Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
	0.10	0.10	0.07	0.05	0.03	0.02	0.02	0.02

(*continued*)

Table 1. (*continued*)

Lectern	Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
	0.40	0.40	0.30	0.20	0.17	0.15	0.10	0.10
Writing board	Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
	0.42	0.42	0.21	0.10	0.08	0.06	0.06	0.06
Table	Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
	0.28	0.28	0.22	0.17	0.09	0.10	0.11	0.11

Fig. 2. Photographs of exterior and interior

3.1 Reverberation Time (T_{30})

Reverberation time, which is defined as the time it takes the sound pressure level to diminish or decay to 60 dB after the sound source has been shut down in a closed space, is one of the most important parameters of the room acoustics [3–5].

Reverberation time values of medium frequencies recommended for the classrooms found in educational buildings are between 0.6–0.8 s [6–9]. In Table 2 and Fig. 3, it can be seen that the reverberation time, in frequencies excluding 8000 Hz, is above the aforementioned ultimate value (Figs. 4 and 5).

Table 2. T_{30}—Reverberation time results

T_{30} (sec)	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Min	1.16	1.17	1.52	1.89	2.55	2.14	1.47	0.76
Max	1.20	1.23	1.56	1.93	2.61	2.18	1.53	0.81
Aver.	1.17	1.20	1.54	1.90	2.59	2.16	1.50	0.79

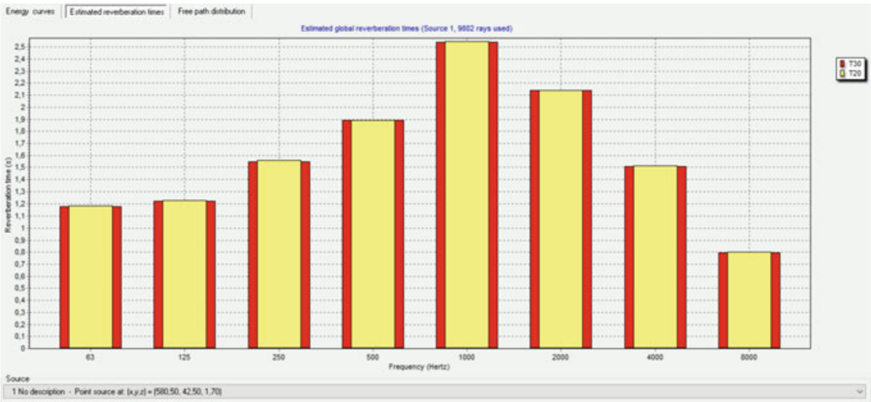


Fig. 3. Reverberation time frequency distribution graph

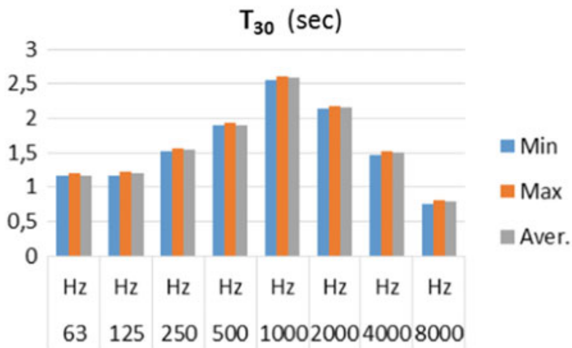
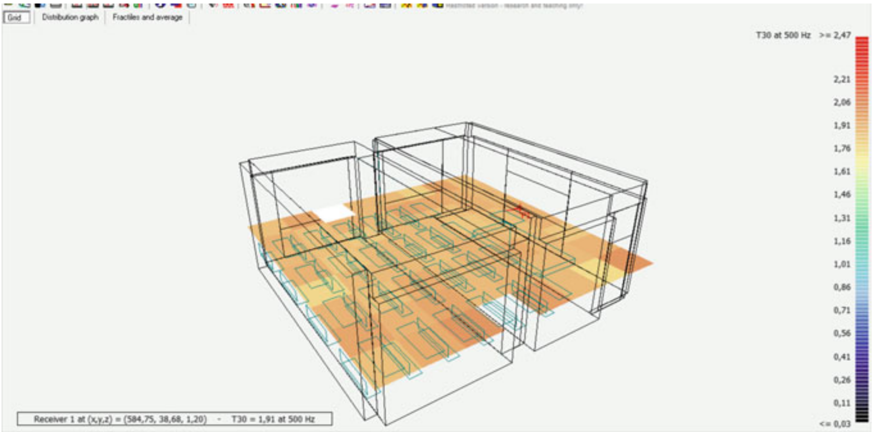
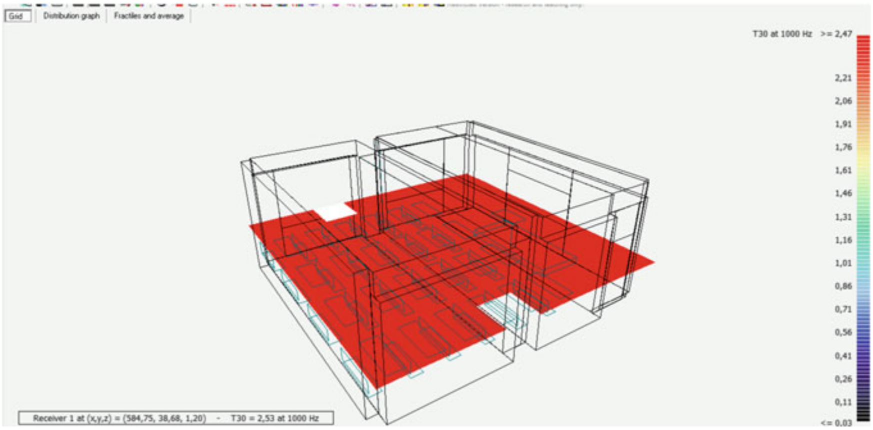


Fig. 4. Distribution diagram of T_{30} parameter



500 Hz



1000 Hz

Fig. 5. 500 and 1000 Hz—Distribution diagram of T_{30} parameter

3.2 Early Decay Time (EDT)

Early decay time represents the initial phase of the decay of the sound pressure level, which is obtained by multiplying by 6, the time elapsed for the decay of 10 dB decrease in sound pressure level after the sound source has been shut down in a closed space [4, 5].

EDT value increases while reverberation time increases. The more the reverberation time increases the more the EDT value increases. In a space that have a sound field which is uniform enough, the EDT value can be calculated according to the reverberation time. It is required that the EDT parameter to be smaller than the reverberation time parameter [10].

Nevertheless, when the analysis results are examined, it can be seen that the EDT values in the medium frequencies (500–1000 Hz) are equal to the reverberation time (Tables 2 and 3, Figs. 6 and 7).

Table 3. EDT—Early decay time results

EDT (sec)	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Min	1.13	1.23	1.50	1.87	2.48	2.08	1.47	0.76
Max	1.26	1.29	1.63	1.98	2.62	2.17	1.58	0.88
Aver.	1.19	1.25	1.58	1.92	2.56	2.14	1.52	0.80

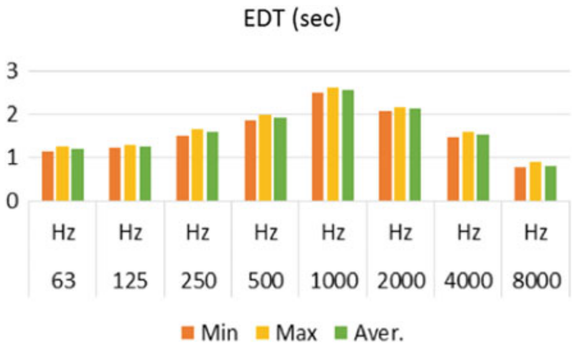
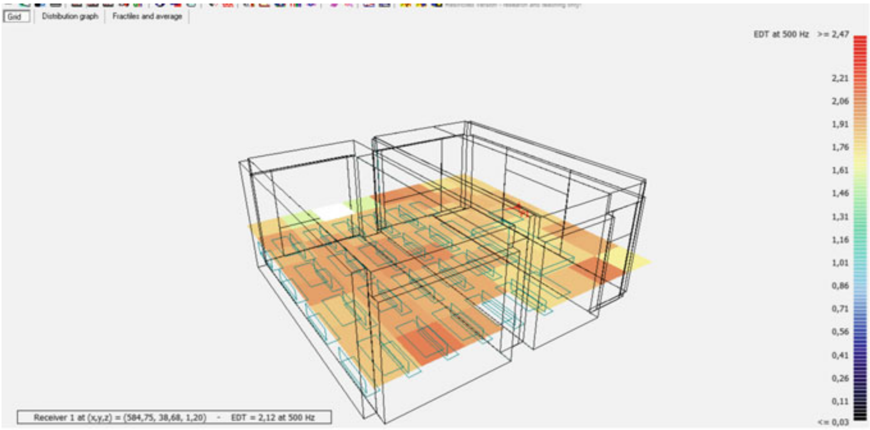
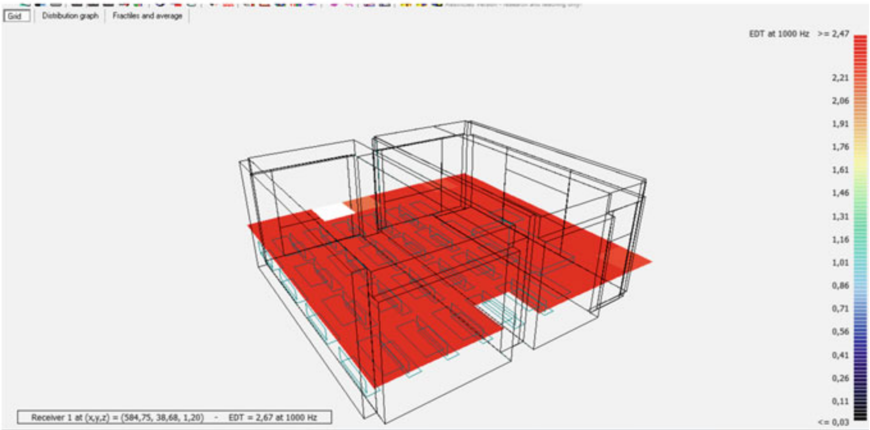


Fig. 6. Distribution diagram of EDT parameter



500 Hz



1000 Hz

Fig. 7. 500 and 1000 Hz—Distribution diagram of EDT parameter

3.3 Speech Transmission Index (STI)

Speech transmission index (STI) is an acoustic parameter developed for the measurement of the intelligibility of the speech based upon the speech transmission channel and speech transmission quality [11].

Given below are the recommended speech transmission index (STI) values and the range of intelligibility [11].

0.30 – 0.45 : bad – poor
0.45 – 0.60 : poor – fair
0.60 – 0.75 : fair – good
0.75 – 1.00 : good – excellent

Table 4. STI—Speech transmission index results

STI	
Minimum	0.47
Maximum	0.50
Average	0.48

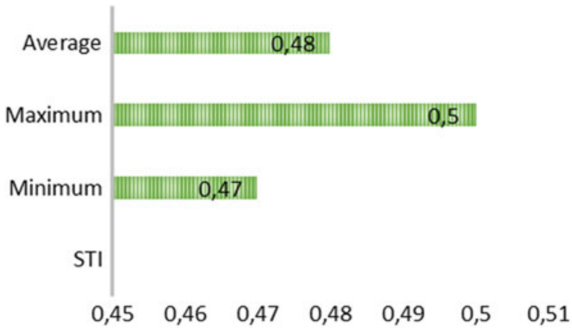


Fig. 8. STI parameter value graph

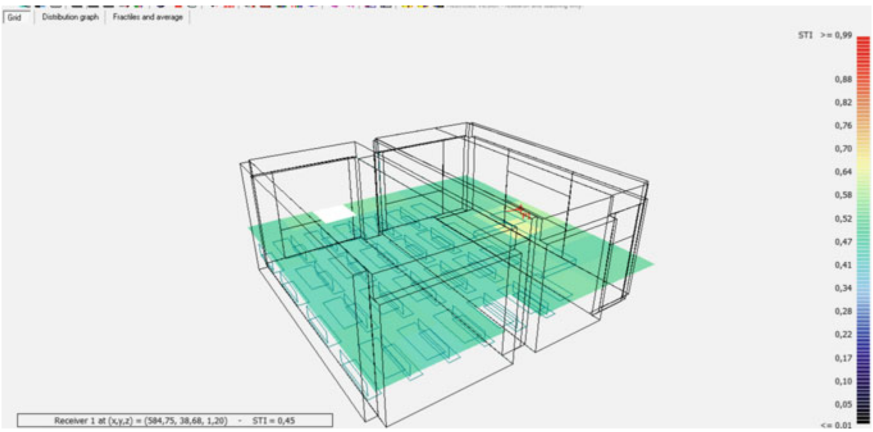


Fig. 9. Distribution diagram of STI parameter

As it can be seen in Table 4 and Figs. 8 and 9 above, the speech transmission index parameter has a value of 0.48; according to the acoustic comfort conditions the intelligibility is poor-fair.

3.4 Definiton (D50)

Definition (D50) is a room acoustic parameter developed for the intelligibility quality of the speech performance. In order the intelligibility quality of the speech performance to be high, it is recommended that definition parameter value would be higher than 0.50 in all frequencies [9, 12].

However in the classroom where the analysis was carried out, it has been seen that this value is only suitable in 8000 Hz frequency (Figs. 10 and 11), Table 5.

Table 5. D50—Definition parameter results

D50	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Min	0.40	0.39	0.31	0.26	0.20	0.23	0.32	0.53
Max	0.50	0.48	0.40	0.34	0.28	0.32	0.42	0.64
Aver.	0.44	0.42	0.35	0.29	0.23	0.27	0.36	0.58

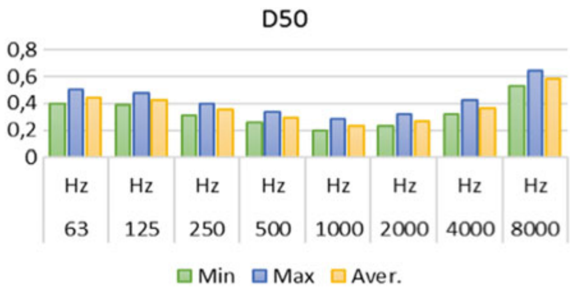
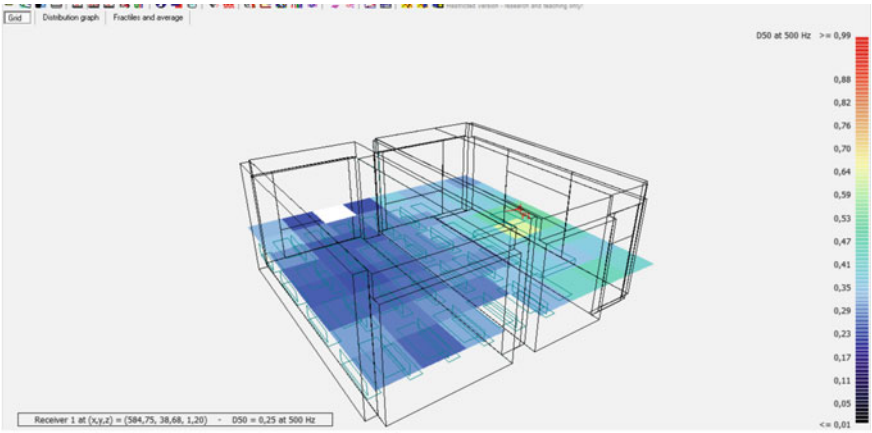
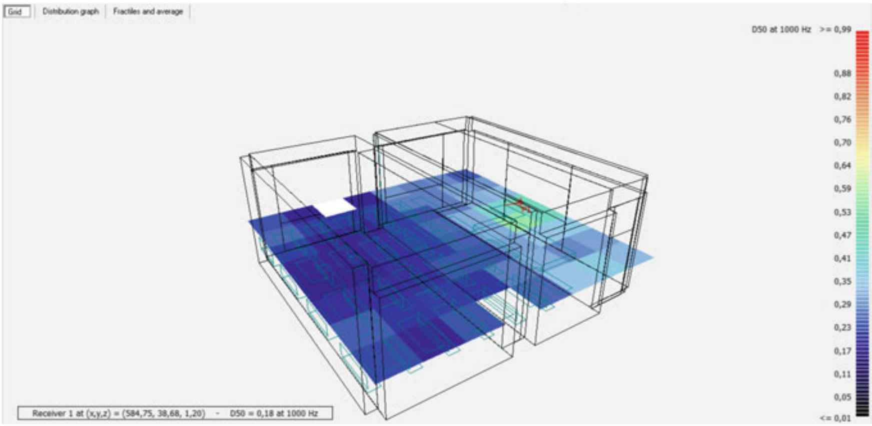


Fig. 10. Distribution diagram of D50 parameter



500 Hz



1000 Hz

Fig. 11. 500 and 1000 Hz—Distribution diagram of D50 parameter

3.5 Sound Pressure Level (SPLA)

In the classrooms where the reverberation time is short, it is recommended that the sound pressure level in the back side of the classroom to be around 50 dB [13].

As it can be seen in the Tables 6 and 7 and Fig. 12, sound pressure level value is convenient.

Table 6. SPLA—A weighted sound pressure level results

SPLA (dB)	
Min	69.7
Max	71.0
Aver.	70.3

Table 7. SPL—Sound pressure level parameter results

SPL	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Min	60.4	60.7	62.2	63.2	64.6	63.5	61.6	57.9
Max	62.1	62.4	63.6	64.5	65.5	64.7	63.2	60.4
Aver.	61.1	61.5	62.8	63.8	65.1	64.1	62.3	59.0

It is also recommended that the minimum change variation in sound pressure level is <10 dB [9]. Within this context, it was determined that the sound pressure level variation in the classroom where the analysis was carried out is within reasonable limits (Tables 5 and 7, Figs. 12 and 13.

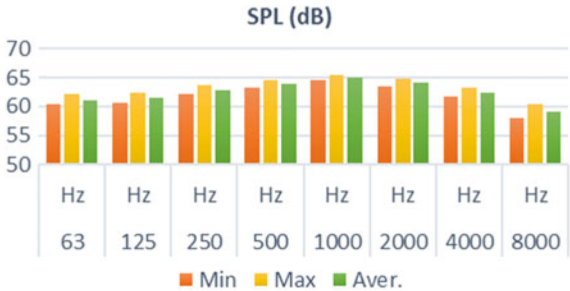


Fig. 12. Distribution diagram of SPL parameter

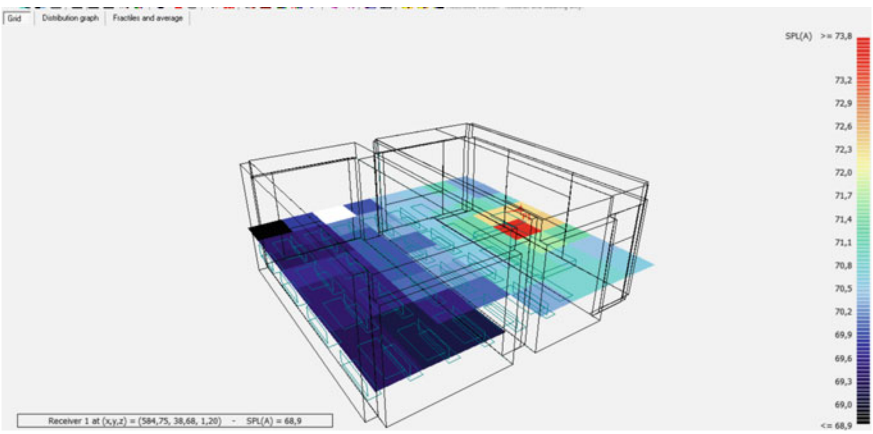


Fig. 13. SPLA—Distribution diagram of SPLA parameter

4 Conclusion and Evaluation

The acoustic comfort conditions necessary to ensure the speech function is analyzed through the simulation program Odeon which is intended for the room acoustic in the classrooms located in the Department of Architecture of Bozok University and is evaluated according to the regulations in force and parameters that are recommended in the literature in national and international standards.

According to the evaluation result, it was determined that the sound pressure level variation is within reasonable limits and that the parameters of reverberation time (T30), early decay time (EDT), speech transmission index (STI), definition (D50) are not suitable for the classroom.

According to the results of the reverberation time presented by the Odeon simulation program, it has been seen that there is not a proper distribution in terms of the frequency in the classroom. It was also determined that with the value of 2.24 s, the reverberation time which is also affecting the intelligibility of the speech specific to the educational buildings is not in between the proper values (0.6–0.8 s) and that the reverberation is high. This circumstance is derived from the excess of the reflective surfaces in contrast with the scarcity of the absorber surfaces. In compliance with this, it is recommended that curtains with a high absorption quality to be used for the windows which are located in the classroom and that on the back wall and on the ceiling a sound absorber material which will ensure the acoustic conditions to be utilized.

EDT value increases while reverberation time increases. The nonconformity of the EDT parameters (Table 8) show that the classrooms do not possess a uniform sound field and that the materials used for the surface were not properly chosen.

According to the result of the analysis (Table 8), it was decided that the parameters which are considered unsuitable regarding the speech transmission index (STI) and the definition (D50), can be decreased by reducing the reflective surfaces and by designing absorber surfaces in proper spots.

Table 8. Evaluation of results

Room acoustic parameters	Optimum values	Analysis results		Evaluation
T_{30} mid reverberation time, sec	$0.6 \leq T_{30,\ mid} \leq 0.8$ (500–1000 Hz) [9]	2.24		Not suitable
EDT Early decay time, sec	EDT < $T_{30,\ mid}$ (500–1000 Hz) [9]	2.24		Not suitable
ΔSPL Sound pressure level, dB	ΔSPL < 10 dB [9]	1.3		Appropriate
STI Speech transmission index	0.60 < Good < 0.75 [11]	0.48		Not suitable
D_{50} Definition	D_{50} > 0.50 At all frequencies [9, 12]	125 Hz	0.42	Not suitable
		250 Hz	0.35	
		500 Hz	0.29	
		1000 Hz	0.23	
		2000 Hz	0.27	
		4000 Hz	0.36	

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Numerical Analysis of a Zero Energy Villa in the UAE

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Abstract. There is significant evidence that the world is warming up and the increasing temperatures will impact the built environment, particularly the energy requirement for airconditioning of the buildings. According to International Panel of Climate Change, during the end of 21st century, there would be steady increase in the global surface temperature [1]. The harsh and extreme climates in the UAE, puts forward various hurdles for different technologies to be used in order to reduce the energy consumption, and make the house more sustainable. In order to reduce the carbon footprint of buildings in the UAE, a villa is designed and modelled to become Zero Energy, located in Hatta, Dubai. In order to achieve the former objective, different insulation materials such as Polyisocyanurate, aerated and low density concrete, high efficient electrical equipment and air conditioning as well as low solar heat gain coefficient windows with a reflective coating were considered in this study. AutoCAD was initially used to sketch the plan of the villa and then further simulations were carried out on IES-VE (2015), to determine the electrical and cooling load of the house. Using the passive technologies, and keeping in mind the Thermal Comfort Index, per the ASHRAE standards, a reduction in cooling load of about 40% is observed when compared with a base case scenario. As the paper mainly focuses on drafting a villa which is off-grid, the energy demand of the house is provided by the PV system. Furthermore, a sensitivity analysis was conducted by varying the orientation and cooling profiles of the house on IES to draft a range of results. Changing the orientation of the house by 90° gave about a 2.3% reduction in the cooling load. When the results were compared with literature and base case, it proved that the values obtained were lower than the ones in similar case studies.

Keywords: IES · NZB · Net zero building · Sustainability · Cooling load

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1 Introduction

Nowadays the energy system model is evolving worldwide; the industrial and government sectors, as well as the societies are more aware of the adverse affects of the greenhouse gases and the economical risks that will befall in the coming years, due to the dependency on fossil fuels. Furthermore, these sectors are well aware that self-sustainable and green houses open a wide range of business opportunities.

Figure 1 clearly shows that the second highest energy consumption, which is 28.78%, is within the residential sector in Dubai. The growth in electrical consumption in Dubai has increased from 28 to 41 Million MWh over the 6 years [2, 3]. Moreover, there has been massive development in UAE's building industry during the past couple of years, and it is believed that the trend is to keep rising, as well as their energy demands. Hence buildings are not only important energy consumers, but they are the place where we spend 90% of our time, therefore, comfort conditions cannot be compromised to save energy [4]. Furthermore, in 2012 UAE was ranked among the highest energy consumers per capita in the world at 11.2 MWh [5] and one of the highest CO_2 emitters at 20.5 tons of CO_2 per capita [5]. As UAE's building environment has grown over the past few years, and the trend will keep on growing, the energy requirements will rise too. Moreover, the growth of residential villas has increased about 300% in Dubai and other regions of the UAE, from 200,000 to 600,000 in the past decade [6]. According to research approximately up to 70% of the building energy consumption is used for air conditioning during summers in UAE [7]. Hence in order to decrease the cooling load, energy efficient measures are being favored in buildings. The most energy efficient method to lower the cooling load in the buildings is opting for solar insulation materials instead of the regular building materials. Moreover, a few construction materials affect the CO_2 emissions too, hence by replacing or at least decreasing the use of a few construction materials such as concrete, reinforced steel, and gypsum board etc., can directly impact the emissions. By doing so, it has been shown that CO_2 emissions can be decreased by 6.9% [8].

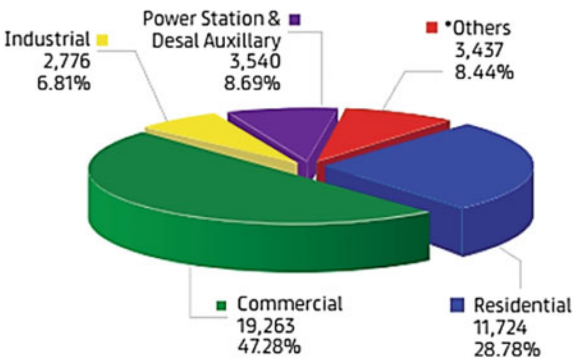

Fig. 1. Annual satistics of energy consumption (GWh) in different sectors in 2015 [3]

According to a study of Zero Energy House in Newfoundland, Zero Energy Villa is defined as: "A home that optimally combines commercially available renewable energy technology with the state of the art energy efficient construction techniques. In a zero energy home no fossil fuels are consumed and its annual electricity consumption equals annual electricity production. A zero energy home may or may not be grid connected [9]." This project mainly focuses on the passive design of the house, to minimize the cooling load, and make the house self sustained, which states that it is not connected to the grid, using energy efficient techniques.

A passive house design begins with optimization of the architectural design, such as windows area and positioning, facades, shades, insulation materials and natural ventilation. According to researches, proper wall insulation can alone cut down up to 50% of the energy used in Middle East and North Africa region, especially in the housing division [4]. Passive cooling is an approach for a building design that mainly focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or nil power consumption. Furthermore this approach reduces the need to use mechanical cooling. By applying passive cooling and design strategies, the differences between outdoor and indoor temperatures are reduced, as well as it improves indoor air quality, making the house a healthier and relaxed environment to reside or work in. According to another study conducted in UAE, several substantial findings were recorded. The strategies considered for this study include evaporative cooling, improved shading and glazing arrangements, enhancing insulation, natural ventilation, radiant cooling and the application of light coloured coatings with high reflection in addition to green roofing. One of the major findings included that by adapting these passive cooling strategies, the total annual energy consumption of a domestic building in Dubai may be reduced by up to 23.6% [10].

2 Objective

The aim of the project is to design and model a villa to become Zero Energy for a family of four, in Hatta, UAE, focusing on key elements of the building that effect the energy consumption and thermal load of the building. Autodesk AutoCAD 2016 was initially used to sketch the plan of the house (shown in Fig. 2), and then further simulations were carried out on IES VE. The core of the project is the use of IES VE 2015, which is a simulation software that allows to compare the cooling load of the

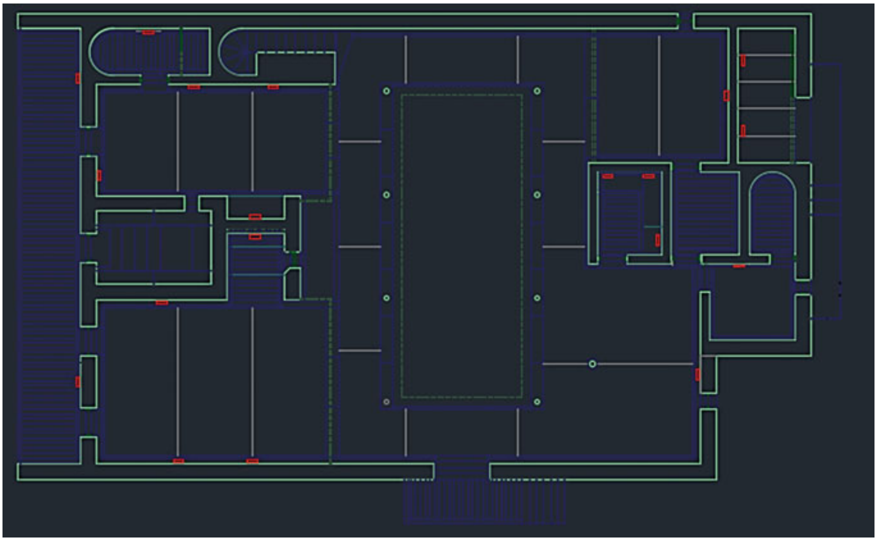

Fig. 2. Sketch of the villa on AutoCAD 2016

house by using different building materials, considering their properties. The outcome of this simulations helps to find the ideal construction and insulation material for the Zero Energy Villa, and compare the impact on energy reduction.

3 Methodology

Firstly, the site location and operative conditions of the house are defined. To define the operative conditions, the weather data for Dubai, UAE is considered. The ambient conditions like relative humidity, and temperature influence the design selection and cooling load of the house. Dubai's summertime comprises of high humidity levels and is categorized by average daytime temperature of over 40 °C, and nighttime temperature not falling below 30 °C. Whereas in the winters pleasant conditions prevail, with daytime temperatures of about 24 °C and at nighttime it falls as low as 14 °C [11]. Another important factor that is kept in mind while designing the house is the Thermal Comfort. As per the Dubai Green Building Regulations the dry bulb temperature should be maintained between 22.5 and 25.5 °C, hence a set point of indoor temperature of 23 ± 1 °C was chosen, which will remain constant during all day and throughout the year [12].

As per the regulations, the air humidity level should be kept between 30 and 60% [12]. The relation between humidity and room temperature is very important, which affects the condensation which can further cause a risk of mold and mildew, as well as high humidity and low temperatures can cause construction damage. Hence as a standard and to avoid all the damage, the wall system should have no more than 9 °C temperature difference between inside wall temperature and room temperature [13]. The ventilation rates defined and set are such that the CO_2 levels in the room are maintained below 1000 ppm. According to ASHRAE, the minimal fresh air flow should be about 5.5 L per second, per person, which is equivalent to 0.153 Air Change per Hour (ACH), when a house has an occupancy of about 4–5 people. Whereas, assuming that there are a few leakages in the house and it is not air tight, the infiltration rate is set as 0.25 ACH [14]. The internal gains generally depend on the lifestyle of the occupants, and as a purpose for this project, an internal heat gain of 5 W/m^2 was chosen [4].

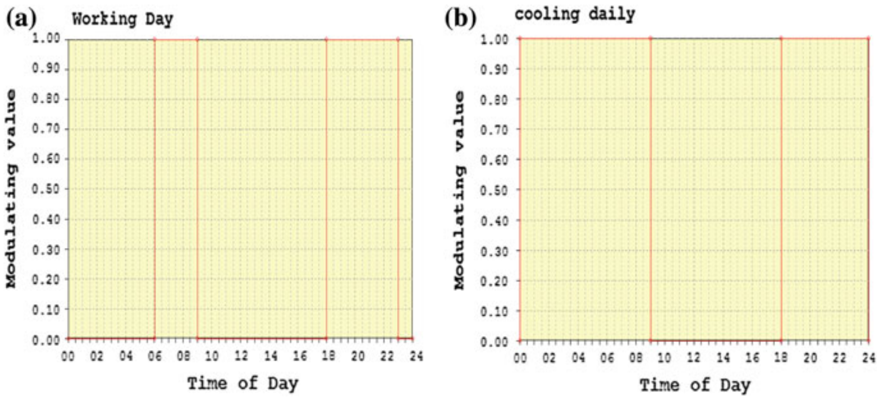

Fig. 3. **a** Electrical load operation profile (internal gains); **b** Cooling operation profile

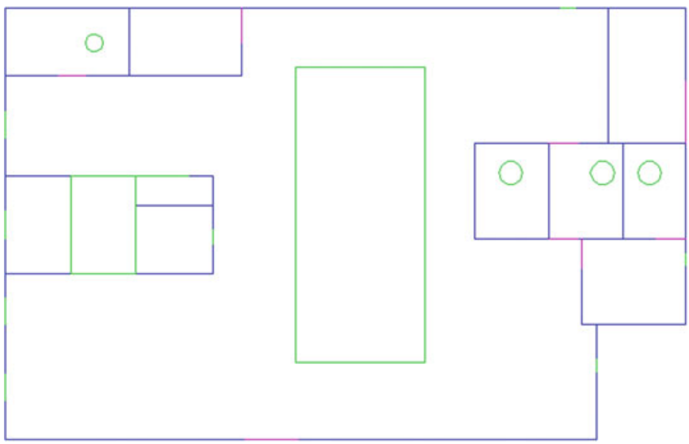

Fig. 4. Sketch of the villa on IES VE

Once the internal requirements of the villa are defined on IES, the internal gains profile (as seen in Fig. 3a) and the cooling operation profile (shown in Fig. 3b) are set to carry on with the simulations. The graph in Fig. 3 is obtained from IES, and it shows when are the profiles operational (y-axis) during the certain time of the day (x-axis). For this project it was assumed that during the weekdays the house was only occupied from 6 p.m. to 9 a.m., whereas on weekends and holidays the cooling is operational throughout the day. The heating profile is set at continuously off, as there is no heating system required in the UAE. The house is spread over an area of about 330 m^2.

Figures 4 and 5 show drawings of the villa designed in IES and the ground floor plan of the house designed in AutoCAD, respectively. Figures 6 and 7 represent the 3D model of the house. The villa comprises of a green glass room in the middle, which allows more natural light into the house. The main facade is located on the west wall and it has the highest windows area of about 25%. The house comprises of one floor, with a 6.7 m high ventilation chimney at the top, towards the west wall.

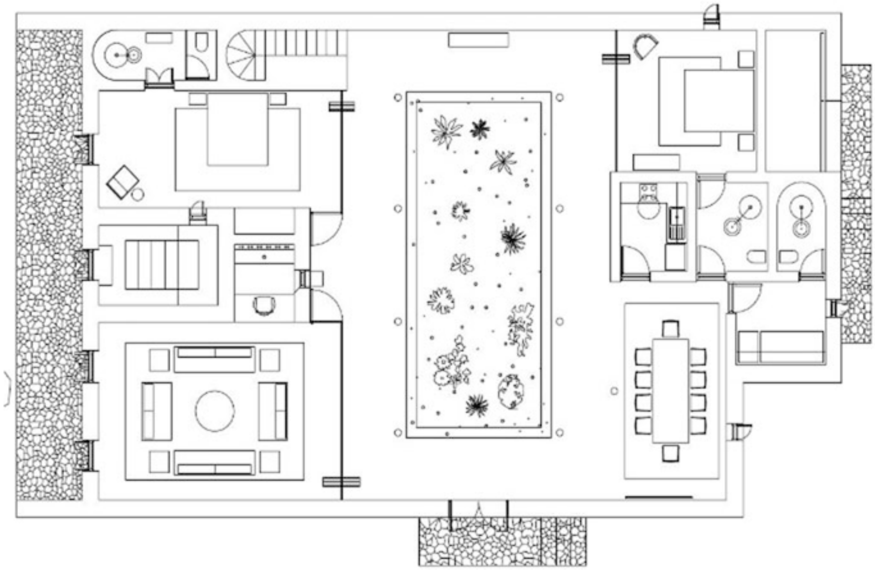

Fig. 5. Ground floor plan of the villa

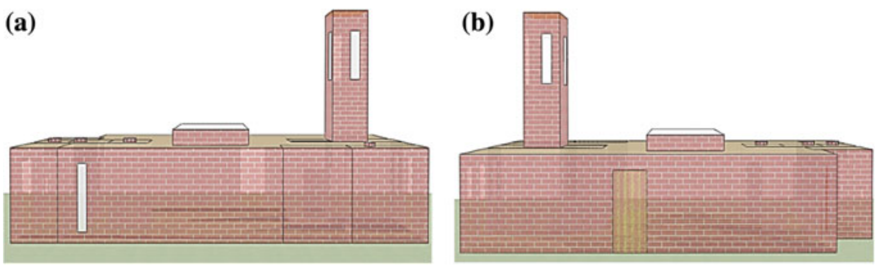

Fig. 6. **a** North facade of the villa; **b** South facade of the villa

The selection of new and high insulation building materials for Zero Energy Villa is made after understanding and comparing the cooling load results of the reference base case with the final design, and hence the ideal passive design of the Zero Energy Villa is obtained.

4 Material Background

Building materials play an important role regarding the energy efficiency of the house, that is to keep away the heat and moisture. The proper selection of the structural material along with the insulation materials and reflective coating will reduce the heat transfer through the walls and roof considerably. Whereas for the windows and any transparent surfaces, glazing and low emissivity glass will reduce the cooling load of the house. The thermal conductivity k (W/mK) is the one that defines the capacity of a material to conduct heat through its mass, which is the principal heat transfer through the building envelope. A low k value means a high thermal resistance (R-value), which indicates a good thermal insulation. According to Passive House Institute standards, a Zero Energy House should have an overall value of heat transfer co-efficient around 0.1 (W/m^2 K) [15]. As for the local standards, building elements that form the external walls, roofs, and floors (where one side of the floor is exposed to ambient conditions) must have an average thermal transmittance (U-Value) which does not exceed 0.3 W/m^2 K for Roofs and 0.57 W/m^2 K for Walls [12]. Furthermore, if the total area

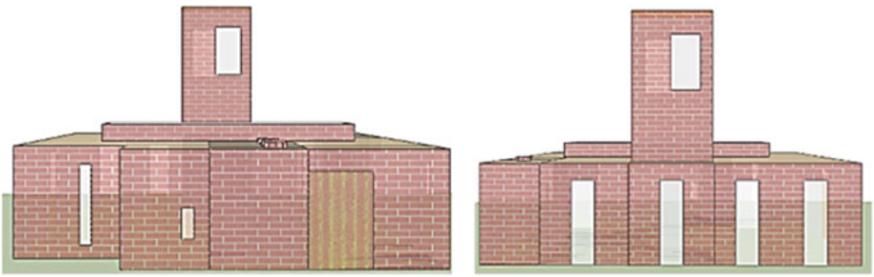

Fig. 7. East and West facade of the villa

of external windows that let in light is 40% or less of the external wall area, then the standard maximum U-value is 2.1 W/m^2 K, with a Shading Coefficient of 0.4 (maximum) and Light Transmittance of 0.25 (minimum). The materials are selected as such that the regulations and standards can be met with the defined wall and roof thickness, that is, 300 mm for the internal walls and 500 mm for the external walls, and 750 mm for the roof.

4.1 Fundamental Building Materials

The most common materials used in UAE are normal concrete or low density Autoclaved Aerated Concrete (AAC). Compared to insulation materials concrete has relatively higher density, and hence a greater thermal mass in the building envelope. An increase in the thermal capacity of the walls and roof of the house means there is delay in heat transfer, hence the house stays warmer or cooler for a longer period of time.

AAC helps lowering the U value because of its properties. Autoclaved Aerated Concrete (AAC) material contains about 80% air by volume and has been commonly used in Europe since the late 1940s. It has higher thermal resistance and hence it has ten times the insulating value of conventional concrete. Moreover, it provides an excellent thermal insulation and permits peak energy usage in the building to be shifted to off-peak hours, thus reducing operation cost for building users and owners, as well as improving comfort of living and reducing the demand on power generation facilities, and hence for this project AAC is used as a structural building material [16].

4.2 Insulation Building Materials

For this project, insulation materials with high thermal resistance and low conductivity are considered, among which include, Expanded polystyrene (EPS), Polyisocyanurate (PIR), and Extruded polystyrene (XPS), are analyzed. PIR provides low thermal conductivity, as well as it is stable and durable. It functions as long as the building stands, and has life period of more than 50 years.

Moreover, the rigid Polyurethane Foam conserves resources and saves energy, as well as it has no abundant amount of emission to the environment [17]. Whereas, EPS and XPS insulation materials are resistant to moisture, and provide low and constant thermal conductivity, as well as a long life cycle. Based on research and analysis on IES, the materials are finalized for the walls and roof [14] (refer to Table 3).

4.3 Windows and Glazed Surfaces

Windows are the core identity of buildings in UAE, and therefore put forward a challenging job when designing a zero energy villa, as they are the highest heat gain source in a building. An important parameter when designing a house is the relation between the windows surface area and the whole surface area, that can range anywhere between 10%, for small houses, to 60%, for high rise buildings [12].

The most commonly used windows nowadays are either double or triple glazed windows, with an air gap in between. The air acts as an insulation, however other fluids with lower thermal conductivity can also be used, such inert gases like Argon or

Table 1. Insulation material specifications

Materials	Cooling load (kWh/a)
EPS	73,376
PIR	73,158
XPS	73,249

Krypton. Out of the types of glazing used for windows, low emissivity glazing is opted for this project.

Low-emissivity (low-e) glass has a special surface coating that considerably reduces the heat transfer back through the window. These coatings reflect from 40 to 70% of the heat that is normally transmitted through clear glass, while still allowing the full amount of light to pass through. Furthermore, the Solar Heat Gain Coefficient (SHGC); which is a parameter that defines the thermal performance of a window and measures the rate of heat that passes through the window compared to the total amount of irradiation that reaches the window; with low emissivity films in double or triple glazed window can reach visibility factors more than 60%, keeping SHGC under 0.4. With the energy efficient measures and the low emissivity glazing, the U-value for windows usually range from 1.1 to 0.3 W/m^2 K [18].

5 Results and Discussion

5.1 Material Selection and Cooling Load Results

The house is modelled on IES VE and the simulations are carried out to evaluate the cooling load, keeping in mind the former mentioned specifications. The best building materials are selected based on simulation results for the zero energy villa to estimate the overall cooling load.

The cooling load simulated for the house is about 118 MWh per anum. This value acts as a reference, which is later compared with the original result to see how much reduction in cooling load resulted from using the insulation materials. This is the base case scenario which comprises of standard building materials and double glazed windows. The following section shows results of different insulation materials simulated and conclusively, the concept of zero energy villa and resultant energy savings are discussed. Material's specifications, such as conductivity, specific heat capacity and density was specified using IES-VE default values and a few through research. Table 1 states the specifications of the insulation materials used to obtain the cooling load results stated in Table 2.

Table 2. Cooling load results

Materials	Density (kg/m^3)	Specific heat (kJ/kg K)	Conductivity (W/mK)
EPS	40	1.5	0.032
PIR	30	1.5	0.025
XPS	45	1.5	0.028

All three materials do not show a huge fluctuation in the cooling load as their thermal conductivity does not differ much, and give a cooling load of approximately about 73 MWh per annum. Based on the former results, PIR is selected as the insulation material for the final design, and details are stated in Tables 2 and 3.

Table 3. Final material details

Walls	Thickness
AAC	External walls: 500 mm Internal walls: 300 mm
Insulated plaster	
PIR	
Roof	Thickness
AAC	750 mm
Insulated plaster	
Reinforced concrete	
PIR	

For windows, triple glazed windows are used. The materials selected prove to be advantageous in various ways:

1. They provide optimum and durable insulation, with no particular drawbacks or repairs.
2. They enhance the quality of life and increase the value of property.
3. It leads to lower heating costs and hence it is very cost effective.
4. Furthermore, it leads to large energy savings and is very easy to install too.

The arrangement selected keeps the U-value of the walls and roof to a minimum (refer to Figs. 8 and 9), around 0.1 W/m^2 K, which prevents the heat from entering the building, and hence eventually saves energy. Similar to the arrangement of construction layers of the external walls (refer to Fig. 8), the internal walls are modelled, having the thickness set to 300 mm, which results in a U-value of 0.1296 W/m^2 K. Furthermore the roof thickness is set to be 750 mm, as stated earlier, which eventually results in a U-value of 0.0732 W/m^2 K. The triple glazed windows have a U-value of about 1.3 W/m^2 K and a shading coefficient of 0.4, both of which fall within range according to the regulations defined by Green Buildings Dubai [12].

Construction Layers (Outside To Inside) System Materials...

Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[STD_SM1] Rainscreen	3.0	50.0000	7800.0	450.0	0.0001	-	Metals
[ACSL] AERATED-CONCRETE SLAB	100.0	0.1000	500.0	1000.0	1.0000	50.000	Concretes
Cavity	53.0	-	-	-	0.1300	-	-
[STD_EPS] PIR	170.0	0.0250	30.0	1500.0	6.8000	-	Insulating Materials
Cavity	54.0	-	-	-	0.1800	-	-
[ACSL] AERATED-CONCRETE SLAB	100.0	0.1000	500.0	1000.0	1.0000	50.000	Concretes
[STD_US1] Plasterboard	20.0	0.3500	44.3	1000.0	0.0571	0.000	Plaster

Fig. 8. Wall material arrangement and specifications

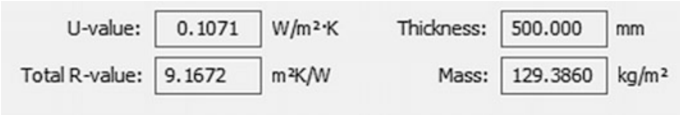

Fig. 9. U-value specifications for the external walls

The graphical representation of the cooling load results over the year is shown in Fig. 10. The total cooling load of the house comes up to 73 MWh per annum, peak load being in the month of July of about 8.5 MWh.

5.2 CO_2 Emissions

This section states in detail the carbon emissions of the house. Table 4 shows the total carbon emissions, which come up to 72 kg CO_2 per square meter. The table clearly states that the peak CO_2 emission results in during the summers, around 2600 kg CO_2, especially around month of July and August, as air conditioning is most operational during these months.

Table 4. Total carbon emissions of the villa

Month	Total CE/kg CO_2	Total CE/kg CO_2/m^2
Jan	1217	3.76
Feb	1327	4.09
Mar	1656	5.11
Apr	1945	6.00
May	2391	7.38
Jun	2467	7.61
Jul	2591	7.99
Aug	2587	7.98
Sep	2318	7.15
Oct	2037	6.29
Nov	1577	4.87
Dec	1298	4.00
Summed total	**23,410**	**72.23**

5.3 Comparison with the Base Case

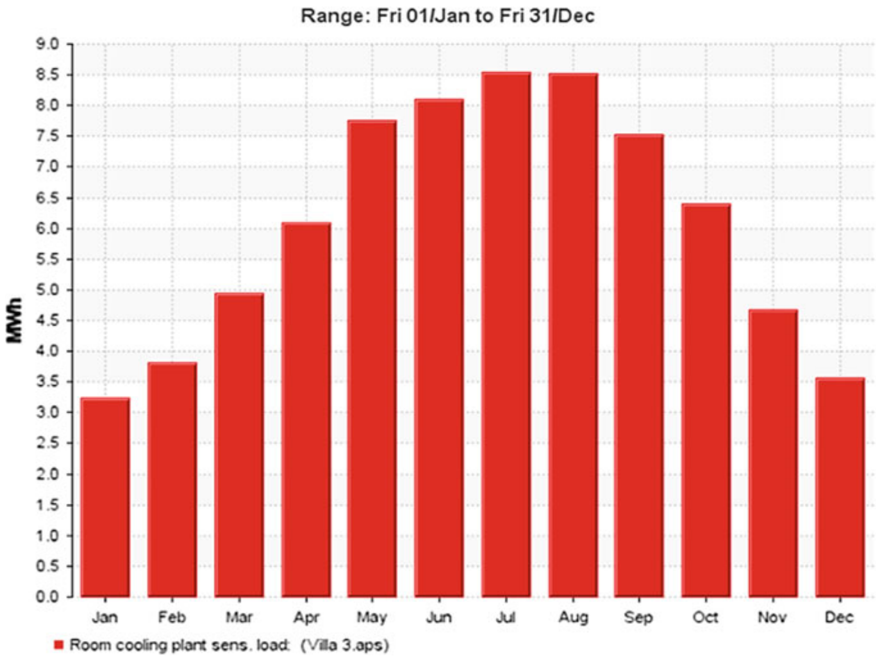

Fig. 10. Total cooling load of the villa, ranging from Jan to Dec

For the simulation, the cooling profile and the profiles for the internal gains was kept same as for the final results, to obtain a more accurate comparison between the two. For the base case scenario, the material selected for the walls and roof was reinforced concrete and insulated plaster. The only factor judged here was the insulation materials of the walls, roof and windows. The results prove how great the impact of just changing the materials is made on the house.

Table 5 shows that the base case scenario results in a cooling load of 118 MWh per annum. When compared with the cooling load of the villa, with the insulation materials, the results show a percentage reduction of about 40% in the total cooling load. Figure 11 shows a comparison of the two, clearly displaying a rise in cooling load without the insulation materials, especially during the summer months.

Table 5. Cooling load for the base case scenario

Month	MWh
January	1.5493
February	2.9504
March	5.2536
April	9.028
May	13.7296
June	15.1674
July	17.1634
August	17.4462
September	14.8077
October	11.6775
November	6.7249
December	2.8485
Summed total	**118.3461**

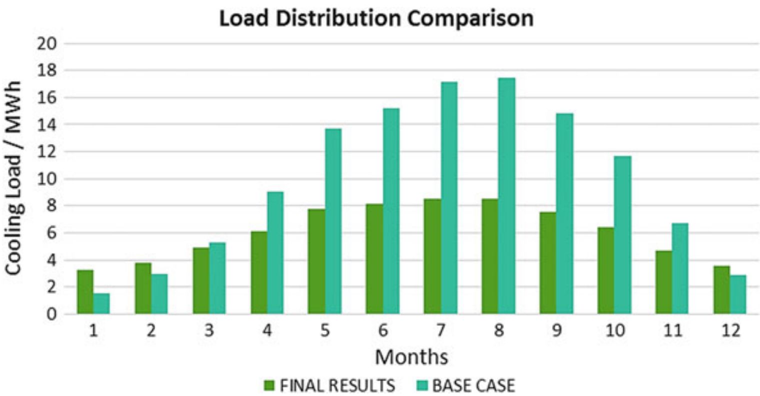

Fig. 11. Comparison of base case and ZEH

A further comparison of the cooling load was done with the results obtained from literature review, for a low energy house in UAE [4]. This house spreads over an area of about 370 m^2 whereas the area of the ZEH designed is 324 m^2. The program VisualDOE; which is a similar software as IES-VE; was used to carry out the simulations, for the reference case, located in Al-Ain, UAE. The settings used in the reference case are very similar to the ones used in IES, including the materials used in walls and roof, infiltration rate, internal equipment and lighting load. It shows that the cooling load for the reference house is 96 MWh per year and result obtained in IES shows a cooling load of about 73 MWh per year. Furthermore another analysis is conducted for the carbon emissions obtained for the house. The literature shows CO_2 emissions of about 197 kg/m^2/year [4].

Compared with the results obtained in IES, that is, 72.23 kg/m^2/year, the decrease in CO_2 emissions with respect to the literature proves that the methodology opted and the results obtained lead to the designing of a Zero Energy House.

5.4 Effect of Orientation on the Villa

Orientation is very important in the construction of a Zero Energy Villa especially in U.A.E, as the solar irradiance is quite high and in order to reduce the temperatures inside the villa, but yet receive the full solar electricity benefit, the orientation has to be optimized. By changing the orientation of the house the change in cooling load is tested.

As it can be seen from the results above, in Table 6 there is not much difference in the annual cooling load, and they are all approximately similar to the originally obtained results, although changing the orientation of the house by 90° gives about a 2.3% reduction in the cooling load. This is because the changing orientation affects the solar radiation entering the house, but as the design of the villa has evenly spread glazed surfaces and windows, hence the change in orientation does not bring about a major change in the results.

Table 6. Results for the changed orientation of the villa

Orientation (°)	Total cooling load/MWh/year
45	72.11
90	71.47
135	72.20
180	73.21
Original result	**73.16**

6 Conclusion

This zero energy villa was designed in terms of energy efficient building insulation and structural materials. The cooling load of the final design of the house was obtained as 73 MWh/year which represents a 40% reduction of the cooling load. In order to achieve this result different parameters were researched and tested on IES. The insulation materials selected were AAC and PIR, as these materials when compared with others on IES provided the lowest cooling load. And the glazed surfaces and windows are selected to be triple glazed, as they provide highest insulation.

Another major factor that was analyzed was the carbon emissions of the house. The design resulted in 72 kg CO_2 per square meter, and when compared with literature it proved that the values obtained were way less than the ones in similar case studies.

Further work suggested for this project involves further sensitivity analysis, which can include varying occupancy and its schedule, which can affect the cooling profile of the house. Analyzing more materials for the house, for example the glass solar cells, shading for the windows and incorporating more advanced technologies, such as solar water heaters, can help further cut down the electrical load of the house as well as the cooling load, and hence result to be more cost effective and have lesser carbon emissions. As a result these further studies can help fully meet the standards and approach the Zero Energy Villa.

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Determination of Saturation Point of Nano Aluminate and Nano Calcite in High Performance Repair Concrete Including High Volume Fly Ash

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Abstract. The components of concrete infrastructure deteriorate due to some reasons in terms of sustainability. Due to these deterioration, the research on the production of high performance repair mortars has increased rapidly. In order to produce high performance repair mortars, two different nanomaterials and fly ash with replacement percentages of 0.5, 1, 1.5, 2 and 55% respectively were added to concrete mix in this study. 50 mm cube samples are prepared with these mixtures for compressive strength in 1, 3 and 7 days. It is observed that the highest compressive strength of samples with nano aluminate and nano calcite is in 1 and 0.5% in 7 days respectively. When nano materials are compared with each other, the highest compressive strength of sample with nano calcite (0.5%) is 56.69 MPa in 7 days and the lowest compressive strength of sample with nano calcite (2%) is 19.23 MPa in 1 day.

Keywords: Nano materials · Fly ash · Repair mortar · High performance

1 Introduction

There are a lot of studies on sustainability in recent years. One of them is repair concrete studies. In general, service life of important concrete infrastructures is between 50 and 70 years. However, the results of the observations and investigations that many structures are degraded after 20 or 30 years due to environmental conditions, poor quality of concrete components. Conventional concrete repairs usually do not have a good durability [1]. The crack formation, which is associated with low strength concrete structures, is one of the main reasons why the service life of concrete structures is much shorter than expected [2–4]. Previously repaired concrete structures suffer from deterioration or distress under combined mechanical and environmental loading conditions frequently. The destroyed structures which repair repeatedly cause serious environmental and economic problems. In recent years, the successful application of High Performance Fiber Reinforced Cementitious Composites (HPFRCC) in the repair and strengthening of concrete structures is observed. Unlike conventional concrete, this kind of new generation fiber concrete after first cracking shows strain-hardening similar

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to a ductile material. Also, it demonstrates a strain capacity hundreds and hundreds times greater than normal and fiber reinforced concrete [5].

High volume fly ash has almost become a necessity for HPFRCC's production because of micromechanics-based design criteria [6, 7]. HPFRCC including high volume fly ash should have both high early age strength and high dimensional stability at the same time for using especially infrastructure's repair works such as road, bridge, tunnel, airport etc. There are some challenges to develop HPFRCC mixtures with high early age strength and high dimensional stability because of its micromechanical based design constraints. At this point, the affirmative studies relating with nanomaterials show that nanomaterials improve mechanical and strength performances of concrete. Also, it brings forward the idea that modified HPFRCC with nanomaterials improves the characteristics such as the early age strength and dimensional stability [8].

2 Material and Method

2.1 Material

In the study, the sand used in the study is silica sand (400 μm). Also, CEM I 52 R type Cement is used for mixtures. In the study, fly ash (F class) obtains from Çatalağzı Thermal Plant. Drinking water is used as mixture water. Calcium formate is used as an accelerating admixture. Therefore, nano aluminate and nano calcite are used as nano materials. For naming the samples, $FA_{55}nAl_{100}$ is used for sample which was 55% fly ash substituted and 1% nano aluminate substituted. Prepared samples are tested on 1, 3 and 7 days in terms of compressive strength.

The characteristics of cement, fly ash and silica sand are given in Table 1. Also, the characteristics of nano materials are given in Tables 2 and 3.

Table 1. The characteristics of cement, fly ash and silica sand

Chemical characteristics	CEM I 52,5 R	Fly ash (%)	Silica sand 400 (μm)
CaO	65.70	2.18	0.05
SiO_2	21.60	55.44	99.31
Al_2O_3	4.05	24.93	0.29
Fe_2O_3	0.26	6.33	0.05
MgO	1.30	2.38	–
SO_3	3.30	0.14	–
K_2O	–	3.87	0.02
Na_2O	–	0.49	–
Ignition loss	3.20	1.82	0.09
$SiO_2 + Al_2O_3 + Fe_2O_3$	–	–	–
Density (g/cm^3)	3.06	2.13	2.65
Blaine fineness (cm^2/g)	4600	–	–
90 μm over size (%)	–	–	–
45 μm over size (%)	–	25.4	–

Table 2. Physical and chemical properties of nano Al_2O_3

Properties	Nano Al_2O_3
APS	20 nm
SSA	~150 m^2/g
Morphology	Nearly spherical
Color	White
Density	3890 kg/m^3
Certificate of analysis—ppm	
Ca	<25
Fe	<80
Cr	<4
Na	<70
Mn	<3
CO	<2

Table 3. Physical and chemical properties of nano $CaCO_3$

Characteristics		Values
Granulation (Malvern Mastersizer Hydro 2000MU)	Average grain size, d50 (μ)	1.55–1.70
	Max. grain size, d97 (μ)	3.45–3.60
	Particle size of less than 2 μ (%)	66.05–73.25
	Covered area of 1 cm^3 (m^2/cm^3)	4.35–4.70
Chemical analysis	$CaCO_3$ (%)	98.88
	$MgO–Fe_2O_3$ (max) (%)	0.5–0.1
	$SiO_2–Al_2O_3$ (max) (%)	0.4–0.1
	The amount dissolved in HCl (%)	<0.75
	Ignition loss (%)	43.50
Physical analysis	Whiteness (L) (ASTM E-313)	>98.50
	Brightness (Ry) (DIN 6167)	>96.00
	Moisture (ISO 787-2)	<0.3
	pH (ISO 787-9)	9.0 ± (0.5)
	Toughness (Moh's)	3

2.2 Method

In this study, some ratios (Water/binder ratio is 0.27, water/cement ratio is 0.62 are fixed and all materials mixture quantities for 1 m^3 are given in Table 4. 50 mm cube samples are produced with these mixtures. The samples are kept in normal water curing until testing time. ASTM C39/C39M (2016) [9] standard is used for compressive strength test.

Table 4. Nano materials mixture quantities for 1 m^3

Material	Nano aluminate				Nano calcite			
	0.5%	1%	1.5%	2%	0.5%	1%	1.5%	2%
Silica sand (kg)	486	487	488	489	486	486	486	486
Cement (kg)	533	532	530	528	533	530	527	525
Water (kg)	328	329	329	330	328	328	328	328
Fly ash (kg)	652	650	648	645	651	648	645	641
Nano (kg)	6.07	12.18	18.30	24.45	6.07	12.14	18.22	24.30
Plasticizer (kg)	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2
Calcium formate (kg)	24.31	24.35	24.40	24.45	24.28	24.28	24.29	24.30

3 Research Findings

It is seen in Table 4 that fly ash/cement ratio is 1.22. The use of high fly ash in place of Portland cement has many positive environmental and economic impacts. Nano materials improve high performance cementitious composite. So, nano materials have recently become indispensable component for high performance cementitious composites.

According to Fig. 1, maximum compressive strength of samples with nano aluminate is observed on $FA_{55}Al_{100}$. It means that nano aluminate is so effective with using 1%. Therefore, saturation degree of nano aluminate from 0.5 to 2% is 1% for 55% fly ash substituted samples.

According to Fig. 2, maximum compressive strength of samples with calcite is observed on $FA_{55}Ca_{50}$. It means that nano calcite is so effective with using 1%. Therefore, saturation degree of nano calcite from 0.5 to 2% is 0.5% for 55% fly ash substituted samples.

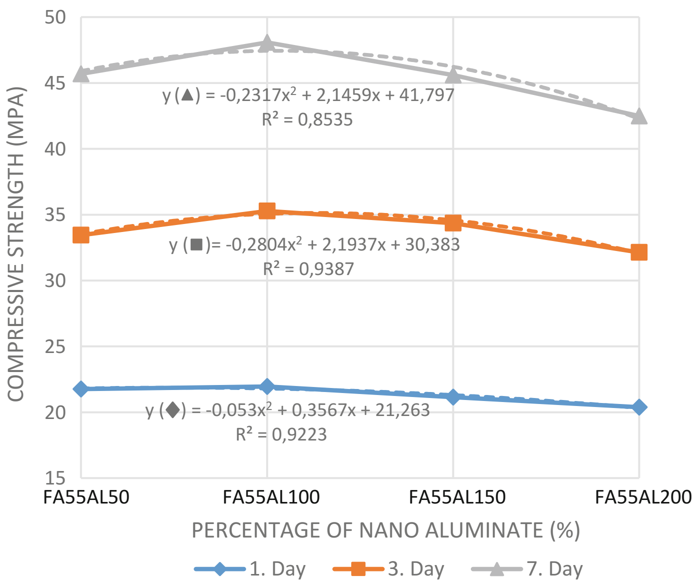

Fig. 1. The relationship between percentage of nano aluminate and compressive strength

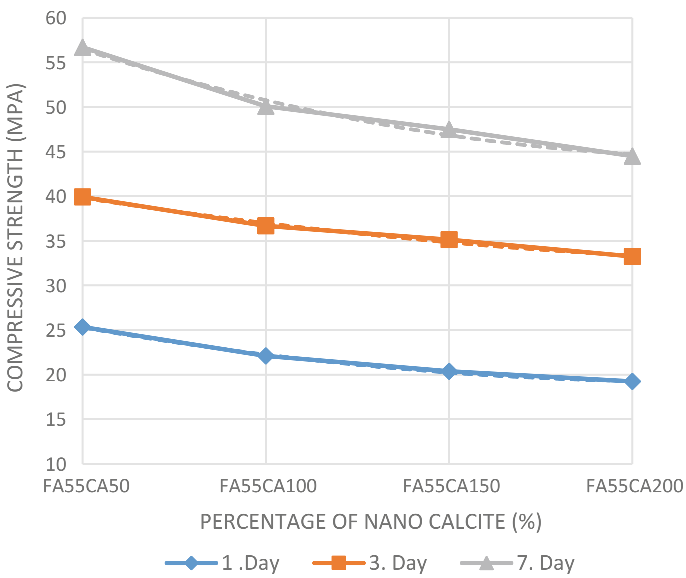

Fig. 2. The relationship between percentage of nano calcite and compressive strength

4 Result

(1) Saturation degree of nano alüminate from 0.5 to 2% is 1% for 55% fly ash substituted samples.
(2) Saturation degree of nano calcite from 0.5 to 2% is 0.5% for 55% fly ash substituted samples.
(3) The highest compressive strength of sample with nano calcite (0.5%) is 56.69 MPa in 7 days.
(4) The lowest compressive strength of sample with nano calcite (2%) is 19.23 MPa in 1 day.
(5) The highest compressive strength of sample with nano aluminate (1%) is 48.08 MPa in 7 days.
(6) The lowest compressive strength of sample with nano aluminate (2%) is 20.38 MPa in 1 day.

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Impacts of Foundations on Embodied Carbon

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Abstract. While a structural engineer plays an important role in the design and construction of a building, initiatives such as the Paris Agreement are increasing the importance of the structural engineer interest in sustainability with it being pushed to the forefront of the design field as a major concern and priority. Given this, the structural engineer needs to initiate sustainable practices in their design outside of testing new materials, as this takes time to research and incorporate into codes, standards, and everyday practice. The additional cost to construct with a new building material is also a factor and may value engineer itself out of the design. What considerations can a structural engineer take while designing a structure to reduce the embodied carbon in a building without increasing the cost? Concrete contains more embodied carbon than other structural materials, and it is also used as a primary material for foundations. Analyzing different framing methods of the structure can greatly impact the amount of concrete needed for the foundation. By reducing the amount of substructure needed a structural engineer can decrease the amount of embodied carbon and cost. This study evaluates how three different framing methods, two conventionally framed (moment resisting and concentric braced) and one less conventional (diagrid), effect the amount of concrete needed in the foundation and the impact of this in the embodied carbon of the overall structure.

Keywords: Structure · Foundation · Embodied carbon

1 Introduction

In the United States (US) the principal method for evaluating the sustainability of a building is the Leadership in Energy and Environmental Design (LEED) rating system. Although the primary metric, the contributions of the structural engineer using the LEED system are not heavily rated, with the "Materials and Resources" category as the primary method for the structural engineer to affect change [1]. Considering recycled structural material can be easily traced back to the 1980s, it is not difficult to achieve the required recycled quantities within the "Materials and Resources" category without much effort [2]. This leaves little motivation for structural engineers and firms to do more than the minimum required by LEED, especially when coupled with the fact that an equivalent number of points are awarded for providing bicycle racks and showers for 5% of the building occupants [1]. Material resources are an important aspect of sustainable design, which presents a great opportunity for structural engineers to

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contribute to reducing greenhouse gas (GHG) emissions, but if the materials specified in the design are inherently recycled materials there is little incentive based on LEED to move beyond the minimum requirements.

Worldwide buildings produce 40–50% of the GHG emissions [3]. Implementation and execution of reducing GHG emissions in the building sector will be crucial in achieving the goals recently passed Paris Agreement. Both operational and embodied energy need to be considered when evaluating the GHG emissions produced by buildings. One consideration for reducing the emissions produced by a structure is to reduce the amount of concrete used. Following fossil fuels, the next largest producer of emissions comes from cement production at 7% [4]. Common practice in the US is to use concrete in the foundations and substructure. By investigating different framing methods of the superstructure, it is possible to reduce the size of the substructure needed and thus in turn reduce the overall amount of GHG emissions produced.

2 Set Up

To assess the impacts of the substructure on the embodied carbon, or carbon equivalents (CO_2e), of a structure three different height structures were considered. SAC, a joint venture project between the Structural Engineer's Association of California (SEAOC), the Applied Technology Council (ATC), and the Consortium of Universities for Research in Earthquake Engineering (CUREE) (the first letter of the names of these three groups create the acronym), created a benchmark study of three different height (3-story, 9-story, and 20-story) structures [5]. The benchmark buildings were designed to study welded steel framed structures because of brittle behavior discovered following the 1994 Northridge earthquake and redesigned for future improvements to earthquake design [5]. Although these structures were created to assess seismic design, this study is utilizing them for the purposes of a base layout to address effects of different framing methods.

Using the three SAC benchmark buildings, three different steel framing methods were applied to each, two common methods, moment resisting (MRF) and concentric braced (CBF) frames, and one not standard method of a diagrid structure. Base parameters were set according to the original SAC design, including maximum floor heights and building shape and size.

Setting the building location in Denver, Colorado, standard design practices were considered. Typically in Colorado, wind controls the lateral design. Wind loading is calculated by a variety of parameters, such as wind speed, building height, exposure, and directionality. The Colorado front range, the area where the foothills turn into the Rocky Mountain Range, has high wind speeds and are determined as case specific when using the American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures (ASCE 7-10) [6]. However, downtown Denver is located just east of this and does not fall into the case specific region. Design wind speeds for downtown Denver are taken at 115 miles per hour per the ASCE 7-10.

With three types of framing and three building heights, a total of nine structures were analyzed for gravity and lateral loads using a finite element analysis (FEA). Images of the MRF, CBF, and diagrid structures for the 9-story building are included below for example as Figs. 1, 2 and 3 respectively. The substructure is designed as spread footings as fewer assumptions are made to design the foundations, and therefore more consistency between framing methods for better comparison.

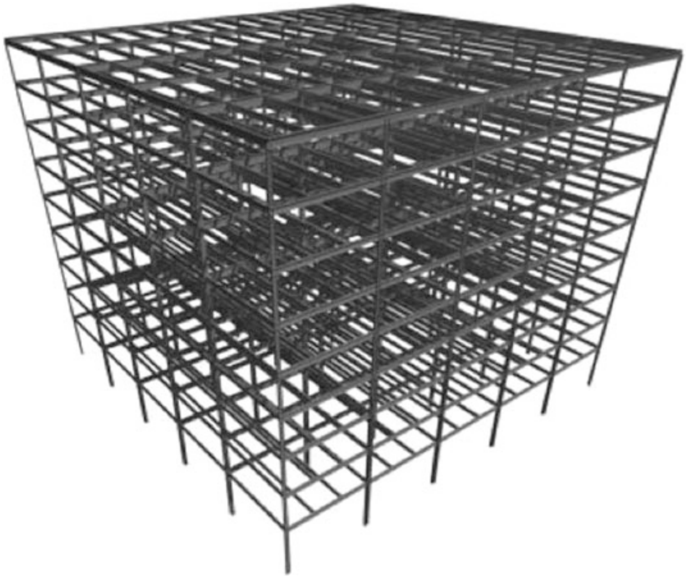

Fig. 1. 9-Story moment resisting frame

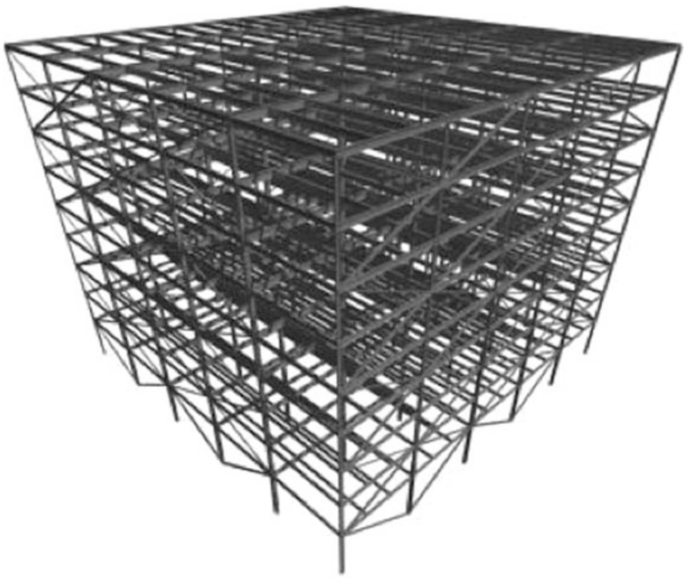

Fig. 2. 9-Story concentric braced frame

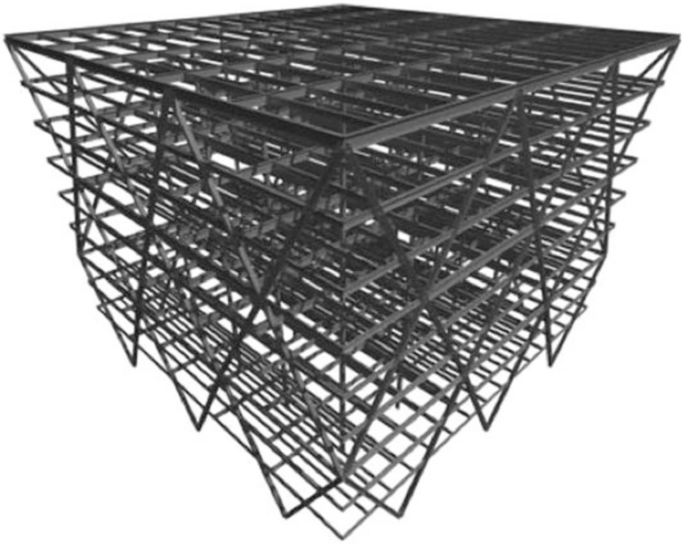

Fig. 3. 9-Story diagrid

3 Results

3.1 3-Story Structure

Below, Table 1 displays the results of the 3-story structure foundation design and equates it back to CO_2e produced. The diagrid has the fewest number of footings, which is related to the number of columns in contact with the ground. Because the diagrid has two columns at the same location around the exterior, only one footing is used. Both the CBF and MRF have the same number of columns and therefore the same number of footings. However, this does not mean that the substructure for the CBF and MRF will be the same. Because the MRF induces a moment into the footings each footing will need to be larger to resist the over turning moments. The CBF and diagrid structures do not induce moments into their foundations, only axial and shear loads.

Table 1. 3-Story foundation results

	# of footings	Weight of footings (tons)	# of reinforcing bars	Weight of reinforcement (tons)	CO_2e (tons)
MRF	33	798	312	7	803
CBF	33	688	300	6	693
Diagrid	26	465	256	3	467

Due to the significant decrease in the amount of concrete needed for the diagrid structure it produced 33% less carbon emissions than the CBF and 42% less than the MRF. Although the CBF presents it's loads into the foundation similarly to the diagrid as axial and shear forces, it is still using more concrete in the substructure. For a structure this size the difference in concrete from the diagrid to the CBF is due to the quantity of footings.

3.2 9-Story Structure

The substructure for the 9-story diagrid structure is similar to the 3-story in that it has the fewest number of footings, and the least amount of concrete and reinforcing, thus producing the least amount of CO_2e. A reverse has also happened though; the CBF produced the more CO_2e for the 9-story substructure at 21% more than the diagrid and 3% more than the MRF. The MRF in turn produced 17% more than the diagrid. Reference Table 2 below for foundation results of the 9-story structure.

Table 2. 9-Story foundation results

	# of footings	Weight of footings (tons)	# of reinforcing bars	Weight of reinforcement (tons)	CO_2e (tons)
MRF	36	1003	392	7	1008
CBF	36	1032	560	8	1039
Diagrid	28	855	272	5	858

Although there is a difference for between the MRF and CBF, this difference can be considered negligible as other factors within the design could change this result. For the 9-story structure the diagrid is still producing significantly less CO_2e than the other structures.

3.3 20-Story Structure

With fewer numbers of columns and height more than twice that of the 9-story, the footings for the 20-story structures are substantially larger. Since this is a hypothetical situation, which takes place in Denver, CO, and typically in Denver drilled concrete piers would be used in lieu of spread footing for a structure this size, but for consistency spread footings were used in these calculations. Refer to Table 3 below for the results of the 20-story foundations. Once again the diagrid had the fewest number of footings. However, with the 20-story structure the diagrid used more concrete in the substructure. This is because there are two diagonal columns at each footing creating larger loads. With larger loads the footings must not only get wider, they must also get deeper to provide the necessary shear strength. Unlike the 3-story, the MRF had the smallest amount of concrete used in the substructure. When the dead loads become large enough it resists the overturning moments. Whereas, the CBF had some challenges resisting the sliding of the concrete footings making them larger than the MRF. The CBF footings produced 4% more CO_2e than the MRF, and the diagrid produced 3 and 7% more CO_2e than the CBF and MRF respectively.

Table 3. 20-Story foundation results

	# of footings	Weight of footings (tons)	# of reinforcing bars	Weight of reinforcement (tons)	CO_2e (tons)
MRF	26	1981	476	86	2043
CBF	26	2072	484	79	2129
Diagrid	20	2113	510	98	2184

3.4 Combined Results

Assessing all of the results together, the diagrid produces much less CO_2e for the substructure than the other two framing methods for both the 3-story and 9-story structures. At some point in between the 9-story and 20-story structure, the substructure CO_2e production converge and the diagrid structure produces more than the other two framing methods, refer to Fig. 4 below. Although, for the 20-story structure all three framing methods are within a 10% production difference of CO_2e for the foundation system and it is likely not a significant difference for the overall structure.

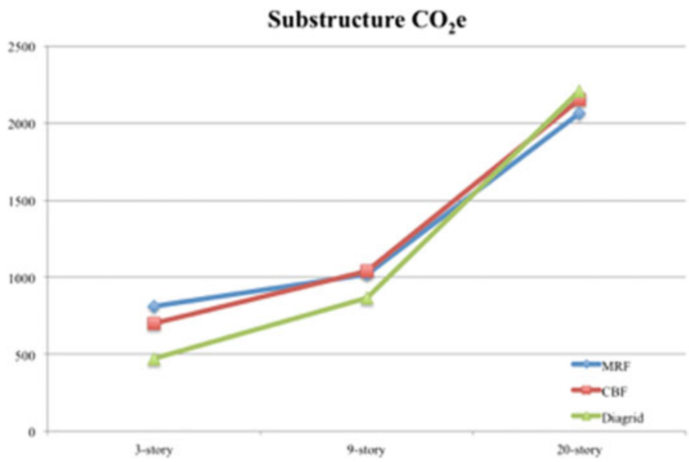

Fig. 4. CO_2e Produced by substructure

The amount of CO_2e produced by the substructure can also be considered on a per floor basis. Considering this, the amount of CO_2e produced per floor decreases as the story heights increase. Refer to Fig. 5 below. Similarly to the overall CO_2e produced by the substructure, somewhere between 9-stories and 20-stories, the diagrid switches from the most efficient structure and trends to the least.

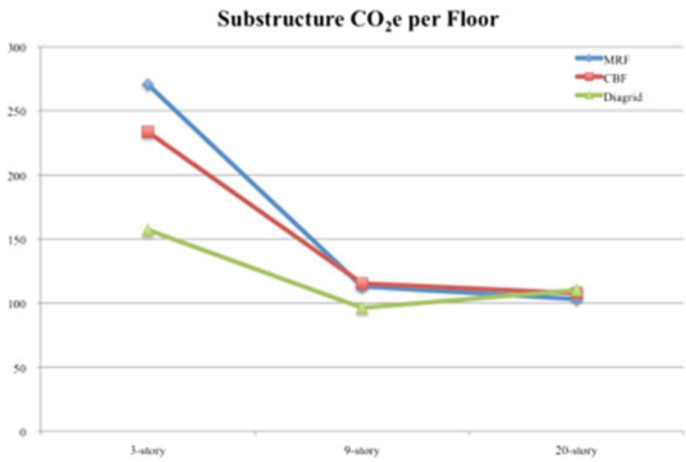

Fig. 5. Substructure CO_2e produced per floor

3.5 Total Structure CO_2e

In order to fully consider the effects of the substructure on the overall CO_2e produced by the total structure, it is important to review the results produced by the super-structure. The 3-story substructure produced anywhere from 66 to 78% of the overall CO_2e produced by the structure, as shown in Table 4.

Table 4. 3-Story total CO_2e produced (tons)

	Steel framing	Concrete foundation	Reinforcement	Excavation	Total
MRF	232	798	5	8	1043
CBF	242	688	5	7	942
Diagrid	263	465	2	5	736

The 9-story superstructure increases it's effect on the overall CO_2e produced, with the substructure producing 51 to 63%, which is down from the 3-story, as shown in Table 5.

Table 5. 9-Story total CO_2e produced (tons)

	Steel framing	Concrete foundation	Reinforcement	Excavation	Total
MRF	616	1003	5	10	1634
CBF	612	1039	6	10	1661
Diagrid	824	855	4	9	1691

As shown in Table 6 below, the substructure for the 20-story building produced anywhere from 57 to 61% of the overall CO_2e produced by the structure.

Table 6. 20-Story total CO_2e produced (tons)

	Steel framing	Concrete foundation	Reinforcement	Excavation	Total
MRF	1586	1981	63	20	3649
CBF	1389	2072	58	21	3539
Diagrid	1452	2113	71	21	3657

The substructure consistently impacts more than 50% of the overall CO_2e produced by the structure, averaging around 69%. This data proves that the foundation system of a structure can have a major impact on the amount of CO_2e produced in a structure.

4 Other Research

In comparing these results with the information found in other research it was found that research done by Panchal and Patel had a different interior framing method than the one used within this research [7]. The SAC structures were laid out on a standard cartesian coordinate system with the beams framing in one direction and the girders running perpendicular to the beams. Panchal and Patel have their framing on a radial grid with the girders framing from the center to the exterior corners. The differences in the interior framing may play a role in the higher success of their diagrid system compared to the MRF.

Moon et al. also use this radial method of framing when studying the optimal angles for 20, 42, and 60-story diagrid structures [8]. For smaller structures, such as the case with the SAC structures, it is common practice to place the framing in bays with the beams in one direction and the girders in another. The radial system evenly distributes the weight of the structure around the entire exterior, which may also aid the foundation design of the 20-story diagrid and potentially help in reducing the number of interior columns.

5 Conclusion

Studying the impacts of CO_2e from the foundation design of multiple framing methods proved to be informative as this is an area that has not received much attention from other researchers. By including the substructure, as it is a necessary part of the entire structure, it became evident that the substructure had a major impact on the overall CO_2e of the entire structure. The foundations produced more CO_2e than the steel for the MRF, CBF, and diagrid structures for all three building heights, demonstrating that substructure cannot be ignored when considering the sustainability of a structure. With only three heights of structures, it is difficult to determine if one specific framing type consistently produces the least amount of CO_2e. However, this study proves the importance on considering the framing method and substructure in determining the CO_2e of the structure.

The role of the structural engineer historically in relation to sustainability has been a much more passive role, relying on other disciplines such as the architect to drive innovation. This research demonstrates how important it is for structural engineers to take an active role employing various techniques to find a more sustainable path for the field, and pushing it to become the new standard expectation.

Investigating the sustainability of different framing types is something that should be employed when starting a new project. This may impact a client's decision as to which framing makes the most sense for the project. By investigating the sustainability of a structure at the start of new projects, the structural engineer can begin to take a more active role in sustainability in lieu of the passive approach currently common.

In summation, there is not one best design or one best approach to sustainability as related to the structural engineer, but a spectrum of opportunity to work toward making the entire field more sustainable all while not costing the client more or sacrificing structural integrity, but reducing environmental impact substantially.

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The Proposal of Restoration of Historical Kastamonu Castle's

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Abstract. Permanence of Kastamonu Castle in Turkey which has been the witness of history emerges as the most important value. Historical places and structures are important expressions of community's culture and identity. The structure can be provided to serve from the past to the future. In this study; characteristical features of Historical Kastamonu Castle, used materials and reasons of structural deterioration are analyzed for restoration suggestion. Historical Kastamonu Castle is important for long-lasting regional culture properties.

Keywords: Historical construction · Sustainability · Constructional deterioration

1 Introduction

Culture can be acceptable as a complete of all abstract and concrete life properties and values of a specific community. All these values are alive just like the people who form the culture, differ according to the conditions, develop and effect their environment. Roots of Turkish culture which lasted to the beginning of global culture, have taken an effective part in shaping all values of the society in high developed and dominating geographies along the time. One of the most important values of these social values is the house which provides basic needs of human beings [1].

2 Kastamonu Castle

Kastamonu Castle which is on 112 m high rocky hill on the southwest of Kastamonu, was built in the period of Byzantium Emperor Komnenos at the end of the 12th century. Outer walls which surround the city and extend to the valley are unable to survive. Only a part of a tower belonging to outer walls is still standing today. Even though the inner castle was built in Byzantium Period, sections which are still standing were built in the period of Candaroğulları. This castle which was repaired in the Ottoman Period was largely damaged in the earthquake in 27th November of 1943. The castle is 115 m long, 30–50 m wide, planned as a rectangle. In the first construction, it was strengthened with 15 big donjons and towers. Stone, lime, and wooden beams

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were used building. Door jambs, vaults, and arches are made of cut stone. Round donjon was covered by tiles. The first and the second door of the castle are low arches. There are vaults which are pointed arches. It is possible to go to the castle through a steep road in the northeast. There is another door in 50 m north of the door which is protected by a rectangular donjon. The road between two doors is protected by donjons. There are ruins of some structures inside the castle. Road shaped corridor which is in the middle of the castle is reached to outer walls from the Castle Door Area. This corridor was used for either supplying or sheltering people during a siege. An important material will be brought to Kastamonu tourism which is covered by a grate today by opening to visitors [2] (Figs. 1, 2, 3, 4, and 5).

Fig. 1. North side [author archive]

Fig. 2. East side [author archive]

Fig. 3. West side [author archive]

Fig. 4. Inner castle [author archive]

Fig. 5. The tunnel, secret connected road with the city [author archive]

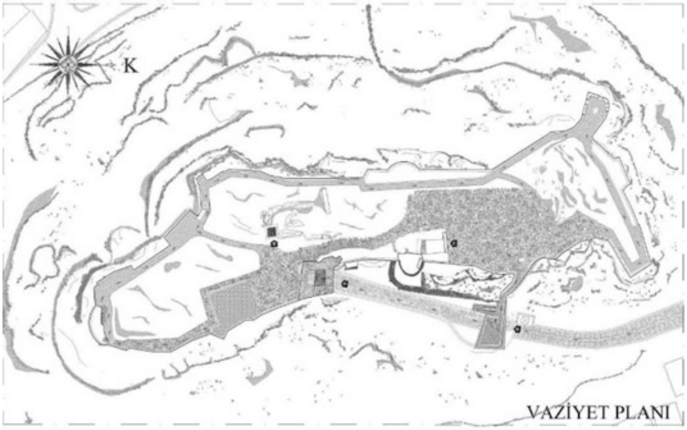

Fig. 6. Situation plan [author archive]

3 Intervention Decisions

See Fig. 6.

3.1 Physical Surface Cleaning

Grout and layers of dirt on castle walls and floorings should be cleaned by carding method firstly. And then they should be cleaned by the micro sandblasting method.

3.2 Herbal Cleaning

On the walls, on the ruins and tree roots growing inside the walls and long roots of huge plants destroy structure materials; cause structural problems as suture discharge on the walls, cracking and collapse. For this reason; these types of plants and their roots should be purified from the walls. Ivies growing in suture gaps inside the walls and in the clefts-cracks inside the stones should be cleaned by drying. Pesticides like weed killers which are not harmful to stone surfaces can be used to clean these types of plant roots. Monsanto mark ROUNDUP ULTRA or RAUNDOP SUPER is suitable for this aim. This product which is sold as liquid should be applied by spraying to fresh leaves of ivies after diluting in water in proportion as 20–25%. By descending from leaves to roots applied product will be effective in some weeks and will cause drying of plants from roots. This application should be repeated several times in every year.

DIESEL can be suggested for drying of alive plant and tree roots which have no leaf. Diesel can be applied by injecting directly to inside the root (Fig. 7).

Fig. 7. Inner castle [author archive]

3.3 Suture Reparation

All cementitious grouts on inner and outer surfaces of the castle should be scraped carefully without damaging original stone body wall. In the repairing adhesive, vapor-permeable, not containing soluble salt, slaked lime origin grout should be used.

On the castle walls poured groutings between stone and brick can be seen. Old groutings should be renewed by a grout which has a similar quality with the original history. In wall reparations, grout mixture rate for plat and copping can be used in suture reparation.

Suggested grout mixture rate is:

1. scale (hydraulic) lime
2. scales washed stream sand (large-grained; 500–1000 μm) 1/5 scale brick dust and fracture.

3.4 Stone Surface Reparation

Stone surfaces of the castle should be re-sutured after extracting cementitious reparation. Stone surface shouldn't be plastered.

On the walls especially on large andesite blocks, clefts and cracks have been occurred in various sizes. These can be strengthened by a suitable rosin injection. Rosins based Ethyl Silicate (Funcosil 500 STE) can be preferred as suitable consolidators. The application form should be like this:

- Rosin should be injected directly to strengthen fine cracks.
- For broad cracks and clefts rosin stone powder which is too fluid (grain size 125–150 μ) can be drained to these parts by mixing in 1:1 rate.

After cracks and clefts are strengthened by this way, they should be closed by lime based grout which is prepared according to the surface color. Grout mixture rates are the same with the preferred rates for plastic completions (Figs. 8 and 9).

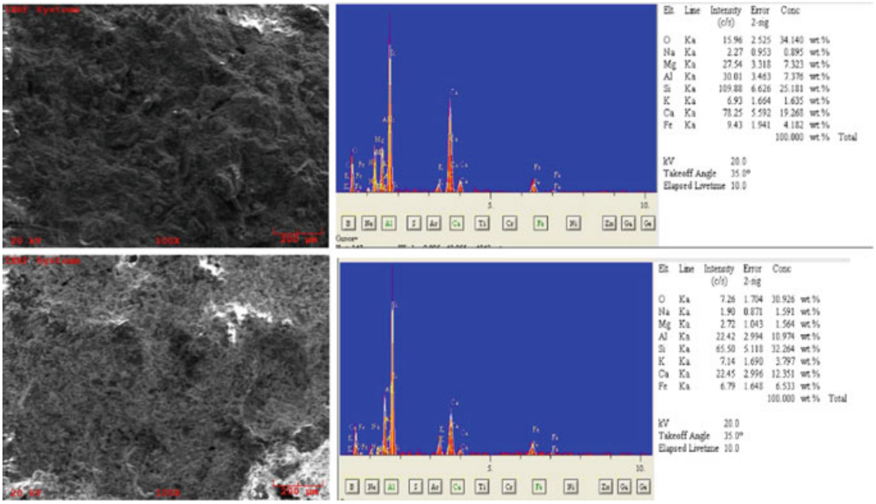

Fig. 8. Chemical composition analysis of stones with EDX

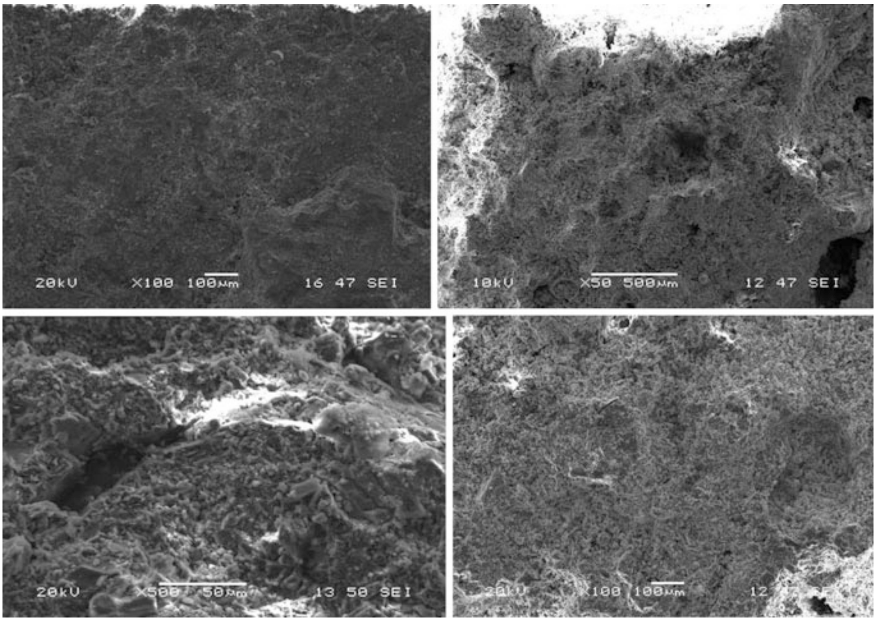

Fig. 9. SEM images of stones

3.5 Stone Wall Completion

Calcium, silicate, aluminate and lesser amounts of iron and alkalis were detected in the chemical composition analyze made with EDX. Generally, in castle restoration completion hasn't been foreseen. A completion limited with original material has only been foreseen because the structure can withstand to natural conditions.

3.6 New Floor Building

After restoration to visit the castle more comfortable and safely, new Stone flooring is suggested which is harmless to the original structure. Final wall heights and pavement steps should be decided in the area according to an altitude of the area.

3.7 Keeping Making

Places on the castle body walls on which won't be made completion walls should be finished by hydraulic lime compost as given in the Project after cleaning covers.

3.8 New Metal Stairs and Parapets Building

Visitors should be provided to use the castle safely by making new metal stairs and parapets in necessary places in addition to Stone stairs. Metal elements should be made less harmful to assembly details (Fig. 10).

Fig. 10. The entrance of the castle [author archive]

3.9 Copping on Wall Ruins

Protecting copping should be done to strengthen upside the strong and/or wreck walls, prevent from rain and wind erosion. Plat height for copping shouldn't be more than 2–3 stone lines (20–30 cm). The cop should be slightly inclined to draining rain water to sides.

Grout should be hardened slowly, for crack prevention newly built regions should be covered up with wet hemp sack. Stones' sizes for copping should be smaller than stone sizes in original lines. By this way, new and original parts will be distinguished.

3.10 New Roof Building

Roof structure should be removed safely without damage, a new roof which is harmless to the original structure and suitable for castle should be made.

3.11 Research Digging

In Kastamonu Castle there hasn't been done enough research yet. In the castle, research digging is suggested under the control of the museum.

3.12 Building Security Cabin

In Kastamonu Castle there isn't any security precaution. With restoration studies, a portable security cabin is suggested to build which doesn't damage the castle. A simple portable unit is suggested to build because of being protected area and harmless for the environment.

3.13 Landscaping

After the security precautions around the castle, visiting the castle more productively and comfortably should be provided by ordering the units like parking area, transportation, WC, gift shops in cooperation with governorship and municipality in the entrance of the castle. It is just suggested here because of being out of the Project area and including different ownerships.

3.14 Opening the Closed Donjon

Nowadays the entrance of the highest donjon is closed. During the application restoration of the donjon should be done by entering the donjon by means of removing excesses like concrete and similar elements with not damaging the original structure. During the application according to new findings survey and restoration projects should be updated if it is necessary.

3.15 Removing Excess Elements

All excess elements in the castle (electric cable, nail, lighting elements) should be removed carefully by not damaging the original structure.

3.16 Reparation of Wooden Beams

In the entrance of the castle reparation and protection will be done in wooden beams, they will be resistant to natural conditions by impregnation by means of reparation with wooden paste by experts.

3.17 Reparation of Floor

All the floors will be completed, protected by healing. During the application original floor elements will be protected by healing, missing elements will be completed according to the original sample.

4 Results

Traditional Turkish Culture has been forgotten as in most of the traditional cultures because of the universalization design concept and pioneer design trends. Traditional Turkish culture which is an inspiration to many civilization and design concepts, can not cherish only with the protection of extant culture properties. These works should be provided to continue their functions strongly with necessary methods in modern life [3–5].

At the same time, it is important for cultural persistence to be compatible with modern life conditions, providing needs and designing traditional new structures and reinforcement. Many reinforcement elements of traditional Turkish houses like an inert cabinet, door, door frame, ceiling hub were taken under protection and they have become necessary reinforcement in a modern structure for today. It has been mentioned that cultural persistence can be provided by designing modern structures with traditional design concept [3, 5, 6].

In the research; during the application of all preferred grout mixtures, in terms of measuring region climate conditions suitability, the most suitable grout mixture and color will be achieved by local trials.

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Life Cycle Cost Analysis for Electrical and Solar Water Heater from a Sustainable Perspective

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Abstract. Global warming jeopardy increases day by day and being green at our era becomes a demand to protect our planet. This paper describes the financial and sustainable impact of electrical and solar water heater from a client point of view on the long-term in residential buildings in Al Ain, UAE. Costs play a vital role in selecting materials by the client. Therefore, current research aims to compare between two types of electrical and solar water heater. This comparison aims to expand the client's prevision to select materials wisely based on its life cycle cost and environmental impact not only based on the initial cost. Electricity cost is always the highest cost at the life cycle cost of the building. Therefore, we focused in our comparison on the electricity consumption and cost during the life cycle of the water heater. Computing life cycle cost based on net present value assists project managers and clients to decide critically between alternatives. To understand client's tendency in selecting materials, this paper applied qualitative and quantitative methods. Interviews with clients allow authors to illustrate the benefits of studying cost over a long-term. Results show that although solar water heater has higher capital cost, it shows a steady and very low increase comparing to electrical water heater.

Keywords: Life cycle cost analysis · Net present value · Sensitivity analysis Water heater · Al Ain · United Arab Emirates

1 Introduction

For several years ago, a great effort has been devoted to study and manage projects in an effective and efficiency way. Life cycle cost analysis (LCCA) is an economic technique that allow professionals to study and predict all pertinent cost during the expected life cycle of the project. It assists in sensitive economic decision-making.

This paper applies net present value (NPV) method along with applying value engineering on one material only used in residential building in Al Ain, in the UAE. It aims to find out the difference between sustainable and unsustainable material. The comparison aims to differentiate between electrical and solar water heater based on their life cycle cost. Thenceforward, sensitivity analysis is applied in order to find out the most sensitive factor during the life cycle of the project.

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2 Literature Review

The paper servers as an introduction to life cycle cost analysis (LCCA) to understand the analysis of all pertinent costs during the life cycle. Also, net present value (NPV), value engineering (VE) and sensitivity analysis is described herein below.

2.1 Life Cycle Cost Analysis (LCCA)

Life cycle cost analysis has been gaining importance throughout the eras. LCCA is a comprehensive financial technique that allows engineers, project managers and cost analysts to study and evaluate all pertinent costs to a project during its lifetime. This project might be a product, system, building or any sequence processes through period with considering possible changes in economic factors over time.

A consensus is forming among experts that LCCA technique is the best technique to assist in making-decision [1–4]. LCCA is used also to compare between alternative [2, 5] by trading off between different materials or systems to find the best economic design during the lifetime of the project.

Life cycle cost for a material includes capital cost, operation cost, maintenance and replacement cost [6]. Equation (1) illustrates the LCC:

$$\mathrm{LCC} = \mathrm{CC} + \mathrm{OC} + \mathrm{MC} + \mathrm{RC} \tag{1}$$

where:

LCC	Life cycle cost
CC	Capital cost
OC	Operation Cost
MC	Maintenance cost
RC	Replacement cost.

2.2 Net Present Value (NPV)

Net Present Value is defined as a tool to measure "the value in today's dollars of its implementation over the specified timeframe" [7]. It is however, important to note some NPV features. Computing NPV facilitates understanding life cycle cost/benefits for each alternative [8]. It used as a tool to compare between different alternatives [9, 10]. NPV was applied as a control mechanism tool that can rank alternatives economically [11].

The method of calculating LCC in present value terms (PVLCC) was illustrated [5] as shown in Eq. (2):

$$PVLCC = \sum_{t=0}^{N} \frac{C_t}{(1+i)^t} \tag{2}$$

where:
C_t relevant costs occurring in year t,
N length of study period, years, and
i the discount rate.

2.3 Value Engineering (VE)

It is defined as "a structured approach for identifying solutions that satisfy given needs with reduced costs" [12]. The aim of applying VE in this paper is to increase the benefits gained from using sustainable material instead of unsustainable material for the same function.

2.4 Al Ain Buildings in Brief

Based on Abu Dhabi Urban Planning Council Al Ain vision 2030 [13], buildings in Al Ain were divided based on the maximum allowable height into buildings up to 12, 15 and 20 m.

Al Ain is an inner city, which 160 km away from the Capital (Abu Dhabi). It has arid weather. The air temperature is always above 40 °C from April to October and reaches 50 °C on June and July. Therefore, we have decided to increase the benefits of the sun by turning the sunrays into a clean energy in heating water. In order to convince property owners that the sustainable option is better we have to defend our selection from a financial point of view also.

3 Methodology

The purpose of this section is to organize the research methodology of this paper. An explanatory mixed method was followed through collecting materials' data before qualitative data. Mixed methods allow quantitative results to support qualitative results.

Quantitative data such as the full specifications for electrical and solar water heater were collected from a leading consultancy and project management company in Abu Dhabi (Abu Dhabi Commercial Engineering Services ADCE) databases. On the other hand, interviews were conducted with professional design review electrical engineers working in ADCE.

This paper compares between electrical water heater and solar water heater as shown in Table 1. We assumed that both water heaters were installed in the same circumstances of residential buildings in Al Ain, UAE. We assumed that the economic life of the residential buildings in Al Ain is approximately 30 years old. Therefore $N = 30$ years. In addition, we assumed that the discount rate equals the inflation rate in the UAE, which is approximately 3.5%.

Table 1. Comparison between electrical and solar water heater

	Electrical water heater	Solar water heater
Capital cost (AED)	600	7250
Maintenance cost (AED)/No. of years	200/4 years	200/year
Replacement cost (AED)	Every 7 years	30 years
Electricity consumption (K Wh)	1.2 KW	–

Operation cost has been calculated from Eqs. (3) and (4) by calculating the annual electricity consumption then multiply it by the electricity tariff of charges in Al Ain.

$$\text{AEC} \;= \text{EC} * \text{hr} * \text{yr} \;= 1.2 * 10 * 365 = 4380\,\text{KW/yr} \tag{3}$$

where:
AEC Annual Electricity Consumption
EC Electricity consumption
hr Number of working hour
yr No. of days in a year.

$$\text{OC} \;= \text{AEC} * \text{tariff EC} \;= 4380 * 0.21 = 920\,\text{AED/yr} \tag{4}$$

where:
OC operation cost
tariff EC tariff of electricity cost.

LCCA and NPV were calculated for both materials as shown in Table 2. Calculations were conducted using Microsoft Excel 2010.

4 Results

This section presents the difference between the sustainable and unsustainable material based on the cost through the life cycle. After that, a sensitivity analysis was conducted in order to identify the greatest impact between variables.

4.1 Comparison Between Electrical and Solar Water Heater Based Through the Life Cycle

Comparison between electrical and solar water heater through all life cycle costs was illustrated at Fig. 1. Results show the huge difference between electrical and solar water heater. Electrical water heater shows very low capital cost and high capital cost for solar water heater. While, the electrical cost shows very sharp increase in cost during 30 years life cycle cost. On the other hand, the solar water heater has a great steady increase in cost. Finally, the total LCC for electrical water heater is three times the total solar water heater.

It has been noticed from Table 2 that operation cost for solar water heater is zero. That is because there is no any electricity consuming at the solar water heater. On contrast, electricity cost made the huge difference during the life cycle of electrical water heater.

4.2 Electrical Water Heater Sensitivity Analysis

Figure 2 shows the sensitivity analysis for two variables, which are the capital cost and the inflation rate after changing in input value by step of 10% in minus and positive. It has been noticed that during the life cycle the change in input value does not have a notable impact on electrical water heater capital cost. On contrast inflation rate has more influence through the life cycle. Change in input by (−30%) shows (10%) below the LCC at zero change. On the other hand the change in input increases to (12%) at change in input by (30%).

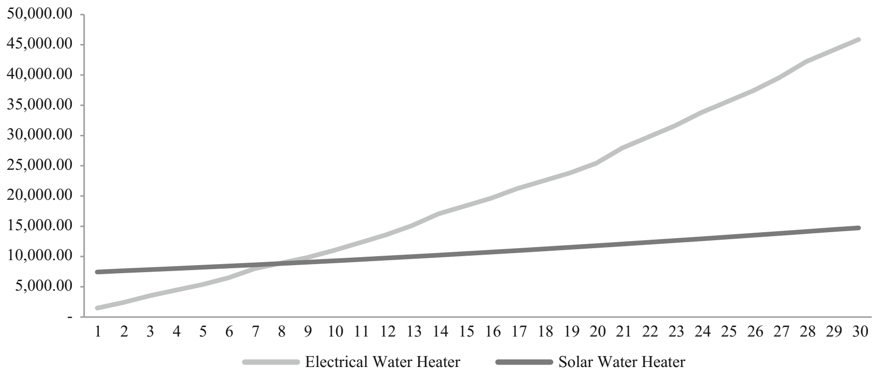

Fig. 1. Commutative present value for solar and electrical water heater through a life cycle of 30 years

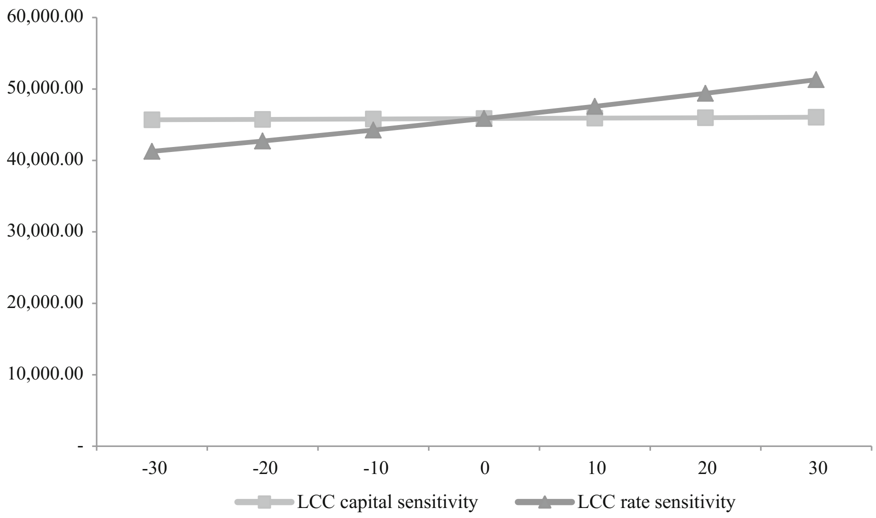

Fig. 2. LCC capital cost and LCC inflation rate sensitivity analysis for electrical water heater

4.3 Solar Water Heater Sensitivity Analysis

Figure 3 shows the sensitivity analysis between same variables, which are the capital cost and the inflation rate after changing in input value by step of 10% in minus and positive. It has been found that LCC capital cost sensitivity has the greatest effect through the life cycle. There is decrease by (15%) at change in input at (−30%), (10%) at change in input at (−20%) and (5%) at change in input at (−10%). Same percentages were found but positive at positive change in input. On the other hand, LCC inflation rate sensitivity were noticed that it does not have any effect through the life cycle when changing the input of rates.

Table 2. LCCA and NPV for electrical and solar water heater

		Inflation rate	3.50%										
		1	2	3	4	5	6	…	27	28	29	30	Total
Electrical water heater	Capital cost (AED)	600	–	–	–	–	–						600
	Maintenance cost (AED)			200			200		350				2200
	Replacement cost (AED)									750			2700
	Operation cost (AED)	920	920	920	920	920	920		1831	1831	1831	1831	40,484
	Total LCC cost	920	920	1120	920	920	1120		2181	2581	1831	1831	45,384
	Total PV	1489	919	1119	919	918	1118		2181	2581	1831	1831	45,865
	Cumulative PV	1489	2408	3527	4446	5364	6482		39,623	42,204	44,034	45,865	
Solar water heater	Capital cost	7250											7250
	Maintenance cost	200	200	200	200	200	200		300	300	300	300	7500
	Replacement cost												–
	Operation cost	–	–	–	–	–	–		–	–	–	–	–
	Total LCC cost	200	200	200	200	200	200		300	300	300	300	7500
	Total PV	7443	200	200	200	200	200		300	300	300	300	14,743
	Cumulative PV	7443	7643	7843	8043	8243	8443		13,843	14,143	14,443	14,743	

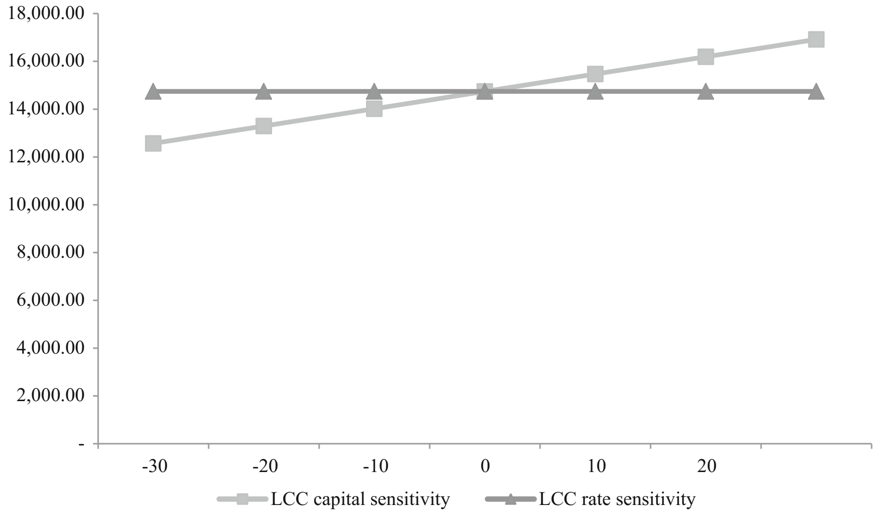

Fig. 3. LCC capital cost and LCC inflation rate sensitivity analysis for solar water heater

5 Conclusion

This paper aims to compare electrical and solar water heater not only from a sustainable perspective but also from a financial perspective. In order to compare between sustainable and unsustainable material, LCCA as a financial technique can assist in making decisions.

After applying LCCA and NPV, on both electrical and solar water heater, it has been concluded that solar water heater has the lowest LCC over 30 years of lifetime. Although the capital cost of solar water heater is 12 times over the electrical water heater, the LCC at the end of life of the electrical water heater is over the LCC of solar water heater by 3 times.

On the other hand, after conducting a sensitivity analysis for electrical water heater, it has been noticed that the inflation rate has the greatest effect during the life cycle. On contrast, it has been noticed that the capital cost of solar water heater has the greatest effect during the life cycle. Finally, it has been concluded that solar water heater is an economic and sustainable selection and it is better than the unsustainable selection (electrical water heater) over 30 years of life cycle.

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Sustainable Transportation

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Abstract. Growing world population and rapid urbanization have increased the demand for mobility. The need for development of transportation technologies and infrastructural systems aimed at satisfying this increased demand is now non-negligible. As the number of private cars has increased after Industrial Revolution in spite of the unsufficient infrastructural capacity, the traffic problems are being confronted nowadays. As a solution to these problems, new roads are being built based on the "predict and provide" method which is part of today's traditional approach to transportation. However, it was found that new roads revive the stagnant demand, which even further complicate the traffic problem. In this context, it is believed that any solution focusing only on increasing the capacity and mobility in order to address the transportation problems will not be neither economical nor permanent. With this understanding in mind, traditional transportation approaches are replaced with sustainable transportation approaches with a trend initiated especially by the developed countries. The purpose of the sustainable transportation approach is to make investments into systems which place importance on accessibility; develop healthy, safe, equalitarian, comfortable and environmentally-friendly vehicle and infrastructure technologies; integrate transportation modes; which properly manage infrastructural capacity, passenger demands and operational supply; and relocate freight transportation to logistics centers. This study presents the historical development of sustainable transportation approaches and explores its principles in terms of environment, society and economy with award-winning exemplary projects, and offers recommendations for solutions to current problems of transportation in Turkey.

Keywords: Sustainability · Transportation · Sustainable transportation
Mobility · Accessibility

1 Introduction

Transportation is a concept which drives the social development, connects people and local communities to the world, creates vehicle markets, and facilitates commercial/logistics operations [1]. Besides, transportation is a system closely associated with the concept of mobility and accessibility, created in order to satisfy the mobility needs of nations, to offer a quality living space for people, and involves the transportation of

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people, goods and services [2]. In transportation, the interrelation of the concepts of mobility and accessibility is similar to the one of “Yin and Yang”.

Mobility is a concept accounting for the transportation of people, livestock, goods and services from one place to another, which often has an influence on smaller groups and which is not limited to the current infrastructure and behavior patterns of the market. Approaches which define the transportation performance from the perspective of mobility consider the basis of transportation in terms of mobility of human beings (people/km) and mobility of goods (ton/km). The transportation performance is measured as the amount of travel per unit, and the main goal is to increase this ratio [2].

Accessibility, on the other hand, is defined as the ease of access to goods, facilities and activities people and businesses need. The main purpose of accessibility is to make better decisions on the land usage at a national and individual level; to improve transportation modes and their quality; to shorten the travel time between two locations; to support non-motorized ways of transportation; to improve public transportation options; and to integrate and enable transportation modes. When it comes to transportation modes, safe alternatives which offer slow transportation on short distances are more commonly preferred over the alternatives offering fast transportation on long distances [2].

Advancing Public Transport (UITP) recommends the “ASI” approach for transportation. This approach involves the following principles; “A (Avoid): Avoid unnecessary transportation”, “S (Sustainable): Adopt sustainable transportation” and “I (Improve): Enhance” [3].

2 The Concept of Sustainable Transportation

The concept of sustainable transportation can be defined as making transportation investments which aim to offer accessibility with effective, safe, equal, healthy, environmentally-friendly, integrated, participative and economical approaches [4]. The main purpose of sustainable transportation is to increase the efficiency of transportation investments without compromising on the quality and ease of access. The success of transportation systems depends on the balanced relationship between mobility, accessibility and interconnectedness of the roads. For example, in a city where the roads are designed to have multiple lanes considering only the mobility of the vehicles, the mobility of the vehicles will be improved. However, such roads will be dangerous for pedestrians and bicycle drivers. Therefore, mobility of pedestrian/bicycles will be limited. The fact that transportation infrastructure is shaped with respect to private cars does not provide the same mobility for all parties and even may eliminate the mobility of individuals who do not drive. In such a system, even the drivers have the mobility as long as they are driving [5].

Integration of transportation modes, development of transportation plans offering mobility with increased accessibility while placing importance on principles such as environmental, social and economic sustainability and development of suitable policies are the goals of sustainable transportation. The following list of priorities must be considered for the traffic if these goals are to be achieved [6]:

- People—pedestrians
- Environmentally-friendly non-motorized vehicles
- Public transportation vehicles
- Moving vehicles
- Parked vehicles

Table 1 shows the main differences between traditional transportation approaches and sustainable transportation approaches [7]. According to the traditional transportation as shown in Table 1, approaches to logic of the plan, sustainability, level of public involvement, internalization of the costs, monitoring and assessment are outdated, and now being replaced by sustainable transportation approaches [8]. The advantages of sustainable transportation when compared to traditional transportation are as follows [9]:

- Satisfying the basic accessibility needs of individuals and nations with respect to human and ecosystem health in a way to provide intergenerational equality;
- Development of a transportation system which is affordable and efficient, which offers multiple modes of transportation and which supports economy;
- Reduction of emissions and wastes originating from transportation;
- Minimizing the production of non-renewable resources;
- Limiting the consumption of renewable resources at the level of sustainable efficiency.

Table 1. Differences between traditional and sustainable transportation approaches

Scope	Traditional transportation approaches	Sustainable transportation approaches
Strategic level/vision	• Mostly short-term transportation plans without a strategic vision	• Long-term transportation plans designed at least for 20–30 years
Planning logic	• Isolated planning approach without regards to environmental, social and other planning aspects • “Anticipate and build the infrastructure (estimate and provide)” approach	• A holistic planning approach to transportation with regards to the other relevant aspects • “From the future to past (consult and decide)” approach which provides assurance
Geographic scope	• An approach which focuses commonly on a single city	• A functional city approach which also involves the neighboring cities/counties/villages
Level of public involvement	• An approach which does not encourage participation of the people, allowing only limited information sharing between project managers and the local authorities	• An approach which places significant importance on the participation of stakeholders and the people

(*continued*)

Table 1. (*continued*)

Scope	Traditional transportation approaches	Sustainable transportation approaches
Sustainability	• An approach which does not necessarily consider sustainability	• An approach that aims to bring balance with regards to social equality, quality of the environment and economic development
Integration of transportation modes and sector	• An approach which does not place importance on the integration of practices and policies of the relevant sector (environment, land use, infrastructure investments, social aspects, etc.) • An approach which does not place importance on the integration of transportation modes	• An approach which places importance on the integration of practices and policies of the relevant sector (environment, land use, infrastructure investments, social aspects, etc.) • An approach which places importance on the integration of transportation modes
Focal point	• An approach which focuses on the traffic and vehicle mobility • An approach which believes more and faster is better	• An approach which focuses on mobility demand management and accessibility • An approach which believes closer is better
Cost internalisation	• An approach which commonly does not consider environmental and social costs	• An approach which reflects all the accurately calculated transportation plans and costs
Institutional cooperation	• An approach which does not necessitate inter-authority collaboration	• An approach which places importance on inter-authority collaboration at levels such as neighborhood, county, municipality, region, etc.
Monitoring and evaluation	• An approach which focuses on general goals and overlooks the assessment process	• An approach which focuses on the success (effects) of measurable goals and results, and which learns by long-term monitoring of the results after the project completion
Thematic focus	• A transportation planning approach which only focuses on highway investments	• An approach in which the transportation plan is designed focusing on public transportation, pedestrians and bicycle drivers • An approach which focuses on the quality of common spaces and decisions about land use

(*continued*)

Table 1. (*continued*)

Scope	Traditional transportation approaches	Sustainable transportation approaches
Internalization of costs	• An approach which disregards the costs	• An approach which involves internalization and accurate detection of external costs and reassessment of transportation decisions with respect to cost and benefit analysis [10]

2.1 The Historical Development of Sustainable Transportation Policy

The concept of sustainability was first defined in the "Brundtland Report" published in 1987 [11]. The first report in which transportation was addressed with regards to sustainability was the European Union Report on "The Future Development of the Common Transport Policy" published in 1992. This report involved subjects such as minimization of private car usage, promoting the use of clean fuel, and development of public projects in order to encourage people to walk and drive bicycles [12].

Increasing traffic congestion, air pollution and rapid decrease in green spaces were discussed in the Transportation Session conducted in "Habitat II United Nations Conference on Human Settlements" in 1996. The issues discussed were directly related to sustainable transportation [13]. With the "Kyoto Protocol" signed in 1997, it was aimed to reduce six types of greenhouse gases (GHG), namely, the carbon dioxide (CO_2), methane (CH_4), dinitrogen monoxide (N_2O), hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and sulfur hexafluoride, emitted in industrialized countries [14].

The level of usage of the current airway and highway transportation modes, their environmental impact and climate change, and sustainable transportation modes were defined in the "Sustainable Mobility Report of The Common Transport Policy—Sustainable Mobility Perspectives for the Future" published in 1998. It was aimed to improve the quality of public transportation vehicles, to ensure transportation safety, to develop intermodal transportation and to design environmentally-friendly transportation alternatives [15].

"The White Paper European Transport Policy for 2010: Time to Decide" was published in 2001 discussing the period of time between 2001 and 2010. This report aimed at traffic congestions reduction, intermodal transportation, preservation of freedom of movement, adaptation of the regulations, reduction of the oil dependency by 98%, using alternative fuels, improving energy efficiency, minimizing the expected increase in mortality associated with transportation and traffic congestions by the end of the 10 years period [16].

The "World Bank Cities on the Move Report" published in 2002 suggested a strategy which included four basic items. These items were structural development/operational efficiency of advanced transportation modes, better focus and interventions to help the poor and policy/organizational reform. Moreover, the report aimed to develop non-motorized transportation modes, to improve the traffic management capacity, to limit the demand, and to increase the reach of BRT (Bus Rapid Transit) systems and to increase the fuel efficiency for those vehicles [17].

"EU Green Paper: Towards A New Culture for Urban Mobility" was published in 2007. The report discusses several subjects such as reducing the tendency to use private cars, encouraging walking and bicycle use, optimizing the private car use with carpool method, reducing vehicle use with virtual mobility (teleworking, teleshopping, etc.), developing parking policies, promoting public transportation, limiting the entry of vehicles into the city center implementing parking rate policies, more efficient transportation planning with Intelligent Transportation Systems (ITS), better integration of freight distribution in urban areas, and encouraging eco-driving with minimized energy consumption [18].

"The EU White Paper" published in 2011 aims at a reduction in the GHG emission share of transportation sector by 60% until 2050, having the GHG emission levels decreased by 80–95%. Additional goals were defined as decreasing the use of vehicles running on traditional fuels by 50% until 2030 and their complete disappearance from the cities by 2050 [19].

The International Maritime Organization (IMO) Marine Environment Protection Committee (MEPC) announced their decision in 2012 stating that the sulfur content of the fuels used in sea vessels shall not exceed 0.50% m/m globally as of January 10, 2020. This measure aims to ensure sustainability in maritime transportation in order to reduce the pollution exposure of the inhabitants of coastal cities [20].

CEDBIK (Turkish Green Building Council) launched the Green Buildings Summit held in Turkey in 2013, and included an article on transportation as part of its Building Certification Guidelines as a criterion. This measure suggested housing projects to be designed close to public transportation network and to minimize the use of private cars having optimized the use of parking spaces with a sustainable transportation approach. In this context, the goal was to promote modes of transportation with no or minimum energy consumption such as walking or driving a bicycle for short distances and the use of public transportation for longer distances in order to reduce the carbon emissions. The guidelines emphasize that the distance between the entrance of a building and a public transportation hub (bus station, metro station, train station, etc.) must be less than 500 m and that regular transportation services must be provided at least once in an hour. Thus, it was aimed to make it possible for the users to be able to transport using methods such as public transportation, bicycle, shuttle, carpool, etc. instead of private cars [21].

In the "UN Sustainable Development Summit" 2015, a number of 17 sustainable development goals were defined which are aimed to be achieved by 2030 with the consensus of 193 Member States of the United Nations [22]. Among these goals, ensuring food safety, health services, uninterrupted education of young people, employment of women and sustainable transportation approach for accessibility of disabled/elderly were of utmost importance [23]. The goal was to, first, create a safe, healthy, economical, flexible, efficient, responsible, equalitarian sustainable transportation approach in order to achieve sustainable development goals [24].

"The National Report for Habitat III Conference" prepared by the Ministry of Environment and Urbanization of Turkey published in 2016 includes a transportation section, which notes that there have been several investments made into railway, maritime (port) and air transportation in Turkey in the recent years as part of accessibility of sustainable transportation modes. National Transportation Master Plan and Logistics Master Plan were developed and new high-speed railways are commissioned. Nevertheless, it was emphasized that construction of metro and light rail transit systems have gained momentum; that two sides of Istanbul is connected with an underwater railway tunnel as part of the Marmaray Project; and that this project is a solution developed in order to preserve the natural and historical characteristics of the city, which is running at high-capacity, environmentally-friendly, reduces air pollution, noise pollution and the dependency on private transportation and highway. On the other hand, the regulations on the reduction of private car use in support of sustainable transportation policies, development of "park and ride" practices, popularizing public transportation, and the use of environmentally-friendly fuel types were underlined. The Report states that there are basic transportation issues in Turkey such as unplanned urbanization especially in terms of city transportation, insufficient infrastructure investments in the face of increasing number of private cars, preference of private cars instead of public transportation, insufficiency of urban railway systems, pedestrian and bicycle paths. Due to such issues, it was reported that the authorities are aware of the fact that the transportation network is unsustainable, high cost, unsafe, and not environmentally-friendly [25]. Turkey's Report was criticized by chambers of engineers and architects, NGOs, universities and media organs. Among these criticisms is the mentality which focuses mainly on the vehicle mobility for urban transportation with the belief that transportation investments made are harmful for the environment and ecosystem. In addition, the most recent transportation projects, namely, the 3rd airport to Istanbul, Canal Istanbul, and the 3rd bridge on Bosphorus are criticized for their impact on streams available in Istanbul, its villages and agriculture in a short time, although these were good news for the land owners, the construction sector and realtors as these projects will lead to urbanization of a very large area [26].

2.2 Principles of Sustainable Transportation

Sustainable transportation involves different principles from environmental, economic, and social aspects, the three dimensions of sustainability. These principles are briefly discussed in this section.

Principles of Sustainable Transportation with Respect to Environment. Environmental sustainability principles of transportation are commonly divided into four categories, as follows:

Reducing Noise and Environmental Pollution. In order to be able to prevent environmental and noise pollution, alternative solutions to motorized vehicle use must be developed. Freight transportation must focus on railway and maritime transportation and freight villages must be built. Measures which favor public transportation, pedestrians and bicycle drivers must be taken and the number of vehicles in the city center must be limited [4].

Reducing the Consumption of Non-renewable Resources. It is of utmost importance to ensure an efficient demand management in transportation in order for the efficient use of resources. In this context, non-renewable resources must be consumed at lower levels when compared to renewable resources. However, the rate of consumption of renewable resources should not exceed the regeneration capacity of such resources [27].

Biodiversity and Protection of Natural Habitats. Agricultural and recreational areas and forest lands must be planned as part of transportation investments in order to support biodiversity without interfering natural life. Infrastructure decisions on the course of transportation applications must be planned with these principles in mind [4].

Prevention of Water Pollution. One of the most important environmental impacts of the transportation sector, water pollution and its prevention is critical for the protection of water resources and aquatic creatures. In this context, necessary limitations must be in effect as part of the regulations on tankers and ships involved in freight transportation by sea.

Principles of Sustainable Transportation with Respect to Economy. Economic sustainability principles of transportation are commonly divided into seven categories, as follows:

Improved Accessibility. Ensuring easy access to social and economic needs with shortened distances is essential in terms of increased accessibility. Systems which support the use of non-motorized vehicles, and public transportation must be developed while ensuring accessibility.

Integration. Vertical integration between government departments and horizontal integration between regions and sectors are critical for sustainable transportation. In this context, all transportation modes must be integrated in a way to promote balanced development in accordance with the sustainable transportation process [28].

Infrastructure Funding. Transportation systems must be able to provide for the needs of the people in the long-term in the most efficient, effective and economical manner, having the necessary risk analyses performed. In this context, increasing the participation with strategic promotion of the competition in the market is important for financial sustainability. Innovative approaches such as land value capture programs resulting from the sustainable transportation systems, green bond investments, and Transit Oriented Development (TOD) must be explored as funding models for transportation investment [28]. It must be ensured that financial management of high budget transportation investments, especially in case of a public-private sector engagement, are not abandoning sustainable transportation principles in the name of profitability. International development funds and environment funds must be improved for sustainable transportation. Moreover, governments must try to improve the credibility of cities with collaborations on both national and local levels [28].

Calculation of Consumer Costs. In order to fund sustainable investments with regards to pricing of transportation systems, users must be asked to pay for carbon tax, congestion tax and others in proportion to their contribution to the pollution. Accurate calculation of investment costs is important for correct and equal allocation of the expenses to users. In this context, hidden and other subsidies must be estimated with respect to transportation investments, and social, economic, and environmental costs must be accurately calculated in order to assess the long-term costs of each transportation model [9]. Fossil fuel subsidies must be decreased by the governments even to a point that they are resolved gradually [28].

Financial Prosperity. Financial policies must enable and support sustainable transportation. Financial tools (tax, etc.) must be developed in accordance with sustainable transportation [29].

Prevention of Accidents. Moving away from highway-weighted infrastructure investment policies is important for transportation safety. Prevention of traffic accidents will minimize their burden on the national economy [30].

Technologic Advances. Result-oriented government and investment policies and incentivizing and supporting the private sector with a number of incentives are important in terms of the development of sustainable transportation technologies. Nevertheless, performance standards which aim at the development of clean and efficient systems and technologies for transportation sector must take effect and must be applied [28]. Recent support in technologic advancements has led to the construction of environmentally-friendly roads in developed countries. For example, the Georgia Interstate Highway located in Troup County, USA, was extended 16 miles about halfway between Atlanta and Montgomery, Alabama, and was the world's first sustainable highway project. With the highways redesigned in the Netherlands, all the street lights were replaced in Studio Roosegaarde, recharging lanes for electric vehicles were added and traffic paintings were placed in order to warn the drivers. In France, a stretch of one kilometer of highway is now producing power using solar energy with the photovoltaic panels [31].

Principles of Sustainable Transportation with Respect to Society. Social sustainability principles of transportation are commonly divided into six categories, as follows:

Equality. Sustainable transportation policies are considered one of the strongest indicators of a strong economy and quality of life in the world. In this context, transportation must focus on equal opportunity to use services, minimization of the differences in available transportation possibilities across groups and reducing regional/social differences while providing for the transportation needs of the people [4].

Education. Governance and Participation of the People: Due to their often high budget needs, transportation investments are generally made by central governments and the locals and local administrations are commonly left outside of the decision-making process. However the benefits of the transportation investments stretch into the nation as a whole, their environmental damages are limited to the local scale. In this case, demands of the locals must be considered in transportation investments with respect to equality in sustainability and it must be ensured that the benefits are equally distributed if it is aimed to minimize the damages in question [32]. Transportation plans must be discussed for their long-term impacts as part of a holistic approach with transparency, asking for the opinion of the people as opposed to an approach based on the income [4].

Information Sharing. It is important to create a technical information network in order to allow the planning and building parties operating in developing countries to be able to access information about the transportation sector and training opportunities available for them. Such a network can be built with the collaboration of multinational banks, international institutions and government authorities at all levels [28].

Safety and Health. Safer and healthy transportation alternatives must be developed and implemented in order to achieve sustainable transportation, having reduced the use of motorized vehicles which are the reason behind the death of approx. 500,000 people due to traffic accidents annually and which contribute to the air pollution by 70% on an average [4].

Personal Responsibility. In order to ensure sustainable transportation in the long term, new generations must be raised with the awareness of sustainability responsibility towards the nature and transportation policies [4].

Aesthetics. Transportation projects must be developed in a way not to disturb the historic and aesthetic texture of the city [4].

2.3 Sustainable Transportation Policies

The success of sustainable transportation projects depends on the government's support with correct management policies applied in the operation stage of the projects. *Demand management*, *supply management* and *capacity increase* must be considered in coordination as part of the sustainable transportation policies as shown in Table 2 [33]. Governments must use discouraging and inhibiting policies for the use of transportation alternatives which have negative effects for the success of transportation investments. For example, discouraging policies for the use of private cares must be implemented; parking space capacity of the city center must be reduced; and a compatible policy must be implemented in the city as a whole as shown in Table 2 when the government invests in a new railway system. Practices such as closing the city center to traffic, pedestrianization or allowing for only public transportation are among discouraging policies [34]. For instance, in Milan-Italy, Regional Environmental Protection Agency (ARPA) found that the amount of airborne particles goes above 130 mg, as the limit value for these particles are announced at 50 mg by the EU. The municipality has banned all the vehicles on Sundays between 10 AM and 6 PM, except LPG and electricity using ones, as part of Ecopass project [35]. Similarly, in London-UK, there are some limitations for vehicle entry to city center, and the vehicles are taxed in proportion to their contribution to the air pollution as part of a principle of "Polluter Pays" [36]. For sustainable transportation systems to be successful, policies which make public transportation more attractive, convenient and comfortable the methods shown in Table 2 must be supported [34].

Table 2. Sustainable transportation policies

Demand management					
Transportation alternatives	Tools for land use	Pricing	Dedicated roads	Public transportation	Freight transportation
Alternating transportation schedule	"Smart growth" policies	(HOT-high occupancy toll lanes)	Match-up for carpool	Reduced fare program	Truck only toll lanes (TOT)
Alternative working hours	Pedestrian/bicycle connections	Parking fees	Carpool (ShareCarGo)	Public transportation oriented design	Lane limitations
Education campaigns for alternatives to private cars	Station and stop design for public transportation	Pricing based on time period	Transportation Management Institutions	Development of high capacity and safe public transportation systems (rail systems)	
Tele-commuting instead of commuting	Public transportation oriented planning and design		Vanpool	Development of public transportation information and safety systems	Time limitations
Pedestrian/bicycle opportunities	Parking space strategies	Congestion pricing at entries to Central Business Districts (CBD)	Parking pricing	Advanced public transportation stations/stops	Distribution limitations
			Parking priority for HOV (high occupancy vehicle)	Itinerary planning	
Alternative toll pricing strategies				Transportation Management Institutions	

Supply management			
Urban arterial roads	Highways and motorways	Public transportation	Freight transportation
Road weather information systems	Transportation control center procedures	Automatic vehicle location (AVL)	Automatic vehicle location (AVL)
Geometric improvements			
Intersection improvements			

(*continued*)

Table 2. *(continued)*

Supply management			
Urban arterial roads	Highways and motorways	Public transportation	Freight transportation
One-way streets	Incidence management	Prior timing/reduced traffic load	Real-time freight information
Accessibility management			
Advanced signalization systems			
Retiming the signalization/its optimization	Activity management	Signalization priority for buses	
Changing lane allocation			
Access road for HOV (high occupancy vehicle)			
"Park and ride" practices	Ramp metering	Bus ramp access	Roadside electronic display/transition programs
Incident management	Lane controls	Real-time public transport information	
Activity management	Managed lanes	Express buses	
Real-time passenger news		Bus services which meet the demand	Combined and intermodal transportation
Limitations to parking in the city center		Toll collection strategies	

Capacity increase	
Highways	Public transportation
New motorways/main streets	New railway lines
Expansion of highways/main streets	New bus lines
Improvement of street connections	New bus lanes/BRT (bus rapid transit)
Designing new toll roads	Additional services to existing lines/courses
Elevation separations	
Managed lanes for HOV (high occupancy vehicle)	Neighborhood/central business districts (CBD) ring lines
Corridors for multiple transportation mode	"Park and ride" centers

3 A Review of Award-Winning Sustainable Transportation Projects

Sustainable Transportation Committee has been awarding transportation projects worldwide applying strategies which improved mobility of all users for the past year, reduced the traffic congestion, GHG emissions and air pollution, improved the safety of pedestrians and bicycle drivers, and offered accessibility since 2005. Table 3 shows the winners of the sustainable transportation awards between 2005 and 2017, and the improvements made as part of these projects are presented with illustrations [37]. Sustainable Transportation Committee consists of The Institute for Transportation and Development Policy/IDTP, The World Bank, WRI Ross Center for Sustainable Cities, Clean Air Asia, The Clean Air Institute (CAI), Cooperation for Urban Mobility in the Developing World (CODATU), Despacio, The Sustainable Urban Transport Project (GIZ-SUTP), ICLEI-Local Governments for Sustainability of Cities), and Bus Rapid Transit (BRT CoE) [37].

Table 3. Award-winning sustainable transportation projects [37]

Award-winning sustainable transportation projects		Practices of sustainable transportation approach
2017 Santiago-Chile Transportation Project [37]	  	• $2.2 million was invested in infrastructure projects • City accessibility was improved for the disabled • Bus system was modernized and roads were expanded • Transportation data and statistical information capacity system was built • Smart applications were integrated to public transportation systems • Dedicated corridors were designed for public transportation • An electric bicycle sharing system was introduced • Street lighting system was improved • City center was closed to traffic except scheduled deliveries • Sidewalks were expanded and new trees were planted • Streets of the old town center were redesigned and transformed into the country's most active pedestrian area • Sustainable transportation training was made mandatory starting from the preschool

(*continued*)

Table 3. (*continued*)

Award-winning sustainable transportation projects		Practices of sustainable transportation approach
2016 Yichang-China Transportation Project [37]	  	• A bus rapid transit (BRT) system operating in the 20 km section of one of the busiest roads of the city was commissioned to serve for 240,000 passengers a day including 200 busses with exits on both sides in order to improve traffic control • Dedicated roads were designed for BRT, smart ticket vending machines were planted, disabled were provided with the priority to get on and buses were provided with the right of way at the intersections • Bicycle and pedestrian improvements were made in connection with BRT system and public space reform • Half of the parking spaces available in the BRT corridor were disposed of while the other half was redesigned which has led to a so-called trail-blazing parking space reform in the city • 30 km of the bike lane planned for the city was built in connection with the project, the conditions of the sidewalks were improved, 700 trees were planted, 29 new secure pedestrian crossings were built and a bicycle sharing system was implemented
2015 Belo Horizonte-Rio de Janeiro ve São Paulo-Brazil Transportation Project [37]	  	• A BRT system spanning 23 km was built in Belo Horizonte and some streets were closed to traffic while a bike lane network of 27 km was built • Four new BRT systems were designed in 2014 spanning 39 km in total for Belo Horizonte with a daily passenger capacity of 270,000 intended for the 2016 Olympic Games • The distance travelled by bus lines was increased up to 320 km while the total span of bike lanes was increased up to 400 km in São Paulo

(*continued*)

Table 3. (*continued*)

Award-winning sustainable transportation projects		Practices of sustainable transportation approach
2013 Mexico Transportation Project [37]	 	• The existing BRT system was expanded with the addition of the 4th line which is a corridor spanning between the old town and the airport designed to improve habitability, mobility and quality of life for Latin Americans • An extensive street parking space reform program (ecoParq) was introduced • Public bicycle system (Ecobici) was developed • Sidewalks and bike lanes were expanded • Public areas such as Alameda Central and Plaza Tlaxcoaque revived
2011 Guangzhou-China Transportation Project [37]	 	• A BRT (bus rapid transit) system of 800,000 passenger capacity was designed; bike lanes and bus rapid transit lines were adapted to the system • A bicycle sharing system was introduced with 113 bicycle stations and 5500 bicycle parking spaces across the BRT corridor • The unattended canal was rehabilitated with the Greenway project and an off-street bikeway of 4 km and green areas were commissioned
2009 New York-ABD Transportation Project [37]	 	• In New York, 49 decares of urban area was pedestrianized with an extensive reform in the transportation with the collaboration of people, government and local authorities • Bike lanes and sidewalks were expanded

(*continued*)

Table 3. (*continued*)

Award-winning sustainable transportation projects		Practices of sustainable transportation approach
2008 Paris-France Transportation Project [37]	  	• An individualized public transportation system, Vélib, was developed. With this system, a revolution was made in the bicycle sharing under the name of "freedom bikes". A system where people can rent a bike from one of the many stations available in the city for small amounts of money was developed and the users were able to leave their bikes at any station conveniently located. By the end of 2007, there were more than 1200 stations and 15,000 bicycles in the Vélib system • A bike lane of 314 km was built • Sidewalks were expanded in the squares with a focus on pedestrians and landscaping was improved • Three BRT (bus rapid transit) system corridors were commissioned in 2007 • The improvements led to a reduction of 20% in the private car traffic and a reduction of 9% in CO_2 emissions
2005 Bogota-Colombia Transportation Project [37]	 	• Bogota was the first winner of the sustainable transportation project award and the city was transformed into a habitable city with this project • Trans Milenio BRT (bus rapid transit) system was built • Bike lane infrastructure was integrated with public transportation • Public spaces were defined again

4 Result and Recommendations

As transportation investments are high-budget projects, having a wide transportation network is associated with having a strong economy. Investments into transportation infrastructure in developing and underdeveloped countries are considered factors improving the level of welfare in the country. On the other hand, owning a vehicle is considered a matter of status in many of these countries. Looking at the transportation sector from a sustainability perspective, it is observed that even the developed countries with the widest transportation network suffer from environmental issues due to intensive vehicle traffic. As transportation investments are less flexible when compared to the other types of investment, it is a must to have efficient long-term plans and to manage the implementation of these plans properly. The most common transportation issues in developed countries; which have diverse transportation modes, have integrated all the transportation modes, have solved the infrastructure issues, have logistics centers for freight transportation management, and observe social equality face; are originating from mainly the intensive vehicle traffic, and the resulting air pollution. Thus, any measure taken with regards to sustainable transportation in a developed country should be facilitated with supportive and discouraging policies. In developing and underdeveloped countries, on the other hand, the main problems are the insufficiency of transportation networks, nonintegrated transportation modes, inability ensure accessibility, and unplanned freight transportation.

Turkey is one of those countries which experience significant transportation issues. The factors to be addressed in order to ensure sustainability in transportation in Turkey can be listed as follows:

- People must be allowed to get involved in the sustainable transportation process. In this context, people's needs must be recognized, analyzed and transportation planning must be completed in a way to solve the problems of the people.
- Connections between transportation modes must be optimized, sustainable cities which have compact areas must be designed for the people in order to provide for their basic needs with short distance commutes [38].
- With the elimination of communication issues in urban areas, unnecessary transportation activities arising from the lack of communication must be avoided. Although slightly, home based working which is becoming popular in the recent years contributes to the solution of the traffic issues.
- Travel time, as defined within the scope of travel time budget, is reaching up to 40 min in city centers and it must be reduced with environmentally-friendly transportation alternatives such as public transportation, bicycle use and railway systems [39].
- Sidewalks must be expanded and infrastructure must be built for bike lanes.
- Private vehicle use must be discouraged. Tax, fund and subsidy policies must be developed in order to discourage motorized transportation.
- In recent years, there have been efforts to pedestrianize especially the areas with historic buildings in big cities of Turkey such as Istanbul, Antalya, Izmir, etc. However, there are no regulations on taxation of the vehicles in proportion to their contribution to the air pollution as the vehicles enter the city center. An alternative version of the road pricing system implemented in Singapore, Hong Kong, London, and Stockholm can be introduced in Turkey only after above-standard public transportation services are offered.
- One of the practices available in Turkey aimed at environmental protection is the mandatory exhaust emission testing for motorized vehicles. With this testing, any vehicle causing environmental damage due to above-standard emissions are banned from traffic. Similarly, vehicles must be taxed in accordance with their emissions, and the characteristics of the urban and regional areas [40].
- The R&D resources allocated to technologies using electric, hybrid systems and alternative fuels must be increased, and necessary infrastructure must be developed in order to support clean vehicle usage [41].
- Sustainable transportation principles must be taken into consideration in the Transportation Master Plan and Logistics Master Plan which are currently being developed in Turkey.
- The field of transportation must be recognized as a separate department, and the concept of sustainable transportation must be integrated to the education [42].
- Owning a private car is considered to be a matter of status and wealth by poor and developing classes living in Turkey, and the comfort of public transportation must be improved in order to overcome this preconception [43].

- Shopping centers, hotels, gas stations, cultural and congress centers, universities, hospitals residence projects with 10,000–20,000 inhabitants must be located at a place allowing for their integration to railway systems and the other public transport modes. Traffic Effect Analysis (TEA) must be a mandatory application, and a part of the licensing process in order to internalize any possible external issues and construction in general [10].
- Transportation projects must meet the criteria for suitable land use, and location selection [43].
- Short-term parking, long-term parking and entry-exit needs in urban arterial and collector roads as a result of intensive commercial usage leads to decreased traffic capacity and threatens the safety in traffic. Detours must be built for short-term parking, long-term parking and entry-exit needs [33].
- With respect to freight transportation, energy management systems must be built at the company-level, spatial planning measures must be taken and freight transportation must be performed in a planned manner with the establishment of logistics centers.
- Traffic flow and driving behaviors must be improved. Traffic flow can be ensured with the increased speed in parallel with reduced number of cars parked for short-term. On the other hand, drivers must be educated especially on the economical driving practices. Thus, GHG emissions will be reduced.
- Parking space management is one of the practices in support of sustainable transportation systems. 'Park and hop on' management is a practice which has the potential to significantly reduce the number of vehicles in the traffic in specific locations [44]. It was reported that the "park and hop on" centers built in 45 different locations in Istanbul by ISPARK (Istanbul Parking Spaces Corp.) provide services to an annual number of 3.5 million people with their total capacity of 14,000 vehicles. Nevertheless, it was stated that it was possible to prevent emission of 700 ton CO_2 and that everyday many vehicles equal to a convoy of 150 km are being parked in these "park and hop on" centers [45]. A similar project was conducted in the Eskisehir city center [46]. Development of 'park and hop on' practices in big cities will contribute to fuel savings and reduction of CO_2 emissions.
- Vehicles with reduced fuel consumption must be preferred over vehicles with strong engines.
- Necessary measures must be taken in order to prevent any possible weakness in public transportation security.
- Without regards to the scale of the transportation project, such projects must be subject to Environmental Impact Assessment "EIA".
- Advanced traffic signalization systems must be used.

In conclusion, it is observed that the recent transportation investment oriented politics in Turkey have negative impact on both the environment and the economy during their operational lifetime due to the hasty attitude adopted in planning. In order for the transportation investments to fully contribute to Turkey's development process, a transportation approach which pays attention to the needs of the people, which was not rushed during planning stage, which has reached to the technical capacity, which is transparent and accountable, which incorporates local authorities to the process without regards to their political orientations, and which place importance on biodiversity and habitat of the species must be adopted.

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3D Printing in Architecture: One Step Closer to a Sustainable Built Environment

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Abstract. Sustainability has become a very popular term in many disciplines and investors/researchers devote a considerable amount of time and money for related studies to define their policies as well as initiatives on this subject. Today CAD/CAM technologies propose a wide range of concepts and implementation that support the concept of sustainability. Recent studies show that, developing computational technologies and 3D printers have potential to change the way we built our environment. From this respect this paper evaluates the use 3D printers in construction through recently built pioneering examples from the sustainability point of view. Results indicate that the special features of the 3D printing process, such as faster and precise construction, reduced labour costs and construction waste etc. these technologies offer a revolutionary approach in terms of sustainability.

Keywords: Computational design · CAD/CAM · 3D printing
Architectural technology · Waste materials

1 Introduction: Digital Design and Manufacturing Paradigm in Architecture

> …Digital technologies are changing architectural practices in a way that few were able to anticipate just a decade ago…
>
> Branko Kolarevic [1]

This century has become prominent with two main concepts in architecture; the first one is sustainability in architecture which has been seeking for a less environmental footprint in the ecosystem and the second is digital technologies that drive a novel approach in all kinds of man made products including architecture [2]. The use of computer aided design (CAD) in architecture has been extended from being a medium of representation to a media of design and manufacturing [1, 3].

Being aware of potentials/transformations in design and manufacturing process and their effects on form/structure and material usage, provide 21st century's designers with new horizons. Especially the concepts and premise applications of parametric design, adaptive design, nanomaterials, Building Information Modeling (BIM), 3D printing and robotics have potentials to radically change the design and the construction processes [4, 5] so the language and identity of 21st century architecture. There is no doubt

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that, CAD/CAM applications have been rapidly changing the conventional architectural design and construction processes since the end of the last century. In this process researchers and practitioners have been seeking for new tectonics and materials which reveals the beauty of using cutting edge technology in a "sustainable" point of view.

In this context, it is possible to argue that, through cutting-edge building technologies, innovative construction materials/methods and better decision-making systems, not only projects are getting smarter but also it is an opportunity to built our environment more sustainable. When the recent concepts and developments in construction are considered it is seen that a number of construction trends shaping the industry. A word cloud is prepared and illustrated in Fig. 1. From this perspective it is possible to claim that, through "computational models", which are the inseparable part of a design anymore, not only all stages of design can be controlled but also manufacturing and management can be achieved.

Fig. 1. Abstract word cloud for construction trends shaping the industry (drawn by the authors)

It is seen that among these trends 3D printers are becoming rapidly spread. Causing a drastic change/transformation in several disciplines has also being experienced in the field of architecture. Their usage in architecture have shifted from producing scale modeling to a full scale end-product [6]. "The potential of using mock-ups as the end product" is one of the most important changes that we encounter in the field of construction of architecture [7]. From this context this papers discusses the shifting practice of 3D prints in architecture with an emphasis on the potential use of recycled material in construction.

2 3D Printing as a Multi-faceted Technology in Manufacturing

> …3D printing technology has the potential to revolutionize the way we make almost everything…
>
> Barack Obama [8]

3D printing or additive manufacturing (AM) is a process of making 3D objects getting all related information from 3D solid models. In an additive process an object is created by laying down successive layers of material until the entire object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object [9].

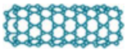
The main principle of 3D printing is "stereolithography", outlined by Charles Hull, in a 1984 patent, as "a system for generating three-dimensional objects by making a cross-sectional pattern of the object to be formed" [10]. It is a process that solidifies thin layers of ultraviolet (UV) light sensitive liquid polymer using a laser. After that, Selective Laser Sintering (SLS) and Fused Deposition Modelling (FDM) Technologies (1988) [11] were the milestones of its development. The evolution of 3D printing technology continues to improve in the speed of processing, the complexity of design, and the variety of materials used. Over the last decade they started to be used in everyday life. According to Hager [12] thanks to the open source systems, prototyping of new product, and innovative applications of 3D printing in various fields are available for everyone. 3D printing technology is cited among a list of 12 potentially economically disruptive technologies in a report by McKinsey Global Institute [13]. They argue that the technologies they mentioned have potential to affect billions of consumers, hundreds of millions of workers, and trillions of dollars of economic activity across industries [13] (Table 1).

Table 1. Economically disruptive technologies [13]

	Mobile internet	Increasingly inexpensive and capable mobile computing devices and Internet connectivity
	Automation of knowledge work	Intelligent software systems that can perform knowledge work tasks involving unstructured commands and subtle judgments
	The internet of things	Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization
	Cloud technology	Use of computer hardware and software resources delivered over a network or the Internet, often as a service
	Advanced robotics	Increasingly capable robots with enhanced senses, dexterity, and intelligence used to automate tasks or augment humans

(*continued*)

Table 1. (*continued*)

	Autonomous and near-autonomous vehicles	Vehicles that can navigate and operate with reduced or no human intervention
	Next-generation genomics	Fast, low-cost gene sequencing, advanced big data analytics, and synthetic biology ("writing" DNA)
	Energy storage	Devices or systems that store energy for later use, including batteries
	3D printing	Additive manufacturing techniques to create objects by printing layers of material based on digital models
	Advanced materials	Materials designed to have superior characteristics (e.g., strength, weight, conductivity) or functionality
	Advanced oil and gas exploration and recovery	Exploration and recovery techniques that make extraction of unconventional oil and gas economical
	Renewable energy	Generation of electricity from renewable sources with reduced harmful climate impact

As Kamath [14] states the "effortless transition from digital to physical" is made possible by digital fabrication technology which can create a physical artifact from a 3D digital file [14]. The reason why 3D printers are very common in all kinds of industrial fields today is obvious because there are distinct advantages that this technology presents. Figure 2 presents the percentages of the disciplines that range from motor vehicles to medicine, from academic works to many other. Furthermore, several annually evaluations release that regarding the current demands, markets for 3D printing are expected to grow rapidly. Such that, according to Wohlers Report 2014, the worldwide 3D printing industry is now expected to grow from \$3.07B in revenue in 2013 to \$12.8B by 2018, and exceed \$21B in worldwide revenue by 2020 [15] (Fig. 3). Wohlers Report 2013 had forecast the industry would grow to become a \$10.8B industry by 2021. If 3DP applications grow rapidly in the next 10 years questions may arise about the sustainability of 3D printing manufacturing processes. Therefore, research into the sustainability of 3DP needs to be performed before the markets explode, so adjustments can be made at an early stage [16].

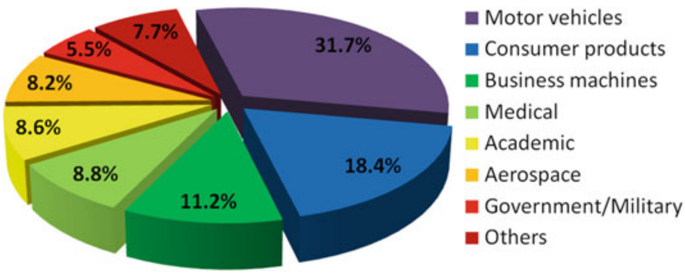


Fig. 2. The range of 3D printing usage according to disciplines [17]

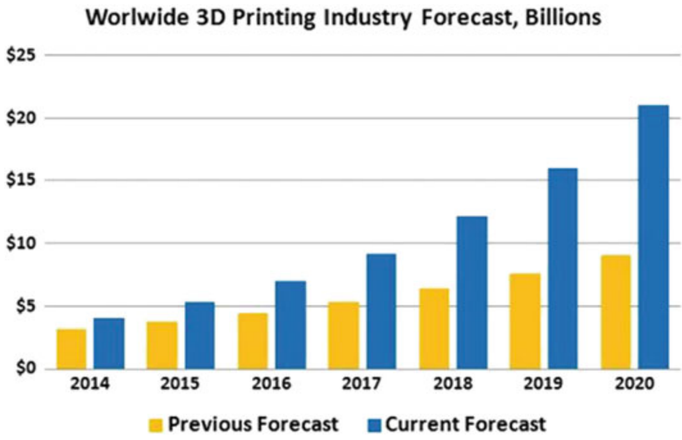


Fig. 3. The worldwide 3D printing industry forecast [18]

Today, among the advantages of using 3D printers in all industries can be listed as follows [19];

- Affordable customization,
- Allows manufacture of more efficient designs; lighter, stronger, less assembly required,
- One machine, unlimited product lines,
- Very small objects (even nano),
- Efficient use of raw materials (less waste),
- Pay by weight; complexity is free,
- Batches of one, created on demand,
- Print at point of assembly/consumption,
- Manufacturing accessible to all; lower entry barriers,
- New supply chain and retail opportunities.

CSC Leading Edge Forum report (2012) highlights that, the following areas need further development [19];

- Printing large volumes economically
- Expanding the range of printable materials
- Reducing the cost of printable materials
- Using multiple materials in the same printer, including those for printing electronics
- Printing very large objects
- Improving durability and quality

Furthermore, Gebler et al. [16] argues that 3D printing technology represents a relative novel technology in manufacturing which is associated with potentially strong stimuli for "sustainable development". Many other researches show that 3D printing is an industrial manufacturing process with the potential to reduce resources and energy demands as significantly well as process-related CO_2 emissions per unit of gross domestic product [20–23].

Contrary to conventional manufacturing subtractive processes, 3D printing performs additive means of production. From this aspect, 3D printers are able to manufacture with a wide variety of different material types, that are supplied in different states (powder, filament, pellets, granules, resin etc.). Table 2 shows 3D printing types that uses different materials. This means all kind of recyclable materials such as, glass, plastic, thermoplastic polymers (ABS), metals, ceramics etc. can be shape during a printing process. Moreover, 3D printing reduces manufacturing-related resource inputs because it only requires the amount of material which ends up in the printed good without too many losses [24]. Support materials can usually be reused [25].

Table 2. 3D printing technology type and materials [26]

Classification	Technology	Description	Materials	Developers (Country)
Binder jetting	3D printing Ink-jetting S-print M-print	Creates objects by depositing a binding agent to join powdered material	Metal, polymer, ceramic	ExOne (US) Voxljet (Germany) 3D Systems (US)
Direct energy deposition	Direct metal deposition Laser deposition Laser consolidation Electron beam direct melting	Builds parts by using focused thermal energy to fuse materials as they are deposited on a substrate	Metal: powder and wire	DM3D (US) NRC-IMI (Canada) Irepa Laser (France) Trumpf (Germany) Sciaky (US)
Material extrusion	Fused deposition modeling	Creates objects by dispensing material through a nozzle to build layers	Polymer	Stratasys (US) Delta Micro Factory (China) 3D Systems (US)

(*continued*)

Table 2. (*continued*)

Classification	Technology	Description	Materials	Developers (Country)
Material jetting	Polyjet lnk-jetting Thermojet	Builds parts by depositing small droplets of build material, which are then cured by exposure to light	Photopolymer, wax	Stratasys (US) LUXeXcel (Netherlands) 3D Systems (US)
Powder bed fusion	Direct metal laser sintering Selective laser melting Electron beam melting Selective laser sintering	Creates objects by using thermal energy to fuse regions of a powder bed	Metal, polymer, ceramic	EOS (Germany) Renishaw (UK) Phenix Systems (France) Matsuura Machinery (Japan) AROAM (Sweden) 3D Systems (US)
Sheet lamination	Ultrasonic consolidation Laminated object manufacture	Builds parts by trimming sheets of material and binding them together in layers	Hybrids. metallic, ceramic	Fabrisonic (US) CAM-LEM (US)
VAT photopolymerisation	Stereolithography Digital light processing	Builds parts by using light to selectively cure layers of material in a vat of photopolymer	Photopolymer, ceramic	3D Systems (US) EnvisionTEC (Germany) DWS Sri (Italy) Lithoz (Austria)

3 3D Printing: An Opportunity to Construct by Using Recycled Materials

In the construction industry, 3D printers are used to create 3D models, prototypes or small, non-structural building components such as landscaping bricks or decorative elements [28]. This technology enabled architects to create scale models faster and economical, in all phase of the design. 3d printers provide architects with better visualization, optimization through tests such as wind, sound, stability etc. applied on scaled models and form finding research during the design process.

3D models of London City Hall designed by Foster and Partners can be given as one of the best examples revealing the power of printing technologies during the form finding process (Fig. 4). Especially the concept of seamless production, file to factory and real time behavior in architecture [29] that 3D printers offer architects resulted in an innovative way of using these technologies; from scale model to the end product.

Fig. 4. 3D models of London City Hall [27]

Within this context the following examples are selected to discuss how 3D printing technologies can transform the way we are going to built in the near future. Particularly, improvement of the printing materials and 3D technology became to be the goal for many companies all over the world from all industry sectors. In 2014, real revolution in construction industry has started, as the first house was printed starting a new chapter in building technology.

3.1 The ETFE Plastic Roof Canopy of the 6 Bevis Marks Building, England

A decorative steel sheath is developed for a canopy on the roof of the refurbished 6 Bevis Marks office building in central London. Priestman, the architect of the project, claims that this is the world's first 3D-printed component for a specific use in the construction industry. The parts serve as complex joints between the building's columns and the arms of its canopy [30]. It's architectural in so far as it's been through an approval process and tried/tested, and actually installed in a building [31] (Fig. 5).

Fig. 5. Sheath for a canopy [30, 31]

According to the Munn [32] most materials can be recycled and it is possible to recycle 100% of steel and aluminium. Recycling reduces the embodied energy of steel by 72% and aluminium by 95%. From this respect due to their ability to use all type of molten metal, 3D printers have potentials to provide sustainability in construction.

3.2 3D Printed Houses, China

Winsun New Materials company's a materials firm in China has developed a way to print 10 houses in a day [33]. A special 3D printer that produces a layered combination of discarded construction materials and cement is an important example to show this technology can be use for recycling. According to Oberti [34], each building is constructed from 3D printed walls and foundations, while the roofs are made of metal construction. As Bartolacci [35] reports, printing each structure costing under $5,000 and a single setting can produce almost four buildings at the same time with very little human labor is required.

The elements of each building are printed in a factory, and then transported on site for assembly. In many of China's cities, where development has been focused on show-stopping mega projects and towering skyscrapers, the country's population continues to urbanize at a rapid rate [36].

To conclude, these efficient and inexpensive system could help the increasing demand for efficient, affordable housing with its pioneering system that has the potential to change the way we building the mass housing (Fig. 6).

Fig. 6. 3D printed house from waste concrete [34, 35]

3.3 3D Canal House, Netherlands

The 3D Print Canal House is research project in Amsterdam, performed by DUS Architects, studying the possibilities of 3D printing in architecture [37]. The aim of the projects is to create a 13 room demonstration house. A special 3D printer called "KamerMaker" was installed inside a shipping container near the Canal [38]. The house is made of many printed elements. Each element showcases a research update in shape, structure and material. The project shows that architecture can be catalyst for cross-sectoral innovation. It is collectively funded by all partners, who contribute to the project with knowledge and financial means [38] (Fig. 7).

Fig. 7. General view of the project [38]

The printer creates wall components from a bioplastic mix of plastic fibres and 80% plant oil. Wall components are then interlocked together and filled with bio-concrete to provide structural strength [39]. It is important to note that all the materials used in the project are recyclable. As an entrepreneurial building project, the canal hose ha a potential to revolutionize the building industry and offer new tailor made housing solutions worldwide [38, 39] (Figs. 8, 9 and 10).

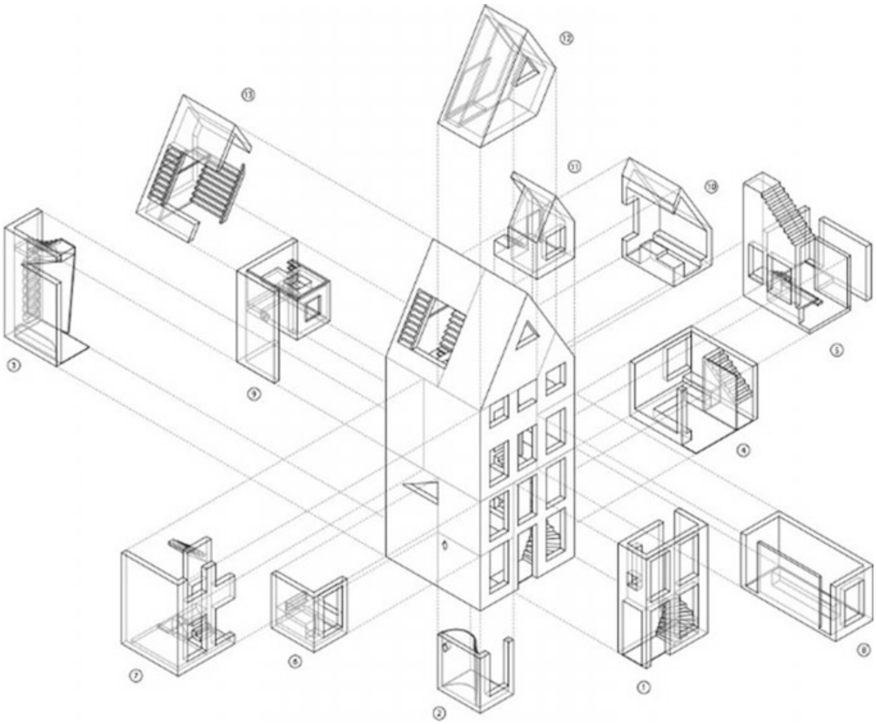


Fig. 8. Decomposition of the model [40]

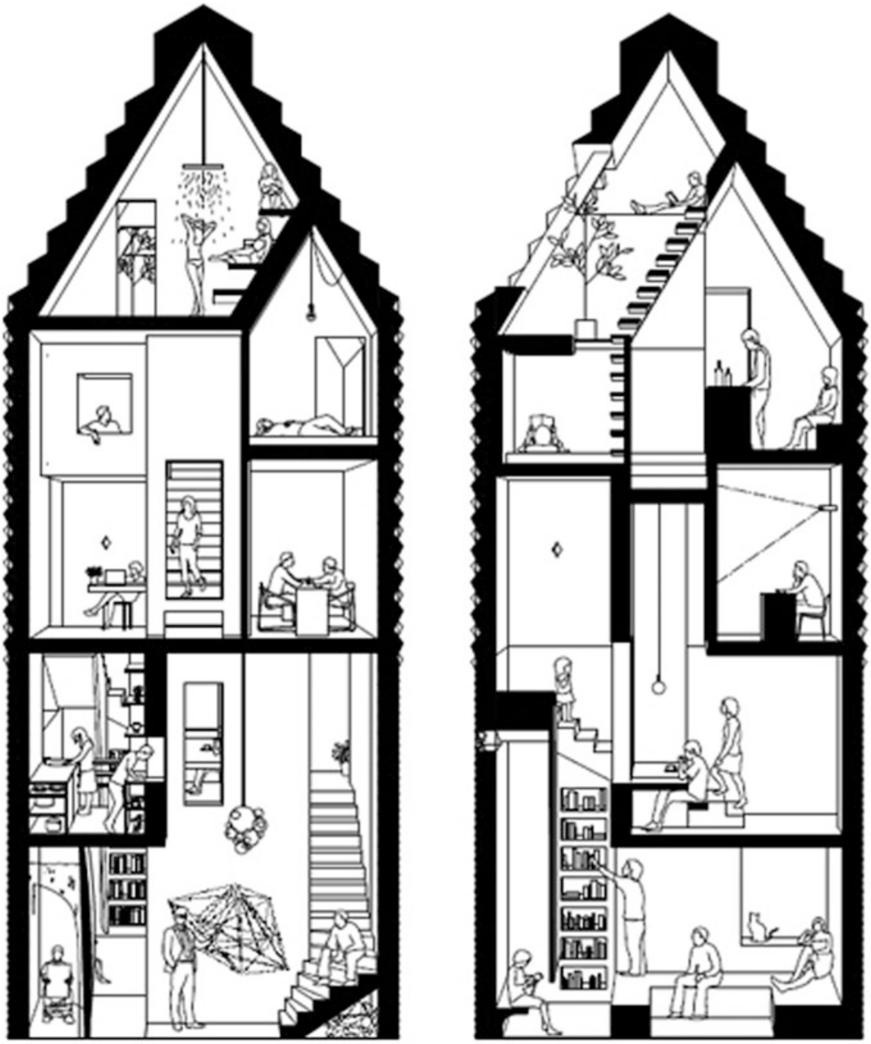


Fig. 9. Section of the project [41]

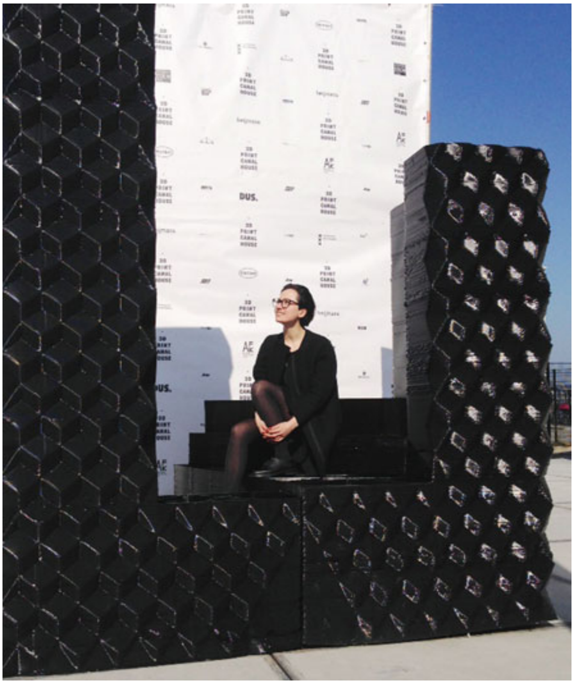


Fig. 10. 3D printed building block [42]

As we learn from the interdisciplinary research team, this initiative developed according to those "research & do" themes:

- KamerMaker: large scale 3D printing
- Sustainable 3D print material for the building industries
- New construction and building techniques
- Downloadable tailor-made architecture
- Smart building
- Scripted city planning [43]

The project is still under construction and planned to be completed in 2017.

4 Conclusions and Future Remarks

3D printing, an automated layer-by-layer production process, is a disruptive technology that can be used in construction industry to achieve economic and environmental benefits. The results obtained from this paper, in particular the analysis of case studies, presents that the potential of 3D printing technology is important for architecture.

These technologies have a potential to shape the future of construction industry. It is possible to claim that if it continues to be developed with a certain speed, it may revolutionize the construction process.

Although still in its infant days, current implementations of 3D printing for the construction industry could offer the following benefits [44]:

- from file to construction/direct printing on-site or in factories,
- using as much material as needed to manufacture the design so produce less waste,
- a variety of raw materials including recycled plastic, bioplastics, concrete and so on,
- precision,
- capable to adopt different types construction methods,
- capable of extruding multiple materials,
- reduced transportation and labor costs,
- to built complex shapes not possible with conventional construction,
- reduced health and safety risks on-site.

On the other hand, current challenges in the construction industry to be overcome can be listed as:

- it is still limited and an expensive technology,
- the industry is not familiar with this technology,
- 3D printers for construction such as concrete construction can be large and transportation to site could be costly.

The initial information indicates that 3D construction process has a potential from the sustainability point of view. Yet, it is necessary to have more practice and experience. Much further research has to be done on still unclear points like structural and mechanical stability, material life, toxic effect of materials etc. Especially, as the use of 3D printing in the construction industry is still in its infancy, the life cycle performance of the printed buildings/building components are still unclear. It is possible to claim that by focusing on these challenges, 3D printing can reach its maximum potential in the construction industry in the near future.

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Nanotechnology in Built Environment: Pros and Cons of Nanomaterial Usage in Architecture

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Abstract. Today, scientific and technological developments directly affecting contemporary architecture. Nanotechnology, as one of the most riveting research areas, is the science designing and manipulating materials at atomic size. It has gradually established itself in the past two decades with novel and useful applications in all disciplines. This revolutionary technology has many potentials to change the way we design and produce. Recent researches indicate that nanomaterials used in built environments have many unique characteristics which can fix the current construction problems, and may change the requirement and organization of construction process as well. Conversely many researches urge that these technologies have demerits which may pose a risk to human health and the environment. In this context, this paper discusses and exemplifies pros and cons of nanomaterial usage in architecture.

Keywords: Nanotechnology · Nanomaterials · Built environment Architecture · Health risks

1 Introduction

Rapidly growing/changing scientific and technological developments like CAD, CAM, BIM technologies, kinematics, artificial intelligence, robotics, genetics, biotechnology, and nanotechnology etc. are directly affecting our built environment and the way we built. Recent researches and implementations reveal that nanotechnology, the science which designs and manipulates materials at atomic size, have potentials to make innovative materials with novel functionalities and improved characteristics of contemporary architecture.

It is widely accepted that nanotechnology helps optimization and improvement of existing products and/or result with nanomaterials and nanostructures, which have advanced properties either adaptation to the environment and responsiveness or self-cleaning, self-healing, lightweight, durable, scratchproof, stainless, antibacterial, flexible and energy reducing surfaces that we use in the built environment. Furthermore thin-film coatings used in transparent components of the building are provided for energy conservation and nanomaterials which are used as lighting elements are also greatly help to save. Such as aerogels, vacuum insulating panels and phase change

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materials are nanomaterials that have superior properties used as insulation material providing more thermal insulation up to several times compared to existing insulation materials. In other worlds, sustainable, economic, high-performance and comfortable solutions are aimed through these technologies. There is no doubt that these improvements might cause a paradigm shift in architecture in a few decades. On the other hand, some of the recent researches urge that nanotechnology have barriers for an extensive acceptance of products having nanoparticles/nanoproducts are high costs, doubts about long-term technical material performance, as well as uncertainties about health risks of nanoproducts. Some other researches proved that, the use of nanomaterials have some negative effects on human health. Nanomaterials shows different behaviors due to the change in the current behavior of the atoms in the nano-scale and quantum physics rules. What kind of a negative effects on human health of nanomaterials are not fully known because it is difficult to detect and control nanoparticles.

This paper focuses on the use of nanomaterials in nanotechnology applications in the built environment. Then study aims to examine the pros and cons of "nanotechnology in architecture"; by making a taxonomic study on the products available in the market, exemplifying and discussing how nanotechnologies can be applied to buildings for better solutions in architecture, and questioning the possible harmful effects on built environment.

2 Nanotechnology and Innovative Material Development

Nanotechnology is science, engineering, and technology conducted at the nano-scale, which is about 1–100 nm. Nano, which comes from the Greek word for dwarf, indicates a billionth. One nanometer is a billionth of a meter, that is, about 1/80,000 of the diameter of a human hair. Nanotechnology can best be considered as a 'catch-all' description of activities (any application of science and technology) at the nanometer scale that have applications in the real world [1]. There are many definitions of 'nanotechnology' yet, it generally refers to understanding and manipulation of matter on the nano-scale, such as from 0.1 run to 100 nm (Fig. 1) [2]. Nanoscience and nanotechnology can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering [3].

It was initially introduced in the speech of the physicist Richard Feynman during his lecture entitled "There is Plenty of Room at the Bottom", that took place in a meeting of the American Physical Society in 1959 [4]. Feynman described a process by which the ability to manipulate individual atoms and molecules might be developed, using one set of precise tools to build and operate another proportionally smaller set, and so on down to the needed scale. He argued that with this manipulation "better electron microscopes, marvelous biological system, miniaturizing the computer, miniaturization by evaporation, problems of lubrication, rearranging the atoms" etc. would be possible [5]. Following, Drexler, who began to develop these theories even before he had heard of Feynman's lecture, first published his ideas in a 1981 journal article. Five years later, he introduced the term "nanotechnology" in his book "Engines of Creation" to describe this approach to manufacturing and some of its consequences. In 1992 Drexler published "Nanosystems", a technical work outlining a way to manufacture extremely high-performance machines out of molecular carbon lattice ("diamondoid") [6]. As Keiper describes, today, in the young field of nanotechnology, scientists and engineers are taking control of atoms and molecules individually, manipulating them and putting them to use with an extraordinary degree of precision [7]. Nano products are everywhere now; in materials, agriculture, medicine, aviation/space technology make-up industry, clothes, education, and even in food and food processing.

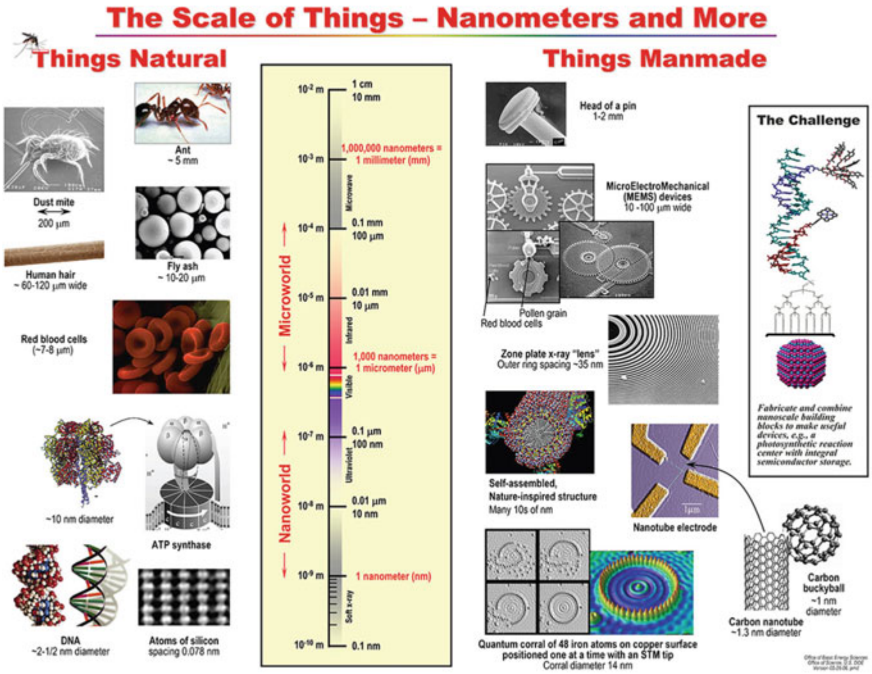

Fig. 1. Scale of things, nanoscale and more [8]

3 Nanomaterials in Built Environment and Architectural Applications

Nanomaterials are an emerging family of novel materials that could be designed for specific properties. These materials will bring significant shifts in the manner that design, produce, and use materials. For example, nanomaterials that are 1000 times stronger than steel, and 10 times lighter than paper, are cited as a possibility [9]. According to a Report of the UK Advisory Group on Nanotechnology Applications, there are two ways to approach the nanoscale: first, shrinking from the top down and second growing from the bottom up. These two models are fundamentally different, both in the approach to creating structures and in the underlying science that will make them possible [2, 10]. Zhu et al. [11] defines that first approach entails reducing the size of the smallest structures towards the nano-scale by machining and engraving techniques, whereas the 'bottom up' approach, often referred to as molecular nanotechnology, implies controlled or directed self-assembly of atoms and molecules to create structures [11].

It is possible to claim that nanotechnology and nanomaterials in particular unavoidably cross the boundaries and bring traditional technologies and materials together. Traditional materials such as metals and ceramics show radically enhanced properties and new functionalities, the behavior of surfaces starts to dominate the behavior of bulk materials [12–14]. Gaining control of structures at the nanoscale results with next generation materials such as carbon nanotubes (Fig. 2), with a tensile strength often quoted as 100 times that of steel [11, 15, 16].

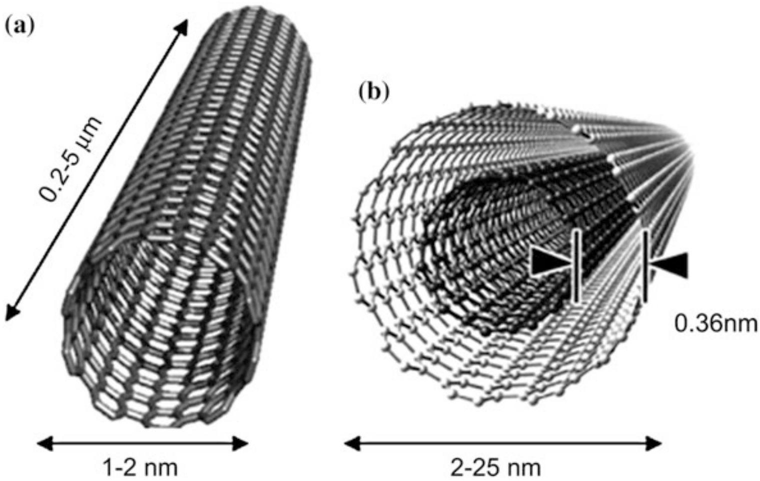

Fig. 2. Carbon nanotubes exists in different forms. It can be a single walled-sheet of graphene rolled up and even closed at both ends—left or multiwalled—more tubes coiled around each other—right [17]

Like carbon nanotubes, several nanomaterials can be used to improve the bulk material properties. By adding nano-particles to the bulk material nano-composites are achieve. For instance, electrochromic windows, nanoclays, sandvik nanoflex™, nanowires, titanium dioxide, nanoceramic coating, nanocrystalline materials, nanosilica, nanocomposites, $MMFX_2$ Steel, nanometals, nanofibres, nanomyte™ mend mw and nanocement etc. [18–20] are the products that we encounter in the market recently used to get nano-composites. They could be used for providing important functions of potential reinforcement, corrosion resistance, insulation, fire protection, temperature resistance, reducing air conditioning loads, pollution control, UV ray absorption, lighting, when used as a part of building materials [18]. It is a fact that, concrete, steel, glass, and timbers are the most common materials, being used in the field of modern construction. Therefore, following section describes the nanomaterials mentioned above improving the properties/characteristics of traditional materials used in built environment:

Concrete: The addition of nano-silica (SiO_2) to concrete can control the degradation of the calcium-silicate hydrate reaction caused by calcium leaching in water. Blocking water penetration improves the durability [21–23]. Moreover, Nanoshel company claims that, carbon nanotubes increase the compressive strength of cement mortar specimens and change their electrical characteristics which can be used for health monitoring and damage detection. The addition of small amounts (1%) of carbon Nanotubes can improve the mechanical properties of mixture samples of Portland cement and water [24].

Steel: It is proved that, the technology relies on the controlling the structure of metals at the nanoscale can imbue those materials with new properties [25]. According to Bullis [26], an inexpensive new process can increase the strength of steel by as much as 10 times, and make them much more resistant to corrosion. Again, Lashmore, a professor of materials science at the University of New Hampshire, says nano-engineered layers can make a material stronger by stopping cracks from moving through it [27]. For instance, copper nanoparticles reduces the surface roughness of steel then limits the number of stress risers and hence fatigue cracking, leading to increased safety [18]. Similarly, the use of vanadium and molybdenum nanoparticles improves the delayed fracture problems associated with high strength bolts reducing the effects of hydrogen embrittlement and improving the steel micro-structure through reducing the effects of the inter-granular cementite phase [28, 29].

Wood: Naturally, wood is composed of nanotubes or "nanofibrils"; namely, lignocellulosic (woody tissue) elements which are twice as strong as steel [18, 30]. According to recent researches, Lignocellulosic surfaces at the nanoscale could open new opportunities for such things as self-sterilizing surfaces, internal self-repair, and electronic lignocellulosic devices, providing feedback for product performance and environmental conditions. Highly water repellent coatings incorporating silica and alumina Nanoparticles and hydrophobic polymers are proper to be used for wood [31, 32].

Glass: One of the most common use of nanotechnology is the application of TiO_2 Nanoparticles to glass so-called "self-cleaning" technology. Due to the nanoparticles photo catalytic reactions, the organic pollutants, volatile organic compounds and bacterial membranes are decomposed. As well, TiO_2 being hydrophilic, his attraction to water forms drops which then wash off the dirt particles decomposed in the previous process. Fire-protective glass is obtained using fumed silica (SiO_2) Nanoparticles as a clear interlayer sandwiched between two glass panels which turns into a rigid and opaque fire shield when is heated [33, 34]. Nanocoatings can also be employed to modify the functional properties of glass fibers. Conventional glass fibers are insulating materials. However, novel conductive glass-fiber-reinforced plastics (GFRPs) have a broad range of applications, including electrostatic dissipation, electric field shielding, and damage detection [34–36].

Coatings and Paintings: Nanotechnology is applied to paints to assure the corrosion protection under insulation since it is hydrophobic and repels water from the metal pipe and can also protect metal from salt water attack [37]. Nano-coatings are materials that are produced by shrinking the material at the molecular level to form a denser product. The appearance and usefulness of nanoparticles brings many advantages and opportunities to paint and coating industry. Coating industry is among the first to tap the potential of nanotechnology [38]. It is applied to paints in order to achieve the corrosion protection under insulation since it is hydrophobic and repels water from the metal pipe and can also protect metal from salt water attack. Others applications refer to coatings that have self-healing capabilities through a process of "self-assembly". In addition to the self-cleaning coatings mentioned above for glazing, the remarkable properties of TiO_2 Nanoparticles are put to use as a coating material on roadways in tests around the world [33, 38, 39].

Thermal Insulation: Micro- and nanoporous aerogel materials are appropriate for being core materials of vacuum insulation panels but they are sensitive to moisture. As a possible remedy, it was produced an ultra-thin wall insulation which uses a hydrophobic nanoporous aerogel structure. Another application of aerogels is silica based products for transparent insulation, which leads to the possibility of superinsulating windows [33]. Gas-filled panels, Phase change materials and NanoCons are other types of thermal insulation can be found in the market [40, 41].

As can be seen from the definitions - building materials domain can be one of the main beneficiaries of these researches, with applications that will improve the characteristics of concrete, steel, glass and insulating materials. Hence, nanomaterials have a potential to be widely used in our built environment [37, 42, 43]. Examples include nanomaterials in conjunction with structure, roofing, walls and flooring, and all types of finishing's are summarized below in Table 1.

Table 1. Possible nanomaterial usage in a building (prepared by authors)

Materials improved by nanotechnologies	Roof	Structure	Facade	Wall-floor	Finishing
Lotus effect and self cleaning			+		
Photo catalyst and self cleaning			+		
Antibacterial materials			+	+	+
Scratching resistant materials				+	+
Coating for thermal insulation			+	+	+
Thin films	+		+		
Aerogels	+		+	+	
Vacuum insulation panel	+		+	+	
Phase changing materials			+		
Insulation coatings			+	+	+
Insulated ceramic tiles			+	+	+
Nanotube solar cell	+		+	+	
Led lights				+	+
OLED				+	+
Quantum dot				+	+
Concrete		+			
Steel		+			
Wood	+	+			
Glass	+		+		
Plastic			+	+	+
Ceramics			+	+	+

4 Pros and Cons of Nanomaterial Usage in Architecture

There is no doubt that, nanotechnology based products can advance the overall competitiveness of the construction [37]. As can be seen in the previous section the building components of applying nanotechnology in architecture are mainly focused on: (1) lighter and stronger structural components, (2) low maintenance coating and self-cleaning surfaces, (3) better properties of concrete, (4) improving the thermal insulation. Besides, the usage of nanotechnology materials while being incorporated in constructional structures would not only help in prolonging their lifetime, but would also keep a check on the energy spent by them and at the same time estimating their reactions and reacting to different agents like fire, corrosion, water penetration, fractures, cracks, etc. [18]. Furthermore, when the cases are examined in detail, for example nano-modified concrete cuts down construction schedules while reducing labour-intensive (and expensive) tasks. Also, it can reduce the cost of repair and maintenance [37]. Below, the figure by Twist (2004) reveals that nanomaterials are everywhere in our built environment and living spaces and making our daily live comfortable (Fig. 3). Over the last 15 years, a number of reports on nanotechnology have been published where the merits of using these technologies highlighted.

1.Organic Light Emitting Diodes (OLEDs) for displays
2.Photovoltaic film that converts light into electricity
3.Scratch-proof coated windows that clean themselves with UV
4.Fabrics coated to resist stains and control temperature
5.Intelligent clothing measures pulse and respiration
6.Bucky-tubeframe is light but very strong
7.Hipjoint made from biocompatible materials
8.Nano-particle paint to prevent corrosion
9.Thermo-chromic glass to regulate light
10.Magnetic layers for compact data memory
11.Carbon nanotube fuel cells to power electronics and vehicles
12.Nano-engineered cochlear implant

Fig. 3. Potential uses of nanotechnologies in a room [44]

On the other hand, with the increasing use of nanomaterials for commercial purposes, human and environmental exposure to those materials has become more likely. Recent studies have shown that the distinctive nano-characteristics of nanomaterials not only make them superior to traditional bulk materials, but also may affect their potential toxicity [45] and present a challenge for the existing regulatory systems [46]. There is a growing body of literature on the potential adverse effects caused by exposure to different types of nanomaterials [47–51] however, there are still numerous unanswered questions that complicate the appropriate evaluation of toxicity of nanomaterials. Most recently added documents [52] such as "How can business respond to the technical, social and commercial uncertainties of nanotechnology", "General Principles and Practices for Working Safely with Engineered Nanomaterials", "Nanosafety Guidelines" principally focuses on the hazards and the potential risks of nanoparticles. Because there are also some potential negative environmental and health aspects that may follow the nanotechnology. One particular example of significant importance for environmental release of ENMs in the context of the outdoor urban environment is the growing use of ENMs for self-cleaning glass and building façade painting in the urban environment. The worldwide coatings market is expected to reach $107 billion by 2017 (Global Industry Analysts Coatings, 2012) [47]. Nanomaterials used in the built environment can penetrate the skin, lungs and intestinal tract with unknown effects to human health as nanoparticles can travel around in the body and reach for example the brain [53, 54] new engineered nanoparticles have novel properties not previously known and it is likely that they exactly because of the novel properties will cause impacts on ecosystems and organisms (Fig. 4).

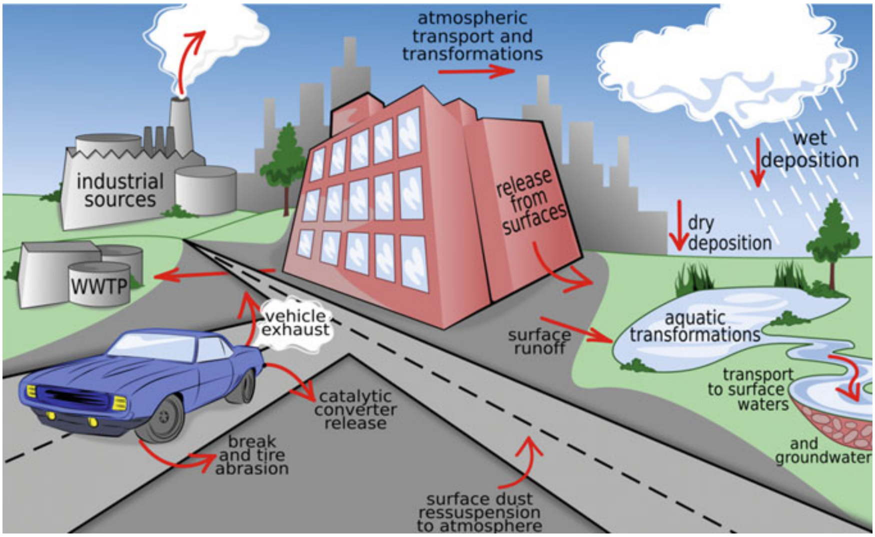

Fig. 4. Sources and pathways of outdoor urban nanomaterials in the environment [45]

They are all applications available on the market. Yet, as there are so many uncertainties, limited knowledge and inadequate feedback, there are few risk assessments have been done so far. So, it is important to investigate the attitutes that producers of these nanotechnologies have, regarding the potential risks to human health and environment and what precautions are taken as well. But this is the subject of another research question. As an example, a study led by Eva Oberdörster found that a type of buckyball—a carbon nanoparticle that shows promise for electronic and pharmaceutical uses—can cause brain damage in fish [55]. Nanoparticles can cause other effects if they react with other substances or even carry other substances into organisms, soil or groundwater [56, 46]. Furthermore, there is a number of studies done that supports the hypothesis that ultrafine particles are able to translocate from the lung into the systemic circulation and reach organs like the liver in animals [47–50] However the amount of particles that translocate into the blood and organs differed among the studies [51] and therefore this hypothesis needs additional detailed and differentiated consideration [46–48].

One type of nanomaterials, the fullerenes are lipophilic and localize into lipid-rich regions such as cell membranes in living organisms, and being redox active and they therefore have the potential to be toxic. A study by Eva Oberdorster showed that fullerenes can induce oxidative stress in the brain of fish [55]. This is the first study done with new nanomaterials showing that nanomaterials can damage aquatic organisms. Further studies that evaluate the potential toxicity of manufactured nanomaterials, especially related with respect to translocation in the brain are needed [46].

5 Results and Future Remarks

Nanomaterials and nanotechnologies have attracted considerable scientific interest due to the new potential uses of particles in nanometer scale and, consequently, large amount of funds and effort have been utilized. Recent researches on nanomaterials and nanotechnologies have highlighted the potential use of these materials in various fields such as medicine, construction, automobile industry, energy, telecommunications and informatics. Thanks to these technologies the following merits can be achieved;

- Lighter and stronger structural composites
- Low maintenance coating
- Improving pipe joining materials and techniques
- Better properties of cementitious materials
- Reducing the thermal transfer rate of fire retardant and insulation
- Increasing the sound absorption of acoustic absorber
- Increasing the reflectivity of glass.

All these merits have many unique characteristics which can fix the current construction problems, and may change the requirement and organization of construction process as well [18–20, 31, 57]. Furthermore, using nanotechnology helps less energy consumption in a building, which is considered one of the main concerns of the world today. On the other hand, recent studies show that these technologies have demerits which may pose a risk to human health and the environment. These issues can be summarized and listed as follows;

- Nano particles being very small in size have the potential to negatively affect the respiratory and digestive tracks and the skin or eye surface thus exposes workers and even users to hazards.
- As related industries are quite new, the worker employed in construction area should educated/informed in an interdisciplinary approach.
- New policies in the context of nanotechnology will require cooperation between various Levels of government, research and development companies, manufacturers, and other industries.

It is hoped that by providing necessary conditions, using nanotechnology in the construction industry would lead to creating safer buildings of higher qualities that are cost effective. Therefore, it is necessary and urgent to regulate the construction and its related performance to sustainable manners. The nanotechnolgy becomes a double-edge sword to the construction industry. More research and practice efforts are needed with smart design and planning, construction projects can be made sustainable and therefore save energy, reduce resource usage, and avoid damages to environment. It is necessary to establish a system to identify the environmentally friendly and sustainable of construction nanomaterials and to avoid the use of harmful materials in the future.

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Performative Architecture: A Holistic Approach for Sustainability

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Abstract. 21st century has become prominent with two main concepts in architecture; the first one is sustainability in architecture which has been seeking for a less environmental footprint in the ecosystem and the second one is digital technologies that drive a novel approach in all kinds of man made products including architecture. This paper discusses and exemplifies the term "performative architecture" as a melting point of these two concepts. It is aimed to show and discuss how cutting edge technologies help designers to design not only the building but also the design of design process in a sustainable way.

Keywords: Performative architecture · Building performance · Sustainability

1 Introduction

Today, the use of digital technologies in architecture has been extended from being a medium of representation to media of design, optimization and manufacturing. There is no doubt that, CAD/CAM/BIM applications have been rapidly changing the conventional architectural design and construction process since the end of last century. In this process researchers and practitioners have been seeking for new tectonics, materials, systems producing its own energy etc. revealing the beauty of using cutting edge technology in a sustainable viewpoint.

When the term sustainability is considered, the better usage of environment and the sources (especially climatic data, water and energy), the better usage of appropriate technologies, minimizing the negative effect on environment, designing the recycling process (water, waste…) using convenient materials could be the first components.

In recent years, some other parameters like being recyclable, being convertible, security, interaction and circulatory systems are being taken into consideration and more holistic approaches are being used under the umbrella of sustainability. The increasing number of design parameters can only be turned out into an economical and aesthetical and performance based/optimized "design" by the help of computational technologies and thus this changing design paradigm evolve design process to an optimization process in which the optimum performance have been explored. In this context, recent studies reveal that these two main concepts can be melted in a pot and called "**performative architecture**" has been spreading day by day. Performative design in architecture represents a combination of two critical characteristics of

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computational design. First, generation of a solid model that enables all kind of analytical evaluation of environmental performance based upon simulating physical conditions such as solar or structural loadings etc. Second, helping designers to create "architecture" performing as an art, with the surroundings, acting as the stage on that the building is able to perform and be on show via computational model that enables from file to fabrication.

In this sense, this paper discusses very recent architectural practices performed under the concept of sustainable architecture which is realized through the rapidly developing digital design, optimization and manufacturing tools. It is also aimed to discuss how cutting end technologies help designers to design not only the building but also the design of design process in a sustainable way.

2 Parametric Thinking and the Changing Role of Architects in 21st Century

In recent years, rapid developments in science and technology have affected the processes and perceptions in all disciplines. Especially in the realm of architecture, computational design and manufacturing methods and implementations/practices have changed the architect's roles and responsibilities. As a well-known architectural figure, Vitruvius defines the three basic parameters of architecture as; *firmitas* (durability aspects), *venustas* (aspects of aesthetics) and *utilitas* (aspects functionality or utility). The first is the idea that architectural accomplishment constitutes a kind of completion, a unity brought to component parts that are very much different. Secondly, by addition of venustas, Vitrivius considers that not only the objects of architecture are important but also their "audiences", and that esthetics can be considered apart from use and even solidity, even when the occupants of a building are busy enjoying its conveniences. The third Vitruvian aspiration seems to be indicated simply by the highly differential nature of the three components: that 'architecture', whatever it might be, is a unity that is not allowed to transcend difference but must find a certain topological congruence that cannot be 'flattened out' on to a map or representation (i.e. considered from some extrinsic point of view outside of architecture) [1].

After the industrial revolution the deep separation has been augmented in the architectural realm. And in the last century the roles of architects and engineers are sharply divided. While architects became responsible for *untilitas* and *venustas* engineers were the masters of firmitas which require mathematics so called computation. Today due to the impact of parametric thinking and computational design/manufacturing technologies on the design process architects should be aware of and control all kind of data, which drives the 3 components of Vitruvian architecture, in the early stages of design process.

From this respect, computational design has becoming increasingly prevalent in architectural design since the beginning of this century. Previous studies reveal that computational tools/medium can advance the design processes in several ways [2–4]. Woodbury claims that parametric thinking and designing supports the creation, management and control of huge amount of data coming from the complex models [5].

Besides, Yu et al. argue that using parametric design tools, designers can make rules according to the performance requirements of a design [6]. They also define a parameter as a value or measurement of a variable that can be altered or changed. Especially in architecture, parameters are usually defined related to building or environmental factors. As Kolarevic defines, "by controlling parameters, a specific design can be created from a potentially infinite range of possibilities" [7].

In the architectural design process, parametric design tools can be employed mainly for form-finding, optimization of multiple design solution, as well as structural (wind, earthquake etc.), physical (acoustics, noise, light, ventilation, heat, fire etc.) and sustainability control. When compared with conventional design, parametric design is, in quite different not only because it offers new design tools/medius but also a new way of thinking [6–8].

3 Parametric Design, Performative Architecture and Sustainability

The adjective "performative", as defined by Merriam-Webster Dictionary, is "being or relating to an expression that serves to effect a transaction or that constitutes the performance of the specified act by virtue of its utterance" [9]. According to Stojanovic the use of the term "performance" within the context of architecture denotes the capacity of building materials, namely their behavior under given conditions, such as those created by atmospheric or mechanical influences [10].

Actually, the terms parametric design and "Performative Architecture" has been discussed and published by Kolarevic and Malkawi to describe the idea of performance as a guiding principle in architectural design [8, 11]. As perceived by two authors, one of the most fundamental issues in the contemporary architectural design process is "the apparent disconnection between the geometry and analysis in the currently available digital design tools" [11]. Their position denotes the dichotomy in the understanding of the "performative" in architecture which separates between "events" and "measures" and points toward the need to establish ways of designing based on the integration between the two polarities [10]. Development of new instruments and methods contribute to a new understanding of the way buildings are imagined, constructed and experienced. Due to recent developments in technology, cultural theory and the emergence of sustainability as a defining socio economic issue, there is an increasing interest in performance as an architectural design paradigm [11]. The paradigmatic appeal of the performative in architecture lies precisely in the multiplicity of meanings associated with it; however, performance is still one of the least defined concepts in architecture [10].

Menges and Hensel [12] discusses that being performative is usually associated with sustainability and complex digital models analyzing the structural and environmental behavior of buildings. This limits performance to a merely technical interpretation [12]. Hagan [13] highlights an important issue and says, performative architecture must also consider other aspects, because architecture has always performed socially, semantically, ideologically, and in a basic manner as a shelter [13]. Therefore, the question "what is architectural performance in the digital age" gains importance: “Is this performance comparable to the performance of a machine or a theatrical performance?” [14]. Oxman [15] argues that, there is no single answer for this question because of the multiplicity of the meanings and connotations of the word performance have [15]. Albayrak [16] concludes that, determining different performative aspects in a particular project and reconciling conflicting performance goals in a creative and effective way are key challenges in performative architecture [16].

There is no doubt that the concept of performative architecture has emerged in recent years with the digital technologies and has been spreading day by day. Gönenç Sorguç and Arslan Selçuk [17] claims that its content and possible expansions have not been examined yet [17]. While Leatherbarrow seeking the answer of this question, he asks another question, what is the function of buildings and what architecture do in fact? He reminds the definition by Aristo “*…architecture imitates human action and life*” for the answer of his question and defines the performance as theme/aim of a building or prediction and then performative architecture is an architecture driving forward these [14]. Buildings are perceived as not only for being complex systems or aesthetic objects but also with their impact, the impact for transforming interactivities, in other words through their performance. Accordingly, performative architecture can be considered as a paradigm that defines complex and ill-defined design problematic, identifies constraints/criteria and goals of design, evolves the designing process to an optimizing process. This definition reflects the “architectural design process for sustainability” accurately. More lightweight structural system, less energy, more day lighting, more natural material, interactive building systems… all these “more” constitutes the themes of performative architecture and provides them being realized through digital designing and manufacturing techniques. Even as the architecture transforms to a meta discipliner identity, it is only possible to construct smart/intelligent buildings via smartness/intelligence of the design process. Actually it is possible to claim that architecture is already and action for sustainability.

4 Case Studies: Simulating the Performance

The term performative may represent a synthesis of two of the essential characteristics of digital design. Digital design processes support transformation and generation of a geometrical model and they support analytical evaluation of environmental performance based upon simulating physical conditions such as solar or structural loadings [15]. Oxman [15] argues that, integration of evaluative simulation processes with digital ‘form generation’ and ‘form modification’ models is a potential so called “Performative Design” [15]. As Kalay defines, evaluation as part of a simulation process serves as an assessment of the expected performance of the architectural design solution [18, 19].

Performative architecture so far as can be summarized as an optimization process of one or more criterion selected through the design process, here the question of how designing process is being designed comes into prominence. This is a **holistic approach** to architectural design. Therefore, it would be easy to understand the increase in the examples of performative architecture since 1990s when the role of computing and information technologies are considered as part of sustainability.

However it shouldn't be perceived as distinguishing properties to define performative architecture when the end product demonstrating advanced technologies or vernacular construction techniques, using new or traditional materials and structural systems.

Actually, design action and processes are evolving, not the end product-building. In this perspective, there are several impressive examples designed through these two approaches by using performative architecture and computational techniques. Generally, it is possible to list the subtitles of performative architecture examples as:

- Buildings based on performance (lighter, less energy, more day lighting…)
- "Smart" buildings
- Interactive buildings
- Biomimetic buildings
- Kinetic buildings
- Innovative forms and structural systems
- Small scale buildings using local materials and technologies
- … etc.

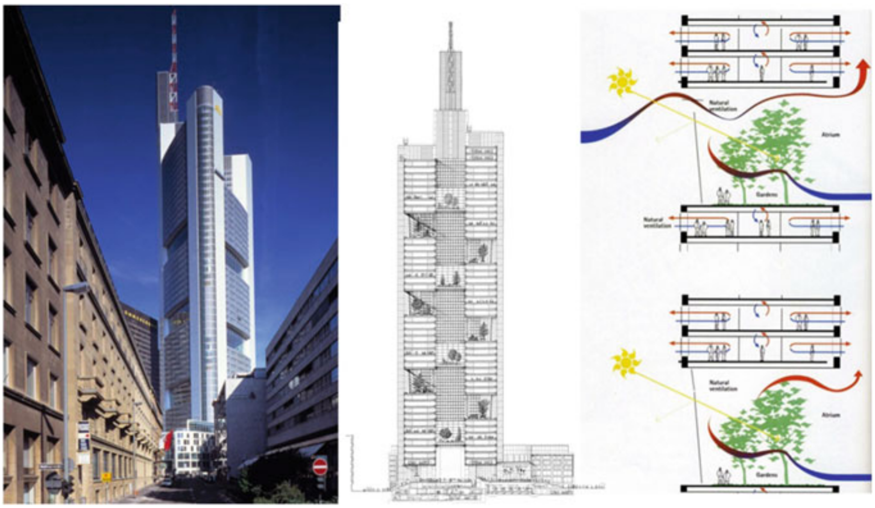

Fig. 1. Natural ventilation principles of Frankfurt Commerze Bank [20, 21]

To exemplify the titles above, the premise example can be given as Frankfurt Commerze Bank, which is the highest office building of Europe. The approach is important not only being a way of diminishing the energy sources used for heating and ventilating but also being a criterion for the solutions of sick building syndrome which is a severe psychological problem of employees working in high-rise buildings. The architect aims to create a sustainable working area through the precautions in courtyards, windows penetrating day light etc (Fig. 1).

The other extreme project can be cited here is the Zollverein School of Business Management and Design building Project realized within the context of re development plan of a mine complex in Essen, Germany in 2002 (Fig. 2). This project is based on the active thermal insulation using 30 °C Coal Mine Water, which is penetrating to environment, through a radiant exterior wall system by considering a symbiotic design approach. The negative effects of this water to the environment have been turned to a positive one. The ground has been lightened 30% and the structure has been re optimized. Transparency and concrete have been used together, this mine area transformed to a new revitalized/zone and then the performance has been obtained from the building. The question here is that, whether the design of building has been created through the architect's vision or formed by the engineering. Indeed isn't it a concurrent and coordinated process? In this sense this project demonstrates how designing action has been evolving.

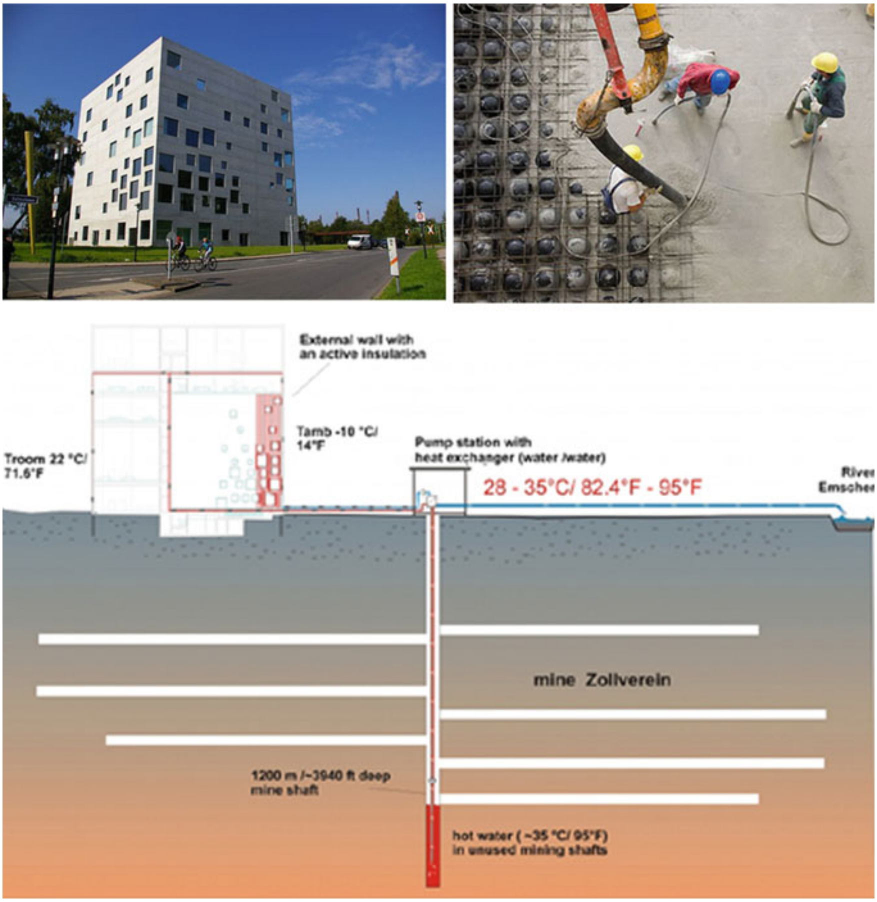

Fig. 2. Zollverein school building: Active thermal insulation [22–24]

After this principle examples, in the 21st century developing simulation techniques let architects to control huge amount of parameters through a basic model which is called **computational** model Computational models are such tools/environment that closes the gap between architects and engineers to satisfy performative architecture. From this respect the rest paper exemplifies the context discussed above within three important examples recently constructed: Al Bahr (Al Bahar) Tower and 1 Bligh Street and Pertamina Energy Tower.

4.1 Al Bahr Tower

Towers Al Bahr seek to provide a contextual and culturally sensitive design while utilizing modern technology to meet the highest standards of efficiency. Powered by computational design team, the work of architects and engineers was to find a parametric description for the geometry of the movable panels on the facade and simulate its operation in response to sun exposure and the consequent change of incidence angles during different days of the year. Each of the 1000 panels is connected to a linear actuator which enables it to function in response to the position of the sun, effectively reducing heat gain and glare by 50% while giving Islamic vernacular a contemporary representation. the intelligent facade, together with solar thermal panels for hot-water heating and photovoltaic panels on the roof, minimize the need for internal lighting and cooling, altogether reducing total carbon dioxide emissions by over 1750 tons per year [25, 26]. Figure 3 shows some snapshots from simulation process and Table 1 represents related information belongs to Towers Al Bahr.

Fig. 3. Al-Bahr tower and images from simulation process [25, 27]

Table 1. Towers Al Bahr

Project/Type	Al Bahr tower—2012
Location	Abu Dhabi, UAE
Description	Al Bahar Towers are located in the United Arab Emirates in Abu Dhabi City. The project comprises two near-identical, 26-storey, 145 m tall office building towers. Each of the two towers comprises over 1000 individual dynamic shading devices that are controlled via the building management system, creating an intelligent façade
Design firm	Aedas architects
Achievement	– LEED silver (expected): The Al Bahar project is being assessed under the US Green Building Council (USGBC) LEED for New Construction version 2.2 (NC v2.2)3 and is predicted to achieve a Silver rating – 1 Pearl rating is mandatory for all buildings in Abu Dhabi, Al Bahar Tower was designed in compliance with Estidama initiative and Pearl rating system that requires an integrated design approach
Simulation tool	Rhino script, BIM, Gehry technologies digital project
Simulation	During design process advanced architectural modelling and simulation tools were used. Architectural design was going in parallel with structural, mechanical and other parts. In order to achieve coherence and consistency one integrated model was used. A script running into Rhino tool generates the floor plates, the structure, the curtain walls and finally the Mashrabiya (shading element name). The development of this integrated model was proven valuable during the delivery of different stages. Floor plates, classing, structure and mashrabiya were all generated from one model (CTBUH [26])
Simulation target	Optimum building shape, design for daylight, design for minimum solar heat gain, solar and climatic analysis, design for external shading. Facade generation, differentiated floor plate and facade generation, structure, energy optimization, Kinetic facade, PV cells

4.1.1 Bligh Street

A difficult site in Sydney's central business district was transformed by 1 Bligh Street's elliptical tower, which offers tenants several ground-breaking technological advances. The centerpiece is Australia's tallest naturally ventilated skylight atrium, trimmed in glass and aluminum, which soars the full height of the building. Other innovations include a double-skin, naturally-ventilated glass façade and a hybrid system using gas and solar energy to generate cooling, heating and electricity for the building. Central element of the building is an atrium that is as tall as the tower. It offers natural day lighting and allows for a natural ventilation of the offices and balconies that face the atrium. Glass elevators go up and down in the atrium, making travel to and from the workplace an exciting spatial experience. Another special spot is the outdoor terrace with a harbor view at the transfer-level in the 15th floor as well as the large roof top terrace at the 28th floor—a unique spot in Sydney. The tower is the first one in Australia to have a double skin facade and to use natural ventilation [28–30]. Figure 4 and Table 2 represents key information about 1 Bligh Street related to the performative approaches and simulation use.

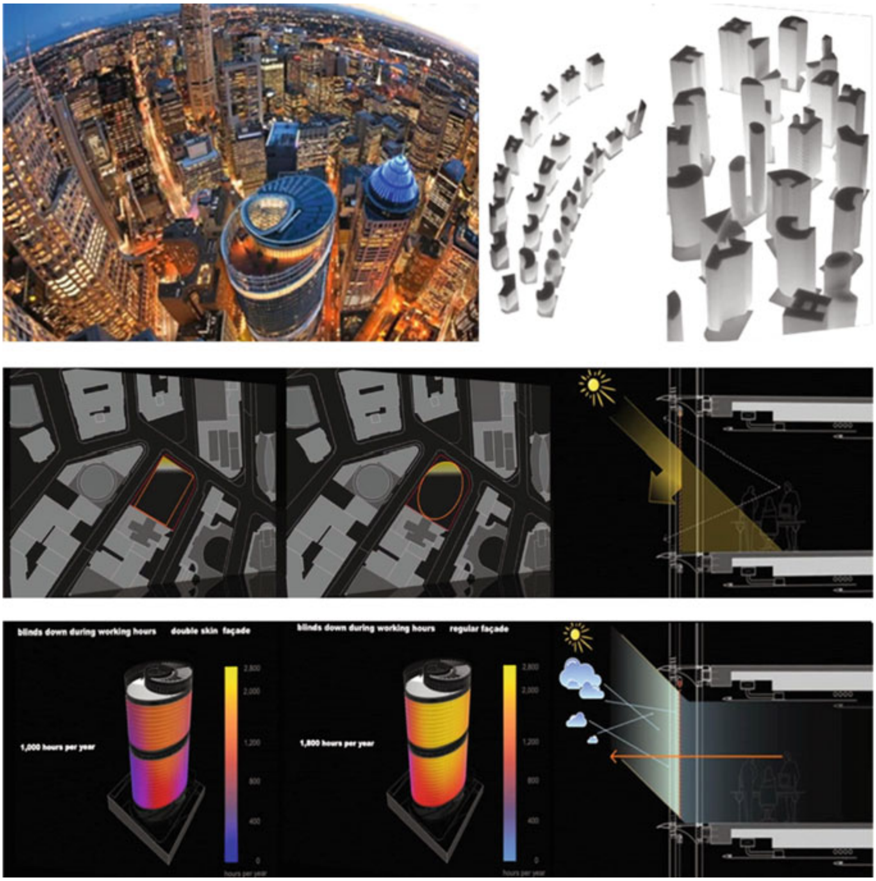

Fig. 4. An image from simulation process of 1 Bligh Street tower [28–31]

Table 2. 1 Bligh Street

Project/Type	1 Bligh street/High rise office building—2011
Location	Australia, Sydney
Description	1 Bligh Street is an elliptical tower, which offers tenants several ground-breaking technological advances. It is Australia's tallest naturally ventilated skylit atrium, which soars the full height of the building. Other innovations include a double-skin, naturally-ventilated glass façade and a hybrid system using gas and solar energy to generate cooling, heating and electricity for the building

(*continued*)

Table 2. (*continued*)

Project/Type	1 Bligh street/High rise office building—2011
Design firm	Architectus +Ingenhoven architects
Achievement	Sydney's first 6 Star Green Star high-rise building First use of double skin façade on this scale in an Australian high-riseFirst Australian building to win International High Rise Award 2012
Simulation tool	The project is entirely modelled and coordinated by Architectus using Revit
Simulation	1 Bligh Street has expanded the use of BIM. Revit Architecture was the basis for modelling and documenting the complex elliptical geometry of the building as well as analyzing the building's sustainable design performance. Models were shared with multi-disciplinary teams for structural analysis and MEP integration, and using the built-in coordination and interference checking tool to reduce errors – A building can achieve the performance objectives before it's built. This means that designers must accurately predict the behaviour of the building and its effect on the environment prior to construction. This type of rigorous analysis relies on the use of a digital simulation of a building. Unlike a traditional CAD model, building information modelling offers the level of detail necessary for such in-depth analyses and this detail is "built in" to the model during the normal course of building design. There's no specialized, redundant modelling work that needs to be done Therefore BIM is essential for cost-effective sustainable building design
Simulation target	Maximum operational performance, resource efficiency and tenant amenity environmental performance, natural daylight, shading, solar gain, atrium's natural ventilation

4.2 The Pertamina Energy Tower

SOM's holistic design approach that integrates architectural design, structural engineering, and sustainable engineering services, Pertamina Energy Tower is the world's first supertall tower for which energy is the primary design driver. Sustainable strategies at the core of its design are exposed in its simple profile yet sophisticated architectural expression [32] (Fig. 5, Table 3).

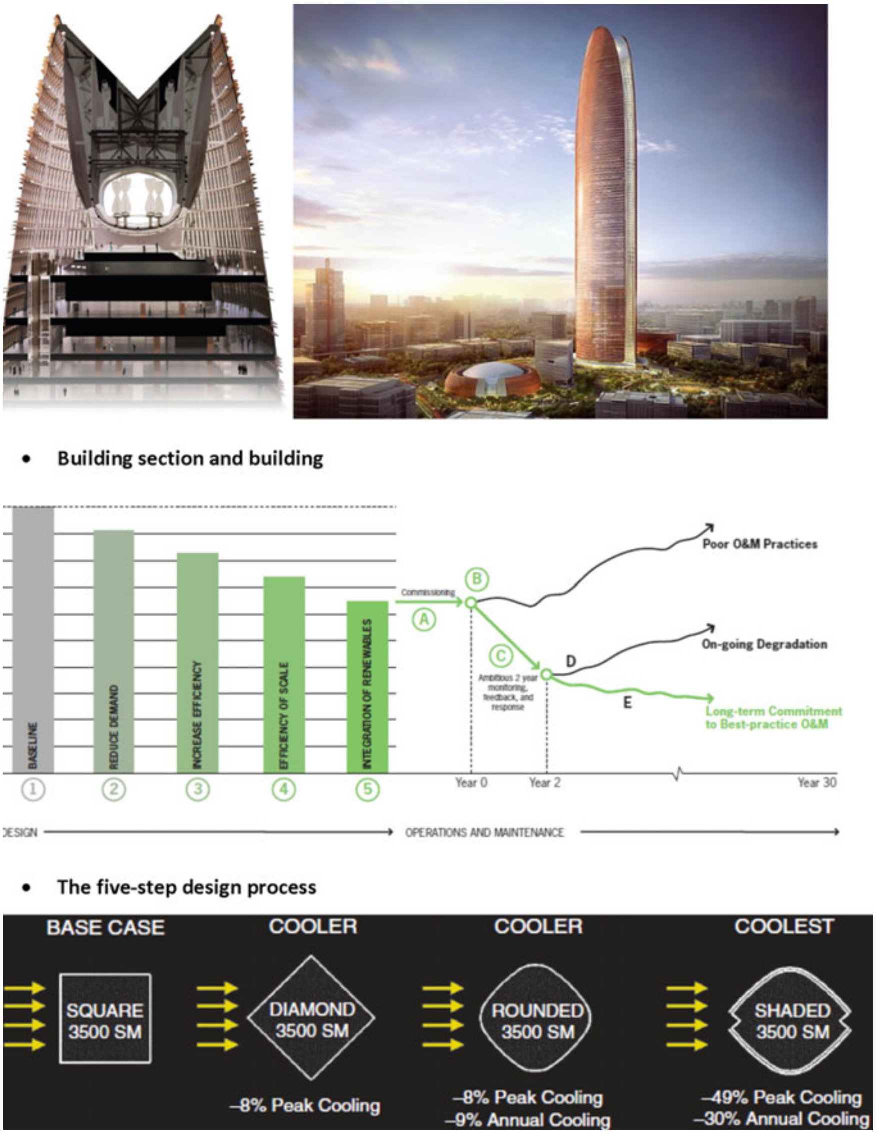

Fig. 5. Performance based studies for the Pertamina energy tower [32–34]

Table 3. The Pertamina energy tower

Project/Type	The Pertamina energy tower (2014–2020)
Location	South Jakarta, Indonesia
Description	The iconic campus will serve as a city that brings together living, working and playgrounds while serving as a model of workplace design based on sustainability, efficiency and cooperation in the city. A central energy facility will serve as the campus's energy production center—a 2000-seat conference room for conferences and shows and a public mosque, moving public spaces and common meeting areas—to be distributed with a metaphorical and metaphorical "heart" of energy and services
Design firm	SOM (Skidmore, Owings & Merrill)
Achievement	– Best Futura Mega Project: Gold Medal MIPIM Asia (2014), LEED Platinum – The world's first net-positive-supertall energy building
Simulation tool	Rhino script, BIM, Gehry Technologies Digital Project, 3D Wind Analysis, BEP calculations and simulations
Simulation	During design process advanced architectural modelling and simulation tools were used. Architectural design was going in parallel with structural, mechanical and other parts. In order to achieve coherence and consistency one integrated model was used. The SOM design team ran an enormous number of calculations and simulations to determine the best approach to address the glare problem and minimize the solar thermal load
Simulation target	Optimum building shape, design for daylight, design for minimum solar heat gain, solar and climatic analysis, design for external shading. Facade generation, differentiated floor plate and facade generation, structure, energy optimization, Kinetic facade, PV cells, The wind energy system design around the building, The geothermal energy system, Glare and Solar Energy Control (Tested) and system. Sustainable strategies at the core of its design are exposed in its simple profile yet sophisticated architectural expression. Gently tapering towards a rounded top, the tower opens up at the crown, revealing a 'wind funnel' that will take advantage of the prevailing winds and increased wind speeds at the upper floors to generate energy

5 Results: Designing the Future

In the last decades very rapid transformations have been observed in the realm of architecture due to the changes in the engineering design paradigm through the computational technologies and the changes of architectural design processes and activities, from design "recipes" to design optimization through the computational technologies. As it is emphasized a number of times in this study, architectural design action has a responsibility of being a primer actor forming the built environment for a sustainable life and is being an interdisciplinary interface evolving with new technologies and knowledge domain. Sustainability has been taken into a wider frame and considered as a performance value/theme or an optimization problem any longer. Optimization is a difficult process for each discipline. Yet, architectural optimization performs a major complexity with its many different dimensions and parameters. Besides, it has to gather and compromise different dimensions.

Architecture based on recipes or prescriptive solutions is not sufficient for an expected architecture which aims sustainability with different dimensions. Architect has to face and internalize a design practice based on performance which requires more effort, more complex process, more risk taking. In recent years, it is possible to say that the realm of architecture has overcome such complexities and design has been evolved to a design process for which optimization of the performance(s) shapes the design paradigm so called performative architecture. Design for energy efficiency in high performance buildings is an essential requirement in today's building industry. Architects needs to interfere as early as possible since minor changes will have greater effect on building's performance, this is much more related when passive design decisions are being made such as building massing and orientation, external shading and design for daylight. In order to handle all kinds of data and respond to building complexity especially in buildings with higher demands and huge size and multiple requirements it is also essential to make use of possible tools, selection of the right tool for the right task gives better results in limited time.

Not only tools are important, it worth mentioning that adopting an integrated design approach assures that different decision makers (Architect, Mechanical Engineer, Energy specialist etc.) are all working in parallel with better communication. It is concluded that the current shift towards BIM and making use of advancements in design computation is the guiding principles in contemporary practices as seen in previously explained case studies.

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Evaluation of Sustainable Education Buildings on Samples

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Abstract. Environmental problems appear due to rapid population growth, uncontrolled urbanization, rapid exhaustion of natural sources, global warming and climate changes. With an aim to find solutions to these problems and to ensure that next generations can live on this planet, the concepts of sustainable architecture and sustainable buildings gained importance. Sustainable architecture is a contemporary and interdisciplinary approach to architecture that works in compliance with environmental systems. It builds on using energy and scanty sources consciously and economically. Sustainable construction design requires the integration of ecologic, economic and socio-cultural sustainability components into the design procedure in a balanced manner. Educational buildings that serve next generations are crucial in the context of sustainable design with their contributions to social awareness and the economy in the country. In this respect, first basic criteria that constitute the sustainability in education structure design, and samples of "sustainable education buildings" chosen from different climate regions around the world have been evaluated according to the defined criteria in the present study. The evaluations have indicated that parameters such as "environmental factors, climate features, land choice, material and construction technology used" are effective in sustainable education buildings designs. The results also underline the need for different designs in the light of the data gathered.

Keywords: Sustainability · Education buildings · Sustainable design criteria

1 Introduction

Developing and growing society harms the natural environment through exposing intervention. After the 1980s with the realization of ozone layer depletion, the ecocide of people to nature and the world has become a highly controversial with actual dimension and turned a popular subject. As global warming, environment pollution, carbon dioxide emission and the following many problems are substantially connected with building industry, various new concepts such as global warming, ecology, sustainability, renewable energy, environmental design, smart structures, energy efficiency conservation are also introduced in architecture science.

The buildings included in group called sustainable architecture are generally erected from materials which generate their own energy, use natural and renewable

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energy sources, include less toxic substance or are derived from recycling. The key feature of this structure type is to damage the environment less by utilizing technological opportunities. It has been increasingly preferred in metropolis by means of these specifications. Besides, rural structure types as a part of an ecological environment and produced are available as well. The most important specification of these structures criticized by architects is to make the buildings lose their esthetics values because of their technological front.

All applications implemented within this framework notably sustainable construction are considered to be significant symbols to raise consciousness to society. Educators have already been making a great variety of studies to create awareness about consciousness of sustainability at the level of primary education. As a supporter of this understanding, the education structures itself are also considered to be a laboratory where taught theoric information can be experienced.

With reference to this motivation, within the scope of this study, first of all basic criteria creating sustainability at the education structure design was determined and later on “sustainable education structure” samples derived from different climates of the world were assessed over the sustainability criteria.

2 Sustainability and Sustainable Architecture

2.1 Sustainability

Sustainability is derived from latin “subtenir” root, which means “conservation” [1]. Operability continuation of society, ecosystem or any system having continuity until further future by preventing depletion of primary sources can be described as sustainability [2]. In other saying, sustainability is to keep alive and maintain without endangering posterity peace and health with holistic view of current economic and social needs [3]. In general manner, it can be interpreted as making the energy using in structures more productive, supervising of structural wastes, warming of buildings without losing comfort conditions according to the changing climate circumstances.

Sustainability was first dealt at the World Environment Conference in 1972 with the titles such as conservation, development and effective use of natural sources. The relations between growth and sustainability were determined in Rome Club at the same years. In 1977, sustainability was argued all science environment with the introduction of Dennis Prages “Sustainable Society” work. In 1987, sustainability was described as a concept which does not deplete sources and is balance of economy and ecosystem as a whole [4].

Sustainability gathers three main components which are economy, environment and society. Economic sustainability can be described as healthy growing and providing high efficiency with low cost for development. Environmental Sustainability is the establishment of sustainable balance to use the raw materials for the people and other creature’s needs within the context of undisturbed ecosystem and other arrangements surrounding this ecosystem. Social Sustainability is on the other hand investments implemented for the benefit of society about the health, nourishment and education issues together with social cohesion, cultural identity, diversity, holism, legislation and regulation components [5].

2.2 Sustainable Architecture and Criteria

Kremes define the sustainable architecture as an architectural design phenomenon aimed to decrease the use of natural sources and stabilize the production-consumption ratios [6]. Holding people and nature relation together, this concept is also described as an approach which should be paid attention using of sources efficiently and that climate and topographic structure should be considered input.

Shaviv organizes the purpose of sustainable architecture as (i) environmentally-conscious, (ii) minimum energy consuming (iii) designing buildings providing healthy indoor comfort for users [7].

The development of sustainability conscious in building sector gained importance as of 1990. In 1987, sustainable design was introduced as the most important subject in the field of contemporary architect and engineering by the United Nations. Shaviv sorts the primary targets of sustainable architect as efficient use of energy and sources, reduction of wastes, avoiding from harmful substances to health and nature, protection of healthy interior quality, conservation of biodiversity, flexible structure design concept [7]. When these criteria are generally evaluated, the subject under the sustainable design approach can be expressed to include many dimensions from municipal scale decision making process to manufacturing type selection of a construction material.

Sustainable architect combines conceptional ideas on the tree primary criteria. These three primary criteria are conservation, source preservation and interior quality. Construction area environment and ecosystem conservation in the sustainable architect comes to the forefront firstly with the correct selection of the land. Source Conservation can be grouped as minimizing of nonrenewable energy sources amount used structure lifecycle (energy conservation), decreasing of water used in structure (water conservation) and selection of local or renewable materials (material conservation) [8]. Interior quality consists of factors such as eligibility of breathing air, providing of thermal, visual, sensory comfort and selection of materials harmless for health [9].

3 Sustainability on Education Structure

It appears to point out importance in recent studies by which environmental conditions that education structure design are requested to have are described. Yudelson [10] emphasizes that the training of public about sustainable life and living buildings are important to be approved of sustainability before society. Within this framework, sustainable construction sample exhibition of education environments for the children to gain sustainability conscious at a young age and if possible, designing of structures in this manner have a potential. According to Prakash and Fieleing [11], sustainable design in a school environment is an dynamic model and perfect learning tool which teaches architect, engineering, construction, environmental science and harmony with nature.

It is considered that healthier and a productive environment for children within the descriptions in the terms of daylight use, clean air, low pollutant materials usage can be created. It is emphasized that schools should be designed in a manners such as comfortable as thermal, contraction with clean air, daylight and scene, having acoustic conditions, providing sports opportunities, introducing environment as a learning source, acquiring good drinkable water, supporting friendship and social development, providing social opportunities, sensible to individual security. With the sustainable school description, energy and water conservation, minimizing of garbage, avoiding potential pollutant, conservation and support of natural habitat, efficient use of cash resources, respect for the participation of people dimensions are dealt [12].

The design of education structures according to sustainability criteria is highly important for the sustainability education. What kind of relation do the sustainable architect and education can have? The answer of the question, as the Prakash and Fielding says, is that places of education themselves are assessed as learning area. It is directly related to enlightenment and comprehension, experience or life. Sustainability education ranks within the social objectives of education in the Convention on the Rights of Children and it is put emphasis on the necessity of individual awareness related to sustainable environment [13]. In this regard, the remark that the school structure notably building should be evaluated as totally learning material increases the value of sustainable school designs. In other words, it is indefinitely important that schools are turned into places gained sustainable experience. When school structures as a first formal learning area where experience and life comes true are designed with positive features, it can create a positive learning environment.

A school designed according to sustainability criteria provides the child green environment conscious, energy savings, thermal comfort and will be a factor to teach many daily beneficial information with the implementing applications. The sustainability can be ensured with the use of effective daylight, selection of minimum energy consumption methods, appropriate climate air conditioning system, use of wind power, provision of water conservation and local material use.

4 Sustainable Education Structure Samples

In 1987, development of sustainability awareness has gained importance as of 1990 since the sustainability was manifested as the most important subject in the field of contemporary architect and engineering by the United Nations. In this context, various studies in the different countries were introduced for the proliferation of sustainability awareness in the world. In this part of the study, “sustainable education structure” samples derived from different climate zones on the world was evaluated over sustainable criteria.

Structures consume natural sources during their formation and while being used, emission of harmful components effects environment. This interaction not only changes the life style of people, but also causes social life and cultures to form again. Sustainability approach which comes to light to decrease the environmental issues, create an opportunity living in a qualified environment and transfer today’s sources to the posterity provides creation and development of awareness passing down with education elements. Within this study, implemented and Aga Khan awarded (aga khan awards for architecture) three education structure within the sustainability context were examined.

4.1 Bridge School China

The Bridge School given in Fig. 1a, b is two-classroom school in the small village of Xiashi, up in the mountains of the Fujian Province in China. The bridge school (China) was designed by taking into consideration of climate conditions of area. Construction is located on the monsoon climate area. Its architect is Li Xiaodong. Construction was designed in 2008. It was designed a contemporary construction instead of traditional material selection at the design of structure.

The structure of the building is of steel trusses with steel members for supporting the roof and the floor. Site area is about 1550 m^2 and building area is 240 m^2. The building height is 6.5 m. The materials used in the building are timber and glass in walls, wood in roof and steel in structures.

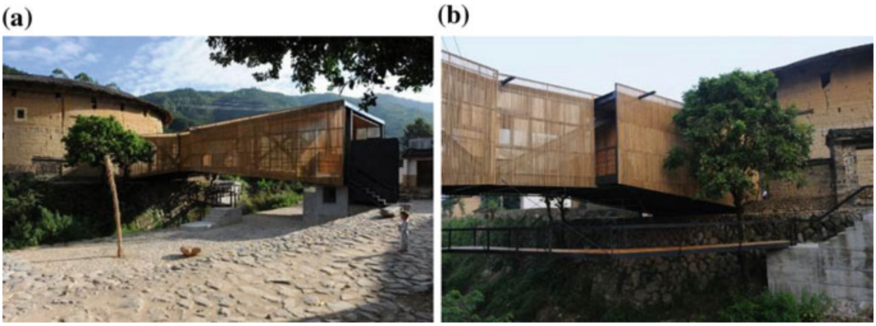

Fig. 1. **a**, **b** General view of the Bridge School [14]

A creek runs through the village and approximately at the center of the village, it is spanned by the Bridge School. The school runs north-south and on either side of it lie the two tools. The one on the north is axially in line and separated from the school by a public space paved with stones. The one on the south is oval shaped and slightly shifted from the school's axis to the east and the space in between is larger and also paved with stone.

The functions to be provided were two classrooms for 15 students each and a library or hall. As the concept of the bridge developed a pedestrian crossing was also incorporated. In designing the bridge there was some extra space in the concrete support on the southern end (higher than the one on the north) where a small shop could be incorporated (Fig. 2a, b).

The building has a simple and effective approach to climate control. It is of one room depth and there is light from both sides (from three sides if the folding or pivotal partitions are opened up) (Fig. 3a, b). During summer the windows in the steel frame can be opened and air flows through the classrooms. The facade treatment of the narrow timber strips helps moderate the light and keep the interior in shade. During winter, the cold is kept out by shutting the windows.

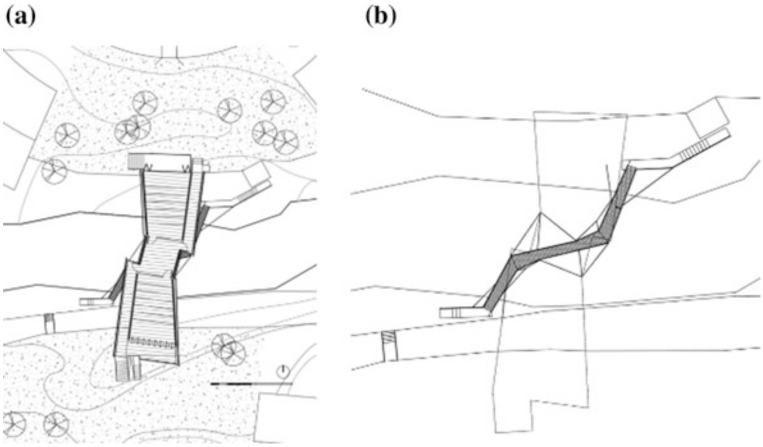

Fig. 2. **a**, **b** School and bridge plan [14]

There is no water supply in the building as there is no need for it. Toilets and water supply sources are close by. Water drains from the roofs and falls through two metal spouts into the creek. Driving rain can be kept away from the indoors by shutting the windows. The bridge school (China) examined in the context of sustainability provides sustainability criteria except for material selection. It ensures social sustainability aimed at education structure.

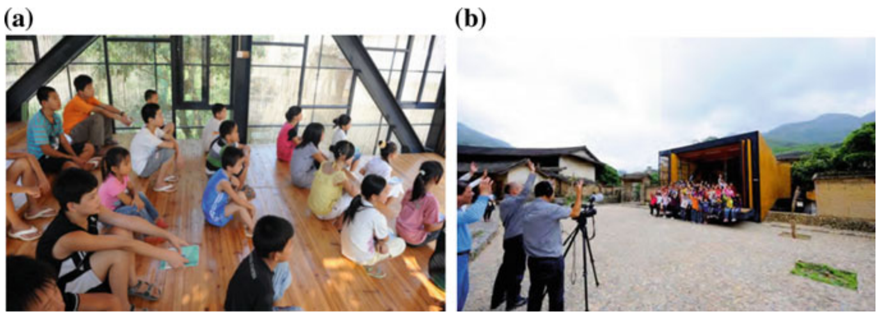

Fig. 3. **a**, **b** Interior view of classroom and view of square [14]

4.2 Gando Primary School

A new primary school, intended to accommodate 280 pupils from the village and the surrounding areas, was built in the village of Gando in Burkina Faso. Gando Primary school was designed by taking into consideration of climate conditions of area. Constructions are located on the subtropical climate area. Its architect is Diébédo Francis Kéré. Construction was designed in 1999. It was implemented a traditional design on the structure design. A simple form of the object, based on a rectangular plan is made of compressed earth blocks a material characteristic of the region, which serves as an excellent heat insulating barrier between the interior of the object and the external space. The building is characterized by a narrow and elongated shape, and the classes inside, thanks to the window openings, are aired throughout.

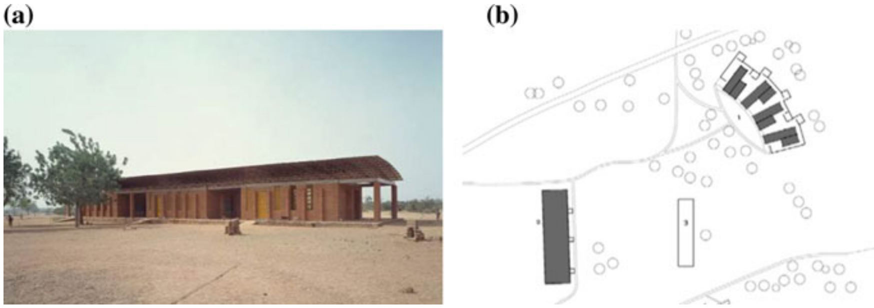

Fig. 4. **a** General view of Gando Primary School [15], **b** master plan of Gando Primary School [15]

The "Primary School for the Village of Gando" project was born of sheer necessity. Given in Fig. 4a, b. The overall School Project comprises of a school complex for 360 pupils, housing for six teachers and their families, sanitary facilities (a dry toilette), a vegetable garden with its own irrigation system, and a school kitchen. The whole Project is so designed that it can be implemented in successive stages. The structure of the building is of traditional clay-building techniques. Site area is about 30,000 m^2 and building area is 526 m^2. The building height is 7.42 m. The materials used in the building are Circular beam (concrete), Supporting clay walls, Reinforcing elements (adobe brickwork), Steel lamella elements in walls, Corrugated metal sheeting in roof and industrial cement (basic structure), stone and poured concrete (foundation), clay bricks in structures, Rampe (natural stone & cast-in-place concrete), Edge strips terrace (natural stone masonery), Terrace covering (hexagonal adobe) in outside areas.

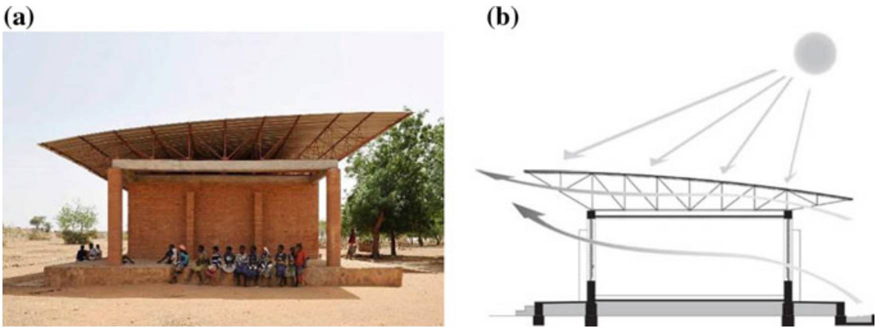

Fig. 5. **a** General view of roof structure [15], **b** schematic representation of air flow in building [15]

Climatic comfort is ensured by the building's orientation, by the nature of the wall materials and by a design that allows the unimpeded flow of air between the roof structure and the ceiling (Fig. 5a, b). Cross-ventilation is further enhanced by abundant use of shutters on the northern and southern walls. Burkina Faso is in the Sahel, the zone immediately south of the Sahara. Thus the climate in Gando is very hot and dry, with daytime temperatures easily reaching 45 degrees in the shade, and virtually no rain between October and June.

The form of the roof was designed to collect rain water into water wells (pupils, vegetable garden, villagers). The wells have been dug to provide the pupils with a source of clean drinking water, and to enable them to water the plants. The wells are also used by the villagers, reducing the distance they have to walk to their nearest water source (Fig. 6a, b).

Gando Primary school (Burkino Faso) is designed considering the climatic conditions and economic situation of the region where it is built. Traditional material selection is used at maximum level and technological equipment and materials are used where necessary. The location of the educational structure is based on wind and daylight. With the designed roof, it was aimed to collect rain water and to use it in necessary places, as well as a built-up ventilation system with water collected. The public also helped build the school. In education structure; Economic, social and ecological sustainability.

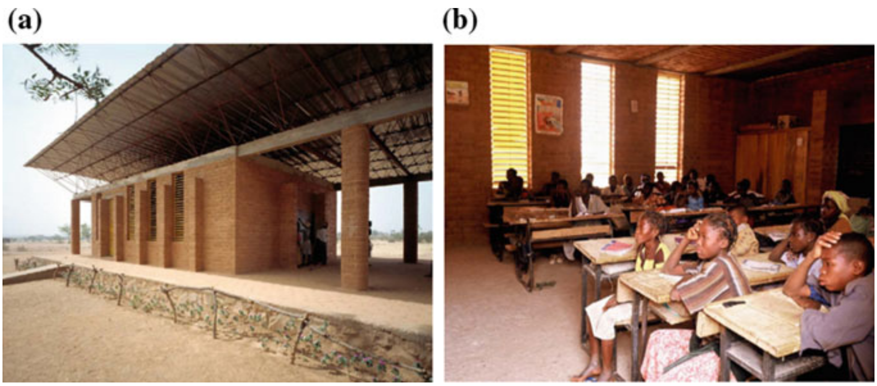

Fig. 6. **a**, **b** Interior view of classroom and view of yard [15]

4.3 Green School

The Green School creates a sustainable campus straddling both sides of the Ayung River in Sibang Kaja, Bali. The Green school is designed considering the climatic conditions of the region where it is built. The building is located in tropical climate area. The architecture is PT Bambu/Aldo Landwehr, John Hardly. The building was designed in 2006. In the design of building traditional materials were used.

The campus given in Fig. 7a, b is situated in a lush jungle with native plants and trees along with sustainable organic gardens. The campus is powered by a number of alternative energy sources including bamboo sawdust hot water and cooking system and a hydro-powered vortex generator and solar panels.

Campus buildings include: classrooms, gym, assembly spaces, classrooms, faculty housing, offices, cafes, and bathrooms. On the Green School campus are a range of inspiring architecturally significant spaces from large multi-storey communal spaces to much smaller classroom spaces. Bamboo is a local sustainable material used in innovative and experimental ways demonstrating its architectural possibilities. The result is a holistic green community with a strong educational mandate that seeks to inspire students to be more curious, more engaged and more passionate about our environment and our planet.

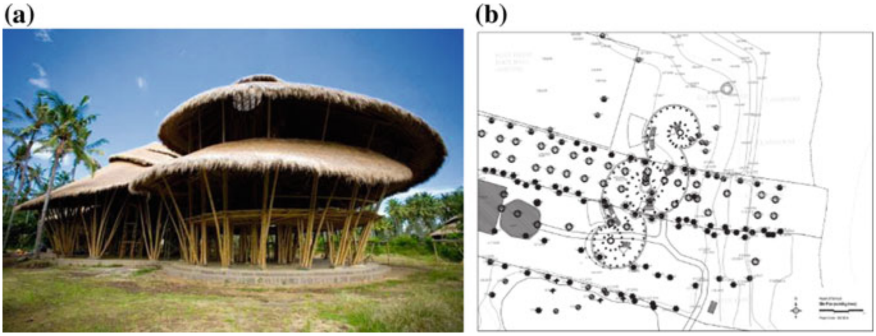

Fig. 7. **a** General view of Green School [16], **b** master plan of Green School [16]

The design team's brief includes site infrastructure as well as buildings to accommodate the school program. Site infrastructure including pathways, landscaping, alternative energy power sources, bridges, parking areas, service zones. Functional program includes: Drop off pavilions; classrooms for children from Kindergarten to Grade 9; main assembly building providing multipurpose spaces for teaching, display, gathering, offices; gymnasium; Mepantigan area for Balinese martial arts; faculty housing; principal's office; staff room; medical station; cafe or warung; composting toilets and change rooms. The structure of the building is of Indonesian bamboo. Site area is about 103,142.63 m^2 and building area is 7,542 m^2. Classroom height is 3.20 m. The materials used in the building are Alang-alang (thatching has been used in Indonesia for hundreds of years and on the island of Bali it is the traditional system of roofing) in roof, Local Mud Mixed 15% cement on floor and grass in outside areas. The Building not has any walls or doors (Fig. 8a, b).

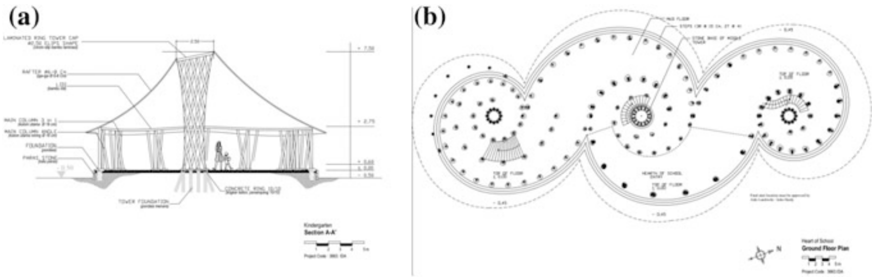

Fig. 8. **a** General view of Green School [16], **b** ground floor plan of Green School [16]

The open perimeter walls and central skylight in the main buildings at The Green School allows ample natural and diffused daylight to enter the building, allowing efficient lighting for teaching needs and eliminating the need for artificial lighting during day light hours. Additional low energy lighting is incorporated for after hour needs, powered by renewable energy such as solar panels (Fig. 9a, b).

The combination of open walls and semi-detached skylight also allows passive cross ventilation and natural upward draft to vent and cool the building. For the hottest days the central 'bubble' which is a canvas cocoon coated with natural latex is fed by a huge fan cooling the students through the peak mid-day sun.

The thermal mass of the Alang-alang grass roof protects the students from direct thermal gain as well as acting as sound absorption for acoustic comfort. The black board and storage units act as partitions and screens adding additional acoustic protection from and to adjacent classrooms.

The large roof forms all have generous overhangs provide additional protection during wet season rains. All pathways for either vehicles or pedestrians use a local volcanic rock and are permeable. Steep hillside drains water to the Ayung River. Bamboo water channels are used to direct flow.

Green School (Indonesia), which has different functions, is designed considering the climatic conditions of the region where it is built. Traditional material selection is used. The educational structure also accepts students from different countries of the world. In education structure; Ecological, economic and social sustainability.

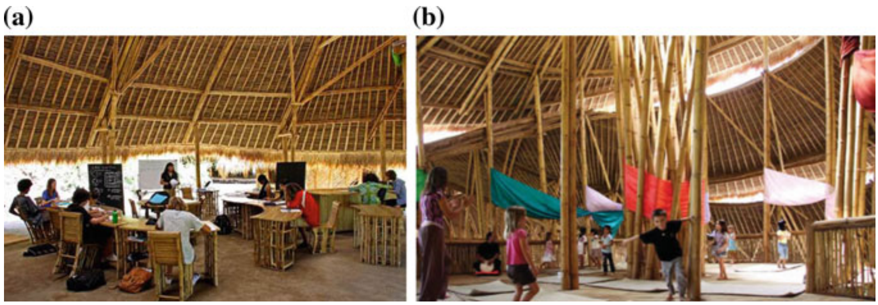

Fig. 9. **a**, **b** Interior view of Green School classroom [16]

5 Evaluation and Results

In this study, examples of "sustainable education structure" selected from different climatic regions were evaluated on the basis of sustainability criteria. First of all, it has been determined that climate is the most important factor in design. The forms of building and passive climate options are changing in the direction of climate data. However, in the context of sustainability, the use of local or recycled materials in the relevant geography is another important influence on design. In addition, it has been observed that different building technologies have been applied in the structure of structures according to economic and regional conditions. It is seen that economic and environmental sustainability can be achieved through the material and construction technologies used in the region and the required climate, while social sustainability is differentiated in order to provide social integrity, cultural identity—diversity and integrality for the benefit of society (Table 1).

Table 1. Analysis of sustainability components of buildings

	The Bridge School	Gando Primary School	The Green School
Climate	Monsoon	Subtropical	Tropical
Material	Timber, glass, steel, wood	Clay brick, metal sheeting, concrete, stone	Bamboo, local mud-cement
Water	Not utilize for pupil and environment	Utilize for pupils, vegetable garden, villagers	Not utilize for pupil and environment
Energy	Sun energy–wind energy	Sun energy–wind energy	Sun energy–wind energy
Structure system	Modern system (steel)	Traditional system (clay-building)	Traditional system (bamboo)

As mentioned in Davis [17], children should not only stay at the theoretical level in order to be able to reach the goal of environmental awareness. It will be possible at a young age to introduce sustainability awareness to future designers and engineers through various channels, such as the creation of guidelines for sustainable school design and the development of sample projects for schools.

It is necessary to make use of structures shaped by the principles of sustainability, especially from educational structures, as a learning resource. In this context, it will be of great benefit to design priority sustainable education projects in order to ensure public awareness for sustainability in most countries. In recent years, it seems that the importance given to sustainability awareness in the construction sector in most countries is increasing. It is intended to provide an "Environmental Friendly Green Building National Criteria List", which is compulsory to be observed by some government agencies in particular. In this context, important initiatives contributing to the field of work are carried out by non-governmental organizations.

Despite its importance, it is also known that the number of designs that still consider sustainable design criteria is not very large. From this point of view, it is thought that this study, which compiles the findings in the literature, will contribute to the development of new designs.

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Effect of Hyper-plasticizer Additive Rates on the Properties of Polypropylene Fibre Tempered Concretes

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Abstract. In this study, effect of different rates of hyper-plasticizer additives on the physical and mechanical properties of polypropylene fibre tempered concretes was investigated. The factors of slump and compaction, which are fresh concrete properties, were also examined. In the study, different types and rates of polypropylene fibres were used. Polypropylene fibres and hyper-plasticizer additives were used in three different rates in the mixture. As polypropylene fibre amount increased in the mixture, hyper-plasticizer additive amount also increased. Fresh concrete slump values were measured between 15 and 19 cm. Impaction factor value was between 0.89 and 0.99. In some mixtures, it was seen that the relation between the slump value and impaction value was disrupted. Abrasion and water absorption values, which were physical properties of the hardened concrete, were calculated. In abrasion tests, it was seen that concretes with C, D and E fibres were eroded less. Polypropylene fibre additive increased the water absorption value of concrete. Its effect on splitting-tensile strength, which was a hardened concrete property, was examined. In splitting-tensile strength experiment, 15 × 30 cm cylinder samples were used. It was seen that the polypropylene fibres increased the splitting-tensile resistance of the concrete at the rate of 80% compared to the polypropylene fibre additive free mixture. Also, deformation meters were placed on the sample in splitting-tensile resistance. Horizontal deformations of samples were measured at the moment of breaking. While horizontal deformation values increased in 7 day samples compared to propylene fibre additive-free mixture, they decreased in 28-day samples. 7 day horizontal deformation values of the samples were measured to be higher than the 28 day horizontal deformation values. This situation can be explained with brittleness of the concrete at the end of 28 days as it gains resistance.

Keywords: Fibre · Hyper-plasticizer · Fresh concrete · Abrasion
Splitting-tensile

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1 Introduction

Recently, polypropylene fibers have been used in the building materials, widely. Many studies have been performed regarding usage of polypropylene fibers in concrete and mortars [1–7]. In the study in which polypropylene fibers additives of 0.45, 0.90 and 1.80 kg/m^3 by weight were used, water absorption and water permeability values increased and wet shrinkage values decreased as well with fly ash and polypropylene fibre additives. They reported that freeze-thaw resistance of polypropylene fibre reinforced concrete slightly increased compared to non-fibrous concrete [8]. They reported that unit weights of concretes, reinforced with polypropylene fibre and fly ash in the ratio of 0.05, 0.1 and 0.20% by volume, decrease even a little, workability decreases, workability increases with addition of fly ash.

The abrasion losses and water absorption values of the concrete, reinforced with fibre in the ratio of 0.2% by volume, increased [9]. 900 g/m^3 polypropylene fiber additive by weight increased concrete abrasion resistance from 0.2860 to 0.3966% [10]. 910 g/m^3 polypropylene fiber additive by weight increased concrete abrasion resistance by 21.24% [11]. The abrasion losses of 0.18% was obtained in the concrete, reinforced with 425% polypropylene fibre by volume. It didn't have much effect on unit weight [12]. Water absorption and water permeability values of concrete, reinforced with 0.45, 0.90 and 1.80 kg/m^3 polypropylene fibre by weight, increased with fly ash and polypropylene fibre additives and wet shrinkage values of those decreased [13]. Industrial wastes and polypropylene fibre additive of 0.2% by volume increased capillary absorption value and water absorption value by weight of concrete [14].

Water absorption values of concrete, reinforced with polypropylene fibre of 2% by volume, and that of concrete, in different water to cement ratios and reinforced with different plasticizer additives, decreased. Abrasion resistance value reliased as 0.8 in additive inclusion of 2%, and 1.97 in additive inclusion of 1% by volume [15].

It was stated that 3.5 kg/m^3-weighed fiber-reinforced concretes are effective, safe and low-cost solutions for road structuring; inside tunnels particularly noting [16]. Addition of 1%-volume fibres procured from recycled PETs increased the flexure strength of the concrete [17]. Addition of 0.1 and 0.5%-volume polypropylene fiber on the other hand decreased compression and flexure strength of the concrete [18]. 12 mm-long polypropylene fiber additive containing metacholinium and art-of-stone-cutting flexure increased its deflection ratio in strength [19]. 0.25, 0.50 and 0.75% polypropylene fiber ratio in different sizes decreased concrete density by 10–30% but increased compression strength by a ratio of 14% [20]. 0.5%-volume polypropylene fiber additive lowered the compression strength by approximately 37.5% whilst this ratio increased the flexure strength by 30% [21]. It was reported that fiber additive triggered high-unit deformation in low-strength concrete in particular and the fiber created a bridge effect whilst in high-strength concrete it diminished the bridge effect of fibres. It was thus concluded that fiber additive increased the ductility of concrete [22]. 1 and 1.5% volume carbon fiber additive, when pure concrete compression strength was measured as 52.8 MPa, compression strength values of carbon fibrous concrete fluctuated between the ratios of 51.2–53 MPa. It was thus concluded that not a significant amount of change occurred in compression strength [23].

Vertical abrasion and water absorption tests of concretes with hyper plasticizer and polypropylene fibre additives in different ratios were performed in this study. The effect of polypropylene fibre additive and hyper-plasticizer admixtures ratio on abrasion and water absorption of hardened concrete was investigated. Splitting-tensile strengths of samples were analyzed. Besides, horizontal deformations in splitting-tensile strength were measured and the effects of different fibres on horizontal deformation were also investigated.

2 Test Method

2.1 Materials and Specimens

Only CEM I 42.5 R type cement was used as a binding agent. Hyper-plasticizer was used as admixture. Amount of admixture was also increased with increasing of fiber in the mixtures to preserve the fluency of fresh concrete. The additive ratios in the mixtures were, 0.6, 0.8, 0.9 and 1.1% of weight of cement. Sand of 0–4 mm and crushed stone with dimensions of 7–15 and 15–22.4 mm were used as aggregate. As polypropylene fiber, 8 different fiber types listed such way A, B, C, D, E, F, G, H were employed (Fig. 1; Table 1).

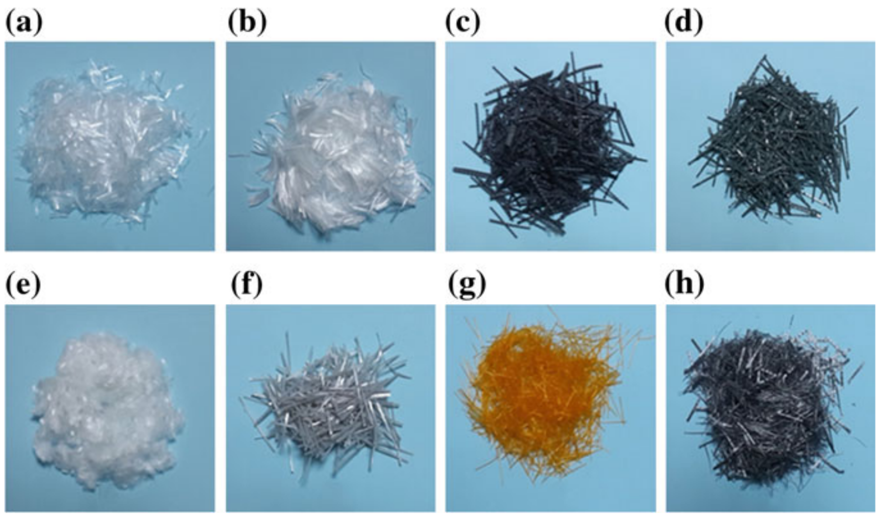

Fig. 1. Polypropylene fibres

Table 1. Technical properties of polypropylene fibers

Fiber	Length (mm)	Width (mm)	Thickness (mm)	Shape
A	12	0.48	0.30	Circular
B	19	0.48	0.30	Circular
C	30	1.20	0.30	Ribbed
D	30	1.20	0.45	Double hook
E	30	0.48	0.30	Circular
F	40	0.433	0.433	Flat
G	18	0.3	0.50	Circular
H	20	0.6/1.3	0.18/0.22	Flat

2.2 Mixture Ratios

Experimental studies were carried out on 25 series of concrete mixtures. One of these mixtures was a control mixture and the others were mixtures with polypropylene fibers. Fiber ratios in the mixture were 600, 1200 and 1800 g/m^3. The polypropylene fibers were indicated by A, B, C, D, E, F, G, and H. For example; A6 indicates containing an additive of 600 g/m^3 of fiber A, B12 indicates containing an additive of 1200 g/m^3 of fiber B, C18 indicates containing an additive of 1800 g/m^3 of fiber C. The control mixture was indicated with CNL. Water to cement ratio (W/C = 0.52) was stabilized in all mixtures. The mixture ratios were given in Table 2.

Table 2. The mixture ratios

Ingredients		CNL	Mixtures with fibre (g/m^3)		
			600	1200	1800
Sand (0–4 mm)	(kg/m^3)	1127	1127	1127	1127
Gravel (7–15 mm)	(kg/m^3)	451	451	451	451
Gravel (16–22.4 mm)	(kg/m^3)	301	301	301	301
Water	(kg/m^3)	156	156	156	156
Cement	(kg/m^3)	300	300	300	300
Polypropylene fiber	g/m^3	–	600	1200	1800
Admixture	%	0.6	0.8	0.9	1.1
Water to cement ratio	W/C	0.52	0.52	0.52	0.52
Unit weight	(kg/m^3)	2335	2335	2335	2335

3 Concrete Tests and Findings

3.1 Fresh Concrete Properties

The slump value of the control sample was measured as 170 mm. The slump values of the mixtures were measured in the range of 150–190 mm (Table 3). The compression factors of the mixtures were measured in the range of 0.89–0.99 (Table 3).

Fiber additive decreased workability and increased the need of hyper-plasticizer additive. It was observed that fiber additives, being added into mixtures, decrease workability of fresh concrete. Fiber agglomeration and segregation weren't observed in the mixtures with fiber additive of 600 and 1200 g/m^3. However, when the amount of fiber in the mixture exceeded the value of 1800 g/m^3, agglomeration and segregation of fibers were observed. Therefore, the amount of fiber didn't exceed the value of 1800 g/m^3.

Table 3. Fresh concrete properties

Mixture	Slump (cm)	C.F	Mixture	Slump (cm)	C.F
CNL	17	0.97	CNL	17	0.97
A/6	17	0.97	E/6	17	0.96
A/12	18	0.93	E/12	16	0.95
A/18	16	0.91	E/18	15	0.94
B/6	16	0.94	F/6	15	0.96
B/12	17	0.89	F/12	17	0.96
B/18	15	0.89	F/18	17	0.94
C/6	16	0.99	G/6	16	0.95
C/12	19	0.93	G/12	17	0.95
C/18	17	0.93	G/18	18	0.94
D/6	17	0.93	H/6	18	0.95
D/12	17	0.94	H/12	19	0.96
D/18	17	0.95	H/18	19	0.96

3.2 Vertical Abrasion Test

Test was done, abrading the samples, 70 × 70 × 115 mm in size, prepared in accordance with the EN 1338 standard, with F80 aluminum oxide abrasive powder in 75 min/cyclic at vertical abrasion device. The abrasion depths were measured from three points on the abraded surface and the average depth of abrasion was calculated (Figs. 2 and 3).

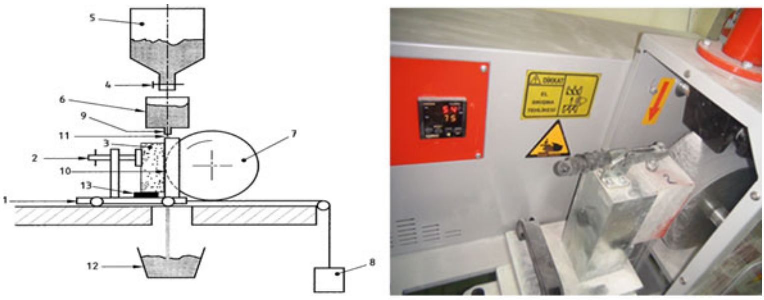

Fig. 2. Vertical abrasion test device

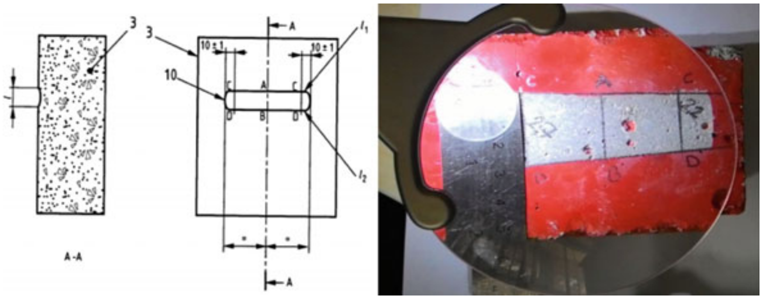

Fig. 3. Measurement of abrasion depths

Abrasion widths on the samples were measured at the end of the tests. Abrasion widths of C12, D6, D12 and E12 samples were measured lower than those of control sample. In other words, these samples exhibited less abrasion compared to control samples. The abrasion widths of other samples were measured higher than those of control sample. The abrasion width of the control sample was measured as 21.5 mm. The abrasion widths of the fibrous samples vary between 20 and 27.5 mm. The highest abrasion width was measured at the sample C6. The lowest abrasion width was measured at the sample D6 (Fig. 4).

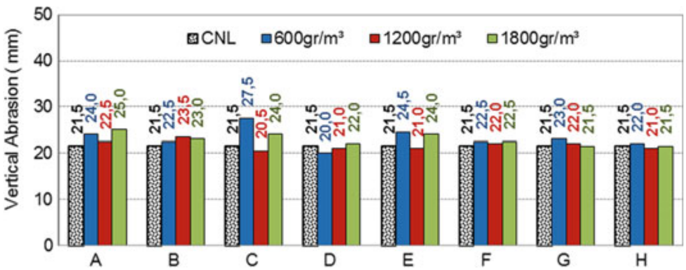

Fig. 4. Vertical abrasion test results

3.3 Water Absorption Test

The samples, weighing less than 5 kg, were prepared for total water absorption test. The samples dimensions were 70 × 70 × 115 mm. The samples prepared were maintained in the container filled with water until they reached to a constant mass (M_1) at temperature of 20 ± 5 °C. The water layer was adjusted in such a way that it would be kept at least 20 mm over the samples. The samples were maintained in water at least for 3 days and weighed every 24 h. The samples, getting out of water for weighing operation, were dried with a damp cloth, soaked and dewatered. Then weighing was conducted.

When the mass difference between two successive weighing yields less than 0.1%, steady saturated mass was considered to be reached. The samples, considered to have reached to saturated mass, were placed to a drying oven so as to remain at least 15 mm distance between them, and they were dried until reaching to a constant dry mass (M_2) at temperature of 105 ± 5 °C. The samples were maintained in the drying oven at least for 3 days and weighed every 24 h. When the mass difference between two successive weighing yields less than 0.1%, constant mass was considered to be reached.

The water absorption value (Wa) of each sample was calculated (Fig. 5). Fiber ratio and admixtures contained in the mixtures increased water absorption values of the samples. The water absorption value of the control sample was calculated as 3.43%. The water absorption values of the fiber mixtures vary between 2.79 and 4.63%. The lowest water absorption value was calculated in D12 mixture, the highest water absorption value was calculated in F12 mixture. The water absorption value increased in all fiber and admixture ratios of the mixtures with B, E and H fibers. It exhibited change depending on ratio of fiber and additive in other fibers.

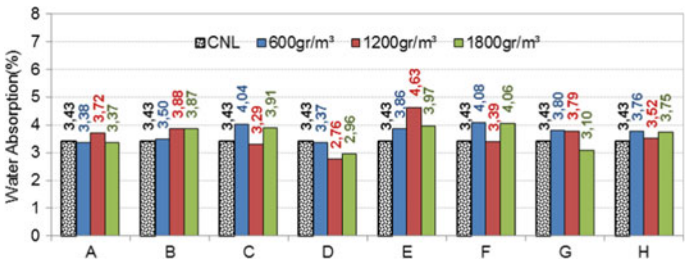

Fig. 5. Water absorption

3.4 Splitting-Tensile Experiment

7-day and 28-day splitting-tensile strengths of cylinder samples were measured in accordance with the EN 12390-6 standard. As 7-day splitting-tensile strengths were analyzed it was observed that as fiber content in C and G fibrous mixtures increased, a corresponding increase was also measured in their splitting-tensile strengths. The highest splitting-tensile strength in fibrous mixtures A was measured in A6 sample. In A12 sample it decreased compared to A6 sample but in A18 sample it increased compared to A12 sample. The highest splitting-tensile strength in fibrous mixtures B was measured in B6 sample. Splitting-tensile strengths of B12 and B18 samples received approximate values.

The highest splitting-tensile strength in fibrous mixtures D was measured in D6 sample. Splitting-tensile strengths of D12 and D18 samples were measured lower than the D6 sample. In fibrous mixtures E and F, splitting-tensile strengths of E6 and F6 samples were measured to be lower compared to control sample. In E12, E18, F12 and F18 samples as the fiber amount in mixture increased their splitting-tensile strengths demonstrated a parallel rise. In the 7-day splitting-tensile strength, the best performance was observed in fibrous mixtures H. In H12 sample, splitting-tensile strength increased by 92.99% when compared to the control sample (Fig. 6).

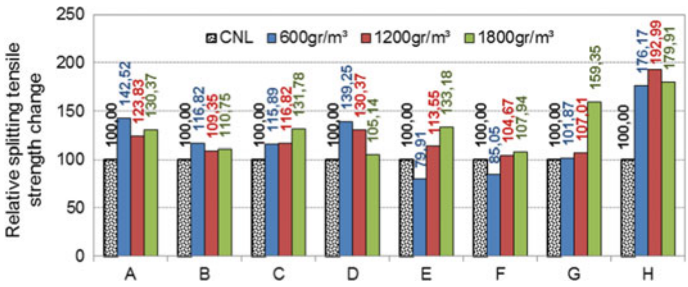

Fig. 6. Relative splitting-tensile strength change

As 28-day splitting-tensile strengths were analyzed it was spotted that splitting-tensile strengths of F6 and G6 mixtures were measured to be lower compared to control sample. In the rest of mixtures, splitting-tensile strengths varied with respect to fiber ratio. In the entire set of mixtures, there was a relative rise compared to control sample. The best performance was measured in fibrous mixtures H. The highest splitting-tensile strength was measured in mixture H12. 7-day and 28-day splitting-tensile strengths of fibrous mixtures H were identical (Fig. 7).

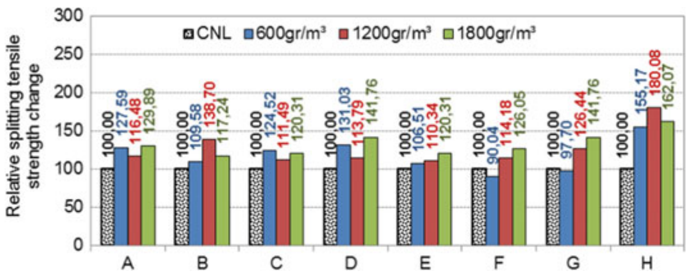

Fig. 7. Relative splitting-tensile strength change

3.5 Horizontal Deformation

Horizontal deformations of samples in splitting-tensile experiment were measured. In splitting-tensile experiment the transducer, positioned in the exact center of the sample, could measure horizontal deformation in both sides (Fig. 8).

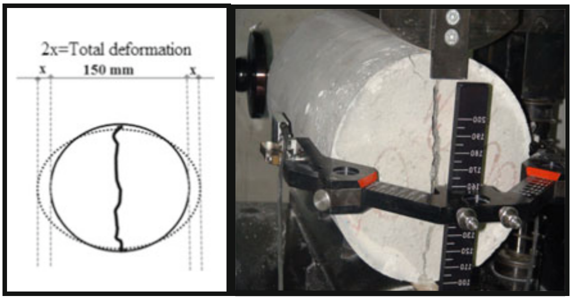

Fig. 8. Horizontal deformation measurement

As horizontal deformations in splitting-tensile strength were analyzed it was identified that in 7-day samples, among all mixtures with B, D, E, F and G fibers, horizontal deformation value decreased compared to control sample. The lowest deformation was measured in sample E6. In sample E6, it decreased approximately by 41% compared to control sample. In fibrous mixtures A it increased in fiber A6 solely. This same value decreased in other mixtures. In fibrous mixtures C there was a slight rise. The highest horizontal deformation increase was measured in fibrous mixtures H. In sample H6, there was a rise of 138% (Fig. 9).

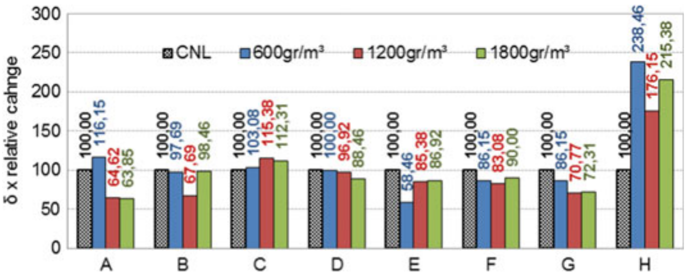

Fig. 9. Horizontal deformation change (7-day)

As 28-day horizontal deformations of samples are analyzed it can be detected that horizontal deformation values of samples B12, D12, E12 and G12 increased compared to control sample whereas in other fiber ratios there was a fall. Within all fiber ratios the ratio was lower compared to control sample in A and F fibrous mixtures. Horizontal deformation of sample C6, compared to the rise in control sample, decreased in the rest of fiber ratios. The best horizontal deformation value was once again measured in H fibrous mixtures. Horizontal deformation value of H12 sample increased approximately by 83% (Fig. 10).

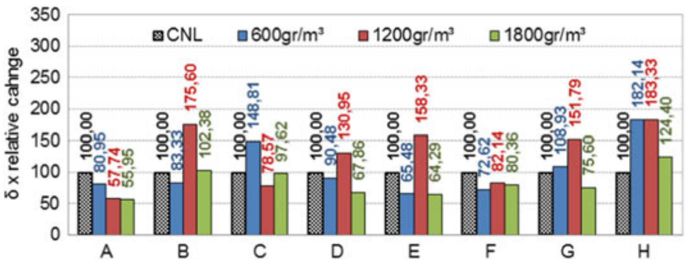

Fig. 10. Horizontal deformation change (28-day)

Figure 11 displays the images of certain samples in the aftermath of splitting-tensile strength. As the amount of fiber additive in the mixture was increased, there was less disintegration of the sample. Specific fibres performed a better bridge performance between two parts. Fibers C and D in particular performed better as bridges since they were clip-hook and ribbed shape. The same instance was evident in fiber H as well. This instance also positively contributed to horizontal deformation at the moment of splitting-tensile.

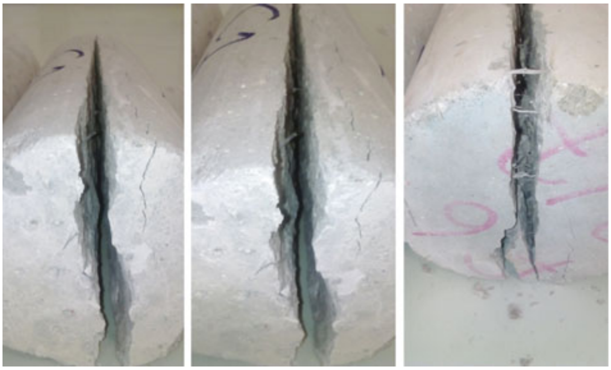

Fig. 11. Post-experiment samples

4 Conclusions

It was seen that polypropylene fiber additive in mixture decreases the workability of fresh concrete. Plasticizer additive need is increased with increasing fiber additive ratio. It was seen that segregation occurred especially when fiber additive of 1800 g/m^3 was exceeded and fibers formed agglomeration in fresh state mixture. Therefore, fiber additive is recommended not to exceed value of 1800 g/m^3 for achieving a proper workability performance in fresh concrete. The abrasion width of the control sample was measured as 21.5 mm. The abrasion widths of the fibrous samples vary between 20 and 27.5 mm. The highest abrasion width was measured at the sample C6. The lowest abrasion width was measured at the sample D. It can be said that amount of fiber additives and admixtures in mixtures have no systematic effect on concrete abrasion.

Fiber ratio and admixture in mixtures increased water absorption values of the samples. This case can be explained with more easily penetration of water into gaps, formed by fibers in concrete. Water absorption value of the control sample was calculated as 3.43%. Water absorption values of fibrous mixture vary between 2.79 and 4.63%.

Fibres increased the splitting-tensile strength of concrete. In fibrous mixtures, at 7-day, the highest splitting-tensile strength was measured in H12 sample and the lowest value was measured in E6 sample. Splitting-tensile strengths of 7-day E6 and F6 samples were measured to be lower than splitting-tensile strength of control sample. At 28-day, highest splitting-tensile strength was measured in H12 sample and the lowest value was measured in F6 sample. 28-day splitting-tensile strengths of all mixtures were measured to be higher than 7-day splitting-tensile strengths. In splitting-tensile strength the best performance was measured in fiber H. 7-day splitting-tensile strength of H12 sample increased around 93%, whilst 28-day splitting-tensile strength roughly increased by 80%.

In terms of horizontal deformation, the best performance was measured in fibrous mixtures H. In all fibres except fiber H, horizontal deformation values of 7-day samples primarily decreased. In H-fibrous 7-day samples, horizontal deformation value increased approximately by 138%. In H-fibrous mixtures among 28-day samples there was an approximate increase by 83%. It can be concluded that fiber H provided a better level of ductility to the concrete. In 28-day horizontal deformations of samples, particularly in 1200 g/m^3 fiber ratio, there was a significant improvement.

In connection with the rise of fibers in mixtures there was less disintegration in the sample utilized for splitting-tensile experiment. It was identified that fibres played the role of a bridge between two separated parts in splitting-tensile experiment. The incident was more evident in fibres C, D and H at most. Since fibres C and D were clip-hook and ribbed it was evidenced that fibres enabled greater bonding with the mortar. Conducted experiments manifested that the best ideal fiber ratio was between the range of 600 and 1200 g/m^3. As the fiber ratio inside concrete exceeded 1200 g/m^3 it started to pose a negative impact on the splitting-tensile strength and deformation.

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Use of Waste Concrete in Cement Production

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Abstract. Use of waste concrete in tempered cement production was examined in this study. Waste concretes were used in limestone-tempered cement production. In tempered cement production, 5, 10, 15, 20 and 28% milled waste concrete was added instead of the limestone. As waste concrete, pressure experiments were performed on those and 15 cm cube samples were used. Compressive strength of waste concretes was 65 MPa on average. At the end of the study, six (6) types of cement were produced, one being without waste concrete addition in total. Chemical, physical and mechanical properties of waste concrete tempered and waste concrete additive free concretes were examined. 2, 7 and 28 day pressure and Flexural strengths of the produced cements were tested. In compressive strength, it was seen that the waste concrete additive-free cement reached its compressive strength values. Waste concrete addition increased the Flexural strength of the cement. Waste concrete addition slightly decreased the water need of the cement. Not a large change was observed in the setting beginning and setting end values. 20 and 28% waste concrete additions instead of limestone decreased the volume expansion value of cement. It slightly decreased its specific weight value. No big changes were observed in its chemical properties. It was concluded that waste concrete can be used instead of limestone especially in mixed cement production. Thus, waste concrete can be put in use for cement production and ecological balance can be contributed, too. However, sortation should be made well in order to use waste concrete in cement production.

Keywords: Waste concrete · Tempered cement · Mechanical properties
Physical properties · Chemical properties

1 Introduction

Taking the aggregate constantly from the nature causes ecological imbalance [1–4]. Construction sector is a source consumer and waste producer [5, 6]. Construction waste materials are generally used as filling material [7, 8]. Waste concrete comprise half of construction waste [9, 10]. Use of waste concrete in structural concretes is important in terms of the environment [11]. In Turkey, after the earthquake in 1999, 2 million tons of waste concrete was produced only in Adapazarı province.

It was estimated that the waste concrete value was 5.5 million dollars [12]. This situation increased the studies for using waste concrete as aggregate in fresh concrete [13, 14]. Its most negative effect on use in structural concrete is the soil mixture

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cemented on it [15]. Grain dimension distribution of recycled aggregate in the concrete is an important factor [16]. Water absorption value is high in recycled aggregates [1, 6, 16–19]. Recycled aggregate and rubber pieces were used in green concrete production [20]. In order to improve the performance of the concrete produced by using recycled aggregate, certain rates of minerals were added in the cement. [21, 22].

The way of using construction and demolition wastes without harming the environment is transforming those into aggregate. Recycled aggregates are put in use generally in construction foundations, coverings and basin stabilization [23]. The importance of using super-plasticizer in the concrete produced using recycled rough aggregate obtained from precast waste wastes was emphasized [24]. The limestone used in cement production is also taken from the nature. The evaluation of construction wastes, ceramic wastes, building tile wastes, floor tile wastes, and marble powder wastes is important in terms of ecological balance. A lot of research has been done on the use of these wastes in cement production [25–34].

In this study, use of waste concretes in cement production was examined. Experimental studies were carried out especially for its use in limestone tempered cement production. The target was put the waste concrete, which comprise the half of construction waste, in good use in tempered cement.

2 Test Programs

2.1 Materials and Specimens

In the experimental study, waste concretes were used instead of limestone in Cem II B-L limestone tempered cement production. As waste concrete, concrete pressure test was performed on it and 15 cm cube samples were used (Fig. 1). The cement used in waste concrete production was Cem I 42.5 R. 5, 10, 15, 20 and 28% milled waste concrete was used instead of limestone additive in Cem II B-L limestone tempered cement production. C1 indicates the limestone cement, C2, C3, C4, C5 and C6 indicate 5, 10, 15, 20 and 28% milled waste concrete tempered cements, respectively. Limestone, Clinker, Gypsum and Waste Concretes were milled in laboratory type millers (Figs. 2 and 3).

Mixing materials were milled in 27 $\times$ 30 min. interval. 6 types of cements were produced in total, 5 being waste concrete tempered and one being additive free. The study was carried out in laboratory. Waste concrete tempered cement compound rates are given in Table 1.

Fig. 1. Waste concrete

Fig. 2. Clinker

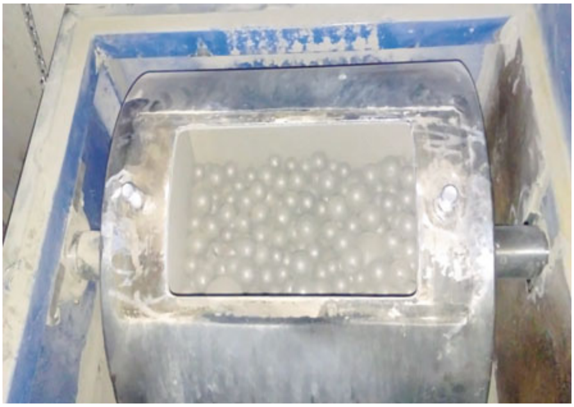

Fig. 3. Laboratory type millers

Table 1. Waste concrete tempered cement compound rates

Cement type	Clinker (%)	Limestone (%)	Trass (%)	Gypsum (%)	Waste concrete (%)
C1	63	28	5	4	0
C2	63	23	5	4	5
C3	63	18	5	4	10
C4	63	13	5	4	15
C5	63	8	5	4	20
C6	63	0	5	4	28

2.2 Waste Concrete Compounds

Waste concrete unit weight was 2395 kg/m^3. Total aggregate amount was 1830 kg/m^3. The cement type used in waste concrete was CEM I 42.5 R. Cement amount was 400 kg/m^3. Water amount was 165 kg/m^3. In the waste concrete production, plasticizer chemical additive was used at the rate of 1.3% of cement amount. Approximately 93% of waste concrete was cement and aggregate in weight.

3 Cement Experiment and Findings

Chemical, physical and mechanical properties of waste concrete added limestone tempered cements were examined. Experiment results are given in Tables 2 and 3. Limestone tempered cement's (Cem II B-L) and limestone tempered waste concrete added cement's chemical, physical and mechanical properties were compared. Not very big changes were observed in Blaine values of the cements. While volume expansion value was measured as same in C1, C2, C3 and C4 cement types, they were measured as half in C5 and C6 cement types (Table 2). Waste concrete admixture reduces special weight of cement. Waste marble powder has increased the special weight of cement [30].

Table 2. Physical and mechanical properties of waste concrete tempered cements

Property	C1	C2	C3	C4	C5	C6
Milling duration (mn)	30	29.5	29	28	28	27
Blaine (g/cm^2)	4.33	4.40	4.41	4.43	4.43	4.41
Special weight (g/cm^3)	3.01	3.02	2.99	2.93	2.92	2.94
Screen analysis (32 μm)	31.0	28.4	30.3	32.0	30.5	29.5
Water need (%)	28.0	27.8	27.8	27.4	27.5	27.5
Setting beginning (min)	190	180	180	195	200	210
Setting end (min)	250	240	240	250	260	270
Volume expansion	1.0	1.0	1.0	1.0	0.5	0.5
Compressive strength (2 Day/MPa)	15.0	17.2	15.0	15.3	14.8	14.7
Compressive strength (7 Day/MPa)	24.1	26.2	24.0	22.8	23.3	24.0

(*continued*)

Table 2. (*continued*)

Property	C1	C2	C3	C4	C5	C6
Compressive strength (28 Day/MPa)	30.3	33.0	30.4	29.9	29.7	30.6
Flexural strength (2 Day/MPa)	2.97	3.43	2.93	3.03	3.10	2.87
Flexural strength (7 Day/MPa)	4.27	4.13	4.27	4.23	4.23	4.23
Flexural strength (28 Day/MPa)	4.97	5.23	5.37	5.13	5.00	5.23

When the chemical properties of cements were examined, Aluminum oxide and ferrous oxide values were increased in waste concrete tempered cements. There was no great change in CaO versus SiO_2 contents. Insoluble residue amount decreased in waste concrete tempered cements (Table 3).

Table 3. Chemical properties of waste concrete tempered cements

Property (%)	C1	C2	C3	C4	C5	C6
SiO_2	15.99	16.26	16.12	16.09	15.86	15.84
Al_2O_3	4.35	4.39	4.42	4.39	4.41	4.46
Fe_2O_3	2.41	2.48	2.44	2.44	2.43	2.47
CaO	59.11	59.23	58.82	58.95	58.88	59.13
MgO	1.58	1.60	1.59	1.61	1.61	1.63
Na_2O	0.12	0.13	0.11	0.13	0.13	0.13
K_2O	0.46	0.48	0.46	0.47	0.45	0.46
SO_3	2.46	2.40	2.51	2.55	2.61	2.68
Insoluble residue	3.34	3.00	3.13	3.08	2.74	2.32
Ignition loss	13.66	12.73	13.48	13.36	13.64	13.41

Setting beginning durations of the cements differed between 180–210 min. Setting beginning duration of waste concrete free cement was 190 min. In 5 and 10% waste concrete additions instead of limestone, setting beginning duration of cement decreased to 180 min. In 15, 20 and 28% waste concrete additions instead of limestone, setting beginning duration of cement increased. The highest setting beginning duration was 210 min in C6 cement with 28% waste concrete addition. It has been observed that setting period is reduced in a study that ceramic, red clay brick and concrete waste were used for 10% cement production [26]. Waste marble powder was mixed with cement clinker at different ratios (2.5, 5, 7.5 and 10% by weight) for cement production. It was observed that the contribution of waste marble dust did not affect the setting period [30].

Setting end durations of the cements differed between 240–270 min. Setting beginning duration of waste concrete free cement was 250 min. In 5 and 10% waste concrete additions instead of limestone, setting beginning duration of cement decreased to 240 min. In 15, 20 and 28% waste concrete additions instead of limestone, setting beginning duration of cement increased. The highest setting beginning duration was 270 min in C6 cement with 28% waste concrete addition (Fig. 4).

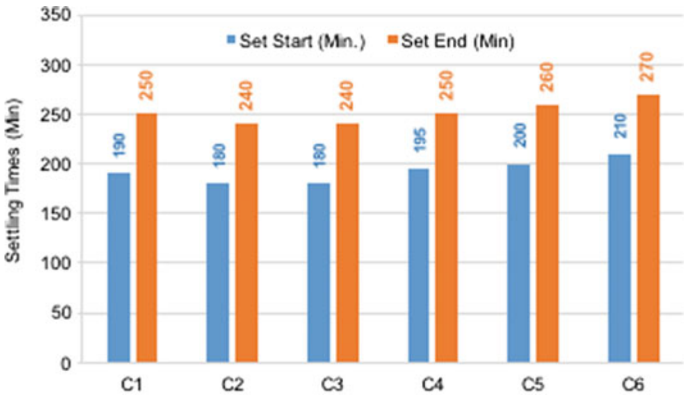

Fig. 4. Settling times

Special weight value of waste concrete free cement was calculated to be 3.01 g/cm^3. Special weight values of waste concrete tempered cements differed between 2.92 and 3.02 g/cm^3. Special weight value of cement with 5% waste concrete addition instead of limestone (C2) increased compared to the waste concrete free cement (3.02 g/cm^3). Special weight value decreased in C3, C4, C5 and C6 cements compared to the waste concrete free cement. The lowest special weight value was in 20% waste concrete tempered cement (C5) with 2.92 g/cm^3 (Fig. 5).

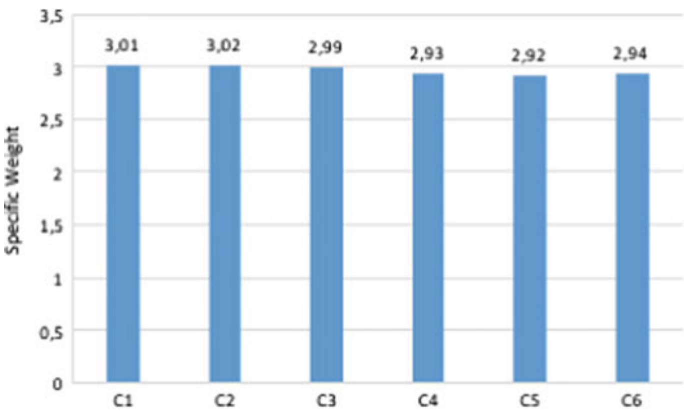

Fig. 5. Specific weight

The highest compressive strength was calculated in 5% waste concrete tempered cement (C5). 2, 7 and 28 day compressive strengths of cements were tested. 28 day compressive strengths of cements differed between 29.7 and 33.0 MPa. 28 day compressive strengths of C2, C3 and C6 cements increased compared to the compressive strength of waste concrete free cement. 28 day compressive strengths of C4 and C5 cements decreased compared to the compressive strength of waste concrete free cement. The lowest compressive strength is in C5 cement (Fig. 6). 2 and 7-day compressive strength results were also similar. In a study conducted, 10% waste concrete admixture has increased one day compressive strength [26].

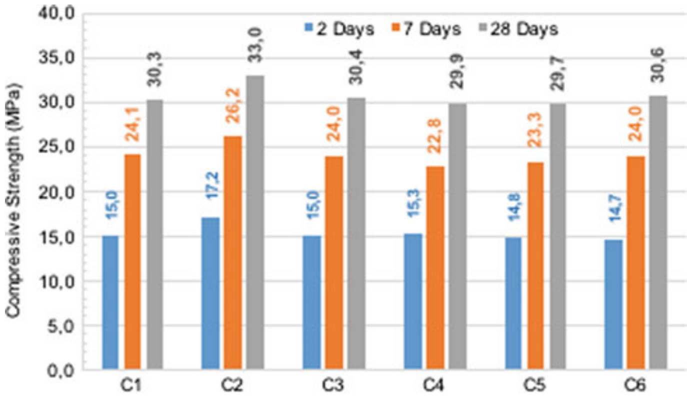

Fig. 6. Compressive strength

2, 7 and 28 day Flexural strengths of cements were tested. 28 day Flexural strengths of cements differed between 4.97–5.37 MPa. The highest Flexural strength was calculated in 10% waste concrete tempered cement (C3). The lowest Flexural strength was in waste concrete free cement. Waste concrete addition increased the cement's Flexural strength (Fig. 7).

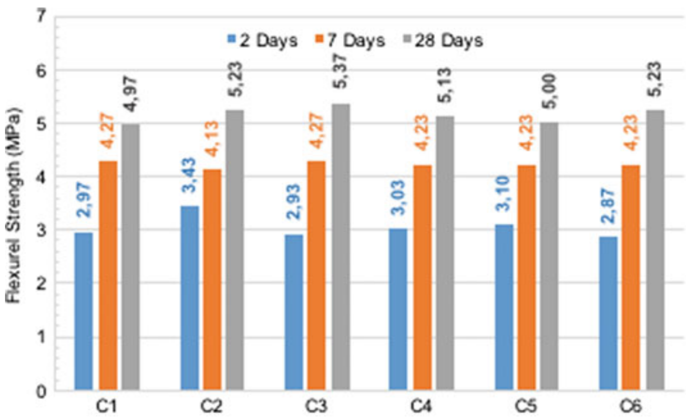

Fig. 7. Flexurel strength

Water need of cements differed between 27.4 and 28%. The highest water need was calculated in waste concrete free cement with 28%. The lowest water need was calculated in 15% waste concrete tempered cement (C4). Waste concrete addition in the cement slightly decreased the water need of the cement (Fig. 8).

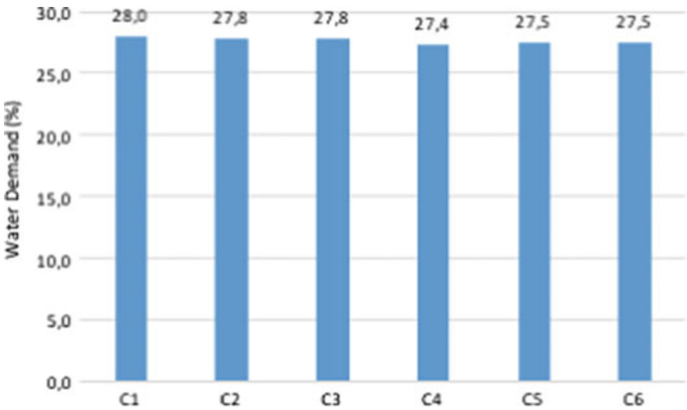

Fig. 8. Water demand

4 Results

Waste concrete addition in tempered cement didn't cause very big differences in the chemical properties of cement. Especially CaO amount remained in same values. Approximately 93% of waste concrete added in the cement instead of limestone was cement and aggregate in weight. Aggregate and cement are also limestone and derivatives.

Waste concrete addition in the cement instead of limestone decreased the special weight value of the cement. Only in 5% waste concrete tempered cement (C2) the special weight value increased. 2, 7 and 28 day compressive strengths of waste concrete tempered cements were close to the waste concrete free cement's compressive strengths. Especially in C2 cement, 28 day compressive strength increased by 10% compared to the waste concrete free cement. Waste concrete addition increased the Flexural strength of the cement.

Water need of cements is an important factor in concrete mix calculations. It is a factor which directly affects the properties of the fresh concrete. According to this, the water need of the concrete and the need for chemical additives are determined. Waste concrete addition slightly decreased the water need of the cement. While the water need of waste concrete free cement was 28%, the water need of waste concrete tempered cement decreased to the value of 27.4%.

In tempered cement production, waste concretes can be used instead of limestone. It will be useful to experiment this laboratory study in industrial production and compare the results. Especially the capacity of laboratory type miller and milling quality may change the properties of the cement. In order to put waste concrete in use for cement production, construction waste concretes should be well purified. Thus, waste concretes can be used in cement production and ecological balance can be contributed to.

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Simulation of Radiation Heat Flux Effect in Buildings on Human Thermal Comfort Under Transient Conditions

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Abstract. The purpose of this study is to investigate the effect of radiation heat flux from lighting lamps in buildings on human thermal comfort. In order to obtain the thermal responses of human body exposed to radiation heat flux from lighting lamps, a mathematical model based on Gagge model with some modifications were developed and the effect of radiation heat flux from lighting lamps on human thermal comfort was examined under transient conditions. The human body was divided into 16 sedentary segments and the variation of sensible, latent heat losses, and skin wettedness were calculated under radiation effect in buildings.

Keywords: Radiation · Thermal comfort · Heat loss · Skin wittedness

1 Introduction

Mathematical modeling of the thermal response of human body under different personal and environmental conditions has attracted great attentions, because the model can be used many applications for buildings [1]. Tanabe et al. [2] developed numerical method for estimating the effective radiation area and the projected area of a human body for any posture. Tanabe et al. [3] developed the new thermoregulation model based on the Stolwijk model. Atmaca and Yiğit [4] examined the relative humidity impacts on skin temperature and skin wettedness for various operative temperatures by means of simulation. In that simulation, Gagge 2-node model was utilized but includes some significant modifications. Atmaca et al. [5] investigated the local differences between body parts caused by high radiant temperature, and to examine the interior surface temperatures for various wall and ceiling constructions with their influence on thermal comfort by modifying Gagge 2-node model. Ghali et al. [6] examined the

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change of the skin temperature at various locations of the human body parts while standing in an asymmetric thermal radiation field generated by a stove-heating unit. Wang et al. [7] investigated the effect of cold radiation from the outer window on human skin temperature and thermal responses in Harbin winter. La Gennusa et al. [8] developed a model for managing and evaluating solar radiation for indoor thermal comfort conditions. Watanabe et al. [9] examined to determine the average solar absorptance of the human body wearing a combination of specific black and white garments and measure the average solar absorptance of Japanese, college-aged male subjects wearing casual summer, autumn, and winter clothing. Kalmár and Kalmár [10] investigated to see which the effect of the room geometrical characteristics is on the obtained mean radiant temperature.

Barna and Bánhidi [11] examined the combined influence of two local discomfort parameters, namely radiant temperature asymmetry and warm floors. Frontini and Kuhn [12] investigated the effect of different internal textile blinds on the operative temperature in working environments together with the cooling load during the summer season. In this study, thermal interactions between human body and environment are simulated to predict radiation effect on sensible and latent heat loss and skin wettedness. 16 segments- Gagge 2-node model [13–15] was used for simulation.

2 Simulation Model

In this paper based on the same approach that was utilized in the study of Olesen et al. [16] in which human body was divided into 16 sedentary parts in this simulation model in order to calculate local sensible and latent heat losses, and skin wettedness. The neutral skin temperatures of the body segments were obtained from the experimental studies are performed Table 1. Dubois surface area, weights and neutral core temperatures of 16 body parts are showed Table 2. To obtain core and skin temperature together with skin wettedness, 16 segments-Gagge 2-node model representing the body as two concentric cylinders (core and skin) is used. In this model, the heat storage equations for core and skin layers can be expressed as follows;

$$S_{cr}(i,\theta) = M - W - [C_{res}(i,\theta) + E_{res}(i,\theta)] - Q_{cr,sk}(i,\theta) \tag{1}$$

$$S_{sk}(i,\theta) = Q_{cr,sk}(i,\theta) - [C(i,\theta) + R(i,\theta) + E_{sk}(i,\theta)] \tag{2}$$

Table 1. The neutral skin temperatures of the body segments

i	Body segments	Neutral skin temperature (°C)
1	Left foot	32.9
2	Right foot	32.9
3	Left leg	32.4
4	Right leg	32.4
5	Left thigh	32.8
6	Right thigh	32.8
7	Pelvis	32.7
8	Head	33.15
9	Left hand	32.9
10	Right hand	32.9
11	Left arm	31.93
12	Right arm	31.93
13	Left shoulder	32.4
14	Right shoulder	32.4
15	Chest	32.5
16	Back	32.7

Table 2. The neutral core temperatures, Dubois surface areas, and weights of the body segments [2]

i	Body segments	Neutral core temperature (°C)	Dubois surface area (m^2)	Weight (kg)
1	Left foot	35.1	0.056	0.480
2	Right foot	35.1	0.056	0.480
3	Left leg	35.6	0.112	3.343
4	Right leg	35.6	0.112	3.343
5	Left thigh	35.8	0.209	7.013
6	Right thigh	35.8	0.209	7.013
7	Pelvis	36.3	0.221	17.57
8	Head	36.9	0.140	4.020
9	Left hand	35.4	0.050	0.335
10	Right hand	35.4	0.050	0.335
11	Left arm	35.5	0.063	1.373
12	Right arm	35.5	0.063	1.373
13	Left shoulder	35.8	0.096	2.163
14	Right shoulder	35.8	0.096	2.163
15	Chest	36.5	0.175	12.40
16	Back	36.5	0.161	11.03
	Whole body		1.87	74

Heat storage rate of core and skin causes instantaneous temperature changes both in core and skin layers of body. This effect can be expressed as follows:

$$S_{cr}(i,\theta) = [1-\alpha(\theta)]\cdot m(i)\cdot c_{p,b}\cdot [dT_{cr}(i,\theta)/d\theta]\big/A_{(i)} \tag{3}$$

$$S_{sk}(i,\theta) = \alpha(\theta)\cdot m(i)\cdot c_{p,b}\cdot [dT_{sk}(i,\theta)/d\theta]\big/A_{(i)} \tag{4}$$

where specific heat of body $c_{p,b}$ = 3490 J/kgK [15].

Convective and radiative heat loss from surface of the each body segment to environment is calculated as;

$$C(i,\theta)+R(i,\theta) = [T_{sk}(i,\theta)-T_o(i)]/R_t(i) \tag{5}$$

Operative temperature can be expressed as;

$$T_o(i) = (h_r\cdot T_r(i)+h_c\cdot T_a)/(h_r+h_c) \tag{6}$$

where T_a is the measured indoor air temperature, air and mean radiant temperatures (T_r) were almost equal.

The radiative heat transfer coefficient (h_r) was taken as 4.9 W/m^2 and convective heat transfer coefficient (h_c) was determined as follows [17];

$$h_c = 5.7.(M-0.85)^{0.39} \tag{7}$$

The total thermal resistance (R_t) of each segment is calculated as below [18]:

$$R_t(i) = R_a(i)\cdot\frac{r(i,0)}{r(i,nl)} + \sum_{j=1}^{nl}\left[R_{al}(i,j)\cdot\frac{r(i,0)}{r(i,j-1)} + R_f(i,j)\cdot\frac{r(i,0)}{r(i,j)}\right] \tag{8}$$

Heat flows from the body parts through alternating clothing and air layers. Thermal and evaporative resistances of fabrics obtained from McCullough et al. [19] are showed in Table 3. The thermal resistance of an air layer and the thermal resistance of the outer air layer are given by:

$$R_a = \frac{1}{h_c+h_r} \tag{9}$$

$$R_{al} = \frac{1}{h_r+k/x} \tag{10}$$

The values of k and x were taken as 24 mm W/m^2 °C and 1.3 mm, respectively.

Table 3. Fabric characteristics and resistance values [19]

Fabric code	Fabric description	Thickness (mm)	Thermal resistance of fabric R_f (m^2 °C/W)	Evaporative resistance of fabric $R_{e,f}$ (m^2 kPa/W)
1	Jersey single knit, 100% cotton	1.270	0.036	0.0040
2	Poplin, 60% cotton, 40% polyester	0.787	0.026	0.0041

Convective and evaporative heat losses due to respiration are:

$$C_{res}(i,\theta) + E_{res}(i,\theta) = [0.0014 \cdot M \cdot (34 - T_a) + 0.0173 \cdot M \cdot (5.87 - p_a)] \tag{11}$$

Heat transfer between core and skin is given by the following equation:

$$Q_{cr,sk}(i,\theta) = \left[K + c_{p,bl} \cdot \dot{m}_{bl}(\theta)\right] \cdot [T_{cr}(i,\theta) - T_{sk}(i,\theta)] \tag{12}$$

where K = 5.28 W/m^2 K is the effective heat transfer coefficient between core and skin;

$c_{p,bl}$ = 4187 J/kg K is the specific heat of blood.

Evaporative heat loss from skin (E_{sk}) by both sweating and natural diffusion of water through skin is calculated by the following expression:

$$E_{sk}(i,\theta) = E_{rsw}(\theta) + E_{dif}(i,\theta) = w(i,\theta) \cdot \left[p_{sk,s}(i,\theta) - p_a\right] / R_{e,t}(i) \tag{13}$$

The total evaporative resistance, can be calculated as below [18]:

$$R_{e,t}(i) = R_{e,a}(i) \cdot \frac{r(i,0)}{r(i,nl)} + \sum_{j=1}^{nl} \left[R_{e,al}(i,j) \cdot \frac{r(i,0)}{r(i,j-1)} + R_{e,f}(i,j) \cdot \frac{r(i,0)}{r(i,j)}\right] \tag{14}$$

The evaporative resistance of an air layer and the evaporative resistance of the outer air layer are calculated by:

$$R_{e,a} = \frac{1}{h_c \cdot LR} \tag{15}$$

$$R_{e,al} = a \cdot [1 - \exp(-x/b)] \tag{16}$$

The values of LR, a and b are 16.5 °C/kPa, 0.0334 m^2 kPa/W and 15 mm, respectively [19].

Skin wettedness (w) is calculated as below:

$$w(i, \theta) = 0.06 + 0.94 \cdot \frac{E_{rsw}(\theta)}{E_{max}(i, \theta)} \tag{17}$$

Maximum evaporative heat loss (E_{max}) can be calculated with Eq. (13) for skin wettedness of 1 (upper theoretical limit).

E_{rsw} is the heat loss due to evaporation of sweat and is expressed as:

$$E_{rsw} = \dot{m}_{rsw} h_{fg} \tag{18}$$

where h_{fg} = 2430 kJ/kg is the heat of vaporization of water.

The rate of sweat production per unit of skin area is predicted by:

$$\dot{m}_{rsw}(\theta) = 4.7 \times 10^{-5} \cdot WSIG_b(\theta) \cdot exp[WSIG_{sk}(\theta)/10.7] \tag{19}$$

Wet part of the body necessary for sweat evaporation is defined as:

$$w_{rsw} = \frac{E_{rsw}}{E_{max}} \tag{20}$$

E_{dif} is the evaporation by diffusion and is expressed as:

$$E_{dif} = [1 - w_{rsw}] \cdot 0.06 \cdot E_{max} \tag{21}$$

Thermoregulatory controlling system, such as vasomotion, sweating and shivering are determined by temperature signals from the skin and core depending on deviations from their respective neutral set points:

$$WSIG_{cr}(\theta) = \begin{cases} 0 & T_{cr,m}(\theta) \le T_{cr,n} \\ T_{cr,m}(\theta) - T_{cr,n} & T_{cr,m}(\theta) > T_{cr,n} \end{cases} \tag{22}$$

$$CSIG_{cr}(\theta) = \begin{cases} T_{cr,n} - T_{cr,m}(\theta) & T_{cr,m}(\theta) < T_{cr,n} \\ 0 & T_{cr,m}(\theta) \ge T_{cr,n} \end{cases} \tag{23}$$

$$WSIG_{sk}(\theta) = \begin{cases} 0 & T_{sk,m}(\theta) \le T_{sk,n} \\ T_{sk,m}(\theta) - T_{sk,n} & T_{sk,m}(\theta) > T_{sk,n} \end{cases} \tag{24}$$

$$CSIG_{sk}(\theta) = \begin{cases} T_{sk,n} - T_{sk,m}(\theta) & T_{sk,m}(\theta) < T_{sk,n} \\ 0 & T_{sk,m}(\theta) \ge T_{sk,n} \end{cases} \tag{25}$$

$$WSIG_b(\theta) = \begin{cases} 0 & T_{b,m}(\theta) \le T_{b,n} \\ T_{b,m}(\theta) - T_{b,n} & T_{b,m}(\theta) > T_{b,n} \end{cases} \tag{26}$$

The average of skin and core temperature can be calculated as

$$T_{cr,m}(\theta) = \frac{\sum_{i=1}^{16} T_{cr}(i,\theta) \cdot A(i)}{A_D} \tag{27}$$

$$T_{sk,m}(\theta) = \frac{\sum_{i=1}^{16} T_{crsk}(i,\theta) \cdot A(i)}{A_D} \tag{28}$$

The average temperature of the human body, blood flow and the ratio of the skin mass to total mass which are used for solution can be expressed as:

$$T_{b,m}(\theta) = \alpha(\theta) \cdot T_{sk,m}(\theta) + [1 - \alpha(\theta)] \cdot T_{cr,m}(\theta) \tag{29}$$

$$\dot{m}_{bl}(\theta) = \left[\frac{(6.3 + 200 \cdot WSIG_{cr}(\theta))}{(1 + 0.5 \cdot CSIG_{sk}(\theta))}\right] \Big/ 3600 \tag{30}$$

$$\alpha(\theta) = 0.0418 + \frac{0.745}{[3600 \cdot \dot{m}_{bl}(\theta) + 0.585]} \tag{31}$$

Metabolic energy production due to shivering is related with two signals by the expression

$$M_{shiv}(\theta) = 19.4[CSIG_{sk}(\theta) \cdot CSIG_{cr}(\theta)] \tag{32}$$

$$M = M_{met} + M_{shiv} \tag{33}$$

where M_{met} = 70 W/m^2 according to ASHRAE [17] is taken as standard metabolic heat production rate for a human body.

2.1 Modification to the Gagge's Two-Node Model

In order to see the effect of radiation on human thermal comfort, radiation heat flux from lighting lamps were included in the model. Radiation heat flux values of lighting lamps are performed Table 4. In present study, radiation heat flux was only considered to be associated with skin layer. In experiments, the subjects who participated in tests for 45 min in the climate chamber were exposed to radiation heat flux from lighting lamb after first 15 min. In the simulation, pyranometer measured radiation heat flux values were included in the heat storage equation for skin layer, starting at the time step when the lighting lamps were switched on (15th min) till the iteration terminated, as performed below:

$$S_{sk}(i,\theta) = Q_{cr,sk}(i,\theta) + Q_{r,sk}(i) - [C(i,\theta) + R(i,\theta) + E_{sk}(i,\theta)] \tag{34}$$

Table 4. Radiation heat flux values (W/m^2)

Body segments	Radiation heat flux values (W/m^2)
Left foot	25
Right foot	25
Left leg	16
Right leg	16
Left thigh	16
Right thigh	16
Pelvis	18
Head	80
Left hand	12
Right hand	12
Left arm	14
Right arm	14
Left shoulder	40
Right shoulder	40
Chest	50
Back	50

3 Results and Discussion

The equations were performed under the mathematical modeling, section of which transferred to Matlab programming language. The model was performed to determine the heat and mass transfer between the body and its environment. For 45 min period, changes heat losses, the core and skin temperatures and skin wettedness were calculated. Variations of sensible and latent heat losses, skin wettedness from the body segments under the radiation effect are shown in Fig. 1. Skin wettedness of the segments have a value of 0.06, which is the minimum value. When lighting lamps switch on the body generates more sweat to increase heat loss. So, the skin wettedness of each segment rises. Skin wettedness of pelvis segment is higher than the other segments, because the pelvis has more clothing insulation among other segments. Indoor temperature was accepted 20 °C at the beginning, and a temperature increase of 5.6 °C due to radiation in simulation. Since temperature difference between the skin and ambient decreases under radiation effect with time, these heat losses decrease, too. Figure 1 performs that the maximum variation of heat loss occurs in head. At the 15th minute of experiments, the sensible heat loss from head is 114 W/m^2, and then it decreases 76 W/m^2 under radiation effect. The accuracy of the simulation model used in this study is shown in the references [20].

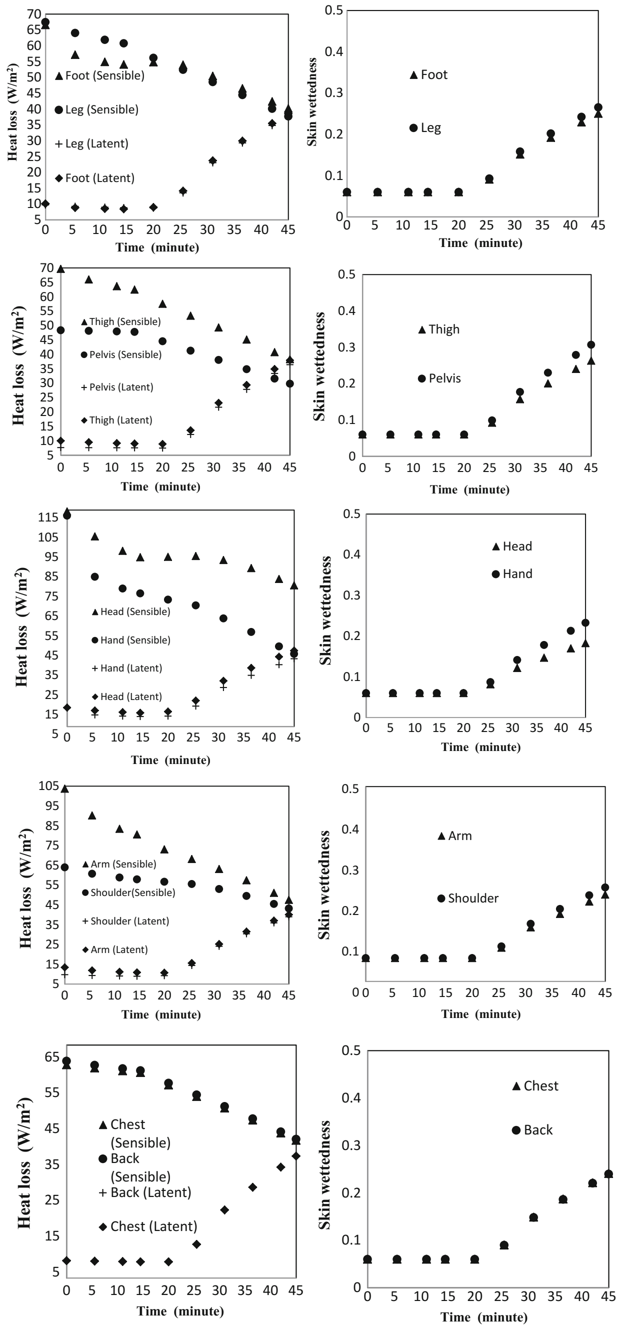

Fig. 1. Variation of sensible, latent heat losses and skin wettedness for human body segments

4 Conclusions

The aim of the present study is to provide a useful model to calculate the transient thermal conditions of the body under radiation effect. In order to perform that the human body responds under radiation effect are investigated in details. Especially pelvis, which has more clothing, have the most skin wettedness. Clothing insulation has a reducing effect on sensible and latent heat losses but also has an increasing effect on skin wettedness. The results demonstrate that radiation heat flux from lighting lamps caused local skin temperature differences. This reason is that head is closer to lighting lamps according to other body segments. Local skin temperature differences between the body segments cause thermal discomfort.

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Nomenclature

A	Surface area, m^2
A_D	DuBois surface area, m^2
C	Convective heat transfer, W/m^2
C_{res}	Sensible heat loss due to respiration, W/m^2
$c_{p,b}$	Constant pressure specific heat of body tissue, kJ/kgK
$c_{p,bl}$	Constant pressure specific heat of blood, kJ/kgK
$[CSIG]_{cr}$	Cold signal from the core, dimensionless
$[CSIG]_{sk}$	Cold signal from the skin, dimensionless
$(C+R)_t$	Total sensible heat transfer, W/m^2
E_{max}	Maximum possible evaporative heat loss, W/m^2
E_{res}	Evaporative heat loss due to respiration, W/m^2
E_{rsw}	Evaporative heat loss due to regulatory sweating, W/m^2
E_{sk}	Total evaporative heat loss from skin, W/m^2
h_c	Convection heat transfer coefficient, W/m^2K
h_{fg}	Heat of vaporization of water, kJ/kg
h_r	Radiation heat transfer coefficient, W/m^2K
i	Body segment number, dimensionless
j	Air or fabric layers number, dimensionless
k	Thermal conductivity of the air, mm W/m^2 °C
K	Effective conductance between core and skin, W/m^2 K
l	Body height, m
LR	Lewis ratio, °C/kPa
M	Total rate of body heat production, W/m^2
M_{met}	Metabolic heat production W/m^2
M_{shiv}	Shivering heat production W/m^2
m	Body mass, kg
m_{bl}	Blood circulation between core and skin, kg/m^2 s
m_{rsw}	Rate of regulatory sweat generation, kg/m^2 s
nl	Number of layers covering segment, dimensionless

P_a	Water vapor pressure in ambient air, kPa
$P_{sk,s}$	Water vapor pressure saturated at skin temperature, kPa
$Q_{cr,sk}$	Heat flow from core to skin, W/m^2
$Q_{r,sk}$	Radiation heat flux from lighting lamps to skin, W/m^2
R	Radiative heat transfer, W/m^2
r	Radius, m
R_a	Thermal resistance of outer air layer, m^2 °C/W
R_{al}	Thermal resistance of air layer, m^2 °C/W
$R_{e,a}$	Evaporative resistance of outer air layer, m^2 kPa/W
$R_{e,al}$	Evaporative resistance of air layer, m^2 kPa/W
$R_{e,f}$	Evaporative resistance of fabrics, m^2 kPa/W
$R_{e,t}$	Total evaporative resistance, m^2 kPa/W
R_f	Thermal resistance of fabrics, m^2 °C/W
R_t	Total thermal resistance, m^2 °C/W
S_{cr}	Heat storage in core compartment, W/m^2
S_{sk}	Heat storage in skin compartment, W/m^2
X	Air layer thickness, mm
t_a	Ambient air temperature, °C
$t_{b,m}$	Average of the body temperature, °C
t_{cr}	Core temperature, °C
$t_{cr,m}$	Mean core temperature, °C
t_o	Operative temperature, °C
t_r	Mean radiant temperature, °C
t_{sk}	Skin temperature, °C
$t_{sk,m}$	Mean skin temperature, °C
w	Skin wettedness, dimensionless
W	External work accomplished, W/m^2
w_{rsw}	Required to evaporate regulatory sweat, dimensionless
$[WSIG]_b$	Warm signal from the body, dimensionless
$[WSIG]_{cr}$	Warm signal from the core, dimensionless
$[WSIG]_{sk}$	Warm signal from the skin, dimensionless
α	Fraction of total body mass concentrated in skin compartment, dimensionless
θ	Time, s

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An Overview of the Signs and Graphical Representations Used in Smart Buildings and Cities

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Abstract. Smart Cities are the names given to technological and environment friendly projects designed to get rid of factors such as bad urbanization, noise, environmental pollution that harm people and nature. Intelligent management of energy in smart cities; if energy efficiency not achieved in this period when the energy resources are gradually decreasing but energy demand is increasing; energy interruptions and high prices are inevitable. Sustainable energy sources such as the sun, hydropower, and wind integrated more and more in the production process, while losses and leaks minimized through information systems that control the network from one end to the other. Transportation intelligence: With the increasing number of vehicles in cities, not only the time lost in traffic, but also the increase in fuel consumption, the increase of carbon emissions and safe driving are the most important issues. In intelligent cities, information technology used to solve transportation, especially traffic. In addition, smart buildings: Today, buildings that consume about 40% of energy will reach 60% as urbanization continues. All living areas and buildings will be equipped with sensors to attract these rates to the lower level. It will be possible to take a number of inland measures such as energy use, security, insulation in the buildings and buildings. All of these intelligent city applications are using visual cues, smart signs and graphical representations. In this study, these demonstrations used in the smart cities examined and various solution proposals introduced.

Keywords: Smart cities · Technology · Visual design

1 Introduction

Smart Cities arise from the shift that is occurring in the ICT industry to a new technology platform for growth and innovation. As cities operate in a globally competitive environment—or workers, tourists, and businesses—the ultimate goal of Smart City initiatives is to attract businesses and citizens to ensure a vibrant city economy. To do this, cities must tackle a wide range of urban challenges (growing demand for power, waste management, traffic management, etc.) Through coordinated and focused

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investment. Smart Building technologies IDC's definition of a Smart City or Smart City project is one that uses intelligent devices, ICT, and instrumentation technologies to achieve the explicit goals of sustainable economic development and quality-of-life improvements for citizens. These goals achieved via improved service delivery, more efficient use of resources (human, infrastructure, and natural), and the implementation of financially and environmentally sustainable practices. Central strategic themes for Smart Cities include:

- Sustainable economic development/revitalization
- Sustainability
- Citizen, community, and business engagement represent one such area of investment that cities need to consider as part of the wider Smart City ecosystem.

The vision of Smart Cities is to provide more inclusive, secure, efficient, and effective services to citizens, thus ensuring the livability and sustainability of the wider city community. Smart City solutions integrate information and operations within and between city systems and domains and engage with citizens, businesses, and the broader community in new ways. In this context, engaging with city planners, private developers, corporate building owners, and property managers that have a portfolio of facilities becomes an essential aspect of sustainable economic development, not only in the context of managing public facilities more efficiently and sustainably, but also by encouraging the more rapid adoption of Smart Buildings technologies in private commercial properties [1].

2 Smart Cities and Buildings

A Smart Building as a facility that utilizes advanced automation and integration to measure, monitor, control, and optimize operations and maintenance. The enabling technologies characterized by a convergence of information technology and building automation. Smart Building solutions give building owners, operators, and other key decision-makers unprecedented visibility into equipment operations and building use courtesy of the real-time data generated by the sensors, monitors, and controls in a Smart Building solution con-figuration.

The development of a Smart Building is a process of investment and transformation in facility management. The process is framed by the integration of advanced controls and automation technologies that utilize analytics and data management within an IT architecture. There is no off-the-shelf deployment of technologies in a Smart Building. In existing buildings, technologies are deployed as retrofits or extensions to existing infrastructure to increase the sophistication of the energy management equipment in the facility.

The most common problems within traditional buildings include lighting, parking, lack of processes and controls, poor services delivery, complex and redundant processes, high-energy consumption/costs, and improper waste management—to name just a few.

As these facilities are transformed into Smart Buildings, they become increasingly instrumented, controlled, and automated, and operators and key decision makers rely more heavily on the analytics and data management aspects of Smart Building solution to make the information from the building systems actionable. The idea is that the smarter the building, the more efficient its operations and maintenance. This, in turn, drives down costs, energy consumption, and the facility's environmental footprint.

For example, Fig. 1 illustrates the process of transforming an existing facility into a Smart Building. In addition, Fig. 2 shows that based on the identified stakeholder needs and the ability to create EPNs, a local actor—named "Energy Positive Neighborhood Service Provider" (EPNSP)—has become a necessity [2].

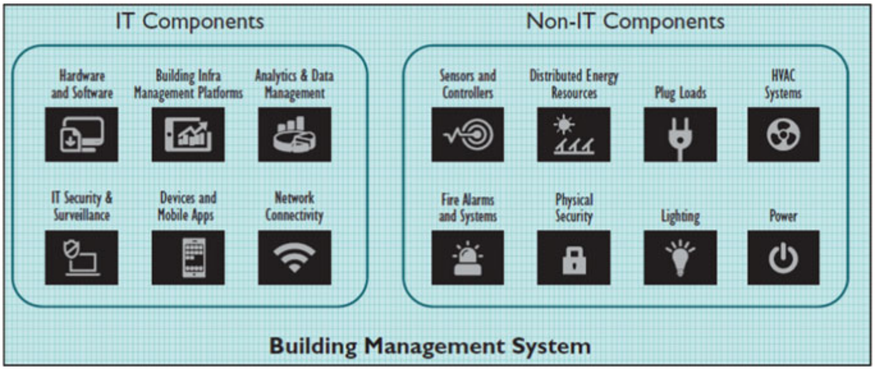

Fig. 1. Building management system [3]

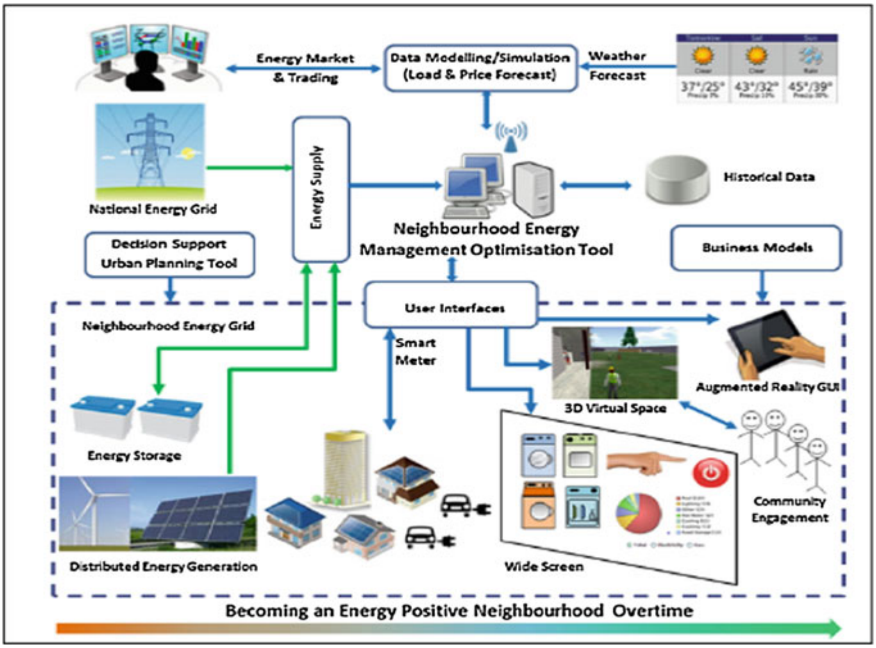

Fig. 2. Elements underpinning the business concept of an energy positive neighborhood service provider [4]

3 The Importance of Smart Signs and Graphical Representations

Smart Signs are a new type of electronic door and way signs based on small computers, which can seamlessly incorporated in the environment. Smart Signs provide personalized context-aware guidance and messaging designed to support wayfinding activities in large indoor spaces and their surroundings.

The system uses the context information such as a user's mobility limitations, the weather, and possible emergencies to improve guidance and messaging. Smart Signs combine the simplicity of traditional static signs with the flexibility and responsiveness of electronic navigation systems.

Smart Signs provide guidance and messaging functionality. The goal of Smart Signs is to combine the advantages of signage—which subsumes traditional directional signs and messages—with the reactiveness and flexibility of personal services, such as navigation systems and SMS.

The Smart Signs system uses context such as user's mobility limitations, the weather, and emergencies like fire or medical needs to optimize routes and messaging. In addition to personalized guidance and messaging, Smart Signs can also present information for user groups and everyone.

For example, the Smart Sign in the Zilverling building shown in Fig. 3 provides some individual directions and messages for everyone, while the big Smart Sign in the Jaarbeurs in Utrecht shown in Fig. 4 gives directions to all visitors of ICTDelta [5].

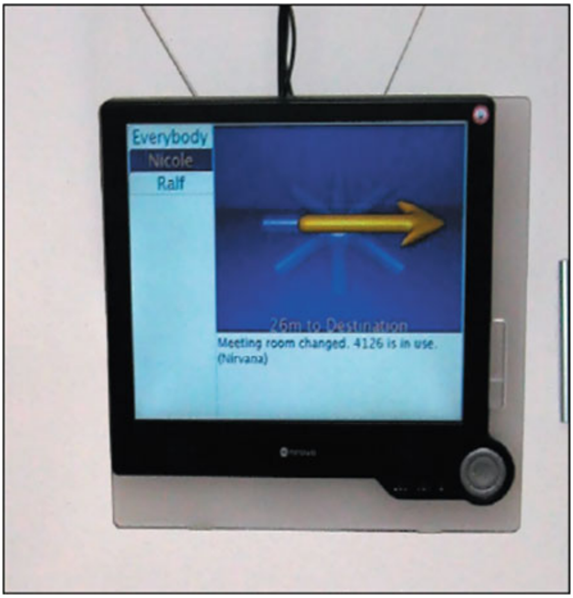

Fig. 3. Wall-mounted Smart Sign in Zilverling [5]

Fig. 4. A big Smart Sign for ICT Delta in de Jabbers in Utrecht [5]

Signage is easy to understand mainly because of our familiarity with it presents information in situ, is ubiquitous and easy to ignore when not relevant. Another advantage of signage that generally overlooked is that it is anonymous, because neither the signs, nor the people who install them know who uses the signs. Thus, traditional signs provide absolute privacy from the point of view of the user.

However, traditional signs have important shortcomings. Using signage for navigation requires that user knows milestones on the route to his destination, because the signs cannot provide directions to every destination. Another shortcoming of signage is that the signs cannot adapt automatically to real time changes e.g., a lift temporarily out of order and it is difficult to keep them up-to-date. Signage providing outdated information becomes annoying. Last, but not least, static signs lack the capacity to show information only to the interested parties, and to display only at the right moment. For example, a Post-it saying ‘Hand in your work to the secretary’ at a researcher’s door clearly not meant for everyone passing by, but just for his students [5].

An important goal of their architecture is to provide ubiquitous guidance and messaging with affordable hardware (important for the signs) and minimal infrastructure requirements (i.e., cabling).

Second important goal is to protect the privacy of the users. Specifically, we want to prevent or make difficult the direct or indirect tracking of users. In this, we follow Langheinrich’s guidelines by considering privacy early in the design, processing the privacy sensitive data as close to its source as possible, and storing it no longer than strictly necessary [6].

Traditional signage is the gold standard regarding privacy, because users are completely anonymous. The system is reactive and personalized; users have to sacrifice some privacy by telling the system where they want to go or to whom they want to post messages. Users also need to carry a tag sending an identifier. In the future, we will reinforce privacy by letting the tags generate forward-secure unique identifiers so that outside attackers cannot track users.

Different from conventional signage, the Smart Signs have to solve the problem of presenting individual guidance and messaging for an unknown, potentially large number of people on a limited screen. Three solutions offer themselves: multiplexing in time, space, or both.

4 Conclusions

Intelligent management of energy in smart cities; if energy efficiency not achieved in this period when the energy resources are gradually decreasing but energy demand is increasing; energy interruptions and high prices are inevitable. Sustainable energy sources such as the sun, hydropower, and wind integrated more and more in the production process, while losses and leaks minimized through information systems that control the network from one end to the other.

Transportation intelligence: With the increasing number of vehicles in cities, not only the time lost in traffic, but also the increase in fuel consumption, the increase of carbon emissions and safe driving are the most important issues. In intelligent cities, information technology used to solve transportation, especially traffic. In addition, smart buildings: Today, buildings that consume about 40% of energy will reach 60% as urbanization continues.

Smart Signs are a new type of electronic door and way signs based on small computers, which can seamlessly incorporated in the environment. Smart Signs provide personalized context-aware guidance and messaging designed to support wayfinding activities in large indoor spaces and their surroundings.

The use of signs and graphical representations in Smart Buildings and Cities are very important to sustainability of life. Be very careful when designing these impressions. Because the slightest faulty display will cause loss of life and property.

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Integrated Building Design Approach: Turkish Case

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Abstract. In Turkey, in terms of final energy consumption, the building sector represents the second-largest energy consumer accounting for 36% of the total final energy consumption in 2008 and the building sector's emissions are 32% of the total national energy-related CO_2 emissions. However, the building sector presents significant opportunities for energy and CO_2 savings, estimated at 30–50% of the current levels. The total population of Turkey increased from 56.5 million in 1990 to 72.5 million by the end of 2009. Along with the increase of the population, Turkey's urbanization rate increased from 52.9% in 1990 to 75.5% by the end of 2009. Between 2000 and 2010, despite two economic crises in 2001 and 2008–2009, the building stock grew around 8.1%. Such rates of increase underline the importance of energy-saving measures in the building sector. In order to find a solution Promoting Energy Efficiency in Buildings Project is being executed by General Directorate of Renewable Energy (YEGM). UNDP is the implementing agency of the Project which is financially supported by Global Environment Facility (GEF). The Ministry of Environment and Urbanization, and Ministry of National Education are other partners. One of the most important output of this Project was Integrated Building Design Approach (IBDA) books which have been published with the help of 15 experts. These books are Adaptation Report, Project Development Process and Implementation Guide, Priorities and Objectives for Building Performance. This paper will give details about IBDA books and the focus on the methodology of "Project Development Process and Implementation Guide".

Keywords: Policy · Global environment fund · Sustainable building
Integrated building design approach · Turkey

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1 Introduction

"Promoting Energy Efficiency in Buildings in Turkey" Project, subject to this notice, is recognized valuable to be explained as it is a good sample. It is good sample for understanding how the co-work of state, funding institutions and university is done in public projects and how to spread the outputs of this work and form adequate consciousness on benefiting from funded projects.

Project has started on March 2011 and targeted to promote energy efficiency in building sector. It is a five-year period project supported by GEF executed by General Directorate of Renewable Energy (GDRE) of Ministry of Energy and Natural Resources under the cooperation with Ministry of Environment and Urbanization and Ministry of National Education. Under the scope of project, in order to promote energy efficiency in building sector, it is aimed; to introduce integrated building design approach, develop a design criteria indigenous to Turkey, apply integrated building design approach to sample projects (to apply on energy efficient demo building providing at least %50 energy saving), including "Regulation on Energy Performance in Buildings", to improve the regulation on energy use and to prepare and apply capacity building programmes for actors effective in the sector. Total budget of the project is 17,580,000 $ [1].

2 Integrated Building Design Approach Outputs: Books

2.1 Adaptation Report

First book contains problems, discussions, findings, evaluations and suggestions that will be framework during IBDA's adaptation to Turkey conditions. This report contributed to both development phase of research and determination of priorities and headings during preparation of IBDA Project Development Process Implementation Guidebook, as a shown in Fig. 1 [2].

2.2 Project Development Process and Implementation Guidebook

Second book emphasizes the mail resource of numerous problems including sub-products such as tender order, implementation capacity of construction sector, material standards in the market, project standards. It determines models for process management to be a solution for problems occurred due to lack of project stakeholders' simultaneous or in coordination presence on providing feedback and knowledge sharing in project phase. On the other hand, it is a path finder for material choice, implementation details and process priorities which are other components of the problem, as a shown in Fig. 1 [3].

2.3 Priorities and Targets for Building Performance

In third book in order to determine performance problems, priorities and targets in buildings and constructed environment in Turkey, process from project phase of constructing a building to the process of building destruction is investigated for improving energy efficiency in constructed environments. Within this scope, problems and solution suggestions taking into consideration different phases from simulation programmes to design processes, from material choice to details, from construction phase to use process are emphasized in continuity that observe their impacts on each other, as a shown in Fig. 1 [4].

Fig. 1. Book cover pages related to IBDA

3 Integrated Building Design Approach in Turkey

"Promoting Energy Efficiency in Buildings in Turkey" Project, subject to this notice, is recognized valuable Integrated Building Design Approach (IBDA) is a process-driven method for improving energy and environment performance of buildings. IBDA provides a framework for efficient cooperation of initial actors on building development, design, construction and management. This approach provides an opportunity synergy in studies and system performance and improves performance levels considerably. While providing a work environment for investors and design team to work together and in coordination, IBDA provides early intervention opportunity to problems. This methodology adopts integrated building design approach. While it gives priority to individual performance subjects, on the other hand it also contains interaction between (for instance benefiting from energy and daily light and indoor standard etc.) performance fields, as shown in Fig. 2 [3].

IBDA also a process contains whole phases of building lifecycle starting with location determination and functional programming, it includes design, construction, execution and future dissemble/destruction. A decision take in a phase will affect the decisions going to be taken in continuing phases; therefore; in order to maximize successful chance, decision makers need to know possible phases in lifecycle and foreseen their impacts on other phases [3].

Existing buildings are holding the significant amount of total building stock among numerous countries. Therefore, IBDA is suggested not only as a method used for construction process, but also a method that can be implemented in alterations projects. However, different design and construction methods used in different methods, additionally previous alternations and changes of each building should be taken into consideration, as shown in Fig. 3 [3].

The purpose of IBDA is finding solutions to whole problems of buildings that are going to be constructed nowadays and under project phase so that to create a common work principle between stakeholders which desire to reach to intended performance targets.

As given in Fig. 2, following the architectural and engineering schematic design, by using information modelling analysis are done to provide optimum conditions. However, Building Information Model (BIM) analysis that show high performance according to the location of the building (for example: if solar energy gain is taken into consideration and valuable increase in energy performance is provided) are the ones need to be take into consideration between the available values. This situation is up to the working style and initiative taking of the design team.

In Fig. 3, in order to provide energy efficiency for IBDA application, existing building decision depends on design repair team investigation on building strength to earthquake and fire for alternation. If current building is suitable for retrofitting, energy and environment analyses are done as by modelling as in the way applied to new building. Also, performance target special to current building will be determined by paying attention to climate, location, early function.

Phases belong to suggested process model for applying special to each project for IBDA are subsidiary to each other and they can provide feedback for reasonable performance values of the building. Phases belonging to the model are as following [3];

Development Phase of Preliminary Project (Concept Project)

1. Identification of environment factors effecting design and construction process
2. Land choice and evaluation of field features
3. Evaluation of current construction in the land
4. Development of functional programme and management process
5. Development of priorities and targets oriented towards performance
6. Selection of design and design development team members
7. Organizing Preliminary Project brainstorming/information sharing meetings
8. Development of schematic design(s)
9. Selection of one schematic design to develop in advanced way
10. Development of settlement plan.

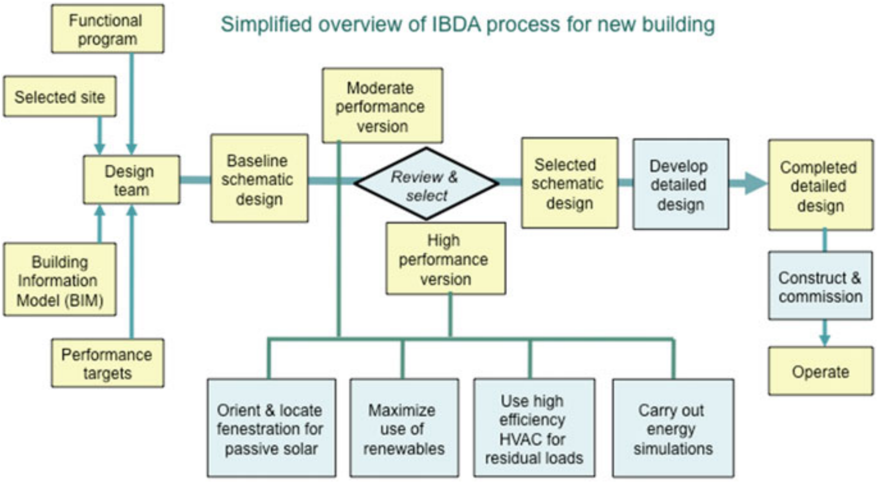

Fig. 2. Phases that can be followed to achieve high performance in new buildings and relations between these phases [4]

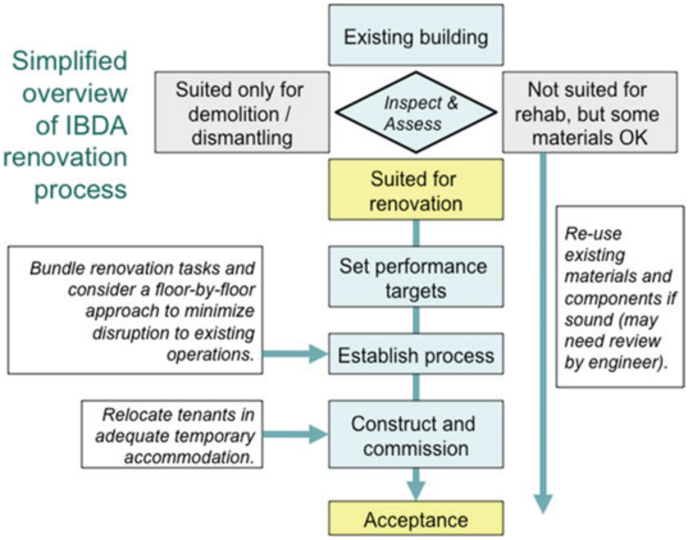

Fig. 3. Phases that can be followed to achieve high performance in existing buildings and relations between these phases [4]

Detailed Design Development Phase

11. Development of Building Information Model (BIM)
12. Development of requirements for schematic indoor design
13. Development of building static construction design

14. Development of building envelope design
15. Development of preliminary strategy for utilization from day light and lighting system
16. Development of preliminary design of power system
17. Development of ventilation, heating and cooling system designs
18. Evaluation of soil or water source-based thermal storage options
19. Development of specifications for building management control system
20. Practicing detailed energy simulations
21. Deciding design options
22. Selection of non-structural materials
23. Completion of project documentation before building construction process
24. Development of quality assurance strategies for construction and activities.

Construction Phase, Activities and Monitoring

25. Preparation and management for performing construction and activities
26. Deliver and preparation of land, completion of major works
27. Demolishing incompatible constructions in the land
28. Evaluation of use of detached materials possibilities
29. Use of recycled materials
30. Management of construction wastes aside
31. Completion of building construction
32. Performing energy simulations on constructed building
33. Application of commissioning process
34. Training execution personnel
35. Training lessees using the building for commercial purposes for efficient management process
36. Training building resident for fruitful management process
37. Building Management
38. Monitoring performance and development of management performance
39. Evaluation following the housing.

In case applications on energy efficiency of existing buildings done applied to these phases, steps under dissemble/destruction phases can be added.

4 Building Evaluation Tool in Turkey

4.1 Building Certification

As is known, in every certification system there is a certification body. Certification body develops a rating system and certification guides for the evaluation of buildings. In most of the systems qualified experts are accredited according to specified criteria to evaluate buildings in line with certification system rules. The final evaluation is done by the certification body. The certification body checks and evaluates the documents provided by qualified experts [5].

Also in all certification systems the applications, assessment and certification procedures are carried out at a specific price. Certification fee varies depending on type and size of building and the evaluation criteria [5].

4.2 General Knowledge of Certification Criteria

In general certification systems determine whether buildings are designed, constructed, renovated, maintained and operated in line with a given set of criteria. The criteria are defined according to the environmental, economic and social impacts. Each criterion has a certain weight in the rating system. After the assessment, buildings are certified on the basis of score received [5].

Typical criteria categories of certification systems include:

- Land planning (construction period is included),
- Life cycle assessment of building and building components,
- Design of the building and innovation properties,
- Construction materials, the use of recyclable materials,
- Water usage and waste management,
- Energy usage.

Some of the criteria are treated as a prerequisite that must be met; therefore no points are given for meeting them. Compliance to national legal requirements is an obligation and remains out of scoring as well.

4.3 Examples of Building Evaluation Tools in Turkey

The most popular certificates are respectively LEED, BREEAM and DGNB in Turkey as we know. But a part of setting up minimal requirements for energy performance of buildings, the government of Turkey has taken an initiative to lay down foundations for the national voluntary certification system by publishing "The Regulation about the Principles and Procedures of Sustainable Green Building and Sustainable Settlement". The regulation identifies responsibilities, qualifications and duties of the bodies that will take role in the certification procedures [6]. The Regulation covers environmental, social and economic performance and sustainability assessment and certification of new and existing buildings and settlements [5].

"ÇEDBİK Green Housing Certification System" is developed by the Turkish Green Building Council (CEDBİK) for residential buildings. The assessment is done under 8 main criteria including integrated green project management, land use, water use, energy use, health and comfort, materials and resource use, life in resident, operation and maintenance [7].

"Safe Green Building Certification System" is developed by Turkish Standards Institute (TSE). The root document for the system is "Safe Green Building Certification Procedures and Principles" which was issued on 05/05/2014. This document aims to implement the national and international green building certification activities and to regulate the use of the brands associated with them [8]. The assessment is done under 10 main criteria including pre-design safe green planning, vital site design, site selection, health security, comfort, efficient use of water, material and resource usage, carbon foot print, energy efficiency, award score, operation management [5].

5 Assessment of IBDA Process as a Building Evaluation Tool

The assessment criteria in given certification systems are emphasized as environmental, social and economic aspects by researchers and authorities. Also scarcely all criteria wasn't constituted from design methodology. IBDA contains both engineering design and architectural design and of course their relevant technical details. Because of that reason, IBDA can give essential information to prepare, classify and mount building evaluation tool or criteria towards architectural and engineering design principles.

Building evaluation tool should include integrated building architectural and engineering design approach. Accordingly first of all every country should prepare self-IBDA in terms of a local-regional materials, cultural realty, climatic, topography, human behaviors, industrial development, traditional construction techniques, etc. Secondly they should classify self-IBDA like three phases hereinbefore in this paper.

Given rating scores should be given the process' itself, because these phases express the process. Rather than result product, process management will bring under control.

Yet already the preparation of "Basic Assessment Guidelines" is being gone on by Ministry of Environment and Urbanization in Turkey. This document will be used for certification of sustainable green buildings and sustainable settlement. Ministry said to take in consideration ourselves IBDA; but yet nobody knows nothing. Because outcome is not ready.

6 Conclusion

IBDA will reveal sustainable criteria; shortly can be defined as rationalism, article by article. Actual aim is to refresh rational habits that sunk into oblivion and societal memory and to reveal details on building construction with more modern approaches with facilities of modern days. Main lines of IBDA will be formed in the virtue of uniting previous experiences and present technology under production principles.

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Analysis of Daylight Control in Advanced Façade Systems for Office Module in Ankara

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Abstract. Nowadays, declining energy resources in the world and enormous energy requirements in buildings sector enforced taking measures for sustainability. Office buildings have high energy consumption profiles. Significant amounts of energy consumption in office buildings are used by artificial lighting. Optimum use of daylight means great potential for the building's energy performance. With the evolving technology, advanced facade systems and shading elements are used for accurate and climate based daylight design. Daylight calculations for the design of the correct facade element are important for thermal and visual comfort of buildings. In this study, facade alternatives were produced by using shading and reflection potential for different facade components like horizontal, vertical and grid elements for south oriented office module in Ankara. Daylight and glare control analyses were prepared by using Grasshopper plug in Rhino and DIVA software. Optimal facade design for office module will be determined in terms of daylight maximization and glare control.

Keywords: Daylight · Advanced daylight systems · Advanced facade systems Glare control · Office building

1 Introduction

In a world newly concerned about carbon emissions, global warming, and sustainable design, the planned use of natural light in non-residential buildings has become an important strategy to improve energy efficiency by minimizing lighting, heating, and cooling loads. Advanced daylighting systems can reduce building energy consumption significantly and can also significantly improve the quality of indoor light [1].

Daylight can be thought of as one of the main factors of sustainable architecture. Light is one of the effective strategies in building energy optimization. Using an improved system of daylight design considerably reduces building electrical consumption. Electric energy consumption is the most important factor in the carbon emissions of buildings [2].

Utilization of daylight for office buildings is one of the major design concerns in terms of both visual and thermal comfort in hot climates. About 30% of energy consumption of office buildings is assumed to be obtained by artificial lighting (Linhart and Scartezzini 2011). Detailed daylight distribution calculations comprise an important part of the process of assessing thermal and visual comfort of the building. This

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calculation is also important in order to assess the trade-off between necessary natural lighting and undesired solar heat gain [3].

Glare is another undesirable consequence of uncontrolled natural lighting. To avoid conflicting situations between the need for shading, overheating, glare and natural lighting, complex shading devices are developed (Schuster 2006) [3].

The purpose of this paper is to examine the commonly used external shading influence on daylight performance and visual comfort in a south oriented office module in Ankara. Horizontal, vertical and grid elements are used as commonly used shading elements.

2 Methodology

2.1 The Characteristics of the Studied Office Room

In this study, the external shading was studied by simulating a room used as a reference office room. The case study was chosen to be located in the city of Turkey, Ankara (40.12 N/32.98 W).

The reference office room dimensions and model are taken from DIVA software's own internet address [4]. Reference office room dimensions are 3.6 m × 8.2 m 2.8 m. The space was considered to be on ground level with a free horizon and no obstructions. The window-to-wall ratio (WWR) is 45% (Figs. 1, 2, and 3).

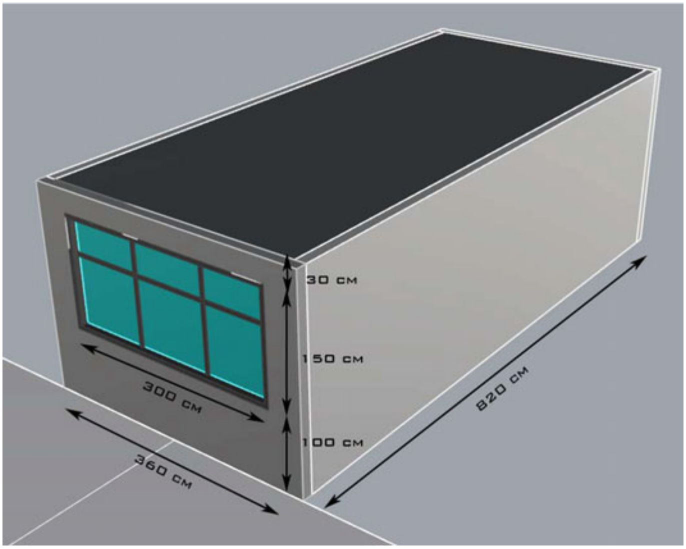


Fig. 1. Perspective view of the reference office

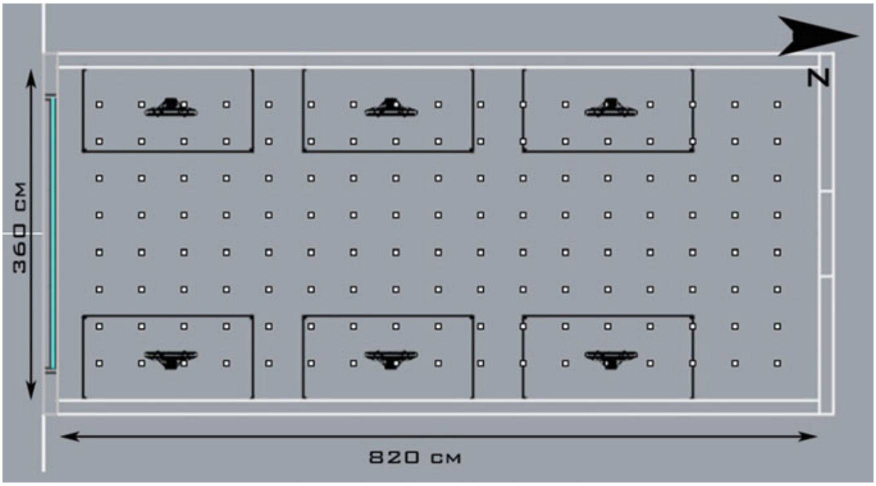


Fig. 2. Sensor Plan (work plane) of reference office

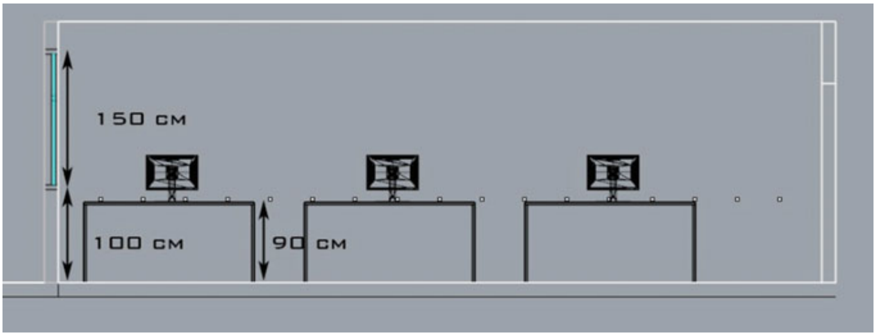


Fig. 3. Sensor Section (work plane) of reference office

For analysing daylight, some sensors were placed 0.9 m above the floor. This surface is called the work plane. One hundred and thirty six (136) sensors were placed in the office room with 0.5 length intervals. The calculated information on these dots is based on height.

The simulation was done with three different shading elements: horizontal, vertical and grid (Fig. 4). Horizontal shading elements vary in the range of 3–5, width 5 cm, and other sizes 10, 30 and 50 cm. Vertical shading elements vary from 3 to 10 in width, 5 cm in width, and 10, 30 and 50 cm in other sizes. The size of the grid shading element was fixed to 5–10 cm. The numbers are simulated as 4 in horizontal and 6 in vertical 6–4, 8–5, 10–6 cm. All shading elements have zero degrees of angles. Simulation studies have been done only for south facade.

The weather file of the Typical Meteorological Year (TMY) for this location has been taken from the database of the United States Department of Energy (DOE) [5].

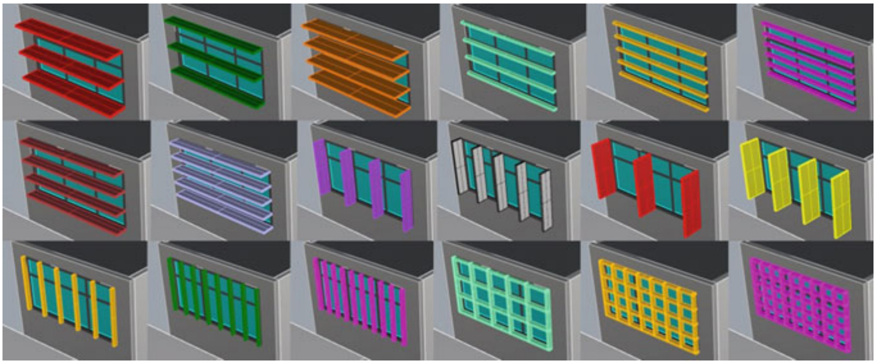


Fig. 4. Alternative facades

The standard materials contained in the DIVA Software are used (Table 1). Since it is thought that there will be other office modules on the roof material, the generic-floor_20 is chosen.

Table 1. Used materials lists

Space and window materials	
Floor level	Ground Level
Walls	Genericwall_50
Floor	GenericFloor_20
Roof	GenericFloor_20
Façade wall	OutsideFacade_30
Door	GenericFurniture_50
Furnishing	GenericFurniture_50
Monitor screen	250cdm2_screen
Mullions	Sheet Metal
Shading elements	Sheet Metal
Glazing	Glazing_DoublePanel_LowE_65

2.2 Daylight Simulation Software

Simulation was conducted using the Diva-for-Rhino V 4.0, a plug-in for Rhinoceros modeling software. It was used to interface Radiance and Daysim for annual simulation and illuminance computation (Reinhart et al. 2011). Simulation was conducted annually for weekdays from 9:00 AM to 5:00 PM which represents a typical office eight-hour working time. The recommended minimum illuminance value used in the tested office space is 500 lx (IESNA 2000) [6]. Daylight availability analysis determines the space usage (occupation), the work hour (in this paper, Week days from 9:00 AM to 5:00 PM) and the minimum received amount of daylight for office room in work plane (in this article, 500 lx). Then it provides data for the year with the sensors that are placed on the working plane.

In the paper, Grasshopper a plug-in for Rhinoceros modeling software is used to create shading elements (Fig. 5).

Fig. 5. Methodology diagram

Determination of daylight simulation parameters is among the most important parts of simulation. The most important parameter is the ambient bounces (ab) amount, which indicates the number of daylight radiance reflections. Depending on the complexity of the model you may want to increase the number of bounces from the default set by the Detail template. Some models which have complex exterior geometry for example require 7 bounces to ensure that the light reflection from exterior building surfaces is correctly treated. Likewise to obtain the correct impact of variations in the floor reflectance you will need to use 4 or more bounces [7]. A lesser or the default amount for the software will result in wrong and unreal findings for shading analysis [2]. The default value of the program is 2. Default setting, but will underestimate illuminance. In order to get more accurate results, as in most studies, a value of 5 was taken in this study [5, 7–10] (Table 2).

Table 2. Radiance simulation parameters

Ambient bounces	Ambient divisions	Ambient sampling	Ambient accuracy	Ambient resolution
5	1000	20	0.1	300

Daylight availability analysis is a combination of “Daylight Autonomy” (DA) and “Useful Daylight Illumination” (UDI) and has a similar, but more suitable function [11]. Daylight availability analysis determines the space usage (occupation), the work hour (in this article, Week days from 9:00 AM to 5:00 PM) and the minimum received amount of daylight for office room in work plane (in this article, 500 lx); then, it investigates and calculates the daylight perceived percent in sensors embedded in the work plane during the year. This measurement is done according to input, simulation results and annual average weather information, such as sky status during the year based on the Radiance software by Daysim. The percentage amount of work time (9:00 a.m.–5:00 p.m.) for which nodes received 500 lx or more during the year is shown in colored degrees [2].

Daylight Autonomy (DA) which is defined as: “the percentage of the occupied hours of the year when a minimum illuminance threshold is met by daylight alone” [12].

Useful Daylight Illuminance (UDI) is another proposed annual daylight metric. Useful daylight is defined as providing ambient light at the work plane at illuminance levels between 100 and 2000 lx. Above 2000 lx, heat gains and glare become potential problems. Potential UDI metrics give thresholds using bins (too low, useful, and too high) for certain percentages of the work plane [12].

Daylight Glare Probability (DGP) DGP represents the probability that a person is disturbed by glare and is derived from a subjective user evaluation. Simulation was conducted using Evalglare for analyzing Radiance based fish-eye renderings of glare situations using the Daylight Glare Probability (DGP), which is a simplified method presented by Weinold (2010) [13]. This simulation was carried out for summer and winter equinoxes at 13:00 noon.

In point in time glare analyses method the glare was divided into four categories: intolerable glare (DGP $\geq$ 45%), disturbing glare (45% > DGP $\geq$ 40%), perceptible glare (40% > DGP $\geq$ 35%), and imperceptible (DGP < 35%).

In this study, daylight autonomy and daylight availability were used to measure daylight values. Annual glare and point in time glare were used to glare control.

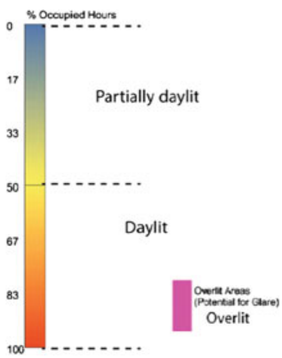
3 Results

3.1 Daylight Simulation Results

By using shading elements such as horizontal, vertical and grid, daylight autonomy and daylight availability analyses for the south façade were made. The aim of this section is to investigate the optimum shading in terms of glare for each scenario made with horizontal, vertical and grid elements.

The scenarios are evaluated based on the degree of color specified in Table 3. Pink areas are overlit area which potential for glare (Fig. 6).

Table 3. Colored degrees of daylit, overlit and partially daylit areas



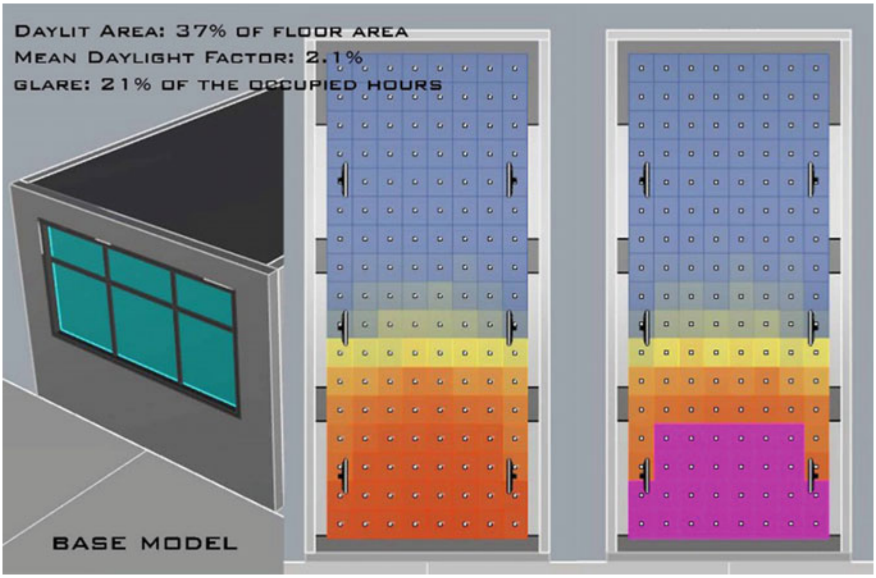


Fig. 6. Daylight autonomy and availability analyses of base model (no shading)

The coding specified in the table shading elements are as follows (Figs. 7, and 8):

Example:

S_H_3_5_30	
S	Shading
H	Horizontal elements
3	Number of shading elements
5	Shading element dimension (cm)
30	Shading element dimension (cm)

S_G_8_5_5_10	
S	Shading
G	Grid elements
8	Number of vertical shading elements
8	Number of horizontal shading elements
5	Shading element dimension (cm)
10	Shading element dimension (cm)

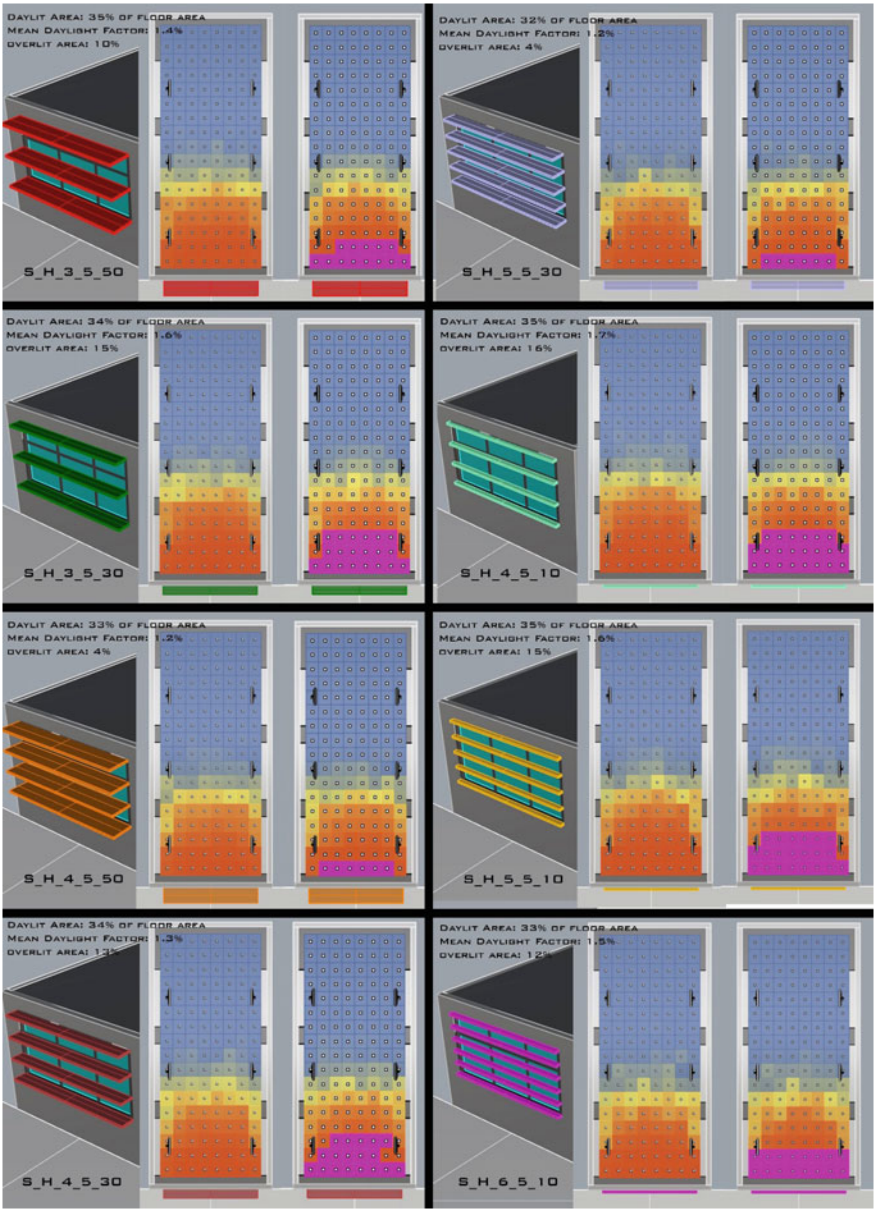


Fig. 7. Daylight autonomy and availability analyses of horizontal shading model

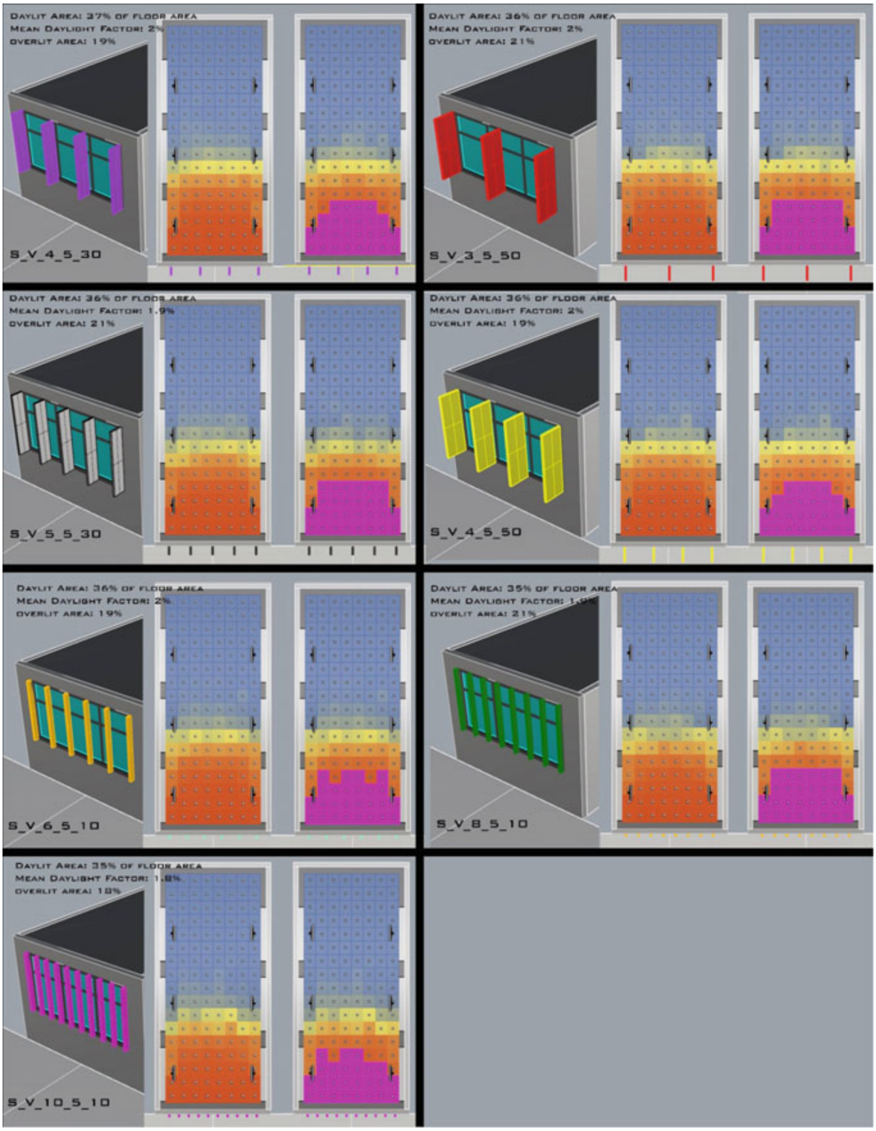


Fig. 8. Daylight autonomy and availability analyses of vertical shading model

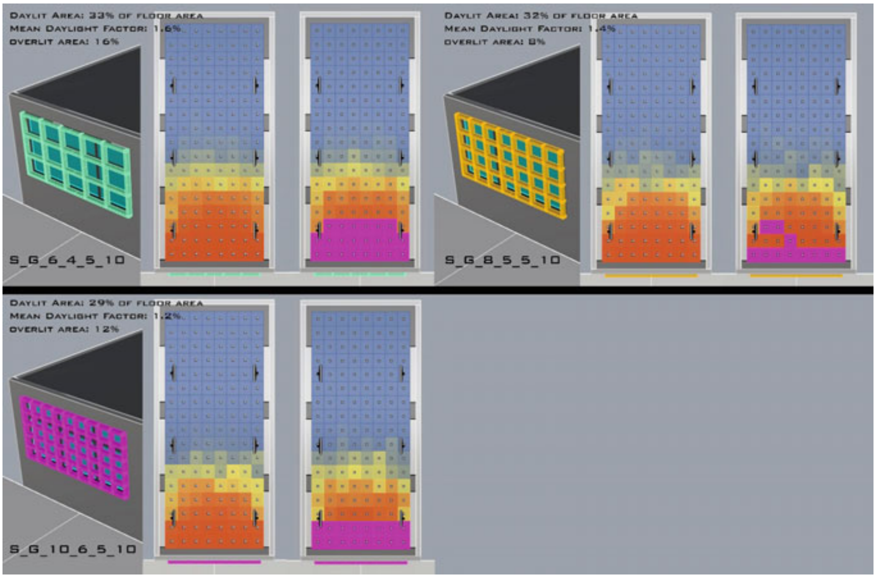
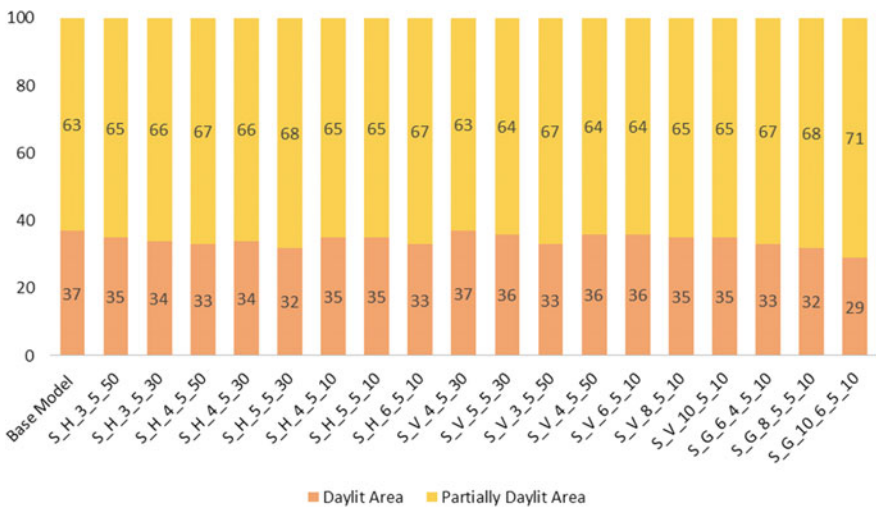


Fig. 9. Daylight autonomy and availability analyses of grid shading model

As a result of the analyses for the vertical elements, it is seen that vertical elements have higher daylit areas than horizontal elements. However, when pink areas are examined, the probability of glare is higher in vertical elements. As the number and size of shading elements increases, the area of daylit decreases.

The following Fig. 9, it is seen that grid shading elements have lower daylit areas than other shading elements. However, when pink areas are examined, the probability of glare is higher in vertical elements (Table 4).

Table 4. Daylight autonomy daylit and partially daylit area results for all scenarios



When simulations with shading elements are examined, daylit area areas decrease as the size and number of shading elements increase. When all the scenarios are compared, it is seen that the S_V_4_5_30 of vertical elements have higher daylit area. However, glare probability range is higher.

3.2 Glare Analyses Results

3.2.1 Annual Glare Analyses

Using shading elements such as horizontal, vertical and grid, annual glare simulations for the south façade were made. Annual glare results are seen for the base model (no shading) in the Fig. 9 (Figs. 10, 11, and 12).

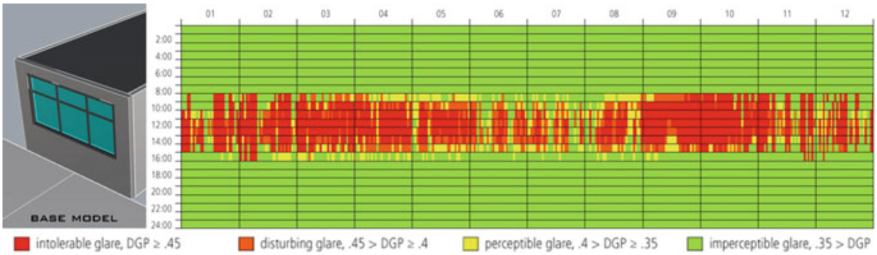


Fig. 10. Annual glare analyses of base model (no shading)

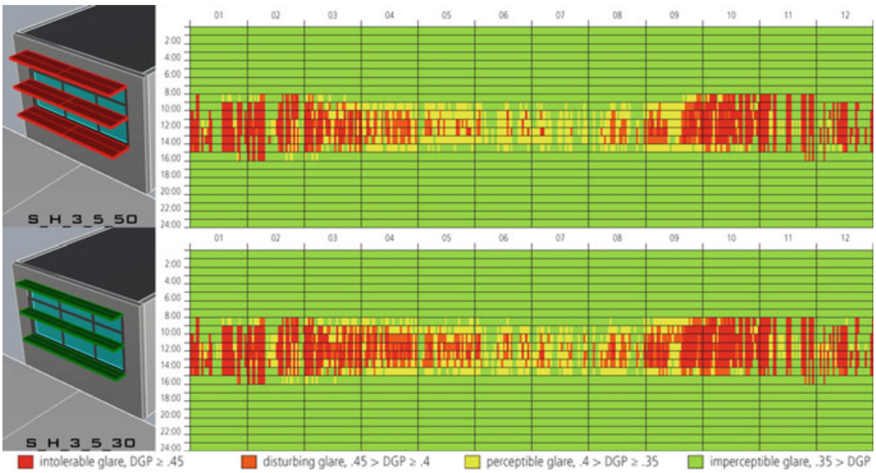


Fig. 11. Annual glare analyses of horizontal shading model

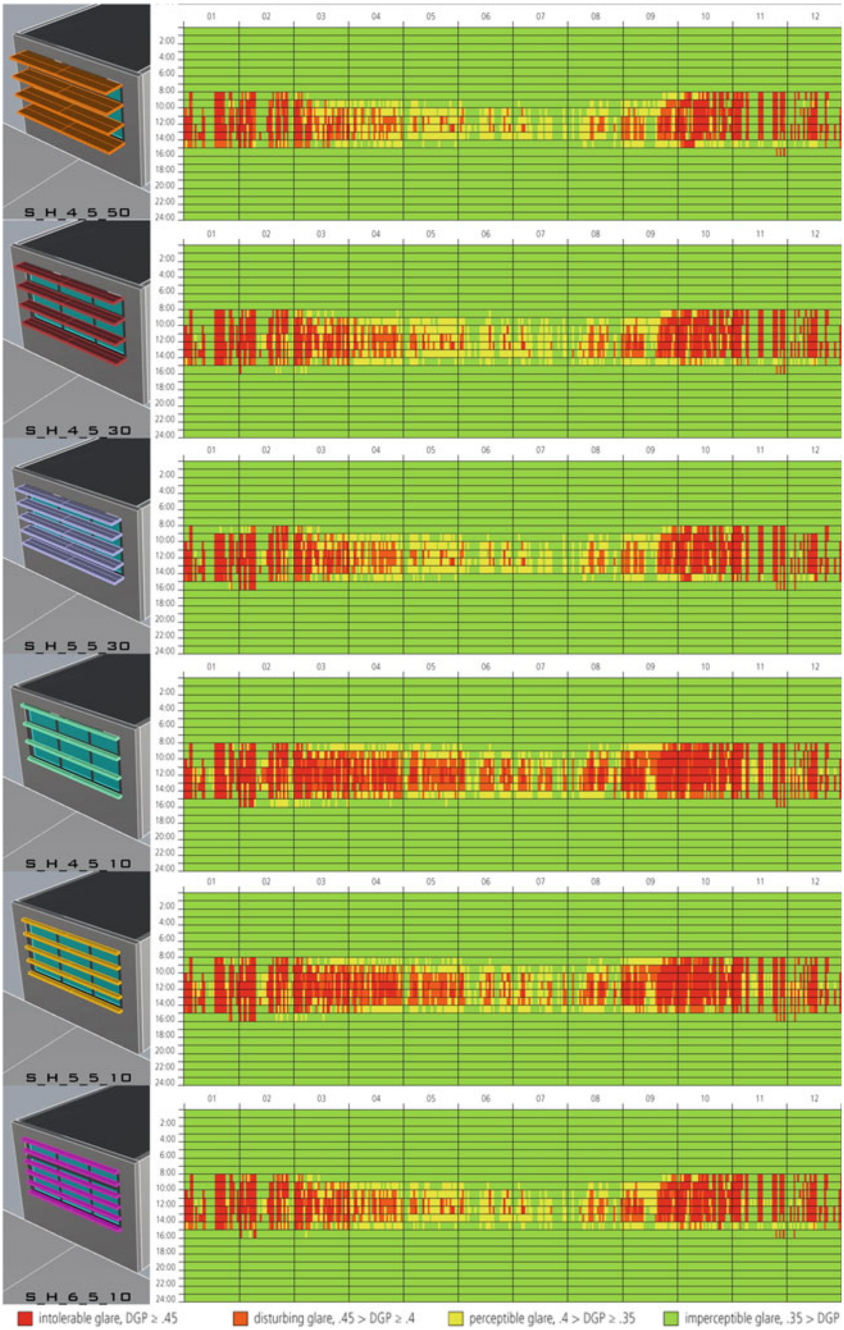


Fig. 12. Annual glare analyses of horizontal shading model

When the annual glare values of horizontal shading elements are examined, it is seen that as the number and size of the shading elements increases, the glare decreases. This is especially true for 5–7 and 8 months (Figs. 13, 14 and 15).

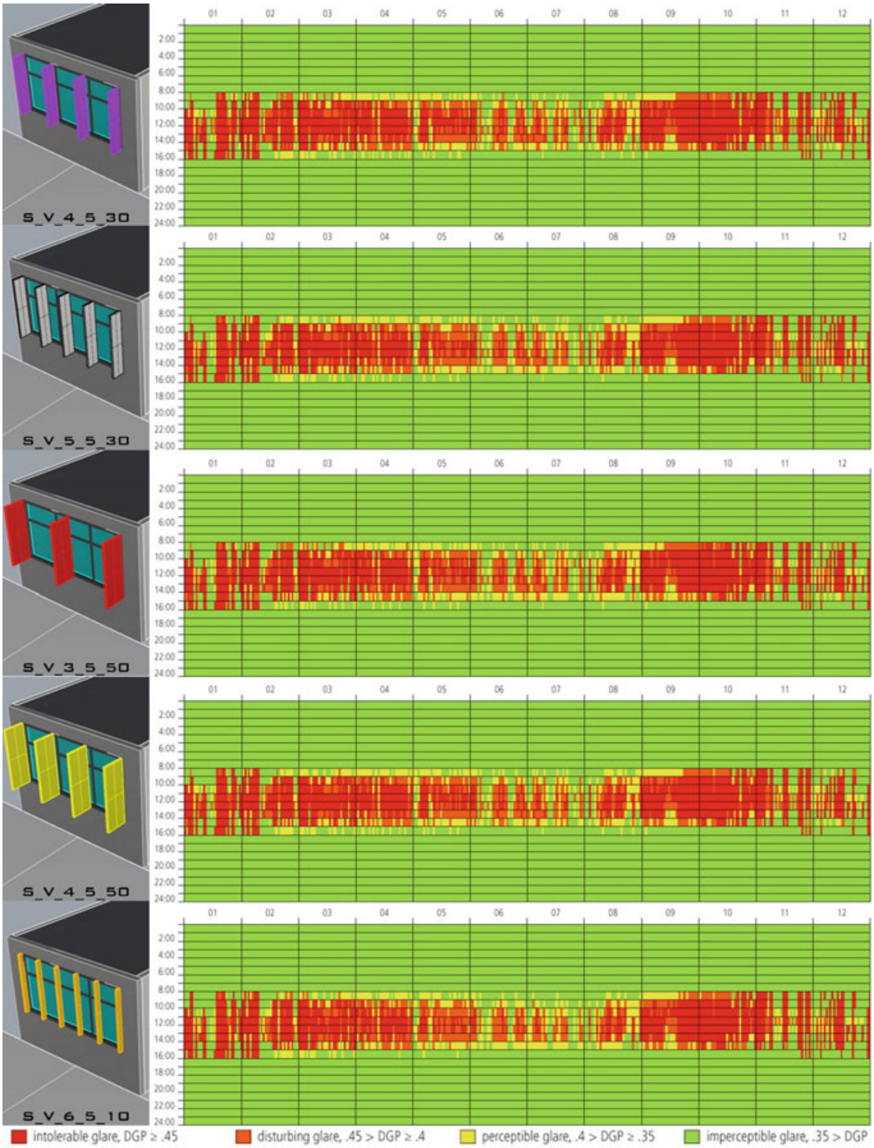


Fig. 13. Annual glare analyses of vertical shading model

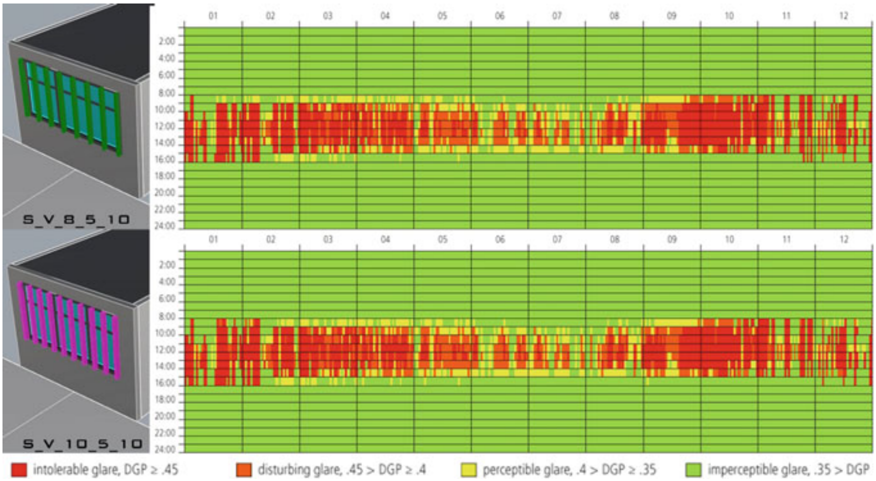


Fig. 14. Annual glare analyses of vertical shading model

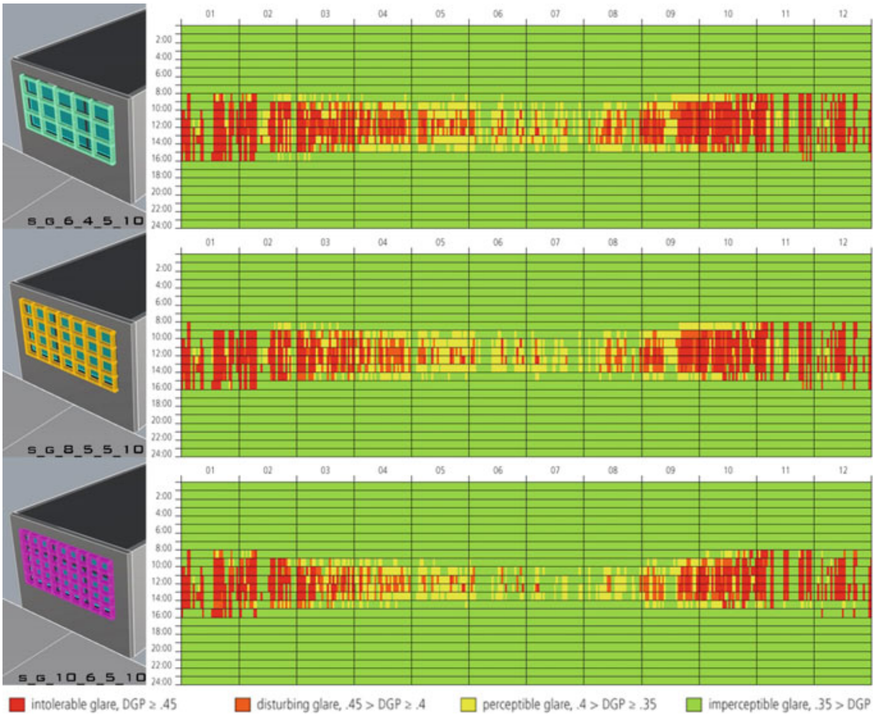


Fig. 15. Annual glare analyses of grid shading model

When glare graphics of vertical elements are examined, it is seen that the annual glare is higher when looking at the vertical elements.

The glare on the graphics of the grid shading elements is close to the values of the horizontal elements. In particular, the scenarios S_G_10_6_5_10 where the horizontal and vertical shading elements are used intensively are the most suitable scenarios in this respect. However, due to the use of intensive shading elements, it is considered that the landscape should be evaluated.

When comparing horizontal, vertical and grid system shading elements, it can be said that horizontal shading elements and grid shading elements are more suitable in general.

3.2.2 Point in Time Glare Analyses Results

Analyses was conducted in summer (21 June) and winter equinox (21 December) dates for 13:00 pm hours. In point in time glare analyses method the glare was divided into four categories: intolerable glare (DGP $\geq$ 45%), disturbing glare (45% > DGP 40%), perceptible glare (40% > DGP $\geq$ 35%), and imperceptible (DGP < 35%).

The following Fig. 16 shows the results of the main model. In the analyses made for 21 June 13:00 pm hours, the DGP value is seen in the level of 29%, that is, imperceptible glare level. In the analyses made for 21 December 13:00 pm hours, the DGP value is seen in the level of 100%, that is, intolerable glare level.

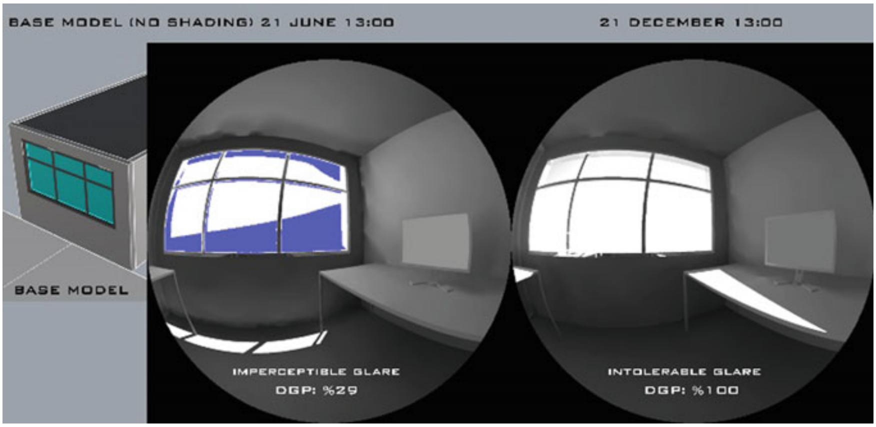


Fig. 16. Point in time glare of base model (no shading)

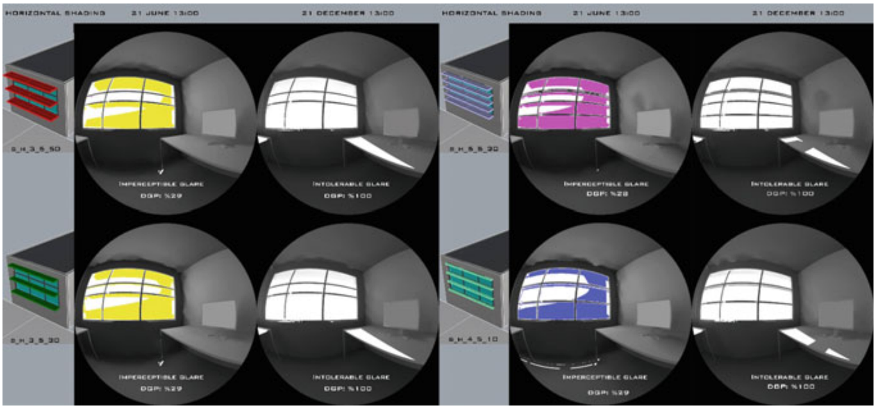


Fig. 17. Point in time glare analyses of horizontal shading model

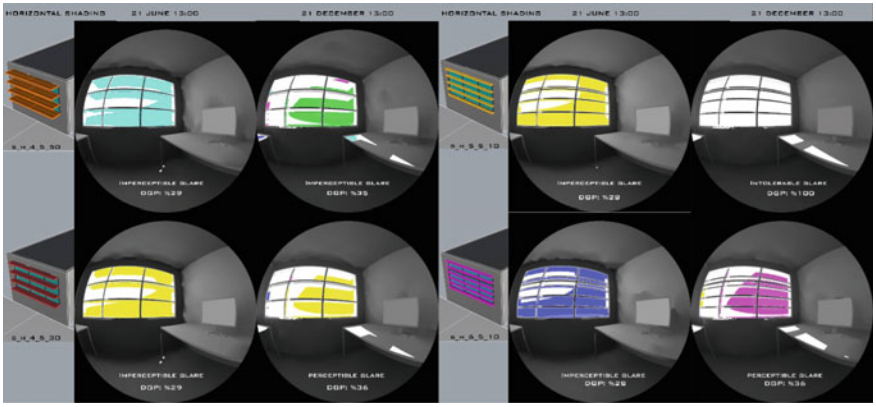


Fig. 18. Point in time glare analyses of horizontal shading model

As shown in Figs. 17, 18, 19 and 20, in summer equinox, DGP is imperceptible glare level that in all scenarios of about 28–29%. In winter equinox, DGP seems to be intolerable glare level of about 100% at S_H_3_5_50, S_H_3_5_30, S_H_5_5_50, S_H_4_5_10 and S_H_5_5_10 scenarios. In S_V_4_5_30, S_V_6_5_10 scenarios, DGP seems to be perceptible glare level that about 36%. In S_H_4_5_50 scenario, DGP seems to be imperceptible glare level that about 35%.

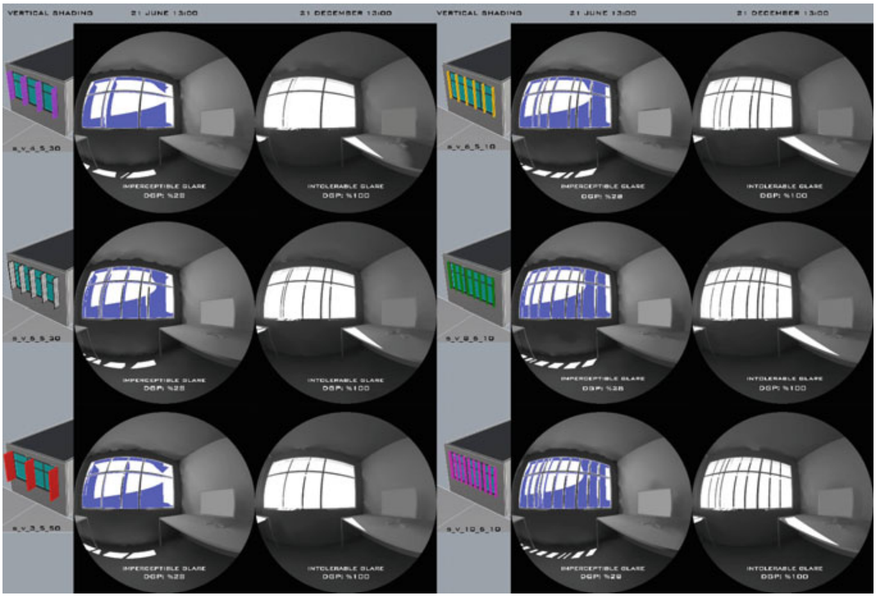


Fig. 19. Point in time glare analyses of vertical shading model

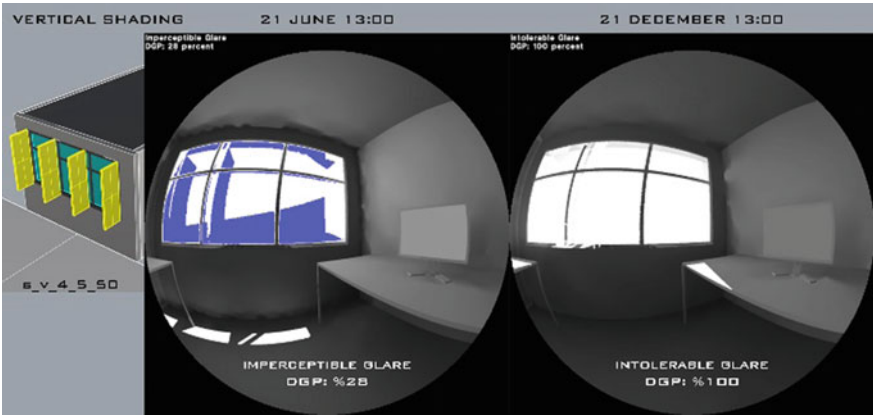


Fig. 20. Point in time glare analyses of vertical shading model

As shown in Figs. 19 and 20, in summer equinox, DGP is imperceptible glare level that in all scenarios of about 27–28%. All values are approximate for all scenarios. In winter equinox, DGP is intolerable glare level that in all scenarios of about 100%.

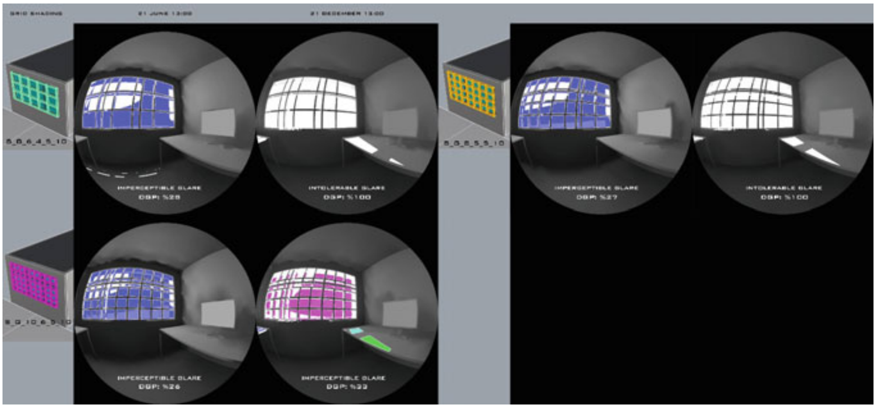


Fig. 21. Point in time glare analyses of grid shading model

As shown in Fig. 21, in summer equinox, DGP is imperceptible glare level that in all scenarios of about 27–28%. In winter equinox, In S_G_6_4_5_10 and S_G_8_6_5_10 scenarios, DGP seems to be intolerable glare level that about 100%. In S_G_10_8_5_10 scenario, DGP seems to be imperceptible glare level that about 33%.

4 Discussion

The present study aimed to investigate the influence of as horizontal, vertical and grid, external shading on daylight performance and visual comfort and achieved significant results in this respect. A total of 18 scenarios were created, including 8 horizontal elements, 7 vertical elements and 3 grid shading elements. In this scenarios, daylight analysis and glare analysis were done. When the daylight and visual comfort are evaluated together in the direction of these analyzes, it is seen that horizontal shading elements are the most optimal solution for Ankara. The brightness levels of the horizontal and vertical elements are approximately the same. However, when glare charts are examined, it is seen that the glare values of vertical shading elements are generally high for all months.

5 Conclusion

The presented study aimed to investigate the impact of external fixed shading elements which considers the size and direction on daylight efficiency and visual comfort in south façade for an office module in Ankara. In order to obtain visual comfort and a suitable daylight distribution for office space, annual and advanced analyses and simulations have been conducted by using Grasshopper plug in Rhino and DIVA software. Horizontal shading elements were found suitable for daylight use and glare control.

In future studies it is aimed to design and analyses the performance of movable, external shading elements for Ankara climatic conditions. It is possible to produce optimum solutions over the last years through increasing parametric designs.

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Usage of Inorganic Based Materials as Flame Retardants in Polymer Composites

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Abstract. Although composite materials have been used to solve technological problems in the material industry, they have been exactly taking attention since the 1960s. Composite materials have become increasingly common engineering materials and have become widely used in many applications such as automotive parts, sporting goods, aerospace parts, consumer products and marine and petroleum products. In this work, reducing the flammability characteristic of polymer-based composites which have the carbon-based matrix due to the presence of inorganic-based compounds added during composite production was examined. Also, preliminary findings of the experimental study on the flame resistance of composite containing sepiolite, aluminum hydroxide, antimony trioxide and zinc borate were presented. Results showed that using some additional materials in mixing design improve the flammability properties of composite materials.

Keywords: Composite · Polymer · Flame retardants

1 Introduction

In the modern world, importance of material science can be explained by concentrating on the production of new materials with different components. In the time-changing world, the value of composite materials is much better understood. The composite sector shows an improvement especially in Turkey over the growth rate of Europe and the world. In the past years, depending on the economic situation of the period, the sectoral growth of composite was observed between 8 and 12% in Turkey. Nowadays, with economic steadiness, growth is realized between 9 and 10%. The growth in 2015 was 2%. When the amount of composite consumption is considered as a "Development Criteria", it is seen that there are significant opportunities ahead of our country. Because the amount of composite consumption is 4–10 kg per capita in the world and it is 3 kg in our country. The average price level in the world is 7.5 €/kg and is 5 €/kg in our country. Both the per capita consumption and the average price in Turkey can be evaluated as an advantage for our country in the coming period. Composite usage distribution in various sectors in Turkey, Europe and the World is given in Table 1.

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Table 1. Composite usage distribution in various sectors in Turkey, Europe and the World

Sector	The World (%)	Europe (%)	Turkey (%)
Structure and construction	24.5	20	22
Transportation and automotive	21	30	20
Electricity and electronics	19	14	3
Consumer goods	6	3	2
Wind power	7	12	5
Pipe and tank	14	13.5	45
Space and aerospace	0.5	0.5	–
Marine	4	5	2
Other	4	2	1

As can be seen in Table 1, composite material in our country is mostly used mainly in pipes and tanks, structure and construction sectors. With the development of advanced technology in our country, it is expected to use more and more composite materials especially in wind energy, transportation and automotive, space and aerospace, electricity and electronics sectors [1]. Composite materials can be defined as macroscopic combination of two or more different materials that are generally insoluble in each other.

Structurally, composite materials are consisted of a matrix forming the continuous main phase of the system and a reinforcement component. Composites can be produced with some advanced properties like high strength, lightness, design flexibility, corrosion resistance, applicability to different surfaces, high temperature resistance and easy workability etc. depending on production process [2].

Composites consist of different materials with a certain layout and can be distinguished from the points of contact. The main purpose of composite materials is to combine the well characterized properties of different materials under a single material. Composite materials are divided into different groups according to their structures and matrix materials. According to matrix materials, it can be examined three groups: Polymer, metal and ceramic matrix composites. Especially, polymer composites produced with commonly used fibers have been developed after 1940 for usage of commercial purposes. Thereafter, polymer composites reinforced with fibers have been used in many sectors [3].

Polymer composites are distinguished by high strength, dimensional and thermal stability properties. They consist of matrix and reinforcing materials. Matrix materials can be addressed as thermoplastics and thermosets. Besides, reinforcing materials may be many kinds of fibers. These materials are preferred at temperatures not exceeding 200 °C in commercial and industrial applications including refractory pipes, valves, pressure vessels and reactors. Some additives are added in order to improve the properties of the polymers.

Furthermore additives can decrease the cost of the polymers. But the additive materials reaches a certain threshold value, it weakens the mechanical properties of the polymer. Additives (filler etc.) are mainly used in thermosetting polymers such as phenolic resins, thermosetting resins and polyurethanes. The additives are mostly used in powder form but also used in granular form [4]. Generally, composites have advanced engineering performances. Contrary to these advanced performances, some weaknesses can take important role on the service life of composites. One of these is weak flame resistance. When related literature is examined, many kinds of studies are seen on using powder materials to improve the flame resistance of composites [4].

Laachachi et al. [5] studied on the usability of expanded graphite (EG) as flame retardant for epoxy resin. Another research on the usability of EG together with some phosphorus compounds is Yang et al.'s [6] study. Yang et al. [7] studied the effects of boron and silicon on the flame retardancy and thermal degradation properties of epoxy resin by obtaining cross-linked hybrid epoxy resins containing boron and silicon. Li et al. [8] studied the effects of aluminum phosphinate (AlPi) addition on the flammability of different polymers. Wang et al. [9] studied the contribution of the combined use of aluminum polyhexane ethylene phosphinate and 9,10-dihydro-9-oxa-10-phosphaphanenanthene 10-oxide as flame retardant compounds in thermoset resin.

In this study, sepiolite, antimony trioxide, aluminum hydroxide and zinc borate were used to produce composite materials with improved non-flammability properties (Fig. 1).

2 Material and Method

In the experimental stage, epoxy resin was used as main material to produce composite samples. Methyl ethyl ketone peroxide (MEK-P) and cobalt octoate compounds were used as initiator and accelerator for polymerization. All these materials were supplied from Superlit Pipe Industries Inc. While preparing the mix of composites, sepiolite ($Si_{12}Mg_8O_{30}(OH)_4(H_2O)_4$–$8H_2O$), aluminum hydroxide ($Al(OH)_3$), antimony trioxide ($Sb_2O3$) and zinc borate ($2ZnO{\cdot}3BrO_3{\cdot}3H_2O$) were added as flame retardant. Sepiolite ($Si_{12}Mg_8O_{30}(OH)_4(H_2O)_4$–$8H_2O$) was obtained from Dolsan Mining Company. Other inorganic compounds; Aluminum hydroxide ($Al(OH)_3$), Antimony Trioxide (Sb_2O_3) and Zinc Borate ($2ZnO{\cdot}3BrO_3{\cdot}3H_2O$) were obtained from EOC Belgium Company. The changes in the flame retardant additive compounds used in the studying during combustion can be summarized depending on the literature in Table 2. When some researchers are examined, reactions of these powder materials during combustion depending on the temperatures can be detailed in Table 2.

Fig. 1. Powder materials used in composites

Table 2. Combustion reactions of additive compounds during polymer combustion

Additive compounds	Reactions during combustion			References
Sepiolite	Temperature	Reactions	Bound water	
	20–200 °C	$Si_{12}Mg_8O_{30}(OH)_4(H_2O)_4$–$8H_2O$ => $Si_{12}Mg_8O_{30}(OH)_4(H_2O)_4$ + $8H_2O$	Hygroscopic and zeolitic	
	200–400 °C	$Si_{12}Mg_8O_{30}(OH)_4(H_2O)_4$ => $Si1_2Mg_8O_{30}(OH)_4(H_2O)_2$ + $2H_2O$	Weakly bound crystal	[10]
	400–600 °C	$Si_{12}Mg_8O_{30}(OH)_4(H_2O)_2$ => $Si_{12}Mg_8O_{30}(OH)_4$ + $2H_2O$	Strong crystal	
	600–875 °C	$Si_{12}Mg_8O_{30}(OH)_4$ => $Si_{12}Mg_8O_{30}$ + $2H_2O$	Phase conversion	
Aluminum hydroxide	200 °C	$2Al(OH)_3$ => Al_2O_3 + H_2O		[4]
Antimony trioxide		SbO + 2HX => 2SbOX + H_2O X: F, Cl, Br, I		[4]
Zinc borate		$2ZnO·3BrO_3·3H_2O$ => $2ZnOB_2O_3$ + H_2O		[4]

When preparing the specimens for combustion test, all flame retardant materials were mixed with 20% by weight of the reference matrix. Methyl ethyl ketone peroxide (MEK-P) was added as accelerator and cobalt octoate was used as initiator in all mixtures. Contents of all mixtures were given in Table 3. Specimens were prepared and kept in desiccators for curing as shown in Fig. 2. Burning tests on cured samples were carried out at Düzce University Scientific and Technological Research Application and Research Center (DUBIT).

Fig. 2. Curing of specimens

Table 3. Contents of all mixtures

	Reference	Mix 1	Mix 2	Mix 3	Mix 4
Flame retardant material	–	Sepiolite	Aluminum hydroxide	Antimony trioxide	Zinc borate
Accelerator	MEK-P	MEK-P	MEK-P	MEK-P	MEK-P
Initiator	Cobalt octoate	Cobalt octoate	Cobalt octoate	Cobalt octoate	Cobalt octoate

In the Research Center, a chamber was used for burning test. The chamber and sample preparation can be seen in Fig. 3a. After preparing the samples, flame length was settled as 125 mm (Fig. 3b) and the degree of flame was determined by a laser thermometer (Fig. 3c). By this test set up, flame was applied to all specimens at an angle of 45°. After flame effect, the specimens were cooled and weight losses of specimens were determined. All of the polymer blends subjected to the combustion test were shown in Fig. 4.

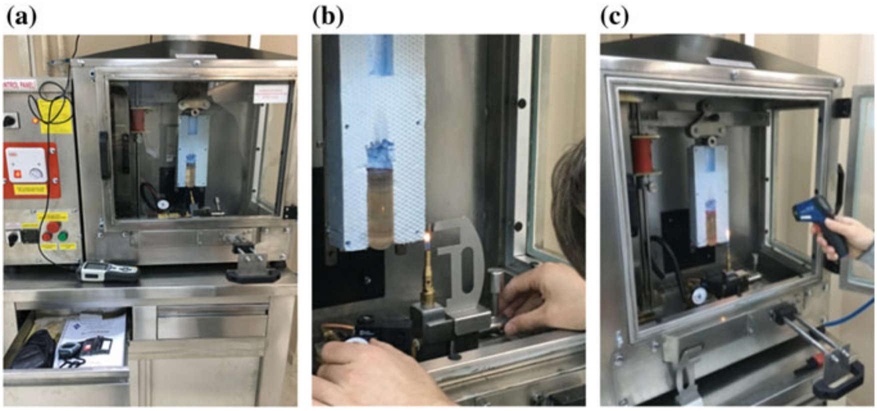

Fig. 3. Test Chamber. **a** Specimen placement to test chamber, **b** setting flame length, **c** measuring flame temperature by laser thermometer

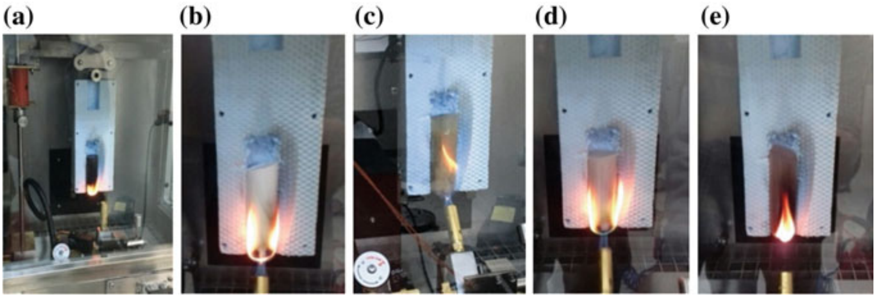

Fig. 4. Burning tests on the produced composites. **a** The reference specimen—pure resin burning, **b** the specimen containing antimony trioxide, **c** the specimen containing sepiolite, **d** the specimen containing zinc borate, **e** the specimen containing aluminum hydroxide

3 Results and Discussion

The mass losses of all specimens were given in Table 4. When the obtained mass losses results are examined, flame retardants added to the matrix reduces the mass losses and combustion. As seen in Table 4, the mass losses rates of specimens containing antimony trioxide, aluminum hydroxide, zinc borate and sepiolite are 2.6436, 0.6642, 1.4682, 0.4332 and 0.6428%, respectively. According to the results given in Table 4, it can be concluded that zinc borate is the most effective additive for retarding the flame effect. Figure 5 was given to evaluate the changes in mass losses. It is clearly seen in Fig. 5 that antimony trioxide, zinc borate and sepiolite decrease the mass losses. In contrary to this additive, aluminum hydroxide did not show a valuable effect on the flame retardancy.

Table 4. The results of the burning test

	Pre-combustion weighing (g)	Weighing after burning (g)	Mass difference (g)	Mass loss (%)	Mass loss (‰)
Pure resin	101.2988	101.0310	0.2678	0.2643	2.6436
Antimony trioxide	120.4387	120.3587	0.0800	0.0664	0.6642
Aluminum hydroxide	121.7817	121.6029	0.1788	0.1468	1.4682
Zinc borate	115.6274	115.5773	0.0501	0.0433	0.4332
Sepiolite	119.6316	119.5547	0.0769	0.0642	0.6428

There was an ignition seen while pure resin tests. But samples containing additives did not show any ignition. This result can be evaluated as remarkable. After applying flame to specimens, their appearance can be seen in Fig. 6. As seen in Fig. 6, the greatest damage was occurred in pure resin and the greatest resistance ability was seen in composite containing zinc borate.

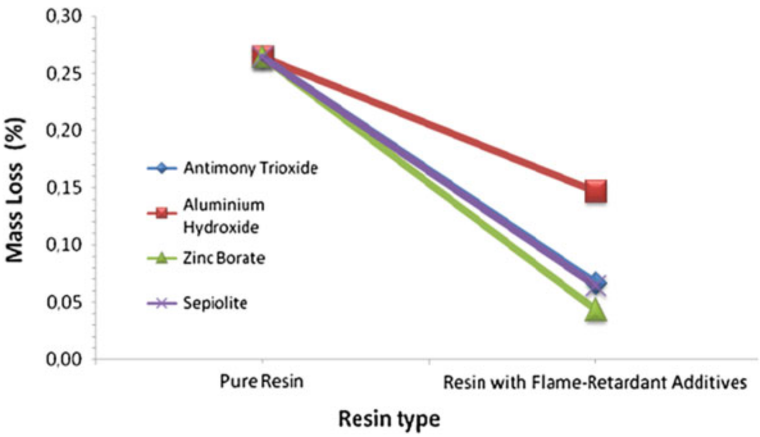

Fig. 5. Mass losses (%)

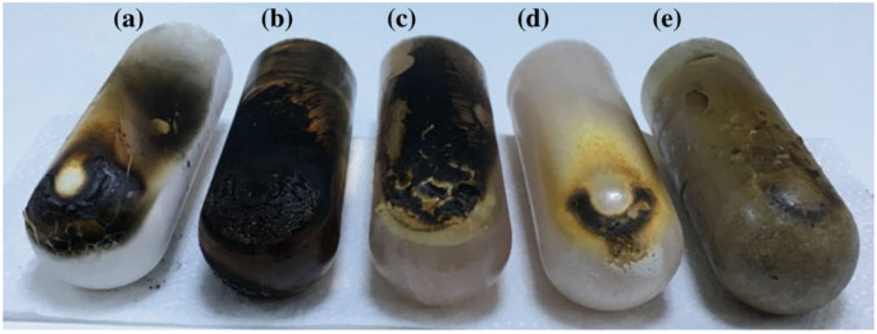

Fig. 6. Display of all materials burned under flame. **a** Antimony trioxide, **b** pure resin **c** aluminum hydroxide, **d** zinc borate, **e** sepiolite

4 Conclusion and Suggestions

In this study, some powder materials were used in production of composite to provide flame resistance ability. The results obtained in the study and suggestions for future studies can be summarized as follows:

Results

- Zinc borate is most useful powder materials to reduce flam effect with 0.0433% mass loss.
- Aluminum hydroxide showed minimum effect to reduce flame effect with 0.1468% mass loss.
- Mass loss under flame was found as 0.0642% in composite containing sepiolite. When this result compared with pure resin (mass loss is 0.2643%) sepiolite can be used as flame retardancy powder additive. This result is important because sepiolite is abundant as mine material in Turkey.
- Figure 6 shows that using pure resin has an important risk under flame.
- It was observed that, zinc borate, sepiolite and antimony trioxide may be useful flame retardant additives to prevent ignition after flame application.

Suggestions

- It can be seen that different additives are effective to decrease flame effect of the polymer. The researchers are important to investigate flame ability of composites containing different powder materials.
- The effect of flame retardant additives on the mechanical performance of composites should be investigated.
- A cost analysis is to be made to determine economical results of using additives to produce composites.

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Effects of Surface and Fiber Types on Mechanical Properties of Fiber Reinforced Polymer Bars

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Abstract. In this study, effects of surface form (sand coated and helical ribbed surface) and fiber types (glass, carbon, aramid and basalt) on tensile strength and elastic modulus of fiber reinforced polymer (FRP) bars were investigated. The results showed that FRP bars with helically wrapped surfaces have higher tensile strength and elastic modulus than those of FRP bars with sand coated surface.

Keywords: FRP bar · Helically wrapped surface · Sand coated surface Tensile strength · Elasticity modulus

1 Introduction

Cracking and spalling of concrete covers associated with corrosion of steel reinforcement have been reported to be the most common problems in concrete structures [1]. ACI committee 440 reported that corrosion problems in RC structures began in the 1960s. Fiber reinforced polymer (FRP) bars can be used to resolve the corrosion problems of reinforced concrete members [2, 3]. FRP can be evaluated as a new type of composite material that incorporates a variety of fibers and resins. In construction sector, it is widely used in strengthening applications. FRP composite materials can be accepted superior materials with their advantages of being lightweight and having a high stiffness-to-weight ratio, excellent chemical resistance, high fatigue strength and potentially high resistance to environmental degradation [4]. One of the most important usages of FRP bars in the field of civil engineering is soft-eye applications which are shaft-out of TBM in tunneling works. Soft-eye application of the TBM shaft-out in the subway tunnel from London Docklands to Arsenal Woolwich and King Albert Park Station in Singapore made by AlpineBau GmbH appears in Fig. 1a, b, respectively [5, 6].

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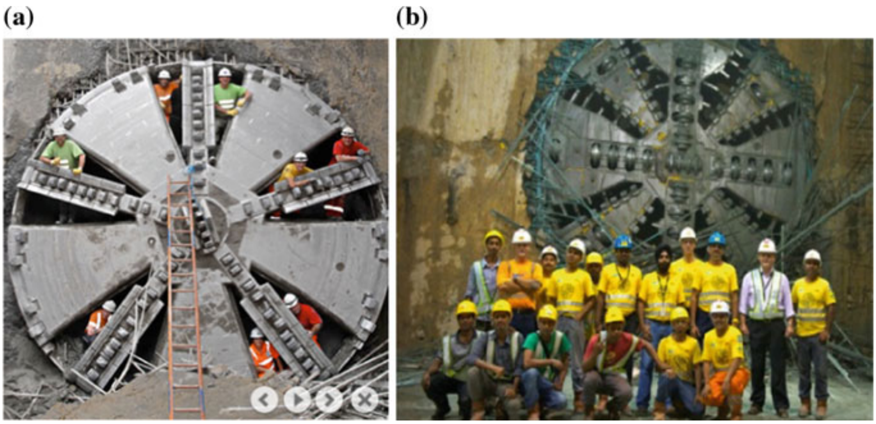

Fig. 1. Using of FRP bars in soft-eye applications (TBM shaft-out in the tunneling works)

Similar to the practice at the Vienna International Airport, the capacity of Zürich Airport which is the Switzerland's largest international airport has been expanded to meet the requirements of the Schengen criteria during 2009–2010 (Fig. 2). In this expansion study, a signaling system was installed inside the floor and FRP bars were used for better system operation instead of steel bars which creates a magnetic field in construction of floor [7].

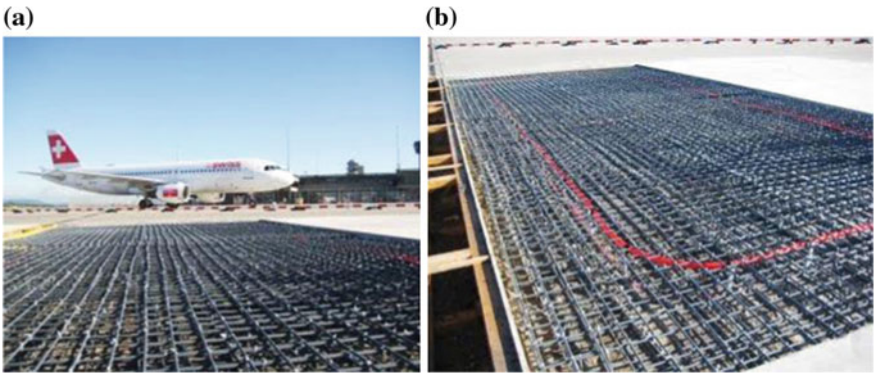

Fig. 2. Use of FRP bars in floor construction in Zurich Airport

2 Material and Method

In the scope of the study, firstly, the production of FRP bars with different surface properties were carried out by using carbon, basalt, glass and aramid fibers. The FRP bars were produced by using pultrusion method. The FRP bars having helically wrapped and sand coated surface properties produced in ESA Chemical Metal Industry Ltd. Company factory were shown in Fig. 3.

Fig. 3. FRP bars produced in the scope of the study

FRP bars have to be kept rigidly by jaws of tensile test machine to obtain reliable results from the tensile testing of FRP bars. For this reason, the ends of FRP bars were capped with epoxy to help to be held of ends by jaws. The epoxy capped FRP bars were shown in Fig. 4.

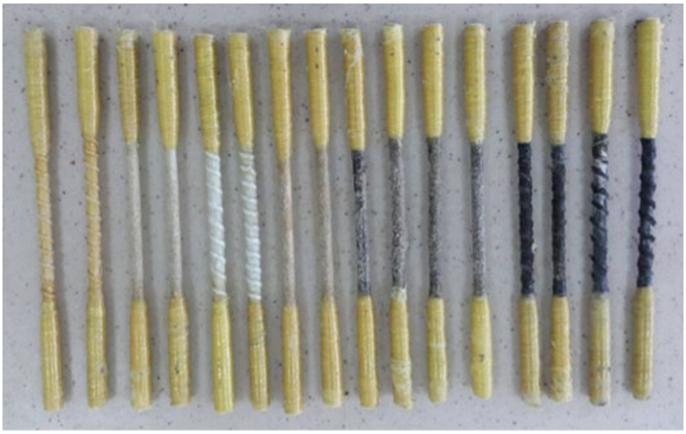

Fig. 4. The epoxy capped FRP bars

Tensile test was carried out on epoxy capped FRP bars. The universal test machine was used for tensile tests (Fig. 5). During the test, the obtained load-elongation values were recorded on a computer. The appearance of a sample after the tensile test is given in Fig. 6.

Fig. 5. Tensile test set-up

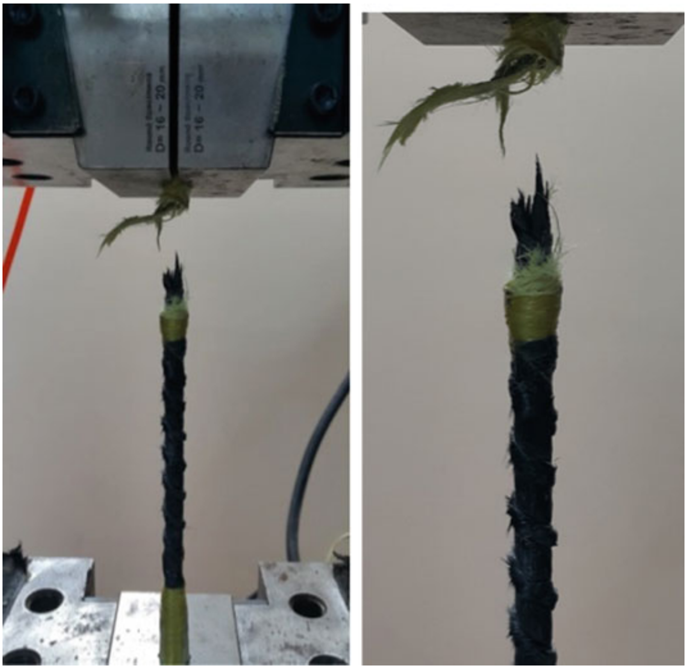

Fig. 6. Tensile test and breaking mode of Carbon FRP bar with helically wrapped surface

3 Results and Discussion

Stress-strain values were calculated using the load and elongation data obtained from the tensile test. Elasticity modulus was determined by using stress-strain data. Stress-strain curves obtained from tensile tests on FRP bars were given in Figs. 7, 8, 9, 10, 11, 12, 13, 14. Besides, test results obtained from the tensile tests were given in Table 1.

Table 1. Mechanical properties of FRP bar

	BFRP		GFRP		CFRP		AFRP	
	Tensile strength (MPa)	Elasticity modulus (MPa)	Tensile strength (MPa)	Elasticity modulus (MPa)	Tensile strength (MPa)	Elasticity modulus (MPa)	Tensile strength (MPa)	Elasticity modulus (MPa)
Sand coated surface	900	36,883	913	35,325	1261	51,293	1113	45,623
H. wrapped surface	980	38,881	956	38,043	1336	58,134	1213	46,552

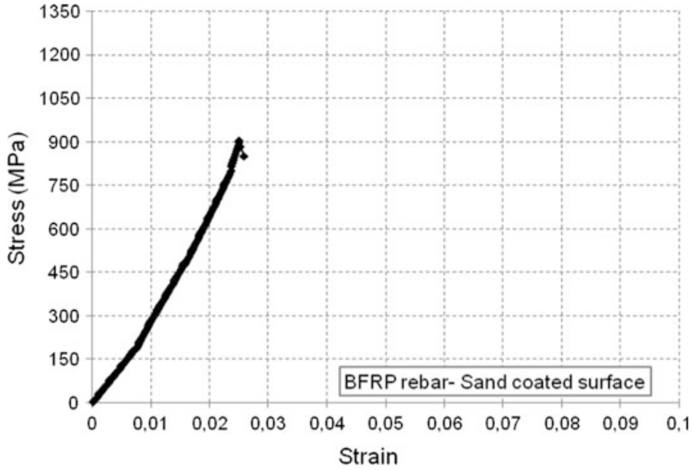

Fig. 7. Stress-strain curve of BFRP bar with sand coated surface

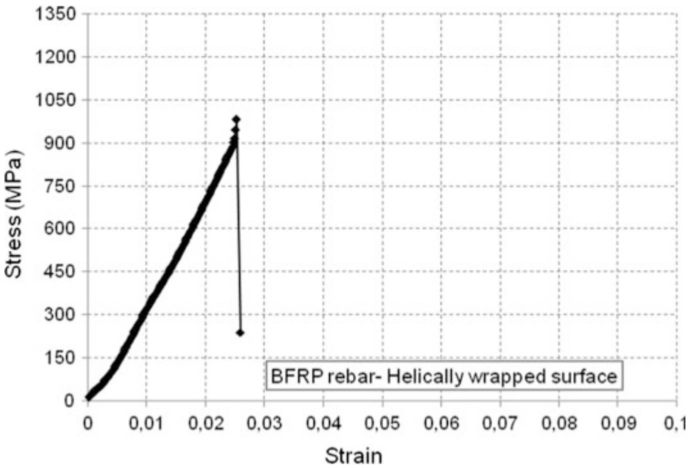

Fig. 8. Stress-strain curve of BFRP bar with helically wrapped surface

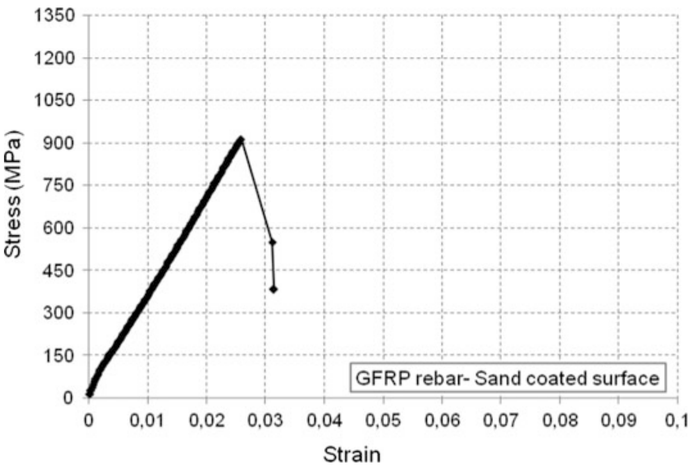

Fig. 9. Stress-strain curve of GFRP bar with sand coated surface

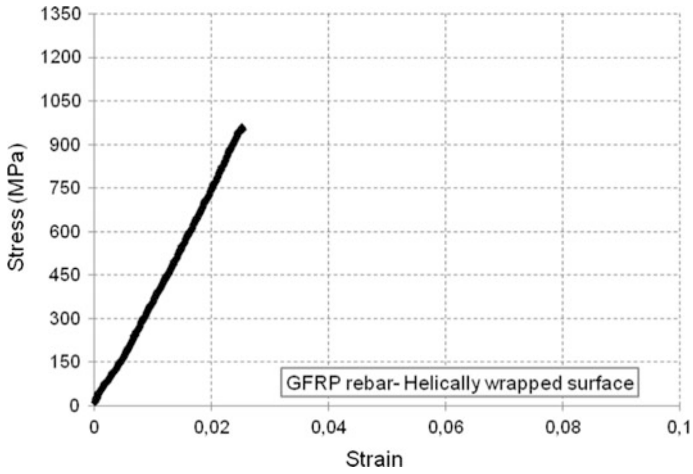

Fig. 10. Stress-strain curve of GFRP bar with helically wrapped surface

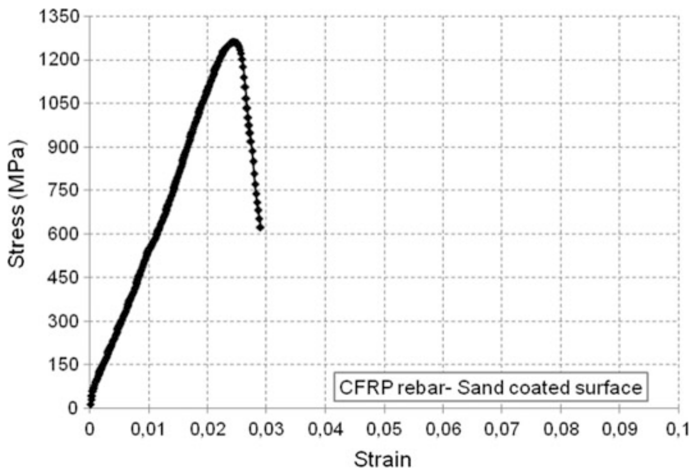

Fig. 11. Stress-strain curve of CFRP bar with sand coated surface

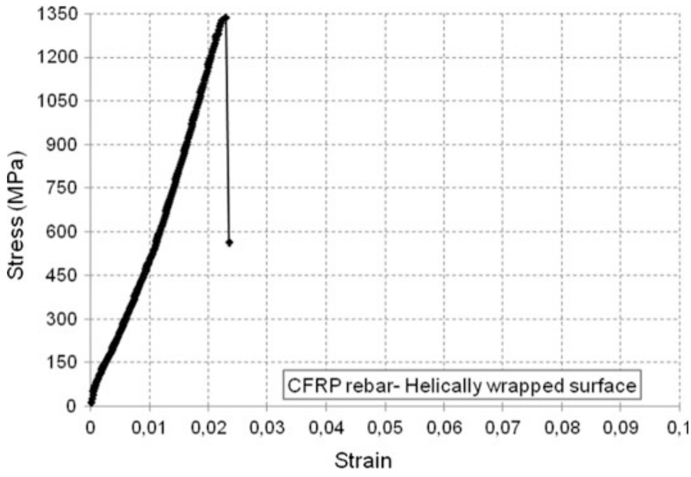

Fig. 12. Stress-strain curve of CFRP bar with helically wrapped surface

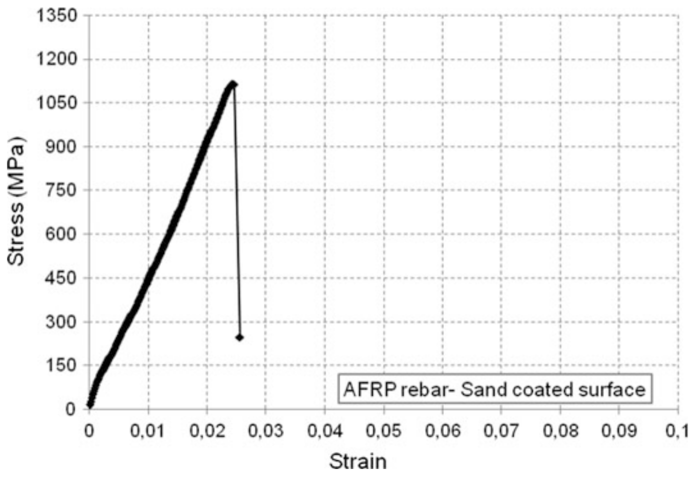

Fig. 13. Stress-strain curve of AFRP bar with sand coated surface

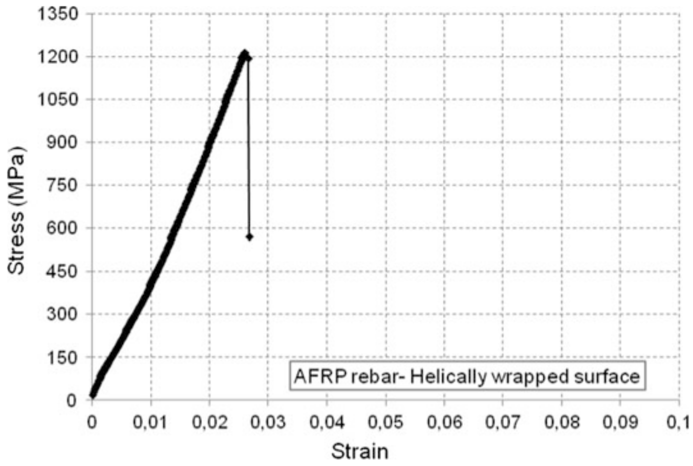

Fig. 14. Stress-strain curve of AFRP bar with helically wrapped surface

According to the test results obtained from tensile tests, the highest and lowest tensile strength values of the FRP bars with helically wrapped surface were found as 1336 MPa for CFRP bar and 956 MPa for GFRP bar. In addition, the highest and lowest tensile strength values of the FRP bars with sand coated surface obtained from tensile tests were found as 1261 MPa again for CFRP bar and 900 MPa for BFRP bar. When the findings are evaluated in terms of modulus of elasticity, the highest modulus of elasticity was obtained from CFRP and the lowest modulus of elasticity was obtained from GFRP, as shown in Table 1. Generally, the values of elasticity modulus obtained from helically wrapped surfaces are higher than those of sand coated surfaces.

When the effect of fiber types were evaluated for both surfaces, the highest tensile strength and elasticity modulus were found on FRP bars produced with carbon fibers.

4 Conclusion

In this study, the effects of surface forms on mechanical properties of FRP bars were investigated. As a result, it was observed that the surface properties affected the mechanical properties of FRP bars and FRP bars with helically wrapped surface showed higher tensile strength and modulus of elasticity than those of FRP bars with sand coated surface. Carbon fiber is the most useful fiber to get high tensile strength and elasticity modulus.

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Climate Responsive Container Design for Sustainable Dwellings

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Abstract. The latent and looming risks resulting from the effects of climate change are currently considered as critical ecological challenges facing the world in the 21st century. The damages caused to fragile ecosystems by an augmented amount of resource extraction and infrastructural development in addition to the depleting ozone layer and a significant level of air pollution are also a cause for concern. This has prompted a need to design environmentally friendly buildings, including sustainable containers. The objective of this project is to draw attention to the significance of adopting innovative approaches and methodologies for sustainable containers designs. It further examines how the sustainable containers can be integrated for utility in different climatic zones to address the shortage of houses. The container's response to the certain climatic zone is analyzed using Ecotect software from Autodesk. Findings suggest that the core objective of sustainable building design should be to reduce the total primary energy needs considerably through an application of renewable resources as well as through incidental heat gains that prompt the comfort system, in addition to a reduced utility of continuous energy importing to ensure comfort. When building fabric is utilized, there is a potential of minimizing artificial heating, lighting, cooling as well as alternative energy importing systems. Overall, shipping containers can be repurposed and converted into modern housing units, cafes, or workspaces as sustainable buildings because of their environmentally friendly nature and capacity to provide low-cost accommodation based on their nature of being reliable, accessible, flexible, and cost-effective. The containers can, therefore, be converted into architectural magnificence to resolve shortage of affordable housing, particularly in Lagos State, Nigeria.

Keywords: Shipping containers · Climate · Comfort · Design strategies UAE · IES

1 Introduction

The potential and imminent risks resulting from the effects of climate change prevail as the major ecological problems the world has to contend within the 21st century. The damages caused to fragile ecosystems by an augmented amount of resource extraction and infrastructural development in addition to the depleting ozone layer is also a cause for concern. Consistent with these undesirable effects, there is also a concern for the

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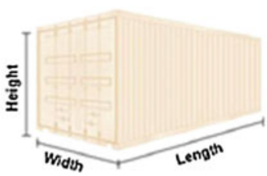
increased level of air pollution because of increasing urbanization. At any rate, climate change has increasingly become a severe and pressing issue. Indisputably, the natural environment and the general ecosystem are highly perceptible to the negative effects of the construction industry. As a result, “Sustainable Architecture Design Approach” has become a major significant issue given that it suggests solutions to environmental challenges as well as provides for the needs of future generations.

A major objective of sustainable design is to apply renewable energy sources, to come up with eco-friendly buildings built with building materials that can be recycled. It is as well clear that containers are entwined with the ecological and sustainable approach. The focus of this paper is on the use of ISO shipping containers as a likely alternative to resolving the challenge of acute living space and the capacity to alter them from dark matt boxes to devise sustainable, livable space.

This project also evaluates containers within the context of sustainable architecture, that have in the recent past become prevalent as an alternative to the current buildings and to design them consistent with the needs of the four key climatic zones. It also examines the challenges associated with the methods of construction and design.

Containers are designed to transmit heavy loads and to be loaded up in high volumes. Shipping containers are designed to have a consistent width, Standardized length and height to offer modular elements, which can be integrated for creating larger structures. The containers are also built to interlock for unproblematic mobility while being transported conveniently. The modular designs of the containers allow for additional construction becomes of the potential to stack the containers. The figure below represents the dimension and weight of containers (see Table 1).

Table 1. Different sizes of the international containers dimensions

	External (20 ft)	External (40 ft)	External (40 ft Hc)	
Length (m)	6.06	12.19	12.19	
Width (m)	2.44	2.44	2.44	
Height (m)	2.59	2.59	2.89	
	Internal	Internal	Internal	
Length (m)	5.87	12	12	
Width (m)	2.33	2.33	2.33	
Height (m)	2.35	2.35	2.65	
Weight (kg)	2.230	3.660	3.840	

2 Aims of Objectives

The objective of this project is to draw attention to the significance of adopting innovative approaches along with the methodologies of sustainable containers designs. It also seeks to how the containers can be devised to address the different needs of inhabitants in different climatic conditions. A brief overview of the ISO shipping containers is provided along with their benefits are recyclable housing components.

3 Literature Review

A shipping container is a high box constructed from steel of standard dimensions of 44′ (13.1 m) by 7′8.25 (2.348 m) wide and 8′10 (2.690 m). The internal space has a minimum floor space of approximately 27.95 and 13.6 m^2, depending on the manufacturer. It is designed to withstand extreme weather conditions during sea voyages and much strength to endure the weight of other containers when stacked up. As a result, they are outstanding modular units with intrinsic strength, weatherproof capability, and availability, which make them ideal for conversion into cost-effective housing units [1] (see Fig. 1).

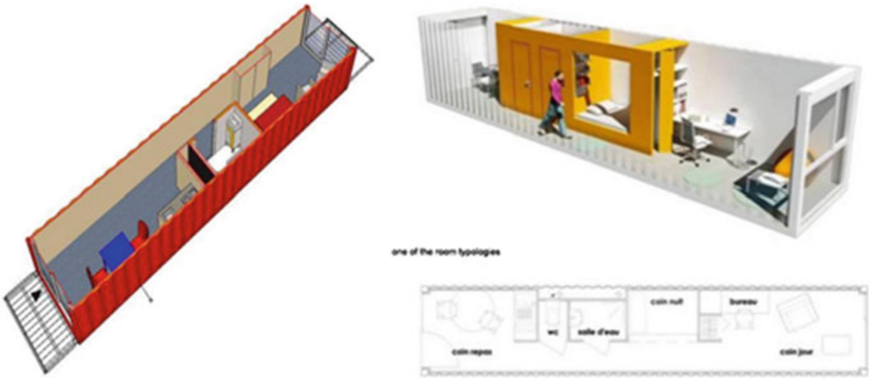


Fig. 1. Standard containers converted into accommodation units

Containers have a potential to offer temporary solutions to housing, space, and accommodation shortage. They can be used in disaster prone and affected areas, student housing, and worker homes. Reusing containers as prefab building units in architectural design offer an opportunity to use a container for the second time and to help in minimising the exemplified energy of buildings that is relatively low to other building materials. The reason for this is because the unit was previously used for different purposes. Accordingly, by its nature of being a by-product of shipping container, is intrinsically a sustainable unit that can be used devised to resolve housing shortage.

A review of the literature shows a paucity of research on how the containers can be converted into architectural magnificence to resolve the shortage of affordable housing, particularly in Lagos State, Nigeria. The containers, which were initially expensive, have become increasingly affordable and many designers have considered a prime housing component alternative because of their low cost, easy availability, strength, and durability. An attractive feature is their capability to be used as modular systems, which is beneficial for the construction of social housing units to resolve housing shortages in Lagos State. Still, containers are associated with several drawbacks. Reuse of containers is a low energy alternative, despite a disregard for some efforts that have to be put into make them more habitable. In his view, the structure has to be sand-blasted bare [1]. Other activities include replacement of the floors and cutting some openings. In the end, an entire container can generate almost 1000 lbs of hazardous waste before it is eventually declared suitable for human habitation.

Construction of a sufficiently sized space requiring combining of multiple boxes, which again demands a lot of energy, as dimensionally, one container only gets to create awkward living space. Indeed, if insulation is taken into consideration, what would result is a narrow box with a ceiling that is a less than 8 feet. Conversely, while shipping is rapidly globalising the production of nearly everything, they are not particularly good for housing as houses should be bigger than a box [2]. Shipping tend to make significant sense in situations of scarce resources, abundant containers, as well as in acute situations where there is an extreme shortage of houses.

4 Methodology

The study sought to examine methods of applying sustainable architecture that has been suggested in theory on containers, which can be adapted for homes. Consequently, two sections are suggested. In the first section, container architecture is introduced alongside an analysis of important criteria (such as settings, sizes, insulation, and thermal properties) associated with designing of the containers to be used as a dwelling. In the second section, the impact of sustainable architecture devised from the containers is integrated on built environment through a consideration of the samples of the container.

4.1 The Proposed City and Its Climatic Conditions

The main climatic zone proposed is temperate climate, which experiences extreme changes in temperature during winter and summer. The proposed city is Adana, Turkey. The daily changes in temperatures in the city are summarised in the graph below (see Fig. 2).

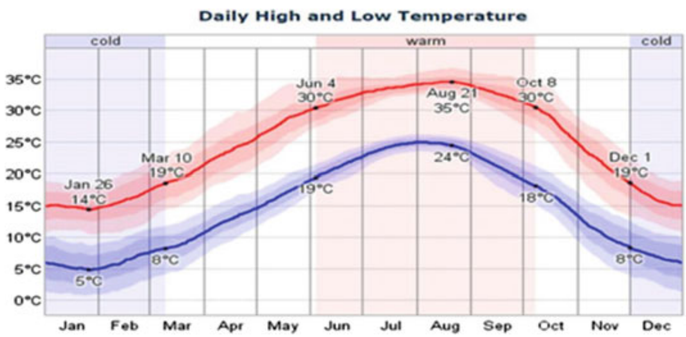


Fig. 2. Daily temperature ranges in Adana

The likelihood of precipitation in the city is high throughout the year, particularly in the months of February and August (see Fig. 3).

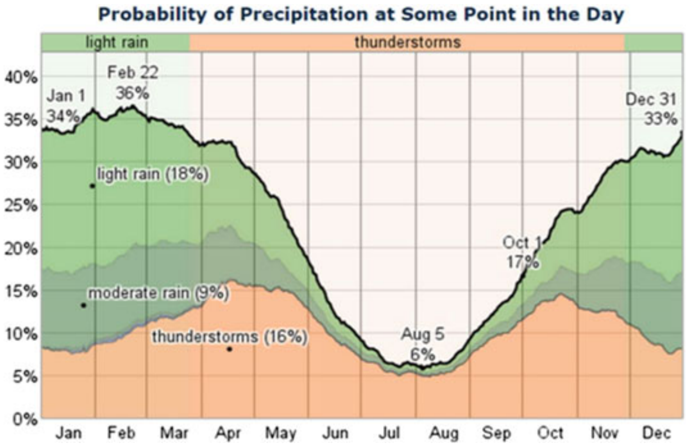


Fig. 3. Monthly precipitation in Adana

The city's relative humidity varies between 35 and 94% all across the year. Lowest. Throughout the year, typical winds range from 0 to 6 m/s.

4.2 Architectural Design Approach

Function: clinic, Number of containers: 3 containers (Fig. 4).

Fig. 4. Temperate clinic containers design approach—Revit software

4.3 Main Design Strategy (Temperate Climate)

In general, the majority of temperature cities need passive cooling and heating. Additionally, the majority of cooling and heating needs do relate, yet divergent levels of emphasis are needed contingent on their respective climatic needs. For heating homes, passive heating is the least costly. Passive solar heating is optimal for keeping out summer sun, although it does also let in the winter sun while making sure that the overall thermal performance of design is retained.

For optimal comfort, buildings in Turkey demand cooling at some durations of the year. The buildings can be designed and modified in a range of ways to attain optimal comfort through passive cooling. At the same time, hybrid approaches that rely on mechanical cooling systems can as well be used.

Some of the most suitable passive cooling strategies for homes include ventilation, orientation, sharing, windows, thermal mass, shading, and insulation. The efficacy of a building envelope can be optimized in a range of ways to reduce heat gain. Maximizing heat loss can be achieved through natural means, such as cooling breezes, evaporation and air movement.

4.3.1 Shading Glass

Is an optimal means for reducing undesired heat gain, given that unprotected glass is a great source of heat that enters a home. Despite this, poor designed fixed shading may also bar the winter sun yet broad sharing in summer also serves to minimize incoming daylight. This increases the need for artificial lighting. At the same time, shading of dark un-insulated walls also reduces a building's heat load (see Fig. 5).

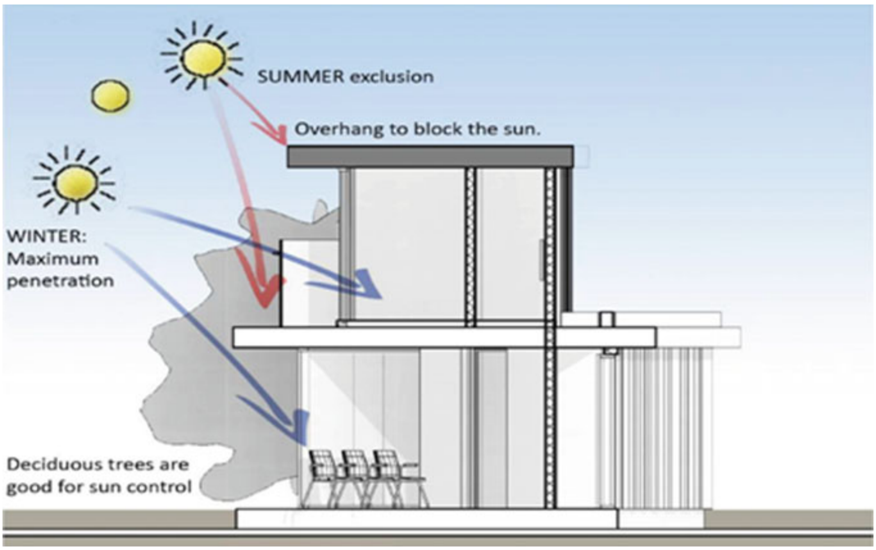


Fig. 5. Shading device for passive cooling and heating

4.3.2 Cross Ventilation

Is a common yet the least costly means of passive ventilation and cooling. Effective wind ventilation can be ensured by encouraging high thermal comfort and sufficient fresh air (see Fig. 6).

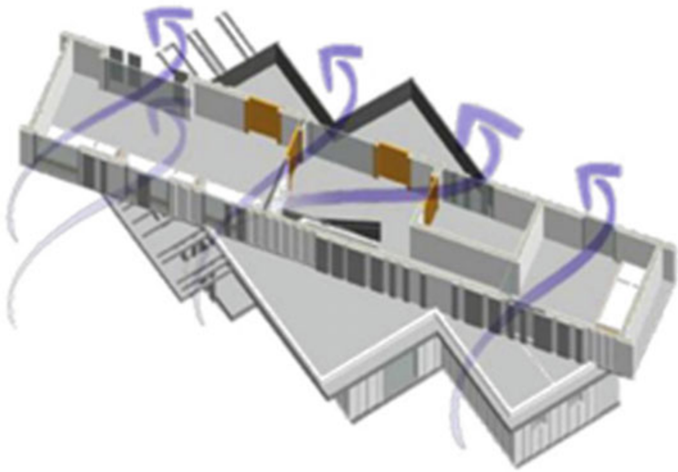


Fig. 6. Cross natural ventilation

4.3.3 Orientation

For temperate climate orientation, where daytime heating yet cool sleeping is needed, a suitable simple configuration that permits for passing heating in the living room is appropriate.

Use of Solar Radiation Technology is appropriate for the analysis of the solar radiation effects on a range of surfaces of a building model. Use of the technology in the conceptual design phase of a project is essential for making fundamental design decisions regarding the shape of the building, its orientation as well as the surface at the outset. The preview of the technology utilises geometric or conceptual massing shapes, rooted in the weather and location.

In the proposed design, the type of analysis that is specifically essential while determining the shading requirements. The technology output indicates that the solar radiation if the containers before and after an addition of the main strategy had been altered from hot surfaces during the month of June to cool surfaces on the same day through an addition of an overhang and shading.

4.4 Desert Climate (Hot Arid)

In desert areas, rainfall is low and falls at less than 25 mm annually, although certain areas may experience absolutely no rainfall. At the same time, desert areas do experience a maximal temperature of more than 45 °C, although night temperature may decline drastically. The proposed city for a desert climate is Phoenix, Arizona.

In summer, Phoenix experience overnight low temperature of 27 °C on an average of 67 days annually.

Dew point is a reliable measure of comfort that an individual can experience in weather. Lower dew points tend to be drier while occasions of high dew points experience greater humid. During the year, dew points tend to vary from −5 to 18 °C. The most comfortable period is between June 27 and October 8.

Regarding wind direction, the wind usually emanates from the east nearly 27% of the times, and from the west nearly 18% of the times.

4.5 Architectural Design Approach

Function: Residential unit, Number of containers: 4 containers (see Fig. 7).

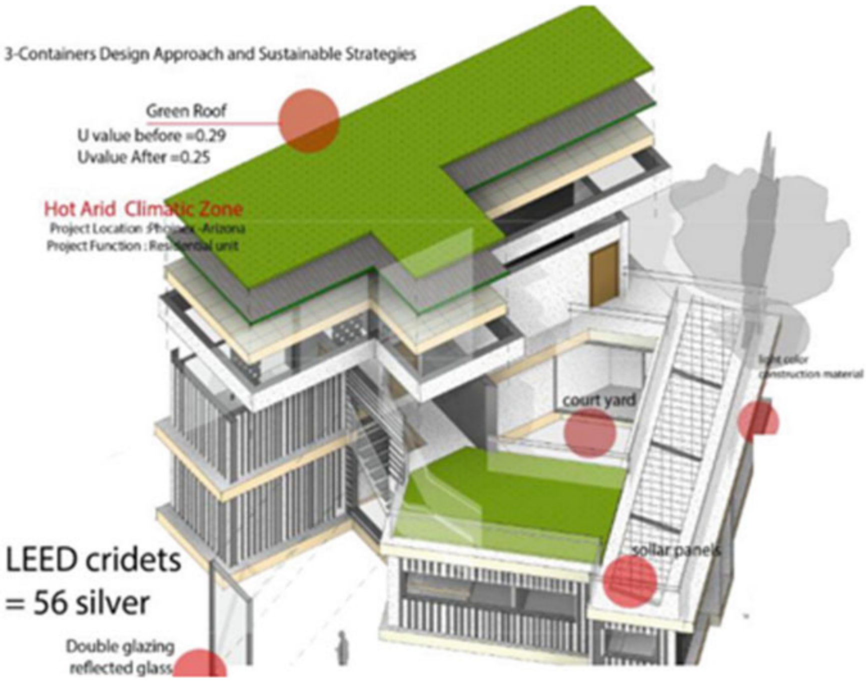


Fig. 7. Hot Arid containers design approach—Revit software

4.6 Main Design Strategy (Hot Arid Climate)

4.6.1 Green Roof

It is a roof that is partly or totally covered with vegetation and facilitates the growth of medium planted over a waterproof membrane [3].

4.6.2 Courtyard

A green roof requires a courtyard, which would serve to moderate internal climate. Courtyard that has vegetation and a body of water facilitates humidity (see Fig. 8).

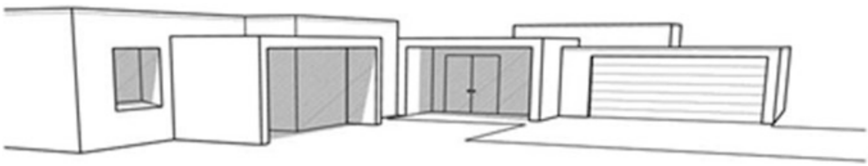


Fig. 8. Courtyard approach

The orientation for a green roof should increase exposure to cooling breezes, yet also minimize passive heat gains from the sun [3]. Shade plantings should be orientated toward the west to reduce solar gains using windows that face to the south during summer [4].

During warm climates, the shade plantings should be orientated to the east, although measures have to be taken to ensure it does not back the breezes [5].

4.7 Hot Humid Climates

The equatorial belt mostly witnesses hot and humid conditions. It experiences high amounts of rainfall and significant levels of sunshine. The proposed city that experiences hot humid climate is the Gan Island, Maldives. The place experiences tropical monsoon climate while the occurrence of a large land mass of South Asia contributes to differential heating of water and land [6]. The island experiences high precipitation in the month of December, while the least amounts are experiences in September (see Fig. 9).

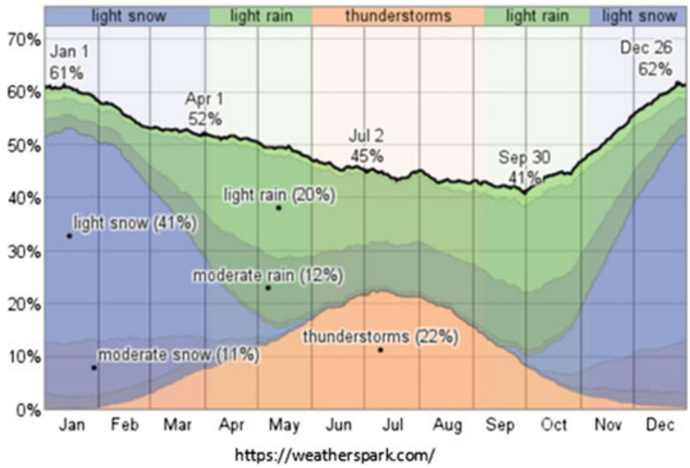


Fig. 9. Precipitation events in Gan

In general, Gan's relative humidity varied from 42% during the comfortable periods to around 95% in highly humid periods and may fall to around 24% in the dry season, such as in May. The dew point may vary from −15% during dry seasons to 23% during very muggy seasons.

4.8 Architectural Design

See Fig. 10.

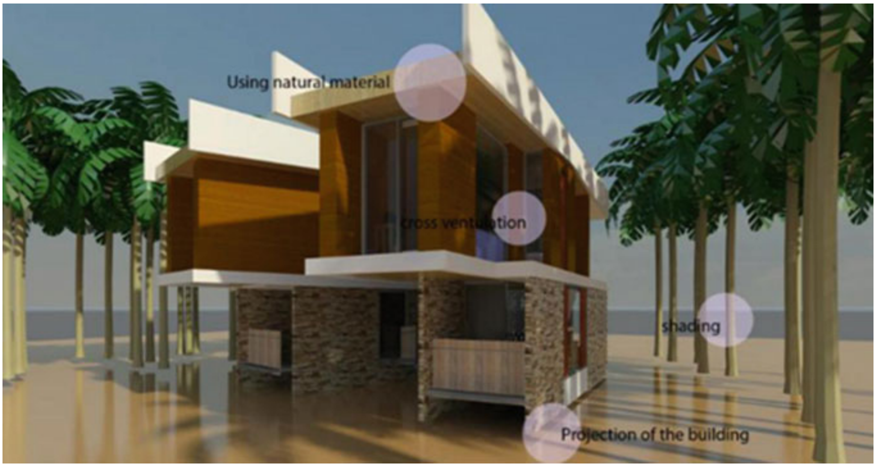


Fig. 10. Hot humid containers design approach—Revit software

4.9 Main Design Strategy (Hot Humid)

4.9.1 Raising Floor

The floors are raised and have no contact with the ground. This permits natural ventilation and prevents transmission of from the ground (see Fig. 11).

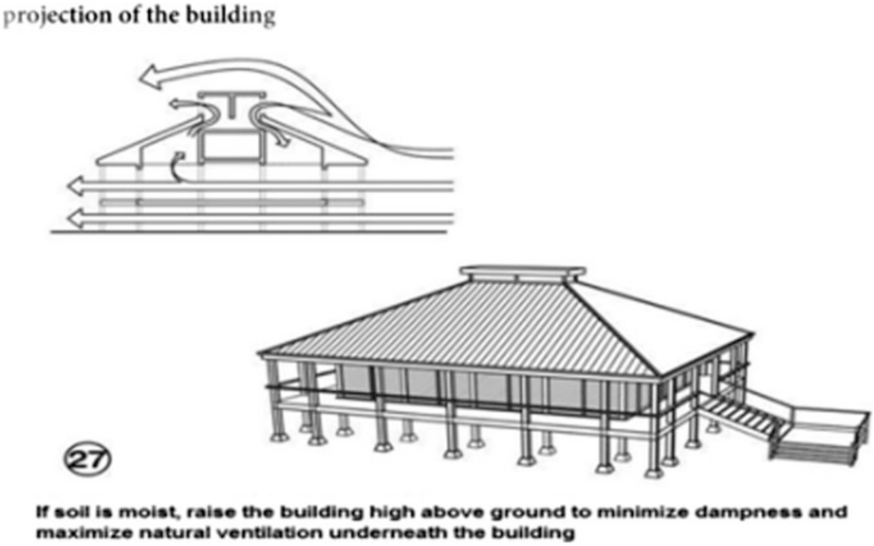


Fig. 11. Hot humid raising floor approach

To validate whether the building's projection during hot, humid climate has a positive impact on the container's sustainability approach, a floor design software was used before and after the projection. In the second case, the temperature of the ground floor was examined above the wind tunnel using Revit solar analysis (see Fig. 12a, b).

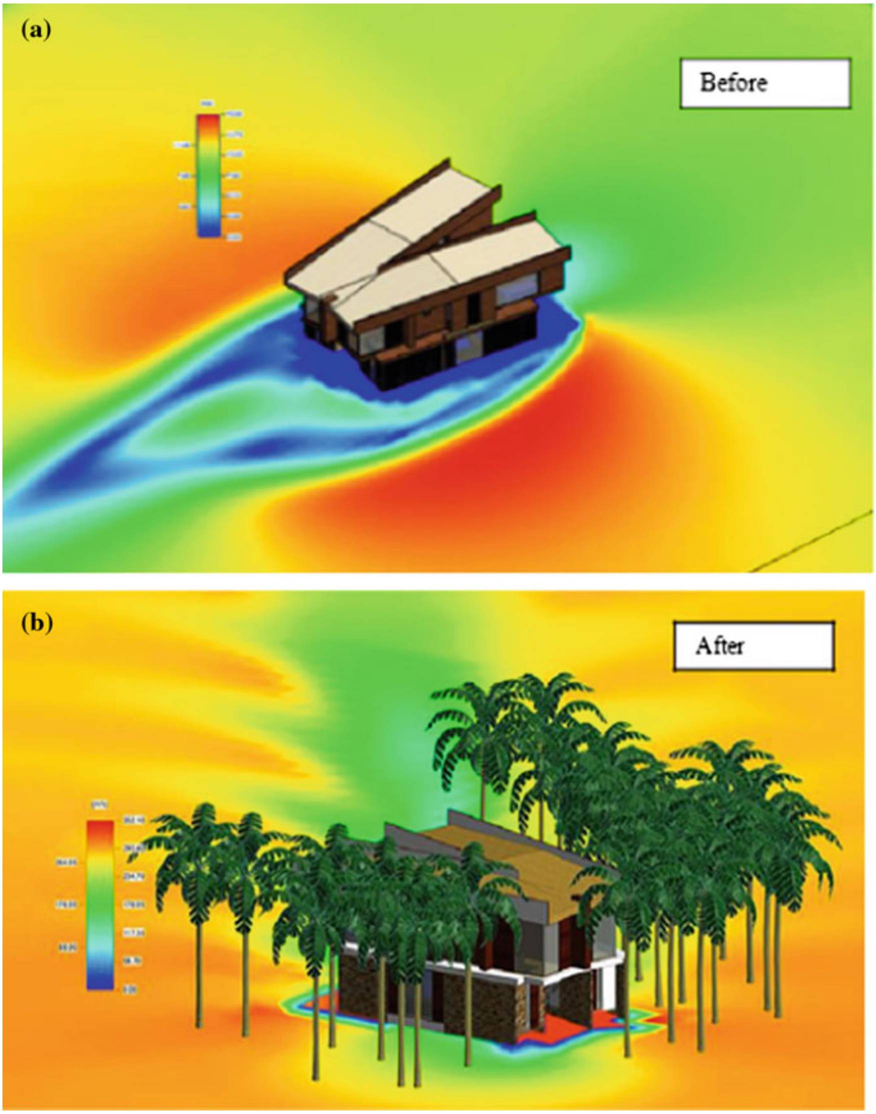


Fig. 12. Hot humid before applying the raising floor strategy

After the floor design had been analysed basing on the speed of the wind before and after the projection, it was found that the speed of wind altered from 2.3 to 5.65 m/s. To validate this finding, the temperature at the ground level of the containers was further analyzed. It was established that it had attained a temperature of 22 °C on June 1st (see Fig. 13).

Fig. 13. Hot humid analysis—Revit software

4.10 Polar Climates

The Polar Regions, such as the Antarctica, experience extremely low temperatures of about −88 °C. The proposed city is Moscow, Russia. The average temperature for each month varies from 19.5 °C in the month of July to about −20.6 °C in the month of January (Fig. 14).

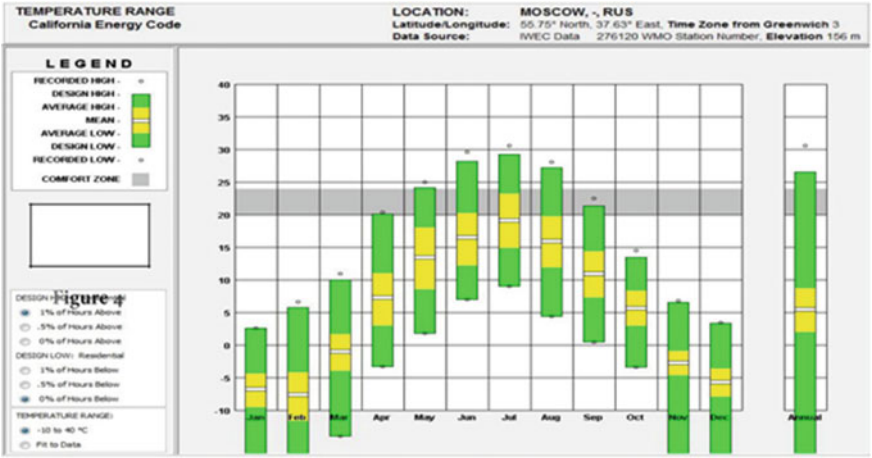


Fig. 14. Average temperature for Moscow (Author)

4.11 Architectural Design Approach

Function: kids learning center, Number of containers: 2 containers (Fig. 15).

Fig. 15. Kids learning center

4.12 The Main Design Strategy (Cold Polar) and Wall Insulation

The design relies on insulation, which bars heat flow and keeps the homes warm during the winter seasons. However, the insulation should also cater to day to day temperature variations [7]. The total R-values are supplied with insulations that are reflective as well as which rely on the products specified for installation. The R-values may be different contingent on the direction of the flow of heat.

4.12.1 Sun Tunnels

The sun tunnels are then used to reduce the darkness of the rooms that lack windows. They function by capturing the rays of light on the roof, which they then transmit through a reflective tube into the room [8] (Fig. 16).

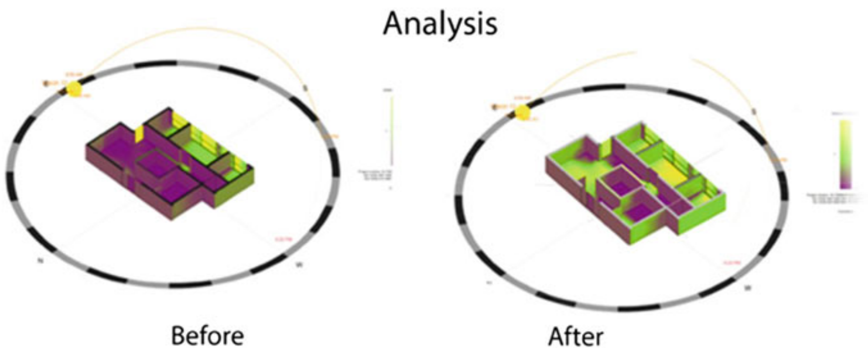


Fig. 16. Simulation and the analysis of wall insulation sing the Revit solar analysis

5 Conclusion

The core objective of sustainable building design should be to reduce the total primary energy needs considerably, through an application of renewable resources as well as through incidental heat gains that prompt the comfort system. It is also prompted by a need for reduced utility of continuous energy to ensure comfort. When building fabric is utilised, there is a potential of minimising artificial heating, lighting, cooling as well as alternative energy importing systems. Consistent with an augmented public discourse on sustainability, designers from across the globe have made significant milestones by devising energy-saving technologies as well as by applying sustainable design approaches in designing more sustainable systems. For this reason, shipping containers have today become repurposed and converted into modern housing units, cafes, or workspaces as sustainable buildings because of their environmentally friendly nature and capacity to provide low-cost accommodation. As established, containers have several significant benefits based on their nature of being reliable, accessible, flexible, and cost-effective. The shipping containers are also beneficial by virtue of being weather-resistant, durability and strength. They provide designers with an opportunity to use low-cost construction technique about what it would cost to construct conventional buildings. In the study to evaluate the container projects, several sustainable design approaches were used in varying degrees. The shipping containers were examined for active and passive designs like the building's location, green roof design, use of rain and green water, and use of durable and natural materials.

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Investigation of the Mantle System Applied to Outer Shell of Apartment Buildings in Terms of Energy Efficiency (Erzincan Case)

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Abstract. Energy is a phenomenon that leads to conflicts, internal conflicts, and antagonism in all areas of life. Considering that we are dependent on foreign countries in the field of energy, the conservation of energy is getting more and more important day by day. A large portion of the energy consumed in Turkey is used to heat houses. It is very important to maintain the heat and keep it on the field as well as to heat the house. It is seen that the best and economical way of keeping the heat is thermal insulation in the apartments. In this study, five apartments in Erzincan which is in the 4th grade climate zone, have been heat insulated by using the mantle system according to TS 825. The annual energy requirement is calculated in the case of heat losses which occur in case of heat insulation and without heat insulation. As a result, it has been determined that the energy efficiency will increase if the apartments are heat insulated. It is also stated that the workmanship is important in heat insulation.

Keywords: Energy · Energy efficiency · Erzincan · Heat isolation

1 Introduction

It is known that energy is one of the key components of economic and social development and plays a vital role in raising the living of standards. It is also well known that a sustainable development will be possible with a continuous and high quality energy supply [1].

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Some reasons have made it more important to use energy more efficiently, such as the increase in world population, the need to meet growing energy needs in line with technological developments, the desire to sustain environmental, social and economic sustainability, and to reduce CO_2 and other greenhouse gas emissions under the Kyoto Protocol [2].

A series of studies are being carried out to reduce energy consumption, to get the most energy with the least amount of energy, and to reduce the air pollution resulting from energy production and consumption. In this context, TS 825 was issued in Turkey. These standards include a set of rules and standards, including the principles of construction and implementation of building and building components. We are largely energy dependent on foreign countries. Because of the wars in some world countries, and so energy has become more expensive over time.

Arslan and Köse [3] have made optimization studies on the exterior wall insulation material thickness of the buildings for Kütahya which has a cold climate structure. In their study, they determined the insulation thicknesses as 0.06; 0.065 and 0.075 m respectively and the energy saving rates as 74.9, 76.3 and 78.8% respectively and corresponding to temperatures.

Koçu and Korkmaz [4] assessed the thermal insulation practices of the buildings around Konya according to TS 825 and examined the effect of deficient and faulty thermal insulation on environmental pollution. As a result, it has been found that the TS 825 is not applied to the thermal insulation application and in consequence of this, increasing the consumption of fossil fuels is excessive for heating.

Yilmaz [5], calculated the heat losses through exterior walls and column-beam (reinforced concrete) areas on a sample building project. He studied on the heat losses of two room walls and column-beam surfaces of a room and calculated that the heat losses of reinforced concrete are higher than the heat losses of the walls. Candan [6] calculated the energy demand and specific heat losses of a sample building. Then, using EPS and XPS, she applied heat insulation to the building in three different ways including inside, outside and middle of the building. As a result, it has been found that the external insulation of the exterior walls provides 40% reduction in the consumption of heat energy and 57% reduction in the specific heat loss of the building.

2 Material and Method

2.1 Material

In this study, the thermal insulation materials applied to outer shell of 5 apartments in Erzincan according to TS 825. A computer program was used for the energy performance account. Horizontal perforated brick, bims block, thermal insulation materials were selected for the building elements in the walls with expanded polystyrene foam (EPS) and extruded polystyrene foam (XPS) samples.

2.2 Method

As a method in this study, studies were limited by selecting samples from the apartments in Erzincan province provincial centers located in the coldest climate region (4th Degree-Day Zone). Projects of buildings inspected from municipalities were then provided. The samples of the projects were taken and the thermal insulation applications were observed in the factories and application and detail photographs were taken.

After all of them, in the case of being no thermal insulation in the building shell, the annual energy requirement and specific heat loss of the building are calculated using the computer program. Later, when the same apartments were heat insulated, the annual energy requirement and specific heat loss of the building were calculated. As a result of these calculations, the annual energy requirement and the specific heat loss of the buildings in the case of heat insulated and non-heat insulated were compared. The efficiency obtained in the case of heat insulation, the problems encountered are explained and solution proposal is presented.

3 The Application of the Coating Process

The initial profile is placed on the surface before the sheet is applied to the surface of the thermal insulation materials. An insulation mortar is prepared to secure the insulation plates to the outer wall surface (Fig. 1a). The heat insulation plate is adhered to the outer wall surface (Fig. 1b). The plate surfaces are gauged to ensure adhesion (Fig. 1c). The wall and heat insulation plate is drilled with a drill and placed in a dowel with 6 plugs per m^2 (Fig. 1d). Then the corner profile application is made to make the corner of the building smoother (Fig. 1e). After the corner profiles are placed, first layer plaster application is performed on the thermal insulation board surface (Fig. 1f). After the installation files are placed on the first layer plaster, second layer plaster application is performed (Fig. 1g). Finally, insulation application is terminated by decorative paint and coating (Fig. 1h).

Fig. 1. The application of the coating process

4 The Investigation of Heat Isolation Upon Energy Efficiency on Model Houses

4.1 Examination of Example 1

The apartment is a double-entry building, consisting of a Z + 2, designed in the form of adjoining buildings. There are 4 apartments on one floor. The apartments are planned as 3 + 1. There are a total of 12 apartments on 3 floors. The walls of the building, which is a reinforced concrete carcass structure, are made of 19 cm bricks. The total area of the exterior wall of the apartment is 560 m^2, gross volume V (gross) 5040 m^3. EPS material with a thickness of 0.05 m and a thermal conductivity coefficient of 0.035 W/mK was used as insulation material. In the wall detail of the Example 1 given in Fig. 2, it is seen that 1 code is 2 cm inner plaster, 2 code is 5 cm heat insulation, 3 code is 19 cm thick brick wall and 4 code is 2 cm inner plaster.

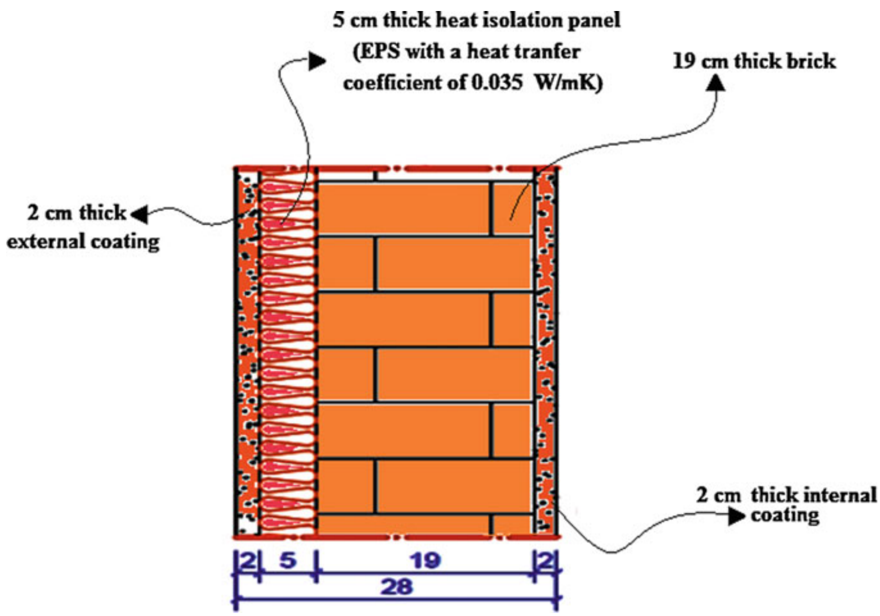

Fig. 2. Details of the Example 1

When the heat insulation is done, there is a loss of energy 171.36 W/K at the floor of the apartment 1, 465.92 W/K from the windows and doors, 207.08 W/K from the ceiling and 380.16 W/K from the wall. In the absence of heat insulation, it is seen that the energy loss of Example 1 was 511 W/K at the floor of the apartment, 465.92 W/K from the windows and doors, 1791.1 W/K from the ceiling and 1260.10 W/K from the wall (Table 1).

Table 1. Heat loss values of Example 1 in the case of heat insulated and non insulation

Construction element	Heat loss	
	With isolation (W/K)	Without isolation (W/K)
Floor	171.36	511
Doors and windows	465.92	465.92
Ceiling	207.08	1791.1
Walls	380.16	1260.1

4.2 Examination of Example 2

The apartment is a double-entry building, designed in the form of adjacent courtyard. There are 4 apartments on one floor. The apartments are planned as 3 + 1. Apartment consists of 4 floors as Z + 3. The walls of Example 2, a reinforced concrete carcass structure, were made of 19 cm bricks. The total area of the apartment is 560 m^2 and the gross volume is 6720 m^3. EPS material was used as insulation material with a thickness of 0.05 m and a thermal conductivity coefficient of 0.035 W/mK.

As a result of the calculations, when the thermal insulation is applied, there is a loss of energy of 171.36 W/K at the floor of the apartment 2, of 465.92 W/K from the windows and doors, of 206.08 W/K from the roof and of 611.66 W/K from the wall. In the absence of heat insulation, it is seen that the energy loss is 511 W/K at the floor of the apartment 2, 465.92 W/K from the windows and doors, 1791.10 W/K from the ceiling and 1688.10 W/K from the wall (Table 2).

Table 2. Heat loss values of Example 2 in the case of heat insulated and non insulation

Construction element	Heat loss	
	With isolation (W/K)	Without isolation (W/K)
Floor	171.36	511
Doors and windows	465.92	465.92
Ceiling	206.08	1791.1
Walls	611.66	1688.1

When the wall detail of Example 2 is examined, like in Example 1; 2 cm interior plaster, 5 cm heat insulation, 19 cm thick brick wall and 2 cm interior plaster were seen.

4.3 Examination of Example 3

The apartment is designed as Z + 2 floors, formed as 4 + 1. The walls of the apartment which is reinforced concrete carcass are built with bims block. The total area of Example 3 (Atop) is 2633.76 m^2 and the gross volume (Vbrut) is 6250 m^3. 6 cm thick XPS thermal insulation material is used.

In Fig. 3, 2 cm inner plaster is 5 cm heat insulation, 19 cm thick bims block and 2 cm inner plaster are seen in the wall detail of the Example 3 in which the heat insulation is applied.

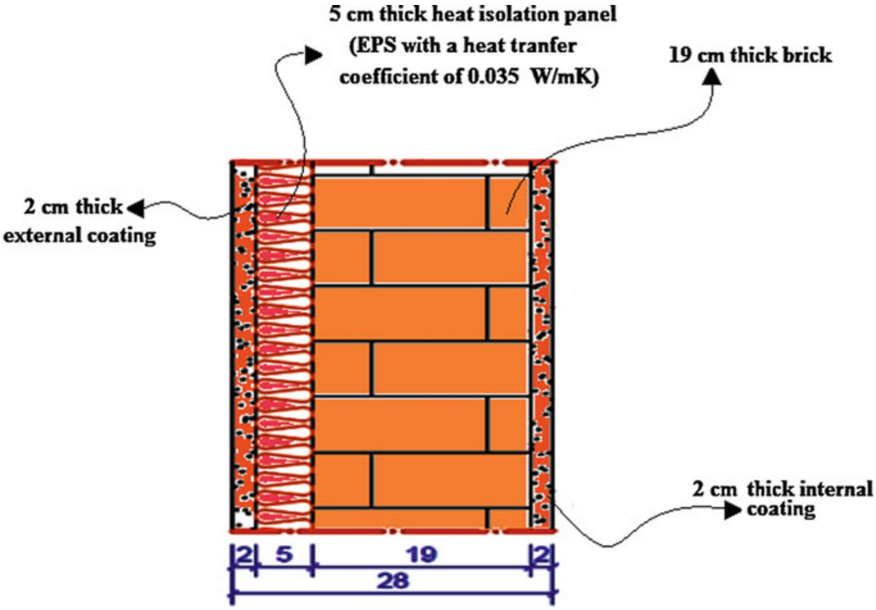

Fig. 3. Detail of the Example 3

As a result of the calculations, when the thermal insulation is done, there is a loss of 163.62 W/K at the floor of the apartment of Example 3, of 218.34 W/K from the Windows and doors, of 164.4 W/K from the windows and of 650.37 W/K from the walls. In the case of no thermal insulation, it is seen that the energy loss of Example 3 is 858.12 W/K at the floor of the apartment, 218.34 W/K from the windows and doors, 1700.4 W/K from the ceiling and 1621 W/K from the wall (Table 3).

Table 3. Heat loss values of Example 3 in the case of heat insulated and non insulation

Construction element	Heat loss	
	With isolation (W/K)	Without isolation (W/K)
Floor	163.62	1235
Doors and windows	218.34	218.34
Ceiling	858.12	858.12
Walls	650.37	1621

4.4 Examination of Example 4

It was designed in the 4 + 1 format, which was launched in 2003 and started in 2005. The building has 3 floors as Z + 2 form. There are 6 apartments in total, including two apartments on each floor. The walls of Example 4, which is a reinforced concrete carcass structure, are made of bricks. In thermal insulation, EPS insulation material is used in the outer walls of 0.05 m, at the edges of the windows of 0.03 m thickness and in the density of 20 densities. The total area of the apartment is 330 m^2 and the gross volume is 3828.

In the wall detail of Example 4, 2 cm inner plaster 4 cm heat insulation, 19 cm thick brick wall and 2 cm inner plaster are seen.

When the sample apartment 4 is heat insulated, there is a power loss of 100.98 W/K on the floor, of 415.7 W/K on the windows and doors, of 121.44 W/K on the pan, and of 598.26 W/K on the wall. In the absence of heat insulation, energy loss is 301.13 W/K on the floor, 415.7 W/K on the windows and doors, 1055.47 W/K on the pan, and 133.73 W/K on the wall (Table 4).

Table 4. The pre and post isolation heat loss values of Example 4

Construction element	Heat loss	
	With isolation (W/K)	Without isolation (W/K)
Floor	100.98	301.13
Doors and windows	415.7	415.7
Ceiling	121.44	1055.47
Walls	598.26	1133.73

4.5 Examination of Example 5

The project is designed as 4 + 1. The building has 3 floors as Z + 2 form. The total area of the apartment is 175.55 m^2 and the gross volume is 1667.75 m^3. EPS material with a thickness of 0.05 m and a heat transfer coefficient of 0.035 W/mK was used for the apartment building. In the wall detail of Example 5, 2 cm inner plaster is 4 cm heat insulation, 19 cm thick brick wall and 2 cm inner plaster are seen.

As a result of the calculations made, when the thermal insulation is applied, there is a power loss of 53.72 W/K from the floor of the apartment of Example 5, 289.88 W/K from the windows and doors, 263.32 W/K from the roof and 170.5 W/K from the wall. In the case of no thermal insulation, it is seen that the energy loss of the apartment of Example 5 is 160.19, 289.88 W/K from the windows and doors, 561.48 W/K from the roof and 724.26 W/K from the wall (Table 5).

Table 5. Heat loss values of Example 5 in the case of heat insulated and non insulation

Construction element	Heat loss	
	With isolation (W/K)	Without isolation (W/K)
Floor	53.72	160.19
Doors and windows	289.88	289.88
Ceiling	263.32	561.48
Walls	170.5	724.26

5 Results and Discussion

5.1 The Effect of Thermal Insulation on Energy Earnings and Evaluation of the Results

In Fig. 4, the annual heating energy requirement (Qy) and the calculated annual heating energy requirement (Q′) of 5 apartments in Erzincan provincial centers are given. According to this table, the apartment with the highest energy requirement is found in Example 5 and the apartment with the least energy requirement is found in Example 2.

	Total Heat Loss Qyıl/kWh			Calculated Energy Need(Q') (kWh/m²)		Standard (Q') Value(kWh/m²)
	Heat Isolation	Non heat Isolation	Ratio	Heat Isolation	Non heat Isolation	
Example 1	164 014,11	421 860,40	2,57	101,7	261,57	122,07
Example 2	209 556,41	485 578,80	2,32	97,45	225,81	117,47
Example 3	171 113	464 417	2,72	27,38	74,30	27,47
Example 4	123 837,23	299 245,52	2,42	101,09	244,29	120,55
Example 5	57 697,8	420 303,15	7,28	108,11	787,56	130,13

Fig. 4. Demand for annual heating energy and annual heating energy for example apartments

As a result of calculations with the formula Q = Q/A, the annual energy requirement for each year is Q = 491.055 kWh/m^2 while the energy demand (Q) for an average apartment without heat insulation. In the case of heat insulation, this figure falls to 170.55 kWh/m^2. If the thermal insulation is done in these 5 apartments in the research, it is reached that the saving is about 65%.

5.2 The Calculation of the Efficiency

Before and after the thermal insulation of the sample apartments, the energy needs were compared and the energy consumption was calculated. In addition, the energy class has been determined according to the rules and standards stated in TS 825. The following formula has been used to find energy efficiency in an apartment [7].

$$\text{The energy efficiency} = (Q_{\text{non-isolated}} - Q_{\text{isolated}})/Q_{\text{non-isolated}} \qquad \text{Formula[7]}$$

In addition, the energy class is determined using the following formulas after multiplying the numbers determined in the Q-value standard (0.99–0.90–0.89), which is the result of calculations.

$$Q_{\text{annular}} \leq 0.80 \times Q'(\text{A type building})$$
$$Q_{\text{annular}} \leq 0.90 \times Q'(\text{B type building})$$
$$Q_{\text{annular}} \leq 0.99 \times Q'(\text{C type building})$$

As a result of the calculations, it was concluded that all the analyzed buildings were B type buildings.

The highest yield in Table 6 was achieved at 74% in Example 5 while the lowest yield was achieved at 57% in Example 2. If the apartment buildings are heat insulated, a yield of about 63% will be achieved.

Table 6. The energy efficiencies of buildings investigated

Model	Isol. mat.	Thickness (cm)	Effic. (%)
1	EPS	5	61
2	EPS	4	57
3	XPS	5	63
4	XPS	4	59
5	EPS	4	74

6 Results and Recommendations

6.1 Conclusions

In this study, 5 different apartments located in the Erzincan district that we chose as the pilot region were heat-insulated. Annual heat energy (Qy), specific heat loss (H) was calculated before the apartments were heat isolated. The same process was done after thermal insulation was applied. As a result of these operations;

- In Example 1, 5 cm thick EPS insulation board was used. 101.70 kWh of energy is spent per m^2 when heat insulation is applied, while 261.57 kWh of energy is consumed per m^2 when heat insulation is not done. In the case of insulation, 61% energy efficiency is provided and energy class B is calculated.
- In Example 2, an EPS insulation board with a thickness of 4 cm was used. When heat insulation is provided, 97.45 kWh of energy is spent per m^2, whereas when there is no thermal insulation, 225.41 kWh of energy is consumed per m^2. In the case of insulation, 57% of energy is provided while the energy class of B is calculated.

- In Example 3, 5 cm thick XPS insulation board is used. When heat insulation is applied, 27.38 kWh of energy is consumed per m^2 whereas 74.30 kWh of energy is consumed per m^2 when heat insulation is not done. In the case of insulation, 63% energy is provided, while energy class B is calculated.
- In Example 4, 4 cm thick XPS insulation board is used. When heat insulation is applied, 101.09 kWh of energy is spent per m^2, but when heat insulation is not done, 244.29 kWh of energy is consumed per m^2. In the case of insulation, 59% of energy is provided and the energy class of B is calculated.
- In Example 5, 4 cm thick EPS insulation board is used. When heat insulation is applied, 108.11 kWh energy is consumed per m^2 whereas 787.56 kWh energy is consumed per m^2 when heat insulation is not done. In the case of insulation, it is calculated that the energy class B is 74% while the energy class is 74%.

6.2 Recommendations

Since Erzincan is in fourth climatic zone in TS 825, the insulation thickness is eight centimeters. However, it is calculated that the optimum insulation thickness for Erzincan is five centimeters. It is determined that the formation of heat bridges will reduce, since the mantling system wraps the building like a mantle. Also, it is reported that the thickness of the insulation material used as decoration profile and workmanship errors are thinner than the values showed in the standards. It is showed that the thickness of thermal insulation materials are two or three centimeters rather than being a minimum of 6 cm.

- ✓ As Erzincan city is in the coldest climate region, insulating heat isolation to the outer shell of the apartment buildings is more advantageous in terms of energy efficiency.
- ✓ During the construction phase of the XPS thermal insulation board, a kind of gas called HCFC has been used. It will be healthier to use EPS insulation material since it releases gas to the surrounding area for a long time after application.
- ✓ It will burn too much fuel for heating. Therefore, the amount of greenhouse gas emitted to the environment is excessive as a result.
- ✓ Energy savings will be achieved in large quantities when heat insulation is made according to TS 825 standards in existing structures and new buildings. This saving is likely to drive the future of the country's economy. For this reason, the importance of heat insulation must be explained to the community and thus the community should be made aware of heat insulation.
- ✓ In our country, specialists in heat insulation should run a seminary about the material thickness, the auxiliary materials used in heat insulation etc. to the building owners who will make heat insulation. In order to be able to use properly for the purposes of heat insulation, technical personnel and applicators should be trained about heat insulation. If necessary, they should be encouraged to participate in trainings such as seminars and courses.

✓ Thermal insulation details should be planned more carefully while drawing apartment projects. Experts should be trained to get ideas about which materials will be more suitable for the apartment. When thermal insulation is applied, building supervision companies need to examine not only the projects but also the application areas.

✓ For the development of thermal insulation materials in buildings, researches should be carried out on the development of contemporary thermal insulation materials without being dependent on foreign countries.

✓ Local governments, building supervisors, media outlets, material manufacturers, universities, building owners, architects, engineers and practitioners must fulfill their responsibilities of applying the heat insulation in accordance with the standards in the existing and construction phases.

✓ Scientific researches should be continued; experts should be trained; symposiums should be organized; our public should make become conscious of the importance of heat insulation through the journalism, and heat insulated buildings should be constructed.

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Effect of High Temperature on Compressive Strength of Concrete Prepared Using Different Types of Aggregates

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Abstract. Concrete is a building material commonly used in the construction structures. There are many reasons why concrete is preferred. One of these reasons is fire resistance of concrete. Concrete is not a combustible material, but it behaves differently under high temperature. Aggregates constitute an important part of concrete volume. Differences in aggregate properties significantly affect the performance of the concrete during heating. Differences in these properties also cause cracks and breakages in parts of the concrete and significant losses in adherence. When we look at these effects, we have seen that high temperature creates a threatening environment for concrete. Therefore, it is necessary to investigate the behavior of the concrete caused by the high temperature. In this study, we investigated the effect of high temperature on the compressive strength of concrete specimens prepared using different aggregate types. For this purpose, 10 × 10 × 10 cm and 15 × 15 × 15 cm cube samples were prepared by using CEM I 42,5 (N) type Portland Cement and two different types of aggregates (basaltic crushed stone, stream aggregate). The Concrete produced using basalt crushed stone is coded as "BCC" and the concrete produced using the stream aggregate is coded as "SAC". These concrete specimens were tested at room temperature and high temperature (300, 600 and 900 °C) after 28 days. We used the remaining samples at room temperature as control samples. We tested the compressive strength on all concrete samples. We studied the relationship between the compressive strength results and the concrete mass size. As a result of this study, it was found that the compressive strength of BCC is higher than SAC. When the relationship between the strength values of the concrete with high temperature effect and the concrete sample size was examined, it was found that the temperature affected the center of the small concrete samples more quickly. The resulting data showed that the 10 × 10 × 10 cm size concretes have low compressive strength.

Keywords: Compressive strength · Ultrasonic test · High temperature
Different aggregate concretes

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1 Introduction

Concrete is a structural material, a mix of cement, aggregates, water and additives, if necessary, which is the final form of cement-which is initially hydrated and in a plastic-like concentration—after setting [1]. Properties of the material used for concrete and their ratios affect the quality and performance of concrete [2, 3]. Each one of the materials used has an impact on the concrete. It is known that aggregates are one of the main elements influencing the properties of concrete as constituent materials. Strength of concrete prepared using different aggregates are not the same under high temperatures [4, 5]. This can be accounted for the mineral structure of the aggregates. When considered as a whole, the constituents of concrete are known to have different thermal expansion coefficients. Therefore, temperature change in concrete will lead to different volumetric changes in its constituents which will lead to formation of cracks and reduced concrete strength. This can be referred to as "thermal incompatibility of concrete constituents" [6, 7].

According to the research, high temperatures affect the durability of a structure and cause significant damage. Such an effect may cause permanent damage in the structure which may even lead to material and immaterial damages [8]. As an example, the fires in the Great Belt Tunnel and Channel Tunnel in 1994 and 1996, respectively, led to explosions and destruction of the concrete profile due to high temperature and the fire after the planes hit WTC in 9/11 claimed many lives in New York, USA. As it is clear from these examples, the thermal resistance of structural material is of utmost importance [9–11].

Concrete can explode under high temperatures. Such an explosion leads to or triggers other dangerous threats. Research tried to estimate the behavior of the structural material during and after a fire in terms of its structural safety and its integrity [12]. Previous studies usually focused on the effects of high temperatures on the "normal-strength concrete" [13]. However, modern structures of today uses "high-performance and high-strength concrete" with the use of chemicals and mineral additives designed for industrial structures, tunnels or customized structures. The reason behind this preference is the economical, architectural and structural benefits of such material. High-strength concrete is advantageous when compared to normal-strength concrete. One of the most important reasons behind the use of high-strength concrete in construction is its use in the structural frame of beams and columns. Provision of appropriate fire safety measures is a necessary aspect of any construction design. The concrete used needs to be identified for its behavior under the impact of high temperature. As the ratio of pores are lower and they have a more compact structure, the performance of such concrete under the impact of high temperature is poor when compared to normal-strength concrete [14, 15].

This study investigates the effects of high temperature on the mechanical properties of concrete with different concretes prepared using different aggregates. For this purpose, two types of aggregates, basaltic crushed stone and stream aggregate, were investigated for their properties both in fresh and set states and the effects of high temperature on different sample sizes were investigated in terms of compressive strength and ultrasound travel speed.

2 Material and Method

Materials and methods used in this study are explained in this section.

3 Material

The materials used to produce concrete are detailed below.

3.1 Aggregate

The experimental study used basaltic crushed stone and stream aggregate, two types of aggregates, for concrete samples. Physical properties of the aggregates are shown in Table 1.

Table 1. Physical properties of aggregates

Aggregate type	Specific gravity (gr/cm^3)	Water absorption (%)
Stream aggregate	2.79	0.93
Basaltic crushed stone	2.70	1.12

The results of the sieve analysis for natural (stream) aggregate and crushed stone aggregate are shown in Fig. 1. Sieve analysis showed that the maximum grain diameter of the aggregate is 16 mm (see Fig. 1).

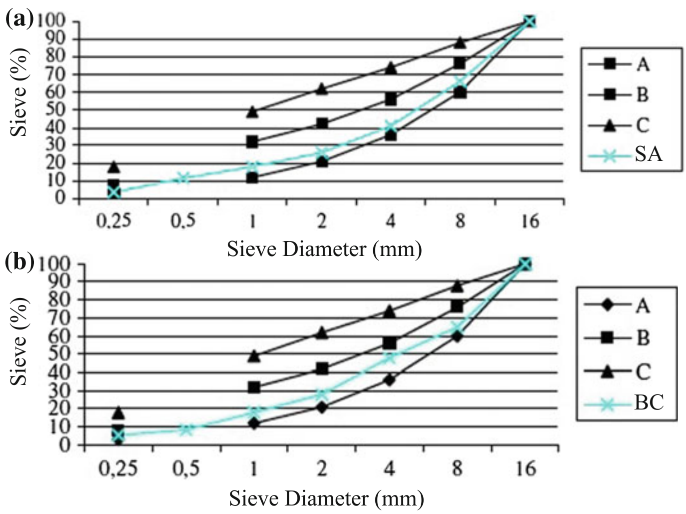

Fig. 1. Aggregate granulometry: **a** stream aggregate (SA); **b** basaltic crushed stone aggregate (BC) [16]

3.2 Cement

The type of cement used in the experiments was CEM I PÇ 42.5 N cement obtained from the Elazig Cement Factory. The dosage of the cement used in the experiments was 400 kg/m^3. Physical, chemical and mechanical properties of the cement are shown in Table 2.

Table 2. Physical, chemical and mechanic properties of the cement used

Chemical composition (%)	CEM I
CaO	62.94
SiO_2	21.12
Al_2O_3	5.62
Fe_2O_3	3.24
MgO	2.73
SO_3	1.79
Loss on ignition	1.78
Physical and mechanical properties	
Density (g/cm^3)	3.07
Specific surface (cm^2/gr)	3382
Compressive strength for 28 days (MPa)	51.7

3.3 Mixing water

Mains water of the city of Elazig was used as the mixing water in accordance with the TS EN 1008 standard for the concrete mix obtained.

4 Method

A total number of 4 cubic concrete samples were produced at two different sizes, 10 × 10 × 10 (10) cm and 15 × 15 × 15 (15) using stream aggregate and basaltic crushed aggregate. The concrete produced were then tested for fresh and set state.

Slump test was conducted on the concrete samples in order to test the placeability of concrete before casting the concrete. Slump test was conducted in accordance with the TS EN 12350-5 standard in order to obtain information on the placeability of fresh concrete and flow diameter range of 420–480 mm was taken for the F3 class available in Table 3.

Table 3. Slump test class table

Class	Flow diameter (mm)	Tolerance
F1	<340	
F2	350–410	
F3	420–480	+30
F4	490–550	
F5	560–620	
F6	>630	

The samples were then casted in molds of 10 × 10 × 10 cm and 15 × 15 × 15 in size. The images of the samples produced are shown in Fig. 2.

Fig. 2. The samples produced 10 × 10 × 10 cm and 15 × 15 × 15 cm in size

After the concrete is completely set, it was removed from the mold and the samples were cured in the water at 23 ± 2 °C for 28 days. Porosity of the samples cured in a tank for 28 days were then calculated. Porosity and weight per unit of volume of the concrete are shown in Table 4.

Table 4. Porosity and weight per unit of volume of the concrete

Material	Porosity (%)	Specific gravity (gr/cm^3)
Stream aggregate	5.98	2.19
Basaltic crushed Stone	4.82	2.3

The samples produced were then subjected to room temperature, and higher temperatures such as 300, 600 and 900 °C and then were subjected to compressive strength tests. Courtesy of Fırat University Construction Labs, Protherm HLF 150 furnace at 6 °C/min heating speed and 1200 °C capacity was used for high temperature tests while 3000 kN automated press was used for pressure tests in accordance with

TS EN 12390-3 standard Each sample was cured in the incubator one day before the test at 100 ± 5 °C until it reached dry saturation and then the samples were tested for temperatures at 300, 600 and 900 °C, respectively. Single axis compressive strength test and ultrasound travel speed test were conducted on the samples subjected to high temperatures.

Based on the lengthwise travel of the sound waves, the ultrasound method is one of the recognized nondestructive methods to be used on the concrete as it is simple and cheap. The speed of ultrasound travels in a medium depends on the porous structure of that medium and therefore its density and elastic properties.

Samples, kept at the room temperature (18–22 °C) for the experiments were used as a control group for the samples subjected to high temperatures.

The results obtained are communicated in the findings and discussion section.

5 Findings and Discussion

5.1 Assessment of the Compressive Strength

Single axis compressive strength test was conducted on the samples subjected to the impact of high temperature (300–600–900 °C) and control samples. These tests revealed the relationship between high temperature and compressive strength of the concrete.

The results showed that the highest compressive strength was obtained from the basaltic crushed stone aggregate (see Fig. 3). It was identified that the loss of strength of the concrete subjected to high temperatures were 5, 45 and 70%, respectively, for 300, 600 and 900 °C (see Fig. 3).

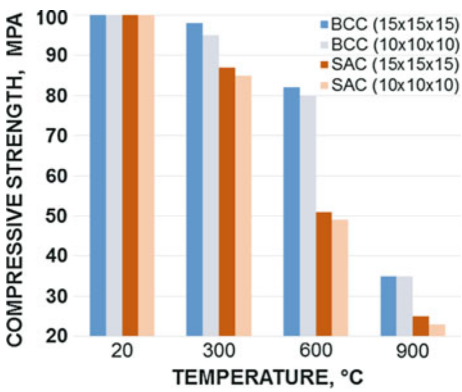

Fig. 3. Diagram for the relationship between compressive strength and high temperature in concrete produced using different aggregates and different sizes (10 × 10 × 10 cm and 15 × 15 × 15 cm)

The solid elements of the calcium silicate hydrate (CSH) which makes up the gel texture of the cement paste binds with the help of adsorption water. Adsorption water of the gel and chemically bound water in hydrates start to evaporate at 300 °C, while the water available in capillary voids may start to evaporate at around 100 °C. Evaporated water results in retreat. The retreat and the vapor pressure building in the concrete lead to cracks and destruction of the concrete. Another important component of the cement paste is calcium hydroxide. $Ca(OH)_2$ takes the form of quicklime at around 530 °C. A contraction up to 33% is the case during this transformation. Cracks in the structure occur as a result of this contraction and volume change, concrete crumbles and it takes a porous structure [15]. As it is found in this study, chemical and physical changes in the concrete due to the impact of high temperature have a negative impact on the compressive strength leading to reduced performance of the concrete.

In this study, the relationship between the concrete sample size and the impact of the high temperature on its compressive strength was also investigated. Concrete samples of 15 cm^3 obtained for this study had a better compressive strength when compared to the concrete samples of 10 cm^3—produced using the same aggregates and methods (see Figs. 4 and 5). Temperature was able to reach to the center of small samples when compared to large samples which in return reduced the compressive strength further (Figs. 4 and 5). Nevertheless, it was found that the concrete produced with different sizes under constant environmental conditions and 900 °C showed a reduced difference in their compressive strength (Figs. 4 and 5).

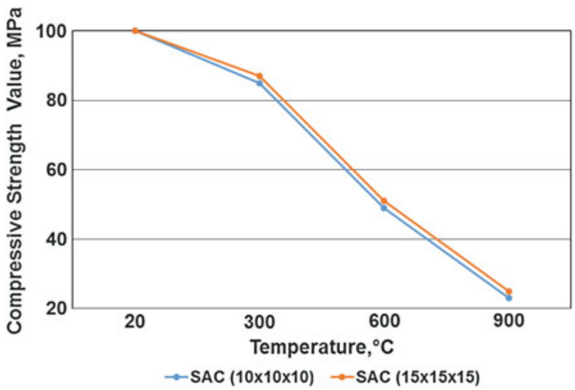

Fig. 4. Diagram for the relationship between compressive strength and high temperature in concrete produced using stream aggregate and different sizes (10 × 10 × 10 cm and 15 × 15 × 15 cm)

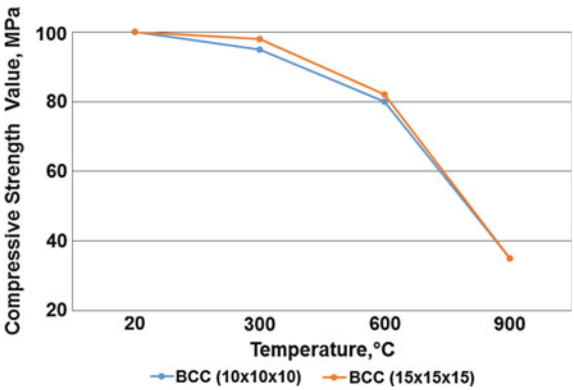

Fig. 5. Diagram for the relationship between compressive strength and high temperature in concrete produced using, basaltic crushed stone aggregate and different sizes (10 × 10 × 10 cm and 15 × 15 × 15 cm)

5.2 Assessment of the Ultrasonic Test

In this study, the effects of high temperatures on the pore structure of the concrete were investigated using ultrasonic measurements (UM) on the concrete samples. Vaseline was applied to the lateral surface of the samples in order to fill the rough surface of the parting line to measure the ultrasound traveling time; A double ultrasound pulse—at 55 kHz transmitting and receiving circuit was placed to the even surfaces of the samples and readings were taken. The readings were recorded, a total of four readings for each sample, two readings from opposing sides. The data obtained are shown in Figs. 6 and 7.

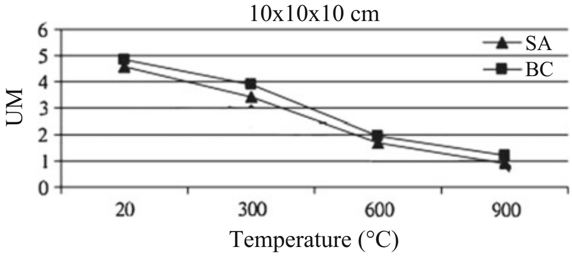

Fig. 6. Ultrasonic measurements of the samples of 10 × 10 × 10 cm in size

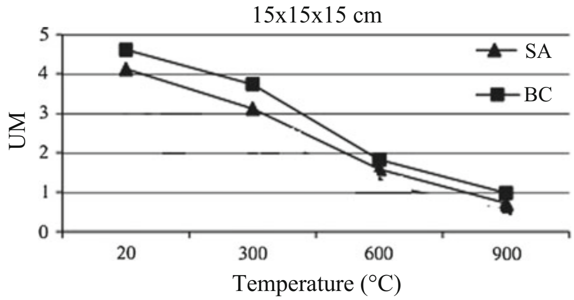

Fig. 7. Ultrasonic measurements of the samples of 15 × 15 × 15 cm in size

It is expected from a concrete sample with higher number of pores to give a longer ultrasound wave travel time. The porous structure of the concrete and its density are closely related to the aggregates used. Thus, when the control samples are examined, it was found that the properties of natural aggregate and crushed stone aggregate concretes have similar properties, however, the one produced using stream aggregate had a lower ultrasound traveling speed.

Among the control aggregates, the lowest ultrasound traveling speed was found for concrete with light aggregate with 3.4 mm/μs while the highest ultrasound traveling speed was found for concrete with crushed stone aggregate with 4.83 mm/μs.

High temperature has an adverse impact on the ultrasound traveling speed of the concretes. According to the results of ultrasonic measurements of all the samples, the ultrasound traveling speed was reduced by 21% for 300 °C; 65% for 600 °C, and 85% for 900 °C. This can be explained with the fact that the impact of temperature increases the thermal incompatibility between the aggregate and the cement paste which leads to increased pore ratio.

6 Results and Recommendations

The results of this study, in which the effects of high temperature was investigated for concrete produced using two types of aggregate at different sizes, can be summarized, as follows:

- The compressive strength of the concrete produced using basaltic crushed stone aggregate was higher than the one produced using stream aggregate (see Fig. 3).
- It was identified that the loss of strength of the concrete subjected to high temperatures were 5, 45 and 70%, respectively, for 300, 600 and 900 °C.
- Compressive strength of the 15 cm^3 concrete produced using the same aggregate was higher than the one of the 10 cm^3 concrete (Figs. 4 and 5).
- Temperature was able to reach to the center of small samples when compared to large samples which in return reduced the compressive strength further (Figs. 4 and 5).

– In addition, it was found that the concrete produced with different sizes under room temperature and 900 °C showed a reduced difference in their compressive strength (Figs. 4 and 5).
– Compressive strength of the 10 and 15 cm^3 samples was found to be different at a range from 0.90 to 0.93.
– The impact of temperature increases the thermal incompatibility between the aggregate and the cement paste which leads to increased pore ratio.
– This was verified with the reduced ultrasound traveling speed.

Additionally, this study showed that the durability of concrete has a relation with high temperatures with respect to the concrete size. Further research must focus on such properties of the concrete.

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Strength-Maturity Relations of Concrete for Different Cement Types

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Abstract. The maturity concept is a basic method to estimate the strength depending on time and temperature. Maturity index, which is a factor for determining the hardening, is used as a non-destructive inspection method for estimating the concrete strength. The method assures a relatively simple approach to make more reliable estimates of in situ strength during construction. However, in order to apply the maturity, during the construction some tests should be carried out to obtain the properties of concrete before initiating the production. Here within, the variation of maturity with different cements was examined. For this reason, two different cements were used. The specimens produced were cured in three different temperatures (0, 23 and 40 °C) for 1, 3, 7 and 28 days. The compression tests were applied on the specimens at the end of the curing time. Equations for the relationship between maturity and strength were developed for the cements used in the study.

Keywords: Concrete · Maturity · Temperature · Compressive strength

1 Introduction

The engineering characteristics of a hardening cement-based material are to a very large extent depending on the microstructural development, and thus on the hydration reactions of the cement. In a fundamental approach, the relation between the driving processes on the microscopic and macroscopic engineering properties can be studied by means of the degree of hydration, using sometimes detailed general hydration models. In a more traditional approach, the effect of ongoing hydration can be estimated by defining maturity or, similarly, by considering the equivalent age of the cementitious material [1]. The strength development of the concrete is depended upon various environmental factors. Of these, the two most important ones are temperature and time [2]. Here, the temperature history is used for calculating the maturity index. Gaining strength is to do with the chemical reaction of the complex compounds of cement with water, also called hydration. This is an exothermic chemical reaction and develops slowly or fast due to the surrounding temperature in which the concrete exists. The maturity method is concerned with the relationship between concrete curing temperature and time. If determined, such a relationship can provide some information as to the early age strength of the concrete without causing any destruction in the

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concrete [3]. Anticipating the early-strength of the concrete is important not only for modern concrete buildings but also in producing structural concrete elements. Preparing the work procedures safely and economically such as moving, loading, installing the pre-stressed connections and removing the molds of concrete elements produced can be fulfilled by predicting early-age concrete strength. The information that will be obtained concerning the early strength of the concrete used in a structure would be particularly vital when the concrete is prepared in cold weather [4].

2 Maturity Concept for Concrete

Basically, maturity is a concept used to determine temperature-time relationship, one of the indispensable compound factors for the strength of the concrete. The surrounding effects have placed an important role for developing concrete strength by time. For this reason, the strength of the concrete at any age is a function of temperature history of the concrete. The specific strength of a concrete mixture is expressed as a function of maturity. When the common specimens taken from the same concrete mixture is kept under different curing temperatures, the strength of concrete placed in moulds can be predicted by using the temperature history of specimens and strength maturity relations. The origins of the maturity method can be traced to a series of papers from England dealing with accelerated curing methods when steam curing was common in England. A newly cast fresh concrete gets strength in time when exothermic chemical reactions occur between the cement and water in it. When the suitable moisture conditions are provided, hydration reactions in the concrete may cause a rise in concrete temperature. This increase, in turn, accelerates this chemical reaction. Hence, environmental conditions prove effective in the development of mechanical properties of the concrete in time. Accordingly, hydration degree and strength of the concrete at any time is attributable to the function of temperature history of the concrete [5].

Determining concrete strength using maturity method can be traced to the beginning of the 20th century. Many researchers have tried to define and use this method. In one of his studies in 1915, Mc Daniel cured the specimens at −3, 1.5, 22 and 33 °C for two days and then tested with them when they were at age 3, 7, 10, 14 and 28 days. In their studies Wiley, Timms and Whitey put emphasis on time and temperature factors. McIntosh first used the term “Basic Age” when he handled the problem of heating concrete with electricity current. According to the Basic Age principle, the starting temperature is shown as approximately 0 °C (32 °F) and the basic age is stated in terms of (°F × hour). So these studies cause a new approach to account the combined effects of temperature and time on strength development of concrete these ideas led to the Nurse-Saul maturity function, which is the most commonly used one [6].

$$M = \sum_{i=0}^{t} (T - T_0)\Delta t \tag{1}$$

In this equation, definitions would be as follows; M maturity index, °C-hours (or °C-days), T average concrete temperature (°C) during the time interval Δt, T0 datum temperature (the temperature that is subtracted from the measured concrete temperature for calculating maturity according to Eq. (1), usually taken to be −10 °C), t elapsed time (hours or days) and Δt time interval (hours or days) [7]. Here the value calculated using the Eq. (1) is called maturity. On the other hand, as a term, it is also used as the temperature-time factor [8]. Traditionally datum temperature is the temperature at or below which cement hydration is assumed to cease. Temperatures taken from the concrete must be referenced to the datum [9]. In 1977, Freiesleben Hansen and Pedersen suggested a new function to calculate maturity index of concrete, making use of its recorded temperature history. This function was developed based on Arrhenius equation that is used to account for the impact of the temperature on a chemical reaction. The new function has enabled us to find equivalence age of concrete [10], where, te the equivalent age at the reference temperature, E apparent activation energy J/mol, R universal gas constant 8.314 J/mol-K, Δt time interval, T average absolute temperature of the concrete during interval Δt and Tr absolute reference temperature (K).

$$t_e = \sum_{0}^{t} \mathrm{e}^{\frac{-E}{R}\left(\frac{1}{T}-\frac{1}{T_r}\right)} \Delta t \tag{2}$$

In the studies carried out in Europe, the relevant temperature is generally used as 20 °C and in those carried out in North America it is taken as 23 °C. The use of Eq. (2) largely eliminated the discrepancies between strength-maturity relationships developed with different initial curing temperatures, that is, it eliminated the discrepancy at early maturity shown in Fig. 1. Here, maturity and correlation of temperature is stated with a value of certain amount of activation energy [11, 12]. The best known of various studies that have been carried out to predict the strength is Plowman's study, which established a relationship between strengthening of concrete against compressive and maturity of concrete. In this study Plowman pointed out that there is a relationship below between the maturity of concrete produced with normal Type I cement and 28 days compressive strength.

$$\frac{f_e}{f_{28}} = A + B \cdot \log \frac{M}{1000} \tag{3}$$

where; A and B constant values, M maturity of the concrete in respect to °F-hours, f_e compressive strength of the concrete at the value of M maturity and f_{28} compressive strength of the concrete for 28 days. Plowman's Eq. (3) is based on maturity concept and is applicable for concrete types cured continuously at 100 °F (38 °C) [13]. Other concrete researchers have indicated that the maturity concept for strength prediction is not applicable to concrete cured at temperatures in excess of 100 °F.

2.1 Strength-Maturity Relationship

The newly cast concrete gains strength with the exothermic chemical reactions. The reaction rate increases as the concrete temperature rises. The type, amount and fineness of cement effect this hydration reaction. Maturity method is a combined technique regarding the temperature and time on strength development. When the same concrete specimens are kept under the healing conditions, the strength can be estimated through strength maturity relations for thermal history of specimens. Maturity method is considered to approximate concrete prediction.

In order to be able to determine strength-maturity relationship, cylindrical concrete specimens are prepared by means of a concrete mixture with the same properties as that which will be used in the construction area. For this purpose, concrete specimens are cast into the cylindrical moulds; thermocouples measuring temperature are put into at least two of the specimens in such a way that they will be positioned right in their centers. Then, these thermocouples are connected to a computer, which can automatically determine maturity, or to a temperature-recording machine. Test specimens are cured in a water tank or in a moist curing room, with at least two of them being tested with compressive strength when they are 1, 3, 7, 14 and 28 days old. During the test, the average maturity values determined by the maturity-meter are recorded. If a maturity-meter has been used, the averages of the values obtained are recorded. If a temperature-recorder has been used, it is possible to compute maturity using equations Eqs. (1) or (2). It is possible for the time-interval of the temperature to be 30 min or lower within the first 48 h [8]. The curve is derived from a function of average maturity of average compressive strength. The curve drawn is suitably adapted in accordance with the data, or alternatively regression analysis can be used to determine the most suitable one to the strength-maturity relationship [14].

3 Experimental Study

Two types of concrete mixture prepared for the experiment, CEM II/B-M 32.5 and CEM I 42.5 R type Portland cements were used. The properties of cements used in experimental studies are shown in Table 1. River sand and crushed stone aggregates 8–16 and 16–32 mm were made use of. Cement dosage, water-cement ratio and size of the aggregates were kept constant as 400 kg/m^3 and 0.57 for two types of concrete mixture. Thus we determined the effect of cement type on strength development of concrete. For this purpose cylindrical specimens produced for the experiments and cured in consideration of ASTM C 192 standards [15].

Thermocouples for “Maturity Meter M-3056”, which measures temperature history, were placed in center of the cylindrical specimens the size of $\phi 15 \times 30$ cm and were cured in water tank heated at a desirable temperature. The conditions of 40 and 23 °C were obtained for the water tank, while 0 °C was obtained through a freezer. At the end of curing time, specimens were initially tested by the ultrasound pulse velocity test. Afterwards, the compressive strength test was carried out on the cylindrical specimens. Next, maturity Eq. (1), compressive strength maturity relationship was determined for three possible conditions that should affect on concrete during construction. While determining the maturity of concrete specimens, the datum temperature (T0) is considered as −10 °C for Type I cement. On the other hand, ASTM C 1074 proposes that datum temperatures, which are defined as the degree at which the strength gaining stops, should be taken as 0 °C for the concretes without admixture [8]. The relationship between compressive strength-maturity and dynamic modulus of elasticity-maturity was also determined.

Table 1. Properties of cements used in experimental studies

Chemical composition	CEM I 42.5R	CEM II/B-M	Physical properties	CEM I 42.5R	CEM II/B-M
CaO	62.16	52.56	Blain fineness (cm^2/g)	2931	3546
SiO_2	20.03	26.06	Specific gravity	3.13	2.97
Al_2O_3	4.3	6.71	Initial setting (hour: minute)	2:10	3:10
Fe_2O_3	3.79	3.55	Final setting (hour: minute)	4:40	6:00
MgO	2.93	2.66	Trass (%)	–	20.21
SO_3	2.36	1.87	Limestone (%)	–	9.85
Compressive strength (MPa)					
2-day				26.6	19.2
7-day				37.1	28.4
28-day				47.4	35.1

4 Test Results

According to the compressive strength test results, when exposing the specimens to a high temperature it can be seen in Fig. 1 that early-age strength is high; however, long-term strengths of the specimens are lower than concretes produced under normal conditions.

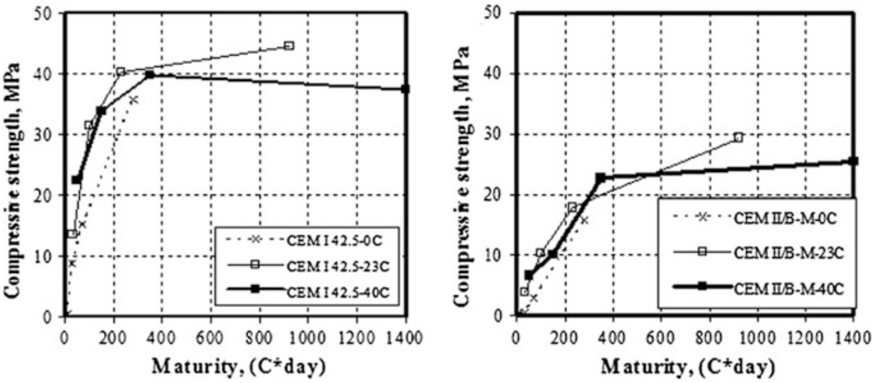

Fig. 1. Relation between compressive strength and maturity

As seen in Fig. 1, the specimens produced with CEM I 42.5 R and CEM II/B-M 32.5 type cements, are cured at 0, 23, 40 °C. When analyzing the results of compressive strength tests, it can be seen that they didn't show a constant variation in the strength gaining duration. So, there exist some strength differences given in Table 2 between the concrete specimens strengths produced by CEM II/B-M 32.5 and the ones produced with CEM I 42.5 R for diverse maturity values.

Table 2. Errors in strength of concrete produced with CEM I 42.5R versus CEM II/B-M 32.5

Maturity (°C × day)	Errors (%)	Maturity (°C × day)	Errors (%)	Maturity (°C × day)	Errors (%)
10	22.36	33	71.95	50	70.51
30	93.63	99	67.23	150	70.12
70	81.04	231	55.56	350	42.99
280	56.04	924	34.36	1400	24.52

When comparing the compressive strength tests depending on the maturity values of the specimens kept in the same curing conditions with the compressive strength results done in other curing conditions, it can be seen that the compressive strength of the specimens produced through CEM II/B-M 32.5 is lower than the ones produced by CEM I 42.5 R cement types. If we examine the results, as the temperature increase in the curing, the difference between the strengths for concretes decrease. It can be seen in Tables 2 and 3 that the concrete specimens produced by CEM I 42.5 R and CEM II/B-M 32.5 cement types are cured at 0, 23, 40 °C.

Table 3. Errors in dynamic *E* of concrete produced with CEM I 42.5R versus CEM II/B-M 32.5

Maturity (°C × day)	Errors (%)	Maturity (°C × day)	Errors (%)	Maturity (°C × day)	Errors (%)
10	17.24	33	35.90	50	44.01
30	34.59	99	15.35	150	34.58
70	50.98	231	9.68	350	15.78
280	23.63	924	6.46	1400	18.04

When analyzing the results of the dynamic E-Moduli estimated in the process of strength gaining of the concrete, it is observed that they showed no regular variation. When comparing the dynamic e-modulus results for those cements, there is a decreasing 16 and 36% for concretes produced with CEM II/B-M 32.5 and CEM I 42.5 R. Analyzing the results, as the temperature of the curing surrounding increases, the differences of the dynamic E-moduli between the concretes produced with those cement types decrease (Fig. 2).

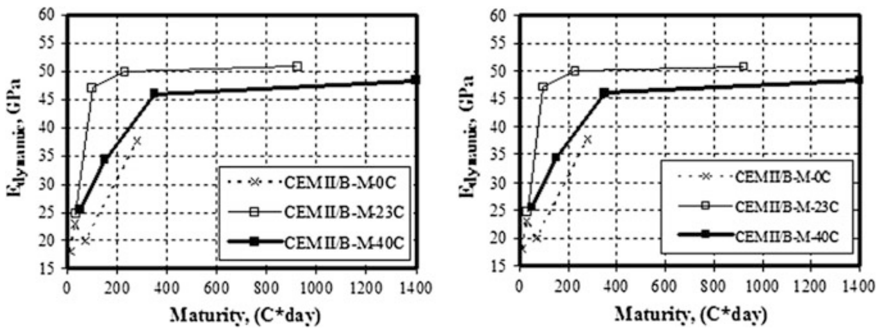

Fig. 2. Relation between dynamic modulus of elasticity and maturity

In the light of the data obtained from the compressive strength test, we determined the relationship between the strength of the concrete and maturity according to Eq. (1). As a result of the analysis done, two equations were suggested; CEM II/B-M 32.5 Eq. (4) and CEM I 42.5 R Eq. (5). In these equations, M is the maturity of the concrete mixture calculated with the Eq. (1) and with (°C × day) type. The correlation coefficients of these equations are 0.94 for CEM II/B-M with the suggested Eq. (4) and 0.87 for CEM I 42.5 with the suggested Eq. (5).

$$f_c = -19.07 + 6.55 \ln M \tag{4}$$

$$f_c = -17.77 + 9.22 \ln M \tag{5}$$

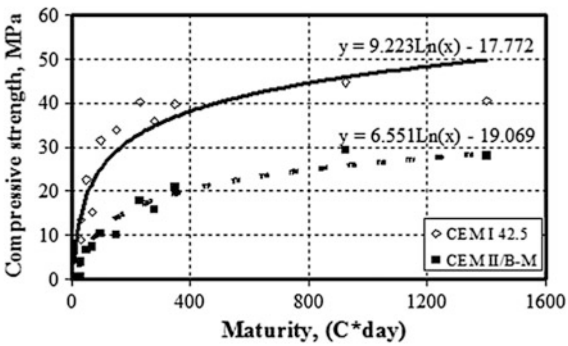

Fig. 3. Development of compressive strength of concretes made for different cements

The strength-maturity relations are given in Fig. 3 as a function of temperature and time for two different cement types. In this way, the approximate in situ strength can be predicted if time and temperature that was exposed is known.

5 Conclusions

Using two different types of cements (CEM II/B-M 32.5 and CEM I 42.5), we suggest the following conclusions as a result of the experiments with concrete specimens with constant mixture ratios and kept under three different curing conditions (0, 23 and 40 °C).

1. The compressive strengths of the concrete specimens produced by CEM II/B-M 32.5 are lower than the ones produced by CEM I 42.5 in the rate of 57%. This decreasing is not a regular variation in the strength gaining process.
2. In the strength gaining process; the difference between the compressive strengths produced with those two different cements get lower when the curing temperature increases from 0 to 40°C.
3. The dynamic E-Moduli of the concretes specimens produced by CEM II/B-M 32.5 is lower than the ones produced by CEM I 42.5 R in the ratio of 26%. This decreasing is not a regular variation in the strength gaining process. As in the compressive strengths, this decreasing did not show a regular change in the dynamic E-Moduli.
4. In cold weather concreting if finer type of the cement is used, the development of the compressive strength occurs faster due to the fast hydration.
5. If accelerated curing is applied to the concrete at high temperatures, the curing process should be less; because, the strength of the concretes could be lower than the ones produced under normal conditions due to the crossover effect.
6. The relationships between different types of cements with different properties and maturity correlations should be investigated more extensively.

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Investigation of Parameters for Energy Efficient Improvement in Transparent Façades

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Abstract. Studies on building skin which promise to help minimizing the loss of energy while maximizing its gain are increasing day by day. Transparent surfaces as part of the building skin play an important role in determining the life and comfort of the buildings. One of the most important problem at the buildings have transparent façade systems with similar qualities on all façade surfaces as independent of location, direction and climatic data is overheating in the summer. Increasing energy loads due to the necessity of using cooling systems due to overheating are another problem to be solved. In order to make a positive contribution to energy performance, it is necessary to take architectural design decisions that take into account the problem of overheating.

Keywords: Transparent façade · Cooling strategies · Energy efficiency

1 Introduction

Energy use in all sectors; It has become one of the most important issues since the industrial revolution that started in the second half of the 18th century and the oil crises since 1970. As in the world, a large part of the total energy in Turkey is also used for heating, cooling, ventilation and lighting purposes in Turkey. In Turkey, approximately 20% of the total energy is used in transportation, 43% in industry and 37% in buildings [1]. The importance of energy-efficient designs is increasing day by day because of fossil-based fuels, which are predominantly non-renewable, are used as energy sources in the construction sector as in other sectors.

In the discipline of architecture, from 1990s onwards, with increasing attendance, eco friendly, building applications aiming to increase energy efficiency are sought for solutions [2]. The high energy consumption of all the buildings with transparent façades, the problem of overheating in summer and the inability to provide the thermal comfort requirements of the users as a result have necessitated reconsideration of the skin designs made with this system. The ideal building skin can be defined as the building skin that provides optimum comfort conditions for building users against the changes that occur between the outdoor and indoor environment without using expensive and complicated equipment based on energy efficiency. In this context, there are many parameters that need to be decided during the design phase for façade design, which provides the thermal comfort of the building without increasing the energy loads.

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2 Transparent Façades

Le Corbusier has made a description for the history of architecture: “This is the story of the struggle of the window.” [3]. In the 20th century architecture, new architectural movements and new façades have been developed with opaque surface proportions decreasing and transparent surfaces expanding. As a result of the breakthroughs in the production and engineering fields that emerged with the Industrial Revolution, the construction systems were able to open more free window spaces on the building façades so that the functions expected from the windows also changed size [4].

The glass façades that emerged in parallel with the developments in materials and construction technology since the 20th century have become an indispensable building shell for short periods of time due to their light weight, their aesthetic appearance, ease of manufacturing and assembly and their resistance to climatic conditions [5]. Beginning to use glass more and more in the construction, it has made transparency stand out in curtain wall systems. As a result, a new concept has emerged that is defined as a transparent façade. Despite the positive effects of daylight on interior volumes, the buildings with transparent façades are also faced with daylight-related problems. In the summer period, uncontrolled and direct entering daylight causes overheating and increased building cooling loads. Uncontrolled and direct daylight dispersed in the inner volume also causes glare by affecting the glare distributions [6, 7]. It is possible to control these problems with measures taken during the design phase of the building. In this study, the measures that can be taken during the design phase will be discussed in the perspective of passive systems.

3 Energy Efficient Design Decisions in Transparent Façades

Transparent façade design has certain parameters that play an important role on energy performance (Table 1).

Table 1. Parameters affecting architectural design

Climate data	Direction of facade	Building form	Glasses	Facade systems	Shading devices
Macro climate	North	Form factor	Glass type	Single skin facades	Type of shading devices
Micro climate	South East	Building height	Properties of glass	Double skin facades	Position of shading devices
	West	Roof type	Glass thicknesses		Material of shading devices
	Northeast Northwest	Facade geometry			
	Southeast Southwest				Angel of shading devices
					Color of shading devices

3.1 According to Climate Data

Buildings should be designed according to the climatic conditions that their land has. Building forms and materials that are used should be shaped according to climatic and topographic characteristics. The climate surrounding the building can be defined in two ways: macro climate and micro climate. Macro climate can be described as climatic data defining the characteristic climate of a specific area or a region. Temperature, humidity, annual precipitation, wind speed and direction, sunshine duration, solar radiation data, atmospheric pollution are important climate parameters. Micro climate is the climate of the building environment. There may be many microclimates around the building, such as neighboring buildings (obstruction of the sun and wind), terrain (rivers, valleys, hills). In addition, different microclimates can be found in different façades of the building: for example, the façades in the prevailing wind direction, south or north façades have different micro climates than others [8].

The heat loss that can occur in the designed building skin must be minimized. In the winter when heating is desired, it is necessary to make maximum use of the heating effect of solar radiation. Natural ventilation and shading gain importance in the summer season.

3.2 Orientation in Façade Design

External climate elements, such as solar radiation and wind, change with direction. The cooling effect of the sun's radiation and the wind vary depending on the direction and therefore, through this parameter, it can be optimized depending on the climatic comfort requirement [9]. In summer the position of the building is important for the determination of the cooling energy. The parameters such as the south direction of the building, the elevation angle of the sun, and the intensity of the solar luminosity are the most important parameters affecting the façade design [10].

Depending on the rise of the summer and winter sun, the southern façade, is the façade that receives the least direct sunlight in the summer. In winter it is exactly the opposite. For this reason, when the commonly used places are located on the south side, the buildings provide the most benefit from the sun (northern front for the southern hemisphere) [8].

3.3 Building Form

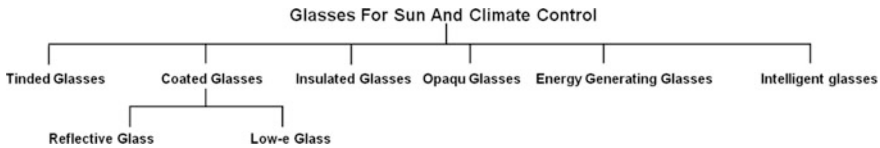
The building's form is an important parameter that determines the building's level of utilization or protection of environmental factors, and therefore its energy performance. Compact forms should be preferred to minimize the area of energy lost surfaces in cold climatic zones. In hot dry climate regions, compact forms and forms with courtyard should be selected to minimize heat gains, to obtain shady and cool living areas. Long elongated forms oriented towards prevailing wind that allowing maximum natural ventilation should be preferred in the hot humid climate region.

In moderate climate regions, as flexible as possible, but more flexible building forms than cold climatic zones are among the issues to be considered in energy efficient design [11].

3.4 Glass

Glasses that provide sun and climate control are used as cover material in curtain façade systems. When choosing the glass in the curtain façades, it is very important to make a selection by evaluating the glass thermal insulation, sound permeability, light transmittance, color and light reflection properties, static strength, fire resistance and safety criteria. Glass should be selected by considering and evaluating these evaluation criteria, the noise level of the zone where the building is located, climate conditions and orientation [12]. Table 2 shows the glasses for sun and climate control.

Table 2. Glasses for sun and climate control



One of the most important features of glass façades is the ability to make use of natural light. They benefit from the amount of energy required for lighting [13]. However, the brightness level of the received daylight should not cause glare problems. When choosing glass, designers need to consider not only the physical and thermo physical properties of glass, at the same time the designer needs to consider the amount of heat that the material under the influence of the sunlight gives to the interior [14].

3.5 Determination of Façade System

Glass façade systems are divided into two groups as single shell façade system and double shell façade system. Jiru et al. [15] defined the double skin façade as a building skin consisting of two glasses, with an air channel between them Double skin façades have been developed to eliminate the adverse effects caused by single skin façades [16]. The ventilated cavity acts as a thermal buffer zone. This space reduces unwanted heat gains during cooling and it reduces unwanted heat losses during the heating period. These systems control the glare problem caused by the sun and provide maximum benefit from daylight. The double skin façade system has become widespread in the building sector, which is looking for a building skin system that aims to minimize energy losses and maximize the energy used. These façade systems perform better than others in terms of energy efficiency and thermal comfort [17]. Double skin façade design, with the right design and control strategies, can affect positively the total energy consumption of the building [18–23]. But, there are studies showing that there are negative effects due to overheating, especially in the summer, and that it increases energy consumption, in addition to its positive effects [24, 25]. Precautions should be taken for overheating problems that will occur during summer months (Fig. 1).

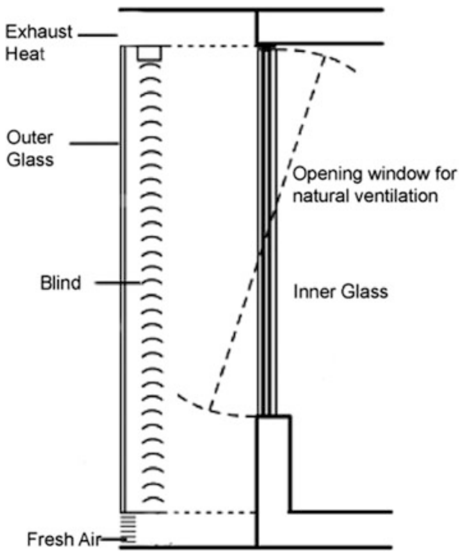


Fig. 1. Double skin façade system schematic section [26]

Gratia and Herde [27] noted that the problem of overheating during the summer months in double skin facades could be solved by natural ventilation methods with well-sized openings. Hien et al. [16] conclude that the natural ventilated and mechanically ventilated double shell façade system is more successful in achieving thermal comfort than the single shell façade system.

In double skin façades, the spacing between the layers have significant effects. Intermediate space distances affect the heat transfer coefficient (u value) of façade. As the void narrows, significant pressure losses occur in the void. This shows that the airflow in the cavity is related to the size and form of the façade. The size of the cavity, vary between 20 and 200 cm because of the aesthetic factors, types of lashing elements, cleaning/maintenance, etc. [28].

3.6 Solar Shading Devices

Solar shading devices are elements that protect building from overheating, reflect the unwanted sun rays passing through the building from the outer shell during the summer season or absorb some of it. They have a positive effect on the building's cooling loads. In general, three types of blind elements are used as blind, jalousie, roller blind. The type, the position (external, internal, central), geometry, the angle, the color of solar control elements, affect significantly the thermal properties of the air cavity in the façade, the air flow in the space, visual comfort of users (Fig. 2).

Fig. 2. Solar shading devices [29]

Gavan et al. study the temperature profiles in the double-skin façade by an experimental setup. As a result of the studies, they found that the temperature in the air cavity and the surface temperature in the facades were dependent on the angle of the sun shading devices [30]. In double skin façades, the position of the sun shading devices also has a decisive role in the thermal performance of the double skin façade. Solar shading devices are usually located in the buffer zone. This ensures that the sun breaker is easier to maintain and clean and less exposed to dust/leathers. Furthermore, the blind which is protected by the outer skin in the buffer zone, reflects the sun's rays more intensely. The thermal conditions in the surrounding area are better than if the blind is located indoors [31]. Gratia and Herde stated that the most effective sun protection position is the outer façade but because of the bad weather conditions it could be positioned in the inner bumper area if the double façade is applied [32]. Lee et al. [33] investigated the relationship between shading elements and ventilation efficiency. They have stated that for proper ventilation the shading elements must be at least 15 cm from the exterior wall.

Another important issue about shading devices is material choice. The surfaces of the shading devices are exposed to high temperatures due to sunlight. Photovoltaic panels can be used instead of aluminum profiles to reduce the surface temperatures of shading devices. This contributes to the energy performance of double skin facade [34].

Most of the high-rise building façades that have developed in recent years are designed transparently with the same character and each have problems in terms of thermal comfort (Fig. 3).

Fig. 3. High-rise buildings [35–37]

For example, The Manitoba Hydro building, has an energy efficient façade system. The 115 m high solar stuck on the northern edge of the structure rises up to the roof from the ground level. Solar stuck designed on the facade emphasizes passive ventilation strategy. As a key point of the passive ventilation system, depends on the natural stuck effect. During the summer months hot weather is thrown out of the sun (Fig. 4).

Fig. 4. The Manitoba Hydro office building (Canada, 2009) [38]

In the case of summer, when the air is warmed up on the double-layered facade, hot air is blown out by windows which are opened automatically by the building automation system (Fig. 5). To minimize the northern edge of the building, the building is to the north shrinking. To take maximum advantage of solar and wind energy the south side of the structure is wider than the other surfaces [36].

Fig. 5. Appearance from the double layer façade system [38]

4 Conclusion

While fossil energy sources are limited, a considerable amount of energy in summer is used for cooling purposes, making it important to produce the building shell in the least energy-consuming way. Transparent façade systems, a type of building skin, should not be designed independently of the developed glass technology, location, direction and climatic data. Some measures must be taken in the design phase in order to be protected from unwanted sunlight coming from the façade, to minimize energy losses and to create comfortable spaces. Some design decisions that need to be made during the architectural design phase play a decisive role in the energy performance of these systems. The location of the land, the climate, the orientation, the type of glass used, the type of shading devices, the appropriate ventilation type and the appropriate façade system are the important parameters to be settled during the design phase. In this study, which is part of the data collection phase for doctoral thesis studies carried out in Gazi University Architecture Department, the design parameters that are effective in the energy performance of the transparent facades have been determined by literature review. In the following stages, the buildings which are built in Ankara and all their facades have been built as transparent facades with the same characteristics and have problems in thermal comfort will be determined. Façades of these buildings will be evaluated by creating variations with the Design Builder Software. The buildings to be analyzed will be high-rise office buildings. Each parameter will be analyzed separately. Existing energy loads of buildings will be revealed and in the summer months, a solution will be developed that will reduce the internal overheating problem and increase the annual cooling load. Approaches will be offered in order to be able to consume energy at the lowest possible level. The study to will be done is expected to reveal design principles that will improve the performance of transparent facades that must be designed in the context of energy efficiency and also it is expected that this work will be a guide.

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Impacts of Bleaching and Varnishing Process on the Amount of CO_2 in Scotch Pine (*Pinus sylvestris* Lipsky) Wood Material

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Abstract. This study was carried out to determine the effects of bleaching and varnishing process on the amount of CO_2 in Scotch pine (*Pinus sylvestris* Lipsky) wood material. For this purpose, samples of Scotch pine wood prepared according to ASTM D 358 [1] contain 18% R1 = ($NaOH + H_2O_2$), R2 = ($NaOH + Ca(OH)_2 + H_2O_2$), R3 = ($Na_2S_2O_5 + H_2C_2O_4$), R4 = ($NaSiO_3 + H_2O_2$), R5 = ($KMnO_4 + Na_2S_2O_5 + H_2O_2$) solution groups, after bleaching with solution groups, water based (Sb), synthetic (Sn), polyurethane (Pu) and acrylic varnish (Av) were applied according to ASTM D 3023 [3] and compliance with ASTM E 160-50 guidelines in combustion tests. Gas measurements were made with the SIGMA 74,172 NSU flue gas device during the combustion process. As a result, the amount of CO_2 in the flame source combustion (ppm); The highest R1 (8.500), the lowest R3 (2.907), the highest R1 in the varnish level (5.314), the lowest Pu (2.853) Av (14.773) and lowest R2 + Sv (0.633) were obtained. The amount of CO_2 in without flame combustion temperature (ppm); the highest values were Sb (6.686), the lowest Pu (5.419), the highest R1 (9.367) and the lowest R3 (5.407) Sb (19.43) and lowest R3 + Sv (1.167). Baking combustion CO_2 content (ppm); the highest Pu (5.127) at the varnish level, the lowest at Sv (2.522), the bleaching materials at the level is highest at R1 (5.980), lowest at R4 (2.180), according to bleaching materials and the varnish type interaction is the highest R1 + P (15.29), also the lowest R5 Av + (0.7833) was obtained. Accordingly, the highest results in terms of the amount of CO_2 in the Scotch pine wood were found in the water-based varnish with the R1 solution.

Keywords: CO_2 · Combustion · Bleaching · Varnish · Scotch pine wood

1 Introduction

Wood material is worn out due to environmental conditions and its components are degraded by chemical and biological means. Drying, impregnation and surface treatment are applied against these drawbacks [7]. Physical characteristics; the smell, taste, color, pattern etc. of wood species of are different. Wood discoloration injuries in live wood, dead knot formation, oxidation of certain chemicals in the wood next to reasons

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such as illness or heartwood of the older generation or tannic result of contact with the metal of the wood takes place with occurring discolorations [11].

In addition, color differences can occur due to the intensity of the annual growth of the wood material (summer wood, spring wood). The color, shape, size, form, balance etc. of furniture. Carpets, curtains etc. used in interior decoration. Besides textile, it is required to be compatible with wall, ceiling, floor coverings [4, 10].

It may be necessary to change the color or open the dark color on the painted wood material surfaces. While wood dyes usually add superficial color to wood, color dyes create a deep light color and shine. The color-changing chemical substances are generally reactants which act on the wood-material side compounds. They do not destroy the colors, they make the side compounds transparent [20].

It is often difficult to remove stains and vein strips from the wood material and uncover the stains without damaging the fibers. In some woody woods (oak, ash, maple, walnut, beech etc.) the color is relatively easy to open [4, 6]. The impregnated wood material surfaces used outdoors are covered with sunlight and rain over time. In this case, coloring can be done [5]. The general purpose colors consist of two solutions. In some cases, the first solution is caustic soda (NaOH) and the second is hydrogen peroxide (H_2O_2). The solution can be applied after the other one as well as mixed. The most effective color rendering is achieved by the combined use of both solutions [8].

The surfaces subjected to the coloring process are warm water, oxalic acid, acetic acid and so on. And the sediments that are likely to remain on the surface are washed and cleaned. At this time, the swollen fibers are smoothened by light sanding [4]. The fires mostly begin with the goods inside the dwelling. It does not directly start from the wood material part of the dwelling. However, during the superficial fires that start within the residence, the temperature reaches a very high level in a very short time causing the fire to start in the construction of all kinds of goods, materials and structures in the surrounding area. Thus the danger and harm is to reach very large sizes [16].

Uysal et al. [18] studied the changes in the static bending resistance of the Oriental, Oriental, Beech, and Sapless oak woods with NaOH + H_2O_2, NaOH + $Ca(OH)_2$ + H_2O_2, HCIO and HCI. It was determined that the reduction in bending strength was caused by the HCIO and HCI solutions in the acidic character.

Uysal [17] study has found that boron compounds used to protect wood from biotic and abiotic pesticides significantly reduce burning in alder wood.

Ozciftci (2001) investigated the burning properties of saplings oak wood which turned red using $C_2O_4H_2$, NaOH, H_2O_2, NH_3 and HCI solutions. The highest weight loss was achieved with NaOH, the highest temperature increase and the highest amount of CO_2 with CO_4H_2 and the maximum amount of ash with NaOH.

Uysal and Kurt [19] used polyvinyl acetate and phenol formaldehyde glues to produce three layers of Uludağ ferns and impregnated with the most resistant zinc chloride from materials they impregnated with $(NH_3)_2P$, $Al_2(SO_4)_3$, K_2CO_3, CaCl, $ZnCl_2$. It has been reported that phenol formaldehyde resins produced using materials.

Peker et al. [12] impregnated with Tanalith CBC, Borax, Boric acid, Boric acid + Borax mixture, Vacsol WR, Polyethyleneglycol 400 and Styrene to determine the effect of some impregnants on the burning properties of spruce wood, applying the vacuum method of spruce wood in the test result When the impregnation is applied, the combustion retardant effect is increased.

2 Materials and Methods

2.1 Wood Material

As a test material, Scotch pine wood, widely used in the Turkish furniture industry, was selected. Wood material is obtained from timber enterprises in Ankara in compliance with TS 2476 principles by random method and it has been taken care to be healthy, smooth fiber, unrecorded, without knots, normal growth, no reaction wood, no fungi and insect pests [15].

2.2 Varnishes

Synthetic (Sn), polyurethane (Pu), water based (Wb) and acrylic (Ac) varnishes were used for varnishing the samples. The amount of solids and the manufacturer's recommendation have been taken into account in determining the amount of varnish to be applied. The properties of the varnishes used in the experiments are given in Table 1.

Table 1. Properties of varnishes used in experiments [9]

Varnish type	pH	Density (g/cm^3)	Viscosity (snDINCup/4 mm)	Applied quantity (g/m^2)	Gun tip clearance (mm)	Air press. (bar)
Pu filler	5.94	0.98	18	125	1.8	2
Pu last floor	4.01	0.99	18	125	1.8	2
Sn	–	0.94	18	100	–	–
Wb AST D17 (Primer)	9.17	1.014	18	100	1.3	1
Wb AST D65 (Filler)	9.30	1.015	18	67	1.3	1
Wb AST D45 (Last floor)	8.71	1.031	18	67	1.3	1
Ac filler	4.3	0.95	18	125	1.8	2
Ac last floor	4.6	0.97	18	125	1.8	2

2.3 Bleaching Solutions

18% solutions used in bleaching, and the solution of these groups are also given in Table 2.

Table 2. Group used in bleaching solution

Chemical materials	Neutralization materials
$NaOH + H_2O_2$ (R1)	Distile water Acetic acid (CH_3COOH)
$NaOH + Ca(OH)_2 + H_2O_2$ (R2)	
$NaSiO_3 + H_2O_2$ (R3)	
$Na_2S_2O_5 + H_2C_2O_4$ (R4)	
$KMnO_4 + Na_2S_2O_5 + H_2O_2$ (R5)	

Chemicals to be used in bleaching process, according to the characteristics and weight (mg) or by volume (Vml) was prepared like 18%. For this purpose,

For those who are in solid state:

$$M_g = \frac{Mc\%M/M}{\%S}$$

M_g The desired amount of solution (g)
Mc Preparation of the desired amount of solution (g)
$\%M/M$ Percentage by weight of the desired solution
$\%S$ Impurity ratio of chemical substance (%)

For liquids:

$$V_{ml} = \frac{Vc\%V/V}{\%S \cdot d}$$

V_{ml} Amount of solution desired (ml)
Vc Amount of solution desired to be prepared (ml)
$\%V/V$ Percent volume of desired solution
d The density of the solution (g/cm^3)

Equations are used [4].

The pH of the bleaching chemical used in the seven experiments is given in Table 3.

Table 3. The pH of the bleaching chemicals

Bleaching chemicals	pH (25 °C)
NaOH	14
H_2O_2	4
$Na_2S_2O_5$	5
$Ca(OH)_2$	10
$H_2C_2O_4$	2
$NaSiO_3$	12
$KMnO_4$	12

2.4 Preparation of Test Samples

The test samples, the annual rings perpendicular to the surface of the sapwood and essential parts are prepared in accordance with TS 53 [14] and ASTM D 358 [1]. Test samples cut in the tolerance gauges were stored at 20 ± 2 °C and 65 ± 3% relative humidity [13]. The air samples were prepared according to ASTM E 160-50 standards, measuring 13 × 13 76 mm (radial × tangent × length). A total of 720 experimental samples (5 × 6 × 3 24) consisting of 4 varnish types + 1 control, 5 color opening solution 1 control, 3 groups and 24 in each group were used in the study. The prepared test samples were 18% NaOH + H_2O_2, NaOH + $Ca(OH)_2$ + H_2O_2, $NaSiO_3$ + H_2O_2, $Na_2S_2O_5$ + $H_2C_2O_4$, $KMnO_4$ + $Na_2S_2O_5$ + H_2O_2 solution groups subjected to bleaching operation.

Bleaching solutions, sponge powder later to assay samples taken parallel to the first fibers and other fibers in the direction parallel to the fiber again, at 100 ± 10 ml/m^2 was applied. The substances forming the solution were applied separately and the second solution was applied after 1–3 min to increase the effect of the first applied substance. After the bleaching process was completed, the mixture was allowed to stand at room temperature for 2 days to increase the depth of effect, followed by neutralization with acetic acid and abundant water. After this process, air samples (12%) of the samples were provided with moisture. The surfaces were slightly sanded prior to varnishing. ASTM D 3023 [3] were conducted according to the example of varnishing. According to this process lightly sanded to eliminate swelling of fiber surfaces will be in operation after the dust varnishing the manufacturer has complied with the recommendation.

Water based varnish application; The finished samples were applied to the completed samples in the direction of the manufacturer's recommendation as three cross layers with high pressure paint gun and 10% water mixed with no filler layer and left to dry for 3 weeks under conditions of 20 ± 2 °C temperature and 65% ± 3 relative humidity for 9% humidity.

Synthetic varnish application; synthetic varnish, hard to try example, it has been 3 times as long bristled brush. The first coat was applied after thinning 15–20% with synthetic thinner to penetrate the wood pores of the verge well. For the application of the other floors, it is thinned by 10–15% with synthetic thinner and 24 h is given between the floors. After varnishing, the samples were allowed to dry at 20 ± 2 °C and 65 ± 3% relative humidity in parallel to the ground plane.

Acrylic and polyurethane varnish application; the application of acrylic and polyurethane varnish was the same. Fillings were applied in the form of dusting in the direction parallel to the fibers. After waiting 5 min, the samples varnished in normal (cross-coat) application were allowed to dry for 24 h. The dried specimens were sanded on a smooth surface with water sandpaper 220 and 320 in equal amounts using an abrasive pad. After the dusts were taken, their weights were weighed on an analytical balance of 0.01 g and the first layer was applied to the final layer. In order to differentiate the layer thickness, after the first layer application, the surfaces are sanded lightly and equally with 400 water sandpaper and the 2nd layer topcoat is applied. Varnish samples were stored for three weeks at a temperature of 20 ± 2 °C and a relative humidity of 65 ± 3%.

2.5 Combustion Tests

The characteristics of combustion in varnished and unvarnished wood materials with bleaching and without bleaching are made in the combustion test device according to ASTM E 160-50 [2]. According to this; each sample group was weighed prior to the combustion test and stacked on the wire stand. The samples on each floor are placed vertically on the floor and the floor above. At the bottom of the Maker type outlet, the flame height was kept constant at 25 ± 1.3 cm when the device was empty and 0.5 kg/cm^2 for the gas pressure on the manometer. When the gas is burned, the thermocouple is continuously mounted on the chimney where the temperature is 315 ± 8 °C. The flame source combustion (AKY) was maintained for 3 min centering on the flame source stack. Following the extinguishing of the flame source, without flame source combustion (KKY) and baking combustion were carried out. In the baking combustion, measurements were made for 15, 30 and 30 s, respectively; CO_2 quantities (ppm) were determined (Fig. 1).

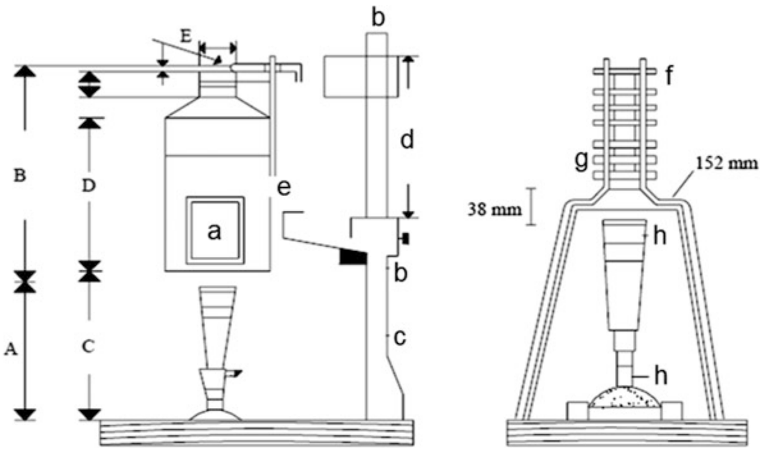

Fig. 1. Combustion testing device. a: Mica glass, b: Sled end, c: Back up guide, d: Slide, e: Potentiometer or Millivoltmeter input, f: Wood samples, g: Wire mesh, h: Waist (marker type), A. 270 mm. B. 430 mm. C. 295 mm. D. 305 mm. E. 38 mm [2]

2.6 Evaluation of Data

In the statistical evaluations, CO_2 amounts of flame source combustion, without flame source combustion and barking combustion parameters were used as data. Multivariate analysis (MANOVA) was applied to the data in the MSTAT statistical evaluation program, and the difference between the mean values was compared with Duncan test when the difference between the groups was significant. Thus, the order of succession of the tested factors was determined by dividing them into homogeneity groups according to the critical value of least significant difference.

3 Results

3.1 The Amount of CO_2 in the Flame Source Combustion (ppm)

According to the average amount of CO_2 induced bleaching solution in the flame source combustion and varnish types are given in Table 4.

Table 4. Average CO_2 bleaching solution according to the types and varnish

Bleaching materials*	X	HG*
RC (Control)	4.492	BC
R1 ($NaOH + H_2O_2$)	8.500	A
R2 ($NaOH + Ca(OH)_2 + H_2O_2$)	4.890	B
R3 ($NaSiO_3 + H_2O_2$)	2.907	C
R4 ($Na_2S_2O_5 + H_2C_2O_4$)	3.868	BC
R5 ($KMnO_4 + Na_2S_2O_5 + H_2O_2$)	5.217	B
Varnish type**	X	HG**
(Vc) Control	8.242	A
(Sb) Water based varnish	4.954	BC
(Sn) Synthetic varnish	5.314	B
(Pu) Polyurethane varnish	2.853	D
(Ac) Acrylic varnish	3.532	CD

*LSD = ±1.675, **LSD = ±1.529, X: Arithmetic mean, HG: Homogeneity group

The amount of CO_2; The highest R1 (8.500), the lowest R3 (2.907), the highest lacquer varnish (5.314), and the lowest polyurethane varnish (2.853), respectively. Bleaching solution and multivariate analysis of variance results for the effect of the kinds of varnish are given in Table 5.

Table 5. Multivariate analysis of CO_2 effects of the bleaching solution and varnish type

Source	Degr. of F.	Sum of squares	Mean square	F value	$P < 5\%$ (Sig)
Factor A	4	312.692	78.173	14.668	0.0000
Factor B	5	273.419	54.684	10.261	0.0000
AB	20	1202.12	60.106	11.278	0.0000
Error	60	319.755	5.329		
Total	89	2107.98			

Factor A: Varnish type, Factor B: Bleaching solutions

The effect of bleaching solution and varnish on CO_2 amount was statistically significant ($\alpha = 0.05$). The results of the DUNCAN test to determine the significance of differences between significant groups in meaningful outcomes are given in Table 6.

The amount of CO_2; bleaching solution in terms of the highest R1 (15.800), the lowest R3 (0.133), while the highest water-based varnish in the varnish (7.633), the lowest in acrylic varnish (0.410) was found. The highest value of R1 + Ac (14.773) and the lowest value of R2 + Ac (2.773) were obtained in terms of coloring retarder + lacquer interaction. According to the process of change to CO_2 chart types are shown in Fig. 2.

Table 6. Duncan test results (ppm)

Process type	X	HG*	Process type	CO_2	
				X	HG*
C	7.533	CD	R3 + Sn	10.400	BC
R1	15.800	A	R4 + Sn	7.817	CD
R2	13.350	AB	R5 + Sn	7.033	CDE
R3	0.133	G	Pu	0.883	FG
R4	5.933	DE	R1 + Pu	4.333	DEFG
R5	6.700	CDE	R2 + Pu	7.773	CD
Sb	7.633	CD	R3 + Pu	0.000	G
R1 + Sb	7.633	CD	R4 + Pu	0.000	G
R2 + Sb	0.000	G	R5 + Pu	4.167	DEFG
R3 + Sb	4.000	DEFG	Ac	0.410	G
R4 + Sb	5.590	DE	R1 + Ac	14.773	A
R5 + Sb	4.867	DEF	R2 + Ac	2.733	EFG
Sn	6.000	DE	R3 + Ac	0.000	G
R1 + Sn	0.000	G	R4 + Ac	0.000	G
R2 + Sn	0.633	FG	R5 + Ac	3.317	DEFG

*HG = 3.745

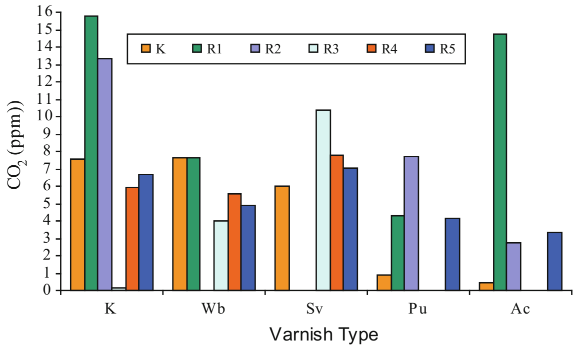

Fig. 2. Change of CO_2 according to flue gas treatment in the flame source combustion

3.2 Amount of CO_2 in Without Flame Source Combustion (ppm)

The average CO_2 amounts according to without flame source combustions and the varnish solution are given in Table 7.

Table 7. Average CO_2 bleaching solution according to the types and varnish

Bleaching materials*	X	HG*
RC (Control)	7.733	A
R1 ($NaOH + H_2O_2$)	9.367	AB
R2 ($NaOH + Ca(OH)_2 + H_2O_2$)	4.957	AB
R3 ($NaSiO_3 + H_2O_2$)	5.407	B
R4 ($Na_2S_2O_5 + H_2C_2O_4$)	5.470	B
R5 ($KMnO_4 + Na_2S_2O_5 + H_2O_2$)	6.743	B
Varnish type**	X	HG**
(Vc) Control	9.239	A
(Sb) Water based varnish	6.686	B
(Sn) Synthetic varnish	5.656	B
(Pu) Polyurethane varnish	5.419	B
(Ac) Acrylic varnish	6.064	B

*LSD = ±2.363, **LSD = ±2.558, X: Arithmetic mean, HG: Homogeneity group

The amount of CO_2; The highest R1 (9.367), the lowest R2 (4.957), the highest water-based varnish (6.686), and the lowest acrylic varnish (5.419) were found in the coloring materials. The results of the multiple variance analysis on the effect of coloring solution and varnish type are given in Table 8.

Table 8. Multivariate analysis of CO_2 effects of bleaching and varnishing

Source	Deg. of Fr.	Sum of squares	Mean square	F value	P < 5% (Sig)
Factor A	4	171.782	42.945	3.3742	0.0148
Factor B	5	215.399	43.080	3.3848	0.0093
AB	20	1559.26	77.963	6.1255	0.0000
Error	60	763.657	12.728		
Total	89	2710.10			

Factor A: Varnish type, Factor B: Bleaching solutions

The effect of bleaching solution and varnish on CO_2 amount was statistically significant ($\alpha = 0.05$). The results of the DUNCAN test to determine the significance of differences between significant groups in meaningful outcomes are given in Table 9.

Table 9. Duncan test results (ppm)

Process type	CO_2		Process type	CO_2	
	X	HG*		X	HG*
C	11.12	BCD	R3 + Sn	8.600	BCDE
R1	8.617	BCDE	R4 + Sn	11.55	BCD
R2	10.40	BCDE	R5 + Sn	5.967	BCDEFG
R3	7.367	BCDEF	Pu	3.867	EFG
R4	10.53	BCDE	R1 + Pu	12.60	B
R5	7.400	BCDEF	R2 + Pu	8.250	BCDE
Sb	12.22	BC	R3 + Pu	0.000	G
R1 + Sb	6.183	BCDEF	R4 + Pu	0.000	G
R2 + Sb	0.000	G	R5 + Pu	7.800	BCDEF
R3 + Sb	11.07	BCD	Ac	4.817	DEFG
R4 + Sb	5.267	CDEFG	R1 + Ac	19.43	A
R5 + Sb	5.383	CDEF	R2 + Ac	4.967	DEFG
Sn	6.650	BCDEF	R3 + Ac	0.000	G
R1 + Sn	0.000	G	R4 + Ac	0.000	G
R2 + Sn	1.167	FG	R5 + Ac	7.167	BCDEF

*HG: 5.773

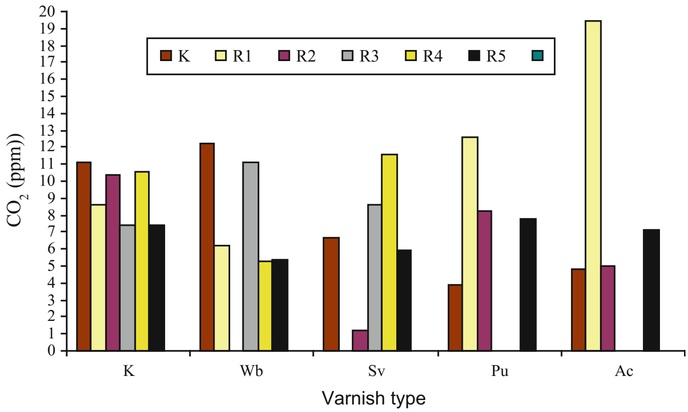

Fig. 3. CO_2 changes according to in the without flame source combustion process

The amount of CO_2; R4 highest in terms of bleaching solutions (10.53), the lowest R3 (7.367), while the highest water-based varnish in the varnish (12:22), the lowest in acrylic varnish (3867) were found. The highest value of R1 + Ac (19.43) and the lowest value of R2 + Sn (1.167) were obtained in terms of the bleaching retarder + lacquer interaction. According to the process of change to CO_2 chart types are shown in Fig. 3.

3.3 CO_2 Amount in the Baking Combustion (ppm)

Baking combustion of bleaching solution and the average amount of CO_2 according to the kind of varnish is given in Table 10.

Table 10. Baking combustion of bleaching solution and CO_2 average according to the kind of varnish

Bleaching materials*	X	HG*
RC (Control)	3.477	AB
R1 ($NaOH + H_2O_2$)	5.98	A
R2 ($NaOH + Ca(OH)_2 + H_2O_2$)	3.639	AB
R3 ($NaSiO_3 + H_2O_2$)	4.73	AB
R4 ($Na_2S_2O_5 + H_2C_2O_4$)	2.18	B
R5 ($KMnO_4 + Na_2S_2O_5 + H_2O_2$)	3.555	AB
Varnish type**	X	HG**
(Vc) Control	3.197	AB
(Sb) Water based varnish	3.797	AB
(Sn) Synthetic varnish	2.522	B
(Pu) Polyurethane varnish	5.127	A
(Ac) Acrylic varnish	4.993	AB

*LSD = ±2.498, **LSD = ±2.281, X: Arithmetic mean, HG: Homogeneity group

The amount of CO_2; the highest R1 (5.98), the lowest R4 (2.18), the highest polyurethane varnish (5.127), and the lowest synthetic varnish (2.522) were found for coloring materials. The results of multivariate analysis of the effect of coloring solution and varnish type are given in Table 11.

Table 11. Multivariate analysis of CO_2 effects of bleaching solution and varnish

Source	Deg. of Fr.	Sum of squares	Mean square	F value	$P < 5\%$ (Sig)
Factor A	4	91.900	22.975	1.9379	0.1158
Factor B	5	125.054	25.011	2.1096	0.0765
AB	20	1269.42	63.471	5.3536	0.0000
Error	60	711.339	11.856		
Total	89	2197.71			

Factor A: Varnish type, Factor B: Bleaching solutions

Bleaching solution and its effects on the CO_2 content of the varnish varieties were significant in terms of statistics ($\alpha = 0.05$). The results of the DUNCAN test to determine the significance of differences between significant groups in meaningful outcomes are given in Table 12.

The amount of CO_2; R3 is the highest in terms of bleaching solutions (7733), the lowest R5 (1.058), while the highest water-based varnish in the varnish (5650), the lowest in acrylic varnish (1.050) were found. The highest value of R1 + Pu (15.29) and the lowest value of R5 + Sb (0.7833) were obtained in terms of coloring retarder + lacquer interaction. CO_2 exchange according to the operation type of the graph shown in Fig. 4.

Table 12. Duncan test results (ppm)

Process type	CO_2		Process type	CO_2	
	X	HG*		X	HG*
C	1.300	CDE	R3 + Sn	2.233	CDE
R1	1.383	CDE	R4 + Sn	4.433	CDE
R2	2.090	CDE	R5 + Sn	1.483	CDE
R3	7.733	BC	Pu	5.067	BCDE
R4	5.600	BCDE	R1 + Pu	15.29	A
R5	1.058	CDE	R2 + Pu	3.357	CDE
Sb	5.650	BCDE	R3 + Pu	0.000	E
R1 + Sb	1.800	CDE	R4 + Pu	0.000	E
R2 + Sb	0.000	E	R5 + Pu	7.050	BCD
R3 + Sb	13.68	A	Ac	4.317	CDE
R4 + Sb	0.866	CDE	R1 + Ac	11.43	AB
R5 + Sb	0.783	DE	R2 + Ac	6.817	BCDE
Sn	1.050	CDE	R3 + Ac	0.000	E
R1 + Sn	0.000	E	R4 + Ac	0.000	E
R2 + Sn	5.933	BCDE	R5 + Ac	7.400	BCD

*HG: 5.586

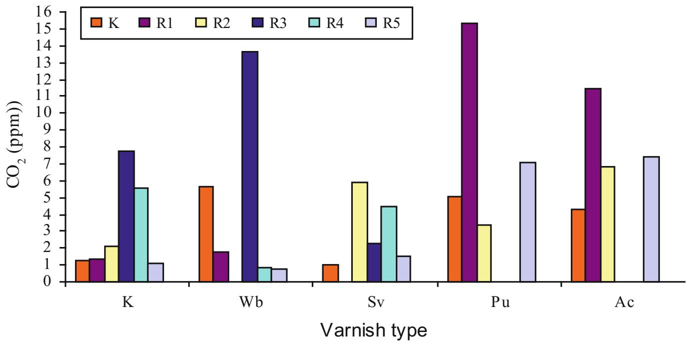

Fig. 4. CO_2 changes according to baking combustion process

4 Conclusion

In this study, some bleaching after applying the water-based bleaching processes with chemicals and examined combustion properties of varnishing wood materials with synthetic varnishes and results obtained from experiments are given below.

The amount of CO_2 in flame source combustion was found to be less in the varnishes than in the control samples. However, in the case of the coloring devices, it was realized in different amounts according to the control samples. R3 and R4 gave lower values. The highest value of R1 + Ac (14.773) and the lowest value of R2 + Ac (2.773) were obtained in terms of coloring retarder + lacquer interaction. Solution R1 showed CO_2 enhancing effect.

The amount of CO_2 in without flame combustion was found to be less in varnishes than in control samples. However, in the case of the coloring devices, it was realized in different amounts according to the control samples. R1 and R5 solutions gave higher values. The highest value of R1 + Ac (19.43) and the lowest value of R2 + Sn (1.167) were obtained in terms of the coloring retarder + lacquer interaction. Solution R1 showed CO_2 enhancing effect.

The amount of CO_2 in the baking combustion was found to be approximately equal or higher in all but the synthetic varnish. The same is true of the coloring tools. R1 and R3 solutions gave higher values. The highest value of R1 + Pu (15.29) and the lowest value of R5 + Sb (0.7833) were obtained in terms of coloring retarder + lacquer interaction.

According to them; the amount of CO_2 was found to be at most R1 in different periods of the reaction. It can be said that the varnishes are less effective in this effect. The maximum amount of CO_2 was obtained on its own. This is important to consider in such applications in terms of fire safety.

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Carbon Dioxide Amount in the Combustion of European Oak (*Quercus petreae* Liebl.) Wood Bleached and Varnished

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Abstract. This study was carried out to determine the carbon dioxide amount in the combustion of European oak wood (*Quercus petreae* liebl.) bleached and varnished. For this purpose, samples of European oak wood prepared according to ASTM D 358 contain 18% R1 = ($NaOH + H_2O_2$), R2 = ($NaOH + Ca(OH)_2 + H_2O_2$), R3 = ($Na_2S_2O_5 + H_2C_2O_4$), R4 = ($NaSiO_3 + H_2O_2$), R5 = ($KMnO_4 + Na_2S_2O_5 + H_2O_2$) solution groups, after bleaching with solution groups, water based (Sb), synthetic (Sn), polyurethane (Pu) and acrylic varnish (Av) were applied according to ASTM D 3023 and compliance with ASTM E 160-50 guidelines in combustion tests. Gas measurements were made with the Sigma 74172 NSU flue gas device during the combustion process. As a result, the amount of CO_2 in the flame source side (ppm); the highest R4 in the varnish level (3.469), the lowest Av (1.236), the highest R4 (3.763), the lowest R2 (1.127), the highest R4 + Sb (7.583), the lowest R5 + Sb (0.8333) was obtained. Amount of CO_2 in the without flame combustion temperature (ppm); the highest RV (r = 7.194), the lowest RV (3.469), the highest R1 (7.820), the lowest R2 (3.277), the highest R4 + Sv (12.73) in the lowest R3 + Pu (3.000) was found. CO_2 amount in the baking combustion (ppm); (7.356), the highest RV (3.540), the lowest RV (3.565), the lowest RV (3.565), the lowest RV (3.522), the lowest R4 + Sb (1.173) was obtained. CO_2 amount in the baking combustion (ppm); the highest R4 of the varnished oak wood (7.056), the lowest Av (3.522), the highest R1 (7.540), the lowest R2 (3.610), the highest R4 + Sv (9.667) in the lowest R4 + Sb (1.173) was obtained. According to this, it can be said that the solutions of R1 and R4 with synthetic varnish are not suitable for poisoning effect in fire risk areas.

Keywords: CO_2 · Combustion · Bleaching · Varnish · Oak

1 Introduction

Wood material is worn out due to environmental conditions and its components are degraded by chemical and biological means. Drying, impregnation and surface treatment are applied against these drawbacks [1]. Physical characteristics; the smell, taste, color, pattern etc. of wood species of are different. Wood discoloration injuries in live wood, dead knot formation, oxidation of certain chemicals in the wood next to reasons

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such as illness or heartwood of the older generation or tannic result of contact with the metal of the wood takes place with occurring discolorations [2].

In addition, color differences can occur due to the intensity of the annual growth of the wood material (summer wood, spring wood). The color, shape, size, form, balance etc. of furniture. Carpets, curtains etc. used in interior decoration. Besides textile, it is required to be compatible with wall, ceiling, floor coverings [3].

It may be necessary to change the color or open the dark color on the painted wood material surfaces. While wood dyes usually add superficial color to wood, color dyes create a deep light color and shine. The color-changing chemical substances are generally reactants which act on the wood-material side compounds. They do not destroy the colors, they make the side compounds transparent [4].

It is often difficult to remove stains and vein strips from the wood material and uncover the stains without damaging the fibers. In some woody woods (oak, ash, maple, walnut, beech etc.) the color is relatively easy to open [5]. The impregnated wood material surfaces used outdoors are covered with sunlight and rain over time. In this case, coloring can be done [6]. The general purpose colors consist of two solutions. In some cases, the first solution is caustic soda (NaOH) and the second is hydrogen peroxide (H_2O_2). The solution can be applied after the other one as well as mixed. The most effective color rendering is achieved by the combined use of both solutions [7].

The surfaces subjected to the coloring process are warm water, oxalic acid, acetic acid and so on. And the sediments that are likely to remain on the surface are washed and cleaned. At this time, the swollen fibers are smoothened by light sanding [1]. The fires mostly begin with the goods inside the dwelling. It does not directly start from the wood material part of the dwelling. However, during the superficial fires that start within the residence, the temperature reaches a very high level in a very short time causing the fire to start in the construction of all kinds of goods, materials and structures in the surrounding area. Thus the danger and harm is to reach very large sizes [8].

Ozciftci [10] studied the changes in the static bending resistance of the Oriental, Oriental, Beech, and Sapless oak woods with $NaOH + H_2O_2$, $NaOH + Ca(OH)_2 + H_2O_2$, HCIO and HCI. It was determined that the reduction in bending strength was caused by the HCIO and HCI solutions in the acidic character. Uysal (1998) study has found that boron compounds used to protect wood from biotic and abiotic pesticides significantly reduce burning in alder wood [9].

Ozciftci, investigated the burning properties of saplings oak wood which turned red using $C_2O_4H_2$, NaOH, H_2O_2, NH_3 and HCI solutions. The highest weight loss was achieved with NaOH, the highest temperature increase and the highest amount of CO_2 with CO_4H_2 and the maximum amount of ash with NaOH [10].

Uysal and Kurt [11] used polyvinyl acetate and phenol formaldehyde glues to produce three layers of Uludağ ferns and impregnated with the most resistant zinc chloride from materials they impregnated with $(NH_3)_2P$, $Al_2(SO_4)_3$, K_2CO_3, CaCl, $ZnCl_2$. It has been reported that phenol formaldehyde resins produced using materials.

Peker et al. [12] impregnated with Tanalith CBC, Borax, Boric acid, Boric acid + Borax mixture, Vacsol WR, Polyethyleneglycol 400 and Styrene to determine the effect of some impregnants on the burning properties of spruce wood, applying the vacuum method of spruce wood in the test result When the impregnation is applied, the combustion retardant effect is increased.

2 Experimental

2.1 Wood Material

As a test material, European oak wood (*Quercus petreae* liebl.), widely used in the Turkish furniture industry, was selected. Wood material is obtained from timber enterprises in Ankara in compliance with TS 1476 principles by random method and it has been taken care to be healthy, smooth fiber, unrecorded, without knots, normal growth, no reaction wood, no fungi and insect pests [13].

2.2 Varnishes

Synthetic (Sn), polyurethane (Pu), water based (Wb) and acrylic (Ac) varnishes were used for varnishing the samples. The amount of solids and the manufacturer's recommendation have been taken into account in determining the amount of varnish to be applied. The properties of the varnishes used in the experiments are given in Table 1.

Table 1. Properties of varnishes used in experiments [14]

Varnish type	pH	Density (g/cm^3)	Viscosity (snDINCup/4 mm)	Applied quantity (g/m^2)	Gun tip clearan. (mm)	Air press. (bar)
Pu filler	5.94	0.98	18	125	1.8	2
Pu last floor	4.01	0.99	18	125	1.8	2
Sn	–	0.94	18	100	–	–
Wb AST D17 (Primer)	9.17	1.014	18	100	1.3	1
Wb AST D65 (Filler)	9.30	1.015	18	67	1.3	1
Wb AST D45 (Last floor)	8.71	1.031	18	67	1.3	1
Ac filler	4.3	0.95	18	125	1.8	2
Ac last Floor	4.6	0.97	18	125	1.8	2

2.3 Bleaching Solutions

18% solutions used in bleaching, and the solution of these groups are also given in Table 2.

Table 2. Group used in bleaching solution

Chemical materials	Neutralization materials
$NaOH + H_2O_2$ (R1)	Distile water Acetic acid (CH_3COOH)
$NaOH + Ca(OH)_2 + H_2O_2$ (R2)	
$NaSiO_3 + H_2O_2$ (R3)	
$Na_2S_2O_5 + H_2C_2O_4$ (R4)	
$KMnO_4 + Na_2S_2O_5 + H_2O_2$ (R5)	

Chemicals to be used in bleaching process, according to the characteristics and weight (mg) or by volume (Vml) was prepared like 18%. For this purpose,

For those who are in solid state;

$$M_g = \frac{Mc\%M/M}{\%S}$$

M_g	The desired amount of solution (g)
Mc	Preparation of the desired amount of solution (g)
$\%M/M$	Percentage by weight of the desired solution
$\%S$	Impurity ratio of chemical substance (%)

For liquids;

$$V_{ml} = \frac{Vc\%V/V}{\%S \cdot d}$$

V_{ml}	Amount of solution desired (ml)
Vc	Amount of solution desired to be prepared (ml)
$\%V/V$	Percent volume of desired solution
d	The density of the solution (g/cm^3)

Equations are used.

The pH of the bleaching chemical used in the seven experiments is given in Table 3.

Table 3. The pH of the bleaching chemicals

Bleaching chemicals	pH (25 °C)
NaOH	14
H_2O_2	4
$Na_2S_2O_5$	5
$Ca(OH)_2$	10
$H_2C_2O_4$	2
$NaSiO_3$	12
$KMnO_4$	12

2.4 Preparation of Test Samples

The test samples, the annual rings perpendicular to the surface of the sapwood and essential parts are prepared in accordance with ASTM D 358 [15]. Test samples cut in the tolerance gauges were stored at 20 ± 2 °C and 65 ± 3% relative humidity

(TS 2471) [16]. The air samples were prepared according to ASTM E 160-50 standards, measuring 13 × 13 × 76 mm (radial x tangent x length). A total of 720 experimental samples (5 × 6 × 3 × 24) consisting of 4 varnish types + 1 control, 5 color opening solution 1 control, 3 groups and 24 in each group were used in the study. The prepared test samples were 18% $NaOH + H_2O_2$, $NaOH + Ca(OH)_2 + H_2O_2$, $NaSiO_3 + H_2O_2$, $Na_2S_2O_5 + H_2C_2O_4$, $KMnO_4 + Na_2S_2O_5 + H_2O_2$ solution groups subjected to bleaching operation.

Bleaching solutions, sponge powder later to assay samples taken parallel to the first fibers and other fibers in the direction parallel to the fiber again, at 100 ± 10 ml/m^2 was applied. The substances forming the solution were applied separately and the second solution was applied after 1–3 min to increase the effect of the first applied substance. After the bleaching process was completed, the mixture was allowed to stand at room temperature for 2 days to increase the depth of effect, followed by neutralization with acetic acid and abundant water. After this process, air samples (12%) of the samples were provided with moisture.

The surfaces were slightly sanded prior to varnishing. ASTM D 3023 were conducted according to the example of varnishing. According to this process lightly sanded to eliminate swelling of fiber surfaces will be in operation after the dust varnishing the manufacturer has complied with the recommendation [17].

Water based varnish application; The finished samples were applied to the completed samples in the direction of the manufacturer's recommendation as three cross layers with high pressure paint gun and 10% water mixed with no filler layer and left to dry for 3 weeks under conditions of 20 ± 2 °C temperature and 65% ± 3 relative humidity for 9% humidity. Synthetic varnish application; synthetic varnish, hard to try example, it has been 3 times as long bristled brush. The first coat was applied after thinning 15–20% with synthetic thinner to penetrate the wood pores of the verge well. For the application of the other floors, it is thinned by 10–15% with synthetic thinner and 24 h is given between the floors. After varnishing, the samples were allowed to dry at 20 ± 2 °C and 65 ± 3% relative humidity in parallel to the ground plane. Acrylic and polyurethane varnish application; the application of acrylic and polyurethane varnish was the same. Fillings were applied in the form of dusting in the direction parallel to the fibers. After waiting 5 min, the samples varnished in normal (cross-coat) application were allowed to dry for 24 h.

The dried specimens were sanded on a smooth surface with water sandpaper 220 and 320 in equal amounts using an abrasive pad. After the dusts were taken, their weights were weighed on an analytical balance of 0.01 g and the first layer was applied to the final layer. In order to differentiate the layer thickness, after the first layer application, the surfaces are sanded lightly and equally with 400 water sandpaper and the 2nd layer topcoat is applied. Varnish samples were stored for three weeks at a temperature of 20 ± 2 °C and a relative humidity of 65 ± 3%.

2.5 Combustion Tests

The characteristics of combustion in varnished and unvarnished wood materials with bleaching and without bleaching are made in the combustion test device according to ASTM E 160-50 [18]. According to this; each sample group was weighed prior to the combustion test and stacked on the wire stand. The samples on each floor are placed vertically on the floor and the floor above. At the bottom of the Maker type outlet, the flame height was kept constant at 25 ± 1.3 cm when the device was empty and 0.5 kg/cm^2 for the gas pressure on the manometer. When the gas is burned, the thermocouple is continuously mounted on the chimney where the temperature is 315 ± 8 °C. The flame source combustion (AKY) was maintained for 3 min centering on the flame source stack. Following the extinguishing of the flame source, without flame source combustion (KKY) and baking combustion were carried out. In the baking combustion, measurements were made for 15, 30 and 30 s, respectively; CO_2 quantities (ppm) were determined (Fig. 1).

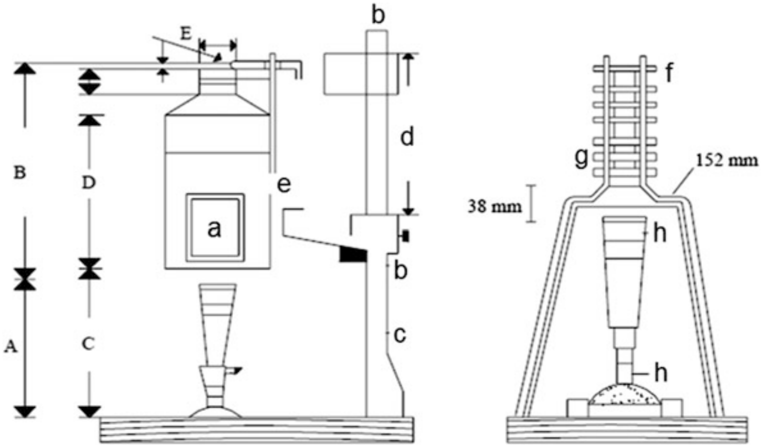

Fig. 1. Combustion testing device, a: Mica glass, b: Sled end, c: Back up guide, d: Slide, e: Potentiometer or Millivoltmeter input, f: Wood samples, g: Wire mesh, h: Waist (marker type), A. 270 mm. B. 430 mm. C. 295 mm. D. 305 mm. E. 38 mm [18]

2.6 Data Analysis

In the statistical evaluations, CO_2 amounts of flame source combustion, without flame source combustion and barking combustion parameters were used as data. Multivariate analysis (MANOVA) was applied to the data in the MSTAT C statistical evaluation program, and the difference between the mean values was compared with Duncan test when the difference between the groups was significant. Thus, the order of succession of the tested factors was determined by dividing them into homogeneity groups according to the critical value of least significant difference (LSD).

3 Result and Discussion

3.1 The Amount of CO_2 in Flame Source Combustion

According to the average amount of CO_2 induced bleaching solution in the flame source combustion and varnish types are given in Table 4.

Table 4. Average CO_2 bleaching solution according to the types and varnish

Bleaching materials*	X	HG*
RC (Control)	2.887	A
R1 ($NaOH + H_2O_2$)	3.010	A
R2 ($NaOH + Ca(OH)_2 + H_2O_2$)	1.127	B
R3 ($NaSiO_3 + H_2O_2$)	2.380	AB
R4 ($Na_2S_2O_5 + H_2C_2O_4$)	3.763	A
R5 ($KMnO_4 + Na_2S_2O_5 + H_2O_{2)}$	2.523	AB
Varnish type**	X	HG**
(Vc) Control	3.625	A
(Sb) Water based varnish	2.742	AB
(Sn) Synthetic varnish	3.469	A
(Pu) Polyurethane varnish	2.003	BC
(Ac) Acrylic varnish	1.236	C

*LSD = ±1.412, **LSD = ±1.289

The amount of CO_2; (3.763), the lowest R2 (1.127), the highest synthetic varnish (3.469), and the lowest acrylic varnish (1.236) for the bleaching tools. Although the results were different, they were found to be approximately equal. The results of the multivariate analysis on the effect of coloring solution and varnish type are given in Table 5.

Table 5. Multivariate analysis of CO_2 effects of the bleaching solution and varnish type

Source	Deg. of fre.	Sum of squares	Mean square	F value	*P* < 5% (Sig)
Factor A	4	72.763	18.191	4.8015	0.0000
Factor B	5	57.409	11.482	3.0307	0.0167
AB	20	334.886	16.744	4.4198	0.0000
Error	60	227.310	3.788		
Total	89	692.367			

Factor A: Varnish type, Factor B: Bleaching solutions

The effect of bleaching solution and varnish on CO_2 amount was statistically significant ($\alpha = 0.05$). The results of the DUNCAN test to determine the significance of differences between significant groups in meaningful outcomes are given in Table 6.

The amount of CO_2, the highest in terms of bleaching solutions R5 (4983), the lowest R4 (1.417), while the highest synthetic lacquer varnish (3700), the lowest in acrylic varnish (1.900) was found. The highest value of R4 + Sb (7.533) and the lowest value of R4 + Pu (0.933) were obtained in terms of coloring retarder + lacquer interaction. The graph of the CO_2 changes according to the process is shown in Fig. 2.

Table 6. Duncan test results (ppm)

Process type	CO_2		Process type	CO_2	
	X	HG*		X	HG*
C	8.833	A	R3 + Sn	5.517	ABCD
R1	3.767	CDEF	R4 + Sn	6.267	ABC
R2	0.000	F	R5 + Sn	1.200	EF
R3	2.750	CDEF	Pu	0.000	F
R4	1.417	EF	R1 + Pu	2.017	DEF
R5	4.983	BCDE	R2 + Pu	2.367	DEF
Sb	1.900	DEF	R3 + Pu	0.933	F
R1 + Sb	1.433	EF	R4 + Pu	3.550	CDEF
R2 + Sb	2.000	DEF	R5 + Pu	3.150	CDEF
R3 + Sb	2.700	CDEF	Ac	0.000	F
R4 + Sb	7.533	AB	R1 + Ac	4.967	BCDE
R5 + Sb	0.833	F	R2 + Ac	0.000	F
Sn	3.700	CDEF	R3 + Ac	0.000	F
R1 + Sn	2.867	CDEF	R4 + Ac	0.000	F
R2 + Sn	1.267	EF	R5 + Ac	2.450	DEF

*HG = 3.158

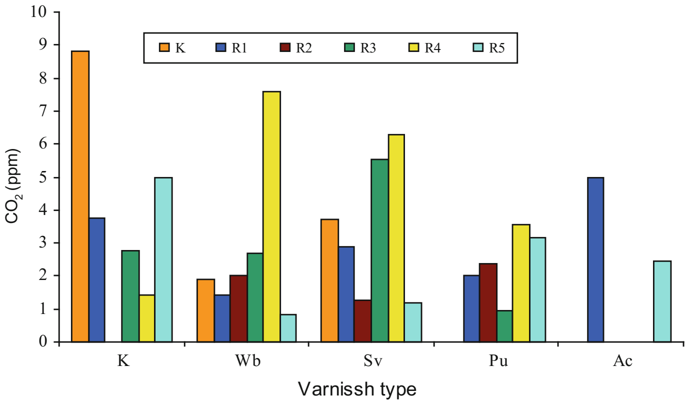

Fig. 2. Change of CO_2 according to flue gas treatment in the flame source combustion

3.2 The Amount of CO_2 in Without Flame Source Combustion (ppm)

The average CO_2 amounts according to the without flame source combustion and the varnish solution are given in Table 7.

Table 7. Average CO_2 bleaching solution according to the types and varnish

Bleaching materials*	X	HG*
RC (Control)	6.223	AB
R1 ($NaOH + H_2O_2$)	7.820	A
R2 ($NaOH + Ca(OH)_2 + H_2O_2$)	3.277	AB
R3 ($NaSiO_3 + H_2O_2$)	7.227	B
R4 ($Na_2S_2O_5 + H_2C_2O_4$)	7.317	B
R5 ($KMnO_4 + Na_2S_2O_5 + H_2O_2$)	5.743	B
Varnish type**	X	HG**
(Vc) Control	8.556	A
(Sb) Water based varnish	6.447	AB
(Sn) Synthetic varnish	8.194	A
(Pu) Polyurethane varnish	4.672	BB
(Ac) Acrylic varnish	3.469	BC

*LSD = ±3.275, **LSD = ±2.989, X: Arithmetic mean

The amount of CO_2; The highest R1 (7.820), the lowest R2 (3.277), the highest water-based varnish (8.194), and the lowest acrylic varnish (3.469). Bleaching solution and multivariate analysis of variance results for the effect of varnish types are given in Table 8.

Table 8. Multivariate analysis of CO_2 effects of bleaching and varnishing

Source	Deg. of fre.	Sum of squares	Mean square	F value	$P < 5\%$ (Sig)
Factor A	4	348.384	87.096	4.2753	0.0048
Factor B	5	204.792	40.958	2.0105	0.093
AB	20	908.215	45.411	2.2291	0.0089
Error	60	1222.327	20.372		
Total	89	2683.717			

Factor A: Varnish type, Factor B: Bleaching solutions

The effect of bleaching solution and varnish on CO_2 amount was statistically significant ($\alpha = 0.05$). The results of the DUNCAN test to determine the significance of differences between significant groups in meaningful outcomes are given in Table 9.

Table 9. Duncan test results (ppm)

Process type	CO_2		Process type	CO_2	
	X	HG*		X	HG*
C	17.70	A	R3 + Sn	12.17	AB
R1	11.12	ABC	R4 + Sn	12.73	AB
R2	0.000	D	R5 + Sn	5.767	BCD
R3	6.767	BCD	Pu	0.000	D
R4	9.117	BC	R1 + Pu	5.833	BCD
R5	6.633	BCD	R2 + Pu	5.800	BCD
Sb	6.567	BCD	R3 + Pu	3.000	CD
R1 + Sb	5.700	BCD	R4 + Pu	7.633	BCD
R2 + Sb	5.550	BCD	R5 + Pu	5.767	BCD
R3 + Sb	9.817	ABC	Ac	0.000	D
R4 + Sb	7.100	BCD	R1 + Ac	9.833	ABC
R5 + Sb	3.950	BCD	R2 + Ac	0.000	D
Sn	6.850	BCD	R3 + Ac	4.383	BCD
R1 + Sn	6.617	BCD	R4 + Ac	0.000	D
R2 + Sn	5.033	BCD	R5 + Ac	6.600	BCD

*HG: 7.323

The amount of CO_2; the highest R4 (11.12), the lowest R3 (6.633) in terms of coloring solutions, and the water-based and synthetic varnish in varnishes. The highest value of R4 + Sn (12.73) and the lowest value of R3 + Pu (3) were obtained in terms of bleaching retarder + lacquer interaction. The graph of CO_2 changes according to the process is shown in Fig. 3.

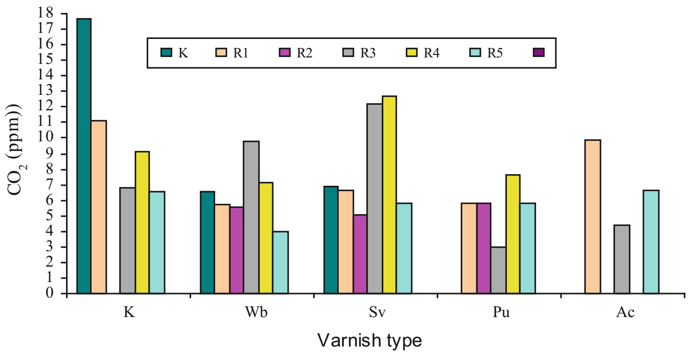

Fig. 3. CO_2 changes according to without flame source combustion process

3.3 CO_2 Amount in the Baking Combustion (ppm)

Baking combustion of bleaching solution and the average amount of CO_2 according to the kind of varnish is given in Table 10.

Table 10. Baking combustion of bleaching solution and CO_2 average according to the kind of varnish

Bleaching materials*	X	HG*
RC (Control)	4.600	AB
R1 ($NaOH + H_2O_2$)	7.540	A
R2 ($NaOH + Ca(OH)_2 + H_2O_2$)	3.610	B
R3 ($NaSiO_3 + H_2O_2$)	6.977	AB
R4 ($Na_2S_2O_5 + H_2C_2O_4$)	5.330	AB
R5 ($KMnO_4 + Na_2S_2O_5 + H_2O_{2)}$	4.687	AB
Varnish type**	X	HG**
(Vc) Control	7.111	A
(Sb) Water based varnish	4.614	AB
(Sn) Synthetic varnish	7.056	A
(Pu) Polyurethane varnish	4.983	AB
(Ac) Acrylic varnish	3.522	B

LSD = ±3.297, **LSD = ±3.010 X: Arithmetic mean

The amount of CO_2; The highest R1 (7.540), the lowest R2 (3.610), the highest synthetic varnish (7.056), and the lowest acrylic varnish (3.522) were found in the coloring materials. Bleaching solution and multivariate analysis of variance results for the effect of varnish types are given in Table 11.

Table 11. Multivariate analysis of CO_2 effects of bleaching solution and varnish

Source	Deg. of fre.	Sum of squares	Mean square	F value	$P < 5\%$ (Sig)
Factor A	4	179.460	44.865	2.1724	0.0829
Factor B	5	171.055	34.211	1.6565	0.1591
AB	20	722.511	36.126	1.7492	0.0498
Error	60	1239.16	20.653		
Total	89	2312.19			

Factor A: Varnish type, Factor B: Bleaching solutions

Bleaching solution and its effects on the CO_2 content of the varnish varieties were significant in terms of statistics ($\alpha = 0.05$). The results of the DUNCAN test to determine the significance of differences between significant groups in meaningful outcomes are given in Table 12.

The amount of CO_2; the highest R1 (13.92), the lowest R5 (2.333) in terms of the coloring solutions and the water-based and synthetic varnish in the varnishes. Bleaching chemicals in terms of varnish interaction highest + R4 + Sn (9667), the lowest R4 + Sb (1.733) was obtained. CO_2 exchange according to the operation type of the graph shown in Fig. 4.

Table 12. Duncan test results (ppm)

Process type	CO_2		Process type	CO_2	
	X	HG*		X	HG*
C	11.53	AB	R3 + Sn	7.717	ABCD
R1	13.92	A	R4 + Sn	9.667	ABC
R2	0.000	D	R5 + Sn	4.950	ABCD
R3	6.733	ABCD	Pu	0.000	D
R4	8.150	ABCD	R1 + Pu	6.733	ABCD
R5	2.333	CD	R2 + Pu	7.267	ABCD
Sb	5.683	ABCD	R3 + Pu	3.817	BCD
R1 + Sb	5.183	ABCD	R4 + Pu	7.100	ABCD
R2 + Sb	3.517	BCD	R5 + Pu	4.983	ABCD
R3 + Sb	7.967	ABCD	Ac	0.000	D
R4 + Sb	1.733	CD	R1 + Ac	4.917	ABCD
R5 + Sb	3.600	BCD	R2 + Ac	0.000	D
Sn	5.783	ABCD	R3 + Ac	8.650	ABCD
R1 + Sn	6.950	ABCD	R4 + Ac	0.000	D
R2 + Sn	7.267	ABCD	R5 + Ac	7.567	ABCD

*HG: 7.373

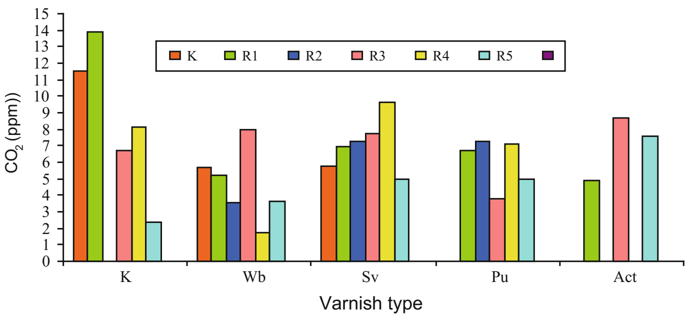

Fig. 4. CO_2 changes according to the baking combustion process

4 Conclusion

In this study, some bleaching after applying the water-based bleaching processes with chemicals and examined combustion properties of varnishing wood materials with synthetic varnishes and results obtained from experiments are given below.

The amount of CO_2 in the flame welded side was found to be less in the varnishes than in the control samples. In bleaching materials it has been realized in different amounts compared to the control sample. R2 and R4 gave higher values in their solutions. Bleaching chemicals in terms of varnish interaction + R4 + Sb (7533), the lowest R4 + P (0933) was obtained. Accordingly, the amount of CO_2 in the flame source combustion increased by R4, showing acrylic varnish reducing effect.

The amount of CO_2 in the without flame source combustion was found to be less in varnishes than in control samples. In bleaching materials it has been realized in different amounts compared to the control sample. R1, R3 and R4 gave higher values in their solutions. The highest value of R4 + Sn (12.73) and the lowest value of R3 + Pu (3.000) were obtained in terms of coloring retarder + lacquer interaction. Accordingly, the amount of self-supporting CO_2 R3 and R4 showed enhancer, acrylic and polyurethane varnish reducing effect. The amount of CO_2 in the baking combustion was found to be less in the varnishes than in the control samples. In bleaching materials it has been realized in different amounts compared to the control sample. R1, R3 and R4 gave higher values in their solutions. The highest value of R4 + Sn (9.667) and the lowest value of R4 + Sb (1.733) were obtained in terms of the bleaching retarder + lacquer interaction.

The amount of CO_2 was found to be the highest on the without flame source combustion, the lowest in the flame source combustion compared to the combustion grade. The burning of the torch is in the process of becoming more than the flame source combustion. It can be said that there is a higher amount of CO_2 in severe burns. In terms of the amount of CO_2, R1, R3 and R4 are more effective in terms of amount of CO_2, and synthetic varnish is more effective in terms of varnish type. This can be taken into account in fire risk areas.

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Part II
Sustainable Planning—Infrastructure and Resilience

A Comprehensive Study on the Effect of Households' Evolution on Residential Energy Consumption Patterns

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Abstract. The residential sector accounts for approximately 27 and 17% of the world energy consumption and its CO_2 emission, respectively. Thus, developing measures to reduce carbon dioxide emissions in this sector, which is highly associated with the rapidly increasing proportion of world's urban population, is crucial to ensuring the sustainable development of the urban environment. However, the majority of the existing expertise on energy sustainability revolves around improving the thermal quality of the building envelop with lesser focus on the social and behavioural aspects of energy consumption. Given the importance of factors pertaining to the latter aspects, which are found to be responsible for 4–30% of the variation in residential energy consumption, this paper aims to address and explore for the first time the impact of the UK residents' life-cycle evolution on their energy usage. To attain this, an official database encompassing around 5000 households observed over the course of 10 years was analysed with the help of specific statistical tests and procedures (e.g. logistic regression). First, logistic regression was employed to determine the socio-economic factors influencing households' evolution from one state to another; consequently, future evolutionary models covering a 10-year window, were predicted. This was followed by analysing the effect of the predicted evolutionary models on the households' gas and electricity usage patterns using point-biserial correlation. Finally, the findings suggest that households' evolution have a significant effect on their energy consumption patterns. However, the magnitude and the direction of this effect is weak and mostly positive, respectively.

Keywords: Urban energy planning · Household transitions · Smart cities
Energy forecasting · Household projection

1 Introduction

The UK residential sector consumes roughly 27% of energy and emits roughly 20% of the country CO_2 [1]. Therefore, developing appropriate policies to cut the CO_2 emission at this sector, is not only indispensable for achieving the imposed CO_2 emission targets but also for ensuring that the development of the urban environment is performed in sustainable way [2]. This has encouraged different researchers to explore

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various solutions for energy sustainability. As a result, a great deal of expertise has been developed. However, the majority of the current knowledge revolves around improving the thermal characteristics of dwellings, their HVAC system with less focus on the social and behavioural aspects. According to the literature, the latter aspects accounts for between 4 and 30% of the variation in domestic energy consumption [3, 4, 5, 6, and 7]. This is evident in the type of measures taken by the UK government promoting dwellings' retrofit such as, green deal, in which certain households are entitled for free cavity wall and loft insulations in addition to boiler replacement [1]. However, since 70% of the UK homes were expected to benefit from cavity and loft insulations by July 2013 [8], the UK government need to consider other alternatives including promoting pro-environmental behaviour and developing socio-economic policies. However, it is important to define the effect of such influencing factors including households' environmental awareness, income, and the level of education. This will help not only to take the right measures based on each scenario but also to predict the implication of such policies before implementation. It should be noted that the behavioural aspect is beyond the scope of this research, please refer to extensive work of [9, 10].

The impact of socio-economic and demographic factors on residential energy consumption has been extensively addressed in the literature [11, 12, 13, 14, 15, 16, and 17]. However, despite the fact that recent studies like [18] have analysed the influence of change in the households socio-economic and demographic circumstances on their energy consumption patterns, until today there is no study that has considered the impact of households demographic evolution on their energy consumption. In other words, the effect of occurring transitions from a family type to another (e.g. from single to couple without children) has not been previously studied, even though the concept of household life-cycle has been largely utilised in marketing as a determinant of consumer behaviour and a prominent principle in market segmentation [19]. Based on that, our research aims to bridge this gap by investigating the effect of UK households transition patterns on domestic energy consumption including gas and electricity. Furthermore, by exploring the factors which, in turn, affect those transitions. We believe that integrating this new knowledge into urban energy planning does not only enhance the process of energy forecasting but also help the development of effective policies that target households at different stages of their life-cycle.

2 Structure of the Article

This study has been carefully structured around 6 sections based on the logical sequencing of the research phases. First, the research problem will be introduced through the analysis of some contextual information in Sect. 1. This will be followed by addressing the methodological choices made in this study in Sect. 3. After that, Sect. 4 will describe and examine the transition patterns of single-non elderly households in the BHPS dataset from 1991 to 2008. Sections 5 and 6; however, aims to explore the socio-economic and demographic factors influencing households' transitions to predict future patterns for the next 10 years. Section 7 investigates the impact of the predicted transitions patterns on the annual households' energy usage. Finally, we will conclude with a discussing a potential application of the study findings in Sect. 8.

3 Methodology

This study embraces a quantitative research methodology, in which secondary data analysis is the main employed research method. More precisely, the British household panel data survey (BHPS) was utilised to address the research problem. This data survey encompasses more than 5500 households annually interviewed on their socio-economic circumstances, demographic characteristics, health conditions, consumer behaviour, social relationships, and energy consumption from 1991 to 2008 [20]. The ability to analyse complex dynamic relationships is the major advantage of panel data (longitudinal data) and the main motivation behind its adoption in this research.

There are three stages of implementation in this research. First, the first stage involves exploring existing households transition using certain descriptive and analytical statistical tools such as, cross-tabulation. As for the second phase, the socio-economic and demographic factors influencing these transitions were investigated using either random or fixed-effects logistic regression models. Random effects models suggest that the variation of dependent variables across groups is random and uncorrelated with predictor. Conversely, fixed-effects models assess how the variation in the predicted variable within each group (e.g. single-non elderly) is influenced by the change in the independent variables within each group. Moreover, they control for time invariant predictors such as, gender [21]. To prevent making any assumptions, Hausman test was employed to decide on the type of model where the null hypothesis indicates that random model is preferred.

Finally, the third stage encompasses the investigation of the impact, strength, and direction of transition variables on the households' energy usage using Point-Biserial Correlation Analysis. The reason behind the choice of this particular correlation was imposed by the nature of the investigated variables which are continuous (energy consumption) and binary (household type variables).

3.1 Data Screening and Transformation

The following data screening procedures were embraced prior to data analysis. First, due to the fact that energy prices variated significantly from 1991 to 2008 (Fig. 1), we decided to convert energy expenditure to quantities in KWh. This was achieved with the help of official inflation index for domestic gas and electricity, retail price index (RPI), more precisely [22]. After that, all income and energy consumption variables such as, rent, household annual income, were normalised using mainly square root transformations except for annual electricity consumption where log 10 was applied. This was followed by checking and deleting outliers in all continuous variable using the labelling method "outlier labelling rule" [23]. However, all the extreme values removed were predicted with multiple imputations.

In addition to the above, household type variables which initially contained 9 categories, was prone to transformation and simplification. We first collapsed the number of categories to 5 instead of 8 while isolating children dependency in a separate variable. Secondly, the simplified variable was transformed into 4 dummy variables prior to performing logistic regression in the second stage of this research.

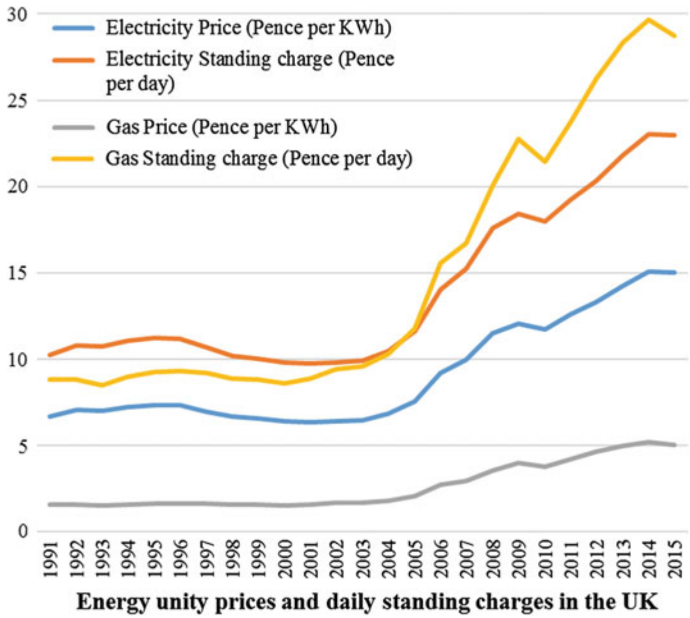

Fig. 1. Energy unity prices and daily standing charges in pence in the UK from 1991 to 2015

4 Single Non-elderly Households Transition Patterns from 1991 to 2008

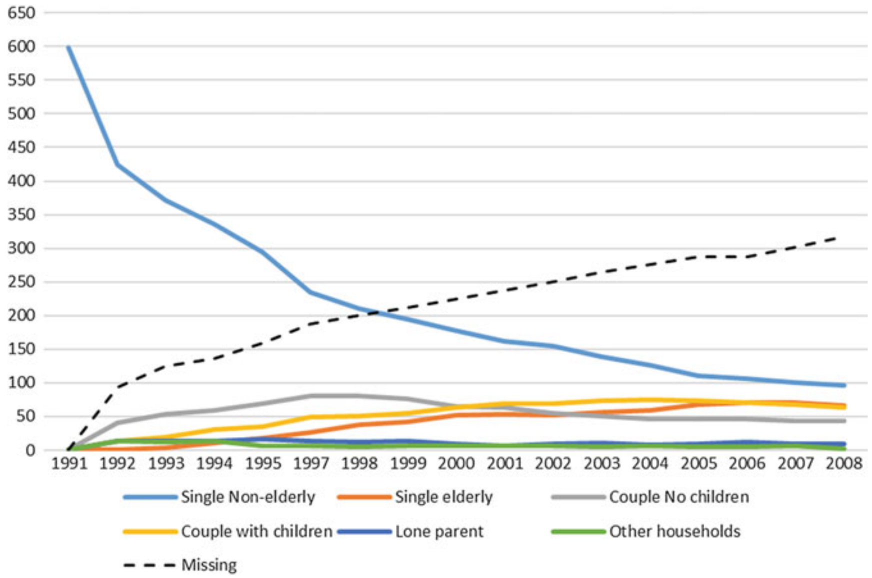

Fig. 2. The change in the number of different households in the utilised BHPS dataset between 1991 and 2008

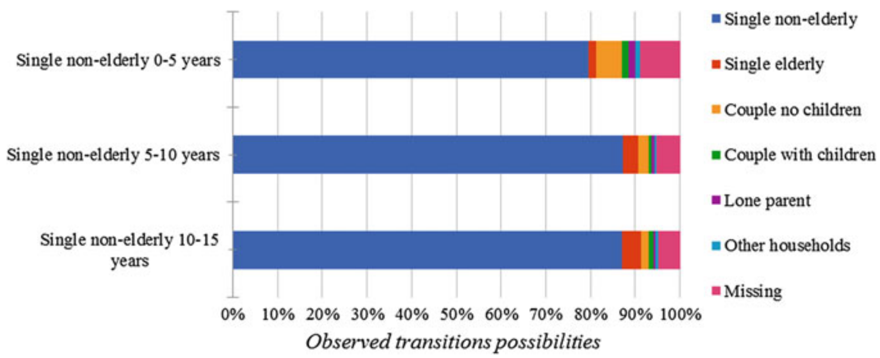

Fig. 3. The observed transition possibilities of single non-elderly households to different family types over 5, 10, and 15 years

Figure 2, is a multiple line graph that represents the global change in the number of different household types in the utilised BHPS dataset between 1991 and 2008. Overall, the number of single non-elderly households decreased significantly over the whole period, whereas the number of single elderly and couple with children increased. However, the proportion of lone parents and other households remains fairly stable. On the one hand, the analysis of this trend suggests the existence of certain transitions patterns between the observed households over the period between 1991 and 2008. On the other hand, it is hard to draw conclusions on the nature and the transition possibilities especially given the increasing number of dropping households over this period. Thus, the stacked bar graph in Fig. 3 has been employed to closely investigate the occurring inner transition patterns, single non-elderly household transitions particularly, over 5, 10, and 15 years, respectively.

From 1991 to 1997, the initial number of single households dropped dramatically by almost 60%, whereas the number of couple no children, couple with children, and single elderly households rise from 0 in 1991 to reach 84, 51, and 26, correspondingly. This is due to the fact that up to 20% of single non-elderly households moved to other family types each year in which roughly 6% became couple no children, 1.8% single non-elderly, around 4% was shared between lone parent, couple with children and other households, and approximately 9% dropped from the survey. Following the 20% yearly transition rate, the decrease in the number of single non-elderly households would have been greater if there were no transitions from the rest of households' types to single non-elderly households. For example, every year, approximately 6.5% of couple no children move to single non-elderly households.

From 1997 to 2002, there was roughly 35 and 32% decrease in the proportion of single non-elderly and couple no children households, respectively. On the other hand, there was around 40 and 100% increase in the number of couple with children and single elderly households, correspondingly. The decline in single non-elderly households was not as important as in the period from 1991 to 1997 for the reason that there was an approximate 7.5% decrease in the yearly transition rate of single non-elderly households. Conversely, the rise in the number of single elderly households was due to the increase in the yearly transition probability to this family type from roughly 1.75 to 3.48%. Similarly, the surge in the number of couple with children households was influenced by the lack of transitions of a large proportion of this household (around 93%) over this period in spite of the decrease in the transition probabilities to this household type from the remaining family types.

Between 2002 and 2008, there were no major changes to report from the previous period except that there was a decrease in the proportion of couple no children households (went down to 20%), and an increase in single non-elderly one (from 100 to 26%). Thus, as expected, the number of couple with children has slightly increased between 2002 and 2004 before remaining fairly steady afterwards.

5 Demographic and Socio-economic Factors Influencing Households Transition

From the premise that the predicted variable is dichotomous, we utilised binary logistic regression which will help determine the socio-economic and demographic factors influencing households' transitions. Subsequently, predict future patterns. For those reasons, we have developed 40 models covering a period of 10 years, where each model represents a given household transition in a given year. However, only the transitions to couple no children in the next 5 and 10 years, will be reported due to simplification purposes and to the wording constraints of this journal paper.

As discussed previously in the methodology section, both fixed and random effects models, were employed. First, fixed effects model is defined in Eq. (1) as follows:

$$\log\left(\frac{P_{it}}{1-P_{it}}\right) = \mu_t + \beta x_{it} + y z_i + \alpha_i \tag{1}$$

P_{it} is the probability that $y_{it} = 1$, z_i represents the group of variables describing the householders and which does not differ across time. Conversely, x_{it} depicts the vector of variables that change over time and individuals. β and y are vectors of coefficients while μ_t is the intercept which can vary over time. α_i represents the differences between householders who are stable over time and those otherwise, based on z_i. After some algebra has been applied on Eq. (1) and assuming the independence of y_{i1} and y_{i2} given any householder i and its α_i value, z_i and α_i will be omitted from the equation as shown in Eq. (2). This will result in the elimination of participants who do not vary with the response variable and to the creation of various scores for all time-varying independent variables [24].

$$\log\left(\frac{\Pr(y_{i1} = 0, y_{i2} = 1)}{\Pr(y_{i1} = 1, y_{i2} = 0)}\right) = (\mu_2 - \mu_1) + \beta(x_{i2} - x_{i1}) \tag{2}$$

On the other hand, a random effects logistic regression model results Eq. (3) from the inclusion of a random intercept ζj ~ N (0, ψ) whose independence from the covariates is assumed.

$$\begin{aligned} \mathrm{logit}\{\Pr(\mathrm{yij} = 1 \mid \mathrm{xij}, \zeta\mathrm{j})\} &= \beta 1 + \beta 2 \times 2\mathrm{j} + \beta 3 \times 3\mathrm{ij} \\ &\quad + \beta 4 \times 2\mathrm{j} \times 3\mathrm{ji} + \zeta\mathrm{j} \end{aligned} \tag{3}$$

It should be taken into account that the responses yij for any householder j and at any given time, are independently Bernoulli distributed [25], which could be defined as below in Eq. (4);

$$\begin{gathered} \Pi\mathrm{ij} \equiv \Pr(\mathrm{yij}|\mathrm{xij},\ \zeta\mathrm{j}) \\ \mathrm{logit}(\Pi\mathrm{ij}) = \beta 1 + \beta 2 \times 2\mathrm{j} + \beta 3 \times 3\mathrm{ij} + \beta 4 \times 2\mathrm{j} \times 3\mathrm{ij} + \zeta\mathrm{j} \\ \mathrm{yij}|\Pi\mathrm{ij} \sim \mathrm{Binomial}\,(1,\ \Pi\mathrm{ij}) \end{gathered} \tag{4}$$

Finally, to select the right type of model, Hausman specification test was used. The null hypothesis H0: is that random effects model is appropriate, whereas the alternative hypothesis H1 suggests that fixed effect model is suitable.

6 Results

6.1 Transition to Couple No Children

Tables 1 and 2 illustrated binary logistic regression models belonging to the transitions to couple without children in the next 5 and 10 years. In general, it is evident that some demographic, socio-economic, and dwelling characteristics have a significant impact on both transitions.

The analysis of model (1) suggests that the odds of becoming couple without children in the next 5 years are 1.745 and 1.985 higher for households aged between 26 and 35 years, and couple with children, correspondingly. This is in line with the UK official reports which suggest that the mean age of couple with children at the first birth is approximately 31.6 years [26]. Regarding the higher odds for couple with children, this could be attributed to possible move to empty-nester households caused by children leaving the household. In addition to that, the odds ratio for household in part-time jobs was 3.25, which advises that some parents with young children may prefer working part-time to save the prohibitive child care cost (11,000 £ on average) according to [27]. The annual pension income of the households was found to be significant but with minor effect as one-unit increase in the square root of this variable is accompanied with 1.5% increase in the odds of being couple no children. Finally, for households living in converted flats, the odds of being couple without children was 7.184. This could be owing to the fact that more than 50% of cohabiting couples without children in the UK lived at least 6 years before the first child birth. Therefore, remaining in flats [28].

On the other hand, as predicted, the odds of moving to couple no children households in 5 years was lower by 65.4 and 85% for cohabiting couples and single-elderly, correspondingly. Similarly, the odds ratio for the following socio-economic classes namely; semi-unskilled manual workers, foreman or technicians, routine non-manual employees, lower-grade professionals, higher-grade professionals, was lower by 83.3, 61.6, 67.9, 70.4, and 65%, respectively. This could be due to the fact that approximately 45% of households from these socio-economic classes have the preference to have at least 1–2 children given their financial stability [29]. Household who rent their dwellings from local authorities and own their dwellings with mortgage, the odds of moving to this household type is lower by 82.5 and 58%, respectively. This was in agreement with the UK government reports on home ownership and renting [30]. Finally, the impact of income variables; however, had a very small impact.

In contrast to model (1), the analysis of model (2) has highlighted the following points. First, unlike in model (1), household type, marital status, dwelling type, employment type, were not found significant. On the other hand, variables pertaining to the householders' socio-economic status and tenure type were consistent in both models but with different magnitudes. For instance, for higher grade professionals, the odds of moving to couple no children was lower by 71.5% in comparison to 65% in 5 years. Conversely, as expected, the effect of age and income benefit variables was contradictory with model 1. For example, the odds of being couple without children in 10 years the odd was lower by 0.0287 which implies possible transitions of householders from this age group to various family types other than couple without children.

Table 1. Part a: transition models to couple without children in the next 5 and 10 years

Variables	(1) 5 years transition model		(2) 10 years transition model	
	(2) Odds ratio	95% CI	Odds ratio	95% CI
Households characteristics				
Single elderly	0.153**	0.024–0.97	–	–
	(0.144)			
Couple with children	1.985**	1.08–3.65	–	–
	(0.617)			
Aged 26–35	1.745**	1.08–2.82	0.0278***	0.0087–0.08
	(0.426)		(0.0164)	
Aged 36–45	–	–	0.192***	0.091–0.4
			(0.0719)	
Aged 56–65	1.755	0.78–3.97	–	–
	(0.729)			
Householder marital status				
Cohabiting couple	0.346***	0.2–0.60	1.634	0.58–4.62
	(0.0980)		(0.868)	
Divorced	0.659	0.26–1.7	–	–
	(0.318)			
Employment mode and socio-economic status				
Higher-grade professionals	0.360***	0.2–0.65	0.285**	0.11–0.74
	(0.109)		(0.140)	
Lower-grade professionals	0.296***		0.281***	0.11–0.71
	(0.0870)	0.17–0.53	(0.134)	
Routine non manual employees	0.321***		0.280**	0.09–0.88
	(0.125)	0.15–0.69	(0.163)	
Foreman and technicians	0.384**	0.15–0.98	0.226*	0.05–1.11
	(0.184)		(0.184)	
Semi-unskilled manual workers	0.167***	0.06–0.47	0.347	0.08–1.44
	(0.0884)		(0.251)	

(*continued*)

Table 1. (*continued*)

Variables	(1) 5 years transition model		(2) 10 years transition model	
	(2) Odds ratio	95% CI	Odds ratio	95% CI
Small proprietors without employees	–	–	0.273*	0.067–1.12
			(0.196)	
Working part-time	3.250***	1.65–6.42	0.452	0.17–1.18
	(1.128)		(0.220)	

Table 2. Part b: transition models to couple without children in the next 5 and 10 years

Variables	(1) 5 years transition model		(2) 10 years transition model	
	(2) Odds ratio	95% CI	Odds ratio	95% CI
Dwelling and tenure type				
Living in a semi-detached bungalow	1.422	0.87–2.32		
	(0.355)			
Living in a terraced house	–	–	0.463	0.14–1.54
			(0.284)	
Living in a converted flat	7.184***	2.24–23.06		
	(4.275)			
Dwelling owned with mortgage	0.420***	0.23–0.77	0.330**	0.12–0.9
	(0.131)		(0.168)	
Dwelling rented from local authorities	0.175**	0.037–0.84	0.0632**	0.0045–0.88
	(0.140)		(0.0850)	
Dwelling rented from private landlords	0.378*	0.14–1.03	0.425	0.08–2.22
	(0.193)		(0.358)	
Household income				
Square root of annual investment income	0.991**	0.98–0.1	–	–
	(0.00401)			
Square root of annual pension income	1.035***	1.016–1.06	–	–
	(0.00975)			
Square root of total benefit income	0.989**	0.98–0.1	1.018***	1.006–1.03
	(0.00524)		(0.00648)	
Observations	1251		662	
Number of PID	125		99	

(*continued*)

Table 2. (*continued*)

Variables	(1) 5 years transition model		(2) 10 years transition model	
	(2) Odds ratio	95% CI	Odds ratio	95% CI
Type of used model	Fixed effects		Fixed effects	
McFadden's R2:	0.22		0.150	

Note CI: confidence interval standard errors in parentheses
*Significance at the 90% level **Significance at the 95% level ***Significance at the 99% level

7 The Impact of Household Transitions on Their Annual Electricity and Gas Consumption

As addressed previously, point-biserial correlation was employed to investigate the strength as well as direction of association between the predicted transition variables and annual energy consumption variables. Although it is considered a special case of Pearson product moment correlation, point-biserial correlation can be performed in any statistical software package such as, Stata or SPSS. Equation (4) shows the calculation of correlation coefficient r_{pb}.

Since the aim of this section is to investigate the strength as well as direction of association between the predicted household transition variables which are dichotomous and the annual energy consumption variables that are continuous, point-biserial correlation was employed. Although it is considered a special case of Pearson product-moment correlation, point-biserial correlation can be handled using Pearson correlation in any statistical software packages [31] (e.g. SPSS, Stata) in which the correlation coefficient r_{pb} is calculated as follows Eq. (5);

$$r_{pb} = \frac{\overline{Y_1} - \overline{Y_0}}{\overline{S_y}} \sqrt{\frac{N_1 N_0}{N(N-1)}} \tag{5}$$

Y_0 and Y_1 are means of observation coded 0 and 1, correspondingly. On the other hand, N_0 and N_1 are the number of observations coded 0 and 1, respectively. N is the total number of observations, whereas, S_y is the observations standard deviation.

7.1 Findings

For simplification purposes, only the impact of transitions to couple without children on annual energy consumption will be addressed.

7.1.1 The Impact of Transition to Couple with No Children Households

Table 3. The impact of couple no children transitions on annual gas and electricity consumption

	CN 1 year	CN 2 years	CN 3 years	CN 4 years	CN 5 years	CN 6 years	CN 7 years	CN 8 years	CN 9 years	CN 10 years
Log10 annual electricity usage	0.11**	0.093**	0.098**	0.094**	0.08**	−0.034**	0.04**	0.03**	0.02	0.008
Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.006	0.074	0.538
Square root of annual gas usage	0.114**	0.091**	0.068**	0.057**	0.05**	−0.09**	0.013	0.001	−0.008	−0.010
Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.290	0.930	0.553	0.419
N	6700	6700	6700	6700	6700	6700	6700	6700	6700	6700

Note CN: couple no children *Significance at the 95% level **Significance at the 99% level

Table 3 represents the correlation matrix between couple without children transition variables and the households' annual energy consumption variables. First, it is clear that the resulting correlations were not significant across all the 10 years. This applies for the correlations between the log10 annual electricity consumption and transitions to couple without children in the 9 and 10th years. Moreover, the association between square root annual gas consumption and the transitions variables beyond year 6. However, all significant correlation coefficients were at the 99% level. Finally, the direction of these association was mostly positive except for year 6.

8 Conclusion

In conclusion, conducting this research has permitted us to generate a new body of knowledge which consists of defining the nature, degree, and impact of households' evolution on their domestic energy usage patterns over 10-year window. We first started by analysing past transitions patterns that occurred in the BHPS data for single non-elderly households from 1991 to 2008. This also allowed for an overall understanding of the transition mechanism pertaining to this household type prior to studying the influencing socio-economic and demographic factors. However, due to the exploratory nature of this research and inconsistent nature and number of influencing factors, it was impractical to report all the possible variables for the 40 models. Therefore, variables of similar type (e.g. marital status) were clustered together. Finally, the interpretation of point-biserial correlation coefficients suggested a weak correlation between household transition and domestic energy consumption variables. However, this association is mostly positive except for transitions to lone-parent households on both gas and electricity variables. This advises and supports the recent UK governments reports which claim that a proportion of this family type is living in consistent fuel poverty owing their low-income.

Based on the above findings, we argue that our study has been the first one to introduce such a prominent and powerful marketing concept (analysis of household life-cycle) into urban energy planning. Furthermore, we believe that this could lead to the development of potential urban energy forecasting systems to support energy planning decision-making. One of the possible abilities of such systems, is to forecast residential energy consumption in relation to different household transitions over their life-cycle. Indeed, an evidence on this argument is demonstrated in Fig. 4, which in turn illustrates the variation in single non-elderly households' annual electricity usage accompanied with their transitions to various family types over 5 years' period.

Overall, the analysis of the findings advised that the transition probabilities from single-non-elderly households to couple without children, couple with children, lone parents, single non-elderly, and other households after 5 years are 19.9, 12.1, 3.1, 46.7, and 1.7%, respectively. For the majority of households moving to single elderly in 5 years, 67.5% consume between 1000–3000 KWh electricity annually. On the other hand, the ones who become couple without children, 4.76, 42.85, and 26.19 of them are expected to consume less than 1000 KWh, 1000–3000 KWh, and 3000–4000 KWh, respectively. As for the majority of households moving to couple with children status (53%), they should use between 2000–4000 KWh annually, whereas 19.6% consume more than 5000 KWh. Concerning households making transitions to lone parent households, around 57% of them should use 2000–4000 KWh, whereas the remaining ones use more than 5000 KWh per year. Interestingly, the annual electricity consumption of the majority of those who remained single-non elderly after 5 years and consumed between 1000–4000 KWh, should increase by an average of 1.02%. Conversely, for those who consumed 4000–5000 KWh and more than 5000 KWh, a decrease of 1.1 and 3%, respectively, is expected.

Undoubtedly, this could lead to further questioning the reasons behind these variations such as, change in lifestyle and socio-economic circumstances, or the generation of appropriate policies. However, this will also enhance the process of demographic projection in function of households' future energy patterns which could result in the following benefits; the ability to forecast and monitor domestic energy consumption and the resulting CO_2 emissions from single consumer to city level; secondly, enable a smarter management of the distribution network.

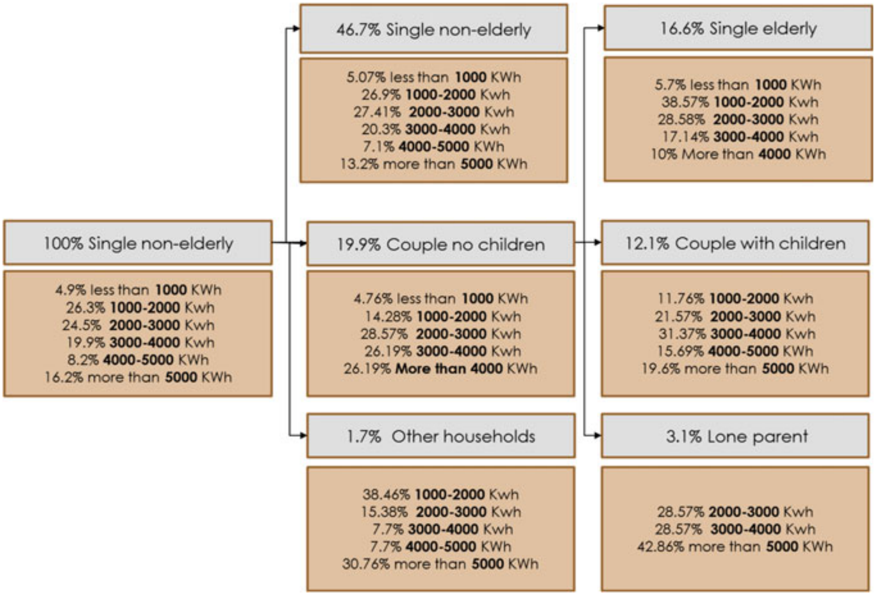

Fig. 4. An example showing the expected annual electricity consumption figures of single-non elderly households before and after their transition to different family types in 5 years

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Effect of Physical Urban Environment on Sustainable Urban Development

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Abstract. Certain features, having significant effect on the shape of the urban areas, could be divided to two, as: tangible and intangible. Tangible features are consisted of the physical elements, which forms the urban environment, as land use mix, density (might be based on population, residential, commercial etc.), urban design characteristics etc. On the other hand, intangible features are comprised of the socio-economic measures of the societies, as demographic, cultural, sociological, economical and historical structure of the related societies. Both tangible and intangible features have a significant role in shaping the physical urban environment and since the inner characteristics of these features cause different kinds of physical urban environment, the inner characteristics of the both tangible and intangible features might have substantial impact on the sustainable urban development. Accordingly, in this study, tangible features related with the urban form, as land use mix, density and urban design characteristics and the effect of these characteristics on the configuration of the physical urban environment in the context of sustainable urban development will be clarified. Pros and cons of the different aspects of land use mix, density and urban design characteristics and their effect on the urban form and the sustainable urban development will be discussed by considering the different variations. Therefore, it could be possible to compose a guide, which leads a way to sustainable urban communities.

Keywords: Land use mix · Density · Urban design · Urban form Sustainability

1 Introduction

The term of "sustainability" has first been used by English political economist Thomas Malthus in the beginning of 1800s, where was the initial age of the industrial evolution [1]. The term has been rising in the period of post-WW2, where there was rapid industrialization. The fact that the rapid capitalist development and the existence of scarce resources, have caused the negative externalities (air, water and soil pollution etc.), as well as unfair conditions in the redistribution of added value to the public. And, since the system of capitalism requires the continuity of the capital accumulation, these negative effects might manifest themselves all the time. Therefore, the vital significance and the popularity of the term of sustainability will never diminish, instead will continue to increase.

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Therefore, the main problem, which starts this paper, is the fact that undesired negative externalities constitute socio-economic and environmental stress factors on the urban settlements, which might adversely affect the current and the next-generations lives. However, it is highly important—now and for the future—to provide the continuity of the urban systems to enable them robust to the external effects. In this context, the term of urban sustainability (another level of sustainability) is gaining importance.

In this sense, when it comes to the point of anything related with the "urban", the urban planning could be considered one of the most significant disciplines related with the settlements, including urban and rural areas. Planning has a vital role in shaping the urban areas and the most concrete effects of planning on the cities are taking shape with the planning decisions related with the "space" (and these decisions are the core of turning space into places) and in the context of urban sustainability, spatial planning decisions, which shape the physical urban environment, have crucial role that are discussed in the following sections.

2 Sustainability and Urban Sustainability

As previously stated, the continuity of the urban systems (socio-economic and environmental etc.) has been in danger due to the increasing demand of current capitalist production system. Thereby, urban sustainability is the main issue, which will be discussed in this paper. Accordingly, first, the definition of sustainability and then the urban sustainability will be clarified here.

The "definition of sustainability concept", included in Brundtland Report (Our Common Future) for the first time. The exact definition was stated by WCED in 1987 as [2]:

> "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

Costanza and Patten [3], on the other hand, defined the sustainability in the terms of various words in the context of various disciplines. For instance, biologically sustainability requires the avoidance of extinction, efforts of survive and reproduction. On the other hand, economic sustainability requires the avoidance of recessions, instability and discontinuity.

And in the context of urban sustainability, Maclaren [4] starts the definition making by dividing the two terms, as urban sustainability and sustainable urban development and proposes definitions, based on the distinct differences between these two terms. In this sense, he defined the term of sustainability as the desired condition or the resistant conditions throughout the time. On the other hand, he defined the term of sustainable urban development as the process which sustains the sustainability.

Basiago [1] defines urban sustainability as a concept, which is aware of the fact that the urban life is a complex system, where the quality of life of its inhabitants and the continuity of its systems is vital for the maintenance of the human (socio-economic) life.

Wu [5] states that urban sustainability is the provision of the scene of the urban landscape as a whole.

On the other hand, Marcotullio [6] asserts that urban sustainability could only be achieved by sustaining the economic, environmental and social wellbeing of the cities.

Similarly, Fedeski and Gwilliam [7] state that urban sustainability is vulnerable to the effects of various environmental, economic and social factors.

In this paper, the relation between urban sustainability and the urban planning, related with the spatial planning decisions will be explained in the context of land use, density and design decisions. These planning decision issues have significant role in the shaping of built environment, where we are living in. To make it clear, mixed land use, high densities and the proper design of the neighborhood units are considered in the related literature, as a catalyzer which boosts the urban sustainability will be explained.

3 Spatial Planning Decisions and Relations with the Urban Sustainability

Spatial planning decisions related with land use, density and urban design will be examined, considering their contributions to the urban sustainability.

3.1 Land Use

The concept of land use here will be substituted by the land use mix, due to the fact that the general tendency in the related literature is to associate mixed land uses as the sustainable urban forms. For this reason, it would be better to emphasize on the term of "diversity" first.

Diversity, as a concept, might have various meanings in the context of urban literature. An urban designer sees diversity as the aggregation of the different building typologies; on the other hand, an urban planner sees it as the gathering of different land uses or people having from different socio-economic status. Similarly, since 1960s, authors from the various disciplines have been emphasizing on the importance of the fact that urban development must have physical and social heterogeneity [8].

Diversity in the urban areas defines itself in the context of spatial sense best, as mixed land use. Instead of the large scale lands, which include only a single land use, an urban morphology, which is comprised of mixed land uses (residential, working, commercial, recreational etc. areas) is considered as more effective in the sense of diversity.

One of the definitions of mixed land use, which intensifies the importance of the diversity, was made by Commission of the European Communities. According to the definition made, the concept of mixed land use promotes the high density, more than one urban usage, as well as social and cultural diversity and this concept models older and traditional European urban life. Additionally, different social and professional groups with different ages could support the coexist of communities [9].

In addition to these, mixed land use, is generally defined as an urban block or an area, where include different usages. So that, people come and go to these places for different purposes and different periods of time [10].

According to the view specified by Smart Communities Network, the zoning practices in USA have been implementing so that urban land uses related with employment, shopping and urban services are isolated from the residential areas, since 1960s. As a consequence of this circumstance, residential areas have stayed distant from the work places and urban service areas. Remarks, promoting the mixed land use concept, state that this kind of divergent land uses might cause the formation of long-standing travel times, travel congestions, air pollution, redundant energy consumption, degradation of open and green spaces, unequal distribution of the economic resources, imbalance of the home-work places and the loss of community sense [11].

One of the authors, who strongly mentions the need of diversity in the urban areas is Jane Jacobs. According to Jacobs [12], four requisites exist to create diversity in the cities, as:

- A major part of the neighborhoods should have more than one primary usage. Having more than two primary usages is preferred. Therefore, people go outside at the different time periods and use the neighborhood for different purposes. Additionally, the same people could use facilities in common.
- The majority of the urban blocks should be short; in other words, streets and the chances to turn corners should be increased.
- Buildings, having different ages and conditions should be together in the neighborhood.
- The density of "people" should be sufficient (in the context of various socio-economic status).

Reaching to the present time, views close to Jacob's views have been developed in time. Hence, Grant [13] listed the benefits of the mixed land uses to the cities and their inhabitants, which promote diversity, as:

- Mixed land use enables cities livable and active throughout the day, in the any time. Moreover, it promotes the optimum usage of the urban infrastructure.
- Elementary families will have more chance, when they are increasing in number (they will not depend only on the single family houses).
- Different residential typologies could decrease the segregation, by increasing the purchasing power and social equality.
- Urban planners could decrease the dependency of the vulnerable people (older people, children, people with disabilities etc.), by proposing the residential areas nearby the commercial and institutional usages.

- The existence of the places, related with shopping, working and spending free times close to the residential areas, might discourage the inhabitants of the cities in the sense of having automobiles and might encourage them to be pedestrians, as well as it might promote the public transportation. Thereby, environmental consequences, arising from the private car ownership could be ignored.

In the light of this information, the effects of mixed land use on social and environmental sustainability will be compiled in the conclusion part of the paper.

3.2 Density

Density, here, will be substituted by compactness, because in the related literature, density and compactness are changeably used. A compact city refuses to urban sprawl, while inhabitants of the compact cities could walk, bike or use public transport to go to the shops and their jobs, since the residential areas are planned close to those areas. Therefore, comparing with the other urban macroforms, compact urban macroform is considered as more energy efficient and less polluter [14].

The characteristics of the compact cities are defined by Neuman [14] as:

- High residential and employment density,
- Mixed land use,
- Spatially lower-scale urban usages (closeness to the various usages and relatively small urban plots),
- Increasing social and economic interaction,
- Close/attached configuration,
- Limited urban development (Meaningful/Legible boundaries),
- Multi-modal transportation,
- High accessibility,
- Efficient, accessible and strong street connections,
- High degrees of impervious surface,
- Low level of open space,
- Possible holistic control in the land development processes,
- Efficient use of public fiscal resources for various urban usages and infrastructure.

On the other hand, Hui [15] states the relation between density and the compact city as that cities might prefer to increase urban densities to overcome the effects of growth pressure, instead of broadening their boundaries. Therefore, a cityscape, including high-rise buildings and compact urban macroform appear.

In this sense, the relation between the density and the compact city could be tied up as that in the case of increasing density, the characteristics of the compact city are becoming intense. The type of the density might be residential density (it is also the proxy for the population density), commercial density, employment density etc.

Additionally, according to Jabareen [16], in order to create the interaction required for to sustain the vitality of the urban functions and the activities, it is necessary to gather people in the certain densities.

Considering in the sense of environmental perspective, densely aggregated buildings enable public transport efficient, since the distance between the various urban usages are getting shorter. Additionally, this situation promotes the decrease of carbon emission, since it limits the usage of automobiles [16, 17]. Similarly, a strong relation among the urban density and activity density with the automobile usage is emphasized [18]. In this context, Newman and Kenworthy [19] assert that some of the transportation variables are directly linked with the urban density, by using linear multivariate regression analysis in 31 cities in the year of 1989. They define these variables, as fuel oil usage, private car ownership, private car usage, the ratio of the employees who use public transport, public transport trips per person and total passenger number who use public transport per kilometers. They state that cities having high densities, are less dependent on the automobiles and having more efficient public transport systems.

On the basis of this information, the overall effects of density (in the context of compact city) on social and environmental sustainability will be explained in the conclusion part.

3.3 Neighborhood Unit Design

Neighborhood design is significant in the sense that design characteristics have a vital role in the continuing of the urban sustainability in the neighborhoods. The principal contributions of the design characteristics on the urban sustainability in the neighborhood scale could be listed as:

- Design enables the urban usages to locate close themselves. Thereby, inhabitants of the neighborhood could walk, bike or use public transport to reach those usages.
  - Design promotes mixed land use, in the context of both vertical and horizontal mixed use. Mixed land use in the neighborhoods, enable different urban usages (shops, schools, houses etc.) to locate closer. Therefore, carbon emission is decreased. Also, mixed land use enables more efficient way of shopping. Inhabitants of the neighborhoods could sustain their needs nearby their homes. This promotes the local economy and contributes the decrease of carbon emission.
  - By design, the streets are interconnected and the length of the building blocks are planned short. So that, people could walk. Promoting walking is the significant part of the ignoring the adverse effects of carbon emissions caused by the usage of automobiles.
  - Enabling proper design features, various urban public usages should be located on the neighborhoods such a way that each person in the city could access to those usages easily. It is significant for social equity in the context of social sustainability.

Design features could change, depending on the scale of the settlement areas. In this sense, design features related with the urban scale are generally separated from the neighborhood scale. In this context, there are some points which constitute the basis of the neighborhood design. One of the most significant is the concept of access distance to the public space and institutions. Within this framework, accessibility to the primary schools is especially important, because children must go to the schools, located in the safe and walkable distances. Additionally, the existence of the small-scale commercial businesses as groceries, tailors, pharmacies etc. is significant in the sense that inhabitants of the neighborhoods should sustain their needs in nearby of their homes. Besides, the existence of the public open spaces, as parks, squares etc. is required for the inhabitants to spend time together, addition to the accessibility and shopping possibility.

The concept of neighborhood design lays of its foundations on English based Garden City movement. Two different design movements have arisen from the Garden City movement, which was developed to relieve crowded city center. Those could be stated as Sunnyside Gardens and Radburn movements, developed in 1920s [20]. Parallel to those movements, being one of the significant advocate of the neighborhood concept, Clarence Perry defined six fundamental characteristics, which a neighborhood unit should have in 1929. Those characteristics are listed as follow [21]:

1. Neighborhood units should be planned as pedestrian friendly and support mixed land use.
2. Many activities in the daily life should be carried in the boundaries of walking distances. This is significant for the vulnerable people, as elderly people, children, people with disabilities etc. Interconnected street network should be designed such that it should promote walking and decrease automobile trips and travel distances.
3. The residential diversity should be provided to sustain the coexistence of the people from different groups, as from different ages, socio-economic status etc. Therefore, it is possible for people having different backgrounds to be together in their daily lives and to strengthen their community ties.
4. It is significant to plan certain building densities and mixed land uses, located on the walking distance to the public transport stops to ignore the automobile usage.
5. Urban, institutional and commercial activities should be located on the neighborhood and district scale. Distant and single land uses should not be promoted. Especially primary schools should be located on the walking and biking distance.
6. The small scale playgrounds to large scale urban parks should be evenly distributed to the urban space. The conservation areas and the open spaces should be well-defined and they should connect the neighborhoods and districts together.

Neighborhood unit design characteristics, described above, is illustrated in the Fig. 1 [21]:

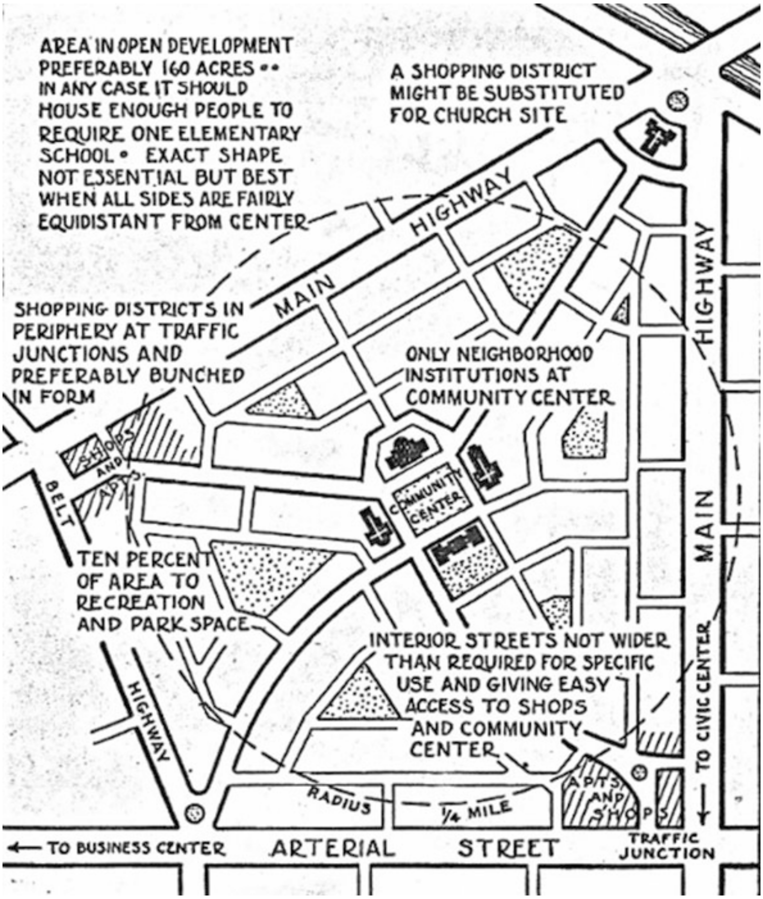

Fig. 1. Neighborhood unit design characteristics [21]

4 Discussions

Until this point, the main characteristics of the land use (in the context of diversity-mixed land use), density (in the context of compact city) and the neighborhood unit design are explained by tying up a relation with urban sustainability. Henceforth, effects of those physical environment features on urban sustainability in the context of social and environmental sustainability are listed separately in this section.

4.1 Land Use Effects

Here, the effects of diverse-mixed land use on social sustainability is discussed:

1. Promoting green transport modes (especially, walking and biking, as well as public transport) nearby the residential areas (namely, creating a mixed-use environment) especially significant for low-income groups to access urban services.
2. Sustaining the diversity in the neighborhoods, by promoting the diverse residential typologies, allows low income groups to live together with the people from different socio-economic groups. This is significant for ignoring the social segregation in the cities.
3. Diverse land uses enable people to use those places at any time in the day and enable people to interact with themselves. Therefore, social and economic interaction are perpetuated.

The effects of diverse-mixed land use on environmental sustainability could be listed as:

1. Aggregation of certain usages on the certain places decreases the distances among different usages. So that, inhabitants could access to the services that they demand by using green transport modes (walking/biking) or using public transportation. Thereby, carbon emission is limited by ignoring the usage of automobiles.

4.2 Density Effects

The effects of density on the social sustainability could be listed as:

1. To provide the continuity of the urban functions and the activities, certain densities should be located on the cities, because since certain densities include more inhabitants, there will be more lively social and economic interactions.
2. Since higher densities converge different usages, interaction level among the people and the economic activities increases.
3. Higher densities enable agglomeration economies more efficient.

Besides, the effects of density on the environmental sustainability could be discussed as follow:

1. Due to the densely urban configuration (buildings and roads), the ratio of the impervious surfaces increases. This might cause the risk of hazards, especially after the severe meteorological events.
2. Open and green space needs of the community cannot be provided easily, due to the dense urban configuration.
3. Promoting dense urban configuration could contribute the conservation of the vulnerable natural conservation areas, as fertile agricultural lands, scarce water resources, historical structures and areas, forests etc.
4. Since dense urban environment enables inhabitants to walk, bike or use public transportation; it enables the carbon emissions to decrease.

4.3 Neighborhood Unit Design Effects

Neighborhood unit design effects on the social sustainability could be explained as:

1. Since different urban usages located on the close distances, especially low income groups could access those usages by using green transport modes. It is significant in the context of social equity, because each person in the community has a right to access those usages easily.
2. Addition to the previous point, close usages are advantageous for the vulnerable groups, as elderly people, children and people with disabilities. Close distances allow them to access urban usages easily.
3. Correlatively, close usages enable inhabitants to shop easier. This promotes the local economy and increases the social interaction.

In addition to these, the effects of neighborhood unit design on environmental sustainability could be listed as:

1. Close location of the different usages enables inhabitants to walk, bike or use public transportation. This promotes the decrease of carbon emissions by decreasing the automobile usage.
2. Interconnected streets and shorter urban buildings easier pedestrians' walking and increase accessibility. Since, it promotes walking, it has a role to decrease carbon emission by diminishing the usage of automobile.

In this paper, the effects of the features of physical urban environment, as land use, density and neighborhood unit design on the urban sustainability, in the context of social and environmental sustainability has been discussed. In the environmental context, physical features only related with the decrease of carbon emissions is emphasized, because this context is limited in the boundaries of urban planning (urban planning is not directly responsible with changing the environmental-sensitive habits of the people, or measuring the some air, water, soil variables to detect pollution as environmental engineers do. It is highly responsible for the setting of the urban environment, which is related with the efficient use of public transportation, walking or biking). It could be stated that the mixed land use, dense urban configuration and the effective neighborhood unit design, most of the time, promotes the urban sustainability, both in the context of social and environmental sense. Therefore, physical setting of the urban environment should be planned considering the basis of these features, because it is highly significant to continue the maintenance of the scarce natural resources to sustain the balance between the human needs and the nature.

5 Conclusion

In this study, the effects of the physical features of the built environment, shaped by the decisions made in the urban planning process in the context of physical, social and environmental sense, are explained in detail. Those physical features are limited to land use, density and neighborhood unit design, which could be considered as the three significant elements of the urban planning process. Planning decisions related with those elements should be fictionalized in depth is highly crucial in order to ignore the undesired conditions, signified especially in the discussions part in this paper. In other words, land use decisions related with land use diversity (i.e. land use mix), decisions related with residential and population density and the design characteristics of the planned neighborhood unit have a vital role in shaping the built environment and directly affects the physical, social and environmental aspects in the urban areas.

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Designing Sustainable Models for Hot Cities: Planning an Energy Efficient Green Dubai

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Abstract. Climate change is happening and happening fast. Cities like Dubai are growing hotter by the day. In Dubai, where temperatures soar to unbearably high levels, work environments, especially for the blue-collar worker, become particularly insufferable. As Gulf News in March '15 quoted, "there is one car for every 2 residents." The needs for reduction in carbon emissions and improvements in human habitability are the needs of the hour. The sustainable design principles that may be employed while designing and planning hot urban environments, which result in an increase in energy efficiency, need to be researched by academicians and practitioners alike. The aim of this research paper is not only to analyze methods and draw on the solutions that have been tried and tested in hot global cities that aid in making urban microclimates more conducive, but also devise new strategies that can prove successful in extremely hot conditions. Having bagged the Expo 2020 bid, the need is larger for the Venice of the Middle East, to both maintain its world-class status and achieve new heights in sustainable city infrastructure. This, in turn, will pave the way for planning future cities with hot climates. There's an urgency in this climate chaotic world for a paradigm shift from pure climate mitigation towards climate adaptation. A place-based approach that harbours healthy symbiotic relationships between physical, social and environmental infrastructural elements is essential in making this city climate resilient.

Keywords: Energy efficiency · Urban microclimates · Liveability
Sustainable design · Public participation

1 Introduction

Dubai is a world of its own and always aspires to be a role model for cities worldwide. With climate change becoming a global burning issue that cannot be ignored any further, the time has come for this city to become a shining example for other cities that have the same climatic conditions. Dubai stands tall as one of the seven emirates that make up the United Arab Emirates (UAE). The UAE lies between the countries of Oman and Saudi Arabia, all three of which are part of the Gulf Cooperation Council (GCC) and the Middle East region. With a population of 9,157,000, according to the United Nations' 2015 population estimate, the UAE happens to be home to an extremely large population of immigrants who come to the country primarily for work. Of that, around 2.5 million reside in Dubai.

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Temperatures reach half the boiling point of water, especially in the sweltering summer months of July and August. The Intergovernmental Panel on Climate Change (IPCC) brought about its 4th Assessment Report, which stated that the climate in the Middle East and North African (MENA) region would likely experience a temperature hike of up to 2 °C within the next 15–20 years alone [1]. These are facts that reiterate the importance of the effects of climate change and the nature of its relevance in places like Dubai.

2 Liveability and Human Health

Modern advancements have facilitated over consumption of our natural reserves in order to satiate the demands that we perceive as integral to our enhanced quality of life. Consequentially, the working ecological cycle that is essential in sustaining our physical and mental well-being is tampered with [2].

The quality of human life is factored into what is known as liveability or the suitability of human living. The Economist Intelligence Unit (EIU) liveability ranking system is widely regarded as one of the most comprehensive and far-reaching ones among others. EIU employs 40 liveability indicators grouped under five weighted categories: stability (25%), healthcare (20%), culture and environment (25%), education (10%), and infrastructure (20%) [2]. In an EIU study titled 'Most improved cities over the last 5 years', Dubai was awarded the 77th position among 140 cities, with an overall rating of 74.2 out of an Ideal score of 100 (as shown in Table 1). Another guide called Mercer quality of life index is followed for businesses that have intentions to relocate or franchise to other parts of the world. In this, prime urban models are identified by cities with analogous environmental characteristics [2]. In 2010, Abu Dhabi, ranked 88, identified the city of Adelaide, ranked 32, as an urban mock-up to collaborate with on issues that related to climate change, urban design, renewable energy, among some others. One of the more recent surveys conducted had placed Dubai at the top of the ladder within the Middle East and African region. Most of the other cities that fall within this region fare poorly in these indices, as they attribute sub-standard living conditions due to inherent civil war and subsequent displacement.

Table 1. Liveability scores over 5 years

City	Country	Rank (out of 140)	Overall rating (100 = Ideal)	Five years improvement +%
Bogota	Colombia	111	59.6	7.9
Harare	Zimbabwe	136	40.7	3.2
Dubai	UAE	77	74.2	2.9
Algiers	Algeria	134	40.9	2.9
Kuwait City	Kuwait	81	72.1	2.5
Dhaka	Bangladesh	139	38.7	2.5

(*continued*)

Table 1. (*continued*)

City	Country	Rank (out of 140)	Overall rating (100 = Ideal)	Five years improvement +%
Taipei	Taiwan	61	83.9	2
Colombo	Sri Lanka	128	49.8	1.8
Bratislava	Slovakia	63	81.5	1.7
Phnom Penh	Cambodia	126	51.4	1.6

Source EIU: Most improved cities over the last 5 years

2.1 Limitations

What factors owing to the adaptation to climate abnormalities have been considerations for estimating liveability according to these indices? Which of these polls may be trusted; is all the research data standardized; who are the people included in the study; have some parameters been prioritized merely because of a positive correlation, rather than a strong statistical significance? There are no definitive answers to these questions, and therefore, more needs to be done in order to address the issue of liveability with regard to the negative effects of climate change. With Expo 2020 on the horizon, the need has never been greater.

2.2 Relationship Between Climate Change and Human Health

According to a report published by the International Labour Organization (ILO), about 90–95% of the workforce are construction labourers and domestic servants. Extreme weather conditions like soaring temperatures, which are byproducts of climate change, affect the blue-collar migrant construction labourers disproportionately, when compared to the white-collar workforce.

While climate change does not discriminate among lines of physical abilities, financial capabilities, age or gender; it, in fact, exacerbates existing inequalities and affects those with poorer adaptive capacities to both gradual climatic changes, and extreme shocks and stresses (gradual, sudden and extreme) unequally [3]. As the construction labourers' are exposed to long hours in the sun, they are therefore excessively vulnerable to heat-related sicknesses and illnesses, some of them life-threatening like the cancer of the skin. The Dubai chapter of the World Safety Organization (WSO) states that heat is the primary cause of illnesses construction workers face. Dubai's Rashid Hospital recorded a figure of 2500 heat-related hospitalizations per month in the year 2004 [4].

The UAE law requires workers to break during the hottest hours, but most of them remain at the job site due to the intervention of companies; and face risk for severe heat stroke and dehydration, often leading to hospitalization. As of recent years, the ILO, Build Safe UAE (BSU) and the UAE Ministry of Labour (MoL) have established benchmarks that regulate federal-level occupational health and safety for the construction sector [4].

3 Directed Approach to Climate-Efficient Design

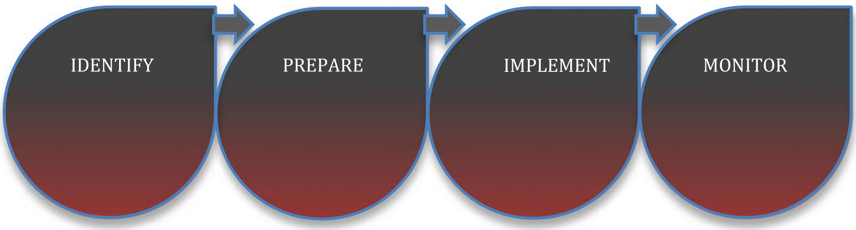

Fig. 1. Generic flow diagram of a Climate-Efficient Plan

According to the World Bank, Dubai is the emirate that is one of the world's largest consumers of energy per capita. This title is not a commendable one to hold. Renowned scientists on the IPCC attribute most of the observed increase in temperature ever since the mid-20th century to human activities, which they claim with more than 90% certainty [5]. The directed approach that needs to be taken to tackle the overarching issue of climate change cannot continue to be a business-as-usual approach. It should instead be a 4-pronged one that utilizes a Strengths Weaknesses Opportunities Threats (SWOT) method (as illustrated in Fig. 1), which begins by first **identifying** the areas that require attention or those that have a scope for improvement. This step also includes identifying vulnerabilities that may be natural, stemming from geography, or vulnerabilities that vary by the adaptive capacity of communities to accommodate and cope with their circumstances, which in turn depends upon level of wealth, governance typologies, and national and local institutional capacities [1].

Once that phase has been dealt with, the next stage involves the **preparation** of a Climate Readiness or Action Plan, which should incorporate a Climate Adaptation Plan or a Vulnerabilities Assessment Plan, both for the short-term and the long-term.

The third phase is the **implementation** phase. Adaptation towards designing for climate change, like retrofitting of existing buildings is a vital component of this process. In order for adaptation to be completely integrated into long-term planning, cities like Dubai, that fall within the MENA region—where community participation is often regulated by the broader political context—will have to welcome the decision-making process with open arms. By doing so, more community input and support for community-level adaptations will then become an indispensable part of efficient planning, especially among populations that are likely to feel the impacts of climate change [4].

This modus operandi should culminate in what is known as the **monitoring** phase, where assessments are conducted based on the progress of the steps that have already been taken.

3.1 Intrinsic Value of Public Participation

The public should get involved in all the phases. Feedback should be routinely collected through surveys, charettes, and interviews, and plans should then be designed by subsuming all the relevant suggestions. Their active involvement is an absolute must for the steady progress of this directed approach. Jules Pretty developed a typology of real world interpretations of terms that range from ‘passive participation’, where people are merely recipients of information about decisions that have already been made, to ‘self mobilization’, in which people take dynamic initiatives that are independent of the participation of external agencies [6].

3.2 Data Analysis: Interviews

To get a clear reflection of the way people (who hold different positions within companies) thought, a set of questions was administered. This, in turn, helped in the data collection aspect of the research project, which then furthered into an analytical study. A few of the questions (italicized) have been listed here (one-on-one, via email and by phone): *Solar power is definitely a resource of the future. Do you hold on to this theory?* There was a 100% consensus to the theory that solar power is, in fact, most definitely a resource of the future. *Do you consider oil to be non-renewable in nature? Why? Why not?* Some of the participants included in the study (mostly persons who had not passed Grade 5) had to be told what the exact meaning of renewable was. Once that was explained in a known language to them, between 90 and 95% of the respondents agreed to oil being a non-renewable resource. *As an esteemed professional in your field, would you be willing to invest in solar power for the benefit of future generations?* As was hypothesized, most of the persons who belonged to higher income groups answered with an emphatic yes!

3.3 LEED Team

A LEED (Leadership in Energy and Efficient Design) team should be formed from the very outset of designing a climate-resilient plan. As soon as a design idea is put to paper, members should be chosen on the basis of their sustainability credentials. Depending on the size of the project, a LEED team becomes absolutely necessary and may comprise of at least one individual who has the minimum qualifications of a LEED Green Associate. While the said idea is being brought into fruition, sustainability criteria will be assimilated into the plan, as and when required. With global societies like ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) setting standards for energy efficient, sustainable design through commitment and continuous research, building **smart** has not only become a very user-friendly option, it has also become an almost crucial component.

3.3.1 Sheikh Zayed Desert Learning Centre (SZDLC): A Case Study

Designed by Chalabi Architekten and Partner, the lead consultant, the SZDLC has been certified with the LEED™ Platinum Standard. It is veritably an edifice that can showcase how the cooling demand is reduced by intelligent architectural design. The building is partially submerged into the ground with an electric grid connection. All of the energy needs are being met through local generation or the energy is transformed as per energy consumption requirements [7]. As-Designed and Baseline models were assembled and simulated for a period of a year to determine the amount of primary energy required to meet the operational demands of the building. As was conjectured, the As-Designed model consumed 36.2% less energy than what was consumed by the Baseline model [7].

3.4 Role of a Champion and Importance of Professional Expertise

A champion or a team of leaders that can take control of the project from the very beginning up until the post-completion period can prove to be viable and beneficial to the workings of a climate-ready design. Professional expertise is key in making decisions, especially when representing the needs of the disadvantaged community [6]. The administrative lead or political head should see to it that everyone in the community, directly or indirectly affected by the plan, be included in the process. The challenges to inclusion should be tided over with the help of this champion(s) who looks into who the participants are, whose decisions are heard and whose suggestions actually end up influencing actual decision-making. Empty promises that benefit only a select few should be avoided and kept in constant check.

4 Application

Place-based initiatives that bring to the table the phenomenon of climate adaptation, instead of pure climate mitigation, must be recognized and promoted. Traditional Middle Eastern architectural marvels such as the wind tower should make a huge comeback. An associate professor of building physics at Leeds University in the UK, Ben Hughes noted that the CO_2 build-up could be reduced by appreciable amounts. This, in turn, will enhance the indoor air quality.

4.1 Microclimates: Building Design

First and foremost, existing physical infrastructure is largely overlooked and sometimes even ignored in terms of designing microclimates. Almost always, research regarding climate-resilient measures that may be introduced into the development of new projects is religiously conducted. A thorough study of refurbishing and retrofitting techniques that can be employed in old developments ought to be done. Innovations in sustainable design should most definitely be utilized, in new and old developments alike.

External building elements, such as shape, glass-wall ratio and orientation, along with internal heat gain techniques that encompass occupant activities, and dissipated heat from appliances and systems, are major parameters to a building's overall performance [8]. Terrace gardens can be designed once building load estimations are made, solar panels can be installed keeping in mind the angle and intensity of the sun's rays, and the orientation of the building.

A building colloquially known as the Oriental Crown or the China Pavilion, erected for the Shanghai 2010 World Expo, is another example that can be a true source of inspiration for designing Dubai's climate-resilient buildings. To lessen energy consumption levels, heat-reflective LOM-E glasses were affixed on doors and windows of the China Pavilion. Solar films with special coatings were adopted, that aided in converting sunshine into electricity, which ultimately provided energy for the lighting of the external wall [9].

4.2 Urban Macroclimates

There are seven major concepts, namely, compactness, sustainable transport, density, mixed land use, diversity, passive solar design, and greening, frequently associated with sustainable urban forms [10].

As urban surfaces play a huge part in altering urban macroclimates, attention needs to be paid to the utilization of energy-efficient materials. The albedo or reflectivity of urban surfaces is altered by the appropriate usage of surface materials [11]. These same surfaces have different abilities while absorbing, conducting and diffusing heat into the urban fabric, and varying capabilities while extracting the same out of the urban fabric [11]. The capacity of the storage heat flux is influenced by the types of surface materials, the general urban structure and the thermal mass associated with the above [11]. Flux refers to the net uptake or release of energy (per unit area and time) by sensible heat changes in the urban canopy's air layer, buildings, vegetation and the earth. When heat is being transferred into the building envelope in the mornings, the storage heat flux is typically larger, helping in increasing the energy available for long-wave radiative exchange [11].

Cities are typically sources of carbon dioxide, unlike vegetated areas where photosynthesis results in the uptake of CO_2 during day [11]. Flux peaks corresponding to heavy traffic are often found during rush hour periods in the early morning and late afternoons. It is here that the magnitude of the fluxes can be directionally modulated, and can be done with the aid of vegetation [11]. Especially on blistering summer days, irrigated grass situated next to a tarred or paved surface will result in advection [11]. Very high surface temperatures in urban areas are experienced, but temperatures are reduced as one moves away from surfaces (i.e., inside building cavities). Urban climates can be positively affected by providing opportunities for architects and planners to manipulate the energy exchanges through the thermal characteristics (material thicknesses and heat capacities) of built materials that take place both within and outside the building [11].

Urban Heat Islands or UHIs have to be adapted, if mitigation does not seem to be an easy alternative. Building materials like paints, and materials employed in the construction of roofs and walls that have higher albedos have been developed so as to minimize radiative loading on urban areas [11]. Also, larger height-to-width ratios would have to be maintained in order to produce lower bulk albedos for urban arrays, provided the surface materials are kept constant [11].

4.2.1 Life-Cycle Assessments

With a huge energy demand that involves huge amounts of fossil fuel consumption, the building sector is one of the biggest perpetrators of CO_2 emissions. Tools that quantify city emissions are essential not only to inform policy, but also to create awareness and build knowledge that allows for coherent future planning (which conforms to low carbon footprint targets) [8]. Performance evaluations conducted throughout the life-cycle of the project (including post-habitation) are not only to rate the building and system designs with respect to their performance, but also to reduce the energy need at the building consumer level [8].

As natural resources dwindle and energy costs rise due to huge investments in the built environment, the need to deliver low-energy buildings becomes all the more paramount. And so, promoting change across the life-cycle of the built environment requires an integrated approach and a plethora of policy instruments [12] (as shown in Fig. 2).

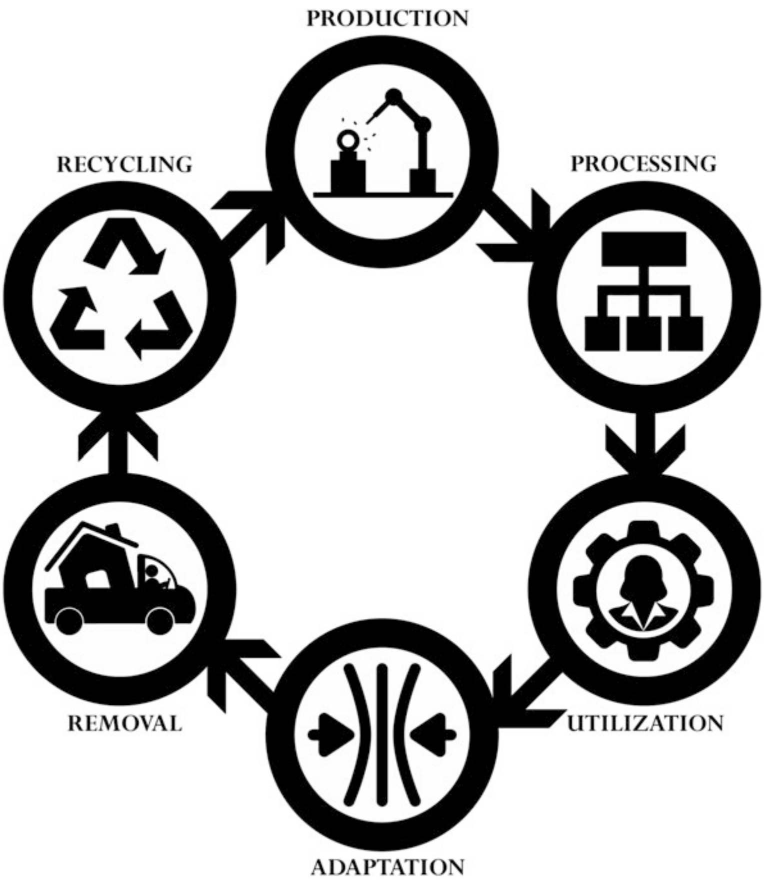

Fig. 2. Project impact on Life-Cycle of building

The Qatar National Vision 2030 (QNV 2030) is one to emulate, especially since it is part of a united vision of the Middle East; one that embraces four main pillars of whole-rounded development: economic, social, human and environmental well-being.

4.2.2 Effective and Efficient Transportation

The answer to 'whether one car for every two residents is a sustainable proposition' is a definitive no; both crystal clear and conclusive. A sense of increased accountability and responsibility is invoked in designers and planners these days, especially in terms of incorporating and advancing energy-efficient measures in upcoming development projects—amid concerns about the negative influences of climate change and carbon emissions associated with auto transportation.

Transit-oriented developments (TODs) should become the 'new normal'. This can and only will happen when attitudinal shifts arise. Workshops should be held highlighting its growing importance, both for the present generations and the generations to come. The focus of TODs should switch from car-centric designs to people-oriented ones. Long-distance, express trains powered by electricity from renewable sources ought to be considered as an alternative to air travel [12]. By curbing automobile usage, the problem is not half solved—different modes of public transportation must be made available and easily accessible. It is up to municipalities to provide these choices, and it is only then that the dependence on the automobile can be significantly reduced.

Dust naturally found in this desert-dominated region, commingled with local anthropogenic emissions associated with increased electrical consumption and automobile transit (byproducts of economic and population growth), owes to the creation of polluted dust. This considerably increases atmospheric heating, which is already at unbearable levels because of the intense solar radiation typically found here in the region [13]. All the same, Dr. Klaus Klingmuller, co-author of the aerosol optical depth study and a post-doctoral research fellow at the Max Planck Institute for Chemistry in Mainz, pointed out that statistical evidence highlighting the relationship of climate change to the increase in occurrence of dust storms is unclear because there are other factors at play [13].

4.3 Innovative Techniques, Research and Development

People should install an affordable, yet effective type of micro generative, energy-efficient system—in their homes, businesses and/or communities. These measures will reap benefits environmentally and economically. Governments and regional municipalities, energy companies, and entrepreneurs and policy-makers should take bold steps to encourage this investment in renewable energy [12].

Most importantly, investors from all walks of life must divest from fossil fuel and nuclear energy, and buy shares in renewable energy and energy-efficiency organizations [12]. This is easier said than done, but a step in the right direction is a big step in itself.

More market incentives have to be made available that encourage energy efficiency —such as varying rates of charges for cars and properties according to their efficiency levels; by reducing up-front purchase and usage charges on the most energy-efficient appliances [12].

Simultaneously, persons in the political circle need to be staunch supporters of renewable energy and energy efficiency, thus creating supportive legislation which builds investor confidence [12]. National legislation has to overcome the bias toward the energy status quo, through measures such as legally binding energy efficiency standards [12].

4.4 Benefits: Short-Term and Long-Term

Time and money, both undeniably crucial, can be saved. In many walks of life, where physical presence is not a must, internet and mobile phone transactions, can reduce travel. Employers (especially large corporations) must be supportive of homeworking, and international businesses should invest in videoconferencing and emerging communication technologies [12]. With this comes added health and social benefits, such as better air quality and general well-being.

4.5 Limitations

Since short-term energy-efficiency capital investments will be high, these investments must instead be converted into investments with payback periods, which will be beneficial in the long run (profits, both monetary and non-monetary in nature). Large sums of money will be needed to install renewable energy-generating stations on a massive scale, modernizing electricity grids, transforming public transit infrastructure and improving the energy efficiency of our existing architectural framework [12].

5 Timeline: Commitments and Achievements

In terms of meaningful, constructive analytical research and intervention, a lot more needs to be done regarding climate-efficient planning and design. All the same, the UAE has managed to make a mark by embarking on the road leading to the Climate Movement.

The UAE, in the year 2005, was one of the first major oil-producing countries to ratify the Kyoto Protocol to the UN Convention on Climate Change. The Government of Dubai issued a set of Green Building Regulations in 2011 for private sector construction in order to achieve 2 results at once—to reduce energy and resource consumption, as well as to improve public health and general welfare. The code was made mandatory for all new structures. Whether new projects followed these stringent rules in order to secure permission is yet to be seen. Here again, installations of monitoring systems becomes nothing less than pivotal. As of 2014, Dubai launched the "Smart City" initiative that spread its tentacles across six main areas; transportation, infrastructure, communications, financial services, urban planning and electricity, with the primary focus on transforming thousand government services into smart ones. This strategy was put into place to lay out steps toward optimizing energy, introducing smarter transport and incorporating recreational areas [14]. Just last December, during the COP21 United Nations Climate Change Conference, the UAE also affirmed its plan to generate 24% of its electricity from clean energy sources by 2021. On the other hand, Abu Dhabi, UAE's capital, has committed to more than 15 billion USD worth of renewable energy programs through the Masdar Initiative [14]. Masdar is a pioneering effort that has been framed for the development and commercialization of technologies in renewable energy, energy efficiency, carbon management and monetization, and water usage and desalination. Reflecting the UAE's commitment to sustainability, IRENA (the International Renewable Energy Agency) laid its foundations by setting up its permanent headquarters in Abu Dhabi's Masdar City in June of 2015.

6 Conclusion

As Margaret Mead, the famous American anthropologist said, "We won't have a society if we destroy the environment." As responsible members of the society that we live and partake in, it becomes our responsibility to take this formidable challenge upon ourselves to build a sustainable world for the children of the future.

Aesthetic architectural grandeur can be intertwined with technological eco-prowess of traditional architecture to create landmarks that will stand the test of time. They will be sustainable in the long run by employing concepts of sustainability and green design. Urban design should inculcate a sense of belonging in all of us, whichever income group, creed or gender we belong to.

Climate change is a pressing issue that cannot be grappled with folded arms; the sooner we realize that, the better. As time waits for no man, the changes that climate brings with it will alter our way of life, and may sometimes strike without warning. A lot of the damage is already done; so, prevention by climate mitigation alone is not the answer. Being prepared to face such circumstances head-on by using climate adaptive methods is an absolute necessity. Dubai needs such people to support, advocate for and create awareness among every consumer, big or small.

As the unsung heroes of Dubai toil every minute of every day to make the city the way it is, it automatically becomes our responsibility to see to it that their dreams are realized by creating conducive, congenial environments that harbours their physical and mental wellness.

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Transition from Conventional to Sustainable Production: A Case Study in OSTIM Organized Industrial Zone

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Abstract. Organized Industrial Zones (OIZ) are places for manufacturing of goods and provision of services, established and operated in accordance with the provisions of the Ministry of Science Industry and Technology of Turkey. The process input-outputs and their environmental impacts are ignored in conventional OIZ's. However, global conditions of competition have changed today and manufacturers need to consider the economic, ecologic and energy factors, reuse of products and raw materials, recovery of waste and the efficient use of all resources. They have to focus on cleaner production (CP) for being competitive in market. As a case study, 10 Small and Medium Sized Enterprises (SME) which are producing in different areas like rubber, metal working, galvanized coating, and casting were chosen. In each company, flow charts were analyzed, inputs and outputs were identified. Raw materials, chemicals, water and energy were taken as inputs. Since there was no continuous production in each company, all parameters were considered annually. All data was benchmarked with Eco-Invent database to make suggestions for clean production to each company. After cleaner production analysis, it was tried to reveal possible symbiotic relations between companies. After all analysis, data showed that energy efficiency based industrial symbiosis (IS) is more possible and efficient than waste-raw material exchange. Based on this, by creating a virtual eco industrial park, possible scenarios for the realization of industrial symbiosis were prepared. Examining the best practices of eco-industrial parks in the world, an eco-industrial virtual park was designed for OSTIM OIZ for sustainable environmental friendly production.

Keywords: Sustainable production · Organized industrial zones
Clean production · Industrial symbiosis · Circular economy

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1 Introduction

Sustainable development was firstly mentioned in Brundlant Report which is also known "our common future" on 1987 [1]. According to this report sustainable development is defined "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Industrial ecology is the system of materials and energy flows through industrial systems. It is defined firstly by Frosch and Gallopoulos [2] and they believed that industrial system should behave like an ecosystem, where the wastes of some industries can be used as a resource of other industries. With other words, for industrial ecosystem there is no waste for any processes and there will be no environmental impact at the end of processes. Sustainable development based on industrial ecology. Industrial ecology is not only based on linear production system where raw material-product- byproduct or waste, but also it is a circular system where waste products can be used again as a raw material or energy for another processes.

Today, basic approach to sustainable development and the environment is based on the idea of protecting nature and establishing a balance between protection and use.

2 General

Industrial symbiosis engages with different traditionally unrelated industries in physical exchanges of materials, energy, water and by-product. Creating and sharing knowledge through the network yields mutually profitable transactions for novel sourcing of required inputs, value-added destinations for non-product outputs, and improved business and technical processes.

For being an eco-industrial park (EIP), there are three dimensions that have to be acquired which are; environmental, economic and social aspects. Human relations and cooperation is the most important part of this kind of parks. In an EIP, all the businesses cooperate with others to reduce waste and pollution with the aim of sustainable and economic developments by sharing resources efficiently. Members seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues. EIP has seven main principals; natural sources, energy, material flow, water flow, EIP management and joint services, sustainable design and construction and community [3].

Kalundborg is the world's first working industrial symbiosis model since 1970s. The Kalundborg Symbiosis is an industrial ecosystem, where the by-product residual product of one enterprise is used as a resource by another enterprise, in a closed cycle. An industrial symbiosis is a local collaboration where public and private enterprises buy and sell residual products, resulting in mutual economic and environmental benefits. In the development of the Kalundborg Symbiosis, the most important element has been healthy communication and good cooperation between the participants. The symbiosis has been founded on human relationships, and fruitful collaboration between the employees that have made the development of the symbiosis-system possible [4].

OSTİM was established in 1967 as a cooperative. It constitutes the starting point of industrialization in Ankara. OSTİM is located Capital Ankara in the west, over 5 million m2 of installation, compatible with easy access to the city is an industrial city and surrounding tissues. It has 139 different businesses in the region. There are 60,000 employees in 17 main sectors employed in 5200 SME's. The common sectors are; machining, electro and electronics, metals and metal processing, plastics, rubber, composite materials, painting, plating, heat treatment. OSTIM companies in Turkey and the main industrial companies in the industry leading position in the world are providing service to public institutions. OSTİM OIZ has gained status in 1997. OIZ Directorate of the region, realizing all infrastructure and superstructure services in the region are increasing companies' competitiveness in the activities (Fig. 1).

Fig. 1. Scene from OSTIM

As an OSTIM directorate, future vision is transforming conventional industry park (CIP) to a sustainable industry park (SIA). According to this vision, starting point is to increase the awareness of SMEs about environment and sustainability. In order to transform from CIP to SIA, we have to focus on three dimensions which are environmental, economic and social aspects. Many topics related to sustainability are already apart of business processes in the companies. Companies must not only cope with their economic tasks as social environmental issues can cause risks. Experiences show that sustainable addressing of social and environmental issues leads to economic advantages such as cost savings. In scope of this vision OSTIM OIZ management needs to carry out some projects to find the way of transforming.

3 Methodology

In scope of this work, ten different companies, which have different types of flows, were chosen from OSTİM for analysis. In order to roadmap, their flows were analyzed for defining inputs and outputs. The possible relations were defined between these ten companies. The joint resource was detected. Thus energy efficiency oriented symbiosis is feasible for these companies. It's created as energy efficiency based virtual eco industrial park for OSTIM with these companies [5]. For this study, assumptions are given as;

- The model is based on regular production which means that every industry has continuous production.
- All quantities for metal raw material are expressed in kilograms.
- All energy consumptions are expressed in kWh.

A tool, which was developed by OSTİM and project partners in scope of ECOMAN INDUSTRY Project [6], was used in this study. By using this tool, a data set was defined as shown in Fig. 2. This data set includes flow management, process management, equipment management, product management and component management. Within this tool each company has their own page which includes data about company itself and process as shown in Fig. 3. We can define cleaner production potential via this tool. We put the consumption to the tool which is shown in Fig. 4 and we can scope CP potential.

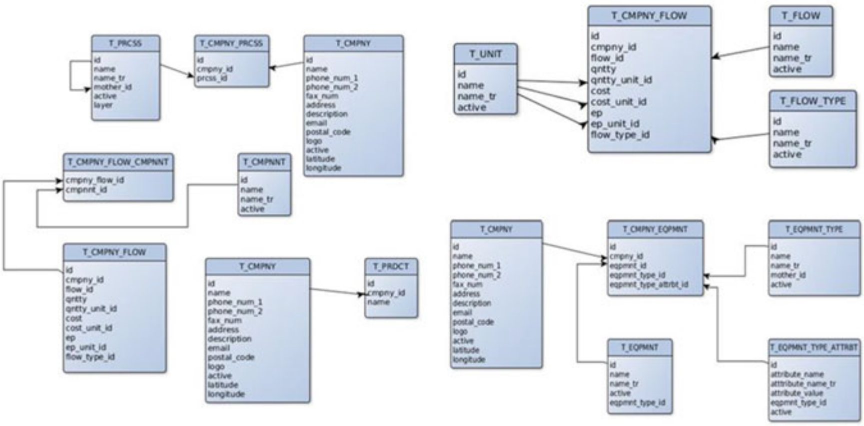


Fig. 2. Data set database table relationship diagram

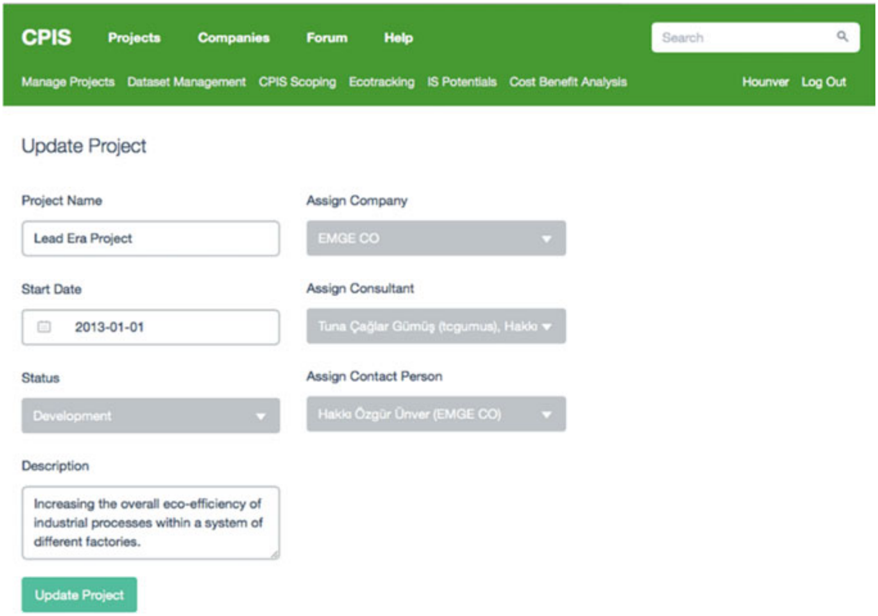
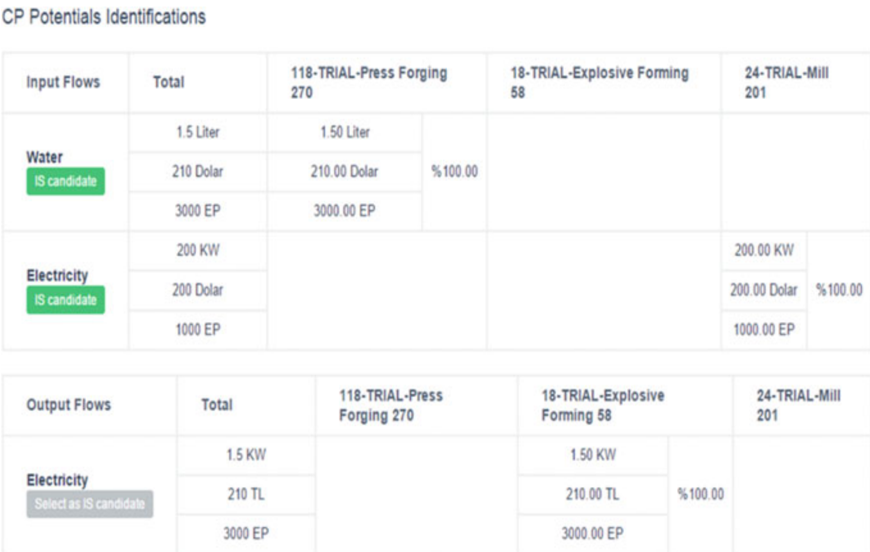


Fig. 3. Company data page


CP Potentials Identifications

Input Flows	Total	118-TRIAL-Press Forging 270		18-TRIAL-Explosive Forming 58	24-TRIAL-Mill 201	
Water IS candidate	1.5 Liter	1.50 Liter	%100.00			
	210 Dolar	210.00 Dolar				
	3000 EP	3000.00 EP				
Electricity IS candidate	200 KW				200.00 KW	%100.00
	200 Dolar				200.00 Dolar	
	1000 EP				1000.00 EP	

Output Flows	Total	118-TRIAL-Press Forging 270	18-TRIAL-Explosive Forming 58		24-TRIAL-Mill 201
Electricity Select as IS candidate	1.5 KW		1.50 KW	%100.00	
	210 TL		210.00 TL		
	3000 EP		3000.00 EP		

Fig. 4. CP scoping

System display in a normalized portfolio graph, shown in Fig. 5, the sum of the costs (x-axis) and the sum of the environmental impact (y-axis) for each process. The process with the highest cost and the process with the highest cost will aligned right. But, this graph can only be created if the user has entered the environmental impact of the flows.

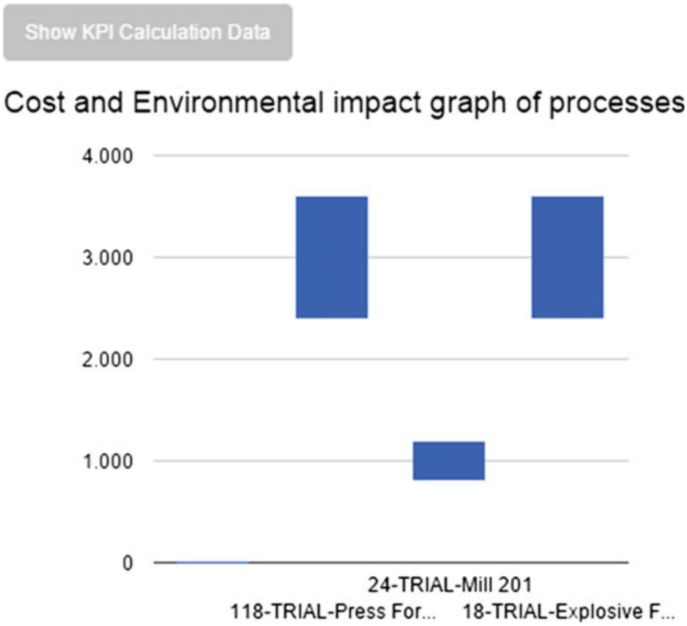


Fig. 5. Cost and environmental impact

Within the chosen companies for this study, for instance the company which produces rubber materials, general workflow was given in Fig. 6. To make improvement for clean production and reduce costs for the company focus point should be production processes. Because of this, annual inputs and outputs were given in Fig. 7. If this company can reduce costs for this mass balance, piece work basis costs will reduce and this company can be more competitive. On the other hand, for industrial symbiosis approach, this company can use heat for molding and hot press from another company's waste heat. According to these relations, industrial symbiosis can be realized between 10 companies.

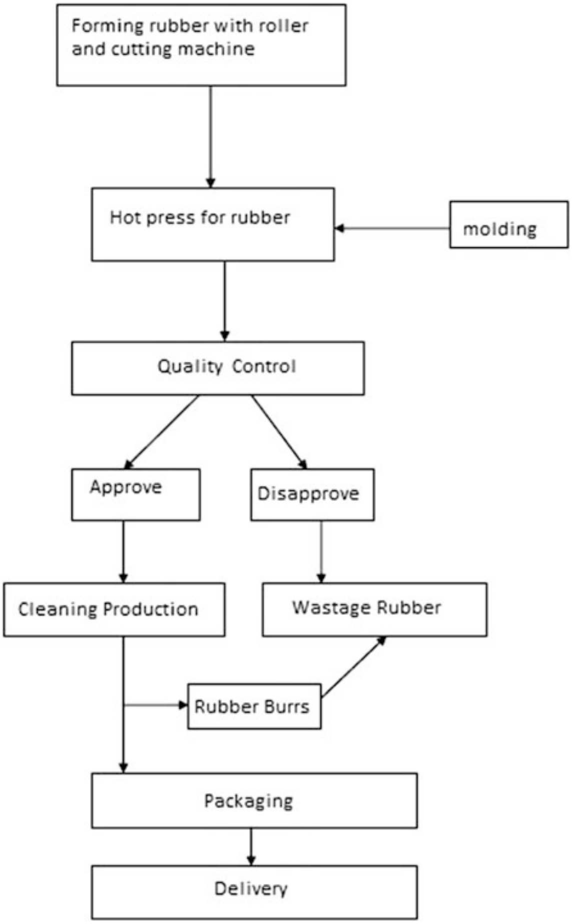


Fig. 6. General workflow for the rubber company

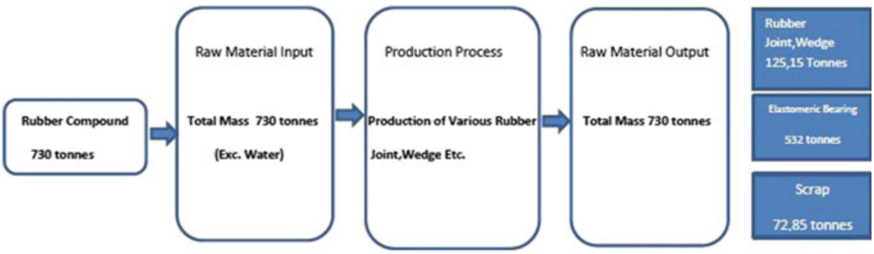


Fig. 7. Rubber compound mass balance

For all different process work flows, mass balance and all materials (water, electricity etc.) were defined and analyzed. IS scoping tool has two tables: first one presents the listing all existing companies and total quantity of every flow category and the other one presents listing all flow categories saved in the database as shown in Fig. 8.

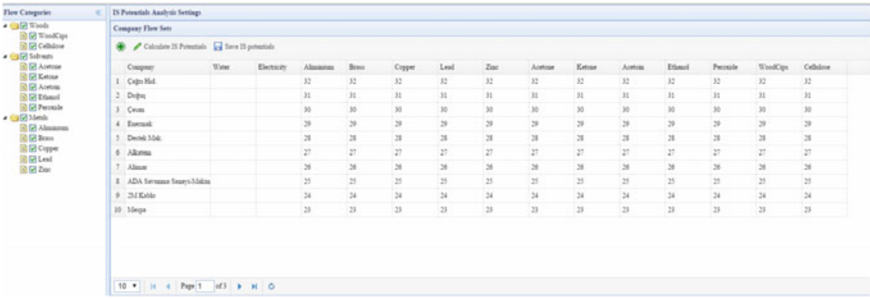


Fig. 8. IS potentials analysis settings

After selecting a flow and a company by pressing "Calculate IS Potentials" button, system displays a dynamic table with IS potentials as shown in Fig. 9.

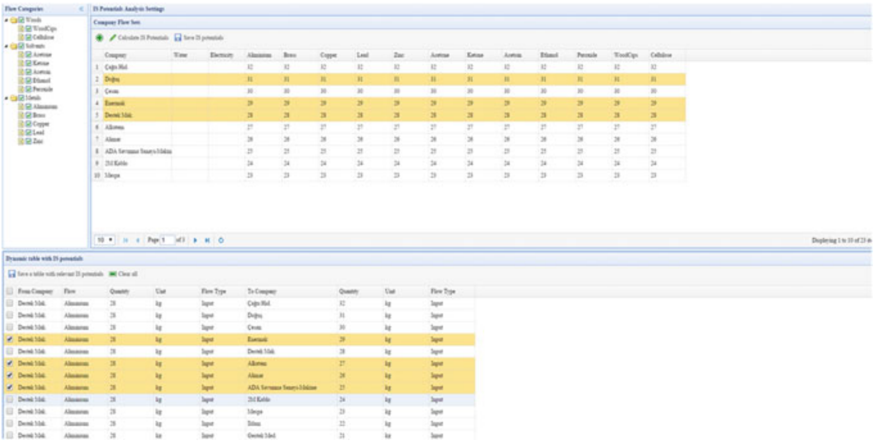


Fig. 9. Calculated IS potentials

4 Discussion and Conclusion

In this study, processes in each company were analyzed. Some suggestions were prepared for increasing efficiency. On the other hand, joint consumptions were detected. Thus, virtual eco industrial park model was based on energy efficiency applications. For the selected companies, manufacturing processes were; machining, rubber technologies, galvanized coating and casting. For each process, each company was analyzed and annual inputs and outputs were defined. Machining process' inputs are; energy (electricity, heat and cooling), metal sheet. Outputs for the same process are; metal chips, waste heat and in small quantities of boron oil.

On the other hand, the inputs for rubber technologies processes are; metal sheet, compound rubber, water, energy. The outputs for the same process are defined as metal chips, rubber waste, hydraulic oil, contaminated waste, packaging waste. Finally, the inputs of the galvanized coating processes are; zinc, silver metal, flux, lead, aluminum, hydrochloric acid, water and energy, whereas the outputs are; acid, waste water, base, solvent, zinc ash and waste heat.

For each process energy efficiency and clean production aspects were considered. The increase in energy efficiency in industrial symbiosis is more efficient than the material exchange. As an example, for efficient use of energy, waste heat of galvanized coating process in one company can be used for heat treatment processes of other companies' production. For conventional production systems, piecework based costs are important. However, for circular economy, sustainable production, inputs, outputs, by-products are valuable contributions of the process. Sustainable development can be achieved via circular economy with social, economic and ecologic aspects. Global competition conditions are changing with the new world system. For building strong and sustainable production systems, source efficiency is the most important point in order to reduce production costs. Due to UN's 17 Sustainable Development Goals, the aim is to make the world a better place to live in the future [7]. Industry has a greatest share in polluting the environment, therefore this leads industrialists to become more responsible stakeholders for the environment. As a conclusion, transition from conventional to sustainable production is a very hard period, but world needs this transition.

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Effect of Height and Water Table Level on Stability Analysis of Embankments

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Abstract. Slope stability is one of the important analysis not only human being and economic issues but also environmental and sustainability aspects as well. There are analysis softwares available to search factors of safety calculations as well as stabilization methods. Slide is one of the most comprehensive slope stability analysis software available, complete with finite element groundwater seepage analysis, rapid drawdown, sensitivity and probabilistic analysis, and support design. All types of soil and rock slopes, embankments, earth dams, and retaining walls can be analysed. In this study, effects of groundwater level is investigated in terms of stability analysis of embankments and earth fill barriers. Embankments and earth fill barriers are constructed on soft clay soil materials. Different scenarios and input parameters are used in the analysis. Embankment and earth fill barriers slope, shape and geometries are taken from according to Directorate General of Road Transport Regulation. Factors of safety are very variable due to changing groundwater locations.

Keywords: Slope stability · Embankment · Factor of safety

1 Introduction

Slope stability is an important field of geotechnics, which is of particular interest to many soil scientists and technologists responsible for soil management and engineering. The idea is to have a means of predicting the balance of actions which are responsible in disturbing or restoring the equilibrium of a given soil (or rock) produced mass, with a given specific geometry and properties. Significant effort has been made in proposing formulae in an attempt to model and predict a "Factor of Safety" (FOS) analytically for man-made and natural slopes.

The most common method of determining the stability of slopes is to use limit equilibrium in order to estimate the FOS at the most critical set of conditions. This objective is attained through a two-step procedure [1]:

- assuming a potential slip surface, and
- applying the limit equilibrium equations and solving the FOS for the soil mass defined by this surface (i.e., the ratio of the stabilising force to the disturbing force or, the stabilising moment to the disturbing moment).

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For simple homogeneous soil, experience indicates that the shape of the slip surface can be idealised as a circle [2]. Circles are convenient and popular for analyses and often approximate to the observed failure surface. However, non-homogeneous problems or complicated geological conditions may require consideration of slip surfaces of non-circular shape.

Assumptions are needed to implement the limit equilibrium equations, since the slope stability problem is statically indeterminate. There is a wide range of possible static assumptions made in order to enable the methods of analysis to be statically determinate.

Limit equilibrium methods are the most widely used in slope stability investigations, although they have a great deal of mathematical calculations needed for the iterations to evaluate a FOS. Some of the most important characteristics of these methods are the inclusion of the pore pressure effect and the calculation of the interslice force in the FOS calculations. Experience shows that these methods can be useful in practise [3–5].

In this study, different soil parameters are used for road subbase foundation as well as taking consideration different physical properties of slope angle and height. All those cases investigated sudden loss of pore water pressure in different embankment scenario with considering static situation.

2 Limit Equilibrium Methods of Analysis

In limit equilibrium methods it is assumed that the slope will slide by a mass of soil sliding on a failure surface. At the moment of failure, the shear strength is fully mobilised all the way along the failure surface, and the overall slope and each part of it are in static equilibrium [5, 6]. Graham [7] stated that the term limit equilibrium is applied to a system of forces, which are just on the point of failing.

The shear strength of the soil is given by the Mohr-Coulomb failure criterion;

$\tau = c_u$ (for total stress analysis), or

$\tau = c' + \sigma' \tan \phi'$ (for effective stress analysis),

where τ is stress, c_u is un-drained cohesion, σ' is effective normal stress and ϕ' is effective frictional angle.

2.1 Factor of Safety

Factor of safety (FOS) is the most widely used index of stability. It may be determined as the proportion of the total force available to resist failure to the total force tending to cause failure. This can be shown as;

$$FOS = \frac{\sum Resisting\ force}{\sum Disturbing\ force} \tag{1}$$

When the total resisting force is equal to the total disturbing force, the slope is in equilibrium and $FOS = 1$. Nevertheless, the slope may fail under the effect of any amount of disturbing actions (loading). Generally, the acceptable FOS for slope stability may vary from organisation to organisation. However, many of them utilise values of 1.2–1.3 for short term, less important slopes and 1.4–1.5 for important long term slopes.

Movements of soils and rock masses may occur under the influence of body forces, e.g., gravity and seismic acceleration. When the disturbing action exceeds the available shear strength of soil on a sloping ground, the latter may become unstable. The resulting mass slide can be serious in damaging properties with potential loss of life. In unpopulated areas failure may only have a small effect, simply being part of the natural deterioration of the earth's surface.

3 Slide Slope Stability Analysis Software

Slide is the most comprehensive slope stability analysis software available, complete with finite element groundwater seepage analysis, rapid drawdown, sensitivity and probabilistic analysis, and support design. All types of soil and rock slopes, embankments, earth dams, and retaining walls can be analysed. State of the art CAD capabilities allow you to create and edit complex models very easily. It is the only slope stability software with built-in finite element groundwater seepage analysis for steady-state or transient conditions. Flows, pressures and gradients are calculated based on user defined hydraulic boundary conditions. Seepage analysis is fully integrated with the slope stability analysis or can be used as a standalone module.

Slide has extensive probabilistic analysis capabilities that one may assign statistical distributions to almost any input parameters, including material properties, support properties, loads, and water table location. The probability of failure/reliability index is calculated, and provides an objective measure of the risk of failure associated with a slope design. Sensitivity analysis allows you to determine the effect of individual variables on the safety factor of the slope [8].

3.1 Embankment Characteristics

In this programme, Factor of Safety results are obtained for the case of static situation according to Republic of Turkey-General Directorate of Highways Technical Specification (i.e., FOS = 1.5). There are two type of road subbase used for foundation soil namely stiff soil and soft soil. Soft soil fill and semi stiff fill soils are used for embankment. Soil parameters as cohesion, internal friction angle and unit weight are given in Table 1. The embankment slope angle are taken as 34°, 45° and 60° [9].

Table 1. Strength parameters for embankment

Type of fill	Cohesion, c (kN/m^2)	Unit weight, γ (kN/m^3)	Internal friction angle, ϕ (°)
Soft fill	5	17	20
Semi-stiff fill	5	19	30

A typical embankment design used for this research is shown in Fig. 1. The embankment head wide is 23 m and it's designed two double return ways. The height of 3, 4, 5, and 6 m are taken for different and the slopes are designed 34°, 45°, 60°. The foundation height is given 10 m (see Fig. 1).

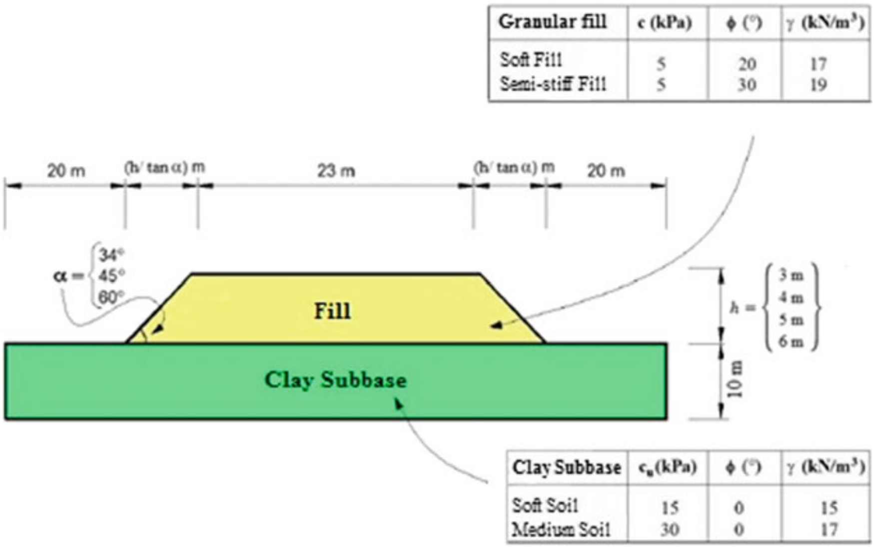

Fig. 1. Embankment fill and it's foundation

3.2 Road Subbase Soil

Two different soil parameters are used for road subbase materials namely soft and medium soil. For clay type of soil, the critical state is un-drained condition so that un-drained parameters are taken for analysis. Hence, the clay soil is fully saturated and therefore internal friction angle is zero (ϕ = 0°). Other parameters are shown in Table 2.

Table 2. Road subbase soil parameters

Type of fill	Cohesion, c (kN/m^2)	Unit weight, γ (kN/m^3)	Internal friction angle, ϕ (°)
Soft soil	15	15	0
Medium soil	30	17	0

4 Results of Analysis and Discussions

Spencer method [10] is used for the analysis. As well known, it takes into account both force and moment equilibrium. The static case analysis is given in Table 3 for the first trial angle of 34° of embankment slope which is created for different scenario to analyse and to have safety factor. As clearly seen in Table 3, when one increases the height of embankment gets the lower factor of safety values as expected.

Table 3. Different embankment height and fill materials for 34° angle of embankment slope

Embankment height (m)	Water table level	Medium clay soil-soft fill	Medium clay soil-semi stiff fill	Soft clay soil-semi stiff fill	Soft clay soil-soft fill
3	0 m (water level at base)	1.525	1.879	1.437	1.587
	1 m	1.504	1.816	1.715	1.730
	2 m	1.771	2.049	2.154	2.037
4	0 m	1.334	1.680	1.088	1.199
	1 m	1.287	1.615	1.240	1.372
	2 m	1.367	1.680	1.446	1.557
5	0 m	1.211	1.557	0.879	0.962
	1 m	1.161	1.502	0.972	1.077
	2 m	1.186	1.508	1.089	1.222
6	0 m	1.127	1.424	0.738	0.811
	1 m	1.085	1.429	0.803	0.885
	2 m	1.114	1.411	0.879	0.981

The second case is 45° angle of embankment slope. The parameters are same for all the cases. Similar trend is also obtained for this case as increasing the height of embankment decreasing the safety factor obtained (Table 4). Especially low factor of safety values are obtained for soft type of soil and fill materials.

Table 4. Different embankment height and fill materials for 45° angle of embankment slope

Embankment height (m)	Water table level	Medium clay soil-soft fill	Medium clay soil-semi stiff fill	Soft clay soil-semi stiff fill	Soft clay soil-soft fill
3	0 m (water level at base)	1.253	1.503	1.432	1.250
	1 m	1.266	1.503	1.521	1.266
	2 m	1.489	1.689	1.689	1.489

(*continued*)

Table 4. (*continued*)

Embankment height (m)	Water table level	Medium clay soil-soft fill	Medium clay soil-semi stiff fill	Soft clay soil-semi stiff fill	Soft clay soil-soft fill
4	0 m (water level at base)	1.079	1.330	1.081	1.080
	1 m	1.067	1.314	1.228	1.068
	2 m	1.147	1.370	1.422	1.145
5	0 m (water level at base)	0.973	1.223	0.869	0.956
	1 m	0.956	1.204	0.963	0.960
	2 m	0.988	1.219	1.08	0.983
6	0 m (water level at base)	0.898	1.145	0.728	0.798
	1 m	0.885	1.128	0.793	0.876
	2 m	0.890	1.127	0.867	0.963

The third case is more steeper slope to analyse as keeping the material properties are same. Factor of safety values started decreasing even 4 m height of slope (Table 5).

Table 5. Different embankment height and fill materials for 60° angle of embankment slope

Embankment height (m)	Water table level	Medium clay soil-soft fill	Medium clay soil-semi stiff fill	Soft clay soil-semi stiff fill	Soft clay soil-soft fill
3	0 m (water level at base)	1.007	1.166	1.166	1.007
	1 m	1.043	1.209	1.207	1.043
	2 m	1.223	1.346	1.346	1.221
4	0 m (water level at base)	0.851	1.016	1.041	0.851
	1 m	0.867	1.025	1.025	0.867
	2 m	0.927	1.081	1.080	0.927
5	0 m (water level at base)	0.758	0.927	0.863	0.758
	1 m	0.760	0.932	0.928	0.760
	2 m	0.795	0.952	0.952	0.795
6	0 m (water level at base)	0.696	0.855	0.722	0.696
	1 m	0.695	0.855	0.788	0.695
	2 m	0.712	0.867	0.861	0.712

The results show that increasing the embankment height clearly result the low factor of safety values for different embankment height, fill and subbase materials. As embankment construction is vital for road building activities, one have to be very careful for embankment design procedure.

5 Conclusion

Many different types of soils may be suitable for use in the construction of an embankment or fill, ranging from granular soils (sand and gravel), which are highly desirable, to the more finely sized soils (silt and clay), which are usually somewhat less desirable. Certain types of soils (such as saturated clays and highly organic soils) are considered unsuitable for use as materials in embankment or fill construction. Regardless of the type(s) of soil(s) used to construct embankments or fills, the material should be well graded, capable of being well compacted, be within a proper range of moisture to optimize compaction, and be free of unsuitable or deleterious materials. The results obtained from this study are:

1. Material properties of fill and constructed embankment fill on top of road subbase are very important in terms of slope stability analysis. In this analysis different scenarios are designed to investigate some effects on the factor of safety calculations. Medium clay soil-semi stiff fill scenario gives higher safety factor then medium clay soil-low bearing capacity fill and soft clay soil-low bearing capacity fill.
2. Embankment fill height is also important factors for factor of safety calculations. As increasing the height of embankment, the lower safety factors are obtained.
3. Embankment slope is also one of the factors that affecting the factor of safety calculations as well. As increasing the slope angles give the lower safety factor.
4. Water level plays very important role for the factor of safety as well. For the low water table level behaves as loading on slope toe and therefore it slightly increases the safety factors.

   Road embankment construction activities are important as the handling of embankments depends upon a knowledge of the material types that will be encountered in cuts or borrow and the construction control that may be exercised.

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Sustainable Urban Conservation and Management of Historical Areas. Come Back to Thirty Five Years (1981–2016) of Observation in Fez Medina, Morocco

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Abstract. Urban conservation has been a subject of academic and professional discourse for over three decades. In Fez medina, urban conservation is linked to urban redevelopment and thereby represents a significant component of urban design with respect to sustainability. The best practice and the constraints and difficulties of the Fez medina sustainable conservation are addressed in this paper, based on observation and a system dynamic approach to describe and analyze the urban heritage safeguarding process, its stages and components during the last thirty-five years. The overall rehabilitation strategy for this historical area is to alleviate the constraints through a sustainable conservation program, especially the historic housing stock, the social development, the historic monuments and the urban environment including the architecture heritage, which could not be launched without seeking adequate tools (institutional, financial and technical) for its implementation. ADER-Fez, the Agency for the Dedensification and Rehabilitation of Fez Medina, places stakeholder participation at the core of its implementation strategy, including social animation and social participation in housing rehabilitation, and sets a program of emergency intervention on historic monuments and buildings, housing units threatening collapse and on infrastructure and urban facilities, with two concerns: the safety of the human lives and the safeguarding of cultural heritage and traditional constructions of architectural quality adapted to the requirements of modern life.

Keywords: Conservation · Safeguarding · Architecture heritage
Rehabilitation

1 Introduction

The medina, historic urban area, is the oldest section and the historic heart of some Moroccan cities (31 medinas as shown in Fig. 1). Various international bodies have instituted policy to save historic monuments and even entire cities: The Global Charter of Historic Cities adopted by ICOMOS in 1987, the 1972 adoption by UNESCO of a convention to protect built and natural history, both include Morocco's medinas in their scope of preservation. In the 1980s UNESCO acknowledged the cultural significance of several old towns in Morocco by including them in the UNESCO world heritage list.

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These medinas are not only a physical environment composed of inhabitants and places of activities, but they are also a social space characterized by historical, cultural and spiritual values. The way of life and the social traditions are the reflections of civilization, which appears even in design, constructions and space organizations.

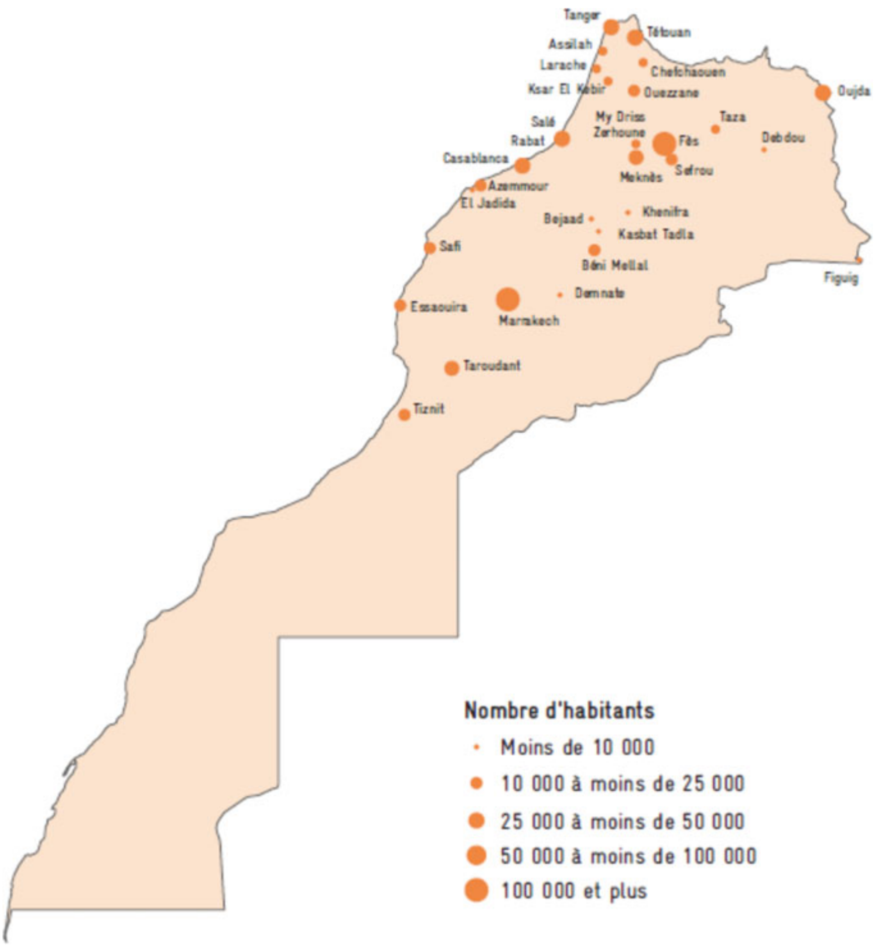

Fig. 1. Moroccan medinas: geographical localisation and population

Fez medina, founded in the 9th century, first reached its flourish in the 14th century under the Marinides and again in the 17th century. It was an example of this type of the urban space organization until the colonial period. Moreover, its urban space was the result of a slow and "integrative" evolution of an urban and architectural production adapted to the needs of the community and to a framework of life with its principal components: habitat, equipment and activities.

Fez, a World Heritage City, is the spiritual, scientific, and cultural capital of Morocco. The importance of its medina is reflected through several factors:

- a vast geographical area: 300 ha;
- a dense medina: 800–1200 persons/ha;
- a large number of historic buildings: 14,000 of which 50% are in good state, 34% are degraded, 14% are threatening ruin or are at risk of collapse, and 2% are in ruin [1];
- a large number of historic monuments (about 3000); 11 madrasas, 43 koranic schools, 176 mosques, 83 zaouias and mausoleums, 117 foundoks or caravansaries;
- a historic university which is considered as one of the oldest universities in the Islamic world: the Al Qarawiyine.

Few years ago, Fez medina offered a striking contrast between areas of thriving economic activity and over-densified residential quarters whose buildings are deteriorating steadily: A cultural heritage and monumental of an exceptional richness, and a degraded historical built environment. The medina is today a major economic centre for the whole urban agglomerate of Fez [2]; its economic sectors are artisanship and tourism. However, this richness does not seem to profit with its population, nearly 160,000 inhabitants, 36% of whom are below poverty level.

The most serious problems of Fez medina included the deteriorating residential zones, the degradation of the infrastructures, the transformation of traditional handicraft activities into partially mechanized small-scale manufacturing, the significant number of low-income households, the complex property ownership and occupancy patterns, and the environmental pollution. In front of that situation, the Moroccan public authorities, supported by an international momentum of solidarity, made safeguard of Fez medina a national priority.

Fez Medina is then subject to an extensive rehabilitation program which started in the year 1981 and runs over thirty years; The safeguard program aims at restoring and preserving the economy, cultural value, and social heritage of the old city.

The paper is based on observation and a system dynamics approach to describe and analyze the urban heritage safeguarding process during the last thirty-five years in order to identify the best practice and the constraints and difficulties of the Fez medina sustainable conservation.

2 The Safeguard Process of the Fez Medina, Its Principal Stages and Components

The overall rehabilitation strategy for the Fez medina is to alleviate the above constraints through a conservation program which could not be launched without seeking adequate tools (institutional, financial and technical) for its implementation. The process of safeguard began from the production of the first urban document, the urban planning orientation scheme of the Fez city (SDUF, Schéma Directeur d'Urbanisme de Fès) which underlined the importance of the medina in the development of the whole of the Fez agglomeration [3]. The first period of the safeguard process from 1980 to 2005 can be divided into 3 principal stages.

2.1 First Stage (1980–1989): Launching of the Safeguard Process of Fez

In 1981, the medina was classified by UNESCO; then the Moroccan government and UNESCO launched in 1985 the international campaign for the Fez medina safeguard. In 1989, the government created ADER-Fez, the Agency for the Dedensification and Rehabilitation of Fez Medina, a new institutional framework to implement the strategic projects for the medina. ADER-Fez is now an agency specialising in the conservation and rehabilitation of the world heritage city of Fez; it has accumulated a long and valuable experience in intervening on the historic fabric of the Fez medina through various local and international initiatives.

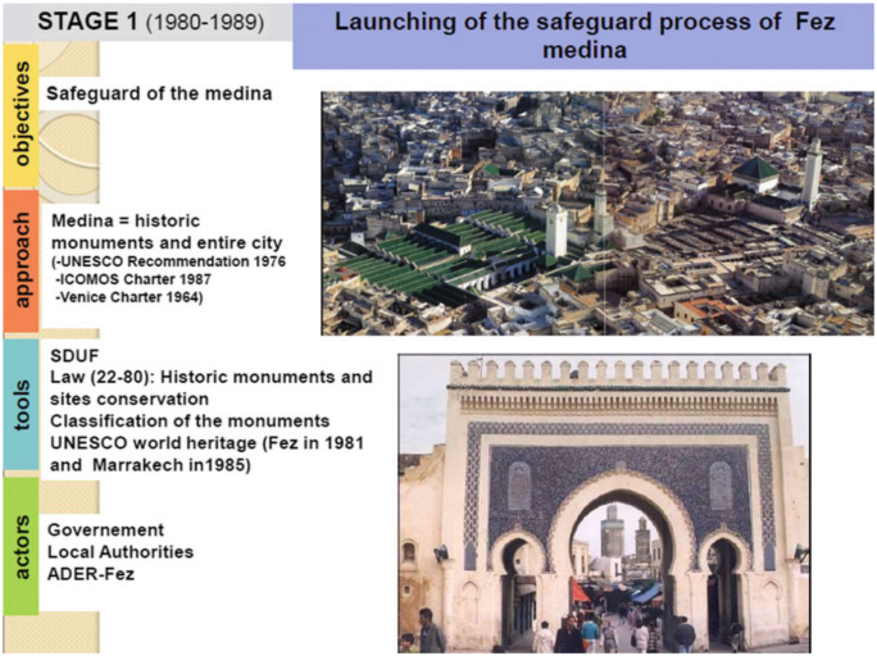

Fig. 2. Stage 1 (1980–1989) of the safeguard process: objectives, approach, tools and actions

2.2 Second Stage (1990–1998): Phase of Deepening and Experimentation

All aspects of the safeguard have been deepened through the examination of the technical, institutional, legal and financial components. This period was also characterized by the realization of the experimental operations: restoration of the monuments, rehabilitation of the houses and the urban facilities, etc. Local capacity to plan and carry out the various project components have been strengthened trough the elaboration of the master plan, the improvement in the field of the restoration and urban rehabilitation, and the implementation of some management tools: GIS, a comprehensive Geographic Information System, linked with planning and cost estimate tools, to support supervision of the rehabilitation project.

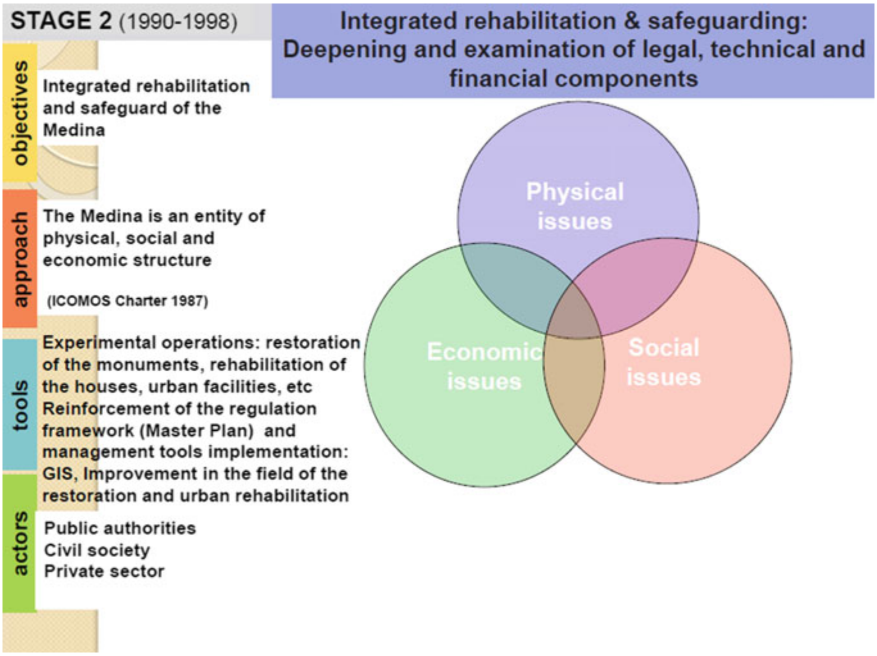

Fig. 3. Stage 2 (1990–1998) of the safeguard process: objectives, approach, tools and actions

2.3 Third Stage (1999–2005): Collaboration with the International Financial Institutions and Launching of the Great Structuring Programs

ADER-Fez was the main interlocutor of the World Bank team [4] in charge with the case of Fez in order to carry out the "Rehabilitation Project of the Medina of Fez". The development objective being "conservation of the Fez medina by mobilizing its inhabitants and local institutions" and more precisely "(a) to support the efforts of conservation in progress; (b) to consolidate the partnerships between public and private and (c) to use the process of rehabilitation to eradicate poverty". These global development objectives fall under the following: Development of the historic buildings rehabilitation programs; Improvement of accessibility and emergency circulation network; Improvement of the medina environment; Exploration of the rehabilitation process to eradicate poverty; and Institutional strengthening and capacity building.

All these components were achieved in 2005, and the project had a positive impact on the development of the medina of Fez [5]. Although in terms of financial indicators, the achievement of a project of such a size is not always fully met, it has generated many synergies of actors and investors pursuing the lines of the components. This established a model in the level of practice of development in a conservation zone.

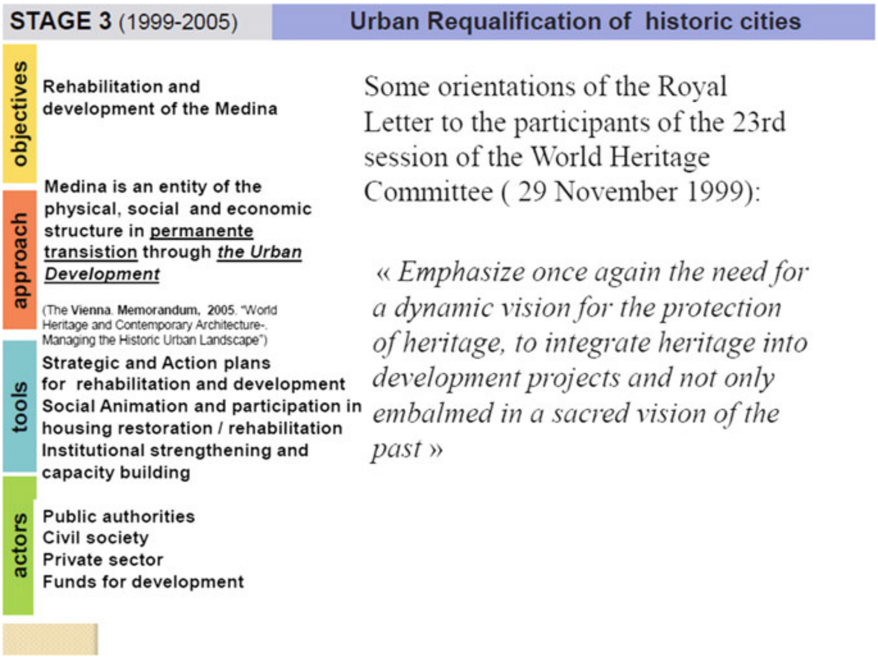

Fig. 4. Stage 3 (1999–2005) of the safeguard process: objectives, approach, tools and actions

In addition to the World Bank loan, other financial actors participated in Fez such as FADES (Arab Fund for Social and Economic Development). FADES has been involved widely in the rehabilitation of the monuments, housing and infrastructure of Fez. Private national and international donors supported the restoration of many monuments in Fez. Other main source of financing for the ADER's operations is the Moroccan government. The different ministries (especially the Ministry of Housing and Urban Planning, the Ministry of Cultural Affairs and the Ministry of Islamic Affairs and Waqf) participate financially in different programs following their prerogatives. The financial structure of the conservation program might reflect a very advanced participation of local authority, municipal councils, NGOs, national/international donors, and national/international financial institutions.

The large number of implemented rehabilitation projects in the medina of Fez has made it a successful case study, particularly in fund raising and financial investment in the heritage sector. Despite the fact that a historic city of 160,000 inhabitants could not be conserved or fully saved from danger, Fez is very advanced in the implementation of its vision of conservation compared to other historic cities in Morocco. The different investments made in the conservation project of Fez between 1981 and 2005 show that infrastructure is the most important with 53% of the whole budget. The second largest investment is made in the rehabilitation of buildings with 22%. The third is the restoration of monuments with 11%. Some of monuments have been restored by the Holding company Al Omrane [6], under the agreement between the Ministry of Culture and the Ministry in charge of Housing and Urbanism.

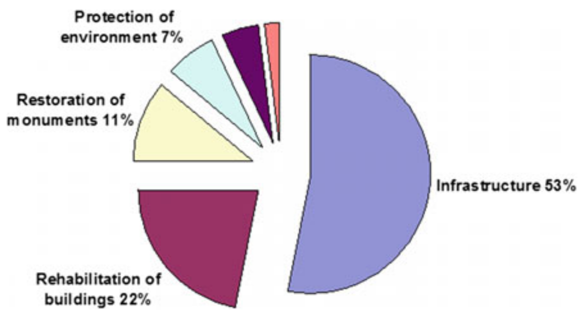

Fig. 5. The conservation project investments between 1981 and 2005

2.3.1 Housing and Social Development

This component includes the following sub components:

- Social animation and social participation in housing rehabilitation:

Early in project preparation, social scientists were recruited from the university in Fez to undertake a participatory and social assessment, which began with data collection on and consulting with a wide array of stakeholders. Government, religious and civic leaders, merchants, artisans, householders, renters, and many other ordinary population contributed ideas for possible elaboration into project components, worked toward consensus on interventions and strategy, and described the social dynamics of the city to assure a match among plans, aspirations, and local capacities.

Participation was high, given the involvement of a number of local NGOs in the project development between ADER-Fez and the population, and of many local stakeholders in the implementation of the social assessment. This had a direct impact on project design. The objectives are the direct involvement of the population in the rehabilitation process in order to improve the living conditions and to fight against poverty by job creation. ADER-Fez presents this participatory process and community development into two forms: A financial aid evaluated to 30% of the cost works and a help out in terms of building materials and technical assistance. The inhabitants contribution is about 70% of the works cost.

- Emergency intervention on housing units threatening collapse:

Housing presents a high risk because of the threat of collapse of their physical structures. In 1991, ADER-Fez launched an innovative emergency actions program that targeted the saving of human lives from this threat. The program consisted of an emergency team of builders, architects, and engineers who engaged themselves in the service of stopping the collapse of the buildings.

Buildings threatening collapse require emergency action involving both the public and private sectors. Beyond consolidation and critical repairs, the municipalities lack the technical capacities and political must enforce building codes. Priority is given to emergency repair of housing units threatening collapse and fronting on improved roads and tourist circulation routes. One of the challenging task of ADER-Fez is to facilitate the reduction of the extremely high population density within the historic urban fabric as this is causing a rapid degradation of the historical and traditional structures. Various programs related to the emergency intervention on housing units threatening collapse have been implemented. The restoration and rehabilitation laboratory was established and it is mainly concerned with the follow-up of stability of physical structures, control of the rate of degradation, as well as the auscultation, diagnosis, and analysis of the quality of materials. The structural laboratory is assisted by the survey and spatial analysis group, a team of skilled technicians whose main task is to gather data and survey the different buildings and structures of the medina. In addition to the scientific data, this laboratory is also exploring the technical know-how of the master builders through the interaction of engineers with the traditional techniques.

At project closing related to the period 1980–2005, the overall state of the housing stock of the medina has not improved, with the exception of the project interventions and of the private investments in the transformation of historic houses and palaces into Riads and guest houses [7]. Indeed, the collapse of housing units due to decay and lack of maintenance has continued, with no losses of human lives, due to the campaign of wooden buttressing of the endangered buildings financed by the Ministry of Housing and Urban Planning and carried out by ADER-Fez.

2.3.2 Infrastructure and Facilities

The success of the revitalization of the medina is greatly associated with the up-grading of its infrastructure and facilities including the following:

- Emergency and liaison circulation networks have noticeable impact on the communication and transportation networks in the medina.
- Traffic organization: the traffic network has been improved especially surrounding the historic walls and their monumental gateways.
- Accesses and parking: the accesses facilitate enormously the parking of cars outside the pedestrian road network, and they contribute to the increase of the economy and real estate value of many parts of the medina because of the easy accessibility.
- Water and sewage system: water supply and sanitation are important basic needs affecting the quality of life and productive efficiency of the medina population. Provision of these basic services continue to be among the core activities of urban local bodies. The municipal council, RADEEF, Régie Autonome de Distribution d'Eau et d'Electricité de Fès (Water Supply and Electricity Public Utility of Fez) and ADER-Fez are the main actors in the improvement of water and sewage systems (both traditional water channels and modern sewage systems).
- Electricity: the municipality and the RADEEF played a major role in the electrification of the whole medina. Public lighting, electricity and telephone networks have increased the number of businesses and the tourism activity.
- Urban facilities: the Ministries of National Education and Public Health have found ways to adapt their equipment norms to the historic building capacity, and then they have built a significant number of schools and nurseries in the medina.

These infrastructures are only examples of the efforts made by many actors to increase the living conditions of the medina.

2.4 Fourth Stage (2005–2018): Continuation of the Safeguard Process with New Development Programs

The process of safeguard continued from 2005 until 2018 through the integrating the development plans and programs at central and local levels. During the period (2005–2103) of this fourth stage, the historical space was able to integrate the new territorial development approaches launched by the National Initiative for Human Development (INDH), the Regional Development Programs of Tourism and Crafts, the Millenium Challenge Corporation, ….

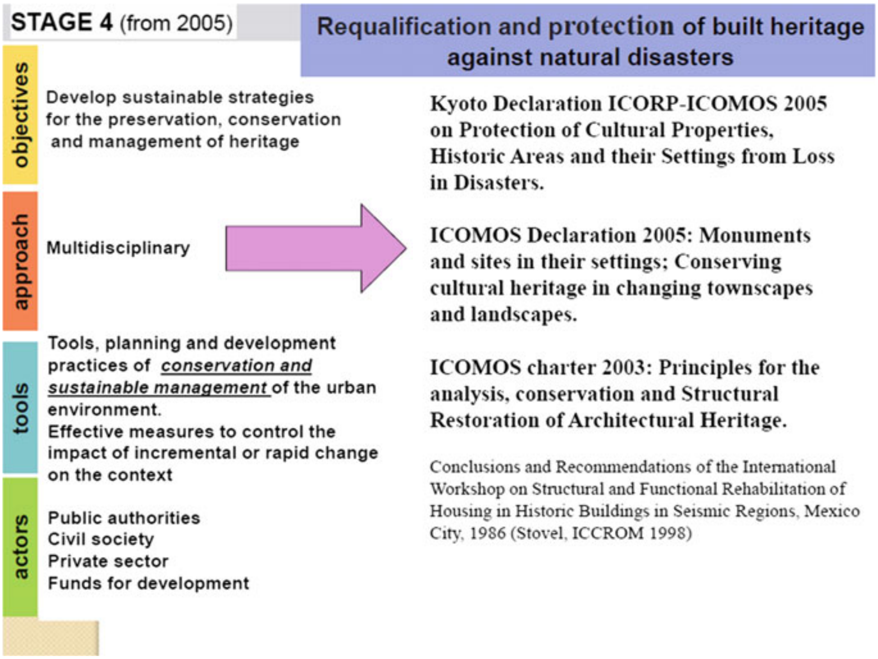

Fig. 6. Stage 4 (from 2005) of the safeguard process: objectives, approach, tools and actions

The second step (2013–2018) of the new development actions concerns the realisation of restoration and rehabilitation programs of the historical monuments and treatment of buildings threatening to collapse.

Fig. 7. Before and after restoration and rehabilitation of some buildings

Fig. 8. Before and after restoration and rehabilitation of some infrastructures and historical monuments

Regarding the conservation and sustainability in this historic city [8] and based on a system dynamics approach to sustainability, emphasis is put on the key actors involved in the system and on the links between them. Only the actors (ADER-Fès, public authorities, civil society, private sector, funds for development,…) as shown in Figs. 2, 3, 4, 5, 6 and interactions comprised within the medina have been investigated. The analysis is based on a Causal Loop Diagram that summarizes some issues of the system [9] (Figs. 7 and 8).

In terms of social sustainability, the safeguarding process of Fez medina has been targeted the participation and the integration of the local society into the sustainability aim of the rehabilitation and conservation project which was and is still substantially profitable to the population.

In terms of environmental sustainability, the environmental quality is essentially improved through public investments in solid waste management, water and sewage system, infrastructures and urban facilities.

In terms of integrated sustainability, it is evident that the investments accompanying the safeguarding process are the main pillar for the conservation and the rehabilitation of Fez medina, as they boost the economy, protect the cultural heritage, and ameliorate the physical environment. However, it is necessary to secure funding for maintaining public investment in the medina and surrounding areas. These can not be thought out, planned and managed independently of the Fez city, and the integrated rehabilitation can not be limited to the technical aspects, it requires a transversal intervention involving all relevant development actors.

3 Conclusions: Lessons Learned

The paper has summarized the basic principles of the sustainable urban conservation of Fez medina and has shown that one of the pillars of the rehabilitation scheme is the reinforcement of the local institutions. This is mainly achieved through securing funding.

It has also shown that there are some positive results of the Fez conservation program, including the social participation which is essential for the successful rehabilitation of the historic housing stock, and the project has demonstrated that reconciling the objectives of urban conservation and rehabilitation with the housing needs of the impoverished inhabitants is feasible, through a process of consultation and social participation in the design and implementation of the interventions on the historic housing stock.

But there are some constraints: The tenure of land and buildings is a critical difficulty in the rehabilitation of historic cities, and the municipality should consider delegating urban rehabilitation operations to competent agencies. The urban rehabilitation projects should be designed according to simple objectives and design. Given the complexities of intervening in historic cities, the related interventions should not try and address all of the needs and opportunities under a single operation, but should rather support a programmatic approach.

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Liquefaction Analysis by Using Laboratory Scale Shaking Table Test Device

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Abstract. Liquefaction is the one of the major problems in geotechnical engineering. Especially; deaths, structural damages and financial loss can occur after liquefaction. Therefore, liquefaction potential of the soils should be determined before the construction. In this study, silty sand soils were taken from the city of Eskisehir, Turkey. Reconstituted samples were tested by using laboratory scale shaking table test device. Liquefaction potential of the soil samples were determined and the test results were discussed.

Keywords: Liquefaction · Shaking table test · Silty sand

1 Introduction

Liquefaction can be defined as the phenomena that related with the earthquakes. Earthquake load causes pore pressure increase and effective stress decrease under undrained conditions. Especially loose silty sand soils tend to liquefaction and show dramatic results. Large soil deformations can be observed and therefore deaths, structural damages and financial loss can occur after liquefaction.

Liquefaction potential of the soils should be determined to take precautions. First research about liquefaction was done by Casagrande at 1930s. Then, damages induced liquefaction increase studies and gained popularity with researches of Seed, Idriss and Ishihara at 1970s.

In the literature, there are lots of studies about liquefaction potential of the soils. Gratchev et al. [1] studied the relationship between soil micro structure and liquefaction potential. Elgemal et al. [2] investigated the liquefaction potential by using numerical analysis. Yang and Elgamal [3] showed a correlation between the soil permeability and liquefaction potential. Hwang et al. [4] studied the loess and their tendency to liquefaction. Bird et al. [5] developed a numerical methodology about liquefaction potential and damage risks. Kevin et al. [6] showed a prediction by using statistical data and 3D analysis on the liquefaction potential. Yuan and Tadunbu [7] studied determination of

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the deformations by using numerical methods and he derived new formulas for the deformations induced liquefaction. Ishihara and Cubrinovski [8] analyzed the liquefaction phenomena after 1995 Kobe earthquake and they found the soil density and compaction have great effect on the liquefaction mechanism. Thevanayagam and Martin [9] tried the soil improvement methods against liquefaction and they suggest compaction methods. Yang et al. [10] investigated the relationship between liquefaction and earthquake movement in vertical and horizontal directions. Adalier and Elgamal [11] wanted to decrease liquefaction potential by using stone column method and they found positive results but stone column application method is remarked. Chang [12] developed a new field test to determine liquefaction potential by measuring pore pressure and vibration. Yunmin et al. [13] investigated the correlation between the shear wave velocity and liquefaction by using dynamic triaxial test.

Liquefaction potential can be assessed by field tests, laboratory experiments or numerical analysis. In this study, silty sand soils were taken from the city of Eskisehir, Turkey. Reconstituted samples were tested by using laboratory scale shaking table test device. Liquefaction potential of the soil samples are determined and the test results were presented.

2 Liquefaction

Liquefaction is one of the most important and complex topics in geotechnical earthquake engineering. The generation of excess pore pressure is the milestone of the liquefaction phenomena. If cohesionless soils are saturated and rapid loading occurs under undrained conditions so excess pore pressure increase and effective stress decrease.

Liquefaction is divided into two main groups: flow liquefaction and cyclic mobility [14]. In the literature, flow liquefaction is seen much less frequently than cyclic mobility but its effects are more severe. Cyclic mobility can occur under a large range of soil and site conditions than flow liquefaction. Flow liquefaction failures are characterized by the sudden nature of their origin but both flow liquefaction and cyclic mobility can produce damages and need a reliable evaluation of liquefaction potential.

Geotechnical earthquake engineers should evaluate potential liquefaction effects by investigating following subjects; soil susceptibility, size of the dynamic trigger and size of possible damage. On the other hand, these subjects called as; susceptibility, initiation and effects [14].

Evaluation include historical, geologic, compositional and state criteria [14]. Compositional characteristics associated with high volume change potential, particle size, shape and gradation. Historical evaluation includes taking observations about liquefaction occurrence from past earthquakes.

Liquefaction potential can be determined by different methods. First one is based on the results of laboratory tests and the second one is methods based on in situ tests in addition model tests can be used. Some methods are given in Fig. 1.

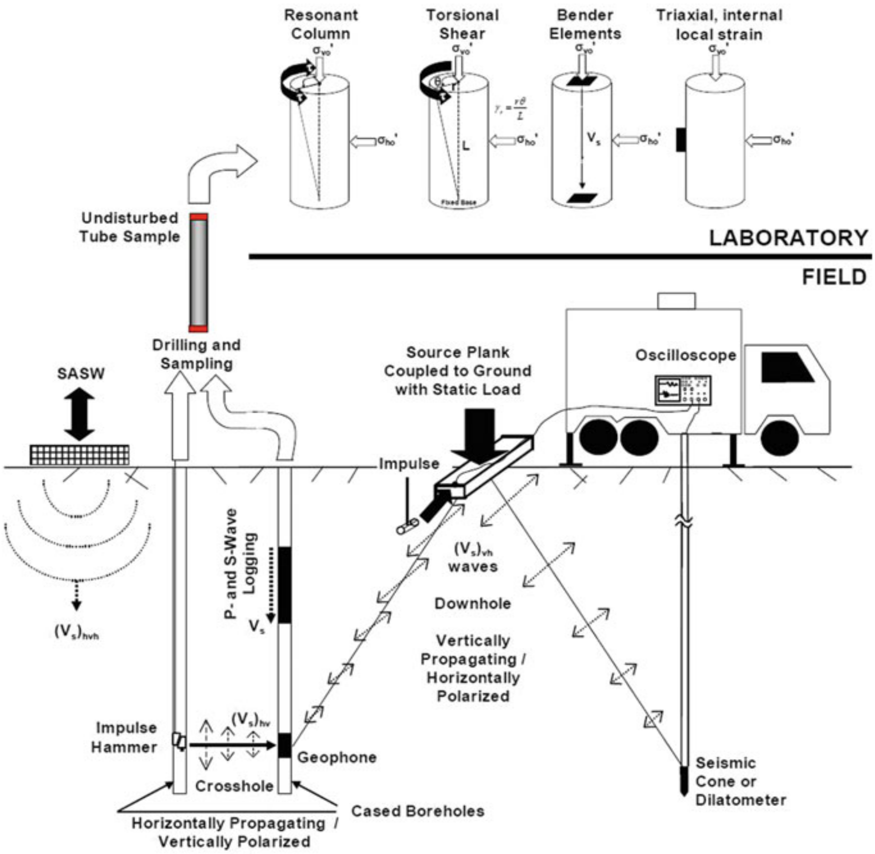

Fig. 1. Some liquefaction evaluation test methods [15]

Soil properties can be measured in situ with low disturbance in large soil volumes by field tests. On the other hand, laboratory experiments provide less time and economy. Field tests classified as two main groups such as low deformation and large deformation tests. Low deformation field tests are known as seismic reflection, cross-hole, down-hole, seismic dilatometer etc. and large deformation field tests are SPT and CPT. Similarly, resonant column, ultrasonic pulse and bender element test are low deformation laboratory experiments; dynamic triaxial, dynamic shear and torsional shear tests are large deformation laboratory experiments.

Modelling tests are known as shaking table and centrifuge test and these tests are also called as prototype tests. Shaking table is a test system to simulate earthquake loading. Large scale soil samples can be tested on a table by applying dynamic loading at shaking table test.

3 Experimental Study

3.1 Materials

Non-plastic and fine-grained silty sand soil was used for the experiments. Silty sand samples were obtained from the city of Eskisehir, Turkey. Firstly, soil index and classification tests were performed according to the ASTM standards. Basic soil characteristics are given in Table 1. In addition, grain size distribution curve is shown in Fig. 2.

Table 1. Basic soil characteristics of the test sample

Description	Result
USCS	SW-SM
Coefficient of curvature	2.45
Coefficient of uniformity	14.66
Amount of gravel	24%
Amount of sand	66%
Amount of silt & clay	10%
Natural unit weight	17.8 kN/m^3
Plasticity	Non-plastic

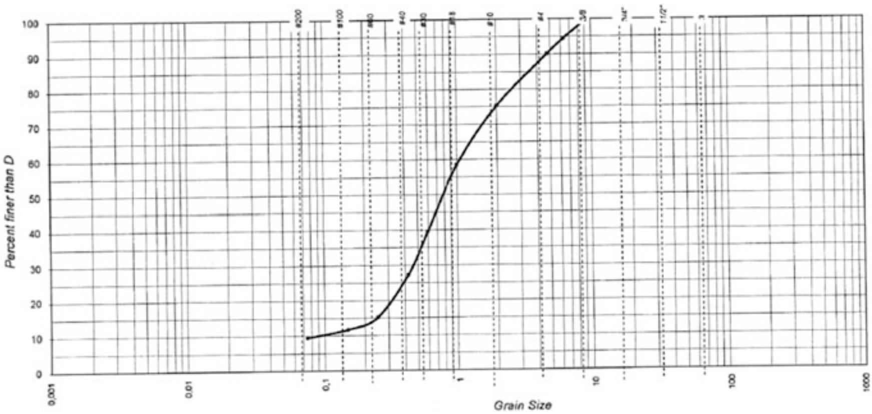

Fig. 2. Grain size distribution curve of the test sample

3.2 Test Equipment

Shaking table is used for shaking models and identify behavior of soils and structures. A laboratory scale shaking table test device was performed for the tests. The shaking table test device is shown in Fig. 3. The system is controlled by a computer and all inputs can be given automatically. The control screen is given in Fig. 4.

Fig. 3. Shaking table test device

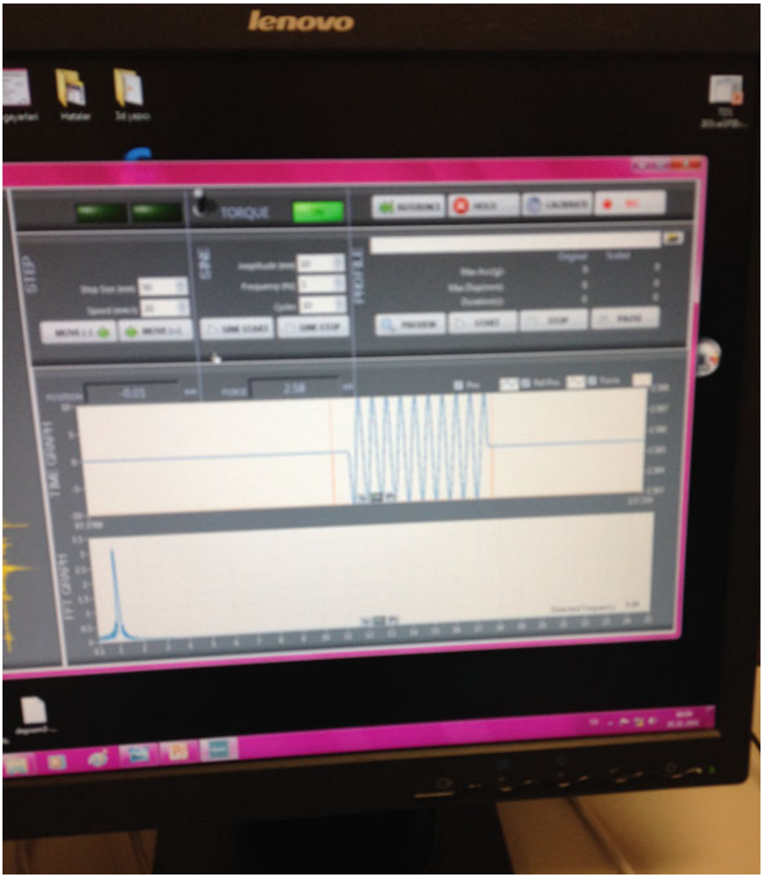

Fig. 4. Input screen

3.3 Test Procedure

City of Eskisehir is located in the second-degree earthquake zone at the Earthquake Zoning Map of Turkey. Especially silty sand and loose sands are mostly seen soil types for the city of Eskisehir according to literature and previous soil exploration reports. Therefore, Eskisehir soils has a liquefaction potential under a possible earthquake.

Firstly, a test program is prepared and relative densities with accelerations are determined. Test program is given in Table 2. Soils were put to the shaking table box according to the relative density. Ground water level is generally high (about at −3.00-meter depth) at Eskisehir so all soil profiles are considered fully saturated in the models. A vertical stress of 50 kPa was applied to the surface of the soil by using a rigid mass.

Table 2. Test program

Test no	Dr (%)	a (m/s^2)	N (cycle)
1	35	0.10	5
2	35	0.30	5
3	65	0.10	5
4	65	0.30	5

4 Results

Liquefaction tests were performed and the results are given in Table 3. Example pictures from the tests are given in Fig. 5.

Table 3. Test results

Test no	Liquefaction
1	Yes with 0.75 cm settlement
2	Yes with 2.78 cm settlement
3	No
4	Yes with 1.12 cm settlement

Results show that excess pore water generation occurs with the dynamic loading. Different settlement amounts were observed. Loose soils let the water upward movement and then soil grains are settled due to the applied vertical stress. Especially amount of settlement increases if the relative density is low and acceleration is high. Therefore, acceleration and relative density has a great effect on the dynamic behavior.

On the other hand, liquefaction potential should be determined by using much more tests. Laboratory experiments should be performed in addition to field tests and model tests. And also, numerical modelling can give an idea about the amount of settlement. If the liquefaction potential is determined by different methods, soil improvement must be done. In addition, this study was performed for specific soil properties and dimensions. Size effect of the test set up and scale factor should be considered for the future studies.

Fig. 5. Liquefaction phenomena

5 Conclusions

Liquefaction is a devastating problem in geotechnical earthquake engineering. Liquefaction potential should be determined and safe solutions must be developed. In this study, silty sand soil samples were tested by using laboratory scale shaking table test device. Results showed that loose silty sand soils have a liquefaction potential. In addition, acceleration and relative density has a great effect on the dynamic behavior of the soils.

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Optimum Building Envelope Solution Strategies Based on the Solar Data in Performative Architecture

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Abstract. The number of the people who are aware of the energy issue is increasing since the fossil fuel reserves of the earth are coming to an end, and this fossil fuel consumption threatens the natural balance of the earth and human health. Considering the fact that the majority of the energy is consumed for constructing buildings and in these buildings after the construction, it is important to take energy-based decisions regarding the designs during the planning process. This study aims to present the optimum building envelope solution strategies by using the solar parameters, which are the most effective environmental factors in Turkey, with up-to-date computer programs making the digital designing process possible in performative architecture. Various samples were analyzed to examine the roles of performative architecture in pre and post-design process, and the relationship between the building envelope and energy was determined. In addition, the importance of using computers during the disregarded design process was emphasized, and awareness was raised in this issue.

Keywords: Performative architecture · Parametric design · Solar energy Building envelope

1 Introduction

Turkey largely depends on foreign countries for their energy sources. Therefore, building sector requires cost-effective and high quality construction solutions with more renewable energy sources.

The technology of the present time provides opportunities to meet this requirement with its digital data format and operation method supporting all project stages. Performative architecture offers an efficient and design-related starting point benefiting from the digital technology and recognizing the sustainability as a whole factor and result concept once the design of the process is highlighted instead of the end products in the architecture.

However, 2013 AIA (The American Instutute of Architecture) Architecture 2030 Commitment Progress report indicates that energy modeling is performed in 66% of the projects. Energy save in modeled projects is 8% higher than those not modeled. When

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considered from this perspective, it is realized that technology is used for design modeling process in the present time. However, for the analysis of the environmental data, the technology is used less frequently. Therefore, it is realized that these samples to guide the designing process are not considered sufficiently [1].

Thanks to its geographical location, Turkey benefits from the sun more than all countries, and maximum efficiency is ensured using this advantage. In this study, sun is regarded as the most effective environmental factor affecting the design and is focused on solar-oriented exterior design. Building envelope configurations were analyzed by the solar data using the model designs examined with Rhinoceros based “Grasshopper” (algorithmic and graphical regulator) program, and the relationship between the building envelope and energy was demonstrated. Creating such a frontage character requires the transfer of the sunlight into a parametric program. Importance of using a computer before the designing process will be highlighted in this way.

1.1 Problem

Since the energy is the leading need of the developed countries, conducting comprehensive studies for designing energy-efficient buildings and generating instructive criteria became obligatory. In this respect, building envelope configured in accordance with the solar data during the designing process should be regarded as the primary element while planning the ecological environment.

For the maximum efficiency in energy save or gain, the configuration depending on the angle of the sunlight for the building envelope constitutes the main problem.

However, end products indicate that the process of evaluating the environmental conditions in a computer in the pre-design process is not considered, and appropriate design concept that will make the design authentic is missed. This is the subtopic of the problem.

1.2 Aim

This study aims to present the optimum building envelope solution strategies on the models by using the solar parameters with computer programs making the digital designing process possible in performative architecture.

With the studies to be conducted for this purpose, minimizing the energy loss in the existing buildings and buildings to be constructed and ensuring optimum energy gain in the buildings are considered to be important actions. This will also ensure energy gain in building sector and thus contribute to the economy of the country.

1.3 Content

Within the framework of sustainable architecture, solar energy is an important part of the solution to the energy problem of the entire World. Sun-oriented building envelope design enabling the relationship between the performative architecture and digital design will suggest and designed using computer programs related to building the samples will be examined.

1.4 Methods

Study background consisted of written sources, internet databases, analyses and photographs, and the topic was clarified with the tables and examples. Performative architecture and digital design will examine, examples of performative design will analyze, and the effect of these examples on the building envelope will present.

2 Opportunities in Performative Architecture, Digital Design and Building Envelope Design

Terms transferred to the glossary of architecture are insufficient in explaining the spatial cases and practices. Therefore, new terms were searched, and the required efficient environment was ensured with the term, performance. This term was entered to the glossary later [2]. Performative architecture is a spiral design approach that considers the sustainability principles in building designs, adds physical environmental conditions to the design process as a digital and measurable factor, performs real time measurements for the building performance and offers solutions (Fig. 1) [3].

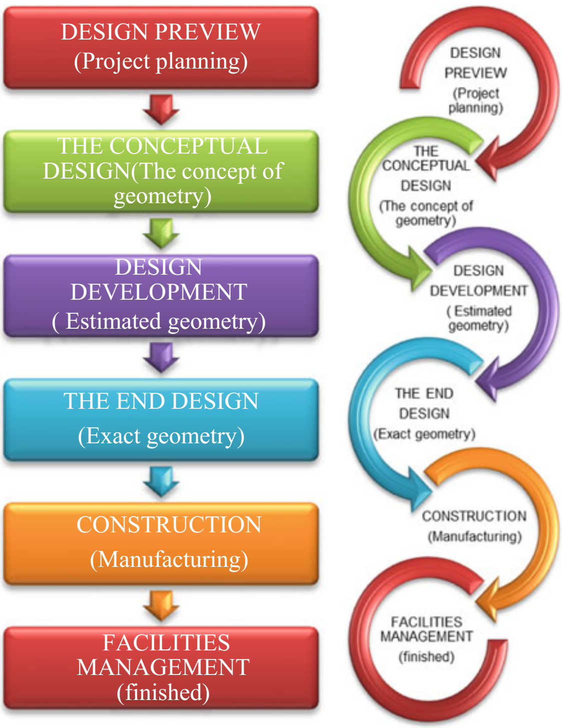

Fig. 1. Linear and spiral design process [3]

2.1 Digital Design Approach and Its Effects on Building Envelope Configuration

Digital methods were developed to effectively model high-performance buildings and correctly analyze the performances for the performative design.

Non-Parametric Building Modeling

Non-parametric modeling tools are largely based on CAD (Table 1) [4].

Table 1. Popular non-parametric modeling tools [4]

Non-parametric modeling tools	Website
AutoCAD	www.autodesk.com
SketchUp	http://sketchup.google.com
Maya	http://www.alias.com
3D Studio Max	www.discreet.com
Houdini	www.sidefx.com
Rhinoceros	www.rhino3d.com
Cinema4D	www.maxon-computer.com
Lightwave	www.newtek.com
Caligari Truespace	www.caligari.com
Softimage	www.Softimage.com

Developing the demonstration methods for the designs with presentational purposes was aimed. The way you design the building envelope determines the way you receive a visual presentation (Fig. 2) [5, 6].

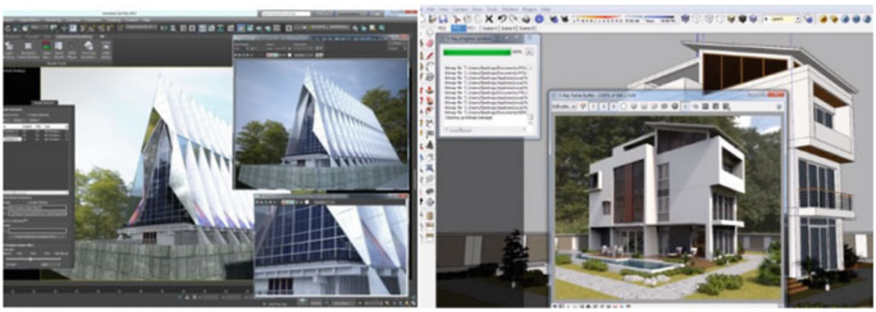

Fig. 2. 3D max and sketch up building modeling examples [5, 6]

Parametric Building Modeling and Its Effects on Building Envelope Configuration

Processes of facilitating the alterations in a parametric system and testing many alternatives by altering parameter values are present. Table 2 includes the most frequently used parametric programs [4].

Table 2. High-end parametric modeling tools commonly used in design practice [4]

Parametric modeling tools	Website
Autodesk Revit	www.autodesk.com
GenerativeComponents	www.bently.com
Rhino-Grashopper	www.grasshopper.com
ParaCloud Modeler	www.paraclouding.com
CATIA	www.3ds.com

Parameters to be used in designing the building envelope may include the height and number of the storeys, base area and environmental data (building direction, received wind energy, sunlight and so on). Any alterations to be made in these parameters are reflected to the model as soon as possible, and the data we obtain will automatically be updated [3] (Fig. 3).

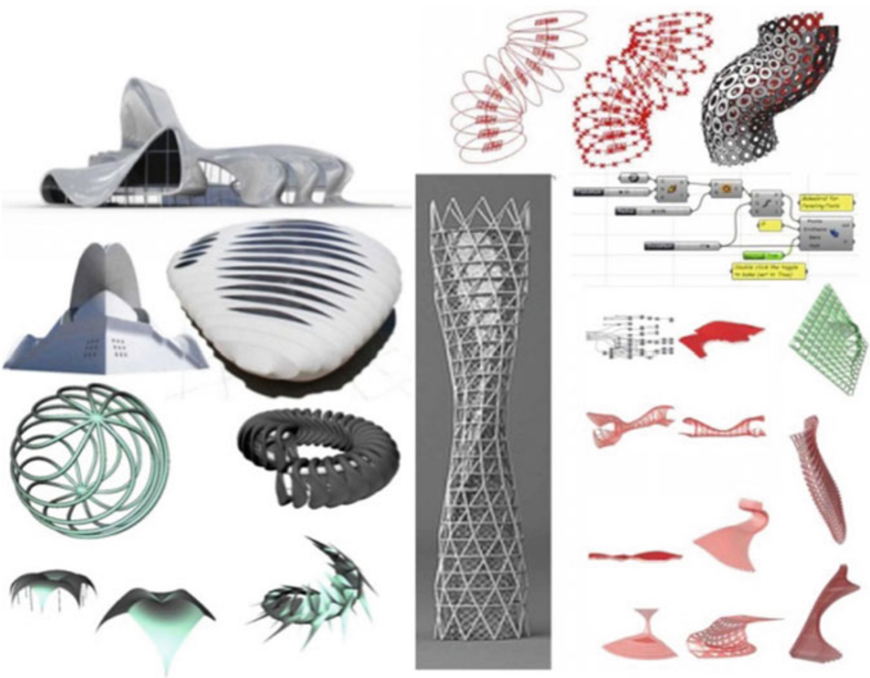

Fig. 3. Parametric design examples [16]

BIM and Its Effects on Building Envelope Configuration

It covers all graphical (geometry, shape etc.) and alphanumeric (material, cost, physical environmental control etc.) data and a 3D model generated with these data (Table 3).

Table 3. Building performance modeling tools for environment analyses [4]

Building performance simulation tools	Website
IES	www.iesve.com
Radiance	http://wapedia.mobi/en/Radiance
Ecotect	http://ecotect.com
Green Building Studio	www.autodesk.com/greenbuildingstudio.com
Hevacomp	www.bentley.com
Energy Plus	http://apps1.eere.energy.gov

Computer-based simulation programs are the collections of complicated and interactive equations formulating the building and its energy, acoustic, visual and thermal performance. Whether or not a building planned with the modeling studies conducted with simulation programs will meet the projected standards can be determined in the designing stage [3] (Fig. 4).

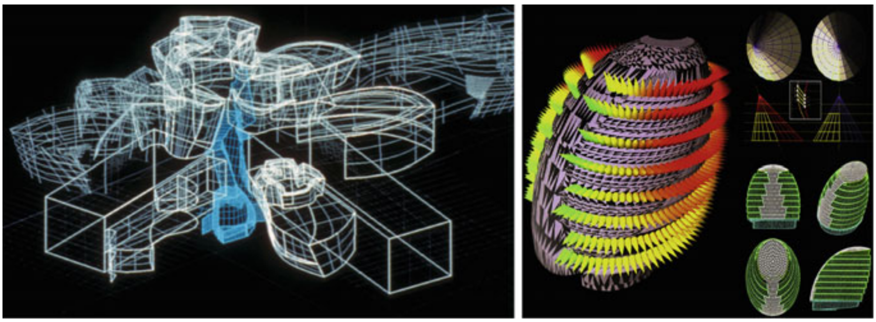

Fig. 4. Full 3D model of Gehry's project and 3D models of the London City Hall [4]

Performing the design with the instructions for generating geometric mass

The last shape in the BIM is related to the architectural elements and converted to a BIM model (Fig. 5).

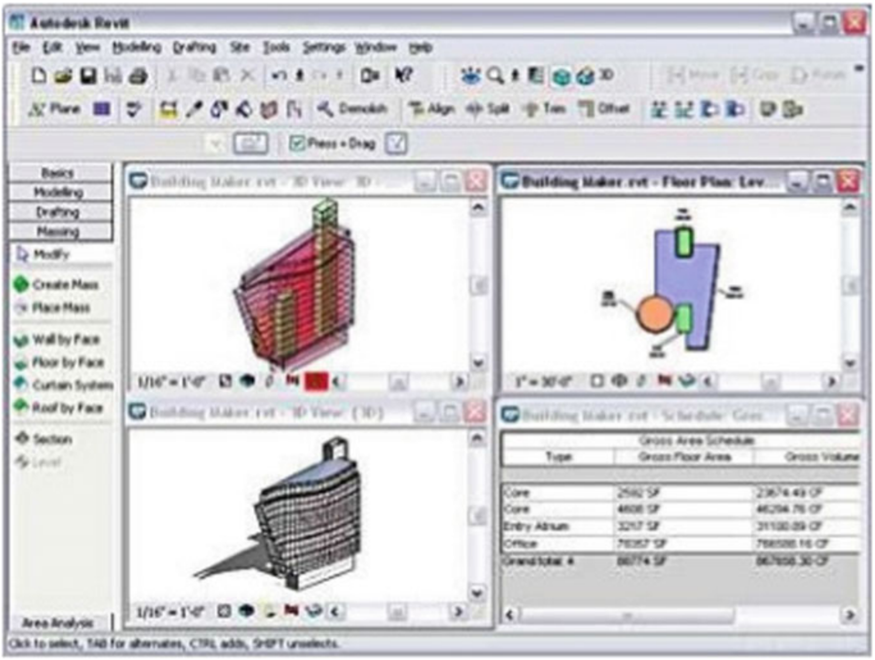

Fig. 5. Generating forms with instructions [15]

Performing performance analysis and developing the design

Various inputs such as the mass of building, indoor areas, frontage elements, space-compactness, material and so on can be used in various simulations with the climatic data. Building performance analysis performed after the simulations makes it possible to revise and enhance the decisions regarding the design (Fig. 6).

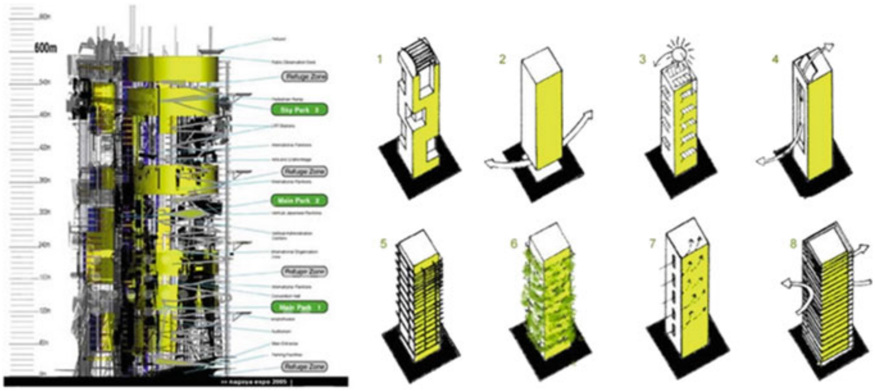

Fig. 6. Nagoya EXPO 2005 Tower, architectural design: Hamzah and Yeang [7]

Designing programs created for the purposes based on the presentations and animations are constantly updated and enhanced, and all types of analyses can be performed with the script programs, called plug-in, used for all non-parametric and parametric designing tools. Switching between the programs during the analysis stages is another solution. But, missing elements and errors may be experienced during the conversions to different formats. Rhinoceros 3D, which is developed for digital and parametric purposes, and particularly free-from NURBS (Non Uniform B-Splines) are used for modeling. Programs such as mesh (framework in mesh modeling) based 3ds max and Sketch up differ by this feature (Fig. 7) [7].

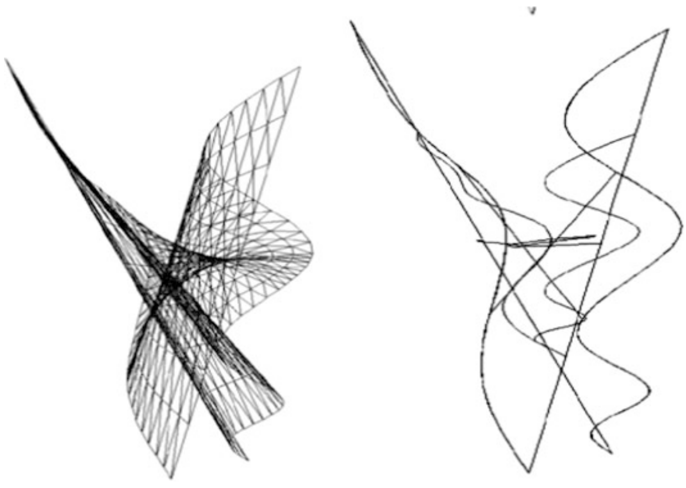

Fig. 7. NURBS and mesh-wire mesh models of a 3D surface [7]

For the samples in the study, Rhino and Grasshopper programs were used. These programs have a very high sensitivity. The sizes and restrictions of the form can easily be modified in Grasshopper, and various parameters can be altered.

3 Reflection of Design Performance Analyses on Building Envelope

3.1 Endesa Pavillion—2011

Designed and built by the Institute for Advance Architecture of Catalonia (IAAC) in Spain (Fig. 8).

Fig. 8. Endesa Pavillion [8]

Angles of the sunlight were determined considering its location in the design, and these details were uploaded to the parametric design program. At the same time, algorithm was used to shape the building for obtaining the maximum photovoltaic generation without compromising on the sunlight or the thermal gains (Fig. 9). Plywood was used as the material, and the pre-installment and construction phases took five weeks [8].

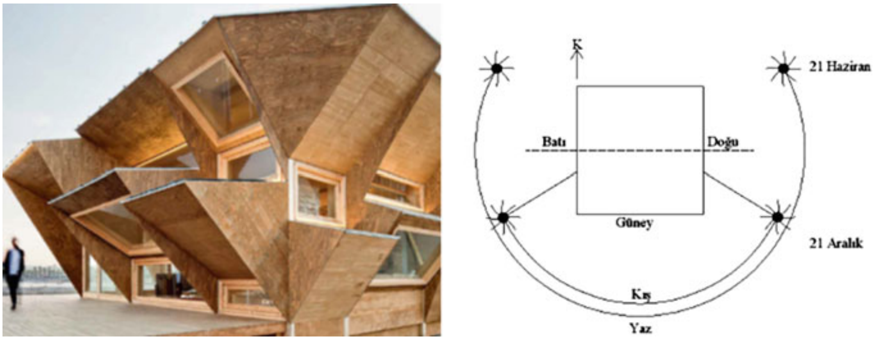

Fig. 9. Endesa Pavillion [8]

Sunlight angles changing in relation to the position of the building in Barcelona were uploaded to Rhinoceros-Grasshopper program, and the frontage was formed considering the solar data in the location (Figs. 10 and 11) [9].

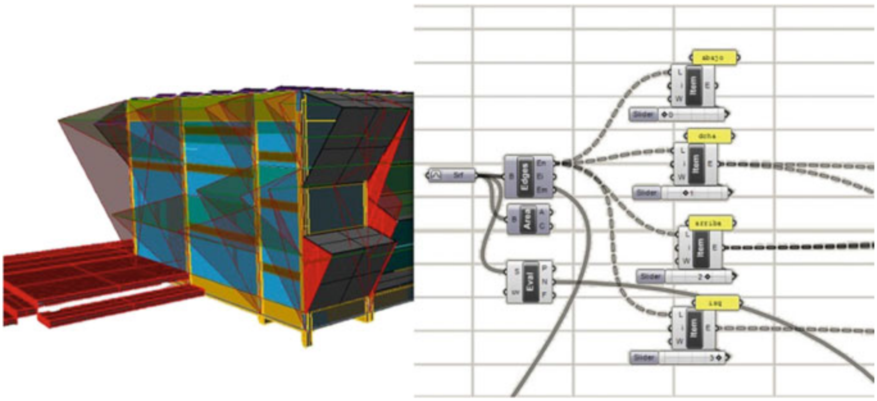

Fig. 10. Uploading the sunlight data to the program [9]

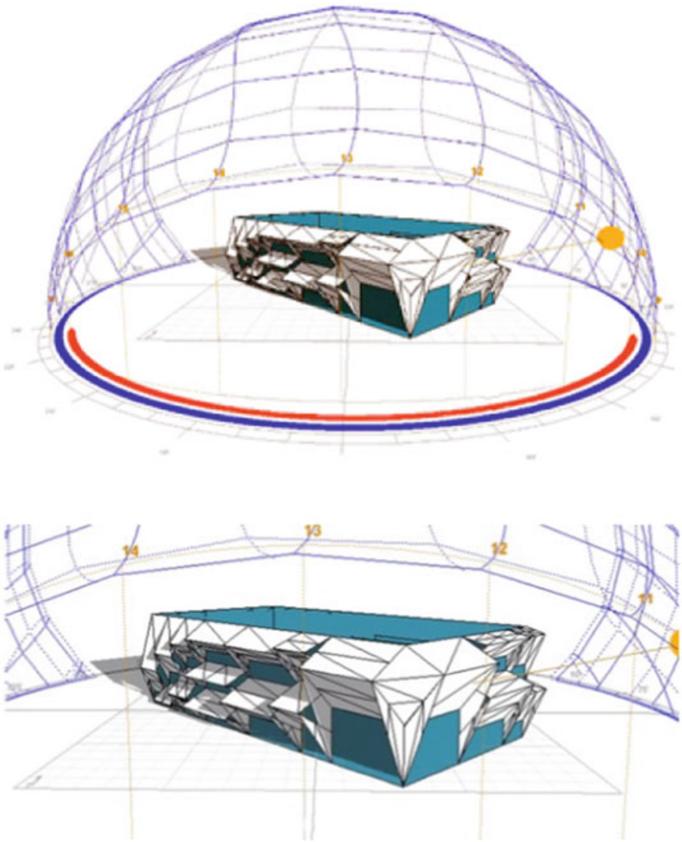

Fig. 11. Designing the envelope in a computer [17]

This configuration was analyzed by the seasons and time separately. For gaining the maximum efficiency from the changing points of the sunlight, it was ensured that the frontage moved to the direction of the light. Therefore, fragmentary frontage modeling, which looks like a bellows and was specialized for the masses, was performed (Fig. 12).

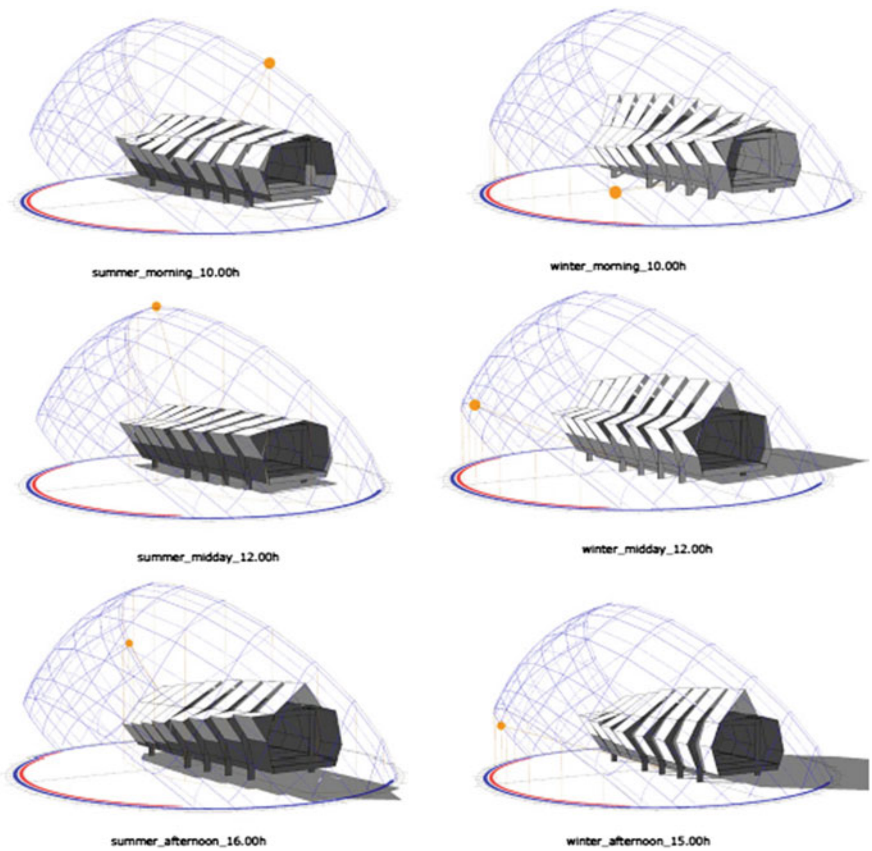

Fig. 12. Configuration of Endesa Pavillion by the sunshine range in the Northern Hemisphere [18]

A wooden envelope, which was based on the digitally-designed elements and parametrically adapted to their different orientations, moves like the leaves of a tree. These moving surfaces are only present in the south, depending on the climatic conditions of the region. Windows, bottom and top of which are protected, in other three frontages enable a natural air circulation (Fig. 13).

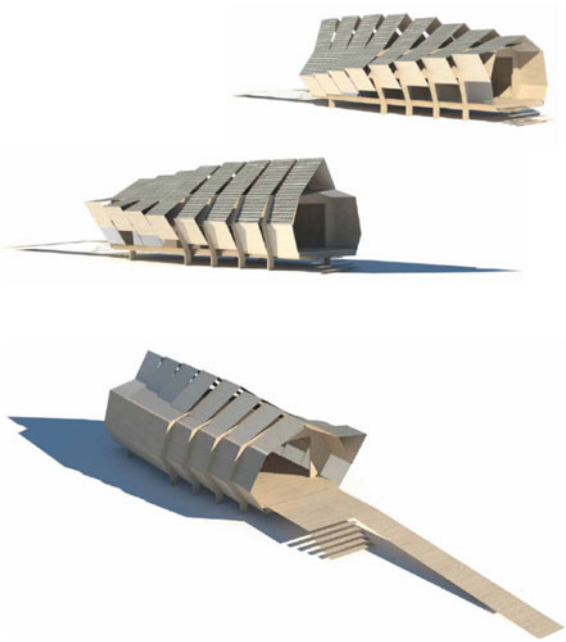

Fig. 13. A series of modules looking like a bellows [18]

At least one surface, on which the spaces for a photovoltaic-coated frontage and a window are present, can be seen in all bellows. Surfaces and angles differing by the sunlight optimize the PV and passive solar impact in all seasons [10] (Fig. 14).

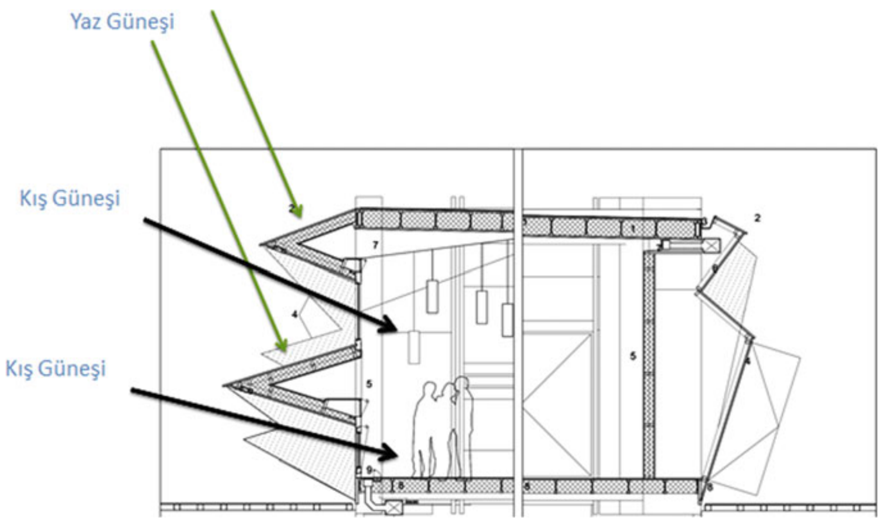

Fig. 14. Sunshine status by the months [10]

Components generate their own energy and a micro climate controlling the shades, air circulation and the light. Photovoltaic panels were used as a construction material in the building, and this made it possible to form a modern and ecological architecture glossary with the support of technology.

3.2 World Fab Condenser—2014

Fab Condenser is a thermodynamic and bioclimatic dome. It has a parametric design based on the passive climatic strategies (Fig. 15), [11]. Envelope material is renewable and organic (wooden and canvas), and it was produced in Fab manufacturing laboratory using the CNC machine. The cover used on this material can easily be detached, reused and recycled (Fig. 15).

Fig. 15. Fab condenser

Its components facing outwards and looking like a sail are cross-connected to accelerate the wind speed and facilitate the management of the wind. The envelope has the Northern-Southern gaps for ensuring the natural air circulation in relation to the mountain and sea directions [12].

The team, bearing the title "World Fab Condenser" in mind, used the world map as the design concept, and generated the modules by deforming the algorithmic forms (Fig. 16).

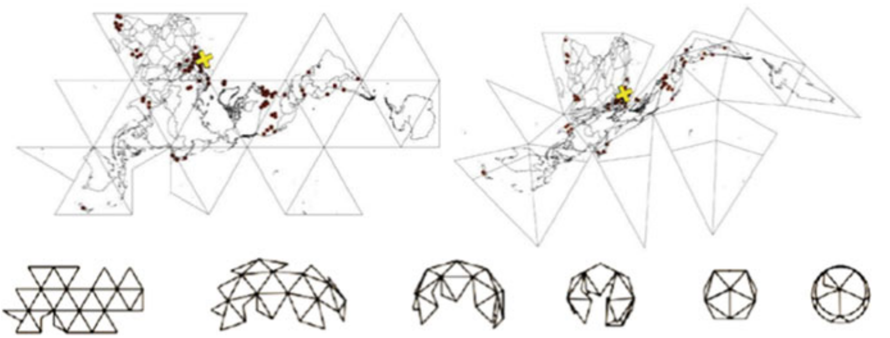

Fig. 16. Generation of the modules [11]

Each of these models is numbered and configured by their directions to the sunlight (Fig. 17).

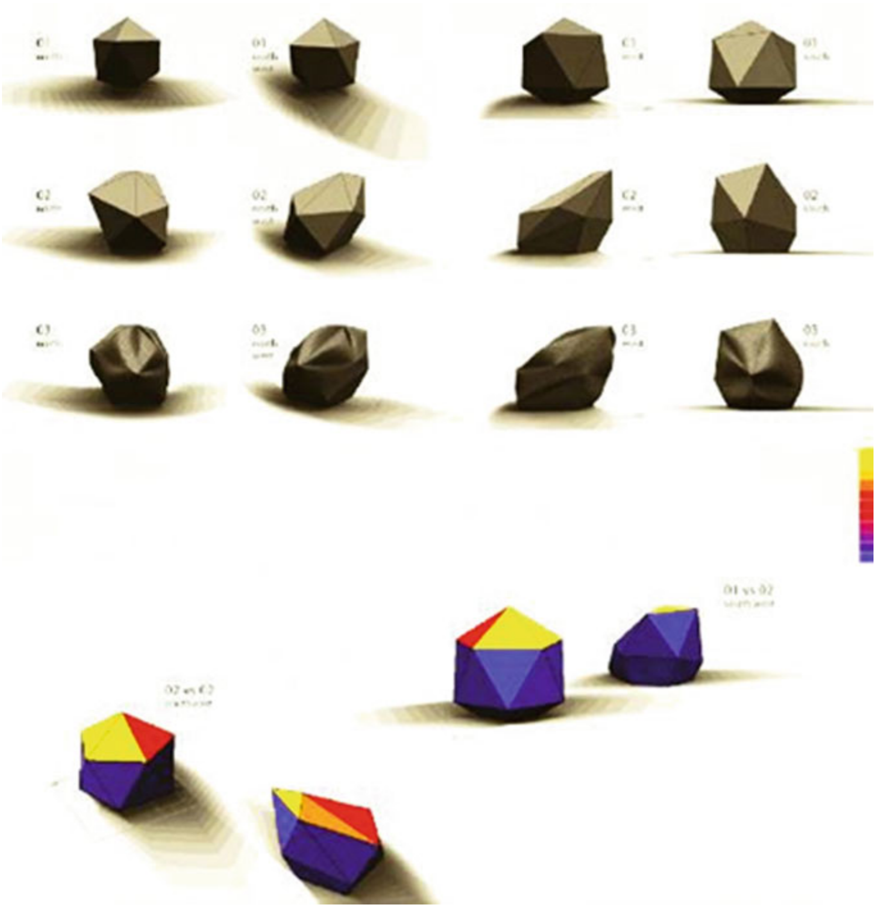

Fig. 17. Configuration of the models [11]

Models were generated ensuring the geometric adaptation with the environmental parameters. The first two models were deformed to minimize the solar radiation in summer, and maximize it in winter. In the third model, the top is emptied to use Northern and Southern winds (mountain and sea) as natural and artificial circulation elements (Figs. 18 and 19) [13].

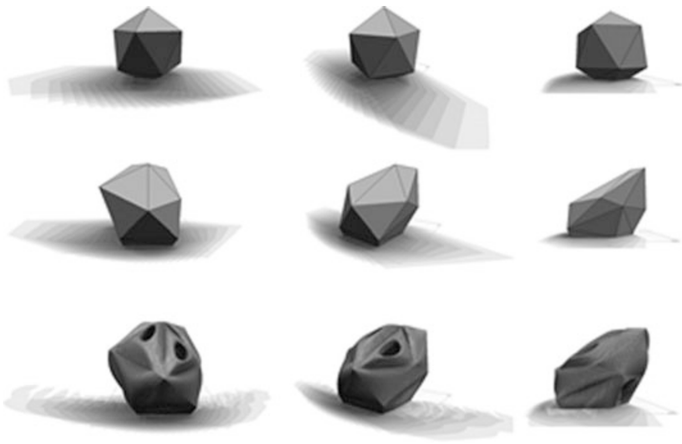

Fig. 18. Configuration of the models [11]

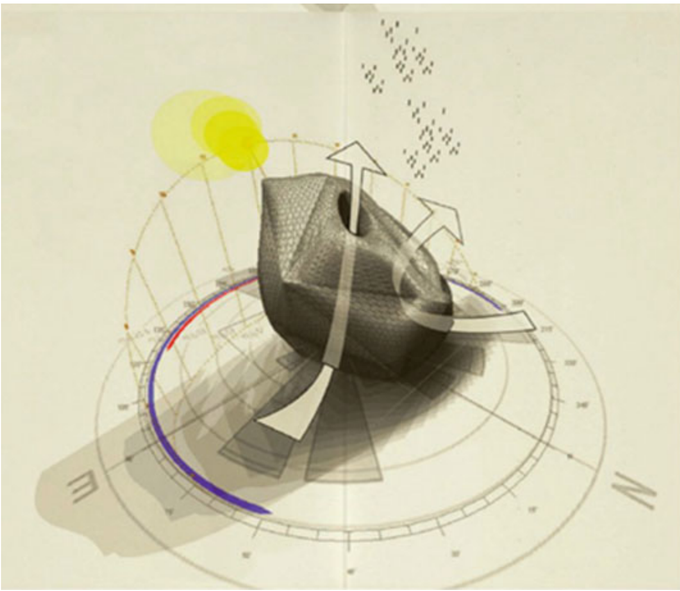

Fig. 19. Configuration of the models [13]

The model to be implemented consists of twenty modules. Its algorithm was designed in two months, and its prefabricated version was completed in five days (Fig. 20).

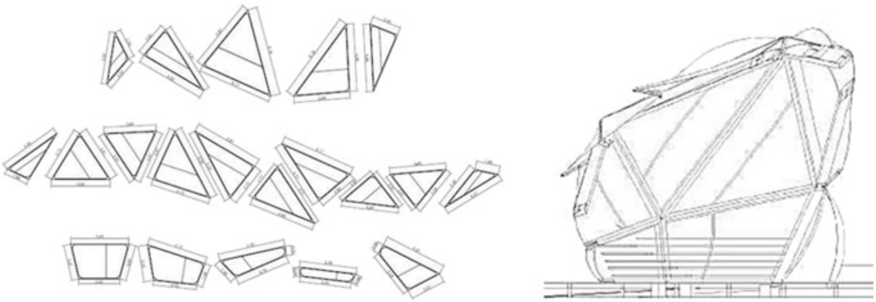

Fig. 20. Modular material and laser cutting [13]

3.3 Office Tower in Kebayoran Lama

For the first step of designing the office building, Grasshopper was used to enter the data regarding the physical area outside the designed area into the interface. A constructional trial and error method was selected as the designing method.

Afterwards, analyses of the building, the environmental analysis of which was conducted before, in different models were calculated converting and considering the angles of the models (Figs. 21 and 22) [14].

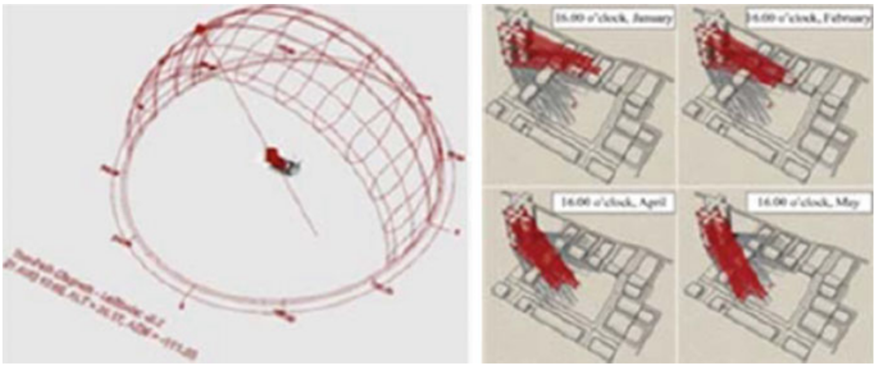

Fig. 21. Overshadow of neighbouring buildings in a year (08.00 am to 04.00 pm) [14]

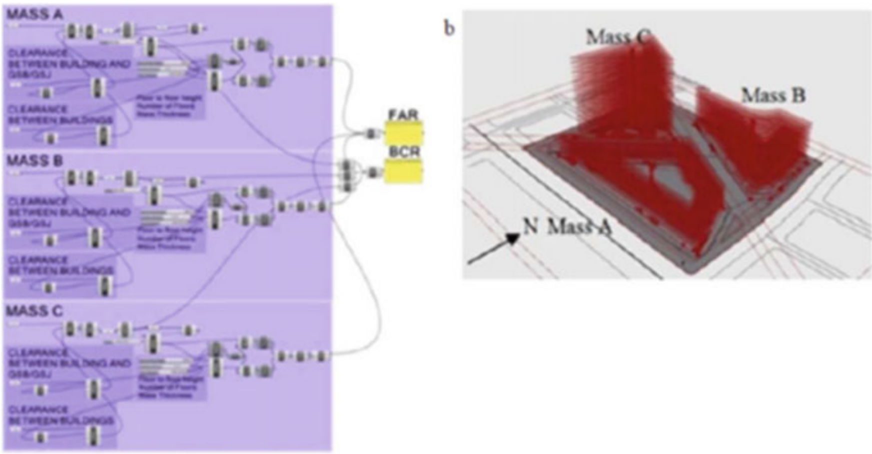

Fig. 22. Massing formula to analyse maximum building's footprint in regard to BCR & FAR

Solar radiation study was performed on the specified alternative models, and the last model was determined (Figs. 23 and 24) [14].

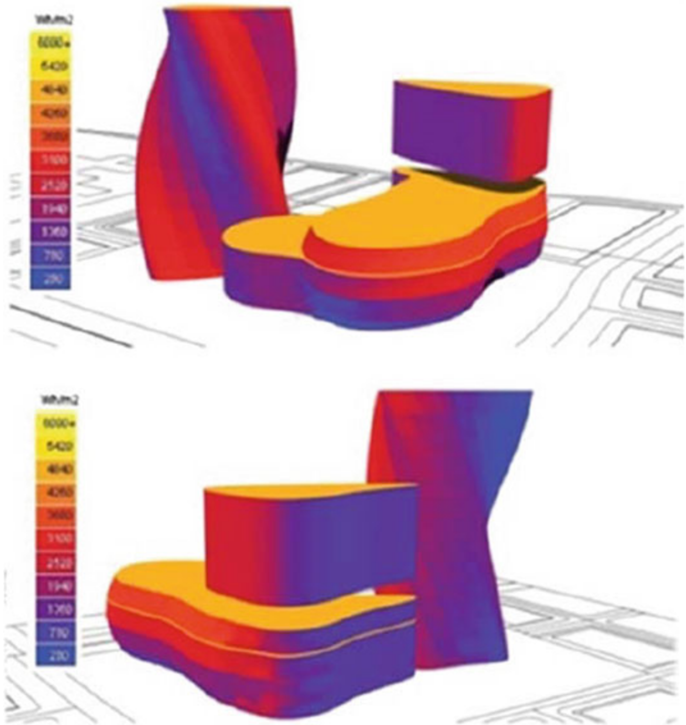

Fig. 23. Study of solar radiation [14]

Fig. 24. Additional shading design, exterior view and bird eye view [14]

4 Conclusion

In regard to the sustainability concept, performative architecture is quite important for including the physical environmental conditions in the design and making the digital design possible. Sun, one of the physical environmental conditions, has been an effective factor for solving the energy issue in the world. Solar energy based building envelope design models, which were examined for the digital designing in the study, were presented with the optimum solution strategies.

Ideal designing process is cyclical. The design can be revised in all stages of the project (Fig. 25) [15].

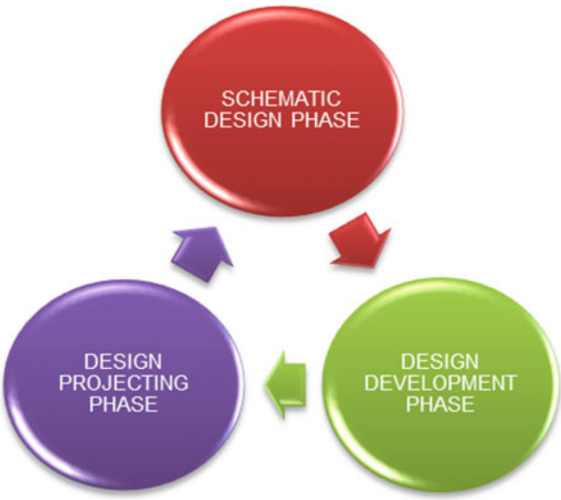

Fig. 25. Cyclical design process [15]

Performative design approach covers this cyclical process since the design includes the capability of performing instant and interactive calculations and real-time tests for the decisions regarding the design. Building envelope optimization based on the solar data was determined in the parametric environment of Rhino-Grasshopper, and any alterations to be made to the parameters were instantly reflected to the model and updated automatically.

If an evaluation is to be performed on the samples examined in this respect, it is realized that the building envelope was configured by the solar movements in different times in the early designing stages of the three samples. Trials indicated that there were models offering optimum energy. The most interesting characteristic of the examined buildings is the effort for evaluating the characteristics of the 'ground' in the best way possible. This effort is distinguished from the others which benefit from the solar energy using certain elements that were integrated later, distort the architectural language and are far from offering solutions providing maximum benefit. With the digital designing support of the performative architecture in the context of sustainability in the building design, it was ensured that a modern and ecological architecture glossary was formed.

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Implementation Issue of "Eco-city" Projects in Turkiye: An Assessment of Problems Encountered

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Abstract. Eco-cities are desired as healthy human settlements in which self-sufficient, targeted to the deterioration of the balance between natural ecosystems and built environment. In the literature; the pre-conditions which is vary in aspects of environmental, social, economic, spatial and legal characteristics as eco-cities are defined. At present, many countries, including Turkey, have been attempting to establish eco-city projects succeed in different levels. In this process, Many issues are encountered as problematic factors. These factors can be categorized primarily as legal, administrative and project related procedures and process issues. The role of 'actors' and actor relations, economic and socio-cultural structures take part in this outlook at different levels. The purpose of this study is to examine the examples of eco-city projects. All such project attempts have varying problems about putting the theory into practice, determine the most effective tools and procedure. As the method of this study, the process of these eco-city projects have been examined with this factors. The methodology includes surveying such as contacting to concerned institutions to identify related problems. In addition; categorically chosen examples of eco-cities around the world have been studied for comparision. The same parameters and methodology have been followed in this comparative study. The comparative outlook helped to grasp the problematic ingredients of the process which determined in the projects' success or failure, through this, whether the parameters in the projects have common characteristics or not, is investigated. Consequently; critical assessment through the findings, and suggestions to increase the success rate in the implementation of the eco-city projects.

Keywords: Ecological planning and sustainability · Eco-city projects
Comparative study

1 Introduction

With rapid population growth, developing technology systems and industrialization; humankind's pressure on ecosystems has increased and it causes the natural environment to gradually disappear and lose renewal power. In return, the sensitivity to

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environmental problems has improved since the 1970s. In the field of planning, evaluation of the natural environment is the most useful form for present and future generations. The ecological planning approach aimed at protection and development of resources connected to it and ensuring sustainability, finding a common usage [1].

Eco-city planning is putting the emphasis on the environmental aspects of planning while sustainable planning treats equally the economic, social and environmental aspects. Eco-city planning and management are based on the principle of a cyclical urban metabolism, minimizing the use of land, energy and materials, and impairment of the natural environment, ultimately leading to zero carbon settlements [2].

Eco-city principles have been defining in many studies both academical and non-academical ones. The following table shows a brief summary of these principles from many sources (Table 1).

Table 1. Eco-city principles [3]

Environmental	• Restoration of natural systems • Usage of efficient and renewable resources • Development of local agriculture and urban gardening • Waste management and recycling
Social	• Social justice • Ecological awareness • Public consciousness • Participation • Protecting and supporting local culture
Economic	• Sustainable and non-polluting economic activities
Spatial	• Compact land use • Mixed use • Reducing car use • Promoting short-distance public transport, pedestrian and bicycle transportation

Although the eco-city principles has defined theoretically at all points, the implementation phases of various eco-city projects are unique processes and each of them has own conditions, requirements and experiences. Like most countries Turkey has its own experiences about building eco-cities. It is more correct to term these experiences as "trying" because there isn't any project yet in Turkey which is successfully ended. The main goal of this study is to evaluate ongoing eco city projects from Turkey and to determine problems which are causing disruptions. As a method of the study, some eco-city projects from various countries were examined and through this examination same questions were asked. These questions are;

- Is the eco-city project designed as a new settlement, or in the existing settlement?
- How large is the project area and how many people are envisaged to live in the project area?
- What are the key principles of the eco-city project?
- What are the prominent potentials of the eco-city project area?
- Who are the actors involved in the project process?

- How and by whom did the project finance?
- Which phases have been defined for the project process?

Projects has been seen from the same view of point in order to build a comparative framework and to notice differences. After noticing the different aspects of the projects, successful examples could help to develop better projects and to eliminate factors causing disruptions.

2 The European and World Approaches Compared

2.1 Tianjin Eco-city

On 2007, the governments of China and Singapore signed the Framework Agreement on the Development of an Eco-city in China. Tianjin, Tangshan, Baotou, and Urumqi cities were candidates for a competitive site selection [3]. Eventually the Tianjin site was selected taking into account considerations such as the state of development of the surrounding infrastructure, ease of accessibility and commercial viability [4]. Tianjin Eco-City is located in the Bohai Rim region, which is the one of China's foremost industrial areas and which has over 240 million residents. Accordingly, Bohai Rim Region is a megalopolis containing country's largest urban agglomerations Beijing and Tianjin (Fig. 1). Bohai Rim also suffers from significant environmental externalities and both environmental and population pressures [5].

Fig. 1. Location of the eco-city project (*Source* www.tianjinecocity.gov.sg)

The Master Plan of the Eco-city completed by end March 2008 (Fig. 2), and the detailed plans of the 3 km^2 start-up area by end May 2008 [6]. The Project area was an empty city and according to the master plan this area will house more than 300,000 residents upon completion [5]. Within the planning process a set of Key Performance Indicators were developed to guide the implementation. 22 of them are quantitative indicators and four of them are qualitative indicators. Quantitative indicators are categorized into ecological and healthy environment, social harmony and dynamic and efficient economy. Qualitative indicators focus mainly on regional coordination and economic integration [3].

Fig. 2. Master plan of Tianjin eco-city project (*Source* www.tianjinecocity.gov.sg)

Key Performance Indicators are preservation and restoration of the natural ecology, recycling and efficient use of resources, social cohesion, green consumption, low-carbon emissions and at least 90% of the residents walking, using public transport or cycling as a transportation choice [6]. Master plan adopts a basic eco-structure expressed in a hierarchy of "live-work-play" spaces, eco-cells, walkable districts, high and tight housing structures and neighborhoods, vegetation spaces, blue water spaces and embedded transportation networks. In addition to that clean energy sources, practical energy solutions such as solar water heaters and geothermal heating systems and energy efficient solutions such as energy saving light bulbs have been adopted [7].

The ground-breaking ceremony for the project was scheduled for July 2008. The Eco-city Project has been developed by a joint venture company formed by Consortiums of Singapore and China, companies such as the Tianjin Binhai New Area Urban Infrastructure Construction Investment Co. Ltd, Tianjin TEDA Investment Holdings Co. Ltd and the China Development Bank [6].

Fig. 3. Project area in years 2007 and 2013 (*Source* www.tianjinecocity.gov.sg)

Tianjin Eco-City is built on a structure of large urban residential blocks separated by wide, multi-lane highways flanked by pedestrian pavements and protected cycle lanes [5]. This view may not evoke an eco-city at first sight but the eco-city project is a considerable effort when you think about non-arable and highly polluted Bohai Rim Industrial district surrounding the project area (Fig. 3). Nevertheless, the [3] highlights the risk of viewing the city's sustainability features in isolation, with limited wider impact unless these are treated as part of a larger regional and economic context (Table 2).

Table 2. Sino-Singapore Tianjin eco-city project

Is the eco-city project designed as a new settlement, or in the existing settlement?	New settlement
How large is the project area and how many people are envisaged to live in the project area?	300,000 residents on 34.2 km^2
What are the key principles of the eco-city project?	Good Natural Environment, Healthy Balance in the Man-made Environment, Good Lifestyle Habits, Developing a Dynamic and Efficient Economy, green consumption and low-carbon operations
What are the prominent potentials of the eco-city project area?	Empty space for the development, Strong political back-up
Who are the actors involved in the project process?	Consortiums of Singapore and China, Tianjin Municipality, Tianjin Binhai New Area Urban Infrastructure Construction Investment Co. Ltd, Tianjin TEDA Investment Holdings Co. Ltd, China Development Bank, World Bank
How and by whom did the project finance?	Cooperation between public and private sector
Which phases have been defined for the project process?	The project developed in three phases between 2008 and 2020: • Phase I: 2008–2010 (covering a start-up area of 4 km^2 and involving a projected population of 85,000) • Phase II: 2011–2015 • Phase III: 2016–2020
When will the project be completed?	It will be completed by 2020
What has been done for the participation of the people in the project?	Public participation before planning
What is the role of the project in the legal structure of the country?	China has a divided legal framework at core, State Council and ministry levels which affect also eco-city projects In the case of Tianjin, political and legal constraints have been successfully overcome through inter-institutional communication

2.2 Freiburg Eco City

Freiburg has been perceived as one of the best ecological model cities since the mid-1980. From this aspect, Freiburg is an early example about eco-city movement. In fact, Freiburg is a city that is more often named as green city rather than eco city. Achievements in environmental policies in Freiburg can be traced back at least to the

1970s [8]. Freiburg is located in the southwest corner of Germany, at the edge of the Black Forest and near the borders with France and Switzerland (Fig. 4). The city of Freiburg was rebuilt with great devotion and effort after its great destruction in World War II.

Fig. 4. Location of Freiburg

The green story of Freiburg began in 1975. Nuclear industry firms and the state government planned to build a nuclear power station nearby Freiburg but the construction site was occupied by a unique mix of local farmers, students from Freiburg and conservative citizens from the region. After this resistance, the government stopped construction of the nuclear power plant and the municipality of Freiburg turned to alternative energy sources [8]. Addition to that the protests became a cross-national environmental movement against the way political decisions were made by regional, national and supra-national governmental bodies [9].

Fig. 5. Overview of the Freiburg City (*Source* http://www.iktisadi.org/wp-content/uploads/2015/07/freiburg.jpg)

In Freiburg not only nuclear power plant site but also former military site, prefabricated high-rise buildings and social housing sites were transformed into ecological friendly settlements. In Freiburg; roofs of buildings that are responsible for 40% of all energy consumption are covered with solar panels, 90% heat insulation provided in buildings compared with others, energy production of the city localized, inner city has become car-free and the transportation system included car sharing, cycling and public transport (Fig. 5). In Freiburg even soccer stadium of local team was built with solar panels. City of Freiburg has succeeded to use solar energy at maximum level although the region hasn't got high level of sunshine duration (Table 3).

Table 3. Freiburg green city

Is the eco-city project designed as a new settlement, or in the existing settlement?	Existing settlement
How large is the project area and how many people are envisaged to live in the project area?	About 220,000 residents are living on 155 km^2 of land
What are the key principles of the eco-city project?	Energy supply concept: insulating and green buildings, the share of renewable energy (solar, wind, landfill gas), the district heating system; Transportation: mix of pedestrian zone, cycling, public transport; Climate Protection; Livable environment that combines tradition and modernity; Local economies and Integrating all strands of society

(*continued*)

Table 3. (*continued*)

What are the prominent potentials of the eco-city project area?	People's high level of sensitivity, Dense formation of green areas, The opportunity of being applicable at different urban scales
Who are the actors involved in the project process?	Municipality of Freiburg, local community
How and by whom did the project finance?	Municipality of Freiburg, local community, eco-industry tourism
Which phases have been defined for the project process?	Beginning of the process was unorganized, but chronologically; – Public intervention to construction of nuclear power plant – Beginning to use sustainable energy sources
When will the project be completed?	Freiburg Green City has an open-ended process because it is not a defined project
What has been done for the participation of the people in the project?	The local people have an active role since the beginning of the process thanks to their high level of consciousness
What is the role of the project in the legal structure of the country?	

2.3 Copenhagen Green City

Copenhagen, which is the capital City of Denmark covers an area of 74.4 km^2 and has population of 541,989 in 2011 [10]. Copenhagen is an important European capital and the largest Scandinavian city (Fig. 6) Instead, the first things to be noticed are the calmed and relaxed atmosphere, the nearness to forests and sea and the ring of bicycle bells passing by. Perhaps these are the factors that make Copenhageners some of the happiest and healthiest citizens in the world. Even though, the city of Copenhagen will be setting new standard for, the healthy and clean cities of the future. City officials have decided to make Copenhagen a better place to live by creating the first carbon neutral capital in the world by 2025, and the first step to achieve this goal is to reduce the CO_2 Emissions by 20% between the years 2005–2015.

This ambitious goal is to make Copenhagen a more pleasant city to live and it will also create new 21st century green jobs introducing Copenhagen as a centre for future sustainable research and development in the international community [11].

Fig. 6. Location of Copenhagen city (*Source* http://www.vidiani.com/large-detailed-road-map-of-copenhagen-city-with-surroundings/)

Copenhagen has set of target in 2015 for its goal of evolving into an “eco-metropolis”—a green and blue capital city with ample biking and a strategy for adaptation against climate change. Copenhagen also aims to become the first climate neutral capital by 2025, a target it plans to achieve through building retrofits and reduced reliance on fossil fuels [12].

2.3.1 Urban Sustainable Planning Strategy

In order to make Copenhagen first Carbon Neutral Capital in the world an intelligent urban planning was allowed the city expand in size and population for a cleaner and a healthier future is required. Copenhagen has always inspired other cities to create a healthier environment, going from the famous blue bicycle lanes to its energy production or the improvement of recreational areas, pedestrian streets and a more active and vibrant social environment for the citizens (Fig. 7) [11].

Fig. 7. View of Copenhagen city

During the 90s, Copenhagen started converting many of its open-air parking lots, into enjoyable public areas. This transition created good business environment a more active life style for Copenhageners and gave rebirth to derelict historical areas. Well-designed urban spaces will encourage more people to walk and more visitors will attract more people; but new public spaces are not the only strategy to help Copenhagen to achieve its goal. The city has initiated an urban scheme called "Green and Blue Capital City" to provide clean parks and beaches for the great majority of Copenhageners, by the year 2015. This fact will attract more visitors and will provide an environment of peace and relaxation as well as a chance for physical activity for the citizens. Today 60% of Copenhageners are living within 15 min walking distance of a green or blue area. Moreover, Copenhagen city officials have decided to provide 90% of their citizens with a 15 min walking distance to a green or blue area by the year 2015. In the words of Jan Gehl, a city planning should consider "Life, Space, Building—in that order" [13].

Transportation

Copenhagen's extensive bicycle lanes have created a more human friendly urban environment, a more liveable city, less traffic congestions, lower noise and air-pollution and a reduction in carbon emissions (Fig. 8).

Currently, cyclists in Copenhagen are biking more than 1.1 million km every day. 36% of Copenhageners choose to go by bike to their place of work or educational institution. This amazing number of cycles is presumably a world record and constitutes an important part of Copenhagen's identity Climate Capital Copenhagen has already taken giant steps in reducing CO_2 emissions.

Fig. 8. Transportation of Copenhagen (*Source* http://ec.europa.eu/environment/europeangreencapital/winning-cities/2014-copenhagen/)

Because most of them regularly use the bicycle, the city has a very low CO_2 emission and very healthy locals. The newest project in Copenhagen is called *The Green Path*—a 9 km long path for biking and walking, filled with benches, parks and playgrounds. Also the scenery changes along the path due to using different terrain.

Sustainable energy

Currently 22% of Denmark's electricity is produced by wind energy. To reduce carbon emissions and to create new high skilled green jobs this number is expected to reach 50% by the year 2020 [14]. Moreover, Copenhagen has one of the most efficient waste management systems sending 2% of its waste to landfill (this figure was 40% back in 1988). Properly filtered waste-energy power plants meet the high Danish emission regulations while providing the city heat and electricity. In addition, 98% of household in Copenhagen are connected to the "District Heating System" that produces energy reusing the surplus heat for heating the households avoiding sea ejection.

2.3.2 Future of Copenhagen

The city of the future is no longer about demonstrating economic power through skyscrapers and bigger highways, but it is about creating a better, welcoming and a vibrant urban environment for all with healthier environment policies. Statistics are showing how Copenhagen has been able to reduce its CO_2 emissions by more than 20% from 2005 to 2011 [15]. City's main strategies for accomplishing are:

- Implementation of smart urban policies to improve pedestrian-friendly
- Environment that will generate better public spaces and healthier
- Outdoor activities for the citizens.
- Development of a more efficient transportation system
- Increase of sustainable energy production with lower energy consumption.

By achieving its goal, Copenhagen will become an important research hub for international green clean-tech companies. With its current district heating system and the existing extensive bicycle lanes, Copenhagen is already a step closer towards its target.

Moreover, one of the city's most valuable assets in this case is the extremely environmentally conscious public opinion, a motivating factor for Copenhagen to become the first carbon neutral capital in the world by the year 2025 (Table 4).

Table 4. Copenhagen green city

Is the eco-city project designed as a new settlement, or in the existing settlement?	Existing settlement
How large is the project area and how many people are envisaged to live in the project area?	About 541,989 residents are living on 74.4 km^2 of land
What are the key principles of the eco-city project?	pedestrian-friendly, better public spaces and healthier\outdoor activities for the citizens, Development of a more efficient transportation system, Increase of sustainable energy production with lower energy consumption
What are the prominent potentials of the eco-city project area?	People's high level of sensitivity, Dense formation of green areas, The opportunity of being applicable at different urban scales\environmental quality
Who are the actors involved in the project process?	Municipality of Copenhag, Danish Ministry of Environment City of Copenhagen Greater Copenhagen Authority
How and by whom did the project finance?	Municipality of Copenhagen
Which phases have been defined for the project process?	(1) The medieval city: Until mid 19th century the city was surrounded by ramparts and 130,000 inhabitants were living on just 3 Km^2 in the fortified city (2) The Tram City: In the beginning of the 20th century Copenhagen incorporated some of its neighbouring towns and the working and middle class areas that was developing there was subsequently served by an extended network of trams (3) The pre-WW2 city served by S-trains: In the 1930s the population of the capital passed one million making further layer-by-layer growths impossible (4) The post-WW2 radial, suburban development The Fingerplan-city
When will the project be completed?	1960s-ongoing
What has been done for the participation of the people in the project?	The local people have an active role since the beginning of the process thanks to their high level of consciousness
What is the role of the project in the legal structure of the country?	Is the general planning understanding of the sustainable planning country. And Copenhagen was chosen as the greenest city

2.4 Curitiba Eco City (Brazil)

Curitiba is located in the south of Brazil (Fig. 9). It is the capital city of Paraná with a metropolitan region consisting of 25 municipalities holding a population of 3.2 million people. Between 1950 and 1980 years Curitiba was the fastest growing Brazilian city with the same poverty and inflation rates as other significant Southern cities in Brazil. At this time most Brazilian cities developed around the automobile by investing in heavy infrastructure [16]. Unlike other cities Curitiba took a different path Despite major challenges that came with rapid growth, significant improvements have been made to the city's quality of life in areas including public transportation, preservation of the city's cultural heritage, expansion of parks and green areas, and social and environmental programs.

Fig. 9. Location of Curitiba, Brazil (*Source* http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/green-city/curitiba-the-green-capital/)

Curitiba has a long tradition of innovative and integrated urban planning geared toward the strategic imperative of making the city a better place to live, as outlined in the city's Master Plan of 1965. In the 1970s and 1980s, physical, economic and demographic growth was rapid and the city became an important industrial and commercial center. Urban planning focused on building the city and decentralizing it. From the 1990s until today, the city's main planning focus has been on sustainable development and integration of Curitiba's metropolitan region (Fig. 10).

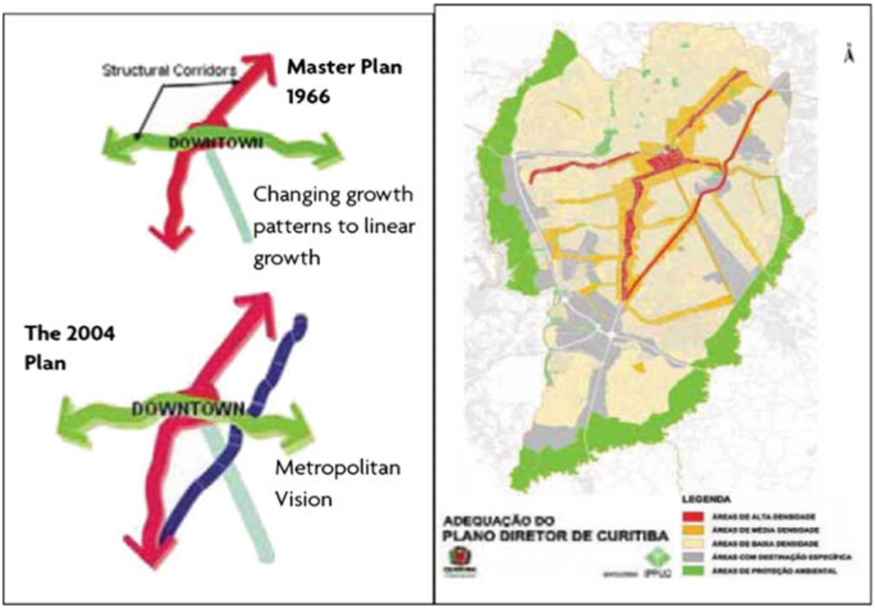

Fig. 10. Ecological planning of Curitiba [17]

The case of Curitiba, Brazil, shows that cost is no barrier to ecological and economic urban planning, development, and management. Curitiba has developed a sustainable urban environment through integrated urban planning. Curitiba adopted an affordable but innovative bus system rather than expensive railways that require significant time to implement. Curitiba's efficient and well-designed bus system serves most of the urban area, and public transportation (bus) ridership has reached 45%. The city now has less traffic congestion, which has reduced fuel consumption and enhanced air quality. The green area has been increased, mainly in parks that have been created to improve flood prevention and through regulations that have enabled the transfer of development rights to preserve green areas and cultural heritage zones. As part of efforts to concentrate shops and facilities in the city center and along dense axes, Curitiba's car- free central city zone (including its main streets and recreational facilities such as parks) has become more walkable, lively [17].

In 2010 the city was awarded with the "Globe Sustainable City Award [18]. Integrated urban planning (political, social, environmental, economical, cultural and technical) and implementation of goals by utilizing practical design solutions are key points in this achievement.

Curitiba's sustainable plan took various innovative approaches to ecological and economic urban planning. The following are the seven major approaches.

- Innovative land use planning integrated with transportation planning
- The integrated public transportation system
- Green area enhancement and flood control
- Solid waste management

- The Industrial City of Curitiba
- Social considerations
- Culture and heritage preservation.

Innovative housing financing system provided private sector housing to lower income groups without the need for large public investments. The well-known public transport and solid waste systems have made the city one of the cities that has maintained sustainability over the world.

Purpose of project;

- Creation of a sustainable urban environment and extensification of urbanization
- Provision of funds and urban land for individual construction projects
- Solution of working and living spaces together with creative and innovative designs.

Transformation

Planners in this city decided in 1969 to focus on an inexpensive and efficient mass transit rather than on the car. Curitiba now has the world's best bus system, in which clean and modern buses transport about 72% of the population every day throughout the city along express lanes dedicated to buses (Fig. 11).

Only high-rise apartment buildings are allowed near major bus routes, and each building must devote its bottom two floors to stores—a practice that reduces the need for residents to travel. Cars are banned from 49 blocks in the center of the downtown area, which has a network of pedestrian walkways connected to bus stations, parks, and bicycle paths running throughout most of the city.

Fig. 11. Transportation of Curitiba [26]

Consequently, Curitiba uses less energy per person and has fewer emissions of greenhouse gases and other air pollutants and traffic congestion than do most comparable cities. The city transformed flood-prone areas along its rivers into a series of interconnected parks. Volunteers have planted more than 1.5 million trees throughout the city, none of which can be cut down without a permit. And two trees must be planted for each one that is cut down [14].

Another feature of the city is the large amount of green space per head of population (52 m^2) which is remarkable in a city that has seen its population triple in the last 20 years (Fig. 12). Much of the green space was achieved by using federal funds for flood control to build small dams across rivers, creating lakes and parks for the city population. There are 28 parks and wooded areas in Curitiba, creating a city landscape which is unlike any other in a developing city [14].

Fig. 12. Cityscape Curitiba (*Source* Institute for Research and Urban Planning of Curitiba (IPPUC)

Curitiba recycles roughly 70% of its paper and 60% of its metal, glass, and plastic, which is collected from households three times a week. Recovered materials are sold mostly to the city's more than 500 major industries, which must meet strict pollution standards. Most of these businesses are located in an industrial park outside the city limits. A major bus line runs to the industrial park, but many of the workers live nearby and can walk or bike to work.

The poor receive free medical and dental, child care, and job training, and 40 feeding centers are available for street children. Poor people living in squatter settlements that garbage trucks cannot reach can exchange filled garbage bags for surplus food, bus tokens, and school supplies. Also, the city has a *build-it-your-self* program that gives a poor family a plot of land, building materials, two trees, and an hour's consultation with an architect. 'Sixty per cent of the lower-income people are involved in the construction industry anyhow', says one executive from COHAB (Curitiba's public housing programme).

Over the past 38 years, a web of partners and funders has contributed, working with local government in the creation of the "social capital," as Curitiba calls itself. City staff, IPPUC, government agencies, research institutions, community organizations, residents, non-governmental organizations and international agencies has all been involved in Curitiba’s ongoing development [14]. Briefly;

- Articulation of strong, local core values in a city plan.
- Creation of an independent municipal authority such as IPPUC to provide continuity and implement plans, as well as to monitor planning and research to improve future efforts.
- Integrated planning processes structured to assure that planners in all areas know the strategy and are working with a shared vision and developing their plans together. This way, many problems of unlinked development (e.g., not enough provision for green space) can be avoided.
- Establish a close relationship between public transportation and land-use legislation as a guidance and development tool. Cities’ environmental quality and economic efficiency are highly dependent on transportation systems that are well-integrated with urban form because this lets them avoid weak transportation systems and unsustainable dependencies on private cars.
- Developing new models that provide inexpensive, creative urban solutions and reflect local values are an alternative to standard, often-higher-cost approaches [19] (Table 5).

Table 5. Curitiba eco-city project

Is the eco-city project designed as a new settlement, or in the existing settlement?	Existing settlement
How large is the project area and how many people are envisaged to live in the project area?	City-wide (3.2 million people)
What are the key principles of the eco-city project?	Waste-transport-housing-social
What are the prominent potentials of the eco-city project area?	
Who are the actors involved in the project process?	City staff, IPPUC, government agencies, research institutions, community organizations, residents, non-governmental organizations and international agencies have all been involved in Curitiba’s ongoing development
How and by whom did the project finance?	IPPUC, government agencies, municipality
Which phases have been defined for the project process?	Master Plan of 1965. In 1970s Urban planning focused on building the city and decentralizing it. 1990s until today sustainable development planning
When will the project be completed?	1964-ongoing
What has been done for the participation of the people in the project?	Planning with participatory planning approach
What is the role of the project in the legal structure of the country?	Is the general planning understanding of the sustainable planning country

3 Eco-city Experiences of Turkey

3.1 Eskişehir Kocakir Urban Transformation (Super City System) Project with Sustainability Performance

The Kocakir is located on the south-west of the Eskişehir city macro form, the distance to the City Center is 10 km, the distance to the city connection is 5 km and the distance to Osmangazi University is 6 km (Fig. 13).

Fig. 13. Location of Eskişehir Kocakır super city project

Within the project the areas under disaster risk are carried out alternately. Sustainability-based credit permits of international and domestic financial institutions in urban transformation has been cerated. To obtain an application standard within the framework of evaluating urban transformation as a tool in order to meet the national requirements of the country on climate change case and to direct the process of obtaining ecological settlement units [20].

For the purpose of reducing the 'carbon footprints' of communities living in it Planning the settlement area that is less damaging than the damage caused by the standard settlement areas.

And the application process and as a result of Ecological Settlement Unit planning which is Environmentally sensitive planning and implementation approach, It will create a better quality and healthier urban lifestyle with Reduced greenhouse gas emissions and High economy will be provided with use of natural resources like Energy, water, etc. [20].

In project scope:

- Producing a draft text for establishing an implementation standard to be used by the Ministry
- To obtain type projects in accordance with energy efficient design criteria considering life cycle analysis
- According to life cycle analysis in settlement dimension, Calculation of the estimated amount of carbon reduction that can be achieved
- The production of a simulation program that can be published through the website.

The output of the website tests 5 pilot field which will be determined by the Ministry according to criteria such as urban location and site size, population, etc. Determination of properties of ideal ecological settlement units according to test results and Calculation of individual carbon footprints was planned around the scenarios of the sites (Fig. 14) [20].

Fig. 14. Top of super city project [21]

In this direction, it predicted that consisting of Energy efficient structure at the optimum level. The other aims of project are;

- evaluating the waste heat generated by the structures cooled by appropriate mixed use,
- producing, storing, using their own energy with renewable resources,
- constituting installation conditions,
- collecting domestic and rainwater in a discrete system,
- treatmenting used waters,
- providing green spaces and urban agricultural land,
- using public transport, pedestrian ways and bicycle paths,

- create their own business,
- limiting the use of fossil-fueled individual vehicles,
- construction waste from the transformation and
- encouraging Applications evaluating other miscellaneous wastes [20].

Cities which carrying performance criteria and all minimum criteria are developed in 6 main application area (Land Use and Urban Design; Energy; Water; Transportation; Materials and Resources; Social and Economic Sustainability, urban Transformation with Sustainability Performance) [21].

3.1.1 Information of Super City Project

Amount of stormwater harvesting is 498.92 m^3/year, total building water usage saving is 3771 m^3/day, amount of wastewater reuse is 8950 m^3/day, %35 less carbon emission (transport related), %28 less carbon emission (settlement related), annual electricity demand is 167,048.80 MWh%4, cogeneration power plant annual electricity supply is 73,629.30 MWh%34, solar energy power plants annual electricity supply is 109,817.30 MWh%66, gross density is 90 ppha, net density is 370 ppha, mixed use area is 176 h, number of dwellings is 18,778, total construction area is 3164.81 m^2 and green area per person is 90 m^2 in project area. Project area population will be 75,000 (Fig. 15) [21].

Fig. 15. View of super city project's simulation [9]

The value of real estate of the dwelling in the super city system will increase so users Have a lifestyle and a higher class housing as pay monthly rent Within the scope of the project in Eskişehir Kocakır, Pilot application of the standard is being carried out In the Reserve Building Area declared by the Ministry (838 ha) and it is aimed to obtain at least four quarters with a size of 100 ha [21] (Table 6).

Table 6. Eskişehir Kocakır super city project

Is the eco-city project designed as a new settlement, or in the existing settlement?	New settlement
How large is the project area and how many people are envisaged to live in the project area?	75,000 residents on 8.38 km^2
What are the key principles of the eco-city project?	Self sufficient, Effective use of renewable sources, Adaptation to climate change, Head island reduction, Carbon emissions reduction Adequate social infrastructure and facilities, Pedestrian, cycling and public transit, Efficient water use and management Recycling, Environment children and disabled friendly, Mixed use and healthy settlements
What are the prominent potentials of the eco-city project area?	Empty space for the development, Strong political back-up and university
Who are the actors involved in the project process?	Eskişehir Metropolitan Municipality, Istanbul Technical University, environment and urban ministry
How and by whom did the project finance?	environment and urban ministry
Which phases have been defined for the project process?	The project developed in four phases between 2016 to • Phase I: (covering a start-up area of 168.55 ha and involving a projected population of 34,144) • Phase II: 104.47 ha and involving a projected population of 14,560 Phase III: 156.76 ha and involving a projected population of 23,888 Phase IV: 135.29 ha and involving a projected population of 2408
When will the project be completed?	It completed in 2016 but The application of the project has not been started
What has been done for the participation of the people in the project?	Public participation before planning
What is the role of the project in the legal structure of the country?	The pilot Project is the only ecological planning example supported by ministry. Is the only super city project in Turkey

3.2 Nilüfer Municipality Eco-city Project (Bursa, Turkey)

Bursa is the 4th largest city in Turkey which located south of the Marmara Sea (Fig. 16). Metropolitan Municipality of Bursa determined a new direction of development in the western part of the city. Metropolitan-level Environmental Master Plan which includes Bursa City was also predict this development. The eco-city concept was adopted for this new development area by Local Government of Nilüfer and a Subscale plan was prepared which was a proposal eco-city model. The project area was a successful site selection according to analyzes that performed on the macro level and have as regards factors such as topography, agricultural lands, forest lands, close to universities around [3].

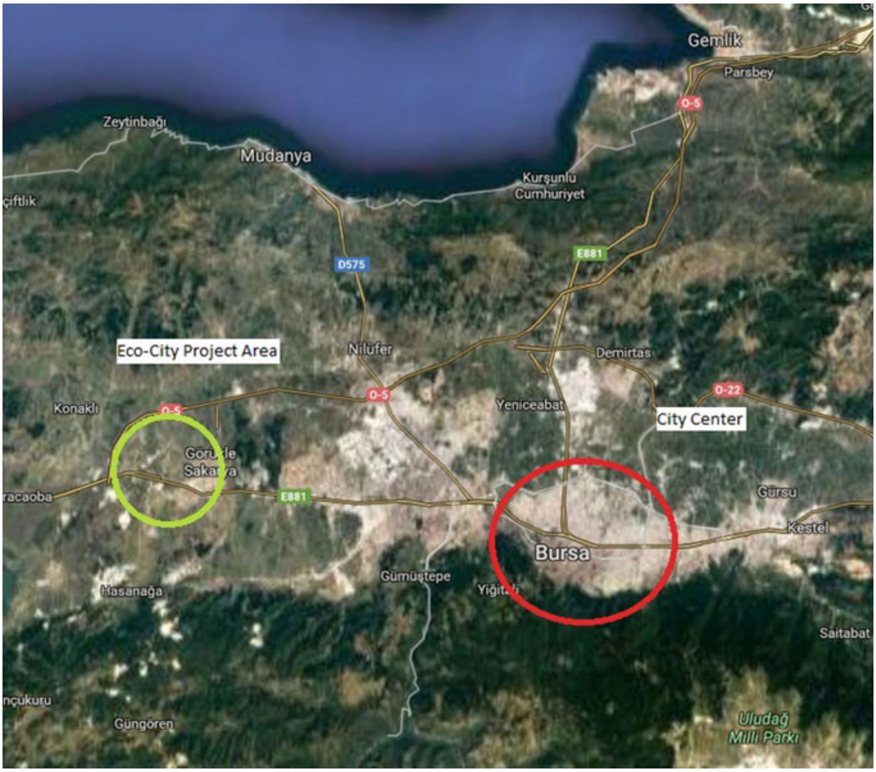

Fig. 16. Location of Nilüfer eco-city

The project area has chosen which will be overcome the new housing needs, will be sufficient in itself in terms of service delivery, will be support sensitive to the natural environment development process and will be provided the functional integration of artificial and natural environment.

The neighborhood unit has been evaluated as a basic data in the housing zone planning process of Bursa-Nilüfer Eco-City Planning Area. In the framework of physical conditions originated by the geography of the planning area, the main entrances of neighborhoods are given through the public transportation system. The entrance of the neighborhood unit has been evaluated as a dense activity zone with the downtown and its environs. Pedestrianization is requisite for the concept of Eco-City with regard to reaching neighborhood schools and green areas of neighborhood units. Different neighborhood units have been planned varying from dense activity areas to

Table 7. Nilüfer municipality (Bursa, Turkey) eco-city project

Is the eco-city project designed as a new settlement, or in the existing settlement?	New settlement
How large is the project area and how many people are envisaged to live in the project area?	About 200,000 people on 21.5 km^2 project area
What are the key principles of the eco-city project?	The components of neighborhood, Topography compliance, Pedestrianization, sensitivity on natural thresholds, Self-sufficiency, Links with Bursa the central area, Integrated Transportation systems, Harmony with the environment, Unity of accommodation and working areas
What are the prominent potentials of the eco-city project area?	Dense formation of green areas
Who are the actors involved in the project process?	Municipality of Nilüfer, Metropolitan Municipality of Bursa
How and by whom did the project finance?	The Project didn't reach yet the implementation phase
Which phases have been defined for the project process?	The project has just planned as master plan
When will the project be completed?	It is unknown currently
What has been done for the participation of the people in the project?	The project has just planned as Master Plan. Master Plans are sharing with community after their approval and people can object to plan provisions but eco-city project didn't approve yet
[What is the role of the project in the legal structure of the country?	Master Plans are in responsibility of both Metropolitan Municipalities and local municipalities. It is possible when local municipality proposes a Master Plan and the Metropolitan Municipality don't approve it. Therefore, planning processes interrupting because of various reasons (political, economic, etc.)

more solitude areas and ultimately the natural areas. Social and spatial diversity have been interpreted in this context [22]. In addition to all these, Master Plan was allowing the high rise housing settlements likewise Tianjin Case. With this justification The Metropolitan Municipality of Bursa didn't approve the Master Plan. Currently a new development plan is preparing by the Municipality which offer lower density of housing (Table 7).

3.3 Greater Gaziantep Municipality's Eco-city Initiation

Gaziantep municipality has been prepared a climate action plan in order to reduce carbon emissions and minimize effects causing climate change. Within the scope of this action, plan is intended to establish an eco-region. It was started in order to take control secondary residential applications which tends uncontrolled development in southwest corridor of the city and create planned urban spaces which aims.

Thus, It aims to build an ecological city—which is 11 km from the city center, includes the secondary housing and contains quality of the trees, planted fields and fertile soil—with a population of 200,000 in an area 3200 ha (Fig. 17).

Fig. 17. The site plan and conceptual plan of "Gaziantep Eco City" model. (*Source* http://egmimarlik.com.tr/2011/10/10/gaziantep-kilis-yolu-kentsel-tasarim-isi/.)

Central business area which is project of 55 ha area of feasibility report has been prepared in terms of energy and water by French Foreign Economy Bank in This Eco-city project (Fig. 18) [23].

Having prepared a climate action plan in order to reduce green house gas emissions. The Gaziantep Metropolitan Municipality's goal is to reduce the per capita carbon footprint and energy consumption by %15 through many projects by the year 2023. As the initial stages of the eco-friendly management concept, the following facilities are settled in Gaziantep [24].

Fig. 18. Gaziantep eco city project (*Source* http://www.gantep.bel.tr/haber/gaziantepin-ekolojik-kent-projesi-dunya-basininda–2979.html)

The energy plant which processes the city's refuse meets, the electrical power requirements of 13,500 households. The biogas cogeneration plants which involves mud tank that are heated by its power generator's heat. The objective of the ecological planning concept is to have Gaziantep join in the grid of ecological cities on a global scale. With the Gaziantep Eco city slated to be envisaged in the Kilis highway region an 'alternative life style zone' is included within the scope of the Project a number of social facilities such as 'an ecological farm, a health care center, as well as a renewable energy museum' will be constructed in the region [24].

Besides, solar-powered homes requiring low levels of energy a tramway line that supports the city's public transport as well as applications aimed at recycling rainwater are slated to be included in the planned zone. Special systems will be incorporated to separate nd store the waste of these eco-homes and ecological farms and bike paths will be established in the close vicinity.

Another objective of the eco city is to balance harmful carbon emissions with green landscaped areas and green roof systems [24]. Planning area covered 3200 ha is divided into five implementation stage. While dividing the stages, areas of the spatial integrity, balance between conservation and us, existing residential areas within interact with present green tissues, basin boundaries of the stream bed were taken into consideration [23].

Table 8. Gaziantep metropolitan municipality eco-city project

Is the eco-city project designed as a new settlement, or in the existing settlement?	New settlement
How large is the project area and how many people are envisaged to live in the project area?	About 200,000 people on 32 km^2 project area
What are the key principles of the eco-city project?	Provide social and cultural needs of the people, safe and healthy environment, improve quality of life, balance the protection and use, create alternative solutions for urban settlement and development trends
What are the prominent potentials of the eco-city project area?	Dense formation of green areas
Who are the actors involved in the project process?	Gaziantep university, Mavi Consultants, private sector, Metropolitan Municipality of Gaziantep
How and by whom did the project finance?	Metropolitan Municipality of Gaziantep, French Foreign Economy Bank
Which phases have been defined for the project process?	1/5000 scale of Development Master Plan and 1/1000 Scale of implementation plans and Feasibility plan
When will the project be completed?	2009—It is unknown currently
What has been done for the participation of the people in the project?	The project has just planned as Master Plan. Master Plans are sharing with community after their approval and people can object to plan provisions but eco-city project didn't approve yet
What is the role of the project in the legal structure of the country?	If it can be applied, it will be the only city planned in Turkey as a eco city plan. In, 2016 The project is still in the process of waiting for the approval of the municipality. Therefore, planning processes interrupting because of various reasons (political, economic, etc.)

The study began with the vision plan of works in 2009. In, 2016 The project is still in the process of waiting for the approval of the municipality. It is not specify a precise timetable for the project, but reaches a level of agreement with the authorities at the municipal level, and private landowners are persuaded, it will be alive in a very short time [25] (Table 8).

4 Conclusion

Tianjin Eco-City Project is an example of an excellent ecological urbanism according to many knowledgeable experts and observers. It is estimated that some positive features of the project led to this success. First of all, Tianjin’s eco-city project has an organizational structure which is a complex partnership involving multiple private and public sector participants from Singapore and China. Experiences of two countries and multiple structure of actors has helped to develop the eco-city project. The project area is a former industrial area which was very polluted. On that sense the project has a meaning about cleaning the area ecologically. It may be considered that the project area contains high density of apartment blocks and population but according to China’s own dynamics these settlements could be evaluate as ‘normal’. Finally, social harmony and public participation are communal causes which bring the project to the success. It is obvious that this eco-city project is a successful implementation although it is not finished yet.

Freiburg city is an example which is a grassroots movement with high level of public consciousness. The choice of green city instead of nuclear power station has predestine the future of Freiburg. Usage of alternative energy sources and transportation has become a life style for everyone who live in Freiburg. High level of consciousness of local community reveals the difference of Green City Freiburg. Because of uniqueness of Freiburg a new tourism a new branch of tourism has been occurred. Eco-industry tourism has also been a financial source which supports continuity of the project.

Curitiba city is an example which put people at the center and emphasized integrated planning—is that the city has become a showcase of ecological and humane urbanism, with ongoing improvements over the past 38 years to social, economic and environmental conditions for its residents. Curitiba has become the most sustainable of cities, in the process proving that applying a city strategy with strong values and a focus on integrated systems can harness the actions of planning departments to meet common strategic objectives.

Over the past 38 years, a web of partners and funders has contributed, working with local government in the creation of the “social capital,” as Curitiba calls itself. City staff, IPPUC, government agencies, research institutions, community organizations, residents, non-governmental organizations and international agencies has all been involved in Curitiba’s ongoing development [14].

Copenhagen 2015 consists of a whole urban plan for a city that already has good infrastructures for a sustainable growth. In both cases public awareness and politics conditioned the planning from diverse points of view but at the same time many common policies and urban development practices were applied.

In the case of Copenhagen, sustainability is a basic right and a concern for citizens and government instead of an asset for economical development thanks to an international event. These facts condition the strategy and its consequences: the city of Copenhagen required a global urban planning strategy urban improvements with repercussions for the city itself and the greater area focusing on the efficiency of the new architecture introduced in the urban grid.

The Project goals as low carbon emissions, improvement of public transport, an accessible city, bike and pedestrian-friendly town, accessible green areas and life quality improvement are present [11].

Nilüfer Eco-City Project is an unapplied example which has limited to only planning process. In Turkey master plan processes are very complicated in terms of competent authorities. In addition to local governments metropolitan municipalities, some ministries, housing development administration and some other institutions have the authority to make master plans. This situation causes many problems. Most prominent ones are fragmented master plans, nonoccurrence and difficulties in implementation. Eco-city project is an example about this complicated process. Local government has prepared the Master Plan of Eco-City but Metropolitan Municipality of the city didn't approve it. Main reasons about disapproval of master plan are high density of population on planning area and some political justifications. After three-time rejection of master plan local government has decided to prepare a whole new plan instead of developing eco-city project. This means that the master plan hasn't reach the implementation phase. Additionally, planning process hasn't included public participation and local community didn't make a claim to project.

Super City project, which will be implemented in Eskişehir basis seems to be a strong project is due to protocol of the university, ministry and the Metropolitan Municipality of Eskişehir. Here we will also consider the success of the local government in the implementation of the other projects, the project envisages a more efficient process than the desired ecological studies in other cities in Turkey. Participation of people in planning is another important issue. The lack of participation in the plan, one of the reasons for the failure of such projects in Turkey. The ministry has problems which is political, in approving these plans. As a result, the Eskişehir super-city project was completed in April 2016 and Waiting for the approval of the ministry (Table 9).

Table 9. Comparison of population density

Tianjin	8771 people/1 km^2
Freiburg	1419 people/1 km^2
Curitiba	16,860 people/km^2
Copenhagen	7284people/1 km^2
Nilüfer	9302 people/1 km^2
Eskişehir	8949people/1 km^2
Gaziantep	6250people/1 km^2

Consequently; It is observed that more comprehensive studies In ecological settlement projects in abroad samples. It is seen that ecological planning approach in all plans for the future of the city. When these projects are planned, it is seen that the city is handled with participation of the private sector, local governments, ministries and people. In Turkey, after the plans are projected, Problems arise during the implementation process due to political or financial inadequacies. Instead of anxious to obtain rent, planning should be adopted for the people who will use the place.

Two of these projects: Gaziantep and Nilüfer, are at various stages of implementation, however planning and developing an Eco-city is a tedious and uncertain process. Attempts to failure of China eco-city is occurred due to implementation difficulties, such as Dongton Ecocity. Similarly, besides state-level factors like political stability and economic growth, factors related to the local-level such as land availability and Infrastructure facilities, and Investment, play a critical role in making Eco-cities initiation a success. Barriers and challenges have been experienced with regards to the Eco-Town initiation in the case of Turkiye as well as the other developing countries' experiences. Moreover, lack of funds devoted to such initiations, and low environmental consciousness experienced at central and local government administrative levels, are important barriers.

It should be understood in Turkiye's case that, eco- cities cannot be formed in isolation from it's surroundings. So, these projects: need to ensure inter-linkages to the present settlements around; and should be aimed to develop such present settlements into eco-settlements as well. Moreover, any planned eco-settlement cannot be successful unless human development is taking place simultaneously. To say that, the socio-cultural aspect of sustainability must also be taken into consideration as a primer condition in the implementation process.

Hence, some of the key aspects to be considered while designing an eco city in such conditions are:

i. Land allocation: Allocated state land and/or land acquisition.
ii. Agreed population: Location and relocation of local people; participated in the process and agreed with the eco-development.
iii. Funding and investments: Preparing for Involvement of multi stakeholders in facing the enormous financial requirements without giving away from establishing environmentally sound technology to reduce carbon emission, recycling waste and water, and to create eco-buildings, eco-city infrastructure and sustainable transport.

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A Study on the Use of Forest Assets as a Means of Producing Land-Estate in Turkey

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Abstract. Publicly known as 2/B (commonly used abbreviation for the provisions of the Article 2/B of the Forestry Law), the law numbered 6292, concerning the sales of the land which has lost its quality as a forest after it is excluded from the forest, has taken effect in 2012. Regulations regarding 2/B had been addressed in several regulations, especially in the constitutions of 1961 and 1982. It was first introduced in the Forestry Law numbered 6831 with a temporary article amended in 24.07.1965. However, the article in question was annulled by the decision of the Supreme Court in 1966. In 1970, a provision on the land which can be left out of the borders of the forest was amended to the Article 131 of the Constitution of 1961. Articles 169 and 170 of the Constitution of 1982 were also amended with provisions similar to the ones in the Constitution of 1961. In 1983, the "Law on Promoting for Forest Villager's Development" numbered 2924 had taken effect. With the arrangement made in the Article 3 of the "Amendment to the Law on the Utilization of Real Properties Held by the Treasury and Value Added Tax" numbered 4706, it was defined how to apply the Law numbered 2924 on the land which is considered out of the borders of the forest pursuant to the Article 2/B of the Forestry Law numbered 6831 and how these lands will be assessed. However, this regulation was annulled by the Supreme Court decision in 2002. Following this decision of the Supreme Court, there was an inactivity regarding 2/B practices and relevant transactions were suspended. Finally, regulations on the land falling within the scope of 2/B were addressed with the Law numbered 6292. In this study, the Law numbered 6292 on "Supporting the Development of Forest Villagers and Utilization of Lands Taken Out of Forest Boundaries and Registered Under the Name of the Treasury and the Sale of Agricultural Lands Owned by the Treasury" which has taken effect in 2012 will be assessed in terms of the Constitution, Supreme Court's previous decision on this subject, zoning law, the prices and their implications on the environment.

Keywords: Forest asset · Environment · Land · Estate · 2/B

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1 Introduction

Forests are natural resources which provide human beings with material and nonmaterial benefits such as accommodation, food, firewood, medication, water, fresh air, panorama, recreation, etc. and they include an ecosystem. The real property system in Turkey involves the legal regulations on both public and private property. Turkey has inherited a real property system from the Ottoman Empire which allows limited private property while being based widely on public property. Forests, both before and after the proclamation of the Republic, are included in the public property. In its historical development, lands considered as forest within the scope of public property system, have always been utilized for agricultural or accommodation purposes. Such lands have been increasing in number due to the lack of monitoring, immigration, unplanned urbanization, insufficient production of land and estate, and political reasons. Legally public properties, such lands were subjected to any kinds of legal procedure except an official registry system such as the one applies for an actual private property. It is required to issue regulations due to the contradiction between public property and private property nature of a land subject to actual utilization and its legal status. A number of laws and other regulations, especially the Constitutions of the Republic of Turkey, have transformed forest land to land and estate subjecting it to private property.

This study consists of three chapters. The first chapter communicates general information on the forest assets and the property of the forests; second chapter explains the legal processes involved in the transformation of forest land into land and estate and the results of such practices; and the third chapter assesses the legal aspect of the transformation of forest land to land and estate and evaluates the SWOT analysis conducted on the 2/B practices.

2 Forests

2.1 Forest Asset

In legal terms, a forest is defined as groups of trees and small trees, naturally grown or cultivated. The scientific definition of forest, on the other hand, refers to an ecosystem signifying the relationships between plants, animals, and microorganisms along with trees and physical environmental factors such as land, water, air, sunlight and temperature [1].

¼ of the total land surface of the Earth (polar areas excluded) consists of forests. The total forest land in Turkey accounts for 21.68 million ha. The ratio of this forest asset to the total area of the country is 27.6%. The average ratio for the world is 26.19% while it is 39% in the EU [2].

2.2 Property Status of the Forests in Turkey and in Some Other Countries

It can be seen that property of forests is governed by public law, private law or both systems in different countries. 70% of the fertile forests are subject to private property in the EU, 66.7% in the US, 59% in the Japan; while 100% of the fertile forests are subject to public property in Russia, 99.9% in Turkey, 89.7% in Canada and 77.5% in Greece [3]. There are 227 private forest lands in Turkey accounting for 0.086% of the total country area along with 51 institutions with public legal entity accounting for 0.07% of the total country area [4].

3 Legal Development of the Transformation of Forest Assets to Land-Estate and the Area Acquired in Turkey

3.1 Provisions of the Turkish Constitutions

The Article 131 of the Constitution of 1961 [5] is titled "Protection of the Forest Villagers and Development of Forests" and it did not include any provisions regarding exclusion of any land from the scope of forest in its original version. The Article 131 of this Constitution was amended with the provision of "there can be no reduction in the forest area except agricultural lands such as vineyards, groves, olive groves, etc. and lands which are beneficial for livestock farming which scientifically lost its forest quality before the effective date of this Constitution and the land where city, town and village structures are available in groups". Thus, the first constitutional basis for exclusion of the land from the forest boundaries was provided.

The Article 169 of this Constitution of 1982 [6] had the provision of "there can be no reduction in the forest area except agricultural lands such as vineyards, groves, olive groves, etc. and lands which have proved beneficial for livestock farming which scientifically lost its forest quality fully before 31.12.1981 and the land where city, town and village structures are available in groups".

The Article 170 of the Constitution of 1982 had the provision of "the Law regulates the monitoring and operating the forest by the State in cooperation with the individuals living in the forest and the neighbouring villages in order for the development of such individuals, and the protection of the forest and their integrity; utilization of the land which has lost its forest qualities scientifically before 31.12.1981; detection and exclusion of the land which is not considered beneficial to protect as forest; relocation of the villagers living in the forest to these areas partially or fully after the State reclaims this land for the utilization of such individuals. The State takes necessary measures to ensure provision of operating tools and equipment and other inputs to the individuals in question. The land once utilized by the individuals of the forest villages is then reforested by the State immediately."

3.2 Provisions of the Turkish Laws

The Article 2/B of the Law numbered 6831 had the provision of "agricultural lands such as vineyards, groves, olive groves, hazelnut groves, peanut groves, etc. and lands which are determined to be beneficial for livestock farming such as pastures and meadows which scientifically lost its forest quality before 31.12.1981 and the land where city, town and village structures are available in groups are excluded from the forest land.

Such lands are excluded from the forest on behalf of the Treasury if it belongs to the State; on behalf of the public institutions with legal entity if they belong to them; and on behalf of the proprietor if they are private forests. As soon as the practice is finalized, revision and registry of the land title is completed. There can be no exclusion from the forest area other than the aforementioned situations."

In the light of the discourse above, it can be said that the legal basis of the land, commonly known as 2/B land, is the Paragraph B of the Article B of the Law numbered 6831 on the practices about these lands. There have been several legal regulations made in parallel to the Article 2/B of the Law numbered 6831. Such regulations are the Laws numbered 2924, 4706 and 6292. According to the provisions of the Law numbered 2924 [7], land which has certainly lost its forest quality were sold to the beneficiaries by General Directorate of Forest and Village Relations after being registered to the Treasury by forest cadaster commissions and then being put under the Ministry of Forests' order. This General Directorate had conducted a high number of sales during the period between 1998 and 2000. Article 13 of the Law numbered 6292 issued in 2012 annulled the Law numbered 2924.

The purpose of the Law numbered 4706 [8] is to make the real-estates belonging to the Treasury a part of the economy as soon as possible. Article 3 of this Law states, as follows;

"The provisions of the Law on the Supporting the Development of Forest Villagers numbered 2924 do not apply to the land which has been excluded from the forest area pursuant to the Paragraph B of the Article 2 of the Forest Law numbered 6831. Upon the request of the Ministry and if it was not surveyed before, such land will be surveyed and then registered to the Treasury including the name(s) of the owner(s) of the developments made on the land or the one(s) who utilize such land, if any, without any announcements except the suspension announcement stated in the Article 11 of the Cadaster Law numbered 3402 with regards to its actual utilization and then it is given to the disposal of the Ministry of Finance. (…)" Once bestowed on the Ministry of Forests with Las numbered 4706 and 2924, the authorization has been allocated to the Ministry of Finance.

Article 1 of the Law numbered 6292 [9] includes the provision of "the purpose of this Law is the utilization of the lands excluded from the forest area on behalf of the Treasury pursuant to the Forest Law numbered 6831 issued on 31/8/1956, creation of new forest areas, relocation and supporting of the development of the village population living in or in the vicinity of National Forests which are decided to be transferred and specification of the methods and essentials regarding the sales of the agricultural land belonging to the Treasury."

Paragraph 2 of the Article 1 and Article 2 of the Forest Law numbered 6831 governs the lands excluded from the forest area on behalf of the Treasury and the agricultural land belonging to the Treasury.

Clause f of the Paragraph 1 of the Article 2 of the Law defines the land on which a squatter or urban transformation project will be applied as confirmed by the Ministry of Environment and Urbanization and the land of which the boundaries are defined by the Ministry of Environment and Urbanization (CSB) and the Housing Development Administration of Turkey (TOKI) or relevant Metropolitan Municipalities or other municipalities and the land to be excluded from the forest if required to improve the integrity of such project. A close look into this article shows that it is possible to apply a squatter or urban transformation project on the land within the scope of the Article 2/B. The boundaries of such land are defined by CSB, TOKI or relevant Metropolitan municipalities or other municipalities and confirmed by CBS.

Satellite images of the project area, plans of any type and scale, if any, zoning plan, property information, cadastre map sections, and current maps are submitted to the CSB by the municipalities using the Governorate and directly by TOKI. According to the Paragraph 2 of the Article 10 of the Law, the income obtained from the execution of this Law are registered as private grant and utilized in the transformation of areas under the risk of natural disasters.

3.3 Actual Status of the Forest Assets Transformed into Land or Estate and the Results of the Practice

Forests are included in the public property as part of the Turkish Legal System. They are not subject to private property. There are customized and strict rules for the land which has lost its forest quality. The actual status of the land which has lost its forest quality with the Law numbered 6292 and other relevant regulations are shown in Table 1.

Table 1. Number of 2/B applications and sales by the type of estate [10]

Type of estate	Number of applications	Number of sales
Land	3.842	2.524
Estate	18.630	13.713
Vineyard-garden	121.034	87.894
Building	5.629	4.703
Empty Lot	514	46
Mining and quarry areas	9	9
Forest	575	83
Common properties	1.041	495
Water and aquaculture areas	81	24
Historical and cultural sites	1	0
Field	411.215	338.367
Vacant	2.342	2.140
Total	565.619	450.636

According to Table 1, the majority of the applications and sales transactions are conducted for field and vineyard-garden by sales to application ratios of 94.10 and 94.59%, respectively. On the other hand, the sales to application ratios of estate and buildings are 4.29 and 4.09%, respectively.

2/B application data obtained from the General Directorate of National Estate of the Ministry of Finance were analysed until 07.11.2016 [10]. The analysis showed that 952,010 applications were received for 685,866 parcels; 610,895 individual sales transactions (84.2%) were made; and 84,336 applications were not approved due to rejection, land being in the project area, return of the property, etc. The total surface area of the 2/B real-estates which were excluded from the forest area as of the effective date of the Law is 314,463 ha. The applications accounted for 238,395; 32,838 ha of this was returned and a total area of 178,519 ha (65.82%) was sold. Among a total number of 21,390 real-estates available in the project areas, 2686 were transferred to TOKI, 728 were transferred to Istanbul Metropolitan Municipality, 6 were transferred to Kocaeli Metropolitan Municipality and 17,970 were transferred to other municipalities. The revenues collected from the 2/B applications after expenses and taxes are subtracted accounted for 1.675; 1.317; 0.822; and 0.612 billion Turkish Liras, respectively for the years between 2013 and 2016. The total revenues added up to 4.475 billion Turkish Liras.

Forest assets are reduced in order to produce land and estate, while trying to maintain the total forest area with new afforestation areas. Table 2 shows the inventory analysis results of the size of the forest areas and the relevant changes in the size by year. According to Table 2, the forest assets are increased by 2.1 million hectares in 42 years.

Table 2. Forest inventory analysis results by year [10]

Year	Forest area (ha)	Ratio in the total country area (%)
1973	20.199.296	26.1
1999	20.763.248	26.7
2004	21.188.747	27.2
2012	21.678.134	27.7
2015	22.342.935	28.6

4 Assessment of the Transformation of the Forests into Land-Estate

4.1 Assessment in Terms of Its Compliance with the Hierarchy of Norms, Price, Environment and Zoning Applications

In the annulation decision of the Supreme Court regarding the exclusions from the forest area dated 2002, it was stated that the land excluded from the forest area can only be used for relocation and transfer of the forest villagers and that it is not possible to sell or transfer these lands to the individuals utilizing them or other, not even the forest villagers. It is also not possible to reach to a conclusion other than the expressions of “allocation” and “utilization of the people” used in the Article 170 of the Constitution. Following the decision of the Supreme Court in 2002, no other practices were done for the lands excluded from the forest are until the Law numbered 6292 took effect.

The Law numbered 6292 involves regulations similar to the ones available in Laws numbered 2924 and 4706, which were annulled by the decision of the Supreme Court. In other words, Law numbered 6292 includes provisions for sales signifying the property transfer. Preference of such a legal regulation without an amendment to the Article 170 of the Constitution, does not eliminate the issue of discrepancy with the Constitution. Nevertheless, the Law was not seen by the Supreme Court with the claim of discrepancy with the Constitution.

There are no other provisions on the zoning of 2/B areas except the provisions available in the Law numbered 6292. Temporary Article 2 of the Law numbered 2981 [11] on the zoning practices on the 2/B areas include the provision of "the settlement areas where city, town and village structures are available in groups and those which has lost their forest quality scientifically before 31.12.1981 are considered excluded from the forest area. Such lands are governed by the provisions of this Law." However, this provision paves the way for parceling having included the 2/B areas in the scope of the reformation zoning plan [12], it was annulled by the Supreme Court in 1995 (published in the Official Gazette in 2002).

Following the decision of the Supreme Court, there were hesitations regarding if 2/B areas can be subjected to zoning. On this controversy, the General Directorate of Land Registers stated that any structure of utilization cadaster in a land which is excluded from the forest area can be subjected to zoning practices, otherwise, this is not possible in another way. 20th Civil Chamber of the Supreme Court and 6th Chamber of the State Council, on the other hand, seem to have different decisions on this subject.

Clause f of the Paragraph 1 of the Article 2 of the Law states that a squatter or urban transformation project area will be defined by the Ministry of Environment and Urbanization (CSB) and the Housing Development Administration of Turkey (TOKI) or relevant Metropolitan Municipalities or other municipalities to include the areas outside of these areas in order to maintain the integrity of the 2/B areas, if necessary. According to the Article 8 of the same Law, it was clearly stated that zoning plans of any scale and any zoning practices based on these plans including the amendments, parceling plans, parceling and incorporation transactions in areas defined as the project area will be conducted by the project area management and confirmed by the Ministry of Environment and Urbanization; which means that 2/B areas are open for zoning plans. Article 4 further states that the Ministry of Environment and Urbanization is authorized for the settlement plans and practices which are not within the scope of the project.

The total area excluded from the forest as settlement accounts for 4% of the total exclusions. Moreover, in cities where estate prices are high such as Istanbul, Antalya, Kocaeli and Yalova [13], higher revenues were expected despite of its rather small share of approximately 4% in total exclusions.

It is observed that the properties on the 2/B areas are subject to different evaluations in terms of their value. Basis value, current value and cost value are observed in real property tax. However, it is possible to have a discount for agricultural lands, and lower deposit and higher number of installments are offered for this value. For real-estate other than agricultural ones, discounts and the number of installments are lower and the deposits are higher [14].

4.2 SWOT Analysis of the Transformation of the Forest Assets into Land-Estate

Table 3 shows the strengths-threats and weaknesses-opportunities defined by the SWOT analysis concerning the transformation of the forest assets into land-estate as part of the 2/B practice.

Table 3. Results of the SWOT analysis for the transformation of forest assets into land-estate

SWOT Analysis	
Strengths	• Availability of land suitable for agriculture and settlement in lands excluded from the forest • Availability of regulations for the exclusion from forest and relevant assessment • Inclusion of satellite images, plans of any scale, zoning plan, property information, cadastre map sections, and current maps of the project area which will be developed as a settlement in the 2/B area • Prevention of any usage out of agricultural in the transfer of land used for agricultural purposes, inability to divide the land to parcels smaller than a defined size, and requirement of the Law on Soil Preservation and Land Utilization numbered 5403 which observes the efficiency and effectiveness in agriculture taken as the basis • Availability of human resources which can develop plans for agriculture and settlement areas • Discounts given to those land to be used for agriculture, and annulation of rights without a time limit when it is detected that such agricultural areas are utilized for other purposes • Giving land titles to the proprietors who have been using their properties without a land title for years, in return, solving the property issues. • Eliminating the court cases between the citizens and the state
Threats	• Reduction of the forest areas due to exclusions from forest • Increased forest occupation activities due to the expectation that exclusions from forest area will be continued • Increased immigration and unplanned urbanization with the new forest areas being occupied • Increased erosion and desertion rate • Reduced agricultural production power due to the use of agricultural land for non-agricultural purposes
Weaknesses	• Aspects such as application and entitlement being subject to not taking action and withdrawal of suit if the action was taken whether the claimant is entitled • Difficulties which may arise in the elimination of conflicts and victimization on this subject due to the provisions about the real-estate to be returned are limited • However, the Law numbered 6292 is about development of forest villagers, the fact that this aspect is not the focus of the Law

(*continued*)

Table 3. (*continued*)

SWOT Analysis	
	• The focus on the revenues when drafting the Law, disregarding the economic, social and environmental factors as a whole • The fact that General Directorate of Forestry was included to the plans and policies with respect to the issues related to forests, while Ministry of Environment and Urbanization, the Housing Development Administration of Turkey and Municipalities were included with respect to issues related to settlements, but Ministry of Food, Agriculture and Livestock was not included with respect to the issues related to agricultural land • The fact that the Law numbered 6292 (2B) proposes property transfer through sales which means the continued discrepancy with the annulation decision of the Supreme Court in 2002 regarding the Law numbered 4706 correcting the method to be used as allocation instead of sales • Not defining the means to develop the forest villagers who have the smallest share in the income distribution in the society and obligation of payment of a price without regarding their purchasing power • The fact that a valuation based on cost value, real-estate tax value and current value may lead to unfair income for specific institutions and individuals • Cancellation of the right to purchase and conveniences when the users cannot claim due to short application period • The updating of the user information of 2/B lands being made before the effective date of the law and the sales price being determined at the time of this update, which may lead to unfair results for the updates to be made in the future
Opportunities	• The possibility of afforestation which can overshadow the land excluded from the forest • Increased agricultural production, evaluation of agricultural land in terms of sustainable development especially with organic agriculture • Possibility offered to the ones whose land titles were cancelled as their lands were in the 2/B area to claim their real-estate free of charge • Possibility of rearrangement of the unplanned settlements with squatter prevention and urban transformation projects; contribution to the modernization of urban infrastructure and structure • Optimal efficiency obtained from agriculture as a production factor • Being able to claim real rights and use the land as capital with the solution of propriety issues; increased tax revenues and contribution to the prevention of unrecorded economy

The following strategies can be defined with a critical approach to the strengths and threats and weaknesses and opportunities listed in Table 3:

- It may be possible to solve the propriety issues and court cases between the state and its citizens as a result of plans which address economic, social and environmental effects of the land excluded from the forest without compromise for any kind of occupation which may lead to further reductions in the forest area.

- Using the experience of specialized personnel for agricultural and settlement areas, it may be possible to reduce the non-agricultural use and the decreased agricultural output with respect to the agricultural land regulations available in the Law numbered 5403 [15], to implement modern urban arrangements and land can be protected against erosion and desertion.
- It may be possible to improve tax revenue and to prevent unrecorded economy, to have individuals use their real-estate as capital once the propriety issues are solved and necessary flexibility is provided to the application period, law suits to be withdrawn for application, real-estate to be returned; possible unfair income due to the evaluation methods used is eliminated, and the price differences due to the information update time differences are solved.
- It may be possible to obtain maximum yield from agriculture especially with organic agriculture and a production factor with customized provisions taking effect for the forest villagers who has the lowest GDP consulting the Ministry of Food, Agriculture and Livestock along with the other institutions bestowed with the planning authorization in the Law and to contribute to the modernization of the urban structure and infrastructure preventing unplanned urbanization.
- A certain amount of money obtained from the execution of the Law can be added to the forest assets with afforestation efforts.

5 Result and Recommendations

A forest is defined as groups of trees and small trees, naturally grown or cultivated. Turkey has a total forest area of 22.3 million hectares. The rate of this forest area to the total land of the country is 28.6% [16].

There have been several Laws in the close past taken effect concerning the sales or allocation of the land which has lost its quality as a forest after it is excluded from the forest area, which is commonly known as 2/B and which means a reduction in the forest areas. Initially taken effect with a temporary article amended to the Forest Law numbered 6831 in 1965, the 2/B process is furthered with the Law numbered 6292 taken effect in 2012. Inventory assessment results for the size and changes in the forest area between 1973 and 2015 in which exclusion from forest areas took place, it can be seen that the total forest assets were increased to 22.3 million hectares with an increase of 2.1 million hectares in 42 years.

Before the Law numbered 6292 on the assessment of the estate defined under 2/B areas, the Law numbered 2924 on the Supporting the Development of Forest Villagers and the Law numbered 4706 on the Amendment to the Law on the Utilization of Real Properties Held by the Treasury and Value Added Tax were in effect. Article 3 of the Law numbered 4706 was annulled in 2002 by the Supreme Court as it was found contradictory to the Articles 169 and 170 of the Constitution of 1982. The annulation decision included the expression of ‘allocation’ which refers to the usage free of charge and stated that it cannot be subject to sales or transfer. This decision brought an uncertainty to the 2/B practices. Articles 169 and 170 of the Constitution of 1982 are still in effect. As the Law numbered 6292 includes regulations similar to the ones in

Laws numbered 2924 and 4706, the issue of discrepancy with the Constitution is still the case today.

It can be seen that there are no regulations about the zoning of the areas excluded from the forest according to the Article 2/B of the Law numbered 6831 [17]. Zoning practices, until the Law numbered 6292 has taken effect, were even interpreted differently by Supreme Court and the State Council. Law numbered 6292 has clear provisions on this subject. It states that plans of any scale can be developed.

Even before the Law numbered 6292 took effect, there were sales figures in the mass media instead of the solutions for the legal problems related to the 2/B areas. Therefore, ones defined as claimants as part of this Law sought the ways to pressurize the lawmakers to define a sales value below the current value of the land and they have succeeded in their pursuit. The sections of the Law numbered 6292 on the price have amended in a short time after the law was issued. However, the expectations of forest villagers and agriculturists are higher. In other words, these expectations can only be met if the current value is discounted and a payment plan of long years is offered.

According to the data from the General Directorate of National Estate of the Ministry of Finance, 952,010 applications were received for 685,866 parcels and 610,895 individual sales transactions were made as of 07.11.2016. As of the aforementioned date, a forest area of 314,463 ha was excluded from the forest boundaries. 32,838 ha of this area was transferred to the claimants as part of the return protocol and 178,519 ha was sold. 21,390 real-estates were designated as urban project areas. Among these real-estates, 2686 were transferred to TOKI, 728 were transferred to Istanbul Metropolitan Municipality, 6 were transferred to Kocaeli Metropolitan Municipality and 17,970 were transferred to other municipalities. The revenues collected from the 2/B applications after expenses and taxes are subtracted accounts for a total of 4.475 billion Turkish Liras for the years between 2013 and 2016.

On the other hand, the results of the SWOT analysis conducted on the Law showed the following:

- It may be possible to solve the propriety issues and court cases between the state and its citizens as a result of plans which address economic, social and environmental effects of the land excluded from the forest without compromise for any kind of occupation which may lead to further reductions in the forest area.
- Using the experience of specialized personnel for agricultural and settlement areas, it may be possible to reduce the non-agricultural use and the decreased agricultural output with respect to the agricultural land regulations available in the Law numbered 5403, to implement modern urban arrangements and land can be protected against erosion and desertion.
- It may be possible to improve tax revenue and to prevent unrecorded economy, to have individuals use their real-estate as capital once the propriety issues are solved and necessary flexibility is provided to the application period, law suits to be withdrawn for application, real-estate to be returned; possible unfair income due to the evaluation methods used is eliminated, and the price differences due to the information update time differences are solved.

- It may be possible to obtain maximum yield from agriculture especially with organic agriculture and a production factor with customized provisions taking effect for the forest villagers who has the lowest GDP consulting the Ministry of Food, Agriculture and Livestock along with the other institutions bestowed with the planning authorization in the Law and to contribute to the modernization of the urban structure and infrastructure preventing unplanned urbanization.
- The target strategies may include a certain amount of money obtained from the execution of the Law to be added to the forest assets with afforestation efforts.

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Evaluation of Urban Transformation in Building Scale in Terms of Social Sustainability: Göztepe Case

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Abstract. In this study, the social sustainability framework and the transformation processes realized in Kadıköy district of Istanbul were examined. Processes covering the general aspect of district have been discussed in detail in the context of social sustainability and related concepts of changing housing profile typology, the effects of street perception on identity, the effects of transformation on building quality on the quality of life and the change of the profile of urban residents in the neighborhood in terms of social sustainability.

Keywords: Social sustainability · Neighborhood · Identity Sustainable community

1 Introduction

Most of the surface area of Turkey, especially Istanbul, which is the most leading city especially in the economy, is located in the earthquake zone. In addition to Gölcük, major devastation occurred in Istanbul which is in the area of impact of Gölcük Earthquake of 1999 and most of the building stock was found to be not resistant to earthquakes in the examinations conducted after the earthquake.

A new law was enacted in 2002 indicating the urgency for improving the quality of building stock in the country promptly and the Law regarding Transportation of Areas under Risk of Disaster took the authority to announce and renew the risky areas to the Ministry of Environment and Urbanization. Thus, the municipalities knowing the local dynamics were eliminated from the transformation process and a centralized method was founded for transformation. With the exclusion of the local dynamics, the local properties were lost in the transformation processes and the danger of standardization of texture of the city emerged.

In 2015, significant losses were experienced in the earthquake of Van located at the southeast of the country and the law was re-organized for accelerating the transformation of risky areas with justification of such losses. In scope of this organization, the Council of Ministers in addition to the Ministry of Environment and Urbanization was authorized to announce the risky areas for disasters; it was decreed that cultural and natural assets may also be subjected to urban transformation and that a city block may

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be subjected to transformation completely in case 65% of such city block was found to be risky [1].

The law was based on the necessity to transform the risky areas for disaster in a fast and solid way and high percentage of building stock with risk of earthquake in Istanbul. Yet, there is no clear information regarding the number of buildings under the risk of disaster in Istanbul, the declarations of municipalities of districts and the explanations of Istanbul Metropolitan Municipality are disputed. With the observations on the implementations, it is observed that the transformation is being realized in the districts which have high land value instead of districts which endured most damage from the earthquake [2, 3].

Kadıköy is one such district with more than on-going one thousand construction sites. The strategic plan of the district aims to "have planning based on city blocks and regions including the functional arrangements and parcel mergences for creating a better infrastructure and superstructure in regions with old building stock" [4] and the transformation is conducted in scale of building instead of neighborhood or structure block. In the process on-going as renewal of building scale instead of urban transformation, the heights, floor spaces and building magnitudes of buildings are changed in a way maximizing the profitability of the construction companies; and as a result, the physical and social structure of the neighborhoods change. No study is being conducted for evaluating the social, ecological or economic sustainability of the processes causing such changes.

This study aims to examine the transformation processes in Göztepe neighborhood, one of the oldest residential units of the district in the framework of social sustainability. Göztepe neighborhood was selected as an example as the district undergoes a similar process completely, the old texture of the district is not lost yet, the neighborhood's advantageous position in urban transportation and the process continues silently but efficiently.

First of all, the concepts used in the study and the relation of such concepts with settlement will be discussed; afterwards, the transformation processes in Kadıköy will be discussed and lastly the space perception, sense of place and concept of attachment will be interrelated over the changing architecture prototype and the impacts of factors filling such concepts and its meaning for social sustainability will be discussed. The changing architecture typology was shown with examples in scope of this discussion and the meaning of change of such typology for the people residing at this place was considered.

2 Social Sustainability and Role of Architecture

The concept of sustainability, first described in 1987 by the Bruntland Report, has been used as an important framework in urban design, planning, urban politics and architecture ever since.

Sustainable development, aiming at achieving the full range of economic, ecological and socially sustainable goals that constitute the three pillars of the sustainability concept, is on a strategic level in both local and regional scale in Turkey. Under the heading of social sustainability which we can define as the social goals of sustainable development, different issues such as social justice, sustainable society, cultural sustainability, social capital and social differentiation was discussed. While defining the social sustainability, the researchers can give priority to one of these different issues.

Vallance et al. [5] have collected the approaches regarding social sustainability under three heading. First is 'development sustainability' which refers to simple needs, social capital, equality, justice and so on; second is 'bridge sustainability' which refers to changes in human behavior while attempting to reach environmental targets, and finally 'preservation', in other words, 'maintenance sustainability' which discusses which socio-cultural characteristics will be preserved at the time of change. The authors made this grouping in order to draw a general framework and stated that there might be definitions that may be excluded. The unique dynamics of each city comes with different conceptual expansions. Vallance et al. [5] define their traditions, their ongoing preferences, and their efforts to understand where they are actively used in the context of maintenance social sustainability. The studies under this heading explore locally differentiating features such as vehicle use, low/high density residential spaces, local and global connections, and conservation of natural areas to understand what needs to be sustained. The Göztepe neighborhood which is the subject of the declaration, is being transformed by justifying it with the risk of disaster, but the dynamics of the neighborhood are completely ignored for economic expansion. It would not be wrong to examine this in the context of maintenance social sustainability.

Dempsey et al. [6] identified two sets of factors for social sustainability in their compilation of studies on social sustainability: physical factors and non-physical factors. While the factors such as urbanization, attractive public realm, decent housing, accessibility, pedestrian friendly are counted among the physical factors; the factors such as social justice, equality, pride/sense of place, communication, social interaction, feelings of security and community stability are counted among the non-physical factors. The factors such as pride of place, safety, communication, and community stability are also considered as important requirements for sustainable community work [7].

While there is no direct reference to spatial perception in social sustainability studies, it is emphasized that the production patterns of the place play a crucial role for the connection between people and the place when we examine the studies regarding the sense of place. The physical structures such as housing, open space, and public space in the urban space are of great importance in construction of the identity of the citizens and establishment of their attachment relations with the place [8–10]. At the end of the sixties, Jacobs emphasized that it was inevitable for the social structure to change in the settlements where the buildings had their function changed to be transformed to be "better" and the apartments were demolished and rebuilt or renovated. While the transformation activities conducted in nearly sixty years later in Istanbul are carried out urban settlements with very different geographical areas and different dynamics, they emphasize economic expansion and disaster risk ignoring the social sustainability principle.

The studies conducted on the sense of place and identity have started to take place especially under the titles of social justice, social capital, architecture, urban design and protection in the last ten years in the Turkish urban literature. However the number of studies that directly relate these issues to social sustainability is low. The studies regarding the relation between identity, architectural form and cultural/social sustainability are generally related with transformation projects that are carried out either in historical neighborhoods or in the neighborhoods where lower economic classes live [11–13].

In this context, Göztepe Neighborhood where the study was carried out, is separated from the fields of other studies in Turkey. As it does not take place in a historical settlement, it is also preferred by the upper middle class of Istanbul. However, being one of the oldest districts in Istanbul, a sense of attachment formed in this neighborhood by the fact that the vast majority of the existing building stock was built between 1960 and 1970 to reflect the architectural typology of that time, and the majority of the user population has been living there for many years have created this sense of attachment. This sense of attachment and the sense of place has an important relation with the physical structure of the space. The fact that the settlement is located in one of the regions with the highest land prices cause ignorance on such embedded structure and emphasize the idea of getting residential spaces at a higher quality.

3 Transformation Process in Kadıköy

The subject of the study, Kadıköy district is adjacent to Üsküdar, Ataşehir and Maltepe districts and has a favorable position in terms of being accessible both by sea and by land. Being the departure point for metro, metrobus and bus stops, the district also has a suburban train line that is not currently in use (Fig. 1).

Fig. 1. Position of Kadıköy District in Istanbul

In addition to being advantageous as a transportation center, Kadıköy is one of the regions with the highest land values. In the province, the lowest prices per square meter unit prices are reduced to 15 Turkish Liras, while the lowest prices in the province are 300 Turkish Liras and go up to 2500 Turkish Liras. In Göztepe, these prices do not fall below 500 Turkish Liras and the average is 800 Turkish Liras. The highest value is 2100 Turkish Liras [14]. After the risk analysis which was conducted after the earthquake of 1999, approximately 22 thousand buildings were reported as risky in Kadıköy district which has approximately 30 thousand buildings; and Kadıköy has become the district with most risky buildings of Istanbul [15]. However, there are two important points that must be considered. The first risk analyses were carried out by the people's own initiatives for almost all of the buildings of the district. High rates even after the earthquake even compared to the districts with visible damage, are directly related to the widespread participation. The second point is that the risk countermeasures are classified in a way providing that each building at risk does not need to be demolished and rebuilt [15, 16].

Although the Gölcük earthquake which affected Istanbul occurred in 1999, the renewal process of the buildings in Kadıköy accelerated after the amendment of the law in 2015. In addition to the law amendment, dominant economic policies aimed at improving the construction sector was also effective. However, the stipulation of the law that "In case that 70% of a city block is damaged, the entire area may be declared as a transformation area", caused the users to rush to renovate their buildings. Users who think they will have to rebuild the building out of their control started to bargain with construction companies.

There is no public information regarding which buildings are at risk in Kadıköy district and where the urgent transformation zones are located. It is possible to reach the information such as the number of constructions in progress, the number of licenses given from the statements given by the mayor of the district. According to the mayor's explanation, there is more than one thousand constructions going on in the district and the applications for the license are still in progress. It is said that the completion of all the constructions in the area will take fifteen years [15]. The number of buildings demolished in the last thirty days is over fifty by December, 2016 [18].

It would be hard to claim that transformation processes in the district are realized in the framework of social sustainability. A completely different settlement texture is being built especially in the slums. For example, in Fikirtepe one of the most controversial transformation projects in the city, more than one thousand five hundred flats were demolished; the new settlement in place consists of high-rise project buildings. The neighborhood where the middle and lower middle-income residents lived is being transformed into a luxurious living space. Although agreements were being made between the owners and the construction companies to ensure the rights of the owners, the tenants were completely excluded from this process. It is highly unlikely that those lived in this district before the transformation will return to their former places after the process.

It is possible to see at also project names that current identity is not desired to be maintained and serves to a new user profile. There are a total of eighteen projects in Fikirtepe that combine housing, office and trade functions, and none of these projects have the name Fikirtepe. As well as the projects with foreign names such as Brooklyn, Concord, Renovia; The names such as Göztepe Konakları, Yenitepe Kadıköy, Pırlanta Göztepe etc. are noteworthy. At the projects that specify the name of the location, Göztepe which is the name of the district and neighborhood area is used but the name Fikirtepe which is name of an old shantytown is avoided.

Fig. 2. An example of Fikirtepe before transformation process. (*Source* http://www.fikirtepegundem.com/images/haberler/fikirtepe_de_son_durum_h3206_98484.Jpeg)

Fig. 3. An example of new construction type in Fikirtepe. (*Source* http://fikirtepeplatformu.org/images/projedetay/703F0465.jpg)

Fig. 4. Drawing of the finished project. (*Source* http://fikirtepeplatformu.org/images/projedetay/3.jpg)

As can be seen in Figs. 2, 3 and 4, the typology of the structure in the district is completely changed. It is obvious that the newly built dwellings appeal to a different income group. Even those who are home-owners of old users return to their quarters, They will have to change their life habits, their self-describing identity, their space perceptions.

Fikirtepe Neighborhood is a settlement where the pre-transformation equipments are inadequate, the housing stock is unhealthy and undoubtedly needs an urban transformation, but the implementation totally ignored the social structure and there were not made any arrangements about social sustainability.

The transformation decision was taken by Ministry of Environment and Urbanization. The plans were made by TOKİ (public housing administration). Although the main task of TOKİ is defined as producing low priced housing for low income dwellers, in the last decade it was mentioned by expensive housing projects, specially gated communities. In Fikirtepe case TOKI and ministry played a mediator role. The construction firms and dwellers try to find a compromise. The Municipality of Kadikoy was excluded from the process.

Fikirtepe and Göztepe are two neighborhoods with extremely different characteristics. The characteristics such as the income status of the living, the relationship they established with the location, the facilities the local possesses and the process of formation of the settlement do not show similarities. Transformation processes are also quite different for two neighborhoods. While there is a total destruction and reconstruction in Fikirtepe, there is a renovation in the building scale at Göztepe. However, although the transformation in Göztepe seems to be much smaller and less destructive, it is evident that there is no effort to provide social sustainability, as it is seen throughout the district in both examples.

4 Transformation Process in Göztepe

Caferağa, Rasimpaşa and Osmanağa neighborhoods on the shore side of the county are historical settlements. However, although the texture has changed over time, most of the city is made up of the oldest districts of Istanbul. Fenerbahçe, Erenköy, Göztepe, Caddebostan and Suadiye neighborhoods, which are included in the study area, were mostly used as holiday places during the Ottoman period and the first permanent settlements were revealed in the last periods of the Ottoman period (Fig. 5).

Fig. 5. Göztepe and neighboring parishes showing similar characteristics

The construction of the Istanbul-Baghdad railway in the 1870s and the opening of the railway crossing between Haydarpasa Pendik in 1873, first settlements started as frame houses with gardens around railroad [19]. As state persons settled here, in a sense, it became on of the first suburbs of Istanbul. Coastal settlements, which were previously independent villages, thus gradually began to integrate into the city [20].

The settlement between Bağdat Caddesi and the railway before the Republic consists of vineyards and gardens divided into large parcels, and the typology of the building consists of wooden pavilions with gardens [21]. Modernization-oriented development campaigns in the post-republic era have begun to show its effect here, and three-four-storey apartments have begun to be built instead of wooden pavilions when the property is moving from the Levantines to the Muslim Turkish population [19]. During this period we can say between 1930 and 1950, the main motivation of the pavilion owners was to have more modern living spaces. The apartments built in this period are structures that established closer relations with the large balconies, gardens, open car parks and the building built in the next period.

Although it was relatively dead in terms of construction between 1950 and 1970, after 1970 construction were increased; parcels were dwindled, vineyards and gardens were opened to settlement and tall buildings were increased by the reason of several factors such as "build and sell" system, development rights given to Bağdat Street and migration of Istanbul [19–21].

It is seen that neighborhood's texture and typology of the structure have completely changed while looking at the shorty history of neighbourhood and it became the part of the city in a short period of a century. However, texture maintained its some features, even if it exposed dramatic changes in terms of street and building heights. The district which reached high level in terms of land and population at the end of the 1990s was known peaceful and settled until transformation period. It is possible to find old apartments as well as in high-rise apartment blocks.

The remaining few villas are usually used as offices. These villas with large gardens influence the appearance of the street even if it lacks the public green space it has positive effect on the street view.

Even if the construction years and heights of the buildings in the neighbourhood are different, but the features such as building-parcel relation, setback distances, balcony usage, type of parking are similar to each other and it creates a specific texture to the neighbourhood. Buildings are usually left in the garden distance between the street which is not fully positioned to the parcel (Fig. 6).

Fig. 6. A sample from the remaining villas

Fig. 7. A sample of the current texture

Fig. 8. A sample of the current texture

Examples are seen from the streets in Figs. 7 and 8. In addition to the apartment buildings of the first period, the elevated buildings built after 1970, which is an example in Fig. 9, show that the towing distances are in accordance with the distance, but the buildings are similar in terms of balcony, garden and parking facilities.

Fig. 9. A sample of the current texture

Avenues, garden apartments and balconies are the most important features for citizens. Because, these features make their neighborhood special for them. The citizens who preferred to live in the neighborhood mentioned about the reasons of why they decided to choose this neighborhood and said that: “settled”, peaceful and decent place and it has more green spaces as to other neighborhood of Istanbul. The vast majority of the population of the neighborhood aroused old citizens and it gives confidence for those [16]. Certainly, it can not be said that neighborhood is a unit not covering all citizens in Göztepe Neighborhood which has a population approximately 40,000. However, the neighborhood has good impression on people with its spaciousness, trustfulness and appropriateness for family. Otherwise, gated communities which builded currently in Istanbul are not in the neighborhood. This reason impact their decision positively. Citizens like neighborhood that provides them directly associated with other people.

However, the typology of the buildings that the citizens find positively in Göztepe neighbourhood has changed swiftly. The existing transformation period in Kadıköy district also continue swiftly in Göztepe Neighborhood. Due to the risk of disaster, buildings are being renovated and attention is not paid to whether the newly constructed buildings are suitable with old structure. Setback distances are changing and the street sense disrupting.

The transformation of buildings started in early 2000s such as in all Kadikoy district. But in last two years, after the declaration of the changes on the Law regarding Transportation of Areas under Risk of Disaster, the process gained dramatic speed. The law gave to the ministry the authority to declare areas as under risk areas. If the sixty five of the total buildings were declared as risky, the all city block could be demolish and rebuild. Even the rest of the buildings were safe. This decision became a tool for construction firms to manipulate house owners. The house owners want to rebuild and renew their houses with their own terms before they were declared as risky. And it is important to point that again the lack of local authority in this process. The municipality of Kadikoy doesn't have a transformation plan, has only the authority to give building license.

Not only consequences but process itself creates disadvantaged conditions for livable environment. With a transformation plan the process doesn't proceed step by step. The constructions yards and vehicles are seen almost every street. So all the neighborhood suffers the traffic caused by vehicles, noises, visual pollution.

Fig. 10. A sample of new construction type

Fig. 11. A sample of the current texture

The photographs in Figs. 10 and 11 were taken from opposite sides of the same street. On one side of the street there are low-rise apartments, on the other hand there is a building perpendicular to the high-rise street. It creates a non-alien and non-textural image that distorts the integrity of the street.

The fact that newly built buildings are incompatible with existing textures, cutting the plots of trees due to the expanding construction bases in the construction process, ruins the green, calm and spacious image of it in the local minds. In addition, ongoing constructions almost everywhere in the neighborhood is causing the residents of the neighborhood to leave their place of residence. Due to construction across the district, the population has decreased from about 744 to 420 by 2016 [15]. This dramatic drop in the neighborhood affected also Göztepe. The population which was approximately 39 thousand in 2014 has decreased to approximately 32 thousand. Inhabitants of the neighborhood moved to districts such as: Ataşehir, Maltepe due to inconvenience of the constructions [16].

Concepts such as community stability, sense of place, belonging and safety, which are often expressed in the concepts of social sustainability and sustainable society, seem to be harmed by ongoing construction in the neighborhood. Due to the construction, the relationship between the streets and the buildings changes and the spacious and green structure which is the reason for the urban people to prefer here is eroded. For this reason, the urban population is moving and thus the population structure is changing.

Newly built houses are offered at much higher prices than old ones, and rental values can rise to 60% higher of the old values for new buildings [22]. In this case, especially the tenants are not likely to return. Housing sizes are also changing, firms that want to get more apartments produce smaller apartments. This change in housing size also changes the structure of the settler's family, addressing a single or childless population. In addition, ongoing construction prevents the physical factors necessary for social sustainability such as attractive public realm and pedestrian friendly.

Fig. 12. An example of ongoing construction in the neighborhood

Fig. 13. An example of ongoing construction in the neighborhood

Figures 12 and 13 illustrate examples of ongoing construction on almost every street. As of December 2016, the number of buildings destroyed in the last 30 days is seven at the district [17]. The number of construction in the area where about 1200 buildings are located is 112 [23]. It is expected that the construction will last for about fifteen years if the almost all of the 1200 building is renewed.

A critical point in the renewal process is the lack of a transformation plan in the district and neighborhood, as mentioned earlier. In the process of ongoing renewals, there are no measures to create public space and no measures are taken regarding the public services that this population will need, even though the projects are obviously going to increase the population. No study has been conducted on the intensity of the traffic that the increased population will bring.

5 Result

Istanbul is a region with a high risk of earthquakes and the majority of the housing stock is made up of unsupported buildings that are not ready to take this risk. After the 2015 legislative change, the central administration, which deals with the transformation power, has entered into renewal projects in the provinces where land value is high due to the influence of dominant economic policy based on construction in the country. Kadıköy is one of the districts where it is felt most intensively and Göztepe neighborhood, which is the subject of this declaration, is heavily influenced by these processes.

The renovation of residential units in a settlement unit and the renewal of unhealthy areas are undoubtedly positive developments. However, when a transformation is to be carried out, this should be done on a large scale basis taking into account the local dynamics of the settlement, not the basis of parcel. It should be seen as an opportunity for the completion of missing public services and it should be adopted as one of its objectives to provide the necessary physical factors to create a sustainable community.

Concepts such as identity, belonging, the influence of architecture on culture are used only in studies conducted for historical settlements. However, an important urban culture was formed in Göztepe, which completed the urbanization process about thirty years ago, and this culture has also formed an important relation with the housing typology and the street.

The ongoing renewal process at Göztepe is far from being an ideal model of urban transformation. In this settlement, where the land values are high, there is no other goal than obtaining more housing. In this process, housing typology and population structure, which is one of the elements that make up the identity of the neighborhood, is changing. Ongoing construction, which is expected to continue in the coming years, is causing community drift and loss of community stability. Similarly, the relocation of urban residents in this area for a long time also reduces the sense of security in the neighborhood. It is unclear to what extent the renewal processes targeting a new and younger population will come to an end with a healthy and sustainable living space.

Briefly, building-based renovation processes in Göztepe are very difficult to return to the neighborhood in terms of social sustainability. The transformation process must be directed at generating applications that take into account the local dynamics and that will create the necessary physical factors that will help to understand what is socially worthwhile to sustain. If conversion is continued with the existing methods at Göztepe, the settlement will lose its original structure and it will become a settlement that is not different from other parts of the city.

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Enhancement of Physicochemical Properties of Dubai's Sand to Conserve Irrigation Water

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Abstract. Freshwater scarcity has been a considerable issue in the Gulf Region. The cities in the region including in the UAE depend mainly on seawater desalination. Their demand escalated about 15% annually regardless of seawater desalination direct cost of 1 US$/M^3. Thus, calling all water conservation techniques to reducing indoor and outdoor water demands is inevitable. Using Hydrophobic Sand (HS) to reduce water seepage and increase the contact time between irrigation water and plants' roots was seen as potential conservation technique. The HS is Normal Sand (NS) coated by a thin layer of hydrophobic organic silica compound called trimethylsilanol. However, concerns were raised about the leaching of harmful organic coating chemicals into the soil and groundwater. Assessing the potential risks of leaching additives is one of the objectives of this research. For some plants, requiring a certain range of soil permeability suggests a mixture of NS and HS. The permeability of mixtures of HS with abundant NS was examined to assess its validity and cost effectiveness when a certain permeability is required. Several elements leaching tests were conducted. The soil was classified and constant head permeability test was conducted for different configurations and mixtures of NS and HS. The leached elements, nutrients and organic silica were within the allowable limits set by the typical standards. Further experiments indicates that HS does not constitute an environmental hazard. Mixing different portions of NS and HS revealed unforeseen increase in the permeability. Instead, some layer configurations could reduce soil permeability.

Keywords: Hydrophobic · Sustainable · Leaching · Permeability
Irrigation

1 Introduction

Water scarcity has always been a challenge ahead of urban development in the Middle East including in the UAE. The records show that the UAE's the average daily sunshine hours is about 9.8 h and average annual precipitation is 94 mm. Average monthly maximum day temperature is greater than 30 °C for 8 months of a year and monthly rainfall is from zero up to the maximum value of 25 mm in February. Dubai is categorized as Hyper-arid zone with sandy soil and minimal organic content. Having top soil with high permeability of 0.0005–0.00065 cm/s is a key reason for typical soil's

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low moisture content in dry days [16]. Such weather condition, soil properties and freshwater water scarcity has been seen as major challenges for the growth of UAE.

Dubai Electricity and Water (DEWA) authority provides 1.5 million cubic meters per day for about 3.6 million consumers [9]. The city does not rely on its very limited groundwater resources since groundwater pumping caused fast intrusion of seawater or deep saline aquifers into shallow freshwater aquifers in the past [1]. Seawater desalination is practiced as main practical water treatment technique to cope with increasing potable water demand in such growing city. Tremendous efforts has been made to improve the sustainability and feasibility of desalination techniques in the region and globally. Employing novel technologies reduced water desalination cost in half to the range of US$0.45–$1.00 per cubic meter [21]. Despite of such substantial enhancements, seawater desalination is not yet cost effective and environmental friendly since it is still highly energy intensive. To cope this financial and environmental burden, Dubai government has implemented all measures to reduce the potable water demand including outdoor water consumption for landscaping.

The region, where Dubai lies, has a desert climate with neither rivers nor lakes and it rarely rains so depending on groundwater as a resource for water is out of question [19]. Dubai, which is one of the main cities in the United Arab Emirates, is also suffering from scarcity of water resources. This city is glowing with modernity and development; nevertheless, it is still fighting to supply water for different demanding sectors. Tourism industry contributes about 20–30% of Dubai's GDP. Dubai is steadily approaching ambitious target to host 20 million tourists by the year 2020 (Emirates NBD-Sector [10]. Studies show that man-made greenery plays a significant role in attracting tourists towards a city [4]. due to the role of greeneries in attractiveness and well-being of the city, Dubai Municipality has planned to expand greeneries from 3.63% in 2005 to 8% in 2020 [14]. Thus, instead of reducing greeneries and park areas, reclamation of water for irrigation has been the main solution to tackle this challenge. Using water conservation techniques including xeriscaping, dripping irrigation and adjusting soil permeability are some practiced techniques to reduce irrigation water demand per unit area [8].

The main challenge is to optimize water demand without negative impact on greeneries' attractiveness and cultivation productivity. One of the most recent techniques for reducing irrigation water is adjusting permeability of soil using hydrophobic sand (HS) layers in the sandy areas like Dubai [19]. HS is Normal Sand (NS) treated with organic chemical materials and turned into hydrophobic soil. Using HS sand is still under investigation in Dubai and is implemented in some limited areas. Given abundance of local materials and existence of local production companies, if it is approved to be safe for the environment and impermeable at practical conditions, it can be regarded as a feasible water conservation technique. Plants' roots in highly permeable sandy soil have considerably limited time to exploit irrigation water as water drains quickly into deeper layers. Such scenario might inevitably sweep soil nutrients into groundwater too. The HS assists to preserve water for longer time; consequently, the plants' roots will have relatively enough time to utilize water and the nutrients which exist in soil [19].

2 Objectives

The objective of this research is to assess the chemical risks that threaten groundwater quality and the environment when adding HS to normal Dubai top soil. The evaluation focuses on the examination and assessment of the HS's tendency to release chemical compounds received during the industrial preparation and coating processes. Leaching tests were carried out to determine both the extent and the rate of chemical release into the seeped irrigation water. Addition experiments were conducted to achieve the optimal soil permeability by mixing different quantities of the original NS and HS.

3 Background

Normal sand: The nature of soils in UAE is mostly of silty sand, the percentage of sand in the soil is about 85%. The concentration of organic matter is very low, between 0.1 and 0.2%. In general, the concentrations of main elements are rather low comparing with other types of soils. For example, the concentrations of nitrogen (N), phosphorus (P) and potassium (K) varies between 5–10, 1.5 and 14–100 ppm (part per million), respectively [18]. The surface of the sand grains is bonded to hydrogen atoms by covalent bonds, which are polar bonds, where pairs of electrons are shared between the solid atoms or water molecules known as polar molecules. Thus they tend to be attracted to the NS grains which is the reason that NS is considered as a hydrophilic material and water spreads into the sand layer without forming drops or bead on top of NS surface [13].

A hydrophobic surface has the characteristic of not adsorbing water since the repulsive force induced by sands surface on water is greater than the water adhesion tendency. When water is added over the hydrophobic surface, water drop is formed which minimizes the exposed surface area of the sand and reduces water infiltration in soil [2]. Using proper nanotechnology, a volatile liquid of an organ silicon compound, for example, trimethylchlorosilane [$(CH_3)_3SiCl$] is exposed to the pure silica particles in NS to form hydrophobicity. Trimethylchlorosilane is a colorless volatile liquid that fumes in moist air that reacts with the silica compounds (SiO_2) on the surface of NS and results a coating layer of hydrophobic methyl groups on NS grains. The trimethylsilane group [$(CH3)_3Si\ldots$] replaces the hydrogen atom H, which is a part of hydroxyl compound in the NS (Fig. 1). The result will be forming a silicone film (monolayer) of an organohalosilane called trimethylsilanol [$(CH_3)_3(OH)$ Si–O] as a thin coating to the NS grains [15]. Some molecules are non-polar, others are polar. How different atoms share electrons is described by chemical polarity. These methyl groups, which are coating the sand grains, are non-polar compounds; they tend to act as a hydrophobic material to the polar molecules of water [13].

This hydrophobicity will create a capillary breaking hydrophobic encapsulation which results a repellent material for water [19]. When HS is exposed to water, the surface area of the sand will minimize as a result of the particles' tendency to approach to each other. Because water molecules are unable to bond to the hydrophobic non-polar groups coating, this will leave a gap of air between the water molecules and sand particles and keep water as drops on the surface of the HS [13].

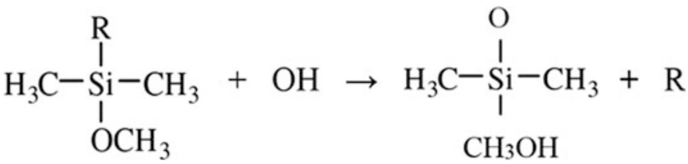

Fig. 1. Anhydrous deposition of silane

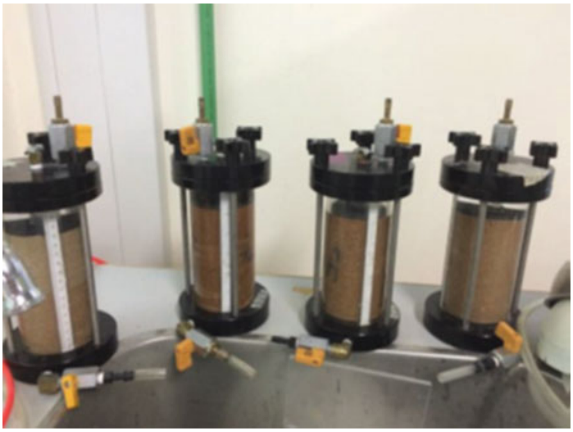

Fig. 2. Samples used for the constant head permeability test

The HS was invented by adding melting wax to heated sand in India [17]. A group of scientists and researchers in Massachusetts, USA invented a procedure to develop a reaction between trimethylchlorosilane and the grains' surfaces of silicate materials, such as sand. Since then a considerable number of studies conducted to achieve the best usages of this treated sand [13] including in plantation and farming in UAE. In UAE, the applicability of HS on the growth of palm trees and grass was evaluated recently. The results showed that the plants have 20% denser roots and rise in harvest quantity by 33%. The HS role to reduce rice farms' water demand was investigated [8]. It could be used also in gardens and parks as a landscape tool for creating a natural looking stream when water flows over the hydrophobic sand. According to researched conducted in UAE, it could save up to 75% of water usage [18]. It can be used around foundations, infrastructure and underground utilities to trapped away salinity and corrosive chemicals and in cold areas reduce damages due to freezing [3]. The HS local producer claims its applicability to be used in sand bag for controlling flood and underneath landfills to reject leachate infiltration [8].

4 Materials and Methods

Sampling and permeability tests have been carried out for pure NS, pure HS and mixtures of NS and HS with different proportions and configurations in order to understand the extent of leaching and find suitable soil configuration. Soil samples have been selected from the UAE to suggest particular solutions for irrigation water conservation there. For this purpose, soil classification tests, permeability tests, leaching tests were conducted to understand the properties and behavior of NS and hydrophobic sands and any potential hazard risk associated to the release of hydrophobic chemicals. The leaching test was aiming to estimate rates of the release of organic silicon (i.e. trimethylsilanol) and other organic and inorganic chemical compounds in soil after using the HS and whether these rates are acceptable or not in the prospective of environmental sustainability.

Both HS and NS (called "NS–site") were carried from a local manufacturing company called "Desert Innovation Middle East LLC." in UAE. In addition, samples of typical NS which were obtained from a random place in Dubai and evaluated.

Soil classification: The soil particle distribution was conducted as it is the main characteristic for soil classification and is affecting soil hydraulic conductivity or permeability. The sizes of soil particles may vary from less than 0.1 μm diameter, such as clay particles, to approximately 20 cm diameter boulders [5]. ASTM standard D422, "Standard Test Method for Particle-Size Analysis of Soils" was followed to characterize soil particle sizes that are larger than 75 μm since the sand particles sizes are mainly greater than 75 μm [11]. The sieve sizes that were used for testing the sand samples were: No. 4, 10, 20, 40, 60, 100, and 200. At this stage, the particle distribution size for the HS will be identified. Afterwards the coefficients of uniformity (Cu) and curvature (Cc) were calculated [11].

Soil permeability: Permeability of soil is described by the coefficient of permeability (K) when water flows through saturated [11]. The coefficient of permeability (K) depends on the soil pores' average size. Generally, when the soil particles are relatively small, the pores would be small and the coefficient of permeability would be low. K is a function of void ratio for a given soil. Also, permeability differs according to the soil stratification and when possible fissures exist is formed in specimen [5]. The range of (K) values for different types of soil is within $1–10^{-10}$ cm/s [5]. The K value is expected to be in the ranges of $10^{-3}–10^{-1}$, $10^{-3}–10^{-2}$ and $10^{-4}–10^{-2}$ for fine sand, silty sand and clayey sand [6]. In order to reduce sand permeability, HS was added in different quantities and configurations to NS and different samples were tested. The permeability coefficient of the mixture is not estimated and requires experimental examination. Constant head permeability test for coarse and grained soil is used for the sand. The permeability tests were conducted as described in ASTM standards D2434 "Standard Test Method for Permeability of Granular Soils—Constant Head" [11].

Permeability test's sets of 4 specimens for different mixtures including mixtures of 100, 50, 25 and 0% of HS mixed with natural sand from Dubai were examined. The test was conducted using a plastic soil specimen cylinder used for placing the sample of soil in, two porous stones to be placed at the top and bottom of the cylinder, two rubber stoppers, one spring at the top of the cylinder, one constant head chamber, a large funnel and some plastic tubes (Fig. 2). The tests were run for both 35 and 101.5 cm water head. Different pressure heads were applied to check the consistency of k values at different pressure ranges. The second set of tests were conducted to study behavior of half a layer of HS when is placed under half layer of NS while all other parameters such as the height of the water head and the weight of sand were held fixed during the tests. Typical compaction for both layers were applied using a tamper. The last set of permeability and tested specimen contained a bottom layer of 50% HS mixed with 50% of NS and top layer of 50% NS. This set was conducted to explore the possibility of constructing a semi-permeable layer under the NS both to reduce the cost of using HS and to assess if targeting a specific permeability is feasible.

Void ratio: Since the permeability coefficient (K) is a function of the void ratio (e), the void ratio of the sand samples should be also investigated. The void ratio is calculated from the specific gravity of soil [6]. In order to investigate the relationship between the weight and volume of soil, the specific weight ratio is considered as a fundamental parameter for this purpose. Thus, specific gravity (G_s), void ratio (e), dry density of soil (ρ_d) and porosity (n) were calculated according to the procedure ASTM D 854-00 (Standard Test for Specific Gravity of Soil Solids) [5]. General range of G_s for sand is 2.63–2.67. The void ratio (e) is defined as the ratio of the volume of voids to the volume of solids in soil, the volume of voids includes the volume of water and the volume of air that fills the voids of soil [6]. The porosity (n) is defined as the ratio of the volume of voids to the total volume of soil. The voids and soil pores transmit water, so larger pores and larger voids results in higher permeability [20]. Measuring and comparing void ratio for the NS sample and the HS sample is relevant to investigate whether transforming NS into hydrophobic will lead to change in void ratio and consequently change in permeability.

Leaching tests: The leaching tests were conducted to evaluate if the extent and the release rate of common nutrients and compounds from the hydrophobic sand. Three sand samples with 400 g mass of HS and NS from factory site (used as raw sand) and Dubai were examined. The NS was used as control samples. Four liters of deionized water was added to each sample and left for a specific period of time then water was decanted from each sample, filtered and tested for different chemical concentrations. The experiment was performed five times for each sample. Each time for a different duration of contact: after 10 min, 1, 8, 24 and 72 h. The tested chemicals, in this set of leaching tests, were chloride–free (Cl), iron (Fe), aluminum (Al), copper (Cu), ammonia (NH_4), nitrogen (N) and phosphorous (PO_4). The equipment used for measuring the concentrations of these materials is a direct read Photometer 9500 from YSI.

The next leaching tests aims to measure the release of trimethylsilanol extracted from samples and is considered as an organic silicon (Si) compounds' indicator. Alkane was used for extraction then measurement of the organic silicon compound from the leachate. Silicon compound including trimethylsilanol with partial hydrophobicity properties are used to coat the NS particles to produce hydrophobic sand. It is partitioned into organic phase such as hexane. Since the hydrophobicity of trimethylsilanol is relatively low, the procedure of extracting the organic Si compound was carried out twice to ensure obtaining almost the whole quantity. Afterwards, the organic Si compound was removed from the water phase.

The HS and both NS from factory and from random places in Dubai were considered as three sand samples. Three samples from each type of sand (totally nine samples) were tested for higher accuracy according to the recently adopted European standard ISO/TS 21268-1 [12]. The last steps of the test were repeated twice after adding another 20 ml hexane to the remaining water phase, to ensure extracting almost the whole concentration of the trimethylsilanol from the sample. The organic Si concentration in samples were analyzed by using ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry, with a Thermal I CAP 6000 instrument). The results were registered and compared to investigate whether leaching of organic Si compounds has occurred.

5 Results and Discussion

5.1 Soil Classification Test

The results of the sieve analysis for all samples were registered. The values of Coefficient of uniformity (C_u) and Coefficient of curvature (C_c) were calculated based on samples particle's size distribution shows uniformly-graded particles which means soil particles for HS have nearly the same size. Particles grading, which describes the range of size distribution for soil particles, has an essential role in controlling the interaction of soils with water along with the size of the smallest particles. Gap graded and well graded soil have higher and lower permeability as compared to uniformly graded soil [5]. Concluded from the above is that HS should have moderate permeability comparing with other types of soil.

5.2 Permeability Tests

The first set of constant head permeability tests were executed. The area was measured accurately (A = 31.15 cm^2) and the height of the cylinder (L = 13.2 cm) and the constant head of water (h) was fixed at 101.50 cm for the initial set of permeability tests. The collected discharged water mass was measured and the collecting time was registered. The test was repeated as described, in the permeability constant head test paragraph, in the Methods section. Then the permeability coefficient for every test was computed as reported in Table 1.

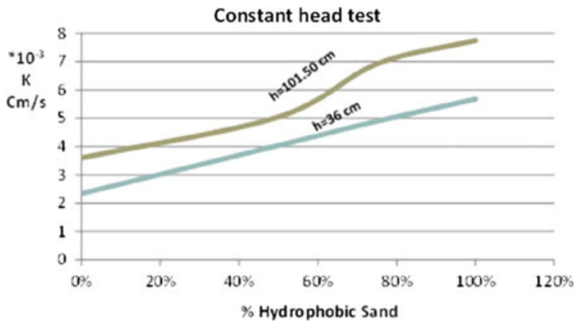

Fig. 3. Permeability coefficient curve for mixtures of HS and NS at different water head levels

The permeability tests unexpectedly showed an increase in the permeability of sand when using the hydrophobic sand. To investigate if this is due to high pressure head of 105.5 m, the second set of constant head permeability tests for lowest possible water head of 36 cm was executed. The pore water pressure consequently become lower and water seepage velocity will decrease as a result [5]. According to Darcy's law, fluid discharge is proportional to permeability, so decreasing the discharge means decreased permeability. The permeability of the NS was still lower than the permeability of sand when mixed with HS or when using a specimen of pure hydrophobic sand. As shown in Fig. 3, these two tests' permeability coefficients revealed that the permeability of HS has reduced as pressure head is reduced.

Table 1. Permeability coefficient (K) values

Specimen type	Permeability coefficient at h = 101.50 cm	Permeability coefficient at h = 35 cm
100% of NS and 0% of hydrophobic sand	3.6×10^{-3}	2.34×10^{-3}
50% of NS and 50% of hydrophobic sand	5.05×10^{-3}	4.04×10^{-3}
25% of NS and 75% of hydrophobic sand	6.93×10^{-3}	4.90×10^{-3}
0% of NS and 100% of hydrophobic sand	7.75×10^{-3}	5.68×10^{-3}

To investigate how mixing the HS with NS is the reason behind unexpected exceeded permeability in the mixture; another constant head permeability test was conducted by separating the NS and the hydrophobic sand. The half bottom of the specimen cylinder was filled with HS and the upper half was filled with NS when pressure head was fixed at 36 cm where other parameters were held constant. The k value of 1.63×10^{-3} cm/s for a specimen of two separated layers of NS and HS shows a considerable decrease in permeability below all K values measured for single sand tests. Consequently, the impact of mixing NS with the HS at the bottom half of the test cylinder, where pure NS layer is set at the top half of the cylinder, was examined. This was planned to investigate if such cost effective arrangement still offers low permeability, lower than the permeability of pure NS. K value of 2.80×10^{-3} cm/s for this arrangement, when equal amount of normal and HS are mixed for the bottom half, revealed that the mixture of these sands did not provide moderate permeability. It was deduced that the sand had its lowest permeability coefficient when the test specimen was composed of two equal separate layers of normal and HS layer which was placed at the bottom. Investigation of the performance of different heights of NS on the top of permeable sand is the objective of teams' further researches in future.

The tested specimens in the permeability tests should be thoroughly saturated before starting to collect the flowing water in the graduated container. The time period needed for pure NS and HS specimens to become saturated were 80 s and 10 min, respectively. Also, it was noticed that saturation in HS was uneven or mosaic saturation and the wetting front proceeded in random areas in the specimen and formed in "finger" flow. After saturation, the volume rate of water through the HS was higher than its rate in NS. This might be due to the intention of the hydrophobic particles of sand to adhere to each other and form clumps to avoid contact with water. Consequently, it forms higher void ratio or great micro channels within the sand. Both of these cases facilitate water infiltration as a reason for higher k values for pure HS as compared to the K value for the NS. The finger flows might be due to channelling water through micro channels which causes partial saturation around channels and without wetting some other clumps of soil. In mixtures of normal and HS exposed to water pressure head, the extent of created void or number of micro channels might be greater as normal dry sand invites water through huge number of random fine paths in the soil the causing formation of more number of small clumps and consequently more frequent microchannel. The reduction of permeability of HS when placed in bottom half of the cylinder might be due to better compression of the bottom sand and more limited micro changeling in such a relatively confined zone.

The sequential permeability tests have demonstrated that the permeability of HS becomes greater as the depth of ponded water increases, which is in agreement with the positive relationship between hydraulic conductivity in soil and water head depth. This explains the lower permeability for the HS when a layer of NS was placed in the upper part of the cylinder, on top of the hydrophobic sand.

The layer of NS has reduced the pressure caused by the column of water on the HS so water ran smoothly into the HS surface layer and pressure of water head became lower than the air entry pressure as addressed in the literature [7]. This has reduced the water discharge and led to a lower permeability. When the HS became totally saturated, the existence of the NS layer on top has continued its impact on the water head pressure and reduced the water flow discharge. The research recommends avoiding mixtures of NS with HS in an agricultural field. Instead, a layer of HS should be placed under a layer of NS. The thickness of the NS layer is determined according to the depth of the plants' roots. In addition, irrigation using drip-irrigation system is preferable to avoid ponding and excessive pressure when water is properly retained around the roots in the NS layer with slow flow toward the bottom hydrophobic sand.

5.3 Leaching Tests

The results of the first set of leaching tests for measuring the concentrations of nutrients and several heavy metals including chlorine, iron, aluminium, copper, total nitrogen and phosphate were registered. The concentrations of the chemicals were below allowable concentration as per maximum allowable concentrations specified by EPA without significant difference between the responses from different sand samples.

The averages of concentrations of silicon (Si) in each type of sand were registered. The initial experiments show that the concentration of Si in the leachate from HS is 12.86 mg/l which is greater than 8.9 mg/l Si concentration from NS. Further examinations revealed that Si concentration did not represent the trimethylsilanol compound but some soluble harmless hydrophilic Si compound in water, most probably silicic acid or silicate. The results do not reject the possibility of the existence of organic trimethylsilanol in the leachate but its concentration was considerably low. It is important to note that although this study rules out significant existence of dissolved organo-Si compounds, it can nevertheless not be excluded that other organic substances (possible transformation products of trimethylsilanol) could constitute a problem. Such organic compounds were not included in the analysis, however.

6 Conclusion

The results from this case study demonstrates that, in order to reduce sand permeability and consequently reduce irrigation water consumption, a separate layer of HS should be placed beneath the NS layer. The thicknesses of the layers depend basically on the type of the planted vegetation. Recommendations are provided to avoid mixing HS with NS as it would lead to increase of permeability. Leaching tests results showed that negligible concentrations of organic trimethylsilanol, used for coating the NS particles, leach into water. In other words, it is safe for the environment and will not lead to potential chemical risks concerning this particular Si organic compound. However, further investigations could be implied to study to investigate whether the organic coating of trimethylsilanol will continue to preserve its hydrophobic characteristics after longer durations of time and its actual expiring date.

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An Investigation on Performance Based Design Determining the Effect of Facade Geometry on the Fire Ways

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Abstract. Historically, with the developing technology, the use of different facade materials and forms, which are the signatures of the architects in the high-rise buildings, have begun to appear as indispensable design entrances. Facade designs, which have become symbols of power and prestige concepts, have become one of the design criteria that should be given special importance in terms of fire safety. For this reason, it has been evaluated that it will not be possible to provide guaranteed and useful solutions for fire safety in the next generation building designs, which are prepared according to the traditional design rules and methods and the codes and regulations currently in force will not suffice. For a new generation of high-rise buildings to assist in the selection of fire-safe façade, a new concept, called performance-based fire design, Participation in the design of the fire has begun to gain importance in making the best technological solution, material selection and façade design. Performance-based fire safety under the modern new building structures to have fire-resistant performance in the shell of the facade systems in Turkey and designed according to the effects of the fire are the goals of the study. In the study, firstly the fire propagation mechanism on the facades will be examined. In this direction, it is aimed to investigate the examples of the necessary precautions and design decisions to be taken according to the results obtained when the concept of performance based fire safety is applied to contemporary facades and to try to determine the relation between facade geometry and fire propagation paths. In this respect, the evaluation of the performance of contemporary facade systems will emphasize the importance of the use of computer programs in the early design stage and that the laws and regulations in force will not be enough for today's contemporary facade systems to provide fire safety.

Keywords: Fire safety · Facade · Fire spread · Performance based design High rise buildings

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1 Introduction

The facades that make up the visible face of the buildings; Surfaces that form an intermediate section between the interior spaces of the structures and the exterior. The facades that undertake an important role in the construction of the architectural form, and in the control of the interior and exterior, if necessary; but also their surroundings, region, or a representation of the most important item in the habitable period of technological, economic, political and social changes are the witness.

Along with the emergence of technology and material diversity on the facades of the building, it has begun to change the concept of designing and aesthetics in an important way to attract attention, especially to the external surfaces, to draw attention by using new technology and materials. In this context, in recent years, structural and constructive sense, glass and with the introduction of steel structure of the production process is the most important design input with power and facade design, which has become a symbol of prestige concept, has become one of the design criteria should be given special attention in terms of fire safety.

Today, fire safety design is examined as fire safety design based on tradition and performance. The fire safety design is based on traditional, enhanced by adding onto the existing codes as new requirements, with the result that the use of new technologies, has become complex and difficult to adapt to new applications. Although with simple evaluation criteria to determine whether it meets current requirements, requirements specification without targets set, the cost-efficient support design, innovative solutions and provide little flexibility for unusual circumstances and disadvantages as used in today's most complex structures, traditional codes to performance-based codes in many countries using has created controversy.

In the work to be done, the sample designs which are created by CFD (Computational Fluid Dynamic) based computer program and it will analyse the surface fire propagation in and reveal the relationship between the façade form and the fire.

1.1 Problem

Majority of the studies carried out concerning the subject of fire in Turkey has been developed with a view to evaluating the conformity to the criteria specified by the applicable regulations and standards, in the building design stage, by way of simulation of indoor smoke distribution and escape routes. Examination of building performance by using simulation programs as regards the external shell and facades was evaluated based mostly on energy efficiency criteria. It has been assessed that the major risk factors such as the behaviours of the buildings in case of a fire and the fire burden caused by these buildings as regards the energy efficient buildings which are now an essential design input of our age as well as the facade systems and the arrangements used in these buildings would be insufficient even when the existing regulation is taken into consideration.

1.2 Objectives

The use of performance-based simulation program intends to emphasise that fire spread routes could be predetermined in the stage of making decisions on facade design and these could be controlled. So, the cases where the criteria set out in the regulations/directives as regards the fire safety fail to satisfy, will be able to guide the planner beforehand, thanks to the mentioned programs. At the same time, the deficiencies in the existing regulation will be identified and suggestions for solutions will be proposed.

It is thought that a significant approach could be created in fire safety by evaluating the optimum fire safety and building initial investment cost in the buildings constructed using contemporary facade systems, thanks to the studies to be carried out to that end. Therefore, the decisions on the fire safety, which will be taken in preliminary design stage in the building sector, will contribute to the national economy.

1.3 Scope

The study will focus on fire safety since it is estimated that the traditional codes and standards remain incapable in securing the safety of buildings for the reason that contemporary facade systems used today began to be used on the surfaces of high-rise buildings especially in large cities. This study will describe the problem of fire safety on complex building surfaces, through the samples carried out via the computer simulation programs within the frame of performance-based fire design.

1.4 Methodology

The subject will be described by creating the infrastructure of the study using the literature, internet databases, analyses and photos and supporting it via the figures, tables and samples. The facade systems, fire spread via the facade and performance-based design were discussed and the samples performed in this scope were evaluated to identify the effects on the spread of fire.

2 Facade Systems

The facade systems today can be studied in two sub groups. The first one can be explained as single-layer faced systems which can be called as cladding facade system and double-layer facade systems which can be called as energy-efficient facades.

2.1 Exterior Wall Systems in Common

2.1.1 Exterior Insulation Finish System (EIFS)

EIFS are attached to the exterior wall substrate to improve thermal insulation, weather tightness or for aesthetics the most basic EIFS consists of this layers. A layer of insulation, usually foamed polymer. Most EIFS use expanded polystyrene (EPS) (Fig. 1), however other types of foamed polymers are sometimes used including phenolic, polyisocyanurate (PIR) or polyurethane.

A reinforcing mesh layer. Typically, fibre glass reinforcing mesh. A base coat and top coat finish. Typically applied with a trowel or sometimes sprayed. The coating material is typically a cement based polymer modified render that is resistant to ignition and combustion [1].

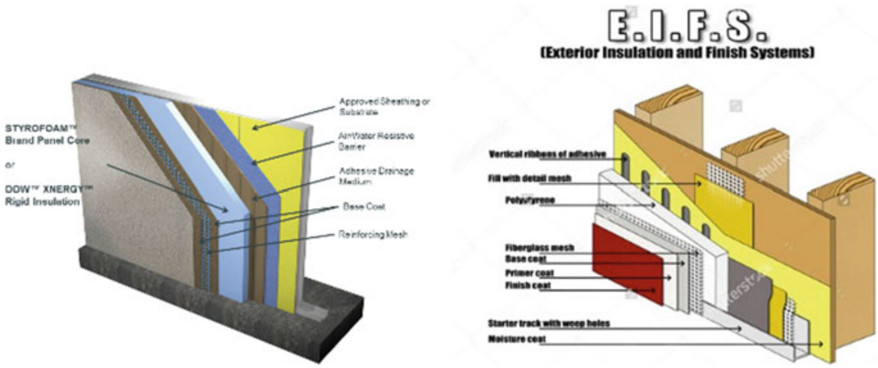


Fig. 1. Typical EIFS applied to constructions

2.1.2 Metal Composite Material Cladding

Metal composite claddings are typically thin section panels also known as Aluminium Composite Material (ACM). Typically, they consist of two 0.5 mm thick aluminium sheets with a core material sandwiched between (Fig. 2). The core material thickness typically ranges from 2 to 5 mm thick. The core material is typically either polyethylene or a mineral filled core which typically consists of polyethylene with a percentage of mineral filler. A high ratio of mineral filling provides significant improvement in fire performance. The surface is typically coated with a fluorocarbon surface coating in a range of different colours. These panels are significantly less expensive than solid metal panels at a thickness required to achieve the same flexural stiffness [1].

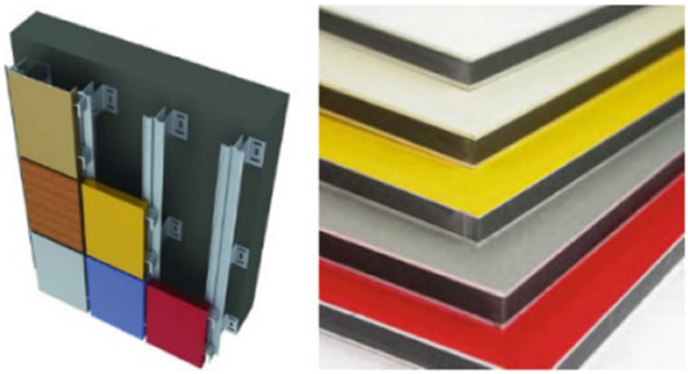


Fig. 2. Typical metal composite claddings

2.1.3 High-Pressure Laminates

Laminate panels are formed by pressing a number of Kraft layers soaked in thermosetting resin, under high temperature (170 °C), the front and rear sides of which are applied with UV-melamine-based décor layer (Fig. 3). The building is cladded with laminate facade system so as to breathe, ingress of rain water is minimised and thus the condensed water can easily be drained. It is possible to obtain different and new appearances on the facades by using aluminium base construction system and compact laminate which allows for a wide range of applications [1].

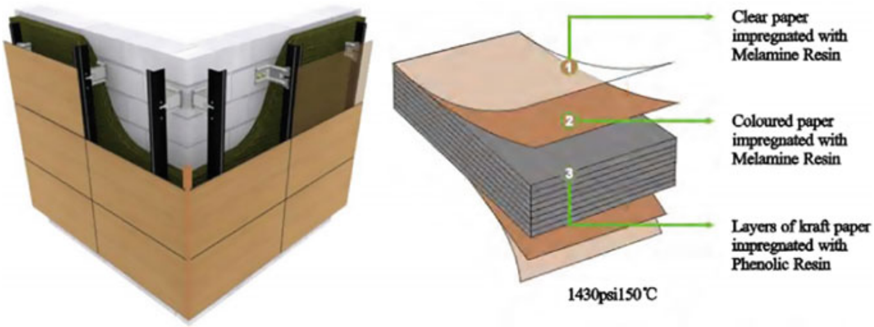


Fig. 3. High pressure laminate cladded façade

2.1.4 Rain Screen Cladding/Ventilated Facades

Rain screen cladding, sometimes referred to as a ventilated façade, is a type of façade construction which typically includes the following elements;

- **The external wall/substrate**—this may be solid masonry or concrete construction or a light weight framed wall lined with an exterior grade sheeting product such as gypsum or cement board or timber board products with a water proof membrane
- **Insulation fixed to the exterior of the substrate**—Typically panels of mineral fibre based insulation or foamed phenolic, polyisocyanurate (PIR), expanded polystyrene (EPS), or polyurethane (PU) may be adhered or mechanically fastened to the substrate. In some cases a spray based insulation may be applied
- **Ventilation cavity and supporting brackets**—a ventilation cavity of at least 25 mm typically exists between the insulation and the rain screen external cladding. The cladding is supported by aluminium or steel brackets which bridge across the air gap
- **Rain screen cladding panel**—A wide range of materials are typically used including metal composite cladding, high pressure laminates, timber products, metal sheeting, ceramic tiles, and cement board products. The cladding may include gaps between edges of panels and usually includes significant openings at the top and bottom of the wall to promote ventilation and drainage though the cavity (Fig. 4) [1].

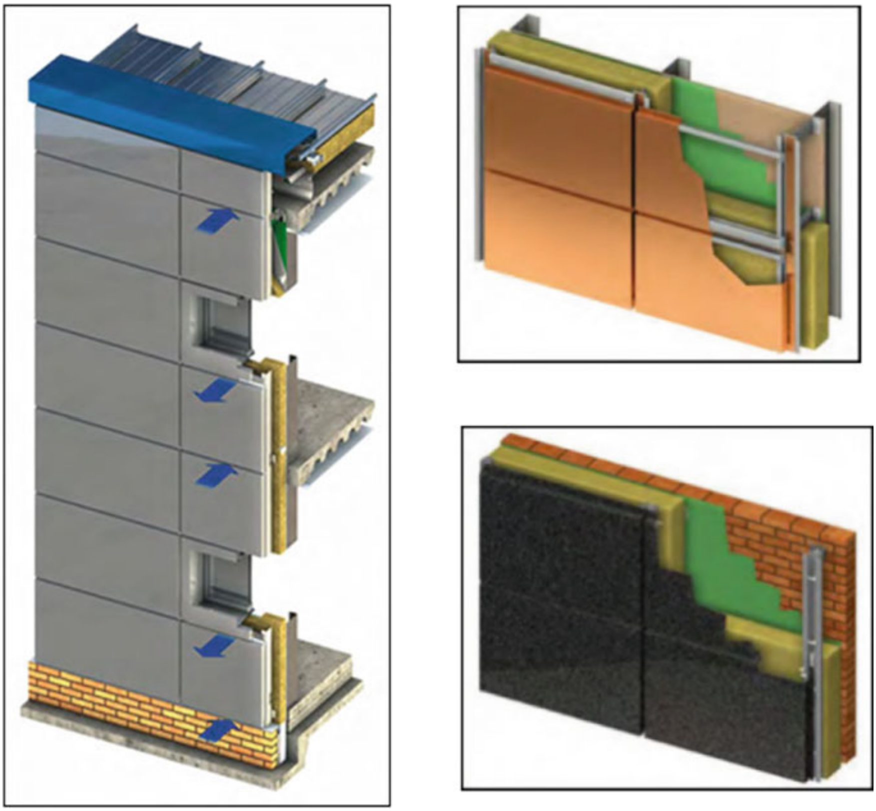


Fig. 4. Typical rain screen cladding installation arrangemets

2.1.5 External Timber Panelling and Facades

Motivation for increased use of timber based materials exists due to increase the renewable composition of buildings. In addition to traditional timber cladding and building materials, cross laminated timber (CLT) is also increasing in use. CLT is constructed of layers of timber, known as lamellas glued and pressed together with the grain alternating at 90 degree angles for each layer (Fig. 5) [1].

Fig. 5. Typical CLT Panels (left), Forte 10 storey residential CLT building in Melbourne (right)

2.2 Energy Efficient (Double-Layer) Facade Systems

It is seen that great changes are experienced in facade formations and the performance expectations of the facades as the energy and designing with an environmental awareness became more and more important. As a result of these changes, energy efficient facade systems have been developed. These facade which are frequently used in energy-efficient smart buildings are usually designed in double shell and provides the designer with wide potentials in terms of energy efficiency. Double-shell facade system is defined as a system which is made up by two or more glass layers separated from each other via an air corridor. The air layer between the glass walls provides insulation resistance against excessive heating, wing and sound as a protection.

The spacing surrounds the areas of use by creating a buffer area such as bulky air channels and forms a new external environment for the artificial environment, which is more useful than the real external conditions.

It is possible to study the facade systems where the gaps can be divided by creating spaces in different geometries, in four groups, shortly as; box window and shaft facade systems in building height, storey height (corridor facade), depending on this variation (Fig. 6) [2, 3].

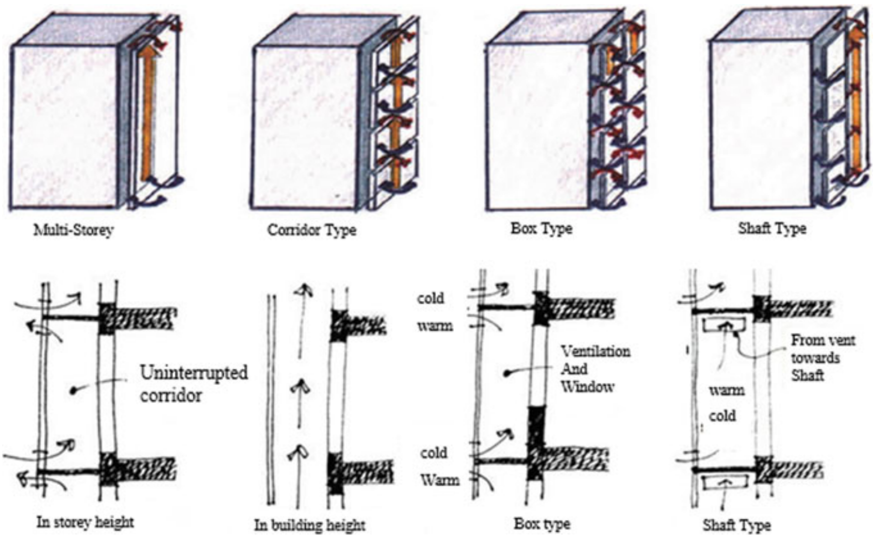


Fig. 6. Energy efficient facade systems

2.3 Fire Spread Routes in Facades

Following possibilities are observed when the common fire spread routes in the facades are examined.

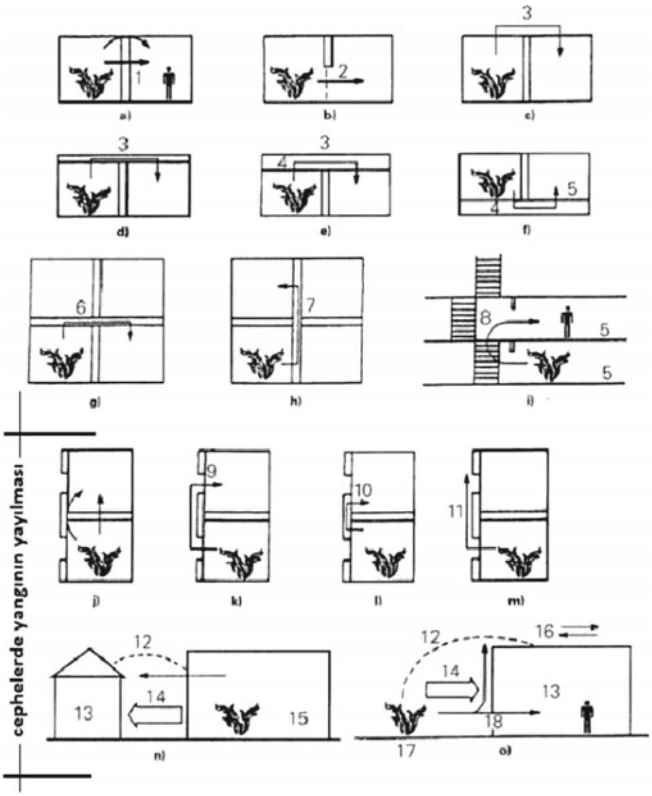
- Spread of fire by passing through the gaps which may develop before the fire between the flooring and wall member or during the fire because of the disharmony of the mobility of the members, as the constructional integrity of the building or heat insulation was damaged (Fig. 7),

- Spread of fire to upper levels through the windows on the external walls or other gaps (Fig. 7):

  (a) The flames (and hot gases) coming out of the windows and/or gaps in lower levels, with a size and intensity that will enable sufficient heat flow, which may set fire to the materials in upper levels. This situation can occur without the contribution of flammable materials on the facade systems.

  (b) The flammable material on the facade surfaces which may cause the flames to spread vertically on the building. In this scenario, it is assumed that the flames come out of a window or another gap on the external wall of a room in a lower level.

- Spread of fire towards the upper levels through the back or inside of the building facades (Fig. 7),
- Heat transfer to the building via radiation occurs through direct flame impact and/or airborne burnt matters from a fire in an adjacent building or from an external fire source outside the building (Fig. 7) [4].



1 Wall
2 Wall gap
3 Roof
4 Space
5 Flooring
6 Horizontal canal
7 Vertical canal
8 Chimney (lifts, stairs, etc.)
9 Window
10 Building facades
11 Building facade surfaces
12 Airborne burnt matters
13 Building subjected to fire
14 Radiation
15 Building exposing to fire
16 Wind
17 External fire source
18 Spread of flames

Fig. 7. Fire spread routes

2.4 Prevention of Fire Spreads on Facades

- **Prevention of indoor fires from migrating to the facade**; The indoor fire can be prevented from migrating to the upper levels by stopping the flame before it hits the facade directly. To do that, fire-resistant partitions are created between the windows of both storeys on top of each other or the flame is detracted from the facade of the upper storey by means of fire-resistant guides/baffles. This usually requires a spandrel height of 100–150 cm. (Figure 8) on the other hand, installation of at least 50-cm long flame guide may prevent the flames from migrating to the upper storeys [4–6].

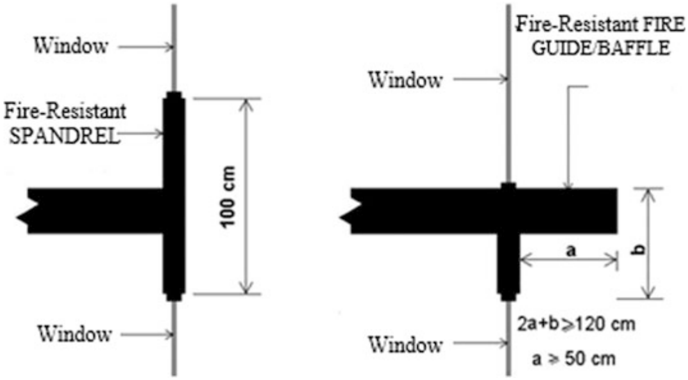


Fig. 8. Spandrel dimension

- **Fire resistance of facade material**; One of the most important issues is the flammability of the facade material since the flames spread along the facade and reach the upper storeys under the effect of an external fire or through the window gap in a fire that breaks out in a lower storey. The term "External facade" means the surface which is or can be exposed to flame spread along the facade and the materials contained in the facade should not catch fire and contribute to the spread of fire in case of a fire and the flammable insulation materials included in the base layer must be cladded/covered with the materials having the required fire resistance properties and possess the integrity specifications [4–6].
- **Facade geometry**; Another major factor that affects the spread of fire on facades is the geometric structure of the facade. Particularly, the vertical protrusions made on the facade may detract the flames form the facade. The balconies, shades and deep partition protrusions around the windows both protect the facade of the building against the flame-over and prevent a bigger fire from breaking out. Danger of fire which breaks out or develops in a sub system of the building may become a structure that promotes the spread to all parts of the building in spite of all fire protection measures taken in all other parts of the building. As an example, a small fire which started in the ventilation duct in a 54-storey office building in Manhattan (New York Plaza) (Fig. 9) could not be controlled and spread due to external shell design and its structure [4].

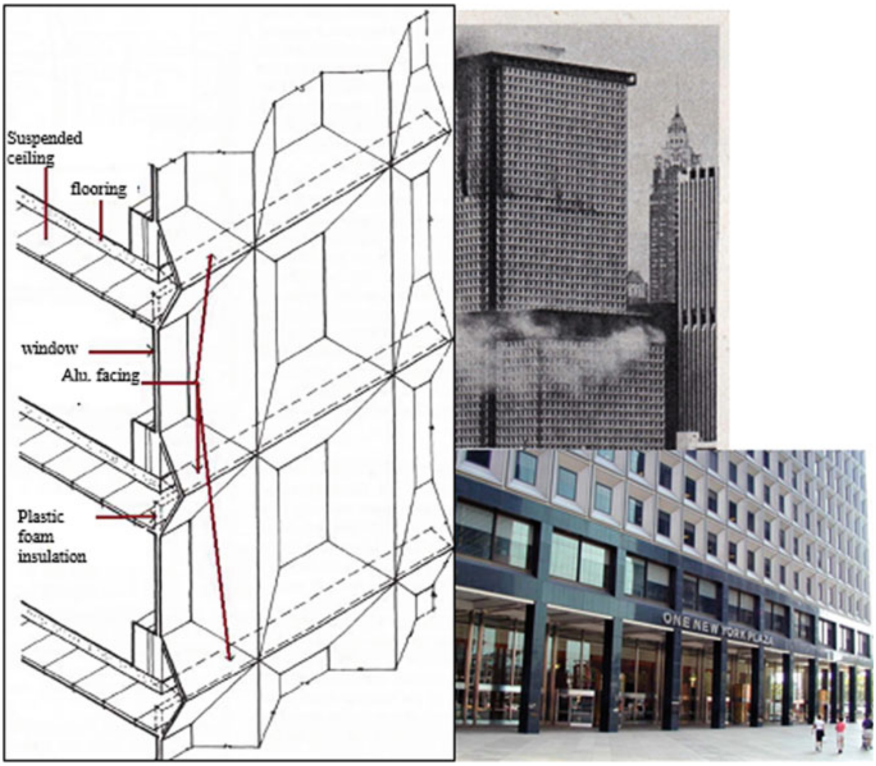


Fig. 9. New York Plaza [7]

- **Preventing the fires that start externally from migrating to other buildings**; The facades are affected by the fires that start externally and may contribute to the spread of fire. In order to prevent this situation, suitable measures should be taken according to the external source (Fig. 10). External source might be another building fire. In this case, the fire can migrate from one building to another through heat transfer via heat radiation, direct flame impact and/or airborne burnt matters. The rise of temperature in the building on fire leads to spread of fire via the radiation and transfer of heat energy. The heat which is transferred by favour of the wind causes the flammable facade to catch fire. Even if there is no wind, the heat radiation which is caused by high temperature heats up and sets fire to the nearby facade. The facade may not reach ignition temperature since it is exposed to atmosphere, however heat radiation may penetrate the windows in proportion to the severity of the temperature of the flame and ignite the furniture inside and thus start a fire in the neighbouring building. The glasses explode and heated facade can catch fire in no time as the fire inside expands, causing fires bigger than the initial fire. The proportion of gaps (unprotected surfaces and windows) to total facade is important in the building which is exposed to a fire. This is particularly taken into account when determining the clearance between these two buildings. For example, a fire that starts on a device in the adjacent building or a material catching fire or set on fire on the floor level, as a fire source outside the building, can cause a facade fire. It was also seen the fire started as the airborne flaming particles in a fire around the building could start facade fires as they hit the building by favour of the wind and set a fire [4].

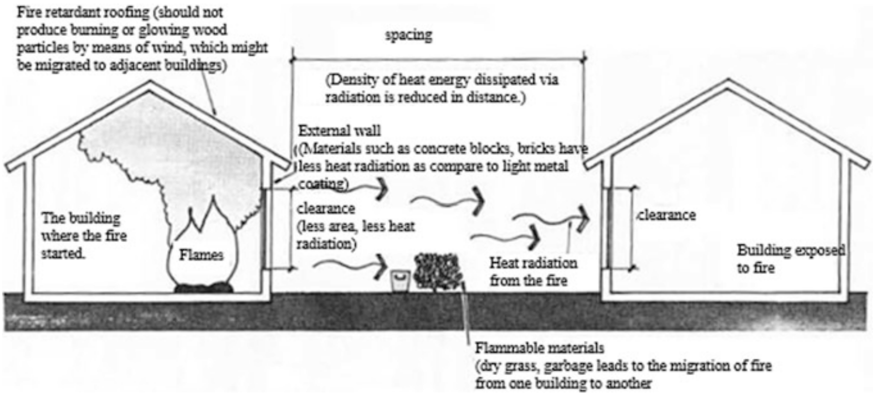
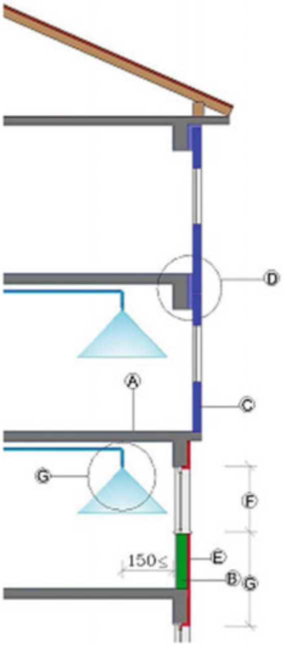


Fig. 10. Spread of fire that starts externally

2.5 National Fire Regulations and Standards

There are two important sources that we have in terms of fire safety in Turkey, one of which is the standards that were already prepared and are being prepared by TSI. Most of these standards are derived from NFPA Codes and EN Standards via translation. Second important source is the “Regulations on Protecting the Buildings Against Fires”, effective from 26 July 2002 upon the Cabinet Decree, to be used across Turkey [6].

It has been avoided to include definitions for the constructional members that make up the building, in order not to restrict the design in BYKHY (Regulations on Protecting the Buildings Against Fires). Therefore, no definition was made about the external facades. When we look at BYKHY, it is seen that three different terms are used; external walls, external facades and external cladding based on intended purpose and place of use and some fire protection measures are taken for these terms (Fig. 11) [4].



Passive Measures			
Fire Resistance			
	Structural Member	Load Bearing	Non-load Bearing
A	Flooring	REI	--
B	External Wall	REI	EI
C	External facade	---	EI
D	Flooring-Wall joint	---	EI
E	Unprotected space	---	---

Reaction to Fire				
	Building Material	Not classified as high building		High building
C	External Facade	Hardly flammable		Hardly combustible
E	External Cladding	(≤2 coats) Normal flammable	Hardly flammabl e	Hardly combustible
F	Unprotected space	--		---
Active Measure				
G	Automated sprinkler system	If the fire resistant full surface (G) = 100 cm, sprinkler heads are installed on the interior side of the facade at a distance of max. 1,5 m. to the facade, spaced at 2 m max.		

Fig. 11. Facade fire protection measures according to BYKHY

3 Investigations on the Implementation of Performance Based Design on Facades for Fire Spread

3.1 Computer—Simulation Research on Building Facade Geometry for Fire Spread Control in Buildings with Wood Claddings—2012

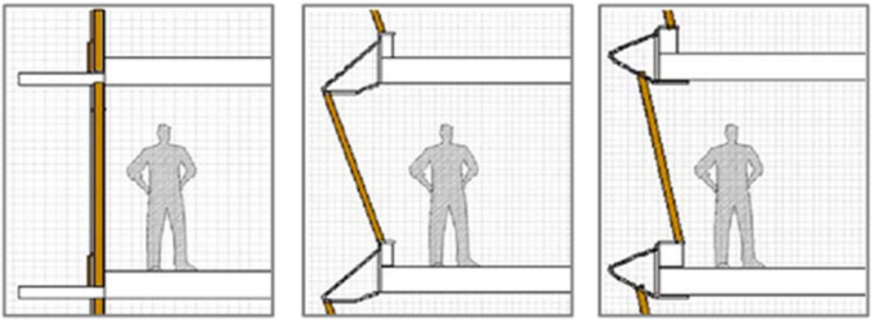
In this study Using FDS programe with modelling techniques and computer fire simulations to evaluate the influence of facade configuration on fire trajectory and the level of protection it can offer at the facade surfaces.

Through the design and geometry of the facade. To use construction elements capable to avoid the contact between the fire plume and the combustible cladding. Providing deflector elements with the ability to change the trajectory of the flames and prevent its passage into other compartments.

Given the influence of the geometric factor in fire dynamics and its spread, this research focuses in the design of the facades as a means of passive protection capable to reduce the risk of external fire spread. The study aims to assess the influence of some geometric factors of the facade on the fire propagation through the whole structure. Moreover, we analyse the level of protection provided by horizontal projection elements and “singular” sloped elements. We focus our study on two aspects.

(A) Comparison of four horizontal projections sizes (non-combustible material).
(B) Assessment of sloping surfaces in two singular designs of facade.

Additionally, the influence of windows size in the development of fire and its external spread has been considered in each study case (Fig. 12).



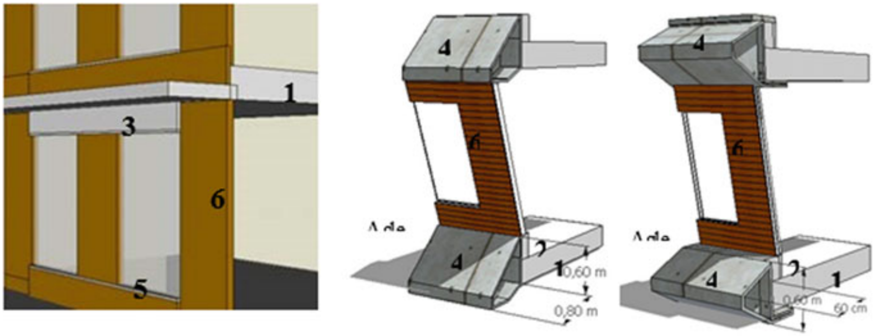
(A) (B1) (B2)

Fig. 12. Description of the geometric variables of study. **A** Different size of horizontal projections (eaves). **B1** and **B2** Two singular facade geometry

Table 1. Study case

Study cases				
Horizontal projections sizes (A)				Windows size
60 cm	80 cm	120 cm	150 cm	Small 1.20 × 1.80 m
60 cm	80 cm	120 cm	150 cm	Large 4.90 × 1.80 m
Singular geometry (B)				
Singular design (B1)		Singular design (B2)		Small 2.0 × 1.80 m
Singular design (B1)		Singular design (B2)		Large 3.90 × 1.80 m

The computational domain size is 6.50 m × 4.90 m × 8.25 m. This consists of 241,920 cells. Each cell has uniform size (0.10 m × 0.10 m × 0.10 m). The total number of cells in each domain is units. The general parameters of the simulation are described in Table 1. Study cases design details Show in (Fig. 13).



1. Structural floor
2. İnner support Wall
3. Lintel concrete (precast)
4. Singular concrete element
5. Sill concrete
6. Exterior timber cladding

Fig. 13. Study cases design details

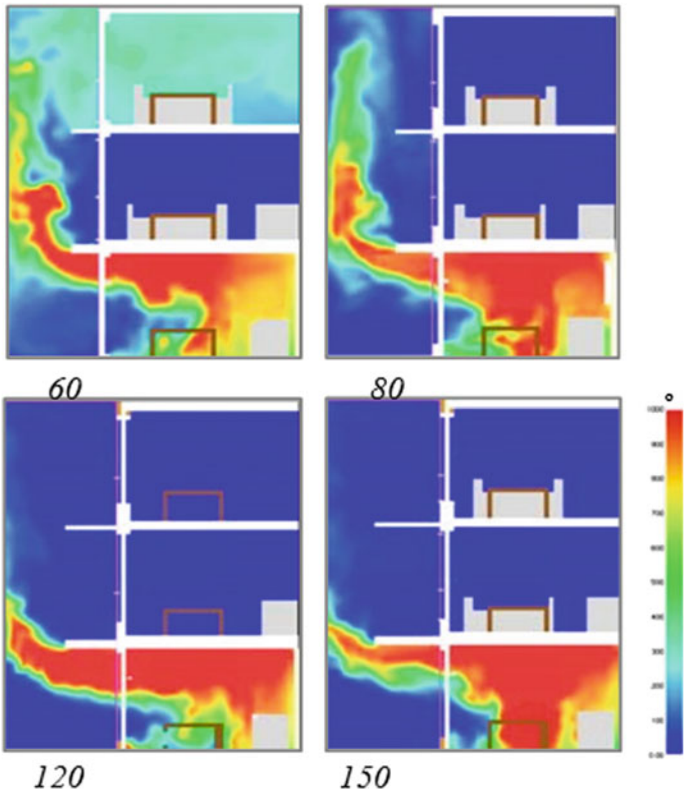


Fig. 14. Different horizontal projection sizes of temperature distribution graphics

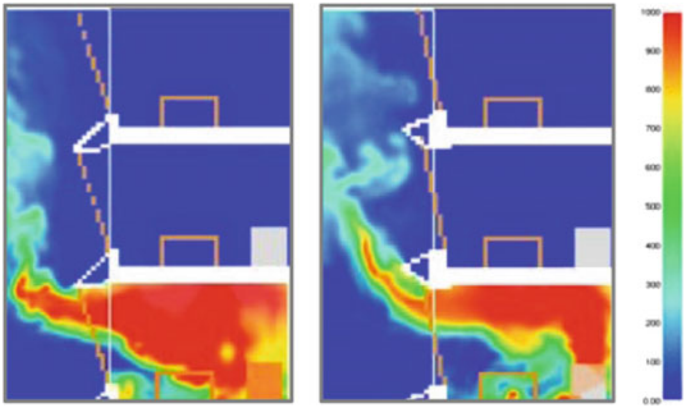


Fig. 15. Singular designs of façade of temperature distribution graphics

In this study outlines;

1. This research shows that the facade geometry of buildings can influence greatly on the behaviour of fire and its propagation.
2. The horizontal projection acts as a flames deflector. Therefore, this type of projections can contribute to prevent the spread of fire through combustible materials cladding such as wood.,
3. Horizontal projections of more than 60 cm are required to deflect the trajectory of the fire plume. However, horizontal projections greater than 80 cm are appropriate to reduce the heat flow on the surface of the facade. When the risk is greatest, for example due to the size of the windows may be necessary to increase to 120 cm depth in order to minimize the incidence of heat flux on the façade (Fig. 14),
4. The windows size is an important issue in the fire spread control through the facades. Small windows reduce the risk of spread because the emitted heat flux is lower in comparison to large windows,
5. The combination of horizontal projections and sloped surfaces could be a good option of facade design to minimize the risk of vertical fire spread (Fig. 15). This type of configurations deserves to be further explored [8].

3.2 Torre Regione Piemonte Building—2016

The façade of Piedmont Region Headquarters ("Torre Regione Piemonte", project of Arch. Massimiliano Fuksas, still under construction in Italy) is examined by fire safety engineering (FSE), as a case study due to its distinctive architectural and technological aspects (Fig. 16).

In the article, the fire resistance performance requirements of structural and glazed elements of the facades and the results of the CFD models are reported. In addition, all the simulated calculations and performance fire resistant requirements assessment process, have been supported by specific laboratory tests. These fire resistant tests have been also carried out in accordance with EN 1364-3 to evaluate the fire behaviour of the chosen glazed façade system.

According to the Italian prescriptive fire codes, the project fire safety requirement should fulfil the following fire safety measures:

1. Each floor of the offices (except the double/triple height zone—entrance hall) should ensure a fire compartment with R/REI/EI 120 fire resisting class and the installation of mechanical smoke and heat exhaust systems and sprinklers.
2. Each Satellite should ensure a fire compartment with R/REI/EI 120 fire resisting class, the installation of sprinklers and water curtain on glazing.
3. Grand Space is the only volume that requires R 60 fire resisting class; it is composed of aluminium façade structure supported by steel elements and is equipped with mechanical smoke and heat exhaust systems.
4. The facade between two macro areas (including the separation between Offices and Satellites) should have EI 120 fire resisting class.

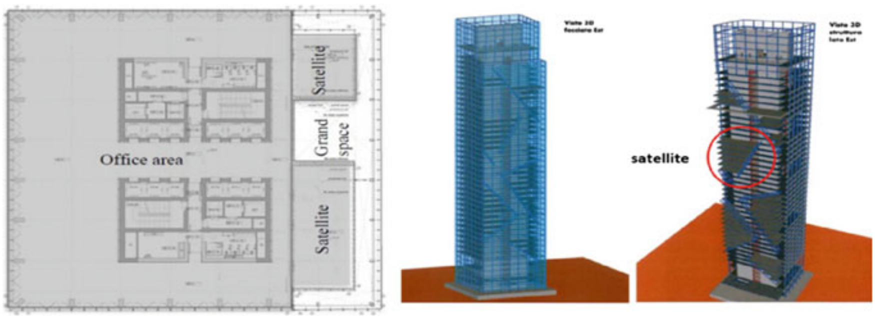


Fig. 16. Typical plan of Tower Piedmont Region Headquarters where are highlighted office area, satellites and grand space

Four models are assembled to simulate six different fire locations. In the following the fire scenarios are listed.

Fire in second basement level inside the Grand Space (scenario 1) (Fig. 17),

Fire in ground floor level inside the Grand Space (scenario 2) (Fig. 17),

Fire inside Offices (scenario 3–4) (Fig. 18),

Fire inside a Satellite (scenario 5–6) (Fig. 19), The present CFD calculations have been performed by CFD program ANSYS CFX in collaboration with Ramboll group.

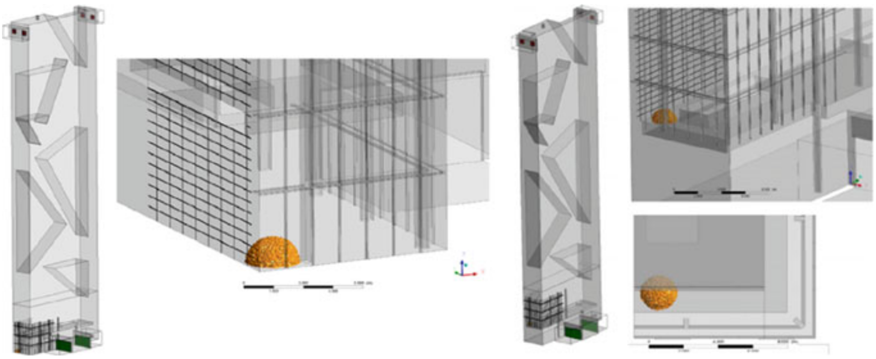


Fig. 17. CFD models for the scenario 1 and scenario 2

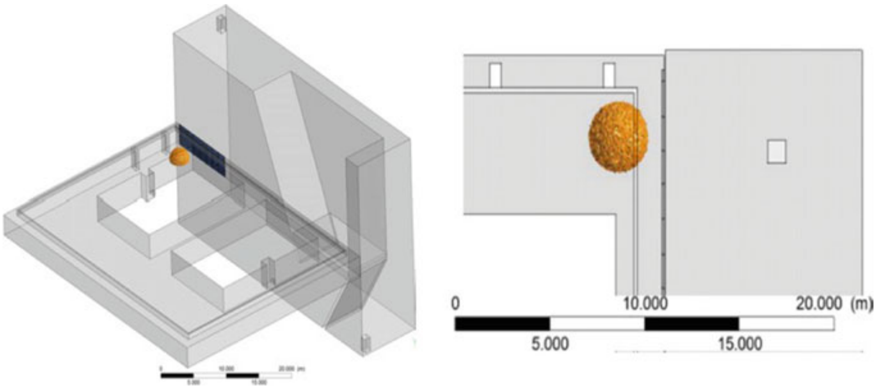


Fig. 18. CFD models for the scenario 3 and scenario 4

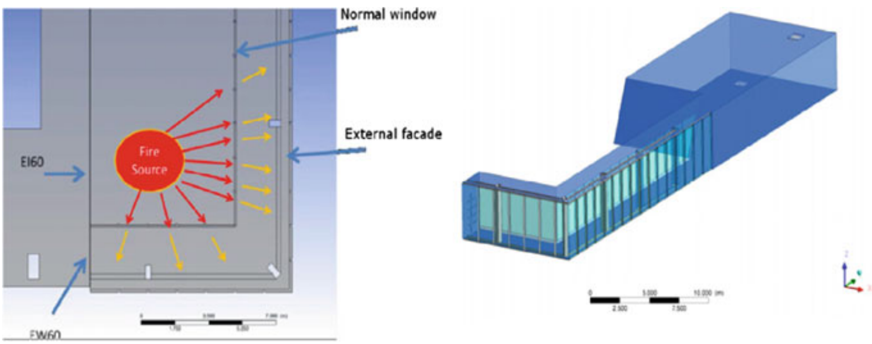


Fig. 19. CFD models for the scenario 5 and scenario 6

The results of the fire scenarios show that fire protection of the steel elements can be made most efficient. It has be seen that there is need of fire protection on Grand Space façade only from level −2 to 0. Furthermore, the presence of EW 60(i → o) façade and water mist system provide the required fire safety conditions in case of an outbreak of a fire for higher building levels.

In addiction, CFD models are performed to optimize the smoke and heat exhaust systems inside the Grand Space and hence, the fire resistance class of the separating façade between Offices and Grand Space can be reduced from EI 120 to EW 60 (i → o).

This case study confirms that performance based approach makes possible to analyze façades complexly, to guarantee the fulfillment of the required fire safety level and to optimize cost and time of construction, reducing the overall maintenance cost and maintenance time of the building [9].

4 Conclusion

Fire safety on the facades of high structures is a complex problem. For this reason, it is considered that fulfilling only the codes and legal obligations in order to raise the fire safety level will not be enough to provide fire safety of the buildings.

According to the examples examined in this context, if an evaluation will be made both from the sample work done in the computer environment artificially and from the sample building during the construction phase; It has been seen that the geometric ceiling of the building can be significantly affected in the fire behavior and its spread.

Therefore, the importance of the use of computer simulation programs in the fire safety has been emphasized within the concept of performance based approach in buildings designed differently from traditional construction system.

At the same time, regarding the national fire safety regulations on curtain façades;

(A) The places where the façade elements and the upholstery that do not have the gaps to which the flames can pass, are insulated until the fireproofing of the flooring to prevent the flames from jumping to adjacent floors.

(B) Façades and insulation materials used in buildings with joints with open or ventilated curtain wall system should be the least difficult to ignite [10]. However, these requirements are considered to be weak in fire protection in today's different facade designs, It should be supervised by institutions.

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Dynamic Analysis of a Reinforced-Concrete Post Tensioned Wind Turbine Tower

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Abstract. Wind energy turbines have drawn great interest especially for the last 2 decades. Today newly developed high-power wind energy generators require long blades and tall towers with large base diameter which exceeds the allowable width for highway transportation. The tower must also be divided through longitudinal and connected on site to overcome transportation problem. In this case welding difficulties, other technological aspects on site increase the cost of steel towers. However, concrete towers precast or cast on site, becomes a competitive alternative to current steel solutions for the wind energy towers, due to its lower cost and higher durability. As the generator on top produces a variable and continues vibration the dynamic properties of the towers becomes more important than any other structures due to resonance effect. In wind turbines, inexact calculation of natural frequencies or change of natural frequencies due to concrete cracking by time may harm the whole structure. So this makes post tensioning very important for wind energy towers. Post tensioning avoids tension strength which in turn prevents fatigue cracks in concrete elements which are exposed to tension strength. In this paper, the concept of a 100 m tall modular prefabricated posttensioned high-performance concrete 3.6 MW wind generator tower is presented. In the study the finite element model of the tower is prepared and under wind and rotor loads the structural analysis of the tower is presented.

Keywords: Wind turbine tower · Post tensioned concrete · Structural analysis FEM

1 Introduction

Wind energy tower options for producing wind turbine towers are steel, concrete and hybrid towers. Steel is very popular in wind energy towers because it has a featured design alternative and steel towers are produced by many manufacturers. Moreover, Steel has high strength to weight ratio and competitive cost in the current market.

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Challenges of steel construction are large sections necessary for taller towers; transportation concerns and transportation limit to 4.3 m and potentially long lead time.

The evolvement in onshore wind turbines are moving in the direction of more powerful turbines which can produce more than 3 MW and have towers exceeding 140 m in height [1, 2]. Diameters of the blades are chosen by the height of the hub height and usually they are chosen same as, a result swept area of the blades is proportional to the square of hub height. This means produced energy is proportional to the square hub height. Steel tall towers, higher than 80 meters cannot be produced due to transportation problem. So concrete towers precast or cast on site or hybrids become a competitive alternative to current steel solutions for tall wind energy towers. Concrete towers are also having lower cost and higher durability [3, 4].

As the generator on top produces a variable and continues vibration the dynamic properties of the towers becomes more important than any other structures. Resonance is a fundamental problem for tall structures and inexact calculation of natural frequencies or change of natural frequencies due to concrete cracking by time may harm the whole structure. In order to overcome this problem, post tensioning has been applied. Post tensioning avoids tension strength, which in turn prevents fatigue cracks in concrete elements.

In this study, the concept of tall modular prefabricated post-tensioned concrete tower design is presented. The tower is composed by precast reinforced concrete elements that are monolithically connected by means of post-tensioning tendons. The finite element model of the tower is prepared in ABAQUS Finite Element (FE) program and the materials properties assigned to the model and post tension exerted and dynamic modal analysis is done. The modal shapes and frequencies are calculated. The proper frequencies of the tower are arranged according to turbine selected. Lastly wind and turbine loads exerted to the tower and analysed. According to the stress and displacement values the safety of the proposed tower is identified.

1.1 Wind Energy in the World and Turkey

Today governments put a special importance on wind energy turbines because wind energy has great potential of all renewable energies. By 2030 most of the developed countries are planning to produce 20% of energy requirement from wind energy. Germany is the leader in Europe with 27000 wind turbines, which have total capacity of 44470 MW [2, 5–7]. The capacity of wind energy in the world is given in Fig. 1. Turkey has given great importance to wind energy since 2006–2015 in 10 years the installed wind energy capacity increased from 51 to 4193 MW (Fig. 2). Aegean and Marmara regions have great importance in wind energy. According to European Wind Energy Association 2015 annual report (AWEA) Turkey is the 7th country in installed wind energy capacity in Europe. According to Turkey National Renewable Energy Action Plan Turkey December report [2, 5–7] Turkey is planning to increase the wind energy capacity to 20000 MW by 2023.

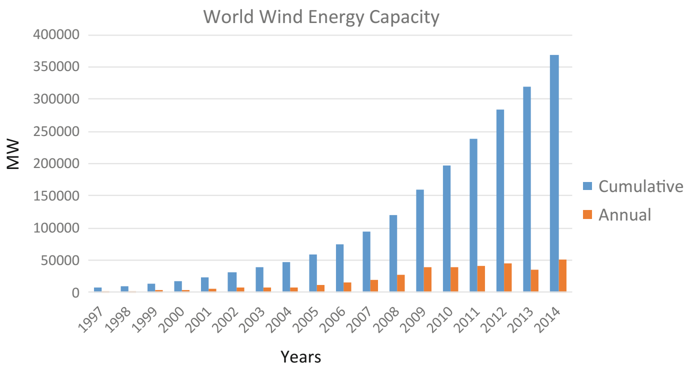


Fig. 1. Annual and cumulative installed wind energy capacity in the world [2, 5–7]

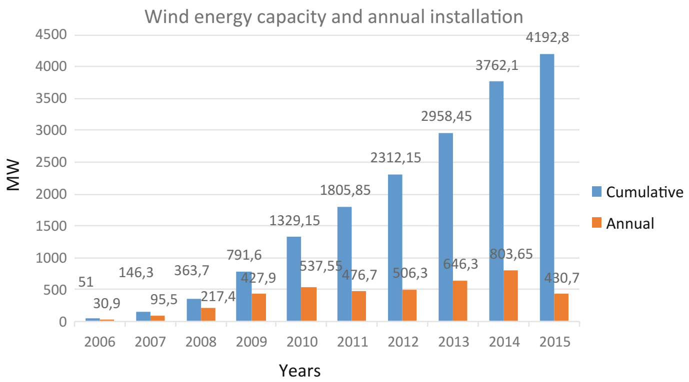


Fig. 2. Annual and cumulative installed wind energy capacity in the world [2, 5–7]

2 Material Method

The calculation of the wind energy tower is done according to the regulations of ASCE 7-10 [8], International Electrotechnical Commission Standards [9], GL Rules [10] and The Lack of US Structural Design Guidelines for Wind Farm Towers [11].

The Design procedure is given in Fig. 3.

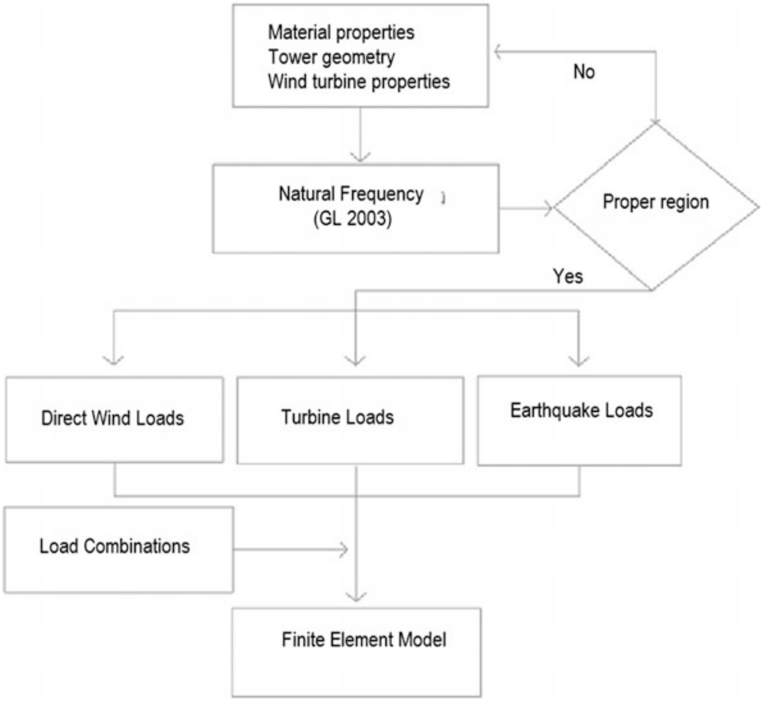


Fig. 3. Design Procedure of the proposed system

There must be an adequate difference between the natural frequencies of the tower and the turbine operation frequencies to avoid resonance of the system. According to the GL Rules, there should be a safety margin between the natural frequency of foundation, tower, nacelle and rotor, and the excitation frequencies [12].

The excitation frequencies of a wind turbine support structure are (Fig. 4):

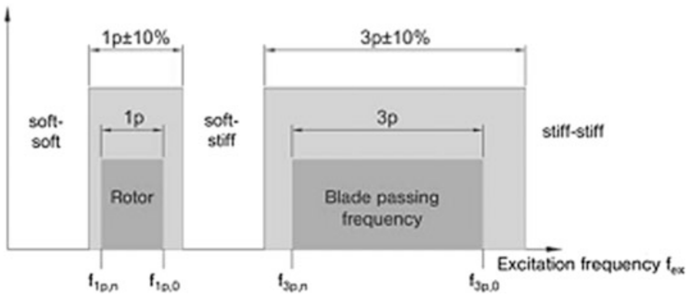


Fig. 4. The excitation frequencies [12]

(a) Periodic excitation with 1 rotational speed (rotor frequency) = 1P excitation.
(b) Periodic excitation with 3 rotational speed from blade passing frequency = 3P excitation.
(c) Whole-number multiples of the rotor frequency.

The ranges of the permissible natural frequencies are shown in the Campbell Diagram, in this figure for a 5 MW turbine (Fig. 5).

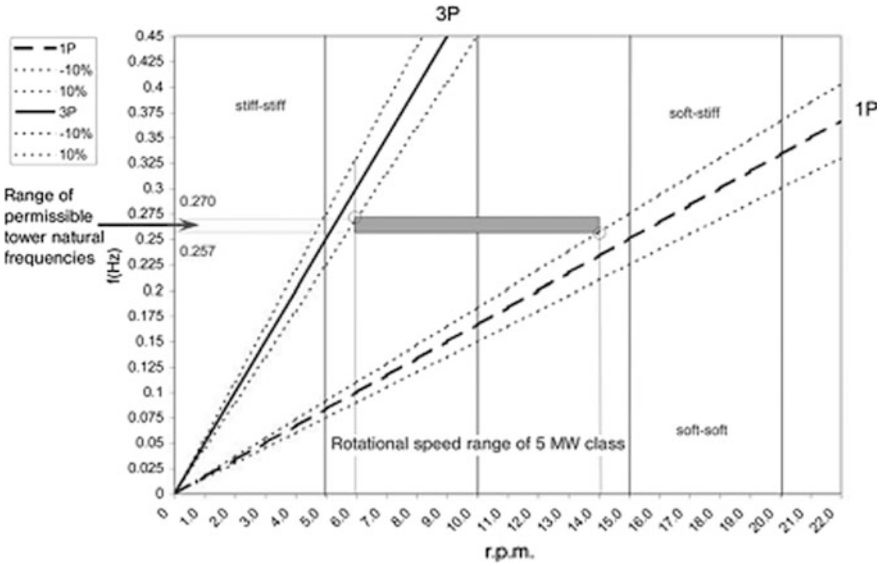


Fig. 5. The excitation frequencies [12]

The selected turbine into his paper has a power of 3.6 MW 14.2 rpm and 0.24–0.27 operation frequency range. So the natural frequency of the tower must be between 0.24 and 0.27.

2.1 Examples of R/C Post-Tensioned Wind Turbines

In 2003 a wind energy tower was erected using prestressed concrete for the very first time in Umiterasu Nadachi wind power plant, Japan (Fig. 6). The plants proximity to the shore was a decisive criteria for choosing prestressed concrete. The use of steel in the salty atmosphere would have been extremely expensive as a result of the cost for corrosion protection and maintenance. Due to the simpler structural design and higher service life compared to steel, the construction of a wind power plant using prestressed concrete was the best economical solution [13].

Fig. 6. Umiterasu Nadachi wind power plant, Japan [13]

Voltalia Energia do Brasil has commissioned two new wind parks in the federal state of Rio Grande do Norte in north-eastern Brazil. The 120 m high tower shafts consist of prefabricated concrete segments that were produced on site in a field casting yard in order to minimize both transportation costs and impact on the environment. The precast concrete elements are post-tensioned against each other using external wire tendons located inside the tower (Fig. 7).

Fig. 7. Voltalia Energia wind power plant, Brasil [13]

At the upper part of the tower, the tendons were anchored in a special ring using fixed anchorages. In the tensioning area of the foundation, the tendons were anchored using stressing anchorages. Low weight Hollow-Piston CFRP Cylinders were used for tensioning the tendons because they could be easily positioned inside the towers (www.dywidag-systems.at).

3 Proposed System

The proposed system is post tensioned prefabricated reinforced concrete system. The system composed of four columns and these columns connected with horizontal steel panels. The section of the tower is a square (8 m × 8 m) at bottom and from above to below the section decreases to 3 m × 3 m at top. The system has post tensioned from top to the bottom. The columns are prefabricated and each column is composed of ten pieces of prefabricated 10 m parts. The total height of the tower is 100 m, the horizontal steel members are used for every 5 m. The section of the columns and horizontal member are presented in Fig. 8a–b.

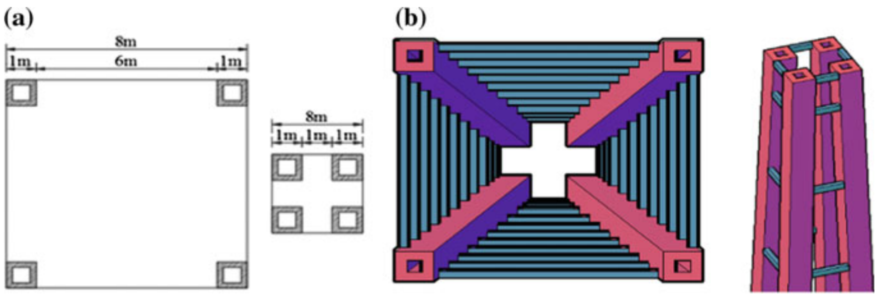


Fig. 8. (**a**) The section of the columns of proposed tower (**b**) Horizontal member of proposed tower

3.1 FEM Model and Dynamic Analysis of the Tower

A three dimensional (3D) finite element model of the wind turbine was developed using ABAQUS software [14]. In the finite element model of wind turbine, 96477 nodes and 369374 tetrahedral (C3D4) solid elements were used. Figure 9 shows a finite element model of wind turbine in this study.

The dynamic characteristic of the wind turbine was determined in the ABAQUS

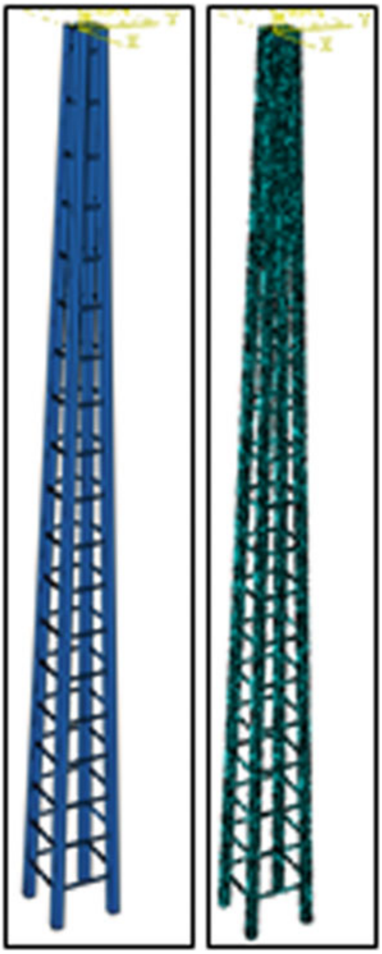
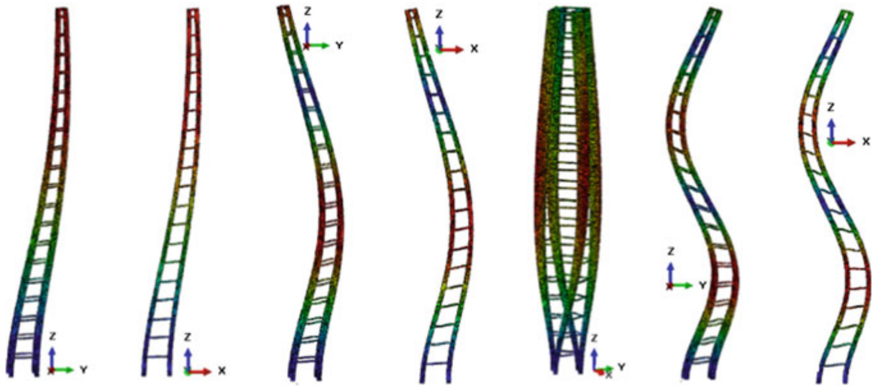


Fig. 9. Finite element model of the wind turbine

software. The natural vibration frequencies and mode shapes belonging to modes were obtained from modal analyses. Frequencies and mode shapes obtained in analyses results are presented in Fig. 10.



Mod 1: 0.266 Hz	Mod 2: 0.267 Hz	Mod 3: 0.634 Hz	Mod 4: 0.635 Hz	Mod 5: 0.824 Hz	Mod 6: 1.335 Hz	Mod 7: 1.337 Hz

Fig. 10. Modal shapes and frequencies of the proposed tower

3.2 FEM Model and Dynamic Analysis of the Tower

According to IEC 61400-1 regulation loading types are; *Normal Wind Profile Model, Normal Turbulence Model, Extreme Wind Speed Model, Turbulence Intensity for Extreme Conditions, Extreme Operating Gust, Extreme Turbulence Model, Extreme Direction Change, Extreme Coherent Gust Direction Change and Extreme Wind Shear*. In this study Extreme Wind Speed Model (EWM) and Extreme Operating Gust

(EOG) loading conditions are used. EWM is a loading condition under extreme wind when the turbine is not operated [8, 15]. EOG is a loading condition when turbine is under operation with maximum wind load. Also these conditions govern the start-up, shut-down, energy producing and fault status.

Direct wind loads. Wind loads are calculated according to ASCE 7-10 for Extreme Wind Model (EWM). However while operation of the wind turbine Extreme Operating Gust (EOG) load conditions are govern and IEC 61400-1 regulation is used for calculation of wind loads. Calculated wind loads are shown in graph (Fig. 11).

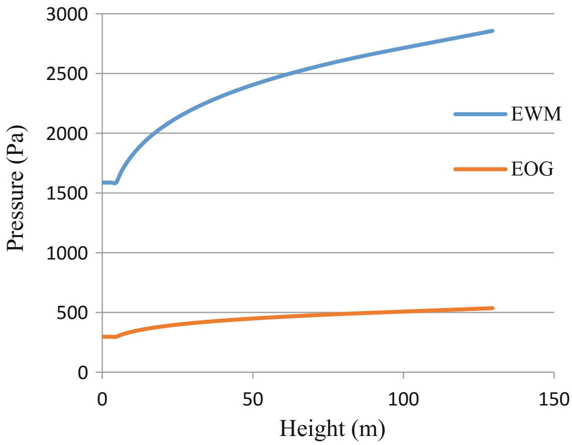


Fig. 11. Wind pressure variation through the height of the tower

Loads and moments from rotor. The drag and lift effect of wind on the blades result with load and moment on the rotor of the wind turbine. This moment and loads are calculated and shown in Table 1 for EOG and EWM loading.

Table 1. Moment and loads on the top of the tower from turbine

Load direction	EWM		EOG	
	Load (kN)	Moment (kNm)	Load (kN)	Moment (kNm)
x–x	495	1063	1192	4261
y–y	658	6711	80	8949
z–z	3087	2576	3087	1595

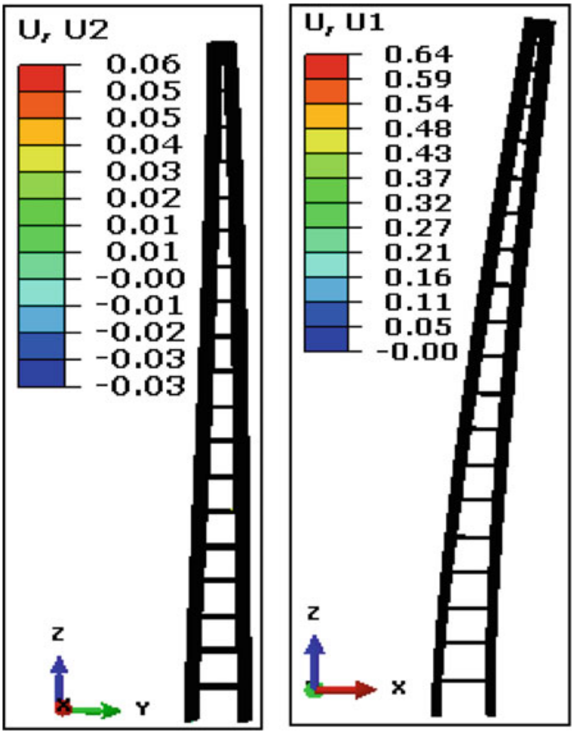


Fig. 12. Displacement of the tower under EOG loading

3.3 FE Analysis of the Tower

According to EOG and EWG loading conditions the analysis results are performed and results are shown below.

EOG loading: The analysis is performed under EOG loading. The maximum displacements for U1 and U2 are shown in Fig. 12, on the deformed model of the tower. The regions shown in red indicate the largest displacements. According to the displacement contours, the maximum displacement in the vertical direction occurred as 64 cm.

Maximum and minimum principal stress contours were show in Fig. 13 on the deformed model of the wind tower. Maximum and minimum principal stresses occur as 15 MPa and 39.5 MPa, respectively. Axial stress contour on columns are shown in Fig. 14.

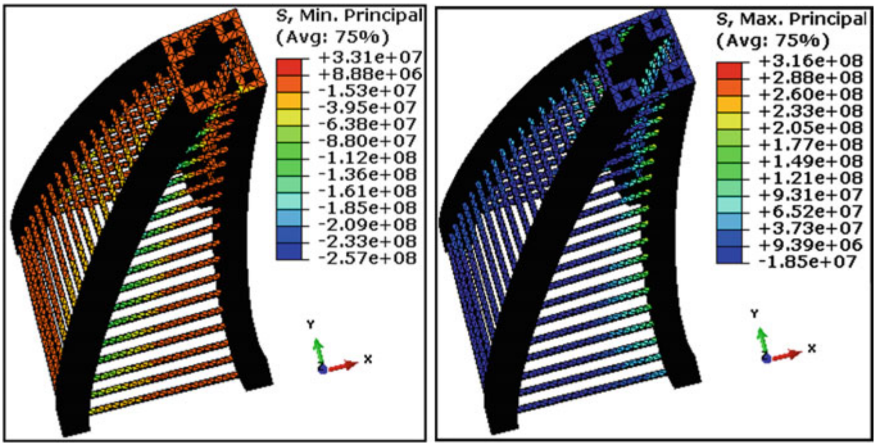


Fig. 13. Maximum and minimum principal stresses contour

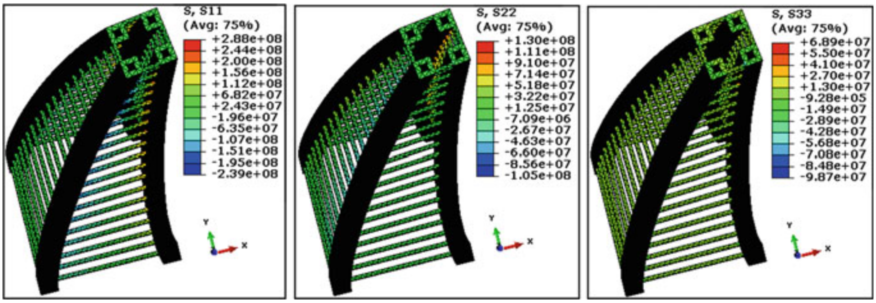


Fig. 14. Normal stress contour on columns

EWM loading: The analysis is performed under EWM loading. The maximum displacements for U1 and U2 are shown in Fig. 15, on the deformed model of the tower. The regions shown in red indicate the largest displacements. According to the displacement contours, the maximum displacement in the vertical direction occurred as 36 cm.

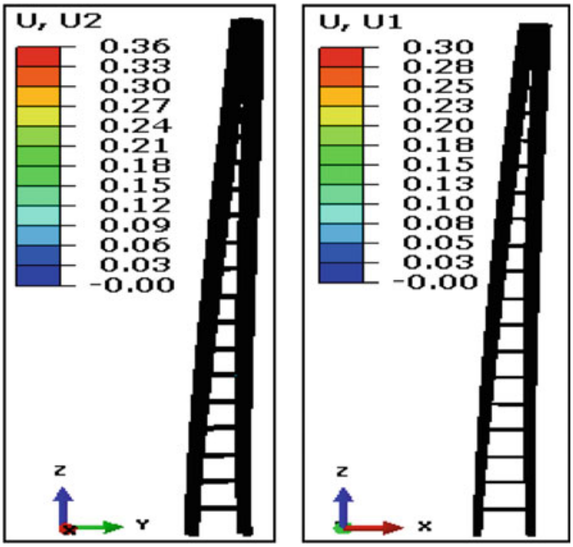


Fig. 15. Maximum and minimum principal stresses contour

The maximum and minimum principle stress values are 11.2 MPa and 36.4 MPa respectively and shown in Fig. 16. Axial stress contour on columns are shown in Fig. 17.

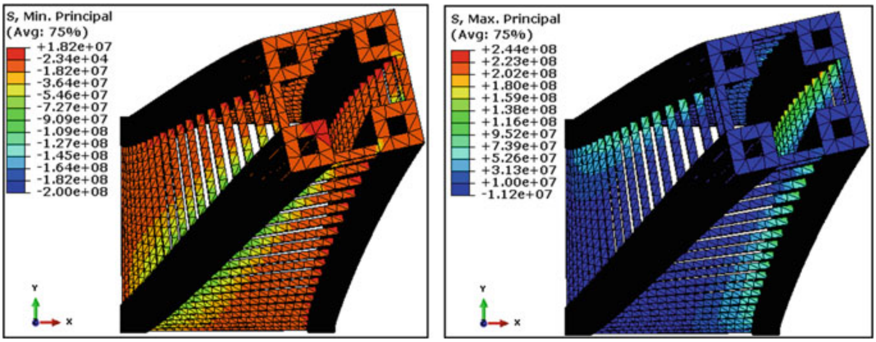


Fig. 16. Maximum and minimum principal stresses contour

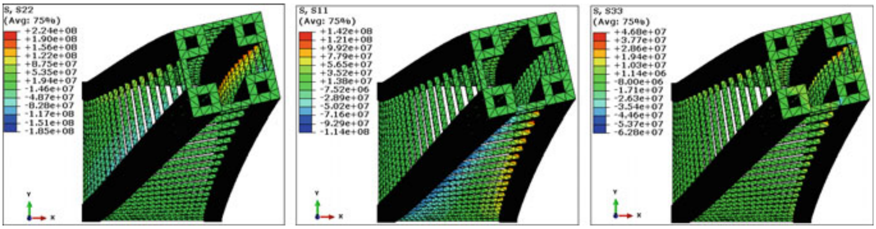


Fig. 17. Normal stress contour on columns

4 Conclusions and Recommendations

Based on the FE results of this study it was found that the tower perform well under both EOG and EWM load of 3.5 MW turbine. Prefabricated columns showed that no damage under loading conditions. Maximum stresses are observed on steel horizontal frames. By choosing these frames steel the allowable tresses are not exceeded. Steel panels may be replaced with post-tensioned. The connection of panels and columns must be also studied. Because the node connection of panel and column has stress of 257 MPa under EOG.

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Markov Chain Optimisation for Pavement Maintenance

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Abstract. The highways network is crucial to the economic and social development of the United Arab Emirates (UAE). The increase in capital spend on highways projects across the UAE has emphasised the importance of optimising the long-term operational and maintenance spend. This paper presents a case study of the application of Markov chains in the optimisation of pavement maintenance decision-making. The theoretical model utilises a simplified staged-homogenous Markov chain to predict future pavement conditions at the network level by comparing the pavement condition with planned maintenance activities against pavement condition without maintenance activities using a Pavement Condition Index (PCI) as the basis of the calculation. Also estimated budget for maintenance work has been achieved.

Keywords: Homogenous Markov chain · Pavement performance
Pavement condition index (PCI) · Preventive maintenance
Correctives maintenance

1 Introduction

Methodologies for managing infrastructure assets are well developed, particularly in the fields of asset management and reliability theory [28]. In the context of Transportation infrastructure, Haas et al. [14] concluded that pavements are arguably the most critical of all infrastructure assets, accounting for approximately 60% of the total infrastructure in the US. It is also considered as oldest and most abundant assets. According to Peters [31], an enormous investment as much as $1.75 trillion was made for highway systems itself in the United States Towards the end of the 20th century, the desire for more sophisticated and reliable systems to manage these assets emerged. Recent announcements by the present administration of the US indicate a recognition of the importance of infrastructure investment, not just as a form of economic stimulus, but as a necessity to ensure critical assets remain functional from an engineering perspective (see the auxiliary spillway on the Lake Oroville dam in northern California). Government departments, as the custodians of most major infrastructure, are increasingly pressured to balance the necessity to ensure critical assets remain operational with the increasing

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demands of fiscal parsimony. Kobayashi et al. [18] states that one of the main obstacles to achieving this balance lies the ability to balance whole-life costs across portfolios of assets. Thus, an agency enable to establish an efficient tool to well monitor the performance of pavement condition [33]. However, limitation on funding trigger the need to seek a more cost-effective methods of pavement maintenance optimization, [19]. Gini [13] states that a shortage of data regarding the efficacy of maintenance treatments is one the major problems in current maintenance optimization modelling. Calibration between the network and project-level performance is necessary to draw investment strategies into pavement preservation. Techniques to improve the capabilities of asset owners in managing their investment decisions in an optimal way are of increasing interest [35]. Markov chains is a good example for such model which is widely used in forecasting deterioration condition in many infrastructure assets such as pavements, bridges and buried infrastructure [1, 9, 17, 29]. The first seen of The Markov chain model was in American standard through the applications called PONTIS. Moreover is common practice in the application of bridge management system [12].

This paper propose a pavement maintenance optimization model using Markov chain theory in order to enable the road authorities to predict pavement performance.

2 Literature Review

2.1 Pavement Performance

Pavement performance is considered as a very crucial component in the design philosophy of pavement structures [14, 16, 32]. Gini [13] introduce pavement performance as tool to measure deformation of pavement condition and the functionality. Abaza [3] emphasis the important of Pavement performance in term of pavement rehabilitation and management applications. He also defined the Pavement performance as a means of performance curve that represents the trend between the pavement distress condition and service time or accumulated load applications as it shown in Fig. 1 which shows a typical pavement performance curve. Lytton [21] concluded that pavement performance can only be monitored by determine the current condition of the pavement and then use the collected data to establish management plan. Abaza [3] added the condition assessment of a pavement structure at a given period can be conducted using three famous performance measurements which are the pavement condition index (PCI), present serviceability index (PSI) and international roughness index (IRI). The PCI measure (or rating) is achieved by a visual inspection of pavement distress. Such measurement are scaled from 100 points. Where 100 is highest values representing new pavement (better) conditions [24, 32]. Abaza [3] concluded that The PCI techniques has been largely applied in pavement management applications. Where the PSI was first introduced in the AASHO Road Test for the assessment of pavement performance especially in pavement rehabilitation and management applications such as overlay design thickness and performing pavement lifecycle analysis [2, 8]. According to Fig. 2 deterioration can be quantified in distress parameter such as Present Serviceability Index (PSI). Gini [13] stated that the condition of pavement will drop due many factors such as assets aging and accumulated axle loads. The main objective is to capture the condition over the time thus the deterioration rate can be measured. therefore many maintenance or rehabilitation alternatives can be introduced to upgrade the condition parameters.

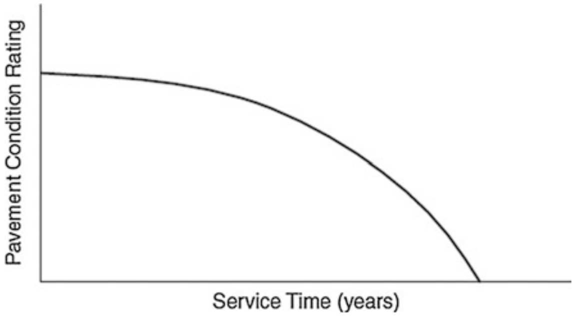

Fig. 1. Typical pavement performance curve

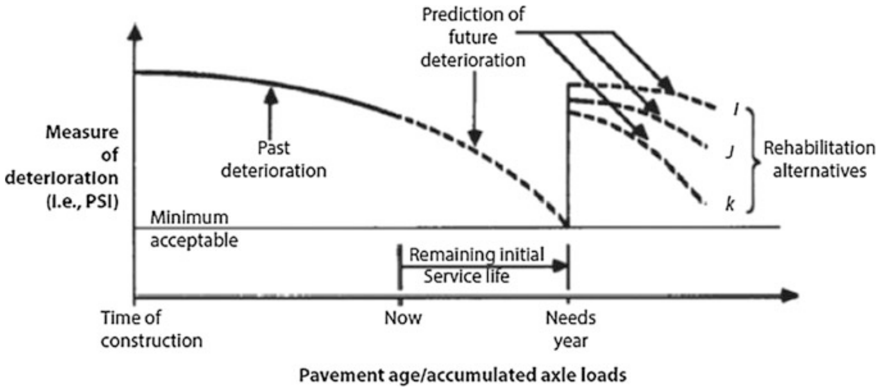

Fig. 2. The deterioration process of pavement (Haas and Hudson 2015)

2.2 Maintenance Types

Pavement condition gradually deteriorates according to its service life unless maintenance treatment is introduced. According to practice, Gini [13] stated that, in the early stages of deterioration activities, the rate deterioration is not as steep as end of the service life. For each phase there is recommended type of maintenance. Preventive maintenance is usually done in the early phase to avoid the declined pavement condition. Preventive Maintenance can also be named as time-based maintenance, used-based maintenance or periodic-based maintenance. Lee et al. [20] stated that Preventive Maintenance approach was initially based on used-based data of a physical asset only where the asset's health status is not in the concern. Abaza [3] added that

Preventive Maintenance can be in the form of crack sealing, pothole patching and localised surface treatments. On the other hand, when maintenance treatment is occurred near the end of pavement's service life, the needed maintenance effort consider to be bigger and the mean of corrective maintenance then applied. Dhillon [10] define Corrective Maintenance is an unprepared maintenance action consist of unpredictable maintenance requirements that cannot be pre-scheduled. Al-Turki et al. [5] present maintenance action the forms of repairing, salvaging, rebuilding or overhauling of equipment. Furthermore, Uday et al. [34] stated that Corrective maintenance can be either immediate or deferred. Immediate maintenance is conducted without delay (urgent) after a fault has been detected to avoid unacceptable consequence. While Deferred, maintenance is not immediately (not urgent) conducted after a fault detection, but action for repairing or fixing delayed based related maintenance rules. Plain overlay, or cold milling and overlay, or removal and replacement of existing asphalt concrete layer could be typical form of corrective maintenance (Fig. 3).

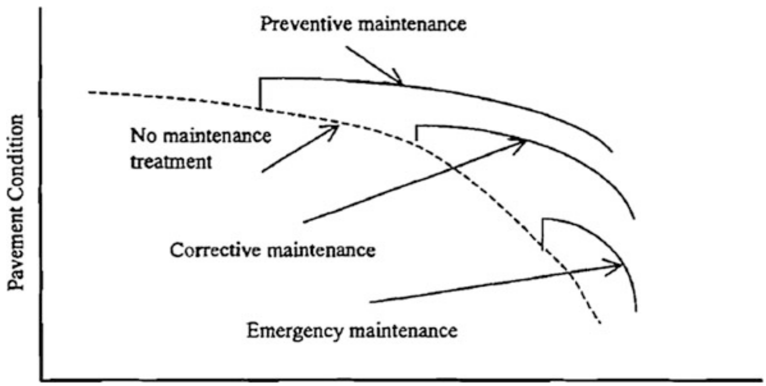

Fig. 3. Types of maintenance [23]

2.3 Prediction Mode

Prediction deterioration model is a mathematical approach that can be applied to forecast how the future pavement is going to deteriorate. Model is totally depend on the existing pavement condition, deterioration factors, and previous maintenance [26]. Gini [13] classified Prediction deterioration into two categories into deterministic model (predict as a exact value based on mathematical functions from observed deterioration) and probabilistic models (predict the pavement condition as the probability of occurrence of a range of possible outcomes) [27]. In theory, probabilistic models applied for Pavement evaluation in network-level. Where deterministic model is only appropriate tool for project-level performance. Moreover, Haas [14] stated that Markov chains are the most accurate techniques for predication models since the future state of the model element is estimated solely for the current state of the element. American standard was the first to apply Markov chain model through the application called PONTIS. Markov chain also widely used in bridge management systems [12].

2.4 Markov Chain Process

Enright and Frangopol [11] emphasized that uncertainties is a big part of prediction deterioration due to complications related with isolating individual random variable. Gini [13] stated that Markov chains has been used extensively to build pavement performance through indication a probability "before" and "after" condition of the pavement. Nevertheless Madanat et al. [22] stated that current approaches used to predict these transition probabilities from survey data (assets condition) are mostly ad hoc process. On the other hand, NAMS [25] added the Markov Chain is a sophisticated techniques to be applied in asset management systems for different type of assets such as roads, bridges and service utilities. The Markov method requires transition probability matrices (TPM) to express the transition from one pavement condition state to another. For the case of pavement, Lytton [21] defined transition probability matrices (TPM) as a collection of pavements of similar age or traffic level, or will shift from one state of distress to another within an identified time period. In order to conduct Markov chain, it is very crucial to estimate the probability of shift from one condition state to another which usually done by expert judgement or based on the analysis of available previous information. The fundamental rule in Markov chains the probability of shifting one state to another is independent of an item's earlier condition history [7, 8].

Parzen [30] expressed a discrete-time Markov technique that future process only depends on the present and not on the past. In discrete-time Markovian-based, there are several versions of model for pavement performance. Abaza [4] stated that the most popular model could be built based on either homogeneous or none-homogeneous type. For a homogeneous approach, Markov chain is build based on the assumption that steady transition probabilities occurs over time taking into consideration no change in traffic loading and progressive weakening of the pavement structural. On the other hand, the none-homogeneous Markov chain can incorporate a different set of transition probabilities for each transition (i.e. time interval) within an analysis period comprised of transitions.

2.4.1 Homogenous Discrete-Time Markov Chain

State probabilities and transition are the two major components in discrete-time Markov model. State probabilities indicates the pavement proportions that may exist in the different position of pavement condition states at any specified time interval [4]. The transition probability present the probability of pavement changing from one condition state to another during one specified period of time. The time interval is defined as a discrete time period which in practice taken every one or two years and each period represent one transition. In practice, quantifying state probabilities need one cycle of pavement distress assessment which surveyed by the road agencies. Normally, the pavement project is divided into small pavement sections to gather a better condition survey and reflect accurate present condition of the pavement. The numbers of pavement sections (Ni) assigned to various deployed condition states can then be used to estimate the state probabilities (Si) as defined in Eqs. (1) and (2).

$$S_i = \frac{N_i}{N} \quad (1)$$

$$N = \sum_{i=1}^{m} N_i \quad (2)$$

where,

S_i is the ith state probability
N_i is the number of pavement sections assigned to the ith condition state
N is the total number of pavement sections used in the study (i.e. sample size), and
m is the number of deployed pavement condition states.

In this research a homogenous Markov chain being applied which we assumed that the transition probabilities remain constant over time (steady-state condition) which results in a homogenous Markov chain. In order to forecast the state probabilities associated with the kth the use of equation below which present the discrete-time Markov model is applied. The model built on the state and transition probabilities. Theoretically, the initial (i.e. present) state probabilities and transition probabilities are known. The initial state probabilities for new pavement can be assumed to take on the values of (1, 0, 0, …, 0).

$$\begin{aligned}
&S^{(k)} = S^{(0)}P^{(k)} \\
&(k = 1, 2, \ldots\ldots, n) \\
&S^{(k)} = (S_1^{(k)}, S_2^{(k)}, S_3^{(k)}, \ldots S_m^{(k)}), \\
&S^{(0)} = (S_1^{(0)}, S_2^{(0)}, S_3^{(0)}, \ldots S_m^{(0)}), \\
&\sum_{i=1}^{m} s_i^{(k)} = 1.0,
\end{aligned}$$

where,

$S^{(k)}$: the row vector representing state probabilities after k transitions
$S^{(0)}$: the row vector representing initial state probabilities
$P^{(k)}$: the transition matrix raised to the kth power
m : the number of deployed pavement condition states
n : the number of deployed discrete-time intervals (transitions).

The transition matrix is a square matrix (m × m) comprising all estimated transition probabilities. The matrix entries (Pi, i) represent the probabilities of pavements remaining in the same condition states after the elapse of one transition or the probability of the portion of the network in the state i moving to state j in one duty cycle. There are two scenarios for transitions. First is the deterioration transition probabilities (Pi, j; j > i) indicate that the probabilities of pavements transmitting to the worse condition states after one transition. Other scenario is an improvement in the transition probabilities. The main diagonal (Pi, j; j < i) indicate the probabilities of pavements transiting to the better condition states after one transition.

$$P = \begin{matrix} p_{11} & p_{21} & . & P \\ p_{21} & p_{22} & . & p_m \\ p_{31} & \ldots & . & P_m \\ p_{41} & \ldots & . & P_m \end{matrix}$$

2.5 Pavement Condition Data

In practice, Pavement condition data can be gathered using automated or manual methods. Every agency or municipality establish their own approach on data collection methodologies, applied software programs and pavement management processes. In terms of data type, there are four general categories of pavement condition used in maintenance planning for pavement: Surface distress (Pavement Condition Index—PCI), Ride quality (International Roughness Index—IRI), Structural capacity (Falling Weight Deflectometer—FWD) and Friction (Skid resistance). For this study, Surface distress (Pavement Condition Index—PCI) is only taking into consideration. Pavement Condition Index (PCI) was first introduced US Army Corps of Engineers is a numerical index from 0 to 100 that rates the surface condition of the pavement depend on the distresses monitored from the surface of the pavement. Such data represent the structural integrity and surface operational condition [6]. The rating ranges from 0 to 100 where 100 is best condition and 0 is worst (Table 1).

Table 1. PCI rating category

Rate category	PCI range
Good	100–86
Satisfactory	85–71
Fair	70–56
Poor	55–41
Very poor	40–26
Serious	25–11
Failed	10 and below

3 Case of Study

The following section will cover a case of study for pavement prediction model using Markov chain. The data was provided from classified source. it is categorized based on PCI value for 4 states. Data are provided is already received maintenance activities. Figure 4 present Modelling Algorithm being followed.

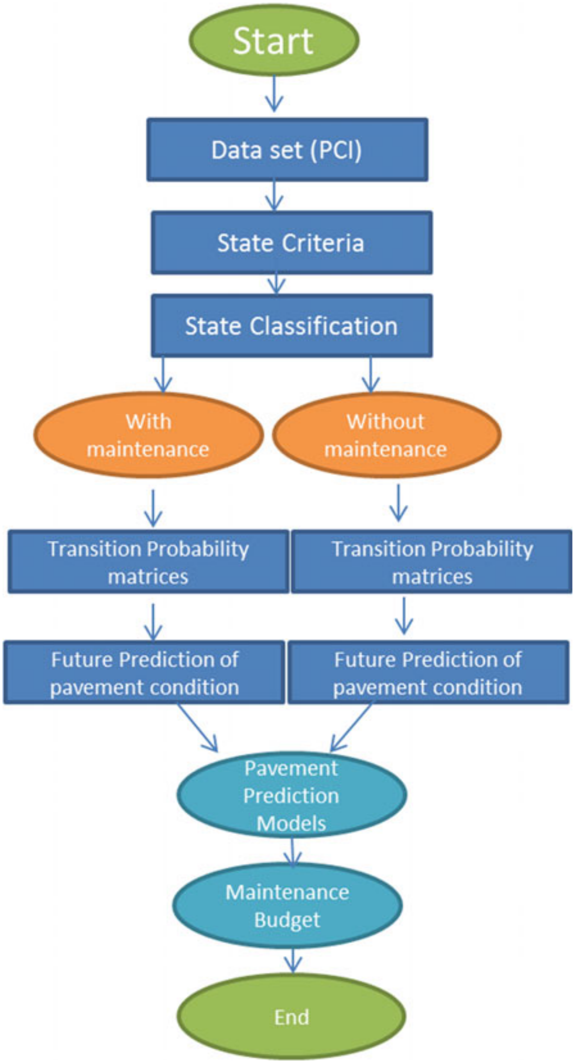

Fig. 4. Modelling algorithm

The following steps are the used methodology to compare between the pavement condition with received maintenance activities and pavement condition without received maintenance activities

A. Analysis the pavement condition index (PCI) and arrange for transition probability matrix (TPA) based on known stated and
B. Assume the starting with distribution of pavement condition at year 0 (initial condition = (1 0 0 0). The model was tested based on pavement condition with received maintenance activities and generate the result

Test the model based pavement condition without received maintenance activities generated the results

C. Define the budget of maintenance for the next 10 years.

The state classification shows the asphalt performance based on the PCI value. State 1 is the condition where asphalt was evaluated to be in the best condition (good) where state 4 indicates that the pavement is in the worst condition (poor) (Table 2).

Table 2. Classification of PCI

State	Rate category	PCI range
1	Good	100–86
2	Satisfactory	85–71
3	Fair	70–56
4	Poor	55–41

The provided data from the consultant is built with maintenance activities. The filtering process results in two set of database to build the prediction models, which are pavement network with and without maintenance based on 4 states ranging from good to poor. However, many assumptions were made to build up data without maintenance. The prediction models are based on Homogenous discrete-time Markov chain where the variables of carriageway number and traffic level remain constant every transition period. On the other hand, there is no sufficient data to fill in the transition probability matrix at least for two consecutive states for transition, then building the model become impossible. In our case 4 consecutive states were provided will lead to build Transition probability matrix (4 by 4).

3.1 Prediction Model with Maintenance Activities

See Tables 3 and 4.

Table 3. State transition for road network (KM), present, with maintenance

State	State 1	State 2	State 3	State 4	N
Good	470	98	222	328	1118
Satisfactory	87	16	54	24	181
Fair	87	14	31	13	145
Poor	51	18	23	10	102

Table 4. Transition probability matrix (TPM)

State	State 1	State 2	State 3	State 4	N
Good	0.42	0.09	0.20	0.29	1
Satisfactory	0.48	0.09	0.30	0.13	1
Fair	0.60	0.10	0.21	0.09	1
Poor	0.50	0.18	0.23	0.10	1

The model was run to simulate 10 years performance starting with distribution of pavement condition at year 0 (initial condition = (1 0 0 0).

$$P = \begin{bmatrix} 0.42 & 0.09 & 0.20 & 0.29 \\ 0.48 & 0.09 & 0.30 & 0.13 \\ 0.60 & 0.10 & 0.21 & 0.09 \\ 0.50 & 0.18 & 0.23 & 0.10 \end{bmatrix} \quad S^0 \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Table 5. Results from Markov model with data condition build with maintenance activities

Year/state	State 1	State 2	State 3	State 4
0	1	0	0	0
1	0.4204	0.0877	0.1986	0.2934
2	0.4847	0.1155	0.2182	0.1815
3	0.4810	0.1058	0.2183	0.1949
4	0.4815	0.1070	0.2177	0.1938
5	0.4814	0.1069	0.2178	0.1940
6	0.4814	0.1069	0.2178	0.1939
7	0.4814	0.1069	0.2178	0.1939
8	0.4814	0.1069	0.2178	0.1939
9	0.4814	0.1069	0.2178	0.1939
10	0.4814	0.1069	0.2178	0.1939

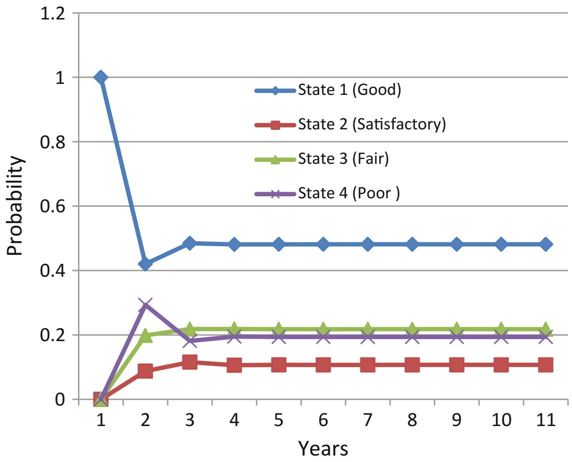

Fig. 5. Probability Graph with pavement condition (with maintenance)

The simulation results are presented in graph (Fig. 5). The graph presents the relation between the prediction year and probability of pavement condition (PCI) at known states for pavement deterioration. It starts with the initial condition S0, which represents the actual probability of state 1–4. This states indicates the condition of the pavement section is new and it is in a good state.

According to the classification State 1 represents the best condition and state 4 represent the worst condition. The first three years cannot be takin into consideration as model need more time to well define the relationship between condition states. From the graph, it can be observed that the probability of pavement sections being in the best condition (state 1) will remain constant after year 3 with probability of 50%, where other condition will act in the same approach with slightly deformation. Every year contains a small different percentage for every state which indicates the dynamic nature of the pavement condition on the network level. However, the constant trend in the lines reveals that Markov chains produce the average expected performance based on the historical observation data. And in practice maintenance activities that have been conducted by authority does impact the rate of deterioration of pavement condition (Table 5).

3.2 Prediction Model Without Maintenance Activities

Transition probability Matrices used in this experiment for data receive no maintenance is shown (Table 6):

Table 6. Transition probability matrix (TPM) data receive no maintenance

State	State 1	State 2	State 3	State 4	N
Good	0.73	0.08	0.19	0	1.00
Satisfactory	0.06	0.62	0.29	0.03	1.00
Fair	0.03	0.09	0.59	0.29	1.00
Poor	0.01	0.08	0.01	0.9	1.00

$$P = \begin{bmatrix} 0.73 & 0.08 & 0.19 & 0 \\ 0.06 & 0.62 & 0.29 & 0.03 \\ 0.03 & 0.09 & 0.59 & 0.29 \\ 0.01 & 0.08 & 0.01 & 0.90 \end{bmatrix} \quad S^0 \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Table 7. Results from Markov model with data condition build without maintenance activities

Year/state	State 1	State 2	State 3	State 4
0	1.0000	0.0000	0.0000	0.0000
1	0.7300	0.0800	0.1900	0.0000
2	0.5434	0.1251	0.2740	0.0575
3	0.4130	0.1503	0.3018	0.1350
4	0.3209	0.1642	0.3014	0.2135
5	0.2553	0.1717	0.2886	0.2845
6	0.2082	0.1756	0.2714	0.3449
7	0.1741	0.1775	0.2540	0.3943
8	0.1493	0.1784	0.2384	0.4339
9	0.1312	0.1787	0.2251	0.4650
10	0.1179	0.1788	0.2142	0.4891

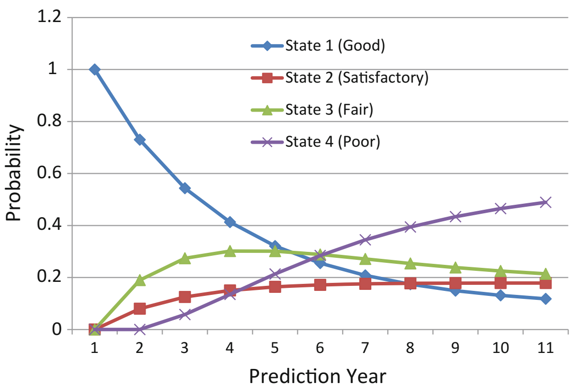

Fig. 6. Probability Graph with pavement condition (without maintenance)

For results are shown in Fig. 6, the graph presents the prediction of pavement performance without maintenance activities with the initial condition S0, which represents the actual probability of state 1 to 4 indicating the condition of the pavement section is new and in a good state (Table 7).

As shown in Fig. 6, the probability of pavement sections drop gradually from the best condition (state 1). Other condition will act in the same manner. Every year is associated with various percentage change in every state which prove the dynamic deterioration that occurs in the pavement condition at the network level. It can also be noted that the probability of state 3 and state 4 (the worse states) will keep increasing over the years. Since the information (data) used to build such forecasting model does not include maintenance activities, it is presumed that the condition of state 4 constantly increases, till the probability of state 4 is larger than state 1. It means that there is a high probability of PCI at worse condition after certain period. The probability of state 4 achieved 43%, state 1 achieve 17%, state 2 and state 3 nearly achieve 20 the end of prediction years of 10 years. For the road authorities, this will be the stage when immediate maintenance action in the form of emergency maintenance is required. The model after some time, it achieves constant level of performance as indicated by steady-state lines in the last few years Obviously the high number of pavement sections in state 4 will disrupt the overall use of the pavement network and the increase of maintenance cost will be enormous.

3.3 Budget for Maintenance Activates

Maintenance decision made by the road authorities on type of treatment for road network is not a straightforward. At the project level, there are different elements need to be takin into consideration such as cost, road type, available budget, location, … etc. Table 8 indicates some parameters for maintenance strategies by classified authority based on the PCI value (Fig. 7).

Table 8. Road network (KM), present, type and cost of maintenance with respect to road condition

State	PCI range	Maintenance type	Treatment (example)	Cost per square meter (AED)
Good	85–100	Preventive	Crack sealing	9
Satisfactory	70–85	Preventive	Crack sealing or mill, seal and overlay	50
Fair	40–70	Corrective	Mill, seal and overlay	106
Poor	Below 40	Full rehabilitation	Reconstruction	216

The assumption was made that the road network is 1000 km long with road lane width 3.65. The following table presents the budget cost based on Table 8.

Table 9. Maintenance cost based on different treatment obtained from results

Year/state	State 1	State 2	State 3	State 4	Budget
0	32,850,000	0	0	0	32,850,000
1	23,980,501	14,600,000	73,510,999	0	112,091,499
2	17,850,692	22,830,750	106,010,607	45,332,998	192,025,047
3	13,566,494	27,428,656	116,750,951	106,404,822	264,150,923
4	10,541,489	29,962,186	116,627,159	168,312,293	325,443,127
5	8,386,079	31,329,708	111,646,264	224,284,201	375,646,251
6	6,838,032	32,044,676	104,999,634	271,892,713	415,775,055
7	5,718,587	32,399,406	98,287,132	310,905,252	447,310,376
8	4,904,380	32,559,296	92,231,223	342,095,805	471,790,704
9	4,309,306	32,617,071	87,087,591	366,609,316	490,623,284
10	3,872,639	32,624,009	82,877,020	385,639,389	505,013,056

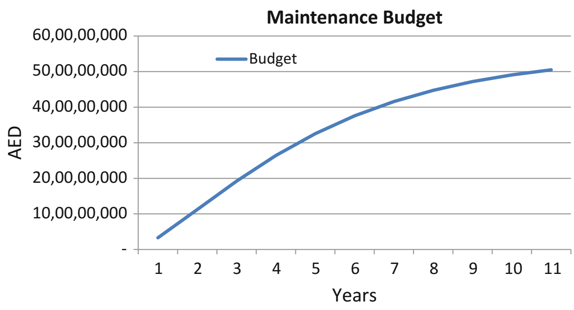

Fig. 7. Maintenance budget

It can be seen from graph that sooner the authority apply maintenance activities the less cost of maintenance expenses will be encored. It is a wise approach to always keep the pavement condition under preventive maintenance program. According to Table 8, the there is a huge cost different between preventative maintenance and full rehabilitation (Table 9).

4 Conclusion

The pavement network is very crucial assets component for government infrastructure which is considered as a backbone to economic activities. Road authorities trigger the need for pavement preservation due to the limitation of maintenance budget and to improve their maintenance optimization model. Accuracy and availability of data on the condition of assets such PCI is very important to define the current condition of the pavement network. Some road authorities suffer from weak integration of project and network-level on prediction of budget as well as measuring maintenance treatment effectiveness. Markov chain techniques has been widely used to develop pavement performance prediction models. Typically the pavement performance models show that different results for the various asphalt surface layers and categories based on the provided data. If there are no maintenance activities conduced, it is believed that Markov chains will undervalue the condition of good pavement and will overestimate the condition of worse pavement networks. It is really suggested that Markov chains performance prediction models results should be verified through interviews with expertise from the road authorities to achieve better insight into influencing elements in the real condition.

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Evaluation of Flexible Highway Embankment Under Repetitive Wheel Loading Using Finite Element Analysis

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Abstract. Within the context of this study, the deformation behaviour of multi layered highway road embankment consist of asphalt concrete supported by the underlying base and subbase layer under repetitive wheel load were analysed using finite element methodology. Plane strain finite element analyses were carried out by using Plaxis software to calculate rutting behaviour of embankment. Asphalt concrete was modelled using linear elastic model whereas hardening soil model with small-strain stiffness (HSsmall) was used to examine deformation behaviour of base, subbase and subgrade layers due to its capability to model stress dependent stiffness, unloading-reloading behaviour and hysteric damping.

Keywords: Highway embankment · Finite element · Repetitive load

1 Introduction

The history of roads as old as history of mankind. But, used materials in road construction, its design and analyses methods are evolved during history of civilization. For road design and construction, the turning point is industrial revolution and invention of motorized vehicles. After these changes, roads had to be able to withstand large loads and high speeds for the transfer of commercial goods.

Tresaguet (1716–1796), Telford (1757–1834) and Macadam (1756–1836) are first pioneers of modern highways. They establish road building and systematic maintenance on a scientific and economic basis. The theory of Macadam was that soil itself can carry any traffic load without rutting that when it is preserved in a dry state. For keeping in dry conditions, pavement surface have to sufficient slope for surface drainage, pavement foundation have to be constructed with higher level from ground surface and also sloped subgrade surface is needed [1].

Although pavement design has gradually evolved from art to science, empiricism still plays an important role even up to the present day. Prior to the early 1920s, the thickness of pavement was based purely on experience. The same thickness was used for a section of highway even though widely different soils were encountered. As

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experience was gained throughout the years, various methods were developed by different agencies for determining the thickness of pavement required [2].

Today, most common road pavements are flexible (hot mix asphalt-HMA concrete surface), rigid pavements (Portland cement concrete-PCC surface) and composite pavements; flexible HMA surface reinforced with PCC base layer.

First asphalt road was constructed in the New Jersey in USA at the end of 19th century [2]. Today, flexible pavements with HMA surface layer are the most used roads in the World. A typical flexible highway road pavement consist of HMA concrete supported by the underlying granular base and subbase layer over subgrade. Those typical pavements can be idealized as a multi layered system with different material properties and deformation behaviours.

Road pavement is under the influence of traffic loads and natural conditions. Traffic loads create radial tension and pressure stresses and also vertical pressure stresses during vehicle movements. The magnitude and extent of the stresses are directly proportional to the repetition and magnitude of the axle loads [3]. Beside the traffic loads, the behaviour of pavement is effected by many other factors like strength and deformation characteristics of material used in pavement structure and subgrade, environmental conditions such as temperature, changes in water table, freezing caused in swelling etc.

Methods of flexible pavement design can be classified into five categories: empirical method with or without a soil strength test, limiting shear failure method, limiting deflection method, regression method based on pavement performance or road test, and mechanistic–empirical method [2].

Today more design method of pavement design is empirical or semi empirical. The empirical methods developed in the 1960s by American Association for State Highway and Transportation Officials (AASHTO) have been used in the performance based design of road pavement in many country up to 2000s. National Cooperative Highway Research Program (NCHRP) 1-37A Project completed in 2004, sponsored by Federal Highway Administration (FHWA), specify the principles of the Mechanistic-Empirical Pavement Design (MEPDG).

As it is well known that granular materials and subgrade soils are behave nonlinearly, deformation modulus of soil changes with level of stresses. In addition, researchers observed during earthquakes that deformation modulus of soil in dynamic condition with small strain is much higher than modulus in conventional tests.

Today many commercial finite element (FE) analysis software is capable of computing many phenomenon's which have to be considered in flexible pavement [4], such as simulating of dynamic loading, deformation behaviour of material under different loading conditions and strain levels, different moisture contents etc.

It is demonstrated by many researchers that stress-deformation behaviour of soils under cyclic load is different from its static loading condition. Main behaviour characteristics of soil deposit under cyclic/dynamic loading are stress dependent stiffness, response to unloading-reloading and hysteric damping because of energy dissipation. Rutting is one of main problems for highway road embankments under repetitive vehicle axle load with different amplitude and frequency. On the other hand, Finite Element (FE) analyses has been used to simulate highway embankment responses under wheel load recently. In this study, deformation behaviour of flexible road pavement has been evaluated with finite element method.

2 Physical and Numerical Models

A conventional flexible highway pavement is multi layered system. Generally consist of hot mix asphalt (HMA) layer supported by the underlying unbound granular base and subbase layer (Fig. 1). The superstructure are placed on subgrade with proper strength. The base layer can be neglected in some design if subgrade have an enough strength or in condition of low volume traffic loads.

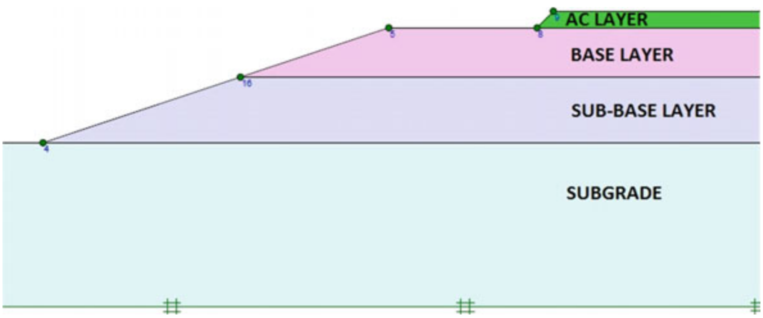

Fig. 1. Typical flexible pavement section

The main task of HMA layer is to protect the pavement from negative external factor and provide adequate comfort by providing enough friction, appropriate noise control, drainage, flexible response to traffic load etc. Base and subbase course supports HMA layer and dissipates surface load to subgrade.

In this study, section of pavement is consisted of 10 cm asphalt concrete (AC), thickness of granular base and subbase was selected as 30 and 40 cm height respectively over layered on clay subgrade with height of 10 m for finite element analyses.

The 42 m × 11 m plane-strain finite element model consisted of fifteen nodded triangular elements with total nodes of 3581 was used to analyse numerical solution (Fig. 2). Standard fixity was used for boundary condition that base of geometry fixed in each directions (Ux = 0, Uy = 0) and ruller condition for two vertical sides of geometry (Ux = 0, Uy = free).

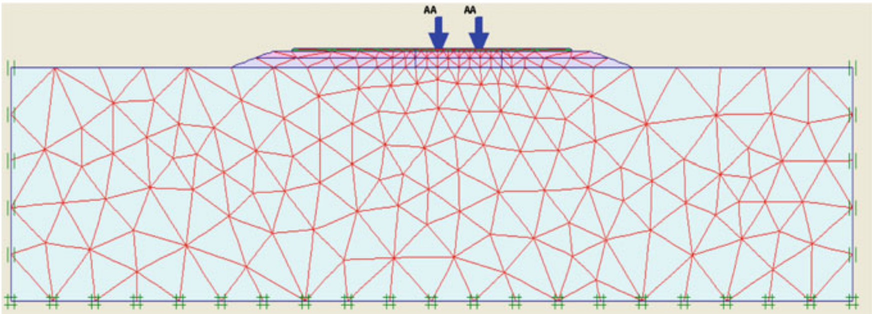

Fig. 2. General view of the finite element model

The finite element mesh is generated finer around the axel load for obtaining more accurate results. Coarse mesh used toward the edge of model and also in subgrade to reduce the calculating time.

The axle load was simulated as a pair of forces separately for each wheel assumed with 300/400/600 kPa contact pressures and a centre to centre tire spacing of 2 m as shown in Fig. 2. Contact width of each Wheel accepted as 300 mm for plane strain analysis.

For accuracy of the numerical results, the mathematical model should represent the actual loading conditions as much as possible. For specific surface load, the stress in given point depends on load position because of elasticity. Maximum stress value is obtained under load. Away from loading point, stress is reduced with distance. According to basic kinematic rules the duration of every load pulse depends on velocity of vehicle.

It is reasonable to assume the stress pulse to be a haversine or triangular loading, the duration of which depends on the vehicle speed and the depth of the point below the pavement surface [2, 5]. Simplified method is assumed that the intensity of load varies with time according to a haversine function [2], expressed in Eq. 1.

$$L(t) = q \sin^2\left(\frac{\pi}{2} + \frac{\pi t}{d}\right) \tag{1}$$

In which d is duration of load pulse depends on the vehicle speed s and tire contact radius a, expressed in the following equation:

$$d = \frac{12a}{d} \tag{2}$$

q is maximum load intensity when load is above the given point, t = 0, as shown in Fig. 3.

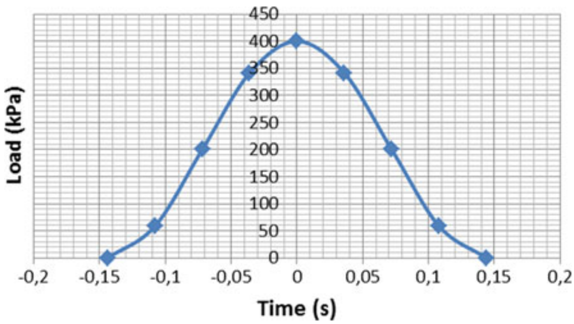

Fig. 3. Dynamic stress pulse

Figure 3 is representing stress pulse of a 400 kPa tire pressure for 300 mm tire contact radius and 0.288 s time duration, used in this study. Load applied to pavement surface with no rest time as given in Fig. 4.

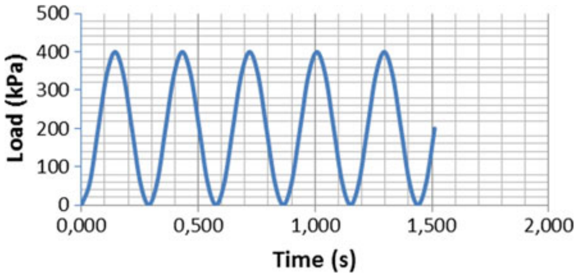

Fig. 4. Load cycle without rest time

Main behaviour characteristics of soil deposit under cyclic loading are stress dependent stiffness, response to unloading-reloading and hysteric damping because of energy dissipation. In addition, at very small strain level soil behaves purely elastic. Plastic behaviour occurs with increasing strain level. Shear deformation modulus of soil is decreased with increasing strain level.

In this study, Asphalt concrete was modelled using linear elastic model whereas hardening soil model with small-strain stiffness (HSsmall) was used to examine deformation behaviour of base, subbase and subgrade layers due to its capability to model stress dependent stiffness, unloading-reloading behaviour and hysteric damping.

In addition shear strength parameter (c, ϕ, Ψ), the basic soil parameters of HSsmall with the Mohr-Coulomb failure criterion are:

Secant stiffness modulus (E_{50}) is expressed in Eq. 3. In which E_{50}^{ref} is a reference stiffness modulus at the reference confining pressure (p_{ref}) of 100 kPa.

$$E_{50} = E_{50}^{ref}\left(\frac{c' \cos\phi' - \sigma_3' \sin\phi'}{c' \cos\phi' + p^{ref} \sin\phi'}\right)^m \tag{3}$$

Oedometric modulus (E_{oed}) expressed in Eq. 4. İn which E_{oed}^{ref} is reference oedometric modulus at the reference pressure ($p_{ref)}$ of 100 kPa,

$$E_{oed} = E_{oed}^{ref}\left(\frac{\sigma'}{p^{ref}}\right)^m \tag{4}$$

In Eqs. 3 and 4, *m* is a parameter, which simulate the stress dependency of stiffness. The parameter *m* is reported by von Soos (1990) to take values between 0.5 and 1.0. Unloading/reloading modules (E_{ur}^{ref}) can be simply taken equal to $3E_{50}^{ref}$.

Shear modulus (G_0), which can be obtained with resonant column test in laboratory or P-wave measurements and threshold shear strain ($\gamma_{0.7}$) at $0.722G_0$ were given in following equations. Those two parameter represent the small strain behaviour of soil were also used in constitutive material model.

$$G_0 = G_0^{ref}\left(\frac{c\cos\phi - \sigma_3'\sin\phi}{c\cos\phi + p^{ref}\sin\phi}\right)^m \tag{5}$$

$$\gamma_{0.7} = \frac{1}{9G_0}\left[2c'(1 + 2\cos\varphi') + \sigma_1(1 + k_0)\sin 2\varphi'\right] \tag{6}$$

In which G_0^{ref} is shear modulus at very small strain of $\varepsilon < 10^{-6}$, corresponding to the reference pressure (p^{ref}) of 100 kPa [6].

Material parameters and soil constitutive models used are shown in Table 1.

Table 1. Material parameters

Material parameters used in FE analysis material	AC	Base (crushed stone)	Sub-base (crushed stone)	Subgrade (clay)
Model	Linear elastic	HSsmall	HSsmall	HSsmall
E(MPa)	4500			
E_{50}^{ref} (MPa)		260	100	35
E_{oed}^{ref} (MPa)		235	100	35
E_{ur}^{ref} (MPa)		608	200	105
G_0^{ref} (MPa)		225	110	55
γ_0		5×10^{-6}	5×10^{-6}	4×10^{-4}
m		0.700	0.700	0.6
v		0.35	0.35	0.20
Thickness (m)	0.1	0.30	0.40	10.0
γ (kN/m^3)	24.00	21.65	21.65	18.00
C (kN/m^2)		40	35	100
ϕ (°)		40	40	10
ψ (°)		10	5	0
Kx/ky (m/day)		864	864	8.64×10^{-3}
Rayleigh α/β	0.001/0.01	0.001/0.01	0.001/0.01	0.001/0.01

3 Analysis and Results

Plane strain finite element analyses were carried out by using Plaxis software to calculate rutting behaviour of flexible highway pavement given in Fig. 5. Repetitive wheel load as defined in Fig. 3 applied pavement surface with different cycle for representing traffic load. Pavement is consisted of asphalt concrete layer supported by the underlying unbound granular base and subbase layer. This supper structure was supported by subgrade of clay with enough strength.

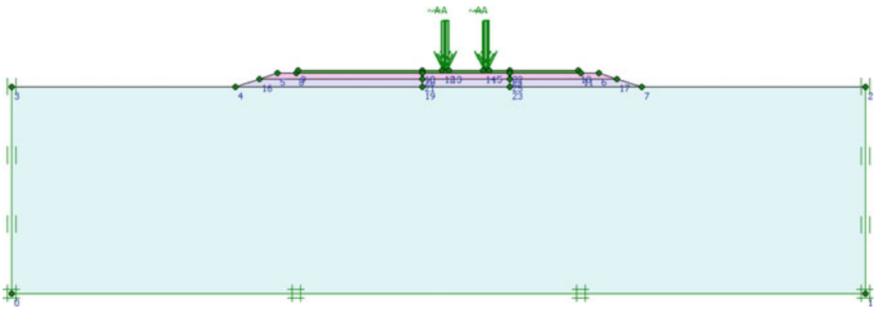

Fig. 5. Embankment model

Each stage of road construction build up in software by staged construction. Construction of subbase layer, base layer and AC layer build up in different numeric stages. Lastly, repetitive wheel loads are effected on surface of embankment with different cycles in one more stages to obtain deformation level of embankment under different load cycles. Staged construction is seen in the following Fig. 6.

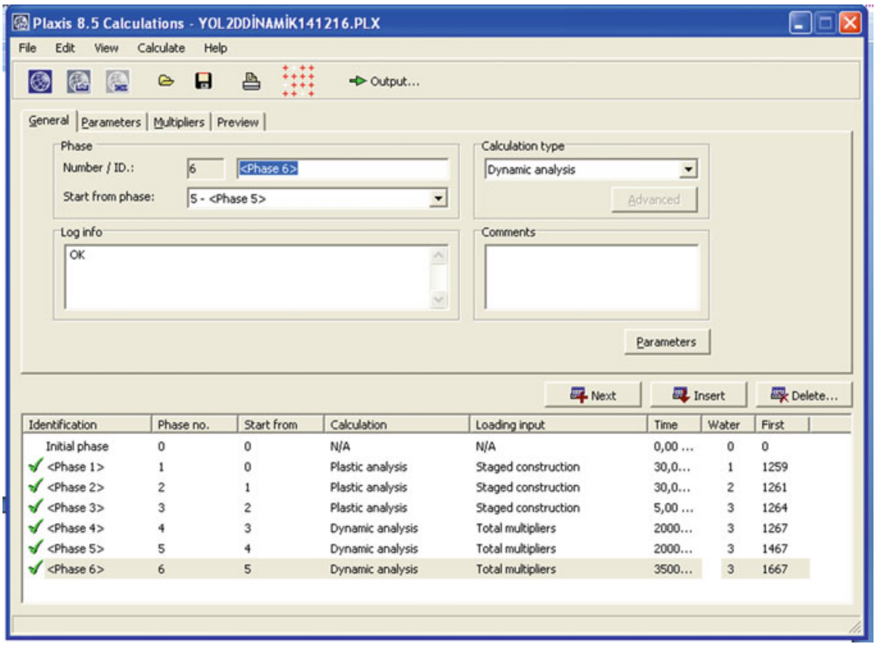

Fig. 6. Staged construction

In first dynamic stage 69.444 load pulses performed and extreme total displacement of 19 mm obtained under left side wheel at the depth of 25 cm, in middle of base layer and also maximum vertical deformation is occurred at same point. Maximum vertical deflection at the AC surface is obtained with value of 16.07 mm. Total deformed mesh, deformation contour in shading window, vertical deformation graph at the different elevation and road surface deformation given in Figs. 7, 8, 9, 10 and 11.

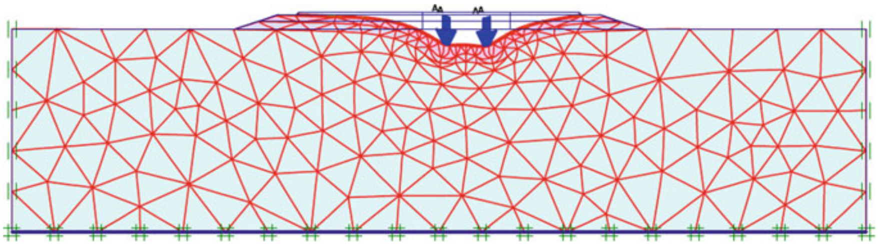

Fig. 7. Deformed mesh under 69.444 load cycles (total displacement 19.06×10^{-3} m)

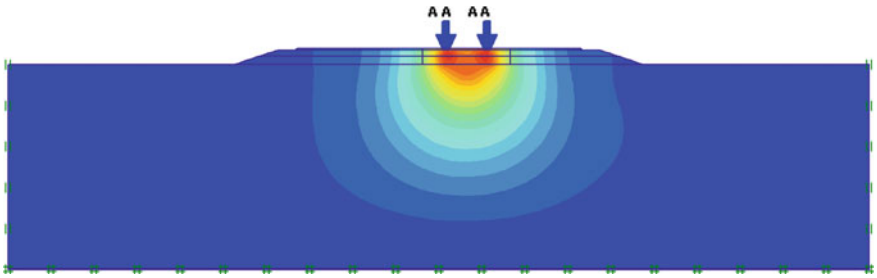

Fig. 8. Deformation contour in shading window

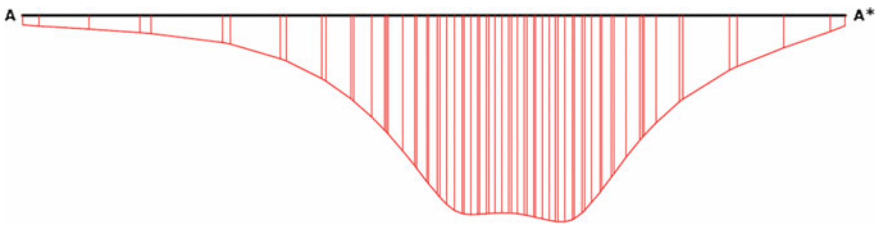

Fig. 9. AC surface deformation profile in horizontal cross-section (16.07 mm)

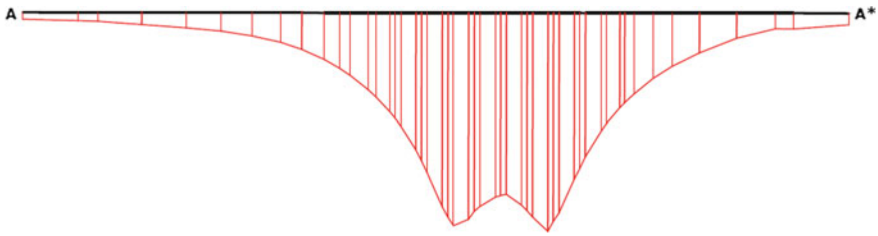

Fig. 10. Vertical deformation profile in horizontal cross-section at the middle of base layer (19.06 mm)

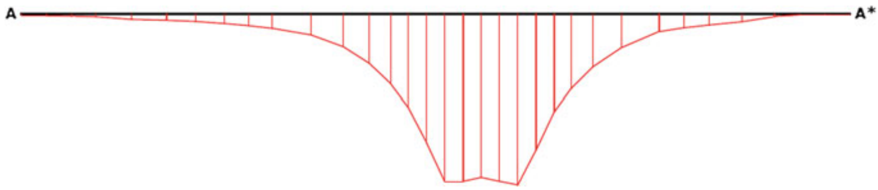

Fig. 11. Vertical deformation profile in horizontal section at the subgrade surface (17.08 mm)

After 138.888 load pulse with amplitude of 400 kPa, maximum vertical deformation occurred with value of 19.58 mm at the elevation of −31 cm, in lower half of base layer (Fig. 12). The location of maximum deformation moved down vertically and increase with percentage of 2.73 (%2.73). But, vertical deformation on AC surface decrease from 16.07 mm to value of 13 mm.

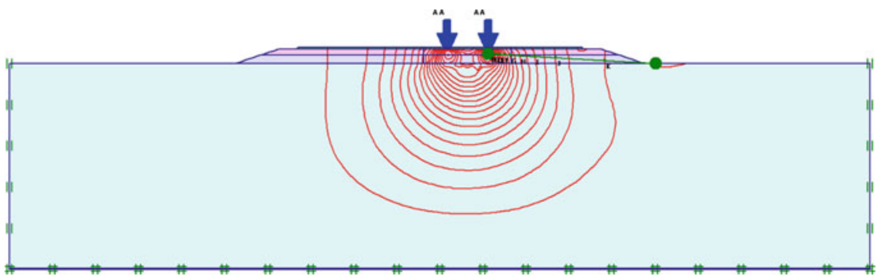

Fig. 12. Vertical deformation contour under 138.888 cycles (19.58 mm)

In Fig. 13, vertical deformation and their direction seen in arrows after 260.416 cycles. At last stage for 260.416 load cycle under 400 kPa tire pressure, maximum deformation was obtained as 26.44 mm at depth of 32 cm below surface.

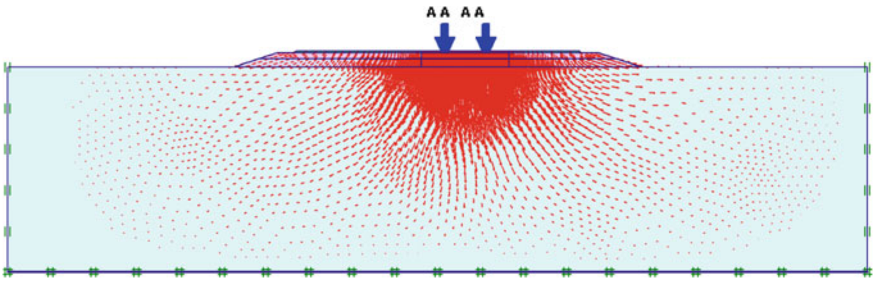

Fig. 13. Vertical deformation under 260.416 cycles (26.44 mm)

Analyses also carried out with 131.319 cycles under tire pressure of 300 and 600 kPa. Vertical deformation profile with depth for different pressure conditions is drawn in Fig. 14.

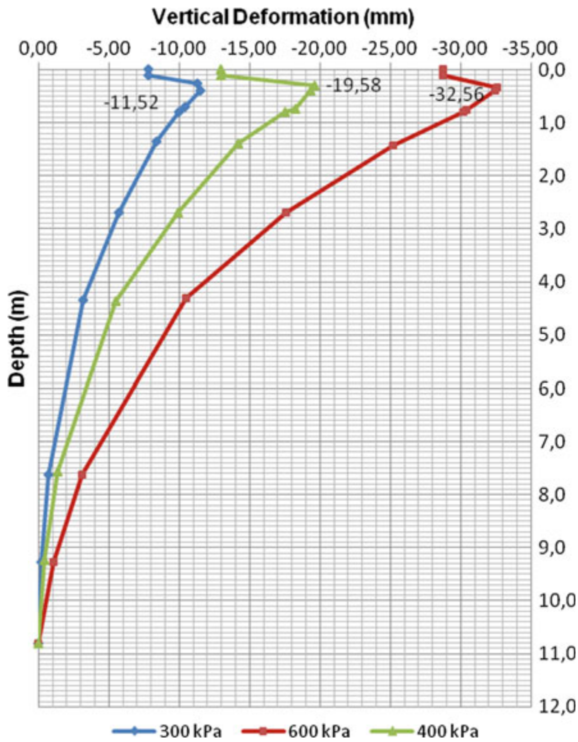

Fig. 14. Vertical deformation profile with depth (131.319 cycles)

It can be seen from Fig. 14, maximum deformation is occurred nearly in same depth in base layer. All graphs of different pressures are have a similar tendency with different values. Vertical deformation profile at the middle of base layer under different tire pressure also seen in next figure (Fig. 15).

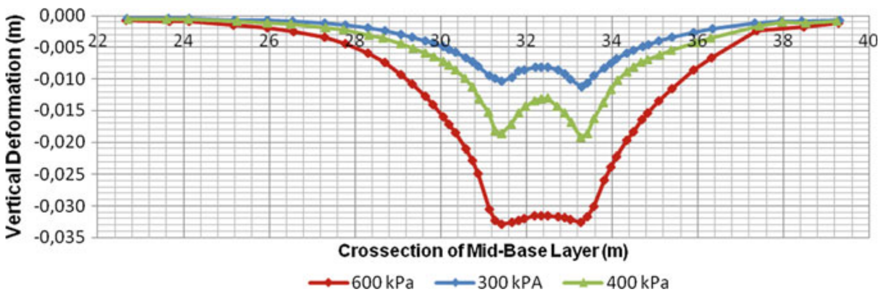

Fig. 15. Vertical deformation profile at middle of base layer under 131.319 cycles

The deformations is increasing as the load increases as expected. But shape of deformation between tires along with of the axle changing with loads. Under great pressure, its behaviour is being evolved from flexibility to rigidity at the depth.

4 Summary and Conclusions

The deformation behaviour of flexible pavement of multi-layered highway pavement consist of flexible AC surface layer, base layer and subbase layer were analysed under repetitive axle load using plain strain finite element. Tires pressures were effected to pavement surface assumed as haversine pulse load. Analysis were carried out with different load cycles under 300, 400 and 600 kPa tire pressures.

The maximum vertical deformations were obtained nearly in the middle of base layer with different values for diverse tire pressure but with similar deformation profile in vertical plane. At the same depth in horizontal plane, the deformation profile is changed from flexible behaviour to rigid behaviour with increasing tire pressure.

It is understood that, despite having some difficulty with changing material data and physical properties of pavement in site tests, using finite element analyses in road design are given some advantages like changing material data, load conditions or design criteria for each different conditions.

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Management of the Organizational and Contractual Risks of BIM Projects in the Architecture, Engineering and Construction Industry (AEC)

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Abstract. The Architecture, Engineering and Construction (AEC) industry has witnessed a revolutionary journey throughout the past few decades in the UAE and more specifically in the Emirate of Dubai, despite the numerous advancements in the tools and technologies used for designing and constructing buildings; there has always been an ambition to increase the efficiency of this process and reduce the time and resources consumed to deliver project products. One of the fastest growing technologies in the global AEC industry is the Building Information Modelling (BIM); a technique that revolves around the idea of integrating different engineering disciplines into a single unit of collaboration. As with all new technologies, there is still a large number of limitations of the BIM application that might jeopardize the benefits and opportunities of implementing it. Aiming to find BIM risks and propose mitigation strategies for them; this research paper begins by providing a brief background about the Building Information Modelling application and its significance in the design and construction processes, after that it identifies the main organizational risks associated with the BIM application, it concludes the findings from the literature review into a conceptual framework that acts as a guideline for managing the BIM organizational risks, reducing their impact and enhancing the overall BIM process, the study then uses a research tool that consists of a questionnaire examining the feedback of architects from the industry about the importance of the BIM organizational risks and their prevention strategies suggested in the research, finally the results of this survey are analyzed in the SPSS software in order to reach useful conclusions and findings.

Keywords: BIM · Building information modelling · Risk management
AEC industry

1 Introduction

The concept of BIM can be traced back to the 1960s when an American Engineer/inventor named Douglas C. Englebart described the idea of entering realistic building data such as dimensions, materials and other specifications into a software, allowing for the examination and control of the integrated model which mimics the

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completed form of the building [25]. Since then, many designations have been given to the BIM application but the most recognized one was stated by The US National Building Information Model Standard Project Committee as: "A digital representation of physical and functional characteristics of a facility" [21]. The committee also claimed that BIM is a means of collective information which creates a solid foundation for decision making throughout the facility's life-cycle. As a result of the speedy growth of the BIM process, a gap has been created between the long-time prospects and future benefits that BIM offers for the AEC industry and the risks that are imposed from its relatively new existence and the industry's reluctance to accept and endorse it. It is widely argued that the BIM process is the future of the Architecture, Engineering and Construction industry [30].

2 Literature Review

2.1 BIM Application Versus Traditional Application (CAD)

The introduction of BIM created many advantages over the typical design process of CAD (computer-aided design); the advantages that BIM offers vary throughout the different phases of a project's lifetime. According to Azhar [3], some of the main advantages that BIM has when compared to the traditional process include its integrated project documents, better model visualization, error/clash detection, and cost estimates. Jones [10] argues that the industry's BIM incorporation has reduced risks in construction projects as well as decreasing overall project budgets; it has also minimized information requests and variation orders and led to improved decision-making.

2.2 Types of Risks of BIM Projects in the AEC Industry

Introducing new technologies always brings a number of risks and uncertainties with it, so is the case of the evolving BIM application; according to Abdelhady [1], the challenges associated with BIM can be grouped within each of the three BIM domains shown in Fig. 1: (non-technical risks; the main focus of this research) includes two types (policy domain risks), which contains all issues between the stakeholders in a BIM project and their contractual arrangements and liabilities and (process domain risks) consisting of risks within the management of the BIM execution process in a company, the ownership of BIM documents amongst stakeholders and BIM knowledge management. The other type is technical risks (technology domain risks) which are linked to the software aspects such as file sizes, software developments and network systems.

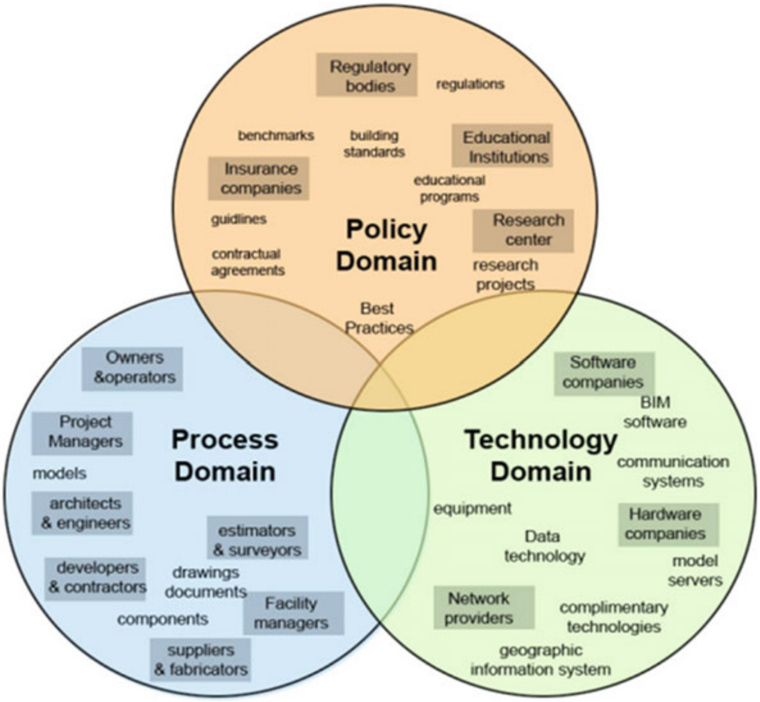

Fig. 1. The three domains of building information modelling (BIM). *Source* Abdelhady [1]

2.3 Main Organizational Risks of BIM

As mentioned earlier, the core focus of this research is on the process/organizational risks of the BIM application. Jung and Joo [11] state that the managerial challenges in construction information systems such as BIM have a greater impact than the technological ones, they also claim that the organizational benefits achieved from BIM when it comes to re-constructing or innovating the business operation must be measured and explained. It has been discussed that the risks of BIM vary based on the size of the firm [10]. Succar et al. [29] argue that the framework for achieving competency in the BIM process is split into four parts as in Fig. 2: ***Resources*** (human and physical), ***Activities***, ***Products*** and ***Leadership/management***.

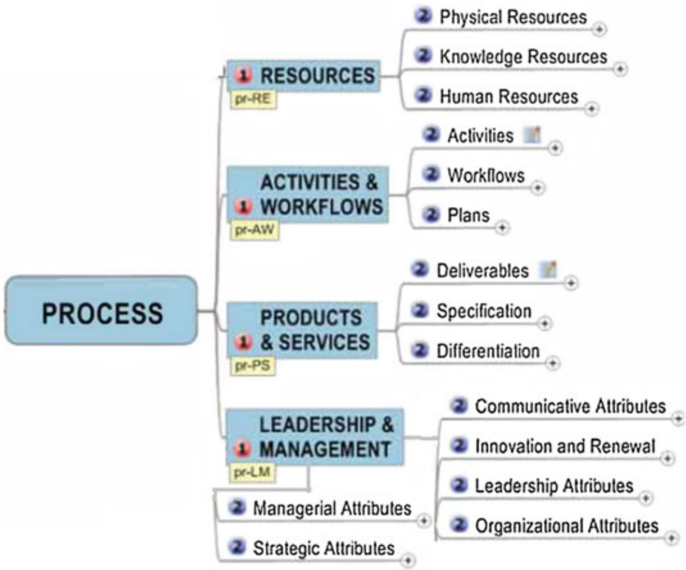

Fig. 2. The framework for achieving competency in BIM. *Source* Succar et al. [29]

Table 1 lists a total of 30 organizational risks of BIM according to the literature review and the authors' citations.

Table 1. Organizational risks of BIM

	Risk factor	Type	Citations
1	Fear of low success/high failure due to team's lack of experience in BIM	Human resources	Azhar et al. [5], Eadie et al. [7], Ku and Taiebat [15], Mayo et al. [19], Migilinskas et al. [20] and Zahrizan et al. [33]
2	Interoperability between BIM programs and loss of valuable data	Informational resources	Azhar et al. [5], Goucher and Thurairajah [9], Ku and Taiebat [15], Olatunji [23], Stanley and Thurnell [28] and Volk et al. [31]
3	Uncertain ownership of BIM model	Contractual	Azhar et al. [5], Khosrowshahi and Arayici [14], Leeuwis et al. [17], Porwal and Hewage [24], Sebastian [26] and Volk et al. [31]

(*continued*)

Table 1. (*continued*)

	Risk factor	Type	Citations
4	The significance of the training and recruiting costs in the BIM process	Human and physical resources	Arayici et al. [2], Azhar et al. [4], Crotty [6], Eadie et al. [7] and Stanley and Thurnell [28]
5	Lack of collaboration of stakeholders	Contractual	Azhar et al. [5], Ku and Taiebat [15], Migilinskas et al. [20] and Volk et al. [31]
6	Absence of higher management support and an organizational culture that supports BIM implementation	Managerial	Migilinskas et al. [20], Porwal and Hewage [24], Sebastian [26] and Volk et al. [31]
7	Resistance to change at cultural and operational levels and difficulty of adapting to a new system	Managerial	Eadie et al. [7], Khosrowshahi and Arayici [14], Smith [27], Migilinskas et al. [20] and Stanley and Thurnell [28]
8	Lack of contractual agreements and legal instruments for BIM	Contractual	Azhar et al. [5], Ku and Taiebat [15], Volk et al. [31] and Porwal and Hewage [24]
9	High overall initial investment costs in BIM	Physical resources	Azhar et al. [5], Eadie et al. [7], Ku and Taiebat [15] and Migilinskas et al. [20]
10	The organization as a whole lacks experience in dealing with the BIM system	Managerial	Eadie et al. [7], Ku and Taiebat [15], Kashiwagi et al. [12], Khosrowshahi and Arayici [14] and Mayo et al. [19]
11	BIM's collaborative approach increases risk sharing between stakeholders and reduces definition of clear liabilities	Contractual	Arayici et al. [2], Khosrowshahi and Arayici [14], Le Masurier [16] and Sebastian [26]
12	Time spent to learn using BIM	Physical resources	Migilinskas et al. [20] and Stanley and Thurnell [28]
13	Lack of client demand in certain industries	Strategic	Eadie et al. [7], Khosrowshahi and Arayici [14] and Zahrizan et al. [33]
14	Unawareness about BIM and its major enhancements to the project delivery process	Strategic	Khosrowshahi and Arayici [14], Newton and Chileshe [22] and Zahrizan et al. [33]
15	The fragmented nature of the construction industry (lack of high-level collaboration, integration of database and commitment to incorporate BIM)	Strategic	Masterspec [18] and Stanley and Thurnell [28]
16	Lack of electronic BIM standards for coding objects and methods of measurement	Strategic	Masterspec [18] and Stanley and Thurnell [28]

(*continued*)

Table 1. (*continued*)

	Risk factor	Type	Citations
17	Unawareness of the strict standards for BIM implementation	Managerial	Migilinskas et al. [20]
18	Unawareness of the contractual implications of BIM implementation	Contractual	Migilinskas et al. [20]
19	Need for numerous new software licenses with different languages	Product specifications and physical resources	Jones [10] and Khosrowshahi and Arayici [14]
20	Long project lifetimes cannot keep up with rapid BIM technological change	Innovation and renewal	Volk et al. [31]
21	Discrepancy in legal BIM frameworks between different countries	Strategic	Volk et al. [31]
22	Lack of distribution of operational/developmental costs of BIM between industry stakeholders	Contractual	Azhar et al. [5]
23	BIM's collaborative approach makes project participants assume accurate input from others	Human resources	Porwal and Hewage [24]
24	BIM's added dimensions (cost and scheduling) creates difficulty in unifying the software and analysis platforms between stakeholders	Product specifications	Azhar [3]
25	The need for sophisticated equipment and programming services requires radical changes in the organization's working system	Product specifications	Arayici et al. [2]
26	BIM specialist usually require higher salaries than traditional CAD designers	Human and Physical resources	Arayici et al. [2]
27	Gap in staff skills in cost estimating and 4D modelling which both have great value to project and organization	Human resources	Wei and Raja [32]
28	Difficulty of BIM adoption in small firms due to investment costs	Managerial	Newton and Chileshe [22] and Zahrizan et al. [33]

(*continued*)

Table 1. (*continued*)

	Risk factor	Type	Citations
29	Reluctance of team members to share information and communicate effectively	Human resources	Eadie et al. [7]
30	The use of different BIM models between engineers lacks integration and reduces modelling efficiency	Managerial	Stanley and Thurnell [28]

2.4 Prevention/Mitigation Strategies of BIM Risks

According to the literature that has been examined, the mitigation strategies of the organizational risks of BIM come at four levels (Strategic/Market, Contractual/Stakeholder, Organization and Project Team). Some of the strategies mentioned for those levels include:

Strategic/Market Level: The first step in efficient BIM implementation is the involvement of the external drivers such as governmental and public authorities as well as the formation of international committees concerned with the BIM execution process.

Zahrizan et al. [33] describes the push-and-pull elements of implementing BIM where governments act as the main pushing component towards increasing the use of BIM by mandating it and giving additional support to the private sector, on the other hand the goal of having an efficient industry is what's pulling the BIM incorporation due to the major benefits of BIM to the industry as whole.

A survey created in 2012 in the UK showed that the majority of construction companies were abiding by the governmental deadlines set to implement BIM [7]. According to Smith [27], one of the governmental initiatives to increase the adoption of BIM in Australia was the creation of the 'National BIM Guide' and the 'National Guidelines for Digital Modelling' by several governmental agencies. Zahrizan et al. [33] emphasize the role of the government in Singapore to incorporate BIM training as part of the curriculum in several educational foundations; they also highlighted the government's approach to assist organizations that are implementing their first BIM project.

Another proposed strategy used by the BCA government in Singapore is the dedication of a special fund that assists in the BIM training costs as well as the costs of purchasing and implementing the required hardware/software. One of the other possible solutions that can be used are the Noteworthy BIM Publications (NBP)s that control BIM execution and gather significant BIM information and expertise [13].

The production of Noteworthy BIM Publications (NBP)s is another solution to improve the information management of BIM, NBPs are derived from the combination of the BIM fields (technology, process, policy) and the BIM lenses (conceptual attributes, geographic scoping, multi-disciplinary knowledge management); they include cumulative BIM knowledge, they are delivered by the BIM players (organizations fully involved with BIM) and they are classified based on the country and its maturity level in BIM.

Contractual/Stakeholder Level: Porwal and Hewage [24] claim that one of the most effective methods of solving the contractual and legal issues of BIM implementation is using the BIM partnering procurement contract; this framework enhances BIM model collaboration, increases the staff's capacity to adapt to the new process and maintained better client participation as well as alignment with governmental standards. With regard to the uncertainty of the BIM model ownership between project parties, Porwal and Hewage suggest investing in the creation and improvement of legal procedures that are specifically concerned with maintaining informational security. Arayici et al. [2] and Zahrizan et al. [33] state that the awareness level of the new roles of stakeholders in BIM must be raised.

Organization Level: Zahrizan et al. [33] suggest that organizations must alter the way they use information and transform their managerial structure to incorporate the new positions in the BIM application and their abilities and expertise. They also claim that companies must adopt incentives and motivational strategies as well as continuous support for their employees in order to make the implementation process faster and reduce the staff's reluctance to adopt the new system. Some of the other proposed strategies within the organization include the creation of detailed project lifecycle cost analyses to encourage clients to use BIM by showing them BIM's long-term benefits, forming positive thoughts about BIM inside the company, dedicate profits for BIM implementation budgets and focus on thorough selection of BIM team members especially high-level positions (BIM managers and coordinators)

On the other hand, companies must create alternative scenarios in the case of lost data due to operability issues, many attempts have been made to overcome the difficulty in transferring information; Porwal and Hewage [24] suggest that the Industry Foundation Classes (IFC) data exchange method can solve many of these challenges, on the other hand, they argue that the IFC method can mostly handle with the preliminary design stages and needs further development for the final and more detailed stages.

Project Team Level: Eastman et al. [8] and Zahrizan et al. [33] emphasize the role of increasing open communication and knowledge sharing between team members to not only reduce the risks of losing important data but minimize the training and recruiting time and costs for the organization as well. The input and role of each team member in the central BIM model must be controlled accurately to avoid liability issues; project managers must also increase the coordination meetings to ensure

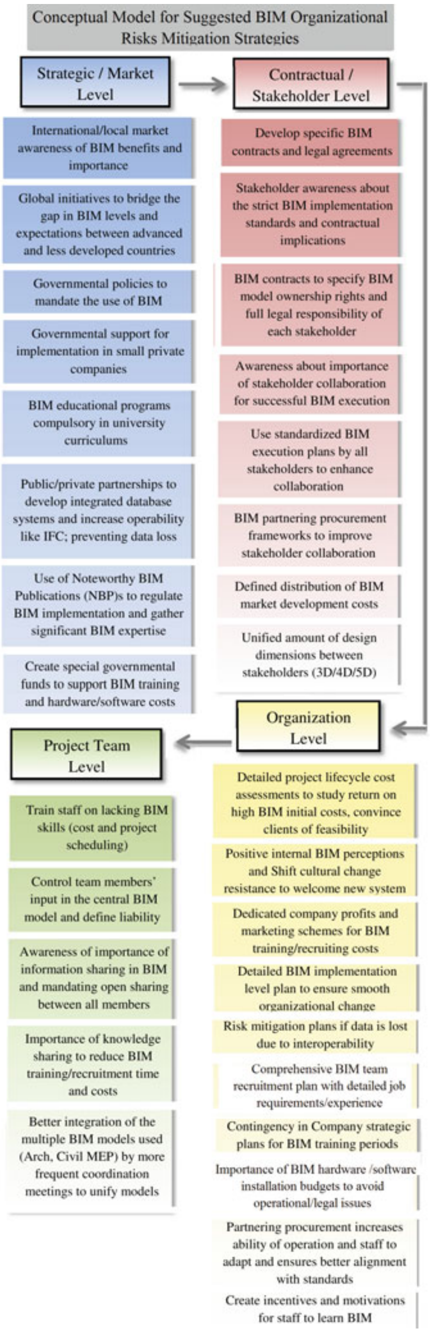

Fig. 3. Conceptual model for suggested BIM organizational risks mitigation strategies. *Source* Researcher

integration of the different BIM models between departments due to the criticality of the information in each one.

Companies must invest in improving its employees in the added BIM design dimensions (project scheduling and cost estimating) as their benefits are very important to the project. According to Khosrowshahi and Arayici [14], a survey was conducted in contracting firms in the UK to study the employees' feedback on how to encourage them to use BIM, some of the responses included attending workshops to follow BIM progress and advise on software/hardware tools, more company involvement in BIM projects and the integration of databases between project participants.

2.5 Conceptual Model

After the theoretical review of the literature concerning the BIM application, its major operational risks and their respective mitigation strategies at the strategic, contractual, organizational and project team levels, the conceptual framework in Fig. 3 represents a guideline for managing those organizational risks of BIM.

3 Quantitative Analysis

This section uses the theoretical data found in the literature in a measurable tool (survey) and then examines the results of this survey to reach certain conclusions.

3.1 Research Methodology

The analysis process begins by grouping the risk factors and prevention strategies based on their types mentioned earlier, then a questionnaire is sent to construction professionals to study their feedback on the importance of the BIM operational challenges as opposed to their suggested ranking in the literature review (based on their citation), the survey also examines the respondents' perceptions of the proposed mitigation strategies in the conceptual framework, the dependent and independent variables are identified and a software analysis of the results is conducted using the Statistical Package for Social Sciences (SPSS) where first, the reliability of the surveyed factors is tested using the values of Cronbach Alpha, then the interrelatedness of the factors is examined using factor analysis and correlation and finally, the proposed significance of the factors is questioned using regression.

3.2 Statistical Instrument: Survey

Targeted Survey Sample: For the goal of having representable and accurate data; the chosen sample frame for the questionnaire included any architect or engineer who has been exposed to BIM by some means; either by experience in official BIM projects or at least a basic background about BIM and its applications. The sampling method is "Random Sampling" which means that respondents were selected randomly from the larger sample frame. The survey was sent using two methods: paper-based (distributed to employees of different companies) and online (sent to candidates using social media posts/messages and phone messages), the respondents were assured full confidentiality and assistance was given when any of the factors were unclear, finally the response rate reached approximately 60–65%. The achieved sample size was 21 people where 3 responses were incomplete and the majority of the respondents were reached online, there were two reasons behind not achieving a considerable sample size: first because most of the small firms that were visited do not use the BIM system and second because of the difficulty of entering into larger firms and the missing cooperation from managements due to the need to occupy the time of their employees.

Structure of Survey and Scale of Data: The original wording of the BIM risks from the literature was simplified and shortened in the survey and technical terms were omitted; the survey starts by introducing the BIM technology and stating that it usually faces challenges when implemented in construction companies, then two main questions are presented: Part one; studies the level of respondent agreement on the importance of the BIM organizational challenges on an Ordinal Scale of 1–5 (Strongly disagree, Disagree, Neutral, Agree and Strongly agree), Part two; examines the rate of agreement of the respondents about the proposed mitigation strategies in the conceptual framework with the same scale in part one.

Dependent and Independent Variables: The dependent variable being examined is the assumed significance of the BIM organizational risks and their prevention methods suggested; this variable is categorical (established significance value (1–5) from literature citation) and it is dependent on the feedback of the respondents (the independent variable) which is also categorical (strongly disagree to strongly agree).

3.3 Key Outcomes of Survey

The main findings of the survey show the importance of the BIM risks and their mitigation strategies in Figs. 4 and 5.

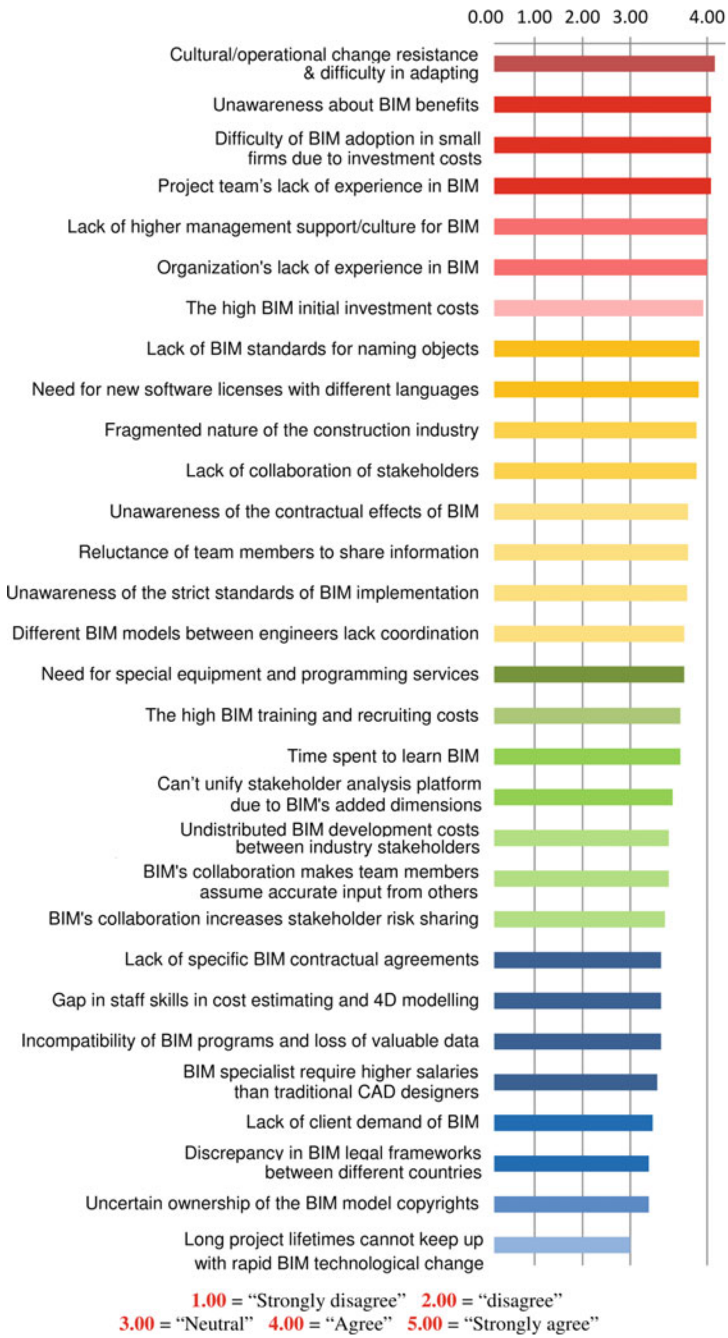

Fig. 4. Survey results of BIM organizational risks' significance. *Source* Researcher

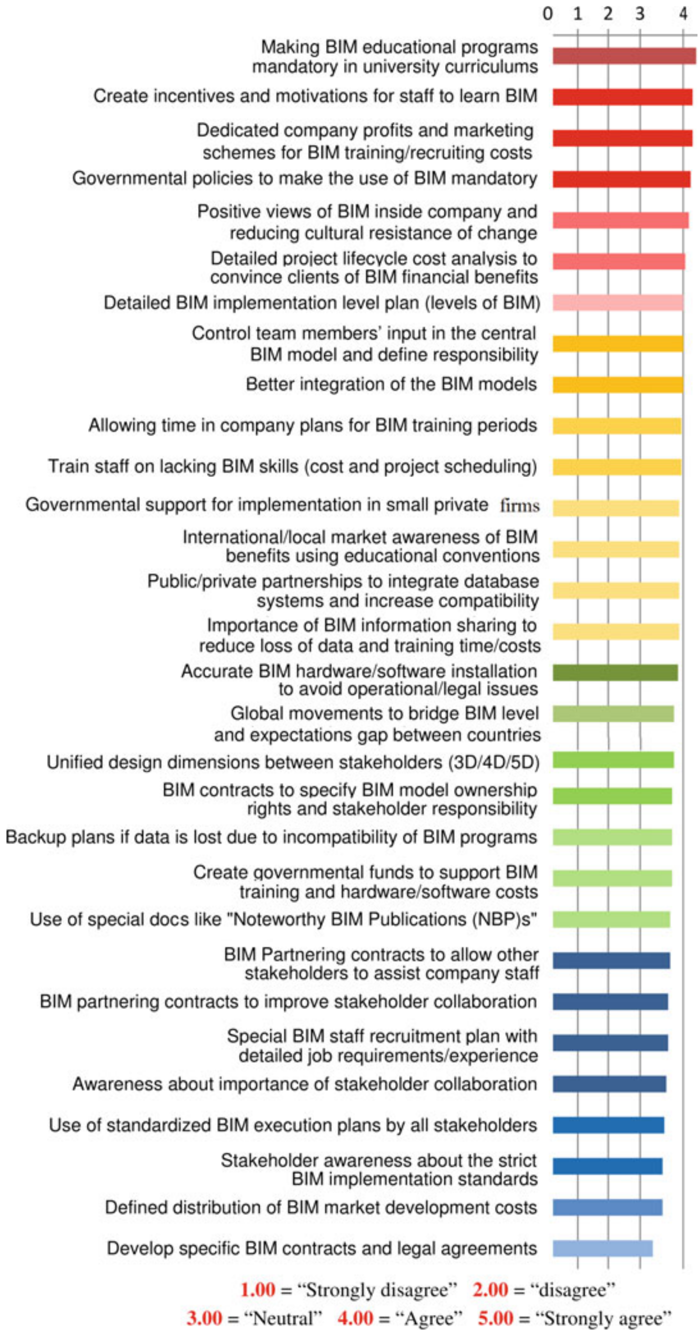

Fig. 5. Survey results of BIM organizational risk mitigation strategy significance. *Source* Researcher

3.4 SPSS Analysis of Survey

The previous findings of the survey were analyzed using the SPSS software, after finding the means and standard deviations of the risk factors; the reliability and correlation of the BIM risk factors are examined, then regression test is conducted based on the guidelines in the course slides (when examining risk factors and both dependent and independent variables are categorical (ordinal); a regression test is valid for analysis).

Standard Deviation: This type of test examines how closely related the survey questions (factors) are to one another. First, the different variables were added in SPSS where respondents were the first type of variable (to enter different respondent answers) and the BIM risk factors (survey weights) were the second type of variable with an ordinal (categorical) scale of 1–5, the factors were labelled with their original numbering (1.1, 2.2, … etc.) with the addition of a letter in the beginning to identify their types (S = Strategic, C = Contractual, M = Managerial, R = Resources) and because SPSS requires an alphabetical letter to start with. After defining the variables, the risk survey weights were added in the data view based on the 18 different respondents' answers (complete results).

Table 2 shows that the average variance between factor weights is 1.025 which is equal to 20.5% (scale 1–5). The average overall mean of the factor weights is 3.717 (range from 3.17 to 4.22), the factor with the lowest weight mean (3.17) and highest standard deviation (1.38) from the overall mean is 1.6 "*Long project lifetime*." while the factor with the highest weight mean (4.22) is 1.2 "*Unawareness about BIM Benefits*", finally the factor closest to the overall mean (with 0.71 deviation) is 2.5 "*Unawareness of the BIM Contractual effects*".

Table 2. Summary of survey means and variances

Summary item statistics							
	Mean	Minimum	Maximum	Range	Minimum/Maximum	Variance	No. of items
Item means	3.717	3.167	4.222	1.056	1.333	0.067	30
Item variances	1.025	0.500	1.912	1.412	3.824	0.118	30

Reliability Test: The reliability of the risk factors is examined using the values of the "Cronbach's Alpha if item deleted", which indicates the internal consistency between the items, according to the course slides a Cronbach's alpha value greater than 0.7 means that the item is highly reliable. Fortunately, all of the surveyed factors had a Cronbach's alpha higher than 0.7 which indicates their consistency and reliability; therefore no factors were eliminated.

Factor Analysis: This test aims at reducing the different variables that were studied (respondent feedback) as well as proving or rejecting any previous hypotheses that categorized or grouped the variables. The test uses the Rotated Component Matrix for the risk factors where 5 components were extracted (out of 18 results), then risk factors were grouped based on common component values (greater than 0.5), these values indicate the interrelatedness between the BIM risks and their significance (high component values), 4.2 "*BIM's collaboration makes project members assume accurate input from others*" has the highest rotated component (0.942) while 4.4 "*Reluctance of team members to share information*" has the lowest (0.425).

The matrix grouping of the risk factors shows that component-1 mainly included high-level risks (market/stakeholder level) as well as a few resource risks, the second group was mainly associated with organization and project team risks, the third included issues of BIM unawareness and team member attitudes, the fourth group consisted of 4 components each representing one of the four levels of the mitigation strategies and finally, the fifth component matrix group incorporated most technical/software risks.

Correlation Test: The goal of this test is to detect factor correlations (inner relationships); it begins by identifying all the bivariate (two-way) relationships between factors with a "Sig. (2-tailed)" value between 0.01 (99%) and 0.05 (95%), then it eliminates repeated relationships and finally, it finds more significant correlations by only highlighting (yellow) Sig. (2-tailed) values of smaller than 0.025. The findings of this analysis show that the lack of client demand of BIM increases risk sharing between stakeholders; they also demonstrate that the absence of specific BIM contracts is affected by the fragmented nature of the construction industry as well as the high initial investment costs of BIM. Another observation shows that the unawareness of the contractual implications of BIM is caused by organizations' lack of BIM experience.

The correlation test indicates that the difficulty in unifying analysis platforms between stakeholders is caused by the undistributed costs of developing the BIM technology. The test also shows a relationship between the strict BIM implementation standards and its adoption in small companies. Another suggested outcome is the lack of coordination between project team members that use BIM is because of their missing experience in the new system.

The outcomes of the test also suggest that the absence of higher management support of BIM adoption and the gaps in staff skills in the new BIM dimensions are concurrent with the high training/recruiting costs of BIM. Finally, it is argued that the incompatibility of the BIM programs might have an effect on team communication and information sharing as well as stakeholder risk sharing due to loss of valuable project data.

Ordinal Regression: This analysis was generated in order to examine the relationship between the suggested significance of the BIM organizational risks based on their literature citation and the established importance of these risks through the feedback of the respondents in the questionnaire. The proposed scale of the risks from research citation is an ordinal measurement (1–2 citations = less significant, 3–4 citations = significant, 5–6 citations = more significant) while the scale of the survey factor significance was based on the average weight of the respondent agreement (average weights ranged from 3 to 4.10 out of 5 which was converted to three categories similar to the first scale; 3.00–3.35 = less significant, 3.40–3.70 = significant, 3.75–4.10 = more significant) (Fig. 6). The resulting data view of the analysis is shown in Fig. 7.

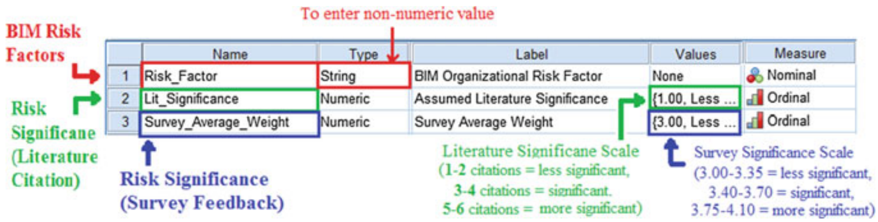

Fig. 6. Variable view of regression analysis *Source* Researcher

	Risk_Factor	Literature Significance	Survey_Average_Weight
1	S_1.1	3.00	3.29
2	S_1.2	3.00	4.05
7	C_2.1	6.00	3.24
8	C_2.2	4.00	3.86
14	M_3.1	4.00	4.00
15	M_3.2	5.00	4.10
20	R_4.1	6.00	4.05
21	R_4.2	1.00	3.50

Fig. 7. Data view of regression analysis *Source* Researcher

The null hypothesis in the regression test indicates that the risk factor significance of both the literature citations and the survey feedbacks are consistent and that the slope coefficients in the model are the same across both variables. In order to prove or reject the null hypothesis, we must look at the chi-square significance value of the regression analysis (if chi-square significance is greater than 0.05 then the null hypothesis is valid). The chi-square sig. value in both the Goodness-of-Fit test and the Test of Parallel Lines is greater than 0.05, this means that we can approve the suggested null hypothesis and therefore the significance of the BIM risk factors is consistent with the achieved significance from the survey results.

4 Conclusion

In reviewing what has been discussed in this paper, the main aim of the study was to present the subject of the Building Information Modelling (BIM) technology and its primary improvements to the project delivery process in the AEC industry. It investigated the major organizational challenges in the BIM implementation process such as risks of international strategies concerning the execution of BIM, liability and stakeholder risks, process, culture and change, system specifications impacting organizational processes and finally human, physical and informational resources involved in the BIM process. After that, the operational risks of BIM were summarized and ordered based on their citation by different researchers, then a conceptual model on how to prevent those risks was given on four levels: strategic, market/stakeholder, organizational and project team levels. The framework incorporated risk mitigation strategies that were suggested by authors or implemented in different locations, some of those strategies included increasing global awareness of the benefits of BIM, public/private partnerships, creating more BIM specific contracts and execution plans to reduce model ownership issues, detailed project lifecycle cost assessments of BIM projects and staff training on added BIM aspects (cost and project scheduling).

The final part of this paper was a quantitative analysis of the findings in the literature where the feedbacks of industry professional on the proposed risks and their prevention approaches were examined. The top 3 important risks of BIM according to the survey were "Cultural change resistance", "Unawareness of BIM benefits" and "Difficulty of BIM adoption in small firms due to investment costs" while the top 3 important mitigation strategies were "Mandating BIM programs in university curriculums", "Create incentives for staff to learn BIM" and "Dedicating company profits and marketing schemes for BIM training/recruiting costs".

The survey results were furthered studied by examining the standard deviation and reliability to determine the internal consistency of the results, no factors were eliminated as a result of the reliability test and then a factor analysis was conducted to find internal relationships between the factors where the grouping was similar to the initial grouping of the risks (Strategic, Contractual, Managerial, Resources). After that a correlation test helped further in finding other internal relations and finally regression analysis was used by studying the significance of the risks in the survey against their theoretical significance from the literature, the results approve the null hypothesis that suggest the consistency of the survey results with the literature review.

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Sustainable Urban Regeneration Strategies for Deteriorated Neighborhoods Centers in UAE

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Abstract. Neighborhoods centers are credible indicators of the vitality of urban communities. A vivid neighborhood center depicts a sustainable community that enjoys high social capital, social cohesion and economic thriving. United Arab Emirates has been concerned with achieving sustainability in its urban housing sector. The initiated *Estidama* (sustainability) Community Pearl Rating System is an obvious example towards this trend. Some new *Estidama*-rated community designs have been developed recently and some are under construction now. But on the other hand, unfortunately many existing local urban communities are claimed to be far from being sustainable. Many of these existing UAE neighborhoods have deteriorated centers where the retail shops are either closed or have a limited economic activity, green areas and children playgrounds are quite rare and so on. This status, of course, hinders realizing the very meaning of sustainable communities. This research has two main objectives. First, is investigating the reasons behind the obvious deterioration of the neighborhoods centers in Al Ain city as an example of the Emirati cities. Second, is proposing strategies for urban regeneration of Al Ain neighborhoods centers, which of course can be extended to all other UAE cities. This research adopts a qualitative/quantitative method suitable for the nature of investigations required to realize the research objectives. Al Salamat neighborhood in Al Ain city was selected as a representative case study and has been investigated utilizing various relevant research tools including field observations, document analysis and the DepthmapX spatial analysis tool of Space Syntax. The defined reasons of the deterioration of the urban neighborhoods centers of the investigated case study have been subsumed under four categories namely; neighborhood density, urban/architectural context, accessibility, safety and security. Accordingly, a strategic framework for urban regeneration of the centers of the existing urban neighborhoods in Al Ain, and other UAE cities, has been proposed.

Keywords: Sustainable · Urban regeneration · Neighborhood center
Al Ain · UAE

1 Introduction

Sustainable community has been defined as one that is economically, environmentally, and socially healthy and resilient. It seeks: a better quality of life for the whole community, healthy ecosystems, effective governance supported by meaningful and

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broad-based citizen participation and economic security. Social wellbeing is one of the essential traits of sustainable community and its realization necessitates satisfaction of basic human needs, affordable provision of quality health care, equitable access to quality education services, formal and informal. On the other hand, economic security of sustainable communities encompasses meaningful employment opportunities for all citizens, responsive and accessible job training and education programs that enable the workforce adjust to future needs and businesses that enhance community sustainability [1].

In his argument, Power [2] determines three core aims of sustainable communities. First, is to achieve a healthy environment that involves minimal ecological impact, minimal waste or pollution and maximum recycling, protection and enhancement of the natural environment, wildlife and biodiversity, so that all may enjoy environmental benefits such as greenery, careful planning for physical and social sustainability, space to walk, cycle, meet, play and relax. Second, is to achieve a prosperous economy that generates wealth and long-term investment without destroying the natural and social capital on which all economies ultimately depend. It also minimizes resource use and environmental impact, develops new skills through education and training and meets basic needs through local jobs and services. Third, is realizing social wellbeing which arises from a sense of security, belonging, familiarity, support, neighborliness, cohesion and integration of different social groups, based on respect for different cultures, traditions and backgrounds.

In another argument, Peck and Dauncey [3] claim that sustainable community is one that provides ample opportunity for sociability, personal development, and community participation. They continue that the New Urbanism movement makes a conscious effort to design for community as a whole, including the community facilities that make a place more than a set of roads flanked by houses. Therefore, for them, sustainable community development requires new ways of thinking about the interrelationship between economy, environment and community and new ways of examining the full costs and benefits of alternatives to conventional approaches to community development. They maintained that the benefits of implementing sustainable communities can be significant in both the short and long terms for developers, residents and society as a whole.

In general, the wide spectrum of sustainable communities literature is concerned with place or neighborhood, which simply means a residential or mixed used area around which people can conveniently walk and its scale is geared to pedestrian access. It is maintained that planners often view neighborhoods essentially as a setting for a particular function such as a base for home life, employment, retail activities and so on. People, on the other hand, often associate experiences, hopes and values to an area, most likely within their neighborhoods. This sense of localness and distinctiveness provides residents with a sense of place. Thus, a neighborhood might well provide hook for feelings of community and the setting for the sorts of relationships and networks that we call ‘community’ [4].

2 Neighborhoods Centers and Sustainable Communities

Neighborhoods centers are the milieu in which local community interaction is taking place. They are the places for community educational, retail, cultural, social, recreational and entertainment services. Neighborhoods in general and neighborhoods centers in specific are influenced by measures of planning, design, density and layout that shape a community. They also affect the level of services and the way people interact with each other and with their environment. For example, low density sprawl makes public transport and local shops unviable. In contrast, higher densities support shops, buses, neighborhood schools and a sense of community. It stimulates, as well, a viable local economy and services that provide the rationale and underpinning for community development and survival [2].

Peck and Dauncey [3] criticize the standard modern residential subdivision which is mostly built without any thought of including a small commercial center within walking distance of most of the homes. This lack of a social gathering place has a subtle negative effect on neighborhood life, since people have less occasion to meet each other and build up the network of relationships that creates a true community. The lack of a close-by commercial center is another encouragement to own and use cars where residents must drive somewhere else to buy a paper or a bottle of milk. They add that conventional suburban development pays little attention to the need for “complete” communities, i.e., a balance among residential and employment development. Without a local economy, usually planned for in the neighborhood center, the residents of a new development are obliged to drive to work somewhere else, leaving the neighborhood empty of life in the daytime, while filling up the roads and releasing more CO_2 emissions.

Peck and Dauncey mention the Village Homes as an excellent example of the way in which something as small and inexpensive as a community barbecue pit on common land within a neighborhood center can bring people together, and add livability. A mixture of design strategies including the provision of greenways, traffic calming and attractive pedestrian connections to and from neighborhoods centers can encourage residents to walk or cycle around, increasing their health and enjoyment, while reducing CO_2 emissions.

Various theories for urban regeneration of neighborhood centers have been developed over the past few decades [5]. Many local authorities in the world have embraced and implemented these theories. For example, Temelova and Dvorakova [6] found out that local accessibility of services, public spaces, and social support are very essential measures for the residents in some studied neighborhoods in Eastern Europe. In another example, Cardiff City Council [7] in Wales, UK, developed an initiative to revive the neighborhoods centers in Cardiff. Cardiff City Council claims that small parades of shops are very important to local neighborhoods across Cardiff as they provide shops, services and community facilities. A lot of these neighborhoods’ small shopping centers are having problems, including anti-social behavior, a run-down environment, and/or closure of small shops. So, an urban regeneration plan has been developed to prevent losing these valuable shops and services. The Council announced that protecting local shopping centers from falling into decline is a priority for them.

Following an assessment of environmental, social and economic conditions of local shopping centers the Council produced the Local Shopping Centre Strategy to prioritize which centers are most in need of help and proposed to improve one center per year, in accordance with the list of priorities.

Finally, quality and diversity of neighborhood center services, facilities and spaces are essential factors in their revival. Barton [8] asserts that the degree to which people choose to use local shops, schools, surgeries and clubs also depends on quality and diversity to match diverse needs in the population. 'Community safety' and the ways in which the planning process can be reformed in order to achieve it in the neighborhood as a whole, and in the neighborhood center in specific, is another vital aspect [9].

3 Research Questions and Methods

In light of the above arguments, the research is posing two main questions for the local urban neighborhoods, mainly inhibited by Emitrati citizens, in the city of Al Ain as it is having frequent housing development projects for local communities:

First: Why the neighborhoods centers have been deteriorating?
Second: What are the appropriate urban regeneration strategies for these neighborhoods centers?

Thus, the main objectives of the research are, first, investigating reasons for deterioration of neighborhoods centers through appropriate methodology and tools, as detailed later, and second, determining the best suitable urban regeneration strategies that are envisaged, if appropriately applied, will lead to more sustainable communities in Al Ain and other UAE cities.

This research is an analytical and deductive qualitative/quantitative research suitable for the nature of investigations required to answer the research main questions and to realize the research objectives. The research adopts mainly the case study method and various data collection and analysis tools. The case study method was chosen because it allows the researcher to conduct a deep and intensive study of a manageably-sized locality. This approach is perceived to be more suitable for the study purposes [10]. Yin [11] argues that a case study, as an empirical inquiry, is the preferred research strategy when "how", or "why," questions are being posed and when the focus of the research is on a contemporary phenomenon within some real-life context, which is the case in the research at hand. Yin emphasizes that the researcher, as in this research, would use the case study method because he/she deliberately wishes to cover contextual conditions, which might be highly pertinent to the thrust of the researcher's study.

To tackle the research questions and to realize the research objectives, the research is going to pursue the following methodological procedures: First, is conducting comprehensive literature review for defining the theoretical framework for the indicators of the vivid and sustainable neighborhood center and its relationship with the principles of the sustainable community development. Second, is defining a representative case study reflecting the status quo of the deteriorated neighborhoods centers in Al Ain city. Third, analyzing the planning/architectural context of the neighborhood center(s) for the selected case study through CAD drawings, aerial images, field observations and—Space Syntax analysis for the studied neighborhood using Depth-mapX software.

The recommended investigation tools include field observations and photographs. This is expected to give better understanding of the individual and collective patterns of use of the amenities/spaces within neighborhood centers. Observations enabled the researcher to analyze the patterns of usage of the utilities/services/spaces of the neighborhood centers. This helped evaluate the relationships between activities carried out in a place and the aspects of the same place [12]. Fourth, compiling the results of the previous investigations to achieve the first research objective and thus answer the research first question. Fifth, is developing proposed strategies for the revival of the neighborhoods centers in Al Ain and thus achieving the second objective of the research. Actually, this proposed urban regeneration paradigm in Al Ain, will be supported on the result of the first research question (the reasons for the deterioration of neighborhood centers). These investigations are envisaged to enlighten the discussion and help devise a new proposed sustainable urban regeneration paradigm for deteriorated neighborhoods centers.

4 Theoretical Framework for Sustainable Neighborhood Center(s)

Based on the relevant literature review about the theoretical and practical studies for urban regeneration of sustainable communities, one might claim that the common features that help realize a thriving neighborhood center(s) are those whose absence cause the contradictory effect of deterioration. The proposed theoretical framework below has been developed mainly based on the work of Peck and Dauncey [3], Lee et al. [13], Barton [8], Raco [9] and also the practical experience of Cardiff City Council [7]. This theoretical framework is subsumed into 6 main categories as follows.

4.1 Provision of Utilities and Amenities Within the Neighborhood Center

This entails the provision of high quality retail, educational, entertainment, recreational and religious facilities as well as appropriate amenities in public spaces. Among the needed services are the pedestrian-pockets/passive parks/tot lots, efficiently designed playing fields, on-street parking lanes, and reduced infrastructure.

4.2 Neighborhood Density

Theoretically, for a neighborhood of about 7000 persons, suitable density would be 60 persons per hectare and its service core may have an area of about 1 ha. This is meant to provide for a sufficient density to support corresponding and viable local services and facilities and to support public transport.

4.3 Urban/Architectural Context of the Neighborhood Center

The urban and architectural context of the neighborhood center is usually a resultant of multiple influencers including applied architectural codes and regulations, landscaped streets and spaces, paving materials and designed street furniture, increased street trees/tree canopy/tree 'pods', unique street pattern that gives a 'sense of place', hidden and shrunken commercial parking lots, and finally the existence of a Main Street.

4.4 Accessibility, Connectivity and Walkability to/from the Neighborhood Center

Vivid neighborhood center would be well-connected with residential clusters with appropriate catchment areas, incorporated with sufficient and efficient mass transit systems. It would be also interconnected through systems of walkways and bike trails, and would have high integration with surrounding neighborhoods centers.

4.5 Integrated Commerce Within the Neighborhood Center

The neighborhood centers should cater for creating jobs close to residences through providing local commercial functions appropriate of course to residential urban contexts.

4.6 Safety and Security of the Neighborhood Center

Safety and security are two major measurements for successfully designed within neighborhood centers. Among the crucial provisions for safety and security are sufficient street lights for both traffic lanes and pedestrian walkways, vertical and/or horizontal traffic calming measures plus, of course, special emergency vehicle access designs.

5 Status Que of Neighborhoods Centers in Al Ain: Al Salamat Neighborhood as a Case Study

United Arab Emirates has been concerned with achieving sustainability in its urban housing sector among other development sectors. Estidama Pearl Rating System for Community [14] is an obvious example of this trend. Recently, some few neighborhoods have been developed as Estidama-rated sustainable urban communities in UAE. But on the other hand, the fairly large stock of existing local urban communities that have been developed over the last two and three decades with the absence of sustainability guidance need to be investigated. The centers of these existing 'conventional' neighborhoods in Al Ain, as in other major cities in UAE, are obviously suffering from urban deterioration where, for example, the retail shops are either closed or have limited economic activity, green public spaces are rarely found, no or little children playgrounds, far away clinics, and so on. A new paradigm in urban regeneration for these neighborhoods centers are desperately needed if sustainable community is to be realized in existing local urban communities in UAE.

5.1 Al Salamat Neighborhood in Al Ain

Most of the existing housing developments in Al Ain, and actually other major UAE cities, are principally sharing the same morphological and urban planning/design traits. Al Salamat District is one of those housing developments. It is located approximately 21 km west of Al Ain city center. It was developed in three main stages (neighborhoods) in 1980, 2000 and 2011. The neighborhood developed in 2000 was selected as a case study as it mostly reflects the commonly adopted sprawl urban pattern for local community neighborhoods in UAE. The neighborhood has main three housing blocks encompassing a vast space allocated for the needed community services and facilities (Fig. 1).

Fig. 1. Neighborhood centers distributed within the inner space of the residential blocks clusters

The following sections are briefly presenting the analysis results for the six dimensions of the previously established theoretical framework for sustainable neighborhood center(s) in Sect. 3.

Provision of Utilities and Amenities within Al Salamat Neighborhood Center(s). The underdeveloped 3 clusters service centers, as shown in Fig. 1, are accommodating: 1 kindergarten, 2 preparatory schools (1 for boys and 1 for girls), 3 mosques (two local mosques and 1 Jum'a (Friday congressional prayer mosque), and recently developed supermarket and public garden. Some small retail corner shops are built juxtaposed to the three mosques. Thus, it is clear that the neighborhood service centers lack basic educational (elementary schools), health facilities, sport and security service. With the sprawl urban form of the neighborhood and the total number of residents which reaches to only about 1494 persons, it seems pretty difficult to provide all the needed services on the same neighborhood. For example, 2 elementary schools (1 for boys and 1 for girls) are located in the adjacent neighborhood. Meanwhile, the residents of this adjacent neighborhood themselves have to rely on the preparatory schools found in Al Salamat.

Al Salamat Neighborhood Density. For an economically and socially vivid neighborhood center there is a need to diversify the customer profile through developing a variety of housing types, ranging from flats in high-density low-rise housing to other forms of family houses. Of course, this is not the case in Al Salamat where only one single family housing model is developed. The site area of Al Salamat is about 132.5 ha. It contains 166 single family houses with plot dimensions of 45 m $\times$ 45 m. So, the gross density is about 11.3 person per ha which is quite low density and apparently insufficient for supporting a thriving neighborhood center.

Urban and Architectural Context of the Al Salamat Neighborhood Center(s). As mentioned earlier, the neighborhood has three service centers contained within vast open spaces located in the middle of the three residential blocks. These huge areas have remained largely underdeveloped through the years. Figure 2a, b illustrates how only few services and facilities have been developed in the three neighborhood centers since 2003.

This can be easily understood in light of the exceptionally low density of the neighborhood itself and maybe also in light of the isolation from other activity and service centers in the adjacent neighborhoods as will be discussed in the following point.

a 2003

b 2016

Fig. 2. **a**, **b** Slow development of neighborhood centers over years while housing plots are changed dramatically. *Source* Google Earth

On the other hand, the streets have been designed to mainly serve vehicular mobility with noticeable lack of appropriate pedestrian realm (Fig. 3) considering frontage, through, furnishing, cycle lane, edge for the street design in these neighborhood centers areas, as proposed in the Abu Dhabi Street Design Manual issued few years back [15] (Fig. 4). All in all, there is no sensible effort excreted in creating a unique identity for the places/buildings which form the three neighborhood centers.

Fig. 3. Lack of appropriate pedestrian realm with frontage, through, furnishing, cycle lane, edge for the street design in neighborhood centers areas

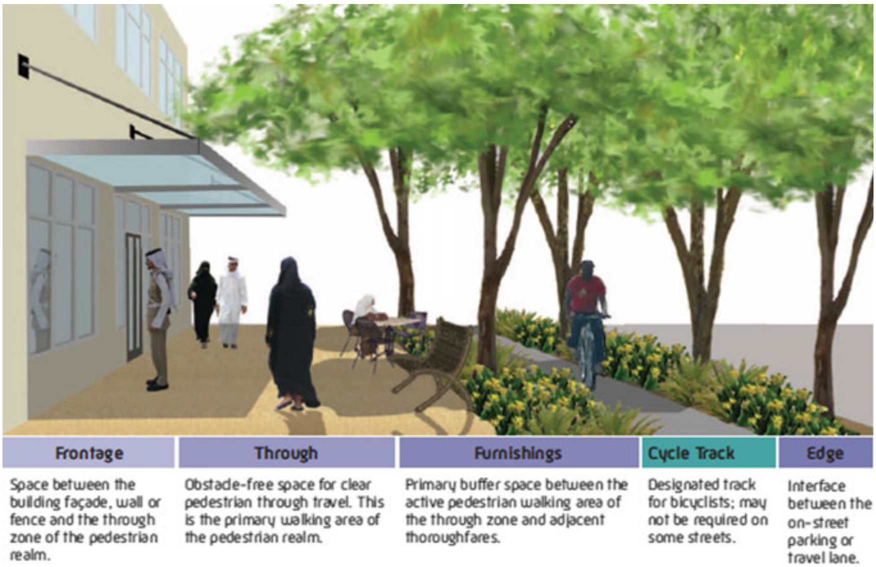

Fig. 4. Standard street section according to Abu Dhabi Street Design Manual. *Source* 15

Accessibility, Connectivity and Walkability to/from Al Salamat Neighborhood Center(s). The three neighborhood centers are totally isolated from the centers of adjacent neighborhoods and almost even from each others. This have made them more like segregated ‘urban zones’. Figure 5 elucidates the car-oriented nature of the development that made it extremely difficult to walk to most of the services except to local mosques. The only two bus stops are located away from Blocks 2 and 3 (Fig. 5).

Services	Distance
Retail shops	800 m
Bus stop	800 m
Park	1.8 Km
Primary School	1.25 KM
nursery	1.25 Km
Police Station	7.7 Km
Mall – Spines	5.4 Km
Clinic or hospital	9.4 Km
Mousqe	300 m

Fig. 5. Catchment areas for the neighborhood centers

Additionally, the Space Syntax angular segment analysis with metric radius (Fig. 6) was utilized here as it has been found to be a reliable instrument in detecting major ‘to’ and ‘through’ movement routes in a street network [16].

DepthmapX software package was used to conduct the angular segment analysis

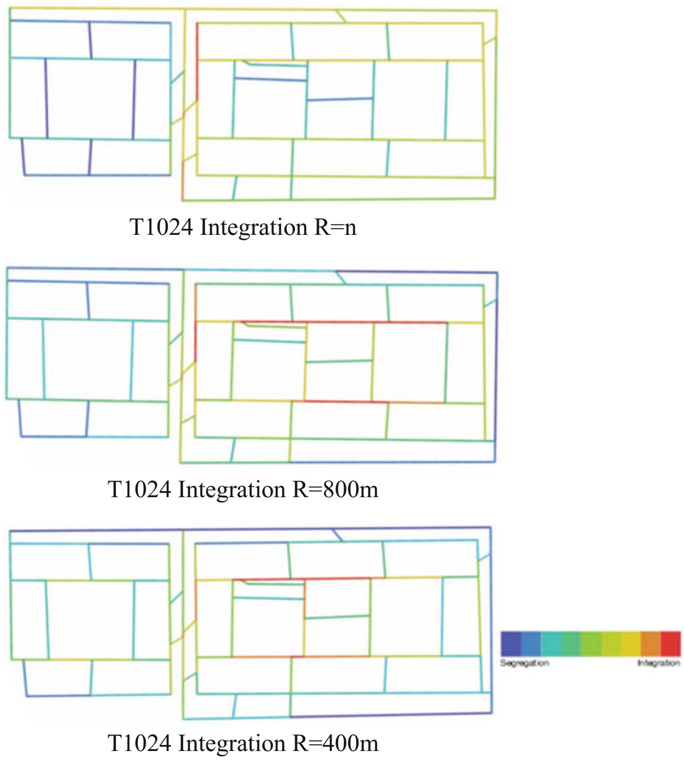

Fig. 6. Integration results for global and local measures using DepthmapX

for measuring spatial integration on the global n (neighbourhood), 800 and 400 m catchment levels. The more integrated space (segment) has been allocated the red color while the least has the blue one. The results (Fig. 6) reveled obvious segregation of the services spaces on the global (whole neighborhood) level (T1024 Integration R = n). Better integration has been noticed on the local catchment scale of 800 m (T1024 Integration R = 800 m) and 400 m (T1024 Integration R = 400 m) except for Block 1 service space. This simply means that the urban form shaped by the mobility grid is not helping in locating neighborhood centers in the most integrated movement routs especially for Block 1.

Integrated Commerce within Al Salamat Neighborhood Center(s). Due to the lack of mixed use development and the provision of diversified commercial activities, local job opportunities are not provided for residents except for the limited vacancies that might be available for residents in the two preparatory schools.

Availability of Safety and Security Measures in Al Salamat Neighborhood Center(s). As it is clear from Fig. 6, safety measures are significantly absent because the 'edge' zone separating the sidewalks from the right-of-way is not considered. Furthermore, the pedestrian walkways themselves are frequently cut by vehicular traffic with no zebra crossing or traffic signals and are, thus, dangerous for residents to use. In some cases, the sidewalk itself is occupied by haphazardly parked cars thus people are forced to walk in the street lane. Cyclists, mainly labor, are usually forced to share the street lanes with vehicles in a hazardous manner as there are no lanes dedicated for cyclists.

For security, the neighborhood centers are usually secure day and night. There are well distributed light posts providing good night vision. People moving to and from local mosques and schools create some sort of urban surveillance. But actually, sense of security is generally high in Al Ain city with its significantly low crime rate.

6 Discussion and Conclusion

The outcomes of the analyses conducted in this research for Al Salamat neighborhood centers, as an example for the existing neighborhoods in Al Ain city and UAE helped determine the reasons causing deterioration of neighborhood centers. These reasons can be briefly referred to the following problems.

The most significant problem is the extremely low density of the neighborhood which mainly results from the adopted sprawl urbanism and the adopted car-oriented planning. Therefore, asking for more provision of services and facilities would not be a practical solution in light of such low density as economic feasibility is hindering any attempt to develop more colorful spectrum of services in the neighborhood centers. The adopted car-oriented planning approach is another chief element in creating this socially and economically deteriorated image.

Lack of integration between the neighborhood centers themselves and the centers of adjacent neighborhoods is another major problem identified through spatial analysis of the neighborhood. Absence of safety measures in the urban space realm within these neighborhood centers is estimated to rigorously contribute to the deterioration of the neighborhood centers.

As most of the existing neighborhood centers in Al Ain are including vast neglected ‘infill’ lands so they actually have better potential for redevelopment and urban regeneration. Greenfield developments always require new land, whereas urban ‘infill’ initiatives are inherently more sustainable, because they re-use land that has already been urbanized. At its best, urban infill is a celebration of city life, bringing new housing, commercial life and neighborhood activity to a neglected or abandoned area. Urban infill can make use of existing infrastructure and help to financially support existing public transit systems and commercial activities [3].

On the other hand, and based on the above findings the research proposes urban regeneration strategies for the deteriorated neighborhoods centers. This strategy relies on the following measures:

- Increasing density by introducing more dense housing patterns such as apartment blocks that can be developed on the vast vacant land in an ‘infill’ development manner.
- Increasing population density is not the only solution here but also there is a need to diversify the social strata through providing various housing types as this will create more demand over different services and amenities.

- Mixed use development should be adopted where for example the ground floor of the proposed apartment blocks can be allocated for retail services while the first floor can be allocated for offices. This would create more job vacancies and more vivid urban spaces for the neighborhood centers. Consequently, urban surveillance would enhance.
- The urban form itself can be upgraded through adding more mobility linkages to the centers urban segments. This would enhance integration of such centers and encourage residents to approach services and utilities provided there.
- Walkability and cycleability are two important measures that can be easily achieved if Abu Dhabi Street Design Manual found its way for implementation. The wide streets might allow this to happen more easily than it might be imagined.
- Spatial integration among neighborhood centers, on one hand, and the neighborhood centers and their adjacent centers would, with no doubt, create more robust economic and social activities. A 'Main Street' urban pattern should be adopted where services and facilities will be linked together and with other neighborhoods to form a vivid mixed used urban realm instead of the currently isolated centers.

Due to the urban contextual similarity among urban neighborhoods in UAE cities, the findings are envisaged to be generalizable. As UAE is adopting a thriving sustainability agenda on all development levels including local community development level, so the outcomes of this research is hopefully will help contribute effectively to the overall sustainability agenda achievement of the country.

Local authorities such as local municipalities, planning directorates and social housing programs can make use of the findings of the research in proposing urban regeneration plans for existing neighborhoods centers. Local professionals especially architects and planners can also make use of the findings of this research while designing new neighborhoods or working on urban regeneration plans.

On the other hand, in the near future, Abu Dhabi Urban Planning Council is expected to propose *Estidama* rating systems for refurbishment of the existing buildings and urban communities in Abu Dhabi to be much more sustainable. Here again the findings of the research will be significant and can be an essential part of the main core of such new rating systems.

Further research work includes conducting more case studies, detailing the proposed urban regeneration strategy and listing to the voice of the residents themselves to fine tune this proposed strategy and to highlight any uninvestigated issues.

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A New Approach in Sustainable Urban Transformation: Super Cities

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Abstract. Cities, which have become more populated crowded as the result of industrial revolution, had also brought many challenges. In the developed countries, these challenges are met with an environmentally prioritized approach; whereas the economic and social aspects are prioritized in the developing countries. The fact that natural sources are under threat of diminishing, caused the rising of "sustainability". With sustainable urban transformation, transformation of cities is getting to handle under principles of sustainability. The 6306 numbered Law of Transformation of Areas under Disaster Risk which aims transformation of 6.5 million structures which have been carrying the risks of lives and property has legalized in 2012. This law aims to bring solutions to the problems deriving from irregular urbanization. Supercity projects were taken into agenda by Ministry of Environment and Urbanization in order to physical, social, cultural and spatial sustainability of building under risk. With this projects, the urban transformation and sustainability principles were analysed together. Supercity projects headline six major performance criteria such as land use and urban design, energy, water, transportation, materials and sources, social and economic sustainability. In areas where urban transformation is implemented with Supercity System, at minimum 44% less management costs, 44% less public expenses, 65% energy productivity, 65% water saving and 55% management productivity are objected. In this paper, Supercity Project pilot practice at Kocakır Eskişehir has been evaluated within conceptual framework determined by principles, strategies and methods subject to urban transformation approach.

Keywords: Sustainability · Urban transformation · Sustainable urban transformation · Supercities

1 Introduction

Cities in time became subject to changes and transformations both in socio cultural, economic, technological and physical aspects [1]. Along with industrial revolution, developments in information and technology caused increasing in migration from rural

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to urban areas and thus concluded rapid urbanization. Huge mass mobilization as result of rapid urbanization and the impact of industrialization on social life caused new problems such as environmental pollution, irregular housing, unqualified living areas and insufficient services.

Urban transformation policies came to the agenda for reformation of unhealthy urban areas and re-evaluation of regions which have already lost their functions. The first transformation practices had been undertaken in old industrial zones and slummed areas where community with the lowest income lives in negative conditions [2]. In the early transformation implementations, the process was undertaken by demolishing all structures in the area and constructing new cities instead. Today, the success of implemented urban transformation depends on whether physical and social cultural characteristics are taken into consideration and a balance has been achieved between sustainable transformation of the city and economy and ecosystem and whether all components of the city are evaluated as a whole [3].

Sustainable urban transformation has gained more importance day by day due to many factors such as increase of energy related with growing subject to rapid urbanization, increase of CO_2 gas emissions due to intense population, environmental pollution, global warming and climate change, management of natural sources, the necessity to inheritance healthy and qualified cities for next generations. With intensifying negative effects of global warming and climate change many countries tended towards urban development models prioritizing the environment and started to reconsider and arrange their urban transformation policies and projects accordingly [4].

When the structures are renewed or constructed from in urban transformation process, it is needed material and energy and while this need is being met, there is an absolute damage to environment in terms of materials obtained from environment and emissions to environment [5]. With this framework, guides, standard and implementation models are being prepared for sustainable urban transformation with minimum impacts to environment undertaken by administrative institutions in Turkey.

In this paper, "Super Cities Project" which is one of these implementation models and has been developed by the Ministry of Environment and Urbanization was evaluated with the example of Kocakır within the context of conceptual framework of principles, strategies and methods related to urban transformation.

2 Sustainable Urban Transformation

Sustainability in urban transformation implementations defines beginning with the choice of area, implementation processes which are designed with social and environmental liability understanding, that are directed to renewable energy sources, consumes equal to the amount of needs, where natural materials that do not produce waste are being used, sensitive to ecosystems and additionally where economic sustainability is being achieved. Within this context, urban transformation principles determined in Supercity Project can be considered as a guide not only for transforming physically or economical damaged areas, but also for contributing to eliminating environmental effects and guiding to implementers [6].

2.1 Urban Transformation and Methods

In literature, the best definition of urban transformation is “a comprehensive vision and action with the objective of bringing solutions to economic, physical, social and environmental conditions of a region which provides solutions to urban problems and which is subject to change” [7]. Despite many definitions both in theory and practice, urban transformation generally means the whole understanding of bringing solutions to urban problems.

Like in many other countries, the search started for solutions to urban problems in Turkey after 1980s. In this period, the negligence of the principles of sustainability by national and international capital while making spatial preference has caused many problems. These problems can be named as the unnecessary expending of the cities, damaging cultural, historical and natural assets of cities, constructing spaces that do not belong to local and natural structure [8]. In this connection, these urban spaces are needed to transformation and renewal. However, the implementation areas considering economic, social and environmental components of urban transformation are so few. Besides, recently in Turkey, urban transformation projects are being implemented where all or some of economic, social and environmental components of urban transformation are taken into account. These projects are mostly implemented in areas with shanty houses, areas under the risk of disaster and old/abandoned industrial zones, evacuated city centres and zones including intense historical structures [9]. The most frequently used ones among the implementation methods are rehabilitation, urban renewal, urban redevelopment, and urban regeneration in literature.

Rehabilitation. Rehabilitation is to increase the value by reparation and restoration of old city texture and urban decay areas while preserving the current structure.

Renewal. Renewal is to complete or partial demolition of structures and building new and modern ones instead, in order to cure economic, social and environmental conditions in the urban decay areas [10].

Redevelopment. Redevelopment is to complete demolition of areas and developing a new urban design, in the urban decay areas with incurable economic, social and environmental conditions, where mostly low income people reside [3].

Regeneration. Regeneration is to reintegrate urban decay areas to the city, by creating a new texture or curing the current state of the area [11]. Regeneration is one the most frequently applied methods in the context of 6306 numbered Law on Transformation of Areas under Disaster Risk [12], which is an important part of the regulations of urban transformation in Turkey.

Legal arrangements in Turkey related with urban transformation are given in Table 1. Furthermore, as it can be understood from Table 1, there are many legal arrangements in Turkey in last 50 years in order to solve the problems deriving from rapid and unsustainable urbanization. 6306 numbered Law [12] among these arrangements assigned important authorities to TR Ministry of Environment and Urbanization, and it opened the way of implementing sustainable urbanization methods for eliminating current problems.

Table 1. Historical development of legislation in Turkey related with urban transformation

Date	Legal arrangements
July 1966	775 numbered Law on Shanty [13]
March 1984	2981 Numbered Law on Transactions that will be applied to Structures against Housing and Anti Shanty Regulations and Law on Changing one Article of 6785 Numbered Housing Code [14]
March 1984	2985 numbered Mass Housing Law [15]
May 1985	Housing Code [16]
March 2004	5104 numbered Law on North Ankara Entrance Urban Transformation Project [17]
July 2004	5216 numbered Metropolitan Municipality Law [18]
July 2004	Changes brought by Law on Changes in 5226 numbered Code of Protection of Cultural and Natural Properties and other legislations [19]
December 2004	5273 numbered Law on Making Changes on Land Office Law and Mass Housing Law and Repealing of Land Office Directorate General [20]
July 2005	5393 numbered Municipal Law [21]
July 2005	5366 numbered Law on Renewing and Protecting of Damaged Historical and Cultural Immovable Properties and their Usage [22]
May 2012	6306 numbered Law on Transformation of Areas Under Risk of Disaster [12]

2.2 Supercities Within the Scope of Sustainable Urban Transformation Approaches

Cities are the main contributors to the global warming. Energy is mostly consumed by three sectors, namely industry, transportation and household [23]. With 40–60% share, household is the biggest part of overall energy consumption. Thus, utilization of energy in the most efficient way is the most important issue in the design and management of buildings [24]. There exist 6.5 million of structures that are planned to be transferred with [25] the scope of 6306 numbered Law on Transformation of Areas under Disaster Risk in Turkey [12]. In this context, maintaining economic, social and environmental sustainability of current structure stock by the synthesis of the urban transformation practices in Turkey and the sustainability principles; thus, extending the environment-friendly urban transformation practice is of great importance for the healthy development of cities.

"Neighborhood Standards" has been developed by the Ministry to help decide on the area to implement the Supercity Projects. It aims a plan and implementation of residential areas causing less carbon footprint than the usual residential areas. Economic, social and environmental criteria also aimed at urban transformation implementations have been determined with the "Neighborhood Standards". They are defined as "performance criteria" in case these criteria refer to carbon emissions, other criteria are considered as "minimum criteria". Minimum criteria act as guide to implementers, while performance criteria measure the success of urban transformation projects. According to requirements of current legislations, environmental impacts of settlements are taken as basis and due to the percentage of difference in performance of projects, the success levels are exposed. A life cycle analysis and carbon measuring software for measurement of success level due to carbon emissions has been developed in the scope of environmental impact assessment. Accordingly, 5 performance levels are exposed in Table 2 for urban areas and buildings. Furthermore, the principle of "do not produce more than you consume" is adopted in all measurements of the system and this is defined with concept "net positive" [26].

Table 2. Performance levels for environmental impact assessment

Performance criteria	Carbon decreasing emission
Base+	0% < … <20% CO_2 decrease
B+	20% < … <60% CO_2 decrease
A+	60% < … <80% CO_2 decrease
Net ~	80% < … $\leq$ 100% CO_2 decrease
Net+	>100% CO_2 decrease

Conceptual framework for sustainable urban transformation approach prepared by TR Ministry of Environment and Urbanization is presented in Table 3. According to this framework, six basic principles such as land use, urban design, energy, water, transportation, materials and sources, social and economic sustainability and by extension strategies to realize these principles have been determined [26].

Table 3. Conceptual framework for sustainable urban transformation approach

Principles (P)	Strategies (S)	
Land use and urban design (LUUD)	Protection of species Protection of water and land Increase of carbon sink	See Table 4 for minimum criteria and performance criteria
Energy productivity (EP)	Green certificate buildings Renewable energy production Heating and cooling at neighbour scale	
Water productivity (WP)	Decrease in water consumption Management of rain water Waste water management	
Transportation productivity (TP)	Management of demand Decrease in use of individual cars with fossil fuel Cycling network public transportation and pedestrian transportation	
Material and source consumption (MSC)	Solid waste management Settlement life cycle Sustainable sources use	
Social and economic sustainability (SES)	Mass housing management SEP social etude program Social contribution	

Considering the conceptual framework in Table 3, principles, neighborhood criteria (minimum criteria, performance criteria) and objectives are presented in Table 4.

Table 4. Principles, neighbourhood standard criteria and objectives subject to sustainable urban transformation [26]

P	Neighbourhood standard criteria		Objectives
	Minimum criteria	Performance criteria	
LUUD	Smart location determination Protection of species under danger and ecological communities Protection of wetland and water sources Protection of agricultural land Staying away from flood and overflow areas Settlement in inclined areas Streets with pedestrian priority Neighbourhood design composed of combined income groups Preventing construction debris Housing-business closeness Combined use neighbourhoods Access to urban and public areas Access to recreation possibilities Design of walking streets with pedestrian priority Neighbourhood schools	Settlement areas with priority Cleaning and reusing of polluted areas Limitation for settlement in open areas and expanding Afforested and shaded streets Local food manufacture and urban agriculture possibilities Adaptation in climate change Net positive land	Increase of green areas Protection of wild areas Increase of trees and plants Increase of agricultural areas Decrease of impermeable surfaces

(*continued*)

Table 4. (*continued*)

P	Neighbourhood standard criteria		Objectives
	Minimum criteria	Performance criteria	
EP	Green certificated buildings at settlement areas Minimum building energy productivity-cost optimum buildings Reducing the effect of heat island Sun orientation Reducing of illumination pollution	Regional energy performance optimization Renewable energy production Neighbourhood heating-cooling systems Energy productivity of infrastructure systems Net positive energy	Energy saving Productive infrastructures and provide saving Energy independent region
WP	Reducing regional water consumption	Reducing of inside building water consumption Reducing of outer building water consumption Rain water management Waste water management Net positive water	Water saving in buildings Water saving in green areas Using rain water Using waste water in cycle Region meeting its own water need
TP	Compact/mass urban settlement areas Communities with strong environmental connections Access to qualified transportation possibilities	Increase of transportation possibilities Management of transportation demand Reducing of parking areas Cycling network and parking areas Net positive transportation	Emission saving related with transportation Energy saving related with transportation
MSC	Solid waste management Sustainable use of material and sources	Reuse of buildings Protection and reuse of historical buildings Recycled and reused infrastructures Life cycle analysis of settlements	Pure material and energy saving Construction of settlement sensitive to environment
SES	Project added value Project mass structure management Project social contribution management	Organization of project mass housing management and starting a new life at the place (SEP + SET) Providing social contribution in planning and construction processes Economic etude program	Sustainability of the project with added value Sustainability-oriented project management Society living project process Consistency between economic and sustainability objectives of the project

3 Eskişehir-Kocakır Supercity Project

Along with 6306 numbered Law on Transformation of Areas Under Risk of Disaster go into operation in 2012, it is understood that possible measures on reducing carbon emissions with proper implementation of urban transformation, would significantly contribute to the cost saving for households of energy, water and transportation. In this direction, a new sustainable urban transformation approach had been developed and TR Ministry of Environment had initiated works of Supercity projects which would compose a sample to ecologic settlement units at neighbourhood scale. With the mentioned project, performing the urban transformations implemented as per the Law numbered 6306 in line with the sustainability principles aims to use the urban transformation as a tool for Turkey to fulfil its responsibilities in the climate change matter and also to make sustainability themed credit opportunities provided by domestic or international financial institutions available for the urban transformation in Turkey.

With projects implemented for this purpose, it is foreseen to encourage the formation of structures that are composed of energy productive buildings, that use the waste heat produced by cooled structures with appropriate combined use, that produce, store and use their own energy from renewable sources, that collect household waste and rain water in a separate system, that treat household waste water and regain waste water (grey water) and rain water, that provide green areas and urban agriculture areas, that have access to facilities and trade and business areas with pedestrian and cycling roads, that create their own business and reinforcements, limit the use of individual vehicles with fossil fuel sources and that utilize both construction and other type of waste [26].

3.1 Scope of Eskişehir-Kocakır Supercity Project

The implementation of this project, which can be considered as a new approach in urban transformation, was planned to be constructed on a reserve area of 838-hectare size determined by Ministry at Eskişehir province Odunpazarı district and Kocakır location. The project, which aims establishing of a new city at Eskişehir-Kocakır for 75 thousand citizens, is composed of four parts. The project area is 11 km from city center, 14 km to organized industrial zone, 2 km to South Highway, 10 km to speed train station, 6–10 km to universities and 13 km to airport.

Development phases of Supercity project which is planned at Eskişehir-Kocakır are presented in Fig. 1. The first phase of the area has the size of 168.55 ha with population of 34.144 and population density is estimated 200 person/ha; second phase area has the size of 104.47 ha with population of 14.560 and population density is estimated 140 person/ha; the third phase has the area of 156.76 ha size with the population of 23.888 and population density is estimated 150 person/ha; the fourth phase has the area of 135.29 ha size with the population of 2408 and population density is estimated 20 person/ha. The phase which does not include housing and business places is estimated to have the size of 205.03 ha and is estimated to include agricultural areas, recreation areas as well as energy and waste water infrastructure facilities which are considered vital for settlement. In the phase are planned to be located without settlement the facilities that will meet the need of electricity and heating. In the planning area

Iran-Turkey Gas Line protection belt is located and this district which in known as forbidden for housing, is planned to be used as urban plantation [27]. General look of Eskişehir-Kocakır Supercity Project is presented in Fig. 2.

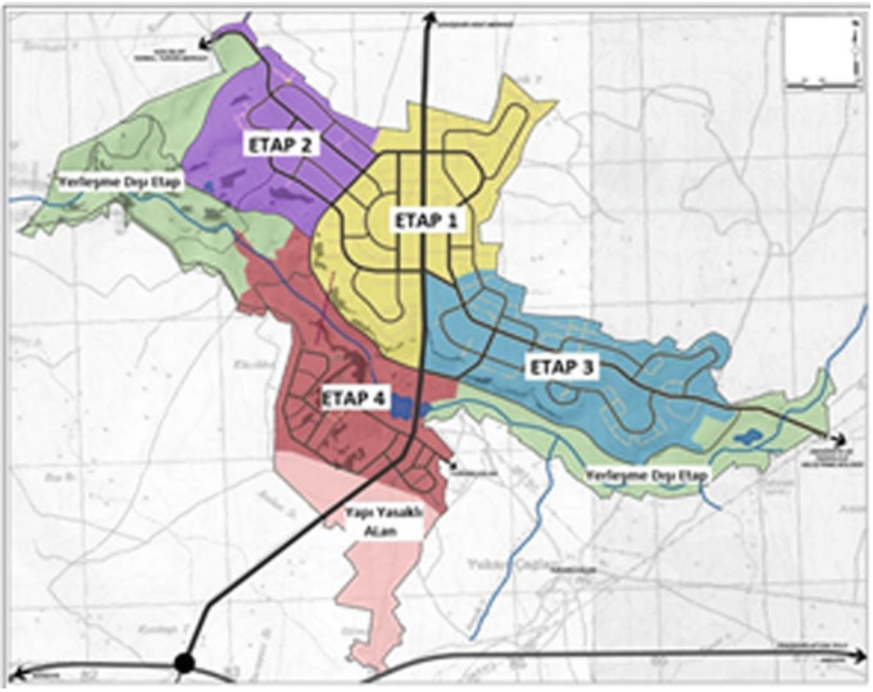

Fig. 1. Development phases of Eskişehir-Kocakır Supercity Project Area [28]

Fig. 2. General look of Eskişehir-Kocakır supercity project [28]

3.2 Evaluation of Eskişehir-Kocakır Supercity Project Within the Scope of Sustainable Urban Transformation Principles

In Eskişehir-Kocakır Supercity Project, it is objected to be realized with optimum performance level of 97%, 93 which is even above European standards. Within the scope of the project, it is planned to have 140% carbon sink, 83.24% energy productivity, 91.30% water saving and 92% transportation productivity [26]. Performance levels and related strategies subject to objected carbon emissions of project that will be implemented in the area are presented in Table 5.

Table 5. Principles, success, carbon decrease ratios and strategies related with Eskişehir-Kocakır project [26]

Principles	Success	Carbon decrease ratio	Carbon decrease strategies
LUUD	Net+	140%	• Low intensity and ground area, increased plant intensity
EP	Net˜	83.24%	• Central CHP and heat distribution network • PV fields and micro network • Sun oriented buildings • Zeroed heat island effect • 75% energy productivity in devices of infrastructure
WP	Net˜	91.30%	• 75% water saving in green areas • 100% water productivity in the buildings • Rain water harvesting and grey water • Use of renewable energy in water treatment
TP	Net˜	92.00%	• 26% pedestrian, 13% bicycle, 55% public transportation, 6% individual vehicle use • Cars with electricity, hybrid, bio diesel, LPG • CNG and busses with electricity • LPG and minibuses with electricity
MSC	A+	65.00%	• 25% recycled content in infrastructure • 50% recycled content in buildings • 97% recycle of debris
SES	Net+	115.60%	• Implementations that will bring added value • Urban agriculture and employment bringing implementations
Total	**Optimum**	**97.93%**	• Average carbon decrease ratio

Many new implementations are planned to be used which had never been used before with Supercity Project that will be implemented at Eskişehir-Kocakır. Such implementations can be defined as follows:

- Not using electricity from national network, regaining maximum amount of water, producing its own water and using waste water in reservoirs and gardening,

- Developing sustainability technologies based on new suggested functions, their implementation and creating of new carbon economies,
- Designing the valley passing at center of area as a natural park and undertaking of outdoor activities such as camps, outdoor sports,
- As result of cooperation undertaken with universities, opening of departments for “green collar” graduates such as environmental engineers, environment consultants, environment protection and eco technology experts and raising qualified personnel for sectors that intensively include green collars like renewable energy sector, energy productivity sector, organic agriculture sector and isolation sector [26].

To contribute to macro-economic development of the city with planned project, and to compose healthy urban areas designed as recreation areas within the scope of the project.

4 Result and Suggestions

Urban transformation methods seem to be significant implementation tools in order to find solutions to the problems of irregular structuring in cities where most of world population live in. Urban transformation methods which are implemented to increase the life quality of the cities, also provide the changes economic, social and environmental conditions that compose the physical environment. Evaluating change process initiated by urban transformation implementations within the scope of sustainability principles, present important opportunities to increase the life quality of cities.

Within the framework of sustainable urban transformation approach, the priorities of Supercity Project are executing of urban transformation areas under disaster risk within the framework of 6306 numbered Law with the principles of sustainability, domestic and international finance institutions evaluating their credit opportunities with sustainability theme in urban transformation, meeting the requirement related with national liabilities of Turkey subject to climate change.

Main acquisitions and basic objectives of Supercity project subject to Eskişehir-Kocakır, can be summarized as follows;

- Buildings with the projects implemented in urban transformation areas will be energy productive and they will produce their own energy, providing maximum amount of waste water recycle, using renewable energy sources and many other sustainable applications.
- With Supercity Project that will be implemented in Eskişehir Kocakır, 44% less management costs, 44% less public expenses, 65% energy productivity, 65% water saving and 55% management productivity will be achieved,
- In urban transformation areas where Supercity projects are implemented, carbon emission amounts will be decreased at the ratio of 97.93% in line with “Carbon Decrease Strategies” defined in Table 5,
- Achieving success in social sustainability of transformation projects by Ministry of Environment and Urbanization as administrative authority organizing the local stakeholders and including them actively to transformation processes,

- Throughout the country, it will be determined guiding national policies and actions for implementations related with transformation of settlement areas under risk of natural disasters,
- Considering special requirements of disadvantaged groups affected by urban transformation implementations, will be pioneered for including these groups into social life.

Conceptual framework, presented for sustainable urban transformation approach, may guide to several disciplines. Even some small scaled sustainable urban transformation implementations started in Turkey, they are not at desired scale and quality. The numbers of these implementations executed by TR Ministry of Environment and Urbanization should be increased and scientific studies should be undertaken and necessary legal works should be made.

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Determination of Local Site Soil Conditions by Microtremor Measurements for Sustainable Buildings

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Abstract. As well known, local soil condition at a specific site affects the significant features of strong ground motion such as amplitude, frequency range and time duration. The effects of site condition depend on the properties of the motion characteristics, material properties, topography and geometry of the field. The bedrock slope at the basin sides also is one of the most important factors in the response analyzing of a specific site in geotechnical earthquake engineering applications. The reflection and refraction waves from the basin edges induce the wave transmission and two dimensional effects. In this case two dimensional site response analyses are required to estimate the behavior of the soil layers. So, local geotechnical site condition should be into account in the design of earthquake resistant building. The bedrock slope of the basin edges should be determined for suitable method in two dimensional dynamic response analyses. In this study, the result of a specific site response based on shear wave velocity profiles determined by microtremor array measurements are presented. The geotechnical properties of the soil layers were obtained from the previous subsurface explorations. Seismic bedrock depth and bedrock slope of the edge were defined by microtremor array measurements. Shear wave velocity value is from ten to hundred meters was obtained from passive surface wave method by employed Spatial Auto Correlation algorithm. Established variation of shear wave velocity with depth models were examined in terms of local site amplification. In order to verify consistency of obtained amplification numbers, empirical and measuremental results were compared for each site. As a conclusion, dynamic properties of local site conditions under earthquake excitation were described in terms of maximum amplification, resonance frequency and predominant period.

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Keywords: Microtremor array measurement · Shear wave velocity model
Soil amplification

1 Introduction

Sustainability in civil engineering is often associated to resource efficiency and more serviceable structures. Thus, geotechnical engineering takes the forefront as the most resource intensive discipline within civil engineering and as an essential component of construction resiliency. Design and construction related to geotechnical engineering consume vast amount of resources, time and energy. Geotechnical researches on sustainability-related issues establish a relationship by using the arguments: application of environmentally friendly ground improvement techniques and alternative materials, recycling and reuse of foundations and energy geotechnics. However, there is a lack of clearly defined framework to evaluate and quantify the relative sustainability of alternative practices in geotechnical engineering [1].

It is important to determine the design parameters required for advisable selection of the geotechnical design in terms of sustainability. The preferred investigation method must be efficient in terms of time, cost and applicability. Sustainable buildings should be design in earthquake resistant. So, local site condition should be considered in design process of sustainable buildings as well as properties of superstructure and earthquake source.

In this study, the geotechnical parameters, crucial for convenient design, such as, engineering properties of the soil layers, seismic bedrock depth and bedrock slope of the edge were defined by microtremor array measurements. Variation of shear wave velocity with depth model is from ten to hundred meters was obtained from passive surface wave method by employed Spatial Auto Correlation algorithm. As a conclusion, maximum amplification, resonance frequency and predominant period were discussed based on site specific soil conditions (Fig. 1).

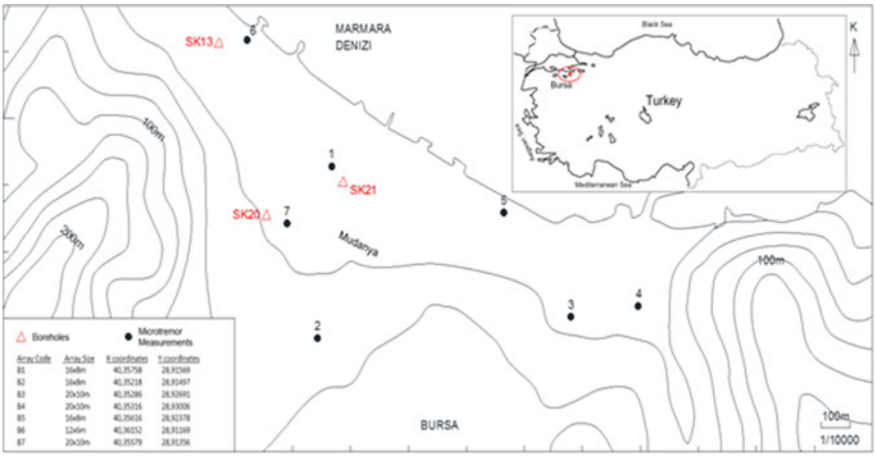

Fig. 1. Locations of site explorations by borings and microtremor array measurements

2 Local Site Conditions

2.1 Regional Geology and Seismicity

Region and in the southern parts of the region includes conglomerate, sandstone, claystone, limestone and marl. The alluvium layer on the shore extends from east to west. This alluvium layer includes clay and is described as sandy clay, sandy gravel and silty.

Rocky outcrops of Triassic mélange are observed in east of the study area. Volcanic units are eocene and neogene andesite in this region. Quaternary old alluvium, swamp and coastal sediments, neogen aged conglomera, sandstone, claystone, limestone and marl are part of main geology of the Mudanya region. In generally alluvium contains clay gravelly sandy clay and silty clay fine grain deposits and there was gravelly silty sand material in coastal sediments. Also, swamp sediments consist of fine grained soil like a silty clay. Neogene sediment deposits that is located south west of region place on triassic metamorphic series and granite intrusion irregularly. Neogene sediments consist of river and lake sediments which can be characterized as soft rocks for the most part of region. Andesites, which are the product of the neogene volcanism are highly deformed and abundant jointed in west of Mudanya region.

Southern Marmara part of North Anatolian Fault Line that is the most active fault in Turkey, placed on the border of the working area and surroundings. When historical earthquakes are examined around Bursa, the most severe earthquakes occured 28 February (Mercalli intensity: IX) and 11 April (Mercalli intensity: X) 1855. The most effective earthquake is expected at Ulubat and Bursa Fault that are parts of North Anatolian Fault Line. Part of the North Anatolian Fault İznik-Gemlik Fault that is placed Located 3–7 m north of the coast and extending East-West and Gençali Foultline that is passing through the lake of Iznik and Eskişehir fault line that came from Eskişehir and reached to Marmara Ereğli, are the most significant fault lines for working area [2].

2.2 Site Explorations and Boring Logs

Observations and drillings made in the sites were used for preliminary information about soil properties. The borehole results indicated that there is a filling layer containing organic materials which is not very dense, between 2 and 4 m from the top of the ground. On the south-western to north-east line, at SK20 and SK21 borings, 4–6 m silt sand layer and about 4–8 m silty clay floors were encountered. Under the clay layers in the boreholes SK13 and SK21, it is understood that the silty sand layer extending as parallel line to the coastal. It has been determined that the groundwater level of the Mudanya district is at 1–2 m depth. In the light of this examination, in the region, where intensive urbanization is, must be examined in terms of the seismic and geological structure of the site, soil properties, bedrock depth and the increase in vibration amplitude during earthquakes. SPT numbers and soil types of the field are shown on the Fig. 2. The SPT-N numbers of soil layers are generally measured as 7–10 blows and reach the highest values of 20–25.

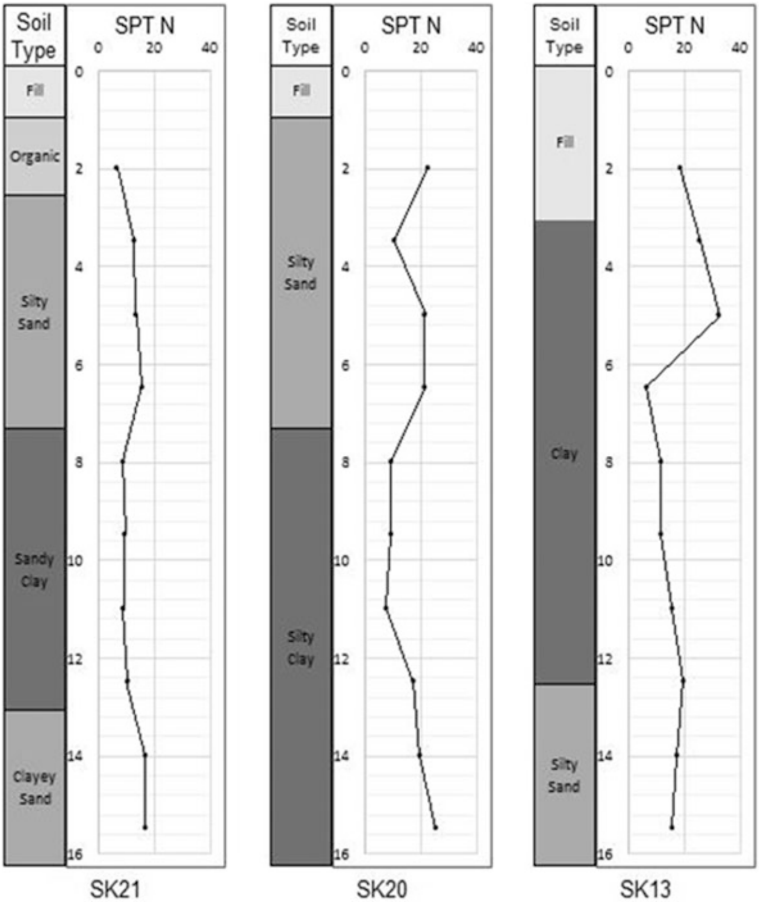

Fig. 2. The soil types of layers and thicknesses with SPT N numbers of borings in residential area of Mudanya-Bursa

3 The Microtremor Array Measurements

It is difficult or impossible to obtain Vs profiles using active-source methods such as seismic refraction or reflection in urban areas. It is possible to obtain shallow (<50 m) profiles due to the high frequencies used by active source in surface wave methods such as spectral analysis of surface waves (SASW) or multi-channel analysis of surface wave (MASW) methods. In order to obtain deep Vs profiles, surface wave methods with passive source based on array measurement of microtremors should be preferred.

The fundamentals of the microtremor survey method is described as detecting the form of dispersion of the surface wave contained in the microtremors and determining the relationship between phase velocity and frequency. After the survey, the band of frequencies relates to the depth of investigation. The longer the period used, the deeper the depth of investigation becomes. Sizes of arrays 10–50 m and 2 Hz geophones are enough for estimating S-wave velocity model of soil layer in most of sites. About 10–20 min of microtremor data record is sufficient for these sizes of arrays.

3.1 Estimating Phase Velocity

In this study, the phase velocities of Rayleigh waves have been estimated by using SPAC method. The method performs computation of cross-correlations between each station pairs on the circular array by analyzing vertical components of microtremors. The array consists of three sensors located on the corners of equilateral triangle and one three-components sensor at the center of the circle. The phase velocities are calculated by using SPAC coefficients ρ(r, w). For different values of frequency w, various combinations of sensor distances r and averaged over all azimuths θ for the determined time segments of vertical components. For the records obtained at coordinates (r, θ) and at the center, ϕ (r = 0, w) is average autocorrelation function at the center and ϕ (r, θ, w) is the cross-correlation function between pairs of data. SPAC coefficient is defined by [3]:

$$\rho(r,\omega) = \frac{1}{2\pi\phi(r=0,\omega)} \int_{0}^{2\pi} \phi(r,\theta,\omega)d\theta \tag{1}$$

Phase velocity calculation contains three main steps as determination of phase differences, cross correlation and spatial auto correlation. The main parameters used to determine the nature of structure, phase velocity c and frequency f are related in the characteristic equation:

$$F(c,f; v_{p1}, v_{s1}, \rho_1, h_1; \ldots; v_{pN}, v_{sN}, \rho_N, h_N) = 0 \tag{2}$$

where v_{pi}, v_{si}, ρ_i and h_i are parameters for the ith layer of the soil layers, P-wave velocity, S-wave velocity, density and thickness [3].

Observations of the vertical component of microtremors show that the phase velocity c in Eq. (2) corresponds to the phase velocity of the fundamental mode Rayleigh wave because of the fundamental mode is dominant mode in the surface wave. This method estimates the phase velocity of the Rayleigh wave from collected dataset of microtremors observed by a circular array for each frequency [4] (Fig. 3).

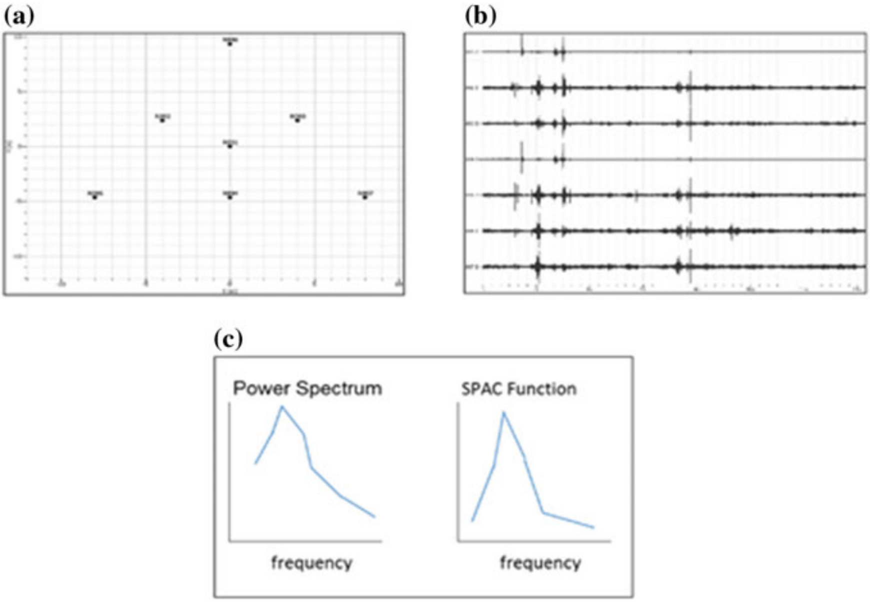

Fig. 3. **a** Array observation schema. **b** Data set. **c** Calculation power spectrum and SPAC coefficient

3.2 Inversion for Soil Structure

In theory, two assumptions are made for to start the procedure: the phase velocity obtained from observation of microtremors fundamental mode of Rayleigh waves and the soil layer under the array of observation is parallel. The dispersion property of Rayleigh waves can be solved considering these restrictions (Fig. 4).

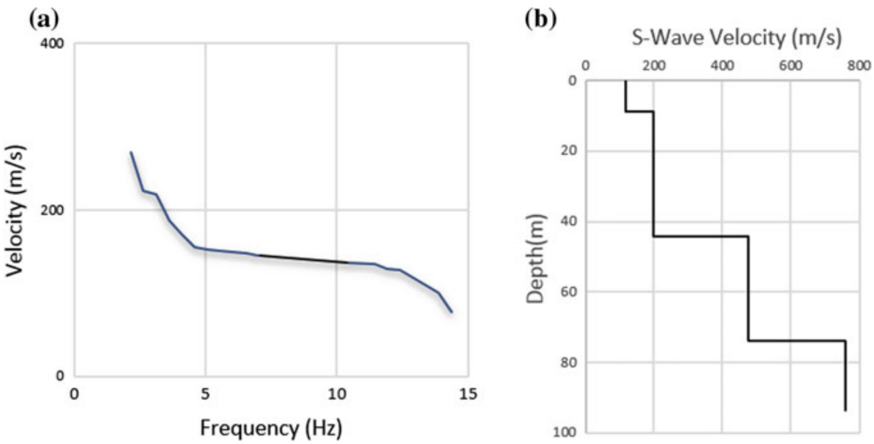

Fig. 4. **a** Estimation of velocities. **b** Layered geological structures

The observed phase velocities are used to estimate the unknown parameters, shear wave velocities and thicknesses of 1-D soil structure model by performing Genetic Algorithm and Simulated Annealing method, generates to optimization by mutation, crossover and selection of individuals in a population [5].

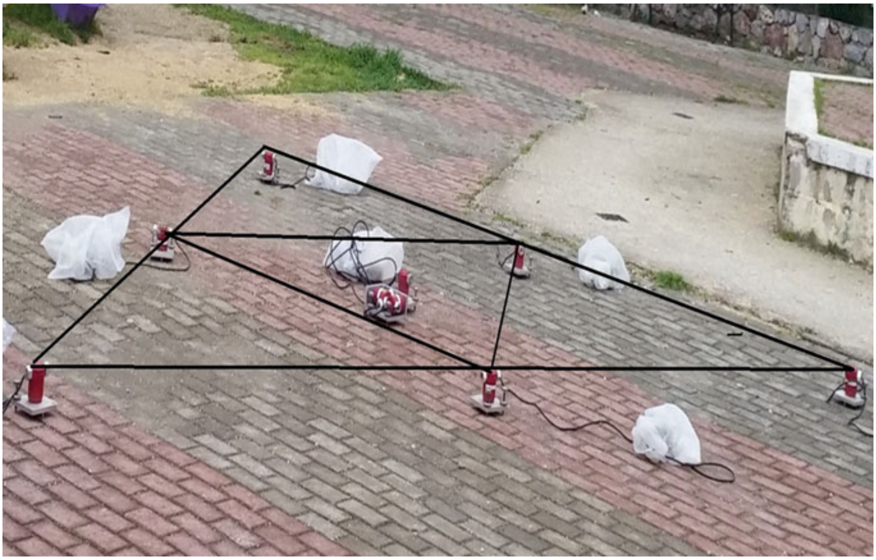

Fig. 5. Array of the accelerometers for microtremor measurements performed Mudanya-Bursa

The dispersion curves obtained by applying the SPAC method to different microtremor measurements at maximum 16–20 m between two sensors at array distances in Mudanya province are shown in Figs. 5 and 6.

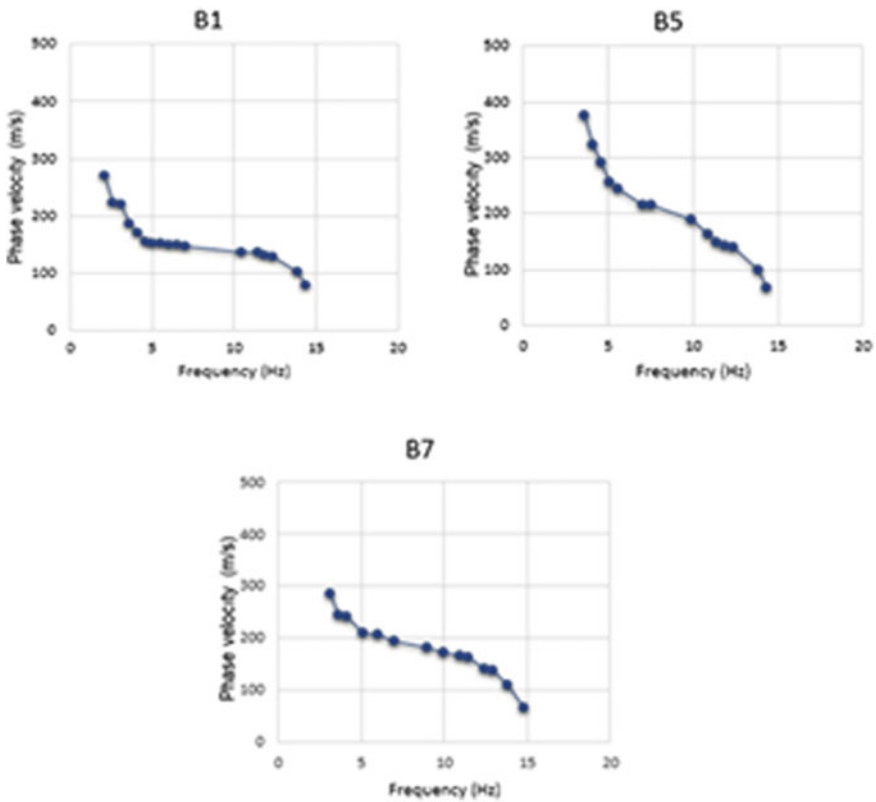

Fig. 6. Obtained phase velocities dispersion curves of different sites of Mudanya-Bursa by the SPAC method

Four-layer models characterized by thickness (h), S-wave velocity (Vs) and the density was assumed to increase with increasing S-wave velocity. Table 1 contains the search limits of each inversion, appointed from dispersion curves (Fig. 7).

Table 1. The search limits and final layer model of average S-wave velocities from inversion

Location of MAM	Search limits for layers		Final consistent layer model		
	Vs (m/s)	H (m)	Vs (m/s)	H (m)	ρ (g/cm^3)
B1	50–150	0–50	118	9	1.80
	150–250	0–50	197	35	1.90
	250–750	0–50	475	29	2.00
	>750	–	>750	–	2.10
B5	50–150	0–50	73	3	1.80
	150–300	0–50	250	26	1.90
	300–750	0–50	484	43	2.00
	>750	–	>750	–	2.10
B7	50–150	0–50	70	2	1.80
	150–250	0–50	199	15	1.90
	250–750	0–50	281	36	2.00
	>750	–	>750	–	2.10

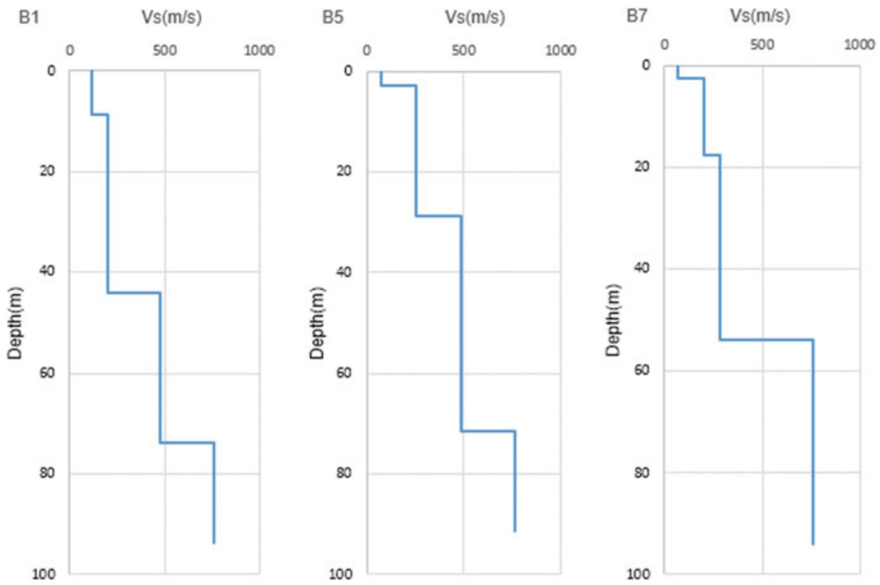

Fig. 7. The S-wave profiles derived from genetic algorithm inversion method for different sites in Mudanya-Bursa

The shear wave velocities calculated with SPT N values and microtremor measurement results for the ground layers. The results obtained by using [6, 7] formulas and the SPAC analyse presented as Vs_{30} for the upper most 30 m were calculated by given equation.

$$Vs_{30} = \frac{30}{\sum_{i=1}^{n} \frac{h_i}{V_i}} \quad (3)$$

i and n denotes the layers and total number of layers in the top 30 m. h_i and V_i give the value of thickness and shear-wave velocity for each layers. Calculated average Vs30 values presented in the Table 2 for different locations. SPT N numbers, obtained from borehole logs, were used by the empirical equations. For the investigation sites, also *Vs* from SPAC results compared with empirical values.

Table 2. Calculated Vs30 from boreholes and microtremor measurements results

Vs30 (m/s)	Borehole SK21 Microtremor B1	Borehole SK20 Microtremor B7	Borehole SK13 Microtremor B6
[6]	186	218	230
[7]	196	228	240
Vs from SPAC	173	222	229

3.3 H/V Results

The soil amplifications were obtained by the formulas in which the shear wave velocity values are used and also ratio between the horizontal to vertical components of the recorded vibrations at single station. H/V method originally is proposed by [8], and wide-spread by [9], consists in estimating the ratio between Fourier amplitude spectra of the horizontal to vertical components of the ambient noise vibrations recorded at single station [10].

The H/V method includes following steps,

Record a 3 components noise signal.
Select the most stationary time windows.
Compute Fourier amplitude for each windows.
Calculate quadratic mean of two horizontal components.
Compute H/V ration for each windows.
Finally calculate the average of H/V ration [11].

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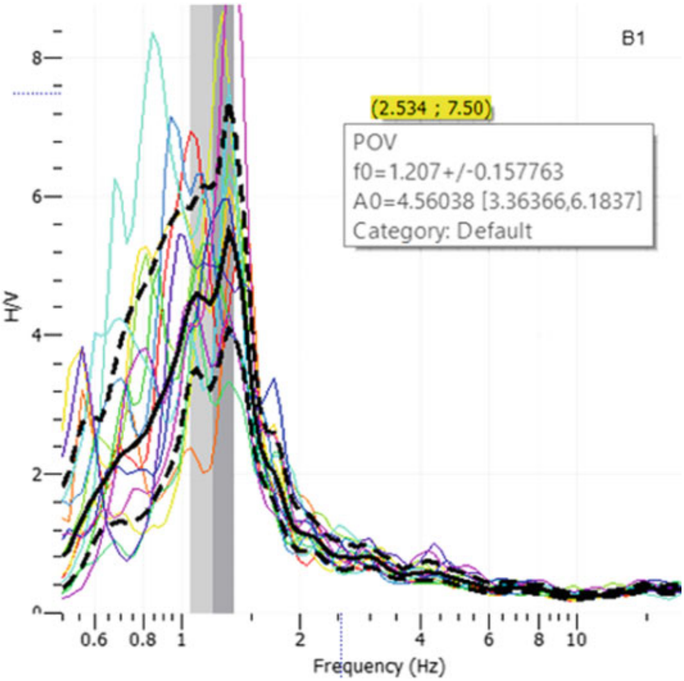

Fig. 8. Measured amplification and predominant period by microtremor measurements

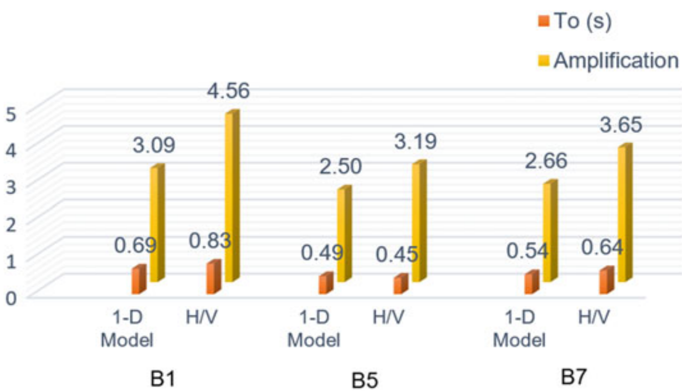

Fig. 9. Amplifications and predominant periods (T0) obtained by 1-D layer models and H/V ratios

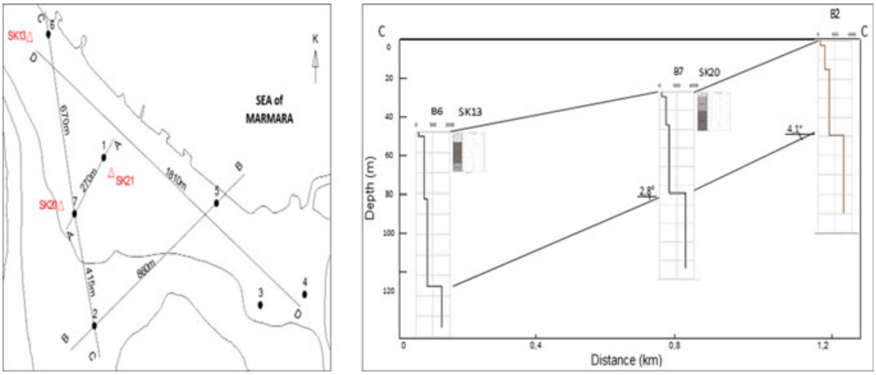

Fig. 10. Deep and shallow soil properties on the sections obtained by microtremor measurements and boreholes

In the regions where structural damage due to soil behavior is predicted to occur, site specific dominant periods and amplification values are determined by using in situ tests, drilling logs, laboratory test results and outputs obtained by field seismic experiments to be performed within the scope of the study. In addition to the effects of differences in earthquake magnitude, distance to epicenter and soil properties, the probable effect of the inclination of the engineering bedrock is tried to be determined by two and three dimensional analyzes. In this context, microtremor measurements can be used to establish the large depth two- and three-dimensional soil models needed to detect the effect of the slope basin edge on the vibrational amplitudes of the ground during earthquake movements [12].

The soil profiles, containing the information of layers, obtained from the data of boreholes and with results of microtremor SPAC analyses are given together in Fig. 10. In these profiles, it was determined that the slopes of engineering bedrock in Mudanya region had a minimum 2° and maximum of 5°. The B-B and C-C sections clearly show that the slope of the basin has a gradient of 4.5° from the inside of Mudanya to the seaside.

4 Discussions and Conclusions

Ongoing geotechnical researches are on the forefront of determination of sustainable design, the appropriateness of the site to be constructed, the improvement and the reusability of existing structures and the improvement of building site conditions to extend the pre- and post-construction lifespan.

Furthermore, it is obvious that the methods of investigation must overlap with the sustainable construction process. For this reason, as well as in situ tests and traditional lab experiments, the developing seismic methods can be preferred because of their low cost, easy application in a short time and almost no damage to the environment. Thus, microtremor array measurements can be employed in pre-design reviews without high resource. So, it should be achieved more consistency of the site investigation results and should be reached the targeted costs of construction. Through the development of investigation methods, the design against the dynamic effects reduce design mistakes caused by incorrect selection of construction areas and using questionable soil parameters.

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The Importance of Geological Conditions' Effects on Construction in Landscape Planning in Turkey

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Abstract. The development of the majority of the cities in Turkey from the point of urbanization were occurred without regard to the effects of the geological conditions of the region that were founded in the past. The settlement, transportation and industrialization greatly influence the natural environmental balance in a region. It is necessary to control the effects of such a development on the natural environment in order to prevent possible damage. For this reason, in addition to the social, cultural and economic conditions of the region, the geological and geotechnical conditions must be assessed very well. However, an urban development envisaged in such as principle may be a living city life with settlement, transportation and industrialization. It is an inevitable necessity and a responsibility at the same time to evaluate the geological structure of the ground, the geotechnical properties and the geological environmental conditions. The possible effects on the construction must be observed very well prior to the construction. The necessary precautions at the same time in the field of urban development are especially regarding the construction problems. In today's urbanization, especially in the construction sector, the importance of geology can only be understand after the events such as earthquakes, floods, landslides, collapses and destruction, which are caused by geological reasons and property destruction caused by them. In this study, the place and importance of the effects of geological conditions in Turkey are investigated and the solutions tried to be proposed.

Keywords: Landscape planning · Geology · Construction

1 Introduction

Geological studies in the urban planning process are generally in two stages. The first stage is the "geological and geotechnical study" which would be the basic for the development plans before the zoning plan made. The second stage is the "soil investigation" that would reveal the ground-foundation-structure interaction required for the design of the structures to construct in the course of implementation decisions after the zoning plan completed [1].

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The main factors restricting urban development are steep slopes; landslides; the wide distribution of problematic soils; flooding; and surface subsidence caused by underground mining. Information theory has been applied to predict the slope susceptibility. The area of surface subsidence caused by mining at present and in the future is delimited using a finite element method. The factors closely related to land use planning are: slope susceptibility and landslides; flooding; collapsible soils; surface subsidence related to mining; and the low bearing capacity of a bearing layer. These are combined to produce uniform engineering geological units. The result of a suitability assessment of the study area is illustrated in the form of a rational land use-planning map [2].

Geomorphology is fundamental to landscape analysis, as it represents the main parameter that determines the land spatial configuration and facilitates relief's classification. For the integral analysis of landscape, a mapping methodology has been set. It comprises a valid criterion for rational and sustainable planning, management and protection of natural spaces [3].

Field observation and GIS analysis indicated that the landscape could be divided into three units along a gradient ranging from the coast to inland locations, based on geology, soil properties, and dominant vegetation [4].

Urbanization has been emerged as a phenomenon of architecture and urbanism. It is a feature that is known for selecting the place in the city planning and for determining the type of building in architecture. It has also to take care of geological and geotechnical characteristics into consideration in choosing the right, sustainable and natural disaster-free place for urban settlements. According to the location of Turkey to the world, all of the majority cities in Turkey have been developed in terms of urbanization, regardless of the geological and geotechnical characteristics of the region. In this research, the importance place of the effects to the geological conditions in land planning in Turkey are investigated and the solutions tried to be proposed.

2 Urban Geology and Geotechnical Applications

Urban Geology is a relatively new branch of the earth sciences that came into life in the past fifty years. It is the study or application of geology to urban centers, urban development and planning. The importance of geology as applied to cities has been stressed repeatedly [5].

Urban Geology is not only important for every urban center or city, it is also cite specific. Each city with its unique set of geological settings and geological constraints poses different or unique sets of problems for the engineers and developers. Since all construction and development works are sited on/in earth materials, geology will indicate the types of problems that are encountered at each site/city.

The last decades, globally, many geological surveys and other institutes have operated "Urban Geology" programs aiming to provide up-to-date information on ground-related issues for the towns and cities. Through the collection and compilation of geological data, Urban Geology projects contribute:

- to the identification and evaluation of geohazards,
- to the development of countermeasures to reduce them,
- to the preservation of urban and surrounding environment [6].

The role of geology and geotechnical information is increasingly becoming important, as legislative changes have forced developers, authorities' planners and regulators to consider the implications and the environment of large-scale development initiatives. Geological and geotechnical investigations that include the details compatible to the planning scale before the planning and design of a city have an indispensable significance in the evaluation of suitability for settlement and land use decisions.

Geological, geophysical and geotechnical limits of the zone has a significant impact on the economy of the urbanization project. The urban planner, in particular, plans and controls assumes full responsibility for the use of land in the direction of geological engineers.

Today, however, the importance of geology in urbanization, especially in the construction sector, can only paid to the people and the public after events such as earthquakes, floods etc. The most important cause of this situation is that the limiting effects of the geological environment have not been adequately considered and assessed in many construction projects and urban planning in general and the necessary measures have not taken in time. Many events are the products of this ignorance, indifference and irresponsibility experienced in all big and developing cities including the capital Ankara [7].

Urban geology; can be defined as the study of geological risk and land resources as they affect to the development and growing or extent of urban areas. For an area where urban planners are thinking to elaborate, their question to the geologists or geological engineers can gather in two main categories:

- Potential land use areas
- This potentially controlling geological limitations.

For example, use of geological limitations for the same area, green space, parking area and raised buildings; and interpret those to the non-lay persons by planners.

2.1 Geological and Geotechnical Parameters of Urban

The main phase of creating sustainable, durable and safety cities is to carry out of natural structures by comprehensive investigations (geological, hydrological, engineering geology, geotechnical, seismicity, natural resources analysis etc.) The main basics parameters that can influence the selection of location in city planning [8]:

1. *Topography*: The topography of an area foreseen for urban planning is the most important parameter that can influence location selection. Because; some high buildings have built on high elevations. On the other hand, topography is also a parameter that controls transportation plans. In Fig. 1 a horizontal plane has been inserted into the three-dimensional representation of the above topographical map.

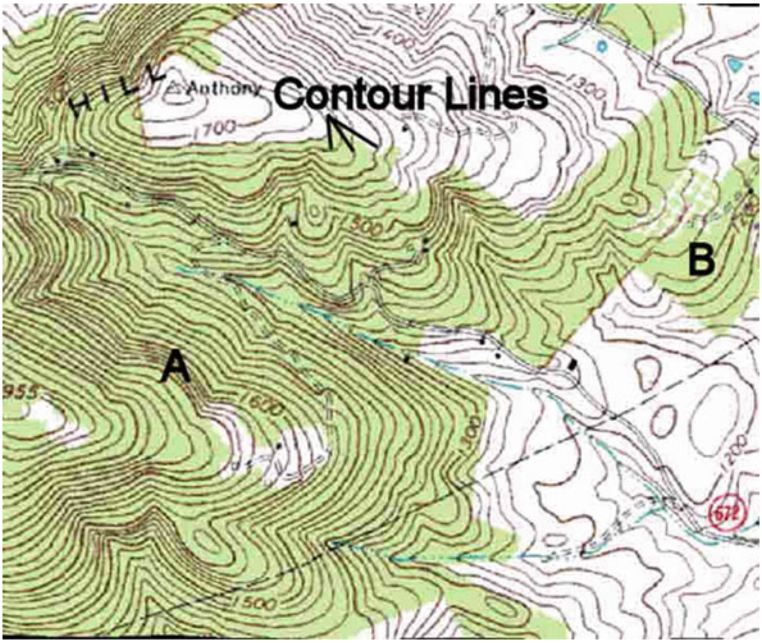


Fig. 1. 3-D topography map

2. *Geological Structure*: Geological structure guide the mining process. Geology structure is the first stage to the regional geophysical and geology surveys aiming at identifying new mineralized provinces especially the big cities of Turkey. Without the input of the geology structure, no geological, no geotechnical, or geophysical study can be done. Hardness, permeability, deformation, erosion, faulting and strength will also affect the geological structure and the choice of the place to build for the buildings to be included in urban planning. Geological structure of the region, will affect the choice of location, base type and depth for some buildings to be included in urban planning.

The distribution and thickness of the geologic units are controlled largely by the tectonic events that produced the basins, uplifts, and associated faults (Whitehead 1996). Diagrammatic sections illustrating the association between generalized stratigraphy and the principal structural features are shown in Fig. 2.

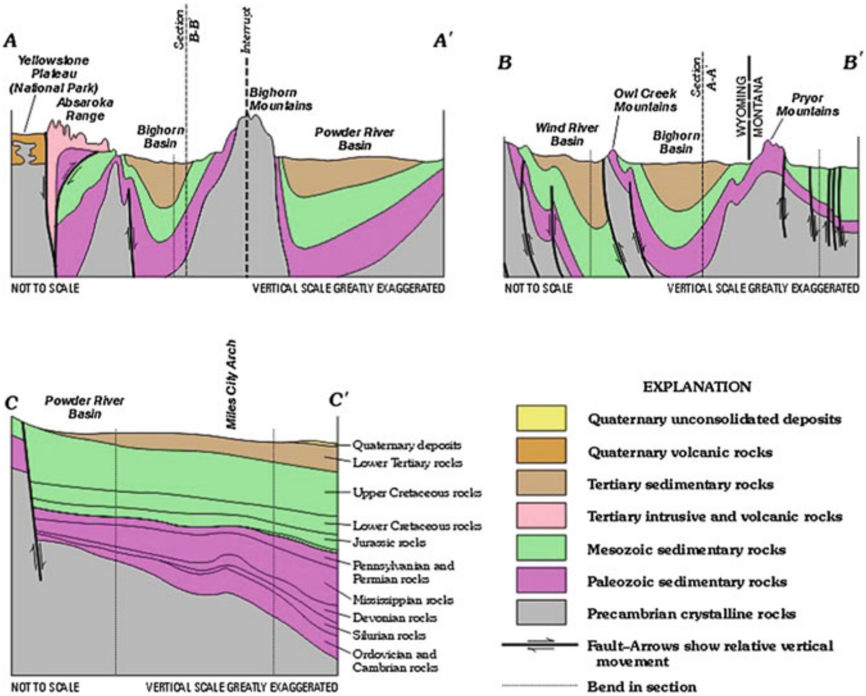
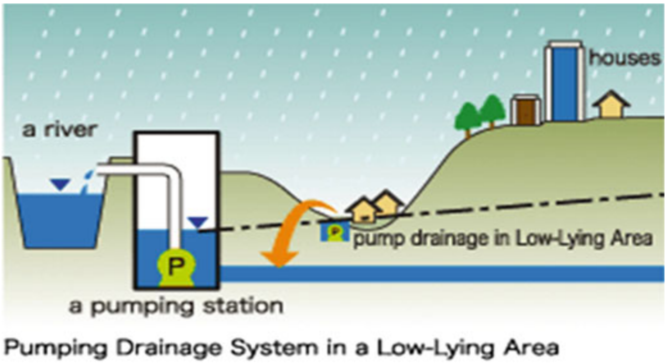


Fig. 2. Diagrammatic sections showing principal geologic structures and groupings of geologic units

3. *Hydrogeological Conditions*: Hydrogeological is the study of the interaction between groundwater movement and geology. Whether it is necessary to meet the drinking and utility water requirements of the city. The hydrogeological conditions of the planning area need to assess very well.

Construction of a large stormwater drainage facility is time-consuming and it may not completely prevent extremely localized floods from occurring in low-lying areas.

Accordingly, Fig. 3 shows that the city is taking localized flood control measures including development of a rainfall information system, construction of storm water reservoirs in such public spaces as parks and schools, and construction of local drainage pumping facilities.



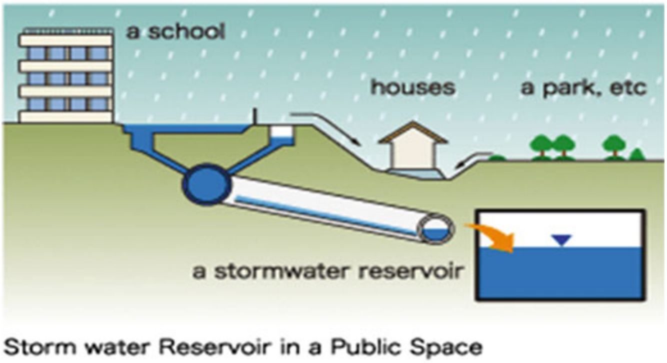


Fig. 3. Local flood control units

4. *Climate Conditions*: Depending on the climatic conditions of the region, daytime temperature differences, amount of precipitation in urban area, the climate of a location is affected by its ground, place, weather and location conditions. To understand the climate conditions involves a variety of aspects of weather and the situation of how air moves and acts to the surface of the Earth. The climate conditions of an urban would be located according to/of its ability to thrive; and after urban placement can be affected by the climate control of an area.

Figure 4 shows various factors that determine a places climate: Latitude, Altitude, Heating of Water bodies and Land Masses, Continental Effect, Air Pressure, Solar Radiation/Angle of Sun, Maritime Influence, Sea Breeze Land Breeze, Cloud Cover and Ocean Currents.

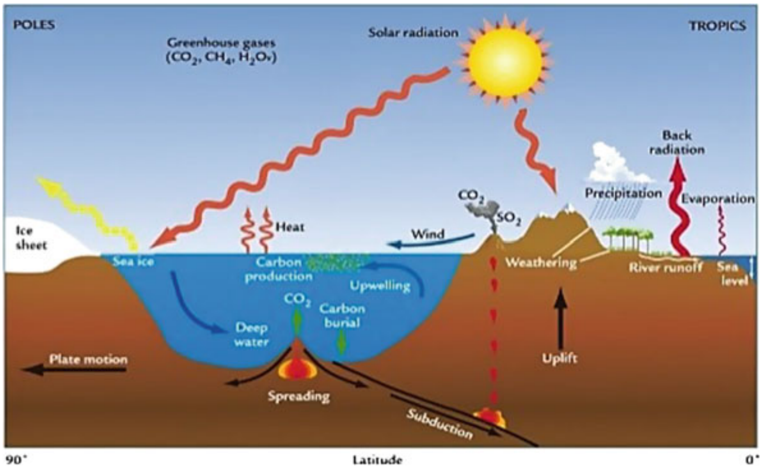


Fig. 4. Factors that affect climate

5. *Building Materials*: The structure materials of an urban have been selected to construct building or other structures' architecture. The study of geological and geotechnical characteristics of the city's construction, is required for the construction of structures located in or near the urban area. It is an important issue directly related to the geology of the region.

Choosing the correct quality of construction materials can sometimes prove to be difficult. Some of the critical construction materials like cement, steel, concrete etc. need to be of the highest quality as these are the essential "backbone" of any construction endeavor. The suitability of these materials for construction purposes can be established through rigorous testing (Fig. 5).

Fig. 5. Construction and building materials

3 Suitable Site Selection in Landscape Planning

Urban planning requires that many disciplines work together. City planners together with architects, landscape planners, geologists, civil engineers, geographers, public administrators, sociologists, lawyers, etc. work together. Urban planning is a group work. Decision-making in planning, specialists will involve in this work group in gathering and interpreting the necessary information in stages. After the collection of necessary data, the city planners play an active role in the use and interpretation.

The data is also influential in the hydrological cycle on and over the natural environment. For example, transportation-engineering studies are required for the route selection of the highway, railway, viaduct, bridge etc. that constitute the detailed network. Route selection made in order to avoid problems of collapse, stability etc. due to the geology of the environment, structural geology and hydrogeology.

Another example, Ecological expectation, water resources and their distribution and geological areas are very important in selecting the dam site. Dam site survey is an engineering geology study. The dam, which built on the selected area, also changes the ecological balance and land use in the immediate vicinity.

The hydrogeological features of the environment take an important place in the selection of settlement areas. Incorrect site selection causes contamination of surface resources and underground spring waters. Besides, it can create stability problems and trigger mass movements [9].

The geological analysis should give importance in the future planning of residential areas. Geological hazards such as earthquakes, floods, landslides, erosion etc.… may be considered for the geological environment. The selection of the most suitable place for different buildings and applications in city planning, the selection of the parameters are necessary to reveal how much they overlap with each other. For the new buildings, traditional place areas and constructions, old lost wells or holes contributes to deforestation, draining and filling of wetlands, disruption of groundwater flows, degradation of the environment, etc.

Micro zonation maps and documents, settlements and development areas improve the living condition of their residents, manage the natural resources in a sustainable condition and can develop the capacity to sustain their production. Advances in geoscience enable such documents to make more precisely today and to measure with a greater number of parameters. From this point of view, it is necessary to develop a new generation urban database primarily for the high-risk settlements.

A well-designed landscape can provide years of enjoyment for your family, and significantly add to your home's value. All good ideas begin with a plan. Homeowners that begin their landscape without a developed plan may end up less than satisfied with the results. Often, a home landscape is accomplished in individual, separate steps that do not coordinate as well together when completed. This is because an overall idea was not formed and resolved first, from which the individual components can then be completed. A plan is actually the result of a logical series of decision-making.

A site analysis is an evaluation or judgement about the conditions of the site elements. Figure 6 shows that a site inventory should include:

Locations of steep slopes, drainage swales, and where site water is draining.

- Soil types and characteristics.
- All existing tree, shrub and other vegetation types and locations.
- Locations of sunny and shady areas of the property.
- Summer and winter wind directions.
- Existing building and neighborhood architectural styles.
- Locations of storage and functional use areas [10].

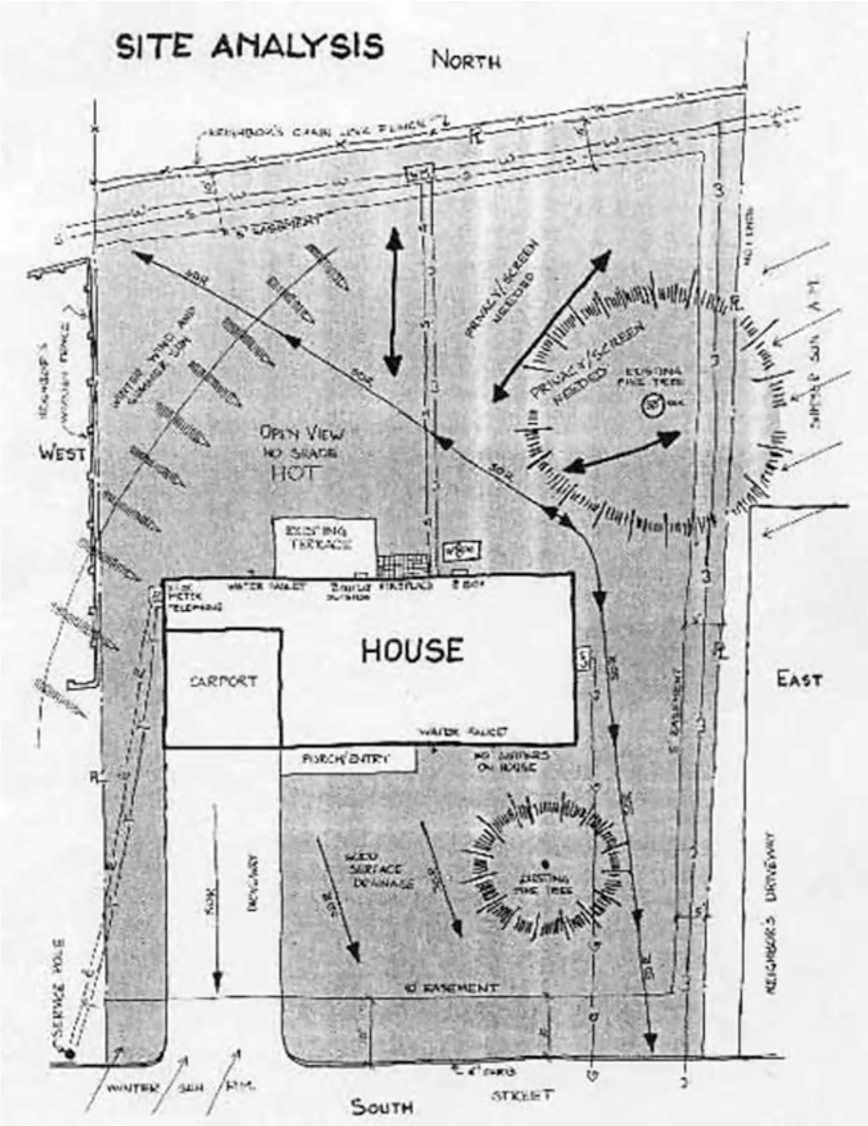


Fig. 6. Site analysis in landscape planning

4 Conclusions

A rational city planning make the attention to all structures of contemporary urbanization. It includes buildings, roads, bridges, industrial facilities, water reservoirs, green areas, waste storage areas etc. Geological and geotechnical factors should be evaluated separately and together, requires that Field Use Maps based on scientific data be prepared using computer and Geographic Information System (GIS) techniques.

Contemporary urban planning also requires that urban planners and all other interested engineers, persons and organizations have a constant dialogue and cooperation in this regard.

In the creation of the earthquake resistant cities, geologist, geotechniciens, engineers, architects and planners should determine the geologic hazard processes in advance and for the reduction of damage. The required precautions should been take the place in an interdisciplinary work.

For that, the main research is to conduct the geological, geotechnical and geophysical analyses that will orient the suitability for settlement and land use decisions.

As in Turkey and as in the world, the primary objective of the planning urban is to create the healthy, reliable and durable living spaces. At this view, generally earthquakes and their effects in Turkey are located on the seismic belts of the world.

According to the legislation, it is a legal obligation to carry out the geological and geotechnical investigation and the soil surveys for the structures, which are essential to the zoning plan, and the control and application control related to these surveys increased.

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An Overview of Urban Transformation Applications in Eskisehir (Turkey) After the 1999 Earthquakes

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Abstract. Cities transformed by their own socio-cultural, economic, political and technological processes from their existed period. An urban transformation project should be planned from a variety of angles such as physical, economic, social and environmental as well as legal, institutional, financial and partnerships to the implementation of the project, and transformation programs should be prepared. In urban transformation projects, it should aimed to develop strategies to restore economic viability in urban parts that have become physical and social depressions, thereby increasing urban welfare and quality of life should also be the other side of the concern. The construction sector is the locomotive sector of the economy all over the world, with the production and the employment provided by the dozens of sub-sectors attached to it. The Turkish construction sector has an important place in the development of the country. In recent years, urban transformation projects in our cities have progressed very rapidly. This process is taking place in Eskisehir after the 1999 earthquakes. However, there are many economic, social and legal problems in this process. In this study, the urban transformation applications in Eskisehir after the 1999 earthquake is evaluated and solution proposals are presented.

Keywords: Urban transformation · Construction sector · Earthquake Eskisehir

1 Introduction

Parallel to the diversification of human needs, cities have always been at the center of change and transformation. Urban transformation gradually emerges in the transformed world system, where the basic factors such as the urban growth of the city and the randomization of the capital accumulation processes in space are changing day-by-day. With the urban transformation applications, it aimed to reveal the quality and livable areas with the social welfare of the people living in the problematic regions in economic, cultural, social and physical direction. Urban transformation, which takes its source from legal regulations, was put into practice in many regions of Turkey. Thus, urban transformation turned to be the most important tool in urban planning [1].

The city of Eskisehir was among seven cities affected by August 17th Marmara and November 12 Duzce earthquakes. At this time, as it occurred during previous years,

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earthquakes caused much more damage and loss of life. Similar structural damages, which were observed highly in reinforced concrete structures caused by previous earthquakes in Turkey, also seen in structures exited in Eskisehir.

In first part of this study, the meaning, purpose and implications of urban transformation are tried to be clarified. In the second part, the legal bases of urban transformation applications in Turkey will be discussed. In the last part, after the 1999 earthquakes, urban transformation applications in Eskisehir (Fig. 1) evaluated and solution proposals presented.

Fig. 1. The location of Eskisehir city in Turkey

2 Urban Transformation

Today, the concept of urban transformation integrates with such as transformation, revitalization, livable spaces and the prosperity of people. However, the rhetoric that has taken place as an urban transformation has actually found an identity in the transformation of different forms by a forced intervention in urban areas. From this point of view, it is more realistic to perceive the concept of urban transformation as urban transformation [1].

With the simple expression of urban transformation, the destruction of the uncertificated buildings that do not comply with the urban development plan and instead the creation of new collective settlement areas in accordance with the urban plans [2].

Even with the recent legal amendment, 6306 Number of Law on the Transformation of Areas under Disaster Relief, the dimension of the interventions made by the urban transformation has completely changed and now it becomes interested in the whole of the cities that have gone beyond the slum areas.

2.1 Purposes of Urban Transformation Applications

The main aims of urban transformation; Physical and environmental objectives, economic objectives, social objectives and cultural objectives (Fig. 2).

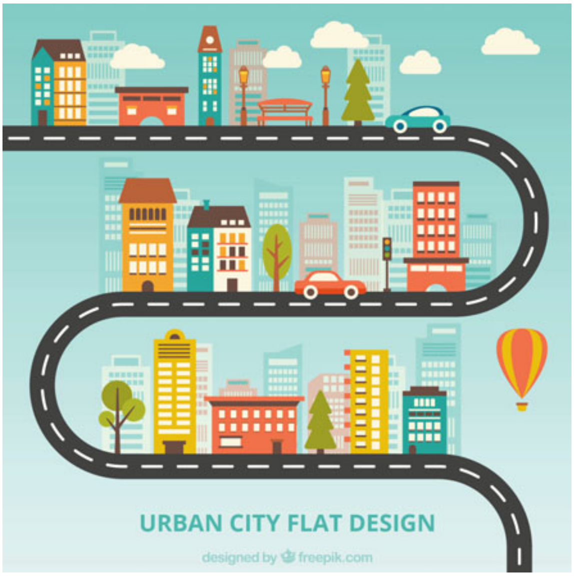

Fig. 2. Urban transformation applications

Physical and environmental objectives; improving environmental conditions, enabling people to live in more peaceful environments, integrating people with their living spaces, increasing the quality of urban life.

Economic objectives; full revitalization of economic life; put forward an economic development approach that enhances urban peace and quality of life.

Social objectives; determining the depressed areas that become a social problem in the urban transformation areas and as soon as possible solving the social problems.

Cultural objectives; transfer of cultural heritage of cities to future generations, preservation of natural, historical and cultural touch [3].

2.2 Purposes of Urban Transformation Applications

The ways in which urban transformation implemented in the world covered under eight basic headings. These briefly listed below in the headings:

2.2.1 Urban Clearance

Field cleaning; in the urban areas of the cities where the cities in collapsed, the physical touch is totally destroyed and replaced with new ones and these areas are brought to a new texture.

2.2.2 Urban Revitalization

Urban revitalization efforts implemented in cities where there is a loss of population, high unemployment, and physical stress.

2.2.3 Gentrification

Gentrification; Socio-cultural and aesthetic significance has been lost, has suffered a collapse, the physical environment has been degraded in the areas of social structure is to be rehabilitated.

2.2.4 Urban Quality Improvement

Promotion of urban quality; socioeconomic status and the quality of life of the people living in urban transformation areas without significantly changing the quality of life.

2.2.5 Urban Renewal

Urban renewal; Is the resetting of the whole of the structures or the part of the structures in the areas where there is no possibility of improving the living and health conditions in terms of the situation of the existing structures.

2.2.6 Urban Restructuring/Development

Urban restructuring or development is the process of expropriating, clearing and reconstructing a pre-built area in accordance with a city-level vernacular plan that reflects long-term land use and population policies, altering the existing land use and changing the distribution pattern of the population.

2.2.7 Urban Regeneration

It includes meanings such as revival, reproduction, recreation. According to this, urban regeneration means that a new structuring movement entered into the depressed areas where the cities have lost their function.

2.2.8 Urban Rehabilitation

It is a rehabilitation of urban areas developed in a planned manner but have lost their value over time, worn, densely populated and unable to function, and infrastructure services usually provided to the slum neighborhoods and this method applied for smooth and low-density areas for the new slum settlements.

As it can see, at the core of all concepts lies the urban interventions directed towards the lost functions of the cities. At the beginning of all these separated aspects of the applications are conceptualizations under different names according to certain purposes. There are also great differences between these concepts in terms of methodology. Between each concept, the nature of the applications, the scope and the consequences of the dissociation observed [4–7].

3 Development of Urban Transformation in Turkey

The history of urban transformation in Turkey dates back to the Ottoman Empire. 1838 Trade Agreement, 1839 Tanzimat Edict, 1859 Islahat Edict and 1858 Land Code were issued in the Ottoman Empire (Fig. 3) for the first time to transfer property lands to the persons and to provide the raw materials needed by the Western countries and to regulate the agricultural infrastructure and property relations in agriculture. Twenty-five years after the publication of the Republic, intense migrations to Ankara began in the process of developing with the influence of Marshall Benefits. These slum regions have become a big problem since they started to migrate to Ankara with the beginning of slum and lack of infrastructure and planning over time [8].

Fig. 3. Ottoman Empires of sultan’s

When the slum areas became a problem, in 1948, the “Law 5218 Number of Law on the settlement of residents of municipalities and the state in Ankara” issued for the first time in Turkey. With the amendment made, new areas opened in the capital and the spread of slum rapidly increased. This law applied primarily in Ankara to rescue the capital city from the slum problem. This law later enacted and enforced as “5228 Number of Law” covering the whole country [9].

3.1 Legal Status of Urban Transformation Applications in Turkey

Urban transformation applications implemented in Turkey in order to solve many problems such as physical, economic, social, cultural degeneration and environmental degradation that take place in long-run cities. In this framework, different legal arrangements and practices regarding the subject passed on. Especially in the process of European Union harmonization, the introduction of action planning period in urban transformation applications has increased the importance of legal regulations and legislation. When assessed from the perspective of the legal basis and the relevance of certain laws to the practices of urban transformation, the date of entry into force of these laws in Turkey is as follows:

(1) Law No. 774 on Slum (20.07.1976)
(2) Mass Housing Law—The Law on Mass Housing No. 2487 (17.03.1984) and the Law on Mass Housing No. 2985 (02.03.1984)
(3) 3194 numbered Law on Reconstruction (03.05.1985)
(4) Law No. 5104 on Urban Transformation Project North Ankara Entrance (04.03.2004)
(5) Metropolitan Municipality Law No. 5216 (10.07.2004)
(6) The Law No. 5366 on the Renewal and Protection of Historic and Cultural Immovable Properties (14.12.2005)
(7) Municipality Law No. 5393 (03.07.2005), Draft Law on Transformation Areas Law Amending the Municipal Law No. 5998 (03.07.2005)
(8) Support for the development of forest villagers Numbered 6292 and the evaluation of places excluded from the forest boundaries on behalf of the Treasury and the Law on the Sale of Agricultural Land to the Treasury (19.04.2012)
(9) Law No. 6306 on the Conversion of Areas under Disaster Relief (31.05.2012)

If the contents of on Municipal Law No. 5393, Amendment of Municipal Law No. 5998, and Laws on the Conversion of Areas under Disaster Relief No. 6306, which are important laws within the legal process of urban transformation applications, The first regulation on municipalities, which is the mainstay of urban transformation practices, has become Municipal Law No. 5393.

Another important legislative act concerning municipalities; with the amendment to the Amendment of the Municipal Law No. 5998, Article 73 of Municipal Law No. 5393 amended. Regarding this legislation, all kinds of planning authority gathered in the metropolitan municipality. County municipalities kept out of this. All the areas within the borders of the municipality meant by the provision that all areas with durability or uninhabited structure can declared as urban transformation areas. This legislation has been the subject of many criticisms in the sense that it could lead to the potential to make urban areas of transformation into many areas [7].

The latest development that broadens the scope of both laws in this regard is the legal regulation on the transformation of areas under disaster relief numbered 6306 issued in 2012. The law states "The principles of improvement, liquidation and renewal of the establishment of healthy and safe habitats in the areas under risk of disasters and in the areas and lands where risky structures are located outside these areas" (Law article 1) arranged in detail.

4 Applications Urban Transformation in Eskisehir City

The city center of Eskisehir (Fig. 4), on the alluvial floor around the Porsuk River and around the risk of liquefaction, has not been a healthy building since 1970s. The process of continuing with the adjacent order, the transition from the low floor to the multi-floor, the apartment building has formed a dense housing texture in the city center. This dense housing structure is unqualified, aesthetically deprived and disaster risk due to economic inadequacy, inappropriate use of materials (such as Eskisehir Sand), and lack of adequate architectural and engineering services. Due to the current building stock, new green areas and social facilities cannot constructed. The fact that the city is single-centered and especially over-growing in the west increases the problems of transportation every passing day.

Fig. 4. The city center of Eskisehir

After an earthquake of 6.4 magnitude in 1956, an earthquake close to this magnitude centered on Eskisehir-Inonu not encountered. The 1999 earthquakes that lived in our country affected by the fact that the average distance to Eskisehir city center was around 200–250 km, but did not cause much damage in terms of structure. In the 1960s, housing texture was not more than three floors. Therefore, it is very difficult to comment on the performance of the building stock that formed since the 1970s. This could mean a catastrophic disaster that would create very serious losses for our city in a possible earthquake (Fig. 5).

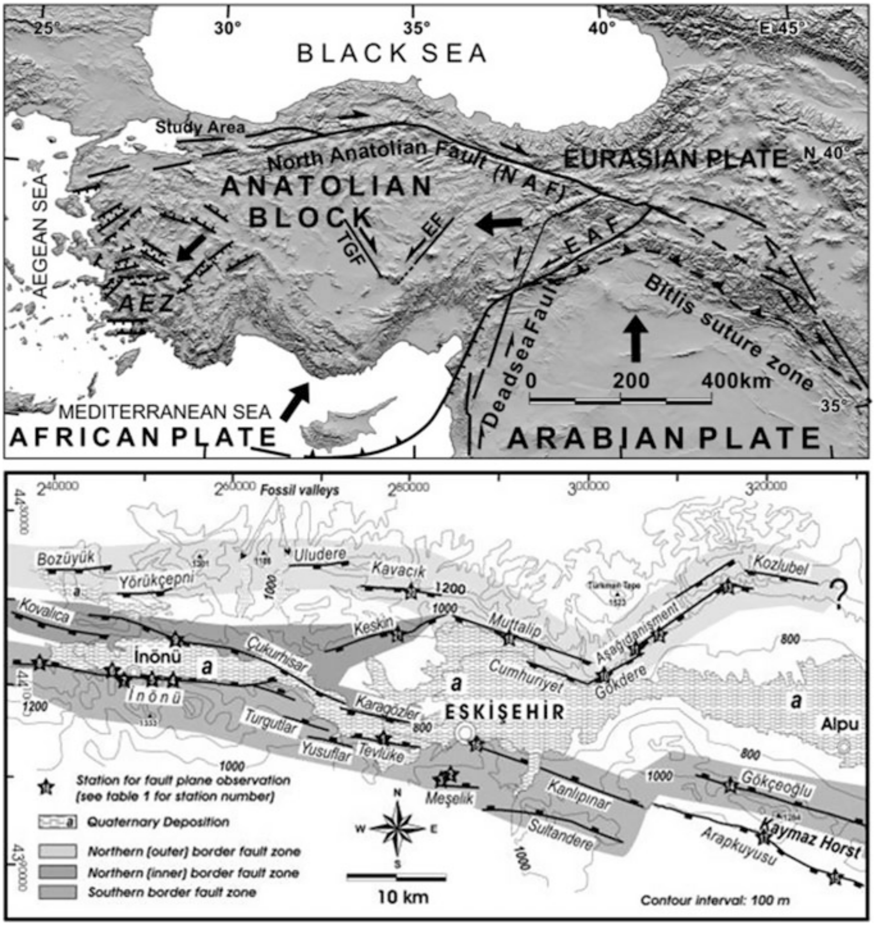

Fig. 5. The fault map of Eskisehir city

Eskisehir is one of the most difficult areas for urban transformation. The building density is very high. The city center trapped and cannot be spread and the application of these laws and regulations will be an important step for planned urbanization and healthy restoration. The determination of risky structures based on parcels will bring more burden on the conversion cost and will most likely lead to the reproduction of the same texture, as well as the intensification of desire to increase density and pressure on the parcel-based increases in density plans.

Eight districts (Mustafa Kemal Pasa, Ihsanıye, Hacıalıbey, Yenımahalle, Isıklar, Mamure, Deliklitas and Kurtulus) (Fig. 6) which declared as “Disaster Risky Area” in Eskisehir based on Law No. 6306. Implementation of specified projects and programs, reproduction of the same touch is very difficult. However, if it succeeds, it will be a good example for other risky areas in our city.

Fig. 6. Eight district map of Eskisehir city in disaster risky areas

There are some anticipations and worries of property owners in these seven neighborhoods:

(1) Safe construction and more development
(2) Reviving your rights
(3) State guarantee
(4) Not to be from the place where you live.

The following alternatives can applied to meet as much as possible and to avoid concerns. First, goodwill should be determined for all residential and business establishments.

The First Alternative; on the island-based basis, the right to choose the one with the highest honor should be given first.

The Second Alternative; parsed satellite urban areas in modern, planned, densely built areas outside the city where the municipality has will have to be created and land should be given priority to the owners of the risky areas in this area again according to the honor. For example, it thought that 100 and 1000-m^2 land would give.

The Third Alternative; property owners according to honor by the municipalities in the planned modernized areas that the municipality owns and which are to be built outside the city. For example, apartments may offered up to three times the size of their property [10].

4.1 Road Map for Disaster Risky Areas in Eskisehir City

Within the scope of the determinations made, the transformation of the areas under disaster risk should be considered with a comprehensive and holistic understanding on the whole of the city, especially the city center which is the busiest commercial and residential area, which carries the greatest risk in the city. At the same time, Directional strategic action plans should established. In this action plan, risky areas, unhealthy urban spaces, areas to protect must identified so that the type of intervention to implement can be determined before the risky area is declared.

In Eskisehir city, it is necessary to transform the dense housing that is single-centered, unqualified and carries disaster risks. For this purpose, the proposal of new centers to reduce the density of the city center and the creation of sample living areas should considered within the scope of the solution. The newly proposed center should offer a sustainable spatial structure, not just the residential areas, but commercial and administrative centers should designed in such a way that the functions, the working areas, take place. Agricultural areas, forests and wet lands must protected. After these centers planned and after the usage opened, reconstruction movements in the existing city center frozen, re-planned, and constructed [10] (Fig. 7).

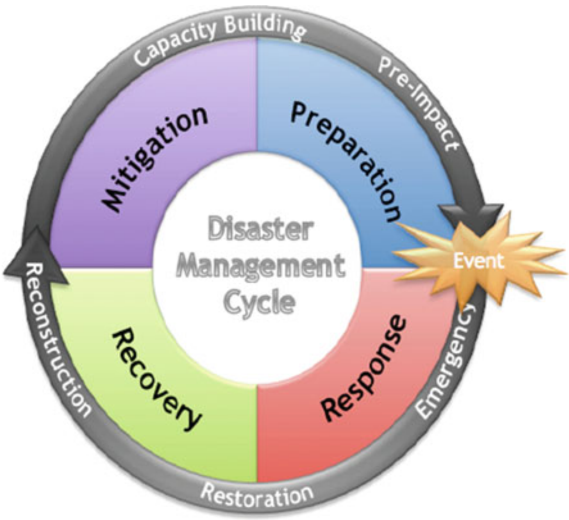

Fig. 7. Disaster management cycle

5 Conclusions

Throughout history, cities have become the center of civilizations. Transformation in a globalizing world, especially transformations, has become an important phenomenon affecting cities. Physical, economic and social problems, which are a consequence of unplanned urbanization, have increased day-by-day and different solutions sought for similar problems in the world and in Turkey.

Urban transformation applications, a tool of urban planning for solving these problems, have become popular. For this reason, the concept of urban transformation and its applications have begun to discuss in literature studies. It aimed to restructure the problematic areas of the cities by making planned and systematic interventions in the depressed areas where the cities lost their functions with urban transformation.

The action plan should address the whole of the city center and the existing structure and level of risk should established without risky area priorities in order not to affect the existing social and economic structure.

Conversion areas, density reduction areas, reserve areas, transfer rights transfer areas should be determined. Risky areas should declared by observing and reconstruction plans and transportation master plans should be revised in the direction of transformation purposes. Within the scope of prepared action plan, proposal and declaration of risky areas should realize in stages. After the determinations to made, a methodology and methods for the applications to made by creating a holistic strategic plan should be determined and a transformation model should established. In this model, planning actions to done in short, medium and long term shall be determined, actions should made for usage decisions and applications to be made within the framework of priorities, and methods and methods for each action should be determined in the action plan.

Current users should considered within the scope of income-generating facilities projects to meet the common expenses that will enable them to continue their lives in the same area after the actual conversion, and solutions should be provided considering the existing socio-economic and cultural structure to be determined because of the researches to be done.

The actors involved in the process should be defined in the action plan and an organizational model should established in which the proprietors of the property owners are involved in the spatial decisions within the scope of their application areas and an Urban Transformation Council should established in which local experts, relevant institutions can monitor and control the process.

Eskisehir city should considered as a pilot region for the administrations concerned, since it may include applications that may be examples of the scope of transformation of disaster risk areas. When transforming the areas under disaster risk, the spatial and physical environment must be improved, ecological planning and design principles must be passed, a sustainable urbanization model should be established, social justice and development must be ensured. In this context, comprehensive and holistic vision and action plans should be put forward.

A financial model based on the solution should constructed. When the model is determined, external borrowing should considered as the last solution and union and agency funds should investigated in this context. The current situation for the construction of action plans should made as follows:

Especially in Eskisehir city, after the 1999 Earthquakes preparation of geological-geotechnical survey reports, disaster risks and local ground problems, Extraction of the inventory of the settlement, Determination of the socio-cultural situation, Determination of the existing infrastructure situation, Determination of the socio—Determination of resettlement preferences and expectations, Making feasibility analysis, Making transportation analysis.

In the spatial decisions to taken for the project areas, the effects on the city as a whole, consistency with the higher-scaled plans should be considered and the projects should be carried out together with the urban development plans. The technical infrastructure and social facilities required to provide in simultaneous use with the residences.

Projects should not use as a means of recognizing privileged development rights aimed at raising the quality of life and securing safety and not building on rent increases. The increase in the right to build after the implementation should made public.

The municipalities should give the opportunity to create enough staff for urban transformation. In addition, a dedicated resource transfer must performed for this job. Urban equipment standards must clearly defined, and the needs of children, young people, and people with disabilities, old people and women who subjected to violence should addressed first. Buildings to build within the framework of urban transformation must certified. This process should carried out in a body composed of Ministry, Universities, Municipalities and Chambers of Profession. These certifications should base on insurance and real estate evaluations.

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Performance of Steel Slag and Fly Ash Added Soil as Subbase Materials

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Abstract. The steel industry, which is an indicator of the developed countries with its production, also brings the problem of waste together. This waste product, that differs depending on the production process and is called slag, is generally referred as solid waste. Many researchers to use for different purposes are examining this type of wastes, which are difficult to store and dispose. It is also investigated about the usability as a filling material in civil engineering. The possibility of using such materials as an alternative to soil stabilization solutions, especially in the areas close to the industries producing these wastes, in the filling of such structures as the roads, railways, airport runways comprise of the basis of the surveys. In this study, the impact of steel slag and fly ash, another waste product released because of combusting lignite coal with low energy at the power plants, on the bearing ratio after blending with kaolin grade clay at different rates was observed. Keeping the 5% clay rate stable in weight, steel slag and fly ash with varying rates were added to prepare the test samples, which were cured for 0, 7, 28 and 56 days under stable conditions and subjected to California Bearing Ratio tests. The results showed that when steel slag and fly ash are used with clay, there were significant increases in their bearing ratios compared to the reference clay sample. While the wet California Bearing Ratio (CBR) was around 15% for the normal clay sample, when it is blended only with steel slag the wet CBR increased up to 70%, and when blended with fly ash the wet CBR went up to 130%. The used materials had very weak and weak binding properties when used alone while their binding properties increased by gaining pozzolanic property within the mix.

Keywords: Fly ash · Steel slag · Subbase behavior · Mechanical properties

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1 Introduction

Access to the natural resources is becoming more challenging day by day for many reasons like restricted resources, environmental effects, costs etc. Population growth and industrialization are also putting a continuous pressure on these resources. Furthermore, population growth and industrialization brings the waste problem with them. More than half of the wastes, especially produced by the manufacturing industry stem from the base metal industry. It becomes inevitable to recycle the by-products and the wastes produced during the metal production and reinforcement, as great problems are faced in their storage and disposal [1].

Symbiosis is a biological term that describes two living things living together as a single organism with the help of each other, and in industry, “industrial symbiosis” is the term used to describe the establishment of long term partnerships and cooperation of two or more industrial enterprises that are physically close to each other, and normally work independently from each other but come together to increase both environmental performance and competitive power. The blast furnace slag, which corresponds nearly half of the slag, the most important waste produced by the iron and steel industry, can be used in clinker production. The remaining steel slag is not yet utilized in a useful way. Studies in the content of industrial symbiosis for the purpose of exploring the uses of steel slag in civil engineering may contribute to the solution of this waste problem to an important extent. When the regions in Turkey, where iron and steel industry is dense, are taken into consideration, it is obvious that waste usage cannot be spread over the country [2].

The infrastructure manufacture costs of transport structures like the roads, railways and airport runways are lower compared to the other manufactures; however, the quality of the infrastructure manufactures influences the cost of the superstructure manufactures. Especially for the manufacture of large volume fillings, when there is not adequate excavation or borrow pit material, it becomes inevitable to use clay materials with low bearing capacity. And if the clay material used does not have the capacity to carry the superstructure load, it is reinforced with additives like lime, cement, fly ash etc.

In this study, as an alternative to the traditional method, the use of steel slag as the filling material has been researched in terms of compaction and bearing capacity.

2 Materials

In this study, steel slag, which do not have much field of usage, was used together with fly ash at different ratios after mixing with a kaolin type clay with 5% fixed ratio in weight. Steel slag and fly ash, mixed or alone, cannot preserve their forms for a long time when they do not have binding properties. For this reason, a fixed rate of clay sample was added to increase their binding properties.

2.1 Steel Slag

Slag is a waste product produced during the stages of transforming iron ore to steel. Slag is produced as waste product while iron ore is combusted in furnace with coke and during the different methods of obtaining steel from iron melt.

These slags are named according to the stages of their formation. The blast furnace slag is produced while producing iron melt, the basic oxygen furnace (BOF-slag) produced in basic oxygen furnaces in integrated plants while producing steel and a different type of slag is formed during steel production in electrical arc furnaces (EAF-slag), which is based on producing steel by melting the steel scraps. This slag is produced in varying amounts due to the production processes. When the steel melt obtained in basic oxygen furnaces or in electric arc furnace production is treated with steel alloy in ladle furnaces, ladle furnace slag emerges. These wastes are stored without being disposed of and are not frequently used in different fields [3–5].

In this study, Basic Oxygen Furnace (BOF) slag, in other words steel slag was used. Steel slag is formed as a result of a chemical reaction process where the carbon dissolved in steel as a result of spraying pure oxygen onto the iron melt (70–75%) added into the ladles of basic oxygen furnaces which include steel alloy or steel scrap (25–30%) to form carbon monoxide, where the heat reaches up to 1600–1700 °C. During this reaction, in order to eliminate the unintended chemical elements, melting agents like lime or dolomite are used. After the melt in the furnace is taken out, the slag obtained from the furnaces in liquid form is treated to obtain the end product, steel slag. The main chemical components of the slag are FeO, CaO, SiO_2. Depending on the productivity of the basic oxygen furnace, the iron content of the slag may vary from 10 to 40% [3, 4].

In the chemical properties of steel slag produced at two different integrated plants operating with high capacity in Turkey are provided [4] Table 1.

Table 1. Chemical composition and some physical properties of steel slag produced at two different integrated plants operating in Turkey [6]

Component (wt%)	Erdemir	İsdemir
SiO_2	12.01	16.0
Al_2O_3	2.91	2.63
Fe_2O_3	17.99	19.59
CaO	51.38	43.23
MgO	4.62	2.41
K_2O	0.04	0.13
Na_2O	0.03	0.24
TiO_2	0.47	0.39
MnO	3.10	4.22
SO_3	0.18	0.29

2.2 Fly Ash

Fly ash is an industrial waste, obtained as a result of combusting coal ground at the thermal power plants, whose flue gas may be carried due to very fine grain sizes, collected using electrostatic or mechanical filters without releasing to the atmosphere because of its environmental impacts. These collected wastes are stored in the vicinity of power plants. The components of the fly ash are SiO_2, Al_2O_3, Fe_2O_3 and CaO and the type of the fly ash is determined according to the ratios of these components. In accordance with ASTM C 618 [7, 8] the fly ash produced from bitumen coal and the total of $SiO_2 + Al_2O_3 + Fe_2O_3$ exceeding 70% and the amount of CaO being less than 10% is called Grade F fly ash. The fly ash produced from lignite or semi-bitumen coal, the total of $SiO_2 + Al_2O_3 + Fe_2O_3$ exceeding 50% and the amount of CaO being more than 10% is called Grade C fly ash. Grade C fly ash are also called high limy fly ash due to its high CaO ratio. In addition, these are pozzolanic and binding [9–12].

In this study, the fly ash obtained from Seyitömer Thermal Power Plant was used.

2.3 Kaolinite

Kaolin is a clay mineral, usually formed as a result of alteration of feldspar rich rocks. The components are mica, quartz, feldspar, titanium oxides and iron in varying proportions. The host rock of kaolin is Al_2O_3, SiO_2 and it includes potassium. During the alteration of leak water or acidic thermal melts, the feldspar loses the whole potassium content and some of SiO_2 and by in-taking some H_2O instead of these, it turns into kaolin mineral that also includes Al_2O_3, SiO_2 and H_2O. Kaolinization is the process where aluminum alkali silicates turn into aluminum hydro silicates. Kaolin is widely used in ceramics, paper, paint, food, pharmaceuticals and dentistry. In civil engineering, it is a problem due to its low bearing capacity and potential for swelling [13]. The kaolin used in this study is pure kaolin obtained from free market Table 2.

Table 2. Chemical composition and some physical properties of flay ash and kaolinite in Turkey (as received)

Component (wt%)	Fly ash	Kaolinite
SiO_2	54.49	45.65
Al_2O_3	20.58	37.63
Fe_2O_3	9.27	0.73
CaO	4.26	0.3
MgO	4.48	0.27
K_2O	2.01	2.4
Na_2O	0.65	0.62
TiO_2	0.00	0.13
MnO	0.00	0.00
SO_3	0.52	0.00

3 Results and Discussion

3.1 Sample Preparation

Steel slag and the materials passed through Sieve No: 4 (4.75 mm) that was used in sieve analysis, were included. All the materials were used after air-drying. The used samples were prepared at the mixture ratios specified in Table 3 (in weight) and subjected to tests.

Table 3. Mixing ratios of samples

Mixture	Steel slag (%)	Fly ash (%)	Kaolinite (%)
S95F00K05	95	0	5
S90F05K05	90	5	5
S85F10K05	85	10	5
S80F15K05	80	15	5
S75F20K05	75	20	5

3.2 Compaction Test

Compaction is the process of compressing the soil by reducing the air gaps between the floor grains with the aid of mechanical means. It is possible to reduce the permeability and control the undesired volumetric changes, provide sufficient strength to carry the loads safely, especially in the construction of fillings, keeping the settlements and deformations under acceptable limits by reducing the gaps.

The approach and compression of the soil grains is achieved only under appropriate static and dynamic loads and by their ability to move relative to each other. The ability of the grains to move relative to each other depends on the magnitude of the applied load (compaction energy) and the amount of water in the soil. The compaction is a function of the water content in the soils. In the laboratory, Standard Proctor Test is applied to find the water content value corresponding to the maximum dry unit weight value and to model the compaction on the land in the laboratory. Compaction tests were conducted as per ASTM D 698 [14]. The sample was placed in the mold in three layers, each layer was subjected to 2.5 kg load dropped from 30.5 cm height and the compaction energy. The test is repeated increasing the water content. The graphic of dry unit weight corresponding to different water contents is drawn to find the optimum water content and maximum dry unit weight values. The results obtained from the compaction tests applied to the mixtures in the content of this study are provided in Fig. 1.

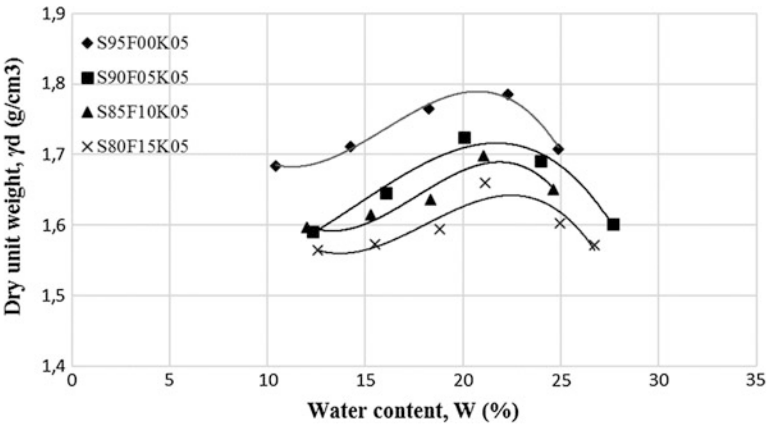

Fig. 1. The results of compaction test

3.3 California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test provides a load-penetration relationship obtained by pushing a cylindrical piston with a cross-sectional area of 1935 mm^2 at a constant speed. In other words, shearing between grains is a measure of resistance. This test shows the relative value of the shearing resistance of any soils compared to the shearing resistance of the standard crushed stone. The CBR test is a penetration experiment that can be applied to all the soils from the clay to the fine gravel, but not for the samples whose bearing ratio is estimated to be less than 5%. The tests were conducted basing on ASTM D1883-07 [15]. The samples prepared at the mixing ratios indicated in Table 3 were compressed in 3 stages in CBR molds according to the maximum dry unit weight and optimum water content values obtained in the compaction test, with the compaction energy obtained by dropping a hammer of 4.5 kg from 46 cm height. The samples placed in the molds were prepared under stable conditions, with 0, 7, 28 and 56 days of curing and 4 different samples were prepared. At the end of the curing times, the test specimens immersed in water for 96 h were placed in the test set and tested. The loads corresponding to the different penetration values of the penetration cylinder at a forward speed of 1.2 mm/min were read and the results were transferred to the graph. In the Fig. 2, uncorrected load—penetration value is indicated. The CBR value of each sample was calculated by reading the load corresponding to 2.5 mm penetration. Table 4 shows the estimated CBR values.

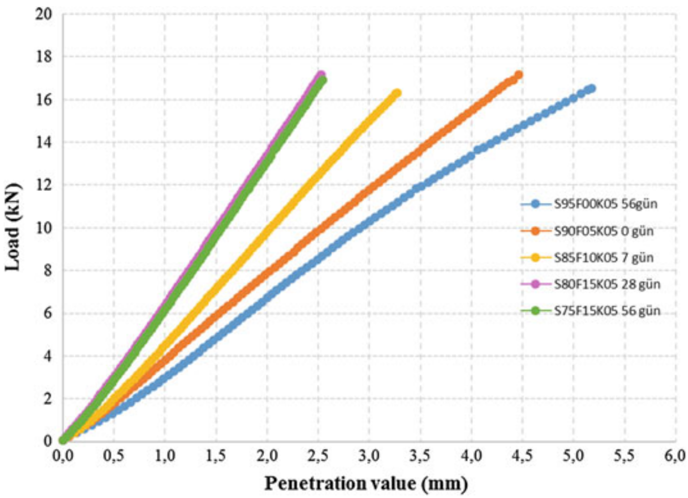

Fig. 2. Uncorrected penetration value-load graphics

As the amount of fly ash in the mixtures increases, the CBR values, the amount of SiO_2 + Al_2O_3 + Fe_2O_3 in the mixture also increase and results in a more active material in terms of pozzolanic activity [16, 17]. When the fly ash ratio reached 20% by weight, the CBR values decreased slightly. Although the fly ash-free mixture had pozzolanic activity, it easily dispersed compared to the other mixtures. The hammer could not break the mixtures containing fly ash that were taken from the CBR vessel, while the fly ash-free mixture was easily broken.

Table 4. Estimated CBR values of mixtures (%)

Mixture	1 day	7 day	28 day	56 day
S95F00K05	70	70	90	90
S90F05K05	80	70	118	118
S85F10K05	100	102	130	123
S80F15K05	102	106	131	131
S75F20K05	98	99	128	128

4 Conclusions

Industry being developed along with the industrial revolution also brought environmental problems as well. The most important environmental problem consists of the industrial wastes. The iron and steel industry is in the foreground with the use of large amounts of natural resources and waste production. Much of this waste produced is stored in facilities and the rest is disposed of. A trace amount of that waste is recycled.

In this study, the usability of steel slag was researched at the point of recovery, especially in construction engineering and in such structures as highway, railway fills. For this purpose, the California Bearing Ratios were calculated using steel slag and fly ash at different ratios, with a constant clay weight of 5%. Although the materials used in the mixtures did not have high strength and binding properties on their own, pozzolanic activity occurred when they came together. With the increase of especially fly ash, the increasing SiO_2 + Al_2O_3 + Fe_2O_3 amount made the pozzolanic activity even greater.

According to the obtained results, the wet CBR value only in clay steel slag mixture was around 70%, and with the addition of fly ash it reached to 90%, and when the amount of fly ash increased, the CBR reached up to 130%. The results show that the mechanical properties of steel slag, which is considered as by-product in Europe rather than waste, increase when it is mixed with kaolin and fly ash. It is evaluated that it is possible to gain steel slag for economy in the field of civil engineering. Contrary to the environmental problems it creates, this product is considered by us to have the quality to create added value. When considered in terms of costs, the steel slag, which has a good gradation, should be utilized in transportation structure fills and subbase layers, especially in the areas in the vicinity of plants producing steel slag.

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Comparison Between Theoretical and Practical Compression Capacities of Deep/Long Piles in Dubai

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Abstract. The rate of build high-rise buildings has accelerated rapidly over the last few decades, due to rapid urbanization and significant improvements in the field of the high-rise construction and technology. Many challenges were faced by the engineers in the design and construction of such buildings. One of the major challenges was the foundation systems, which are required to ensure the stability of the buildings. The common type of foundation system which is used in case of high-rise buildings is piles foundation system. Furthermore, in the most standards and codes of practice such as British Standard, the piles specifications and recommendations are stated for short piles which has a maximum depth range between 18.0 and 20.0 m. As well as, the theoretical equations for pile design, charts and different soil factors and parameters are based on old studies of short piles behavior. In this research, a comparison was conducted between the theoretical pile compression capacity which is calculated from the theoretical equations and the practical pile compression capacity which is derived from the results of pile's static load test. The study covered three different cases of bored piles constructed in U.A.E. especially in Dubai. The piles used in this research have a depth ranging from 30.0 to 65.0 m. This type of piles is classified in this research as long or deep piles. A finite element model of each participated pile modeled by using PLAXIS 2D software, to judge between the practical and theoretical piles capacities. It was found that the theoretical compression pile capacity is 60–70% of the practical pile capacity with the same specifications (pile diameter and pile depth). As a conclusion of the results, the estimated piles diameter and depth in the concept design stage can be improved based on the results of this research.

Keywords: High-raise buildings · Piles · Long piles · PLAXIS 2D
Piling equipment

1 Introduction

Piles are a structural element its function is to transfer the superstructure loads through the weak soil layers to the hard soil strata or the rock soil. The piles may be required to resist the uplift force when it's used to support a high rise building subjected to overturning force or to support a structure subjected to uplift force from the water table

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more than the structure's weight. This type of piles is called tension piles. As well as, the piles may be used to resist a compression force from the superstructure and in this case the piles are classified as a comparison piles.

Reinforced concrete piles, which was developed as a structural element in the late last two centuries, largely replaced the timber piles for high-capacity piling works. It can be formed in different shapes to suit the structure requirement and the imposed load. The durability and the reaction with the different types of the soil layers gives the concrete another advantage. Steel piles are a common type of piles especially in the marine structure due to the ease of the installation. And nowadays there are different types of paints and chemicals can be used to improve the steel resistance to corrosion and can increase the steel piles durability.

In terms of constructability and due to the significant development of the piling machines, the piles nowadays can be reached to depth equal to 60–70 m. Generally, these types of deep piles are used in the construction of high-rise buildings. This research will compare between the theoretical and practical compression capacities of deep piles. In addition, a finite element software PLAXIS 2D will be used to model the pile and to judge between the theoretical and practical capacities.

2 Literature Review

2.1 Ultimate Load Capacity of Single Piles

The principle approach used to calculate the piles capacities to resist the compressive loads is the static or soil mechanics approach. During the past years, more research work done to express a method based on the practical soil mechanics theory. For example, the calculation of skin friction on a pile shaft was based on a simple relationship between the effective overburden pressure, the drained angle of shearing resistance of the soil and the coefficient of earth pressure at rest, but they realized through the results of the practical tests and researches that the coefficient of earth pressure must be modified by a factor takes into consideration the installation method of the pile.

In the same way, the calculation of the pile end bearing resistance was based on the undisturbed shearing resistance of the soil at the pile toe level, but they recognized the importance of the pile settlement at the working load and methods have been evolved to calculate this settlement, based on elastic theory and considering the transfer of load in shaft friction from the pile to the soil.

A pile is subjected to a progressively increasing compressive load at a steady rate of application, the resulting load—settlement relationship plotted in Fig. 1. There is a straight-line relationship up to point A on the curve, this is mean if the load released at any stage up to point 'A' the deformation or settlement of the pile head will return to its original condition. when the loading increased beyond point 'A' the relationship will have changed from linear to nonlinear relationship, and there will be yielding at the pile—soil interface till reaching the maximum shaft friction point 'B'. In case of load releasing at this stage the pile head will have reached to point 'C'. and the distance 'OC' will be the movement required to mobilize the maximum pile shaft resistance, usually this distance is equal to 0.3–1% of the pile diameter. The pile base resistance requires more downward movement to full mobilization, point 'D', that movement is based on the pile diameter, and it is ranged between 10 and 20% of the pile diameter. after point 'D' the pile will move downward without any increase in the load "failure point".

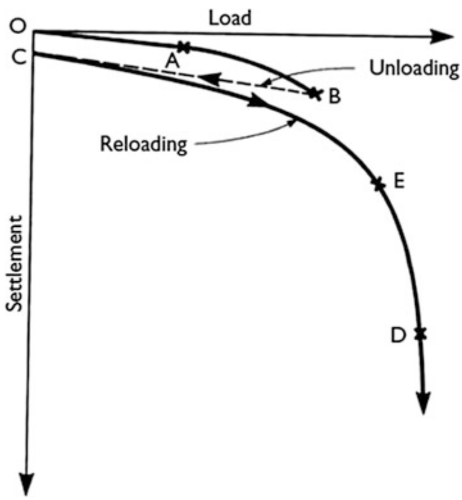

Fig. 1. Load/settlement curve for compressive load to failure on pile

2.2 Piles in Sand Soil

The ultimate pile capacity, Pu, of a single pile is equal to the summation of the ultimate skin friction and end bearing resistances, less the pile weight;

$$P_U = P_{SU} + P_{BU} - W_P \tag{1}$$

where,
P_{SU} Ultimate pile skin friction resistance
P_{BU} Ultimate pile end bearing resistance
W_P Pile weight

According to Tomlinson and Woodward [1], the classical equation to calculate the compression pile capacity in the sand soil is;

$$Q_P = N_q \sigma'_{vo} A_b + \frac{1}{2} K_S \sigma'_{vo} \tan(\delta) A_S \tag{2}$$

where,
σ'_{vo} effective soil overburden pressure at the pile base level.
N_q pile bearing capacity factor.

A_b the area of the pile base "cross sectional area".
K_S coefficient of the soil horizontal stress.
δ the angle of friction between pile and soil.
A_S the area of the pile shaft.

The factors N_q, K_S are empirical factors have been obtained from the results of piles static load tests, δ is obtained from the field test and laboratory tests on the friction angle between the different soil types and different pile materials. The value of the empirical coefficient of the pile bearing N_q was by Berezantzev et al. (1961) and it has been found that this coefficient is based on the drained angle of shearing resistance ϕ and the ratio between the pile penetration depth over the pile width (diameter), this relationship is shown in Fig. 2. Vesic [12] confirmed that these N_q values give results which is almost near to the practical conditions. Another criterion developed by Brinch Hansen to evaluate the factor of the pile bearing N_q, but the values should be multiplying by a shape factor 1.3 for the square and circular pile's base cross section.

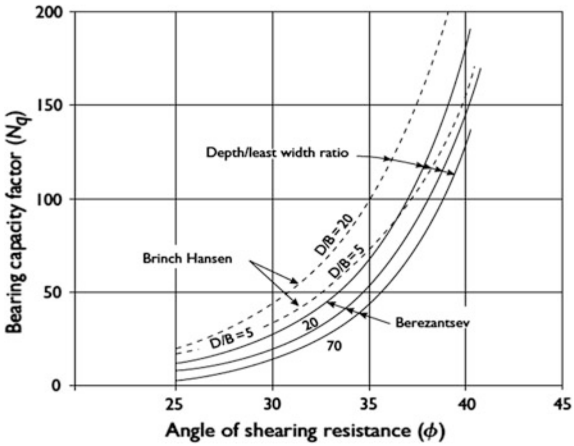

Fig. 2. Pile bearing capacity factor N_q

The second term in Eq. 2 is used to calculate the pile skin friction resistance to the compression loading. The value of the factor K_S is very critical and difficult to evaluate, because it is depending on the stress history of the soil and the installation method of the piles. For example, the using of driven pile technique is increasing the horizontal soil stress from its original K_O value and the using of bored pile technique can loosen the soil, and reduce the horizontal soil stress. This factor is governed by the following items;

(a) The stress history of the soil.
(b) The ratio between the pile penetration depth and the pile width or diameter.
(c) The shape and the stiffness of the pile.
(d) The pile material (Table 1).

Table 1. The coefficient of the soil horizontal stress, K_S

Installation method	K_S/K_O
Driven piles, large displacement 15 mm	1.00–2.00
Driven piles, small displacement	0.75–1.25
Bored and cast-in-place piles	0.70–1.00
Jetted piles	0.50–0.70

The friction angle between the pile and the soil δ is obtained by factored the effective angle of shearing resistance ϕ of the soil as determined from the relationship with standard penetration test SPT values as shown in Fig. 3. This factor is depending on the pile surface material. Kulhawy [7, 8] established some values for this factor based on the pile/soil interface condition and it can be applying for the driven and bored piles (Table 2).

Table 2. Values of the angle of pile to soil friction for various interface conditions per Kulhawy [7, 8]

Pile/soil interface condition	Angle of friction between pile and soil δ
Smooth (coated) steel/sand	(0.5–0.7) ϕ
Rough (corrugated) steel/sand	(0.7–0.9) ϕ
Precast concrete/sand	(0.9–1.0) ϕ
Cast-in-place concrete/sand	(1.0) ϕ
Timber/sand	(0.8–0.9) ϕ

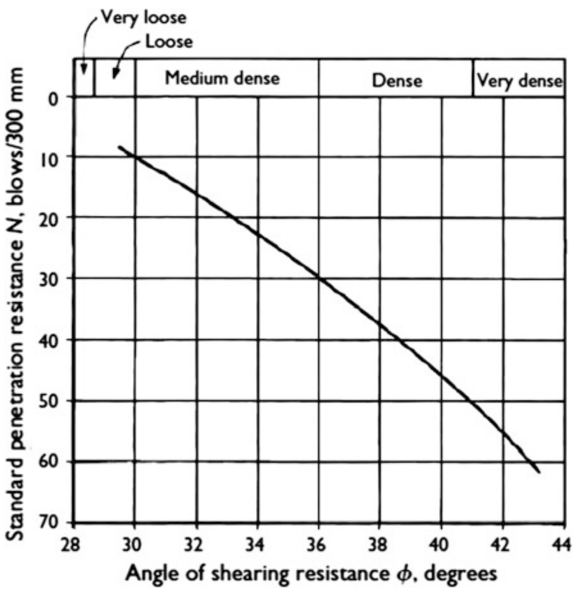

Fig. 3. Relationship between standard penetration test N-values and angle of shearing resistance

2.3 Piles in Rock Soil

For bored and cast-in-place piles which are drilled into rock soil layer act as friction and end bearing piles. Wyllie [14] estimated the factors and coefficients which are governing the development of shaft friction through the rock socket depth. For the end bearing and pile settlement factors are summarized in the following items;

(a) The socket length to the diameter ration.
(b) The strength and modulus of elasticity of the rock layer.
(c) The base condition of the drilled pile hole with respect to the removal of the drilled material.
(d) Creep of the material at the rock/concrete interface.
(e) Settlement of the pile in relation to the elastic limit of the side-wall.

The condition of the pile's surrounding soil layers is very important factor, and it has a significant impact on the pile skin friction. For example, the drilling in clayey shale, or clayey weathered marl cause a softening in borehole wall. As well as, the using of the bentonite slurry in the drilling process has the same impact on the pile skin friction. This impact can be avoided by using a temporary casing technique in the installation of the pile, the casing should be extending to the head of rock soil layer. Wyllie [14] stated that if the bentonite slurry used in the drilling process of the pile, the rock socket shaft friction should be reduced by 25% compared to clean rock socket, unless pile load test done to verify the actual value of the friction resistance.

The shaft resistance of the pile in the rock soil, is depending on the bond between the pile material which is concrete and the rock soil. The bond between the concrete and the rock soil is depending on the unconfined compression strength of the rock soil, the rock socket bond stress has been developed by Horvarth [6], Rosenberg and Journeaux [11], and Williams and Pells [13]. The ultimate pile shaft resistance f_s, in the rock soil can be calculated by the following equation;

$$f_s = \alpha \cdot \beta \cdot q_{uc} \tag{3}$$

where;
α reduction factor related to q_{uc} as shown in Fig. 4.
β correction factor related to the discontinuity spacing in the rock mass as shown in Fig. 5.

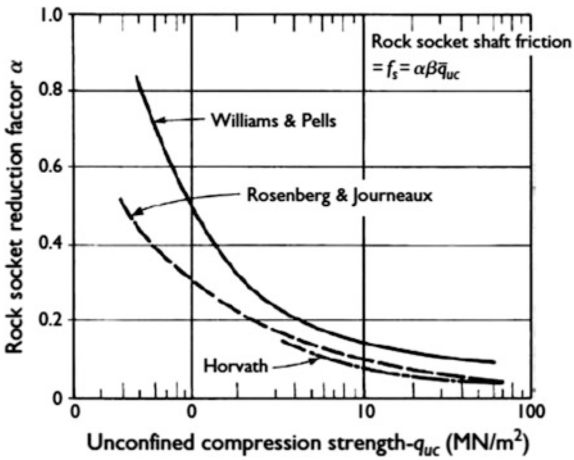

Fig. 4. Reduction factors for rock socket shaft friction

The Williams and Pells [13] curve in Figure 13 is higher than the other two curves, but the β factor is having the same value in all curves and it is depending on the mass factor, j, which is the ratio between the elastic modulus of the rock mass and the intact rock as shown in Fig. 6. In case if the mass factor j is not known from the loading test, it can be estimated with respect to the rock quality designation (RQD) or the discontinuity spacing quoted by Hobbs [5] as follows (Table 3).

Table 3. Mass factor j value with respect to RQD and the discontinuity spacing

RQD (%)	Fracture frequency per meter	Mass factor j
0–25	15	0.2
25–50	15–18	0.2
50–75	8–5	0.2–0.5
75–90	5–1	0.5–0.8
90–100	1	0.8–1.0

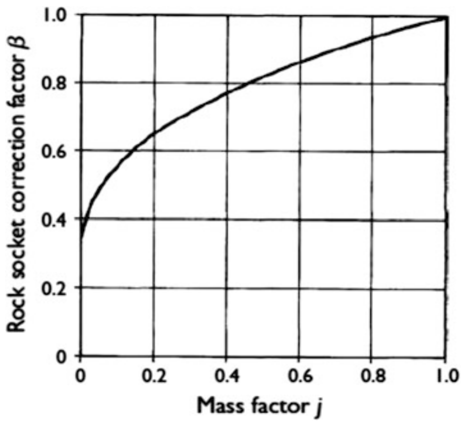

Fig. 5. Reduction factors for discontinuities in rock mass (after Williams and Pells)

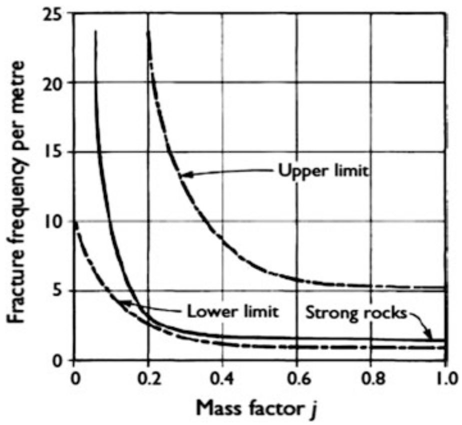

Fig. 6. Mass factor value (after Hobbs)

The method is used to calculate the pile ultimate bearing resistance assume that the pile capacity is a combination between shaft and base resistance. Both resistances are based on correlations between the pile static load test and the result of filed test in rock formations or laboratory tests. The following is the equation which is used to calculate the pile base resistance for the driven and bored piles;

$$q_b = 2N_\phi \cdot q_{uc} \tag{4}$$

where the bearing capacity factor N_ϕ is equal to;

$$N_\phi = \tan^2(45 + \frac{\phi}{2}) \tag{5}$$

The pile bearing resistance in weak rock soil depends on the drilling techniques. The use of percussive drilling machines causes a formation of a soft sludge at the bottom level of the drilled pile shaft. This is not only weakening the base resistance; it makes it difficult to identify the accurate classification of the rock soil and difficult to estimate the soil parameters at the base level. In case of weathered mudstones, siltstones and shales undisturbed samples should be collected during the soil investigation stage and shear strength tests should be made and the results will be used to calculate the base resistance.

For the moderately weathered mudstones, siltstones and shales uniaxial compression tests should be made on the rock cores samples to obtain the compression strength. The base resistance can be calculated based on the uniaxial compression test results by using the relationship between q_{uc} and RQD as shown in Table 4.

Table 4. Ultimate base resistance of piles related to the uniaxial compression strength of the intact rock and the RQD of the rock mass

RQD (%)	q_{uc}	C	ϕ
0–70	0.33 q_{uc}	0.1 q_{uc}	30
70–100	0.33–0.8 q_{uc}	0.1 q_{uc}	30–60

It is recommended that the pile base resistance which is calculated based on the above description, should be adopted with caution due to the risk of high base settlement. Usually a reduction factor equal to 20% is used to control the high values of pile base resistance. In case of using low values of safety factors in the calculation of pile load capacity, this may lead to that the resulting shaft settlement could break the bond between the rock soil and the pile material and this will affect directly the calculated pile load capacity especially when the pile capacity is shared between the base and shaft resistance. Therefore, it is recommended to use a reduction factor equal to 30–40% to the high value of pile skin friction resistance.

2.4 Prediction of Pile Capacity from Non-destructive Static Load Test—Chin's Method

Static load testing still the most reliable method to determine the actual pile ultimate capacity. This method involves physical loading of the pile by using for example concrete cubes with specific dimensions and weight at specific time interval and monitoring the pile settlement of the pile head until failure. The applied load should be increased gradually up to the maximum value of the applied load or up to the maximum allowable pile settlement (pile failure point) then the load should decrease gradually as well.

The results of the static load test are plotted as load—settlement curve. And the failure load is calculated, the failure load is the load where the pile is subjected to excessive settlement under small or no load increase.

The pile static load test can be categorized to two categories; the first category is the failure load test where the pile is loaded until the failure. The failure load test is necessary to determine the pile's ultimate capacity. The second category is the proof test which is used to check the ability of the pile to support a specific service load, usually the loading is up to 1.5–2.0 times the design load. Most of time the proof test does not provide the pile's ultimate capacity, therefore this test is not providing a clear information about the pile capacity and it is not support the geotechnical engineers to do a cost saving in the foundation cost. Vesic [12] stated that the scale of the load—settlement curve is based on the elastic deformation of the pile and is expressed as;

$$\delta = \frac{PL}{EA} \tag{6}$$

where;

δ elastic deformation of the pile.
P applied load.
L pile length.
E elastic modulus of the pile's material.
A cross sectional area of the pile.

2.5 Chin's Method

Chin's method (Chin and Vail 1973) is the most developed method to predict the ultimate pile capacity from the results of non-failure static load test. It is assumed that the load-settlement relationship is hyperbolic, and the ultimate pile capacity can be predicted by plotting a curve between the settlement Δ/load P in the vertical axis and the settlement Δ in the horizontal axis. Then plot the best fit line through the data points. The ultimate pile capacity is derived from the inverse slopes of this line.

$$\frac{\Delta}{Q} = C_1 \cdot \Delta + C_2 \tag{7}$$

$$Q_u = \frac{1}{C_1} \tag{8}$$

where;

Δ pile displacement.
Q_u ultimate pile capacity.

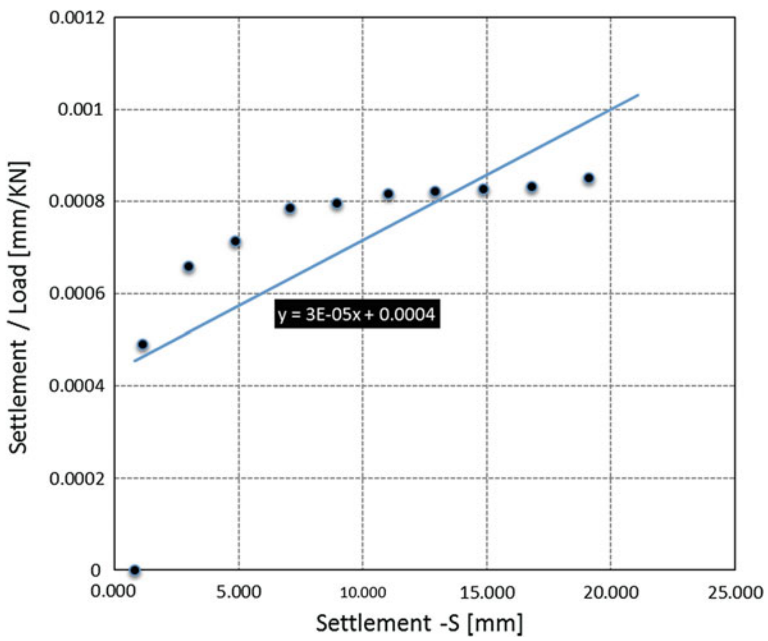

Fig. 7. Sample of Chin's method diagram

3 Case of Study

The following section will cover a case of study for long pile has been installed and tested in Dubai since 2015. The data was collected from the project consultant for the research purpose, and it is categorized as per the following items;

(a) Project's soil investigation report including the piling recommendations.
(b) Project's piling drawings.
(c) Static load test report for the selected type of pile.

3.1 Research Methodology

The following steps are the used methodology to compare between the theoretical, practical and numerical pile compression capacity.

(a) Select one pile type from the case of study's piles types.
(b) Collect all the required data from the soil investigation such as (soil layers' classifications, soil parameters and piles recommendations).
(c) For the theoretical pile capacity, it can be extracted from the piles recommendation in the project's soil investigation report.
(d) For the practical pile capacity, it will be estimated form the results of the static load test by using Chin's method (refer to Sect. 2.5).

(e) For numerical pile capacity, a finite element model will be modeled by using PLAXIS 2D software to get the piles compression capacity.
(f) Comparison between piles capacities in the different cases will be discussed in details.

3.2 Theoretical Pile Capacity

Reference to the soil investigation report from M/S Arab Center (specialist soil test laboratory in Dubai) REF: SD14000067 dated on 31th December, 2014, the compression capacity of the pile with diameter equal to 900 mm and its toe level is −31.0 m from cut off level equal to +3.375 m was 9015 kN. This compression capacity calculated by using set of theoretical and empirical equations which are used to calculate the skin friction and end bearing pile capacities in sand and rock soils (refer to Eqs. 2, 3 and 4). Table 5 summarize the selected pile details.

Table 5. Selected pile details

Pile cut off level (m)	Pile toe level (m)	Pile length (m)	Pile diameter (mm)
+3.375 DMD	−31.0 DMD	34.375	900

3.3 Practical Pile Capacity

Static load test has been done to the selected pile type by the piling specialist contractor (test No. PTP 02), and the test was monitored by M/S Arab Center (specialist soil test laboratory). The static load test has been done by using Kent ledge blocks method. The purpose of the test was the critical evaluating of the following pile's characteristics;

(a) Load settlement behavior of the pile during the load test up to 250% of the pile's working load.
(b) Load transfer and distribution along the pile shaft during the pile's compression load test.
(c) Skin friction along pile shaft during pile load tests in compression.

Table 6 represent the static load test results of the selected pile.

Table 6. Static load test results of the selected pile

Load—P (kN)	Settlement—S (mm)	Settlement/load (mm/kN)
0	0.793	0
2240	1.100	0.000491071
4490	2.960	0.000659243
6780	4.850	0.000715339
8970	7.060	0.000787068
11,210	8.935	0.000797056

(*continued*)

Table 6. (*continued*)

Load—P (kN)	Settlement—S (mm)	Settlement/load (mm/kN)
13,460	11.000	0.000817236
15,690	12.900	0.00082218
17,940	14.850	0.000827759
20,180	16.800	0.000832507
22,430	19.100	0.000851538

The pile did not reach to the failure point during that static load test. Therefore, Chin's method will be used to predict the pile capacity from Non-Destructive static load test (refer to Sect. 2.4). Figure 7 illustrate the results of the static load test by plotting the settlement of the pile on the horizontal axis and the settlement/load on the vertical axis. By using Chin's method technique, the practical pile capacity can be predicted by using Eqs. 7 and 8 as follow;

$$\frac{\Delta}{Q} = C_1 \cdot \Delta + C_2 = 3.0E - 05 \cdot \Delta + 0.0004 \tag{9}$$

$$Q_u = \frac{1}{C_1} = \frac{1}{3.0E - 05} = 33{,}333 \text{ kN} \tag{10}$$

$$Q_w = \frac{Q_u}{F.O.S} = \frac{33{,}333}{2.5} = 13{,}333 \text{ kN} \tag{11}$$

The practical pile capacity by using Chin's method for Non-Destructive static load test is 13,333 kN. And the expected pile settlement under the working load from the results of the static load test is 10 mm.

3.4 Numerical Pile Capacity

Finite element software used to model the selected pile with the soil layers, the used software is PLAXIS 2D. The pile was modeled by using axisymmetric option, the soil layers were modeled by using Mohr-Coulomb as material model. Prescribed settlement will be applied to the pile head and the force—settlement curve will be plotted to predict the numerical pile capacity. The following are the model's boundaries which were used;

Graphical boundaries.

See Fig. 8.

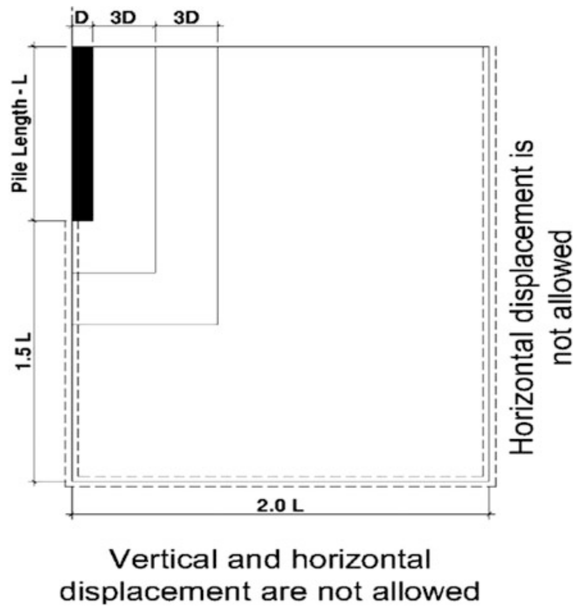

Fig. 8. Graphical boundaries

Soil layers' classifications and soil parameters.

See Table 7.

Table 7. Soil layers' classifications and soil parameters

Soil layer	Layer depth, m (DMD)		Engineering parameters				
	Depth (m)	To	Unit Wt (kN/m^3)	E (MPa)	Poison ratio	C′ (KPa)	Ø
Silty fine sand	13.0	−10.0	18	25	0.35	0	34
Dense to very dense sand	0.7	−10.7	18	50	0.35	0	36
Calac-renite/sand-stone	3.3	−14.0	22	200	0.3	70	32
	2.0	−16.0	22	200	0.3	100	32
	2.0	−18.0	22	200	0.3	80	32
	2.0	−20.0	22	200	0.3	60	32
	2.0	−22.0	22	75	0.3	20	27
	2.0	−24.0	22	75	0.3	27	27
	4.0	−28.0	22	150	0.3	60	32
	5.0	−33.0	22	250	0.3	120	32
	5.0	−38.0	22	250	0.3	130	32
Sand-stone	5.0	−43.0	22	400	0.3	85	34

Pile and soil interface reduction factor.

One of the important factor which has a significant impact on the pile skin friction resistance is the pile and soil interface condition. There is a reduction factor should be used in the modeling of pile, this factor is based on some items as follow;

(a) Soil layers' classification.
(b) The pile material.
(c) The method of the installation, for example the using of bentonite slurry in the pile installation has a negative impact on the skin friction resistance because it generates a smooth surface between the pile and the surrounding soil. Therefore, the reduction factor in this case will be small compare to other installation techniques.

Generally, the reduction factor of skin friction resistance duo to interface condition has a value between 1.0 and 0.5, in this model the used reduction factor for the first two layers (sand soil) is 0.8 and the value of the other layers (rock soil) is 0.9 (refer to Table 2; Fig. 9).

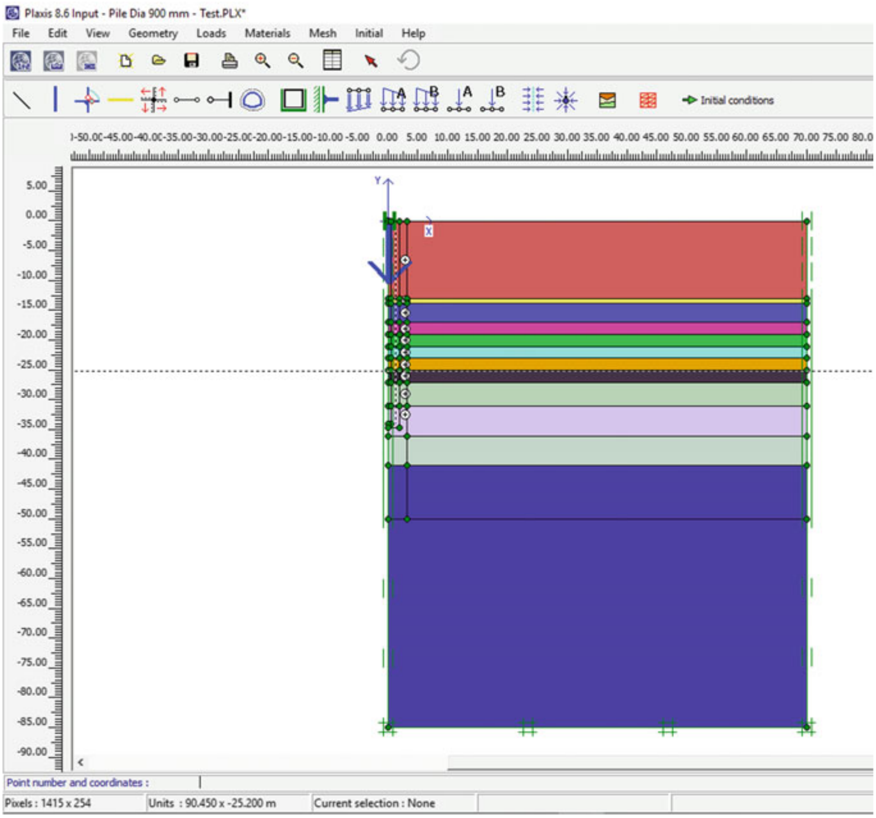

Fig. 9. Selected pile model by using PLAXIS 2D

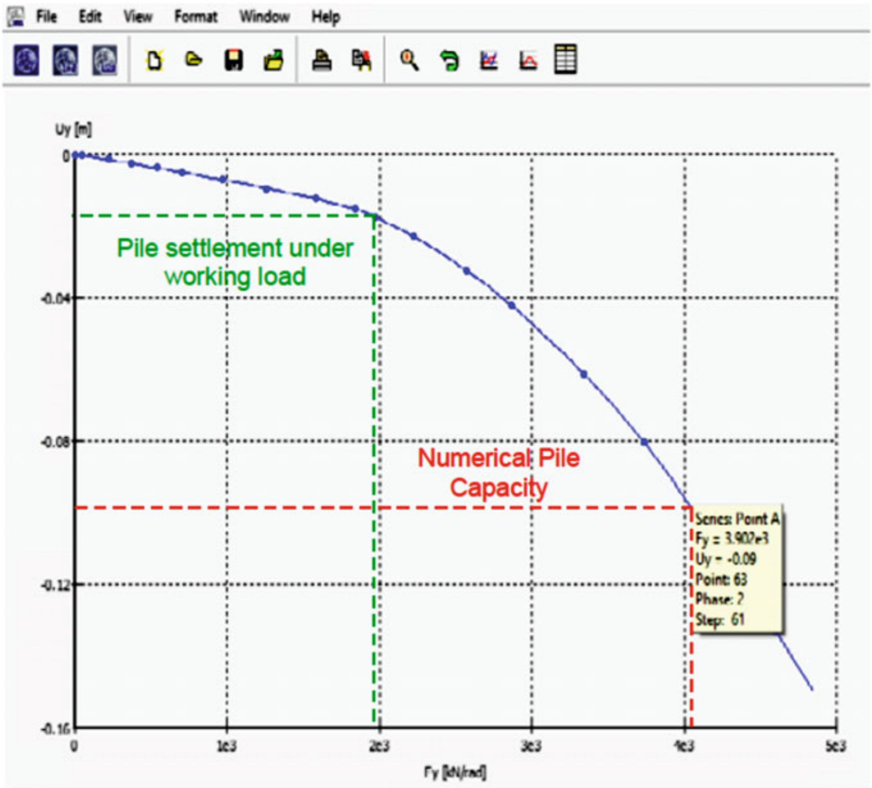

Fig. 10. PLAXIS 2D output_load—displacement curve

Figure 10 illustrate the relation between the vertical displacement of the pile head on the vertical axis and radial force or resistance on the horizontal axis. Reference to the British standard BS 8004: 1986 defines that the ultimate pile capacity is the load at which the resistance of the soil becomes fully mobilized and goes on to state that this is generally taken as the load causing the head of the pile to settle a depth of 10% of the pile width or diameter (failure point).

- 10% × 900 mm (pile diameter) = 90 mm.
- From Fig. 10, $Fy = 3902\ \text{kN/rad}$ at displacement equal to 90 mm.
- $$Q_u = Fy \times 2\pi = 3902 \times 2\pi = 24{,}504\ \text{kN}$$
- $$Qw = \frac{Q_u}{F.O.S} = \frac{24{,}504}{2} = 12{,}252\ \text{kN}$$

The numerical pile capacity by using PLAXIS 2D software to model the selected pile is 12,252 kN. And the expected pile settlement under the working load 1950 kN/rad from Fig. 10 is 17 mm.

3.5 Comparison Between Theoretical, Practical and Numerical Pile Capacities

Table 8 summarize the predicted pile capacities for each case and illustrate the differences between them (Fig. 11).

Table 8. Pile capacities details

No.	Pile capacity	Pile capacity (kN)	Percent (%)
1	Theoretical pile capacity	9015	100
2	Practical pile capacity	13,333	147
3	Numerical pile capacity	12,252	135

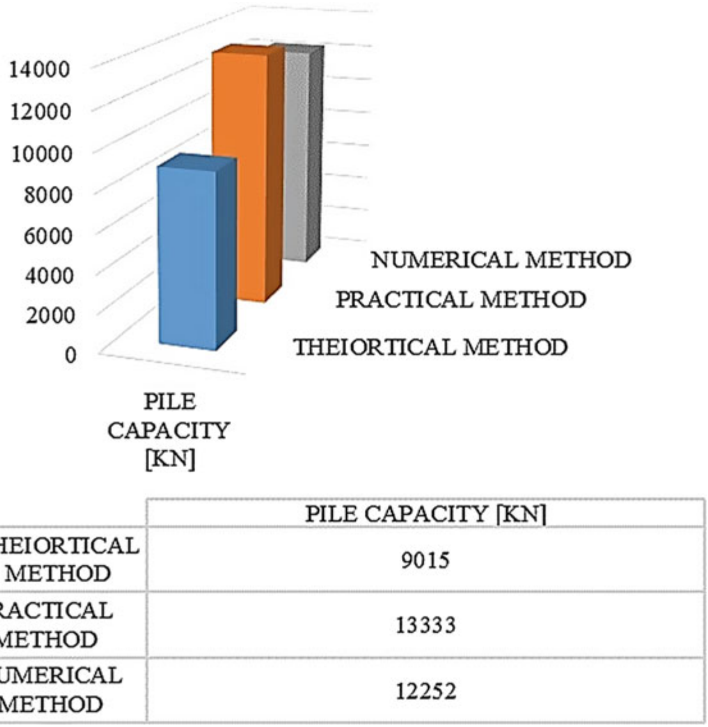

Fig. 11. Pile capacities chart

4 Conclusion

Proper soil investigation from specialist soil test laboratory during the design stage is essential, to provide a suitable information about the soil layers' classifications and soil parameters such as soil unite weight, internal angle of friction, cohesion and the modulus of elasticity of each soil layer. All these parameters are very important during the design stage to design the pile foundation or to model it by using any geotechnical software and to achieve results near from the practical condition.

The theoretical equations which used to design the pile foundation are based on some parameters, these parameters have been estimated from the results of pile's static load test. This test has been done on piles have a short pile's depth not exceeding 20 m. But nowadays, the piling equipment has been developed to reach a depth equal to 60–80 m. This is to provide a suitable pile foundation system can be used to achieve the stability of the high rise buildings or to transfer the building load from the weak soil strata to the hard soil strata. Therefore, these equations need more development by using the results of long piles' static load tests and by using a finite element software to model the piles and the soil layers to have a better results compared to the theoretical method.

This research provides a comparison between the theoretical, practical and numerical pile capacities for one case of study has been installed and tested in Dubai. The research result is that the practical pile capacity is higher than the theoretical pile capacity by around 47%. And the numerical pile capacity is higher than the theoretical pile capacity by around 35%. As a result, the pile capacity from the theoretical equations should be increased by 30–40%. This will provide the ability to reduce the cost of the piles foundation system by around 30%. As well as, reducing the required pile's materials which is considered as a sustainable practice for our environment.

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Behavior of Dams Under Earthquake Loading-Case of Lower San Fernando Dam

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Abstract. Soil liquefaction is seen where the water table is high and soil is cohesionless. Especially, it occurs when drainage is not possible or limited. Consequently effective stress decreases as result of increasing pore pressure during shearing. The significant majority of damage of buildings, roads, bridges and dams in earthquakes are due to soil liquefaction. Recently, the importance of soil behavior during the earthquakes has begun to be discussed. In particular, soil liquefaction can cause serious damages to earth—rockfill dams constructed in earthquake prone areas. In 1994-USA, 105 dams were affected within a 75 km radius from center of the Northridge earthquake of 6.7 magnitude. Some of these dams are earthfill and others are rockfill and not all of these dams were in danger of collapse. However, settlement cracks and/or slope movements have been observed. Others did not affected. Besides, many of these dams experienced the San Fernando Earthquake which has a magnitude of 6.5 occurred in the same area. In 1918, the Lower San Fernando Dam having a height of 42 m which was built using "hydraulic fill" technique was heavily damaged. In this study, Lower San Fernando Dam and earthquake loading is modelled using a finite difference program FLAC which contains Finn liquefaction model. At the end of the analysis, damage to the dam section, plastic shear deformations, distribution of pore pressure and deformations are compared with the real case.

Keywords: Liquefaction · San Fernando Dam · Earthquake · Dam failure

1 Introduction

Many dams constructed for various purposes such as irrigation, energy production, flood control, recreation and earth structures such as highway embankments have been located in earthquake-prone areas. There are a significant number of seismic incidents during which these structures are subjected to partial or total damage [1]. Some older earthfill dams, known as hydraulic-fill dams, were constructed by using water for transporting embankment material to its final position in the dam [2].

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Several important problems are natural for these structures. Perhaps most significant, but unrecognized at the time most hydraulic-fill dams were built, is that this type of construction leaves a relatively loose soil structure that is subject to liquefaction during an earthquake and failure of the dam can result [2].

The term "liquefaction" describes a phenomenon in which a cohesionless soil loses strength during an earthquake and acquires a degree of mobility sufficient to permit movements ranging from several feet to several thousand feet [3]. Liquefaction occurs when soil is on the dry side of critical states, near zero effective stress, and in the presence of high hydraulic gradients [4]. Liquefaction phenomenon causes some failures during the earthquake such as bridges, superstructures, dams, ports, wharf and marine and water tank etc.… In the past earthquakes, some dams effected negatively because of liquefaction such as Sheffield Dam, Mochikoshi Dam, Chang Dam, Fatehgadh Dam and The Lower San Fernando Dam.

Sheffield Dam was failed during the Santa Barbara Earthquake, 1925 (Fig. 1). Fatehgadh Dam, showed longitudinal cracks which may indirectly relate to liquefaction of foundation soils in the Bhuj Earthquake, 2001 [5]. Chang Dam underwent almost a complete collapse because of liquefaction of shallow foundation soils [6].

Fig. 1. Sheffield Dams failure [7]

The best examples here are the Mochikoshi Dam in Japan which failed during the 1978 Izu-Ohshim-Kinkai earthquake due to liquefaction induced flow slides resulting in release of the tailings as shown in Fig. 2 [8].

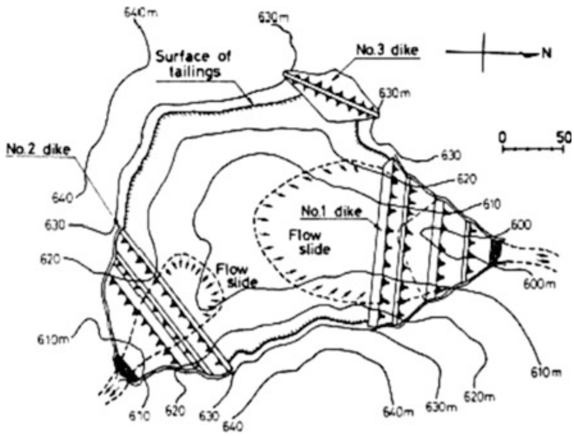

Fig. 2. Plan of Mochikochi tailings dams [9]

The other dam failure was San Fernando Dam. There was a significant earthquake in Southern California in 1971, which is referred to as the San Fernando earthquake. The earthquake occurred on February 9, 1971 at 6:00 a.m. local time and had a 6.6 Richter magnitude.

The Lower San Fernando Dam in Southern California developed a major slide in the upstream slope and crest as a result of the 1971 San Fernando earthquake [10]. The field investigation showed that the slide occurred due to liquefaction of a zone of hydraulic sand fill near the base of the upstream shell, in Fig. 3 [11].

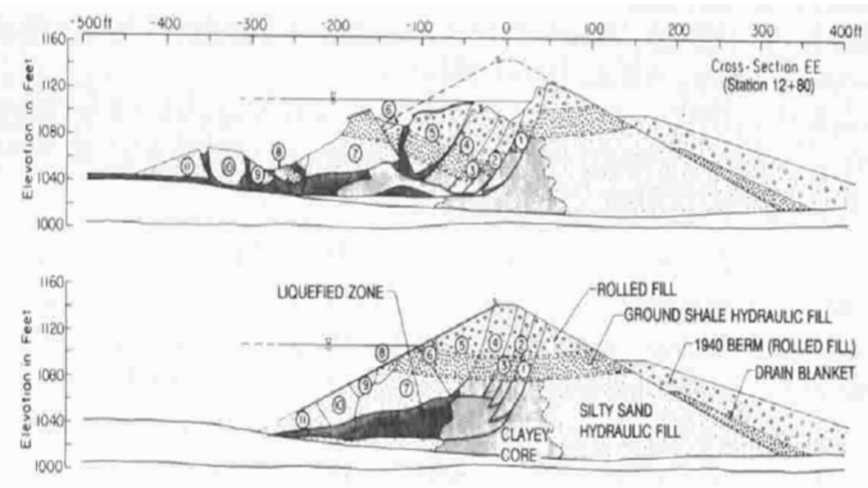

Fig. 3. Cross section through Lower San Fernando Dam showing: **a** conditions after 1971 earthquake, **b** schematic reconstruction of failed cross section [10]

The San Fernando dam is a very important case for geotechnical earthquake and earthquake engineering. So, there are a lot of research and publications about it. Data from accelerometers located on the abutment and on the crest of the embankment indicated peak accelerations of about 0.55 and 0.5 g, respectively, and an analysis of the acceleration record on the dam crest indicated that the slide occurred about 20–30 s after the earthquake shaking had stopped [12].

In this study, Lower San Fernando Dam was analyzed using FLAC to determine distribution of plastic shear deformations, excess pore pressures and deformations.

Results of numerical simulations were compared with the case.

2 The Structural Properties of the San Fernando Dam

The geometry and soil layers of the Lower Dam was idealized as shown in Fig. 4. The dam height is 44 m with 2.5h:1v side slopes. The downstream side has a berm with a side slope of 4h:1v. The dam was constructed directly on the stream-bed alluvium, which is about 5 m thick [13].

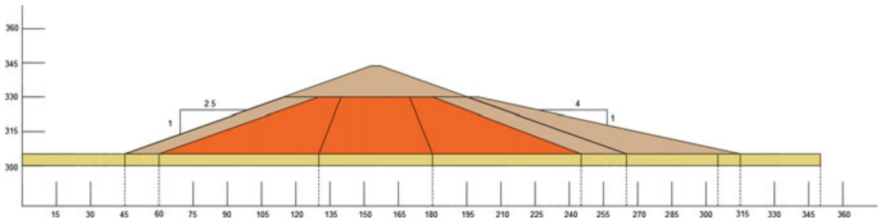

Fig. 4. Numerical analysis model of the Lower San Fernando dam

The dam was constructed primarily by hydraulic fill placement. The fill was loosened in the borrow area by hydraulic jets of water and then transported to the site by means of wooden sluice troughs [12]. The dam was constructed primarily by hydraulic fill placement. The fill was loosened in the borrow area by hydraulic jets of water and then transported to the site by means of wooden sluice troughs [12]. Dykes of dry fill were placed at the outer edges of the dam to contain the slurry. The material in these outer dykes was likely more dense and competent than the slurry fill in general, and this is the reason for the outer shell in the cross-section in Fig. 5. The hydraulic fill placement was used to construct approximately the lower two-thirds of dam. The construction was completed by placing rolled fill on top of the lower hydraulic fill. The upper rolled fill apparently had minimal compaction [12]. Sometime later a berm was constructed on the downstream side. A granular layer was placed between the original dam and the berm. The dam was constructed by "hydraulic filling," which involves mixing the fill soil with a large amount of water, transporting it to the dam site by pipeline, depositing the soil and water on the embankment in stages, and allowing the excess water to drain away [14].

Fig. 5. The San Fernando dams a reservoirs

The dam is located in the lower left corner of this areal view. About 80,000 people living in the area downstream were threatened by the failure of the embankment and the very real possibility that the dam would fail completely, inundating the area by a catastrophic flood wave. Disaster was narrowly averted by drawing down the reservoir before the remaining remnant of the crest gave way [14].

3 Numerical Analysis of the San Fernando Dam

In this study dynamic numerical simulations of the dam were performed using FLAC2D [15] which is an explicit finite difference program. To model cyclic response of the non-liquefiable soils elastic—perfectly plastic constitutive model with Mohr Coulomb failure criteria was used. On the contrary Finn Model is used for liquefiable soils.

3.1 Soil Parameters

Generally, the streambed alluvium, outer shell, top rolled fill, and downstream berm are treated as somewhat more competent as the hydraulic fill [13].

In the FLAC2D analysis, soil properties were used that showed Table 1 and region of the soil Fig. 6. Average unit weight is 19 kN/m^3.

Table 1. Soil properties for using FLAC2D analysis

Bulk modulus (kN/m^2)	Shear modulus (kN/m^2)	Cohesion	Friction angle
6.667×10^4	3.077×10^4	5	38
25,000	11,538	5	30
17,500	8077	5	27
17,500	8077	5	27
17,500	8077	40	8
50,000	23,077	30	40
6.667×10^4	3.077×10^4	5	38
6.667×10^4	3.077×10^4	5	38

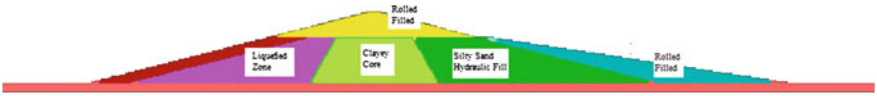

Fig. 6. Region of the soil properties

4 The Liquefaction Analysis of the San Fernando Dam

It is now generally recognized that the basic cause of liquefaction of saturated cohesionless soils during earthquakes is the build-up of excess hydrostatic pressures due to the application of cyclic shear stresses induced by the ground motions [11]. In this study, Finn model is used for the liquefaction model, Table 2 and Fig. 7. By using this model, permanent volumetric unit deformations can be calculated to find a pore water pressure during the dynamic analysis. In addition to, void ratio can be determined as a function of the volumetric unit deformation and other parameters.

Table 2. Finn Model for liquefaction region area for FLAC2D model soil

Model soil layer	Density	Bulk modulus (kN/m^2)	Shear modulus (kN/m^2)	Cohesion	Friction angle	Dilation angle	Region number
Finn model	2	17,500	8077	1	27	0	125-20
Finn model	2	17,500	8077	1	27	0	94-21

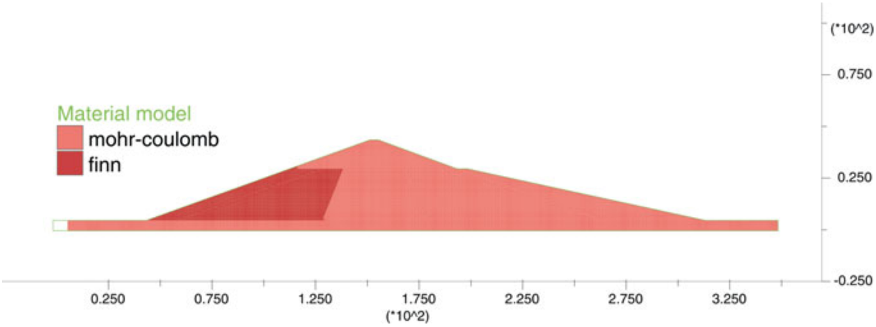

Fig. 7. The constitutive models in FLAC2D model for liquefaction

5 Earthquake Records

San Fernando Earthquake was occurred in the Southern California on February 9, 1971 and its moment magnitude was 6.6. In Fig. 8, San Fernando Earthquake's acceleration-time history is shown which was used in the FLAC2D analysis.

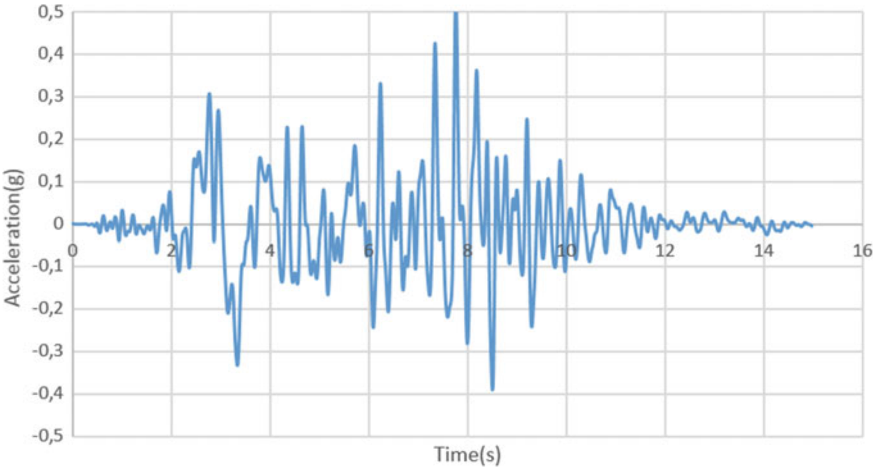

Fig. 8. San Fernando earthquake acceleration-time history

6 Results

For the numerical simulation staged analyses were performed. In the first stage, in situ stress distribution jest before filling of the dam was calculated. After this initial stage a seepage analysis was performed for the determination of steady state pore pressure distribution. This stage was fallowed with a mechanical calculation step to determine mechanical response of the dam for changing pore pressures—effective stresses. Final stage was the dynamic simulation in time domain using San Fernando Earthquake acceleration record.

According to the numerical simulation results up stream side of the dam is failed. Figure 9 presents the displacement vectors at the end of earthquake shaking at the upstream side. Figure 9 clearly shows that the upstream side is unstable. Figure 10 shows the distribution of plastic points at the end of the dynamic analysis stage.

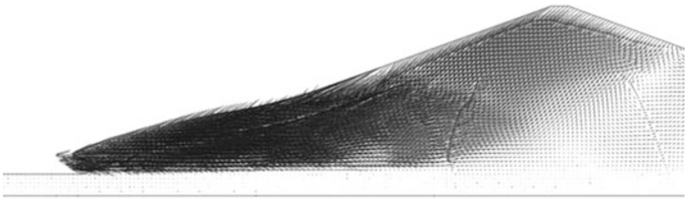

Fig. 9. The displacement vectors at the end of earthquake shaking at the upstream side

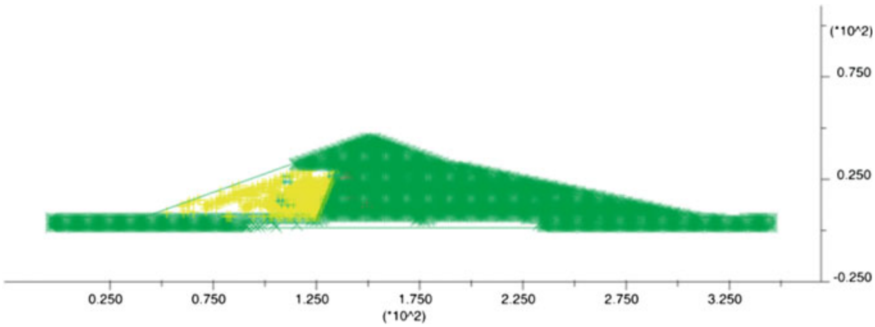

Fig. 10. The distribution of plastic points at the end of the dynamic analysis stage

In Fig. 10 light colored points show elements that are in shear failure. In Fig. 11 distribution of pore pressure at the end of earthquake loading is given. As it is clear from Fig. 11 pore pressures increased from static values especially at the upstream toe of the dam. It can be stated that the increase of pore pressures led to failure of the upstream side of the San Fernando Dam. FLAC2D with Finn liquefaction constitutive model successfully predicted the failure of the Lower San Fernando Dam.

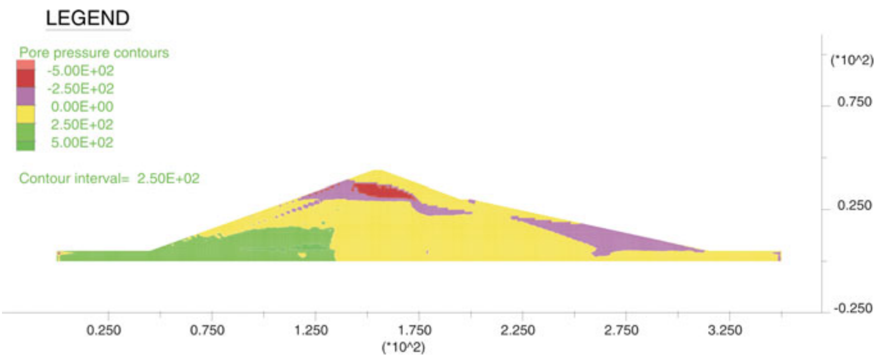

Fig. 11. Distribution of pore pressure at the end of earthquake loading

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A Multidisciplinary Approach in the Context of Earthquake Sensitive Cities

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Abstract. It is necessary to develop a multidisciplinary approach in the sense of creating earthquake sensitive urban areas, though the decisions made by the urban planners are considered as prior. In its basis, urban planning process begins with the geological and geotechnical etudes and continues with planning and land use decision-making within the context of implementation plans. Then, design and construction processes follow those stages. In the period of whole procedure; urban planners, geological engineers, designers, architects, civil engineers and the other related professionals should be included in order to take a common approach. The contributions and the tasks of those disciplines to create earthquake resistant cities vary. In this study, a systematical theoretic perspective in the context of creating earthquake sensitive cities in a multidisciplinary way will be developed. Within this scope, the deficiencies and the necessity of the multidisciplinary collaboration in the implementation sense will be discussed.

Keywords: Earthquake · Urban planning · Geology · Construction

1 Introduction

The earthquakes could negatively affect people, houses, large buildings, dams, power plants and infrastructure, such as roads, tram tracks, airports, pipelines etc. earthquakes can destroy big cities, and take millions of lives, if proper urban planning, land use and site selection and construction are not carried out. In hazardous areas, millions of people live, especially in underdeveloped and developing countries. Therefore, the risk increases due to the uncontrolled population growth. Earthquakes, which could be defined as the most devastating ones, occurred in the world in the last century could be listed as: San Francisco (1906, USA), Messina (1908, Italy), Tokio (1923, Japan), Ketta (1936, Pakistan), Concepcion (1939, Chile), Erzincan (1939, Turkey), Agadir (1960, Fas), Chimbote (1970, Peru), TienShan (1976, China), Guetemala (1976), Mexica (1975), Spitak (1988, Armenia), San Francisco (1989, USA), Rudbar (1990, Iran), Kobe (1995, Japan), İzmit (1999, Turkey), Hint Ocean (2004), Sichuan (2002, China), Haiti (2010), Maule (2010, Chile), Honshu (2011, Hapan), Nepal (2015). In Messina, Italy, 100,000 people; in Peru, 77,000 people; with the effects of earthquake on Hint Ocean, 300,000 people and 17,000 people in Marmara Region died due to earthquakes. Approximately 1 million earthquakes a year could be felt by people [1]. In

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Iran, 40,000 people; in Nepal, 8000 people and in Haiti, 240,000 people died in the earthquakes.

Magnitude, distance from the epicenter, local geological conditions, construction constraints and topography are the significant parameters determining the earthquake catastrophe and damage. Therefore, multidisciplinary approach is needed to decrease disaster damage. In order to provide earthquake sensitive cities in the context of sustainable urbanization, Urban planners, civil engineers, architects, geological engineers, geophysical engineers should work together.

In this study, the roles of those disciplines and their effects on the process of earthquake resistant urbanism are evaluated and the framework of the multidisciplinary approach in this process is fictionalized.

2 Fundamental Disciplines and Their Roles in the Context of Developing Earthquake Resistant Cities

This section will be examined under the three sections as, geology, urban planning and design relation, as well as construction and design relation.

2.1 Geology

In a general perspective, while evaluating urban earthquake risks:

- Tectonic characteristics and active faults of the region should be analyzed and their effects on the urban area should be determined,
- Structural geological characteristics of the region should be examined (location, layout, age, standing in the underground and characteristics of the geological layers),
- Regional and urban topography should be analyzed,
- The location of the underground water resources on the regional, urban and local scale and the related water level height should be examined,
- Geotechnical characteristics and seismic behavior of the ground in the local settlement and construction scale should be examined.

All of the related geological maps in the national, regional and urban scale, engineering geology maps and micro zonation maps are the leading resources for planning and design. Risk factors (related with liquefaction, landslide, active fault crack etc.) which are obtained from those resources should be evaluated well in the planning process. Because, for instance, a hillside might mobilize during an earthquake and those kinds of issues (landslide in this example), called as secondary risks, are as harmful as the earthquake itself.

As in the case of landslide, ground subsidence, as a secondary risk, might cause building damages and collapses after earthquakes. Therefore, ground characteristics and geological-geotechnical data are significant in the sense of building systems selection, as well as in the planning process. The behavior of the building is shaped based on the ground behavior. For this reason, design parameters could not be thought independent from the ground characteristics.

If ground-structure interaction parameters are not well evaluated and the building design is not based on the geotechnical characteristics of the ground then, it is not possible to preclude resonance, soil amplification and liquefaction problems. Therefore, vulnerability of the urban area increases.

Earthquake waves pass through the loose and rock soil in different velocities. The waves have different velocity while passing through the loose and aqueous ground. Therefore, ground shaking is more intense and long-continued, comparing with its velocity while passing through the rock soils. This reveals the term of soil amplification. In other words, a building, which is located on the loose soil, is exposed to ground shaking more intense and long-standing. On the other hand, a building located on a rock soil is exposed to ground shaking less intense and short time, during a probable earthquake. Hence, the loose ground increases the earthquake over strength factor.

Liquefaction, on the other hand, means that cohesionless ground flows due to the hydrostatic pressure, which is caused by the rise of groundwater level during the earthquake. In the meantime, the ground transforms from solid state to liquid state. Liquefaction, occurred in the building foundation, might cause the building embedded into underground, as well it might cause building to fall its side, depending on the amount and direction of the liquefaction. It is significant in the sense of ground-building interaction.

Besides, shaking, ground failure, fault displacement, liquefaction, landslide, flooding etc. could be listed as the direct and indirect influences caused by the earthquakes. Critical facilities as water lines, electrical lines, storage spaces of hazardous waste, nuclear power plant stations, dams, hydro electrical stations etc. could be affected by the earthquakes, if necessary cautions are not taken.

Constructions located nearby the fault zone could be affected more. But it is not always the case. For instance, İzmit earthquake in 17 August 1999 caused a huge damage in Avcılar, where is located on 100 km away from the epicenter. Geomorphology, geology, foundations and structures in Avcılar area were stated as the reasons for this damage [2]. Hence, it could be stated that the damage could be far away from the location of epicenter point.

In addition to these, magnitude of the quake and distance from the epicenter, regional geology, local geological conditions, geotechnical properties of underlying soils and rocks of the settlement area in urban environment, topography, and foundations and structural aspects of the buildings affects the loss caused by the earthquakes. On the competent rock material, earthquake waves move faster, comparing with the weak rock material. Besides, waves move faster in the weak rock materials than in the soils like alluvium. As a result, waves are in tendency to gain momentum in amplitude and decelerate in velocity, while waves move from competent rock to less competent rock and unconsolidated soil to saturated soils. Shake of the ground lasts longer in unconsolidated and water-saturated materials. Buildings located on weak and saturated soils could expose major damages.

Most of the time, hazards as, landslides, liquefaction, subsidence, flooding and tsunamis are observed after the earthquakes and they are called as secondary natural hazards. It is significant in this sense that potential sensitive liquefaction, landslides and the other ground failure areas (geotechnically) should be pre-determined. Most of the damage caused by 1999 Marmara Earthquake was due to the geotechnical and geological conditions, as liquefaction.

Additionally, the other significant secondary risk observed after the earthquakes are claimed as fires. Turkish Petroleum Refineries Corporation, İzmit Refinery and Petrochemical Plant were burnt after 1999 Marmara Earthquake and this caused 80 million damage [3].

Microzonation maps, including seismic, geologic and geotechnical etudes should be used as base maps in the urban planning process. Hence, there will be earthquake sensitive planning. This type of planning highly requires the holistic integration of physical, economic, social, cultural and sustainable thinking. Pre-earthquake preparedness, risk reduction, rescue and recovery stages should be carefully considered in the urban planning process. Analyses related with the natural and built situation of the urban areas should be conducted. In the context of natural situation, these analyses should be considered:

- Geologic, geotechnical etudes
- Topographic etudes
- Seismic danger and risk analyses
- Flood analyses
- Erosion analyses
- Mass movements
- Volcanic and tsunami related analyses.

In addition to these, built environment analyses could be listed as:

- Land use analysis
- Residential typology, quality and age of the buildings, building settlement layout, as well as storey height analyses
- Urban solid-void analysis
- Existing built stock and its distribution
- Examination of the hazardous waste storage and the sites of the facilities, which produce hazardous waste
- The distribution of the significant public structures
- Infrastructural systems analyses
- Transportation systems analyses
- Approachability and the impact analyses
- Risk analyses related with the vital infrastructural systems (lifeline analyses).

Besides, demographical analyses should be carried out could be listed as:

- Population development,
- Growth rate,
- Population structure and
- Density analyses.

Those structures should also be analyzed as:

- The existing sufficiency and the distribution of the urban facilities, public open spaces, hospitals, fire stations as well as,
- Analysis of the earthquake resistance of the significant engineering structures as, Nuclear power plants, dams, hydro electrical plants, viaducts, bridges, tunnels etc.

It is important to use scientific mathematical and multi criterial statistical methods to determine the earthquake resistant urban development and settlement areas.

Site suitability analysis should include geological features as, closeness to the fault zones, the geotechnical characteristics of the ground, liquefaction and landslide potential, tsunami impact evaluation etc.

In addition, linear settlement layout should not cut the fault zone vertically.

From a natural protection point of view, The primary aim of the planning decisions should include the protection of the aquifers and the groundwater resources, as well as the protection of the forestry areas and the agricultural areas.

With the result that, the fundamentals of developing robust, safe, sustainable and earthquake sensitive urban areas depends on the proper integration of the geotechnical data with planning and design processes.

2.2 Urban Planning and Design

Initially, upper scale urban planning approach in the sense of earthquake sensitive cities is mentioned.

Creating earthquake sensitive cities in the context of urban planning discipline starts with upper scale plans and goes through the implementation plans in the local context. In this sense, all of the related stages are consisted of earthquake sensitive planning approach and site selection attitude. Within this cope, the existing situation of the region and the urban area should be analyzed in the sense of upper scale planning to the lower scale plans. Depending on the issues in the related plans, a region development strategy should be developed compatible with the macro plans.

This strategy should be in a hierarchy as, regional planning, metropolitan planning, urban planning and urban design, respectively. Studies related with predisaster in the context of earthquake sensitive planning and urbanism are one of the most fundamental and significant steps in the sense of damage reduction and prevention. Therefore, urban planning discipline is the initial actor, which leads the earthquake sensitive urbanism process with the required guidance by geological engineering discipline.

The fundamental processes of creating earthquake resistant cities could be listed as:

- Developing settlement policies in the national and regional context,
- Developing national and regional physical plans in the earthquake sensitive perspective,
- Constituting urban land use decisions related with natural hazards, earthquakes and risks,
- Developing strategies related with implementations of earthquake resistant structure design,

- Developing strategies related with transforming, renewing or removing abandoned areas structures, which completed its lifetime.

In the context of the implementations of urban and regional planning discipline, geological data should be considered as a base in the sense of decision-making processes related with investment and site selection decisions. Besides, policies should be developed in order to sustain balanced distribution of the population and the economical activities. Population should not allowed creating a risk factor in the earthquake danger areas. For this reason, development plans and national scale decisions are significant in the pre-spatial planning process in the context of earthquake sensitive planning.

Data set of the national plans should be evaluated as earthquake based, while preparing the regional plans. Besides, social, spatial and technical data in the regional scale should be analyzed by synthesizing and should give feedbacks to the national planning studies.

Synthesis in the national and regional scale should be used for creating policies and strategies in the sense of earthquake sensitive urbanism.

Questions listed below should be answered to prepare seismic safety and recovery programs in the development plans [4] (Şengezer and Kansu 1999 as cited in Kanlı ve Ünal 2004):

- “What are the potential natural hazards in the region?
- What are the possible dangers in the settlements?
- What is the acceptable risk?
- Which of the risk area should be prioritized?
- Which option has the least cost in the sense of decreasing those risks?
- Are those strategies are compatible with the other political goals?”

Besides in the development plans, those listed issues should be decided as [4] (Şengezer and Kansu 1999 as cited in Kanlı ve Ünal 2004):

- “Promoted architectonics and in which conditions those architectonics are promoted,
- Settlement policies and in what size urban areas is promoted to develop,
- Formation of the legal framework related with the land use policies (making definition of hazardous and non-hazardous areas, related criteria and limitations),
- Sustaining the development of structure technologies, leading the distribution of the industries related with the structure technologies,
- Developing education policies for raising the awareness of the public,
- Decisions related with occupational organizations and their control systems,
- Developing seismic safety policies and renewal programs.”

In addition to these, metropolitan plan decisions should be compatible with regional planning decisions. Earthquake hazard areas, where limits the urban development, and the related actions which reduces the risks of those areas should be included in the context of planning decisions. Hereby, an urbanization process which reduces the negative effects of earthquakes and the other hazards will be achieved.

Socioeconomic, development, regional, master and implementation plans, which are prepared in the context of earthquake sensitive urbanism, will provide earthquake sensitive, healthy and sustainable urban areas and settlement layouts.

The following process will continue with design, construction and implementation processes leading by the civil engineers and architects, after the initial contribution of geological science and geological engineering discipline.

In the sense of urban earthquake risk evaluation and risk reduction processes, vulnerability situation of the nuclear power plant stations, dams, natural gas and petrol pipelines, electricity distribution units and hydro electrical facilities should be determined. Schools, hospitals, fire stations and the regions where the population density is high should be evaluated by considering their earthquake sensitivity.

Techniques, such as multi criteria decision support systems based on GIS should be used for urban site selection and land use. For the priority areas, earthquake resistant building design parameters should be specified. For example, comparing with a dangerous material storage area, a single storey material or raw material storage area has different risk level. Initially, priority area (such as schools, hospitals, chemical plants, dams, etc.) risk levels should be decreased.

There exist various key issues to the development of the planning strategy for coping with a major earthquake in the sense of earthquake damage reduction [5]. Maps, including seismological risk of the city and its surroundings should be prepared. Urban planning processes should depend on those maps.

Earthquake sensitive planning gives importance to risk reduction. Thereby, microzonation maps, as well as geological investigations, are required to decrease the risk level in the context of mitigation precautions [6].

Urban planning is vital in the sense of mitigating vulnerabilities of earthquakes. In the context of urban planning and design, there exist various preparedness and recovery stages for before and post-earthquake period. Those stages include network, urban structure, public space, open green areas and accessibility issues in the context of planning.

"Urban structure" as a term is defined as the pattern and relationship between blocks, streets, buildings, open space and landscape which constitute urban areas [7] (Llewelyn et al. 2000 cited in Brand and Nicholson 2016).

Additionally, transportation, energy, fuel-oil, water, healthcare services constitute vital significance, since they should ne resilient during an earthquake. Urban planners have a significant role in making accurate spatial decisions to locate these functions as part of earthquake sensitive urban planning. For instance, a resilient transportation system should include alternative roads in the case of emergency. Therefore, if the first road get damage in the earthquake, then the second alternative road could be used to escape. Hence, it could be stated that resilient urban planning should consider alternatives to sustain the maintenance of the urban systems like water supply, highway system, escape routes, electrical system, gas system.

In this sense, four parameters were defined by Tsionas et al. [8] as, the buildings lining the street, buildings' heights compared to street width, street slope and street traffic conditions. Those parameters applied to the street segments to see post-earthquake evacuation routes Then, streets are ranked according to their risk levels [8]. Therefore, neighborhoods should be supported by diverse street network, connecting with open spaces to decrease their vulnerability levels. An urban structure having wide gridded streets, widespread and rich network of parks, powerful lifelines (as water supply, highway, electrical, fuel and gas system), easies recovery process after earthquake.

In the same way, parks in the neighborhoods allow recovery after the earthquakes. They constitute gathering points for the community. Green and open spaces provide temporary camping sites for the community.

In this context, a resilient system must be able to function even in the case one of its components fail [9]. Polycentric urbanism is significant in this sense. Physical and spatial vulnerabilities could be decreased in the context of polycentric urbanism, which provide various linkages among its centers.

Against earthquake vulnerability, it is necessary to provide the link between connectivity and mobility. The capacity and variety should be sustained among the centers. In this sense, suburbs should have wider street network and large open-green spaces.

Residential areas should have easy access to the streets and the related highways. Additionally, denser areas should include more open spaces for evacuate. Design should consider existing urban form, topography and geomorphology for recovery and reduce earthquake risks to sustain resilient urbanization. In this sense, each city has different characteristics and capacity to cope with the risks caused by earthquakes.

Therefore, it could be stated that the resilience of an urban area depends on its specific structure and function. To enable an earthquake resistant city, cities should be planned by considering their physical and geological features.

A polycentric urban form, encouraging the transportation link among the centers, development of the sub-central functions' sufficiency, discouraging the urban growth and the sprawl and the development of the urban hierarchy should be promoted.

Hierarchical street network and the connections among those streets should be provided. the distribution of the open-green spaces, parks and public open spaces should be balanced and their numbers should be increased for the temporary sheltering zones.

The polycentric urban form should be promoted by a transportation network, built between the centers and the settlements. Besides, population density should be balanced.

In brief, an earthquake resilient and low-risky urban area is possible with a multidisciplinary team, including geological engineer, city planners, urban designers, architects and civil engineers and the other related disciplines working in close cooperation.

Because the process continues as national plans, regional plans, metropolitan plans, urban design and construction, respectively. In each stage of the process, disciplines have different roles and they act as multi-disciplinary. Besides, geology science is in interaction with the other disciplines in each of those stages.

2.3 Construction and Design

Neighborhood design is significant in the sense that design characteristics have a vital role in the continuing of the urban sustainability in the neighborhoods. The principal contributions of the design characteristics on the urban sustainability in the neighborhood scale could be listed as.

Fundamental rules related with robust construction in the context of creating earthquake resistant cities vary in the sense of civil engineering and architecture disciplines. Those related parameters could be listed as the form, geometry, irregularity, carrying system selection, material characteristics, workmanship quality, building quality, the properness of the building design parameters, depth and the type of the building foundation, the relation between building height and foundation depth, geotechnical characteristics of the ground which the building is located on, building-foundation relation, rigidity, resistance, ductility etc. of the building.

Building should stand, the ductility of it should be provided, its stability should not break down and it should be robust to the earthquake loads in the horizontal and vertical exes, considering the earthquake forces.

The existence of the horizontal elements, which hold together the structure are necessary. Besides, horizontal elements or diaphragms should be constituted to distribute the effects of horizontal earthquake forces towards vertical carrying systems [10].

Required criteria, which enable earthquake resistant buildings to be robust during the earthquakes, are generally classified as two by the researches [10] (Bayülke 1998 as cited in Akçaer et al. 2015): as: design criteria in the horizontal axis and vertical axis.

The basic criterion in the horizontal axis is straight plan geometry and form. On the other hand, conditions for the vertical axis could be stated as below [10] (Bayülke 1998 as cited in Akçaer et al. 2015):

1. "Designing the buildings, considering their basements in the design process,
2. Adapting the ratios, which determine the relation between building height and its foundation depth,
3. Properness of the ratio between the building height and the building width to the standards,
4. The building should be designed by disallowing the formation of the overturning moments,
5. The building load and the rigidity should linearly decrease from the lower storeys to the upper storeys,
6. Major height differences among the components of the same building should not be constituted."

Structures themselves and settlement layout could be determinants of the impacts of the earthquakes, in the evaluation process of earthquake vulnerability. In the most risk level, unreinforced masonry constructions are included. On the other hand, reinforced concrete buildings are in much less risk level. Additionally, steel-frame buildings are considered as much more elastic to earthquake effects. Modern steel-frame buildings generally are flexible enough to absorb shock due to their ability to absorb ground-shaking. However, some rigid elements as glass etc. are considered still vulnerable in those buildings [11] (Jaffe et al. 1981, as cited in Randolph 2004).

During the earthquake, damages and collapses could happen, generating due to the carrier system of the structure. In order to provide earthquake resistancy; buildings should have adequate strength, rigidity and ductility [12]. That's why the selection of the carrying system of the buildings and the implementation are significant in the sense of earthquake resistant design.

After 1999 Marmara Earthquake, in Kocaeli Province, Öztekin and Yıldırım [13] stated that reinforced concrete framework system on the apartment house types, which were collapsed in the earthquake, were exposed to collective collapse on a large scale.

They claimed the reason as [13]:

> the usage of concrete with weak strength and the use of concrete produced from unappropriate materials, as well as reinforcement inadequacy in the context of columns and beams which constitute the main bearing system of the concrete framework system. Additionally, weak column and beam connections, poor workmanship, building construction inconsistency with its project, disregarding the ground characteristics and related ground-building interaction, building activities through the incompatible ground characteristics, added extensions and storeys in defiance of construction permit, modifications damaging the bearing system of the construction, ground-floor commercial usages, reinforcement activities for the structures damaged in the previous earthquakes could be listed as the other reasons

In the case of probable earthquake, buildings' vertical system is significant in the context of determination of the risks. Also, elements as floor number, location, order, soft storeys and short column formation of the buildings are significant in the sense that they increase the earthquake risk level.

Earthquake damage issues also could be observed due to the characteristics of the ground, where the structure is located on. Building system and its basic design should be based on the characteristics of related building-ground interaction. Improper design of the structures in the context of ground behavior is considered as one of the significant parameters in the sense of earthquake damage. Various earthquakes happened in the world and Turkey verified this fact. For instance, buildings constructed on weak ground in Sakarya collapsed in 1999 Marmara Earthquake. On the other hand, buildings having the same characteristics, which were constructed on a stable and hard ground, did not collapse. This situation once again indicates the importance of ground-structure relation.

During an earthquake, amplitudes of the earthquake waves (P and S waves) change, depending upon the ground characteristics, where the structures are built on. Those waves apply pressure on the structures in the vertical axis (with P waves) and apply cutting force in the horizontal axis (with S waves). Buildings not having necessary foundation depth and the buildings, which are not constructed depending upon the earthquake resistant structure design parameters and the relation between ground-structure, expose to vertical and horizontal movements, arised from P and S waves. Therefore, it conduces to structure damage and collapses.

Gündüz and Arman [14] states that problems arising from the structure foundation were caused generally by the way of foundation design, during 1999 Marmara Earthquake in Adapazarı. Besides, they presents those problems on the buildings, explained below:

1. "Liquefaction and the related carrying capacity loss (due to local geological and geotechnical conditions),
2. Carrying capacity loss on the clayey soil, due to knead caused by the earthquake loss (due to local geological and geotechnical conditions),

3. Ground carrying capacity loss, due to inadequacy of foundation depth (in proper foundation design),
4. Problems relating with ground carrying capacity, arising from the inadequacy of foundation depth (in proper foundation design),
5. Horizontal movements, arising from the inadequacy of foundation depth (in proper foundation design),
6. Vulnerability of high structures with inadequate foundation depth and the related bearing capacity loss (relation between high of the structures and foundation depth)."

Especially, if proper foundation depth is not determined for the higher-multi storey buildings, depending upon the building load and the size; bearing capacity of the ground will easily exceed, considering the building load and the earthquake forces relation. This might cause building damages and collapses. Increasing earthquake wave amplitudes could cause the deformations on the foundations of the structures. Because of those deformations, ground bearing capacity loss could exist.

Durmuş et al. [15] state various inaccuracy, which caused damages during 1999 Marmara Earthquake in Kocaeli. Those inaccuracies are summarized in the context of 11 items, listed below as:

1. "Deep beams are generally located on vulnerable columns with stirrup. Within this scope, beams are stronger than the columns. Therefore, buildings collapse due to the formation of the column mechanism on the lower storeys.
2. Short columns created with window bays and staircase intermediate ding beams. So, stirrups remain insufficient and this situation causes brittle fracture.
3. Since one of the column cross section dimensions is immense comparing with the other, those columns could not carry the earthquake component on the direction of the short edge.
4. Although the distance between the centroid and the rigidity center of many buildings is higher than the minimum value described in Turkey Earthquake Regulations, twisting calculations of the buildings are not calculated.
5. Although the column cross sections are the same, being lower storeys of most of the buildings higher than the other storeys and being lower storeys' void ratio higher make those buildings vulnerable and cause soft storey formations.
6. Buildings have grand oriels and heavy roofs. Heavy roofs cause mowing away of the centroids of the buildings far from the ground. This is incompatible with the earthquake resistant building design.
7. Some buildings do not have adequate rigidity. This causes exceeding of the acceptance boundaries of the horizontal movements.
8. Buildings not having beams or hollow-tile floor slabs, also do not have reinforced curtain wall or diagonal members.
9. The damage situation of some of the buildings indicates that the buildings' period overlaps with the predominant period of vibration and this causes mass movements. It shows that the site selection of those buildings are determined by not considering their periods.
10. Some buildings having gable wall do not have adequate stable connections. Therefore, those walls have collapse risk.

11. Attached houses do not have joints with adequate width, described in the earthquake regulation. Those buildings crash, during the earthquakes. Due to this situation, many buildings were get damaged."

However, as is known, designing earthquake resistant cities and buildings, determinant parameter is not limited to only the selection of the carrying systems. Architectural design, which links the proper form and the related proper structure, is considered as one of the determinant parameters of designing earthquake resistant cities and buildings.

For this reason, earthquake resistant building design should start in the beginning of the architectural design, based on the experiments from the earthquakes happened in Turkey and in the world [10] (Bayülke 1998, as cited in Akçaer et al. 2015).

As is seen, it is necessary to test site selection, design and engineering parameters in the ground and site selection process proper to the building in the context of earthquake resistant construction and urbanization. In order to provide ground-building interaction in the sense of building site selection and the determination of local geologic and geotechnical conditions, geology engineers, urban planners and civil engineers should be in cooperation.

3 Conclusion

Earthquake sensitive urbanism process requires a multi-disciplinary approach. Each stage of the process takes shape in the context of the responsibility and the roles of the related disciplines. The fundamental base begins with the geology discipline, the data of this discipline play a significant role in the following stages, and those stages are completed with urban and regional planning, urban design, architecture and civil engineering in a multi-disciplinary way. De-linking or a weakness on those stages might affect the urban area. Those stages process in both multi-disciplinary and inter-disciplinary. Therefore, it is significant for those disciplines to constitute a loop, which they could find a middle ground and give feedbacks to each other.

Each year, tens of destructive earthquakes occur in the world and those earthquakes cause loss of lives and million dollars. By the moment, although the human being could not predict the time when the earthquake happen, it is possible to live with earthquakes in a peaceful and compatible way. What is matter is to create solutions by not interfering with the nature.

As a result, in this paper, a theoretical approach is presented related with the roles and responsibilities of the disciplines, which constitute the roots of earthquake mitigation and sustainable urbanism.

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Two Examples on Urban Renewal in Eskişehir

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Abstract. This study explores architectural and interior design features of the residential housing projects built in the Eskişehir Tepebaşı region along the 1st and 2nd Ismet Inonu Avenues, and focuses on the rapid transition that these projects carried out within that area. Construction was not permitted in this area until 2007, due to its historical importance as the city's former industrial area. With an emphasis on residential housing projects, construction commenced in 2009, and since then, the area has evolved into a popular residential and commercial center. Along with this popularity, the demand for these residential projects, as real estate, has also increased. The typology of these buildings features an atrium with either four or eight stories, hotel-style design and various advanced technologies of the day. The projects were conceived as highly exclusive residential houses offering residents special utilities such as professional facility management, access control systems, social areas, fitness, recreational facilities, parking lots and security services. The first residence project, Eldem Residence, was built in 2009. It was followed in 2011 by Aytepe Residences and the Akademia Suites projects, which were in turn followed by Başak, Two Towers and Atrium Park. The intensive urban renewal of the former industrial area has continued rapidly since then.

Keywords: Residence house · Interior design · Urban renewal
Lifestyle

1 Introduction

Globalization, socio-economic, technological and social changes have affected the urban space and have caused continuous changes and transformations in housing typologies and interior spaces. Like the spatial transformations and changes that globalization creates in all the world cities, there is a rapid change and transformation in the city of Eskişehir. It has become a regional attraction center in the geographical area where universities, industry, health facilities and developing tourism are located. After Tepebaşı District former Factory Area opened in 2009, İsmet İnönü 1st and 2nd Avenue were quickly constructed and mixed-functional buildings started to be built on

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the protected land. Many of these buildings were presented to consumers as "high-quality luxury residences" with high investment value under the name "Residence". Espark and Özdilek Shopping Center, residential projects, hotels and luxury residences have been changed as a means of public transportation. In addition, the social and commercial areas built on the ground floors of these buildings brought vitality to the region and accelerated the development of this region in the economic and social areas. In 2011, the Eldem Residence project was followed by Aytepe, Residence and Akademia Suit projects. Then Başak, İki Kule and Atrium Park residence projects were built. The transformation of the former factory districts into the accommodation, commercial and residential area, where the intense structuring the intensive urban renewal of the former industrial area has continued rapidly since then.

2 Residence House Definitions

The places where the effects of the globalization process are observed the most are the cities. In the cities, the living spaces of different social groups began to separate from each other with certain lines. This situation has two basic reasons: "In parallel with the intense flow of people heading towards the cities, the center of the upper-middle income groups is looking for a living space far from the negative living conditions and shaping the urban space according to the ideological structure of the consumer society [1]". Developments in the world, unlimited communication possibilities, make important changes in everyday life. "Developments in the field of design, developments in information, entertainment and production systems Innovations in the energy field are closely affecting the life and production systems [2]".

Global factors have created spatial changes and transformations in metropolitan cities. As housing becomes a İnstrument for consumption cultures, the demand for high-income consumers in housing is high, resulting in increased demand for new mixed-use settlements made up of residences. Consists of permanent residences, five star hotel services, shopping and working areas. Vertically rising and creating solutions to all the needs of everyday life in itself are constructs. These new types of residential buildings, which are rising vertically in the center of the city, are called residences and meet increasingly short-term accommodation needs for students and business people due to the increasing shifts in the world due to increased business potentials.

The appreciation of the place in the city center means that it is stacked vertically as part of big projects including commercial office spaces and shopping areas of residential structures. "These new mixed-use blocks offer both flexibility in the business life and 24-h activity in the building's life cycle [3]. Residential typology is a mixed-use field of activities that combines functions such as trade, are also provided by the service. Generally, it is not necessary to expect a high rise. When we look at the examples in the world, most of them are high-rise buildings. They are made up of multiple towers. They are creating a private living space in the urban arena, covering a considerable area as a scale in the interest of private investors.

In the beginning, mixed-use constructions for the purpose of securing security in major cities and providing prestige to the upper income group were first seen in the USA and soon spread to the same continent. The first example of these buildings, built as Gated Communıty and Residence typology, was Marina City, built in Chicago between 1959 and 1964. In Turkey these types of constructions have started with Akmerkez in Istanbul Etiler. “The housing sites that started to be seen in the walls of the cities after 1980 in Turkey, together with the foreign influences, are in the dynamics of Turkey after 80, mainly in the context of consumption culture [4]”.

The income distribution profile, the emergence of a new elite layer, the search for status and identity of this stratum, escape from the city, longing for rural life, limited urban space, In the past, housing has mainly met the need for housing, but today it has become a prestige and investment object. As an investment object, it ensures that individuals look ahead to the future. In the past, the way of life defined by the dwelling has become a matter of investment and consumption, as it is the family continuity, affinity and belonging feelings. Housing is a basic living space where people spend a large part of their lives in secondary activities such as sleeping, eating and personal cleaning as well as recreational activities such as recreation, study and socialization. “Houses are built to keep people safe in their lives. They have been constantly changing from ancient times to day-to day with human life [5]”. Responsibilities such as police protection, leisure activities, socialization, sports, and entertainment are provided by the community, which constitutes gated communıty, in urban life. “Only a private world is created that is shared with its neighbors. The disintegration of the city in this way threatens social life. The international rise of cape settlements continues [6]”.

The place, functions and services offered by the property influence the quality of the property, the brand, and the trends of the day and the choice of fashionable housing. In addition to the housing function, parking lot, social and sporting areas, security, management systems are features that are effective in the selection of the users. Demand for residences as a new type of housing has increased as a result of housing becoming an instrument of consumerism, high expectations of consumers in the high income group, high demand for housing, and the emergence of new lifestyle discourses. The residences built as mixed-use buildings in the diversity of today’s housing are composed of five star hotel services, permanent residences, shopping and study areas. Rising vertically in major urban centers close to the main roads, these are the ones that produce solutions to all the needs of everyday life. These new types of houses rising vertically in the center of the city are called residences. As a result of increased business potential in addition to the function of accommodation, the increasing placements around the world meet the needs of short-term accommodation. Often daily, weekly, monthly usage is seen.

In the TDK dictionary, the definition of “residence”; “Housing” and “palace housing”, which are reserved for the sitting of high government officials, ambassadors and so on. According to the Architecture Dictionary, it is defined as Residence [7]. The residence is a high-quality luxury residential unit with services that facilitates life through security and parking solutions that include functions such as shopping, cafes and workplace built by large real estate partnerships, usually in the city center or close to the center and public transportation vehicles. It offers an individual lifestyle as luxurious luxury residences for investment purposes. “The residence typology has been described as “a style of presentation” which is generally constructed in the city center as a condominium and serves only to the upper income group and therefore serves a homogenous community [8]”. “The residence housing is defined as the “luxurious residential alternative structures with the use of the high income class, close to the center, social areas for the use of people living outside the residential areas [9]”.

Housing is one of the basic needs for housing needs for the lower income group, more prestigious for higher income groups, and one of the indicators of people’s lifestyle and social status. In the old and central residential areas of the city, the individual lifestyles of the young professional population come to the forefront and these areas are transformed into marketable areas by raising the urban rent [10]. Residences typology is a mixed-use building where services such as trade, service and housing are combined and accommodation is provided. “The integration of functions outside of the housing functions of the residence buildings into the urban life, the establishment of the limited space in the city by breaking the user out of the city with the variety of functions, creating separated regions [11]”.

Residences marketed with advertisements sell “lifestyle”. The locations of the houses and the properties they possess have a value and prestige that cannot be seen. “It is said that the effects of fashion are not only in clothing, and decoration, but also in a wide range of activities, including lifestyles and activities [12]”. As a marketing method of housing, advertising has promoted the role of the dwelling in the consumption cycle, causing individuals to be presented with different purposes and methods. In this sense, “luxury apartments consisting of low-rise apartment blocks which have emerged in Istanbul in recent years for the middle, upper-middle and upper income groups and the luxurious multi-storey houses which are historically seen in the late period and which are called as residences, powerful advertising texts aiming to accelerate consumption [13]”. In certain places, those who acquire housing will acquire a tangible, unobtrusive value added with it beyond just acquiring a real estate of the same square meter. “This added value is the ‘World of Privileges’ which they present to their owners [14]”.

The first example of residences in the US was Marina City, built by architect Bertrand Goldberg in Chicago. Due to the globalization effect, it is rapidly increasing in large metropolises in various places of the world. These cities are the cities that have the characteristic of being a world city. Examples are Hong Kong, Kuala Lumpur, Beijing, New York and Istanbul. Generally, it is not necessary to expect a high rise. When we look at the examples in the world, most of them are high-rise buildings. They are made up of multiple towers. They are creating a private living space in the urban arena, covering a considerable area as a scale in the interest of private investors.

3 Residence in Eskişehir

Eskisehir Tepebaşı Region in 2000 after years of urbanization efforts gained speed and new construction and zoning regulations began to build in accordance with. This settlement is made especially in the area where the former factory buildings are protected, which is not allowed to be built for many years. Although some buildings have been protected under this area, most of them have been opened to the restoration. The restructuring in areas outside the 13–14 buildings registered with the protection board in this area continues increasingly. The residence buildings were built as a building shaped in line with the zoning rules of the city which is not a multi-storey building in Eskişehir scale.

This region has a special and distinctive place in the historical development of Eskişehir as a city. Most of the factories, which have a 70-ha area, are tile and brick factories and some of them are flour factories, have been destroyed and residence, luxury residence, plaza, hotel, shopping mall, buildings have been made instead. “These areas, which have a great importance in the formation of urban image as well as in city and technology history, have become a very attractive area in terms of urban transformation due to their proximity to the center and their main transportation axes and have lost their identity to a great extent [15]”. District Residence has become a new attraction center especially for the young population by being equipped with luxurious housing, hotel, entertainment place, shopping center, cafe, and restaurant. Projects are being produced that show how these valuable land in the city, which is observed in the transformation projects, can be brought to a more valuable and more profitable position for commercial purposes. It is about becoming a living space or investment area for the upper income group.

Residency projects in İsmet İnönü 1st and 2nd avenue in Eskişehir and which are still under construction and taken as a sample have been examined and a determination study has been carried out by arranging the accessible data. The Eldem Residence, Başak Residence, Aypalas Residence, Two Tower Residence, Atrium Park Residence, Akademia Suit, Aytepe Residence buildings were constructed between 2009 and 2014 and the usage was opened (Table 1).

Table 1. Case study residences

No	Name	Local	Street	Year
1	Eldem Residence	Tepebaşı	İsmet İnönü 1. Avenue	2009
2	Başak Residence	Tepebaşı	İsmet İnönü 1. Avenue	2014
3	Aypalas Residence	Tepebaşı	İsmet İnönü 1. Avenue	2014
4	İki kule Residence	Tepebaşı	İsmet İnönü 1. Avenue	2014
5	Atrium Park Residence	Tepebaşı	İsmet İnönü 2. Avenue	2014
6	Akademia Suit	Tepebaşı	İsmet İnönü 2. Avenue	2011
7	Aytepe Residence	Tepebaşı	İsmet İnönü 2. Avenue	2011

Especially on the ground floors, it is seen that the district is a new city center with social and commercial areas opened to use (Fig. 1).

Fig. 1. İsmet İnönü 1st and 2nd Avenues. *Source* Google Maps

A mixed use development which has office, retail, hotels and residential spaces. Residences are "mixed-use" buildings that offer a variety of different life proposals as well as housing functions. Residences are constructed on Ismet Inonu 1st Avenue from the residence buildings. Eldem Residence is made of 8 stories and two tower residences ten stories. The Başak Residence built on this street was built on a five stories Atrium plan type. Housing sizes range from 45 to 100 m^2. A small number of apartments over 100 m^2 were seen. The ground floors are commercial and social areas; the upper floors are residences. Entries are designed with a hotel concept. Reception service is provided. On the basement floors there are parking and plumbing systems. The ones built on Ismet Inonu 2nd Street were made of four five stores Atrium plan type. The Akademia Suit accommodates social life and sports areas with residential apartments in the size of 40–110 m^2. Arranged in a common inner garden of 4 floors. The central area is covered with a transparent roof material in Aytepe Residence, Akademia Suit, Başak Residence buildings. All of the examined buildings are managed with a professional management system by hosting the reception area in the entrance halls. There is parking on the basement floors. Vale service also serves to the users in the social area. Entrance to the living area is from the front or rear, and commercial and social entrances from the front (Fig. 2).

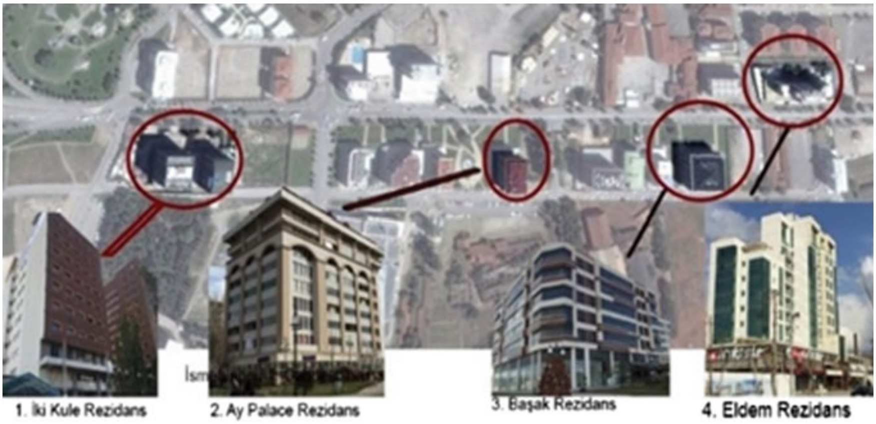

Fig. 2. Eskişehir Tepebaşı 1st Avenue. *Source* Google Maps (Erişim tarihi 20.05.2014)

There are integrated design constructions, quality materials and special designs in the living spaces of residence apartments. Suspended ceiling lighting systems, internet, sound, antenna installations, heating, ventilation installations have created hotel comfort. The selected material and designs were influenced by fashion. The concept of luxury has been used for residential buildings today, for villa residences over the past few square meters. The change in the perception of luxury housing has been shown to be influenced by fashion and advertising campaigns. When looking at the usage that is seen from the sale or rental advertisements, residence dwellings which are formed in the region, besides housing function, front office, office, shopping mall, day-to-day usage front plate were seen. It is marketed as a new lifestyle discourse with the words of luxury and elitism in small square apartments. In this sense, two examples residence buildings were selected from this new life center (Fig. 3).

Fig. 3. Eskişehir Tepebaşı 2nd Avenue. *Source* Google Maps

4 Examples of Residence in Eskişehir

4.1 Case Study: Eldem Residence

Eldem Residence building on the Eskisehir Tepebaşı District of Old Factory İsmet İnönü 1st Avenue was built in 2009. This is the first sample of a residence Typology. The building has an 8-storey, total buılt-up area of about 1665 m^2. The building contains 55 1+1 and 2 3+1 apartments. The apartments range from 75 to 125 m^2. The 24-h security service of the building with indoor and outdoor parking lot is provided by closed circuit camera systems. It is within walking distance of public transportation, City center and shopping centers. The building which is resistant to depression is heat insulated. Internet, cable TV, fire and air conditioning system. On the ground floor there is a café, business and restaurant. Entrance of residential areas and commercial areas are separated on the ground floor. Entrances of commercial areas the entrance of residential areas from İ. İnönü 1st Avenue is the back of the building. Eight-stores building has been applied to the hotel type design (Fig. 4).

Fig. 4. Eldem residence exterior view. *Source* Author's Archive 2015

Eldem Residence combines concepts of hotel and home. In the entrance hall of Eldem, there is a reception and lobby which are adopted from hotel concept. A material used in entrance has also 5 star hotels characteristics. Ground floor serves as a management floor. Valet parking and helping hands services provided here (Fig. 5).

Fig. 5. Eldem residence site plan. *Source* Google Maps

4.2 Eldem Residence Type 1–2

The reception and waiting area are designed to provide security and controlled access in the main entrance hall of the building (Fig. 6). Eldem Residence Type 1 is one-bedroom apartments. When looking at the Eldem Residence Type 1–2 apartment plans, type 1 apartments and type 2 apartments are designed symmetrically as 1+1 apartments the apartment was entered through the entrance hall. In this area, the gateway of the bedroom and the living area opens. The door is designed. Opposite the entrance hall is the entrance to the bedroom. The bedroom has a double bed and bedside tables and wall surfaces.

Fig. 6. Eldem residence reception. *Source* http://eldemrezidans.net/

The wardrobe is located on the opposite wall. When entering the living room from the entrance hall, a seating group and a TV unit were placed. It is designed in an open-plan style in the same space as the American kitchen in the living space (Figs. 7, 8 and 9).

Fig. 7. Residence plan type 1 (1+1) 75 m^2. *Source* http://eldemrezidans.net/

There is a dining table for six people in this area. The fact that the house is planned in front of the window is a positive feature. A very wide window system has been used to view the living area. In wet space; Toilet, washbasin, shower cabin are placed and covered with special design ceramics.

Fig. 8. Eldem residence type 2 (1+1) 75 m^2. *Source* http://eldemrezidans.net/

Fig. 9. Eldem residence living area. *Source* http://eldemrezidans.net/

4.3 Eldem Residence Type 3 Apartments

Eldem Residence type 3 apartments has L-shaped plan layout. A coat-locker was designed in the hallway and room distribution was provided. When entering the living room from the entrance hall, a seating group and a TV unit were placed and a dining table for six people was used. The living area has been opened on the balcony. The kitchen was designed as a separate room and a spacious bright room was provided with a window opening to the balcony. There is entrance of the bedroom directly opposite the entrance door. There are double beds, wardrobe, and bedside surfaces in the bedroom separated by walls from the living area. In wet space; Toilet, washbasin, shower cabin are placed and they are covered with special design ceramics (Fig. 10).

Fig. 10. Type 3 plan 90 m^2 (1+1). *Source* http://eldemrezidans.net/

4.4 Eldem Residence Type 4 Apartments

Eldem Residence Type 4 is duplex apartments. Downstairs has living areas, kitchen and wet space, upper floor has bedroom and bathroom. The living area is provided with a balcony outlet with an open-plan design, internal staircase and a street view. The kitchen consists of a sink, cooking facility, branded countertops, refrigerator, and kitchen cabinets. There was a bar chair and an island countertop as a space separating element and no dining table was used. The space was created with special colors and equipped to create a bright and spacious environment. It was attempted to create a luxurious living space sensation in a small square meter with the light and the view that the window systems are floor-to-ceiling windows. Suspended ceiling lighting elements, floor coverings, wall coverings, graphic elements on the walls were used in the living area by using a holistic design method and the library was designed along the floor height. The equipment used is quality and branded products (Fig. 11).

Fig. 11. Type 4 duplex apartments plan 116 m^2. *Source* http://eldemrezidans.net/

Window systems in residence apartments, especially in living areas, have been made up to the level of the ceiling, providing a wider and brighter perception than interior space (Fig. 12).

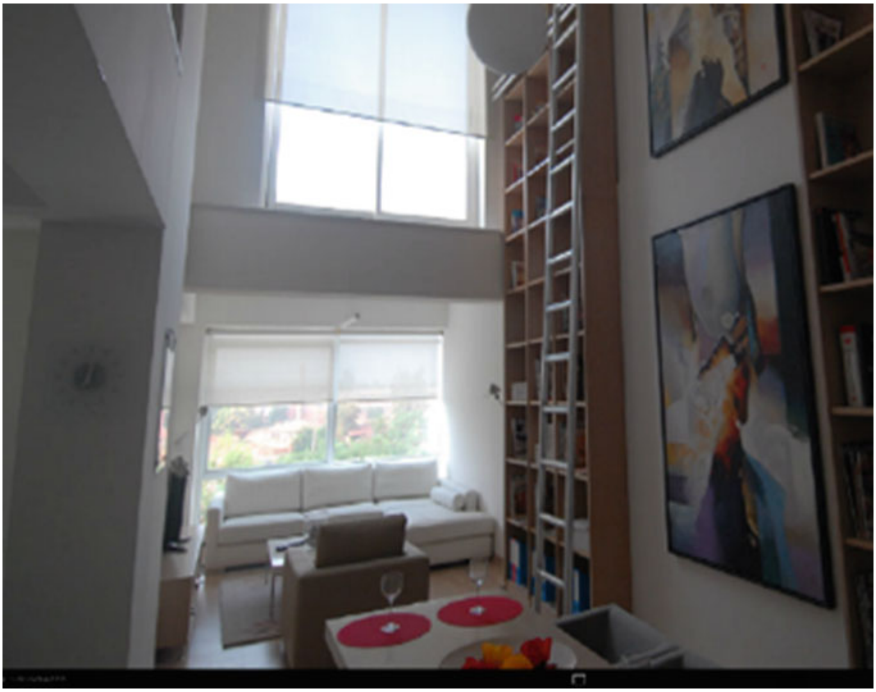

Fig. 12. Apartments living area (type 4). *Source* http://eldemrezidans.net/

5 Case Study 2: Akademia Suit

Akademia Suit is located in Ismet Inonu 2nd Avenue in a residential area close to Anadolu University. The building is designed as five-stores, the ground floor consists of 4 commercial and 66 1+1 residence apartments. There are 3 different size for apartments: 70, 64 and 84 m^2. Total construction area is 6370 m^2. The construction was completed in 2012. Some of services they can benefit residents in Akademia Suit Residence; 24-h concierge, security, technical support, dry cleaning and drinking water services are provided. Internet access, cable TV, air conditioning system. The heating system was built as a central system (Fig. 13).

Fig. 13. Akademia suit outside view. *Source* Author's Archive 2015

Akademia Suit is located near public transportation, health buildings, shopping malls, highways. The entrance of the shopping places on the ground floor is given from İsmet İnönü 2nd Avenue. Entrance to the residence was given from the rear. The entrance to the apartments is through hallway in Atrium. Although it could be used as a social, recreational area, it has no function in these buildings. Due to the transparent roof of atrium the space is bright and airy. In order to give open-air feeling, entrance to the apartments built in the middle floor (Atrium) in the 1st floor is provided from this area. Atrium is covered with a transparent roof material while the floor covering is made of wood-like covering and artificial green space (Fig. 14).

Fig. 14. Common space atrium. *Source* Author's Archive 2015

Building is accessible for a person with disabilities. Use of mirrors in the atrium creates a spacious atmosphere (Fig. 15).

Fig. 15. Akademia suit entrance hall. *Source* Author's Archive 2015

When the Akademia Suit apartments plan is examined, 3 types of apartments are seen. Hotel style design has been applied in 1 studio type 1+0 apartment on each floor. In the plan, Type 3 apartments are placed in 4 front and rear facades. The places that make up the apartment are composed of living area, bedroom, bathroom, and entrance hall and kitchen niche. Type 1 is placed on the right and left side of the apartment. The kitchen is designed in the entrance hall of these apartments. There is a living area with dining table. It is directly related to the balcony. The balconies are surrounded with glass and the living area is designed here (Fig. 16).

Fig. 16. Akademia suit normal floor plan. *Source* Seçkin Kaya Construction Catalog

Privacy is an essential factor in obtaining a protected space. Privacy is the control of the visual or auditory relationships of persons or groups with other persons or groups. It is the property of the person and has the right to legal and statutory control. It is a protected area with borders that are defended against foreign and foreign threats [16]. Security is provided by using electronic encryption system at the entrance door. An electronic border was created without being surrounded by walls and the security of the residences was ensured. A small Reception area is planned for the control of apartment entrances and exits. The services offered by the residence are managed from this place. Vertical transportation is provided by the two staircases and two lifts.

The entrance is designed according to accessibility principles. On the opposite wall in the entrance hall, a spacious space sensation is provided by using a mirror (Fig. 17).

Fig. 17. Akademia suit reception. *Source* Author's Archive 2015

5.1 Type 5 Akademia Suit Apartments

The Type 5 Akademia Suit Apartments is designed as 1+1 with a size of 84 m^2. On the right side of the apartment entrance door is an optimum designed bathroom. Suspended ceiling lighting system is used indoors. Glass shower, closet, washbasin, washing machine. Bedroom has single bed, nightstand, work desk and single seat. The kitchen is planned as a niche in the entrance hall. There are sink, cooker, under-counter refrigerator, dishwasher and breakfast table. It is equipped with modern kitchen cabinets and built-in products. A window in the form of a bathroom window was placed on the wall separating the living area for illumination. In the living area there is a living room, dining table, TV unit, coffee table. The living space is oriented to the outside. With the windows up to the balcony exit, sufficient illumination of the interior has been provided. The balcony, which is designed using the folding glass separators, is an important design element that makes an external connection as an open space in living areas. Floor coverings are covered with laminate and walls are covered with color and pattern suitable for interior design. Ceramics were used as floor coverings in wet spaces (Fig. 18).

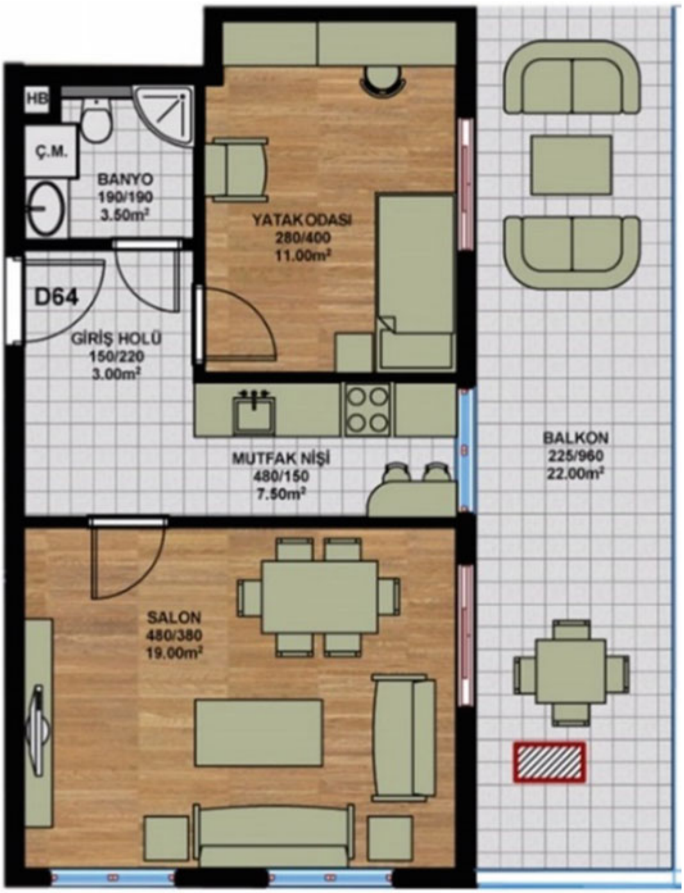

Fig. 18. Akademia suit type 5 plan. *Source* Seçkin Kaya Construction Catalog

6 Conclusion

This study explores architectural and interior design features of the residential housing projects built in the Eskişehir Tepebaşı region along the 1st and 2nd Ismet Inonu Avenues, and focuses on the rapid transition that these projects carried out within that area. Common features of examined residence buildings:

- Residence projects in Eskisehir in the Tepebaşı region along the 1st and 2nd İsmet İnönü Avenues offers an alternative solution for the new housing needs. Beside these residence projects, there are several ongoing hotels constructions in the region.
- Construction of further residence projects continues.
- The construction standards of these buildings are very high. These are isolated, earthquake-resistant and fire secure buildings.

- These houses are marketed as 1+1 luxury houses; they claimed that they provide luxurious and exclusive living environments. Therefore, these houses perceived by users as luxury.
- Entrances of residential and commercial areas in these buildings are divided.
- In the main entrance of residences reception service is provided. These buildings are located in a very advantageous location. They are located in walking distance to city center, shopping malls, highway and university.
- Examined buildings contains parking lot, security service, commercial stores, recreational and sport areas. Beside their use as residential areas, they also serve as offices.

There are mainly two users of these buildings tenant and investors. Because of the advantageous location of buildings, prices of lands (estate) in the area increased drastically which resulted an increase in the prices of residences [17].

Users of these residences are generally high-educated and coming from high socio economical demographics. This research indicates a need for planners to provide appropriate and viable alternatives design to current house forms.

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The Guidelines of the Eco-City Based on Sustainable Urbanism

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Abstract. Along with the population growth and industrial revolution, migration from the countryside to the cities increased greatly and unplanned urbanization is brought out. This condition conclusions such as troubles faced for the use of resources, increasing environmental pollution, global warming. Unplanned growth of cities leads to serious destruction not only on the natural environment but also on the human nature. A successful sustainable urbanization is possible that both physical and social sustainability studies are accomplished in integration with each other. Cities have continually been destroying nature due to the lack of recycling technologies, unplanned settlement and desire for constructing houses to green areas, air pollution and unhealthy infrastructure. As a result of them sustainable urbanism focused on the term of eco-city. Eco-city is a city designing and application approach in which human, city and environment issues are handled in relation and interaction with each other. In eco-city design, some principles such as reducing the effect of cities on environment, the use of renewable energy sources, the lowest level of waste production and the use of renewable energy sources have been taken into consideration. The eco-city provides healthy abundance to its inhabitants without consuming renewable resources than it produces, without producing more waste than it can assimilate, and without being toxic to itself or neighboring ecosystems.

Keywords: Eco-city · Sustainability · Urbanism

1 The Concept of Urbanism and Sustainability

1.1 The Concept of Urbanism

Cities are the settlements where the cultural activities, social relations population density of which differ from country sides where living sources of the population is out of agriculture and stock raising. This type of urbanization has resulted in diminishing resources, increasing environmental pollution, global warming and the destruction of some plants. Cities have continually been destroying nature due to the lack of recycling technologies, unplanned settlement and desire for constructing houses to green areas, air pollution and unhealthy infrastructure [1].

Urbanism means that the increase in the number of cities and the population who live in the cities. This term can be identified such as the migration of the population from the country sides and agricultural areas to the cities, and also, the move of the

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population working on agriculture and stock raising, mainly industry, toward sectors out of agriculture. So, it is wrong to identify urbanism only with the increase of population.

Additionally, urbanism means adopting of the population the norms and living standards of cities becoming cities demographically and economically. As a result of the population increase and industrialization has brought many problems, such as stress, noise, rising in rental prices, it also has negative effects on environment such as air pollution, water pollution etc. These are the socio-economic effects of urbanism.

Problems Occured by Urbanism. The huge growth that urbanization has created has resulted in many problems. The problems occured by urbanism can be divided in three sections:

The first one is the population crowd which caused by dense population in cities. Many people change places in central transport with the loss of time due to the traffic jam and waste of fuel oil. In addition, the stress of the people causes the fall of productivity.

The second is the increase in rents along with the housing crisis. It should be pay attention to the taxation. Also, the disadvantage of income distribution should be eliminated.

The third is the construction of the houses without the necessary permits. Aesthetic problems have arisen due to random urbanism. In addition to technical, administrative and financial measures, there is also a need for politicians' resolute attitudes in the solution of housing problems. The uncontrolled growth of cities with increasing costs is a major problem for the country's economy. The excessive increase in costs has brought a great burden on the economy.

In conclusion, in addition to the problems listed above, due to political pressures and bureaucratic problems, the productivity of personnel is decreasing. The increase in the number of staff also increases the cost. Some suggestions have been developed for solving the problems caused by urbanization. Reducing the density of population in cities and preventing the expansion of cities are some methods to decrease the main problems of urbanism in cities [2].

1.2 The Concept of Sustainability

Sustainability concept was explained in Bruntland Report published by United Nations Environment and Development Commission in 1987. According to the report, sustainability meets the needs of current generations from the needs of future generations. Sustainability concept has been examined in to the scientific studies through sustainable development concept. That's why, the meaning of sustainable development concept in order to identify and apply sustainable urbanism and sustainability concepts. Sustainability concept began to be used widely in many areas such as security, energy, city planning etc. in the years of 1990. This concept is presented as an alternative solution to solve the problems between economy and environment [3].

In the 21st century, the need to create a sustainable city has arisen due to the environmental pollution and resource depletion in the global world and the difficulties of finding clean resources. Sustainability means saving resources in a more conservative way and to turn to renewable energies. In the view of sustainability, both the economy and society are limited by their environment. The interconnections among economy, society, environment, and the distribution of resources and opportunities (see Fig. 1).

Usage of insufficient resources and management of them form a view of social and economic branches and innovation have been on search. Due to this new material choice, new production methods occur in the architectural design, thus new era of architectural design is started and named as "eco-city". In the rural area, new social relations are appeared in daily life of cities.

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The concept of sustainability is based on three themes: the environment, the economy, the social aspect [4, 5].

Social wellbeing, cultural, economic and spiritual needs limit to maintain natural resources and the ecosystem in the definition of sustainability. Sustainable development improves the quality of human life by supporting ecosystems [6].

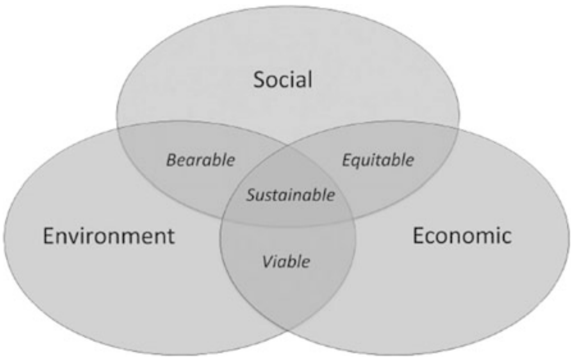

Fig. 1. The concept of sustainability [4]

The reflections of them to the guidelines for eco-city are:

→ healthy housing and workplaces
→ industrial ecology and environmental protection
→ re-use of materials, life-cycle production, and renewable energy
→ ecological infrastructure
→ ecological education
→ economic security
→ people's quality of life
→ empowerment with responsibility [6].

Eco-cities development has emerged as a way to address sustainability issues in the context of cities. The Eco-City Builders expanded upon the definition of the term initially to be focusing on "reshaping cities for the long-term health of human and natural systems". Therefore, a successful Eco-city takes into consideration the synergy and interdependence of environmental, economic, and social sustainability and their fundamental ability to support and strengthen each other in the city context. Developers of Eco-cities need to put in place the foundations to enable choices across all aspects of living and working to be sustainable ones. These include energy efficient buildings, renewable energy, resource efficient infrastructure and proximity to employment and services [7].

1.3 Sustainable Urbanism

In the process of moving from agriculture to industry in developing countries, increasing problems of outskirts, appearing of infrastructure problems as a result, increase in the rates of crimes, lack of education and health services etc. all make cities places that cannot be lived by degrees. Sustainability concept was identified in Bruntland Report published by United Nations Environment and Development Commission in 1987. According to this definition, sustainability means to be able to meet the needs of current generations without making a concession from the needs of future generations.

Sustainability concept has entered into scientific studies through sustainable development concept. For that reason, one should initially examine the meaning of sustainable development concept in order to identify and apply sustainable urbanization and sustainability concepts in all other fields. Sustainability in every field is directly related to this concept. Sustainable development concept was initially adopted by Earth Protection Strategy dated 1980. Later on, it has been identified with the concept of sustainability in a report in 1987. Additionally, Rio Summit, Agenda 21 Document and World Businessmen Council have adopted sustainable development concept in their policies and applications [3].

Sustainability concept began to be used widely in many areas such as security, energy, city planning etc. in the years of 1990. It was put forward as an alternative way of application in the solution of problems occurring out of mutual interactions of concept, economy and environment. One of the most significant problems of sustainability is excessively increasing population. For meeting the needs of the increasing population, the need for supplementary service in cities reveals the definition of sustainable development on its own. This concept which envisages a full integration of environmental, economic and social goals meets the needs of present generation and covers being taken notes of the demands of future generations to natural sources as well. For the realization of sustainability, four important approaches exist:

1. Eliminating poverty and deprivation. This situation draws the attention of poor persons who have no remedy but to destroy the environment.
2. Development which does not drop environmental quality. This situation provides the continuation of the removal of poverty.
3. Widening the idea of the necessity of attempts the center of which is human.
4. Combining economy and ecology at decisions in every stage, in other words, realization of institutional change [8].

Sustainable urbanism consists of harmonious and balanced growth of the city with ecological system in a way to be reflected toward future. This understanding aims at leaving cultural, historical and natural inheritance to future generations in addition to living in a humanely urban environment of societies today.

The most important problem occurring on this stage is at which rate the sustainability of cities could be realized. Because, horizontal and vertical growth of cities lead to damages both in nature and human's nature dependent upon the recovery of living conditionals. The presence of sustainable urbanization is possible on condition that both physical and social sustainability are integrated with each other [1].

For providing the continuation of physical sustainability; one should prevent unplanned construction, save up infrastructure investments providing vertical growth of cities not horizontal, prevent building houses to green areas, change the transport system (using transport by sea or tubes instead of highway vehicles) and use recycling technologies in every field. Social problems experienced by city human must be removed through social sustainability [9].

2 Eco-City Guidelines

The term of eco-city is identified by Eco-city builders that a whole systems approach integrating administration, ecologically efficient industry, people's needs and aspirations, harmonious culture, and landscapes where nature, agriculture and the built environment are functionally integrated. Eco-city is a city designing and application approach in which human, city and environment issues are handled in relation and interaction with each other (see Fig. 2) [4].

The word of eco-city was first used in 1987 by Richard Register in his book, Eco-city Berkeley: Building Cities For a Healthy Future. In Eco-city design, some principles such as reducing the effect of cities on environment, the use of renewable energy sources, the lowest level of waste production and the use of renewable energy sources have been taken into consideration [4].

Fig. 2. The content of eco-cities [12]

Many of the identities of eco-cities development branches are located:

1. Development of different agricultural systems. For example, in suburban and city center parcels Agriculture at scale. With this application, the distance of food and transportation is reduced.
2. Renewable energy sources such as wind turbines, solar panels or bio-gas from waste. Cities have economic scales that make these energy sources vital to their structure.
3. The biggest energy demand is to reduce energy use in cooling and heating, planting and illuminating surface colors for natural climate systems and minimum 20% green surfaces coverage, increase in water content.
4. In order to reduce carbon dioxide emissions of vehicles to increase the frequency.
5. Far away from an urban Heat Island Effect supporting the building block by public transport.
6. Reducing urban expansion with a policy to keep people closer to their workplaces: Smart Growth.
7. Green roofs.
8. Zero carbon dioxide emission transport.
9. Zero energy construction.
10. Sustainable urban drainage system.
11. Systems or equipment that will reduce energy production.
12. Garden and landscape designs for water conservancy (Xeriscaping) [4].

Although there is no universally acceptable definition of an eco-city, there is some consensus on the basic features of an eco-city amongst the available definitions (see Fig. 3).

Fig. 3. The silhouette of eco-cities [4]

The concept of eco-city is closely linked to the concept of sustainable development, and the construction of such cities is identified:

1. revise land-use priorities to create compact, diverse, green, safe, pleasant, and vital mixed-use communities near transit nodes and other transportation facilities;
2. change transportation priorities to favor foot, bicycle, cart, and transit over cars, and to emphasize "access by proximity";
3. restore damaged urban environments, especially creeks, shore lines, ridgelines, and wetlands;
4. create decent, affordable, safe, convenient, and racially and economically mixed housing;
5. nurture social justice and create improved opportunities for women, color people, and the disabled;
6. support local agriculture and urban greening projects;
7. promote recycling, innovative appropriate technology, and resource conservation while reducing pollution and hazardous wastes;
8. work with businesses to support ecologically sound economic activity while discouraging pollution and waste;
9. support voluntary simplicity and discourage excessive consumption of material goods;
10. increase awareness of the local environment and bioregion through activist and educational projects that increase public awareness of ecological sustainability issues [6].

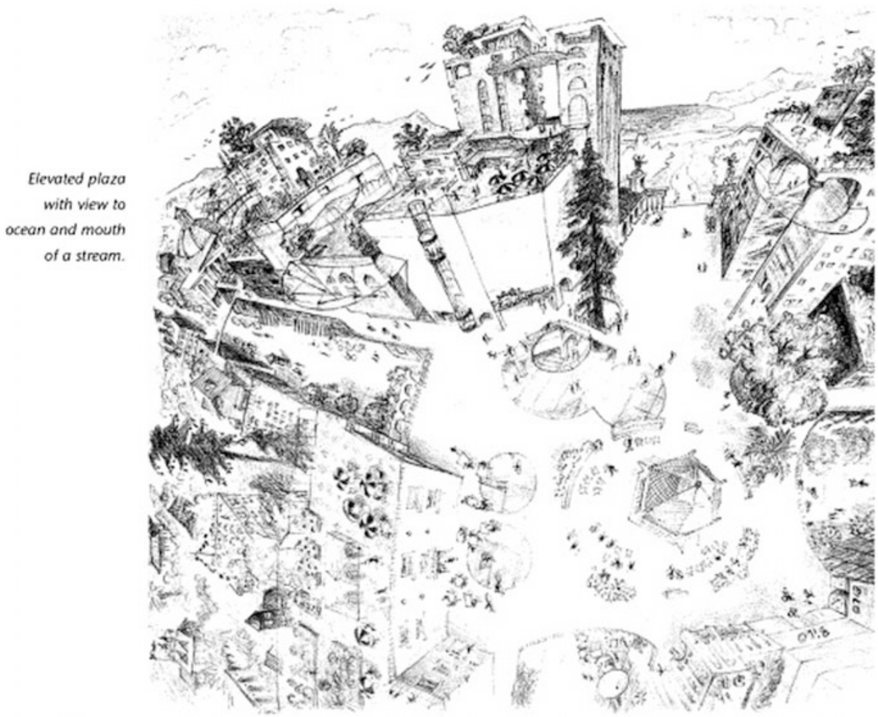

Fig. 4. A square and its surroundings in eco-cities [4]

Although city areas cover only 2% of earth, they consume four third of the sources. For instance, the city of London needs 125 times more earth of its area so as to meet its own consumption. According to many environmentalists, cities are the main source of many environmental problems such as pollution and carbon dioxide oscillation. The solution is to protect the rest part of nature and to start building cities with a new understanding. According to specialists, city understanding needs a radical change. For that, environmentally friendly cities that meet its own consumption with its self-production must be created (see Fig. 4) [10].

In any way; governments, planners, architects and engineers have begun to realize this idea and have started to search new ways for environmentally friendly cities. Their approach depends on two main principles: recycling of anything possible and minimizing the use of cars. As well as developing energy-activated buildings, it has been paid attention to arrange [11].

3 Conclusion

Sudden and scary climate changes and the issue of environmental damage experienced today have become more visible and sensitive in great walks of society. In fact, limitless consumption of limited sources to create for future generations was on agenda since 1970's.

According to the expectations from the Future of Eco-cities; The Jacque Fresco with a movement under the name of "Zeitgeist Movement", the world is defending the dangerous end. A sample transportation in eco-cities can be seen in Fig. 5 [4].

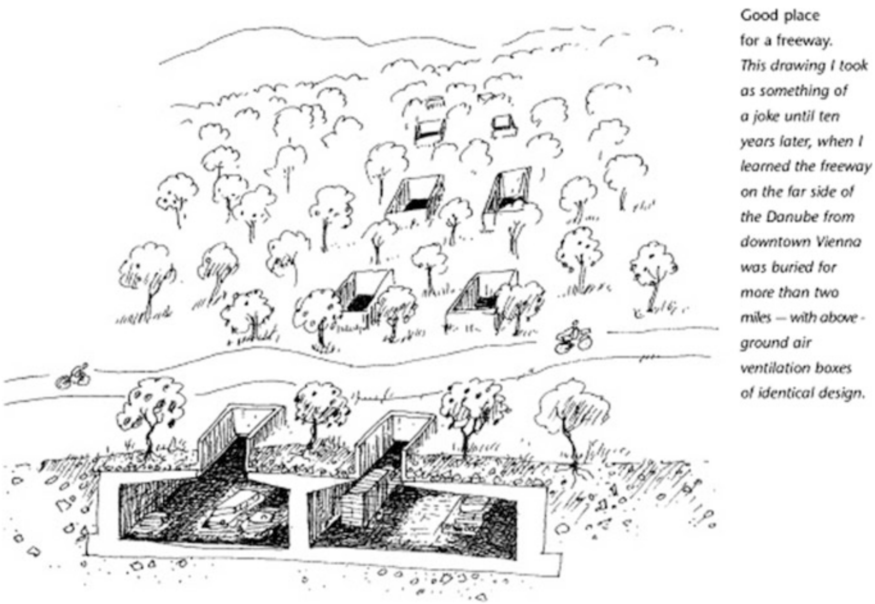

Fig. 5. A sample transportation in eco-cities [4]

However, large scale measures taken on the levels of government suit to closer duration of time. In this frame, the concepts:

— sustainability
— sustainable development
— sustainable urbanism [3]

The development of eco-cities requires high capital and long-term investment. Today, the economic hardship puts pressure on existing Eco-city projects and many are postponed for financial reasons. Governments are looking at their original concepts and designs in order to reduce costs and get faster returns for investors. Eco-cites should be competitive with traditional cities.

All of these terms are connected to each other for leaving a more livable world to future generations have been started to be pronounced. The application of these three concepts which cannot be envisaged different from each other will be possible on the level of urbanization with environmental new cities mentioned as eco-cities. Despite the fact that it has not been completed yet, eco-city projects, still in charge, are promising applications that can partly remove the ecological problems of future generations if they succeed [3].

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Sustainable Operation of Dams Under the Sediment Threat

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Abstract. As 97% of the world's water is salt water, only 3% of the remaining water is fresh water. Depending on population growth, freshwater resources are gradually decreasing due to its use for irrigation applications and energy needs and as drinking water. The most important structures for water storage, regular distribution and flood control are the dams. Dams contribute significantly to the areas where they are located in terms of socio-culture, economy and ecosystem. For this reason, it is very important to extend the lifetime of dam reservoirs in a project and it is even possible to provide sustainability with correct planning. In the reservoirs, the sediment is placed in two forms, as suspension load or bed load. Sediment can affect the performance of dam reservoirs. The lifetime of the dams is determined by the volume of sediment the dam receives during the operating period. The sustainability of the operation of the dam ceases when the dead storage, which is considered to be the sediment deposit, reaches to the limit. Sedimentation occurs not only in the dead storage, but also in the active (beneficial) storage. This situation also affects the performance of the dams and prevents the dams serving their purpose. In this study, different reservoir management strategies and measures that can be taken in sediment conservation for sustainable dam management are discussed.

Keywords: Dam operation · Reservoir · Sedimentation · Sustainability
Sediment control

1 Introduction

Twentieth century has seen the focus on developing new resources. In the twenty-first century, this approach is now changing in order to include preservation of available resources along with developing new resources [1]. Water is one of the elements human beings need for their survival. Experts planning and managing available water resources are now facing a number of questions such as which policy is the most suitable one considering the climate change and what are the resulting environmental effects [2]. Decreasing rainfall in some areas in the recent years due to climate change, and increasing water consumption due to global population growth and improved

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living standards make it necessary for us to use our water resources more efficiently and more insightfully. In order to be able to do this, we need to monitor our available water resources and to store the free running fresh water in dams, lakes and pools [3].

Dams are barriers built between the sides of a valley in order to contain water or to create a reservoir [4]. According to the estimations of the International Commission on Large Dams (ICOLD), the dam-industry built more than 40,000 large dams until the end of the twentieth century and most of these dams were built after 1950. A large dam is defined by ICOLD as storage dams with a height of 15 m from deepest foundation level to crest with a reservoir capacity not less than 1 million m^3. According to ICOLD, the number of dams in the world added up to 49,697 in 2003 [5].

On the other hand, a reservoir is natural or artificial water mass used to store, manage and control water resources [4]. Figure 1 shows the storage zones and water levels of multipurpose reservoirs.

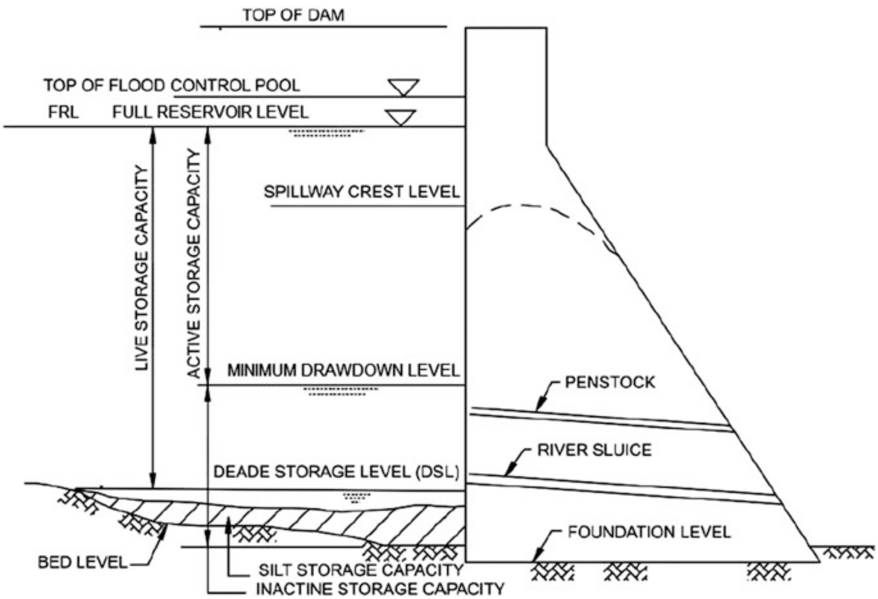

Fig. 1. Storage zones and water levels of reservoirs [6]

One of the current threats on the water masses such as dams, lakes and pools, is water pollution and the accumulation of deposits (sediments, dregs, mud, etc.) carried by water. This may lead to accumulation of sediments especially in some lakes and dams, water pollution and the loss of storage volume which will reduce the useful life of the reservoir [7, 8].

Sediments are soils and rock particles carried by water from the place they originate from to the place they are deposited. In waterbeds, sediments include alluvial material carried in the water as suspension load or bed load [4]. Built on river valleys, dams lead to significant changes in the transportation of suspension load and bed load. Sediments accumulating in the reservoir will lead to reduced dam capacity and drastically changes the flood valley morphology of the dam [9]. Natural course of a river is generally in a morphologically stable state, that is, average sediment input and output is in a balance. Sedimentation occurs due to reduced flow rate and reduced transportation capacity. Sedimentation will continue until a new balance is achieved in the input and output sediment amounts which will in return lead to sediment accumulation in the reservoir, therefore, reduced storage capacity [10].

Dams are traditionally designed as non-renewable structures. As streams will fill up the reservoir with sediment transportation which reduces reservoir storage capacity, useful life of a dam reservoir will be reached earlier than planned [11]. Reservoirs are traditionally designed, constructed and operated with an estimated finite life-span of approximately. 100 years depending on the sedimentation [12]. Environmental effects, limited number of locations suitable for dam construction and high development costs have led to a tendency to maintain the storage capacity of existing dams instead of building new ones in the recent years [13].

2 Reservoir Sedimentation

Sedimentation is the accumulation of suspended material available in the water with the effect of gravity [4]. Sedimentation is one of the significant issues in the operation of water resource systems. Dam reservoirs, on the other hand, are structures commonly susceptible to this issue. Reservoir sedimentation reduces the life-span of dams and lead to operational issues. Constructed with high costs and intensive labor, dams have economic and strategic importance for the region and the country and the inability to operate these dams due to sedimentation is, therefore, unacceptable. The level of sedimentation in a reservoir must be monitored regularly and the operational scheme of the dam must be defined accordingly in order to minimize the issues related to reservoir sedimentation [14]. Soil particles may be transported from a flood plain due to rainfall as part of the erosion process [15]. A reservoir is a natural means for the accumulation of sediments carried by water [16]. A reservoir is also an efficient sediment trap. The flow rate of a stream is reduced when it reaches to a reservoir, therefore, making it possible for the sediments to be deposited easily. The location and amount of sediments deposited in a reservoir depends on factors such as storage time, shape and size of the reservoir, operational time and others [17]. Figure 2 shows the types of sediment accumulation in a reservoir and the cross-section of the particle size distribution at the reservoir bed.

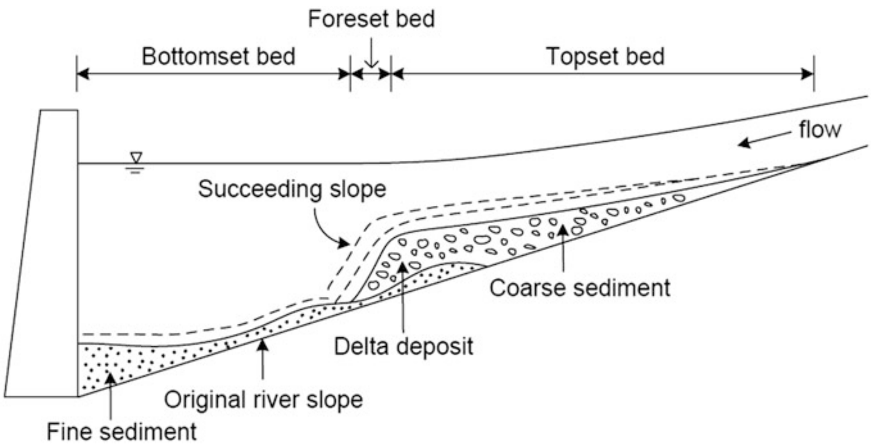

Fig. 2. Typical formation of delta in a reservoir [11]

Sediment accumulation is the most common problem all reservoirs are exposed to and it shortens the useful life and benefits of a dam. However, the amount of sedimentation may vary due to stream flow characteristics and the sediment load [1]. A cross-section of the main sedimentation types are given in Fig. 3.

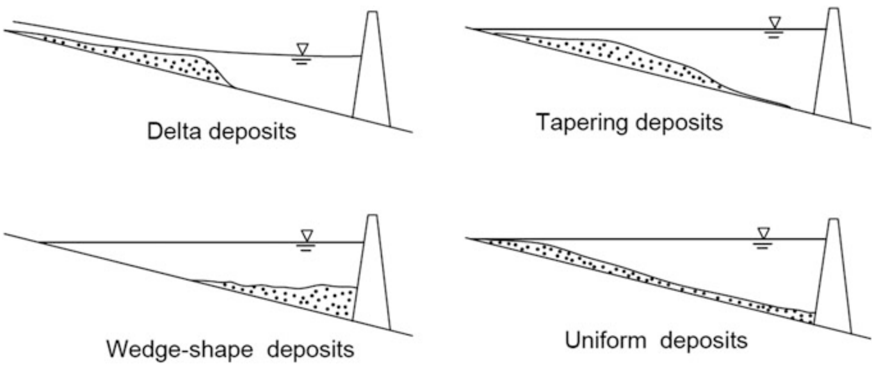

Fig. 3. Basic types of deposition [11]

The need for water is increasing all over the world. However, the overall reservoir storage capacity is also decreasing. The estimated annual loss of total storage capacity worldwide due to reservoir sedimentation is 0.5–1% [18, 19]. On average, the loss in storage adds up to 45 km^3/year. This percentage is equivalent of the volume of 300 large dams in an annual basis and the cost of such a storage capacity is approximately $13 billion not including the environmental and social costs associated with building new dams [20]. These estimations show that many reservoirs built for irrigation, flood control, power production and as a water resource will lose their storage capacity by

50% in the next 50 years, especially in arid areas, and this will have critical economic and environmental consequences. Nevertheless, sedimentation may also prove consequential for the ecosystem of large river systems, coastal development and downstream formation [21, 22].

For example, Welbedacht Dam located on the Caldon River in South Africa, the main water resource of Bloemdontein, has lost 86% of its original storage capacity since it was completed in 1973. One third of the capacity was lost in the first three years [23]. Another example is the Tarbela Dam located on the Indus River which provides the most important service to Pakistan; the dam lost 20% of its storage capacity in 23 years after being commissioned [24].

The most important impact of sedimentation is the loss of storage capacity which has a wide effect on the development of water resources with respect to the reduced efficiency of flood control, decreased amount of irrigation water, reduced hydropower production and loss of fresh water source [10]. Moreover, energy turbines are eroded in hydropower station due to the impact of sediments [25].

3 Management of Reservoir Sedimentation

Among the sediment sources available in basins are surface erosion, landslides and slope failure, coastal and bed washout, physical abrasion of rock formations, and waste, trash, and debris produced due to road, infrastructure and mine construction [26] (Figs. 4, 5, 6 and 7).

Fig. 4. Gully and surface erosion, Çayırhan Town, Nallıhan, Ankara [27]

Fig. 5. Slope failure and landslide [27]

Fig. 6. Sediment flow in stream, Bozluca stream, Fethiye, Muğla, [27]

Fig. 7. Tallow thrown into the Kabaca stream from the Murgul Copper Operation, Artvin, [27]

Development of preservation methods for reservoir storage capacity dates back to decades ago. The literature defines applications which may be used for this purpose under three categories [28]:

- Methods aimed at the reduction of the amount of sediment entering the reservoir;
- Methods addressing the hydraulic characteristics of the stream flow in order to reduce the accumulation of sediments in the reservoir or methods aimed at the transportation of the deposited material;
- Transportation of the materials from the reservoir using hydraulic and mechanic methods.

The methods to be implemented vary depending on the geographic characteristics of the basin, characteristics of the stream, sediment grain size, sediment density and flow rate. Thus, it is of utmost importance to perform cost-benefit analysis before implementing a method. The reason behind it is that the method used will have different consequences for each reservoir.

3.1 Methods Aimed at the Reduction of the Amount of Sediment Entering the Reservoir

Many researchers who investigated the methods to maintain the reservoir capacity have suggested that the most suitable method involves the efforts to reduce the amount of sediment entering the reservoir [29]. Accordingly, meticulous analyses for the selection of the reservoir zone are proposed as the first step to minimize the sediment accumulation in the reservoir [30].

There are studies aimed at taking the erosion in the river basin under control in order to reduce the amount of sediments entering the reservoir. However, such large-scale measures are generally costly in large basins and their results are not immediate [18, 31, 32]. In this context, among the significant efforts are prevention of landslides and soil erosion in the basin. Forestation of the basin, increasing the vegetation covered land, development of suitable agricultural areas, etc. are commonly used practices.

3.2 Methods Aimed at the Reduction of the Sediment Accumulation in the Reservoir

One of the important practices is to analyze the flushing and flushing efficiency of the project in the planning and project developing stages of a reservoir with foreseeable high sediment deposit.

3.2.1 Flushing

Flushing is a method used to increase the sediment transportation increasing the flow rate of the reservoir. Flushing technique often involves the use of an outlet. Fine material is transported when the outlet is first opened. The impact area of such a flushing and transportation process is limited to the area around the outlet [30]. A cone-shaped pocket is often formed when outlet is operational. Figure 8 shows this pocket in a cross-section and plan graph.

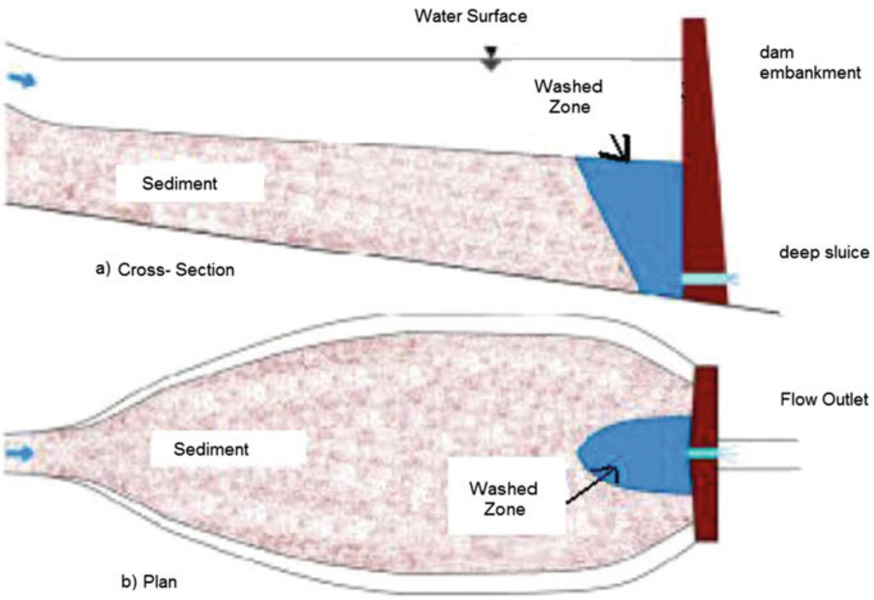

Fig. 8. Washed zone looks plan and cross-section [33]

Dawans studied the flushing process conducted on the Gebidem Dam reservoir located on the Massa River, Switzerland. The study showed that it is possible to flush the sediment load the reservoir receives in a year if the outlet is operated at least 15 times annually. The fact that the valley bed of the reservoir is narrow significantly increases the efficiency of flushing [34].

3.2.2 Sluicing

Sluicing can be defined as transferring the sediment density current to the downstream before sediments are deposited. Sluicing the stream with high suspended sediment concentration is considered to be more effective than flushing the already deposited sediments in the reservoir to the downstream [32].

One of the best examples of sluicing process is the one conducted for the Old Aswan Dam located on the Nile River, Egypt [18]. The operation of this dam involves transferring the flood flow rate into the downstream without allowing for the reservoir water level to increase.

The same method was also used for the Roseires Dam located on the Blue Nile River, Sudan. However, the sediment drainage process was not as effective as the Old Aswan Dam, as the Roseires Dam has a larger reservoir in comparison.

3.2.3 Density Current Flushing

Transfer of the density current to the downstream is considered an effective method especially used to prevent sediment accumulation in a storage reservoir. It was underlined that the efficiency of density current and flushing depends on the outlet elevation while their capacity depends on the water level during the release and the flushing flow rate [31].

This method was used successfully on the Emda Dam reservoir located in Algeria. It was possible to transport 45% of the sediment load this reservoir receives to the downstream using density currents.

3.3 Transportation of the Materials from the Reservoir Using Hydraulic and Mechanic Methods

3.3.1 Dredging

Dredging or mechanical cleaning is commonly used as an alternative to flushing and sluicing. Dredging can be used provided that the following conditions are available [31]:

- In case of a failure in the flushing, lack of sufficient amount of water for flushing or when flushing will require great amount of power consumption;
- In cases where construction of bypass channels are not physically and economically viable;
- In case of inability to lower the reservoir level due to the water need in the region;
- In case of the method used to reduce the amount of sediments available in the reservoir is not economical due to the power consumption requirements of flushing with lowered reservoir level or drainage of the reservoir.

Flushing is the commonly preferred reservoir sediment transportation method due to the high cost of dredging. The cost of a classic dredging process per 1 m^3 is $2–3 without the waste processing costs [18]. On the other hand, replacement of a reservoir at the full capacity with a new reservoir costs approx. $0.12–0.15 per 1 m^3. Therefore, dredging is much more suitable for smaller reservoirs [32].

The efficiency of dredging is much higher than the efficiency of flushing in terms of the material removed and the water loss. Although dredging is advantageous in terms of minimal water loss, it also has a number of disadvantages such as reduced deposition capacity during the process and the pollution caused by the increase in the suspended material due to bed disturbance.

Overall, dredging is a quite expensive method when the material removed from the reservoir is not repurposed. However, it is possible to repurpose the coarse grains removed from the reservoir as construction material and the fine grains can be used in construction material production [30] (Fig. 9).

Fig. 9. Dredging application [35]

In Japan, an annual amount of 150,000 m^3 of sediment consisting of fine clay and silt is removed from the Akiba Dam located on the Tenryu River with the use of dredging method and then transferred to the downstream with the use of flood flow rates being transported to a location close to the dam.

3.3.2 Siphoning

Siphoning method differs from the classic suction dredging method and the power needed for the sediment drainage is obtained from the elevation difference between the upstream and downstream.

4 Conclusion

It is clear that the incoming sediment to the reservoir can be reduced but not terminated. Thus, in years, many methods are explored in order to improve the sustainability of reservoirs and to extend their useful life.

These methods showed that the efficiency of the results depends on the size of the reservoir, geographical characteristics of the basin, characteristics of the stream, and the amount of transported and deposited sediments.

Flushing and sluicing are economical methods when compared to dredging. However, with the increasing demand of water today due to factors such as climate change and increasing population, these methods are revisited especially in semi-arid regions.

Although the sediments obtained from dredging are repurposed as aggregate or construction material, it is not an efficient method in terms of cost-benefit analysis considering the continuity of the sediment transportation.

Therefore, careful modeling of the sediment transportation is required in the planning and operating processes of a dam.

It is of utmost importance to ensure the sustainability of a dam with the implementation of the planned operating strategies and further developing these strategies.

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Review of Liquefaction Around Marine and Pile-Supported Wharf Structures

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Abstract. Earthquake recossaince survey showed that liquefaction of soil caused severe damage to pile-supported structures, for example bridges and marine-wharf structures. Marine wharf structures provide logistic support to shipping, distribution, and other facilities for the transport of cargos via water. Thus, these structures must be less affected from seismic related hazards such as liquefaction, lateral spreading and settlement. Literature review showed that damage to pile supported wharfs often occured due to lateral movement of liquefiable soil which caused horizontal displacement of structures and also settlement. As a result, pile supported marine structures were badly damaged. In this study, a review of typical damages to marine and pile-supported wharf structures observed in the past earthquake is presented Based on the observed damages and current understanding of pile failure, criteria for design of pile-supported marine structures is presented.

Keywords: Liquefaction · Pile-supported · Wharf structures
Marine structures

1 Introduction

The import and export of merchandise is often carried out through seaport and is the economic backbone for some countries. Therefore, even after an earthquake, pile-supported wharf structure need to stay up and operating. Marine structures in seismic countries are subjected to variety of loads such as from earthquake, environment (wind and wave), dynamic effects of impact of ships and boats. In many seismic countries (such as Japan, India, Turkey) many of marine structures are located near the in fault zone and it is exposed to high seismic hazards. In addition, marine structures are generally supported on the driven piles.

Piles supporting marine structures such as jetties, relieving platforms, quay walls and fixed offshore structures are subjected to lateral loads due to berthing and mooring forces, wind, waves, storm surges and current forces [1].

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Past earthquakes have damaged port structures leading to large economic and social losses on national, local and individual scales [2]. Thus, their design must be built adequately.

Liquefaction is a term used to describe the underlying mechanisms of strength loss and ground deformations that occur due to the accumulation of excess pore pressures [3]. Liquefaction phenomenon effects many structures such as building, bridges, ports, wharf and marine etc. In marine structures, earthquake threat to such as quay walls, piers, dolphins, breakwaters, buried pipelines, sheet-piled structures, containers/silos/warehouses/storage tanks located in coastal areas, etc. Owing to the growth of activities in the marine environment, the phenomenon of fluid–soil structures around marine infrastructures has attracted great attention among coastal and geotechnical engineers [4].

In recent years, marine structures are damaged by the strong earthquake and as result this is an area of active research interest, see for example Boulanger et al. [5], Takahashi and Takmura [6], Groot et al. [7], Sumer et al. [8], Hancox et al. [9]. Table 1 collates a summary of observed wharf-port failure. For example; The main port in Port-au-Prince suffered extensive damage during the Haiti Earthquake, Fig. 1. The North Wharf collapsed, most likely due to liquefaction-induced lateral spreading and the damage to the piles supporting the South Pier, the abutment also experienced liquefaction-induced lateral and vertical displacements [10]. The other example of the port collapse is Takahama Pile-Wharf, Kobe in which these steel pipes buckled at the pile heads and cracks were observed at the pile cap to concrete beam connection located most landward, Fig. 2, [2].

Table 1. Wharf-Port failure examples

Name	Earthquakes	Magnitude	Damage caused by liquefaction	References
Takahama wharf, Kobe, Japan	1995 Hyogo-ken Nambu Earthquake	7.2	Backfill and underling sand layer on permanent deformation on the pile and caissons	Takahashi and Takmura [6]
Tuzla Port, Turkey	1999 Kocaeli, Turkey Earthquake	7.4	Horizontal displacement of structure and settlement occur about 0.1 m	Disfani et al. [11]

(*continued*)

Table 1. (*continued*)

Name	Earthquakes	Magnitude	Damage caused by liquefaction	References
Kobe Port, Japan	1995 Hyogoken-nanbu January	7.2	Virtually all of the 240 berths within the port experienced at least some damage, and in many cases the damage was severe. On the landward side of the quay walls increased the lateral earth pressures applied to the caisson quay walls which, in turn contributed to large seaward displacements of the walls	Werner et al. [12]
Tuzla Shipyard, Block-type quay Wall, Turkey	1999 Kocaeli, Turkey Earthquake	7.4	The backfill area settled by O (20 cm) Two rows of blocks between −1.7 and −6 m depth moved seaward relative to neighboring blocks by O (20 cm)	Sumer et al. [8]
Hakozaki Wharf in Hakata Port, Target Quay	2005 Fukuoka Earthquake	7.0	The sand boiling phenomena, the damage due to liquefaction at the apron and the quay wall moved the maximum placement of 56 cm the horizontal direction The sheet pile wall was inclined at 4 degrees	Hammoto et al. [13]
North Wharf Area in the Hitachinaka District of Ibaraki Port	2011 off the Pacific coast of Tohoku Earthquake	9.0	Subsidence was 1.7 m at maximum, which was larger than the lateral displacement of caissons in some parts of the quay	Suganoa et al. [14]

(*continued*)

Table 1. (*continued*)

Name	Earthquakes	Magnitude	Damage caused by liquefaction	References
Port de Port-au Prince, The North Wharf, Haiti	2010, Haiti Earthquake	7.0	The North Wharf collapsed, most likely due to liquefaction-induced lateral spreading. 42 are sand boils and can be seen in the eastern half of the container storage yard and behind and between the two warehouses	Eberhard et al. [10]
Port of Oakland, USA	1989, Loma Prieta Earthquake	6.9	Extensive liquefaction with nominal lateral spreading and post seismic ground settlement, and widespread damage to piles. Permanent ground surface lateral displacement of the rock dike on the order of 15–30 cm, with approximately 13–30 cm of settlement	Dickenson et al. [15]
San Antonio Port, Chile	1985 Chile Earthquake	7.8	Backfill liquefaction and the strong earthquake motion caused 271 m of the total 452 m length of the wall to collapse	Tsuchida et al. [16]
Kandla Port, India,	2001 Bhuj Earthquake	7.7	Horizontal displacement of structure and settlement occur 0.3 m	Dash et al. [17]

(1)

(2)

Fig. 1. Damage at the port. 1, Damage to piles supporting the pedestrian bridge connecting the South Pier to the island. 2, Extensive damage to the landward row of piles [10]

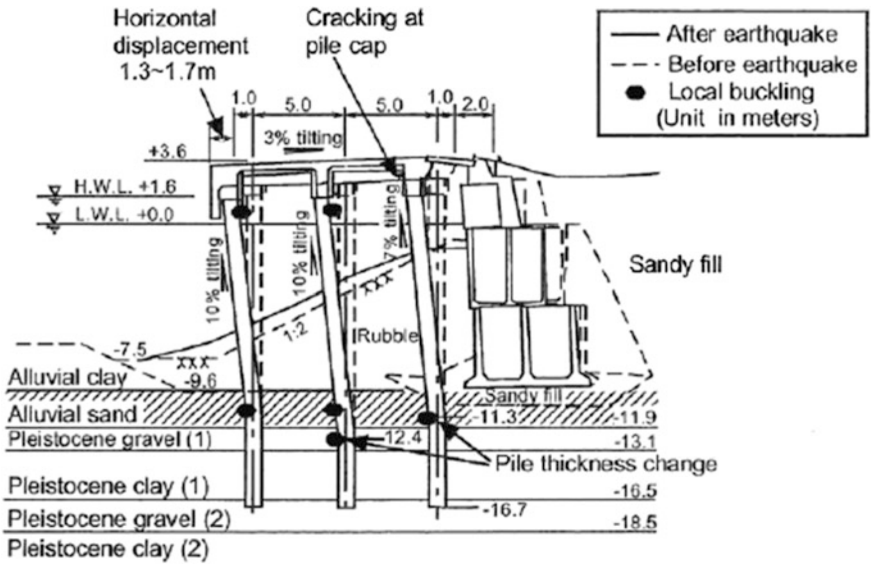

Fig. 2. Sketch of the earthquake damage of Takahama Pile-Wharf, Kobe, Japan, [2]

2 Kind of Wharves

Wharves can be separated into two title; Open Type and Closed Type. Open type wharves are constructed in such a way that sea-water can run below the platform which generally rests on piles or columns embedded in an embankment and Closed type wharves are generally made of a vertical wall which divides the sea from the shore, and backfilled with soil material and topped with a concrete deck or platform [2]. The type of the wharves are in the Table 2.

Table 2. The type of the wharves

Open type	Close type	
Large diameter pile supported wharf	Pile walls	Gravity walls
Small diameter pile supported wharf	Sheet pile wall	Caisson quay-wall
Column supported wharf	Stiff pile wall	Massive quay-wall
–	Sheet pile with platform	Cantilever quay-wall
–	–	Block quay-wall
–	–	Cellular block quay-wall
–	–	Quay-wall on rock

3 Pile Damaged Under the Marine Structure

3.1 Scour Due to Waves and Current

Marine structures are supported piles and they are damaged from severe scour. Clearly, scouring at the piling is of importance in connection with the stability of the structure and extensive scour may reduce the stability of the structure, leading to its failure [18].

The effect of scour depth combined with other parameters such as different pile arrangement, spacing between piles and pile slenderness ratio were investigated [1].

3.2 Corrosion of Pile in Marine Structure

Corrosion of steel structure is one of the important problem in the marine structures. Especially, when the marine structures are supported by sheet piles or steel piles. Knowledge about the corrosion rate is also important when verifying the remaining bearing capacity of existing structures, and estimating the remaining service life time according to bearing capacity [19].

3.3 Liquefaction

Liquefaction phenomenon is very important soil around the marine structure because of waves and earthquake effects. Liquefaction can also occur under the cyclic impact of storm waves and under the cyclic compression of the crushing of sea ice and may also be produced by the impact of rapidly placed hydraulic fill on the previously placed sands, resulting in flow slides [20].

4 Liquefaction Effect on the Wharf Pile Foundation

In loose saturated sandy soil, as the shaking continues, pore pressure will build up and the soil will start to liquefy [21]. Figure 3 shows a schematic diagram of the different situations of loading on a pile-supported structure during liquefaction process. $P_{gravity}$ (Stage I) represents the axial load on the piles in normal condition and this axial compressive load may increase/decrease further due to inertial effect of the superstructure ($V_{inertial}$) as shown in Stage II [22]. When soil liquefies, the pile becomes unsupported and acts like a long slender column as described in Stage III condition [22]. Ground movement such as flow failures or lateral spreading can also induce additional kinematic loads on the pile foundations and is shown in Stage IV loading [22].

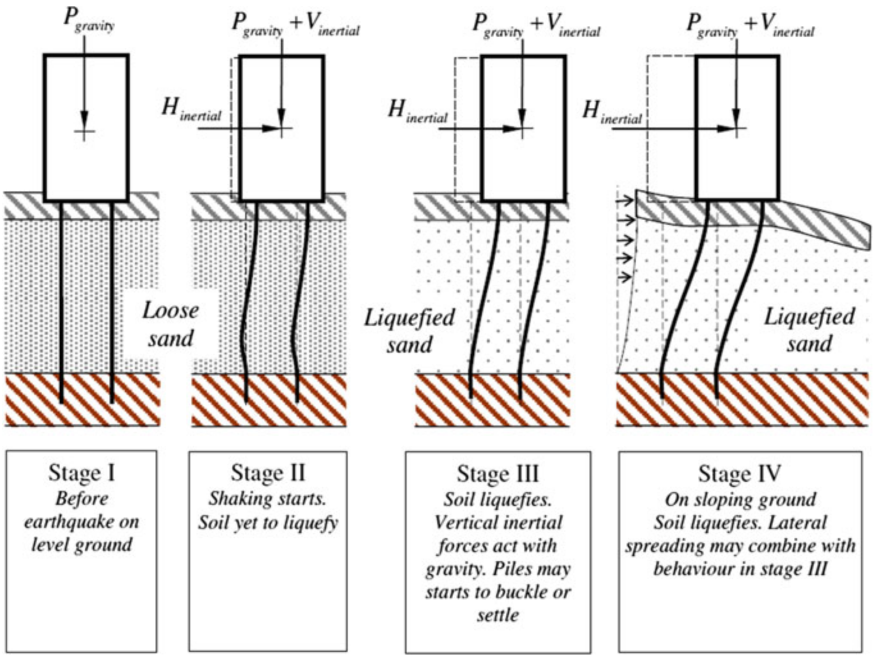

Fig. 3. Different loads acting on a pile [22]

The main mechanisms can cause pile failure which are shear failure, bending failure, bucking failure, dynamic failure. Shear failure becomes because of lateral loads such as inertia or kinematic loads or a combination of the above. Bending failure is occurred by the combined effect of lateral and axial loads. In addition, the performance of the piles can be reflected by the moments developed in the piles during the seismic load. In the design of pile-supported wharves, it is desirable to keep the pile moments less than the plastic moment to prevent excessive deformations and loss of capacity [23]. Bucking failure; in slender piles, due to the effect of axial load and the loss of surrounding confining pressure provided by the soil owing to liquefaction [24]. Dynamic failure; the dynamic soil-pile interaction becomes much complicated and the additional stresses may be induced in the pile due to the altered dynamic properties of the soil and the structure [25].

5 Essential Design Criteria

Following the work of Dash and Bhattacharya [25], a safe design procedure should ensure that the piles have enough strength and stiffness to sustain the following:

1. A collapse mechanism should not form in the piles under the combined action of lateral loads imposed upon by the earthquake and the axial load. At any section of the pile, bending moment should not exceed allowable moment of the pile section.

The shear stress load at any section of the pile should not exceed the allowable shear capacity.

2. A pile should have sufficient embedment in the non-liquefiable hard layer below the liquefiable layer to achieve fixity to carry moments induced by the lateral loads. If proper fixity is not achieved, the piled structure may slide due to the kinematic loads. Typical calculations carried out using the method proposed by Davisson and Robinson [26] shows that the point of fixity lies between 3 and 6 times the diameters of the pile in the non-liquefiable hard layer. Details can be seen in Bhattacharya [24].
3. A pile should have sufficient capacity to carry the axial load acting on it during full liquefaction without buckling. It has to sustain the axial load and vibrate back and forth, i.e. must be in stable equilibrium when the surrounding soil has almost zero stiffness owing to liquefaction. As mentioned earlier, lateral loading due to ground movement, inertia, or out-of-straightness, will increase lateral deflections which in turn can cause plastic hinges to form, reducing the buckling load, and promoting more rapid collapse. These lateral load effects are, however, secondary to the basic requirements that piles in liquefiable soils must be checked against Euler's buckling. This implies that there is a requirement of a minimum diameter of pile depending on the likely liquefiable depth.
4. The pile should have sufficient capacity to carry the additional dynamic forces along with the static forces without exceeding yield. During earthquakes, the frequency of the pile-supported structure should not be close to the driving frequency of earthquake.
5. The settlement in the foundation due to the loss of soil support should be within the acceptable limit. The settlement should also not induce end-bearing failure in the pile.

6 Discussion and Conclusion

During the entire earthquake, the pile should be in stable equilibrium, the amplitude of vibration should be such that no section of the pile should have an ultimate limiting strain for the material. This criterion automatically ensures that no plastic hinge will form and no cracks will open up. Steel tubular piles are ductile i.e. they can withstand large amount of inelastic strain before yield and thus can be a good choice.

Pile-supported wharves are very complicated structures so it must involve soil-structure interaction and behavior of the piles, wharf and soil. Pile-supported wharves are related with soil-structure interaction so when the seismic load effect the structure, the combination of the inertial and kinematic are taken into account and design is made according to performance analysis. The dynamic soil response should be analyzed the local site effect. Liquefaction potential and soil failure should be analyzed. Then the wharf structure should be performed in the seismic effect.

Two common causes of the wharves structure are structural and geotechnical failures. Generally, structural failures were occurred deck slabs collapse, short-column effects, pile head cracks, pounding, permanent ground deformation and large displacement demand on pile foundations, cutoff walls and anchor systems, and appurtenant structures. Geotechnical failures were occurred liquefaction, cyclic degradation, slope instability and settlement etc.…

The poor performance of many wharves and marine structures was due to liquefaction of soil during the past earthquake. In order to meet functional and structural requirements, the design and analysis of a wharf structure must be made in seismic performance. Besides, some recommendations to practice will be made. They are:

1. Codes of practice need to include a criterion to prevent buckling of slender piles in liquefiable soils. The designer should first estimate the equivalent length for Euler's buckling, by considering any restraints offered by the pile cap, or the zone of embedment beneath the liquefiable soil layer. It is then necessary to select a pile section having a margin of factor of safety against buckling under the worst credible loads.
2. Designers should specify fewer, large modulus piles, in order to avoid problems with buckling due to liquefaction.
3. Cellular foundations of contiguous, interlocked sections should also be effective. In addition, performance criteria are determined together with the earthquake levels.

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Thermally Comfortable Housing in Iraq—Prospects of the Courtyard Pattern in Achieving Energy Efficiency

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Abstract. Iraq suffers from large housing problems. It is estimated that there is a shortage of around one million dwellings, which is equal to one-fourth of the total housing stock in the country. As a part of the solutions, the country needs architectural designs that satisfy three main conditions: enable an increase of the housing production, be affordable and satisfy people's residential requirements. The latter includes, for instance, providing suitable layouts, comfortable environment and the required level of privacy. Within this spectrum, this paper focuses on providing a thermally comfortable indoor environment. The importance of this aspect is raised by the high temperatures in Iraq, the unreliable electricity supply, reducing the running costs and the need to maintain the environment at comfort conditions. The paper explores the courtyard pattern as an approach to achieve a thermally comfortable indoor environment, and studies how courtyards might be adopted within multistory residential buildings in order to reduce the costs and support the housing production. It reports on an extensive literature review that investigates published scientific studies within the last ten years about the thermal efficiency of the courtyard pattern and its design features. To propose design solutions, the paper considered the investigation's results and the main residential buildings criteria and standards. The research results define the courtyard pattern thermal efficiency and demonstrate the importance of adopting the courtyard pattern's design features to provide a thermally comfortable indoor environment. It also proposes two architectural solutions for Iraq that include using courtyards in multistory residential buildings.

Keywords: Affordable housing · Courtyard residential buildings
Thermally efficient housing · Housing in Iraq

1 Introduction

Satisfying the housing needs has been one of the main challenging issues around the world. Most countries have worked on having sufficient housing production and to providing decent housing conditions for people [1]. However, there are many countries around the world that are still suffering from housing shortage and inappropriate housing conditions [2, 3].

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In Iraq, because of prolonged war conditions since the 1980s and the current instability, there are large housing problems. The housing shortage is estimated to be around one million dwellings. This number represents 25% of the total housing stock in the country. The housing production is weak, while the financial system is inefficient. There are problems with the infrastructure services and construction materials availability. Furthermore, part of the housing stock is deteriorating. Slums are spreading in some parts of the country [4–6]. In response to these problems, various efforts have been taken to reverse the situation. Among the most important of them is the introduction of a National Housing Policy in 2010, which was prepared by the Iraqi government in cooperation with the UN. It defines the problems and proposes a general solution framework [5]. The National Housing Policy advocated proposing architectural solutions that can help to solve the problems. These proposed solutions should help to increase the housing production, provide affordable housing and at the same time satisfy the various people's residential requirements. This paper explores some ideas to propose an efficient and appropriate architectural solution for Iraq focusing on providing a thermally comfortable indoor environment. This aspect represents one of the Iraqis' first residential priorities because of the high temperature during summer and the unreliable electricity supply.

2 The Comfortable Indoor Environment

Having a comfortable indoor is one of the most important priorities for people, as they spend much of their time inside buildings. There are studies that have suggested strong relationships between having a comfortable indoor environment and the health and productivity of buildings' occupants. It has been argued that adverse indoor environmental conditions may lead to a short term and long term illness [7].

There are four factors that determine the characteristics of buildings' indoor environment: Indoor air quality (IAQ), thermal comfort, acoustics and the visual features [7–9].

- Indoor air quality (IAQ): Polluted indoor air has short term and long term negative impact on people wellbeing. It has been argued that fundamentally there are two ways to reduce or deal with indoor air pollution. The first one is through providing appropriate ventilation (fresh air supply) and the second one is by reducing the sources of pollution from inside and outside buildings [7–9].
- Thermal comfort: Having a thermally comfortable indoor environment is also among the most important factors and may be the most sensitive one. It has a large impact on people wellbeing and productivity. Feeling thermally comfortable inside buildings is affected by several factors: air temperature, mean radiant temperature, humidity, air speed, people metabolic rate and clothing insulation. The first four factors are classified as natural factors and the other two as personal factors [7–9].
- The Acoustic Comfort: One of the comfortable indoor environment conditions is to provide the voice privacy for the occupants and to protect them from the unwanted level of sound and noise. The appropriate characteristics of sound depend on building functions and affect occupants' productivity [7–9].

- The Visual Comfort: The other factor that affects occupants' comfort and productivity is the visual comfort. It includes, first of all, providing sufficient and appropriate natural lighting and then appropriate glare, colors and outside view [7–9].

This paper focuses on the thermal comfort because, in Iraq, it is the most studied aspect of residential building performance studies. The reason for this is that Iraq is located in a hot arid location. Summer lasts from around seven months in which the temperature reaches more than 45° [10]. The country thus is out of comfortable limits during most the year [11]. As a consequence, in a typical year like 2002, 92% of the generated power was used for the domestic purposes, and 63% of it was for air-conditioning during summer [12]. In a more recent study, by Hasan in 2012, it has been stated that 60 and 70% of the total consumed energy in Iraq is used for air-conditioning during summer and winter respectively [10]. The problem becomes larger with the electricity supply frequent interruptions that have existed in Iraq since the 1990s. The nationally generated power provides only 50% of the needs [13, 14]. Because of these conditions, there has been an especial focus on designing more thermally efficient buildings using passive systems to provide a comfortable indoor environment, reduce the energy consumption [15, 16], and become less reliant on the continuous supply of electricity.

2.1 The Possible Architectural Alternatives

There are a number of architectural archetypes that can be considered to be used. One of the main aspects of defining the possible architectural solution is to define the residential building pattern. In Iraq, there are seven possible building patterns. Four of them are single family housing and three multi-story housing (Fig. 1).

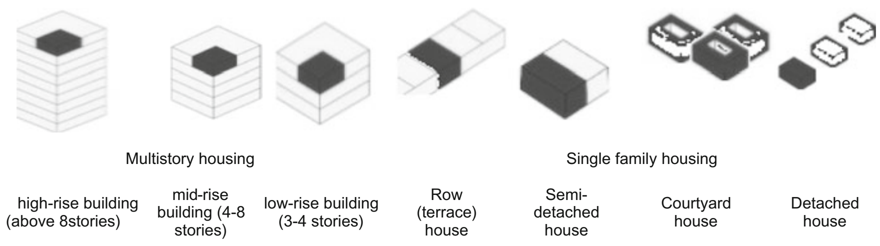

Fig. 1. The residential buildings patterns in Iraq. *Source* The author depending on [17, 18]

3 The Research Aim and Methodology

The main aim of this study is to investigate the courtyard pattern thermal performance and to define potential thermally efficient architectural solutions for Iraq with considering the housing concerns of increasing the housing production and housing affordability.

To achieve this aim, the paper depends on exploring wide-ranging literature about these issues. First of all, it explored existing views on the efficiency of the seven architectural patterns in addressing the issues of increasing the production, achieving affordability and providing a thermally comfortable environment. This was used to develop a concept for a thermally efficient solution that will be studied in future studies by means of building performance simulation.

4 Defining an Efficient and Appropriate Architectural Pattern

There are many studies that have focused on defining the architectural patterns efficiency in satisfying the various residential requirements. Table 1 summarizes findings from previous literature. It can be seen that the previous studies have identified the courtyard single family housing as an efficient approach to providing a comfortable indoor environment and that multistory residential buildings help to achieve affordability and support the housing production.

Table 1. Previous literature evaluation of the various architectural patterns

Housing patterns	Evaluation aspects		
	Providing thermal comfort	Supporting the housing production	Achieving affordable housing
Detached			
Semi-detached			
Terrance			
Courtyard	[19–23]		
Low-rise		[19, 24]	[19, 24–27]
Mid-rise		[19]	[19, 27]
High-rise		[19]	[19, 27]

4.1 Investigating the Courtyard Pattern Thermal Efficiency

It has been argued by a number of studies that the courtyard pattern has been an efficient and appropriate pattern to achieve a thermally comfortable environment in the hot arid zone, in which Iraq is located. Among these studies are [20, 21, 28].

Reference [21] presented an experiment that included measuring the temperature in two models: courtyard one and non-courtyard one. The experiment showed that while the outside temperature was 35° in the morning, the temperature in the courtyard house was 30° and in the non-courtyard house was 40°. In the afternoon at 12:00, the temperature outside and in the non-courtyard pattern was around 40°, while it was 35° in the courtyard house. In the night, the outside temperature decreased to 38°.

The non-courtyard house tended to keep the heat inside while the courtyard one lost it. The temperature in the former was 40°, which is higher than outside, and in the latter, it was around 30°.

Reference [20] presented a courtyard house constructed in Baghdad in the 1980s, which was evaluated and won the first prize in Iraq for being the most energy efficient model in the country in 1992 (Fig. 2). The measurement of the temperature in the constructed house showed the efficiency of this pattern in providing a thermally comfortable environment. The measurements were taken in August, which is the hottest month in Iraq. The study demonstrated that while the outside temperature was 43°, the temperature in the courtyard was 30.5°, in the ground floor rooms was 28° and in a first floor room was 30°.

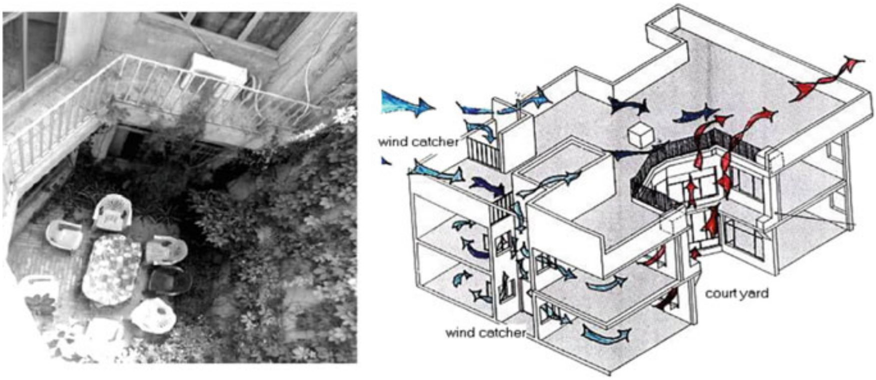

Fig. 2. The courtyard house in Baghdad. *Source* Al Jawadi [20]

Finally, Ref. [28] presented another experiment in a courtyard house, but it was in Saudi Arabia. The experiment included measuring the temperature difference between the inside and outside in a courtyard house. It found that the courtyard pattern was able to reduce the temperature by 6.7° in the courtyard and by 9.9° in the rooms. Furthermore, it found the efficient performance can be supported by using a wind-catcher with a fan and sprinkling water. Using this approach, the temperature further decreased and the difference reached to 11° between the outside and the courtyard and to 13° between the outside and the rooms.

4.2 Exploring the Courtyard Pattern Design Features

The thermal efficiency of the courtyard pattern depends on systematically integrated design features and elements [20, 22, 29]. The main principals of its work include providing shading to reduce the heat gain and air movement to reduce the felt temperature. The air movement results from the pressure differences between the cold shaded areas and the hot sunny areas. In these two areas, the hot air is lighter, has less density and moves upwards to be replaced by the heavier and more density cold air. This generates low pressure area and high pressure area and leads to cause air movement [22, 29, 30]. These two principals have been used ages ago in the old traditional cities in the hot-arid climatic zone. It has been applied and supported by using a number of design strategies and features. They can be seen clearly in the old traditional courtyard neighborhoods, but not the modern grid-iron ones [30]. Basically, there are six design elements and features in the courtyard house pattern that should be considered integrally to achieve thermally efficient housing. This paper is focusing on investigating these six elements and what can be done to support and enhance the courtyard house performance.

- Urban Fabric compactness: The first design strategy is on the macro scale. Traditionally, the courtyard houses have existed in residential neighborhoods where houses are highly attached to each other. The circulation networks depend on organic narrow paths and relatively large private and public plazas inside and outside the buildings. This kind of compact development provides high shading for the buildings and paths, reduces the exposure to the sun and causes continuous air movement due to the pressure differences between the sunny and the shaded areas [29, 31]. Reference [32] showed that, in Mosul city, the temperature difference between the modern grid iron urban fabric and the old compact traditional one is between 3° and 9° (Fig. 3).

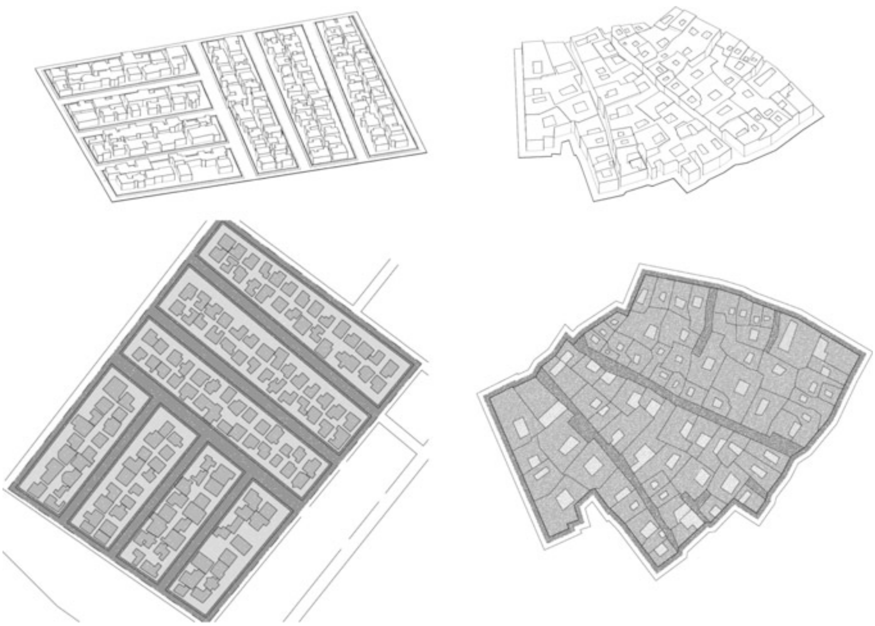

Fig. 3. The compact fabric (left) and the grid iron one (right). *Source* The author depending on Google map

- The Courtyard: it has worked on the micro scale as the main element to regulate the temperature. It works integrally with outside circulation paths depending on the pressure differences between the various areas. In the first morning hours, it is kept shaded by the surrounding walls which enable it to stay cold. At night, the surround rooms and walls radiate their stored heat to the sky through the courtyard. The hot air is replaced by cold air which helps to reduce the temperature and causes air movement in the courtyard and in the surrounding rooms (Fig. 4) [19, 21, 30, 33].

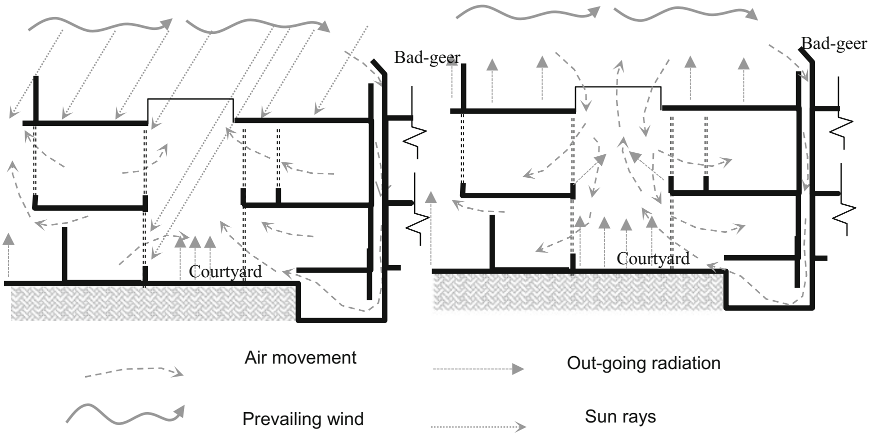

Fig. 4. Air movement during daytime (left) and nighttime (right). *Source* The author depending on [21]

- The Wind-catcher (the Bad-geer): This element works to support the courtyard in generating air movement and providing cold air for the house. It includes an upper opening on the roof and a duct that is built across the longitudinal section of the house to be opened in the basement that is opened to the courtyard through windows. The upper opening is directed towards the prevailing wind in summer to catch the cold and clear air. By being moved across the basement, the air becomes colder before reaching to the courtyard (Fig. 3) [16, 20, 29, 33].
- The building envelop: It represents the main element that governs the heat exchange between the inside and the outside. Two factors affect the envelope's thermal performance: its design elements and its construction materials. Regarding the former, in the traditional courtyard houses, the envelope elements were designed in a way that provides self-shading to the elevations. Traditionally, this has been achieved through the stone or brick ornamental details, the rough surfaces and some projected element. In addition to that, there has been no opening or small ones to provide privacy and reduce the crossed sun rays. Concerning the latter factor, the outside walls have been constructed using traditional materials like stone or mud brick with a thinness that ranges between 50 and 75 cm. These construction materials with this thickness delay the heat transfer and increase the thermal insulation [16, 21, 30].

- The Mashrabia (The Shanshool): It is a projected spatial element to the outside on the first floor that has different functions including supporting the thermal performance of the courtyard house. It is mainly an ornamentally latticed opening to the outside alley. This composition enables it to provide an opening to the outside with keeping the inside privacy, as it is designed in a way that provides the ability to see from the inside but not the inverse. Thermally, it provides shading for the outside and the inside and keeps air moving through it. Water pitchers are used to be put inside to cool the moving air through it (Fig. 5) [16, 22, 29, 30].

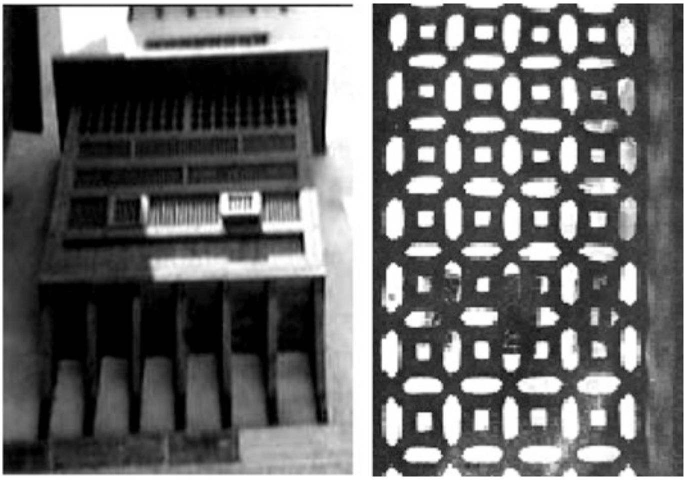

Fig. 5. Air movement during daytime (left) and nighttime (right). *Source* The author depending on [29, 30]

- The water elements and planting: Water has been used to increase the humidity and mitigate the temperature. It helps through its evaporation in reducing air temperature. In addition to that, passing the moving air over a water surface helps cooling it. Because of this, several water elements have been used to increase the thermal performance of the courtyard house. Among the most used elements are the fountains, which have been built in the middle of the courtyard, and the Salsabeel, which is a marble surface with water passing over it in front of the wind-catcher openings. Planting has been used also in the courtyard to increase the humidity and reduce the temperature [16, 20, 30].
- The basement: It is a space built to be under the ground. The aim of this space is to provide thermally comfortable space in summer benefiting from being surrounded by soil. This help to neutralize the impact of outside temperature on the inside one. It also works with the wind-catcher to cool the crossed air before reaching to the

courtyard space [21, 29, 30]. Reference [21] presented a study that showed that in summer when the outside temperature was around 45°, in the basement it was around 25°.

4.3 Other Discussion Points: Courtyard Other Advantages and Disadvantages

In addition to its efficient thermal performance, there are other advantages of adopting the courtyard pattern. Among them, is that it has been efficient in providing natural lighting and ventilation [28, 34]. It has been efficient in satisfying the social and cultural requirement of providing high privacy degree by being opened to the inside and closed to the outside [28]. Finally, its design provides a flexible internal layout that suits a variety of functions [19].

However, the courtyard pattern has been gradually abandoned in all of the Iraqi cities since the 1950s. Houses styles have changed from being according to the courtyard pattern with a limited opening to the outside to the current outside opening modern forms [35, 36]. This changing in the adopted architectural style has been affected by the country general conditions, which for instance included the political and social changes that accompanied the ending of the Ottoman Empire and the British occupation of Iraq in the beginning of the 20th century. In addition to that, it has been affected by the architectural trends around the world, the local architects' views, the social preferences and the developments in the construction and materials industry [37–39].

In addition to these factors, there are some environmental disadvantages associated with courtyard pattern that may affect people preference for the modern houses styles. Among these disadvantages, is that the courtyard does not provide thermal comfort during periods of the year. The passive design strategies sometimes become not efficient to deal with certain degrees of hot or cold weather conditions, spatially in the winter when it becomes very difficult to warm the spaces. The open courtyard is also not efficient to deal with the rain storms in winter or dust storms in summer when the atmosphere becomes breathless. Natural lighting doesn't reach the courtyard and the surrounded rooms sufficiently in winter. Another point is that it becomes so moisture in winter in some spaces, especially in the basement [22, 33].

4.4 Improving the Courtyard Pattern Performance

To support the courtyard house performance and to overcome its disadvantages, there are some studies that have focused on exploring strategies to enhance this performance. Reference [22] presented the use of mechanical heating and cooling systems and artificial lighting to improve the house's performance. Reference [28] argued that by using simple fans in the wind-catcher the thermal performance of the courtyard house increases. It showed this through an experiment in which the temperature decreased 3.5° and 5.5° in the courtyard and the surrounded rooms respectively more than if it is used without fans. Reference [20] showed a developed model of the courtyard house pattern. It included surrounding the courtyard with glass walls to neutralize the unwanted climatic conditions when it needed with getting the benefits of the courtyard when it is possible.

5 Proposing an Architectural Solution for Iraq

After exploring the courtyard pattern's efficiency, its main design features, its weak points and some of the ideas to enhance its performance, the paper proposes two architectural design solutions for Iraq. Both of them include using the courtyard pattern within multistory residential buildings. The paper suggests this kind of solutions as an approach to achieve affordable and efficient housing production and at the same time provide a thermally comfortable environment. It proposes these two solutions to be developed and tested in future studies to determine their potential environmental performance in addition to determining their efficiency in addressing the other residential requirements.

The proposed models in Fig. 6a, b are three stories buildings. The first one includes one bedroom flats, two bedrooms flats and three bedrooms flats and the second one only one and two bedrooms flats. In both of the proposed solutions, each flat has its own private courtyard which is surrounded by the various living spaces. A wind-catcher is also provided for each flat. The courtyards are surrounded by glassed walls to neutralize the impact of the undesirable weather conditions and benefits of their efficient performance when it is possible. The paper also supports using some of the modern mechanical air-conditioning devices to support the courtyard when it cannot provide the required conditions.

Building on the explored literature, the paper suggests the potential air movement that will occur in the proposed solutions. As it is shown in Fig. 6a, b, the wind-catcher will catch the air, with considering directing its upper opening to the correct direction, and directing it to the courtyard from which it will be distributed to the surrounded spaces. A water surface can be put in the bottom of the wind catcher to cool the air before reaching the courtyard.

In designing the two proposed solutions, the paper considers providing other main design requirements, which include providing privacy [40, 41], appropriate and standard layouts and areas [42, 43].

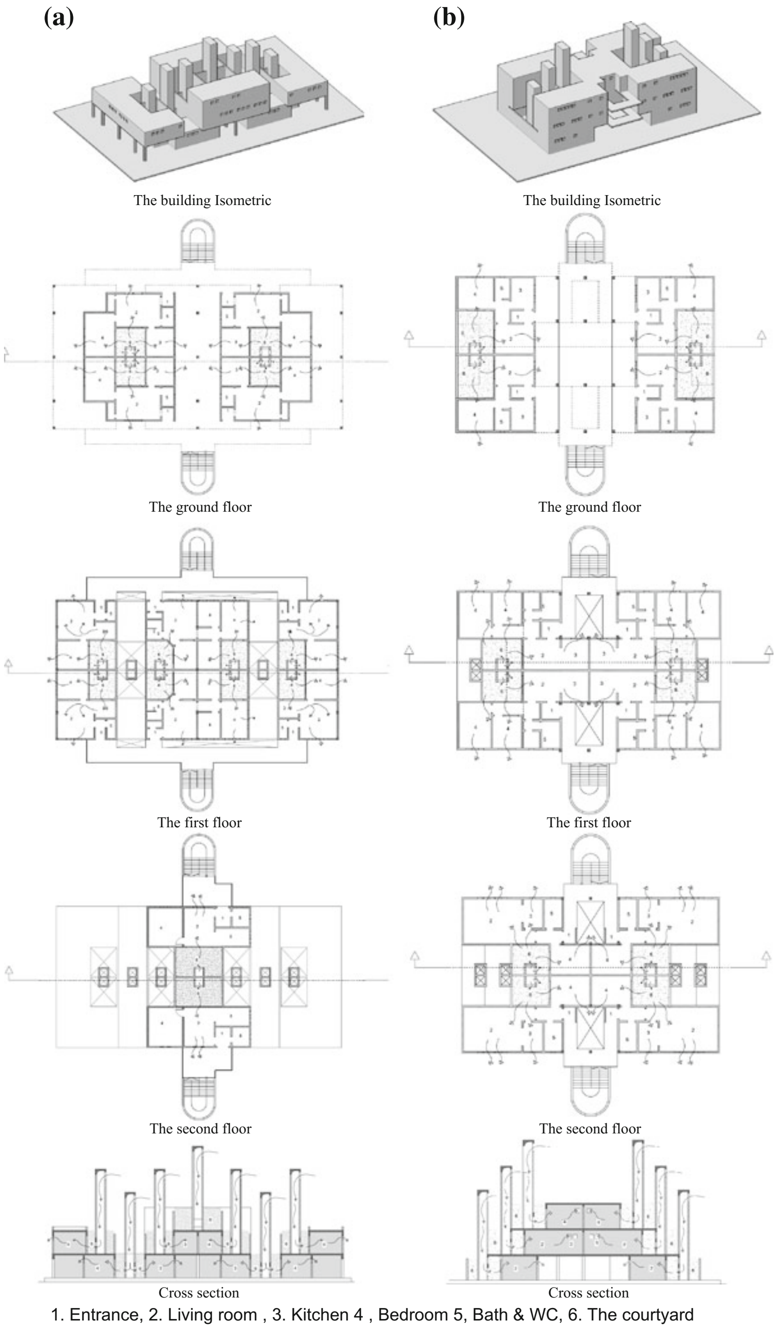

Fig. 6. A three stories residential building

6 Conclusions and Discussion

This paper reports on an investigation of the use of the courtyard pattern in the context of multi-story residential buildings in Iraq.

Previous work suggests that the courtyard pattern can be used as an efficient solution to provide a thermally comfortable indoor environment. However, the designs should incorporate all of the integrated design features and strategies to have an efficient solution. This implied using the courtyard element with other supporting elements including the wind-catchers, the mashrabia and the water elements in a compact urban fabric. Using all of these elements integrally is vital to activate and support the two main principles of courtyard performance: shading and natural ventilation.

The paper also explores the prospects of developing the courtyard house pattern and enhances its performance by using modern artificial technologies that might provide more control on the climatic conditions inside the house. This includes using mechanical ventilation and lighting and surrounding the courtyard with glass walls to neutralize unwanted climatic conditions.

Finally, the paper investigates possibilities for using the courtyard pattern in modern multi-storey residential buildings. It suggests two design solutions that adopt the courtyard pattern in three stories residential buildings. They supposed to provide a thermally comfortable environment and at the same time support increasing the housing production and providing affordable housing.

The paper recommends conducting studies that focus on testing and determining this kind of design solutions performance from different aspects. This might include conducting simulation studies to test and determine their environmental performance and energy consumption with considering the impact of their various design features. It might also include conducting surveys and interviews with public people and experts in the housing sector to determine the applicability and acceptability of this kind of design solutions and the possible ways to develop it.

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Bearing Capacity and pH Value of Stabilized Soils with Class F Fly Ash and Cement

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Abstract. The California Bearing Ratio (CBR) test determines behaviour of road sub-base and granular layers for flexible pavement. In the conventional CBR test, compacted sample was waited in air for 24 h and in water for 4 days. In this study, the fresh and 28 days curing effects were examined and pH values were measured end of 28 days curing on the CBR percent of soils stabilized with F class fly-ash and cement. There are two main matrix material in this study. One of the matrices consists of Bilecik Clay and Lime and other consists of Bilecik Clay, Bentonite and Lime. In samples, fly-ash (Class-F) and cement were used as additives. Different mixtures which were obtained with various combinations of these materials were prepared and end of compaction were cured in various moulds depending on test. The mechanical strength test as wet CBR, triaxial and unconfined strength tests were performed on the mixtures and physical characteristics as CBR percent and chemical characteristic as pH values were measured.

Keywords: CBR · Fly ash · Lime · pH · Unconfined compression test
Soil stabilization

1 Introduction

Mankind use solid fuel sources for the energy demand. Low calorie lignite coal is not suitable for domestic use for heating. But lignite as a source of energy is useful for thermal power plant in pulverized shape. In this way the cheap and useless lignite turn an economical substantial object. There is 43% waste leftover after the burning of coal. The waste ash is a mix of bottom ash and fly ash. The fly ash is in micron size and graded material that is separated from the exhaust gas after the burning by electrostatic methods. Total amount of fly ash is left 23% of all lignite coal of burning. In Turkey 55 million tons of lignite is burned and 13 million tons of fly ash is come into the picture in a year. Orhaneli, Bursa-Turkey, thermal power plant produces 400 thousand tons of fly ash every year. 170 thousand of fly ash is used by concrete producers.

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The remaining fly ash is thrown away to ash-dam in the nature. This causes big environmental problems which have to be overcome [1].

The fly ash which can bring into play in many civil constructions though does not exploit enough. Some (of fly ash) is used in concrete sector and cement industry but that is not enough amounts to be decreased of waste reserves. They can be used as road sub-grade chemical additives material or for clay sub-grade improvement as cement surrogates. This bring two benefits (1) fly ash mixed soils of strength, bearing capacity, grain size distribution is in increase also some geotechnical parameters as compressibility, permeability, swelling capacity are in decrease and (2) to bring away the disposal of this huge fly ash poses a serious problem in term of land use and potential environmental pollution. To overcome this, strong economic and environmental imperatives exist for effective use of this fly ash.

Researchers tried to investigate the scope of commercial utilization of fly ash, and a wide variety of applications for high volume use of fly ash have been conceived. However, for efficient and economic utilization, the physico-mechanical characteristics of fly ash must be established. To date, very little knowledge of the physico-mechanical characteristics of class C fly ash are available. Therefore, there is a need to study these characteristics in detail. Moreover, for wide acceptance of fly ash construction material the following aspects need to be addressed:

(1) Perception of non-uniformity of the by product.
(2) Inadequate design criteria and quality control guidelines for ash utilization.

In order to obtain higher strength from class F fly ash which has not self-hardened characteristic and to make hardening more quickly, researchers have discovered that Lime should be added in 5–20% to mixtures [2].

Waste ash is mixed with filling material, lime and fly ash in contents of optimum water. It is applied to bottoms of road [3, 4]. The fly ash which has pozzolanic characteristic raises the strength of road, and thus waste of fly ash can be utilized as a construction material. In conventional CBR Test, compacted specimen is waited 24 h in air and 4 days in water. The researches have shown that these periods are not enough to complete pozzolanic reaction [2]. Consequently, this period should be extended and the reaction between mixture of clay-cement or of clay-fly ash should complete at least 90%.

In this research, we have studied two different artificial soils as a matrix, one of which has not expected that it can swell. One matrix used was Kaolin (K), and other matrix is made of Kaolin + Bentonite (KB). These matrices were stabilized by adding class F fly ash and cement in different proportion. At the end of different cure times, mechanical strength tests and physical tests were performed on the mixture. The effects of curing time on the California Bearing Ratio (CBR) and swelling potential, unconfined pressure and shear strength by triaxial compression test and activity, pH values were examined. In order to finish pozzolanic reaction, the mixtures were waited in CBR mould for 28 days than saturated CBR test was applied, and their swelling was measured. Furthermore, Triaxle test of unconsolidated and undrained (UU) was applied to every single mixture which was waited 28 days. The results have shown that soil stabilization added fly ash could not be explained via CBR Tests.

2 Materials

In this study, two groups of matrices were considered to refer soil which will be stabilised. The first group of these matrices is Bilecik clay + Lime, and other is Bilecik clay + Na Bentonite + Lime. The percentage of Lime in these matrices is assumed to be 5%.

Bilecik clay (K) is being produced by dilution from natural clay, which belongs to Bilecik district with no chemicals. Some characteristics of clay which were taken from clay producer who sells clay to ceramic factories were given in Table 1.

Fly ash (class F) used in this study was taken from Orhaneli, Bursa, thermal power plant. Activity characteristics of fly ash are given in Table 2. The strength activity and pozzolanic activity of fly ash are compared according to TS 639 and ASTM C618 [5, 6].

The results of chemical analysis which were taken from thermal power plant are given in Table 3. The comparison with standard values of chemical and physical characteristics of fly ash is shown in Table 3. The Orhaneli's fly ash is class F. It has lower percentage of calcium in other words it is non self-cementing fly ash. The grain size distribution of fly ash is shown in Table 4.

Pozzolanic reaction is a reaction among silica (SiO_2), alumina (AlO_2) and calcium (Ca). New mixture is obtained end of this reaction which is called cementing and it occurs very stable calcium silicates (CS) and calcium aluminates (CA). This reaction depends on the duration of the process, test temperature and humidity [1]. In a pozzolanic reaction, two types of reactions occur which are named colloidal and connective. Ca++ ions change place with fine particles and other ions on clay surface. Clay surface charges positive ions and grains become cohesive because of surface-end gravity. Soil grains get greater size. Liquid limit decreases, in other words mixture is less plastic than before. The occurred reaction is a sudden reaction and it does not depend on time. Silicates on clay surface react with calcium ions (Ca++). End of reaction calcium silicate (CS) occurs and it hardens. This structure is fairly resistant and it does not melt in water. If there is no silicate in environment CS will not occur. This reaction is a timed-reaction [2].

The cement (C), used in test, is CEM I and 42.5R strength class of Portland cement and its specifications are given in TS EN 197-1 [7]. The cement is supplied from concrete plant as bulk. Calcium Lime (L) is class CL80 and it is used according to TS EN 459-1 [8, 9]. Its specific gravity is determined to be 2.42. Grain size distribution of lime is given in Table 4. Bentonite (B) is supplied from Ankara Karakaya bentonite clay factory. Physico-chemical and geotechnical characteristics of this clay are given in Table 3.

Table 1. Mineral and geotechnical characteristics of Bilecik clay [2]

Mineral	Contents (%)	Geotechnical characteristics	Quantity
Kaolin	79–83	Liquid limit (LL)	43.3
Free quarts	12–14	Plastic limit (PL)	25.6
Illit	2	Indies of plasticity (Ip)	17.7
Others	3–6	Specific gravity (Gs)	2.54
Component	**Quantity (%)**	**Soil category TS 1500 USCS**	**CL**
Sand	0.0	Loss of ignition (LOI) (%)	10–14
Silt	52.4	Optimum water contents (wopt) (OWC) (%)	21.1
Clay	47.6	Maximum dry unit weight (γd) (kN/m3)	15.9

Table 2. Class F fly ash strength activity and pozzolanic activity requirements

Curing time (day)	Activity index (%)	Standards		Pozzolanic activity (%)	Standard
		TS 639	ASTM C618		TS 639
7	61.2	–	–	58.0	–
28	76.0	Min 75%	Min 75%	70.9	Min 70%
90	86.2	Min 85%	–	78.5	–

Table 3. Characteristics of bentonite used in the mixtures

Additives	pH	CVC	EC	WC	QOM	GSG	UVG	Grain size distribution (%)				
		(meq/100 g)	(mS/cm)	(%)	(%)		(gr/l)	Sand	Silt	Clay	Cu	Cc
Na-Bentonite	9.50	90.22	2.69	12.7	6.82	2.76	0.94	2	46	52	40	0.8

CVC: Cation variation capacity; EC: Electrical conductivity; WC: Water contents; QOM: Quantity of organic material; GSG: Grain specific gravity; UVG: Unit volume gravity

Table 4. Mixture percentage of materials used for tests

Mixture percentage	Notation
100% Bilecik clay	K (control specimen)
100% Bilecik clay + 5% lime + 5% fly ash	KL-5F
100% Bilecik clay + 5% lime + 10% fly ash	KL-10F
100% Bilecik clay + 5% lime + 15% fly ash	KL-15F
100% Bilecik clay + 5% lime + 5% cement	KL-5C
100% Bilecik clay + 5% lime + 10% cement	KL-10C
100% Bilecik clay + 5% lime + 15% cement	KL-15C
90% Bilecik clay + 10% bentonite	KB (control specimen)
90% Bilecik clay + 10% bentonite + 5% lime + 5% fly ash	KBL-5F

(*continued*)

Table 4. (*continued*)

Mixture percentage	Notation
90% Bilecik clay + 10% bentonite + 5% lime + 10% fly ash	KBL-10F
90% Bilecik clay + 10% bentonite + 5% lime + 15% fly ash	KBL-15F
90% Bilecik clay + 10% bentonite + 5% lime + 5% cement	KBL-5C
90% Bilecik clay + 10% bentonite + 5% lime + 10% cement	KBL-10C
90% Bilecik clay + 10% bentonite + 5% lime + 15% cement	KBL-15C

Note: K = Bilecik clay; L = Lime; F = Fly ash; C = Cement; B = Bentonite

2.1 Preparing Mixtures

Clay was grained finely and was sieved with 1.18 mm sieve to be used in mixtures. Fly ash, cement, lime bentonite and Bilecik's clay which were added mixture were utilized after being dried in oven at 105 ± 5 °C for 24 h. Optimum water contents (OWC) of mixtures were determined. By adding calculated amount of water the mixture was cured in desiccators for one night. After this procedure, the different cure-times were applied to mixtures depending on what tests would be performed.

The curing was performed 1 day (in air) + 4 days in water and 28 days (in air) + 4 days in water for California Bearing Ratio (CBR) and 28 days for the unconfined test and 1, 7, 28 and 56 days for triaxial test respectively. During the cure time the samples for unconfined pressure test and those for UU test was in mould as cylindrical form which has 3.6 cm diameter and 7.2 cm height and the CBR test mixtures were in the CBR mould. During the curing procedure, the samples in the test moulds or those which were formed as cylindrical were waited at 20 ± 2 °C in curing box and doubled plastic bag that the air and the sunlight could not influence them. Additional temperature and humidity were not applied to the samples.

In this study 13 different mixtures were utilized (Table 4). The mixture ratios were determined by their gravity and are shown in Table 6. In order to control test results, check samples were prepared. The first of these samples was prepared with Bilecik clay as 100% and other with Bilecik clay as 90% + 10% Bentonite clay as example for expanded soils. The matrix was assumed 100% and additive quantities are added in matrix.

3 Results and Analysis

Specific gravity, optimum water contents and dry unit weight which were measured by standard proctor test were given Table 5 and values of pH were given in Table 6. After cure procedure for 28 days, physical test as Atterberg Limits, grain size distribution (Hydrometer), wet sieving and CBR, unconfined pressure, triaxle (UU) tests were performed.

Increasing of pH value of stabilized mixture, enables clay can be use in deponi areas, clay can custody pollution inside. That can make clays pollution store. pH value of soils is fairly important for decreasing amount of harmful metal. In order to prevent pollution of soil, pH value of soil must be at least between 6 and 8.

Table 5. Mixtures optimum moisture content and maximum dry unit weight

Mixtures	Gs	Optimum moisture content, wopt (%)	Max. dry unit weight γd (t/m^3)
K	2.54	21.07	1.62
KL-5F	2.58	25.39	1.48
KL-10F	2.57	24.90	1.48
KL-15F	2.56	24.78	1.48
KL-5C	2.61	24.85	1.51
KL-10C	2.62	23.77	1.53
KL-15C	2.63	24.14	1.54
KB	2.66	25.94	1.52
KBL-5F	2.58	25.58	1.46
KBL-10F	2.56	24.87	1.47
KBL-15F	2.54	24.29	1.47
KBL-5C	2.65	24.50	1.48
KBL-10C	2.63	24.57	1.51
KBL-15C	2.62	24.68	1.51

Notes: Gs, specific gravity; wopt, optimum moisture content; γd, dry unit weight

Table 6. pH values of mixtures measured after 28 days curing

Mixtures	pH (28 days + hours)			
	1	24	48	72
K	8.9	9.0	9.4	9.4
KL-5F	12.3	13.1	13.1	12.9
KL-10F	11.8	12.1	12.2	11.9
KL-15F	12.6	12.8	12.8	12.6
KL-5C	13.0	13.2	13.2	12.9
KL-10C	12.3	12.6	12.6	12.6
KL-15C	13.2	13.4	13.3	13.4
KB	10.8	12.0	11.9	11.6
KBL-5F	10.2	11.6	11.4	11.4
KBL-10F	10.7	11.9	11.8	11.9
KBL-15F	10.1	11.7	11.7	11.7
KBL-5C	12.2	13.0	12.8	12.7
KBL-10C	12.3	13.0	12.9	12.9
KBL-15C	12.7	13.4	13.2	13.2

3.1 California Bearing Ratio Test (CBR)

The analysis for California Bearing Ratio (CBR) was conducted to investigate the performance of Class-F ash as a base course material. Table 7 shows the relation between the CBR with the dry density of the mixtures for optimum water contents. The aim of this investigation is to determine the CBR for the curing time of interest. In the analyses, the minimum CBR value for 1 day is 18, and that for 28 days' cure is 26 for 0.1 in. (2.5 mm) or 0.2 in. (5 mm) penetration grade material. If value of CBR is between 30 and 50%, the mixture is perfect as sub-base material.

According to [10–14], if value of CBR is between 20 and 30%, the mixture is perfect as sub grade material. If value of CBR is between 30 and 50%, the mixture is perfect as sub-base material (Fig. 1).

Table 7. Maximum CBR values of mixture

Penetration	Conventional CBR			CBR 28 days later		
	Maximum wet CBR (cured 4 days in water)			Maximum wet CBR (cured 28 days in air + 4 days in water)		
	Bearing ratio	Penetration (kN)		Bearing ratio	Penetration (kN)	
		2.5 mm	5 mm		2.5 mm	5 mm
K	9	1.14	1.43	9	1.14	1.43
KL-5F	25	3.38	4.28	26	3.47	3.90
KL-10F	21	2.81	3.90	35	4.66	5.47
KL-15F	18	2.38	3.24	34	4.52	5.09
KL-5C	73	9.80	10.00	52	6.99	6.95
KL-10C	133	17.90	18.00	88	11.80	12.10
KL-15C	170	22.70	20.80	93	12.40	13.70
KBL-5F	19	2.57	2.85	30	4.00	4.19
KBL-10F	20	2.66	3.04	54	7.18	7.18
KBL-15F	26	3.38	3.38	49	6.52	5.90
KBL-5C	50	6.66	7.56	89	12.00	7.71
KBL-10C	123	16.60	16.70	81	10.90	11.70
KBL-15C	165	22.10	11.40	76	10.20	11.80

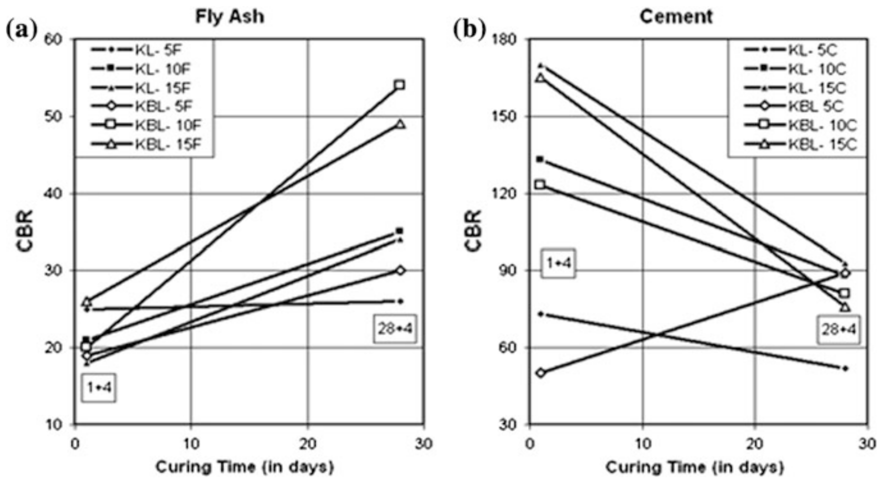

Fig. 1. Curing time effects on CBR **a** fly ash additive **b** cement additive

3.2 Unconfined Compression Test

The Unconfined compression tests were performed to determine shear strength of soils. In laboratory, curing effects for shear strength are determined for 28 days and the values are shown in Fig. 2 for each mixture. The highest shear strength values are obtained for 28 days curing in 10%F and KBL-15%F mixtures. Shear strength has decreased in 15%F additive mixture. During tests in KL-15%F and KBL-15%F samples deep cracks are observed in vertical direction. 15%F additive has caused more ductile material. Therefore, shear strength was decreased in 15%F additive mixture. The same vertical cracks were also observed in KL-15% C and KBL-15% C and consequently strength weakness was occurred.

4 Conclusions

Due to complex structures of soils, it is not observed equal improvement in equal strength value for equal quantity of additive materials, thus preliminary work is needed. Geotechnical parameters should be obtained by mixing with additive material in different rates. Especially if there is pozzolanic additive stabilization, strengths and bearing capability of materials should be measured after curing for 28 days.

Obtaining accurate mixture rate, additive soil should be utilized as filling material (sub grade) and as sub-base or road base layer. The results in stabilization of Bilecik clay + lime with and without Bentonite matrices with fly ash and cement are following;

Class-F fly ash has a difference from Class-C flay ash that can be stored until to be mixed with lime and water, because it is none self-cementing.

Adding Lime, cement and fly ash have changed grain size distribution of kaolin. It has increased quantity of silt and has decreased quantity of clay.

The strength of cured mixtures gradually increases in rate of 10%F and 10%C but strengths of 15%F and 15%C additive mixtures slightly decrease. In CBR test with cured 28 days, in terms of unconfined compression and triaxial tests, profound cracks were observed. The reason of these rifts is due to the fact that 15%F and 15%C additives make samples more ductile materials.

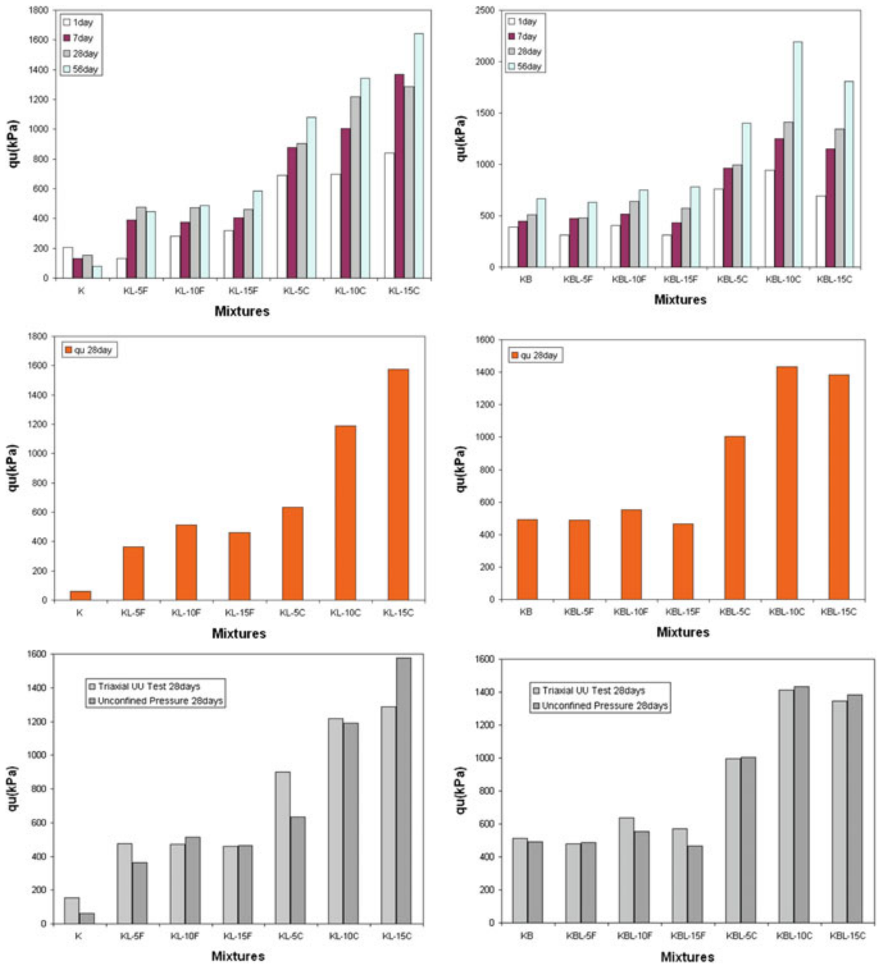

Fig. 2. Results of triaxial compression tests (UU) and unconfined compression test

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