Lecture Notes in Civil Engineering

Ar Meor Mohammad Fared Bin Meor Razali
Mokhtar Awang
Seyed Sattar Emamian *Editors*

Advances in Civil Engineering Materials

Selected Articles from the International Conference on Architecture and Civil Engineering (ICACE2020)

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Preface

This book presents a compilation of research works covering the fields of architecture and civil engineering. All manuscripts in this volume were presented during the 4th International Conference on Architecture and Civil Engineering 2020 (ICACE 2020) which was conducted through a virtual presentation on 19 August 2020. This conference holds a vital role in as a catalyst in seeking wisdom and sharing thoughts and opinions to promote better understanding of engineering and information technology and to strive for quality research towards Fourth Industrial Revolution (IR 4.0).

The editor(s) of the proceeding would like to express the utmost gratitude and thanks to all reviewers in the technical team for making this volume a success.

Serdang, Malaysia	Ar Meor Mohammad Fared Bin Meor Razali
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The editors would like to thank all the members of the local organizing committee who helped organize the 4th International Conference on Architecture and Civil Engineering 2020 (ICACE 2020), which was conducted through a virtual presentation on 19 August 2020. We would like to thank the colleagues and staff members at the institutions and organizations that served as partners for the international conference. Their support in organizing a successful conference has helped the editors to gather ideas and papers presented in this book. The editors are grateful to all the speakers who attended the conference and shared from their wealth of experience some exciting findings who have further propelled us to publish this book.

The editors also appreciate various people, including the production team at Springer, who helped and contributed to the creation of this book. We thank all the authors and contributors who presented at the conference and sent us their papers for peer-review. The editors would like to thank and appreciate the peer-reviewers for their suggestions, comments, efforts, and time spent to go over all the papers.

The editors appreciate the support of the leadership team of their respective institutions for the support, encouragement, and enabling environment created to prepare this book. The conference has inspired and brought the editors together from different disciplines and institutions across different countries and continents of the world to work on this book. The creation of this book has helped us to become a formidable team. The process has been enjoyable, challenging, inspiring, and more peaceful than we ever thought. We thank you all!

Contents

A Review of Daylight Impacts on Luminous Comfort in Libraries

Sahar Mortazaee and Syarmila Hany Haron

Abstract People concern about their living conditions in recent years. There are different factors that could be applicable to improve public living conditions. One of these essential factors is daylighting. Therefore, daylighting is implemented in modern buildings to use natural light into the spaces more efficiently while improving comfort and living conditions, including acoustic comfort, thermal comfort, and as well as luminous comfort. Satisfaction with daylight should be the prime concern in luminous comfort studies. In the past and recent, many studies have been conducted about daylighting in buildings. However, in a few studies, satisfaction with daylighting has been considered as a main impressive element in luminous conditions of buildings. One of the most critical places where daylight issue should be concerned is the libraries. The proper luminous conditions in the library could lead to boosting users' productivity and psychological health. Therefore, this paper investigates the factors that influence levels of satisfaction with daylighting in libraries. According to the importance of daylight satisfaction in the level of luminous environment, these factors also cause to improve luminous comfort. The study reviews the factors including physical environment, feelings towards daylight, and interior design with the aid of figures.

Keywords Daylight satisfaction · Luminous comfort · Luminous environment · Psychological health · Productivity

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1 Introduction

Daylight is an effective factor that could have a significant impact on users' wellbeing in buildings. It could also lead to stimulating and regulating the circadian system so that it influences the mood and alertness [1, 2]. Hence, applying windows could cause to promote the occupants' mood [3, 4]. Furthermore, daylight provides luminance and colour variation that makes the spaces more attractive and desirable [5]. Daylighting is also utilized to provide high-quality and healthy visual work environments by considering the best illumination in the building [6]. Regarding the benefits of daylight, the deficiency of daylight can deteriorate people's psychological health and productivity [7].

The libraries are the crucial places that can provide users with access to perpetual information, sources of data, and documents. Hence, the design of libraries is critical because it can promote the users' motivation in using them most of the time, including during exams and their leisure time [8]. Lighting, as one of the architectural tools, affects noticeably on library users' comfort in the visual term. Accordingly, proper daylighting should be provided in libraries as utilizable buildings. Despite the hints mentioned above, the daylighting concept is not correctly considered in most of the library designs. Consequently, the users do not satisfy with the luminous environment [8].

2 Daylight in Buildings

Manning [9] has indicated that the daylighting method is applied to bring natural light into the room for replacing with artificial lighting. In daylight studies, different solutions have been presented to improve daylighting conditions in buildings. Some solutions have been suggested for daylight transmission such as light shelves [10], atriums [11], light pipes [12], and remote source lighting systems [13]. Hence, these methods could cause to bring daylight into spaces effectively and provide luminous comfort. Luminous comfort is regarded as people's satisfaction with the luminous environment [7]. The luminous environment is related to the duration of sunshine hours and sky condition, two major climatic factors determining the quality and quantity of daylight [14]. The luminous environmental quality is significantly essential to conduct a work task properly [15].

Furthermore, the luminous environment impacts users in psychological and physiological terms [15]. In the past, studies of the luminous environment have attempted to bring about observers' visual satisfaction through developing luminaires with high performance and great colour rendering. However, recent studies have investigated the non-visual impacts of luminous environments on observers. Hence, they have developed luminaires by considering both the physiological and psychological aspects [16].

3 Daylight and Luminous Comfort

The level of luminous comfort is mostly impressed by daylight quality. Therefore, satisfaction with daylight ought to be considered as the main factor in studies of luminous comfort [17]. For instance, in a café at Laval University, it is demonstrated that the diversity of a luminous environment, which is created by applying daylight, provides visual satisfaction for occupants [18]. Moreover, based on the study about indoor lighting impacts on occupants' visual comfort, it was found out that there is a notable correlation between occupants' satisfaction with luminance distribution [19]. According to another conducted survey in residential buildings, Hong Kong, it was realized that 90% of the occupants have a concern about the performance of daylighting in their living rooms [20]. As well as these, the result of a survey in healthcare buildings demonstrates that user satisfaction could be raised by increasing the amount of daylight [15]. Kilic and Hasirci [8] have stated that daylight has significant effects on users' satisfaction in university libraries.

Satisfaction with daylight involved three primary aspects, which are shown in Fig. 1. The first one is the physical environment [21, 22], which includes five key elements: (1) External obstruction; (2) Orientation; (3) Window area; (4) Shading and (5) floor level. The next one is the users' feelings towards daylight [7], which incorporates four elements: (1) Skylight, (2) Perception of uniformity, (3) Sunlight access time, and (4) Sunlight problem. The last one is interior design [23]; this aspect consists of three elements which are (1) Arrangement of bookshelves, (2) Circulation area, and (3) Seating layout. The elements of interior design are undoubtedly proper for the evaluation of daylighting in libraries and not in other types of buildings such as residences.

Fig. 1 Satisfaction with daylight as a primary principle in luminous comfort

3.1 Physical Environment

Some fundamental building parameters influence the interior daylight. They are introduced as physical environment parameters in this research (see Fig. 2). According to the findings of a survey in Hong Kong, occupants would like to have an unobstructed view in their living room [24]. Therefore, external obstruction is one of these parameters. External obstruction has an impression on the performance of daylighting in two phases. The first phase is about the part of the sky, which is obstructed or unobstructed. The second is about reflected luminance from the obstructing buildings, which is influenced by the external surface finish colour [21]. Another physical environment parameter is the orientation that affects interior daylight illuminance [25]. For instance, research about daylighting performance in obstructed residential buildings shows that the rooms directing to south and south-east would absorb more daylight in Hong Kong [21]. The window area, which determines the transmitted daylight availability, is the third parameter. It is expressed by the window to wall ratio (WWR). Most of WWRs is between 25 and 30%. Buildings with low WWRs are usually located in densely populated and older areas [21]. Shading devices as one of the physical environment parameters prevent penetrating of direct sunlight (glare); however, it allows diffuse daylight to be received [21]. Li and Tsang [22] have also considered all the mentioned parameters in their study, which is about daylighting performance in office buildings. Xue et al. [7] have added one more physical environment factor to their survey, which is floor level.

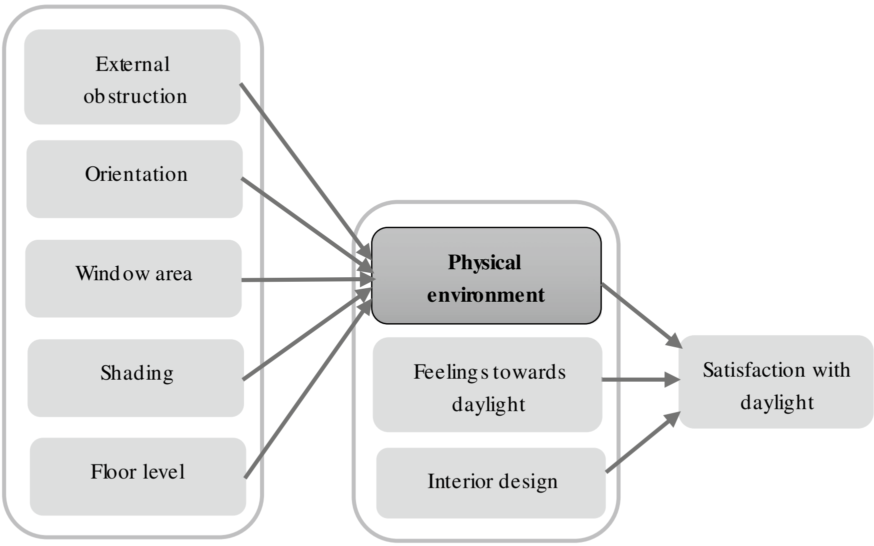

Fig. 2 The effective parameters of the physical environment in boosting daylight satisfaction

3.2 Feelings Towards Daylight

Xue et al. [7] have deduced that the users' feelings towards daylight have a considerable effect on satisfaction with daylighting. The factors of feelings towards daylight are skylight, perception of uniformity, sunlight access time, and sunlight problem (see Fig. 3). The utilization of daylight has been considered as an essential factor in architecture during history due to creating a comfortable visual environment [26]. Daylight is a combination of two components: sunlight and skylight. Sunlight relates to the direct solar beam, which arrives directly at the surface of the earth. Skylight, sometimes perceived as 'diffuse skylight.' It is the light from the sun spreading in the atmosphere before arriving at the earth's surface, and sky conditions determine it [27]. The skylight as a fundamental source is helpful for the design of interior daylighting. Nevertheless, the direct sunlight is eschewed because its heat and glare can bring thermal and visual discomfort for occupants. The amount of daylight illuminating in the interior is dependent on the position and size of the openings (window, skylight, and atria) and the distributions of sky luminance [28].

Therefore, Xue et al. [7] have evaluated the occupants' preferences associated with sunlight access time and sunlight problems in a luminous comfort study. Accordingly, they have concluded that thermal discomfort as the most remarkable sunlight problem and the hours of solar access have a principal influence on daylight comfort.

The perception of uniformity should always consider as the main factor in association with daylighting performance [7] because extreme sunlight in an interior can lead to occupants' discomfort [29]. The combination of maximizing daylight levels inside buildings and optimizing the luminous environment quality could lead to successful daylighting. In other words, the main point in daylighting design is not only controlling light levels but also managing the distribution and the direction of light [29].

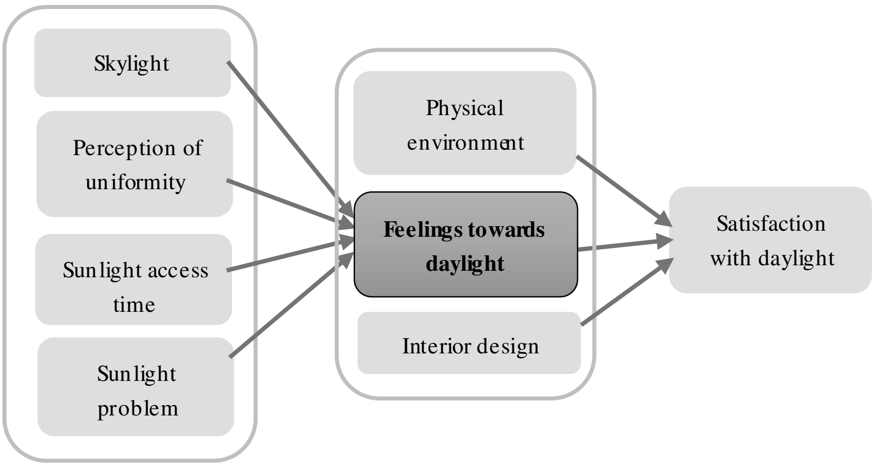

Fig. 3 The effective parameters of feelings towards daylight in boosting daylight satisfaction

Side lighting and top lighting are two daylighting techniques to diffuse lighting. Side lighting systems could resolve the issue of uneven natural light distribution, which is originated from traditional side windows. Effective side lighting systems diminish the extreme levels of daylight around the windows and raise them in spaces away from the windows. Thus, it causes adjusting daylight distribution throughout the space. For instance, bringing daylight through two different sidewalls results in evener distribution of daylight. As well as this, it leads to a decrease in the daylight glare [29].

In addition to the side lighting system, top lighting systems are the second daylighting technique. In this technique, light penetrates the interior from the top of a building. In this technique, it is usually created a horizontal opening in the building roof due to capturing sunlight during a sunny day and diffusing light from the sky into the room under the skylight. Regarding an even distribution of daylight, several skylights should be distributed uniformly across the ceiling [29].

3.3 Interior Design

Othman and Mazli believe that the design of seating layout, circulation area, and arrangement of bookshelves could optimize daylight in the library. Therefore, they have a notable effect on occupants' satisfaction in terms of daylight [23]. These elements have been considered as interior design factors in this research, which were illustrated in Fig. 4. Kilic and Hasirci [8] have stated that designing of these elements should be according to the recommended light level for their functions.

A comfortable and pleasant library for study can be created by designing the circulation areas and the bookshelf schemes based on maximum use of daylight. The bookshelves should be positioned perpendicular to the library windows; hence,

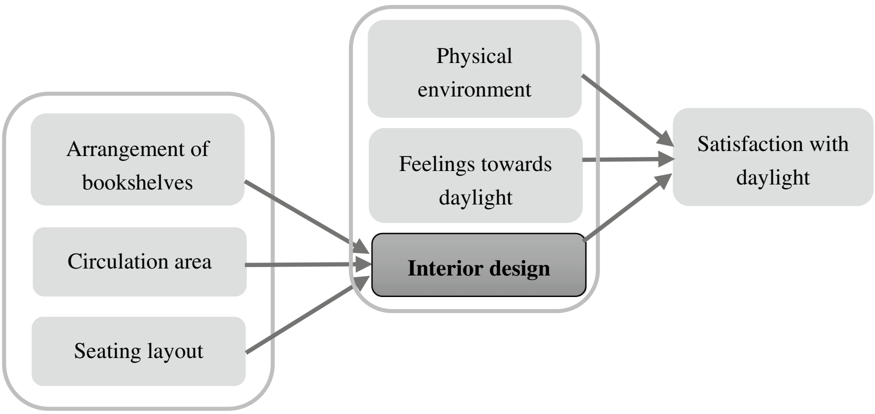

Fig. 4 The effective parameters of interior design in boosting daylight satisfaction

daylight is not obstructed, and bookshelves also prevent the interior space from the extensive glare from outside. Circulation paths could also be located perpendicular to the study carrels. This kind of layout design helps to control daylight in the work zone so that it causes to create a pleasant library space for the users [30].

Kan [30] believes that there is a relationship between users' comfort and their seating preferences based on daylight. It means that users prefer the seat that receives the maximum rate of daylight to spend their time in the library. Regarding that, the seating layout has an impression on users' efficiency and performance in the reading task [23]. The seating layout could be designed with locating the individual study carrels near a window. Low partitions allow taking controlled daylight and view from outside to the work area [30]. A view from outside is advantageous to users, and it influences their satisfaction with their workspace [31].

4 Outcomes of Luminous Comfort—Psychological Health and Productivity

The luminous environment has a critical role in the public's psychological state [15]. It also affects human productivity and performance [32]. Moreover, access to daylight promotes the public's psychological health [19] and productivity [33]. Thus, luminous comfort can lead to psychological health and productivity for users (see Fig. 5).

4.1 Psychological Health

Psychological health has been conceptualized as an absence of mental distress or psychopathology [34]. There are lots of studies that prove the positive impact of daylight on psychological health. Therefore, some studies associated with this issue have been provided below.

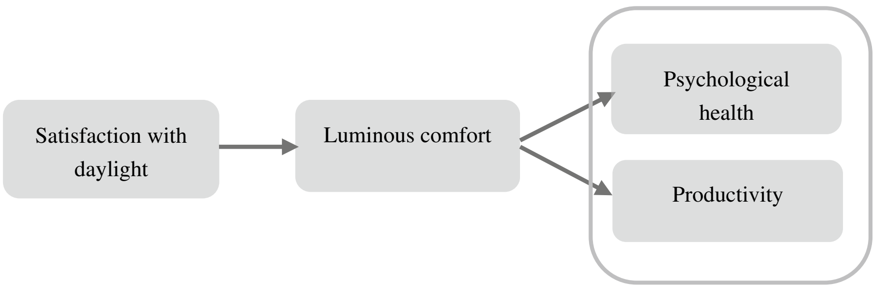

Fig. 5 The outcomes of the luminous comfort

According to the conducted study in an office building in the USA, almost all occupants in the office thought that daylight is beneficial for mental satisfaction and visual health, as well as office appearance and pleasantness [35]. Additionally, the lack of daylight in the hospital can cause to work stress and burnout for nurses [36]. Therefore, at least 3 h of access to daylight can decrease burnout and stress [37]. Roseman and Booker [38] found out that the nurses make more medical mistakes in midwinter rather than in the summer or fall. It means that there is a remarkable relationship between medical mistakes rate and outside darkness, whether the reasons for these mistakes are because of stress or psychological problems. In another study, it is demonstrated that daylight enhances patients' health in physiological and psychological terms [39]. Moreover, a study was conducted in the windowless environment of a factory. Then, it is recognized that the workers were miserable, and they were suffering from general depression. Therefore, they would like to access the outside space to overcome their problems [40].

4.2 Productivity

Productivity refers to the measured output of an employee within a specified time [41]. Some studies have been conducted based on the lighting impact on productivity, demonstrating the effect of daylight on performance [7].

It is recognized that windows view [42], and the light effect on circadian rhythms can affect productivity [43]. In another study, it has been confirmed that the amount of light, specifically, daylight has a tremendous impact on task involvement, reading, and productivity. Hence, the productive daylight use in educational environments and libraries is essential [8]. In addition to previous studies, Boyce et al. [44] have stated that productivity at work can be evaluated by several various elments. One of these effective elements is the lighting of the interior. As well as these, most university students in Canada believes that it is better to work under daylight rather than artificial light [45]. Natural light could also cause to enhance sharpness for monotonic work during office hours [46].

5 Conclusion

The lack of daylight and inappropriate luminous conditions could have unpleasant results for the users of buildings such as performance reduction and unhealthy conditions both in psychological and physiological health.

Libraries, as one of the critical places, are appropriate for studying or even doing leisure activities. Therefore, the principal design of libraries could promote users' motivation. One of the most fundamental elements in designing libraries is daylight. Daylight satisfaction could be achieved in libraries by considering three key parameters, including physical environment, feelings towards daylight, and interior design.

Satisfaction with daylight causes to provide suitable luminous conditions for users. The proper luminous conditions could assist in improving users' performance and mental health.

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Barriers and Strategies of Green Procurement in Malaysian Construction Industry

Nik Norzahariah Ashikin Bt N. Mohamed and Gunalaan Vasudevan

Abstract This research to discuss the strategies of green procurement in Malaysia and to outline the barriers faced. In addition to that, the objective of this research is set to expand its existing measures by providing suggestions based on other successful countries as references to achieve sustainable development for a greener environment. The research methodology that are being applied includes both quantitative and qualitative approaches. Using a combination of qualitative and quantitative data enables us to compare and contrast results and data collected in deeper insights. To support the objectives of the study, questionnaire is being used as the main primary data. The respondent who have taken part in the questionnaire are those construction companies registered under CIDB, following the list given by our college during the internship programme. All the answers of the respondents are being recorded to draw conclusion and analysis regarding to green procurement. The data is analyzed through relative importance index method in order to rank the factors, challenges and strategies relevant to the research objectives. From the data collected from 50 participants who have taken part in the survey, the results show that majority of them have agreed that green procurement helps to improve health and quality of life of occupants of the green building as the main benefit gained from implementing green procurement.

Keywords Green procurement · Implementation procurement · Barriers and strategies procurement

1 Introduction

Green Procurement is defined as the act of purchasing goods or services which brings minimum negative impact to the environment. Though the term is often used interchangeably with sustainable procurement, it is important to note that the latter focuses on three main factors, including environment, social and economic factors, aiming to

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achieve positive impact throughout the life cycle of the goods and services procured. According to the Australian Sustainable Procurement Guide, some of the key principles in sustainable procurement include reduction of unnecessary consumption of resources like water and electricity, predominant usage of recyclable or reusable goods, implementing sourcing practices which abide by ethics and legislations, emphasizing innovation in sustainable products, sourcing for products which have reduced adverse impacts on the environment by looking into the production, usage and disposal of the product. These principles are then incorporated into the Australian government's main concept for procurement, which is 'Value for Money' [1]. The implementation of green procurement specifically in the construction industry has been around in Hong Kong since 2000, with measures introduced by the government including the use of electric vehicles during construction, usage of waste glass and etc. [2]. Though Malaysia has started to follow in its footsteps, much still needs to be done and therefore the study aims to aid in the implementation of green procurement in the construction industry in our country.

2 Problem Statement

Studies in developed countries have shown that 40% of the country's natural resources were used by the construction industry, temperature control in buildings accounted for 50% of energy usage, and 40% of materials globally were used for buildings and required operations in construction accounted for 30% of total energy usage [3]. The construction industry which has flourished in this era of globalisation has undeniably brought a negative impact to our environment. According to the Scientific and Industrial Research Organization, the embodied energy for cement is 7.8 MJ/kg, making it the highest CO_2 producing construction material. Globally, the usage of cement can increase up to 5 billion metric tonnes in 2050, accounting for 4 billion tonnes of CO_2 emission which further exacerbates the greenhouse effect, leading then to climate change and rising sea level waters [4]. This highlights the importance of implementation of the green procurement framework in the construction industry as a joint effort by all developing countries, including Malaysia. Under the MyHijau initiative by the Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC) in Malaysia, the Government Green Procurement (GGP) plan has been implemented since 2012. Though this brings us one step closer to a safer and greener environment, much work and effort still needs to be put into ensure the ultimate objective is reached. A noticeable gap between the introduction of government green procurement policies and the actual implementation in the construction industry is also seen in Malaysia, further dampened by the fact that there is also few literature research on the assessment of its implementation.

3 Literature Review

3.1 *The* Green Procurement in Malaysia

The Malaysian government plans to make building and infrastructure development, sustainable by establishing green procurement policies and strategic planning as support. The Ministry of Energy, Green Technology and Water and the Ministry of Finance responsible developing the mechanism for green procurement under the MyHijau program [5]. This includes working with Malaysia's research and standards development organisation (SIRIM) to develop a green procurement manual, procedures and standards, a certification and labelling mechanism to facilitate the management of green purchasing in the public and private sectors. The National Sustainable Consumption and Production (SCP) Policy framework produced in the form of the SCP Blueprint and input into the 11th Malaysian Plan (11MP; 2016–2020). Green procurement is a growing area of research in Malaysia. Previous studies have discussed individual green practices and, so far, the focus has been on fragmented and isolated strategies to promote green building. Green procurement is seen as an important tool to integrate these practices; however, currently in Malaysia there is limited research on green building procurement arrangements and strategies [6].

3.2 Barriers and Strategies in the Implementation of Green Procurement Policy in the Construction Industry in Malaysia

3.2.1 Barriers

Some main barriers that are present include *lack of political effort*, in which there are lack of incentives and proper guidelines available [7]. Even though there are existing policies and legislations for example, the Environmental Protection Act, Clean Air Act and Energy Policy Act, the lack of enforcement by proper regulatory bodies fail to implement green procurement in Malaysia successfully [8].

Besides that, the *lack of client's demand* which is important as a driver for the construction companies to opt for green procurement plays a big role in this issue too. Without the drive and demand, even though developers and contractors have the will to adopt green procurement in their construction projects, not much achievement would be seen. The clients might include purchasers or tenants, which represent 'the market' [9]. False perception that green buildings incur more costs and bring less profits. Even through it is true that the initial construction plan might bring in extra costs, however the clients aren't aware of the extra savings in the long run through benefits like increased energy efficiency and increased productivity [9].

Other difficulties that need to be overcome include *lack of knowledge and expertise*. Studies have mentioned that most SEA countries still rely heavily on foreign countries for construction projects. They still adopt traditional methods which are often 'outdated' and less energy efficient than the latest practices. This is worsened by the fact that some westernized methods are sometimes inappropriate for our climate conditions [10]. Members of the core project team do not have adequate knowledge, technical understanding and qualifications to execute the green building project with ease, therefore serving as a major barrier in the implementation of green procurement in the industry.

Lack of availability of green product is the next barrier. Green procurement much more challenging than traditional ones as it is much harder to find suppliers who are providing materials at a reasonable price. Even though Malaysia has seen an increase in advancement of green technology, a large portion of those is still being imported, for instance, the technology used to accumulate low stream water structure and grey water reusing structure and as such, increasing its associated costs [11].

Lastly, another barrier in implementation of Green Procurement is *perception of higher associated costs*. Even though numerous studies have proven that green procurement in the construction industry has shown that it brings a positive impact in the financial sector, many developers are still sceptical about it as they hold on to the belief that anything other than 'business as usual' would be costlier [9]. According to a study conducted in Malaysia, environmental consultants pointed out that there is an additional 15% increase in cost compared to traditional schemes and they have also stated that the population would not be willing to fork out higher rental prices for their houses [9]. The higher initial construction costs are due to higher priced green products, employment of skilled labour like environmental consultants and also green building assessment fees.

3.2.2 Strategies

Government's Role

The governments active efforts have a direct a cause and effect relationship with the implementation of green procurement in the construction industry [6]. First and foremost, the government needs review all existing policies and legislations which are present and make amendments if needed. Stricter legislations would serve as a pressure to the existing construction companies to adopt green procurement and in the long run, increasing their involvement and awareness in this area [12]. An advisory body can also be introduced in order to aid the politicians and stakeholders to make decisions regarding this issue. Environmental consultants, skilled engineers, quantity surveyors who are experienced in this field should be elected as part of this advisory body so that they can provide the authorities with the necessary information and skillset to make relevant decisions on suitable policies and guidelines.

National and local governments should take steps including providing more financial incentives to developers who opt for green buildings in contrast to traditional ones as this can help them to cover the high up-front cost of the construction project, thus encouraging them to take on more green based projects. In Malaysia, The MyHijau initiative also encourages more business owners to gain proper environmental accreditation of the services and goods they provide or purchase in order to be eligible for certain incentives.

Research and Education Sector

Aside from reviewing policies, legislation and incentives, the education and research sector also plays a vital role [9]. For instance, green procurement should be included as a core module in the current curriculum by tertiary institutions to ensure future professionals are equipped with the required skills to carry out their responsibilities.

Besides that, more programmes on the fundamentals on green procurement and eco-friendly technology should be made available to encourage continuous professional development (CPD) among building professionals [9]. A suitable platform where latest updates can be found should also be established and promoted among them so that they can keep up with the latest news and information on their own field.

Private Sector's Role

The private sector should give its full support to the governments' efforts in green procurement implementation [6]. This can be done in a variety of different ways, for example, conducting research and experimenting with new green technology to increase the number of green products and services which are available in the local market. This is extremely important as it is one of the factors taken into account by a construction company to determine if they would opt for green procurement.

Construction companies should also serve as advocates on behalf of green procurement implementation by adopting their own green procurement policy within their organization. Additional training should also be conducted to increase their employee's skillset and to familiarise themselves with green procurement [13].

4 Research Methodology

4.1 Techniques for Data Collection

The methods of collecting data can be categorised into primary source and secondary source [14]. Both primary and secondary data are used for this research in order to achieve the objective of the study and ensure that every aspect of study is covered.

4.2 Primary Data Collection

Primary data is information that is obtained and collected for the first time by the researcher for a specific purpose. Primary data is original in nature and the main purpose of collecting primary data is to address the problem which is related to the problem at hand. There are various sources of collecting primary data such as questionnaire, observations and personal interview. Primary data is often used as it has a high reliability and accuracy of data. In this study, quantitative method was used through questionnaire.

4.3 Secondary Data Collection

Secondary data represents existing information that is already collected by past researchers. It is used to gain insight into the research problem and analyse the information collected from primary data. In this study, secondary source is used in the previous chapter, literature review, where different research materials were being reviewed, for example, case studies, conferences, national guidelines and journals. In this study, journals, which provide information collected by past researches were primarily used as the main secondary source. National guidelines were used mainly to compare how different countries adopt green procurement into their industry and how they can be used in relevance to our case here in Malaysia. Case studies were rarely used.

4.4 Data Analysis Technique

The data analysis method chosen for this survey is the relative importance index (RII) method. The relative importance index which is calculated is then used to rank the factors, challenges and strategies relevant to the research objectives. The RII is calculated using the formula below, where A represents the highest weightage or scale, in this case, 5 and N represents the total sample number. W represents the weightage assigned by each respondent on a scale of 1–5, which corresponds to 5 being strongly agree and 1 being strongly disagree.

$$RII = \frac{\sum w}{AN}$$

This analysis method is used to analyse the data collected from Section B, C and D. The RII values for each component is then ranked according to their order of importance, where the higher the RII value, the higher the importance of the component.

The data obtained to carry out this study by using the questionnaires method. The questionnaire covers the research topic extensively as the series of questions asked are related to the topic. The online questionnaire forms are sent to the respondents, which are those construction companies registered under Construction Industry Development Council (CIDB), using the list given by our university during internship programme using email, by providing a link on google forms [15]. The data collected from 50 participants who have taken part in the survey was analysed through relative importance index method in order to rank the factors, challenges and strategies relevant to the research objectives. The data collection primarily focused in Selangor only.

5 Result and Discussion

5.1 Relative Important Index Analysis of Challenges in Green Procurement Implementation in Malaysia's Construction Industry

Table 1 shows the ranking of the challenges of green procurement implementation in Malaysia after performing RII analysis. Based on the answers given by the 50 respondents in the questionnaires, majority of them choose perception of higher associated costs as the main challenges faced in green procurement implementation. Ranking second and third is the higher costs of green products followed by lack of incentive. Most of the respondents feel that one of the most important challenges in implementing green procurement is due to the fact that the public and the developers perceive there is a higher associated cost that comes with it [9]. This, as explained in the previous chapter on literature review, is due to the fact that they only look at the initial costing, rather than its lifecycle. They are not well aware of the savings that

Table 1 Challenges in green procurement implementation

Challenges	RII	Rank
Lack of incentives	0.840	3
Lack of enforcement of legislation	0.828	4
Ineffective government policies	0.780	5
Lack of client's demand	0.660	9
Lack of educational programmes	0.672	8
Lack of post construction long term management	0.688	7
Lack of availability of green products	0.764	6
Higher costs of green products	0.900	2
Perception of higher associated costs	0.920	1

could be made in the long run through energy efficiency. Some green products do indeed come at a higher cost, which is chosen as the second most common challenge faced in green procurement implementation. This is because some green products are still being imported as the technology is still not available in our country, therefore increasing its costs [11].

The third most common challenge chosen is lack of incentives provided by the government as the incentives available are not enough to compensate the higher initial costing of green products. In short, these three challenges are again correlated as they are linked to a much more economical aspect and it also represents the importance of reduction of initial costing in order to encourage more developers to opt for green procurement, which will again be highlighted in the last analysis on strategies [16].

The least chosen challenge is the lack of client demand. Most of the respondents did not agree with this as one of the challenges in the implementation of green procurement as they felt that the availability of green products and green construction projects plays a much more important role. This is because they felt that when there are more green procured construction projects in the market, the public's attention and interest can be gained and demands can be increased. As such, it is not chosen as the main challenge in green procurement implementation.

5.2 *Relative Important Index Analysis of Strategies in Implementing Green Procurement in Malaysia's Construction Industry*

Table 2 demonstrates the ranking of strategies in implementing green procurement in Malaysia by conducting RII analysis. After analyzing the questionnaires filled in by the respondents, most of the respondents agreed that providing financial incentives is the main strategy in implementing green procurement. This is in accordance to the previous analysis on challenges which has shown that the most important

Table 2 Strategies in implementing green procurement

Strategies	RII	Rank
Strict enforcement of legislations	0.828	4
Establish an advisory body for the government	0.756	7
Set up eco labelling programmes	0.760	6
Provide financial incentives	0.900	1
Incorporation of green procurement in curriculum	0.756	7
Organise campaigns to increase environmental awareness	0.756	7
Increase educational workshops for long term professional development	0.796	5
Expanding Research on Green technology	0.848	3
Increasing promotion efforts on green products	0.868	2

strategy is to reduce costs beared by developers in order to promote green procurement. This is because incentives serve as a motivation for developers to take the risk of taking the alternative to traditional procurement for construction projects. This is due to the fact that when more research is invested in developing green technology in our own country, we can reduce and even eliminate our dependence on imported technology and products which incur a higher cost. Moreover, the availability of reasonably priced green products will be increased and this serves as a vital factor taken into consideration by construction companies on their decision on green procurement implementation in their projects. Strict enforcement of legislations is also an important strategy as it is ranked fourth in the survey. This method puts pressure on the developers to opt for green procurement as they need to follow mandatory requirements for their construction project to avoid legal punishments.

6 Conclusions and Recommendations

The overall this research aims to encourage the implementation of green procurement in the construction industry in Malaysia. This study helps to highlights the challenges faced by the country and also provides a comprehensive outline on effective strategies that should be in place to tackle the problems faced. This research allows effective, evidence-based strategies to be carried out by all relevant stakeholders in our country as it provides them with an understanding of the current situation faced by the country and also reminds them of the importance in green procurement implementation in the construction industry. Developers, contractors, quantity surveyors and also the government will benefit from this research study as they would have an idea on which area or problem to work on first to facilitate the effective implementation of green procurement in the construction industry. Future research studies should be conducted using a much larger sample size representative of the whole population to produce more accurate results. A more thorough research on sample size should first be done before conducting further studies. Moreover, studies on green procurement specifically for construction industry should be increased as the literature regarding the subject is limited. Further studies to evaluate the efficacy of the strategies which are in place to encourage the implementation of green procurement in the construction industry should also be considered. This is important as it allows the government to assess its strategies so that amendments and improvements can be made.

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Evaluation of Mechanical Properties of Eggshell Powder and Palm Kernel Shell Powder as Partial Replacement of Cement

Gunalaan Vasudevan and Navisha Marimuthu

Abstract This study showed the results of experiments evaluating the use of eggshell powder and palm kernel shell powder from egg waste production industry and palm oil waste production as partial replacement for ordinary portland cement. Research on the reuse of waste materials in the concrete industry has been quite intensive in the past decade. The objective of this research is to identify the performance of eggshell powder and palm kernel shell powder as a partial cement replacement in the production of concrete. Eggshell powder and palm kernel shell powder of various amounts, namely 5, 10, 15 and 20% by volume, was added as a replacement for ordinary Portland cement. The results showed that eggshell powder and palm kernel shell powder concrete greatly improved the compressive and flexural strength of concrete. The rate of water absorption of eggshell powder and palm kernel shell powder concrete was reduced as eggshell powder and palm kernel shell powder filled up the existing voids, making it more impermeable. However, the compressive strength of the eggshell powder and palm kernel shell powder concrete decreases gradually when the amount of eggshell powder and palm kernel shell powder increased. It can be concluded that the optimum percentage of eggshell powder and palm kernel shell powder as a partial cement replacement is 15%. In this direction, an experimental investigation of ultrasonic pulse velocity, carbonation test, compressive strength, flexural strength and water absorption was undertaken to use eggshell powder and palm kernel shell powder and admixtures as partial replacement for cement in concrete.

Keywords Eggshell powder · Palm kernel shell powder · Mechanical properties and admixtures

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1 Introduction

Concrete is one of the most widely used creation substances within the international. It is miles a super and key structural cloth in human history. Man consumes no fabric besides for water in such brilliant quantities [1]. Concrete is effortlessly available, fairly cheap, strong and durable. Concrete is one of the oldest and maximum widely used construction substances within the global. Cement production is a critical a part of the economic system of most cement generating international locations the world over. The manufacturing of Ordinary Portland Cement (OPC) no longer most effective consumes limestone, clay, coal and electricity however additionally releases waste gases inclusive of carbon dioxide (CO_2) which can make a contribution to the greenhouse effect. Consequently, a sustainable development approach need to be devised for cement production and the benefits of the usage of diverse wastes or via-products in concrete must be sought. Such method has a crucial aim that can be accomplished through complete utilization of business waste or by means of merchandise as opportunity cementing materials in concrete [2]. Concrete been used broadly in production enterprise and additionally referred to as one of the maximum materials used in creation. The combustion manner in producing cement contributes to emission of CO_2 which contributes to fundamental greenhouse fuel. Other than that, it does make contributions to climate changes inclusive of rising sea ranges, rising temperatures, warmness associated health problems, storms and wooded area fires which influences the integrity of the earth. Therefore, a necessity to provide you with an alternative fabric to replace concrete utilization in creation enterprise [3]. The trouble that is related to eggshell waste is the big quantity of waste produced each single day. Accordingly, large hassle of pollution is generated as well as it can entice rats and worms due the natural protein matrix, resulting in a trouble of public health. Subsequent, the problem with oil palm cultivation is, the biomass waste generated after harvesting the oil palm fruits, palm kernel shell or palm oil processing. Each the eggshell and oil palm through products this is made into ash disposed to open subject wherein it is able to be used as fertilizers because of its much less nutrient price. Consequently, research has a look at approximately use of a waste cloth as an alternative cement and aggregates is vital to behaviour as recycling eggshells and palm kernel shell into the beneficial product gives proper potential advantage on many degrees, each for food manufacturers and a far wider construction industry. This research will recognition on the utilization of eggshell powder and palm kernel shell powder in the concrete manufacturing due to the concrete as a chief building cloth [4].

2 Literature Review

The research at the reuse of waste materials within the concrete enterprise has been pretty extensive in the past decade. Alternatively, the objective of this studies is to perceive the performance of eggshell powder as a partial cement alternative inside the production of concrete beneath each water-cured and air-cured regimes. Eggshell powder of numerous amounts, specifically 5, 10, 15 and 20% with the aid of quantity, became brought as a substitute for regular Portland cement [5]. The charge of water absorption of eggshell concrete became reduced by means of about 50%, as eggshell powder filled up the existing voids, making it more impermeable. but, the compressive strength of the eggshell concrete decreases regularly while the amount of eggshell powder multiplied, all through immersion in acid and alkali answers, because eggshell includes a high amount of calcium, which reacts readily with acid and alkali solutions. As the eggshell content material will increase. The use palm kernel shell powder as an alternative to the convention cementious material. The research on the use of industrial waste materials such as palm kernel shell powder from palm production is envisaged. Consequently, the quest for alternative cheaper materials and utilization of industrial waste and by-product materials in infrastructure development is proven economically viable when environmental factors are considered and these materials meet appropriate performance specifications and standards. Consequently, the production of palm oil result on waste by products such as palm kernel shell powder, Palm Kernel Fiber (PKF), Palm Oil Mill Effluent (POME) and Empty Fruits Bunches (EFB) [6]. The objectives of this observe are to conceptually design and economically examine a whole bioethanol plant using electrolyzed-reduced water because the pre-remedy approach [7]. To achieve the first objective, a complete model of the bioethanol manufacturing plant is developed using a procedure simulator on the premise of an experimental look at in a pilot plant.

3 Result and Discussion

3.1 Sieve Analysis

Sieve analysis show in Fig. 1, also known as gradation test, is the distribution of particle sizes expressed as a percent of the total dry weight. Gradation is determined by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom and weighing the material retained on each sieve. Hence the gradation determines the compliance with the design, production control requirements and verification specifications.

3.2 Compressive Strength Test

Based on the result shown in Fig. 2, the compressive strength of eggshell powder and palm kernel shell powder increasing due to the days of curing and also the right amount of by product materials replaced by percentages. The controlled mix without

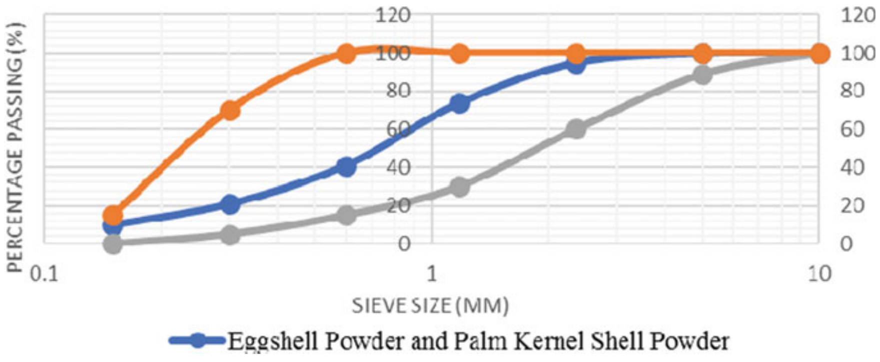

Fig. 1 Grading curve of eggshell and palm kernel shell powder

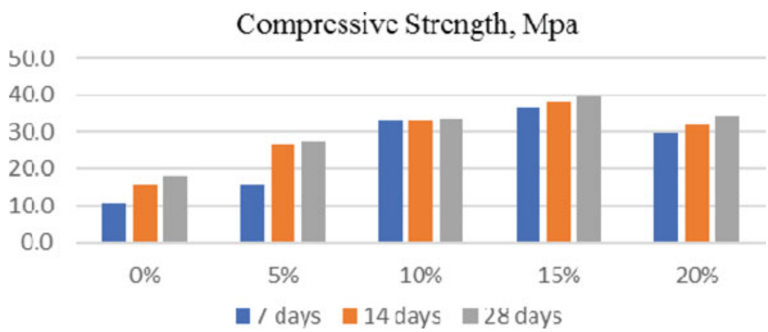

Fig. 2 Compressive strength test

the eggshell powder and palm kernel shell powder is achieving the compressive strength of 18.0 at the age of 28th days and increasing compared to the controlled mix on the 7th day of curing [8]. Besides, the results have proved 15% replacement of eggshell powder and palm kernel shell powder has achieved the highest strength at 36.6, 38.0 and 39.3 Mpa for the days of 7, 14 and 28 day comparing to other percentages and ages of the test. To summarise, 15% replacement of eggshell powder and palm kernel shell powder had achieved the highest compressive strength compared to other percentages of replacement of eggshell powder and palm kernel shell powder which is due to the strength of the by-product material.

3.3 Ultrasonic Pulse Velocity (UPV)

Based on the Fig. 3, at the age of 7th day of curing, 15% replacement of eggshell powder and palm kernel shell powder were achieving the highest ultrasonic pulse

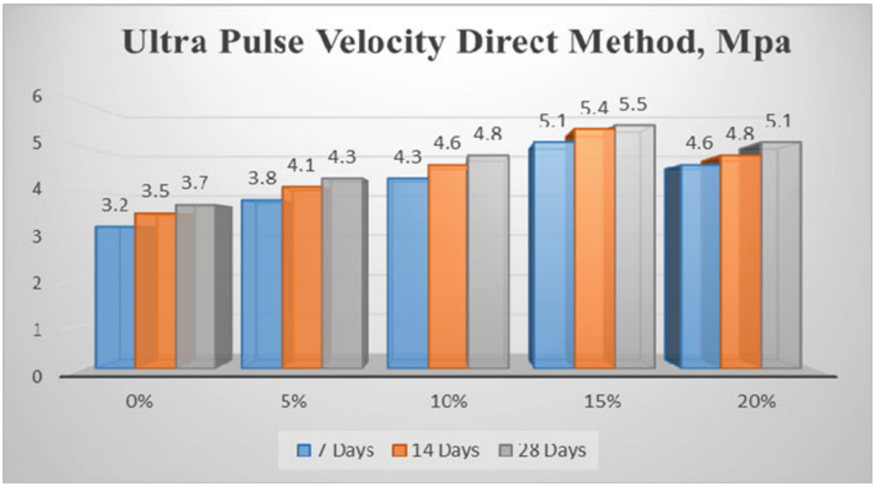

Fig. 3 Ultra pulse velocity test

velocity value in direct test which is 5.1 km^{-1} compared to other percentages replacement of eggshell powder and palm kernel shell powder on 7th day. There is a drastic change of value increase from 0% until 15% and a value drop at 20% replacement of eggshell powder and palm kernel shell powder [8]. However, on 14th day, 20% replacement of eggshell powder and palm kernel shell powder still drops and but somehow the value is still higher than 7th day 20% replacement. At the 28th day, the test has achieved the best value in direct test of UPV due to the philosophy the longer the curing time, the more quality the concrete is. In a nutshell, 15% replacement of eggshell powder and palm kernel shell powder of 28th days has the best value compared to other percentage of replacement.

3.4 Flexural Strength Test

The values of flexural strength of the all test specimens are shown in Fig. 4 which presents the change in flexural strength due to the addition of eggshell powder and palm kernel shell powder in the sample concrete. The flexural strength of the samples increased with curing time but decreases with an increase in eggshell powder and palm kernel shell powder replacement beyond 15%. When eggshell powder and palm kernel shell powder is ground to a reasonably high fineness, the rate of flexural strength gain of the samples were significantly improved due to the hydration reaction, nucleation effect, packing effect and pozzolanic reaction. These results conclude that eggshell powder and palm kernel shell powder with high fineness can be used as a good pozzolanic in cement-based materials and can be used to replace OPC up to 15%.

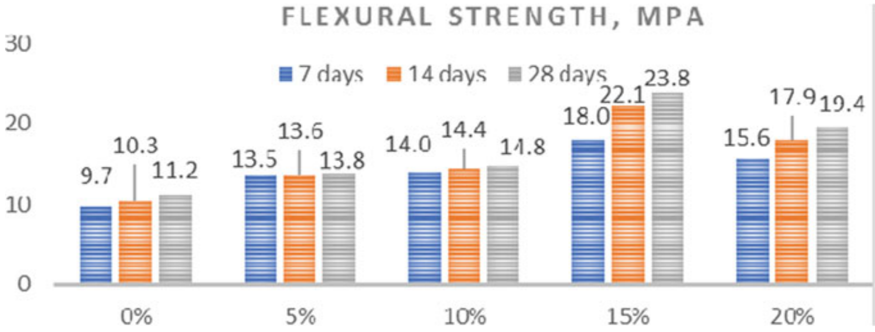

Fig. 4 Flexural strength test

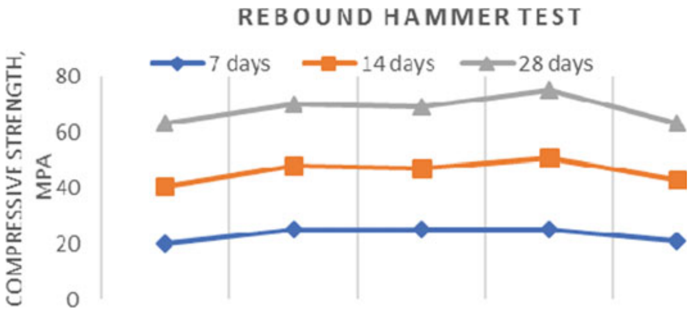

Fig. 5 Rebound hammer test

3.5 Rebound Hammer Concrete Test

According to Fig. 5 rebound hammer test the best result at the 15% of replacement. Results indicate that the trend of the rebound hammer results in high performance concrete with eggshell powder and palm kernel shell powder is similar to the trend of compressive strength. It is found that the trend in rebound hammer values shows an increase with increasing compressive strength for all the mixtures. In other words, an increase in rebound is accompanied by an increase in the compressive strength [8].

3.6 Microstructures of Palm Kernel Shell Powder

Scanning Electron Microscope (SEM) test was conducted on the control mix sample and on the 15% eggshell powder and palm kernel shell powder, 28 days cured sample. Adding eggshell powder and palm kernel shell powder to the concrete had provided additional calcium oxide which is an important component in producing secondary

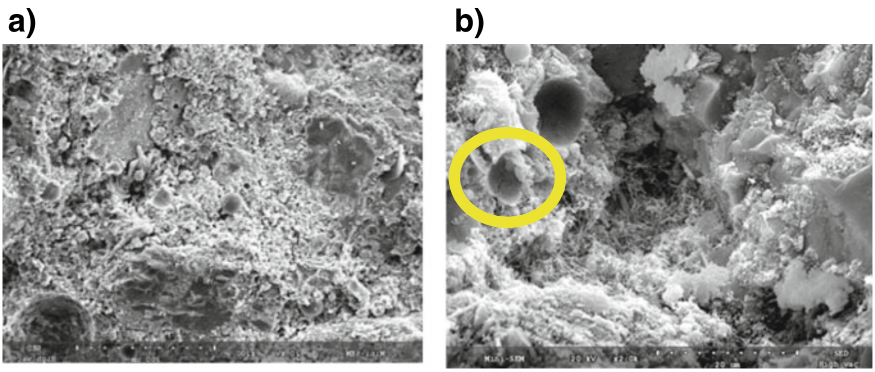

Fig. 6 **a** SEM images of control mix. **b** SEM images of Palm Kernel Shell Powder and Eggshell Powder

calcium-silicate-hydrate (C–S–H) gel. It is found that by adding eggshell powder and palm kernel shell powder into the sample, small pores are formed in the structure and C–S–H covers almost the entire fractured surface [9]. The majority large spaces were filled with C–S–H gel because of the increased pozzolanic reactivity and hydration rate thus creating a denser structure compared to the controlled sample. With increasing curing time, production of $Ca(OH)_2$ decreases leading to an increased formation of C–S–H. Hence, eggshell powder and palm kernel shell powder can still be used as a partial replacement for cement without affecting the water absorption rate (Fig. 6).

3.7 FTIR Spectra and TGA Analysis

Based on the results from Fig. 7a IR spectra palm kernel shell powder and eggshell powder were determined by transform infrared (FTIR) spectrometry of untreated and treated palm kernel shell powder and eggshell powder respectively. The presence of characteristic band of –O–N=N– group at 1401.2 cm^{-1} and C–O stretching at the region of 1300–1000 cm^{-1}. Figure 7b shows result from TGA showed that there were two stages of weight losses. For the first stage, minor weight loss occurred at temperature below 200–400 °C attributed to water molecules to the surface of the material and loss of organic compound.

3.8 Carbonation Test

Carbonation is a consequence of the transformation of calcium hydro-oxide [$Ca(OH)_2$] to calcium carbonate [$CaCO_3$] altering the microstructure of the cement

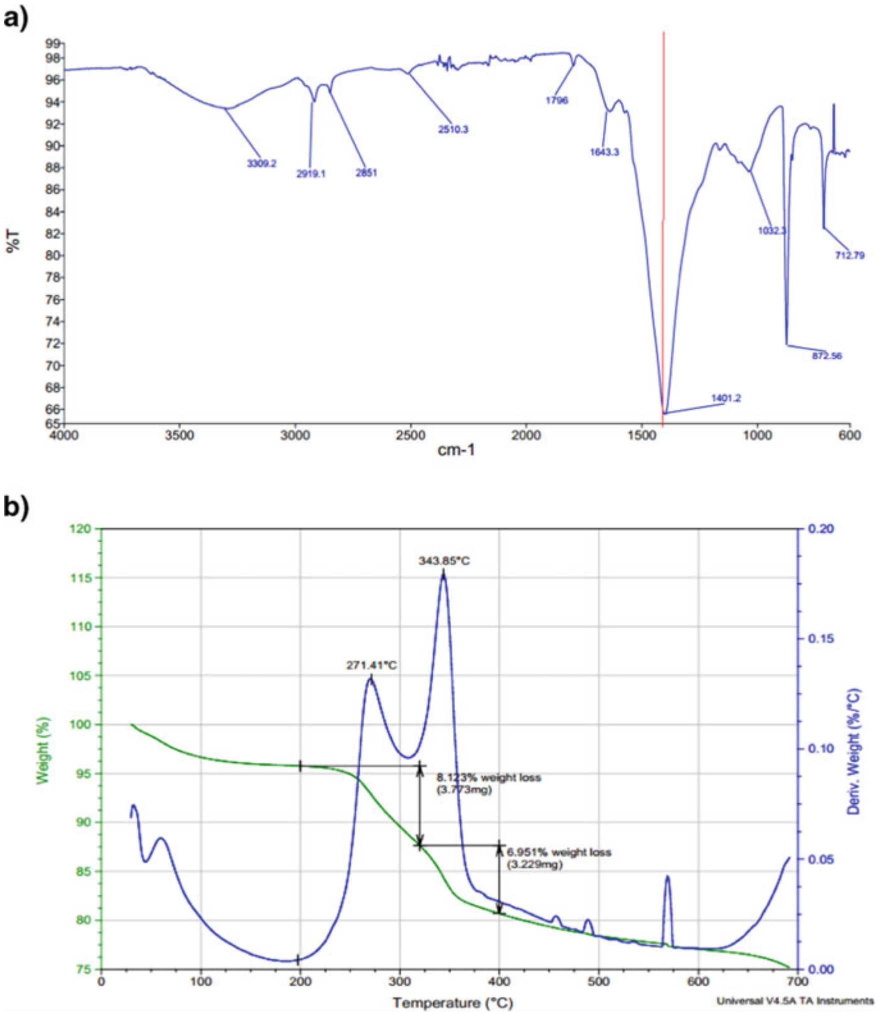

Fig. 7 **a** FTIR spectra for raw Palm Kernel Shell Powder and eggshell powder. **b** TGA analysis for Palm Kernel Shell Powder and eggshell powder

paste by decreasing porosity. Samples subjected to about 50% relative humidity (RH) and about 5% CO_2 for 28 days can cause the pore voids being filled and also likely for C–S–H attack which is what defects reinforcements. Oxygen and moisture are the components required for corrosion of reinforcement steel. Thru this test, the depth of carbonation is determined. The test is carried out by spraying Phenolphthalein indicator on freshly exposed surface of concrete sample. Carbonation depth is accessed when the indicator turns pink in contact with alkaline in sample with pH value greater than 9. At lower lever pH, the indicator is colourless as the sample is carbonated and the protective layer gets destroyed exposing the reinforcement

Fig. 8 Concrete cube with carbonation test

to corrosion. With enhanced dispersion and filler effect, the sample shows a fairly low carbonation which indicates that eggshell powder and palm kernel shell powder can serve as a favourable pozzolanic material to replace OPC in producing a low carbonation depth and high strength mortar (Fig. 8).

4 Conclusions and Recommendations

This part The overall objective of the work was to investigate the feasibility of palm kernel shell powder and eggshell powder as a partial replacement pf cement to concrete mix. This study included the preparation of concrete mixes containing and the evaluation of palm kernel shell powder and eggshell powder concrete properties in fresh and hardened states. The studying properties involved mix workability, compressive strength and flexural strength. According to experimental results, the usage of in palm kernel shell powder and eggshell powder concrete mixes as an alternative of disposal for palm kernel shell powder and eggshell powder is possible. The current type of palm kernel shell powder and eggshell powder accumulated in dumping sites and the expected future type were used in making concrete mixes [10]. The influence of both types on concrete properties was studied. The study showed that the palm kernel shell powder and eggshell powder can be used in production of cement without changing the normal industrial process. Recommendation for further research The following recommendations are proposed for further research and study in order to from a complete picture of using palm kernel shell powder and eggshell powder in concrete mixes:

(1) Investigation is needed on the different admixture used together with palm kernel shell powder and eggshell powder in the concrete mix design.

(2) Study is required for palm kernel shell powder and eggshell powder mix with other by-products in the concrete mix design.
(3) Further investigation of the higher percentage of replacement of the cement by the palm kernel shell powder and eggshell powder in concrete mix design.
(4) Longer curing time is required in order to understand the behaviour of the concrete, and it might be giving the different result for palm kernel shell powder and eggshell powder concrete.
(5) Durability test such as sulphate attack test must be further study in order to understand percentage loss in weight of the palm kernel shell powder and eggshell powder concrete by sulphate attack.

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Safety Management Model During Construction Focusing on Building Information Modeling (BIM)

Bilal Manzoor and Idris Othman

Abstract In construction industry there has not been a significant decrease in number of fatality rates, injuries and death rates in construction site despite of the efforts made by safety experts and government officials. Some of the factors which are playing a vital roles are inappropriate work planning, ineffective way of communication between workers and supervisors and poor safety planning. Construction industry is one of the most hazardous industry around the globe because of its nature of work and environment. The aim of this research is to highlight the factors that are responsible for causes of accidents in construction projects and to elaborate the visualization technology in construction safety management. Furthermore, the research design and methodology will also presented which will serve as a guidance to the construction safety model. The project results will help in creating a platform for safety management model in order to improve the safety performances and to help in reduction in accidents in construction sites.

Keywords Construction safety management · Building information modeling · Visualization technology

1 Introduction

Safety has one of the main importance in the construction industry. The statistics of safety in construction industry shows high rate of casualty, illness and injuries around the globe. In construction industry, the large amount of development has taken place in the period of ten years but the safety reports in the construction industry remain the poorest [1]. Safety management is part of the construction management process but is typically carried out to a certain extent separately from other project

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planning and control tasks [2]. In construction sector, the highest number of accidents occurred having an alarming situation. In working construction site, 60,000 workers died ever year. Due to these accidents not only financial losses but also threaten for many lives. In order to have a better safety in working sites the building information modeling (BIM) with safer design and work statement method was introduced [4]. It is because of the Building Information Modeling (BIM), the contractors investigate the conditions in site area and also highlights the hazards [3]. Furthermore, due to lack of identify the hazards in working site can cause a serious accidents. Because of this, a safety culture through observing of safety rules and regulations are very important. Moreover, BIM can help the effectiveness of construction projects in many ways to enhance the construction safety performances. The process of BIM is faster and effective one in order to share the information among the construction workers. The real-time early warnings can be detected with the application of BIM. Furthermore, with the help of GPS, the position of construction workers can easily assessed. Therefore, BIM technology can facilitate in developing this approach [5].

2 Construction Safety Management Using Concept of BIM

Basically construction safety management is a process to control safety polices, practices and procedures on construction sites [6, 7]. Whereas the concept of Building Information Modeling (BIM) was first of all presented by Professor Charles M. Eastman since 1970 [8]. First country to implement BIM in their construction process is US [9]. Furthermore, in United Kingdom (UK), Denmark, Finland, Australia and Hong Kong, the BIM technology has been used in many projects [10]. While in 2007 the concept of BIM technology was inserted by public work department (PWD) in Malaysia [8]. With the implementation and application of BIM technologies, the safety management in construction activities can be monitored effectively. As a result there were many significant outcomes that were measured like construction cost decreased, lessen the design issues in planning phases and also the awareness of government. In addition, it has also been seen that BIM as a jointly action among architects, engineers, project managers and contractors [11].

The goal of the construction industry is not only to produce high standard buildings but also focus on safer environments in construction areas due to the fact that safety and quality are two important parameters of construction projects [9]. The safety is very important element on construction areas and safety of workers can never be neglected, because accidents happen on construction areas cause serious problems like human injuries, low morale of construction workers, the construction activities are disturbed, the progress of the project is delayed, the construction cost of the project is affected [12]. Identification of safety risks are done with the help of BIM as well as preparation of construction works and to complete the working tasks in well-organized manner. Furthermore, the ease of communication between different team members is done with the application of BIM in design and in construction stages [13].

3 Causes of Accidents in Construction Industry and BIM

Accidents can happened if there is no planning, controlling and monitoring effectively [14, 15]. Normally the accidents which lead towards the injuries or casualties gain more attention of people [16]. An accident which is happened in construction sites, it does not mean that it is related particular to injury or casualty but sometimes it lead towards to the destruction of construction tools and materials in construction sites. The 99% of accidents which are happened in construction sites are due to unsafe acts or unsafe conditions in working area [17]. There are the precautions that should be taken in order to avoid the future accidents [18].

The accidents in the construction industry of USA are classified into two main factors, which are human and physical factors [19]. The causes of accidents are the poor safety awareness from top leaders, lack of training, lack of organizational commitment, lack of technical guidance, uncontrolled operation, unwillingness to input resources for safety, lack of certified skill labor, unsafe equipment, lack of first aid measures, lack of rigorous enforcement of safety regulation, lack of personal protective equipment (PPE), lack of protection in material transportation and storage, lack of teamwork spirits, shortage of safety management manual, lack of innovative technology and poor information flow [20]. The accidents which are happened in construction sites are due to drinking of alcohol or taking drugs which may affect the power of decision and due to this they are not doing good in working environment and lead towards the wrong decision making [21]. The alcohols and drugs addiction are the main reason of many accidents [22]. The health of the workers were badly affected by an unhealthy environment. With the involvement of occupational risks, it decreases the worker satisfaction, motivation to do work and performances [23]. Within all industries, the construction industry has the maximum cases of accidents, and in terms of injuries it is considered as the most serious accidental site [24]. Around the globe, in construction industry, approximately 108,000 workers are killed in working construction sites which shows about 30% of all working place accidents [25]. In USA, approximately 21.1% of accidents happen in construction industry which leads towards the death [26, 27]. Whereas, in Singapore about 29% is working force in construction sector and 40% of accidents happened in working construction sites [28]. Similarly, the risks related to other construction industry are three to six times higher than that of other industries [29]. The accidents in the construction industry not only cause of worker's death but also affect the life cycle of projects. Because of this the safety is considered as a peak attention by policy makers, academics and practitioners. Furthermore, the high risk works are involved in construction industry [30, 31]. The visualization technology in construction industry is advanced now a days and their applications are increased, but their adoption in construction industry is not much influence as compared to other industries. Safety risks identification helps safety manger, site supervisor and construction officer in safety planning of construction projects [32, 33]. Visualization is the most important feature of BIM. In construction projects, there are many benefits of using BIM-based visualization. With the help of visualization technology, the solid platform can be provided for effective safety training. In order to help the construction workers, the safety related information is combined with visualization to maintain the coordination among the workers. The virtual 3D site modelling was proposed and it illustrated the real site conditions such as materials, workforce and temporary facility. With the help of this model the safety plan related to building construction was prepared. For operation and maintenance of the construction works the application of AR (Augmented Reality) was introduced, that helps the workers to identify the work condition as well as to know about the location of the job [34].

4 Research Methodology

The research aim is to develop a model for safety management during construction with the help of BIM. To achieve this aim, objectives are:

1. To analyze and rank the BIM safety factors influential accidents in construction projects
2. To develop a model for safety management during construction phase using BIM.
3. To validate the model by site safety experts in construction industry.

To achieve the above mentioned objectives the literature review, questionnaire survey, and real case study will be carried out. The detailed research methodology is shown in Fig. 1.

1. Literature Review: To define and redefine the research outline a detailed literature review will be carried out; for example adoption of BIM in safety management, highlight the benefits and barriers. The review will cover academic, industrial, journal papers and websites.
2. Questionnaire Survey: Based on the detailed literature review a questionnaire survey will be developed in order to investigate the adoption of BIM in safety management. For this purpose a questionnaire survey will target such as, 300 safety experts, safety supervisors, safety professionals and safety officers). The above results and safety management model will be validated by the safety experts and professionals.
3. Real Case Study and Validation: From the above results gained from questionnaire survey, there will be validation of model through safety and BIM experts. For this purpose, five case studies related to the safety and BIM will be carried out.

5 Conclusion

Although there is a much more advancement in technologies, however the causalities and injuries rate in construction industry remains same. This is because of the fact

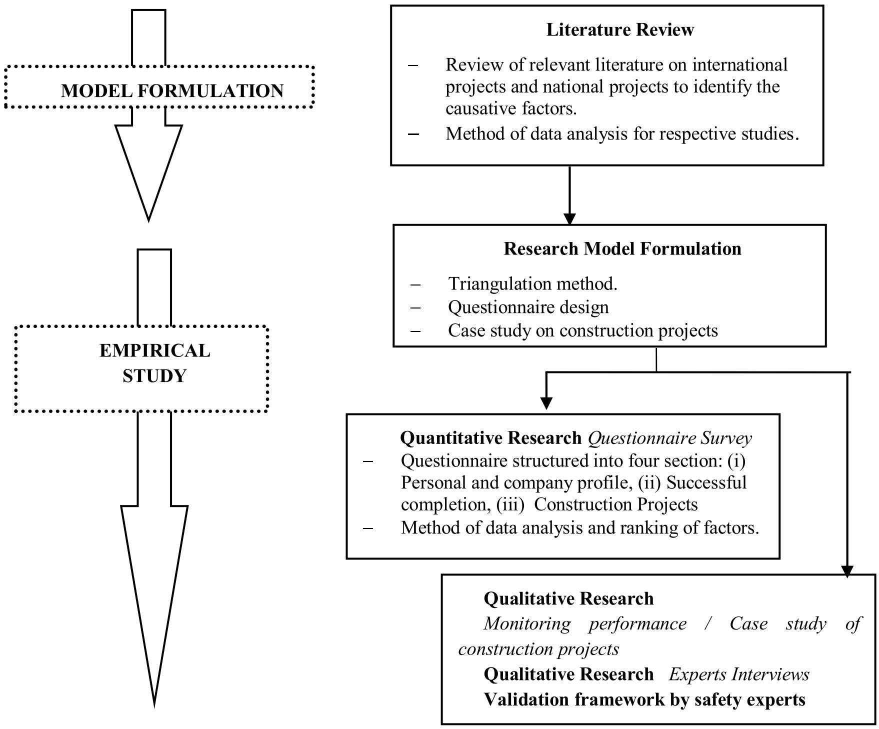

Fig. 1 Research design process

that to identify the safety risks in pre-construction phase is a difficult task for contractors. This research outlined a model development for construction safety in order to reduce the accidents in construction sites as well as to control the safety measures in the working area. The highest moderately awareness level of BIM implementation was found to be in Melaka with 39% then Kedah and Sabah with 21% and 28% respectively. It is anticipated that with the help of implementation of BIM and its application can help to make the construction projects safer. The contribution of this research can help the owners and stakeholders to conduct the construction activities during construction more effectively.

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The Influence of Wind Effects on Street Canyon Width at the Pedestrian Level in Iraq

Ali Hussein Khan, Siti Sarah Herman, and Mohamad Fakri Zaky Jaafar

Abstract High-rise buildings and other low-level buildings influence on the pedestrian-level wind (PLW) environment quality especially in street width, wind velocity, and wind direction. The study investigates the design that creating different street width dimensions based on the analysis of the wind conditions. The wind around buildings may create uncomfortable zones and dangerous problems in cities and would lead to the inconvenience to the occupants of high or low buildings. In spite of large numbers of on-going and previous research, the results of scientific research haven't yet been quite enough on residential projects in the hot-dry climate of Iraq. The airflow around two or more buildings it is even more complicated than individual buildings, a recirculating wind flow will happen in the street canyon through the buildings. As well, wind characteristics will be formed the disturbance level to the occupants of pedestrian regions. This paper takes the residential building as a case study in Najaf-Iraq and applies quantitative methods to enhance pedestrian-level wind on street canyon through using Computational Fluid Dynamics (CFD) simulation analysis. The results of this study revealed that the effects of building height to street width aspect ratios (H/W) on the pedestrian-level wind and presented the comfortable zone between the residential buildings in Iraq.

Keywords Pedestrian level wind (PLW) · Wind velocity · Computational fluid dynamics (CFD) · Residential buildings in Iraq

1 Introduction

The environment of pedestrian-level wind has a significant effect on the nature of urban occupant's daily life in urban areas. It plays also an important role in the efficiency of natural ventilation, the dispersal of traffic-related wind, pollutants around buildings, and thermal comfort of pedestrians. The presence of the building may alter urban regional wind conditions. Furthermore, the wind comfort standard, the

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long-term statistical wind data and the pedestrian wind speed are quite essential for PLW studies [1]. These standards often contain a threshold comfortable and wind velocity a most permissible acceptance likelihood for different pedestrian performances. Various comparisons of diversity wind comfort standard curried out, and the great variation has been revealed that exists between various criteria by these comparisons, for instance the ones showed in [2–4]. Ali and Mayer [5] investigated thermal comfort environment in the street canyons of an dry climate on the radiant environment with emphasizing on the effects of aspect ratio and orientation (height to width ratio, H/W). While, Yuan and Ng tested architectural design alternatives with regard to wind scope at PLW, based on a case study in Hong Kong and computational fluid dynamic simulations [6]. Al-Hussieni [7] investigated the wind energy possible from 2004 to 2008 in Basra-Iraq. So as to show the wind energy potential, where wind velocity measurements were utilized of five years' for this city by the statistical data. The Weibull distribution method has been evaluated to assess wind characteristics behind the meteorological information. The data was also specified that the numerical values of the scale parameters for Basra varied via large zone. Whereas another study, Alobaydi showed his study of the central region for Karbala–Iraq. Two simulated samples have utilized to examine the wind flow velocity and behavior for both the new and old urban structures while the other two samples applied to assess the local average of air age. The results of analysis models have compared to determine the variation of dynamic wind flow circulations before or after the alterations in the urban buildings [8].

In Iraqi residential buildings require to sustainable environment as well as it should be promoted towards wind effects so as to be eligible to supply optimal thermal wind comfort in urban zones. Ali et al. showed empirical data that may work as beneficial basis for the planning of future urban regions [9].

2 Street Canyon Width

Depending on time and climate, air motion in streets can be eligible in streets of hot climates to dismiss surplus heat from the roads and cool people; it also becomes a possible resource to cool constructions by cross-ventilation. This is significant especially at night in arid climates and all the time in humid climates. Furthermore, wind maximizes infiltration heat losses of buildings and minimizes pedestrian comfort in cool seasons [10].

The method of an outdoor wind flow is usually guided or blocked via high-rise constructions and formed complex air flow patterns that are interactively affected by many factors until it flows out at a street corner after moved toward a street canyon. The wind speed inside the street canyon will be increased and then cause an immediate intense wind that is an annoyance due to the channeling effect inside the street canyon. The wind flow characteristics are influenced by the approaching width of the street canyon, and the buildings heights inside the street canyon [11]. Tsang et al. investigated the consequence of various building dimensions, and spacing arrangements on PLW about buildings. The result of study also revealed that a wider street width can effectively enhance the PLW intense wind in street canyon width [12]. Moon, et al. utilized computational fluid dynamic simulations to examine the flow feature of the complex urban street canyon thru high rise buildings. Their outcomes presented that wind directions take control the flow characteristics in the street canyons width. This happen when winds blow up perpendicular or obliquely to the street canyon. When winds blow parallel to the street canyon, jet-like flows are found between tall buildings along the street canyon, which that mean velocity is maintained in the street canyon at a moderate level [13]. Kuo et al. conducted inside the street canyon for the pedestrian-level wind flow characteristics. Also, the researcher has explored in many places the wind speed measurements, including downstream of the street canyon, inside the street canyon, and the front of the street canyon, to quite understand the flow around the two adjacent buildings. And it spotted the change heights of building inside the street canyon has greatly affected in the wind flow [11]. Pancholy study recommended the total wind speed inside the street canyon close to the downwind building up to the middle of the road increases with expansion in the street width. It spotted also from this study that, with a raise in the building width the wind velocity also has raised inside the canyon void. In the case of W/H = 3, roughly 75% are inside the canyon cavity can be seen to be in the disadvantageous zone for pedestrians. However, for the condition of W/H = 4 and 5, the region of discomfort has been decreased relatively [14].

The major aim in this paper is the effect of airflow on different street width dimensions based on the analysis of the wind conditions on pedestrian level wind under hot dry climate conditions. In spite of large numbers of ongoing and previous research, the research gap in this study is a lack of researches and the results of scientific research haven't yet been quite enough on residential projects in hot-dry climate of Iraq. The air flow around an two or more buildings it is even more complicated than individual buildings, a recirculating wind flow will happen in the street canyon through the buildings. As well, wind characteristics will be form the disturbance level to the occupants of pedestrian regions.

3 Research Methodology

This study reveals to manage the present practices of wind flow in Iraqi buildings. Thus, the paper will present research methods that includes case study research and qualitative methods through using computational fluid dynamic (CFD) simulations. The data can be also quantified and subjected to statistical treatment through quantitative research that contains the data collection [15, 16]. Furthermore, the researches majority has proceed with wind tunnel modeling in the past, as well; wind tunnel experiment is utilized to study the outdoor wind climate. But wind tunnel experiment has some drawbacks for practical application. They are complicated and costly to design with errors composite. On the other hand, CFD simulation became as a major tool and has applied in many researchers [17]. Moreover, CFD simulation can prevent several of the problems and will be an effective tool. CFD simulation plays an important role to enhance the designs of buildings. The paper revealed some cases relating wind-flow enhancement with CFD simulations, and provided some concepts to building suitable conditions. Generally, it assists engineering's and architects to improve designs and re-form their works manner which is considered appropriate for environment. Additionally, CFD methods have utilized to study wind-flow between the buildings. Where W. D. Janssen carried out CFD simulation at PLW for the Eindhoven University campus and set a various comparisons for wind comfort criterions [4]. Zheng, et al. studied the effect of building shape, separation, and orientation on PLW effects [18]. On contrary, some studies carried out CFD simulation and wind tunnel of PLW conditions on outdoor zones of high buildings [19]. The study determined Autodesk©2018 CFD simulation software to analyze the street canyon width on wind-flow among the buildings and used the κ-ε turbulence model. The study will be applied in the Najaf city of Iraq as a case study; as well the environment will be dry hot climate in summer season through all the processes.

3.1 Study Area

The dry hot climate is prevailing in all Iraq cities including Al-Najaf city. Further, the case study will be executed in Al Salam Residential Complex. Al-Najaf city is situated south of Baghdad and it is far about 160 km [20], as shown in (Fig. 1). Al Salam Residential Complex is located in the northern part of the city of Najaf-Iraq.

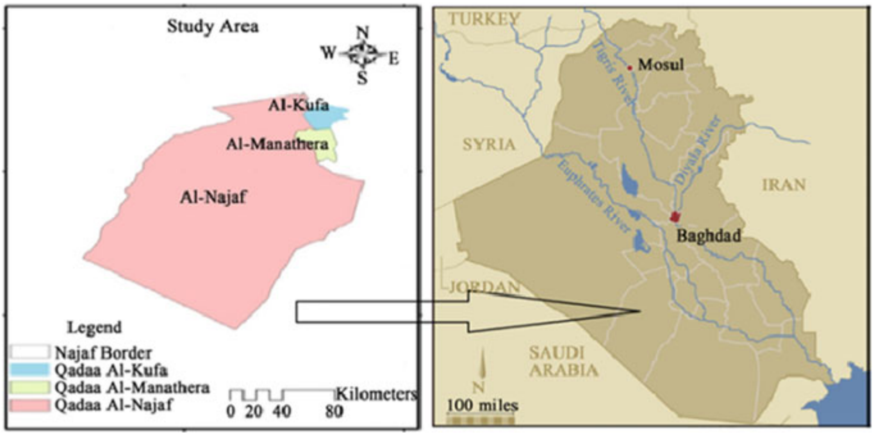

Fig. 1 Regional boundaries of Najaf city-Iraq [21]

3.2 Data Collection

The data obtained from Al-Najaf meteorological organization that includes the records of weather. Iraqi urban planning ministry provided the plans and all elevations that required in research operation. The data collection will be analyzed and designed various cases in that area to conclude the optimal results. The investigations could supply various results for the case study at the end of the research via utilizing computer applications, for instance 3d max software to design the shapes and using Autodesk©2018 CFD simulation to analyze the inputs.

3.3 Analysis Scope for Street Canyon Width Based on CFD Simulations

According to Najaf Meteorological Organization in 2019, the average annual rate of wind speed is 2.2 m/s, it set for the outdoor wind environment for the process of simulation. As well, the wind prevalent is North-West winds. Thus, the power and direction wind in Najaf were considered as well the wind pressure during the simulation. In this paper, the study is carried out to the streets width and the density of the buildings of the two models and compares them to all tendencies and chooses the model that achieves the optimal guidance, as well as the optimal distance between the elements. To conduct this study, two models were developed and placed within a group of buildings to be the ratio of building height to street width (H/W) is as follows:

1. The building height 1.5 = time street width or H/W = 1.5
2. The building height = street width or H/W = 1.0
3. The building height = half street width or H/W = 0.5

According the prevailing wind in Iraq summer, each of these models have two cases as shown (Figs. 2 and 3) tested with wind path from the northwest corner towards the southeast corner of the site. Generally, this study will show a complete of several various choices to get optimal result.

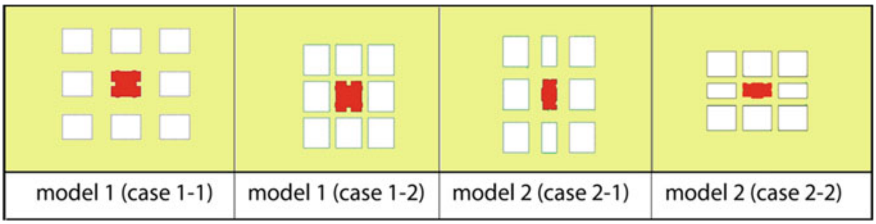

Fig. 2 The density of adjacency buildings and streets width

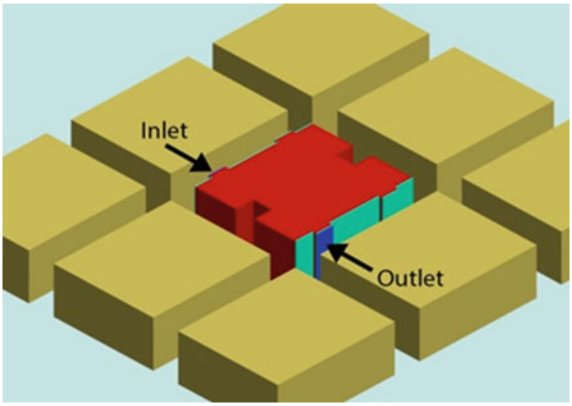

Fig. 3 The inlet and outlet walls which selected in the target building

4 Results and Discussion

The wind velocity will create a convenient feel for the persons if the wind speed is around the buildings with appropriate range at the PLW. For human body, there is a special sensation ranges which it will differ through wind speed. Generally, the acceptable velocity is between the range of 1–3.8 m/s as shown in Table 1, as well it may be considered to be the most satisfied comfort for the buildings occupants and physical environment [22].

The simulation was done for two different directions from the first model, and two directions from the second model. Then extract the following data: 1—the average of wind speed in front of and behind the building to determine the thermal comfort external to the pedestrian, 2—the static pressure difference between the front and back wall (Inlet and Outlet)—as shown in the (Fig. 3).

Table 1 Land Beaufort's standard which shows wind influence on humans [4, 23, 24]

Beaufort number	Description	Wind speed at 1.75 m height (m/s)	Effect
0	Calm	0.0–0.1	
1	Light air	0.2–1.0	No noticeable wind
2	Light breeze	1.1–2.3	Wind felt on face
3	Gentle breeze	2.4–3.8	Hair disturbed, clothing flaps, newspaper difficult to read
4	Moderate breeze	3.9–5.5	Raises dust and loose paper, hair disarranged
5	Fresh breeze	5.6–7.5	Force of wind felt on body, danger of stumbling when entering a windy zone

4.1 Simulation Results for Model 1

The main difference in static pressure between building facades was in case (1–2) as shown in Table 2. While the lowest value of the pressure difference between the facades was in case (1–1) A. In all cases, the pressure groups increase with the increase in street widths and distances between the buildings as shown in the (Fig. 4).

Wind pressure performs play fundamental role in the pedestrian level wind environment in an outdoor zones. In case 1–1 and case 1–2 show the wind speed effects

Table 2 (Case 1–1—Case 1–2) pressure differences [Pa(ΔP)] between the north and south facade of the building

Case 1–1				Case 1–2			
Status	Type	Pressure difference	Results	Status	Type	Pressure difference	Results
Status 1	A	ΔP	0.94525	Status 1	A	ΔP	0.991255
Status 2	B	ΔP	1.240713	Status 2	B	ΔP	1.497001
Status 3	C	ΔP	1.780904	Status 3	C	ΔP	2.171527

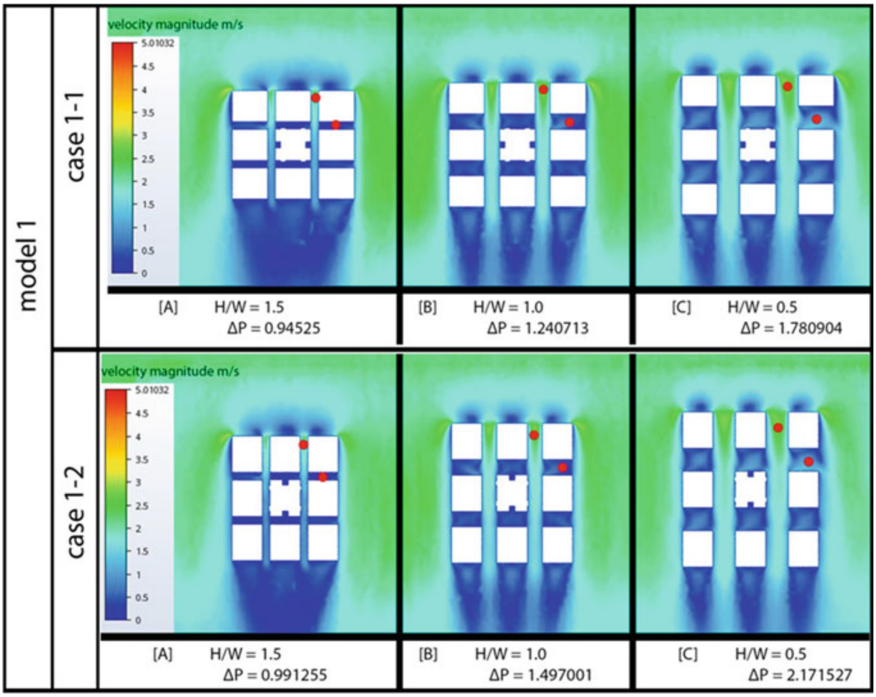

Fig. 4 Case 1–1 and Case 1–2 pressure difference [Pa(ΔP)] between the north and south facade of the building

around the buildings selected two points at 1.5 m height from the earth. As it is determined in two figures through the points, the wind velocity in open up- space is lower 0.4 m/s in some area when H/W = 1.5 and the winds velocity arrive to the maximum of 2.5 m/s in another areas. While. In addition, in both of cases the wind velocity has escalated from 0.4 to 1.1 m/s in stagnant areas when H/W = 0.5 which the width of canyon is equal tow times the height.

4.2 Simulation Results for Model 2

As shown in (Fig. 5), the pressure on the walls was monitored for all cases and the average static pressure was higher in case (2–2) B.

Also, it is noted from Table 3 that pressure on the front wall is the highest in both cases, while the lowest on the back wall so it will take into consideration the difference between walls as the maximum pressure difference between the wall facing the wind and non-facing the wind.

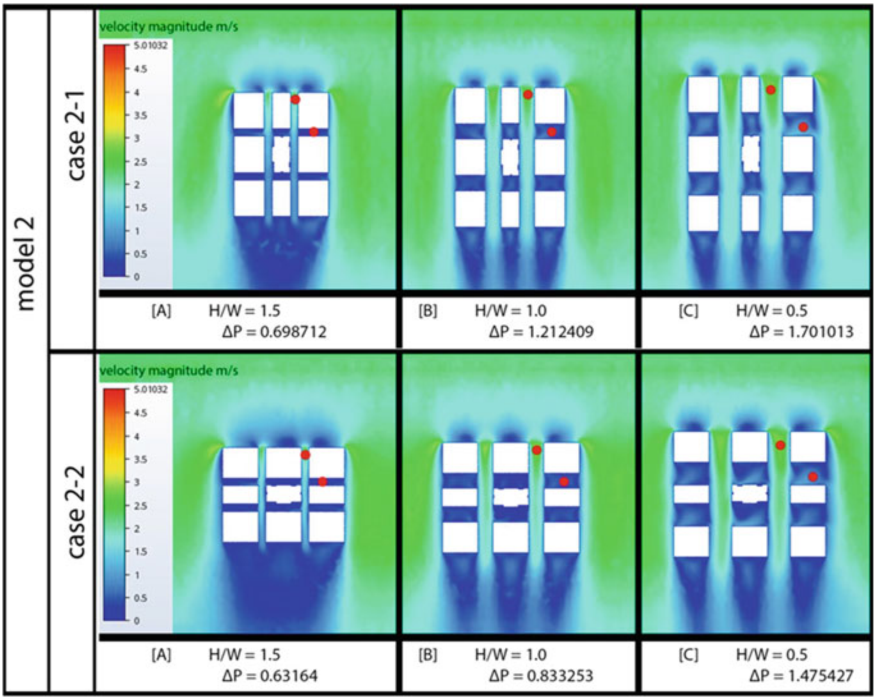

Fig. 5 Case 2–1 and Case 2–2 pressure difference [Pa(ΔP)] between the north and south facade of the building

Table 3 (Case 2–1—Case 2–2) pressure differences [Pa(ΔP)] between the north and south facade of the building

Case 2–1				Case 2–2			
Status	Type	Pressure difference	Results	Status	Type	Pressure difference	Results
Status 1	A	ΔP	0.698712	Status 1	A	ΔP	0.63164
Status 2	B	ΔP	1.240713	Status 2	B	ΔP	1.497001
Status 3	C	ΔP	1.212409	Status 3	C	ΔP	0.833253

In case 2–1 and case 2–2, the wind velocity in the stagnant zones has enhanced to be 1.1 m/s as the street canyon width expansion. It can also be noticed that the result of the velocity of wind at the windward side of the buildings entrances increased gradually when H/W = 0.5 and reached the maximum of 2.7 m/s as shown (Fig. 5).

Generally, [14] Pancholy study's recommended the overall wind velocity inside the street canyon near the downwind building up to the center of the street increases with an increase in the street width. It has shown the pedestrian wind categorization plot for varying building width at the pedestrian height of 1.5 m. It can be observed from this figure that, with an increase in the building width the wind speed also has increased inside the canyon gap. and these results are compatible in this paper.

The study is also matching with Tsang and Kuo study's [11, 12], where the wind speed inside the street canyon has increased and effectively improved the PLW intense wind in street canyon width. As well, the wind flow characteristics are influenced by the approaching width of the street canyon, and the buildings heights inside the street canyon. From this parametric study for a uniform street canyon using the street width and building width as influencing parameters, it can be observed that an increase in the street width introduces high wind speed at the pedestrian level. Whereas, the decrease in the building width introduces high wind speed at the pedestrian level. This high wind speed converts favorable zones into unfavorable zones inside the street canyon. Consequently, this study has agreed with the CFD results there is big difference in static pressure between building facades. The pressure groups increase with the increase in street widths and distances between the buildings. Furthermore, the wind speed for the streets entrance has been increased with increasing street width of case study in Al Salam Residential Complex. And it resulted high velocity in some areas.

5 Conclusions

CFD simulation takes an important role in the optimization of wind flow that could help the designers to evaluate the thermal behavior of wind flow and complete qualitative analysis. Simulations of street canyons in residential buildings areas have focused on wind field and pedestrian comfort. Consequently, the pedestrian level-wind and changings ratio of the height of the building to street width (H/W) reacted with climate design, which provided the occupant's direct solutions for their problems with the environment. In this study, the wind speed inside the street canyon has changed and gradually the winds improved at the PLW in street canyon width. The final results showed that the pressure winds escalated with the increased width of streets canyon and distances between the building. As a result, the wind speed for the street entrances has been enhanced when H/W = 0.5 of the case study in Al Salam Residential Complex. So as to give some solutions to building wind environment optimization, it is better to be the ratio of streets canyon width is two times the height of buildings when the buildings have similarity heights. Hopefully, it could help designers enhancement their work methods in the future, abide by the general principles of architectural buildings that are environmentally friendly.

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Ultimate Strength of Glass Fibre Reinforced Polymer—Engineered Cementitious Composites (GFRP-ECC) Sandwich Composite Sections

Mahmoud Anwar Gad, Ehsan Nikbakht, Anas Khaled, and Ahmed Al-Raeeini

Abstract Steel Sandwich composites have been used widely in offshore industry. However, the use of steel is unsustainable and require expensive maintenance. Glass-Fibre-Reinforced Polymer plates are potential replacements as they possess high tensile strength and many advantages. In this research, GFRP sandwiches with one and two-face configurations and Engineered Cementitious Composites (ECC) as the core are constructed to investigate their ultimate behaviour against bending. Mechanical Connectors are used as shear-resistant elements. Moreover, the effect of shear span to depth ratio (a/d) is investigated. Results show that load resistance increases with thickness of ECC core. However, the use of GFRP plates in the compression zone of section rendered ineffective due to the fact that GFRP cannot act in compression. All slabs tested have not experienced any diagonal shear cracks while all crack formed were flexural. All slabs showed a significant deflection capacity and ductility prior to failure.

Keywords GFRP · ECC · Sandwich section · Ultımate load · Slab

1 Introduction

Sandwich sections consisting of two stiff panels connected by mechanical headed studs and separated by a lightweight material [1], are being used widely in many applications. Most commonly used are Steel–concrete-steel sections. SCS sandwich structures exhibit excellent performance, with high integrity, impact resistance, crack control and leakage prevention, which offer the advantages of shortened construction time, saving formworks and promoting construction efficiency [1, 2]. Apart from serving as shielding structures for nuclear power plants, popular applications of the

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SCS sandwich structures include tunnels, bridges, coastal, and offshore applications [3].

However, high density steel is not ideal for offshore applications due to lack of corrosion resistance and strength-to-weight ratio [4]. An alternative known as Glass Fibre-Reinforced Polymer, GFRP, is being researched for its promising potential. GFRP is a flexible, corrosion-free material having adequate strength and stiffness compared to steel. "GFRPs are preferred over steel for their small dimensions, low weight, high strength and superior durability properties" [5].

Engineered Cementitious Composite (ECC), also called Strain Hardening Cement-based Composites (SHCC) or more popularly as bendable concrete, is an easily moulded mortar-based composite reinforced with fibres [6]. Engineered Cementitious Composites (ECC) with high strength and tensile stain hardening behaviour prior to crushing failure will be incorporated in the sandwich composite systems. The term strain hardening refers to the fact that after first cracking, the material will continue to gain strength with increasing strain [7]. Besides, high mechanical properties [8, 9], ECC also exhibits an excellent durability characteristic [10].

This research proposes to study the incorporating GFRP composites as facing plates in order to enhance the ultimate strength and deformation capacity in the sandwich composite systems of ECC core.

2 Experimental Program

Three 400 mm × 1500 mm slabs were fabricated as GFRP-ECC sandwich sections in this study. Engineered Cementitious Composites (ECC) is incorporated as core between facing plates. The configurations of the slabs are the slabs with one face GFRP plate at the bottom, and with two faces of GFRP plates at top and bottom. The geometry and configurations of the slabs are shown in Table 1, and Fig. 1. Moreover, the mixture design of ECC and characteristics of GFRP plates used in this study are shown in Tables 2 and 3, respectively. Bolted shear connectors of normal mild steel was used in this study as shown in Fig. 2, The bolts have a diameter of 8 mm with a longitudinal spacing of 100 mm and transverse spacing of 200 mm. Three-point bending tests were carried out on the specimens using the setup illustrated in Fig. 3.

Table 1 Specimen dimensions

Slab ID	Length (mm)	Span, L (mm)	Shear span,a (mm)	Width (mm)	GFRP plate thick, t (mm)	Effective depth, d (mm)	a/d	Skin configuration
1	1500	1200	600	400	10	75	8	Bottom only
2	1500	1200	600	400	10	125	4.8	Bottom only
3	1500	1200	600	400	10	75	8	Top and bottom

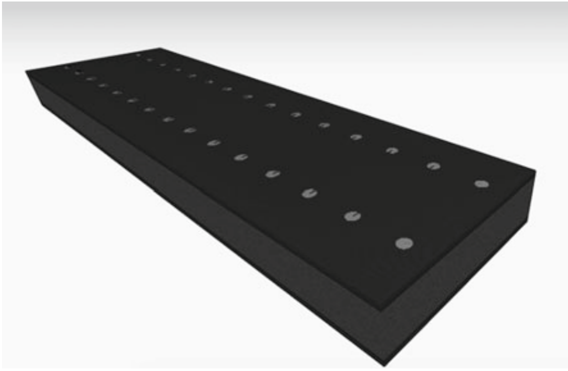


Fig. 1 2-face composite section GFRP-ECC-GFRP

Table 2 ECC mixture design

Ingredients	Quantity (kg/m^3)	
Binders	Portland cement	547
	Fly ash	656
Aggregate	Fine	438
	Coarse	–
Water	312	
Chemical admixture	Superplasticizer	5
Fibres (% vol.)	Steel hooked end	–
	PVA	2.0% volume

Table 3 Characteristics of GFRP plates according to manufacturer

Mechanical	
Tensile stress	207 MPa
Tensile modulus	17,237 MPa
Compressive stress, axial	207 MPa
Flexural stress	207 MPa
Flexural modulus	11,032 MPa
Notched Izod impact	1.28 kJ/m
Short bean shear	31 MPa
Physical	
Barcol hardness	45
24 h water absorption	0.5% max
Density	0.060–0.070
Thermal coefficient	4
Electrical	
Arc resistance	110 s
Dielectric strength	1378 kV/m

Fig. 2 Preparation of slabs

3 Results and Discussion

3.1 Mechanical Properties of ECC Core

The results of compressive and tensile tests for the three slabs are shown in Table 4. As stated in Table 4, the range of compressive strength for ECC used in the three slabs is between 48 and 53 MPa, the tensile strength of specimens are between 3.2 and 3.6 MPa.

3.2 Slabs

Figure 4 shows the ultimate loads and ultimate displacements for the tested specimens. It is clear that slab 1 and slab 3 exhibited the same behaviour although slab 1 did not have a skin plate in compression zone while slab 2 had. This might be explained as the GFRP plate did not contribute to the compressive strength of the

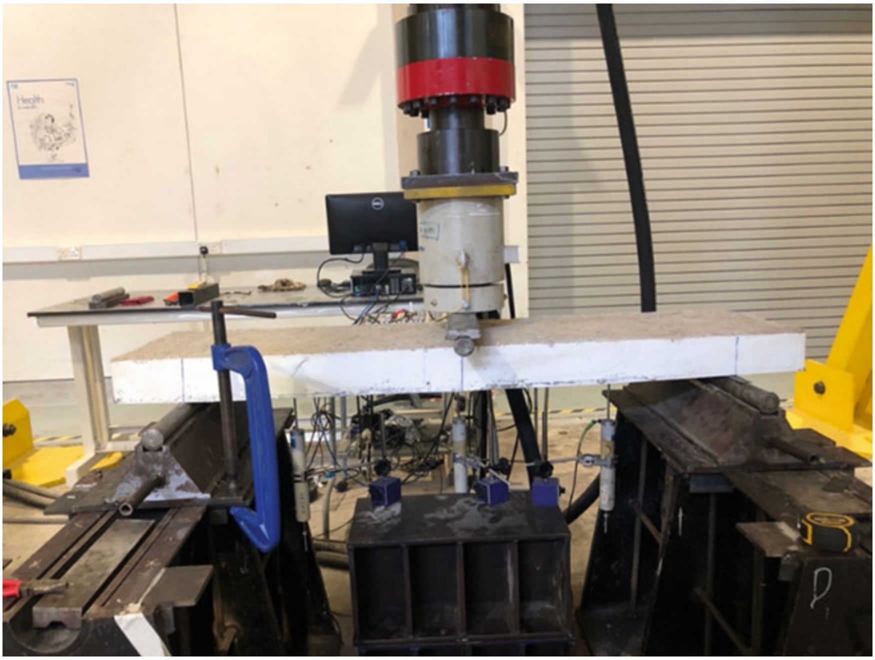


Fig. 3 Test set-up

Table 4 The results of compressive and tensile tests for ECC patches

Sample	Test	Results (MPa)
Slab ID.1	Compressive	50
Slab ID.1	Tensile	3.233
Slab ID.2	Compressive	48
Slab ID.2	Tensile	3.302
Slab ID.3	Compression	53
Slab ID.3	Tensile	3.576

slabs. Another possibility for this similarity is the weak composite action contributed by the shear connectors due to the large spacing to the depth used for theses slabs. Crack development for slab 1 and slab 3, shown in Tables 5 and 7, support the weak composite action hypothesis as the initial cracks at early loading stages developed between the bottom skin plate and the concrete core. In addition, excessive slippage occurred at the final loading stages, which means that early debonding of tension plate occurred leading to the deterioration of section.

As shown in Fig. 4 and Table 6, slab 2 exhibited a larger capacity with a better composite action due to the low shear connectors spacing to depth ratio. The initial

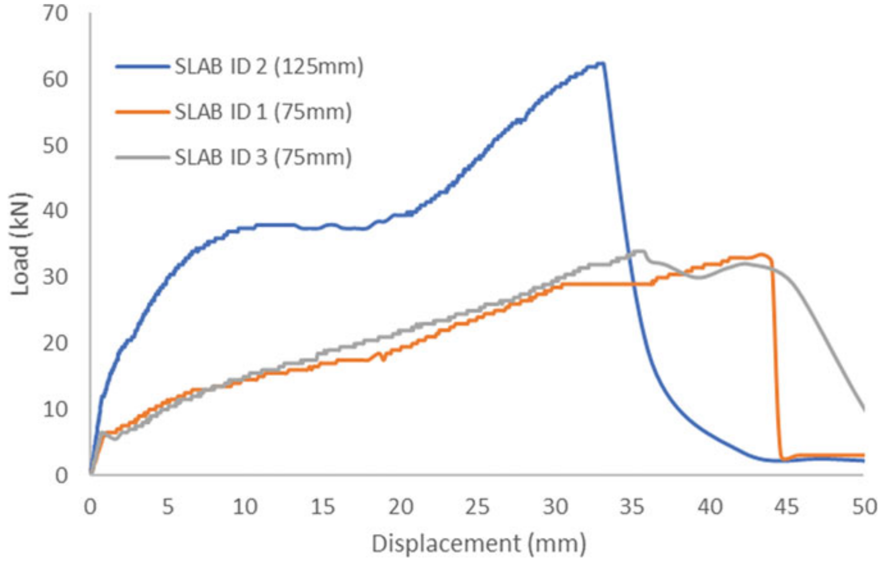


Fig. 4 Load–displacement of slabs

cracks started to occur late at 20 kN between the bottom skin plate and the concrete core. The load-deformation relationship showed elastic behaviour of the specimens until the load value of 30 kN.

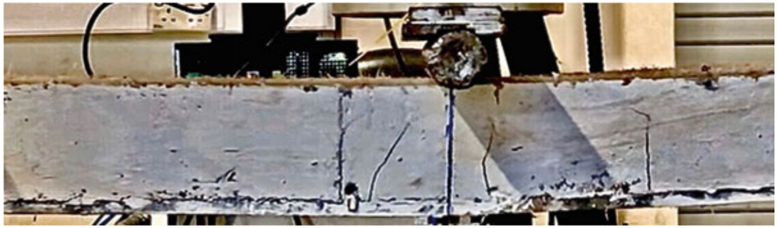
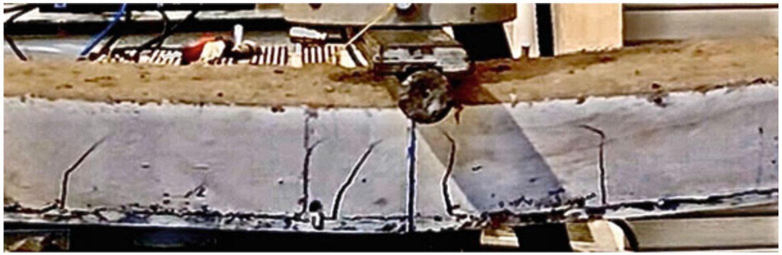
4 Conclusions

Sandwich composites have been used widely in the industry for its advantages. The use of Steel plates is the most common plate material implemented in those composites. However, Steel is unsustainable and requires intensive maintenance. Glass Fibre Reinforced Polymer is a better alternative in some cases such as offshore applications. Its considered advantageous due to its corrosion free nature. In this paper, two 1-face and one 2-face slabs have been constructed to investigate the influence of parameters such as span-to-depth ratio, mechanical connectors, and the effectiveness of multiple plates.

Load versus deflection responses of the slabs shows that the thicker the core concrete, the more load can be resisted. However, on the contrary, deflection decreases. Although the high-performance concrete used was relatively low in strength (to compensate for low strength GFRP plates), it showed tremendous ductility in all slabs which is considered an advantage in failure cases.

The use of GFRP plate in the compression section influenced little to no difference in the failure behavior. GFRP is not suitable to be used in compression side.

Table 5 Crack development with the increase of loads for slab 1

Load (kN)	Slab ID. 1
12.54	
20	

(continued)

Table 5 (continued)

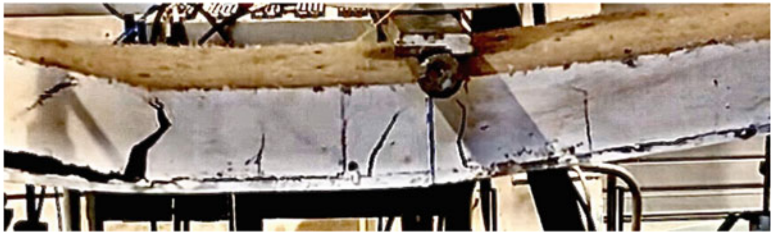
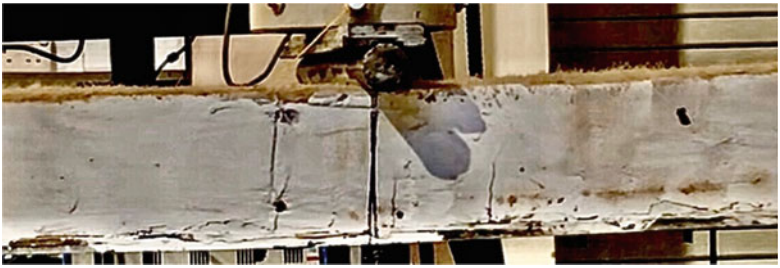
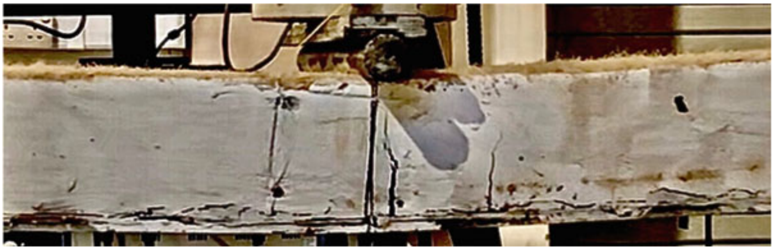
Load (kN)	Slab ID. 1
33.40	

Table 6 Crack development with the increase of loads for slab 2

Load (kN)	Slab ID. 2
18.86	
31.96	
62.23	

The ratio between the longitudinal spacing of shear connectors and the effective depth of section is very crucial to the behaviour of the sections; the increase of this ratio leads to the decrease of the degree of the composite action and accordingly the capacity of the section.

Table 7 Crack development with the increase of loads for slab 3

Load (kN)	SLAB ID. 3
10.33	
22.45	
33.90	

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Value Management Activities in Building Projects in Developing Countries

Ahmed Farouk Kineber, Idris Othman, Ayodeji Emmanuel Oke, and Mohanad Kamil Buniya

Abstract In the past decade, value management (VM) has become an established practice using widely known techniques and practices. VM is also exposed to demand of time and resources. Nevertheless, the actions/methods of this approach are linked to informal approaches in developing countries. However, previous research has suggested that many VM activities and elements for delivering VM in construction projects. This research aims to verify these activities through qualitative thematic analysis approach. The thematic analysis confirms the necessity of the VM activities identified in the previous research for managing construction investment and provides directions for construction organisations to improve VM adoption. The study also revealed five (5) phases of value management activities/methods for the Egyptian construction industry, including information, function, innovation, evaluation and development and presentation phases. The findings will support and improve the implementation of VM applications in Egypt's Therefore, the results reflect the need to adopt the method in line with the formal VM approach in Egypt and other developing countries.

Keywords Value management · Building projects · Construction projects · Egypt · Thematic analysis · Developing countries

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1 Introduction

VM is a main element of project productivity, consumer satisfaction and infrastructure development in the construction industry in developing countries [1]. Currently, VM has not been completely incorporated into the construction market of developing countries [2, 3]. The application of VM in building industry provides important value for capital in the development of infrastructure projects. This kind of projects itself needs tremendous capital investment, subsequent in extraordinary secure costs for every business [4]. The motivation to spend money in infrastructure relies on the importance and advantages of this project. Increasing principal cash flow returns involves methods and strategies that make it easy to find alternate ways of fulfilling the customer's practical needs at the lowest possible expense. The advantages of VM application are well known in all facets of the economy of the world. Performance has been seen in the settlement of a variety of problems in construction sectors in countries such as the USA, the England and Australia [5].

One of the advantages of VM is that it saves investment by decreasing unnecessary spending on energy and tasks. Yu et al. [6] said that the U.S. government had allowed the use of the VM system in federal systems based on the perceived cost benefits of the VM. Kineber et al. [7] noted that VM, a standardised and innovative approach system, is an outstanding approach to the incredibly challenging issue of global investment and client gratification. Mariathasan [8] found VM to be a tool that requires both gatherings to take part in the decision on the suggested construction project. The VM concept requests for an analysis of all the alternatives available for the design and execution of the project, thereby strengthening the concept brief and eliminating some budget constraints [9].

VM was a framework that maximises project performance by handling the design from commissioning to execution by auditing the value system decisions of the clients. In this article Short et al. [10] refer to the central definition of VM, which includes a standardised and organised approach, multidisciplinary evaluation, task evaluation, start-up and execution of practical projects, optimal value, average project costs and refund on initial cash flow. Oke and Ogunsemi [11] have thus described VM as a systemic and multidisciplinary approach for evaluating project functions from start to finish (by undertaking audits or reviews) to achieve the maximum value for capital and revert on initial expenditure at the minimum possible cost. This study explored the activities of VM activity in the field of analysis with a view to increasing the production and utilization of capital.

2 VM Background

2.1 Definition of VM

Various scholars and professionals worked in the construction industry throughout VM. By managing the design to be employed as "an efficient, creative, problem solving or data management service which maximizes the functionality of a project," Male and Kelly [12] have identified VM. The method uses coordinated, team-oriented activities that deliver and evaluate existing or established solutions based on customers quality requirements. The American Value Engineers 'Society (SAVE) [13] further described VM as an effort to evaluate the project functions such that the highest benefit is obtained at the lowest overall life cycle costs. These principles suggest that VM facilitates quality production through a value-for-money approach to the project and promotes collaboration by improving the working relationship with the team. A recent VM summary states that the project management approach is a methodology and computational technique using a dynamic and cross-disciplinary means of measuring elements or objects' roles over the life cycle, with the goal of delivering better results in exchange for productivity and increased returns at the lowest possible cost [8].

2.2 VM Activities Stages

Seeley [14] found the VM should be applied at any stage in the design phase in order to complement the construction cost planning process. Nevertheless, VM is more effective in improving the possibility to streamline the project, according to Ahuja and Walsh [15]. Ellis et al. [16] suggested that many companies would like to participate in the VM program early to define the strategic plan or the specific needs of the project. The Department of Housing and Works [17] also found that the benefits of VM technology are best early in projects for growth, with performance enhancement exceeding time and energy. It is specifically the case if the proposal is executed during the design phases as the planning processes extend beyond the implementation point, having the potential to affect the results.

Dallas [18] said VM is working to organize structured workshops in the project. The first is often at the concept phase (early level) which includes negotiation of the partners' various points of view to ensure the appropriate proposal is in order to satisfy consumer expectations. While that is the case, Clifford [19] states that VM will run through all phases of the construction project, often up to one, two or three VM assessments per job are conducted based on the specifications of the client and the financing costs. Despite common belief, VM activities will also be more effective if the question seems beatable or if the gap of opinion seems irreconcilable. A description by Clifford [19] VM Workshop is used to develop a project concept statement and to plan feasibility studies to enhance the meaning of capital projects.

It may also be used in a different manner, such as reviewing construction choices, assessing building strategies, choosing sites and agreeing on points of entry.

Ellis et al. [16] suggest that a VM workshop environment brings together project partners and that collaboration with clients is also established. The design for the VM workshop was developed for the Society of American Value Engineers (SAVE) [13], which records sequential data, structural analysis, development and evaluation. In the workshop chosen team members would be invited to explore the project [16]. This cycle leads to: What is an element? What does it do? What does it do? What is it doing? What is it doing? What else is it feasible to do? Which else would it do? What else? What is it? What is it? Who is it? Where is it? What good is it? What good is it? When introduced, numerous alternatives are developed, and the best cost-effective alternative is developed. Table 1 defines the VM activities.

3 Study Analysis

The aim of this research is to enhance the VM adopting in building projects in the Egyptian construction industry. However, this paper is part of bigger research aimed to explore VM activities in construction projects [23]. Qualitative approach, based on the philosophical interpretative assumption, has been introduced so that the research paradigm is understood more clearly, and knowledge is gained for future research. Semi-structured interviews were used to gather qualitative data relevant for specialist building practitioners' interpretations and perspectives [24]. The interviews were intended to help validate the findings of the study, making them applicable to the actual needs of the building industry. The questions from the interview were:

1. What is your description of VM?
2. When did you start VM procedures?
3. What has motivated the company to adopt VM?
4. What are advantages of VM?
5. How long did it take to implement the VM? (Please specify)
6. Which VM tools and methods do you use?
7. What were the activities and elements encountered before and during the VM adoption?
8. What is the most significance activities lead VM implementation?
9. What is the common groups for VM adoption in the Egyptian construction industry?
10. What does your organisation do to improve the VM knowledge and practice?

Purposive sampling was used to pick interview subjects for this study. Fifteen interviews have multiple positions are useful for analysis as they allow industry practitioners with different management roles to validate the proposed relationships among VM activities. Samples are small, so the results of this analysis have to be carefully interpreted and applied [25]. The authors agree that samples are not huge. In order to maintain its relevance, the conclusions were related to the current literature.

Table 1 VM activities in construction industry

Group names	Activity name	References
Information phase	Carry out a site visit	[13]
	Collect related historical information on the proposed project	[20]
	Establish the time period and scope of the project	[13]
	Involve stakeholders in the initial stage of the project;	[21]
	Involve and allocate duties to construction specialists at the initial stage of the project;	[20]
	Clarify relevant details and limitations of the project	[13, 20]
	Share project knowledge between professionals	[21]
	Identify the project's high-cost areas	[22]
Function phase	Make client express the scale and predictions of the project explicitly	[22]
	Presentation by stakeholders of project restrictions	[21]
	Express and understand the goals and roles of the project	[13]
	Create and identify functions with their related costs into essential and secondary objects	[13, 20]
Evaluation phase	Estimate the cost of each alternate life cycle	[23]
	Assess brainstormed alternatives to fulfill the desired functions	[22]
	Investigate the alternative assessment criterion	[23]
Creativity phase	Brainstorm on solutions and concepts to accomplish the desired functions and costs	[13, 20]
	Categorize brainstormed session alternatives and suggestions into realistically appropriate to be adopted	[20]
	Defining the project procurement and contract strategy approach	[22]
Development and presentation phase	Establish a short-term alternative action plan	[13, 20]
	Meet and request a review of the action plan	[20]
	Track a VM output action plan	[23]

3.1 Findings and Discussion

In the form of a particular interview and a list of literature activities of VM, the authors who produced the transcript and all the studies questioned if they had taken into account any current activities that were irrelevant or indicated any activity that they considered to be important but not mentioned. Several activities were revised and a couple added to the list. Modified and incorporated tasks have been used to construct a primary questionnaire. Every face-to-face interview was reported immediately by the researcher. The interview notes were written and loaded into the accompanying transcript archives. The information was encoded and processed in a separate file in order to allow the interview details to be checked. The core definition can be condensed and formalized, which can then be converted into key features in all VM-related variables. Some topics are discussed more often than others to-person interviewed, which is important since they are specific to the field of expertise.

The thematic review was carried out on the basis of the six phases suggested by Braun and Victoria [26]. The detailed thematic review method conducted is as follows:

1. The first phase was data familiarization, where all interviews were transcribed and re-read for accuracy and data incorporation. Notes and suggestions were inductively jotted down during the rereading process.
2. In the second stage, the initial data codes were created and compared to the data extracts.
3. Step three included sorting the codes into possible themes, which culminated in the discovery of five themes, including knowledge, purpose, creativity, assessment and production and presentation stages. Relationships between themes and subthemes have also been discussed at this point.
4. In stage four, the clusters and themes have been revised and improved to ensure that the data inside themes are consistent and that there are specific differences within themes.
5. Step 5 identified and labelled themes by defining the nature of each theme and deciding what element of the data each theme collects. The tale that each theme tells must fit into the wider overarching storey of the data in relation to the analysis goal.
6. The final step of the thematic research was reporting in order to inform viewers of the merit and relevance of the analysis. This study not only explains the data, but also contains theoretical narratives and claims relevant to the analysis objectives.

Finally, through the analysis it is necessary to remember the difference in importance for each subject in the area of expertise of the respondent [27, 28]. The role of private sector expertise is furthermore related to reduced costs and the viability of their programmes is sustained. Experts themselves have a more managerial role to play during interviews during the first period of project growth. Almost all the interviewees thought that the introduction of VM had an impact on the working environment and that the main problem with VM had to be better tackled and could not be completed quickly at the initial stage of the design process. Following a combination of research and progress evaluation, the findings of these interviews showed five phases of VM activities.

4 Conclusion

This study aims to recognize VM's activities to check and improve the application of this tool in the construction filed in developing countries. The study was performed by 15 directly involved building experts, especially building projects, in the Egyptian construction sector. Experts were also selected based on the expectations of participating in the implementation of project projects, particularly by contractors, consultants and clients, in the construction of projects. The findings achieve the purpose of the study and divided VM's activities into five structures. The results of this study provide an overview of VM activities as well as various factors influencing its generation to help improve the current situation in Egypt as a whole. The need for the use of VM methodology in Egypt is to follow a structured structure for the construction project to maximize performance.

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International High-speed Rail Stations—'Airports' in City Centers

Yann Hui and Michael Mak

Abstract This paper seeks to create awareness of the international High-Speed Rail (HSR) station, a new building typology of airport significance. Due to the ongoing planning of the Pan-Asian Railway (PAR) (South-East Asia), it is beneficial to understand the international HSR developments in Asia and Europe to date, as well as to study built examples of the international HSR Station. The PAR network will be introduced and a summary of the HSR networks within the United Kingdom (UK)/Europe (EU) and Hong Kong Special Administrative Region (SAR)/China (CN) will be given. The St. Pancras International Station (SPIS) in London (UK) and the West Kowloon Station (WKS) in Hong Kong SAR (CN) are selected as precedents for investigative purposes, to further understand the features of this new building typology. International HSR stations comprise of a complex building program and are expensive to construct. Consideration should be given at the outset of the project, to determine the exact building requirements and desired aspirations for the level of architectural status (iconic landmark/standard design). International HSR Stations act as a catalyst for urban redevelopment [(King's Cross Central Development) (KCCD) (UK)] and development [(West Kowloon Cultural Development) (WKCD) (HKSAR)], thus creating new destinations within cities of a contemporary yet forwarding image.

Keywords Architecture · Aviation · Rail · Sustainability · Urban

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1 Introduction

The continued advancement and development of High-Speed Rail (HSR) technologies have enabled the implementation and running costs of HSR to be lowered, allowing for HSR to become a viable means of mass transportation covering long distances.

During the last 2 decades (2000–2020), the continued rapid expansion of domestic HSR networks have taken place in East Asia. China, Korea and Taiwan have followed the Japanese HSR transportation model and have developed HSR networks serving major cities within each country.

The proposed Pan-Asian Railway (PAR) comprises of a new international HSR network linking up the South-East Asian peninsula and crossing the borders of 7 countries, it is envisaged that several new international HSR stations will be required at strategic locations within the network.

New international HSR stations will act as an urban catalyst for the development/re-development of existing city's core(s) due to the large volume of passengers feeding into various associated large-scale urban developments. During the initial planning stage, the location of the Terminus must be strategically determined. Consideration must be given to how the Terminus will serve a larger masterplan (generally consisting of mixed-use developments), its relationship to the existing central business districts, connections to other public transport interchanges and the airport. Due to its potential impact, it is important to recognize the special role of the international HSR station at the project inception stage in order to maximize its contribution to a city.

At present, there are two international HSR stations in operation: St. Pancras International Station (SPIS) in London, United Kingdom which was opened in 2007 and the West Kowloon Station (WKS) in Hong Kong SAR, China which was opened in 2018.

The Paper carried out an overview of certain design aspects of SPIS and WKS and is followed by a discussion on the similarities and differences of both schemes with a view to identify distinctive building programming features and commonalities shared. It is hoped that the review can provide an outline understanding of the particular building typology of international HSR stations.

2 Methodology

Firstly, a summary of the current HSR developments in South-East Asia will be provided.

Secondly in order to develop an outline awareness of the international HSR station building typology, a brief review of 2 such stations is carried out:

- West Kowloon Station (WKS) in Hong Kong Special Administrative Region [(SAR) (China)] [1, 2, 9].

- St. Pancras International Station (SPIS) in London (United Kingdom) [3].

Thirdly, an analysis of the 2 case examples, citing the similarities and differences.

The WKS and SPIS projects serve as pioneering cases for the international HRS station building typology, serving as exemplar precedents.

3 Proposed Pan-Asian Railway Network

The proposed Pan-Asian Railway network covers the South-Eastern Peninsula linking the following cities and countries via the Central, Eastern and Southern Routes:

- Central Route: Kun Ming (China), Vientiane (Laos) and Bangkok (Thailand).
- Eastern Route: Kun Ming (China), Hanoi (Vietnam), Ho Chi Minh City (Vietnam), Phnom Penh (Cambodia) and Bangkok (Thailand).
- Southern Route: Bangkok (Thailand), Kuala Lumpur (Malaysia) and Singapore (Singapore) (Fig. 1).

Fig. 1 Above: Map depicting proposed Pan-Asian Railway (PAR) international HSR network. *Source* Bangkok Post (2020) [11]

4 Features of St. Pancras International Station (SPIS), London, United Kingdom (UK)

The SPIS is part of the UK/Europe (EU) international HSR network (operated by Eurostar) which connects SPIS in London (United Kingdom) to Gare du Lille Station in Lille (France), Gare du Nord in Paris (France), Midi Station in Brussels (Belgium) and other mainland Europe destinations.

Refer to the UK/Europe international HSR network map (Fig. 2) and travel times (Table 1) for further information.

Project Summary: The SPIS (operating since November 2007) was the UK's first international HSR station. The original St. Pancras Station consisted of George Gilbert Scott's Midland Grand Hotel (Grade I listed) and William Henry Barlow's Train Shed (Grade I listed), commissioned by the Midland Railway company.

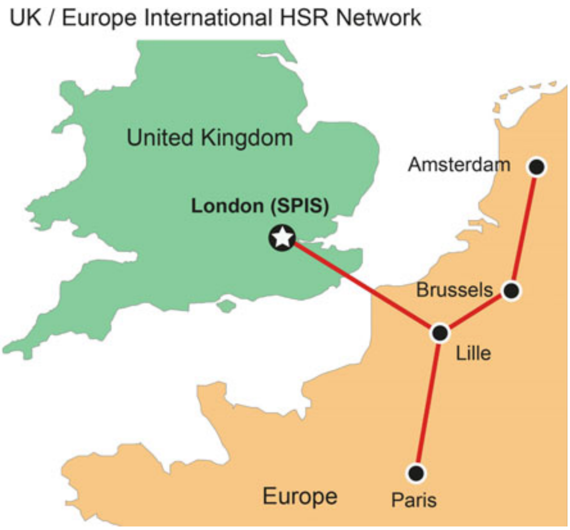

Fig. 2 Above: Map depicting UK/Europe international HSR network. *Source* Hui (2020) [13]

Table 1 Below: A selection of 3 UK/Europe international HSR routes originating from London (UK)

From London (UK) to	Time (h/mins)	Range
Lille (France)	1 h 22 mins	Medium-Haul
Paris (France)	2 h 22 mins	Medium-Haul
Amsterdam (Netherlands)	4 h 7 mins	Medium-Haul

Note that the first and furthest international destination together with an intermediate station is considered. *Source* Eurostar (2020) [10]

Fig. 3 Above: Aerial view showing St. Pancras International Station (SPIS), King's Cross Station, King's Cross Central Development (KCCD) and Regent's Quarter. *Source* Chapman Taylor (2020) [4]

The listed buildings were fully restored and expanded for international HSR train usage; longer Eurostar trains (400 m) called for the extension of the station via the addition of a box-type train shed (Fig. 3).

Project location: The SPIS is located in the borough of Camden in London (UK), within proximity to the British Library, Euston Station and Regent's Park.

Surrounding master plan development: The King's Cross Central Development (KCCD) (27 ha site area, ex-brownfield land site) [5], situated in between SPIS and King's Cross Station, comprising of: Arts and Cultural Facilities, Educational Facilities, Offices, Food and Beverage Facilities, Civic Amenities and Parks. The KCCD site is sat within 2 Conservation Areas and contains listed buildings and buildings of heritage value.

Associated public transport: The SPIS is connected (via pedestrian link) to King's Cross Station (Metro, Circle Line, Hammersmith and City Line, Metropolitan, Northern Line, Victoria Line and National Rail) and Euston Station (Metro, London Overground Line, Northern Line and National Rail) is within walking distance.

International airport connection: Heathrow International Airport (HIA), can be reached via transfer (walking) to King's Cross St. Pancras Station (Metro), taking the Metro to Paddington Station (Airport Rail/Metro) and taking the Airport Rail directly to HIA, total travel time from SPIS is 46mins [6].

SPIS function:

(a) a station entrance building (SEB) (hotel and residential usage);
(b) 15 (9 domestic non-HSR and 6 international HSR) platforms;
(c) dedicated arrivals and departures facilities;

(d) co-location of joint (UK and European Union) customs and immigration facilities.
(e) retail and food and beverage facilities.
(f) station carpark and vehicular pick-up and drop-off.

Station design: The SPIS SEB comprises of the former Midland Grand Hotel (built in 1873), renamed to the St. Pancras Chambers (1935) and was later used as rail offices (1935–1980s), re-opening in 2011 as the St. Pancras Renaissance Hotel. The hotel complex serves as the SPIS's Southern Main Entrance (facing Euston Road) and forms the SPIS external façade (Victorian era, Gothic style) on the eastern, southern and western frontage, wrapping around Barlow's Train Shed. The Eastern Main Entrance (facing Pancras Road) is located on the eastern side of the SPIS (Fig. 4).

Barlow's Train Shed features an arched glazed canopy 210 m-long and 30.4 high with a span of more than 74 m. Structurally the terminus roof is a tiered arch, with a row of 46 huge iron girders (ribs) running the width of the station [3].

The Train Shed has been totally restored to its pre-World War II condition with ridge and furrow glazing over the crown and 300,000 handcrafted Welsh slates over the remainder [3].

Under the Train Shed, the platform structure has been substantially altered. The Victorian platforms and track originally supported by 800 wrought-iron columns and a grillage of wrought iron beams. The original platform was removed and a new platform (HSR train compliant) laid on top of a heavily reinforced concrete trackbed. The wrought-iron columns were retained and used to support the new trackbed, albeit

Fig. 4 Above: St. Pancras International Station (SPIS) interior view, William Barlow's Train Shed fully restored and adapted for modern High-Speed Rail usage. *Source* Chapman Taylor (2020) [4]

with bearings added to their tops to take into account movement from above and the extra weight of modern-day rolling stock [3].

Maintaining the original design intent, the restored Train Shed is an enormous internal spatial volume filled with daylight, illuminating the platform level; lightwells were created within the platform slab to allow for daylight to illuminate the Basement 1 level below, as well as to allow views up to the magnificent roof canopy.

The extension to the Train Shed is a new-build (110 m width, 200 m length) steel structure canopy with glazed facades.

4.1 Features of West Kowloon Station (WKS), Hong Kong Special Administrative Region (SAR), China (CN)

WKS in Hong Kong SAR is China's southernmost international HSR Terminal connecting to Futian Station in Shen Zhen (China), Guangzhou South Station in Guangzhou (China) and connecting into the mainland China HSR network.

Refer to the Hong Kong SAR / China international HSR network map (Fig. 5) and travel times (Table 2) for further information.

Fig. 5 Above: Map depicting Hong Kong SAR / China International HSR network. *Source* Mass Transit Railway Corporation (2020) [12]

Table 2 Below: A selection of 3 Hong Kong SAR/China international HSR routes originating from Hong Kong SAR (CN)

From Hong Kong SAR (China) to	Time (h/mins)	Range
Futian, Shenzhen (China)	14 mins	Short-Haul
Chang Sha (China)	3 h 51 mins	Medium-Haul
Beijing (China)	8 h 56 mins	Long-Haul

Note that the first and furthest international destination together with an intermediate station is considered. *Source* Mass Transit Railway Corporation (2020) [12]

Project Summary: The WKS (operating since September 2018) is currently one of the world's largest underground HSR stations. The majority of station facilities are underground, freeing up the site for a generously sized Civic Plaza, Green Roof and Landscaped Deck. The topside is planned for commercial development (Fig. 6).

The complexity and size of the WKS project are comparable to building a world class international airport 30 m below ground level within a dense urban city setting [7].

Fig. 6 Above: Aerial view of the West Kowloon Station (WKS), Station Entrance Building (SEB) and Civic Plaza. The WKS top-side Commercial Development provision is located on the northern-end of the Civic Plaza. Austin Station (Metro Station, standard box-type SEB) with top-side development (Residential usage) is sited in the background. *Source* Aedas (2020) [2]

Project location: The WKS is located in Kowloon (Yau Tsim Mong district, HKSAR) within close proximity to the Victoria Harbour, orientated towards Hong Kong Island.

Associated master plan development: The West Kowloon Cultural District (WKCD) (400,000 m^2, reclaimed land site) [8] situated on the southern-end of WKS, a world class arts and cultural destination, comprising of: Arts and Cultural Facilities, Educational Facilities, Residential, Food and Beverage Facilities, Civic Amenities, Parks and a Promenade (2 km length).

Associated public transport: The WKS is connected (via pedestrian link) to Austin Station (Metro, West Rail Line), Kowloon Station (Metro, Tung Chung Line; Airport Express) and the Public Transport Interchange (bus terminus).

International airport connection: Hong Kong International Airport (HKIA), can be reached via transfer (walking) to Kowloon Station (Airport Rail/Metro) and taking the Airport Rail directly to HKIA, total travel time from WKS is 35 mins [9].

WKS function:

(a) a station entrance building (SEB);
(b) 15 (6 short-haul and 9 long-haul) International HSR platforms;
(c) dedicated arrivals and departures facilities;
(d) co-location of joint customs and immigration facilities (Hong Kong SAR and China);
(e) retail, food and beverage facilities;
(f) station carpark and vehicular pick-up and drop-off.

Architectural design: The lower portion of the SEB roof rises from the northern-end towards the southern-end, marked by the Eastern Arch (Southern Main Entrance) and the Southern Main Glazed Façade. The free-form SEB wraps around the Civic Plaza and the SEB roof consists of a Green Roof and Landscaped Deck, establishing pedestrian links from the proposed top-side Commercial Development to the Civic Plaza. Despite the SEB being a large-scale building, the WKS project integrates seamlessly into the site and its surroundings (Fig. 7).

The SEB roof structure is a free-form curved long-span curvilinear roof (180 m long, 50 m high), highly complex in geometry, supporting a landscaped pedestrian-enabled Green Roof and Landscaped Deck above.

Structurally the roof structure consists of '3' V-shaped mega space trusses, interconnected horizontally by secondary trusses and complex stability systems, supported by nine groups of mega-columns, allowing for large spans of the Central Atrium and Departures Hall to be column-free. A standard structural grid system is used for the majority of the station area, facilitating other Front of House and Back of House functions.

Daylight floods into the Station's Departure Hall below via glazed strip-shaped skylights (double-glazed units), set in-between the steel fins, between the main curvilinear free-form 'V' space truss steel members.

Fig. 7 Above: Interior of the West Kowloon Station (WKS), underside of Station Entrance Building (SEB), curved mega-columns supporting a free-form roof, allowing daylight to flood into the Departures Hall. *Source* Aedas (2020) [2]

5 Analysis: St. Pancras International Station (SPIS) in London (UK) and West Kowloon Station (WKS) in Hong Kong SAR (CN)

Architectural design: In terms of architectural design, the SPIS and WKS are different. SPIS is a redevelopment and expansion of an existing over ground rail terminus building (Victorian era, Gothic style) and the WKS is a new-build underground rail terminus (Modern architectural style) with a top-side SEB (Table 3).

Both SPIS and WKS serve as International HSR Stations, functions and operations are similar, albeit deployed at a larger scale at WKS.

The underside of the SEB roof (SPIS and WKS) is clear of Mechanical and Engineering and Plumbing (MEP) services to ensure a clutter-free surface, allowing the roof structure(s) to be aesthetically expressed in a minimal manner.

A common design principle found in both projects is the utilization of daylight to illuminate vast internal volumes (SPIS, Platforms at GF level and B1 level) (WKS, Departure Hall at B3 level)], to create dramatic spaces of substantial proportions.

Table 3 Below: Comparison of SPIS and WKS

Comparison of International HSR Stations		
Category	SPIS	WKS
(1) Type of build	Redevelopment of heritage building and expansion	New-build
(2) Station type	Overground rail terminus	Underground rail terminus
(3) Type of architecture	Iconic/renewal of victorian-era gothic style	Iconic/modern architectural style
(4) Site area	57,000 m^2	100,000 m^2
(5) Project gross floor area	100,000 m^2	400,000 m^2
(6) Rail platforms	6 International HSR and 9 Domestic Rail	6 International HSR (Short-haul) and 9 International (long-haul)
(7) Co-location of joint customs and immigration	Yes	Yes
(8) Top-side development	Commercial usage	Hotel/residential usage
(9) Master plan development	KCCD (area = 27 ha)	WKCD (area = 40 ha)
(10) Airport rail link	Yes (1 transfer)	Yes (direct connection)

Source Hui (2020) [13]

Both SPIS and WKS are iconic building of landmark status and destinations within the city’s center (Fig. 8).

Station circulation: For the SPIS, Arrival and Departure passenger(s) go through the Customs and Immigrations Facilities [(UK/Europe) (Arrivals and Departures

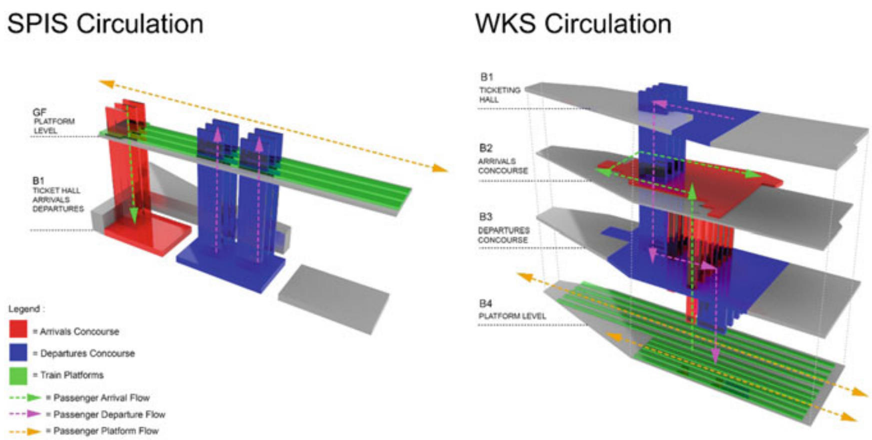

Fig. 8 Left: SPIS passenger flow for Arrivals and Departures sequence. Right: WKS passenger flow for Arrivals and Departures sequence. *Source* Hui (2020) [13]

Facilities separated)] at the point of alighting and disembarkation of trains, at all other times passenger(s) await within the terminus' Ticketing Hall.

For the WKS, the Departure passenger(s) arrive at the terminus' Ticketing Hall, go through security screening to the Departures Facility, onwards for Customs and Immigration (HKSAR/CN) processing and await within the Departure Hall prior to boarding trains. Arrival passenger(s) proceed to the Arrivals Facility, onwards for Customs and Immigration (CN/HKSAR) and exit the terminus, passengers are not encouraged to congregate within the Ticketing Hall.

To summarize, the Customs and Immigration Facilities of SPIS and WKS are similar to that of a modern airport. Airports operate on the basis of Land-Side and Air-Side principle, similarly international HSR stations operate on the basis of Land-Side and Rail-Side. It is important to note that country (UK/Europe and HKSAR/China) jurisdiction changes upon the point of immigration clearance within the station(s) (Fig. 9).

Associated Master-Plan development: Both SPIS and WKS are well connected to major Public Transport Interchanges and linked to master-plan developments (KCCD and WKCD).

Such mixed-use urban developments are of a certain density, utilizing high-quality civic and landscape features; contributing to a safe and highly accessible urban environment.

Certain urban development themes have been deployed, for example the KCCD has an emphasis as an Information Technology hub and the WKCD has an emphasis as an Arts and Cultural hub. Both master-plan developments incorporate mixed-use projects and include provision for civic amenities and residential buildings.

Fig. 9 Left: Map showing the SPIS project in relation to the KCCD. Right: Map showing the WKS in relation to the WKCD. *Notes* (1) Radii of 500 m/1000 m depicts pedestrian accessibility via walking. (2) M = Metro Station and T = Train Station. *Source* Hui (2020) [13]

A key difference is the local geography and site conditions, the KCCD is land-bound and relies on the redevelopment of heritage architecture and the existing Regent's Canal and Locks to form the Master-Plan identity. The WKCD is sited near the Victoria Harbour's edge and utilizes the panoramic views towards the opposing Central Business District (Hong Kong Island) to create Master-Plan identity.

Essentially new world class Master Plan districts (KCCD and WKCD) within city centers are created, either by urban redevelopment or development of new urban precincts, synergized via the international HSR station(s) and Public Transport Interchange(s).

6 Conclusion

An international rail renaissance has begun, a transition from a domestic-only HSR network to the incorporation of both domestic and international HSR routes, concurrently taking place in Asia and Europe.

International HSR transportation requires the implementation of a new building typology, the international HSR station. As this building typology is still in the primary stages of architectural design evolution, it is vital that exemplar building precedents are considered prior to subsequent realizations of future projects.

To conclude, it is evident that the following must be considered during the planning stages of international HSR stations projects:

- International HSR station project(s) are of a mega-scale nature, highly complex in terms of building programming (similar to an airport) and expensive to construct.
- Airport significance should be applied to the international HSR station building typology, to ensure careful consideration for the building requirements can be applied at the very outset of the proposed project.
- There is not a 'one size fits all' design approach, as each project will need to suit different building requirements, site conditions and city context.
- The desired architectural status (iconic or standard design) of the international HSR station should be determined at the very outset of the project, with special attention paid to the SEB.
- International HSR Stations act as a catalyst for urban redevelopment (KCCD, UK) and development (WKCD, HK) within City centers and are agent(s) for economic stimulus.

It is the hope that as international HSR transportation and networks develops, that further relevant building case examples can be investigated and analyzed, thus further defining such benchmark.

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Elements of Safety Program Implementation in Developing Countries Construction Industries

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Abstract The construction industry has always been considered as one of the most hazardous industries globally. The condition is worse in developing countries due to poor implementation of safety management. To overcome this problem, there is a need to focus on improving the implementation of safety programs. This paper aims to identify the elements of safety programs in construction projects in developing countries. An extensive review of literature found 25 elements. Sixteen semi-structured interviews with experts in the Iraqi construction industry was conducted to gain in-depth insight and understanding of these elements. The interviewees confirmed the relevance of the elements and emphasized on the importance of several elements, including safety objectives, safety policy, safety committee, training. These elements can used as a procedure to implement safety program in developing countries construction industry. The findings can used in the Iraqi construction industries and in developing countries to support the implementation of safety program.

Keywords Safety management · Safety program · Construction projects, developing countries, iraq

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1 Introduction

The building industry is regarded as one of the world's most dangerous industries. This fact demonstrates clearly how necessary it is for the construction industry to enforce the safety program [1]. In construction projects, accidents are unacceptable and have many negative implications. It entails additional direct costs including medical and indirect expenses, such as delays and interruptions, credibility deficiencies and poor staff morale [2, 3]. Owing to the lack of health legislation and inadequate implementation of regulations [4–8] this situation in developed countries is even worse.

The safety program is a constructive way of enhancing health on building sites in such a volatile work environment [7, 9, 10]. The specific features of the construction market, such as the intensive labor, complex and weather exposure, are also leading to the industry's poor safety performance [11, 12]. Top management plays an integral role in executing this system as it allocates money to guarantee the program success [4, 9, 13]. A proper safety program could eventually lead to positive safety culture [14].

The aim of this research is to identify the elements of safety program in the construction industry. To identify these elements, a systematic literature review was conducted, while semi-structured interviews were used with the construction industry experts to verify safety program elements in developed countries.

2 Major Elements of Safety Program

The safety program is an important part of any company's business strategy, big or small, whether connected to construction whether the operation. Beyond the regulatory requirements, it is critical to have a safety plan to manage the risks associated with any project. The safety plan will involve all management procedures that define, assess, track and monitor all aspects of the project where workers are injured. It is best achieved by a risk evaluation of employee-led practices. This will provide a detailed analysis of the activities and resources used on and off premises. Employees and managers at all levels should be consulted when performing this study because they are the main source of knowledge on workplace hazards.

The program's development, activity, and monitoring duty should be clearly established at the start of construction activities. The plan will include elements of a detailed safety policy statement, and pre-construction and construction safety analysis. On-site inspection and housekeeping are also one of the things to remember.

Tam and Fung and Poon et al. [15, 16] indicated that the post-accident investigation is the most successful site-accident mitigation technique. They concluded that such an investigation would identify reasons for construction site incidents and take effective preventive steps.

Table 1 Element of safety program

Elements	Sources	Elements	Sources
Safety objectives	[17–19]	Investigating accident and near misses	[20]
Safety policy	[17–19]	Injury and illness trend analysis	[21]
Safety rewards	[19]	Engineering controls	[21, 22]
Safety committee	[9, 23]	Preventive maintenance systems	[21, 24]
Visible leadership	[25]	Emergency preparation	[12, 21]
Involving the employee in decision making related to safety	[25]	Medical program	[22, 24]
Adequate safety authority	[12]	Safe work practices	[26]
Giving and receiving accountability	[21]	Administrative controls	[24]
Safety program evaluations	[12, 13]	Personal protective equipment (PPE)	[22]
Comprehensive hazard identification	[22]	PPE hazard assessment and training	[24]
Safety inspection	[18]	Systems to track hazard correction	[26, 27]
Reporting hazards	[27]	Safety induction	[15]
		Safety training	[28]

Tam and Fung [7] reported that reducing accident rates can be reached by using safety induction. Good working conditions are important in the construction industry. He noted that it is often believed that new employees have received additional safety training from previous employers. This presumption may be catastrophic for both the organization and new hires because the design of their current job (e.g. layout, equipment) can vary entirely from their previous projects.

Findley et al. [17] promoted the use of full-time safety managers and safety practice instructions as core elements for superior safety performance. They claimed that safety functions cannot be conducted efficiently without the appointment of full-time on-site safety managers who can provide the leadership required to provide preventive and corrective guidance (Table 1).

3 Qualitative Method

A semi-structured interview is a qualitative method was used to collecting the expert knowledge for this study. The interviews based on checking the importance of the 25 safety program elements identified from the literature review in the context of the Iraqi construction industry. Furthermore, the interviews aimed to recognize other elements not included in the research and obstacles to the introduction of safety programs. Before the interviews, interview questions were sent to interview participants, enabling them to address the questions thoughtfully [29]. To ensure confidentiality, participants' names and their respective building organizations were coded [30–32]. Thematic analysis was used in this study, From the last interview, only a few new codes were found that show the theme saturation and that the number of interviews was sufficient [33].

4 Demogrphic Information

Selecting interviewees started by contacting several private and public construction firms to seek their help in selecting specific interviewees. Sixteen interviews were conducted with Iraqi construction experts and professionals. As seen in Table 2, all interviewees had extensive construction industry experience ranging from eight to 40 years. Their roles often varied, including site engineer, contractor, project manager, senior manager, and president. They worked in the public or private sector or as independent consultants, while organizations' main roles include all key players in industry, client, consultant, and contractor, ensuring rich data from various perspectives.

5 Interview Result

Every interview was transcribed, and any additional notes were taken immediately after the interview. This information was then coded and organized in a separate folder to enable using thematic analysis. When conducting the thematic analysis, each transcript was repeatedly checked to narrow down and organize key themes that became the research's main findings. The interviewees were asked to indicate their views on whether or not they found the elements important to the Iraqi construction industry and if there are new elements not included in the list. Some elements were changed based on interview results. The validated elements would be used in the second phase of the study, focusing on establishing relationships between the elements and implementing safety programs.

Interviewees verified the importance of most identified components. Some elements were listed more frequently than others (safety objectives, safety policy, safety committee, training), indicating their relative importance.

Both interviewees recognized the importance of safety and its impact on productivity, staff morale, the achievement of project goals and company credibility. They decided that introducing safety programs is an essential step towards improving safety in Iraq's construction industry. To successfully implement safety programs, several elements are considered especially important by the interviewees.

Table 2 Demographic profile of the interviewees

No.	Position	Education level	Experience (Years)	Sector	Organization function
1	Director	BSc	30	Private sector	Contractor
2	Project manager	PhD	28	Government	Client/Developer
3	Site engineer	MSc	20	Government	Contractor
4	Senior manager	BSc	24	Private sector	Client/Developer
5	Consultant	PhD	40	Independent Consultant	Consultant
6	Senior manager	PhD	30	Independent Consultant	Consultant
7	Project manager	PhD	35	Independent Consultant	Consultant
8	Site engineer	MSc	15	Government	Client/Developer
9	Director	PhD	28	Independent Consultant	Consultant
10	Site engineer	MSc	12	Independent Consultant	Consultant
11	Site engineer	BSc	8	Private sector	Client/Developer
12	Director	MSc	25	Independent Consultant	Consultant
13	Project manager	PhD	22	Private sector	Contractor
14	Senior manager	MSc	15	Private sector	Contractor
15	Site engineer	BSc	10	Government	Client/Developer
16	Consultant	MSc	25	Independent Consultant	Consultant

First, safety objectives should practical, actual and clear to all staff to prohibit the employee's discouraged from achieving the goal. Second, safety policy. The foundation of safety management should be safety policies. Safety policies include the direction to reduce hazards that's may causes injuries and to improve the effectiveness of safety program.

Third, the safety committee tries to encourage workers' protective practices and injury prevention. It also offers a useful way to support prevent accidents in the workplace. The safety committees will help review and update the safety rules of employment and implement preventive control measures based on the findings of accidents, on inspection results, on hazardous work reports of employees and on acceptance and response from employees of unknown concerns and suggestions [9, 27]. Forth, safety training is another aspect often stated by the interviewees. Safety training is clearly important to improve the safety skills and awareness of the project workers. Such training is often required in order to educate workers before undertaking any research on the risks and hazards.

In addition, the interviewees suggested to use the previous elements as an activity to achieve the goal of safety and improve safety performance by implementing safety program. Furthermore, these activities can used as a procedure to implement safety program in developing countries construction industry.

6 Conclusions

The aim of this study is to identify the elements of safety program implementation in developing countries. Interviews conducted with industry practitioners in the Iraqi construction industry. The interviewee was selected based on the experts on construction industry particularly by contractor, client, and consultant. The interviewees confirmed the relevance of 25 safety program elements and suggest using the elements as a procedure to implement safety program in developing country construction industry.

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Impact of Coir Geotextiles to Reduce Soil Erosion and Surface Runoff

Muhammad Talha Zeshan, Muhammad Raza Ul Mustafa, and Khamaruzaman Wan Yusof

Abstract Soil erosion is a serious environmental concern in which soil particles are detached and ultimately cause land degradation. This process occurs abundantly in watershed areas of Malaysia due to the exposure of heavy rainfalls throughout the year on steep slopes. It has been observed that geotextiles are effective in minimizing soil loss and runoff. In this study, coir geotextile was used to analyse its impact in terms of soil loss and runoff control at rainfall intensities of 40 and 60 mm/h, which are average rainfall intensities of Perak, Malaysia. The experiment was performed in the laboratory using sandy loam soil as a substrate under a rainfall simulator at a steep slope of a 30° angle. The decrease in soil degradation from treatment in comparison to the bare slope was observed to be very remarkable, i.e., up to 99% at rainfall intensities of 40 and 60 mm/h. Similarly, the effectiveness of coir geotextiles to minimize runoff was also found significant, approximately 4% at rain intensity of 40 mm/h and 7% at precipitation intensity of 60 mm/h. The study has effectively shown the ability of natural geotextiles for soil protection and runoff control.

Keywords Soil erosion · Geotextiles · Soil conservation · Surface runoff

1 Introduction

Land deterioration which is mainly caused by farming, harvesting, mining, logging, and development activities, leads to increase soil erosion rates, ultimately giving rise to the destruction of economic, social, and environmental aspects [1–5]. The highest rate of soil erosion is typically established in areas influenced by development, construction, or industrialization [6]. In general, the issue of soil erosion has a social, environmental, and economic effect across the World [7]. In Malaysia, significantly a large area is used for cultivation and farming which causes the upper layer of soil becomes soft, which promotes the degradation of the soil particles particularly becomes severe due to the strong impact of heavy rainfall. Soil erosion, with an

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estimated annual load of 2 to more than 100 tons/ha/year of sediments, was recorded from the year 2010–2013 [8].

Civil engineering works are often exposed to unvegetated slopes, which are vulnerable to soil erosion and are induced by the effect of raindrops or surface flow [9]. The rate of soil erosion on these slopes can be minimized by growing thick and well-established vegetation cover [10]. However, the growth of vegetation covering may be interrupted during the initial stage of plant growth, rendering these slopes susceptible to more erosion events with adverse effects for the sustainability of the slopes [9]. Since soil plays a significant role in atmospheric processes such as nutrients, carbon, and water while holding the primary number of species on earth. Thus, the need to preserve the soil is very important [11]. That is why there is a rise in soil conservation work with vegetation, mulches, and other measures to control soil erosion [12]. Therefore, different geotextile materials are used for better conservation of soil on these slopes. The adoption of geotextiles as flood prevention tools has been recorded since the thirteenth century [13]. Geotextiles made from natural materials are incredibly efficient in reducing erosion and promoting the growth of vegetation. These natural materials can be more effective than synthetic counterparts in mitigating deterioration due to their improved ability to adhere to soil [14]. Many studies have focused on determining the efficiency of environment-friendly geotextiles for the reduction of soil degradation and runoff [15, 16]. The effectiveness of geotextiles is based on the length, gradient and type of slopes that are to be protected. It has been observed that the high intensity of runoff with increased sediment detachment is generally caused by prolonged and steep slopes [15].

It appears from literature that mostly studies were conducted in the field on small slope angles and there are only limited studies observed on steep slopes. Therefore, this study mainly focused to evaluate the effectiveness of coir geotextile materials under laboratory conditions at steep slopes. Hence, the objectives of this study are (i) to assess the impact of coir geotextile to minimize soil erosion and runoff in any catchment and (ii) to compare the efficiency of the coir geotextile material with a bare slope of the same angle.

2 Materials and Methods

Coir material was used as a geotextile mat for surface covering of the exposed slope. A rainfall simulation system was utilized to distribute rainfall at the measured intensity on the slopes. The Total suspended solids (TSS) filtration system was used to measure soil loss. A 2100P Portable turbidity meter was used to measure the turbidity of the water sample. Whatman no. 1 filter paper was used for filtration of the soil particles from runoff samples.

2.1 Framework of Experiment

The laboratory experiments were performed using the rainfall simulators in the Hydrology lab at the Universiti Teknologi Petronas, Perak Malaysia. The setup was preferred to be installed in the laboratory to decrease the disruption that is caused by unpredictable climatic conditions in the field, i.e., intensity and duration of rainfall, temperature fluctuation, variation in the length of slopes etc. Rainfall simulators are being used by researchers since the 1930s to evaluate soil erosion by the impact of rainfall [3, 5]. The formation of the laboratory-scale setup for observing soil loss and surface runoff (Fig. 1).

Before the experiment, the soil to be utilized in the slopes was air-dried for 24 h and then filtered through a circular sieve with a diameter of 18 mm. The substrate for the composition of the bed of slope was the soil accessible on-site, which was compressed with a steel rod of 2.45 kg weight after each addition of 3 cm of soil. To ensure that a uniform bulk density of 1.1 g/cm^3 was achieved for soil, the same soil volume was homogenously compacted for the container of geotextile covered slope [17]. The description for the experiment is shown in Table 1, the rainfall was directed to the slope at a rate of 40 and 60 mm/h, and soil erosion was measured. The detached

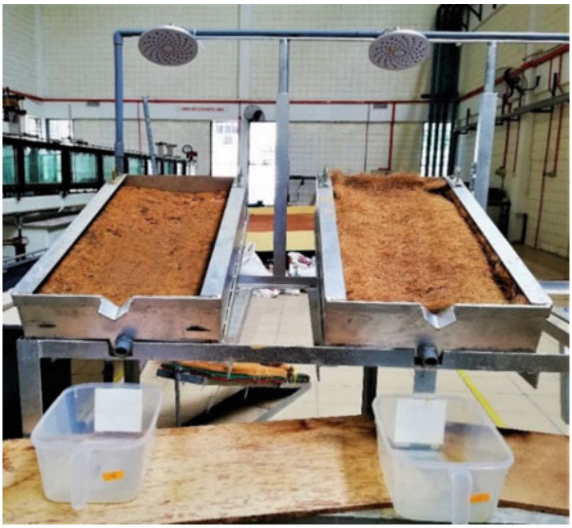

Fig. 1 The illustration of the laboratory-scale configuration used in the experiment

Table 1 The description of laboratory experiments

Type of substrate	Slope (°)	Rainfall intensity (mm/h)	Duration of interval (min)	Cover type	No. of experiments
Sandy loam	30	40, 60	10	Bare, coir geotextiles	40

Table 2 Important properties of geotextiles material

Treatment	Fibers	*RS (m^2)	Thickness (mm)	*M/A (g/m^2)	*TS (kN/m)	Durability(years)	*E%
Coir mat	100% coconut	10*1	11	360	10	3–7	11

* Roll size; * Mass/unit area; * Tensile strength; * Elongation at break

soil particles and runoff produced from the slopes were captured in the beaker after every 10 min interval. The quantity of runoff gathered was estimated. After runoff was measured, it was transferred through the Total Suspended Solid (TSS) filtering system. Where the separated soil particles were measured at each interval, and the soil loss was achieved.

2.1.1 Materials Utilized to Analyze the Impact of Soil Erosion and Runoff

The two materials (bare and coir geotextile) were analysed on a 30° slope. The main characteristics of geotextiles material used in the experiment are given in Table 2. Coir geotextiles are popular natural fibre material mainly applied to impermanent soil stabilization and erosion protection. Coir matches natural soil in its ability to control sunlight. It ensures that there is no chance of overheating, which often occurs in the context of synthetic materials [18]. The material is exceptionally resistant to degradation and can withstand high stress, is highly durable, but relies on the environment and conditions used. It retains less water so that it does not degrade quickly [9].

2.2 Data Collection

After the application of rainfall on the slope, loss of soil and runoff was assessed. The runoff depth was calculated directly in the beaker, while the TSS filtration system was utilized to evaluate soil loss. Runoff samples were evaporated in the oven at 110 °C until the water was dried up to estimate the remained sediments. By summarizing, the factors measured for each plot and event were soil erosion (g/m^2), the turbidity of flowing water (NTU), and runoff (mm^3/l). To achieve a mean value, three observations of each sample were averaged. For the comparison of soil erosion and runoff from bare (control) and coir geotextiles covered slope, soil loss reduction effectiveness (SLRE) and runoff reduction effectiveness (RRE) were calculated by using Eqs. 1, 2 [12].

$$RRE = \left(\frac{(R_{control} - R_i)}{R_{control}}\right)100 \tag{1}$$

$$SLRE = \left(\frac{(SL_{control} - SL_i)}{SL_{control}}\right)100 \tag{2}$$

3 Results and Discussion

3.1 Soil Loss Analysis

The soil loss attained at 30° bare and geotextiles covered slopes having a rainfall intensity of 40 mm/h (Fig. 2a). The amount of soil loss obtained at bare slope having 10 min interval was 57.41 g/m^2 and at 100 min 79.33 g/m^2. However, in comparison to the bare slope, soil particles detached at slope covered with coir geotextile material was decreased due to the protective action of coir geotextiles. The quantity of soil particles degraded at 10 min was 0.1452 g/m^2 and rose consistently with a peak value of 0.1649 g/m^2 at 100 min interval.

The relationship between the amount of soil loss obtained at bare and coir geotextile covered slopes at 30° angle with rainfall intensity of 60 mm/h (Fig. 2b). The amount of soil achieved on the bare slope at 10 min interval was 94.03 g/m^2 which increase consistently with the increase in time having a peak value of 113.36 g/m^2 at 100 min interval. On the other hand, the soil loss observed at the coir geotextile covered slope was 0.1614 g/m^2 at 10 min which steadily grow until 40 min interval with average soil loss of 0.1790 g/m^2. The abrupt reduction in the rate of soil loss was attributed to the blockage of soil particles in the fibers of coir geotextiles [12]. The peak value of soil loss was estimated at 100 min interval with 0.1806 g/m^2.

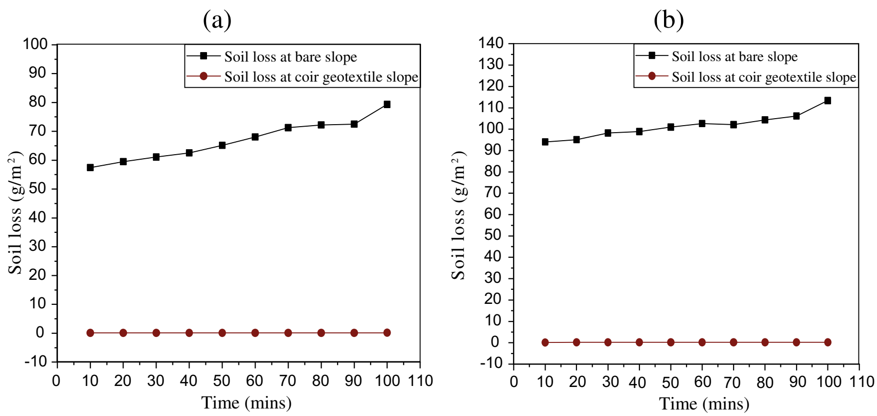

Fig. 2 Soil loss at bare and coir geotextile covered slopes with rainfall intensities **a** 40 mm/h at 30°; **b** 60 mm/h at 30°

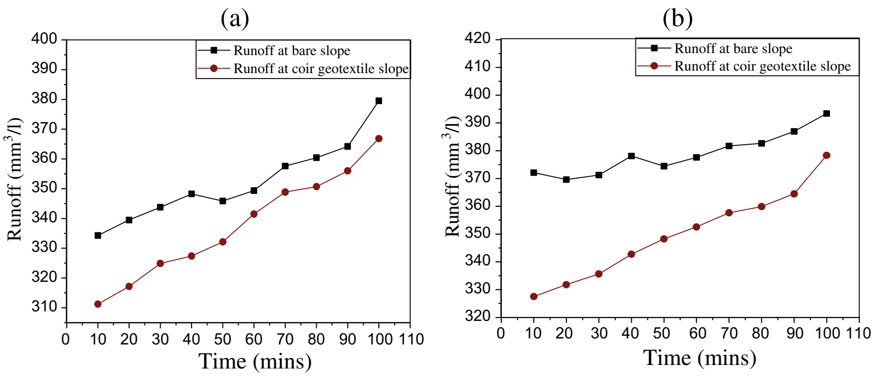

Fig. 3 Runoff generated at bare and coir geotextile covered slopes with **a** 40 mm/h at 30°; **b** 60 mm/h at 30°

3.2 Runoff Reduction Analysis

The comparison between the volume of runoff obtained at 30° bare and coir geotextile covered slopes (Fig. 3a). It was assessed that runoff was approximately ascending with increment in time; at 10 min, the runoff produced was 334.31 mm^3/l, which proliferate to 379.52 mm^3/l at 100 min interval due to continuous impact of rainfall on the slope. While runoff generated at coir geotextile was observed to be less as compared to the bare slope due to the absorbance of runoff water in the soil by infiltration. However, at this slope quantity of runoff enhanced consistently having 311.24 mm^3/l of runoff at 10 min to the maximum value of 366.86 mm^3/l at 100 min.

The relation of runoff flow at bare and coir geotextile covered slope having rainfall intensity of 60 mm/h (Fig. 3b). It was observed that the amount of runoff collected on the bare slope was 372.13 mm^3/l, which increases with time and escalates up to 393.41 mm^3/l at 100 min. In comparison, on coir geotextiles covered slope, the amount of runoff obtained at 10 min was 327.52 mm^3/l and rose to 378.35 mm^3/l at 100 min interval.

3.3 Turbidity Comparison of Water Samples

The comparison in turbidity of water samples obtained from 30° bare and coir geotextile covered slope at rainfall intensity of 40 and 60 mm/h (Fig. 4a, b). It was observed that the value of turbidity was maximum at the bare slope relative to the coir geotextile slope. This was estimated that soil particles that flow in the form of runoff were blocked in the twisted fibers of coir geotextile that causes a reduction in the quantity of soil in the water samples obtained from the slope.

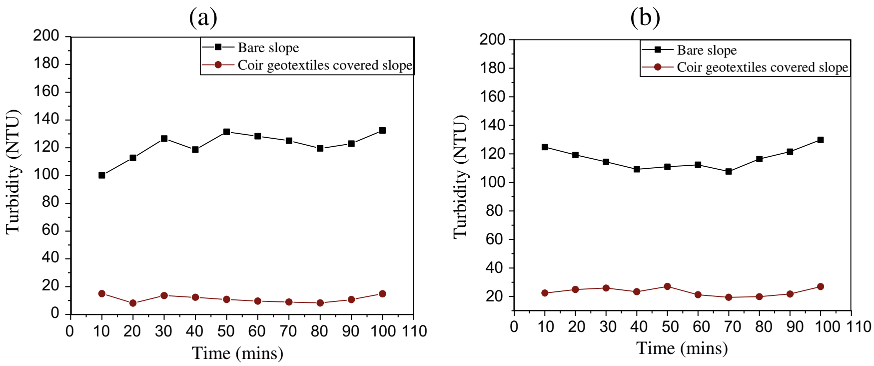

Fig. 4 The water quality measured at rainfall intensity **a** 40 mm/h; **b** 60 mm/h

4 Conclusion

Coir geotextile has tremendous potential for alleviating soil degradation, maintaining the fertility of the soil and promoting vegetation development in those areas that are prone to soil erosion. In this study, the response of coir geotextile under simulated rainfall based on a lab-scale setup was observed. The arrangement of the experiment includes severe conditions, involving steep slope and multiple rainfall occurrences.

Based on the results, the following conclusions were obtained:

- The coir geotextile effectively reduced soil loss up to approximately 99% on 30° slope at both rainfall intensities (40 and 60 mm/h).
- The effectiveness of coir geotextiles to reduce runoff at 30° slope with rainfall intensities of 40 and 60 mm/h was up to 7% compared to the bare slope.
- Similarly, the rate of turbidity was also decreased in the water samples obtained at slope covered with coir geotextiles with a peak value of 14.90 and 27.03 NTU at rainfall intensity of 40 and 60 mm/h.
- The maximum turbidity values of 132 and 129 NTU were obtained in the water samples collected from the bare slope at rainfall intensity of 40 and 60 mm/h, respectively.
- Moreover, the experimental studies indicated that the intensity of precipitation events play a key role in causing soil erosion.

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A Study on Spatial Healing Environment for Post-traumatic Stress Disorder

Nur Atilia Ahmad Sani and Mohd Hafizal Bin Mohd Isa

Abstract Spaces for healing represent some of the most personal and complex services provided: intimate personal information must be shared with strangers; complex and often frightening situations might occur, where the staff speaks an entirely different language [1]. Studies have shown that buildings that are designed with little therapeutic qualities then frequently heighten the levels of stress in patients, staff, and families. A lot of beliefs and possibilities in terms of designing a healing environment through spatial awareness regarding all the social and humanities issues that have been evaluated. Thus, the focus of this study is to highlight the possible architectural solutions in creating a healing environment through spatial quality in space design. Based on the research that has been done, architectural elements and principles to be applied on spatial healing have a high tendency to restore the healing environment with the stimulation of human senses. These architectural elements will stimulate a positive healing environment that can enhance and support the care of mental health.

Keywords Spatial healing · Spatial awareness · Architectural elements · Stress · Social issues · Positive healing environment

1 Introduction

"Healing environment" can be described simply as the overall environment (both physical and non-physical) created to aid the recovery process. In contrast to curing, healing is a psychological and spiritual concept of health. As perception is also psychological, there is a likelihood of a relationship between healing and the physical environment [2]. The principle of healing atmosphere is a technique that Florence Nightingale has developed since 1859, using the theory of nursing called for nurses to control the environment to be therapeutic where the parameter produces a calming environment to enhance the patient's self-healing capabilities [3].

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The objective of this study is to identify what are the spatial environments that can help in an improving healing healthcare environment and focuses on the exploration of the insight of live experience on spatial awareness and on the individual's ability to heal. It involves understanding the relationship within the spaces when there are changes done. User situations, conceptual meanings, materiality, and user experiences are analysed to study architecture as an urban piece that can be adapted to a variety of situations. This study also seeks to provide a medium for creating an intimate connection between human beings and architecture, hence triggering the human senses in a way that viewers cannot remain as pure spectators but must become players within the spaces.

2 Literature Review

This section highlighted literatures reviewed relevant to the study, from understanding the relations of mental health disorder, going deeper into type of stress disorder, the kind of treatment related to the disorder connected to the cognitive study of healing environment towards psychological impact on humans with elaboration of architectural design elements that can create spatial healing environments.

Health is a state of complete physical, mental, and social well-being, not just the absence of illness or infirmity. Mental health definitions include subjective well-being and acknowledgement of the ability to realize one's intellectual and emotional capacity [4]. Mental illnesses are medical conditions that often lead to a diminished ability to cope with ordinary life-related demands, and post-traumatic stress disorder (PTSD) is one of the most serious mental illnesses. 'Healing environment' can be defined as the overall environment generated to help the process of recovery where the interaction between patient and staff produces positive health outcomes within the physical environment [5]. Globally, interest in the creation of a healing atmosphere has increased [6].

Understanding mental health disorder where the psychological well-being is more than just a lack of mental disorders. It is a disease that affects memory, emotion, and behavioral regulation and greatly interferes with children's ability to learn and with adults' ability to function in their communities, at work, and in the wider society [7]. Many mental illnesses were associated with an irregular functioning of circuits of nerve cells or pathways that bind brain regions. There are factors that may be involved in the development of mental health disorder include: genetics, brain defect or injury, environmental exposures before birth, early life environment, trauma and stress, and personality factors. There are many types of mental health disorders and there almost 300 different types that are affecting people. Some of it are, anxiety disorders, mood disorders, psychotic disorders, personality disorders, obsessive-compulsive disorder, and post-traumatic stress disorder. PTSD is a disorder developed by some people after experiencing a shocking, frightening, or dangerous event. The fear triggers many split-second changes in the body to respond to danger in the future and help a person avoid danger. The symptoms of PTSD involve reliving the trauma in a way like getting upset when confronted with a painful reminder, staying away from places or people reminding you of the trauma, and things like watchfulness, irritability, or easily startling [8]. Three different types of symptoms experience people with PTSD. The first collection of signs involves reliving the trauma in a way like getting upset when confronted with a painful reminder or worrying about the trauma while attempting to do something else. The second set of symptoms include either staying away from places or people reminding you of the trauma, isolating or feeling numb from other people. The third set of symptoms includes things like watchfulness, irritability, or easily startling [8].

Healing is a dynamic process of mind, body, and soul healing, and transformation on the road to becoming a happier individual. It is an emergent process of the person's whole system-physical, mental, social, spiritual, and environmental. Globally, there has been an increase of interest in the creation of a healing environment [6]. Through enforcing this effect, architecture has the power to indirectly improve the immune system and this theory can be used as a guide for designing spaces for healing. Healing by architecture and architectural design discusses how a healing space's architecture can become an integral part of healing itself and how it can play an active role in the healing process.

Through the identification of living patterns, it plays important relationships between system elements and provides a unique and valuable method for complexity management and organization. Behaviour patterns in any field of human activity, evolve over time with constant repetition, each repetition being rooted in and learned from its predecessors. Behaviour patterns in any field of human activity, evolve over time with constant repetition, each repetition being rooted in and learned from its predecessors. A dozen living patterns selected from Christopher Alexander's *A Pattern Language* [9] can help architects get beyond this deplorable practice. Reading these living patterns should evoke a sense of human space that envelops and nourishes the healing spirit that can go far beyond strict mechanical utility. There is a lot of effort that has been categorized into cataloguing design trends that can be successfully implemented for our daily humanity [9]. Spatial orientation and situational awareness are words often used to explain how people can identify where they are in space and how they can avoid getting lost or disoriented [10]. Wayfinding possibilities must be strong—finding your way to wherever you want to go must be convenient. Good orientation requires both indoor and outdoor landmarks, ability to survey upon arrival, a minimum of choices to be made within the main entrance, and a simple, distinct traffic hierarchy. Creating a social atmosphere with a view to seclusion by attempting to orient each wing in the direction that could work optimally could also help to give the consumer the secluded effect by separating the spaces by its purpose. Users need to be motivated and embraced by having a space that is usual and familiar. To give the user their own identity and the ability to choose between seclusion and sociability to help them feel open to communicating with this social support [11].

In relation to [12], understanding the role of sensory stimulation in the architecture field is important because "we experience the world through our senses; it is through them that a relationship with the world is made possible". Integrating all the senses helps to complete an environment's highest potential to allow healing to emerge. The sound of moving water, for example, is one part of a room that can evoke feelings for relaxation and peace. Architectural colours provide the occupant with visual stimuli that can produce positive and negative emotions depending on their environment. The colour's properties can also set the tone for spaces, requiring some emotion. Colours can affect many aspects of our lives, including our mood, mental state, and energy level, depending on colour therapy.

The surface and edge tactile qualities we experience affect one's haptic sense and trigger specific movement. Textural variations can prompt users to speed up or slow down their travel rate, or to indicate areas inside buildings. By using textures and tactile qualities in a variety of ways, designers may create a full "movement choreography." [10]. This element of the tactile contact mode is fundamental to human spatial experience and was used as a powerful force in the building design. We live in a world of colour [9]. According to various researches, the colour that surrounds us in our daily lives has a profound effect on our mood and on our behaviour [6]. In clothing, interiors, landscape, and even natural light, a colour can change our mood from sad to happy, from confusion to intelligence, from fear to confidence. It can be used to "level out" emotions or to create different moods [8]. The design of an environment through a variety of means such as temperature, sounds, layout, lighting, and colours can stimulate perceptual and emotional responses in consumers and affect their behaviour [12]. Besides, Light creates more than just visual effects (image, shape, intensity, perception, contrast, etc.); it also has biological and psychological effects that can impact the health and wellbeing of humans. The intensity of light could also have an impact on the intensity of our emotions [4]. Kaplan and Kaplan (1989) found that when we are exposed to a new environment, we tend to cognitively try to find a match in our memory that fits the new environment. This is where lighting can come in. It can be used to highlight building elements, spaces, paintings, textures, etc. that people may find familiar [13]. The presence of daylight reduces pain and the incidence of depression [11]. Healing gardens are places to enhance or restore the mental or physical health of a person. Today, a rising facet of landscape architecture is therapeutic landscape design. Basic design features in a calming garden can help users spend time alone or socialize, walk freely or more aggressively, and enjoy the warmth of the sun or shade shelter. Ecotherapy provides a healthy environment for people and it gives people permission to admit that they are out of balance and help in balancing the pace and stress of life [14].

3 Methodology

The main data collection approach included questionnaires and through case study building that are designed to learn more about human perspectives towards human personalisation with traumatic stress and the effect of the healing environment towards their emotions, their senses and how it affects their psychological experiences within the built spaces. Data collection included evaluating respondents 'psychological condition to allow researchers to examine the mass society's emotions, opinions, behaviours and beliefs. Through considering the respondent's preference of spatial healing designs and their sense of how it contributed to their interaction with the physical space and its features (e.g., inpatient room, lighting, and colours). Qualitative data were obtained by asking respondents and professionals in similar fields to assess specific aspects of their experience and the physical environment. Through case study building, a building has been chosen as a reference to study the feature of designs implemented in the building design that seems can contribute to the healing process. There are certain criteria that has been considered through the case study building which are daylighting, ventilation, view, and gardens, and also the health benefits that the building might consider its design can contribute.

4 Data Analysis

As the researcher reviewed the result data from the questionnaire and the transcribed notes from the interviews, key phrases were analysed that explained how respondents identified their current psychological condition, their perception of healing spaces, and their physical care environment healing experiences. Results were analysed and summarized to reflect the concept of the healing spaces felt by respondents. The relationship between space phenomenology and healing factors will be further discussed in exploring how space design elements can induce some healing spaces by manipulating design principles. From the questions in the questionnaire in Section B, the questions are most likely linked in determining the levels of stress and anxiety of respondents, where it can be inferred here that most of the respondents involved will have general symptoms of stress and anxiety. Some have characterized symptom-free as having almost never encountered respiratory difficulties (e.g. overly rapid respiratory, physical exertion). The experience of stress and anxiety are basically typical symptoms that people might have experienced sometimes. Some of the respondents described that they are often to have the symptoms of stress and anxiety in their daily life as they feel quite often to feel worthless and keep getting impatient when things are not going the right way. Participants described a healing space in terms of the physical attributes of the space and its relationship towards occupant's movement.

They decided mainly to have enough space and the most listed were not feeling crowded or closed in. Certain physical qualities associated with healing spaces included feeling intimate, natural lighting and nature incorporation within the designated spaces. Many respondents agree that a spatial healing atmosphere will turn you into a healthier state. They focused more on seeing views of nature as therapy for healing. The ceiling height also has a major impact on a person's mental, as most respondents prefer spaces with a high ceiling level that can generate more ease of feeling towards the occupants. The respondents have selected the combination of natural lighting and artificial lighting higher and they also choose spaces designed with curved walls, accompanied by a combination of curved walls and linear walls in the built spatial. It is likely that certain environmental factors that have been shown in the questionnaire plays an important role for lessening stress and aggression and some features may interact.

In summary, spatial awareness may diminish the occupants 'obstacles to express their changing state of mind, soul, and feelings. Respondents defined healing spaces that are built with delicate features that consider occupants' opinions may create a positive feeling state or feeling of comfort evoked by the room.

5 Conclusion

Spatial awareness plays important roles as one of the solutions to stimulate the healing environment in a building. Although healing is more involving psychological state in a person, with more research done, it does affect physical health also. Spatial healing environments suggest readdressing user's problems and to invoke a sense of creating an environment, indoor and outdoor, that can incorporate occupants' psychology. Thus, spatial awareness is important to highlight the 'healing environment' by considering the user's feelings towards the overall phenomenology of space for healing.

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The Application of Textile Waste as a Sound Insulation Building Material

Muhammad Ersyad Ahmad Jailani and Mohd Hafizal Mohd Isa

Abstract It is essential to adopt more sustainable behaviours in today's world. In this research study, the potential of textile waste as a sound insulation panel to solve the problem of noise pollution is identified. The aim of this paper is to investigate the type of textile waste that can potentially be converted into insulation material to solve the problem of noise pollution. The sound that is too high in decibel may create noise and harms the humans' hearing ability to the point it is called noise pollution. A quantitative approach is adopted in this study which is by conducting the sound absorption coefficient measurement method. The results show that the application of textile waste as sound insulation is able to absorb sound and reduce the reflected sound. The usage of cotton as sound insulation shows better sound-absorbing efficiency compared to other materials. The usage of textile waste not only able to reduce the noise levels but also can give a positive impact on the environment and economy.

Keywords Sound insulation · Noise control · Building insulation · Sustainable material · Textile waste

1 Introduction

Textile recycling is the process of recovering fabric or other textiles and reprocessing the material into useful products [1]. Textile production wastes cover all those raw materials which are either accruing or being used in the textile industry such as production remnants, wastes from fibre and filament manufacture, wastes from spinning, weaving, knitting and making-up as well as reprocessed materials and textile [2]. This trend has been seen growing globally since there is awareness of textile waste. The consumption of global textile is estimated at over 30 million tons per year, which has a significant impact on society and environment in the supply chain [3]. Hawley [4] proved and has overseen this very trend of recycling textile due to

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overconsumption and waste generation in global fashion and culture, textile recycling has becoming key issues in achieving sustainable fashion worldwide. Globalization has led to a “fast fashion” trend where clothes are considered by many consumers to be disposable due to their increasingly lower prices [5]. This shift of movement is the main event that has caused textile to be overproduced in a quick period of time, where the supply exceeds the demand.

Textile recycling techniques have been developed to cope with this increase in textile waste and new solutions are still being researched [6]. Globally, the amount of textile waste produced is vast as mentioned in this context. Although textiles are said 100% recyclable [7], the ratios of textile recycling even for developed countries such as the United States are as low as 15% [8]. This shows that the rate of textile recycling is still low and is not enough to prevent the generation of textiles completely. As textile waste is continuously growing and public health faces harmful effects, it coherently gives humankind so many problems, especially with the prevalent water and air pollution.

Noise control issues and the emergence of sound quality are becoming very important in automotive product design, insulation, acoustic material and is increasingly relevant to engineers, designers, and manufacturers from a broad image of industries [2]. Sound absorptive materials are generally used to counteract the undesirable effects of sound reflection by hard, rigid and interior surfaces and thus help to reduce the reverberant noise levels [9]. In a human’s environment, acoustic comfort is one of the basic needs. The use of sound insulation is crucial in keeping the balance of comfort in humans’ lives. As it is known that noise interferes and disrupts communication, by having textiles as new innovations of sound insulation help to improve acoustic comfort in room. In fact, many geographical areas or particular jobs may be at a higher risk of constant exposure to high levels of noise.

It is important for research and development of efficient and environmentally friendly sound insulation materials [10]. The objective of this research is to identify the potential of textile waste as sound insulation. This research also investigates the type of textile waste that can absorb sound efficiently to reduce noise. In this context, by using textile waste as sound insulation, it is like killing two birds with one stone. Both types of pollution can be controlled and reduced simultaneously. Apart from that, as technology thrives to discover the optimum sound insulation, researchers too are making an initiative to study and analyse the best composition for maximum absorption of sound with minimal production cost.

2 Research Methodology

Most past researches that are involved with sound insulation adopted a quantitative approach. In order to evaluate the performance of sound insulation materials, the sound absorption coefficient measurement method is carried out. The properties of the samples are measured before carrying out the experiment. This method is used to analyse the correlation of the sample properties and sound absorption coefficient measurements. The results of the sound absorption coefficient between each sample are analysed through the values of the Noise Reduction Coefficient. This is to determine the efficiency of sound absorption for each sample.

2.1 Sample Fabrication

The five common types of textile waste were identified which are polyester, silk, linen, viscose, and cotton. These types of textile waste were also selected based on availability which was supplied by Kloth Cares. This organization collects both pre-consumer and post-consumer textile waste to provide new purpose to textile waste. Sample fabrication consists of two phases. The first phase is the pre-treatment phase. All unwanted elements like buttons, metal parts, and sewing thread are removed. The textile wastes were washed to remove any dirt and contaminants. Later, the washed textiles were sun-dried to eliminate water. The second phase is the preparation phase. Small pieces of 5 cm length were cut from each type of textile. A few layers of small pieces were then bound together with PVA (Polyvinyl acetate). Each type of textile was then pressed into a mould of 0.5 cm thickness to produce a round shape and size that can fit the impedance tube measurement system. Each sample was given enough pressure to bind while retaining the sample porosity.

2.2 Porosity Measurement

In order to collect the porosity of each sample, the thickness, mass, and fiber density are identified (refer to Table 1). Textile porosity refers to the total void space within the volume of the textile. The porosity, $P(\%)$, of the graft is calculated as seen in (1).

$$P = 100\left(\frac{1-M}{1000} \cdot h \cdot \rho\right) \tag{1}$$

M mass per unit area (g/cm^2) of the textile

Table 1 The properties of the samples

Textile fibers	h, thickness (cm)	M, mass (g/cm^2)	ρ, fiber density (g/cm^3)
Polyester	0.5	13.93	1.22
Silk	0.5	12.42	1.32
Linen	0.5	10.80	1.50
Viscose	0.5	10.07	1.53
Cotton	0.5	9.68	1.55

h thickness (cm) of the textile
ρ relative density of the fibre (g/cm^3).

2.3 Sound Absorption Coefficient Measurement

A sound wave incident on a material can be absorbed, reflected and/or transmitted by the material. These three phenomena are all possible depending upon the types of material. The absorption of the incident sound wave is an effective way to control noise [11]. The impedance tube measurement system is used to carry out the sound absorption coefficient measurement [12]. The sound absorption coefficient of sound insulation material is obtained from the ratio of reflected and incident waves produced which expressed in the range of 0–1. The calculations for sound absorption coefficient (α) measurement can be expressed as seen in (2).

$$\alpha = 1 - \frac{I_r}{I_i} \tag{2}$$

α = sound absorption coefficient
I_r = Intensity of reflected sound wave
I_i = Intensity of incident sound wave.

At different frequency ranges, the value of sound absorption coefficients is varied makes it difficult to determine which are the better materials in absorbing sound [13]. Based on Thumann and Miller [14], the Noise Reduction Coefficient (NRC) is used to indicate the value of the sound-absorbing materials. Equation (3) is the calculation of NRC.

$$NRC = \frac{\alpha_{125} + \alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}}{4} \tag{3}$$

3 Results and Discussion

The collected porosity and sound-absorbing coefficient data are tabulated in Tables 2 and 3. The porosity value of the samples ranges from 0.67 to 0.79 while the mass ranges from 9.68 to 13.93 g/cm^2.

Each sample was recorded five times for each frequency. Then, the mean of recorded data of each frequency is plotted (refer to Fig. 1). From the data collected, it is identified that each type of textile gives a very significant difference in the sound absorption coefficient. Different types of textiles produced varied porosity values. It is observed that the porosity is influenced by mass and fiber density. These properties have affected the surface and thread form of the textile. This in turn affects the quality

Table 2 The porosity of the samples

Textile fibers	*h*, Thickness (cm)	*M*, mass (g/cm^2)	*P*, porosity (%)
Polyester	0.5	13.93	0.79
Silk	0.5	12.42	0.75
Linen	0.5	10.80	0.74
Viscose	0.5	10.07	0.69
Cotton	0.5	9.68	0.67

Table 3 The sound absorption coefficient of the samples

Textile fibers	Thickness (cm)	Frequency (Hz)					NRC
		125	250	500	1000	2000	
Polyester	0.5	0.12	0.52	0.65	0.72	0.56	0.51
Silk	0.5	0.14	0.50	0.68	0.80	0.56	0.54
Linen	0.5	0.15	0.52	0.74	0.88	0.61	0.58
Viscose	0.5	0.18	0.54	0.76	0.89	0.66	0.61
Cotton	0.5	0.22	0.55	0.83	0.95	0.75	0.66

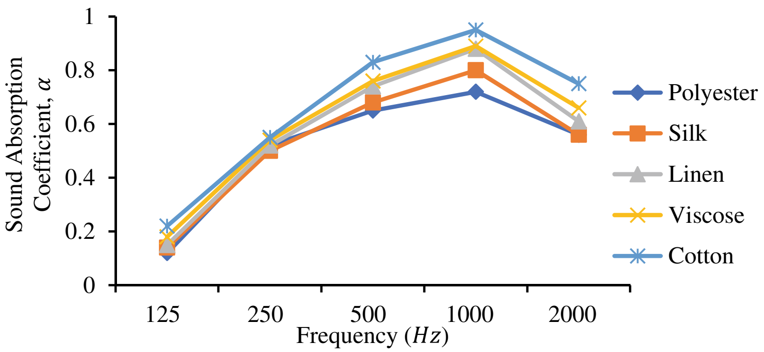

Fig. 1 The sound absorption coefficient of the samples

of the sound absorption. The line graph increases from frequency 125 Hz and peaked at 1000 Hz but starts to drop at frequency 2000 Hz. This can be due to the coincidence dip phenomenon which occurs when the incident sound wave is in phase with the reflected wave from the sample. This means these materials are not able to absorb sound efficiently at a frequency higher than 1000 Hz.

Based on the data of porosity, the polyester has the highest porosity value. According to Gajjar et al. [15], the material has more porosity if the value is near zero. However, the polyester produced the least sound absorption coefficient compared to other types of textiles. The porosity property influences the value of the sound absorption coefficient. This indicates the number of pores on the material surface needs to

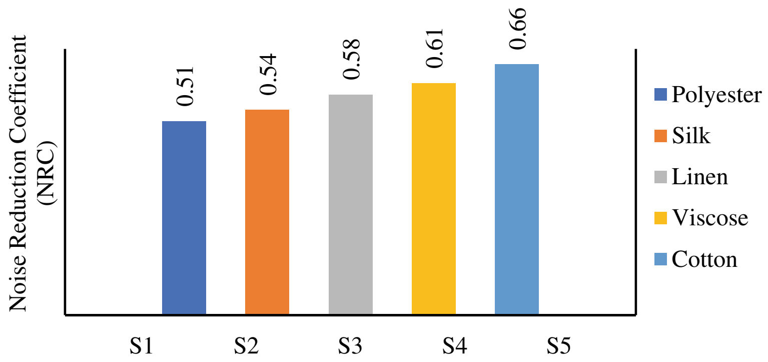

Fig. 2 The noise reduction coefficients of the samples

be sufficient for the sound to enter which will eventually get dampened. This can be supported by the cotton sample which has the lowest porosity value. Nevertheless, cotton produced the highest sound absorption coefficient. This means cotton has more porosity compared to other materials. If the material has more porosity, it has better ability in damping sound as sound can easily pass through.

Referring to Fig. 2, all types of textile have a very high Noise Reduction Coefficient (NRC) value. The value ranges from 0.51 to 0.66. This shows that these types of textiles can absorb sound since at least 61% of the sound is absorbed by the materials. These materials can be produced as sound insulation. However, this needed to be further studied in a bigger scale experimental procedure. Cotton has the highest NRC value which is 0.66. However, there is a major drop in NRC value when polyester is used. The major reason is the porosity properties that lead to absorption efficiency [16]. Polyester reflects more sound rather than absorbing it since there is less porosity compared to cotton.

4 Conclusions

The usage of textile waste as a sound insulation panel is beneficial as it costs less than using raw materials which is scarce. By using textile waste, it will also keep textile away from landfills. This study promotes an approach that does not only solve the issue of noise pollution but at the same time giving a value-added to the product. Followings show the potential of textile to be developed as a sound insulation panel:

- It is important that materials able to damp sound in a frequency range from 100 to 5000 Hz. All samples tested have the ability to absorb sound at a frequency of 1000 Hz. Most sound is absorbed by the materials which reduce the reflected sound that can cause noise.
- The existing porous structure of the textile helps to absorb the sound. This confirms that textile represent a valid option for sound insulation panel.

- Cotton material shows a better sound-absorbing property compared to other materials. Cotton has the best efficiency in absorbing sound due to its number of pores present in the material.

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Design for All Senses: Architecture and Cognitive Learning for the Visually Impaired

Lim Poh Im and Khoo Qian Sang

Abstract The paper discusses potential improvements of building spaces to aid cognitive learning of visually impaired persons. It begins with identification of sensory perceptions of the visually impaired, i.e. how the five senses are used in navigation, followed by challenges encountered in pedagogy and cognitive learning. This paper combines interviews with blind individuals and field observations carried out at the Malaysia Association for the Blind (MAB), Kuala Lumpur. The participants of this research consists of members of the MAB and a few other individuals. Findings revealed their the unique experiences, the role of sensory features, and the connections between architecture elements and cognitive learning of the visually impaired. The paper ends with a discussion on possible improvement to the design and conditions of their learning spaces.

Keywords Design for visually impaired · Architecture for visual impairment · Cognitive learning spaces for the visually impaired

1 Introduction

Architecture is commonly taken as a visual phenomena. The non-visual aspects of architecture however, appears to be utmost important to people with visual impairment, due to their special and unique sets of needs. These special needs ought to be recognized and be incorporated in special education, and in the design of their learning spaces. In Malaysia, recent statistics have shown that only one percent of the population had undergone special education compared to the global estimates of average ten percent.[1] As such, it is not uncommon to find that many visually impaired students are still attending schools where the environment are not able to meet their needs. Students with visual impairments have difficulty in recognizing objects and

[1] The low number is due to insufficient specialist, lack of universal approaches for detection and the under-utilization of screening tools (Malaysia Education Blueprint 2013–2025, 2013).

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people, let alone to learn in normal classrooms. This study seeks to investigate how visually impaired persons use their senses to accurately comprehend their environment and how building spaces can be improved to aid learning processes of the visually impaired persons.

2 Literature Review

According to the US National Library of Medicine, "Blindness is a lack of vision; referring to a loss of vision that cannot be corrected with glasses or contact lenses." There are two types of blindness. First is 'visually impaired', which is partial blindness where one has limited vision. Second is 'complete blindness' which means one cannot see anything and does not see light [1] Visual impairment can cause a decline in social and cognitive learning. This impairment can complicate learning ability and improvement of personal talents, resulted from the affected personal activities. Visual impairment makes it difficult in interpersonal relationships, for instance, in starting relationships, communications, or in understanding of others. Besides difficulties in comprehending the meaning of words, missing the messages, they can be perceived poorly in communication. When private needs of disabled persons are not provided, then improvement of the other abilities can be problematic.

A study by Hazelwood school team concluded five themes or factors, which would help to create a healthy educational and living environment for the visually impairment students.[2] These five factors include access to nature; kitchen and dining as primary social space; texture, colour and lighting to enhance sensory perception experience; landmarks and shorelines to support circulation, movement and navigation; and social interaction and community involvement.

Circulation and mobility are important as they define our existence in the world. The arrangement of a space should be dynamic, yet simple and clear. Consistency and repetition helps a person to orient and find ways. Other important component is colour, contrast and shadow. Research by the Alan Dunlop studio show colours of orange, red and yellow spectrum are the most recognizable for the visually impaired [2]. Specific selection of colour for different areas help students in way finding as well as orienting themselves in a space. Sound and space can also influence the living environment for visually impaired. Sound can also help in distinguishing open space from conventional classroom. Using different level of flooring to mark movement corridor from activity areas can produce change in sound, which can inform one whether he is standing on a movement corridor or an activity area [3].

Indeed, multi-sensory design is vital for the success of cognitive learning. It will stimulate the perception modalities, which in turn will have a positive effect on the visually impaired person's emotional state and learning process. According to [4] the tactile sense in human being is placed at the first place and it only needs

[2]Institute for Human Centred Design, Universal Design Case Studies—Hazel Wood School, retrieved from https://universaldesigncasestudies.org/education/primary/hazelwood-school.

other senses to further develop the experience. Visual sense in human cannot exist independently whereas tactile sense can. Architecture with good sensorial features helps in recognizing building layout, contributing to navigation and rehabilitation process by expressing space through materiality. The innovative selection of materials based on tactile, acoustic and aromatic properties can translate the use, scale and privacy of a space. Materials can give tactile, aromatic and acoustic clues about the route and surrounding spaces, which aid the process of way finding.

3 Method

This study employs mainly in-depth interviews and third-party observation strategies. The interviews were conducted with the visually impaired students between the age group of 13–26 from the Malaysia Association for the Blind (MAB). MAB is a premier voluntary organization in Malaysia serving visually impaired persons. A third party observation was conducted at the premise of the MAB. It was carried out by observing how the visually impaired users carried out their daily practices and routines. This method aims to investigate the barriers in the learning environment and highlight examples of good practices in the cognitive learning processes.

4 Findings and Discussions

4.1 Use of Five Senses in Space Navigation

For space navigation, the visually impaired persons preferred wide unobstructed spaces. No physical barrier such as furniture and decorations should be placed at the corridors. Other unwanted obstacles include open drains and sign posts. Furniture arranged in 'island' layout should be avoided to prevent 'tripping over'.

Landmark is an important clue in navigation. Just as normal persons use visual landmarks, the blinds use 'non-visual landmarks' to identify a location. The tactile experience is important as the blinds rely heavily on it to gather information about objects around them in navigation. Floor coverings play a vital role, just as using a cane as an extension of the arm. As the students walked down the hallway to the cafeteria, they tapped their canes along the tiled floor. They heard the cane taps and counted the doors to know where they went.

Most of the visually impaired interviewees preferred textured surface compared to flat surface. One participant, Siti[3] (not her real name) said she did not have any specific preference on tactile experience but as long as the materials were different.

[3] Siti is 25 years old, her highest education is secondary school in Setapak Blindness Special Education Secondary School (SMPK) (SMK Pendidikan Khas Setapak (B). She lost her sight after an accident when she was 12 years old.

To Pei Ling[4] (not her real name), “Most of the building surface in Malaysia are similar, unlike those in United Kingdom”. The placement of tactile blocks can be confusing, as some were not sure whether they should walk on it, or walk next to it as the blocks were not comfortable for walking. Carpet density is another important feature as it provides tactile clue to aid navigation.

Other than the sense of touch, senses of familiarity and memory are as important in navigation. According to Divya (not her real name), “The biggest challenge was that you could walk by something and not know what it is.” To orient in space, there is a need to know and remember where one is, to decide where and how one wishes to go. It is important that building elements provide a sense of empowerment to the users. For example, the blinds preferred manual doors compared to automatic doors as they allow independence in movement, which gives them better sense of control and confidence.

In the absence of sight, sound is another key navigational tool. The blinds are consistently good at determining the exact origins of the sound. According to Fizal[5] (not his real name), what helped him to orientate himself at the entrance of the building was to listen to sounds of people walking and the directions. He could tell “if something was blocking the way”; while to Ahmad,[6] “I can estimate the volume of a space by listening to the reflective sound (echo)”. Ali (not his real name) used reference points to tell where he was, and where he was going. He could tell an atrium from a hall or an enclosed room. “The sounds that could be incorporated into a building could be as direct as a tonal beep for a specific classroom or as subtle as the hum of florescent lights”, Ali lamented.

It should be emphasized that the visually impaired persons are not completely blind, so lights and color actually play a role in how the building is perceived. People with low vision can differentiate lights and colors. Ali[7] (not his real name) mentioned that he could see glares from window openings and doors; he can orientate himself by following the lights. When using color in designs intended for the visually impaired, it is best to pair highly-contrast colors placed with one another, as it is the ‘contrast between colors’ and not the color itself, that makes a hue easy or hard to see. Classroom especially, must be designed in such a way to stimulate the use of other senses to comprehend the environment.

On the connections of building elements such as ceiling height, lighting and acoustic levels, Hafiz (not his real name),[8] referring to the conditions of the reflexology room, pointed out that “high ceiling emit loud echo sound, makes it hard for students to concentrate; the spot lights too, emits glare that disrupts comfort to those

[4]Pei Ling is a visually impaired English teacher in MAB. She has 10 years’ experience as an English teacher and has been teaching in MAB for 4 years.

[5]Fizal had a visual impairment since birth. A few of his family members have the same condition.

[6]In primary school Ahmad ‘had normal vision, more or less’, but his sight deteriorated ever since, and he now only has vision in one eye and ‘everything is basically fuzzy, silhouetted’.

[7]Ali lost his vision when he was 13 years old and he is currently taking his degree in Sport Management, University Malaya.

[8]Hafiz is 40 years old reflexology coach with normal vision. He has taught massage course in MAB for seven years.

with low vision". Hence, it is essential to design the lighting in such a way as to minimize the glare.

4.2 Teaching and Learning Environment

Generally, teaching the visually impaired persons can be very challenging as there are many aspects to consider. According to Zhi Ying[9] (not her real name), who was teaching piano at MAB, it could be difficult to explain certain concepts to students because they cannot see, while some have learning difficulties. One consideration was how to sustain their interests during lessons. Interactive methods such as games was used. "It's a fun challenge… My students taught me how to teach". Liyanna[10] (not her real name) said that her teaching strategy was to start with least instruction, but subsequently turning to tactile or 'hand-on-hand' in her instructions. Although the visually impaired persons cannot see, their other senses are very sensitive". For Sumitha[11] (not her real name), a 'multi-handicapped' teacher, one teaching strategy was to wear bright coloured clothing was a way to catch the attention of students, especially those with low vision.

All interviewees preferred quiet environment to learn as they relied very much on hearing. They mentioned that if the classroom is surrounded by noisy environment, it will be difficult for them to focus. Other than quiet environment, almost all of the interviewees liked outdoor spaces such as gardens and trees. They found peace just by listening to water flowing sound from the garden.

The basic tool used in teaching the blinds is the use of braille and tactile diagram. The challenge however, was the reproduction of braille. The participants commented that it was difficult to get extra teaching materials due to high printing cost for braille. This was a serious issue as the materials are essential learning tools. To Fizal, a solution for the lack of print materials was "Newsline," a news source run by National Federation of the Blind that can be accessed by telephone. Another solution was "KNFB Reader" app for the iPhone, which was used in taking pictures of the text and have it read back to the users.

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[9]Zhi Ying is 38 years old and she is a piano teacher with ten years of experience. She has deep passion for music and has been teaching in MAB for five years.

[10]Liyanna has 'Norrie syndrome', which resulted in her being 'totally blind in her left eye, she has 25% vision in her right eye since birth. She can read size 18–24 font, and uses 'zoom' on her iPad and other devices to access text.. She has eight years of experience in teaching computer courses in MAB.

[11]Sumitha is 42 years old and she is a sighted muti-handicapped teacher. She has 22 years of experiences teaching multi-handicapped children.

5 Conclusions

In this research, we studied how the blinds and visually impaired used their senses to navigate and explore the learning environment. They rely on all senses especially the sense of tactile and hearing. Under normal circumstances, building qualities such as the use of openings to let in light, stimulative color pallets, and other architectural elements, are created for heightened visual enjoyment, but in designing for the visually impaired, these aesthetically appealing elements could work in the opposite. This research has provided insights as to how these blind and visually impaired navigate and their learning journey. The information can be useful to incorporate in building design to assist the visually impaired in learning and in experiencing the built environment.

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Square Steel Tube Impressed Current Corrosion Rate in Term of Linear Polarization Resistance (LPR) Method

Ahmed Saleh Alraeeini, Ehsan Nikbakht, and Mokhtar Che Ismail

Abstract Most of the civil engineering laboratory experiment induces the rate of corrosion process based on current value Am/cm^2 to represent the effect of corrosion, however this method has lack of quantifying the actual mass loss rate of steel in the natural environment. This paper presents the Linear Polarization Resistant (LPR) experimental test technique as supplementary method for supporting the impressed current method validation and result for square tubes with 3 mm thickness. The most important parameter of the current impressed method is the length of time required to run the test, size of the sample, and amount of current applied to achieve laboratory corrosion rate close to the natural rate. On the other hand, the linear polarization resistance (LPR) needed only 24 h to complete, and the result in this paper found correlation between the impressed current corrosion, to the LPR system in term of mass loss. Based on result of the tests, the mass loss of the impressed current can be validated by LPR mass loss yearly, which reveal the equivalent number of years needed to have natural corrosion as the same sample used in laboratory with accelerated impressed current method.

Keywords Induce corrosion · Impressed current method · Linear polarization resistant (lPR)

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1 Introduction

The corrosion effects can be seen in our daily life, which can cause a sudden accident and failure in industries, highways, and structures. It's considered a huge financially waste of the industrialized nations. By knowing the science of material, electrochemistry, corrosion estimation, and behavior could save the nation some of their loss. Usually the corrosion major aspect relies largely in natural causes, so a theoretical body is needed for the understanding the corrosion problems and solve it. Furthermore, Experimental research in corrosion must be performed properly and extensively to manage, control corrosion and have safe economic structure.

The corrosion attacks the steel in the marine environment or de-icing situation in staged and gradually manner, hence, it reduces the steel cross section, which, consequently, effect the inner face of steel concrete. Austin [1] prove the efficiency of using accelerated corrosion technique, But, the mechanism electrochemistry and reaction still show some differences from the natural corrosion.

The main objective of accelerated corrosion is to achieve naturally corrosion steel in term of behavior of attack, and type product, So, it can be understood well and reduce its deterioration on the properties. Meanwhile, the behavior of attack and type of product got similarities and difference, which needs to be able to make the perfect decision regarding the effectiveness with proper implementation of method and techniques. This paper aims to produce artificial corrosion, and artificial corrosion rate reference for steel tubes using LPR test, to value and specify the amount off mass loss by time of years. In natural environment, the corrosion varied from one place to other, due to the variation of curing, salt, temperature, and permeability of concrete, which result in producing different densities of corrosion. Correspondingly, different corrosion has different time to spend, but with the aim of using current flow and reference corrosion rate, this time can be limited to reach the capability of natural normal steel corrosion.

This study contributes the enhancement the knowledge for civil engineer to produce accelerated structural corrosion similar to the natural corrosion by using impressed current method in reference with LPR. The time of mass loss produce of accelerate corrosion will be represented in in term of LPR test for the same steel size and type. The linear polarization resistance (LPR) test mainly give the result of determination instantaneous reaction rates such as corrosion rates and exchange current densities [2].

This experimental test has been used in the laboratories measurement techniques to categories and evaluate the reinforcement concrete and steel corrosion rate, which all accurate and specific reliable measurement [3]. Lankard et al. [4] made the attempt of using the LPR method as a diagnose measurement for accelerated corrosion and verify the capability of value the ongoing corrosion, which studied corrosion measurement on the post tension grout on the bridge. Alexandar et al. [5] extensively applied the same procedure with different parameter of using LPR as reference measurement of corrosion rate structure.

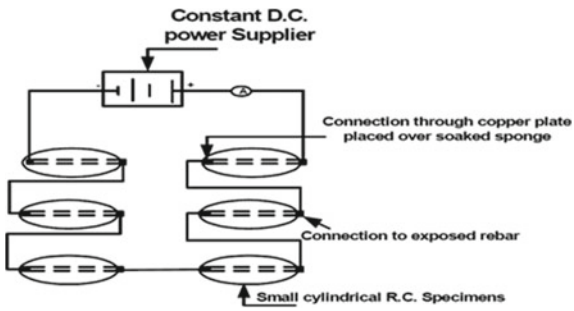

Fig. 1 Maaddawy and Soudik [11] loop connection

So far, researchers have been conducted the accelerated corrosion investigating different parameter such as mix proportion, mix type, additional material, different cross section, and different type of steel. Ahmed [6], Cairns et al. [7], Mangat and Elgarf [8], Ha et al. [9], all used accelerated corrosion using impressed current method, with various parameter, and achieved a proper result depended on factor such a current density ant time provided. Azad et al. [10] conducted experiment for multiple samples at the same time for one DC power supply and one circuit. this method was suggested by Maaddawy and Soudki [11] which all specimens were connected in series as shown in Fig. 1.

2 Test Procedure

The test procedure presents the accelerated corrosion procedure using impressed current method, also quantify this method with the LPR test procedure.

2.1 Impressed Current Method

The steel tube sample with dimension of 1.6 × 1.15 cm, and weight of 2.61 g has been used for impressed current method, the steel tube sample has been used as anode, while the stainless steel used as a cathode. Both connected to DC power supply with 1500 μA/cm^2 for 72 h. Meanwhile, the water was mixed with 3.5% of NACL to help transfer the current through the system as shown in Fig. 2.

2.2 Linear Polarization Resistance (LPR)

The experiment of LPR was conducted for the square steel tube with 3 mm thickness, which used as CFST or CFDST in the construction field. The sample has dimension

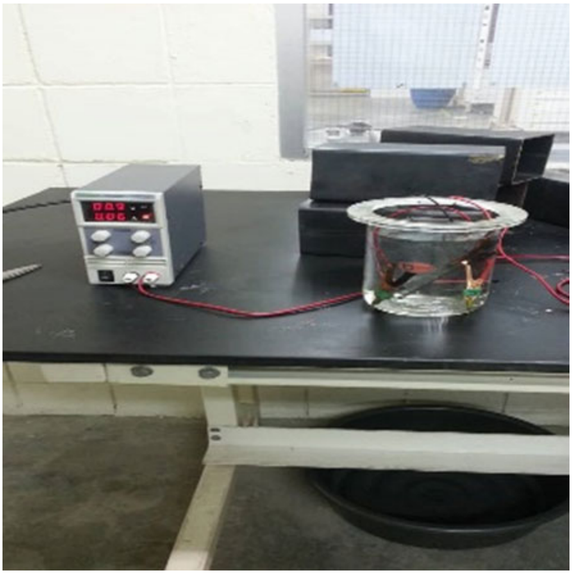

Fig. 2 Impressed current setup

of 1.6 × 1.15 cm. The solution preparation started by adding 3.5% NaCl into one liter of water. Followed by solder process of the wire to the surface contact of the sample, then put the specimen into mold with epoxy mixed with hardener with ratio 4.4% of epoxy then left it for 24 h to get harder and able to protect wire copper during experiment.

After the mold was hardened the grinding process was don for 60,120,400,800 paper according to the standard. The experiment prepared using three props, which are ribbon electrode, auxiliary probe and references probe. The electrode of the sample was immersed into the solution. Then LPR uses the direct current and connected to the ACM software as shown in Fig. 3.

2.3 Theoretical Analysis

In this section, the result of the experiment of the impressed current mass loss was calculated. The aim of the theoretical model is to convert the mass loss into corrosion rate then compare it with LPR corrosion sample, as both samples have the same type and size of steel.

Faraday's low considers one method to predict the degree of corrosion of steel structure, which depends on the steel dissolving and rusting. Equation one used to calculate the predicted mass loss of the steel type by using the amount of current and time used in the accelerated experiment.

$$M_{theo} = Wit/AF \tag{1}$$

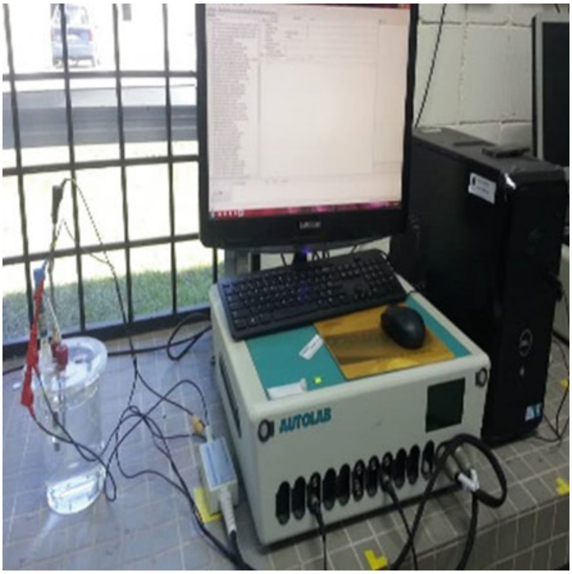

Fig. 3 LPR setup with ACM software

where Mtheo is the theoretical steel loss in gram per surface area, while the W is weight of steel (28 g), I is the current in A/cm^2, t time in second, F is the Faraday's constant (96,500 A/s), and A is surface area.

The actual mass loss Mact per surface area is calculate in accordance with ASTM G1 [12] in concrete structure as Eq. (2),

$$M_{ac} = \left(W_i - W_f\right)/A \tag{2}$$

where Mac is the mass loss in g/cm^2, Wi sample weight before testing, Wf is the sample weight after testing.

Equivalent corrosion current density can be calculated by assuming the Mac is equal to the Mtheo, as Eq. (3),

$$I_{cor} = \left(W_i - W_f\right)F/AWT \tag{3}$$

The corrosion rate is calculated using the gravimetric method [12]. This method is depending on the weight loss of sample in calculating before and after testing as Eq. (4),

$$r = 8.76 * 10^4(\Delta m/\rho At) \tag{4}$$

where r is the corrosion rate the Δm is the weight loss in g, ρ is the metal density in g/cm^3, A is the surface area, and t is the exposure time in hour.

3 Result and Discussion

The discussion is about comparing the corrosion rate based on the artificial acceleration corrosion, with the LPR corrosion rate. This is to simulate the service life of steel and the time to achieve that degree in naturally.

The experiment for impressed current method conducted with Icor 1500 $\mu A/cm^2$, with the use of 3.5%NACL for 72 h. The sample was weighted before testing 2.61 g, and after testing with 2.49 g, then the mass loss was 0.12 g. From equation one, Faraday's low used to calculate the theoretical mass loss of 0.113 g/cm^2, which is not the same as the actual mass loss of 0.03 g/cm^2. This difference may vary due to type of electricity to initiate the corrosion, also the steel mineral as mentioned by Austin et al. [1].

The current density Icor can be calculate from equations three theoretically and observed from the experiment during the experiments of both the LPR and accelerated corrosion of impressed current method. The theoretical equivalent corrosion current density Icor is equal 400 $\mu A/cm^2$, and for the LPR is 15 $\mu A/cm^2$. The difference in theoretical due to the assumption made by equaling the Mtheo with Mact, when there is differences in the mass loss as well [1]. Meanwhile if the current density applied for the experiment is based on the cathode size the Icor is equal to 1500 $\mu A/cm^2$.

The gravimetric method used to calculate the corrosion rate of the mass losses in gram. This method used by ASTM G1 [12] to evaluate and calculate the corrosion rate based on mass loss of steel. The corrosion rate of steel is 5.05 mm/year as calculated by equation four.

The Linear Polarization Resistance (LPR) experiment conducted for 24 h, the corresponding record was every half an hour. Figure 4 showed the test result for corrosion rate in corresponding to the time. The peak corrosion rate is 0.2024 mm/year

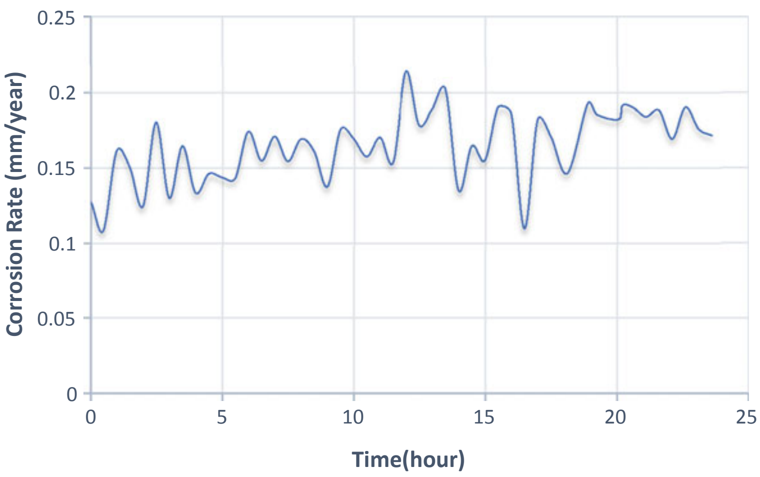

Fig. 4 LPR corrosion rate mm/year versus time

after passing 990 min, while the average value of corrosion rate is 0.165 mm/year as shown in Fig. 4.

In comparing the corrosion rate from the experiment of acceleration corrosion to the corrosion rate from the LPR. The corrosion rate experimentally in accelerated corrosion is 5.05 mm/year as calculated with equation four. Meanwhile, LPR is used to give the metal mass loss per year naturally in normal exposure environment time. The LPR corrosion rate is 0.165 mm/year, which reveal the amount of corrosion loss for this metal per year. In comparing the results of the acceleration test method with 1500 $\mu A/cm^2$ for 72 h to the LPR test, it needs 30 years to reach the degree of corrosion achieved by the acceleration method test according to LPR corrosion rate.

4 Conclusion

In conclusion, the LPR corrosion rate test can be used to evaluate the accelerated corrosion mass loss in term of corrosion rate and give the approximate exposure time in natural environment for this degree of mass loss. For this experiment the corrosion rate is 5.05 mm/year for accelerate induce corrosion, and 0.165 for the LPR. So, in representing the corrosion rate of 5.05 mm/year in term of LPR, it needs 30 years in normal service environment life to achieve that degree of corrosion. Finally, LPR can be used to evaluate and categories the accelerated experimental corrosion, which could help the for further understanding the steel structure corrosion risk, life, and how to measure it and evaluate it.

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Addition, Adaptation, Elements and the Palimpsest: A Case Study of the Angkasapuri Complex's Timeline Through Diagram Analysis

Siti Balkish Roslan and Ahmad Nazmi Anuar

Abstract The paper looks at the selected Modern building, the *Angkasapuri* Complex, as an archetype for interrogation via layered analytical diagrams. Angkasapuri was completed in 1968 at a pivotal phase of Malaysia, where it was seeking to formulate a national identity through various enterprises, including architecture. Layered analytical diagrams is used to document a building's change over time, considering it manifesting multiple entities, taking into account contextual influences that it had had on the building's design. The figurative concept of the palimpsest is used as a method to analyze the building in its embodiment of socio-culture, economy, technological and political influences through addition, adaptation and architectural elements. This creates a historical narrative of the monumental and ambiguous changes inflicted onto the building which allow for a contemporary and modernist discussion. Visual representation is critical in capturing changes allowing for an anticipation of emerging layers within the chronological timeline to encapsulate the building's reading. This allows for a comprehensive understanding of historical value and an open discussion through visual clues and analytical diagramming. The diagrams in a palimpsest form is relevant to the application of Malaysian modern architecture where since the Malaysian Independence, the buildings have changed to accommodate new functions and programs. With this, the sense of reinterpretation, rewriting and rearranging the palimpsest accommodates to architecture being progressive and in constant shifts.

Keywords Malaysian modern architecture · Analytical diagramming · Layering · Palimpsest · Addition · Adaptation · Architectural elements

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1 Introduction

When discussing the history of Modern architecture, it is imperative to include non-Western cases like those from Asia to expand the social base for discussion to include and enrich the fabric of architecture history education. Eisenman commented that there was a scarcity of critical architecture in Asia where no mechanism was clearly developed to produce a critique, rather the architecture accommodated and did not embrace transgression imposed on the status quo. The forces of external factors that embrace the influences of socio-culture, economy, technology and politics are to be included into the narration of the buildings history [7]. The approach also needs to be open to permitting a Western frame of reference, as Angkasapuri was a product of influence from the Western canonical of Modern architecture. What is interesting to note, Michael Hay formulates that critical architecture is firstly oppositional in terms of resisting, distancing, and differentiating and oppositional to both conventional and cultural manifestations [6], which is not the case for Malaysian Modern architecture as it stemmed from the influences of an immensely rich historical background.

An indicative relation to the past is usual within history and modernity. This is where the notion of palimpsest is reviewed and measured against the history of the building to tell us that it is not either the past, present or future, but it is the past, present and future that is important. We can observe that among historians and architects, they do not allow for the buildings to be changed, whether in terms of use or function, this is however strange as buildings long after it is built, becomes inhabited day in and day out [9].

With such rich information surrounding the building, in this case the archetype, *Angkasapuri*, a visual representation was formulated to allow for an easy reading of the historical value and an open discussion through visual clues and chronological analytical diagramming.

2 Methodology

a. *Identification and Literary Investigation*
Angkasapuri was chosen as the archetype for interrogation for the clear visual changes that developed and eventuated through three major phases contributing to the chronological historical layering of the building. The chronology of the building were divided and concentrated on 3 major phases of the building's life span, (1) 1968, which was the conception of the building, (2) 1972–1988, which saw the second stage of the buildings extension to accommodate *Wisma* Radio, Engineer Department, auditorium, International Broadcasting Center and finally (3) 2012, *Wisma Berita* RTM was completed.

b. *Field study*
Angkasapuri was visited to obtain and collect information unattainable via literary means. The current form of Angkasapuri was explored and compared

to the building's physical form of the past and the future; annotations were documented on site. This was further used to develop sketch maps, measurements, drawings, recordings and field notes that frame the conjectures to form a narrative that achieves a weighted and an informed opinion [5]. Once the information was obtained, comprehension of interpretive analytical thinking towards the context and content of the architecture looks at the addition, adaptation and artistic intervention of the building. The information was then combined to form a conclusion in form of a layered diagram.

c. *Layering and diagramming*

In reference to the three major phases this paper focuses on, it highlights a representation of condensed information into a graphical notion to show a depth of relation towards the design, content and context in a layering and diagram form. We observe a perspective and analysis, particularly in orthographic form of diagram, depending on the focus of subject, which at times are not represented well using other methods and mediums. The diagrams used, apply a varied range of graphical indicators; with the main criteria looking at the ideas and development of the palimpsest in terms of addition, adaptation and architectural elements.

The base of the diagram, as shown in Fig. 1, is used as a point of reference for interrogation. The diagram is developed from a computer 3D software (SketchUp) which allows for multiple readings from various orthographic angles. The ideal outcome is a series of diagrams that show a representation of a clear chronological progression of the palimpsest of the *Angkasapuri* complex of the 3 main phases covering the 3 criteria that is addition, adaptation and

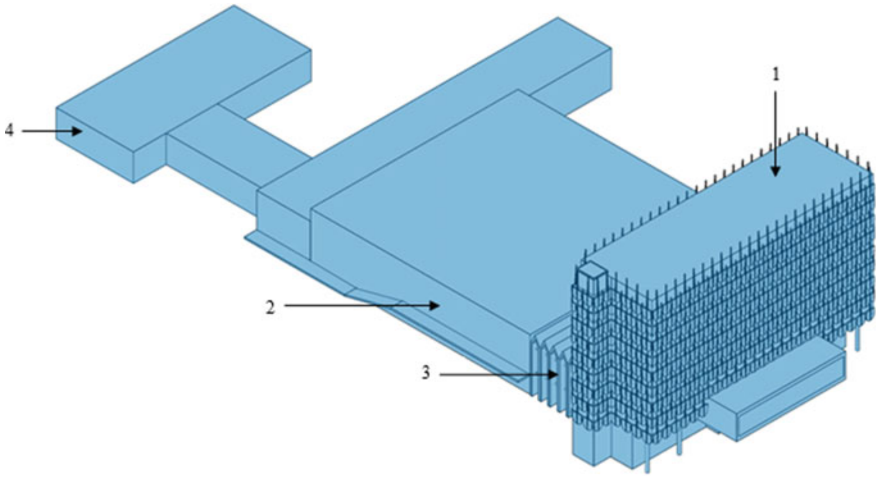

Fig. 1 Diagram showing the building components built during the first stage of construction for the Angkasapuri Complex. The blocks are (1) Wisma Angkasapuri—administration, (2) Television House—tv production facilities, (3) Entrance Hall—connecting Wisma Angkasapuri and Television House, (4) Service Building—air conditioning and electrical plants

architectural elements. This allows for a clear visual representation supporting a proposed analysis focusing on the idea and development of the history of the building.

d. *Interpretive Design Learning*
Interpretive design learning and research is the primary approach used. It developed a method of documenting in the production of a diagram analysis that considers the chronological changes and measured against the buildings palimpsest. Because there are two main varying factors that were taken into consideration; the history and palimpsest, where the history is looked at chronologically and the palimpsest takes into account all factors and analyzes past, present and future in one principal view, the building is looked at through these two lenses. Ambiguous and hidden information are dissected and investigated against the multifaceted content and context. From here the analysis is constructed concentrating on the focused criteria that is (1) addition and adaptation and (2) architectural elements.
Once the diagram of *Angkasapuri* has been drawn out, an iterative process of interpretation is applied, moving back and forth from the entirety of the context and content to reconcile the collected data [1]. The information was constructed to an observation that can further fuel the theory pertaining to the history and palimpsest of *Angkasapuri.* This method is applied to avoid theoretical saturation, which commonly happens with history subjects.

3 Palimpsest: Interrogation of Angkasapuri via Analytical Diagrams

a. *Addition and Adaptation*
The *Angkasapuri* Complex at present day went through a series of phases where multiple blocks were added, spanning over several decades. The additions form the palimpsest where the *Angkasapuri* Complex is understood via layers of the physical additions, read in parallel with the growth and expansion of the radio and television service in Malaysia. The palimpsest becomes a series of architectural additions in order to adapt to the expansion of *Radio Televisyen Malaysia's* (RTM) role amidst the evolving media landscape.
The first stage of construction of the Angkasapuri complexed commenced in 1966, which is the base of the palimpsest. Then Prime Minister, Tunku Abdul Rahman, laid the foundation. It consisted of a 10-story administrative block, *Wisma Angkasapuri*, which is known for its iconic façade termed the 'pineapple skin', functioning as a *brise soleil* [2]. The Television House is a 3-story building that contains production facilities and control rooms, whereas the 2-story Entrance Hall, with a prominent concrete barrel vault roof connects *Wisma Angkasapuri* to the Television House. Within the complex is a 1-story service building containing electrical and air-conditioning plants. The complex was completed in 1969, which was identified as the first phase of

layering and palimpsest of the Angkasapuri Complex, marking the birth of RTM (*Radio Televisyen Malaysia*), a merger between *Radio Malaysia* and *Televisyen Malaysia.*

The second phase of layering and the palimpsest of the Angkasapuri Complex was identified with the completion of *Wisma Radio* and its adjoining auditorium in 1972. Within this phase, the International Broadcasting Center was added in 1988 and Wisma Berita in 2012. On going construction of RTM's Media City project is expected completion in 2020 [3]. The project is predicted to become a regional media hub with an addition of state of the art media and broadcasting facilities. The palimpsest discussed and identified corresponds with RTM's adaptation to the technological progression involved in media production.

When the complex with its buildings as components are viewed as a whole, it reflects the growth of RTM as a media service provider. In an architectural perspective, it reflects the evolution and progression of how the socio-culture, political climate, and technological change influences the expansion of the Malaysian architectural expression. It adapts the modernist approach while maintaining the integrity of the national spirit in form of visionary ideas. Tajuddin Rasdi noted how the 'modern expressionist' language was employed in many important Malaysian public buildings in order to formulate a national identity [8]. The first layer expressed a language of Malaysian Modern Architecture of the post-Merdeka period, demonstrating sensitivity to the local culture and climate. However, an observation noted is the architectural expression transgressing from a modernist design to a contemporary design in the second phase. The contemporary design can be identified in the architectural rendering, showing the expansion of the facilities in the ongoing Media City project by a local Malaysian architecture company, GDP Architects [4] (Fig. 2).

b. *Architecture Elements*

Another form of palimpsest identified within the Angkasapuri complex is through the application of architectural elements. This was observed through the 3 phases, with the focus on the buildings constructed in 1968. The a priori palimpsest of addition and adaptation, the 'modern expressionist' language was used to express a sense of national identity, combining the elements and principles of the international modern architecture whilst considering the context of the tropical climate [8].

Western canonical expressions is identified with a combination of local modern influences via the façade design. The form however takes on a progressive modernist approach, prevalent in the Modern architectural style, a building of mass and volume with a flat roof. The façade however, takes on an expressive shield like shape which is termed as the 'pineapple skin'. It acts as a *brise soleil*, a pre-casted sun shading panel that covers the entire main building, *Angkasapuri.* The panels are positioned to protect the interior spaces, acting as an architectural element layered over the building, subverting the reading of the repetitive individual floors in favor of an expressive and unique building as a whole (Figs. 3, 4 and 5).

The layering of architectural elements within the entrance hall connecting *Wisma Angkasapuri* and the Television House, with the adjoining courtyard, is regarded

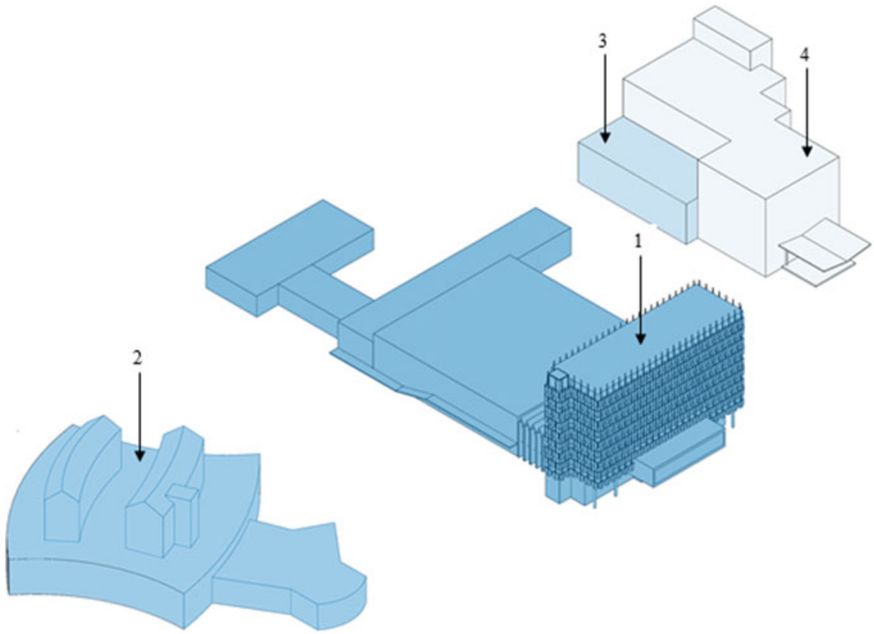

Fig. 2 Diagram showing the different blocks of the Angkasapuri Complex, built at different times in a process of addition and adaptation. Together these blocks make up layers of the Angkasapuri palimpsest, recording not only changing architectural styles but also the expansion of RTM's role amidst the evolving media landscape. The blocks are 1 Wisma Angkasapuri and Television House—1968, 2 Wisma Radio—1972, 3 International Broadcasting Centre—1988, 4 Wisma Berita—2012

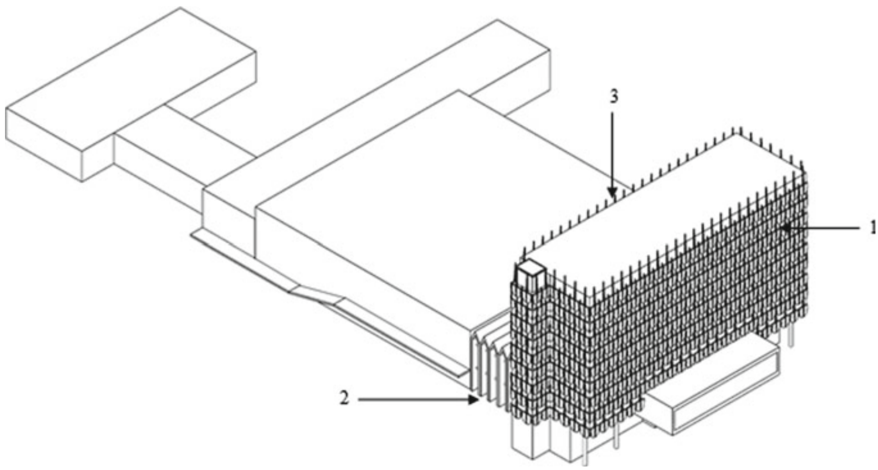

Fig. 3 The Angkasapuri palimpsest could also be read as the layering of architectural elements applied across time within the buildings built in first stage of construction completed in 1969. These elements are 1 sun shading panels of Wisma Angkasapuri, 2 concrete vault of the Entrance Hall, 3 inner courtyard elements

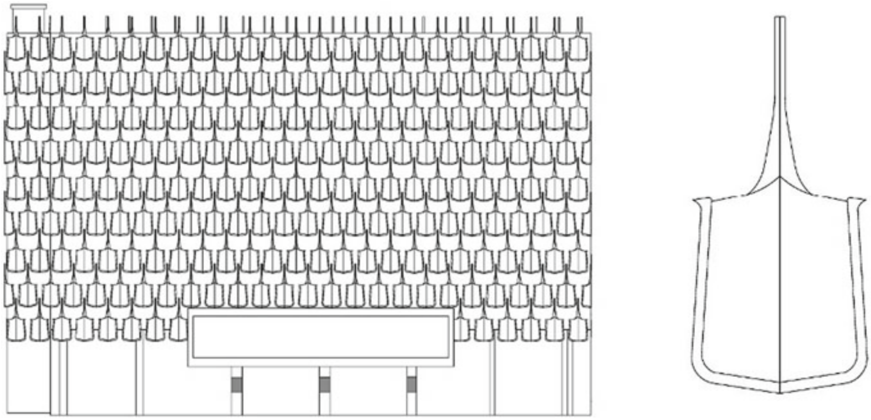

Fig. 4 The ‘pineapple skin’ sun shading panels on the façade of Angkasapuri, a successful combination of Western canonical influences and local modern contextual architecture in response to local climactic sensitivities enriching the architecture language and fabric of Malaysian Modern architecture

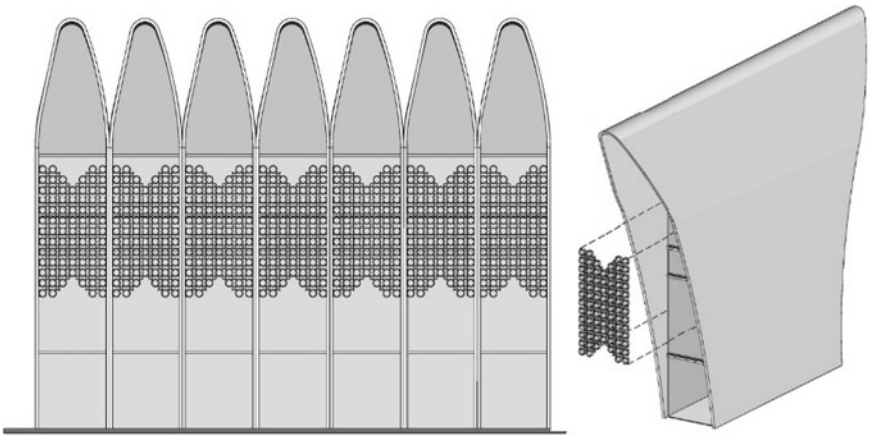

Fig. 5 The concrete barrel vault of the Entrance Hall connecting Wisma Angkasapuri and Television House. The glazed façade allow for an abundance of natural light while a metal grill in repetitive circular patterns protect the glass from direct sunlight

as a palimpsest in terms of architectural elements. This is read in the diagram to be a parallel with the implementation of the national identity in architectural form. The concrete barrel vault roof of the Entrance Hall is identified as the first layer. Completed in 1969, the Entrance Hall is consisted of seven bays of thin reinforced concrete shells, which extend from the roof down to the façade of the Entrance Hall. Its glazed sides allow for an abundance of natural light into the Entrance Hall while a metal grill in repetitive circular patterns—commonly used in the 1960s—protect the glass from direct sunlight. These highly expressive elements belong to the same ‘modern expressionist’ language which was employed in many important public buildings during the post-Merdeka period. Without any allusion to a specific ethnicity, these elements express and embody the shared identity of Malaysia as a modern, progressive and ethnically diverse nation.

The Angkasapuri complex architectural elements applied to its form is considered as modernist according to Western canonical views, with the influence and reference of the local context, which includes the socio culture, political, technological and economic influence. In the case of the façade, it is a direct response to local climate among the other intrinsic influences. This is considered as part of the fabric of Malaysian Modern architecture. The elements that were applied during subsequent renovations post 1968 present a different approach and narrative, evident around the courtyard adjoining to the Entrance Hall. A distinct application of Islamic geometric form and motifs are found in the design of the fountain and floor pattern, both employing the geometric form of an eight-pointed star. The decorative grills applied to the walkways around the courtyard also show a distinct application of Islamic geometric motifs, in comparison to the modernist geometric motifs found on the metal grill shielding the façade of the Entrance Hall. The two layers of these differing architectural style reveals a shift in narrative of identity from a more pluralistic identity based on local interpretation of Malaysian Modernist ideas towards an identity that is monolithic, a palimpsest of transcending architectural identity (Fig. 6).

The identification and analysis of the Angkasapuri complex palimpsest from the perspective of architectural elements is comprehended and read in parallel with the narrative of the formation and unravelling of the national identity. The layering of architectural elements from different architectural languages over the course of time (from modern expressionist to Islamic geometry) reveals a subtle yet monumental shift in the narrative of identity from a pluralistic standing to monolithic.

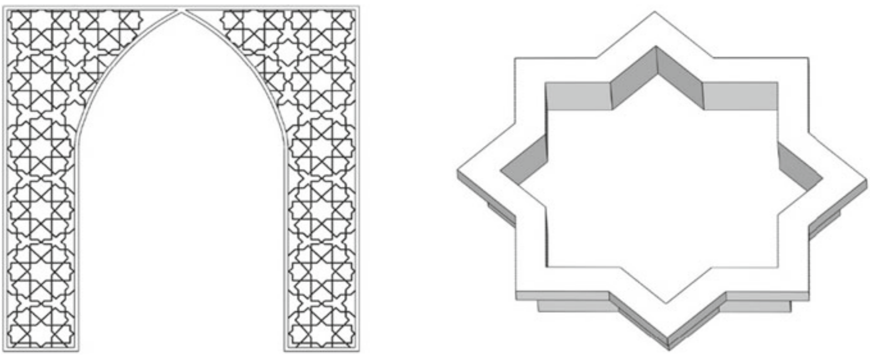

Fig. 6 The decorative grills applied to the walkways around the courtyard and the design of the fountain demonstrates a distinct application of Islamic geometric patterns, compared to the modernist architecture language found in the barrel vault and metal grill of the Entrance Hall

4 Conclusion

Angkasapuri is unique in viewing its ideas, development, and palimpsest through the aforementioned criteria due to its close link to technology, socio-culture, economic and political influences. With its nature in disseminating information, and the constant change of technology, space and form have transformed to adapt to these changes. The transformations can either be momentous (such as with the introduction of the internet) or it can be ambiguous (application of certain by-laws). Although, certain changes maybe intangible and others may be tangible, it is important to note as to how it is tied and influences the architecture of the *Angkasapuri* complex.

Diagramming at the 3 main phases gives an initial form of representation of condensed information that can later be developed as more information is discovered. This is where the layering of diagrams of the *Angkasapuri* complex achieves the compilation of its past, present and future in a form of representing through its palimpsest in the simplest form of reading. Palimpsest in forms of diagrams is relevant to the application of Malaysian modern architecture where since the Malaysian Independence, the buildings have changed to accommodate new functions and programs. With this, the sense of reinterpretation, rewriting and rearranging the palimpsest accommodates to architecture being progressive and in constant shifts.

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Exploring the Evolution of the Digital Future and Its Impact on Mosque Architecture

Hidayati Ramli, Amr Alkhiami, Fadrul Hisham Mohamad, and Siti Balkish Roslan

Abstract This paper begins with a curiosity in the subject of futurism concerning the changing social landscape and its effects on its community. And then it tries to imagine the implications of these changes towards mosque designs as architecture often are reflections of human's technological progress. Scholars in architecture often debate and challenge the validity of 'Islamic architecture' concerning mosques as its often seen as having been borrowed and then expanded the language of other architectural civilizations. However, the dawning digital evolution of the future would potentially even deconstruct these 'Islamic sacred architecture' as technology evolves people's livelihood and sacred spaces get reinterpreted. This study will investigate the evolution of digitality through various works of literature and its impact on spirituality, religiosity and eventually the mosque as a sacred space. Through qualitative research, it tries to speculate on the evolution of mosque architecture in a projected future.

Keywords Digitalization · Digital society · Theoretical speculation · Mosque architecture

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1 Introduction

Society is increasingly digitalized and connected, with computers and algorithms mediating much of people's daily activity in one way or another [5]. Often when we envision the future and its environment, we are influenced by popular culture's fantasy of living among robots that are a near-future potential through Artificial Intelligence and is deemed as the next step of evolution [17]. Still, we seldom realize that we are already immersing in technology and becoming digital nations where future theorists imagine our consciousness being downloaded onto a computer replacing being with digitalism and the body as a mere vessel [6, 16, 23]. Furthering the post-human debate is venturing into questions of choosing mind uploads or having the flesh as digital parts [8]. For several, this is considered a frightening development as it questions our interpretation of what constitutes traditional human narratives. It complicates our gathered knowledge over the phenomenological understanding and its subjective contextualized lenses. However, Dufva [5] opines that digitalism reconstruct our understanding of embodied knowledge as it is often experienced through the interface between the digital and physical. Moreover, digitalism is often a built system that is invisible to the eyes, making us unaware of its processes and how it rewires our brain. Likewise, Dreyfus [4] echoes this argument on the transformation happening to us through the use of the internet and digitality as a ubiquitous tool in our everyday lives.

Following the current climate, this article tries to relate the expansion of our embodied knowledge towards the evolution of our spiritual experience in the digital era and then significantly projects the impact on mosque architecture. It explores the response of religious space, specifically mosque architecture that is influenced and impacted by this development. It is evidenced that digitality with the inference of the internet has substantially rewired our spiritual experience thus far [20]. And that researchers believe religious spaces often tend to evoke psycho-spiritual responses [10]. Seeing how these two subjects inter-relates or potentially collide in the future, it is thus imperative to understand the development of spirituality in the digital age, since digitality is a prevalent experience in human lives [5].

2 Methods

This paper is based on qualitative research by gathering various works of literature about the evolution of spiritualism and connecting them to support theoretical speculation of the evolution of spiritual experience and what it entails to the development of sacred spaces of mosque architecture in the future of digitalism. The research is structured first from the curiosity of; the emerging technologies impacting the trend of life and spirituality. It then queries how these development affect Muslims way of life and the consequent architectural modifications to religious spaces.

The work selects technical research literature that contextualizes trends and investigates future implications towards mosque architecture forty years from now. The 40-year projection is used as a time estimation made in relation to the internet age and the probability of its potential development. Meanwhile, the literature is structured to discuss the advancement of technology and the evolving environment of the digital age's contemporary spirituality and religiosity. From there, the study will address the possible development as a result of these advances.

3 Literature Review

3.1 Spirituality in the Digital Age

The internet demands more sociological attention because of the sheer amount of time many spend on it and because of the possibility that it subtly restructures thinking patterns, behaviours and response and reaction towards others. Furthermore, its usage decreases the likelihood of being religiously affiliated [20]. This is due to the strengthening of individualism as the internet separates the physical communal experience of society through religious affiliation such as mosque attendance as compared to the private experience of using the internet. Dreyfus [4] and, Dufva [5] stressed that digitality transforms our way of being and further tinkering the concept of religious identity. Religiosity has been a fixed experience that is generally exposed to the internet by its use, to a more dynamic, inclusive and transient spiritual experience, as it provides more data on multiple and relational perceptions of spirituality and even consciousness. The impact shows a more plural and inclusive consciousness but complicates metaphors of space and place, including the belief that audiences are separate from each other [20]. In addition, the internet could potentially homogenize the spiritual experience of a person, particularly because the primary search engine Google, with its improved tracking algorithm, would often recommend similar interests to an individual's search data. The algorithmic peculiarities towards the personality or religious affiliation of an individual impedes the capacity for understanding others' plural consciousness by the sheer volume and expansive web content. Perhaps because of this, many young adults don't make time for religious activities because they're either busy, distracted or concentrating on the internet. Most are overwhelmed by all the new knowledge that can be explored through an infinite open-ended network [20].

Moreover, the internet is easily integrated into almost all of modern lives to an extent that it is no longer a tool that eases day to day activities but has become an integral part to modern living. However, critical research has often depicted Islamic modernity representing Muslims as 'conscripts of Western modernity; as an external force colonizing their lives.' Jung [15] however, stated that this assessment is made from the trajectory of the Western prejudices as Muslim societies have often constructed their reality with a firm reference to Islamic traditions [15]. He added that Muslims combine religious language, symbols and practices in idiosyncratic ways. They interlace political ideologies, neoliberal imaginaries, and various forms of consumptive practices with digital technologies. Yet they maintain Islamic traditions as the authoritative measures in defining Muslim identity. Concurrent to this perspective, the physical space is evolving with the digital influence of the internet on Muslim communities. The transference of the phenomenological knowledge to a virtual experience is predicted to amalgamate realism of religious and spiritual spaces with virtual architecture.

3.2 The Digital Age and Muslim Religiosity in Cyberspace

Due to the high volume of Islamic related content and large internet presence, the paper limits the exploration of findings on the usage of the internet in the medium of the podcast, YouTube and Virtual Reality (VR).

Non-conversely, the internet has become a significant platform of communication for modern Muslims and an authoritative source for their perceptions, beliefs, and social networking. Islam is the world's fastest-growing religion, while the internet is the fastest-growing mass medium. The merging of the two, Islam and online communication, appears to be a global force that may shape the future [36] in which the Muslim community is not separate from the globalization experience which was commonly conjectured by social theorists addressing Islamic modernity. A great deal of scholarly attention has been given to the role of the internet in contemporary Islamic discourse [3] enabling new forms of associations, interaction, debate, in changing both economies and sociology of Islamic knowledge, the possibilities, and conditions of the collective actions [11], thereby reshaping the norms and institutions of religious authority [18].

As was discussed, the phenomenology knowledge through embodied experience and its deconstruction through the medium of cyberspace is seen in a *Khutba* or an Islamic sermon. The sermon commonly delivered in a mosque is as an emotionally tangible experience, could now be, albeit decontextualized, heard and experienced through YouTube. Experiments in Devotion Online: The YouTube *Khutba*, examined that the experience of hearing the *Khutba* in a mosque contrasts with experiencing it through the media of YouTube significantly from the absence of presence; replacing it with a wider, less defined emotional pathway [11].

Apart from a pivotal shift in the perception of phenomenology of consciousness through experiencing Islam in cyberspace, the medium as noted by Scholz [30] might also become an important instrument not merely for reconstruction, but the deconstruction of religious authority in the Islamic context. Through the afforded participation in Web 2.0, individuals can easily upload one's content and opinions, contributing to an alternative online discourse that potentially challenge an already established authority in the real world granting the possibility of myriad representation. Scholz [30], made this observation by studying the pattern of Islamic discourse through the use of podcast, which is among the medium used by Muslims on the internet. Muslims either use it for *da'wah* purposes—to propagate Islamic teaching or as a self-identification tool in the digital age. Consequent to the possibility of Web 2.0, the consumer is now the prosumer. It gives users access to be an active contributor in any discourse, particularly religion at such an accessible speed, breaking the linear participation of religiosity in the real world which further challenges the mould of established religious authority. Due to the fluidity and permissibility of variety, the internet is a system which permits renegotiation, redefinition and possibly reinvention of Islamic religious authority. To appreciate the significance of this development towards mosque architecture is to highlight that a mosque can be a political tool as much as it is a sacred space.

In addition, adopting the internet in modern times means that Muslims adapt their religiosity inside the cyber sphere, which introduces numerous websites dedicated to Islamic education and learning. These religious spaces, recognized as 'virtual mosques', are a new trend in modern Islam that houses Islamic content under one umbrella, such as IslamOnline.com. Evidently, when the internet meets Islam, interesting new relationships, both in the physical world and virtual emerge [37] for instance Virtual Reality is embraced to immerse participants in experiencing Islamic rituals like *Sai*' without being in Mecca. This is done with an avatar implementation in a virtual reality environment using situated learning [22]. *Sai*' is one of the rituals of *Hajj*, the Muslims annual pilgrimage in which the activity consists of walking back and forth between the hills of *as-Safaa* and *al-Marwa.* The research showed that experiencing the simulation in the role-based environment through customized avatar can offer immersion, realism and interaction through multimedia communication along with realistic virtual 3D environment increases the understanding on the *Sai'* ritual easier [22]. Integrating modern Muslim life in the digital environment, a leading tech-team created a CollabDeen app for Muslim communities to connect and interact within Smart Mosques. The phone app, a wordplay between collaboration and *deen* among other usage is primarily designed to connect local mosques with its congregants in which every information and latest activities are updated through its feed. Currently, CollabDeen allows its' members to control the managing aspects of the Smart Mosque like memberships, donations, shared resources and community news and updates through their smartphones.

As such, these technological advancements are taking place in cyberspace, Virtual Reality and augmented reality; in which all these technological advancements have impacted Muslim religious experience in unprecedented ways that permits theoretical speculation on the evolution of mosque architecture in the future (Fig. 1).

3.3 Muslims and the Digital Mosque

Much of the technological advancement today, relating to the physical spaces of mosques are used to visualize earlier mosque architecture using Virtual Reality [31], such as the modelling of the Prophet Mosque [13] or for conservation efforts [26]. Meanwhile, given these possibilities, Imdat [1] in his research, The Digital Mosque:

Fig. 1 Mosque congregants trying VR in experiencing Kapitan Keling Mosque, Penang [38]

A New Paradigm in Mosque Design, reimagines the possibilities of new designs that will fit the digital age. He argues that the symbolic tradition of praying in mosques lies not in its form but in man's setting. As a result, he proposes a mosque typology that converges the physical and the virtual into one embodied experience through symbiotic relationship in his Convergent Mosque [1]. This typology is credible since the transformation of our perception in cyberspace creates a new form of tele-presence as real-time telecommunications happens at live speed [35]. This implies that we can virtually be at any place at any time simultaneously rewiring our phenomenological knowledge, therefore reshaping the perception of our built environment. This virtual mosque is a domain in which participants congregate to pray in a space even when they are physically apart but are experiencing each other in virtual presence.

However, Imdat [1] realizes some rituals cannot be experienced online, like performing ablution, in which a distinct separation between the hardware (physical) and the software (space) into an experience as experiential boundaries are drawn. This is shown in Table 1.

Table 1 The distribution of mosque activities into virtual and physical spaces [1]

Space function	Performed physically	Performed virtually
Adhan (call for prayer)	Use minaret for the call to worship and to indicate the location of prayer space	Online *adhan* service providers, a list web portal on affiliated Websites and search engines
Ablution	Provide ablution—fountain	Ablution ritual and online tutorials
Khutba	Provide screen and required equipment for the projection of preach from Ka'ba	Open portals for listening and watching previous teachings
Praying	Offer space for praying postures like sitting, bowing and prostrating	Provide a portal to attend prayers
Learning	Provide imam for consultation and technical issues	Online educational portals, supply multimedia application

Interestingly, preliminary explorations indicate that the physical and virtual built environments are experienced in a similar manner. Nevertheless, expectations of scale, distance, and other critical variables relevant to architectural experience do not seem to vary substantially between the built and corresponding virtual environments. Whereas these similarities are more pronounced for virtual settings of higher fidelity which allow for a higher degree of interaction, multi-sensoriality, and presence feelings, even fairly simplistic virtual environments may elicit complex logical responses. In reality, using immersive technologies (e.g. head-mounted displays [HMDs]) and a high-fidelity, interactive model that integrates some degree of multi-sensoriality (e.g. incorporating sound), would allow a more precise comparison of virtual and built environments [24]. In short, the experience of virtual environment elicits the same spiritual feeling psychologically as the real thing. Thus allowing the futuristic vision that, through technological advancement, the reality and virtual may merge completely.

4 Speculative Theory and Discussion

Sand [28] opined that it is not unreasonable to entertain a vision despite its improbability. Most people are passive bystanders in techno-visionary dynamic. They lack anticipatory capacities to assess the long term prospects of emerging technologies. However, their passivity could impel them powerless in making a change to particular visionary discourse [14]. It is through this vein that the research speculates these technological development's impact on the future of mosques as to imply relevancy in future discourses suggested by Grunwald [7] that one should scrutinize and understand the emergence of those futures as its visions are already having an impact [28]. This paper postulates the evolution of mosque architecture through the prism of the urgent technological advancements that are already rewiring phenomenological understanding of spiritual and religious experiences. It improves on Imdat [1] thesis and proposes three types of Mosque typology in the future,

(1) Fully Virtual Mosque: accessible through Virtual Reality devices where people could all meet, interact and pray in one virtual space. 360-degree VR film preview in a mosque, allows viewers to experience being 'inside the mosque' as if they are part of the congregation of the faithful.
(2) Semi-Virtual Mosque: any mosque typology with virtual support.
(3) Typical mosque.

The proposed future mosque (see Fig. 2) integrates the virtual and physical spaces into one in which the mosque makes a shell; a sacred area to supplicate is developed inside an enormous circle, within the arch that bats for the petition is also driven speakers to convey the data; are technologically enhanced building components that would contribute 'sensorial awareness' for the congregation. The interior design of this mosque relies on its speakers driven at the focal point of the mosque as participants setting zones are radially structured around it. Hologram and virtual-guide make a “planetarium” like space at the main mosque corridor that would be designed as the building itself enjoining the ritual and religious exhortation of the sublime and encourages individual experience in a communal presence; as part of a whole, both through the prism of the mind (virtual: individual) and presence (space: collective). The future mosque is the spiritual and religious pilgrimage of an individual: a journey through an immersive experience from auditoria to sensorial perceptions of virtuality. These stimulants are perceived through the mind, impacting the fundamental essence of devotion of an individual and thus the congregation.

Referring to Fig. 2, the future mosque and the first mosque Fig. 3 lies in stark contrast by illustration but the first historical mosque is considered the most important building in a Muslim community. Therefore, the development of a Muslim community depends on the mosque itself. Many architectural scholars advocate the real function of a mosque is a community center for Muslims. It is not solely a ‘house of worship’, but also functions as a community center for both Muslims and non-Muslims alike. Looking at the history of the early Prophet Mosque in seventh century Medina, the Jewish community frequented the Prophet’s Mosque for meeting with Prophet Muhammad [27]. Aslan [2] elaborated that historically, the vast Islamic

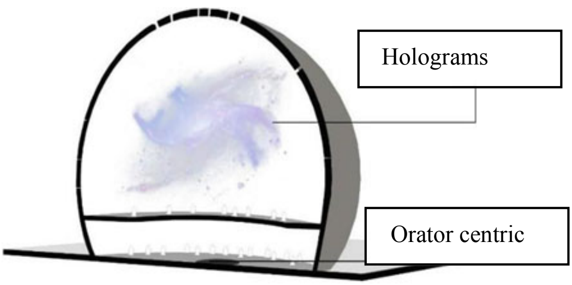

Fig. 2 Proposal of a futuristic mosque, a holographic dimension

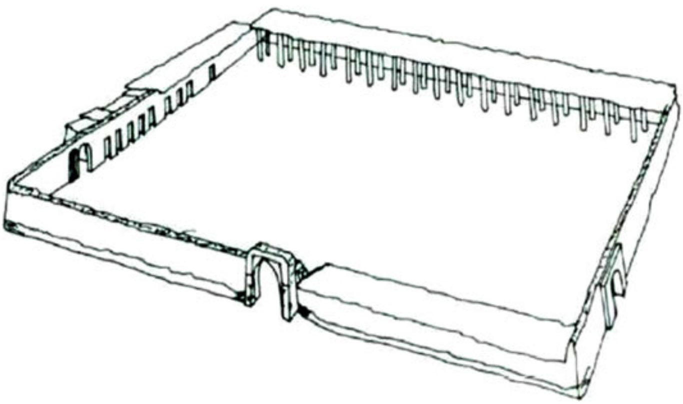

Fig. 3 The first mosque: prophet mosque [27]

Ummayyad empire had established a separate role of a ruler and the role of the *ulama*. The divide, separated administrative buildings and place of worship, between the secular space and the sacred space would eventually become a model of what a mosque typology is today—a singular purposed place of worship.

This historic distinction ultimately developed into a monumental symbolic representation of the state, the more luxurious the state, the bigger the population, thus, the exuberant the mosque would be. In due course, these religious buildings are used for political agenda. Likewise, many newly independent Islamic countries in the early twentieth century wanted the mosque to be a symbol of unity, sense of achievement and pride [12] thus attaching themselves to historical precedence in 'spatial melancholia [25]. Conversely, Mastor [19] added that the true definition of a mosque, is not about its physical form, rather the 'prostration' act of prayer that can happen anywhere provided the space is clean. Therefore, he suggested for the physical form of a mosque to be designed to suit the needs of its community and is relative to time and context. Furthermore, several authors from an anthropological perspective pointed out that sacred space is defined by ritual activities rather than the space itself. The status of a building as a religious or even a sacred space is situational [21, 32, 34], which suggests that the definition can never be static.

Hence, with the possible deconstruction of religious authority and potential reinterpretation of Islamic context from the digital impact, this paper proposes that the mosque as a state's agenda could be renegotiated and reimagined too. The mosque is always an extension to present-day needs, meaning it highly depends on cultural and technological development. At present, the mosque acts like a community center, in the future, the mosque constitutes certain religious sensorial attributes and experiences that impact upon a religious individual. In projection, its virtual-religious architectural form has the power to evoke a sense of effervescence that intensifies religious feeling, where the religious space-making is part of the ritual rather than a mere container of rituals [34]. The form oriented towards the Kaaba, the ontological axis of prayers for Muslims, also acts as the space that provides inward direction from the vastness of the cyberspace towards the individual. It invites present consciousness within the tangible form of space, seeking the transcendental. Meanwhile, Daniel Miller argues that although religion by definition strives for the immaterial beyond the material echoing Mastor [19], which is why the religious experience of prayer could be replaced through cyberspace of Virtual Realism, however, it ultimately needs the material to evoke the immaterial [34]. With this argument, it maintains that mosques as space, even in any distant future, would be more relevant as people need to navigate a sense of belonging in a society that is more secularized and devoid of meaning to a religious individual, as was posited by Yuval Noah Harari in his 'Homo Deus: A Brief History of Tomorrow',

> Modern culture is the most powerful in history, and it is ceaselessly researching, inventing, discovering and growing. At the same time, it is plagued by more existential angst than any previous culture. [8, pp. 235–236]

5 Conclusions

In summation, the digital future offers limitless potential but the controversial reality of deconstructing traditional experience through new technological ventures (e.g. virtual mosques) may also provide chaos. The typical mosque as a religious space in the future, would soon suffer cultural inertia in need of context. Especially when religious meaning is highly dependent on context and people's needs. Thus, the mosque as a human-created space has an impact on human interactions and provides opportunities for identification processes within a particular social context [34]. Religious architecture according to Verkaaik [34], is relevant as it not only expresses identities but also performing religious identities, both from external attachment and representation of one's internalized faith. The statement suggests that the mosque in the future would not only offer communal belonging but evolve more to become a learning center for the community in which the mosque is the center of Islamic learning in the future where the data itself is religion [9]. The mosque will then integrate both virtual (data of congregants, mosque websites) and rituals (tradition, prayers) much what was proposed by Imdat [1]. However, the mosque as a building becomes a religious place that Muslims, individually or collectively, engage with. From the literature study, it is evident that the technological evolution is not only inevitable, but it is unprecedented, and its effects go beyond telecommunication and is far-reaching to cognitive psychology and philosophy as much as sociology [29]. Future theorists anticipate this digital development to be a technological revolution [33] ushering in a new era. This continues to mobilize citizens to move towards a 'utopia of a better society through technology' and participate in the construction of the utopian new world [29]. This theoretically concludes that the mosque will inevitably be re-contextualized as all human lives would also be impacted. Therefore, designers are encouraged to develop mosque typology, design and curate its narratives attuned to current and future reality. It should integrate the Islamic prayers that serves dynamic interrelations of practice with space. Irrespective, people will seek the sublime in the material. Therefore, mosques of the future have the potential to be the architectural oasis in the hyper-virtual world, offering commune, presence, identity in a more disparate reality.

Notes

da'wah	The practice or policy of conveying the message of Islam to non-Muslims.
Deen	Islamic religious observance.
Ummayyad	Islamic Empire from AD 660 (or 661) to 750 and Moorish Spain 756–1031.
Ulama	Muslim scholars.
Sunnah	A collection of Prophet Muhammad's traditions.

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Traditional Architectural Methods' Sustainability to Improve Schools Buildings in Refugee Camps in Syria

Manar Fayez Kanah and Muna Hanim Binti Abdul Samad

Abstract Disasters pose a great danger to societies due to the impact on various aspects of life such as social, educational, economics which calls to find better post-disaster solutions. This paper is highlighting the war in Syria as one of the human-made disasters that threaten Syrian's children present and future. Education is an essential factor in terms of societies' recovery and to children's recovery process and overcoming the trauma of war. Providing post-disaster school building is an essential part of children's post-war recovery. The current paper is trying to identify a modular system suitable for school design and propose a school model that depends on natural materials available in the area and using the traditional architectural methods in an attempt to construct a building with a good efficiency and at lower costs. The methodology is based on a survey on a number of schools in Syria to show the impact of the war on the school buildings. The paper suggests an architectural design system to achieve the best environmental results in terms of thermal comfort and ventilation in order to minimize the cost of air-conditioning and mechanical equipment.

Keywords Disaster · Post-disaster recovery · Children rehabilitation · School buildings · Architectural design · Traditional architecture

1 Introduction

Natural or Man-made disasters leave the affected regions in humanitarian, economic, environmental, educational, and social issues as well. In 2011 Syria turned to be a land on fire because of the war 21, 018, 83 people were the last population statistics before the war refers to after the war the number decreased to 18,284,868 (Worldometers 2017)."Syria become the biggest humanitarian emergency of our era, yet

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the world is failing to meet the needs of refugees and the countries hosting them," said António Guterres, the U.N. High Commissioner for Refugees, there were 87 attacks on education facilities, including 76 attacks on schools and 11 attacks on teachers and education personnel, the results were killing and injuring of more than 250 children. At the end of 2016 more than 1.75 million school-aged children were out of school (down from 2.12M the previous year) and one in three schools was damaged, destroyed or occupied. Since the beginning of the crisis, more than 4000 attacks on schools recorded. Half of the school-age children were not enrolled in school in the 2014–2015 school year, according to the Syrian Centre for Policy Research [8]. After eight years of crisis, Syria has a generation with no education, and there is a lack of schools to offer primary education. There is havoc being wreak on these children's hopes of an education and the likely consequences for the region's future.

One of the most dangerous impacts of conflicts is using the child as soldiers, Poverty, and living in a combat zone can increase the probability of a child becoming a child soldier. Some children decide to join a military organization if there is a lack of access to education or to end a poverty cycle. Knowledge is life-saving and life-sustaining, providing a sense of normalcy to children's lives, psychosocial support, strengthening survival skills and coping mechanisms. It is critical for cognitive and developmental needs of children and help with early recovery.

It is essential to open the eyes of the world on the Syrian children crisis towards the better and comprehensive method in providing access to schools for Syrian children to help them to overcome the crisis and design a post-disaster school prototype that can develop and modified to use for the same or another different situation.

There is no question that such overwhelming experiences have an impact on the development of children, their mental health, their attitudes toward society, their relationships with others, and their outlook on life in general [6]. According to (UNICEF), 8.4 million children—more than 80% of Syria's child population—have been affected by the conflict, either in Syria or as refugees in neighbouring countries. The conflict in Syria is entering its eighth year. Every day the crisis is prolonged, the pain endured by innocent families grows—leaving deep scars that are likely to disfigure the Middle East and beyond for years to come [12].

Some of the refugee students can be classified as SLIFE (Students with Limited or Interrupted Formal Education). While fleeing, students do not have any access to schools and familial needs, such as working to provide food or money, frequently that take precedence over going to school [4].

The research questions are:

- How conflicts affect children future and how can education improve the process of their recovery?
- What are the appropriate design criteria required for school design to Syrian culture and environmental factors?

And the objectives are

- To highlight the situation of the school building in Syria.

- To suggest a characteristic of modular architecture focusing on school shelters in aspect of the design, technological and systems adopted.

2 Problem Statement

There is no question that such overwhelming experiences have an impact on the development of children, their mental health, their attitudes toward society, their relationships with others, and their outlook on life in general [6]. According to (UNICEF), 8.4 million children—more than 80% of Syria's child population—have been affected by the conflict, either in Syria or as refugees in neighbouring countries. The conflict in Syria is entering its eighth year. Every day the crisis is prolonged, the pain endured by innocent families grows—leaving deep scars that are likely to disfigure the Middle East and beyond for years to come [12].

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3 Purpose of the Study

Through statistics and successive events, it is urgent to have an excellent educational environment that capable of addressing the children trauma who are displaced and considered as refugees.

The importance of education for national and individual civic leaders and social scientists have long recognized the development alike. But whereas civic leaders are inclined to see education as primarily functional in the production of skilled human resources to fill technical and administrative positions in society, social scientists are more apt to stress the role of education in "working to change the balance of different attitudes and values in the population [2].

4 Research Methods

The paper used a qualitative method in order to highlights the school building situation in Syria to help briefing the critical problems and help to suggest a design a prototype model of a school for refugee camps in Syria with consideration of the building (daylighting, natural ventilation and thermal) that can be achieved by the traditional architectural methods.

5 Building's Natural Environmental Control

In order to design a convenient school building an essential variable should be taken in consideration, and the most important are the natural variable that effects the building such as thermal comfort, natural ventilation and natural daylight. There is a rich diversity in building types can be recognized in Syria according to the region and people's lifestyles. The traditional houses were environmentally designed to be functional under the with extremely hot-dry climate [11]. The traditional Syrian architecture is characterized by using the architectural and structural patterns that can be replicated in various types of construction such as vault, domes, corridors, and courtyards.

- The courtyard constitutes a fundamental traditional structure of thermal control, that reflects the wisdom of traditional Mediterranean architecture and the countries with hot climates, in which the sun is desirable in the winter while cooling and ventilation are necessary for the summertime, the courtyard is unique and indispensable elements of local architecture [5] (Fig. 1).
- The Malqaf (wind catcher): Windcatcher is a traditional Persian architectural element to create natural ventilation in buildings used to cool the inside of the area. It is essentially a tall, capped tower with one face open at the top. This open side faces the prevailing wind is catching it and brings it down the tower into the heart of the building to maintain air flow [9] (Fig. 2).

This type of architecture includes the concept of sustainability and can be modified to be a guide in contemporary sustainable design.

The principles of traditional buildings are:

1. Adaptation: which is the exploitation of potential resources in harsh environmental circumstances and dealing with these circumstances to achieve heat comfort to dwellers and to exploit natural sources of energy.
2. Protection: to eliminate the harsh environmental impact.

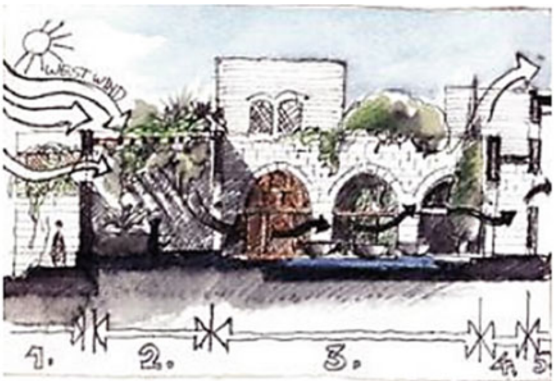

Fig. 1 The air flow and heat transition in courtyard [5]

Fig. 2 The traditional wind catcher—Bastikia district, Dubai [5]

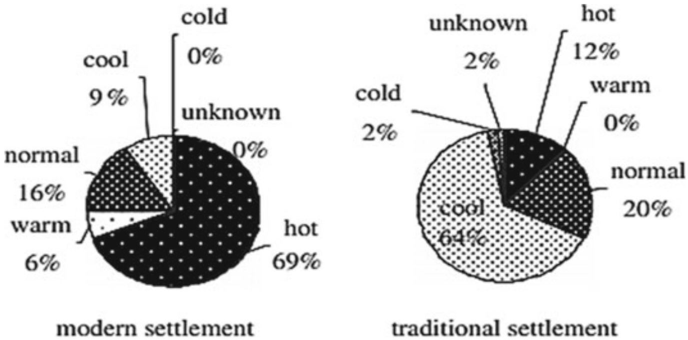

Fig. 3 A comparison for users' perception of indoor temperature in summer in hot-dry region [7]

The opening towards an internal courtyard protects against climatic factors. Natural light and natural ventilation Through planting and using fountains to make the courtyard shaded and the air cool and transmitted to all rooms. The air moves from the shaded areas through the courtyard into the internal spaces, the courtyard's temperature drops in the evening because of the temperature exchange by pulling cool air from the top and transfer the hot air outside the building (Fig. 3).

6 Findings

Reports showed that 74% of the schools included in the analysis (2843 out of 3842 schools) are considered safe. 21% of the surveyed schooled are deemed unsafe, three percent are considered relatively safe, and two percent are at high risk. Functional schools were classified into four groups: formal, rural, safe educational places, and temporary. Formal schools buildings meet the standards such as the capacity consideration of the building, provide a fenced open space for recreation, toilets, high ceilings and have several windows for ventilation and wide corridors while the rural and temporary schools have been in Syria before the war begins were mainly, it found in small villages that did not have enough students to justify the construction of a permanent buildings. Rural schools consist of several rooms inside a country house and are meant to accommodate primary learners.

Poor economic conditions impede children from getting an education. Expenses burden families and prioritize sending young children to primary school for basic knowledge. It may suggest that parents prioritize foundational skills of reading, writing, and numeracy over secondary education or that the fees related to textbooks. At the secondary education, coupled with transportation cost and safety concerns are prohibiting parents from sending older children to school. Child labour also is a contributing factor in the drop-out rate. It is important to note, however, that the education policy in practice obliges the student to keep on their school attendance, for learning, up to the age of 15. This policy, coupled with the possible continuation into, and the availability of the secondary level of education, may also be one of the factors contributing to low drop-out rates [10] (Figs. 4 and 5).

The assessed schools in Syria 2018

Governorate	#of Districts	#of Sub-districts	#of villages	#of assessed schools	#of functional schools	%of functional schools (%)	#of non-functional schools	%of non-functional schools (%)
Idleb	5	26	428	1213	1119	92	94	8
Al-Hasakeh	4	8	135	349	231	66	118	34
Ar-Raqqa	3	9	181	500	392	78	108	22
Quneitra	1	3	23	69	66	96	3	4
Aleppo	7	19	431	753	611	81	142	19
Hama	3	5	53	214	94	44	120	56
Homs	2	4	37	188	144	77	44	23
Dar'a	2	11	55	372	362	97	10	3
Deir-ezor	3	7	54	260	3	1	257	99
Rural Damascus	4	7	18	161	111	69	50	31
Total	34	99	1397	4079	3133	77	946	23

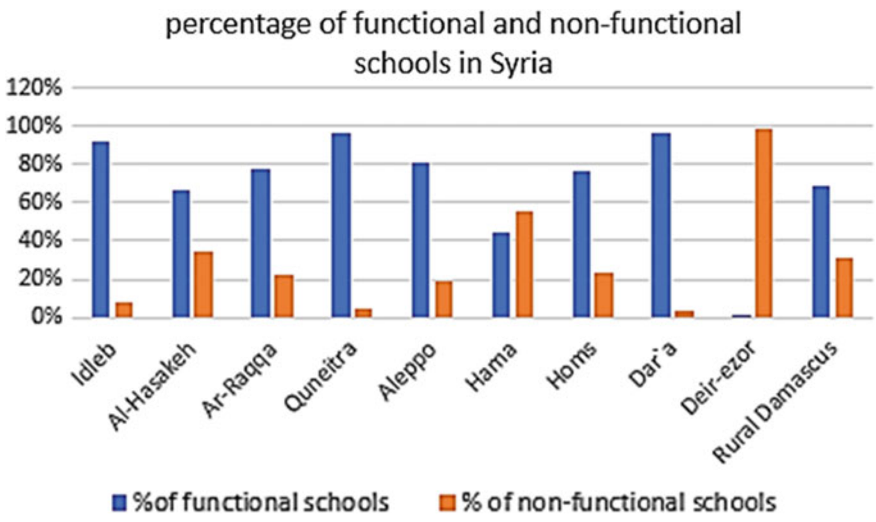

Fig. 4 A chart shows the percentage of functional to non-functional schools in Syria after the conflict for the year 2018

7 Design Suggestions

For an emergency school, the design must be simple that helps to save time and can be done with the help of local people in the camp. The design should focus on the most important units which are the classrooms than the other services, there are some variables in school design which are School design variables (Shape (Layout) and Orientation) and Classroom design variables such as (area, windows, ventilation and thermal comfort).

- School layout: The standard forms (L,U) of the school are better in terms of design and structure for an emergency school and they serve the purpose well [3].

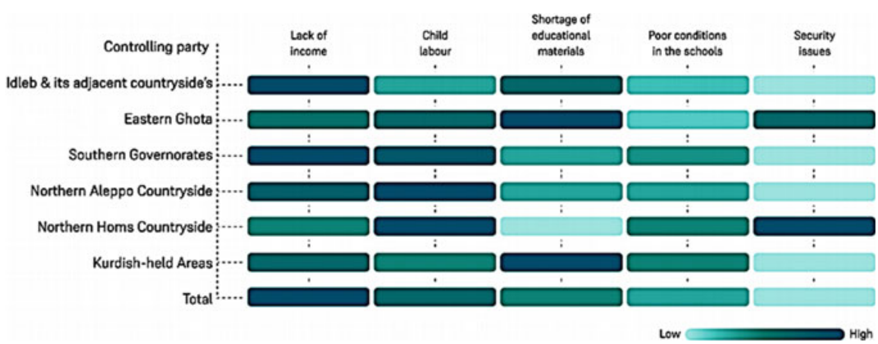

Fig. 5 Students dropping out of schools reasons [1]

- Building orientation always follows specific geographic coordinates and it is affected by the sun path and wind. The best orientation for a building helps to get the best daylight and best ventilation. The climate in Syria is continental which is very hot in summer and day up to 42 °C and very cold in winter and night, while the winter is considered mild. The prevailing summer winds come from the coast which is northwest Syria. The northwest winds and west and southwest as the wind roes are the desirable winds in Syria, therefore it is preferable to direct the building in this direction, as this directive provides one of the most important factors affecting educational classes, which is the reception of fixed natural lighting from the north, which ensures that the level of natural lighting does not change in most of the day (Figs. 6 and 7).

The building plan is inspired by the style of ancient Arab house due to its ability to provide the appropriate atmosphere to suit the climate of the region. Consists of three zones serving students with an internal courtyard. It is a simple building so the local people of the camp can participate in the construction process (Figs. 8 and 9).

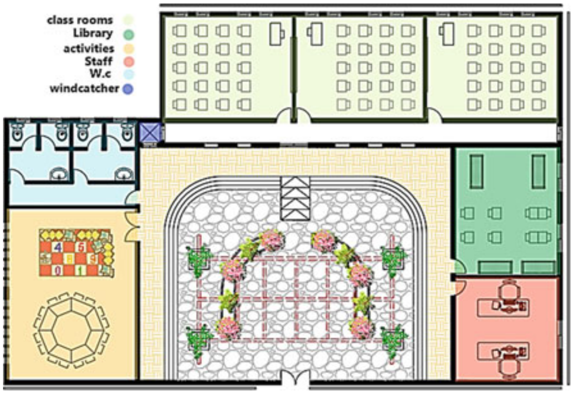

Fig. 6 Suggested school plan

Fig. 7 Section for the building

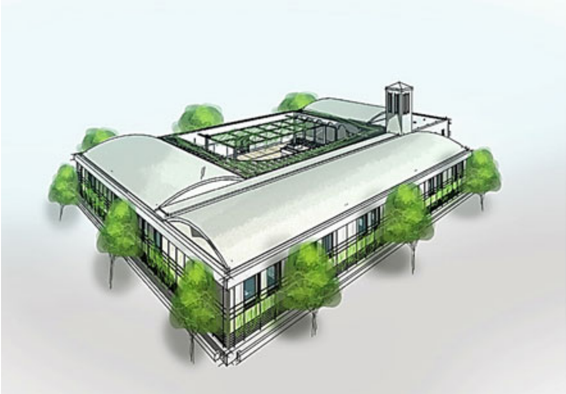

Fig. 8 A perspective view of proposed school building from the classrooms side

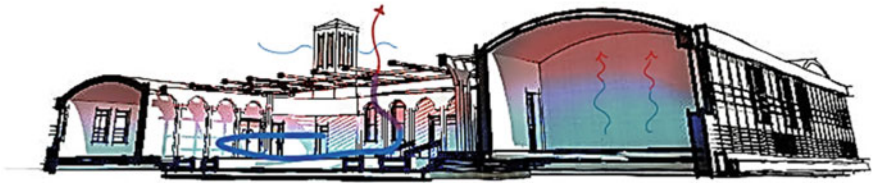

Fig. 9 The thermal transmission in the building

8 Conclusion

Related to Q1 and Q2, the first contribution of this paper is identifying the impact of conflicts on Syrian children's educational future to fulfill the first objective of the paper, the results show that 21% of the surveyed schooled are deemed unsafe, 3% are considered relatively safe, and 2% are at high risk, also showed that large numbers of children are impeded from getting an education because of the Poor economic conditions impede. The second contribution is to suggest a characteristic of a modular architectural system that suits Syria's environment and weather, accordingly, the design depends mainly on natural materials which are available in the region to reduce costs, with the adoption of traditional design solutions that enable the building to be a suitable environment for learning, this traditional method of architecture reliance on Natural solutions to achieve thermal comfort, ventilation, and natural lighting as part of the proposed solutions and it results in a suitable educational building.

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Implementation of BIM with Integrated E-Procurement System in Malaysian Construction Industry

Gunalaan Vasudevan and Chong Cheng Wei

Abstract This research report shows the results of survey regarding Building Information Modelling (BIM) and E-procurement system in Malaysia. The construction industry is constantly evolving throughout the decade. The objective of this research is to identify the adoption, barrier of implementation and strategy of implementation of BIM and E-procurement system in Malaysia construction industry. 100 respondents' response were analysed and the data are discuss and tabulated. The results show that majority of the respondents are aware of BIM and E-procurement system and their advantage and barriers of implementation in Malaysia. The respondent response towards BIM is more positive due to its clear advantages, while many still have doubt about the E-procurement. However, both BIM and E-procurement were being agreed as being the future of construction industry in Malaysia if given proper strategies of implementation. It can be concluded that both BIM and E-procurement is still in early phase of implementation in Malaysia construction industry. However, once implemented, the advantages and benefits of these software will bring the industry to a whole new level.

Keywords Implementation BIM · E-procurement · And building information modelling (BIM)

1 Introduction

The Building Information Modelling (BIM) system is an advanced process that utilizes a computer generated virtual visual model of a building to simulate the planning, design, construction and operation phase of the facility. The information generated will represent the actual real-life life cycle of the facility from conceptual phase to completion phase. The engagement of innovation and creativity features of BIM that distinguishes it from the other known design technologies is that it is not only seen as three dimensional geometric modelling, but as well as functioning

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as a structured information that is organized, defined and exchanged [1]. In BIM, every section of the building is modelled carefully with all the required details shown clearly. The model will then build up in a virtual reality world for visualization to allow further development of alternatives route for the building and also enables the stakeholders to view the outcome of the building before the commencement of the project. The essential design documents will then be generated accordingly to the information provided by the model created in the system [2].

2 Literature Review

Interoperability issue has been known to be one of largest issue in the construction industry as it is one of the influencing factor that will affect the outcome productivity and the quality of the project. Although, BIM with E-Procurement System have been introduced into the industry, the implementation is still considered to be low in the local construction industry. It is suspected that this phenomenon is caused by barriers in terms of technical and human. These could be further categorized as internal or external. In term of the internal usage of BIM and E-Procurement System, the main issue is mostly focused on the cost and human issues especially in learning and mastering the new tools and processes of the software. Most of the time, the learning process is shown to be costlier than purchasing the actual software or hardware. Studies has shown that high investment cost and the constant need to upgrade the hardware and software has been 2 of the most major obstacles for companies to adopt the systems. Also, when comparing the cost of the system with the unclear benefits of implementing them, has caused several participants in the industry to stray away from it. Meanwhile, the external barriers include the legal aspect of implementing BIM which have been an area of concern to many participants of the industry [2, 3]. Legal aspect related to ownership of the model and responsibility for model accuracy and also the responsibility of cost of producing and managing the model has been top tier list of potential legal obstacle to embrace the BIM and E-Procurement process. Furthermore, technical issues mainly related to the insufficiency and reliability of interoperability between software applications are also huge obstacles. Most companies have almost no experience and awareness of the use of shared BIM and E-Procurement System [2, 3]. With that being said, the current industry lacks agreement and common standard practice concerning the utilization of integrated BIM and E-Procurement System. The sluggish adoption and acceptance of BIM and E-Procurement System in the current construction industry is mostly because of the lack of awareness, technical complexity, and absence of interoperability between various software that are been previously engaged in generating the creation of the Model. However, the degree of these factors has yet to be identified. Therefore, research had to be commenced for the sake of identifying the degree of the factors.

3 Research Methodology

See Fig. 1.

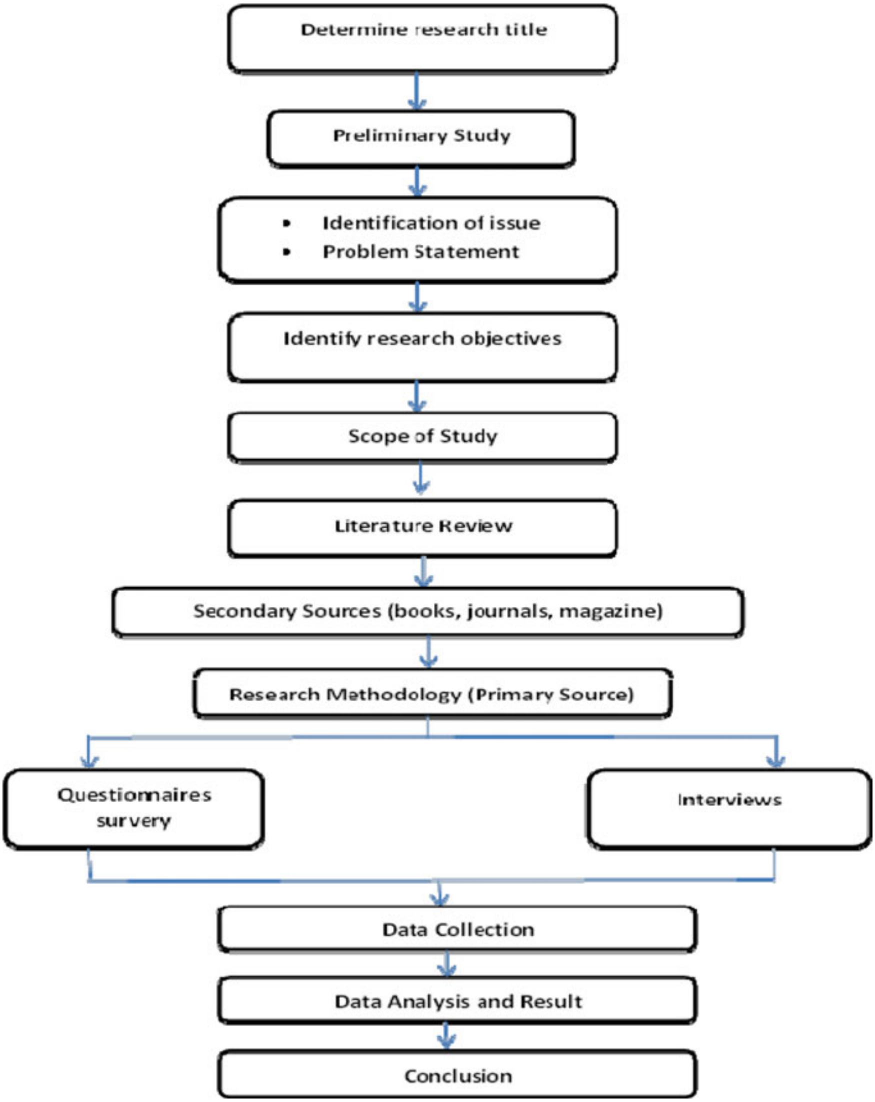
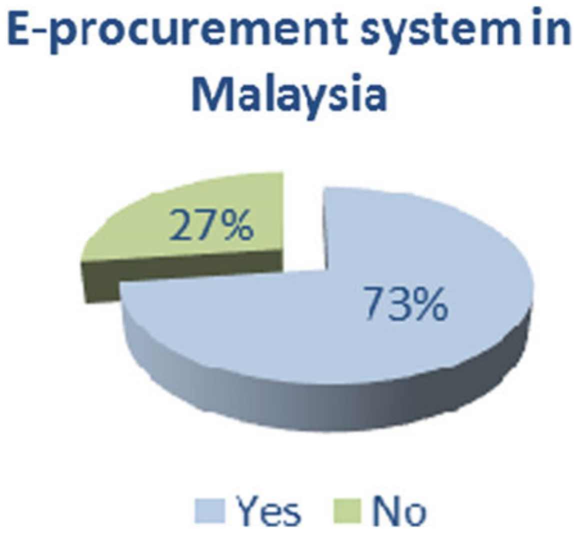


Fig. 1 Research methodology flow chart

Fig. 2 Awareness of e-procurement system



4 Result and Discussion

4.1 Adoption of E-Procurement

Based on Fig. 2, the adoption of E-Procurement in Malaysia is considered to be quite high with a percentage of 73% out of 100%. This shows that majority of the participants in the construction industry in Malaysia knows the existence of this technology.

4.2 Strategies to Improve Implementation of E-Procurement

Figure 3 is a chart that shows the result of the respondent's opinion on whether will E-procurement system being part of the future of the construction industry in Malaysia given that more new strategies is implemented. According to the chart, it clearly defines that 73% of the majority agreed that if more strategies has been developed for E-procurement system, it will have the potential to be part of the future of construction industry. This result indicates that, if E-procurement is well-developed and promoted in the industry, people will be willing to accept and adopt the system into their project.

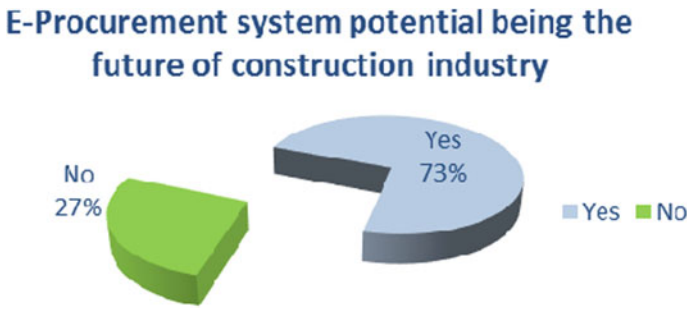


Fig. 3 E-procurement future potential chart

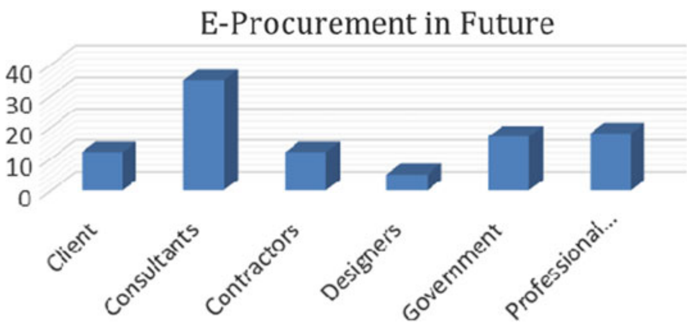


Fig. 4 E-procurement driving force

4.3 E-Procurement Driving Force

Based on the Fig. 4, the respondent's response regarding the driving force for E-procurement system in Malaysia. According to Fig. 4, the majority of the respondents (35%) indicate that the consultants should be the driving force for E-procurement system. Since consultant plays the role of advising the project design, the consultant can promote E-procurement to the project team and share the benefits of implementing E-procurement into the project. By doing so, the potential and popularity of E-procurement system will increase as the user's increase. This will potentially solve the problem of the E-procurement system platform being unsaturated.

4.4 Barrier of Implementation of E-Procurement

Table 1, the respondents were asked to rate the barrier of implementation of E-procurement system. According to the results tabulated in Table 1, 'Inadequate of information available to the supply chain' tends to be the most important barrier of

Table 1 Barrier of Implementation

Barrier of implementation	1	2	3	4	Total
Lack of skilled personnel in conducting E-Procurement for construction industry	15	21	34	30	100
Inadequate information available to the supply chain	10	16	41	33	100
Steep learning curve for those who unfamiliar with the technology	13	35	25	27	100
People rejection/reluctance to learn new technology	23	25	30	22	100
Client embrace traditional procurement method for construction	24	18	30	28	100
Lack of clear advantage of implementation in Malaysia	17	18	35	30	100
Unreliable information and supplier data	18	21	33	28	100
Time required to adapt to changes	23	24	28	25	100

1—Strongly disagree, 2—Disagree, 3—Agree, 4—Strongly agree

implementation for E-procurement system. Even though, E-procurement has been on the market for a period of time, it proves that many of the industry's participant did not fully took part into adopting the system into their projects which leads to the platform having inadequate users and information [4]. The 2nd most important barrier of implementation for E-procurement system is 'Lack of clear advantage of implementation in Malaysia'. This can clearly be seen due to the fact that not many people discussed and actually promote this system in the construction industry in Malaysia. Also, without much people participate in it, the platform for E-procurement is not saturated enough to attract users to take part and fully understand it potential advantages [5]. Therefore, with less and less participants towards the software, the advantages of implementation of E-procurement remained unclear for future users. This causes more people to prefer the traditional method over E-procurement system.

5 Conclusion and Recommendation

The overall objectivee BIM and E-Procurement system is well aware in Malaysia. The level of both software implementations is still in early phase, therefore more implementation strategies are needed to be done in order to promote this software into the construction industry Malaysian to a whole new level. For E-Procurement, the barrier of implementation is due to inadequate of information available to the supply chain and lack of clear advantage. The lack of information is due to many of the industry's participant did not fully took part into adopting the system into their projects which leads to the platform having inadequate users and information [6]. As for the lack of clear advantage, due to the fact that not many people discussed and actually promote this system in the construction industry in Malaysian, this caused the software to be less popular over time and its advantages also become lesser known to the industry. Recommendation for further research The following recommendations are proposed for further research and study in order to from a complete picture E-procurement system in Malaysian Further investigation and research needs to be done in perspective of BIM and E-procurement [7]. Try to take part in actual training programs to gain more field knowledge and understanding regarding the software. Do the survey with larger number of samples from other location in Malaysian rather than only in Klang Valley. Interview a few key persons who took part in E-procurement and BIM in the construction industry.

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Built Environment for Memorisation: Enhancing the Hafazan Performances Through Learning Spatial Quality and Sitting Styles

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Abstract Past studies have reiterated that environmental quality is the key to better education. A well-defined learning environment is not only promoting a better learning engagement and emotional impact. It also contributes to students' positive perception of their ability to succeed. The need for improvement should be extended to all education streams, including the quality of the Islamic education institutions. This paper aimed to explore whether the students' learning environment and the sitting facilities play an important role in achieving better performance. The objectives of the study were to: (i) analyse the effect of the learning environment on the performance of *tahfiz* students between gender in Quran memorisation and (ii) investigate the impact of students' sitting style towards their Quran memorisation performance. A total of 24 *tahfiz* students were selected to participate in the 10-day experiment. In knowing their perception in each sitting, each student was required to complete a different *hafazan* task in various positions provided during the experiment. The findings showed that the male students were affected more emotionally and performance when they sat on a chair as compared to sitting cross-legged. Conversely, female students claimed both sitting styles had similar effects in terms of condition, which caused sleepiness, sickness and delays throughout the experiment. Concisely, both gender seemed to have better performance when they sat cross-legged, regardless of their perceptions towards the sitting condition. The findings propose that these could be due to their common sitting style (cross-legged) practices and adapted before the experiment. This research can be a turning point in improving the quality of *tahfiz* learning premises for better learning experience and performance.

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Keywords Tahfiz · Quran memorization · Sitting style · Hafazan performance

1 Introduction

The need for quality education has prompted a continuous effort to improve the students' learning environment in all educational spectrum, including in the Islamic education stream. Studies showed that student's environment and their learning style have significant influence [2]. Sze [12] added that the performance could be influenced by colours stimulation from the environment, sitting style, cognitive ability and personality of the student. In terms of performance between gender, previous studies found that female students' performance was typically driven by their self-motivation and attitude. The male students' performance, on the other hand, was more influenced by their self-interest in a particular subject [9]. This study specifically investigates the impacts of students' learning environment and their sitting style on the performance amongst *tahfiz*[1] students in memorising the Quran. In doing so, several objectives were set. The objectives are to analyse whether the learning environment could affect the performance of *tahfiz* students of different gender in memorising the Quran (i) and to investigate if the students' condition is affected by their sitting style while memorising the Quran (ii).

1.1 Research Hypothesis

This study has the following hypotheses:

H1. There are no differences in the effect of students' condition by sitting style.

H2. There are no differences in the performance of students by sitting style.

2 Literature Review

2.1 Design Elements of Learning Space Influence Students' Performance

A good learning environment can motivate students in learning [7]. According to Xiong et al. [15], there were various influences of environmental elements on learning. They claimed that the most common factors to affect learning efficiency

[1]An Arabic word means 'to memorise'. In this context, it is referring to the student who memorising Quran.

were temperature, noise and illuminance of the learning space. A class's environment can be categorised as good and suitable for learning when there are good aspects of lighting, temperature and air quality [4, 6]. Not only that, the interior design elements, such as colours used in the classroom, play a vital role, whereby this aspect can influence students' mood and performance [1, 4, 5]. Previous studies mentioned that warm colours could lead to active learning areas that can stimulate communication and increase interactions amongst students. In contrast, pale colours (high value–whiteness) make students less active and energetic, and thus less motivated to study [2]. Besides the interior elements, a study by Beckers et al. [5] has highlighted that natural elements also gave a significant impact on students' learning performance when facing natural views. Another aspect that takes into account the learning environment is the classroom layout [5]. There are common agreements by previous researchers that space and privacy are also factors for better learning and influence learning behaviour and performance [6, 8].

2.2 Sitting Styles Affect the Comfort of Students While Learning

Poor sitting can lead to musculoskeletal [10]. Woo et al. [14] posited that sitting on a cross-legged posture for a long time can cause lumbago,[2] fatigue, impaired cardiopulmonary function, neurotic and psychiatric problems due to asymmetric posture. Sitting posture is vital in learning because each learning style may provide student's comfortability [11]. Previous studies found students preferred to sit on a chair, tiered seating with appropriate lighting, which led them to be more motivated in learning. Somehow the result found no significant correlation between the learning environment (furniture) with an improvement in their performance. In many *tahfiz* centres, sitting cross-legged are commonly practised and in some places is the only type of sitting used. Based on the previous findings, this study also intended to find the influence of sitting styles on students' memorisation.

3 Method of Study

This study utilised primary data to answer specific research questions through a questionnaire survey and experiment. The sampling type used in this study was simple random sampling which acquired 24 students aged 20, who were equally divided between gender. This study approached the descriptive analysis to analyse the mean score of *tasmik*[3] performance. Additionally, the data will be interpreted in Tables 1, 3 and 4 as well as Figs. 1, 2 and 3 to examine the students' conditions according to

[2]Pain in the muscles and joints of the lower back.

[3]Examination of Memorising Quran.

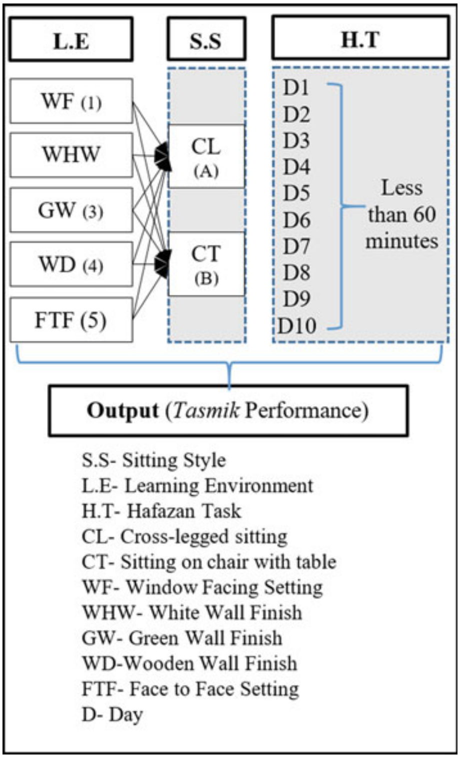
the types of sitting by generating the mean score. Figure 1 indicates the experiment modelling, whereby the sitting arrangement was set up for the *hafazan*[4] task during the 10-day experiment. There were five types of learning environment which included window facing setting (WF-1A and WF-1B), white wall finish (WHW-2A and WHW-2B), green wall finish (GW-3A and GW-3B), wooden wall finish (WD-4A and WD-4B) and face to face setting (FTF-5A and FTF-5B). Subjects were assigned to both sitting types; sitting on a chair with a table and cross-legged in 5 different learning environments for 10 consecutive days. All settings have a similar layout, light fittings and ceiling fan. The experiment was conducted in the morning from 8.00 am until 9.00 am. The time of the experiment, type of class, the instrument for the performance assessment and the experiment program was carefully design and plan according to their actual learning ecology and practice. The purpose of the experiment was to examine whether their performances could be affected by the changing environment. In this case, they were assigned to one seat from 1A to 5B, as illustrated in Fig. 1.

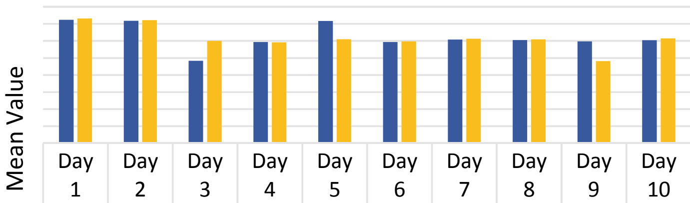
Table 1 Condition of male students during *hafazan* tasks

Condition of male students according to the type of sitting						
	Condition causes sleepiness		Condition causes sickness		Condition causes delay	
	On chair with table	Cross-legged	On Chair with table	Cross-legged	On chair with table	Cross-legged
Day 1	8.33	7.17	9.33	7.83	7.33	7.00
Day 2	7.75	7.50	9.25	8.25	6.75	7.25
Day 3	9.67	7.40	9.25	7.25	8.75	6.75
Day 4	8.40	6.00	9.33	9.80	8.83	9.00
Day 5	8.40	8.83	8.83	7.40	7.80	7.67
Day 6	9.00	6.40	10.00	9.40	9.20	6.40
Day 7	8.20	8.20	9.60	9.00	8.80	8.60
Day 8	7.00	6.00	9.60	8.60	7.60	7.80
Day 9	7.50	8.60	9.80	8.25	9.40	7.25
Day 10	9.67	8.00	9.50	8.50	8.75	6.33

[4] Act of memorising Quran.

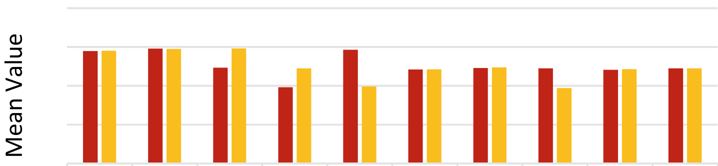
Fig. 1 Experiment of learning environment versus performance modelling





	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
On Chair with Table	144.8	143.6	96.67	118.6	143.5	118.6	121.5	121.0	119.5	120.8
Cross-legged	146.1	144.3	120.1	118.3	121.8	119.5	122.6	121.6	96.33	123.0

Fig. 2 Mean score of male students according to type of sitting



	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
On Chair with Table	144.83	147.83	123.33	98.33	146.5	121	123	122.5	120.67	122.5
Cross-legged	145.33	147.5	148.33	122.5	99.17	121.33	123.83	97.17	121.5	122.67

Fig. 3 Mean score of female students according to the type of sittings

Table 2 Difficulties of *hafazan* task by students in 10 days in percentage

Difficulties of *Hafazan* task						
Surah per day	Male (%)			Female (%)		
	Easy	Moderate	Difficult	Easy	Moderate	Difficult
Day 1—Fussilat (verse: 12–20)	–	100	–	–	75	25
Day 2—Al-Syura (verse: 16–22)	33	67	–	58	42	–
Day 3—Al-Syura (verse: 45–51)	11	78	11	27	72	–
Day 4—Al-Zukhruf (verse: 23–33)	–	50	50	–	50	50
Day 5—Al-Zukhruf (verse: 34–47)	9	64	27	20	60	20
Day 6—Al-Zukhruf (verse: 48–60)	10	60	30	20	80	–
Day 7—Al-Jathiyah (verse: 14–22)	30	70	–	50	50	–
Day 8—Al-Jathiyah (verse: 23–32)	10	70	20	22	67	11
Day 9—Al-Ahqaf (verse: 15–20)	–	89	11	20	50	30
Day 10—Al-Hadid (verse: 25–29)	10	80	10	20	60	20

4 Finding and Analysis

4.1 *Male Students' Performance and Sitting Condition for 10 Days*

Base on the results in Fig. 2, it was identified that the performance mean score seemed affected on Day 3 of the experiment. The result might be due to variations in the environment, as claimed by Ansyari [3]. For example, on Day 1 to Day 2, students would do their *hafazan* tasks at a similar learning environment (Fig. 1) but in a different sitting style, either cross-legged or sat on a chair. However, on Day 3, the students had to switch position to the next different learning environment. This would cause a drop in terms of their performance due to the non-adoptive environment [13].

Apart from that, the result in Table 1 indicated that male students who sat on chairs portrayed worse performance, which led to sleepiness (9.67), sickness (9.25) and delays (8.75). Apart from the changing environment, difficulties in *hafazan* task may also affect performance. In Table 2 none of the male students stated that the task was difficult on Day 1 and Day 2 of the experiment. Therefore, the mean score graph (Fig. 2) for Day 1 and Day 2 of the experiment illustrated the highest compared to the other days. On Day 4 of the experiment, the male students stated that the task was 50–50%, either moderate or difficult. Therefore, the graph (Fig. 2) does not drastically change from Day 3 to Day 4. The performance mean score portrayed slightly similar in terms of sitting style, which were 118.67 and 118.33, respectively. However, the male students claimed that the conditions for both sitting (on a chair with table and cross-legged) caused sickness (9.33, 9.80) and delays (8.83, 9.00). In Table 1, the mean score of students' condition portrays less difference. Somehow, the result revealed that male students seemed a bit more affected in terms of sleepiness, sickness and delays when they sat on a chair.

4.2 Female Students' Performance and Sitting Condition in 10 Days

The result revealed that female students' performance from Day 1 to Day 10 was mostly higher than the performance of male students. Previous studies found that male students' performance accorded to their interest level, while female students were less associated with their interests [9]. This means that female students could score better performance than male students, regardless of their learning interest levels. In terms of sitting style, the performance was higher when the female students sat cross-legged instead of sitting on a chair. The graph (Fig. 3) illustrates that female students' performance has fluctuated in 10 days of the experiment. It was found that the pattern was much alike the male students' performance on Day 1 to Day 3. The pattern could be for a similar reason whereby the students experienced a different learning environment on Day 3 of the experiment. The findings found that the students' performance of both genders seemed affected when they changed the learning environment.

In the matter of female students' condition, both sitting types affected the female students. The results were based on the mean score of students' condition (Table 3). The higher the mean score, the more significant the impact on their conditions. Therefore, sitting cross-legged seemed to give a more significant impact which can cause sleepiness as compared to sitting on a chair. Meanwhile, sitting on a chair affected more, whereby the condition caused delays compared to sitting cross-legged. Somehow, the female students claimed that both sittings could cause sickness. Therefore, H1 was rejected as there were differences in the performance of students by sitting style for both genders. Meanwhile, H2 was also rejected as there were different effects by students' sitting style, which can cause them sleepiness, sickness and delays. In conclusion, the studies have achieved the objectives that the performance of students (i) is affected by changing the environment and (ii) the condition of

Table 3 Condition of female students during *hafazan* tasks

Condition of Female Students According to the Type of Sitting						
	Condition causes sleepiness		Condition causes sickness		Condition causes delay	
	On Chair with table	Cross-legged	On chair with table	Cross-legged	On chair with table	Cross-legged
Day 1	6.33	7.50	8.67	9.17	5.67	7.83
Day 2	5.20	7.86	7.80	9.29	7.00	8.71
Day 3	6.00	5.33	9.20	6.33	8.40	6.67
Day 4	6.25	6.50	7.75	8.83	7.00	6.50
Day 5	7.00	6.60	8.40	8.20	7.20	6.80
Day 6	5.50	5.50	9.00	8.83	6.75	7.50
Day 7	6.33	4.75	9.17	8.00	7.50	7.00
Day 8	6.75	6.20	7.75	9.60	6.50	9.00
Day 9	4.75	7.00	8.50	8.50	7.75	5.33
Day 10	6.57	6.67	9.00	9.00	7.71	7.00

students are affected by the sitting styles which can cause three significant conditions (sleepiness, sickness and delays) (Figs. 4 and 5).

Fig. 4 Views of window facing (WF) setting and white wall finish (WHW) setting

Fig. 5 Setting of face to face (FTF) with cross-legged sitting style

Table 4 Performance of students according to gender in various settings

	Male		Female	
	Sit on chair	Cross-legged	Sit on chair	Cross-legged
Window face setting	143.50	143.60	145.50	147.20
White wall finish	146.20	146.00	**148.00**	**147.50**
Green wall finish	145.30	145.82	147.00	145.82
Wooden wall finish	144.22	145.38	145.30	146.63
Face-to-face setting	144.27	144.80	147.00	147.14

5 Conclusion

As a whole, it is pertinent to note that male students' performance is better when they sit cross-legged in any different learning environment (Table 4). In contrast, the female students showed better performance when sitting on a chair in the white and green environment. Conversely, at the 'window facing setting' (WF), wooden wall finish (WD) and 'face-to-face' setting (FTF), female students showed better performance when sat cross-legged (Table 4). Although previous studies mentioned the adverse effect of cross-legged posture, in the long run, the effects found in this study was only for short term whereby the findings showed mixed findings, with both positive and negative effects found between the gender. In terms of the learning environment provided, students managed to get the highest score in the white wall finish class for female students, regardless of their sitting styles. This finding was contrary to previous studies, whereby Al-Ayash et al. [2] claimed that high-value colours (whiteness) make students less motivated to study. However, it was not clear if it affected their performance. Therefore, in terms of performance, students who sat at the white wall finish setting during the *hafazan* task, either cross-legged or sat on a chair, portrayed the highest score than the other setting types. Further investigation with a more significant sample size and context of setting is needed to generalise the findings.

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Ion Chromatography Test in the Conservation of Fort Margherita, Kuching, Sarawak, Malaysia

Chin Ling Tan and A. Ghafar Ahmad

Abstract In Malaysia, rising dampness is one of the most common building defects in heritage building, especially the masonry structural heritage building which is built of bricks. The dampness or moisture brought the soluble mineral salts from the ground and damaged the masonry building structures through capillary effect. The salt residues inside the columns, walls and other structures will weaken its structural stability. Besides that, high salt contamination in masonry structures of a heritage building will cause extensive crumbling and damage of wall plaster especially the lower part of the walls. According to National Heritage Act 2005 (Act 645) and Guidelines on Heritage Building Conservation (2017), the implementation of scientific tests in heritage building conservation practice in Malaysia is encouraged and recommended by the National Heritage Department of Malaysia [1, 2]. Thus, ion chromatography test or salt test is conducted in heritage building conservation projects to investigate the level of salt embedded in the columns, walls, structures and components of a heritage building. This paper is based on the study on documentation recording the ion chromatography test conducted in the conservation of Fort Margherita, Kuching, Sarawak, Malaysia (2012–2014) such as the ion chromatography test report and the final conservation report. The result of the ion chromatography test on the conservation of Fort Margherita, Kuching, Sarawak, Malaysia (2012–2014) was evaluated based on the literature review on ion chromatography. The research findings revealed the purpose and basic procedure in conducting the ion chromatography in masonry heritage building conservation in Malaysia.

Keywords Ion chromatography · Salt · Conservation · Masonry heritage building

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1 Introduction

Fort Margherita is located at Kuching, Sarawak, Malaysia. It is situated on a hill at the north bank of the Sarawak River. It was built in 1879 by Charles Brooke, the second Rajah of Sarawak. Fort Margherita was named after Charles Brooke's wife, Ranee Margaret. The conservation of Fort Margherita, Kuching, Sarawak, Malaysia was started in 2012 and completed in 2014 [3]. Ion chromatography test was conducted to investigate the salt contamination problem and to ensure the effectiveness of the salt desalination treatment.

Desarnaud, Bonn and Shahidzadeh (2016) revealed that salt weathering affects porous materials including the engineering structures, monuments, and artworks [4]. Ghafar and Harris (2010) reported that rising damp and salt attack are the common building defects in heritage buildings in Penang, Malaysia where the existence of mineral salts may weaken the building components [5]. According to the Woolfitt (2000), soluble salts are a principal agent which caused decay in porous building materials and there are various types of soluble salts such as sodium chloride, carbonates, nitrates and sulphates of calcium, magnesium, potassium, sodium sulphate and magnesium chloride which can cause damages to building masonry [6]. Nien Wei and Azree (2017) mentioned that sodium, potassium, magnesium and calcium are common cations found in masonry wall, while chloride, sulphate, nitrate and carbonate are common anions found in masonry wall (see Tables 1 and 2) [7]. Ghafar and Harris (2010) stated that there are three (3) types of destructive soluble salts which can be found in the masonry wall of heritage buildings such as chlorides (Cl), nitrates (NO_3) and sulphates (SO_4) [5]. All of these salts can be detected by ion chromatography test. Ion chromatography or ion-exchange chromatography test or

Table 1 Cations commonly found in masonry wall

No.	Cations
1	Sodium (Na^+)
2	Potassium (K^+)
3	Magnesium (Mg^{2+})
4	Calcium (Ca^{2+})

Source Nien Wei and Azree [7]

Table 2 Anions commonly found in masonry wall

No.	Anions
1	Chloride (Cl^-)
2	Sulphate ($SO_4{}^{2-}$)
3	Nitrate ($NO_3{}^-$)
4	Carbonate ($CO_3{}^{2-}$)

Source Nien Wei and Azree [7]

salt test is a chromatography process that separates ions and polar molecules based on their affinity to the ion ex-changer (Wikipedia n.d.) [8].

2 Methodology

The literature review on ion chromatography test was compiled from several sources such as the research papers, laboratory's reports and interview sessions with the local heritage conservation experts. The case study data was collected from the final conservation report and ion chromatography test report for the conservation of Fort Margherita, Kuching, Sarawak, Malaysia (2012–2014). The data was analysed and evaluated to reveal the purpose and basic procedure in conducting the ion chromatography in masonry heritage building conservation in Malaysia.

3 Discussion and Findings

In masonry heritage building conservation in Malaysia, ion chromatography test is conducted to investigate the level of salt embedded in the masonry brick wall. There are three (3) types of destructive soluble salts such as chlorides (Cl), nitrates (NO_3) and sulphates (SO_4) which commonly found in the masonry heritage buildings [5]. In practice, ion chromatography test is conducted in three (3) phases which are before salt desalination treatment, during salt desalination treatment (after the application of first round cocoon poulticing and before the application of second round cocoon poulticing) and after salt desalination treatment. It is critically important to identify the salt contamination problem in masonry heritage buildings and to ensure the effectiveness of salt desalination treatment.

The research findings identified that ion chromatography test has three (3) major functions in masonry heritage building conservation. Firstly, ion chromatography test is applied to identify the salt contamination problem. Second, it is an important test to investigate the level of salt embedded in the walls, columns and other building components and elements. Furthermore, ion chromatography test also play an important role in determining the effectiveness of salt desalination treatment.

In conservation of brick masonry heritage building, brick dust samples are required for ion chromatography test. The brick dust samples were collected from four (4) spots on masonry walls of Fort Margherita, Kuching, Sarawak by drilling at three (3) different dept such as 10 mm, 20 mm and 40 mm on a spot. The test was conducted for three (3) stages which are before, during and after the salt desalination treatment process [3, 9, 10]. All the sample collection spots were recorded on drawings and report for future reference. It is crucial to avoid sample collection during the raining day. The samples should not be polluted before and during the process of ion chromatography test at laboratory. Salt desalination treatment for Fort Margherita,

Table 3 Ion chromatography test result of samples at location 1 (before salt desalination treatment)

Location 1								
Salt Dept (mm)	Mineral							
	Na%	K%	Mg%	Ca%	Cl%	NO_3%	SO_4%	Total
10	0.287	0.137	0.052	1.694	0.123	0.100	0.027	2.421
20	0.245	0.149	0.047	1.307	0.062	0.012	0.039	1.861
40	0.234	0.142	0.076	1.092	0.152	0.100	0.064	1.860

Source Tan [3] and Westox Systems Sdn. Bhd., [9]

Table 4 Ion chromatography test result of samples at location 1 (after first cocoon application)

Location 1								
Salt Dept. (mm)	Mineral							
	Na%	K%	Mg%	Ca%	Cl%	NO_3%	SO_4%	Total
10	0.167	0.117	0.032	0.790	0.223	0.050	0.327	1.707
20	0.105	0.049	0.017	0.807	0.022	0.002	0.030	1.032
40	0.134	0.062	0.016	0.078	0.052	0.050	0.064	0.465

Source Tan [3] and Westox Systems Sdn. Bhd., [9]

Table 5 Ion chromatography test result of samples at location 1 (after second cocoon application)

Location 1								
Salt dept. (mm)	Mineral							
	Na%	K%	Mg%	Ca%	Cl%	NO_3%	SO_4%	Total
10	0.009	0.022	0.007	0.012	0.080	0.021	0.030	0.181
20	0.030	0.003	–	0.005	0.016	0.027	0.014	0.095
40	0.012	0.023	–	0.007	0.029	0.006	0.038	0.188

Source Tan [3] and Westox Systems Sdn. Bhd., [10]

Kuching, Sarawak is considered effective as the total salt content was reduced after the salt desalination treatment (see Tables 3, 4, 5 and 6).

4 Conclusion

In conclusion, all decision making process in heritage building conservation should be supported by evidence-based approach. Salt attack or salt contamination is one of the major building defect found in Fort Margherita, Kuching, Sarawak, Malaysia before the conservation works in 2012–2014. The soluble salts will affect the structural stability of the masonry heritage building. It should be removed from the

Table 6 Summary of ion chromatography test result (total 4 locations) for Fort Margherita, Kuching, Sarawak (2012–2014)

Stage	Total salts content (%)	Total salts extracted (%)
Before salt desalination treatment	20.442	Nil
During salt desalination treatment	10.724	52.46
After salt desalination treatment	1.729	91.54

Source Tan [3] and Westox Systems Sdn. Bhd., [10]

masonry heritage building to safeguard its architectural value and authenticity. The ion chromatography test can assist in identifying the building defect such as salt contamination, investigating the level of salt embedded in the walls, columns and other building components and elements and ensuring the effectiveness of the salt desalination treatment. Furthermore, the basic procedure in conducting ion chromatography test such as the sample collecting process must be conducted according to the requirement to ensure the quality of the test result.

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Achieving Zero Defects Strategy: A Quantitative Report Adjudicating the Most Common Building Defects to Look Out for

Roslan Talib and Mzailan Sulieman

Abstract As buildings, age and natural deterioration occur, many types of defects are common and can be found in these buildings. Some of these defects can affect the security of building structures while most are local and non-structural. To address these issues, the study intends to identify how common is the common defects that typically happened. Using Quantitative Research Method to emphasize the objective measurements through the statistical, mathematical, or numerical analysis of the data collected through questionnaires online surveys. The finding shows how typical building defect can be so repetitively expected and common and this illustrates that perhaps effort to provide defects solution guide for the building construction players need to be stepped-up. One of the analytical variables; Concrete Flat Roof (CFR) affecting defect factor positively by letting the water to seep through its roof. Thus, this negative act impacting the interior space and qualitatively become the defects of most pertinent evidence. To conclude, there is a significant correlation between the selected building variables (for this case) and how they play the most typical defects role that indicates these evidence facts should come to grips with.

Keywords Building defects · Construction defects · Zero defects · Quantitative method · Defects statistical

1 Introduction

It's not easy to find out what are the most common defects that always happening within the construction sector in Malaysia. However, the industry players need to know about the typical building defects regardless it is a latent or non-latent defect to ensure repeating defect are not going to be repeated. Failing to trace the defects can pave the way to increase the economic budget in creating the building structure [1]. Warned to the designers to be aware of the importance to get to know on the building defects cause failures.

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The article will cover the quantitative method approach study onwards the construction industry players (n = 86) in regards to determining the most defects types that occurred within the construction industry in Malaysia. The study will be conducted online using the Google Form format with the respondents working and used to work within the construction industry or the built environment theme located within the Malay Peninsula's western coast of Malaysia.

This study is considered important due to the outcome of the study can benefit the construction industry by identifying the typical or most defects happened. Once the defects are identified, the same defects can be marked and can be avoided [2]. Even though this survey focusing on during the construction phase, it can also be linked to the other 2 phases of construction which are during the design phase and the post-construction phase. Once the defects have been traced during the construction stage, the affected defects can also be traced during the design part and the maintenance period. So the elimination action can be done earlier as well as the repeated defects will not be happening during the maintenance period [3]. Urged everyone involved with a project—from both the design team and the construction team—must do their part to avoid defects.

2 Literature Research

A literature review is an important and critical evaluation that summarizes research finding pieces of evidence [4]. Most of the good literature book references written focusing on the defects problem concerning the writer's environmental condition of their locality. Thus the defects local conditions are different from Malaysia's local tropical climate construction detail. This is where it is important more write-up about the tropical detail condition in tackling the building defects been initiated [5] like through this research.

Identifying building defects at any construction stage is critical to any research being done to diagnose and avoiding building failures [6]. Literature review on these matters is critical and knowledge on defects identification helps to reduce the problem thus enhance the quality of the structure internally as well as externally. Literature study indicated that certain factors are contributing to let defects to happen. These factors will exist for the first time and can be repeating unless the construction players look-into these matters seriously to avoid them.

The conclusion derived from the Literature Review indicated that regardless the defects are latent or non-latent in nature, as mentioned by [7], the tracing and identification of the latent or seen defects is the important starting point where the defected construction events can be avoided. The review indicated that not many literature covering on the tropical defects problem as many literature resources especially book references have been written in regards to the temperate climate.

3 Methods

The philosophical underpinning this research method simply make—use of the quantitative approach method as this method is the most appropriate to answer the identified selected research question. For this survey exercise, it is important to determine the most typical defects that always happened during the construction period. 7 dependent variables have been identified to this one particular case. However, the independents variable is identified to only 1 variable which is on the pattern of the common defect. In other words, the independent variable for this case is on the defects pattern variance where it can keep on changing depending on how critical or how bad is the condition of the defect will be.

Again, using the quantitative method approach, to test this particular census, 86 respondents (n = 86) has been identified among the Malaysia industry players to answer 7 dependent variable observations using 5 Likert Scale answering method. For information, this particular questionnaire is among 65 numbers of total questionnaire categories designed to tackle the whole research empirical study. The numerical results of the survey will be analysed using the statistical analysis tools (IBM's SPSS v. 24 as well as Microsoft Excel). This will help the researcher in performing the analysis for the research project.

Talking about the importance of Quantitative Research, this method of research was selected because the method is more reliable and objective. The method can use statistics to generalise a finding. It often reduces and restructures a complex problem to a more established relationship between variables [8]. For this study scope, this particular questionnaire has been identified compared to others due to its important criteria concerning the defects scenario. Once the research questions and research objectives together with the research hypothesis has been identified and formulated, the quantitative style questionnaires have been designed to answer the research hypothesis.

The demographic survey on the respondents reveals that good and fair combination of the construction players has been kind enough to give the response for the online survey through email and face-to-face interview sessions. The interview result using the particular questionnaire then being converted and transferred into the Google Form email format for central collection data process.

4 Results and Discussions

4.1 Mean and Standard Deviation Statistical Analysis

For this chapter (following with the sub-chapters) a series of statistical analysis has been identified to test variables validity. As a start, the 1st theory of interest is to use the hypo of prediction of the mean ($\bar{x}$). The ($\bar{x}$) implies the average and it is the sum of a set of data divided by the number of data. Mean can also prove to be an effective tool when comparing different sets of data. Many statistical analyses use the mean ($\bar{x}$) as a standard measure of the centre of the distribution of the data (Rasli, 2006). For this statistics observation analysis (sample census with n = 86) (see Table 1 [Sect. B1 Q11.a, Q11.c [i and ii] and Q11.b), with $\bar{x}$ = 4.5233, $\bar{x}$ = 3.3605 and $\bar{x}$ = 2.9767 mean the scores indicate that all 3 variables which area ranges from the highest; concerning from the common defects founds through the water seepage at CFR, cracks at wall and floor and defects due to moisture problem; show that the 3 variables are positions closer to the slight- middle to the highest scale of 3–5 of the 5 Likert Scale. The statistical finding demonstrates the figures are just very slightly within the perfect significance level. This delivers quite a significantly better result on the proved that most of the defects occurred through cracked CFR, wall, floor as well as having a problem with internal moisture. However, the rest of the $\bar{x}$ data which are 1.7442, 1.7326 and 1.7209 representing Sect. B1/Q11.d, Q11.e and Q11.f]), positioned within the 1.7 range cast a new light on the understanding that least common defects contributed from the last 3 variables which are on material deterioration, leaked RWDP and expired sealant. This delivers provisionally just very slightly missed the perfect significance level which is a slightly less good result on the related questionnaires variables issues but delivers significantly better result with less defect which is good for the practice.

As far as the Standard Deviation (σ or SD in short) is a concern, a σ which is close to 0 indicates that the data points tend to be very close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values (Cunningham and Aldrich 2012). So with σ ranges from 0.62735, 0.71910, 0.83895, 0.76981, 0.75808 and 0.77689 indicated that that values are <1 which can be considered low (see Table 1). It shows that the data are clustered closely around the mean which indicated more reliable and statistically significant. This is a better statistical analysis result for the analysis study on the variable.

4.1.1 Reliability Test

For reliability test, Cronbach's alpha is the most common measure of internal consistency ("reliability"). It is most commonly used when you have multiple Likert questions in a survey/questionnaire that form a scale and you wish to determine if the scale is reliable [9], b [ii], c, d, e and f) and with 2 Cronbach Alpha of each scale, r = 0.718 indicated that it is >0.70. The general rule of thumb is that a Cronbach's Alpha of 0.70 and above is good and reliable. This means that the closer each respondent's scores are on 0.70 and 00.80, the more reliable the test measure (and the higher the coefficient of stability will be). Below this value ($r < 0.70$) the internal consistency of the common range is low. Thus, the finding proved that important external portion of buildings including the main building's material components easily allowing water through the buildings and creating construction defects (Table 2).

Table 1 Statistical analysis on mean and standard deviation for Q11a to f

Statistics							
Question 11 (Section B1)		(a) Most common defects—water seepage through cracked CFR	(b) Most common defects—moisture problem	(c) Most common defects—(i) wall and (ii) floor crack	(d) Most common defects—material deterioration	(e) Most common defects—gutter /RWDP leaked	(f) Most common defects—expired sealant
N	Valid	86	86	86	86	86	86
	Missing	0	0	0	0	0	0
Mean		4.5233	2.9767	3.3605	1.7442	1.7326	1.7209
Std. deviation		.62735	.71910	.83895	.76981	.75808	.77689
Percentiles	25	4.0000	3.0000	3.0000	1.0000	1.0000	1.0000
	50	5.0000	3.0000	4.0000	2.0000	2.0000	2.0000
	75	5.0000	3.0000	4.0000	2.0000	2.0000	2.0000

Table 2 Statistical analysis on reliability test of 7 items for Q11a to f

Reliability statistics		
Cronbach's alpha	Cronbach's alpha based on standardized items	N of Items
0.718	0.701	7

4.1.2 Median, Variance, Kurtosis and Range Statistical Analysis

Following the previous subchapter and using the same testing selection, the use of "median" ($\tilde{x}$ "x-tilde") as shown at the 1st row of Table 3 emitting another way to measure the centre of a numerical data set. The $\tilde{x}$ "x-tilde" is exploring the "middle" value in the list of the numbers and the indicators truly in the middle of the data set. To find the median, the observations have been arranged in an orderly fashion from smallest to largest value. If there is an odd number of observations, the median is the middle value. If there is an even number of observations, the median is the average of the two middle values. For this 6 (Sect. B1-Q11a, b, c, d, e, and f) selected opinion pools variable analysis, the $\tilde{x}$ "x-tilde" recording numbers are 5.0000, 3.0000, 4.0000, 2.0000, 2.0000 and 2.0000. The data provides evidence that these selected inventory questionaries' survey (var. no. 1, 2, 3, 4, 5 and 6) statement with $\tilde{x}$ "x-tilde" cast to as being statistically quite significant all at acceptable range from 2.0000 to 5.0000. This indicates the respondents hugely agree that var. a, c and b are the said variables on the verge of being quite significant and giving positive impact to the study. This observation contained logically astonishing news to the project scope as the statements are not the obvious pertinent promising findings tabulated in the study's scope.

Next, the 2nd row of the data being analyses which are Variance (S2) as part and parcel of the statistic test component. Variance measures how far a set of data is spread out. A high variance indicates that the data points are very spread out from the mean, and one another. Variance is the average of the squared distances from each point to the mean [10]. For this most typical defects found variable, the numbers cranked out from the analysis are 0.394, 0.517, 0.704, 0.593, 0.575 and 0.604. It seems like the S2 numbers are all higher than 0. This means that with higher S2, more heterogeneous of the data points being spread out. This indicated that for the 6 variables (Q11 a to f) on the typical most defects found strongly supported the idea of there seems to be that the building defects can happen and water can easily penetrate through most of the building's external components. However, Q11a's S2 number which is the highest (S2 > 0=5) told on its strongest statement where CFR seepage needs further attention. Additional, when the variance is zero, it implies that all the values are equal.

For Table 3 [refer to 3rd row], among the important indication of the statistic shows negative kurtosis means that the distribution is flatter than a normal curve with the same mean and standard deviation. Kurtosis is a statistical measure that is used to describe the distribution. Negative (excess) kurtosis (−0.084 for Q11a and −0.001 for Q11c) means that the outlier character of the data is less extreme than expected

Table 3 Statistical analysis on median, variance, kurtosis and range for Q11a to f

Statistics							
Question 11 (Section B1)		(a) Most common defects—water seepage through cracked CFR	(b) Most common defects—moisture problem	(c) Most common defects—(i) wall and (ii) floor crack	(d) Most common defects—material deterioration	(e) Most common defects—gutter/RWDP leaked	(f) Most common defects—expired sealant
N	Valid	86	86	86	86	86	86
	Missing	0	0	0	0	0	0
Median		5.0000	3.0000	4.0000	2.0000	2.0000	2.0000
Variance		0.394	0.517	0.704	0.593	0.575	0.604
Kurtosis		−0.084	1.233	−0.001	0.150	0.313	0.154
Std. Error of Kurtosis		0.514	0.514	0.514	0.514	0.514	0.514
Range		2.00	4.00	4.00	3.00	3.00	3.00

had the data come from a normal distribution. This means the leakage seepage at CFR and seepage through the wall and floor (Q11.c [i] and Q11.c [ii]) were the less extreme contributors in producing the most building defects from the survey. On the other hand, statistically, positive Kurtosis (excess) kurtosis means that the outlier character of the data is more extreme than expected had the data come from a normal distribution. This can be seen from Q11b with 1.233, Q11d with 0.150, Q11e with 0.313 and Q11f with 0.154. Hence, the distribution (using Likert Scale 1–5 with n = 86) of the statistical indicators for the most defects happened to part of the study having more extreme and mostly positive Kurtosis excess and still indicates good defects variables indication of the research.

This section touches on the Range (denoted as Var(x) or σ^2) is the size of the smallest interval (statistics) which contains all the data and provides an indication of statistical dispersion. It is measured in the same units as the data. The result as indicated at row 5th of the table show the value having such as no.; 2.00 (Calculated as 5.00–3.00 = Var(x)). This small range value (Q11.a) indicates that there is less dispersion in the data. The result casts a new light on a small range value (2.00 [Q11.a], 3.00 [Q11.d], 3.00 [Q11.e] and another 3.00 [Q11.f]) indicates that there is less dispersion or less spread-out occurred in the data. This means that the test scenario showed that the variable of the typical water defects (latent or non-latent) gave focus impact statement as what the intention is which is statistically fine. Moreover, if the spread of values in the data set is large (for this case it got 2 = 4.00 and 4.00 as for Q11.b and Q11.c), the mean is not as representative of the data as if the spread of data is small.

4.2 Crosstab Statistical Analysis Focusing on Pearson Chi-Square

Following the sub-sub chapter above, this crosstab analysis as shown in Tables 4 and 5 (Sect.B1/Q11a), continuing with the Pearson chi-square (χ^2) test to calculate the p-value for both variables. Using the most important variable of the result; the 2-sided Asymptotic Significance the p result show 0.324, 0.224 and 0.424 which all above 0.05 (>0.05) shows a little less significant relationship between the two variables. All the 3 components of the p result indicated that the value >0.05 and the value determines that there is a less significant relationship between the 2 variables. The fewer significance values that are p-value associated with (χ^2) meaning there is little less strong evidence of rejecting the null hypothesis of no fit. It means not a perfect fit. To add to the statistical information, χ^2 goodness of fit is a non-parametric test. This set of crosstab examination maybe not the ideal chose variables such as the first variable (dependent variable); to agree that water seepage through CFR is the most typical problem concerning building defects and the second one (independent variable); respondent's working experience, but it implicates at certain degree there may be better variable to test into. However, the χ^2's 2 variables result still can be

Table 4 Statistical analysis on Crosstab Test based on the dependent variable (Q11a) and independent variables (work experience)

Crosstab

Count

		Working experience							Total
		1–5 years	6–10 years	11–15 years	16–20 years	21–25 years	26–29 years	More than 30 years	
Most common defects-water seepage through cracked CFR	Neutral	3	2	0	1	0	0	0	6
	Agree	5	5	3	5	6	3	2	29
	Strongly agree	8	7	16	8	7	4	1	51
Total		16	14	19	14	13	7	3	86

Table 5 Statistical analysis on the pearson chi-square test for Q11a based on crosstab of dependent and independent variables (work experience)

Chi-Square tests			
	Value	df	Asymptotic significance (2-sided)
Pearson chi-square	13.639[a]	12	0.324
Likelihood ratio	15.321	12	0.224
Linear-by-Linear Association	0.639	1	0.424
N of valid cases	86		

[a] 14 cells (66.7%) have expected count less than 5. The minimum expected count is 0.21

considered valid as the working experience seems very important to match with CFR leakage defects factor variable. This is due to the job experience variable involved the classification of the respondent's (n = 86) professional expertise within the construction industry which carry a heavy variable. Overall, this makes the tabulation a little less valid and a little less relevant to the study' over-all CFR leakage vs working experience scope but still shows near-marginal significance result comparison and useful for research purpose.

4.3 Median, Variance, Kurtosis and Range Statistical Analysis

A histogram is a chart representing a frequency distribution; heights of the bars represent observed frequencies. In other words, a histogram is a graphical display of data using bars of different heights. It is similar to a bar chart but it uses a vertical column to display data [9]. For this statistic test as shown in Fig. 1 (using Questions 11 a, b, c, d, e and f; Section B1 in the Google Form online survey sheet), it is important to focus the graphs on the 3 most important histograms starting to the second most right bottom (X1 = Agree, Y1 = Strongly Agree), middle chart [2nd most right, 2nd row from bottom] (X2 = Agree, Y2 = Agree) and the middle, most bottom histogram (X3 = Neutral, Y3 = Strongly Agree). For Fig. 1, the Independent (X) Variable (X1, X2 and X3) representing the Occupation variable with 8 classification categories. Next, for the dependent (Y) variable, there will be 2 variables has been clicked-out for the test. Those are Y1, Y2 and Y3 which are on the most common defects found on the wall and floor's cracks and the most common defects found through the cracked Concrete Flat Roof (CFR) water seepage.

As far as the histogram distribution is a concern, it seems like it all has asymmetric bell curve pattern. Asymmetric histogram means the cutline is it down in the middle and the left-hand and right-hand sides resemble mirror images of each other. For the 1st chart (X1, Y1) with Frequency total of 42 ([5 + 8+2 + 3 + 3] * 2) and with the addition of bottom middle graph (X − 1, Y − 1) with Frequency of 20 ([1 + 5 + 2

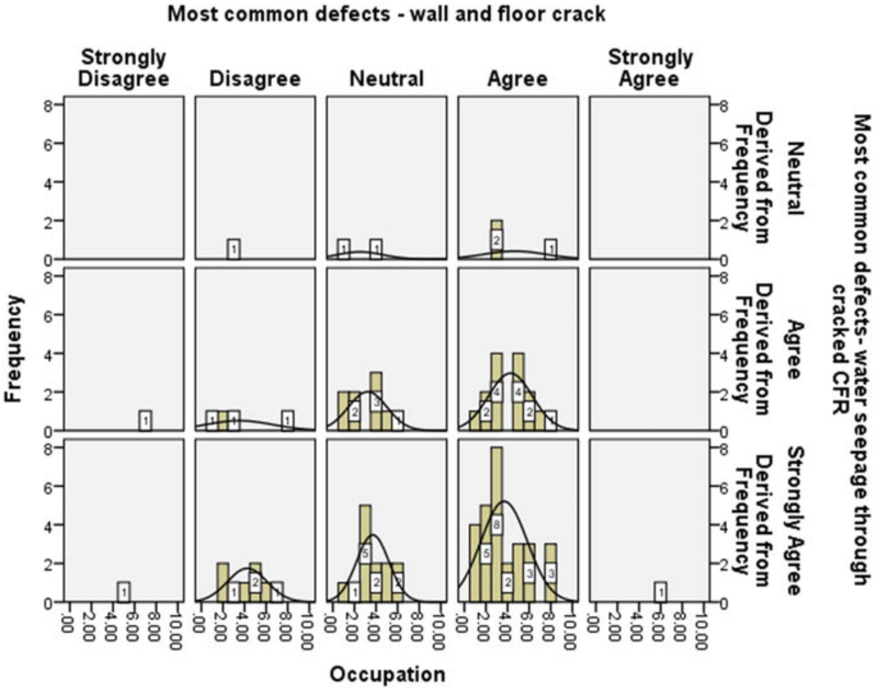

Fig. 1 Series of histogram charts analysis concerning 2 variables Q11a and Q11c (i) and (ii)

+ 2] * 2), it shows clearly most of the respondents (with n = 86) positively agreed on the variables statements.

As most of the active histogram charts happening on the Agree and Strongly Agree (with 4 and 5 in Likert Scale) which show the normal distribution where it represents an ideal data set that has lots of numbers concentrated in the middle of the range, with the remaining numbers trailing off symmetrically on both sides. This clearly shown that the test has a positive score in the survey indicating the visible evidence on a certain part of the building proofed that it is the water that originated the cause of the defects problem is convinced. In this case, the water penetrated through convincingly upon the online survey (n = 86); through CFR and the cracked part of the wall and floor of the structures.

5 Conclusions

There is high evidence that building defects occurred originated 99% from water seepage problem into the structure of the buildings. So, it is very important to design the building's external protective layers with a water-tight preventive system in mind. This type of building's protective system requires enough waterproofing prevention method knowledge to implement it. The study result indicated that water originated factor lead the way in creating Building Leakage Defects (BLD) and the symptom called Building Leakage Syndrome (BLS). No doubt that the statistical analysis measurement indicators gave evidence that all the 7 dependent variables quantitatively approved that identified factors furnished building defects are major in effects and need to be addressed correctly.

Lastly, in principle, most building defects are avoidable by they still occur; not through a lack of basic knowledge but by non-application or misapplication of it [1]. A sequence of the selected identified statistical analysis indicated that the research's results display how straightforward are the water can confer immense impact to building defects and this requires serious investigation to be done and to identify all the factors and all the links tracing how the defects are happening and been repeating.

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Kinetic Façade Design to Enhance Daylight Performance for Office Building in Malaysia

Omran Subhi Moesas, Nor Azlina Alias, and Aznida Azlan

Abstract Daylight design performance is a significant architectural factor and facade design has a great effect on its performance. In order to predict environmental changes and achieve more efficiently behaviour, kinetic facade is an architectural approach that use for higher effectiveness. This paper presents a facade design correspond with LEED v4.1 and Daylight Availability. It relies on Origami's technique of papers foldability where the facade morphs through rotation motion to enhance daylight performance. Rhino platform and its plugins Grasshopper and Diva through Daysim and Radiance engines were used for a parametric daylight simulation through two phases for an office facade oriented to east in Cyberjaya, Malaysia. Base cases simulations and simulations for a specific classification of rotation angles and size variable were conducted in first phase through parametric optimization process. 50 cm of radius façade size and 20° of rotation's angle reached outcome that achieve LEED v4.1 demands. a comparative simulation was conducted in second phase between the previous optimized result which exemplify the static base case with proposed dynamic system where second phase is a current development of phase one. The simulations were conducted on two days of solstice and two days of equinox for each working hours from 8AM–6PM. Lastly, a comparative analysis for the same days of parametric simulation results. Results proved that daylight achieved a better performance in comparison with optimized static case in all seasons approximately.

Keywords Daylight performance · Kinetic facade · Dynamic facade · LEEDv4.1 · Daylight autonomy · SDA · ASE · Daylight availability

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1 Introduction

The use of large glass facades in office buildings in Malaysia is widespread without consideration the tropical climate, which lead to presence of over-lit area and glare thus, increasing the cooling capacity need and affecting the social sustainability of users comfort [1]. Therefore, facade must reinforce to adapt with the climate and achieve better performance for the buildings sustainability. A huge burden lies on office buildings in energy using to maintain the comfort interior condition of the building after isolating building facade and envelop from its role which represent an administrator of energy saving. Kinetic facade achieve specific targets through adjusting itself to enhance daylight performance and improve user comfort thus decrease using electrical system [2]. However, initial design process rarely evaluate the performance of dynamic interfaces because of the difficulty of its qualitative and quantitative assessment. In contrast with static devices that is easily evaluated [3]. During the day, month and year, solar behaviour change's which cause a problem in offering a constant rate of daylight within the space. Moreover, in an irregular pattern the clouds in tropical sky constantly during minutes change as the cloud blocks the sun's rays and cause indoor lighting damage [4]. In this paper; parametric design and optimization tools is used and the key performance standard is daylight to evaluate a kinetic facade for office space. The findings in this study is initial for an ongoing research for one of methods of improving energy efficiency in building through develop dynamic solar facade system that adapt with climatic variations [5].

2 Kinetic Concept

The geometrical transformation of physical structure of building facade in space is what is called the actual motion of the kinetic façade, but without compromising the overall structure integrity [2]. Applying dynamic facade enhance aesthetic qualities of building. In addition to achieve an objective of responding environmental changes conditions which consider impossible task in static interfaces. Technological development in engineering seeks contribution in merge buildings in many aspects [6].

3 Origami in Architecture

Techniques of folded paper to reach for many different cut outs design geometries are what called Origami. Since the invention of paper it was used and became one of section of computer science which is Computational origami to solve paper folding problems through algorithms. In addition, origami was the inspiring that many new applications applied through. such as solar panels, self-folding robots [7]. A desire

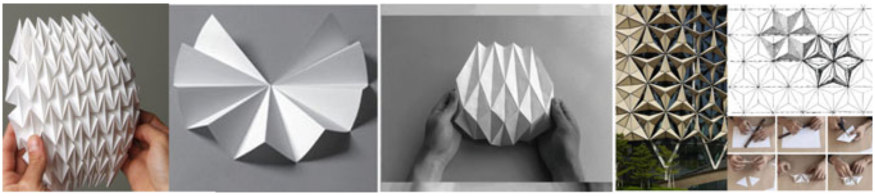

Fig. 1 Examples of Origami art foldable paper [10] and Al Bahar Towers façade [9]

of creating a 3D geometry from a flat sheet without cutting by folding has led to re-search interest in engineering and math. Thus, the dynamic concept is not considered an originally smart where either controls the all structure or part of it [8]. Moreover, screens based origami provide an effective method of decreasing heat gain and provide appropriate daylighting. An example, the twin office towers in the United Arab Emirates which merge the concept of origami façade with the smart sensor controlled to adapt automatically with the sun through expose the building by opening the facade structure or close it by folding to shade [9]. Figure 1 shows examples of origami art and practical façade.

4 Logic of Façade and Design Inspiration

Islamic architecture has used the Mashrabiya to maintain privacy and reduce glare and solar heat. The hexagon was one of the most important geometric shapes used, therefore, the facade was inspired by Mashrabiya in the form of a hexagon, as it opens and closes in the form of a Japanese fan. The final shape of the facade is modelled in a flower-like fashion and the angle of rotation is the movement leading to the opening and closing as a way of responding to environmental changes as shown in Fig. 2.

Parametric design in the modelling of shapes is based on a script from geometric commands where script is created that has the ability to modify in any part of it without affecting the entire shape in order to determine the fixed and moving parts of the interface. Rhino platform and grasshopper was used to type the script. The design starts with two hexagons to form the parameter model with a different radius but from one centre. The diameters of the larger hexagon are fixed frames while the smaller hexagon's diameters are frames that move according to their rotation. The area formed within the hexagons represents the concept of the proposed interface where the surfaces are folded during the rotation process to create a space between completely closed or fully open. On one hand, The proposed interface can be applied to all types of polygon, from trigonal till dodecagonal polygon. Figure 3 illustrates all of the above.

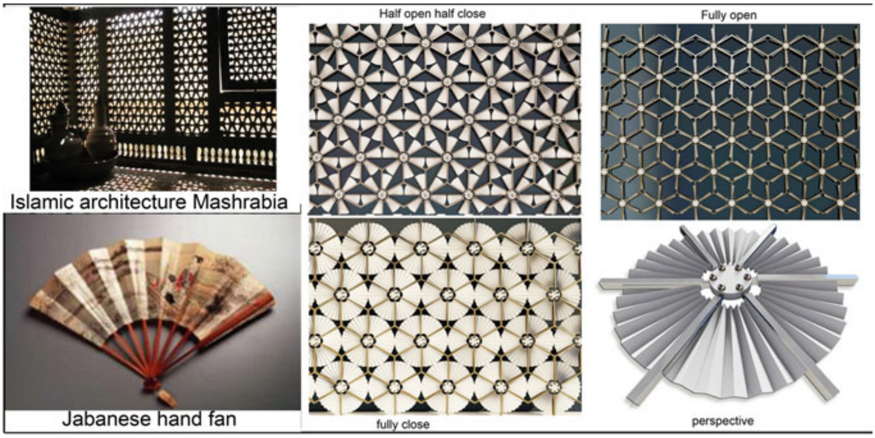

Fig. 2 Façade Inspiration components [9] and facade cases

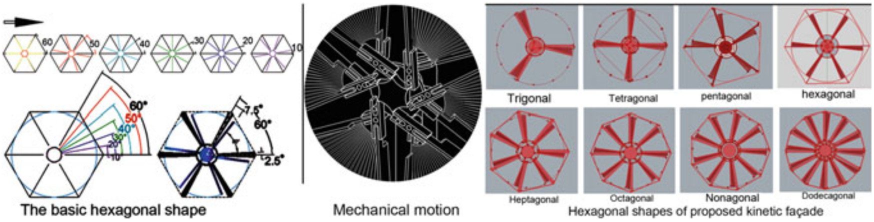

Fig. 3 The design façade details and motion mechanism

5 Parametric Modelling Potentials

Parametric design arises from mathematics and depends on the concept of adjusting parameters and variables to effect on the equation results for fixed shading devices [11]. It is often used in architecture as an aesthetic aspect [12] and its effectiveness or focus in its application to environmental purposes is ignored [13]. Architects today face a challenge in creating complex models based on parametric design for application in improving environmental performance as well as the aesthetic form of structure design by reaching several results using several variables and parameters that can control the design of the structure [14]. Thus achieving several results and solutions depending on the number of variables that enable the designer to choose the optimal solution.

6 Tools of Daylight Simulation

Diva was used for calculate daylight where allow conducting an environmental analysis through it [15]. Diva is an improved plugin to implement analysis such as (illuminance computation and annual simulation) through Rhino and grasshopper platform [16]. The study has merge another plugin, Ladybug which enable to import the weather file (EPW) [3, 17] and perform many analysis and integrate the environment with 3d model [18].

7 Objective

Study the application of kinetic façade is the study aim in order to enhance the performance of daylight in office building. the objective is achieved based on identify best size/rotation angle by fulfilling both LEED V4.1 daylighting requirements and the Daylight Availability. In addition to evaluate the dynamic facade system quantitatively and compare with static system.

8 Climate Calculation

The study has visualized some environmental aspects graphs and presented outputs such as sun path in order to deduce the sun position during workhours for equinox and solstice days. In addition to specify longitude, latitude and analyse the sun radiation for specific period of year and thus evaluate the amount of radiation as shown in radiation rose and sky dome in Fig. 4. Ladybug through "EPW" Energy Plus weather file was used to produce all outputs graphs.

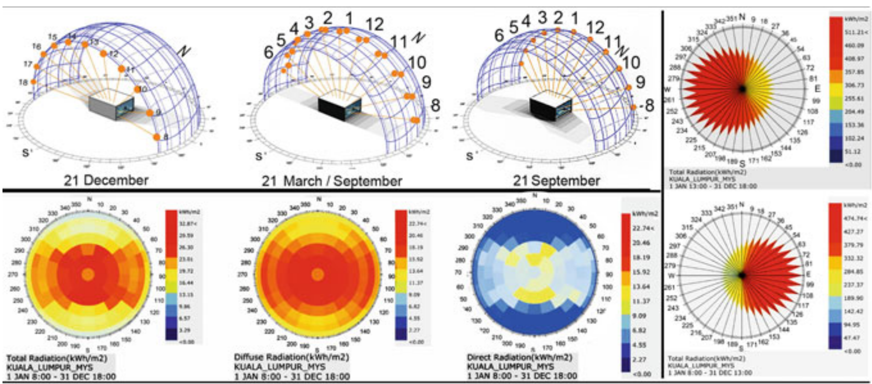

Fig. 4 Sun path for tested days, Radiation rose and sky dome radiation

Fig. 5 Star Central Typical plan A and office space proportions

9 Methodology

The methodology was divided into two phases. The first stage simulated the basic case by analysing the annual performance of daylight and then with a specific classification of the proposed facade by parametric optimization to achieve the optimum level of adequacy of daylight. The results of the first stage represent annual results to simulate a static shading system. In the end of next phase a comparison between static and dynamic system will presented. An iterative simulations has performed in phase two for four dates of the 21st of month 3, 6, 9 and 12 for the previous optimum case of rotation angle for each workhour from 8 am to 6 pm. In addition to perform a parametric hourly simulations and analytical comparison of results for same dates. The study applied simulation on side-lit office at the first floor with 48 m^2 and oriented to east direction located in Star Central Blocks, Cyberjaya, Malaysia. Office space and facade structure is shown in Fig. 5. The proposed façade will be installed on east office facade. It worth to mention that the simulation accuracy outputs is based on many factors, modelling of the office space, details and complexity of façade system and the most significant of these are the modelling of the office space details and geometrical and photometrical properties used. The façade design, space properties, and window described in Table 1.

10 Simulation Logic

(ASE) Annual Sun Exposure and (sDA) Spatial Daylight Autonomy are metrics that codified from (LEED) Leadership in Energy and Environmental Design. Both metrics offer an performance evaluation for daylight Autonomy [19]. sDA calculates the percentage of space area receives sufficient daylight, which should achieve for at least 55% of the floor area 300 lx/50% of the annual occupied hours to achieve 2 credits on LEED v4.1. No upper limit in sDA on luminance levels. Therefore, the measurement percentage of floor area that receives at least 1000 lx for at least 250 occupied hours per year, which must not exceed 10% of floor area has calculated by ASE metric [20]. Because it can cause visual discomfort or increase the cooling loads. Both metrics were set for static buildings performance evaluation, which should be modified to

Table 1 Main parameters

Main parameters of office space	
Space area and dimensions	8×6 m = 48 m^2
Direction	East
Height	330 cm
Window wall ratio (WWR)	90% approximately
Overhang	50 cm
Glass visual transmittance and type	90% Single pane clear glass
Floor material	20% of reflectance
Ceiling material	80% of reflectance
Wall material	50% of reflectance
Façade skin material	Metal diffuse reflectance
Floor level	An intermediate floor
Schedule of occupancy	08:00–18:00

adapt with the dynamic buildings changeability. For the dynamic system evaluation in phase two, it should trace the daily, monthly and annually façade response for climate changes through establishing some point in time performance evaluations of the working hours must exist. Therefore, HsDA (Hourly spatial Daylight Autonomy) is used. HsDA must exceeds 300 lx for at least 55% of the floor area, and Hourly Sun Exposure (HSE) is measured instead of the Annual Sun Exposure (ASE). HSE measures the percentage of floor area that receives a least 1000 lx per hour and must not exceed 10% of floor area. The simulation process integrate LEEDv4.1 and daylight availability requirements. The outputs of daylight Availability (DA) divide the space into three parts: day-lit, partially-lit, and over-lit zone. When the area receives sufficient daylight for minimum half year of occupied time is described as day-lit area. The partially day-lit area defines the area which did not achieve a sufficient daylight for the half year of occupied time. The over-lit area is the area that get an oversupply 10 times of level illuminance of daylight for minimum 5% of the year-round occupied time [3]. IES and LEED criteria is described in Table 2.

10.1 Phase One

Base case of office space façade without install any shading device was the first simulation of this phase. It is an annual simulation with 90% of WWR to evaluate the annual daylight performance for east direction facade as shown in Fig. 6. The value of sDA achieved 100% of the office space. However, the high and dangerous value that recorded is ASE value with 53% which cause a visual damage and glare. Moreover, discomfort internal environment for occupants and increasing cooling loads. The results also presented in three parts for daylight availability metric that

Table 2 LEED and IES daylighting criteria

Evaluating criteria for daylight performance		
Spatial daylight autonomy (sDA)	(LEED v4.1) > 40% 1 credit on	
	(LEED v4.1) > 55% 2 credits on	
	(LEED v4.1) and (IES) > 75% 3 credits	
(ASE) Annual sunlight exposure	(IES) The best case: <3%	
	(IES) Preferred: <7%	
	(LEED v4.1) and (IES) Must be: <10%	
Illuminance target	300 lx	
(DA) Daylight availability	Day lit	≥50% of hours between 300 and 3000 lx
	Partially lit	<50% of hours less than 300 lx
	Over lit	<5% of hours exceed 3000 lx

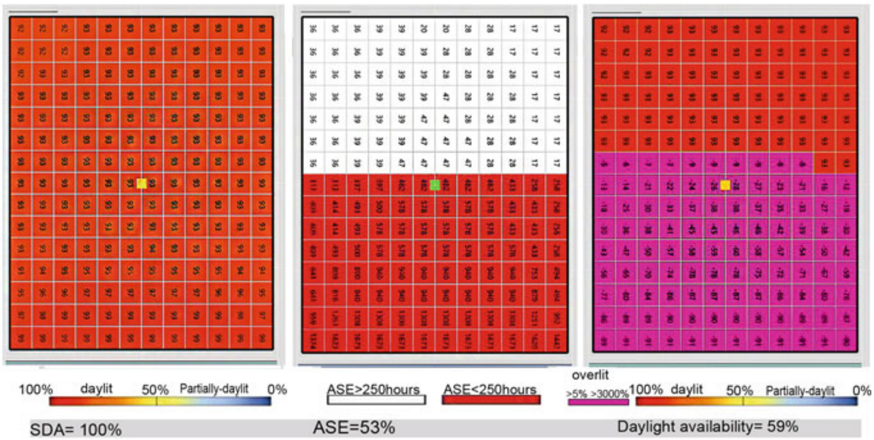

Fig. 6 Results of annual simulation for base case without shading device

offer more understanding of daylight performance. Partially-lit 0%, 59% of Over-lit area and 41% of day-lit area.

Façade rotation angle is the main variable of the design which is controlled through numeric slider to test daylight performance all around the year. Different rotation angles ranging from 0° to 50° which represent the motion field with a step of 5° but with 50 cm of radius façade size. Optimization Parameters, All model parameters were fixed except rotation angle as shown in Fig. 7.

A previous simulation had conducted which dealt with facade size variable to evaluate the effect of different facade pattern sizes of daylight performance and identify the best size performance to be used in other study simulations. The simulations starts from 50 cm till 120 cm of facade radius and with step 10 cm and with specific

Fig. 7 Variable of rotation angle configures

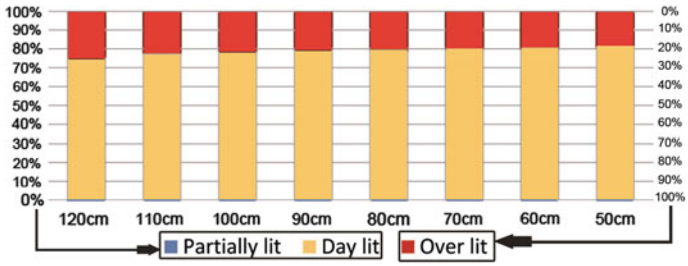

Fig. 8 Previous simulation results for size variable

Table 3 Simulation radiance parameters

Ambient bounces ASE	0
DA and sDA ambient bounces	6
(Ambient resolution) AR	300
Division ambient	1000

typology in facade opening (half opened) region in west direction of office facade. whereas, this paper is a current improvement of continued research that examine the proposed facade design to enhance daylight. Figure 8 shows the simulation results for different radius sizes variable and Table 3. illustrates Diva simulation parameters. Lastly, the rotation angles simulation results for east direction is shown in Fig. 9.

The results shows that the daylighting performance results are gradually enhanced till the optimized angle. The optimization objective was set to maximize the day-lit area and to minimize the over-lit and partially-lit areas. The simulation of rotation angle 20° in the optimization process reached the optimum solution which eventually give a good performance and can easily achieve 3 credits according to LEED v4.1 requirements. sDA = 89% which is more than the required 75%, and the ASE is equal to 9% which is less than the required (10%). Furthermore the daylight availability metric shows a comparable performance, even with 6 bounces the Illuminance levels did not exceed 3000 lx at any point except the same points which were declared by ASE metric and it is 5% of floor area. A comparison evaluation was made to verify the reliability of the optimization results. The comparison results are illustrated in Table 4. All configurations was tested at 90% WWR.

The comparison illustrates the efficiency of the proposed kinetic facade compared to the types of glass shading materials. It is clearly obvious that using glazing materials in east direction in Malaysia only impossible to achieve LEED requirement and Daylight Availability criteria where the over-lit area was quite high from case A to

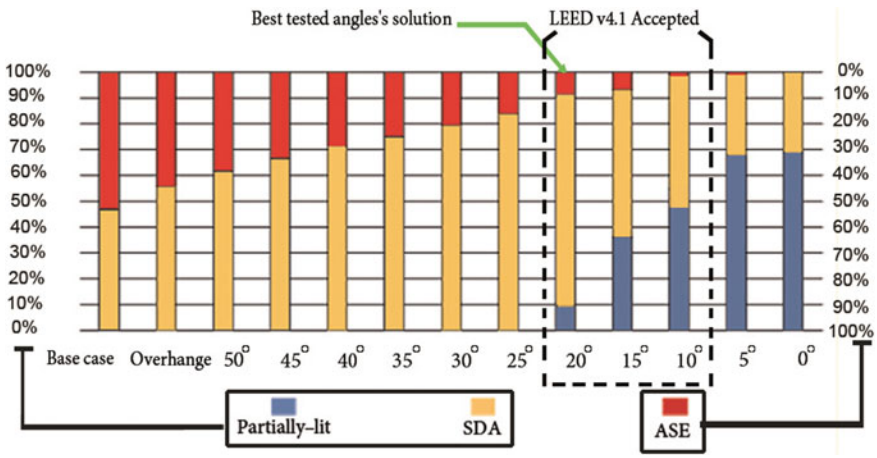

Fig. 9 East annual simulation results for rotation angles from 0° to 50°

Table 4 A comparison cases through daylight availability(DA) performance

Type	Day-lit (%)	Partially-lit (%)	Over-lit (%)	Cases
A	41	0	59	simple pane glaze (Base case)
B	48	0	52	50 cm of overhang
C	55	0	45	low E-65 Double pane glaze
D	60	0	40	krypton-47 triple pane glazing
E	55	0	45	electrochromic 60%vt
F	53	24	23	electrochromic 30%vt
G	43	57	0	Generic Translucent panel 20
H	53	23	24	Roller shading device
I	50	47	3	50 cm of size and angle 10°
K	80	11	9	K: optimum solution, 50 cm and 20°

E which will cause a burden on cooling loads by increasing the internal heat. Using Generic Translucent panel 20 case G has achieved 0 over-lit area but it increased the partially-lit area more than half of total space area with 57% of partially-lit.

10.2 Phase Two

In order to determine and know the performance of the different facade configurations per hour of the simulated days, the second stage evaluated the rotation variable for each configure angle at all hours of the day using a parameter simulation (point in time) from the annual simulation performance for dynamic system evaluation. Four dates of the year, 21 of March, June, September and December were simulated as a tested days from hour 8 till hour 18. HsDA and HSE were the assessment metrics for simulation. However, to evaluate (HsDA) hourly Spatial Daylight Autonomy, the graphical interface tool of DIVA cannot conduct a straightforward process. Therefore, the study improved the calculation process by calculate the analysis grid percentage per hour for illuminance level that override 300 lx which must be minimum 55% of space area as mentioned before. On one hand, to calculate the illuminance level above 1000 lx (HSE) measure the analysis points percentage of space area without any contribution from the sky and the filtration process of the illuminance values of each analysis point was completed by Grasshopper. Figure 10 shows the hourly performance from 8:00 till 18:00 for all rotation angles and shows office space hourly results without shading device. The figure is arranged as the vertical columns shows the tested hours while the horizontal rows shows the tested days. The results show multi alternatives for the for the façade configurations.

According to the used variable in optimization process, the results has achieved a high performance sometimes depending on the variables configures Thus, led the study to classified the configure into two groups of possibilities which could belong to be open cases angles or closed cases angles. The study categorize them as preferable opened cases or preferable closed cases. This classification has different purposes either to provide a privacy as in preferable closed cases or interact with the external environment through in preferable opened cases. Figure 11 shows this comparison.

The study found out that after evaluating the performance of the dynamic system, it is the best solution of high daylight performance compared to the fixed system. Where the interface tracked through the variables the movement of the position of the sun per hour dynamically in contrast to the improved static system, which was unable to achieve good performance in many hours of days of months tested. In

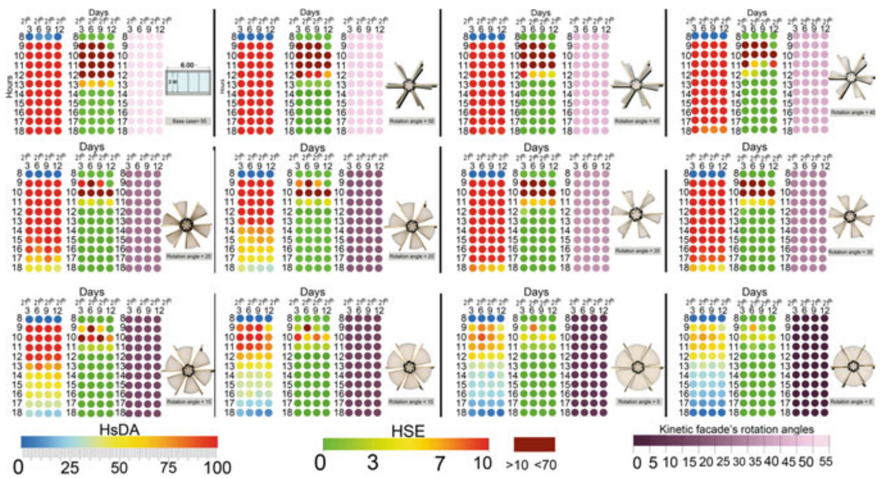

Fig. 10 Hourly simulation results for different rotation angles

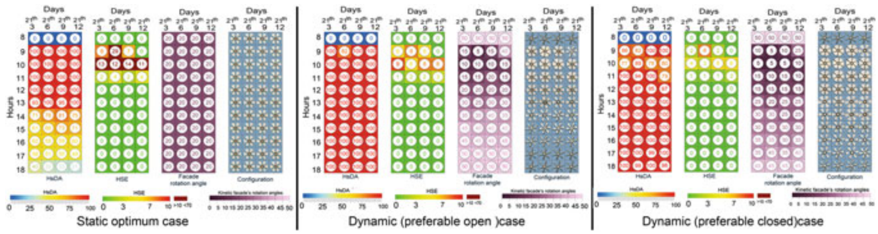

Fig. 11 A comparison between static system and dynamic system façade

both static and dynamic cases the daylighting autonomy didn't reach any noticed results in HsDA at 8 am. HsDA starts to decreased from 2 pm till it reached to 31% at 6 pm. In contrast with dynamic system where the HsDA reached to 100% in most hours specially with preferable opened façade. The critical hour that override LEED requirement in static system was 10 am in all tested days has been solve it in dynamic system to be under 10%. Last but not least, the dynamic system has exceeded the daylight requirement of LEED and daylight availability metric in it's both two classifications. Consequently, HsDA values were better in preferable open cases and HSE values were better in preferable closed cases. in addition to that, daylight availability area parts specially over-lit area percentage was less 5% of total space area. Finally, the HsDA results from hour 13:00 till 18:00 are gradually start to decrease in static system till it reach to unacceptable results at 5 pm and 6 pm. In contrast with dynamic facade where HsDA values were more than LEED requirements specially in preferable open configuration.

11 Discussion and Conclusion

Thermal loads performance will be included in the future simulations in this continued study. The simulations show that contributing in daylighting and enhance its performance by optimize parametric façade geometry can be through integrate parametric design and simulation tools. The study suggest evaluation the possibility of achieving a balance between thermal and daylight performance as well.

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An Absorptive Capacity (AC) Concept of External Knowledge and Experience on Building Information Modelling (BIM) Implementation Among Construction Stakeholders in Malaysia

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Abstract Building information modelling (BIM) has been adopted in the construction industry in the last few years due to its potential to enhance construction business performance in terms of efficiency and effectiveness. In Malaysian construction industry, BIM appears as innovative technology to escalate the performance and productivity in handling a construction project. The impact of BIM knowledge and years of experience on the absorptive capacity (AC) of construction stakeholders to adopt new information for organizational learning is investigated through this study. Hence, the main objectives from this study which are to identify the application of the absorptive capacity concept of external knowledge and experience on BIM implementation among construction stakeholders. The data collected by using questionnaire survey which distributed within Selangor area that represents the highest value of construction work done. The data were analysed by using SPSS software. As a result, the finding demonstrated 5 of the main factors on external knowledge and experience on BIM implementation with a value of Mean Ranking Analysis almost 80%. While 1 main factor which is knowledge and experience of BIM as a prerequisite to secure project has a value of mean about 75% only. Thus, it is expected that the finding shall bring significance and knowledge for the construction practices adopting BIM across the construction projects and become one of the main digital tools to improve construction projects effectively.

Keywords Absorptive capacity · Building information modelling · External knowledge · Experience

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1 Introduction

Construction industries in Malaysia faces huge challenge from the society in order to increase their productivity and quality of work in term of management process including cost overrun, project delay, design clashes are the most crucial problem that occur in the construction industry [15]. These issues occur when there are too many parties involves during the construction process. According to [15], the process of exchanging information itself and late of getting information among the stakeholders results in misunderstanding and miscommunication especially when the information is not properly documented. Therefore, Building Information Modelling (BIM) is one of the best platforms in order to manage the information properly as all the stakeholders can receive the information simultaneously [15].

BIM is a collaborative platform that used by architectural, engineering and construction (AEC) industries based on a number of software solution [10]. The essential of using BIM implementation is to manage and coordinate the information to ensure all of the construction parties are able to receive the right information at the right time. BIM is a process to establish and obtain the building data during all the project lifecycle. It includes the activity of design, cost estimation and project scheduling [10]. In addition, it is important to avoid any issues at the construction site regarding the construction planning.

In 1970, Chuck Eastman also known as Professor Charles M. Eastman who was the person that responsible to introduce BIM concept [10]. He was also a Professor in the Colleges of Architecture and Computing at Georgia Institute of Technology, Atlanta. He has been active in building modelling research since the 1970s and currently works with a variety of industry groups developing BIM technology [4].

The AEC industries started to implement this concept starting mid 2000 in the construction project [3]. According to [2], in 2007 the idea of implementing BIM concept was introduced by the Director of Public Work Department. In the same year, August 27, PWD committee was formalized by the government to choose correct BIM platform in order to ensure the availability of computer system and software gather information. Multipurpose Hall of University Tun Hussein Onn (UTHM) in Southern region of Malaysia was the first project in Malaysia that involved in BIM concept. It was fully completed in August 2012 [10].

There are a lot of benefits in BIM implementation such as reducing time for cost estimation, increasing smooth coordination and information among parties, and increasing constructability [15]. Although BIM is known as the expensive software to be adopted, but it has been proved to provide the alternative solution due to the construction problem [10]. In the beginning, it shows some difficulties because a few of stakeholders are reluctant to change the established traditional process to advance technological approach [15]. So, it is advisable to implement it slowly phase by phase and it will take time to be fully implemented.

Currently, the government's aim is to improve the quality product from the construction industry yet to implement BIM in the public construction project [15]. One of their initiative is through Construction Industry Development Board (CIDB).

CIDB has formed and facilitated the first BIM Steering Committee at headquarter of CIDB in Kuala Lumpur [2]. The committee member includes of public sector, private sector, professionals and academician. The setting up of the committee is an effort to plan development of BIM in Malaysia and responsible to guide construction stakeholders by providing strategic direction to the implementation of BIM in construction project [2].

Thus, this research regarding about the absorptive capacity concept on ability of the construction stakeholders to value the information regarding BIM, explore the knowledge and transform it into reality as building construction.

2 Absorptive Capacity in BIM Implementation

Ahankoob et al. [12] stated that a strong absorptive capacity in organization construction will help to improve the productivity of an organization by synchronizing people capability, process involves and technology used. Different people have different background of studies. For instance, most of engineers and architect with strong background of construction field will not have any problem to absorb new knowledge approach in regard to construction projects as they are very familiar with their working environment. In contrast, other manpower at the construction site such as due to lack of theoretical knowledge and poor proper background in construction, they are unable to absorb the recent technological knowledge on BIM implementation efficiently.

Zahra and George [14] stated that well-developed absorptive capacity concept in an organizational company are more likely to build business empire through innovation and sustained superior performance. It is crucial to have good records of company background especially for contractors who would want to survive in construction industry. Therefore, the organization will compete among them in term of implementing new technology in construction site thus improving the quality of productivity in business performance of the organization. According to [13], the successful innovation of the technology depends on the structure and processes at many levels of business environment.

Besides, [8] explained that the successful establishment of absorptive capacity will lead to an organizational achievement of competitive advantage. Model of absorptive capacity established by [14] provides an overview of an efficient and effective processes to implement BIM in construction project. Probably, the issue is not about how to adopt new technological knowledge but it is about the involvement of the construction stakeholders in accepting new technology and technological application which will be beneficial to community and society success. The BIM implementation will depend on the credibility of a leader to lead an organization. Kamal and Flanagan [7], described that an application of new technology may enhance the performance of some organization but it might not make any difference for some others.

Based on Fig. 1, Zahra and George [14] suggest that the firm's potential absorptive capacity influence by external knowledge sources which is experiences. The external

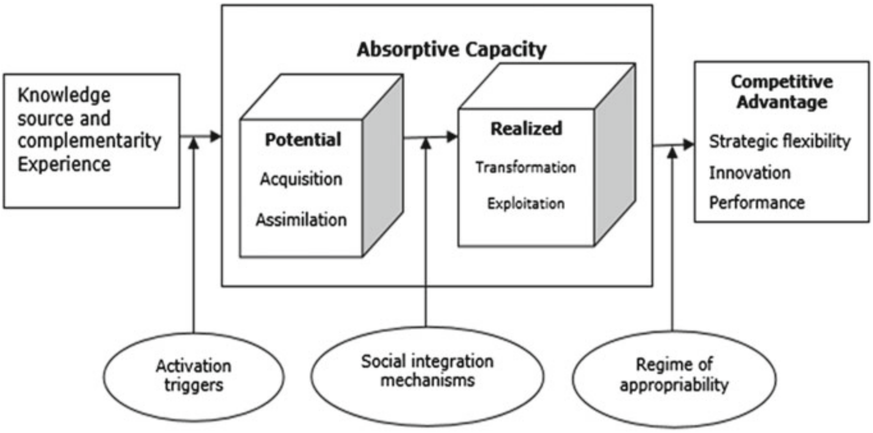

Fig. 1 A model of an absorptive capacity [1]

knowledge itself referred to BIM implementation among construction stakeholders. For example, how the construction stakeholders manage to handle the knowledge and apply it to the construction project with compromising of beneficial to each of them.

According to [14], they added that, external knowledge and experiences from past project did not well enough to create an absorptive capacity development in an organization. The model signify that activation triggers have biggest impact to an organization in development of absorptive capacity. It is also known as an encouragement factors that the company to respond towards BIM implementation.

Absorptive capacity divided into two component subsets which are potential absorptive capacity (PACAP) and realized absorptive capacity (RACAP). PACAP, involves acquisition and assimilation of the knowledge especially on BIM implementation. Kamal and Flanagan [7], acquisition concerns with the organization's ability on how they identify and generate the knowledge. Apart from that, assimilation concerns on how an organization capture, analyze, interpret and comprehend the information obtained from the knowledge. Between both PACAP and RACAP, social integration mechanism develops on the communication skill of the top management on how they deliver the knowledge to the staffs in contribution on BIM implementation. Reducing the obstacles for information sharing is one of the aims in accomplished the successful absorptive capacity development [6].

Transformation and exploitation lie under component subset of RACAP. Based on [6], they simplify that transformation defines as organization ability to develop and clarify the routine of new environment. In sense of BIM implementation, the organization needs synchronize routine that incorporate with recent knowledge and apply it through operation and practices. Likewise, exploitation, the theory behind BIM implementation reflect the organization's ability to exploit the knowledge and assign it as common practices.

According to [14] model, regime of appropriability defines as the organization ability on protect and value their new product of BIM where all the advantages comply in regime of appropriability being maintained. Lastly, according to [6], an organization with well develop of an absorptive capacity especially on BIM implementation will create a business advantages through innovation and technological advanced. For example, in order for a company to sustain last long in this construction industry, it is crucial for them to enhance the performance of working environment in terms of positive effects to the company. Once the company has positive effects, it will build an improvement of productivity as well as integrity of the company.

3 Methodology

For conducting this research, questionnaire survey method was considered as the suitable method to be used. There are several common approaches on quantitative research includes survey research and exploratory research. Hence, quantitative research method is more applicable throughout this research and the questionnaire distribution will be done randomly via mail and direct visitation to company. The questionnaire forms produced by using Likert Scale which was develop by Rensis Likert in 1932 [9]. Before distributing questionnaire to construction stakeholder within Selangor, small scale of preliminary study known as pilot study was conducted. The two respondents were from engineers from Public Work Department which have more than 15 years of experience in construction industry and very knowledgeable about BIM. For this research, there are two procedure in analyzing the data collection. Firstly, the reliability test analyses by using statistical analysis software known as SPSS software. This step has been used for pilot study and main study. For pilot study, it helps to find out the reliability of the questionnaire before proceed with the main study. Data preparation involved data collection from distributing the questionnaire and convert the information gathered into readable form without affecting the accuracy and consistency of the question itself. Next, to establish the rank of all factor by using Likert Scale, average index calculated which than reflect the rating of five Likert Scale category which consist of (5) = strongly agree, (4) = agree, (3) = neutral, (2) = disagree, (1) = strongly disagree. Next, the second procedure to analyse data collection by using mean ranking analysis. In order to identify the mean ranking analysis of the BIM implementation, a five-point Likert scale range from 1 which represent the strongly disagree to 5 which represent strongly agree being used to capture the knowledge on BIM implementation in Malaysian construction industry.

4 Results and Discussions

4.1 Reliability Test

i. Reliability Test on Absorptive Capacity Concept on External Knowledge and Experience.

Questionnaire reliability test concerned with internal consistency, stability and dependability of the scores [8]. Reliability test is used to check the reliability of data before the data were analyzed which normally ranges between 0 to 1. The closer of reliability coefficient to 1 indicates the greater internal consistency reliability of the criteria [13]. For this research, the reliability test was carried out on external knowledge and experience on BIM implementation by using SPSS based on the Cronbach's Alpha. According to [8], if the alpha value is greater than 0.7 is considered acceptable. For the alpha value is higher than 0.9, the internal consistency of the questionnaire considered excellent. Excellent internal consistency which indicates on a respondent more prone to answer the questionnaire positively. The result of reliability test for this research is tabulated in Table 1.

From Table 1, there are 6 item that were examine to conduct this reliability test. This reliability test is calculate based on 6 item which address external knowledge & experience. From the analysis, it was found that the Cronbach's Alpha value is 0.921. This indicates that the internal consistency of questionnaire of this study is considered as excellent.

4.2 Mean Ranking Analysis

i. Mean Ranking on Absorptive Capacity Concept on External Knowledge and Experience

The mean ranking is used to establish the rank of all factors based on Likert Scale and average index calculated reflect the rating of Likert Scale. The Likert Scale consist of 5 categories, i.e. (5) = strongly agree, (4) = agree, (3) = neutral, (2) = disagree, (1) = strongly disagree. The average index analysis for each variable can be calculated by using the following formula (Al-Hammad et al. 1996):

$$Average\ Index = \left(\sum ai\ xi\right)/\left(\sum xi\right)$$

Table 1 Reliability test on external knowledge and experience

Cronbach's alpha	Cronbach's alpha based on standardized items	N of Items
0.921	0.923	6

Table 2 Level of agree and evaluation for average index analysis (Cokla and Sahin, 2011)

Average index	Level of agreement of evaluation
1.0 ≤ Average Index ≤ 1.5	Strongly disagree
1.5 ≤ Average Index ≤ 2.5	Disagree
2.5 ≤ Average Index ≤ 3.5	Neutral
3.5 ≤ Average Index ≤ 4.5	Agree
4.5 ≤ Average Index ≤ 5.0	Strongly agree

where;

ai = constant expressing the wight given to i
xi = variable expressing the frequency of response for
i = 1, 2, 3, 4, 5,…, n
i = 1, 2, 3, 4, 5 similar to explanation below
x1 = respondent frequent for "Strongly Disagree" for a1 = 1
x2 = respondent frequent for "Disagree" for a2 = 2
x3 = respondent frequent for "Neutral" for a3 = 3
x4 = respondent frequent for "Agree" for a4 = 4
x5 = respondent frequent for "Strongly Agree" for a5 = 5.

In this study, the level of agreement by the respondents with 6 items of external knowledge & experiences are summarized based on the classification of the rating scale has been adopted by Cokla and Sahin (2011). The classification of the rating scale is shown in Table 2.

There are six main factors were identified based on model of an absorptive capacity concept on external knowledge and experience is provided in Table 3. These factors explained the implementation of BIM for the construction industry in Malaysia.

Table 3 indicate the mean ranking on absorptive capacity concept of external knowledge and experience of BIM implementation among Malaysian construction stakeholders. Based on the table, it was noted that there are five main items from one (1) to five (5) with mean values closed to 80% which represent the ranking number 1. While for the factor number six (6), the mean value is 75%, hence categorized as ranking number two. For item one which is the knowledge & experience of collaboration among stakeholder using BIM in construction project with a mean value of 78.8%, the results can be supported by the statement from [3, 6, 15] which all of them agree that enhancement of collaborative work processes among construction stakeholder will decrease the barrier in implementing BIM throughout construction project. In addition, the second item which is knowledge & experience of BIM consideration among stakeholders has resulted in a mean value of 78.6% and ranked as 1. This can be supported by [5] that the strategy to consider towards full implementation of BIM acts as an effort geared towards sensitizing of construction industry. Moreover, the statement by [15] that says in order to speed up the process of learning new knowledge, strong support from management together with training for the staff should be complemented as a good education. Organizational staff also need to participate in BIM training such as seminar and workshop on handling BIM

Table 3 Mean ranking on absorptive capacity concept of external knowledge and experience of BIM implementation among malaysian construction stakeholders

Item	External knowledge and experience	Mean[a] (%)	Ranking	Level of agreement
1	Knowledge & experience of collaboration among stakeholder using BIM in construction project	3.94 (78.8% ≈ 80%)	1	Agree
2	Knowledge & experience of BIM consideration among stakeholders	3.93 (78.6% ≈ 80%)	1	Agree
3	Knowledge & experience of BIM software such as Cost-X, Revit MEP, Revit Architecture and Tekla Structure	3.92 (78.4% ≈ 80%)	1	Agree
4	Knowledge & experience of BIM individual in construction project	3.91 (78.2% ≈ 80%)	1	Agree
5	Knowledge & experience of BIM usage to help the organization in effectively deliver the project	3.91 (78.2% ≈ 80%)	1	Agree
6	Knowledge & experience of BIM as prerequisite to secure project	3.74 (74.8% ≈ 75%)	2	Agree

[a]Percentage (%) is calculated based on maximum mean ranking of 5

software. This supports the third item which is knowledge & experience of BIM software that is ranked as 1 with a mean value of 78.4%.

Besides, in order to ensure the success of BIM implementation, individuals within the organization should be fully equipped with the knowledge of BIM itself where it contributes to the awareness of BIM knowledge [3, 6, 15]. This supports on the factor of knowledge & experience of BIM individual in construction project with a mean value of 78.2% and ranked 1. All parties involved from the beginning of project life cycle should plan an effective strategy on how to achieve the goal so that the organization imply BIM to effectively deliver the construction project. As cited by [6], where it is crucial for the organization to set targets not only for fully implementation of BIM but also the activities that influence the decision so that BIM can be implemented in construction project. Ahankoob et al. [1] also stated that, BIM implementation in Malaysia construction industry will gain more information on how the stakeholders practiced to achieve objectives by implementing BIM in their projects. This supports item 5 with a mean value of 78.2% and ranked 1. Lastly, the item number six (6) on knowledge and experience of BIM as prerequisite to secure project is, however, only 75% which categorized as ranking number 2 is indicate that some of the respondents are not aware of BIM requirements to secure the project.

The results from the respondents are in parallel with the previous studies by [11] which explain a lack of experience and skills in an organization being reluctant in considering the new technology as the biggest challenged in adopting BIM for construction project in Malaysia.

5 Conclusions

The application of BIM is currently developed and it was not fully implemented in construction industry. Therefore, the main objective is to identifies that the application of an absorptive capacity concept of BIM implementation among construction stakeholders started from external knowledge and experience. It can be concluded:

1. 80% of the respondent from various stakeholders are aware on the usage of BIM in construction project which help the organization quality of work as compared to traditional approach, high level of awareness in BIM software and also involvement in collaboration project with other organization regarding BIM implementation.
2. The respondents are well aware about the external knowledge and experience of absorptive capacity that can accelerate the BIM adoption in Malaysian construction industry.
3. The respondents are aware with the benefits of BIM in construction but consideration of BIM as benchmark when accepting the job of construction project is still low.

Therefore, it was suggested that the local government's effort in presenting BIM in construction industry compromises valuable opportunities to all construction stakeholders.

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A Method for Formulating Architectural Value in Johor Bahru Tourism Building

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Abstract Architectural value can be seen in aesthetic form to make that physical form easy to recognize by surrounding people. For instance, iconic buildings can make cities easily known, historic buildings that capture the commemoration of famous events and people, and galleries and museums that hold and display cultural values and serve as places of focus and inspiration that bring people (communities)

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together (Scerri et al. 2016). Aesthetic value is a subjective evaluation; as researcher's view the value can be defined as the beauty of the physical form, function, components, details and others. Value of the aesthetic can be obtained through the contribution of identity, vision and reputation as ways in which groups, institutions, and cities express an ideas, ambitions and intentions (Scerri et al. 2016). Other than that, architectural value able to create "sense of welcoming" for the destination and make the area rich in culture. Cultural value creates a sense of place by connecting location, context and patterns of historical development incorporating cultural symbolism and social meaning (Hayllar et al. 2008). The aesthetic and cultural value creates intangible social and community benefits while architecture value creates tangible benefits to a destination. This paper will describe researcher's methodology consist of site study, method of research including qualitative and quantitative instruments which is describe in detail. It also identifies sampling for data collection process, purposive sampling used because it has special relevance in this study. It is very important to ensure that this research is not misleading with the objective. In addition, purposive sampling signifies strategic choices about with whom, where and how they can give information through the research. All information obtained is based on several instruments to get views from various aspects and angles. The researcher found a research gaps; the value of architecture is not widely mentioned in many studies as it is a subjective subject for assessment and the tourism industry does not emphasize the importance of architecture, whereas it is a key element of the industry's success. In conclusion, this research plays important role in explaining the key components of the study which can be a guide for another researcher. The study will conduct to analyze value of physical structure as tourism attraction and explore urban tourism elements which is an important factor to forecast tourist motivation in urban area for tourism activities. Thus, the activities will contribute to the economic growth of the place.

Keywords Architectural formula · Architectural method · Architecture in tourism

1 Introduction: Urban Tourism Issues Relating to Architectural Value

Architecture is an important element in shaping sustainable tourism. This research will focus on a framework for formulating architectural value which is considered highly impossible and subjective to assess. However, researcher have found a formula that can be used by improving the suitability of the study. The value of architecture is important to know because each building has its own aesthetic value and has many opinions of their own reason. For example, each country has unique architecture and has its own story. Cultural and natural recourses is required to make a place have its own charm, other than that, historic and archaeological also become a part of attraction such as museum, landmark state, parks, sculpture, monuments and others. This is where the importance of architecture must be preserved in order to maintain the identity of a region. Nowadays, historical buildings as a part of cultural heritage have become a significant tourism product and thus many destinations have funded and supported their renovation and reuse. Over time, historical buildings as cultural heritage assets are threatened with demolition [1]. Architecture is an essential in tourism image and the elements must be preserved in order to protect identity of place.

Johor Bahru cityscape has challenges due to some public spaces do not present a sense of inviting to attract people for sitting and rest due to congestion even on the pedestrian walkways, lack of proper sit-outs, pollution and absence of well-landscape open space and street light (Rahely et al. 2013). It can be seen that most of the weakness are caused by lack of architecture value such as street architecture, landscape architecture and others. It is difficult to discuss tourism without discussing architecture. Architecture is a commodity of touristic consumption and objectified cultural capital [2]. According to Maitland and Newman (2008), Visitors are not drawn by tourist attractions but by "qualities of place and culture—'architecture', 'people', 'food', 'culture' and 'diversity'".

Johor Bahru was develop to cater local population needs rather than as a tourist attraction area. According to Zhe and Jacobs (2016), the city it was very difficult to sustain after surrounding flat demolition because decrease population in the town. According to [3], Johor Bahru was never positioned for tourism and the main problem was Johor Bahru city just as a crossing country rather than tourism destination. It clearly shows a huge loss to the city as its strategic location (Malaysia Southern Gate) is not seen as a contributor to tourism activities. All these challenge will involve placemaking strategy to enhance urban tourism activities in the town and at the same time to help increase the number of tourist arrivals. In addition, Johor Bahru has a weakness of focal point as a world-class city [3]. There have more bottlenecks traffic, congestion, safety issues, pollution and unsafe environment [3].

2 Architectural Elements

The architectural works as a building is composed of two main elements which is physical structure and spatial form. According to Mitias (1999), physical structure which comprises the material medium of the buildings and spatial form which comprises the spatial dimension of the building. These two elements determined the fundamental to value aesthetic value for architectural works. Aesthetic judgement are very subjective. However, since they become actual in the aesthetic experience, a careful study of this judgement should lead to a reasonable understanding about nature of architecture [4].

An architectural works is a physical object that occupy a place and endure for a period of time. It is also influence of natural forces for example, heat gravitation and pressure. It is maintaining a relatively stable structure and exhibit different type of qualities including color, texture, motion, rest, solidity, extension, smell and temperature [4]. That qualities is a basic knowledge to know or to have idea about nature of architecture as perceptual qualities that can be see, hear, smell, touch or feel. Physical structure is a general idea that refers to building for instance, mosque, palace, hospital, police station, shop houses and others. These structure is an importance to determine the use of space—spatial form.

A building is a spatial formation constructed for a purpose to perform a function which defined according to established rules, conventions, and practices [4]. In addition, spatial formation is involved in the total utilization capacity. Aesthetic value in architecture can make the physical object and their space as an art. That is an important to make the architecture as a tourist motivation.

3 Aesthetic Qualities in Architecture

Architecture value is a subjective thing to be measure. However, these aesthetic values can be measured using qualitative and quantitative method depending on researcher intend. In this study, researcher will explore the significance of the quantitative aesthetic assessment of architectural forms based on this Birkhoff's formula as an analytic and critique tool for the assessment or architectural aesthetic. This research focus on the Formal Aesthetic features that related to structure of form and mathematically relations which can be qualitatively assess [5]. Birkhoff's (n.d) formula can be employed in Architecture by redefining the equation's parameters; Order and Complexity, where it acts as an index of natural beauty/architectural life the building has. Noteworthy that this measure neutralizes the effect of buildings' historical background, function, and other affecting factors under the notion of searching only the formal aspects of the building [6]. The aesthetic measured involves Order and Complexcity as below

3.1 Birkhoff's Formula:

$$(\text{The Aesthetic Measure (M)} = \text{Order (O)/Complexity(C)})$$

3.2 The Order (O) of architectural elements structures is computed by five (5) items namely Symmetry (S), Repetition (R), Equilibrium (E), Disposition (D) and Color Harmony (H) and Randomness considered as a negative factor affecting Order (5).

Order (O) = Symmetry (S) + Repetition (R) + Equilibrium (E) + Disposition (D) + Color Harmony (H) – negetive factor.

$$\text{Order} = \text{S} + \text{R} + \text{E} + \text{D} + \text{H} - \text{n.f.}$$
$$\text{Since}: 0 \leq \text{O} \leq 10$$

3.3 The Complexity (C) represent the factors responsible for increasing the feeling of tension and effort tension. Generally, complexity is measured by Form

Complexity (F.C), Ornament (Om), Silhouette differentiation (S.d), and Color Contrast (C.c) [5].

Complexity (C) = Form Complexity (F.C) + Ornament (Om) + Silhouette differentiation (S.d) + Color Contrast (C.c)

$$\text{Complexity} = (\text{F.C}) + (\text{Om}) + (\text{S.d}) + (\text{C.c})$$
$$\text{Since} : 0 \leq C \leq 8$$

4 Method for Formulating Architectural Value in Johor Bahru

This research bring the same approach as the above formula, building selection based on tangible and intangible product which depicts Johor identity and become as tourist motivation by information obtained from the research. For instance, Sultan Abu Bakar Mosque, Royal Abu Bakar Museum., Sultan Ibrahim Building, Royal Crown., KTM Museum, Johor Bahru Town Heritage Shop houses, Bazaar Karat, Segget River and others. This method will use questionnaire form distribute by online and face-to-face between researcher and sampling to determine building aesthetic. A total of 150 sampling will be undertaken consisting of various backgrounds. The questionnaire have five (5) section as mentioned in Table 1.

Section C will be given more attention as a major question on the form related to architectural elements. The reseacher provides a clearer and concise description of each variable to facilitate the assessment process (Table 2).

The Method to apply Birkhoff's formula on different situation of building aesthetic from building with lower, average and higher preference. To determine several cases of building aesthetic a preference test will executed by different sets of judges; professional architects, architectural students, landscape architectural background, tourism planning background, tourist and laymen to give their aesthetic opinion on a list of buildings showing different aesthetic, cultural, historical, and functional aspects. Likert scale will be use to rate each the building judgment from (3) Higher Preference Characteristic Stated, (2) Average Characteristic Stated and (1) Lower Characteristic Stated.

5 The Selection of Johor Bahru Architecture as a Tourist Attraction

Johor is a state that holds monumental, histories, resplendent cultures, heritage and memoirs of intellectual achievements from generations that proudly portrays the

Table 1 Reseacher's questionnaire information adapt from Tourism Planning Research Group, Centre for Innovative Planning and Development (CiPD), UTM (2018)

Section	Item	Explanation
A	Demography profile	• Contain five (5) question • This section contains relevant information about gender, age, origin, occupation and income level
B	Trend and arrival factor	• Contain five (5) question • This section contains about tourist travel behaviour such as how they plan a trip, whim whom they come, length of stay, main purpose visiting Johor Bahru and breakdown expenditure during the trip including accommodation, activities, transportation, souvenir or others
C	Architectural elements	• Contain thirteen (13) question • This section is to measure architectural value by Likert scale to rate each building judgement from (1) lower characteristic stated, (2) average characteristic stated and (3) higher preference characteristic stated • Characteristic which is taken into account is symmetry, repetition, equilibrium, disposition, harmony color, negative factor, form complexity, ornaments, silhouette differentiation and color contrast • The specified architectural elements are Sultan Abu Bakar Mosque, vRoyal Abu Bakar Museum, Sultan Ibrahim Building, Royal Crown, KTM Museum, Johor Bahru Town Heritage Shophouses, Bazaar Karat, Segget River, Johor Bahru Gateway, Shopping Mall in JB city and Danga Bay
D	Tourism image	• Contain one (1) question that covers some of the popular tourism places in Johor Bahru (18 places listed) • The answer is in the form of information such as (V) have been visit, (H) have heard, (W) want to visit and (N) never heard
E	General perception	• Contain six (6) question • This section contains relevant information about general perception. For example, their opinion and suggestion for Johor Bahru tourism especially on architectural value and urban tourism placemaking

civilization of Johor and its citizen [7]. Johor Bahru, the southern gateway into Malaysia, offers tourist a unique look into the rich history and tradition of the city. The place have colonial style building to modern theme parks, from century old places of worship to glitzy structure. Johor Bahru is a myraid of modernisation and old world charm (JOTIC, 2018).

Johor Bahru cityscape is chosen because researchers are very interested to know the value of architecture there and relation that architecture with tourism industry. The selection of the place is exactly in line with the goal of the state to become as tourist destination center. Johor Bahru is no longer just a transit point for travellers but now as top tourism destination [8] (Fig. 1).

Table 2 Reseacher's variable adapt from Megahed Y. S. (2010) explanation

Variable	Formula	Explanation
Order (O)		
Symmetry	S	The reflection of same shape or elements
Repetition	R	Repeated shape or elements
Equilibrium	E	Balanced design (balance, stable and safe)
Disposition	D	Stands for the 2D relation of vertical, horizontal, and diagonal lattices
Harmony color	H	Matching color in interior or exterior
Negative color	n.f	Imperfection and dissatisfaction
Complexity (C)		
Form Complexity	F.C	Architecture has many detailed elements; curves, mass differentiation and complicated grid.
Ornaments	Orn.	Architecture rich in decor and detail elements
Slhouette differentiation	S.d.	Image of human, animal, object or scene with dark color
Color Contrast	C.c	Unique color and different with surrounding area

The selection of building as a tourist attraction based on qualitative method. Qualitative research is a source of universal methods for assessment architectural elements such as building, zones, interiors, outdoor spaces, and others to provide recognition of user's opinion. The approach to design with using research fits into the current trend, associated with quality assessment in architecture known as research by design and design by research [9]. Qualitative research can help in the correct diagnosis of future groups of users (customers) and their desire. Currently in the world, qualitative research is budding and widely used in all highly developed countries [10]. The Qualitative research will use two method which are depth-interview and observation. Table 3 show the selection of the parties involved to provide relevation information in this research. Relevant information importance in this study to achieve research objective and answering research question below.

This study will focus on valuing several popular architectural building that becomes as tourist attraction around Johor Bahru cityscape such as Sultan Abu Bakar Mosque, Abu Bakar Royal Museum, Sultan Ibrahim Building, Royal Crown, KTM Museum, JB Town Heritage Shophouses, Segget River, Bazaar Karat, Johor Bahru Gateway, Shopping Mall in JB, Danga Bay development and others. This research bring the same approach as the above formula, building selection based on tangible and intangible product which depicts Johor identity and become as tourist motivation by information obtained from the qualitative method.

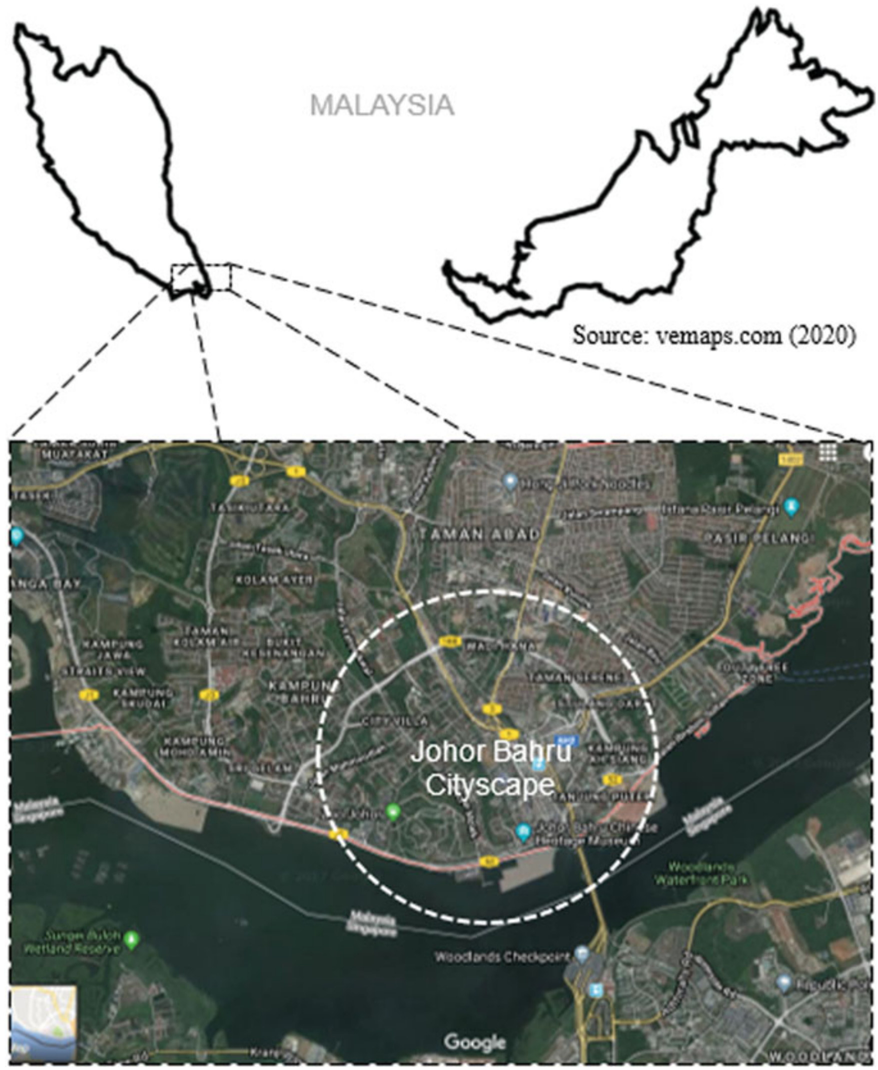

Fig. 1 Johor Bahru map. *Source* Google Map (2020)

Table 3 Qualitative research activities

Qualitative method	Activities
Depth-interview	Interview session with Government sector, private sector, non-profit organization (NGO) and tourism player such as tourist agency, tourist guide, shop owner surrounding Johor Bahru cityscape and others
Observation	Taking picture and make an assessment on tourist places. Informal interview session with tourist. The place to visit is a tourist spot based on media social research as well as a list provided by Ministry of tourism Malaysia, Tourism Johor and tourist agencies

6 Research Variable

The design variable for this study using an experimental studies method by referring the description from [11] that is to evaluate the comparison between two or more sets of data. It also helps researchers to answer some questions related to architectural value in tourism. The design of experimental studies is done by making changes to the independent variable and observing the effects of its variations on dependent variables (Fig. 2).

The purpose of experimental studies in this research is to understand the relationship between variable through the fast and friendly identification and measurement (Fig. 3).

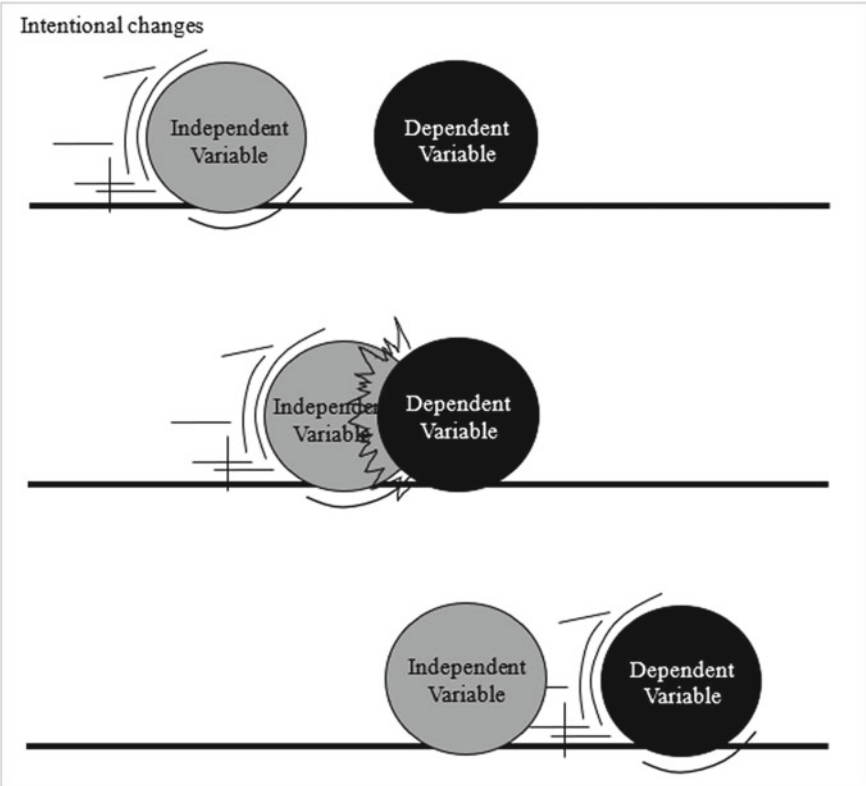

Fig. 2 The researcher's experimental study design concept adapts by Piaw (2014)

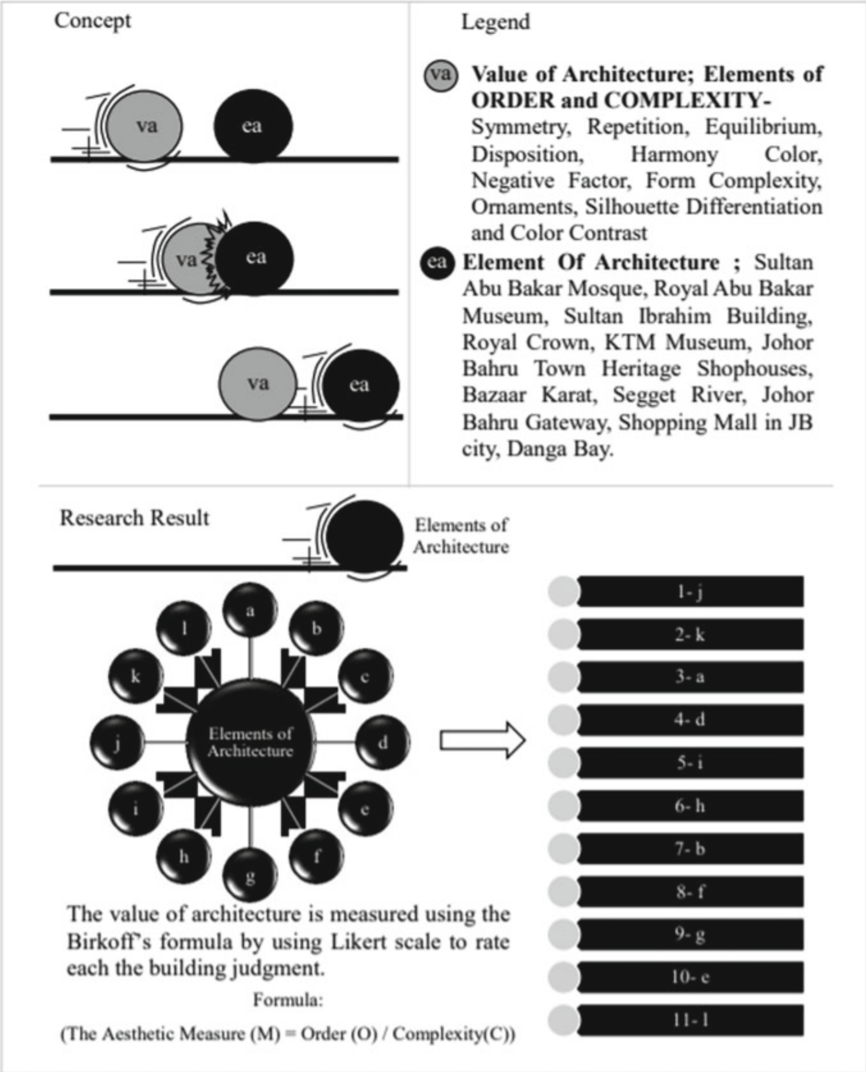

Fig. 3 The researcher's concept

7 Analyzing Architectural Value

To analyze the architectural value in Johor Bahru cityscape, this study using qualitative and quantitative approach. Qualitative approach has been involved tourism player in Johor Bahru which is Government Sector; Majlis Perbandaran Johor Bahru: Building Department and Planning Department, Iskandar Regional Development Authority (IRDA) and Johor Tourism. Private Sector; Think City, Tourist Agent

Table 4 Questionnaire design

Building name			
Building image to assist in the assessment			
Symmetry—The reflection of same shape or element	3	2	1
Repetition—Repealed shape or element	3	2	1
Equilibrium—Balanced design (balance. stable and safe)	3	2	1
Disposition—Stands for the 2D relation of vertical, horizontal, and diagonal lattices	3	2	1
Harmony color—Matching color in interior or exterior	3	2	1
Negative color—Imperfection and dissatisfaction	3	2	1
Form complexity—Architecture has many detailed elements; curves, mass differentiation and complicated grid	3	2	1
Ornaments—Architecture rich in decor and detail elements	3	2	1
Silhouette differentiation—Image of human, animal, object or scene with dark color	3	2	1
Color contrast—Unique color and different with surrounding area	3	2	1

and Shop owner (Historical shop houses in Johor Bahru). Quantitative approach involving 132 sampling which is consist of Architect background, Planning background, landscape architect background, tourist and layman. This is because to measure value of architecture, the sample must have basic knowledge about architecture itself. However, tourist and layman opinion without architectural background is also considered in this study to assess the value of architecture in the eye of the public.

Architectural value is very subjective to be evaluate. However, it is not impossible since architectural value can be measured using Birkoff's Formula. Now, the method is being used and improved upon the suitability of the researcher. The questionnaire form is designed with graphic for easy-to-understand to everyone. It aims to achieve the objective of obtaining architectural value with the great judgement. The following is an example of evaluating selected Johor Bahru architecture as dependent variable while Complexity (C) and Order (O) elements as independent variable. The architecture is evaluated using the Likert Scale method. For instance,

3—Higher Preference Characteristic Stated

2—Average Characteristic Stated

1—Lower Characteristic Stated (Table 4).

Then, the value is measured using researcher's formula (Table 5).

8 Conclusion

- According to this research study, Johor Bahru has diversity of Architecture. For instance, Royal Architecture, Religious Architecture, State Administrative

Table 5 Measuring method formula

Step	Method
1	Total of independent variable ÷ Total of sampling = Architecture value [a]*this calculation needs to be done for each independent variable*
2	All architectural values are calculated using this formula $\text{Order} = \text{S} + \text{R} + \text{E} + \text{D} + \text{H} - \text{n.f.}$ $\text{Since}: 0 \le \text{O} \le 10$ $\text{Complexity} = (\text{F.C}) + (\text{Om}) + (\text{S.d}) + (\text{C.c})$ $\text{Since}: 0 \le \text{C} \le 8$
3	All of these values will be calculated using Birkoff's formula: The Aesthetic Measure (M) = Order (O)/Complexity(C)

Building Architecture, Modern Architecture, Landscape Architecture, Street Architecture, Cultural Architecture and others.

- The features of the Johor Architecture are unique and have their own historical value. Building or physical structure is an important element to shape identity of the city, create sense of welcoming and make the city easy to recognize for first timer tourist and re-visit tourist. This is where the value of architecture must be preserve in order to enhance destination image and tourist motivation to the place.
- Other than that, this research can still be developed because the value of architecture is not widely mentioned in many studies as it is a subjective subject for assessment. Thus, this study is very important to add research gap which can be further refined.

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Effect of Coconut Fibre on Coconut Shell Concrete

Noor Aina Misnon, Shahiron Shahidan, Faridah Hanim Khairuddin, Nur Liza Rahim, Siti Khadijah Che Osmi, and Hapsa Husen

Abstract Previous studies on coconut fibre reinforced concrete, and coconut shell concrete showed the potential of these wastes to be used as alternative materials in building construction. Presence of coconut fibre and coconut shell gives beneficial to concrete in increasing concrete toughness and produced lightweight concrete. In this experimental study, a combination of these coconut components (fibre and shell) was used as concrete composite to investigate its physical properties and compressive strength. Three types of concrete were cast, i.e. normal concrete, coconut shell concrete and coconut fibre reinforced coconut shell concrete. The amount of coconut fibre added in coconut shell concrete was 0.5% of mass volume. The results showed that replacing aggregate with coconut shell reduced the concrete density and compressive strength. Additional coconut fibre aided in holding the coconut shell concrete material and improve the slump value.

Keywords Coconut fibres · Coconut shell concrete · Lightweight aggregate concrete · Sustainability · Green material

1 Introduction

Coconut trees or *Cocos Nucifera* can be found in tropical countries with humidity that is suitable for its growth. In general, coconuts are considered as food with main products of the crops are juice, oil and milk. Not only the crops but also the wastes are very useful to human activities, make these fruits are so special. Recently,

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coconut components i.e. coconut fibre (CF) and coconut shell (CS) are broadly used as composite materials for engineering application due to their characteristics that can improve the mechanical behaviour of the composites [1–3]. The utilisation of agricultural by-product as new materials is encouraging recently as it can minimise waste production towards sustainable development.

Coconut fibre reinforced concrete (CFRC) has been introduced as new building construction materials with comparable performance with normal concrete even better in flexural and tensile strength [4–6]. It was initiated by producing non-structural elements such as cement boards, partitions and roof materials. Existing of CF in CFRC helping in minimise micro-cracks by bridging the concrete constituents i.e. cement, sand and aggregates. Roofing materials made of 7.5% CF content with the length of 37.5 mm found to have comparable mechanical properties with existing corrugated galvanised iron and asbestos [7]. A similar finding was reported for roofing tiles with natural fibres, including CF, revealed satisfactory physical and mechanical performance in accordance with Brazilian standards [8]. Aggarwal [9] reported the optimum length and CF content to produce coir-fibre reinforced cement composites were 30 mm and 15% fibre content (by weight) and performed similar physic-mechanical properties to wood-based cement-bonded particle boards. Furthermore, CF also acts as noise reduction panels, which could prevent the noise from dispersing to other space [10].

Coconut shell concrete (CSC) is categorized as lightweight aggregate concrete (LWAC) because the density of the concrete which less than 2000 kg/m^3 [11, 12]. LWAC is beneficial in self-weight reductions that offer structural efficiency. In addition, due to lower modulus of elasticity it is also flexible and thus, suitable to be applied on structures that experience seismic loading [13]. Previous studies on CS as lightweight aggregate were conducted as aggregate replacement, partly or completely replaced. Increasing CS content from 10–20% in concrete reduced the compressive and splitting tensile strength of concrete; however, increased the sorptivity [14]. Olanipekun et al. [12] reported that CS was better than palm kernel shell to be used as aggregate replacement in concrete mix by considering cost and strength ratio.

With advantageous in self-weight reduction and comparable strength to conventional concrete, both CF and CS showed a good potential as an alternative in building construction at lower cost. This study was conducted to investigate the physical properties of concrete added with coconut fibres and coconut shell.

2 Material Characterisation and Experimental Setup

2.1 Materials and Sample Preparation

Three types of concrete were cast: normal concrete (C1), CSC without coconut fibres (C2) and CSC with coconut fibres (C3). C1 samples were consist of ordinary Portland cement (OPC), sand, crushed aggregate, while C2 and C3 samples used CS

Fig. 1 Crushed coconut shell

Table 1 Proportion of $0.01m^3$ batch of concrete samples

Constituents	C1	C2	C3
OPC	6.40	6.40	6.40
Sand	9.40	9.40	9.40
Aggregate	4.20	–	–
Water	2.70	2.70	2.70
Coconut shells	–	4.20	10.24
Coconut fibres	–	–	0.24

Note All units in kg

to substitute whole coarse aggregates. The nominal size of crushed aggregate was 13 mm and crushed CS sizes was between 5 and 13 mm (Fig. 1). The mix ratio used was 1: 1.46: 0.65: 0.42 (cement: sand: aggregate/coconut shell: w/c) with cement content of 500 kg/m^3 that was adopted from Gunasekaran et al. [11]. 50 mm length of CF with amount 0.5% of concrete mass volume was added into the C3 mix. The crushed CS were treated by soaking in tap water for up to 24 hours prior to the mixing process. This process was conducted to produce saturated and surface dry (SSD) conditions of CS to maintain the water content while mixing the concrete. Table 1 shows the mix proportion of each constituent of the samples. All the samples were demoulded after 24 hours and immersed in water tank for water curing up to 28 days.

2.2 *Fresh State Concrete Test*

Fresh concrete test was carried out to determine the workability of the concrete mixes using the slump test as shown in Fig. 2. The test was conducted in accordance with ASTM C143. The slump value was immediately measured by taking the differences between the top of the cone and top surface of the specimens (Fig. 2b).

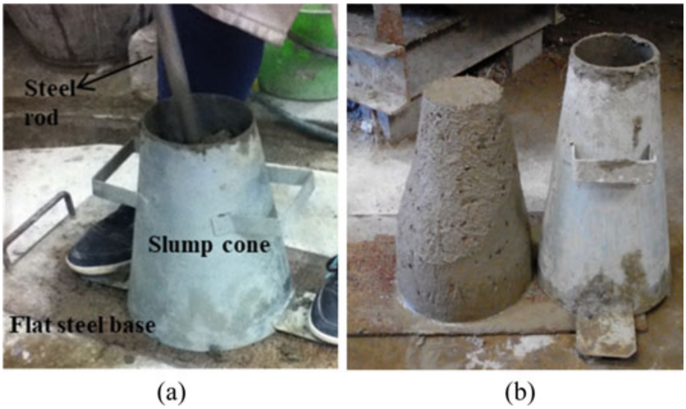


Fig. 2 Slump test: **a** Apparatus, **b** measurement

2.3 Moisture Content Test

The moisture content test was conducted according to BS 812-109. The cured samples were oven-dried with temperature ±105 °C approximately about 1 hour. After cooling down process, the sample were weighed and immersed under water up to 24 hours. The samples were cleaned before undergo final weighed.

2.4 Compression Test of Samples

Total numbers of nine-cylinder samples (100 mm diameter × 200 mm height) were prepared for C1, C2 and C3. The samples were used to determine the compressive strength which were conducted in accordance with BS EN 12390 [15]. The compression test was conducted to obtain the maximum loading that concrete can withstand before its failure. In this study, the compression testing machine, and linear variable differential transformers were used to obtain the compressive strength and corresponding strain respectively. All the samples were capped with plaster of Paris for uniform loading prior to the test.

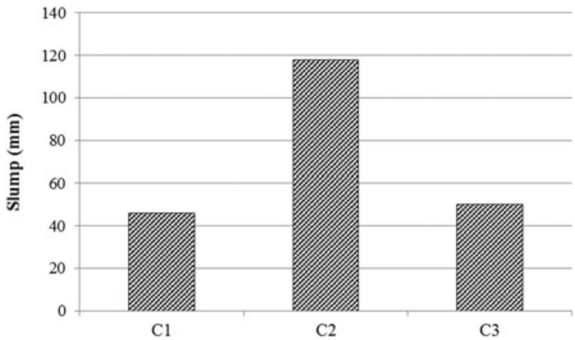
3 Results and Discussion

3.1 Slump Test

The type of slump was obtained from the experimental study was true slump for all batches of concrete (see Fig. 3). The slump values of the concrete are in the range

Fig. 3 True slump of coconut shell concrete **a** Without fibre, **b** with fibre

Fig. 4 Slump values for different concrete samples



of 46–118 mm as illustrated in Fig. 4. The C2 mix showed the highest slump value indicates the highest workability compare to C1 and C3 mixes. Replacing crushed aggregate with CS increase the workability of the concrete mainly due to the smooth surface of CS. However, adding the CF into CSC mix (C3) reduce the workability about 8.7% and 57.6% compared to C1 and C2 respectively. The presence of fibre in concrete mix was found aided in holding the concrete matrix together (see Fig. 3b).

3.2 Density

The effect of replacing normal aggregate with crushed CS in density of the concrete is shown in Fig. 5. As expected, the density of the concrete decreased about 14% when replacing the crushed aggregate with CS in concrete mix due to its light in weight. C2 and C3 densities are 1895.14 kg/m^3 and 1767.13 kg/m^3 respectively, and can be classified as lightweight concrete [16]. Incorporating CF in CSC reduced approximately 7% the density. This is might be due to the existence of the fibre produces more void in the concrete mix.

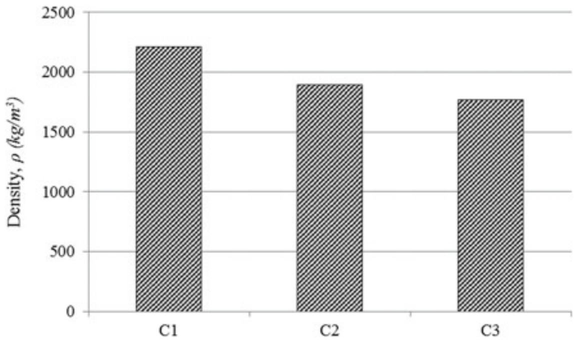


Fig. 5 Density of concrete samples

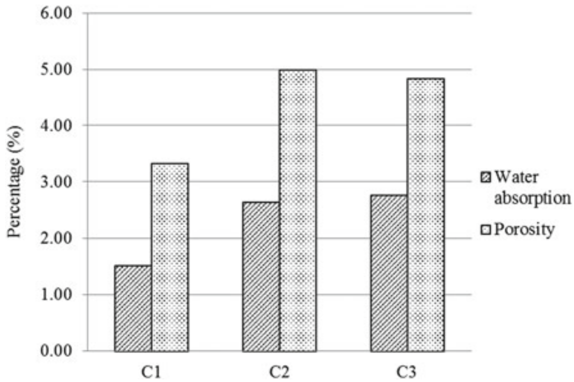


Fig. 6 Percentage of water absorption and concrete porosity

3.3 Water Absorption and Apparent Porosity

Water absorption and porosity have relationship with the existing of the voids that can affect strength of the concrete. Figure 6 shows percentage of water absorption and porosity of the samples. C2 indicates highest porosity up to 5% while the lowest is C1 with 3% of porosity. Even though C3 poses the highest percentage of water absorption approximately 3% but it has lower porosity. This suggests the addition of CF filling up the present pores in concrete thus reduce the porosity. It can be inferred that the density and water absorption are inversely proportional. The higher percentage of water absorption, the less density was obtained that indicates more voids present.

3.4 Compressive Strength, f_c

From the visual observation (see Fig. 7), the failure patterns of the samples are consider as satisfactory [15]. It is apparent that sample C3, which contains CF,

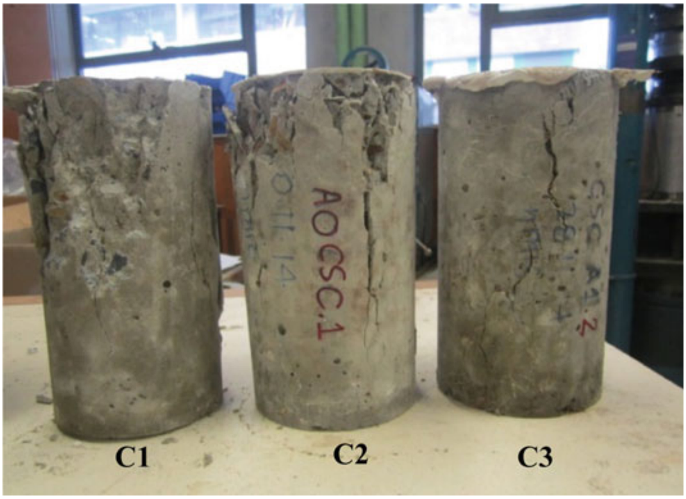


Fig. 7 Failure pattern of the concrete samples

Table 2 Compressive strength result of the concrete samples

Sample no.	Compressive strength (MPa)		
	C1	C2	C3
1	34.69	17.94	17.22
2	23.92	23.73	20.38
3	28.15	23.08	15.19
Average	28.15	21.59	17.60

shows less damage compare to sample C1 and C2 resulted by the presence of fibres that minimizing the damage by holding the materials together. Table 2 summarises the results collected from the compression test. Figure 8 presents the average of

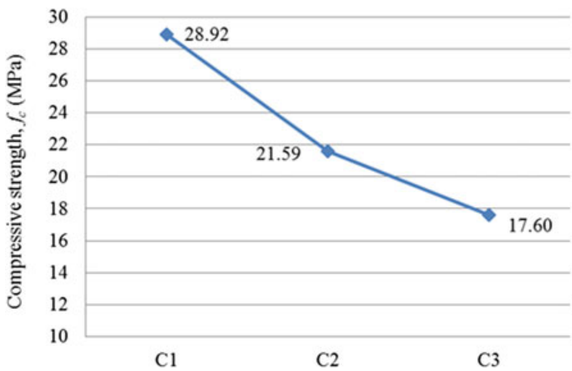


Fig. 8 Average compressive strength of the concrete samples at 28 days

compressive strength, f_c of the samples at 28 days age. Presence CS (C2) in concrete was slightly reduced the f_c approximately 25% relative to the normal concrete (C1). In general, the strength of the concrete is depending on the bond between the aggregate and cement paste. The rougher surfaces of the aggregate result in better bond [17]. The strength reduction in CSC samples mainly due to smooth surface of CS caused poor bond between the CS and cement paste. Additional CF in CSC samples reduced the *fc* approximately 18%. However, both C2 and C3 are satisfied the minimum strength of lightweight concrete which is 8 MPa [16].

4 Conclusions

The experimental campaign of concrete composite of CSC and CF discovered the potential of these coconut wastes to be combined to produce lightweight aggregate concrete for building construction. From the results, it can be inferred that,

i. Replacing crushed aggregate with coconut shell reduced the density and increase the water absorption of concrete,
ii. Coconut shell concrete without and with coconut fibre can be categorized as lightweight aggregate concrete since the density is lower than 2000 kg/m^3,
iii. Compressive strength of CSC decreases with additional of coconut fibre; yet the values satisfy the minimum requirement for LWAC structural purpose.

Further comprehensive studies on coconut shell with coconut fibre should be carried out ensure these materials are promising as good materials for building construction.

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Effect of Black PET Fiber as Additive on the Mechanical Properties of Stone Mastic Asphalt (SMA) Mixtures

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Abstract Stone Mastic Asphalt (SMA) is a type of gap-graded hot mix asphalt which consists of a coarse aggregates' skeleton and high binder content. This type of mixture has been used in many countries due to its toughness, stability and rut resistance mixture that relies on stone-to-stone contact for its strength and a rich mortar binder for its durability. On the other hand, there are some distresses that occur in SMA road pavement, which leads to a significant decrease in the life of the asphalt pavement. Therefore, the asphalt mixture needs to be modified by additive, such as fiber, to improve its mechanical properties and delay the deterioration. In this study, the influence of black PET fiber as an additive in the SMA mixture was focused. Six sets of asphalt mixtures were prepared using different proportions of black PET fiber content (0.2%, 0.4%, 0.6%, 0.8%, and 1.0% by the total mixture weight). Volumetric properties, Resilient Modulus, and Indirect Tensile Strength performance were investigated. The result showed that the optimum binder content for SMA mixture was 6.22%. It is also indicated that the use of black PET fiber as additive improved the Resilient Modulus and Indirect Tensile Strength performance. In conclusion, the use of Black PET fiber in SMA mixture indicates a positive potential to be applied in flexible pavement construction.

Keywords Black PET fiber · SMA mixture · Resilient modulus · Indirect tensile strength

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1 Introduction

Asphalt mixture is mainly constructed from three materials; aggregate (fine and coarse), asphalt binder, and filler. In SMA, there are small amounts of fine aggregates, which results in higher air void content that increase the mixture permeability. Drain down and raveling are considered common problems in SMA mixture, as it will usually lead to a significant decrease in the life of the asphalt pavement [1]. These problems led researchers to search for solutions to improve the mixture properties by incorporating various additives in the mixtures, especially fibers. Waste fibers that were used in asphalt pavement may come from different sources. Many studies focused on the use of waste fibers as additive in asphalt mixture such as; yarn bobbin [2], Posidonia oceanica [3], straw composite [4], coconut fibers [5–7], sisal leaves [5, 8–10], Jute plant fiber [11] paper mill sludge [12], date palm fibers [13, 14], oil palm fibers [15, 16], scrap tire fibers [17, 18], waste carpet fibers [17, 19], waste plastic fiber [20–23], kenaf fibers [24], Bagasse fibers [25, 26], Bamboo fiber [27], Banana fibers [7, 9], waste nylon wire [28], and wool [29, 30].

This research study focused on the use of black PET fiber as an additive in asphalt pavement. The primary objective of this study was to study the effect of black PET fiber on some mechanical properties of Stone Mastic Asphalt (SMA) mixture. The mechanical properties, namely, volumetric properties, resilient modulus, and indirect tensile strength tests were conducted on asphalt mixtures containing different content of black PET fiber (0.0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0%, from the total of mix weight).

2 Materials

2.1 *Asphalt Binder*

80/100 penetration grade was used in this study as the binder. The properties of the asphalt binder are presented in Table 1.

Table 1 Properties of asphalt binder

Property	Temp	Unit	Reference	Value	Requirement
Penetration	25 °C	0.1 mm	ASTM-D0005	87	80–100
Softening Point	–	°C	ASTM-D0036	46	45–52
Rotational Viscosity	135 °C	Pa s	ASTM-D4402	0.31	< 3000
Rotational Viscosity	165 °C	Pa s	ASTM-D4402	0.1	< 3000
Specific Gravity	25 °C	–	ASTM-D0070	1.020	–
G*/sinδ	58 °C	kPa	ASTM-D7175	1.576	> 1.0

2.2 Aggregates

The crushed granite aggregates used in this study were collected from the same aggregate supplier to maintain the quality and results in reliability. The aggregate gradation used in this study was Stone Mastic Asphalt (SMA) 20, that is accordance to the specification of the Malaysian Public Works-Road Department (JKR) [31], as shown in Fig. 1. Meanwhile, the physical properties of granite aggregates for SMA20 are tabulated in Table 2.

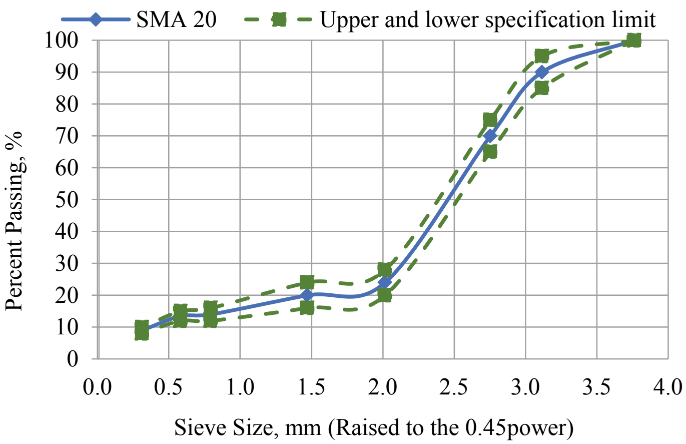

Fig. 1 SMA20 aggregate gradation

Table 2 Physical properties of SMA20 granite aggregate

Property	Test method	Value	KJR requirement
Los Angeles abrasion	ASTM: C131-14	19.8%	<25%
Flakiness index	BS 182: Part3	7.3%	<25%
Elongation index	BS 182: Part3	13.4%	<20%
Impact value	BS 812: Part3	10.3%	<15%
Specific gravity of coarse aggregates	ASTM C-127	2.61	–
Water absorption of coarse aggregates	ASTM C-127	0.65%	<2%
Specific gravity of fine aggregates	ASTM C-128	2.59	–
Water absorption of fine aggregates	ASTM C-128	1.19%	<2%

2.3 Black PET Fiber

Black PET fiber was used as an additive in this study. Black PET fiber was obtained from a local factory which involves in the interior fitting for the automotive industry in Malaysia. The waste black PET fiber was loosed, and cut into small pieces with an average length of 4 mm (Fig. 2). According to JKR specification [31], the fiber length should be less than 6 mm if it is to be used as an additive in the SMA mixture. The physical properties of black PET fiber are tabulated in Table 3.

Fig. 2 Loose black PET fiber

Table 3 Physical properties of black PET fiber

Property	Unit	Value
Dimeter	microns	40
Length before cut	mm	77
Length after cut	mm	4
Elongation	%	67
Shrinkage	%	3.6
Moisture	%	0.4
Density	g/cm^3	1.38
Water solubility	–	Insoluble

3 Mix Design and Experimental Program

Six different asphalt mixture proportions were prepared. The first one was the control mixture. In the other five mixtures, the black PET fiber was used as an additive with the percentages of 0.2%, 0.4%, 0.6%, 0.8%, and 1.0% by the total of mixture weight. The SMA mixture samples were prepared using Marshall Mix Method in accordance to ASTM D6926 [32] and the Malaysian Public Works-Road Department (JKR) [31]. Meanwhile, the SMA mixtures with black PET fiber incorporation were mixed through the dry process. Three duplicates samples were weighted for each combination of aggregates mixture. The aggregates were put in the oven for 3 hours at the temperature of 160–170 °C. Meanwhile, the asphalt binder was heated up to a mixing temperature of 150–155 °C for 1 hour. The blended mixture was compacted using 50 blows at each side at a temperature of 140–145 °C. The samples were kept in the moulds for 24 hours. The samples were remoulded after 24 hours and were kept for related tests. Through the Marshall stability and flowability test, the optimum binder content was determined. Through calculation, the optimum binder content for SMA mixture was 6.22%.

4 Mixture Performance Tests

To evaluate the mechanical properties of SMA20 mixtures, the samples were tested for different tests such as volumetric properties, resilient modulus test, and indirect tensile strength test. Each test is described in the following sections.

4.1 Volumetric Properties

Volume of asphalt binder and aggregates is highly affected by the volumetric properties of the required asphalt mixture. The volumetric properties of the asphalt mixture are among the critical factors that affect pavement performance and durability [33, 34]. In the SMA mixture, the air voids were considered to be one of the main factors in the mix design [6, 35–37]. In this study, the volumetric properties, such as density, air voids, and voids in mineral aggregate (VMA) were calculated. The density was determined according to D2726 [38], and the air voids and VMA were determined according to D3203 [39].

4.2 Stiffness Modulus Test

The stiffness or resilient modulus test was carried out using a universal materials testing apparatus (UMATTA) machine, in accordance with ASTM D4123 [40]. The samples were prepared with an average of 101.7 mm diameter and 65 ± 1 mm thickness. The test was carried out at the temperature of 25 °C. The resilient modulus of the samples was calculated automatically based on the following equation:

$$\text{StiffnessModulus(MPa)} = \frac{P(\nu + 0.25)}{HxT} \tag{1}$$

where, P is the peak load (N); v is the Poisson's ratio; T is the average thickness of the sample (mm) and H is total recoverable deformation on the horizontal axis (mm). Each sample was tested three times. The position of the vertical dimension plan of the cylindrical sample was modified for each test. Finally, the results of the three duplicate samples were averaged and recorded.

4.3 Indirect Tensile Strength Test

According to AASHTO-T283 [41], the purpose of this test is to determine the tensile strength along the diametral direction of compacted asphalt mixture samples. Three duplicate samples with 101.6 mm diameter and 65 ± 1 mm length were prepared and compacted to achieve about 7.0% air voids. The test was carried out at the temperature of 25 °C, and the load was applied on the diametral direction at a constant deformation rate of 50 mm/min. The load at failure was recorded to calculate the tensile strength, as follows:

$$S_t = \frac{2000xP}{\pi xTxD} \tag{2}$$

where, St denotes tensile strength (KPa), P signifies maximum load (N), T refers to sample thickness (mm), and D indicates sample diameter (mm).

5 Results and Discussion

5.1 Volumetric Properties

The effect of black PET fiber content on the volumetric properties such as the bulk density, air voids, and VMA are graphically presented in Figs. 3, 4 and 5, respectively.

Figure 3 indicated that black PET fiber affected the density of the mixture as the density of the compacted sample decreased with an increment in black PET fiber

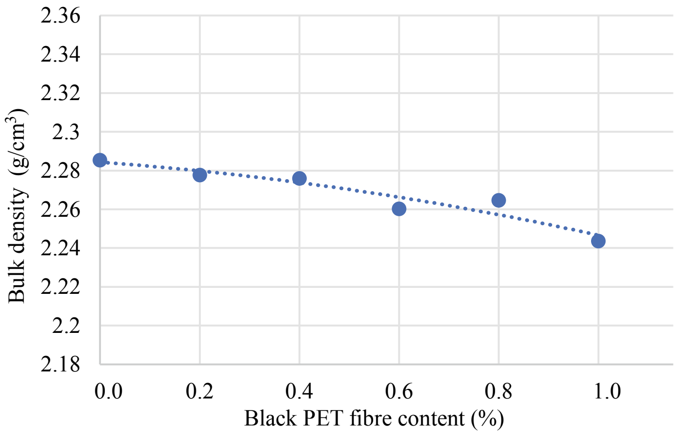

Fig. 3 Bulk density for different black PET fiber mixtures

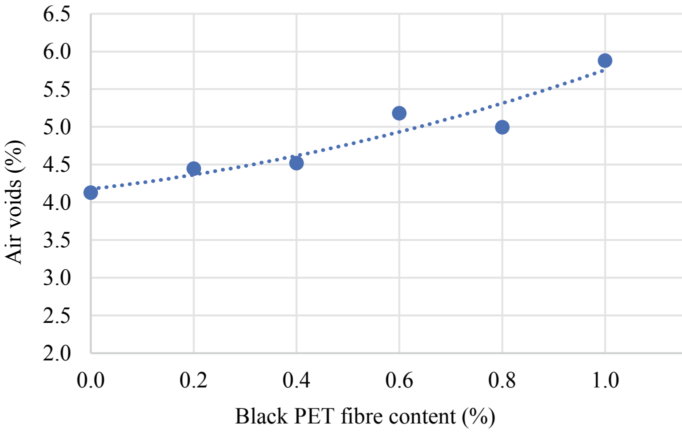

Fig. 4 Air voids for different black PET fiber mixtures

content. Furthermore, all the mixtures with black PET fiber additive showed lesser density values compared to the control mixture. This is because of the lower specific gravity of black PET fiber (1.39) as compared to the aggregates (2.62).

Figure 4 showed the mixtures air void values versus black PET fiber. All the mixtures air voids were within the range except mixture with 1.0% fiber showed higher value, 5.9%. Additionally, the figure indicated that with an increase in the black PET fiber content, the air void values of the mixture will also increase. The observation signifies that by adding black PET fiber to the SMA mixture, it will affect the mixture air void values. Apparently, the performance of the asphalt mixture is dependent on the air voids in the mix. For SMA mix, the air voids should be 3–5% [31]. Too many air voids in the mixture will lead to asphalt cracking due to low

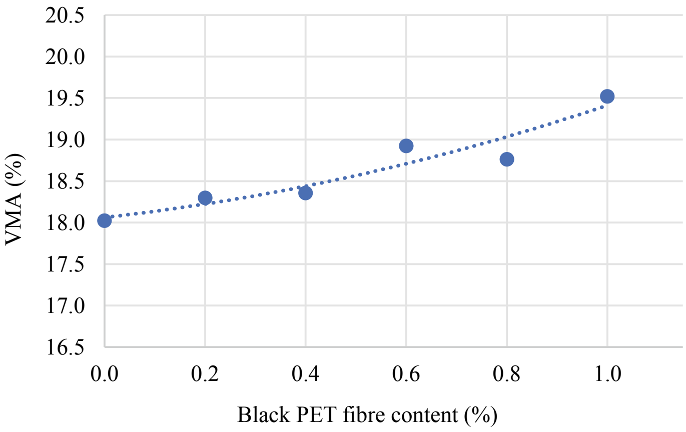

Fig. 5 VMA for different black PET fiber mixtures

asphalt binder content, resulting in its failure to coat the aggregates in the mixture, while too few air voids in the mixture may result in more deformation and asphalt binder bleeding [42].

Figure 5 showed the values for different black PET fiber mixtures. All mixtures fulfilled the standard requirement of the minimum value of VMA for SMA mixture, that is, 17% [31]. The results showed that the VMA value increased as values black PET fiber content increased. As the stems from the fibrous material was added to the mix, the fiber increases the resistance to the sample compaction, hence resulting in VMA increment value.

5.2 *Stiffness Modulus Result*

Figure 6 presented the stiffness modulus for different black PET fiber mixtures. It can be seen that the resilient modulus value of mixtures with black PET fiber showed higher stiffness as compared to the control mixture. Moreover, the stiffness modulus value increased by the increment of black PET fiber content until 0.6%. The stiffness modulus value for 0.6% was 12,867 N/mm^2. This increment was probably due to the black PET fiber, in where it binds and restricts the movement of aggregates. This makes the asphalt mixture become stiffer. Whereas, the resilient modulus value decreased at 1.0% for black PET fiber. The decrement of the stiffness modulus values was most likely attributed to the high surface area of black PET fiber, that need to be coated by the asphalt binder. Therefore, the aggregates and fibers were not fully coated by the binder, hence resulting in the asphalt mixture become less stiff.

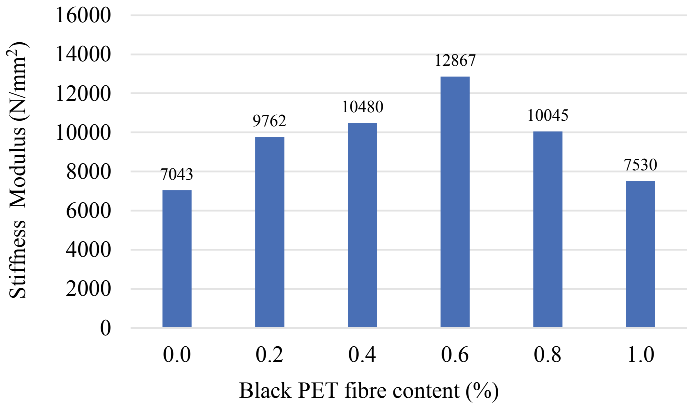

Fig. 6 Stiffness modulus for different black PET fiber mixtures

5.3 *Indirect Tensile Strength Result*

Indirect tensile strength values for different black PET fiber mixtures are presented in Fig. 7. Clearly, the addition of black PET fiber increased the indirect tensile strength of asphalt mixture. All mixtures with black PET fiber had higher strength values than control mixture (without fiber). Furthermore, the indirect tensile strength value increased until it reached the maximum value of 699.9 kN/m^2 for mixture with 0.6% fiber. However, the indirect tensile strength value was decreased when the black PET fiber was increased to 1.0%. Based on these results, the asphalt mix with 0.6% fiber appeared to be the optimum mixture, which showed better performance as compared to the other mixtures.

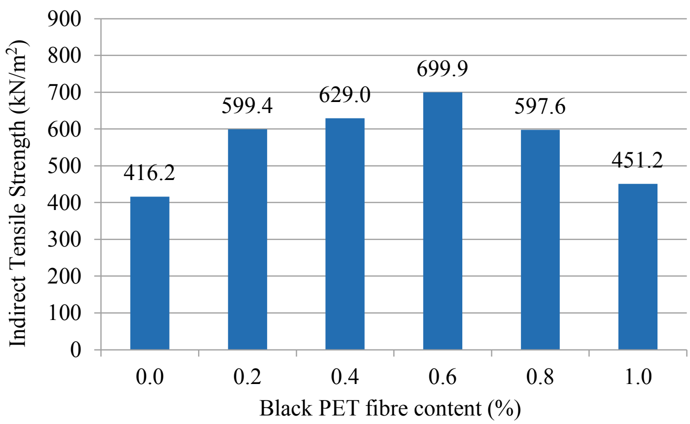

Fig. 7 Indirect tensile strength for different black PET fiber mixtures

6 Conclusion

In this study, the feasibility of using black PET fiber as an additive in SMA mixture is investigated. Based on the results and analysis, the following conclusions are derived:

(1) From volumetric properties, it can be concluded that using black PET fiber as an additive in the SMA mixture posed insignificant effect on the mixture's density, air voids, and VMA. The addition of black PET fiber decreased the density and increased the air voids, and VMA of asphalt mixture.
(2) For stiffness modulus performance, the stiffness modulus value increased by the increment of black PET fiber, which indicate that the SMA mixtures with black PET fiber will result in a high rutting resistance.
(3) For indirect tensile strength performance, the strength value increased by the increment of black PET fiber. Hence, adding black PET fiber to SMA mixtures will enhance the strength property and made it stiffer.
(4) Overall, the black PET fiber was found to be appropriate to be used as an additive in SMA mixture. The optimum percentage of black PET fiber was found to be 0.6% from the weight of the total mix. Hence indicating better performance in comparison to the other mixtures.

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Effect of Aging on the Chemical, Morphological and Wettability Characteristics of Polyurethane Modified Binder

Faridah Hanim Khairuddin, Nur Izzi Md Yusoff, Khairiah Badri, Suhana Koting, Siti Nooraya Mohd Tawil, Choy Peng Ng, and Noor Aina Misnon

Abstract Aging of asphalt binders occurs when oxidation takes place in the binder, and this in turn causes the deterioration of pavement. This paper presents the effect of aging on 60/70 penetration grade asphalt binder incorporated with polyurethane (PU) in terms of chemical interaction, morphological and wettability properties. The chemical characteristics of the base binder (BB) and polyurethane modified binder (PUMB) was evaluated using Fourier Transform Infrared while the morphological properties were analyzed using Raman Spectroscopy. Contact angle test was performed to determine the wettability of PUMB over the aggregates. In this study, the BB is modified with 3 wt% PU. Rolling Thin Film Oven and Pressure Aging Vessel tests were conducted to simulate the short-term aged and long-term aged of the samples. Results showed that the addition of PU to BB has no significant effect on the chemical interaction in the modified binder before and after aging. The incorporation of PU and the aging of modified binder resulted in a reduced bee-structure in the BB, which in turn reduced the wettability of the asphalt binder. The incorporation of PU to the BB improved the oxidative aging of the binder.

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1 Introduction

Flexible pavement is often used in the construction of roadways to provide driving comfort and safety to road users; this type of pavement also has the benefit of lower level of maintenance. In spite of this, flexible pavement is prone to failure such as permanent deformation, cracking and fatigue, all of which have adverse impact on the performance of the road [1, 2]. The aging of asphalt binder due to oxidation resulted in increased stiffness of the binder; this in consequent affect the adhesion property of the binder, which ultimately reduces the durability of the asphalt pavement [3]. Asphalt aging is classified into two phases, short-term aged (STA) and long-term aged (LTA). STA affects the adhesion force of asphalt binder while LTA reduces the adhesion in the binder.

In order to preserve the properties of asphalt binder and asphalt mixture, the binder and mixture have to be modified with materials such as crumb rubber, nanoclay, geopolymer, epoxidized natural rubber, and other suitable materials [4–6]. One of the promising modification methods is the addition of bio-oil as a modifier or as a replacement in asphalt binder in an effort to reduce the usage of binder. Investigations have been carried out on the use of bio-oil and crumb rubber, and results have shown that the physical properties of the modified binder are similar with those of the conventional binder [7]. Khairuddin et al. [8] used polyurethane (PU) as a binder modifier and observed that the incorporation of PU enhanced the physical properties of base bitumen and increased the resilient modulus and permanent deformation of asphalt mixtures; these are an indication of improved fatigue and rutting. Another researcher investigated the effect of incorporating PU and WMA additives in asphalt binder and found that the addition of PU has the effect of increasing the asphalt binder's viscosity and improved the adhesion between the binder and the aggregates [9].

The present study was conducted to evaluate the chemical, morphological and wettability properties of a 60/70 penetration grade asphalt binder modified with PU under aging conditions. The effects of this new material were investigated using Fourier Transform Infrared (FTIR), Raman Spectroscopy and contact angle tests. The results of each test for the unaged (UA), STA and LTA unmodified and modified samples were compared.

2 Materials and Sample Preparation

The 60/70 penetration grade base binder (BB) used as the control sample in this study was supplied by Cenco Science Malaysia. The PU was prepared by combining palm kernel oil polyol (PKO-p) and 2,4-diphenylmethane diisocyanate (MDI) using

Table 1 Physical properties of BB

Asphalt binder test	Asphalt binder grade 60/70			Standard test		
	UA	STA	LTA	Specification	Value	ASTM
Penetration (0.1 mm) at 25 °C	68	56	39	60–70	66	ASTM D5
Softening point (°C)	46	50	55	49–56	49	ASTM D36
Viscosity (mPa.s) at 135 °C	513	750	1025	550	100	ASTM D4402
Ductility (cm) at 25 °C	180	–	–	100	550	ASTM D113
Specific gravity (g/cm^3) at 25 °C	1.03	–	–	1.0–1.06	1.03	ASTM D70

pre-polymerization method. Following this, 3 wt% of PU was added to the control sample and blended for 15 min at 110 ˚C to obtain a homogeneous polyurethane modified binder (PUMB) [8]. Table 1 presents the physical characteristics of the BB for UA, STA and LTA conditions.

3 Laboratory Testing

3.1 Short-Term Aging and Long-Term Aging

The STA samples were prepared in accordance with ASTM D2782 [10] using Rolling Thin Film Oven procedure. Pressure Aging Vessel equipment was used to prepare the LTA sample in accordance with the procedure described in ASTM D6521 [11]. STA simulates the condition of asphalt binder during production in plant while LTA simulates the service life of a pavement. Figure 1a shows the preparation of the samples for STA while Fig. 1b shows the preparation of samples for LTA.

3.2 Fourier Transformed Infrared

FTIR was performed to evaluate the chemical interaction through oxidative aging of carbonyl and sulfoxide groups using the Perkin Elmer-1650 spectrometer manufactured by Bruker Corporation, U.S. The wavenumbers selected for quantifying the chemical groups range from 600 to 4000 cm^{-1}.

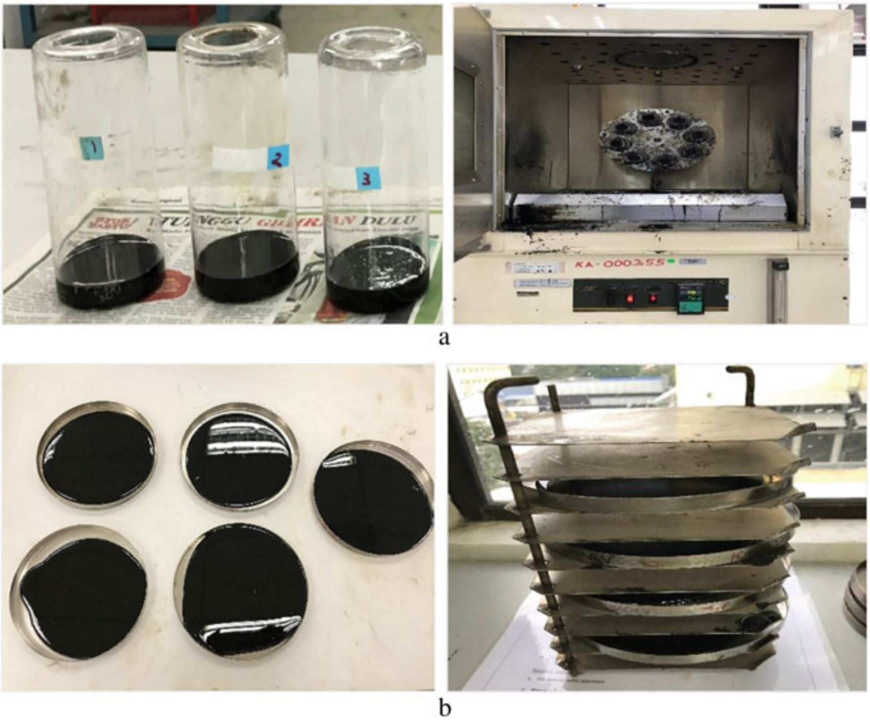

Fig. 1 **a** Sample preparation for STA condition. **b** Sample preparation for LTA condition

3.3 Raman Spectroscopy

Raman Spectroscopy was performed to determine the effect of aging on the Raman shift in BB and PUMB. The inVia confocal Raman microscope was used to measure the Raman spectrum, namely the D band (disordered) and G band (graphitic). The measurement for all samples was made three times within a spectral range of 0 to 3000 cm^{-1}.

3.4 Contact Angle

The contact angle was measured using a goniometer in order to determine whether the PUMB is a hydrophobic or hydrophilic material. A hydrophobic material is resistant to water while hydrophilic material dissolves or absorbs water quickly. The sessile drop method is used to measure the contact angle of a material, which is then used to determine the characteristics of the material.

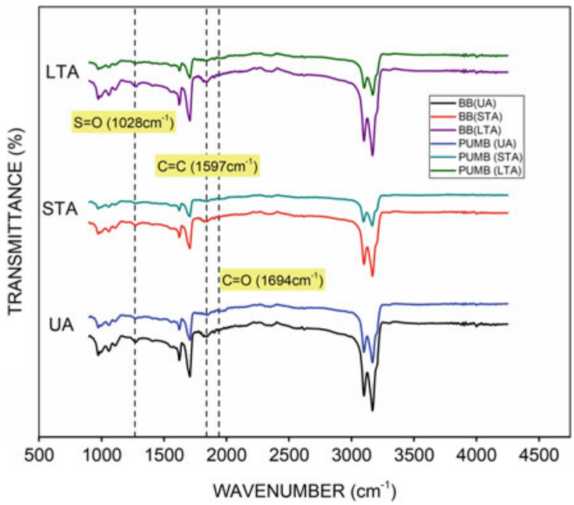

Fig. 2 FTIR results for BB and PUMB under aging conditions

4 Results and Discussion

4.1 *Fourier Transformed Infrared*

Measurement of the chemical interaction that occur in BB as a result of the addition of PU was made by FTIR analysis. The two major bonds evaluated are the carbonyl bond (C=O/C=C) and sulfoxide bond (S=O) in the infrared spectra. The peaks were measured at the wavenumber of C=O (1694 cm^{-1}), C=C (1597 cm^{-1}) and S=O (1028 cm^{-1}) as an indicator for the aging of the binder. The results of FTIR presented in Fig. 2 show a similar wavenumber for all tested samples before and after aging. The absorption peak of 1653 and 1655 cm^{-1} for BB and PUMB, respectively, in aromatic hydroxyl, C=O, is similar to those in normal condition. The absorption peak due to C=C stretching bond was observed at 1596 cm^{-1} for BB and at 1598 cm^{-1} for PUMB for the UA condition. The sulfoxide bond S=O peak was observed at 1026 cm^{-1} for BB and PUMB. The results for aging effect showed that the wavenumber for all major bonds are similar to those for the unaged samples. This spectra shows that the addition of PU did not cause any chemical interaction and significant shift in all evaluated peaks before and after aging [4, 5, 12].

4.2 *Raman Spectroscopy*

Figure 3 shows the 3D perspective of the Raman peaks for unmodified and modified asphalt binders. The D band and G band have similar peaks for the unaged and aged conditions. In this test, the D band at a frequency of 1350 cm^{-1} and the G

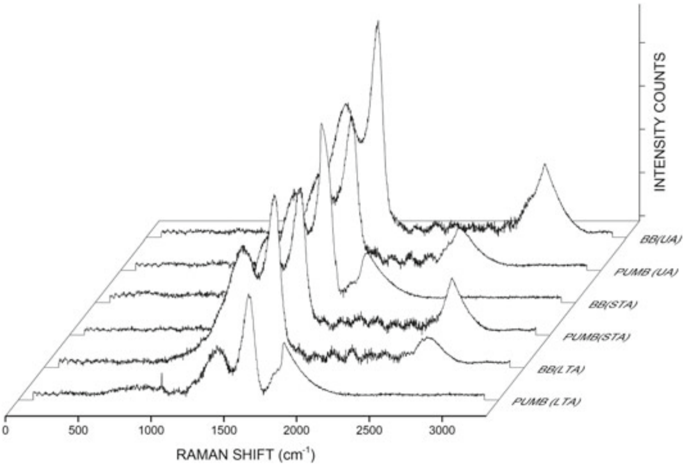

Fig. 3 3D Raman shift for aged BB and PUMB

band at 1580 cm^{-1}, which are the ideal graphite crystal, were evaluated. These band correlates with the in-plane stretching vibration of the aromatic carbon [13].

Figure 4 shows the Raman shift and intensity for UA, STA and LTA of BB at the peak position for the D band and G band. The Raman peak for the BB subjected to STA shifted slightly from 1355 to 1375 cm^{-1} while the peak for the LTA BB shifted to 1379 cm^{-1}. The G band for BB occurred at 1384 cm^{-1} and decreased by 24 cm^{-1} for STA BB and increased back to 1589 cm^{-1} for the LTA BB. Figure 5 shows that the addition of PU caused a shift in the D band and G band for all three conditions. This is because PU is a urethane chain with a strong carbonyl compound [14]. For the UA PUMB, the peaks for the D band and G band are at 1373 cm^{-1} and 1589 cm^{-1}, respectively. The Raman peak for the D band shifted by 1.5% in STA condition and 1.8% in LTA condition. The peak for the G band of both aging condition increased by 2 cm^{-1}. These results are consistent with those obtained in a previous study where all unmodified and modified asphalt binders are in the limitations of D band and G band after aging [15, 16].

Asphalt binder is an amorphous material with a complex microstructure composed of wax. The morphology of asphalt binder is similar to the 'bee-structure' shown in Figs. 4 and 5 [17]. Asphalt binders with higher wax content have clearer bee-structure. PUMB has less bee-structure content compare to that of the BB, which shows that the addition of PU reduced the wax content of the asphalt binder. As aging take place, it is noted that the bee-structure has reduced and cannot be seen especially in PUMB at LTA condition.

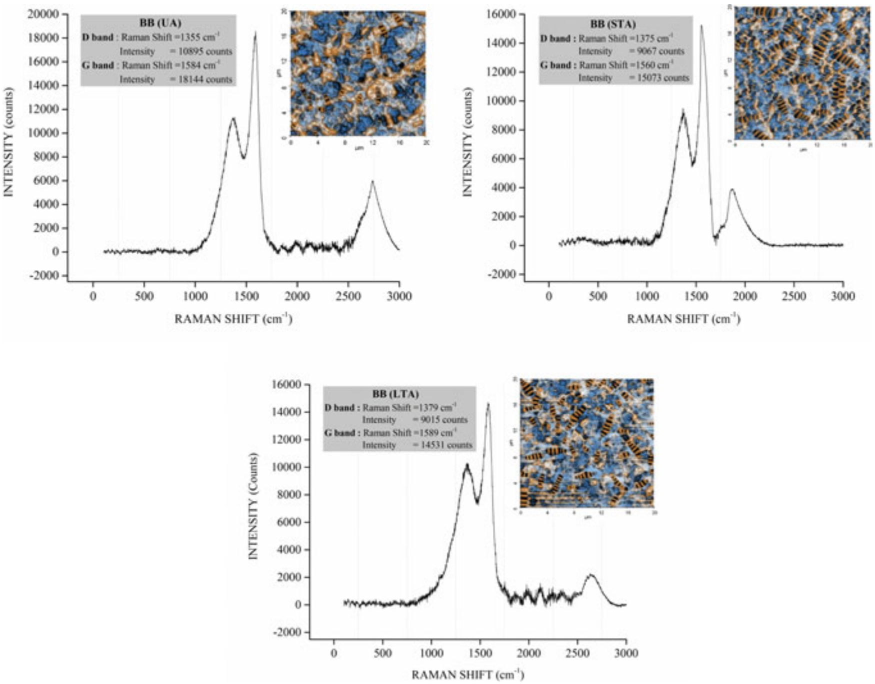

Fig. 4 Raman spectra and bee-structure for UA, STA and LTA BB

4.3 Contact Angle

Contact angle test was performed to evaluate the wettability of the binder surface since asphalt binder has a thermoplastic characteristic that is able to resist water. Three types of solvent were used in this test, namely distilled water, formamide and glycerol, to observe their spreading ability on unmodified and modified binder before and after aging. Materials with a contact angle of less than 90 °C are classified as hydrophilic whereas those with a contact angle greater than 90 °C are hydrophobic. Figure 6 shows the results for all tested samples. Contact angle values for BB and PUMB tested with distilled water and glycerol are greater than 90 °C indicating a hydrophobic surface for all three conditions. However, hydrophilic surface was observed in BB and PUMB before and after aging when formamide was used as solvent with the contact angle values are less than 90 °C.

When water was used as solvent, both BB and PUMB showed a similar trend where the aging condition increased linearly with the contact angle value. However, the use of formamide and glycerol as solvent produced varying contact angle values although a consistent pattern was observed for BB and PUMB before and after aging. The contact angle for BB after STA decreased 5.9% and 2.2% for formamide and glycerol, respectively. The lower contact angle indicates better wetting of the substrate following STA. However, the contact angle for the UA binder increased

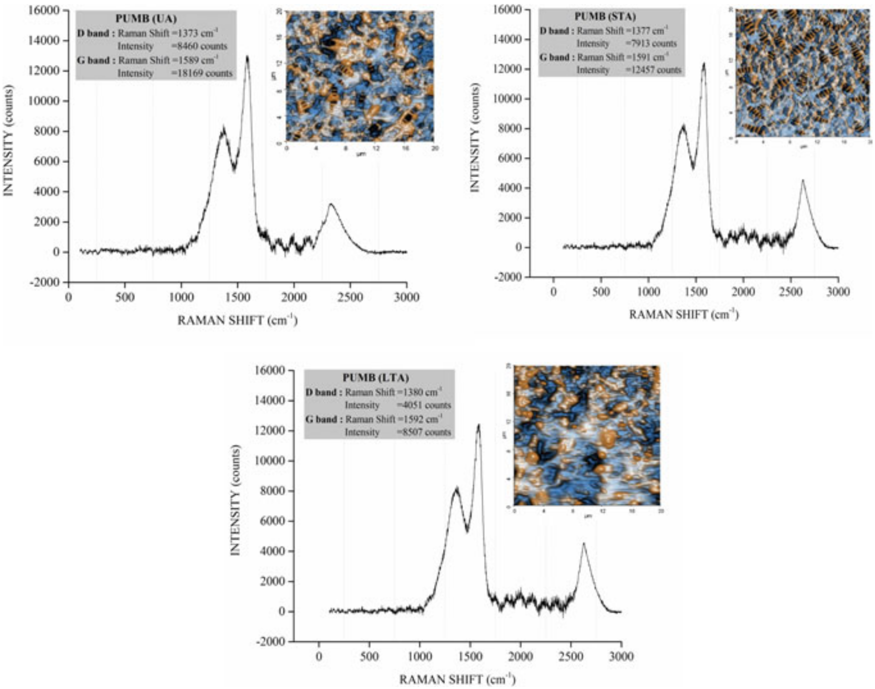

Fig. 5 Raman spectra and bee-structure for UA, STA and LTA PUMB

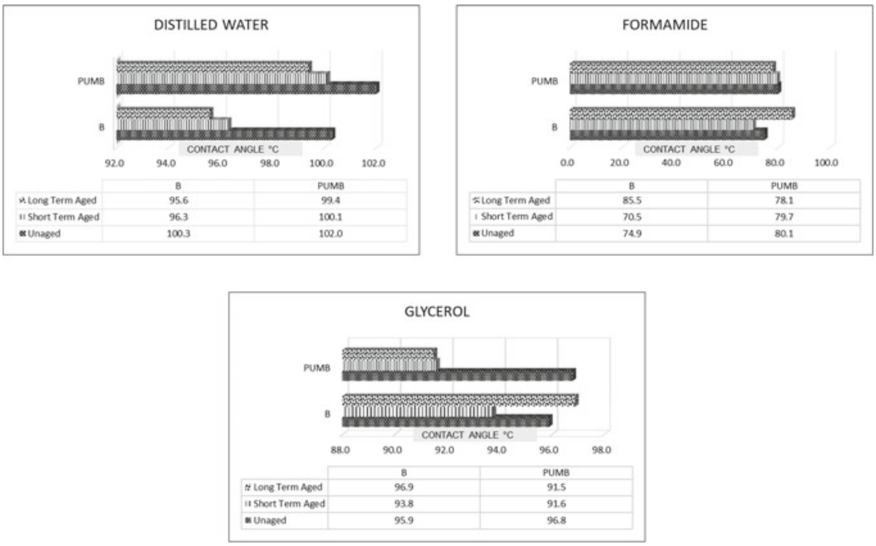

Fig. 6 Contact angle for UA, STA and LTA BB and PUMB

10.6 °C following LTA when formamide was used as solvent. This is consistent with contact angle value for glycerol which showed an increase of 1% following LTA. An increase in wettability indicates better adhesion properties of a binder [3].

The incorporation of PU into BB and subjecting the modified binder to aging resulted in reduced wettability of the modified binder. The results for both formamide and glycerol showed a decreasing contact angle value for PUMB following STA and LTA. An earlier research has demonstrated that the moisture resistance of asphalt mixtures may increase or decrease after oxidative aging depending on the type of binder [18].

5 Conclusions

This study has investigated the chemical, morphological and wettability properties of PU used as an asphalt binder modifier following STA and LTA. Results showed that the addition of PU did not bring about significant changes in the chemical interaction. Furthermore, the Raman Spectroscopy revealed that the order structure of the D band and G band are still within the limitation of the band structure. The addition of PU reduced the wax content of the asphalt binder, and the subsequent aging of the binder resulted in reduced bee-structure in the catana phase of the asphalt binder. The wettability test revealed that the contact angle of PU modified binder is smaller when the binders were aged. In conclusion, PU has very promising potential for use as an alternative material for asphalt binder.

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The Integration of Building Information Modelling (BIM) and Prevention Through Design (PtD) Towards Safety in Construction: A Review

Assrul Reedza Zulkifli, Che Khairil Izam Che Ibrahim, and Sheila Belayutham

Abstract The integration of Building Information Modelling (BIM) and Prevention through Design (PtD) concept is a proactive initiative towards facilitating the visualisation of safety features for designers to minimise risk and hazards at early design phases. Despite the explicit benefits of both BIM and PtD, studies focusing on the BIM-PtD integration remain elusive. This research aims to explore the potential of adopting BIM in the PtD approach with the role of designers incorporating safety measures in their design solution. The research firstly identified the link between BIM capabilities and the PtD concept for designers to incorporate safety elements in their design through optimising use of BIM capabilities. The methodology of this study is by linking BIM capabilities and PtD principles through literatures pertaining to the area of safety and BIM in construction research, established by perception by the designer on how to use BIM to incorporate safety design. A number of papers on safety with PtD concept and BIM with safety were screened, reviewed, and critically discussed, subsequently highlighting the roles and obligation of the designers to implement PtD by using BIM. Findings from the literature was further validated through a pilot interviews with designers in Malaysia, who have been using BIM to implement safety in design of construction projects. Finally, the concept BIM-PtD for the designer to implement design for safety is proposed to fulfil their obligation over the whole construction project lifecycle; and is known as the attributes of BIM-PtD for designers. The significance of BIM-PtD attributes will enhance the designers' understanding on how to incorporate safety elements in their design solution that could further benefit all the stakeholders in construction projects.

Keywords Building information modelling (BIM) · Prevention through Design (PtD) · Safety · Design · Construction

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1 Introduction

The law and enactment on the safety, health, and welfare of persons at work in construction has been mandated, and enforced to ensure the safety, health and well-being of the workers at the construction sites. It also aims to reduce fatality accidents in the construction industry. However, the accident rate in the construction industry is still on the rise due to many other factors. Even though safety law has been enacted and enforced by government, the responsibility to implement a safety system at construction sites lies with the main and sub-contractor. Safety in construction projects must be ensured by the contractor during the construction stage through measures of engineering control and the use of personal protective equipment's (PPE) [1].

There are many other factors that may contribute to the increasing rate of accidents in construction projects such as worker's negligence, lack of safety procedures and lack of enforcement during construction stage. One other compelling factor that contribute to accidents is design errors. An analysis carried out by Health and Safety Executive 2003, based on 100 accidents, approximately half the incidents could have been prevented by design alterations [2].

Prevention Through design (PtD), Construction Design Management (CDM), Design for safety (DfS), and other similar concepts place responsibility to address construction project safety on all of the parties involved in the project (CDM, 1994) [3]. These concepts integrate hazard analysis and risk assessment in the early stages of a construction project lifecycle which is the design and engineering stage [4].

Building Information Modelling (BIM) on the other hand is a collaborative platform used by architectural, engineering and construction (AEC) industries based on a number of software solution [5] that can be used to address safety in the design stage and also for the whole lifecycle of the project. By understanding BIM capabilities in addressing safety in design, will allow the designer to incorporate safety in their design. The objective of this paper is to link BIM capabilities and the PtD concept by optimising BIM capabilities for designers to incorporate safety elements in their design.

2 Prevention Through Design (PtD) and Similar Concept

The design stage in the project lifecycle involve the design of the permanent structure and material and equipment which affected the overall project lifecycle and give the huge impact on construction and operation stage. The risk that associated with the design is usually is the risk that can be minimize by using a proper risk management or other similar approach. The risk that associated in the design that can be manage is the backbone of the PtD concept. The concept of PtD was promoted by National Institute for Occupational safety and Health (NIOSH) United States in 2007 [4], whereby the core of the concept addressed workplace hazards using the highest level of control in the Hierarchy of Control (HoC) which focus on elimination and substitution. The mission of PtD is to reduce the risk of occupational injury and illness by integrating decisions affecting safety and health in all stages of the design process in preventing or minimizing work related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment. This concept introduced to tackle the safety and health issues in construction and operational stage by the involvement by all the stakeholders in construction project namely client, designer and contractor on their afford toward ensuring the project is safe to construct and to operate.

This concept introduces safety features at the design stage before the project goes into the physical construction provided the risk is already known during design stage and it can be eliminated or substituted. According to Szymberski (1997) time-safety influence diagram, the ideal time to consider construction safety is during the conceptual and preliminary design phases [6]. According to Manuele, 2008 the success of PtD implementation relies upon with the involvement of the business decision maker and not the limited to the design professional [4].This requires the clients, designers, and contractors to work together to address risks at source and plan for a safe workplace with regards to a building or any of the construction projects in overall construction project lifecycle (Fig. 1).

The Construction Design Management (CDM) is a similar concept of early stage safety consideration by all the construction stakeholders that was introduced in United Kingdom in 1994 to address the safety issues in construction during the design stage. CDM came into the UK regulations, which place responsibility to address project safety by all the parties involved in the project (CDM 1994). It made mandatory for client, designer, and construction companies to address safety and health during the design phase of projects in 1994. In 2007, CDM was revised to simplify and rationalised, integrating for better with implementation that suits to EU legislation and to tackle small-scale construction projects. In 2015, it was replaced

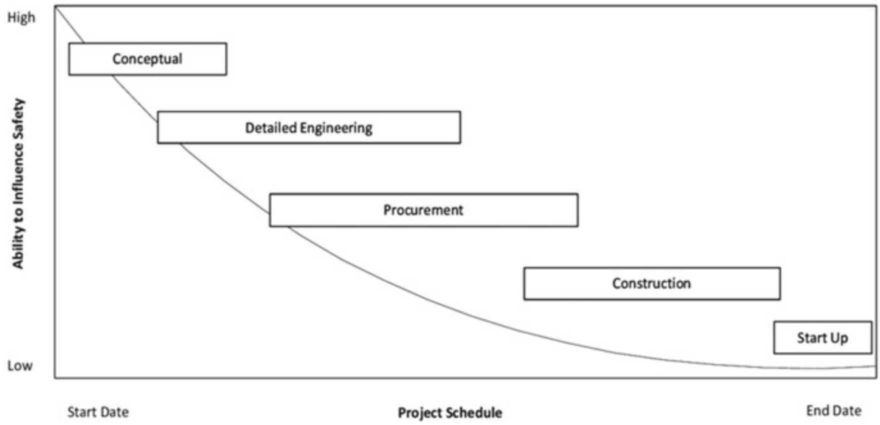

Fig. 1 Szymberski (1997) time/safety influence diagram, [6]

with 'Guidance on the Construction (Design and Management) Regulations 2015′ and this law applies throughout the construction process and all construction projects, from concept to completion and each stakeholder should comply with the law to ensure projects are carried out in a way that secures health and safety.

In Australia the Guidance on the Principles of Safe Design for Work was published in 2006 [7] in addressing their fourth National Occupational Health and Safety (OHS) strategy 2002–2012 which is to eliminate hazard at design stage. In Singapore, the concept known as Design for Safety (DfS) was implemented requiring the DfS consultants to tackle safety from design up to the implementation stage. DfS Regulations intent to direct stakeholders to work together to perform their DfS duties and promote safe execution of construction and maintenance works so that buildings or structures can be safe workplaces. It was first issued in the year 2008 and the first revision made in 2011.

Department of Safety and Health (DOSH) of Malaysia introduced Occupational Safety and Health Construction Industry Management OSHCI(M) in 2017. OSHCI(M) is adopted from the PtD and CDM concept which requires participation from all the stakeholders in construction industry to look into the safety measures in a construction project to avoid accident [8]. The previous safety & health regulation is more focus on the construction and operation phase and the higher ranking of HoC. OSHCI(M) in Malaysia started to develop since 2017 by DOSH of Malaysia and supported by Construction Industry Development Board (CIDB) is the similar concept in addressing the safety issues with regard to permanent design for construction project. OSHCI(M) in Malaysia was officially launch in December 2018. These initiatives is to complement the current initiative to reduce the accident rate in construction industry. Apart from the previous initiative by statutory bodies in Malaysia related to safety in construction, OSHCI(M) is the added value for the construction project to ensure safety in overall construction stages.

In summary, the focus of PtD, CDM, DfS, OSHCI(M) and other similar safety approach is to ensure the safety and health aspect is being addressed by the designer to reduce or prevent occupational injuries, illness and fatalities. The designer roles to mitigate the foreseeable risk during design is the thought of the PtD concept that lead to better coordination to improve safety and health for the whole lifecycle of the project that has shown in Fig. 2. From the literature finding, PtD is presented by these 5 principles; PtD requires the commitment by client, collaboration between all the stakeholders, it flows throughout the overall lifecycle of the project, it requires systematic risk assessment and management, and its requires safety knowledge, information and communication. (e.g. [9–14]).

3 Research Method

This section outlines the systematic review method in correlation with the finding from the pilot interview section in validating the BIM-PtD attributes for the designer and all the stakeholders to address safety for construction project. A systematic

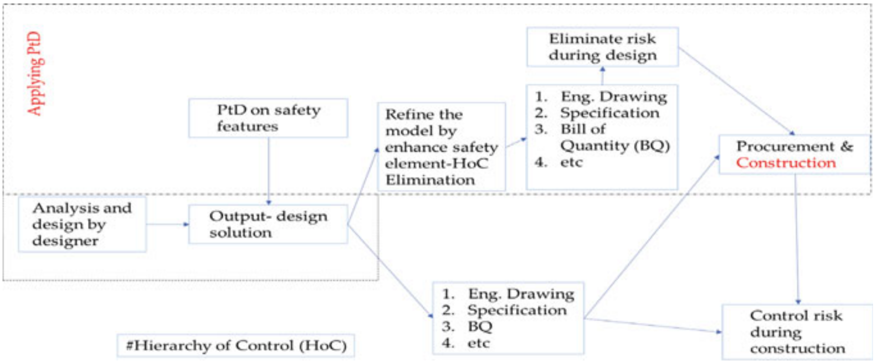

Fig. 2 Designer roles in implementing PtD for Construction project

review is used to identify, select and scoping down all the literature based on the agreed quality relevant to the research question [15]. The systematic review is used to gather the PtD principle and matrix with BIM capabilities to suits to the PtD principle in addressing safety design. The Scopus Elsevier's database sources is used based for the selection of the papers where the quality of the database papers is highly being reviewed each year. The search by using "title/abstract/keyword" was made on December 2018 begin with "BIM safety" and updated in February 2019 resulted a total number of 509 papers appears. Within these 509 papers, it is scoping down to 144 papers appear by using keyword prevention through design. Out of these 144 papers, the top 7 most relevant journal and 1 conference in the area of construction, engineering and construction safety is chosen. The basis of the selection of the journal is by focus area of the journal in accordance scope related to construction engineering practice and safety. The cite score is the proof of the quality, comprehensive, transparent and current view of the impact of the selected journals and conference. From 509 papers of BIM-Safety only 95 were screened. From 95 papers is reduced to 48 papers is screened by using keywords of Prevention through design. From the 48 papers the only selected journals and conference only 20 papers. The list of selected journal and conference are as shown in Table 1.

From the previous section of this paper entitled "**PtD and other similar concept**", 5 principles of PtD is made as a basis in the method to map the PtD and BIM capabilities. Then from these 5 principles of PtD, the BIM capabilities that suit with designer task is established and tabulate as BIM-PtD for designer. From the search of literature, current approach on the implementation of PtD using BIM capabilities is referred and map to the 5 principles of PtD. After the screening process, from the "BIM-safety-PtD" papers were reviewed and classified based on construction project lifecycle practice where comparison to traditional approach was made. This is to understand the flow of the BIM-Safety related process in all the construction project lifecycles. The reviewed and classified papers are based on the BIM-PtD

Table 1 List of selected journal and papers to review

	Journal/conference	Component criteria			
		BIM-safety	BIM-safety -PtD	Selec-ted	Cite score (2017)
1	Automation in Construction	44	22	6	5.36
2	Procedia Engineering	19	5	2	0.89
3	Safety science	12	10	5	3.22
4	Journal of Construction Engineering and Management	10	6	2	2.36
5	Engineering Construction And Architectural Management	4	2	2	1.9
6	Advance engineering informatic	4	1	1	4.17
7	Journal Of Civil Engineering And Management	1	1	1	1.86
8	ARCOM 2010 (26th Annual Conference)	1	1	1	
	Total paper selected	95	48	20	

implementation that suits to different stages of construction project lifecycle. The 5 principles of PtD is then matrixed with the BIM capabilities in its overall application to address safety in the design that contributes to the enhancement of the safety aspect in construction and operational phase. A total of 20 papers selected and reviewed. The screened and reviewed papers were then comprehended by a survey asking the current approach on implementing safety in design stage. The findings from literature and survey further correlate with the pilot interview in validating the BIM-PtD attributes. BIM-PtD attributes is mapped based on the statement given by the interviewer on the current practice of the designers including the BIM-PtD integration. The Interview was conduct on 18th and 19th of February 2019 and the respondent is C&S designers during PtD workshop organized by DOSH and CIDB. First respondent is from consulting firm who has 21 years of experience involve majority of infrastructure project. The second respondent and the third respondent is also from consulting firm who has more than 15 years of experience who involve majority for designing a building project and the fourth respondent is from the perspectives of client engineers who has 10 years of experience. The analysis of the pilot interview is using content analysis where the keyword that suits to PtD principle and link with BIM capabilities is captured. The interview question focused on their current safety consideration approach in their design and construction and the question on BIM usage to address safety in the design. The response is linked with the two most significant BIM-PtD attributes.

4 Result and Discussion

From the paper reviewed in Scopus Elsevier's database by using keywords BIM-Safety and PtD and matrix it with the BIM-PtD Attributes. A total of 20 papers were reviewed to develop BIM PtD attributes based on the principle of PtD and BIM capabilities. The interview section revealed the current approach on the safe application in real construction project. BIM-PtD attributes were mapped and the finding reveals that safety is a responsibility of every stakeholder, it fits throughout the lifecycle concept of the building, it is a systematic risk management, it requires knowledge and capabilities as well as information transfer and collaboration. Table 2 shows the result after the screening process and mapping 5 principle of PtD concept with the trend of literature related to BIM-PtD. Table 3 shows the established BIM-PtD attributes by both systematic review and comprehended by pilot interview on the current practice of BIM-PtD. From the findings, the current safety consideration approach by the designer that links to the attributes of BIM-PtD depends on the code or standard that governs the engineer and architect in ensuring the design is safe during operation and construction. It also depends on the safety standard stated in the contract. These codes and standards can be incorporated using BIM safety rules features. The other current practice that suits to PtD principle of design mitigation approach, is where the risk assessment made in the design stage is relying on the type of the project, the client's requirement and the government mandate and regulation. An example of BIM-PtD attributes is by using guideline or code of practice to review the method statement prior to commencement of works. This is where 4D BIM capabilities can be used to review the working method prior of approval from the consultants. Another example is integration of urban Stormwater Management Manual for Malaysia (MSMA) with the design for cut and fill and other safety standards for infrastructure works. Uniform Building By-Law (UBBL) is a standardised set of building regulations in Malaysia which provides the minimum requirements for the control and construction of street, drainage, and building. All this law and code can be incorporated in BIM safety rule system to enhance the safety that suits to BIM-PtD attribute of risk mitigation and design for constructability. Based on the interview, the current practice in construction project in Malaysia on the usage of BIM in enhancing safety can be seen as reverse BIM process where the original design is converted to 3D file for better visualization and for clashing analysis during the construction stage. According to The Star News 21st December, 2018, one of the project in Malaysia that implemented BIM is the Mass Rapid Transit Corporation (MRT Corp) that has become the first infrastructure developer in Asia to achieve Level 2 accreditation in the usage of BIM. The project that adopts BIM process and

Table 2 Categorization of BIM-PtD integration based on 20 papers selected

No	References	BIM-PtD integration				
		Lifecycle approach	Risk assessment review	Integration with all discipline	Constructability review	Operational review
1	[16]	√	√	√	√	√
2	[17]		√	√	√	
3	[18]				√	
4	[19]				√	
5	[20]		√	√		
6	[21]		√	√	√	
7	[22]		√	√		
8	[23]		√			
9	[24]				√	
10	[25]		√	√	√	
11	[26]		√	√	√	
12	[27]		√	√	√	
13	[28]				√	
14	[29]				√	
15	[30]		√	√	√	
16	[31]		√	√	√	
17	[32]	√	√	√	√	√
18	[33]		√	√	√	
19	[34]		√	√	√	
20	[35]		√	√	√	
	Total	2	15	14	17	2

incorporate safety in the design stage presents a BIM-PtD attribute of Design with safety consideration and produce database in overall lifecycle of the project.

4.1 BIM-PtD Integration Concept

Various of application of BIM tools that would benefit the construction project, is the triggering factor of construction project stakeholder using its. BIM process is fundamentally designed from the early stage of a construction project by the consideration of the whole lifecycle of a building or any infrastructure project which will enhance the productivity of the project in many aspects. BIM is the digital revolution that can be used by the designer to address the safety element in their design and in ensuring the project is safely construct and operate. According to Latiffi et al. (2013) BIM is

Table 3 Pilot interview on the current practice on BIM-PtD attributes

Interview questions	Content analysis on safety for current approach	BIM-PtD attributes		BIM-PtD attributes as designer current approach
What is your roles to ensure the design is safe to construct and operate?	depend on the code and standard by the designer	Lifecycle Safety in design Initiated by first stakeholders (client)	Design with safety consideration and produce database in overall lifecycle of the project	The client approach to address the safe design toward overall **lifecycle of the project**
How do you mitigate risk in your design?	1. Consider higher risk and project code and regulation 2. Depend of the method of construction by contractor	Design with risk assessment and mitigation measures review	Design with constructability review	Design review must incorporate **constructability and risk assessment**
Give example on the design for safety that you apply?	using standard code and requirement in design	Design with risk assessment and mitigation measures review	Design with constructability review	
How do you apply BIM in design stage which relate to safety in design?	1. Hire third party BIM consultant to reproduce the BIM model. 2. Risk review by generating clash detection report 3. Visualize the method statement using video simulation	Design with sequence of construction consideration	Design with the integration with others discipline review	Design with consideration sequence of construction with the **integration of others discipline**

a collaborative platform used by architectural, engineering and construction (AEC) industries based on a number of software solutions that can be used in the project towards better coordination in the early stage and better visualization and execution and further for better management in managing the assets [5]. By various BIM solution and application for construction project, it can be used to enhance the safety aspect in the project lifecycle. The collaborative work environment by implementing BIM, suits to the PtD principle that can be used to assist the designer in finalizing their design solution towards safety in all the construction project lifecycle. From

Table 2, the BIM-PtD integration is tabulated as Lifecycle approach, Risk Assessment review, Integration With all Discipline, Constructability review and Operational review. From 20 paper that being reviewed, most of the paper discussed and revealed that BIM capabilities that suits to PtD principle is Risk Assessment review, Integration With all Discipline, Constructability review. The BIM-PtD integration is the approach to implement the safe design in construction by all the stakeholders and throughout the lifecycle of the project. For various capabilities of BIM, can be utilised in the design stage incorporated with PtD to ensure the design is safe to construct and to operate. Kamardeen, 2010 revealed the potentials on various capabilities of BIM in eight dimensions 8D that could be used to incorporate PtD in the design stage [16]. From the safety risk knowledge, it can assess the risk by using the visualization capabilities before finalizing the design. Zhou, Ding, and Chen, 2013, projected the practical application of four dimensional (4D) BIM visualization for safety management in metro construction [36]. Since then, BIM is technological based platform, and safety in construction project is one of the crucial element in making the construction project running smoothly, BIM tools related to safety continue to evolve, based on the latest development of risk database on safety rule checking using BIM tools.

The capabilities of BIM which can ease the designer in enhancing the safety measure to their design that can be made through constructability review, sequencing program 4D and integrate with many others BIM capabilities that can suits to the PtD approach. In the latest development of BIM for safety, Getuli et al. [30] define safety & health using BIM based design composed with the construction project flow and requirement using the BIM capabilities of rule base checking that would enhance the practicality of design for safety and safety in construction phase [30]. Hossain, Abbott, Chua, Nguyen, & Goh, 2018 research revealed DfS knowledge database using BIM in reviewing risk for the building construction project which defines the functional areas, design element and by condition of the works [37].

This is an indicator that tremendous effort and movement toward safety and health by using the latest BIM technology in the AEC industry by all the parties in AEC projects throughout the overall lifecycle of the project. The other standard that established by British Standard Institution (BSI) on to implement BIM for construction project is based on various of BIM capabilities and its stage for construction project lifecycle. PAS- 1192–6:2018 2018 is the guideline that established to support the used of BIM specifically, to address safety and health for construction project. PAS stand for publicly available specification (PAS) which this document standardized best practice on a specific subject, can commission a PAS, subject to the BSI acceptance process [38]. This code specifies requirements for the collaborative sharing of structured safety and health information using BIM throughout the project and project life cycles. These code state the application of BIM capabilities of 3D and 4D models in design to supports the principles relating to the safe design and the legislative duties on designers.

BIM-PtD approach enable the designers to identify "foreseeable risk" that associated with their design. The use of digital information from design stage and with the modelling software applications increase the designer's ability to expect and foresee the hazards and risks in the design. The various of applications BIM software which

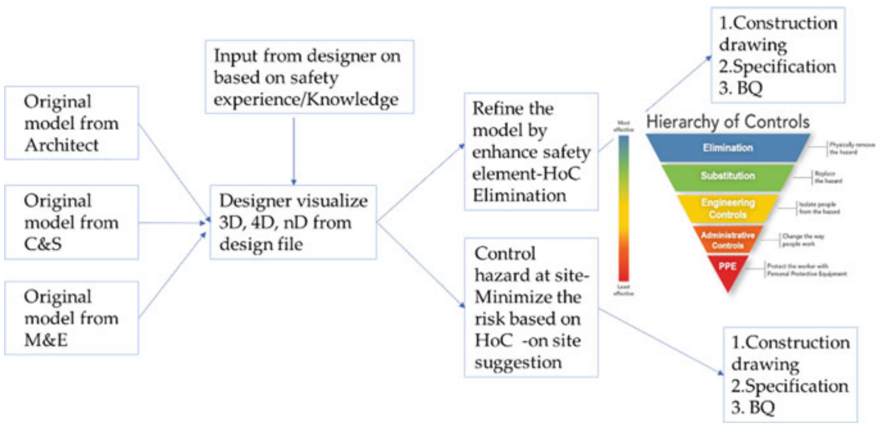

Fig. 3 Implementation of PtD using BIM by designers

the designer can use to accurately visualize and sequences the activity that relate with their design that realistically that enable them to enhance the safety element in the design before finalising it. From BIM-PtD integration concept, the used of BIM for the designer to address the safety approach in their design and with the PtD principle that could guide and give the direction to the designer toward how to increase the safety and health for the whole lifecycle of the project.

As in Fig. 3, it shows, the designers task is to design a permanent structure. When designing a permanent structure, the PtD principle of collaboration by the need to all stakeholders to collaborate from collaborate the model from discipline in order for the designer to visualize and coordinate before finalize the model. By visualizing the 3 Dimensional model and n Dimensional model, it will enhance the understanding of the designers, when the designers have the knowledge and experience towards safety, the designers will refine the model by implementing the HoC concept. If the model cannot be refine due to some constraints, the model is remain the same and just control the hazard by lower HoC element then only all documentation is being finalize.

5 Conclusions

BIM technology is drastically improving the safety and health aspect in construction industry which will further improve the construction industry. The attributes of BIM-PtD as revealed in this paper are the approach to address the safety aspect from the design stage until the operation and maintenance stage where the designer need to ensure risk assessment and constructability approach is incorporated in their design. The integration with others discipline model is one of the key elements to ensure the safety in design where the collaboration among the construction stakeholders is take place. BIM capabilities enable the designer to improve their design towards safety in overall lifecycle of the construction project. BIM-PtD attributes can be used as a guideline, a tool, and a resource in performing the PtD in the design process. With the implementation of BIM in addressing the safety using PtD principle, it would further benefit the overall project lifecycle toward better safety management and safety design that could enhance the efficiency in project delivery for construction industry.

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Impact of Drying-Wetting Cycles and Geometrical Parameters on the Cracking and Shrinkage Behavior of Composite Liners Made of Fly Ash

Abdullah All Noman and Islam M. Rafizul

Abstract In this study an investigation was performed to know the effect of drying-wetting cycles and geometrical parameters on the cracking and shrinkage behavior of composite landfill liners. To these attempts, composite landfill liners were prepared with fly ash at varying mixing proportions of 20%, 30%, 40%, 50%, 60% and 70% by dry weight with different water content. Experimental work has been carried out with three different mixing water content equals to optimum moisture content (OMC), plastic limit (PL) and liquid limit (LL) of composite soil slurry. In this study, steel mold of 30 cm diameter at different thickness of 10, 20 and 30 mm was used. Result reveals that cracking and shrinking behavior in terms of crack intensity factor (CIF), crack density factor (CDF), shrinkage area, crack length and crack width decreases with the increasing fly ash content, while, increases with increasing water content in liners. In addition, CDF, shrinkage area and crack width increase, while, CIF and crack length decreases with the increasing of liner thickness. With the multiple drying-wetting cycles, amount of cracking did not change significantly after 2nd wetting-drying cycle. The image processing technique through this study provided a better and easiest way to analyze cracking and shrinking behavior of liner.

Keywords Composite landfill liners · Effect · Cracking and shrinkage behavior · Fly ash · ImageJ · MATLAB

1 Introduction

Desiccation cracking of landfill liners is a major problem because it causes cracks and shrinkage on liners in field which reduces strength and sealing function dramatically. Desiccation induces cracks on soil liners and moisture can migrate into the

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landfill through the cracks and contaminated leachate with surrounding environment including surface water, ground water and underlying soils [1]. The Landfills liner system are required to be constructed to reduce the leachates from municipal solid waste (MSW) and protect surrounding environment. Temperature distribution, non-uniform water content and mineralogical composition of soil are responsible for cracking and shrinkage characteristics on soil structures [2]. On the other hand, particle's orientation and amount and types of cations in pore fluid are also affect cracking and shrinkage behaviour of landfill liners [3]. To overcome this, reinforcing soil masses by adding admixtures with soil were practiced by early civilizations [4]. Now a days it is used lime, sand, cement, fly ash, brick dust and gravel to stabilized soil in landfill. A researcher Tiwari (2015) conducted his study using bentonite and fly ash to investigate the effect of fly ash content on the plasticity, compaction properties, cracking behaviour, etc. of composite soils [5]. It is very essential to quantify and analyze the cracking and shrinkage behavior of liners using quick, easy and better techniques for better performance. Recently, Image-base analysis techniques are gaining popularity to quantify crack development and characterization. Researchers Puppala et al. (2004), Lim (2013) and Tiwari (2015) used image analysis techniques to quantify cracking and shrinkage behavior in terms of crack intensity factor (CIF), crack density factor (CDF), cracks area and shrinkage area of landfill liners [5–7]. If directly measure this cracking and shrinkage parameters, larger error will fabricate in actual results due to irregular length, width and shape of cracks [8]. In this study, to prepare composite liner and analyze cracking and shrinking behavior of composite soil, a commonly available admixture like fly ash at varying mixing proportions were mixed with soil. A coding was developed in MATLAB to quantify and analyze the cracking behavior of landfill liners. Moreover, ImageJ and MS excel ware used to calculate cracking parameters. The CIF was measured from direct MATLAB coding. In addition, other cracking parameters such as CDF, shrinkage area, cracks length and crack width were calculated through ImageJ software and MS excel. Through this present study, a new window will may open for researchers to prepare cap and base liners easily and economically without further details analysis.

2 Material and Method

The following materials and methods were implemented to fulfil the desire objectives of this study and hence discussed in the following articles.

2.1 Collection and Characterization of Soil

Disturbed soil samples were collected at a depth of approximate 5 feet below existing ground surface from a selected waste disposal site at Rajbandh, Khulna, Bangladesh. In this study, soil samples were first air-dried and then powdered by mixing machine.

Table 1 Physical and index properties of soil used in this study

Properties	Unit	Values	Analytical method
Initial moisture content, w	%	38	ASTM D 2974
Optimum moisture content, OMC	%	20	ASTM D 558
Maximum dry density, MDD	gm/cc	1.59	
Specific gravity, G_s	–	2.61	ASTM D 854
Liquid limit, LL	%	54	ASTM D 4318
Plastic limit, PL	%	31	
Plasticity index, PI	%	23	
Shrinkage limit, SL	%	35	ASTM D 427
Shrinkage ratio, SR	%	1.28	
Volumetric shrinkage, VS	%	79.4	
Linear shrinkage, LS	%	17.7	
Sand: silt: clay	%	4.6:64.7:30.7	ASTM D222
Soil type	CH (Fat clay)		

The powdered samples were then sieved through #4 sieve and then the sieved samples were used to prepare composite liners. In the laboratory, the physical and index properties of soil were measured through the standard test methods and depicted in Table 1. The soil was classified according to unified soil classification system and the soil was categorized as fat clay (CH).

2.2 *Collection and Characterization of Fly Ash*

To prepare composite landfill liners, fly ash was collected from local market. In this study, the physical and index properties of fly ash were measured in the laboratory through the standard test methods. The values of optimum moisture content, maximum dry density, specific gravity and liquid limit of fly ash were 34%, 1.52 g/cc, 2.23% and 42.6% respectively.

2.3 *Determination of Water Content for Soil Slurry*

At first, in the laboratory it has been intended to prepare soil slurry with fly ash and soil, soil samples were mixed with pre-selected amount of fly ash content in percentages. The mixing contents of fly ash with soil were 20%, 30%, 40%, 50%, 60% and 70%. After mixing a particular amount of fly ash, the Atterberg's limits and Proctor compaction tests were performed. In this stage, it was intended to determine the required amount of water to prepare composite liners. A study conducted by

Table 2 Results of plasticity properties and compaction properties of composite slurry with fly ash

Soil slurry (%)	Atterberg's limits (%)		Optimum moisture content (%) from proctor compaction test
	Liquid limit (LL)	Plastic limit (PL)	
S100, FA0	55	31	20
S80, FA20	53	30.11	19
S70, FA30	52	29.55	18
S60, FA40	51	29.43	17.5
S50, FA50	49	28.86	17
S40, FA60	48	28.32	16.5
S30, FA70	46	28.02	16

Tiwari (2015) and prepared composite liners with admixtures at varying mixing water content equals to liquid limit (LL), plastic limit (PL) and optimum moisture content (OMC) [5]. In the present study, the statement postulated by Tiwari (2015) was followed to prepare composite liners [5]. In this study, the amount of mixing water content was determined from Atterberg's limit and proctor compaction tests. This study also aims to investigate the effect of water content on the cracking and shrinkage parameters of liners. To these attempts, different water content interms of LL, PL and OMC were computed from Atterberg's limit and proctor compaction tests. The results of plasticity properties and compaction properties of soil slurry with fly ash content is provided in Table 2.

2.4 Preparation of Composite Liners

In this study for laboratory investigation, it was intended to prepare composite liners with fly ash at varying mixing proportions of 20, 30, 40, 50, 60 and 70% by mixing soil with dry weight. Experimental work has been carried out with three different moisture content equals to OMC, PL and LL of mixing soil slurry to ensure a uniform slurry. In this study, diameter of steel circular mold of 30 cm was used. In addition, the thickness of liners of 10, 20 and 30 mm of liners were considered to prepare composite liners. To ensure uniform water absorption the mixing soil pastes were kept in air tight polythene bags for 2 h.

2.5 Drying and Image Taking Process

After the preparation of composite liners specimens, the desired amount of composite slurry was poured in mold and kept the mold in the wooden chamber shown in Fig. 1, where six heat lamps of 100 W light bulbs were connected. Due to evaporation of

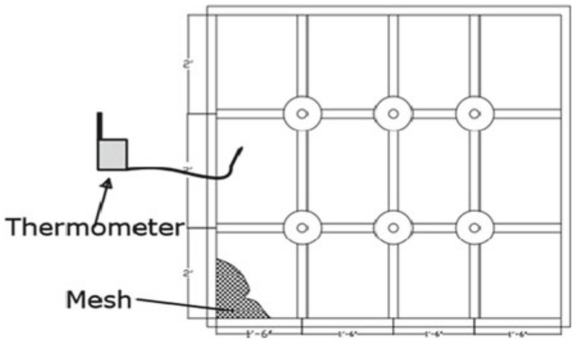

Fig. 1 Chamber system for drying of soils (top view)

water from liner desiccation cracks would be formed on the liner specimens. In this stage, it was ensured that each specimen could get equal heat. Moreover, a thermometer was connected to the chamber to measure the variation of temperature in a regular basis and the temperature was found approximately 38 °C. During drying process, a digital camera (Nikon COOLPIX S2900) which was mounted at top of sample soil through steel made camera stand, used to take image of dying sample. A 1.5 feet of constant height was always maintained for taking image of one-day interval.

2.6 Wetting and Drying Cycles

Initially, all liners specimen were subjected to two cycles one is drying cycle and another is wetting–drying cycle. Two cycles of wetting and drying were subjected on the prepared composite soil to simulate the field behavior of liners in landfills. In drying cycle, the formation of cracks were constant after seven days (168 h). After end of first drying cycle with constant crack area at 168 h for both liners, desired amount of water was applied to start a wet cycle. In the wetting cycle, approximately 250 ml/day of water for 4 days were used through spraying nozzle to simulate the percolation behavior of clay shown in Fig. 2. In wetting cycle, developed cracks became zero for both liners after 4 days. For this reasons the duration of the drying cycle was considered as 7 days and for wetting cycle it was 4 days.

2.7 Image Analysis

Image processing is a method which extracts useful data from image clicked by digital camera. Generally, two steps are required to analyze the cracking characteristics of liners. In the first step, RGB image is prepared for next steps using different stages. The first step involves the image processing in which image is prepared in various

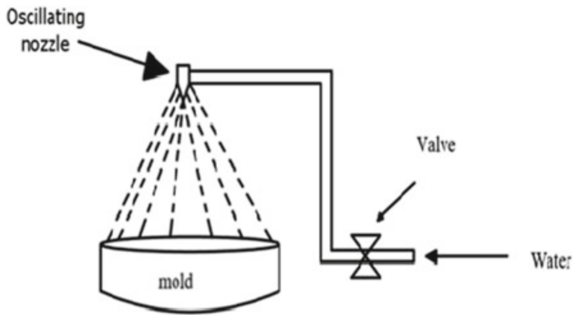

Fig. 2 Spraying nozzle setup for spraying water on specimen

stages for further analysis. Its include cropping unnecessary part of raw image and covert to binary image which was obtained by thresholding the RGB image. Second step leads to analysis the proceeded image which was obtained from step 1 to calculate the cracking and shrinkage parameters interms of crack intensity factor (CIF), crack density factor (CDF) and shrinkage area.

RGB Image obtained from camera were analyzed in MATLAB using a developed coding to gain useful information. The coding was developed in such a way that compute area of black pixels of proceeded image which was represent are of cracks. In addition, summation of black and white pixels were also calculated. The summation of black and white pixels represents area of reduced specimen in pixel. Then set a program in MATLAB of the ratio of black pixels to the summation of black and white pixels which is known as CIF using the following Eq. 1. ImageJ and MS excel software were used to determine other cracking and shrinkage parameter like CDF and shrinkage area. For the determination of diameter of reduced specimen, a known distance in the proceed image like the diameter of mold is marked by straight line. Then a scale is set in ImageJ software by going to the option Analyse—Set Scale—give value 30 cm. Length of the reduced specimen was calculated by measure command (Analyze—measure). Area of shrinkage were calculated through Microsoft excel which was calculated by subtracting reduced specimen area from the total specimen area. Length of the crack was measured using skeletonize command and average crack width was calculated by dividing the crack area to the length of cracks. In addition, crack density factor (CDF) was computed using Eq. 2.

$$CIF(\%) = \frac{Crack\,area * 100}{Reduced\,specimen\,area} \tag{1}$$

$$CDF(\%) = \frac{(Crack\,area + shrinkage\,area) * 100}{Reduced\,specimen\,area} \tag{2}$$

3 Results and Discussion

To fulfill the desire objectives, composite liners with fly ash at varying mixing proportions such as 20%, 30%, 40%, 50%, 60% and 70% with different water content equals to OMC, PL and LL as well as the geometric parameters line liner thickness of 10, 20 and 30 mm were used. The variation of cracking and shrinkage behavior of composite liners with 20% of fly ash content having 10 mm liner thickness were only presented and hence discussed in this paper. In this study, as a tropical effect on liners, two cycles one was drying cycle and another was wetting–drying cycle were applied.

3.1 Effect of Cycles and Mixing Fly Ash Content

The effect of cycles on cracking and shrinkage behavior in terms of CIF and CDF with in relation to the changing proportions of fly ash content as 20, 30, 40, 50, 60 and 70% at water content equals to OMC having 10 mm liners thickness were presented and hence discussed here.

3.1.1 Crack Intensity Factor

The effect of drying and wetting cycles and changing proportions of fly ash content like 20%, 30%, 40%, 50%, 60 and 70% at water content equals to OMC having liners thickness 10 mm are on the behavior of CIF is shown in Fig. 3. The values of CIF were varied with changing of drying and wetting cycles and fly ash content

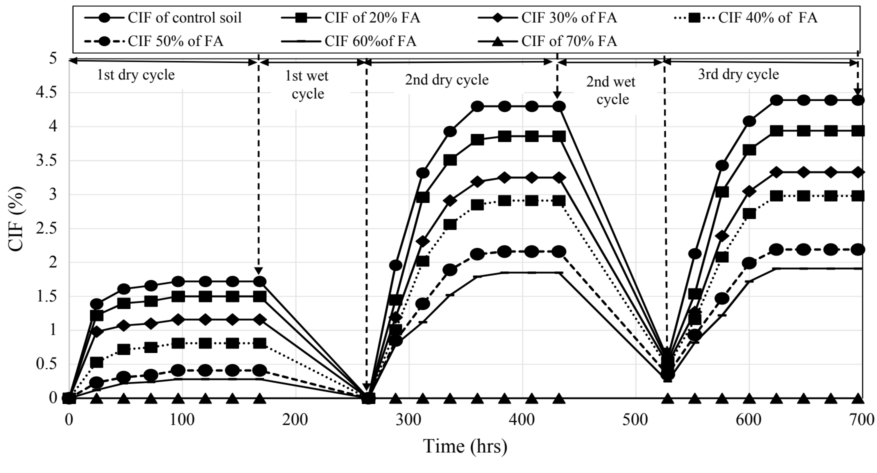

Fig. 3 Variation of CIF with time of liners with fly ash having 10 mm thickness for multiple cycles at OMC

in landfill liners. In the 1st drying cycle, CIFs were subjected very low which was less than 2% and it was measured 1.5%, 1.16%, 0.81%, 0.41% and 0.28% for fly ash content like 20%, 30%, 40%, 50% and 60%, respectively. In this study, series of drying and wetting cycles were performed on the liner specimens to simulate the climatic effect on landfill liners in field. Therefore, approximately 250 ml/day water was applied to circulate wetting cycles on liner specimens. Cracks on liner became zero after spraying water about four days. Figure 3 reveals, cracks developed rapidly at the beginning of 2nd dry cycles and gradually propagated after rapid cracking development period. Additionally, during drying stage, due to evaporation of water from liners, the tendency of shrinking potential increases which eventually implies the increasing of CIF. It was observed that CIF were increased significantly after 1st drying cycle. At control soil, CIF was measured 1.72% during 1st drying cycle and reached to 4.30% and 4.39% in the 2nd and 3rd cycles, respectively. The rearrangement of fabric diminishes of soil structures and eventually ceases subsequent to one or two drying and wetting cycles. Therefore, with the multiple cycles experiment, CIF did not change significantly after 2nd wet and dry cycles. Additionally, the intensity of cracks didn't reduce to 0%. Because, the application of water on liners soil surface didn't results in closing all of cracks.

3.1.2 Crack Density Factor

The CDF of liners with varying mixing percentages of fly ash content varies with the changing of drying and wetting times shown in Fig. 4. CDFs were measured by

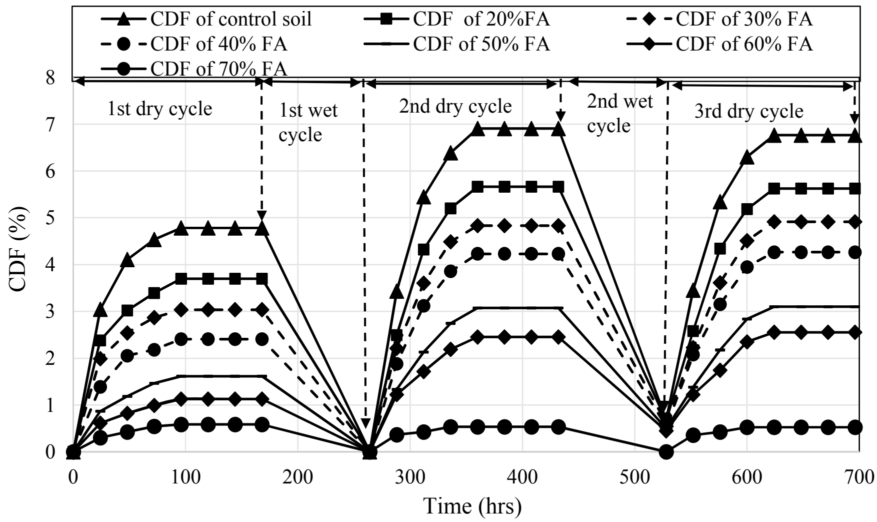

Fig. 4 Variation of CDF with time of liners with fly ash having 10 mm thickness for multiple cycles at OMC

using ratio of surface cracks area to the total specimen area. The values of CDF were increased rapidly in 1st 2 days (48 h) and then it gradually increased and became constant after 4 days. In the 1st drying cycle, maximum CDF was measured in control soil and it was 4.78%. This value decreased with the increasing of fly ash content in the specimen and it was found 3.70%, 3.04%, 2.41%, 1.62% and 1.13% for the liners with 20%, 30%, 40%, 50%, 60% and 70% fly ash content, respectively. In the 2nd cycles this values increased significantly and observed 5.66, 4.83, 4.23, 3.07, 2.45 and 0.54 for the same liners. Due to the rearrangement of soils fabric diminishes the density of cracks were remained same in the 3rd cycle.

3.2 Effect of Moisture Content and Thickness

The effect of moisture content and geometric parameter like liner thickness on cracking and shrinkage behavior interms of CIF, CDF and shrinkage area as well as crack length and crack width of liners with 20% fly ash were observed and present in the following articles.

3.2.1 Crack Intensity Factor

The effect of liners thickness like 10, 20 and 30 mm as well as different moisture content equals to OMC, PL and LL for 20% fly ash content on CIF are shown Fig. 5. Cracking behavior such as CIFs were increased with the increase of water content in the composite liners while decreased with the increasing of liners thickness. Generally, water are evaporated from soil on to application of temperature on landfill liners. Water are evaporated from soil and very small particles of soil are moved

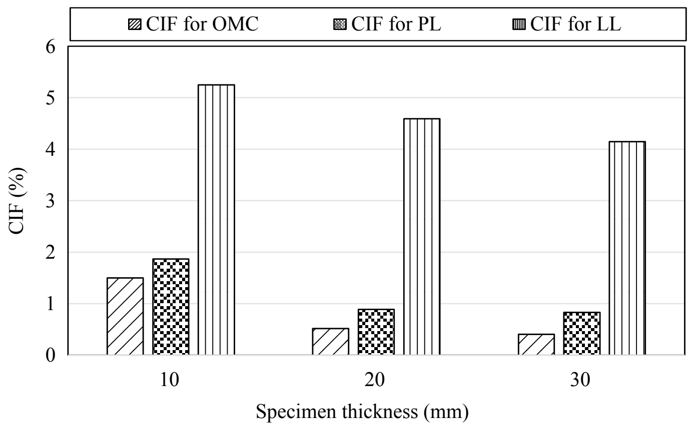

Fig. 5 Variation of CIF with 20% fly ash content at OMC, PL and LL for all the specimen thickness

inwards rapidly due to their high cohesion behavior. This inwards movement of soil particle depends on the mixing water content and percentages of solid particle. The movement of soil particles will be more if the percentages of solid particles are less or mixing water content is more in the liners. This inwards movement of solid particles are responsible for cracks on the landfill liners. More inwards movement of solid particle leads more cracks on the liners. Therefore, the intensity of cracks at mixing water content equals to LL was higher than that liners with OMC and PL. The values of CIF were measured 1.5%, 1.87% and 5.25% for 20% fly ash having 10 mm liner thickness with mixing water content equals to OMC, PL and LL, respectively. However, the tendency of cracks were observed higher in thinner liner specimens due to high rate of desiccation. CIFs were counted 0.52%, 0.89% and 4.59% having 20 mm as well as 0.41%, 0.83% and 4.15% having 20 mm liner thickness with varying mixing water content equals to OMC, PL and LL, respectively.

3.2.2 Crack Density Factor

The CDF of different mixing water content equals to OMC, PL and LL for 20% fly ash content varies with the changing of liner thickness of 10 mm, 20 mm and 30 mm shown in Fig. 6. Density of crack depends on liner thickness and mixing water content. The values of CDF were increased due to increase of moisture content and liner thickness. The density of cracks for liners at mixing water content equals to LL were found more than that liners with OMC and PL. CDFs were measured 3.70%, 6.43% and 11.97% for 20% fly ash having 10 mm liners at varying water content equals to OMC, PL and LL, respectively. Increase in liner thickness lead to uneven drying of the layer of soil which increase surface shrinkage area of a liner specimen. Therefore, density of cracks were increased due to increase to liner thickness. CDF

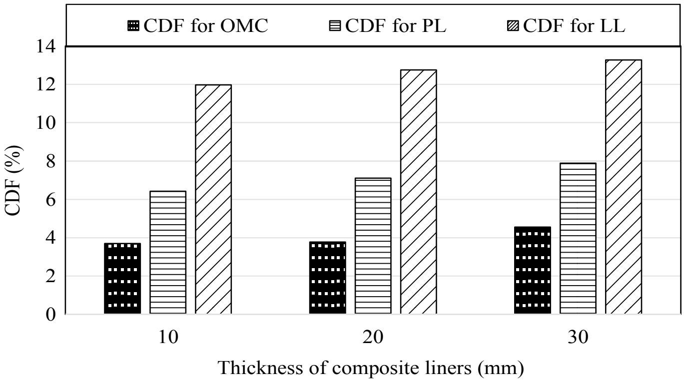

Fig. 6 Variation of CDF of stabilized soils with fly ash content at varying water content and liner thickness

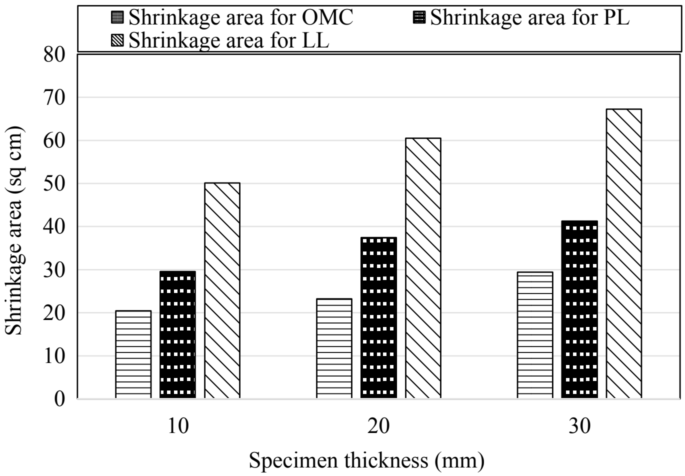

Fig. 7 Variation of shrinkage area with fly ash content at OMC, PL and LL for all the liner thickness

was counted 6.43%, 7.11% and 7.89% at PL as well as 11.97%, 12.78% and 13.27% at LL having 20 and 30 mm liner thickness, respectively.

3.2.3 Shrinkage Area

The variation of shrinkage area with varying moisture content and liners thickness for 20% fly ash content are present in Fig. 7. Shrinkage area are related to water content in soil and liners thickness. More shrinkage were observed due to increasing water content while less shrinkage were detected with the increasing of liners thickness. During drying process due to loss of water in time, shrinkage occurs. The clay soil with finer particles and water shows more shrinkage. Therefore, shrinkage area with water content equals to LL was observed more than that of OMC and PL. It was measured 20.46 cm^2, 29.56 cm^2 and 50.12 cm^2 shrinkage are having 10 mm liner thickness with water content equals OMC, PL and LL, respectively. Additionally, the tendency of shrinkage behavior were observed higher in thicker. Shrinkage area were found 23.21 cm^2, 37.40 cm^2 and 60.53 cm^2 for 20 mm liners as well as 29.43 cm^2, 41.23 cm^2 and 67. 27 cm^2 with water content equals to OMC, PL and LL, respectively.

3.2.4 Crack Length and Crack Width

The variation of crack length and average width with varying moisture content and liners thickness for 20% fly ash content is depicted in Figs. 8 and 9, respectively. Crack length and average width are decreased with the increasing water content in the liners. Due to uneven drying though the number of surface cracks decreases

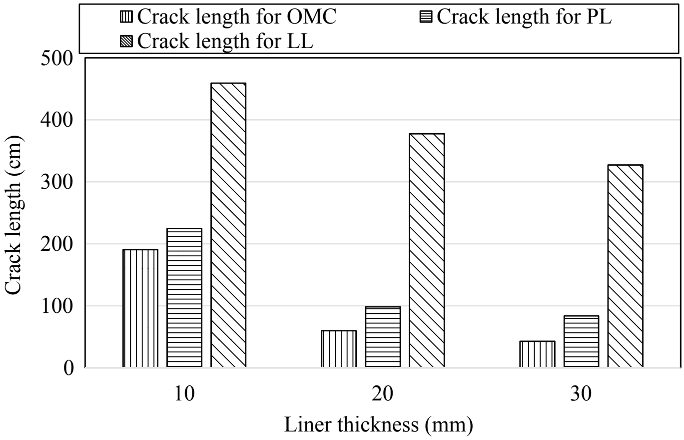

Fig. 8 Variation of crack length with fly ash content at OMC, PL and LL for all the liner thickness

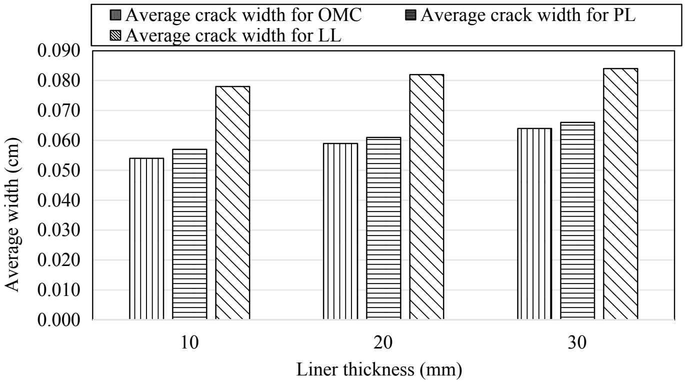

Fig. 9 Variation of average crack width with fly ash content at OMC, PL and LL for all the liner thickness

the cracks length as well as its width increases. In addition, with the increasing of liner thickness crack length are decreased while average width of cracks are increased. It was measured 190.5 cm, 224.6 cm and 459.3 cm crack length as well as 0.054 cm, 0.057 cm and 0.078 cm average crack width for 20% fly ash content having 10 mm at varying mixing water content equals to OMC, PL and LL, respectively. Moreover, crack length was decreased while average crack width was increased with the increases of liner thickness.

Table 3 Results of CIF, CDF and shrinkage area of composite liners at varying water content

Composite liners	CIF (%)			CDF (%)			Shrinkage area (cm^2)		
	OMC	PL	LL	OMC	PL	LL	OMC	PL	LL
S100, FA0	1.72	2.17	5.81	4.78	7.43	13.39	22.0	26.1	56.9
S80, FA20	1.5	1.87	5.25	3.70	6.21	11.97	15.8	18.9	50.1
S70, FA30	1.16	1.49	4.48	3.04	5.01	10.20	13.5	16.1	42.4
S60, FA40	0.81	1.36	4.04	2.41	3.90	8.42	11.4	12.8	32.3
S50, FA50	0.41	1.04	3.34	1.62	2.73	6.62	8.6	9.6	24.0
S40, FA60	0	0.78	2.83	1.13	1.80	4.85	6.0	7.3	14.7
S30, FA70	0	0	0	0.58	0.70	1.28	4.1	5.0	9.1

3.3 *Effect of Admixture and Moisture Content*

The effect of admixture content and moisture content on cracking and shrinkage behavior interms of CIF, CDF, and shrinkage area as well as crack length and average width having 10 mm liner thickness were observed provided in Table 3 and present in the following articles.

3.3.1 Crack Intensity Factor

The variation of CIF at varying mixing proportions of fly ash content and mixing water content with liner thickness 10 mm is provided in Table 3. CIF decreases with the increase of admixture content like fly ash. Moreover, the intensity of crack in specimen was found higher for liners with water content equals to LL than that of liners with OMC and PL.

3.3.2 Crack Density Factor

The effect of CDF with in relation to proportions of fly ash content at varying water content equals to OMC, PL and LL having 10 mm liner thickness are provided in Table 3. Addition of fly ash in soil mean reduction of proportion of high shrinkage materials in the mixtures. Therefore, with the increasing of fly ash content in composite liners are decreased the percentages of overall surface shrinkage in the liners. The finding results reveal, CDFs were decreased with the increasing of fly ash content while increased due to increasing of water content in the liners. For control soil, CDF were found 4.78, 7.43 and 13.39% having 10 mm liner thickness with water content equals OMC, PL and LL, respectively.

Table 4 Results of crack length and crack width of composite liners at varying water content

Composite liners	Crack length (cm)			Average crack width (cm)		
	OMC	PL	LL	OMC	PL	LL
S100, FA0	210.3	254.9	486.4	0.056	0.058	0.082
S80, FA20	190.5	224.6	459.3	0.054	0.057	0.078
S70, FA30	150.8	178.9	393.4	0.053	0.057	0.078
S60, FA40	114.8	162.6	365.0	0.049	0.053	0.076
S50, FA50	59.5	143.2	311.3	0.048	0.050	0.074
S40, FA60	0.0	95.5	171.5	0.000	0.048	0.069
S30, FA70	0.0	0.0	0.0	0.000	0.000	0.000

3.3.3 Shrinkage Area

The variation of shrinkages area at varying water content equals to OMC, PL and LL having 10 mm liner thickness with changing proportion of fly ash content are provided in Table 3. Result reveals area of shrinkage are reduced due to increase of fly ash content while increases with increasing of moisture content. The liners with fly ash has a tendency to decrease shrinking potential due to low swell and shrinking capacity of fly ash. Results reveals shrinkage area decreases due to increase of fly ash in liners. Shrinkage area was measured 22.03 cm^2, 15.82 cm^2, 13.46 cm^2, 11.41 cm^2, 8.57, 6.01 cm^2 and 4.13 cm^2 having 10 mm liner thickness with water content equals OMC, PL and LL for 20%, 30%, 40%, 50%, 60% and 70%, fly ash content, respectively.

3.3.4 Crack Length and Crack Width

The variation of crack length and average width with in relation to the mixing percentages of fly ash content having 10 mm liner thickness at varying water content equals to OMC, PL and LL are provided at Table 4. Crack length and average width decreases with the increase fly ash content, while, increases with increasing water content in liners. Due to uneven drying though the number of surface cracks decreases the cracks length as well as its width increases. It was observed 210.3 cm, 254.9 cm and 486.4 cm crack length as well as 0.056 cm, 0.058 cm and 0.082 cm average width at mixing moisture content equal to OMC, PL and LL, respectively.

4 Conclusions

The cracking and shrinkage behavior such as CIF, CDF, shrinkage area as, crack length and crack width decreases in relation to the increasing fly ash content, while, it increases with the increasing of mixing water content in liners. In addition, the values of CDF, shrinkage area and crack width increase while CIF and crack length decreases due to the increasing of liner thickness. With the multiple drying-wetting cycles, amount of cracking did not change significantly after 2nd drying-wetting cycle. A new window will may open through this study for other researchers to prepare cap and base liners in waste landfill easily and economically specially in least developed Asian countries like Bangladesh.

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Challenges to the Installation of Building-Integrated Photovoltaic on an Atrium in Malaysia

Muhammad Azzam Ismail, Fahanim Abdul Rashid, and Tan Aik Peng

Abstract The Green Energy Office (GEO) building showcases the sole building-integrated photovoltaic incorporated into its atrium architecture in Malaysia. Previous studies focus on the energy performance and indoor environment of this atrium. However, architectural design issues and challenges of integrating a photovoltaic (PV) system onto this building atrium were not studied and discussed. This paper presents findings from semi-structured interviews involving relevant stakeholders and site observations. Results reveal various challenges such as aesthetic concerns, indoor environment, project costs, rainwater leakages, and compatibility of the installed inverter. This study presents a path for solutions to BIPV installation issues. It provides recommendations for improvements to form references for future installations of BIPV systems onto building atria in Malaysia and other similar contexts.

Keywords Building-integrated photovoltaic · Atrium architecture

1 Introduction

A building atrium is generally known as a large enclosed building space that is attached to the main building with at least one glazed façade [1]. It could also have a partially glazed roof for natural daylighting into the building atrium and its adjacent spaces [2]. Commonly, the building atrium functions as a social space for interaction and activities in an office or commercial buildings [3]. The development of building atrium in Malaysia began with the introduction of an open courtyard in the typical Malaysian shop houses that provides daylight and natural ventilation to the internal space [4, 5]. The first building atrium at a commercial building was at the Portman's

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Hyatt Regency Hotel, followed by the Sungei Wang Plaza shopping mall that used the building atrium to attract the crowds of consumers and boost commercial activities [6].

Building atrium invites natural daylight and promotes air ventilation within the building and thus creating a thermally and visually comfortable indoor environment for its inhabitants [7]. Besides this, the building atrium also provides ideal spaces for socialization and interactions for its inhabitants by bridging different stories of spaces within the building [8]. Hence, the building atrium positively contributes to the market value of buildings [9].

Modern building atria originated in temperate climate regions in the early 1960s [10]. These modern atria are covered with glass walls and canopies to shelter its inhabitants from outdoor environments besides providing natural daylighting, space, and vegetation [11]. However, the design of modern building atria neglected the environmental factors of solar radiation, winds, and other natural factors, particularly in other regions with different climates [4]. More emphasis was given to aesthetics without consideration of site context, the suitability of building materials, and design strategies [8]. Consistently, building atria in Malaysia frequently suffered from heat surplus conditions throughout the entire year due to the tropical climatic conditions [8]. The high solar altitude causes this situation, and vertical penetration of sunlight into the atrium increased solar heat gain in the building [12]. As a result, this caused overheating at the atrium and upset the energy running costs by increasing the cooling load in the building [13].

Furthermore, Ab Ghafar [4] highlighted that the indoor temperature for an enclosed tropical building atrium could be higher than the outdoor temperature, affecting human comfort levels. She outlined that it is crucial to have a careful design of thermal comfort, visual comfort, and luminance value for the building atrium to lower the energy consumption on the cooling load. These parameters are essential in designing low-energy office buildings as it can create a thermally and visually comfortable indoor environment for the inhabitants [14].

1.1 Building-Integrated Photovoltaic (BIPV)

Building-Integrated Photovoltaic (BIPV) system serves as part of a building envelope while simultaneously generating electricity [15]. In other words, the system uses solar PV materials to replace conventional building materials that are in parts of the building envelopes, such as the rooftops or walls [16]. It does not create fuel wastes, air pollution, or greenhouse gases (GHG) to the environment while generating renewable energy out of sunlight [17] as compared to conventional energy sources. The application of BIPV technologies converts buildings from energy consumers to energy producers [18]. The application of BIPVs is divided into the integration of roof structure and the integration of wall structure [15]. Façade cladding, windows, and curtain wall are the façade application of the BIPV system, whereas skylight and roof cladding are the roof application of the BIPV system. Both greenhouses and shading devices are categorized for both applications of the BIPV system [19].

BIPV products can be categorized into foils, tiles, modules, and solar cell glazing [20]. BIPV foils are lightweight and flexible, and easy to be installed on roofs. They are often made from flexible thin-film solar cells to maintain the foil flexibility and efficiency under high temperatures, particularly on the non-ventilated roof [15]. Apart from this, BIPV tile products may cover the entire roof or selected parts of the roof building and are arranged similarly to conventional roof tiles [15]. This arrangement allows for BIPV tiles to replace and retrofit old building roof tiles [17].

Meanwhile, BIPV module products are almost identical to conventional solar PV modules [17]. BIPV solar modules can potentially replace various kinds of roofing systems [17]. Alternatively, BIPVs glazing products have great varieties of color and transparency options for windows, facades, and roofs [17]. These features contribute the aesthetical value to the building apart from giving water and sun protection to the building.

The consultants must audit the compatibility in terms of installation methods, reliability, and operational elements of PV devices to building structures before the installation of the PV system onto the building [21]. Then, the connections of the mounting systems can be made by adding extra weight or using screws. Those connection methods must be done according to the manufacturer's specification standards and procedures [21].

The building atrium of Brundtland Centre, an exhibition and conference center in Toftlund, Denmark, showcased the integration of PV elements in its atrium glazing [22]. PV panels are embedded into the South-facing glazed roof of the central atrium of the building to shade off excess sunlight that causes overheating in the building atrium [4, 23]. As a result, there is a reduction of 80% of solar radiation gain in that building atrium space while the atrium glazing could generate electricity [22]. Moreover, diffused light penetrated through the PV panels, creating a pleasant and comfortable internal environment with attractive ambient light and beautiful shadow casting [22]. Advantageously, air circulates under the PV modules to prevent overheating and the subsequent loss of efficiency, unlike typical roof-integrated PV modules where there is no provision for ventilation under the modules for cooling [24]. In 1995, the Brundtland Centre won the European Solar Prize for the innovative integration of PV panels into atrium glazing [22].

The development of BIPV in Malaysia began with the introduction of PV technology in the 1980s to generate electricity for rural areas [25]. Then in 1998, Tenaga Nasional Berhad (TNB) set up the grid-connected PV systems for the national power. Then in 1999, they also built a single-story house with a 3.6 kWp PV installation to showcase the feasibility of a PV integrated roof and installed the first Malaysian 3.15 kWp BIPV system at a TNB senior officer's house in Port Dickson. TNB eventually in 2002 built the Prototype Solar Houses near Kuala Lumpur as a part of an Industry Research and Development Grant Scheme (IGS) project [25]. After that, in 2005, the Malaysian BIPV project was launched, which led to the "SURIA1000" program, and BIPV showcase projects such as the construction of a Green Energy Office (GEO) building in Bangi [25].

Fig. 1 Aerial view of the Green Energy Office (GEO) building, Bangi, Selangor. *Source* ESCI [27]

1.2 Green Energy Office (GEO)

The Green Energy Office (GEO) of Malaysian Green Technology Corporation (MGTC) in Bangi, Selangor, was designed to be a Zero Energy Building (ZEB) to demonstrate the integration of green technology innovations and renewable energy to the public [5]. Energy efficiency and BIPV technology were the main focuses in the design of the building [26]. To achieve this status, the roofs, including the glazed roof over the atrium, are covered with PV systems that could provide shading, natural daylighting, and produce electrical energy [26]. Besides generating electricity, the integration of solar systems over the atrium increased the aesthetical value of the building. [17] (Fig. 1).

The design of the building took advantage of its location near the Equator with a consistent amount of daily solar radiation of 4500 kWh m^2 and abundant sunshine of about 12 h a day [28]. Six distinct types of PV systems were installed on various locations at the GEO building, including an 11.6kWp glass-glass monocrystalline PV module on the atrium. The GEO building has successfully set the energy efficiency (EE) standard in Malaysia with an energy index of 65 kWh/m^2/year as compared to a conventional office building in Malaysia, which is 250–300 kWh/m^2/year.

1.3 Integration of Architectural Design with BIPV

According to Emrah et al. [15], BIPVs have a significant impact on the functionality of the building and the energy system of the building. The BIPV must take over the functions and associated constraints of the building envelope elements it is replacing, such as glass, cladding, and roofing materials while preserving the aesthetic quality of the building [29]. It must be buildable, in line with the building design, durable, easy to maintain, complies with standards and regulations, safe, performs at the designed level, and limits environmental issues. Furthermore, architectural integration quality emphasizes the coherent integration of functionality, techniques, economics, indoor environment, and aesthetics [29]. Hence, the stakeholders need to realize the fundamental challenges and requirements of integrating the building atrium with BIPV systems in achieving green building goals [5]. Therefore, this research aims to study the integration of PV technology on a building atrium canopy in Malaysia by assessing the design and installation requirements of the PV atrium.

2 Research Methods

This research was done using qualitative research methods because it is primarily based on the experiences and knowledge of stakeholders involved in the studied issues. Therefore, semi-structured interviews were conducted to generate insight and an in-depth understanding of the topic. Purposive sampling technique was used to determine the samples for this research, who were stakeholders that were involved in the design, construction, and maintenance of this PV atrium. The researchers interviewed the energy consultant, structural engineer, solar specialist sub-contractor engaged in this project, a client representative, and an MBIPV Team representative. The interview questions were open-ended and based on the research objectives and research questions, which were to determine the design challenges and installation issues of integrating PV technology on a building atrium. Then, orthographic transcription was used to focus on transcribing spoken words in recorded data before a coding process for thematic analysis was conducted. Lastly, the meaning of the primary data was interpreted, and outcomes were then used to answer the research questions and to formulate conclusions to the research.

Also, a guided site observation at the PV atrium of the GEO building was conducted. The internal environment under the PV atrium was also observed, including the canopy construction details using notes, sketches, and photographs. Meanwhile, verbal explanations by the MGTC guide were also recorded using a recorder. Eventually, the data gathered was analyzed using the descriptive analysis to support the findings from the semi-structured interviews.

3 Research Findings and Discussions

3.1 Challenges in the Design of the PV Atrium

There are five fundamental challenges to the design of the PV atrium, which include satisfying daylight factor, and thermal comfort requirements, structural design, project costs, and selection of suitable PV technology.

3.1.1 Daylight Factor

According to the Energy Consultant, the daylight factor is an essential benchmark for them to assess the internal natural lighting level as perceived on working planes or surfaces. Thus, the daylight factor plays a crucial role in architecture and building design to determine if the light is sufficient for occupants to conduct normal activities. Therefore, the Energy Consultant pointed out that the daylighting factor in the atrium must be 0.01 to achieve the optimum luminance level concerning the human activities in the building. The Energy Consultant had done a series of building simulations and scientific calculations by using Integrated Environmental Solutions (IES) software to determine the number of gaps between the solar panels to control the optimal amount of diffused sunlight into the building atrium. As a result, the number of gaps between the solar panels was optimally set at 13% of the total surface area, which evenly distributed on the PV glass panels to filter out the excess daylight from entering the building atrium. Therefore, these PV panels were specially designed and custom-made with chauffeured edges and thus creating gaps in between the PV panels, as shown in Fig. 2.

The Energy Consultant further highlighted that these gaps could help in optimizing the amount of sunlight into the atrium space below and eventually achieving 300 lx of light intensity in the atrium space. Referring to the office average luminance value in MS1525: [30], the lux value created ideally falls within the recommended range of 200 lx values to 400 lx value, which is optimum for human activities and ideal for the office environment.

The daylighting level and visual comfort of building atrium also have been proven with the observations done during the site visit. The building was visited in the morning (8.30 am) and afternoon (2.00 pm), and during both visitations, the atrium space was brightly lit and required no artificial lightings, as shown in Fig. 2. Therefore, it was visually comfortable to be in the area as there was no glare from the direct sunlight coming from the skylight of the atrium. Hence, it can be said that the project team has successfully controlled the daylight factor in atrium space.

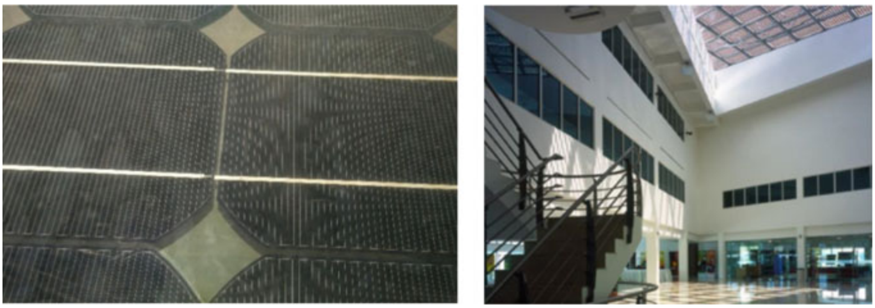


Fig. 2 Gaps between PV glass panels of PV Atrium allowing more daylight into the brightly lit atrium below. *Source* Author

3.1.2 Thermal Comfort

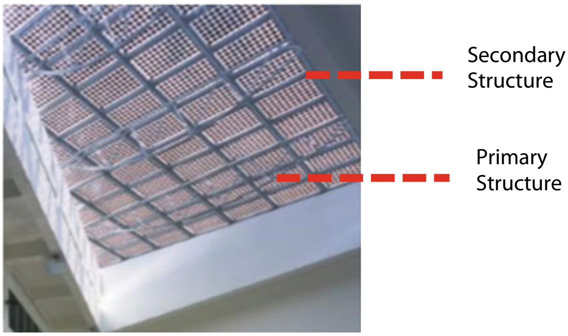
According to the Energy Consultant, solar radiation from the direct sunlight is the primary factor that caused heating within the building atrium and thermal discomfort to the occupants inside the building. Thermal comfort in a building is closely related to the productivity and health of its occupants [31]. Office workers who are comfortable with the thermal conditions of their office environment tend to be more productive [32]. Thus, it is crucial to block solar radiation to monitor the thermal comfort within the building atrium space. Therefore, the Energy Consultant had come out with the solutions of integrating the opaque PV panels into the glass canopy on the building atrium. Eventually, solar radiation penetration is restricted by the PV panels, which covered up to 87% of the total canopy area. At the same time, the 0.3 embedded low emissivity glass further filtered the solar radiation passing through gaps between the PV panels. This low emissivity glass helps to reduce the solar radiation, particularly infrared (IR) and ultraviolet (UV) light, into the atrium space and eventually regulate the room temperature in the atrium space [26].

The Energy Consultant also highlighted that the triple volume of the building atrium helps in maintaining the thermal comfort on the ground floor. Through the process of convection, the warm air would rise from the ground floor to the roof canopy and leaving the cold air on the ground floor in the building atrium. At the same time, the lifted canopy contains the hot air at the top of the building atrium, ensuring the hot air does not circulate within the atrium space and affecting the thermal comfort of the occupants below. It is noticeably comfortable to be in the atrium space even at midday with the scorching sun outside. Occupants of the building also did not switch on the air conditioning to regulate the room temperature in the atrium space.

3.1.3 Structural Design

According to the Structural Engineer, there is a steel truss system as a primary supporting structure and PV's steel frame structure as a secondary supporting structure in the PV Atrium, as shown in Fig. 3. These structures are specially designed

Fig. 3 Structure System for the PV systems. *Source* Author



in consideration of the weight of the PV system, the load of the structure itself, and wind load. As the canopy is primarily made up of the glass materials, which is very heavy, thus the engineer stressed the need to have precise engineering calculations to obtain the required strength for the structural design.

For aesthetics purposes, the entire structural system consists of lightweight and long-span steel truss systems. Besides, these structures are also specially designed to conceal off the cables and wirings of the PV system from the views of the public as shared by the client representative. According to the structural engineer, reinforced concrete beam was not chosen as a structural support system for the PV atrium as it could not withstand on its colossal weight, particularly over the long span of the PV atrium, apart from its bulkiness and low aesthetical value as compared to lightweight steel truss. A flat roof surrounds the PV atrium for the ease of maintenance and cleaning. Whereas the PV panels are slightly inclined up to 3 degrees to run off the rainwater during storms, and the joints of the steel frame structure are sealed with silicon to prevent rainwater leakages.

3.1.4 Project Costs and Limited PV Technology

The cost of building a PV atrium in 2005 was high as compared to a conventional building atrium. It is because there were limited choices for the technology available then. Moreover, only a few key players in Malaysia specializes in the integration of PV technology onto the canopy of building atrium at that time. Therefore, the PV panels had to be custom-made and imported, causing the increase of building costs as shared by the energy consultant. Another challenge for the design of this PV atrium is the limited budget from the MBIPV project. Fortunately, the project was funded and financially supported by the international community to make it a success. Therefore, there was an open tendering process in which the consultants made recommendations for the client. Then, the client would decide on choosing the type of PV technology accordingly within the project budget.

3.2 Challenges on Installation of PV Atrium

As the technology was still new in Malaysia at that time, the stakeholders were facing challenges of having limited choices of technology available and service providers who were lack of experience during the pre-installation stage for the PV atrium. This situation was highlighted by the MBIPV's representative, which quoted:

> …there were not many key players pioneering the solar industry in Malaysia back then in the year of 2005…also it was hard to access the technology as the availability of PV technology in Malaysia at that time was limited….
>
> —A representative of MBIPV Team.

Regarding this, the MBIPV team had set up a team to conduct a series of induction lessons to provide training for the service providers on the PV technology. Then they certified those service providers who completed the training and were competent to install the PV technology on the buildings in Malaysia, including the GEO building. Since it is expensive to reconstruct and rectify the defects of the PV atrium, the consultants then had to make sure that there are no flaws or errors in the design of the PV atrium's roof.

Therefore, the MBIPV Team created a sample mock-up mimicking the PV atrium for them to run a series of tests and simulations in the testing laboratory at the Nanyang Technological University in Singapore. According to the representative of the MBIPV Team, they would rectify any errors discovered during the tests immediately to minimize the risk of malfunction of the PV atrium later at the actual building. Later, during the installation of the PV atrium, the service providers and solar specialist sub-contractor faced delays due to were mismatches of PV supporting components with the building structure and required immediate rectifications on site. The sub-contractor had to spend more time to do modifications to the structure of the PV atrium without affecting the PV system on the building atrium. Besides, the safety of the workers during the installation of the PV atrium was also a significant concern. Those workers risked their lives to install the PV panels on the building atrium, which is a triple volume from the ground. According to the solar specialists, the workers had to practice strict safety protocols that have been set up by the authorities, which is Construction Industry Development Board (CIDB), which guarantees their safety during the installations.

3.3 Challenges After Completion of PV Atrium

After the successful installation of the PV atrium, the stakeholders quickly realized that the building atrium had rainwater leakages. Eventually, they sealed off gaps in the structural frame with the sealant product of 3 M Company from the United States, as shown in Fig. 4. The sealant is long-lasting and required maintenance only for every 5–7 years. According to the stakeholders, this solution is practical and economically sensible without rectifying the whole PV system structure.

Another major issue found after the installation is the constant breakdown of inverters, which are incompatible to the installed PV system. According to the stakeholders, it is costly to maintain and repair those inverters. Eventually, they decided to replace them with new compatible ones. Besides, the client representative highlighted the water ponding issue on the roof surface of the PV atrium caused by the 'paddy field framing' Fig. 4. This framing is slightly higher than the roof surface of the PV glass panels, causing accumulation of rainwater and dirt at the lower edge of the frame whenever there is rain.

Consequently, this blocks the surface of PV glass panels and thus reduce their performance. Routine cleaning is required to maintain the performance of PV panels.

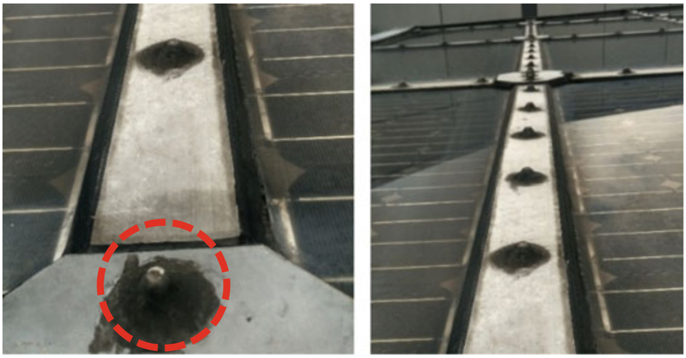


Fig. 4 Sealant (marked in red) for waterproofing and 'paddy field framing,' causing water ponding. *Source* Author

Therefore, as one of the future PV atrium design strategies, flushing the frame with the surface of the PV panels could get rid of water ponding.

3.4 Prospects of PV Atrium

The interviewees were enthusiastic about the prospects of PV atrium in the future because of the progressive advancement of PV technology and the abundance of solar energy in Malaysia. However, they were concerned about the perception and willingness of specific stakeholders to invest in this technology considering the building purpose, payback period, and returns to have a PV atrium in their building. They believed that the reduction of cost for PV technology could attract more people to invest in PV atrium as only 60% of the Malaysians are willing to invest in solar energy if the costs are as cheap as the electricity generated from fossil fuels [33]. The interviewees also believed that the government could play an essential role in promoting PV atrium through their solar energy policies and promotional efforts such as the Net Energy Meter (NEM) scheme by the Energy Commission of Malaysia. On top of that, they believed that the development of PV technology also helps in promoting PV atriums.

4 Conclusion

The conclusions that can be drawn from this study are as the following:

- Design stage challenges included the optimization of daylighting factor and thermal comfort within the PV atrium, structural design, aesthetical values, selection of PV system, and project costs. These problems were solved via systematic and extensive coordination among the stakeholders and a series of simulation and mock-up tests on the proposed building design. Induction programs by the MBIPV team were also conducted to train service providers and contractors who lacked experience and expertise to install the PV atrium during the pre-installation phase.

- During the installation phase, there were some concerns over the completion of works on time and the health and safety of workers, which were addressed by having a stricter working schedule and on-site safety protocol.
- Post-installation issues included rainwater leakages, incompatible inverter, and dust clogging after the completion of the PV atrium. These issues were rectified by applying sealants on the PV roof to prevent rainwater leakages, replacing the old PV inverters with new and more compatible PV inverters, and conducting routine cleaning and maintenance for the PV roof.
- The stakeholders admitted that it was challenging to integrate PV technology into a building atrium. However, they still felt positive towards the development of PV atrium in Malaysia, given its numerous benefits to building design and the advancement of BIPV technology.

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Creative Economy Space with Vernacular Approaches in Banyuwangi–Indonesia and Its Challenges During the New Normal Period

Nina Nurdiani and Natalia Christina

Abstract Banyuwangi is the city in Java Island–Indonesia with the potential of natural and cultural tourism, and have many creative economic activities which need to be developed. The local wisdom and cultural activities that reflect the creativity of community can provide economic values through the cultural tourism. Planning and designing creative economy space for cultural tourism has been done by the local society suitable with their social and economic conditions. During the Covid-19 pandemic, the cultural tourism in Banyuwangi has been down. The objective of this study is to identify the characteristics of architectural design of creative economy space for cultural tourism in Banyuwangi that built by society, and what is its challenges during the new normal period. The method of this study uses a qualitative descriptive method. The results of the study provide an overview that the architectural design of creative economic space that built by society in Banyuwangi generally use vernacular approach. The local government provides a stimulus (funding, training of hard skill and soft skill) to revive tourism, and ensure all tourist destinations must meet and have Covid-19 health protocol certification in the tourism sector.

Keywords Banyuwangi cultural tourism · Creative economy space · New normal period · Health protocol · Vernacular

1 Introduction

The creative economy is a strategic sector in Indonesia, because it contributes significantly to support the national economic. The creative economy can create added value with a knowledge base, including cultural heritage, and existing technologies from creative ideas and innovations, until creative ideas become creative works, which can be used and have a market [1]. In addition, Indonesia's creative work can elevate the Indonesian people outside as well as build a sense of pride inside. Creativity

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and innovation also create a conducive business climate [2]. To accelerate the development of the creative economy in the next five years (2015–2019) synergy and coordination with all creative economy stakeholders (actors/practitioners, academics, communities and government agencies) should be carried out. The creative economy subsector that will be developed, includes: (1) Architecture; (2) Design; (3) Film, Video and Photography; (4) Culinary; (5) Crafts; (6) Mode; (7) Music; (8) Publishing and Printing; (9) Interactive Games; (10) Advertising; (11) Research and Development; (12) Fine Arts; (13) Performing Arts; (14) Information Technology; and (15) Television and Radio.

Creative economic space is a room or place of activity to develop the potential of human resources. The legal basis for the creative economy is Presidential Instruction No. 6/2009 concerning the Development of the Creative Economy.

Creative economy is an economic concept in the new economic era that intensifies information and creativity by prioritizing ideas and knowledge from human resources as the main factor of production. According to the United Nations Conference on Trade and Development (UNCTAD), the creative economy is a developing economic concept based on creative assets that have the potential to produce economic growth and development. In other words, the concept of creative economy places more emphasis on creativity, ideas, and human knowledge as the main assets in driving the economy.

The cultural heritage of the archipelago is very diverse in forms. The cultural tourism area is one of the potential locations for the preservation of architecture and cultural arts of the archipelago, as well as a place for the development of the creative economy of the local community, which can be of economic value to the community through the visit of tourists who want to feel the atmosphere of the local culture, taste the local cuisine, and appreciate the results of the arts and culture of the people [3].

The success of efforts to preserve the cultural heritage of the archipelago needs to be supported by the provision of good quality space for daily activities and creative economic activities of the community, and also needs to develop a creative economic space model that can support the improvement of the welfare of the local community [3, 4].

Based on the background above, planning and designing creative economy space for cultural tourism has been done by the local society suitable with their social and economic conditions. During the Covid-19 pandemic, the cultural tourism in Banyuwangi has been down. The objective of this study is to identify the characteristics of architectural design of creative economy space for cultural tourism in Banyuwangi that built by society, and what its challenges during the new normal period.

2 Method

Research on Creative Economy Space with Vernacular Approaches in Banyuwangi–Indonesia and Its Challenges during the New Normal Period was carried out with descriptive methods aimed to identify the characteristics of architectural design of creative economy space for cultural tourism in Banyuwangi that built by society, and what its challenges during the new normal period.

Collecting data was done through observation fields before pandemic of Covid-19 at Kemiren Village, as one of many Cultural Tourism Areas in Banyuwangi. Literature study also has been done to collect information during pandemic and new normal period. The data was analysed descriptively to be able to answer the research questions.

3 Results and Discussion

One of the locations in Indonesia that has creative economic potential is Banyuwangi Regency because it has regional potential that can be developed, such as in the tourism sector and agro-based creative industries, such as coconut fiber crafts, Barong dances and so on. Creative industries in Banyuwangi Regency can be said to have promising prospects because most of the production is able to be exported abroad through Bali or directly to the destination country.

Some Creative Economy Industry business actors in Banyuwangi Regency, such as Sanggar Sapu Jagad Kemiren Village are able to absorb a large enough workforce, even able to accommodate most of the handicrafts of local residents, such as coffee and batik. This has an impact on reducing unemployment, especially in the creative industry centers because they have odd jobs for residents who already have jobs and as permanent jobs for residents who do not have jobs. Thus, the development of the creative economy industry in Banyuwangi Regency will have a great impact both for the local population and for the regional development of the Banyuwangi district. The development of the creative economy industry in Banyuwangi Regency had an impact, both in terms of the economy and in the social sector of the community so that in the end it helped encourage the implementation of regional development.

Kemiren Village is one of the villages in Banyuwangi which is also actively trying to realize Osing cultural tourism destinations by utilizing the potential of arts in the Kemiren village such as the Gandrung dance and other arts. This cultural art performance still utilizes the land that they have personally. People in Kemiren village sell art packages for wedding celebrations or other ritual activities. This cultural tour package is also displayed when there are tourist visits as requested by travel agents [3]. Local people create creative economic areas where they sell batik cloth, batik crafts and traditional food and drinks around the venue. Bamboo material is widely used to realize the creative economic space, both for the audience seats, building sales facilities, a place for gamelan instruments and accessories that beautify the area of

Fig. 1 The physical quality of creative economy space at Kemiren Village

art and cultural performances (see Fig. 1). Tourists are quite enthusiastic about the existence of this cultural tourism activity; economic value begins to grow and can be developed in the community.

The history of the formation of villages, socio-cultural activities, topography and kinship systems are elements that influence the settlement patterns of the Kemiren community. The village of Kemiren is said to have been formed originally from the clearing of the candlenut and durian forests around the 1830s to make a highway that runs from east to west. Settlements are centered in the center of the village area surrounded by large agricultural areas and their development tends to be linear on two sides following the village's main road.

Kemiren community socio-cultural activities are activities related to agriculture and culture and religion. The livelihoods of the people of Kemiren are based on the agricultural sector which manifests itself in various celebrations. Some activities use micro space in the form of houses, and macro space in the form of rice fields for the implementation of the salvation event. Therefore, rice fields are a cultural space for the community. Meanwhile, the Kemiren community's socio-cultural and religious activities that are routine and use permanent spaces, form a temporary spatial pattern in settlements which includes houses, yards, art galleries, roads and springs.

The topography of the village area of Kemiren is surging. The physical boundaries of the area in the north and south are in the form of rivers which are the source of irrigation of rice fields of the population that still dominates the village area. Meanwhile, the central part of the topography is quite flat compared to the northern and southern parts, so that residential areas are also located in the area. In residential areas, the mosque's position is in the middle of the settlement and at the highest point which shows that the mosque is a sacred building for the people of Kemiren, while the position of public cemeteries is in the lower area in the easternmost position. However, uniquely, at the highest point in Kemiren there is the tomb of Sang Danyang Desa (great-grandchildren). This tomb is considered as the most sacred place that is almost always visited by residents every time praying on Sunday or Thursday afternoon, and also when the community will perform cultural rituals before the performance.

One of the creative economic spaces in Kemiren Village is Sanggar Sapu Jagad, owned by Mr. Suprapto who is a Barong Kemiren Cultural Conservation Artist in Banyuwangi. Sanggar Sapu Jagad Kemiren is an Original Osing Art Studio in Kemiren Village, Glagah District, Banyuwangi Regency. Located on the rice field area, so that the arrangement of the building involves natural beauty and art (see Fig. 2). Sanggar Sapu Jagad Kemiren has several musical instruments, such as Angklung Paglak, Kentulitan, which accompany Gandrung Dance and Barong Appearance.

Fig. 2 The location of Sanggar Sapu Jagad at Kemiren Village

Utilization of natural or climatic potential that can be used as a basis for consideration in determining the division of functions within the site. The sun that rises from east to west is used as natural lighting in buildings. The temperature around the site is not too hot because the site is surrounded by trees. The rice fields around the site flow the yard with the wind filtered by trees around the site, so that the air that flows is cleaner and cooler.

After analyzing the environment around the site, then performed the placement of functions around the site, namely the residential buildings of artists and their families, buildings for storing art equipment, buildings for training and performance, supporting facilities (toilets), culinary area, places exhibition and sale of craft arts, and agro-industry from the local community. All available functions are arranged according to public, semi-public, private and service zones (see Fig. 3).

The concept of buildings in Sanggar Sapu Jagad does not eliminate the traditional elements of the Kemiren traditional house, is expected to be a building that is able to maintain the characteristics of the village of Kemiren (see Fig. 3). Some parts that

Fig. 3 The creative economic space that built by community

were built by the studio owners which reflects a vernacular approach by society in their village to maintain and preserve local culture:

1. Gate is the main gate that can become the entry identity for the Sapu Jagad Studio in Kemiren Village. The concept used in this gate is the use of natural materials from young coconut leaves (palm leaves) that stick down.
2. The buildings in the Sapu Jagad Studio use the concept of using environmentally friendly materials. In addition to the goal of not eliminating the characteristics of building materials in Kemiren traditional houses, it is also to utilize local materials (wood and bamboo) and reduce the use of excessive energy. The roof design on the Sapu Jagad Studio is a characteristic roof of the Kemiren traditional house. The shape of the open building with 4 main pillars without walls can maximize the natural ventilation of the building for practice and performing arts. The shape of the roof of the building with a very long overhang provides maximum protection when it rains or when the sun is high enough.

Currently there are many local communities in Banyuwangi try to maintain and preserve the authenticity and beauty of traditional house in order to develop become Cultural Village. The buildings are made using wood materials and woven bamboo walls (chamber/bilik). House building materials include clay roof tile for roof; woven bamboo (bilik) for ceiling and wall; wood for house poles; wooden boards for floors or walls. Finishing the house generally use chalk paint / wall paint (see Fig. 3).

The Covid-19 pandemic which began at the beginning of March 2020 greatly affected the tourism sector in Banyuwangi, namely the decrease in the number of tourists coming to the city of Banyuwangi. This has a significant impact on the economic downturn in the city, where the regional income is predominantly derived from natural and cultural tourism. Cultural Festival performances which are routinely held every week are all canceled. Local people are forced to accept the current conditions that prohibit the gathering of the community. In fact, creative economic activities in Banyuwangi generally take the form of cultural performances and celebrations.

After four months of stopping various cultural activities, at the beginning of July 2020 the Banyuwangi regional government began preparing to re-open the natural attractions or agro-tourism in stages, such as Kawah Ijen tour, protected forest and savanna tours, beach tourism, waterfall tours, and other tours with implementing strict health protocols (see Fig. 4). Festival activities that can bring in foreign and domestic tourists are still postponed until the end of the pandemic. The Provincial Government of East Java also ensured that each tourism village destination must

Fig. 4 All tourist destinations must meet and have Covid-19 health protocol certification

meet health protocol standards in the middle of the Covid-19 Pandemic through the Covid 19 health protocol certification program in the tourism sector conducted by the Banyuwangi Regency Government. The government provides thermal guns, face shields and masks to officers on duty and provides facilities such as facilities for washing hands [5, 6].

The local government is taking advantage of the current situation of creative and cultural economic activities by providing funding stimulus as well as various training and skills to support creative economic creative activities so that it also leads to online business or digital platforms. So that activities do not stop even expected to be able to improve the economy of the community and the wheels of business running in Banyuwangi.

4 Conclusions

The creative economy space at Kemiren Village in Banyuwangi is built by local community with vernacular approach because of:

- The community want to maintain local culture and local resource
- The cultural activities give economic values through tourist visit.
- The community are creative in shaping and realizing space, and also utilizes local natural conditions that are still natural. Bamboo and wood are the dominant materials used in creating creative economic spaces in Kemiren village.
- The development of the creative economy industry in Banyuwangi has positive impacts, both in economic and social aspects.

In the new normal period, Banyuwangi Regency Government provides a stimulus (funding, training hardskill and softskill) to revive tourism and ensure all tourist destinations must meet and have Covid-19 health protocol certification in the tourism sector.

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Fly Ash and Silica in Expanded Polystyrene Concrete Finding the Research Gap (Preliminary Study)

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Abstract There are various types of lightweight concrete that already exist today. In producing lightweight concrete, the use of added materials in lightweight concrete has been widely studied. Among of those materials, fly-ash and silica-based material are commonly being used as additive material in concrete. The purpose of this literature research is to determine the extent of the use of fly-ash and silica in Expanded Polystyrene (EPS) lightweight concrete. From several studies that have been done previously, lightweight concrete from EPS was quite significant to give good results in order to reduce the unit weight of concrete but has not shown the expected compressive strength results. The literature review method to gather information about the use of fly ash and silica in EPS lightweight concrete will be conducted in a systematic way. Data search was performed on qualified journal databases such as Science Direct and Scopus. The timeframe of journals taken was that published between 2000 and 2020 to ensure getting the latest research. From the results of observing and searching the article, there were at least two methods of using fly-ash and silica as added material, which were in pure/as-is form (as part of concrete mixture material) and modified form (both modifying the form of fly-ash and silica or as part of modifying the aggregate). The use of fly-ash and silica have shown positive results in improving the quality of lightweight concrete. But from the literature search results, there were still many gaps or things that can be developed and processed to look for other mixed methods and materials. This can increase the ability of fly-ash and silica as an additive material in order to create better EPS lightweight concrete.

Keywords Lightweight concrete · Expanded polystyrene · Fly ash · Silica · Literature review

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1 Introduction

There are various types of lightweight concrete that already exist today. Lightweight concrete is concrete that has a weight less than 2000 kg/m^3 [1]. There are 3 methods for creating lightweight concrete. Those method are by removing fine aggregate components, by creating air bubbles in the concrete or often called aerated concrete [2], and by using/replacing coarse aggregate with light weight materials. This kind of material could come from natural resources, fabricated material, or made on purpose/artificial [3, 4]. An example of the use of fabricated materials that have been widely used as lightweight aggregates in concrete is Expanded Polystyrene [5]. The use of Expanded Polystyrene (EPS) is proven to be able to reduce the dead weight of concrete [6], and has good heat insulation capabilities [7]. However, EPS concrete still has weaknesses, including low compressive strength and a lack of resistance to fire [8]. Therefore, although a lot of research has begun to be done to overcome this weakness, further research still needs attention and becomes an interesting topic to discuss.

The use of additives in the concrete mixture is expected to be able to improve performance and cover the shortcomings of lightweight concrete. Fly ash (FA) and silica based material are kind of material that commonly used as an additive in concrete. Fly ash is the residual burning material from coal from power plants [9–12]. The chemical composition of FA consists mostly of silicate dioxide (SiO_2), alumina (Al_2O_3), iron dioxide (Fe_2O_3), calcium oxide (CaO) [6]. Based on the composition of these constituents, there are two categories of fly ash, namely class C and class F. Class C is fly ash with a CaO content of more than 20%, and a combination of other compositions ($SiO_2 + Al_2O_3 + Fe_2O_3$) of at least 50%, while class F fly ash has a CaO levels less than 10% with other compositions ($SiO_2 + Al_2O_3 + Fe_2O_3$) of at least 70% [12]. As for the physical appearance, FA can be in the form of powder [13] but also in the form of hollow grains or cenosphere [14]. The use of cenospheres fly ash tends to have the ability to create better density [15] which can lead to better compressive strength and low water absorption. However, the use of metakaolin seemed to have a better result in permeability than the fly ash [16]. Moreover, class C cenosphere influenced the reduction of the compressive strength at temperatures above 400 °C due to the dehydration and dehydroxylation processes [17].

The use of fly ash in the concrete mixture usually functions as a binder and replaces a portion of the cement volume based on a certain proportion starting from 10% [6, 18], 30% [19, 20], 50% [9, 21], even up to 70% [22]. Furthermore, another application of fly ash has been successfully used as a coating material using the encapsulation technique in order to make artificial aggregates [23] and is also used as a brick making material [24] even though it has not shown satisfactory results yet. On the other hand, because of FA has cementitious material properties, it is potential to be used as a full subtitution material of the portland cement in the concrete mixture [25] especially for class C fly ash [12]. This kind of concrete, which produced from fly ash as a cement substitute, is called geopolymeric concrete [10, 26–28]. Geopolymeric concrete is believed to be concrete that is more environmentally friendly. Apart from as a waste/residual material from burning coal, the use of fly ash is also expected to reduce or even eliminate dependence on cement. Until now, cement still has been the main component in making concrete. However, the cement production process, which leaves a large carbon footprint, is feared to have environmental damaging effects in the long term. Therefore, researchs on component reduction or even substitution of cement materials that are more environmentally friendly are interesting topics to study.

Materials containing silica (SiO_2) become interesting to study since these components are also present in cement with a composition of about 20% [4, 23, 29]. Silica-based materials are believed to have an impact on the properties and characteristics of concrete. Therefore, many studies have used silica-based aerogels [8, 30–32], silica fume [20, 26, 33] or natural silica sand [34] with the aim of adding value to the concrete. Airgel based on silica material with a composition of 94–99% of the volume being air voids [8] effective to produce a lightweight concrete (410 kg m^3) with thermal conductivity value (0.085 Wm ~ 1 K ~ 1) [30]. On the other hand, silica in powder form or often known by other names such as micro silica, condensed silica fume, volatilzed silica or silica dust [35] is proven to have a positive impact in increasing the compressive strength of concrete [36]. However, the excessive use of silica fume actually has an impact on the increasing need for superplasticizers [37] and it is advisable to limit it to the percentage of replacement for cement to an amount of 10% micro-silica and 2% for nano-silica.

There have been many studies and articles discussing the use of fly ash and silica in concrete. However, specific research that discusses the use of fly ash and silica fume especially in lightweight EPS concrete still needs to be explored more because of its good potential as an environmentally friendly building material [38]. This literature review will aim to identify and analyse the development of research on EPS lightweight concrete, especially in the use of fly ash and silica as an additive/supporting material.

2 Methods

A systematic literature review (SLR) adapted from Wahono 2015 [39] was used as a method in this study. This SLR consists of 3 major stages, namely: the planning stage, the conducting stage and the reporting stage.

In the first stage the requisite for systematic review was identified. Then, a guidance or protocol was made to driven the searching of the suitable literature. This stage include the preparing of the search string or keywords by using boolean operator system. The next stage, the selected articles/papers were analysed and then finally that findings being reported. The significances conducting the literature review were discussed in the introduction previously and transformed into research questions (Fig. 1).

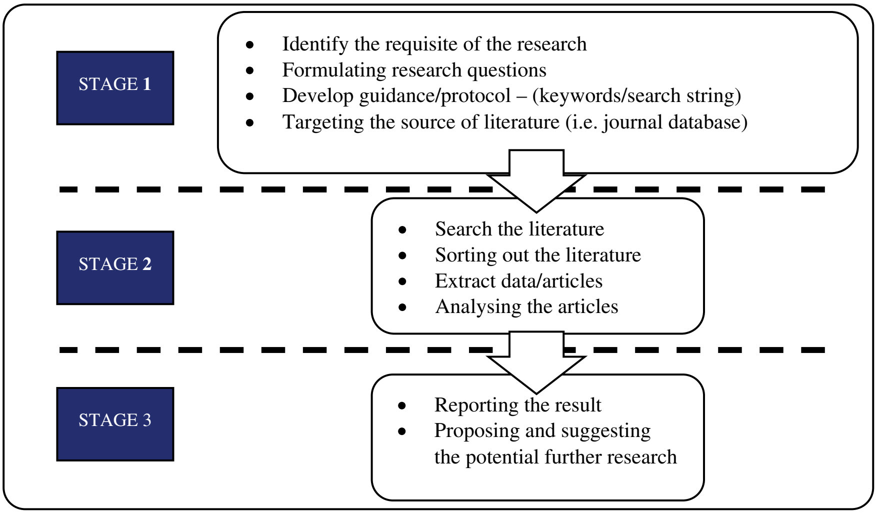

Fig. 1 Literature review stages

Table 1 Summary of CIMO

C (Context)	Previous study/research related to EPS lightweight concrete
I (Intervention)	Additive material that can enhance and give beneficially impact to concrete properties
M (Mechanisms)	A systematic literature review to gain information and supporting data
O (Outcomes)	Better properties of EPS lightweight concrete

The research questions designed with the help of CIMO-logic [40] instead of using SPIDER [41] or PICOC [39]. Table 1 describe the CIMO structure as the basic for formulating research questions (Table 2).

After determining the direction and purpose of the research, the search process begins by preparing keywords to be used as search strings on search engines in electronic journal databases. The process of making search strings is carried out with the help of boolean operators ANDs and ORs, by combining keywords that can

Table 2 Research questions

Research Questions	Aim and Objectives
What types of additive are currently widely used as additives	Identify characteristics of additive material (fly ash and silica)
How the added material affects the properties of the concrete	Identify the method, and impacts of additive material (fly ash and silica) on EPS lightweight concrete
What are the opportunities for further research	Identify the gap from previous research

Table 3 Inclusion and exclusion criteria

Inclusion	Article which contain and discussing: fly ash, silica, expanded polystyrene, and concrete
Exclusion	Articles not written in English; repository access

reflect the purpose of the research, and ensuring article searches can be more directed and as expected. Keywords/search string used in the search process: ("lightweight concrete") AND ("expanded polystyrene") AND [(silica) OR (fly ash)].

The designated electronic journal databases were Scopus and Scicence Direct. The selection of this database is based on the consideration that these two sources are trusted journal indexing institutions and are connected with many prestigious journals that publish articles resulting from good selection or review processes. Journal databases cannot be accessed by just anyone, especially when doing data extraction/downloading articles. Therefore, with the access that the researcher has, who is currently a post graduate student at Coventry University-United Kingdom, it is possible to do this. The search for articles is limited to the year published in the last 20 years (2000–2020) to ensure that the articles obtained were the result of the most recent studies. From the search process that has been previously carried out, it is also necessary to limit the choice to only review and research articles to reduce data which is sometimes only a table of contents from a conference.

There are 179 articles from the search results of the journal ScienceDirect journal, and 15 articles from the Scopus database. The total number of articles detected was 194 articles. From these 194 articles, a sorting process was carried out with the help of a reference manager software by first extracting/downloading metadata containing the article identity and abstract. The software used is Mendeley. Mendeley itself is free software and is quite easy to use. From the results of this collection, it was detected that there were 8 similar articles (duplicate articles). For this reason, at this stage the first selection process was carried out, leaving only 186 articles left. Of these 186 articles, the titles and abstracts of the articles were screened. This screening process used criteria that have been previously prepared (Table 3).

After going through the sorting stages based on the title and abstract, there were 54 suitable articles and then the data extraction process was carried out by downloading the complete articles. The articles are then stored and managed using Mendeley software, then the analysis process is carried out with the help of NVivo data analysis software. Unlike Mendeley, which can be accessed for free, NVivo is a software produced by QSR International and Coventry University has a licence for it so that it can be used by students.

Of the 54 articles obtained, not all of them discuss the use of fly ash or silica in EPS concrete. Many articles were found to contain only one keyword to be discussed. Therefore, another selection was carried out to select articles as the main articles that were in accordance with the research objectives. From this process, 13 articles were obtained which were deemed very suitable for the research objectives. However, from those 54 articles several data and information were observed related to the

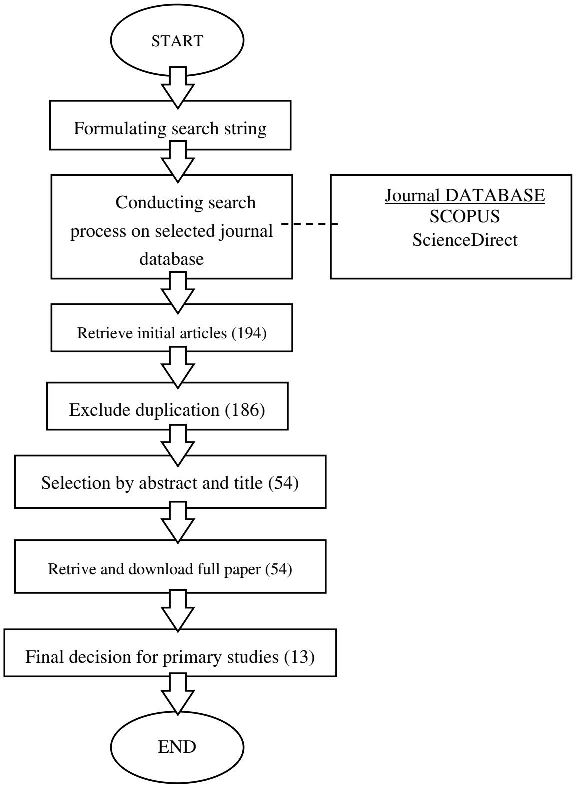

Fig. 2 Searching and selecting process

research about fly ash and silica in lightweight concrete. The process of searching and selecting articles is briefly shown in Fig. 2.

3 Result, Analysis and Discussion

This section will present several things that specifically discuss the effect of fly ash and silica on EPS lightweight concrete. While the search results of literature on fly ash and silica in general have been explained and used as an introduction.

In previous research, Cadere [6] observed that fly ash in EPS concrete was not enough to uniform the distribution of polystyrene granules [6]. This result was different from what Wu [42] had previously done, which stated that there was no bad distribution or segregation in EPS concrete [42]. There is a possibility because Wu [42] first activated fly ash by using an alkaline solution. Activated fly ash was able to produce better concrete mixing.

Fly ash is also able to provide an effect on the level of workability and flowability which is very good when used as an additive to EPS self compacting concrete [43], although not as good as the effect produced when using silica fume [44]. Nekooi's research can answer the problem that have occurred in previous studies [25] which showed a decrease in the value of workability along with the addition of fly ash content. From the explanation in Herki's article (2013) which includes information about the high carbon content, it can be predicted that the fly ash used by Herki was classified as fly ash class C different from that used by Nekooi [43]. This showed that although class C fly ash classified more cementitious material than class F fly ash, the influence on the level of workability and flowability is not good. There are opportunities to do more research on the types of class C fly ash.

The problem of segregation in EPS concrete can be overcome by adding silica to the concrete mixture, but this becomes less effective with the addition of EPS beads content in the concrete [36]. by adding silica to EPS concrete can produce concrete that has a good density, because silica is able to fill the gaps between the agegrat with cement paste. Moreover, the smaller the silica grain size, the better the concrete density [45]. Silica makes the bond between EPS beads and cement better, but too much silica can increase the need for superplasticizer to maintain good workability [37].

Both fly ash and silica fume are able to cover the weaknesses of EPS concrete regarding the compressive strength of concrete. Fly ash [21] dan silica [45] as a substitute for some of the cement elements it can increase the compressive strength value of concrete, even though the value decreases with the increase in the amount of EPS in the concrete. The increase in compressive strength of concrete using fly ash tends to be slow in the early ages of concrete [21], but it still showed a trend of increasing concrete strength as the concrete ages. On the other hand, EPS concrete containing silica shows a very rapid increase in the early age of the concrete [33]. The more silica content the faster the development of the increase in compressive strength [46]. Therefore, the use of silica-based additives can be an option if you need concrete that has better early-age performance [43] (Table 4).

Data analysis software can be used to find words that are often used in articles. This is useful for knowing what sections get the most attention or are discussed in selected articles. The analysis result showed that the word "strengths" was quite dominant comes after the words "concrete" and "EPS". This showed that the selected articles mostly discussed the strength or mechanical properties of concrete (Fig. 3).

Apart from compressive strength, the addition of fly ash [20] and silica [37] on EPS concrete is able to have an impact on reducing the water absorption value. This can be possible because the element of EPS beads is hydrophobic and there are also added materials such as fly ash and silica which can increase the density of the concrete. With a good density level, EPS concrete with fly ash or silica has the potential to be more resistant to high temperatures, corrosion and other chemicals attack. From the results of this literature search, there is still lack of information about the influences of fly ash and silica in EPS concrete related to its performance on thermal conductivity.

Table 4 Selected article as the primary studies

	Chemical Composition	Silica (SiO_2)	Alumina (Al_2O_3)	Ferric oxide (Fe_2O_3)	Calcium oxide (CaO)
Babu [33]	Cement	21.78	6.56	4.13	60.12
	Fly Ash				
	Silica	74.07	2.22	1.57	2.95
Chen [45]	Cement				
	Fly Ash	Not recorded			
	Silica				
Babu [21]	Cement	21.78	6.56	4.13	60.12
	Fly Ash	58.29	31.74	5.86	1.97
	Silica				
Babu [20]	Cement	21.78	6.56	4.13	60.12
	Fly Ash	58.29	31.74	5.86	1.97
	Silica	74.07	2.22	1.57	2.95
Wu [42]	Cement				
	Fly Ash	57.8	29.5	2.9	0.7
	Silica				
Chen [36]	Cement	21.6	4.13	4.57	64.44
	Fly Ash				
	Silica	92.4	0.8	0.5	0.91
Chen [46]	Cement	21.6	4.13	4.57	64.44
	Fly Ash				
	Silica	92.4	0.8	0.5	0.91
Madandoust [44]	Cement	21.46	5.55	3.46	63.95
	Fly Ash				
	Silica	91.7/99.9	1	0.9	1.68
Sadrmomtazi [47]	Cement	21	4.6	3.2	64.5
	Fly Ash				
	Silica	91.1	1.55	2	2.42
Herki [25]	Cement	22.8	3.8	1.4	66.5
	Fly Ash	13.2	6.7	6.2	1.4
	Silica				
Nekooie [43]	Cement	23.5	5	3.4	62
	Fly Ash	51.2	24	6.5	5.6
	Silica	93.7	0.29	0.36	0.4

(continued)

Table 4 (continued)

	Chemical Composition	Silica (SiO_2)	Alumina (Al_2O_3)	Ferric oxide (Fe_2O_3)	Calcium oxide (CaO)
Fathi [37]	Cement	27	5.2	4.6	65
	Fly Ash				
	Silica	85–92/99	1	2	10.5
Cadere [6]	Cement				
	Fly Ash	*18.37*	*13.09*	*4.01*	*3.17*
	Silica				

Fig. 3 Most frequent words from selected paper

4 Conclusions

From the results of the literature review activities that have been carried out, several conclusions can be drawn as follows: From the results of the literature review activities that have been carried out, several conclusions can be drawn as follows:

1. Planning and conducting searches and systematically analyzing literature from journals can help to find articles that can answer our research questions. Searching and analyzing articles in a systematic manner allows for a more comprehensive source of information and reduces the researcher's subjectivity and bias. By applying these stages, the literature review process can be justified and may give better confidence in reading the results of the review.
2. Fly ash and silica fume have a positive impact on lightweight EPS concrete. However, the use of these materials will be maximized when combined with other materials.
3. Class F fly ash tends to be more widely used as an additive to lightweight concrete, especially lightweight EPS. Although the chemical composition of class C fly ash contains more CaO, which can make this type of fly ash more like cement, class C fly ash is not widely used. Maybe this is due to the difficulty to get it. However, we can observe that Fly Ash class C has the potential as a better cement substitute and is interesting for further study. Activated fly ash has a better effect than unactivated fly ash. There are still opportunities for further

research on modification of the use of fly ash in order to provide added value and maximize the potential of the fly ash material itself on the properties and characteristics of the resulting concrete.

4. The use of silica-based materials in lightweight EPS is still a lot of powder, both micro and nano-sized. The smaller the size of the silica particles will have an impact on the density level of the concrete which is denser, but with the consequence of the increasing need for water as a solvent or the need for added materials such as superplasticizer which can increase the cost of making concrete. Based on previous research on other types of lightweight concrete, the use of silica-based aerogel is very effective at reducing the weight of the concrete and is also able to provide other added values such as insulation ability. There have not been many studies regarding the combination of this material with EPS as concrete aggregates which can be used as a discussion that has the potential to be further explored.correctly.

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A Review of Hybrid Piezoelectric-Photovoltaic System for Lighting a Pedestrian Walkway

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Abstract Generally, pedestrian walkway are designed to provide an accessible and safe path for people who prefer to walk. The walking activity can benefit both people and society in term of health and environment conservation through reducing usage of vehicle transpiration. Hence, the pedestrian walkway can serve more than providing a safe path and are potential to be an energy efficient space. This study aims to review renewable energies exist in pedestrian walkway spaces. Therefore, two sources of walking energy and solar energy is selected and harvesting technologies are investigated. Among the different mechanism piezoelectric transduction is selected and fundamentals and circuitry are discussed. The results show that in order to harvest optimum energy, arrangement of harvesters is an important factor. Moreover, system sizing is important in the design of hybrid renewable energy system.

Keywords Piezoelectric material · Kinetic energy harvesting · Renewable energy · Hybrid system · Footstep energy · Solar energy

1 Introduction

Walkways and sidewalks are essential elements of streets and roadways, which can provide safety, comfort, accessibility, and efficient mobility for pedestrians through separating them from vehicle traffic. The term "walkway" is often taken synonymous with "sidewalk." In general, sidewalks refer to the paved, usually cement concrete, surfaces along a road or street, but raised from the street level, and separated by a curb. Whereas, walkways include a wider range of either raised or at-grade improved paths for exclusive use by pedestrians [1]. According to this definition, the term of walkway is more proper for this study. Also, the term of pedestrian generally is defined as a

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person who walks, or not related to any vehicle mode [2, 3]. Walking as the most basic and simple mode of transportation [4], is an activity, which can increase interaction of human with the urban environment [5]. It can be a pleasant mode of travel, when the space provides safe, comfortable and convenient walking [6]. Pedestrian friendly walkway design is mostly encouraged by several planning and design instructions at the local and regional levels. Generally, the "pedestrian friendly" walkway design, integrate elements in order to improve the safety, security, comfort, and mobility of pedestrians. Therefore, understanding the needs of pedestrians and effective factors on their travel are important for designing facilities and providing pedestrian friendly walkways [7].

Majority of walkways need lighting due to safety and security reasons. Besides, providing sufficient lighting to ease pedestrian movement at night [8]. "Pedestrian lighting," is described as any type of lighting that illumines pedestrian facilities [9]. Improving pedestrian friendly features such as lighting fixtures will assist in developing complete streets within the city. As a consequence, it encourages pedestrian use, and causes people feel comfortable and safe in all ages with different abilities. Furthermore, it contributes in developing a transportation system offering zero-emissions by selecting walking travel option. In addition to developing pedestrian friendly walkways, increasing use of energy-efficient lighting, can contribute in improving air quality and saving energy, as well. Several authorities legislated policies and many researches are conducted in response to the increasing of the sustainability concern, climate change and reduction of greenhouse gases [10]. Renewable sources are clean and eco-friendly energies, which contribute in reducing greenhouse gas emissions. Lighting system is also positively impacted by green technology [9]. However, currently, solar, wind or other renewable energy equipment of lighting is in the initial stages [10]. This study explores the issues and problems in the design of a pavement for pedestrian walkway. It provides a comprehensive set of recommendations and practices to address pedestrian walkway pavement as an ergonomic and energy efficient surface. The dissertation aims to use kinetic energy of body as a type of the renewable resources, in order to generate electricity. Since, pedestrian walkways are an appropriate spaces for harvesting kinetic energy of walking by pavement and solar energy through the roof. Then, the generated energy will be used for public consumption, which in this study will supply lighting system of the walkway.

1.1 Energy Efficient Pedestrian Walkway

By increasing urban population, one of the issues that cities are facing is environmental risks and concerns such as environmental pollution [11]. The excessive growth of cars causes environmental problems due to air and noise pollution, and high dependency on fuel. Therefore, there is a need to support non-motorized vehicle, and promoting walking activity. Walking is one of environmental friendly activities that relates to sustainable energy, and non-motorized transportation; which leads to less noise and air pollution [12]. Providing walkable spaces, necessitates lighting system to enlighten the path at nighttime due to the safety and security issues. Since, the lighting system of walkway mainly depends on the fossil fuel, harvesting renewable energy is a promising method to provide an environmentally friendly walkway.

Green technologies, such as new light bulb design, solar power, and wind power, are reshaping the energy prospect throughout the world. Shielding practices, direct light more effectively to areas where it is needed, and consequently contributes in saving energy and avoiding light pollution. Energy efficiency is always a concern from both a financial and an environmental perspectives. New lighting equipment, although are costly for initial installation, offer great opportunities for operational cost-savings over time [9]. Lighting system also have to preserve natural resources. Inappropriate lighting system wastes fossil fuels resources and pollutes the air and water, as well [13]. Enhancing the quality of lighting illuminance or increasing the lighting applications may enforce cost and increase energy consumption. Hence, study of saving energy would result in energy efficient lighting system which either uses renewable energy sources or efficient lighting control system. This study aims to investigate an energy efficient pavement for pedestrian walkway that can generate electricity by harvesting kinetic energy of pedestrian body motion during walking and solar energy, as well.

1.2 Lighting System Based Renewable Energy Technologies

Fossil fuels are the main energy resources in global energy consumption. Over the last 100 years, fifty percent of the primary energy resources, like oil, gas and coal have been consumed, continually. This growth causes danger of global warming. The fossil fuel like crude oil and natural gas may totally deplete in future. In addition, they will cause the climate change issue and significantly greenhouse gas emissions [14]. Global warming and managing environmental resources are the main concerns in recent years [15]. To tackle climate change and reduce primary energy consumption, increasing use of renewable energies and sustainable approaches is suggested [10]. As the key factor for sustainable development is energy [15], using sustainable energies for development has been growing due to the climate change issues and exhausting the fuel energy resources [16]. Renewable energy sources contribute in reducing greenhouse gas emissions and in the sustainability of future energy systems [17–21]. The renewable resources are clean and eco-friendly energies. Electricity, thermal and mechanical energies can be obtained by using renewable energy technologies [16]. Renewable energy includes energy derived from natural processes such as solar, wind and mini hydropower, biomass and geothermal energy [22]. However, renewable energies still play minor role in global energy consumption [22]. Lighting system also have to conserve natural resources. Inappropriate lighting system wastes our limited supply of fossil fuels and pollutes the air and water [13]. The reduction of CO2 emissions will be achieved through the introduction of new energy efficient lamps [10]. Currently, there are some innovations in lighting system using solar, wind or other renewable energy equipment. For instance, Wu and et al. [23] stated in term of investment return, savings, payback time, and lighting lifetime, lighting using high-power LED either by grid power or solar power is economically feasible. They also claimed that solar-powered LED roadway-lighting systems can save 75 percent on energy consumption compared to the mercury lamp [9]. However, these innovations are still in the early stages and needs some improvement in term of cost and energy efficiency [24, 25]. This study is also in line with saving energy approach and aims to introduce and design a lighting system based on renewable energy generation technologies.

2 Renewable Energy Harvesting

The study goals to harvest renewable energy for lighting system of the walkway during nighttime. "Energy harvesting" is the process of converting wasted energy into usable energy, usually in the form of electricity [26]. The example of harvesting energy from sources such as motion, sunlight, and temperature changes are electronic self-winding wristwatches, solar-powered calculators, and thermal-powered wristwatches, respectively [27]. Both the vibration and solar energy harvester can provide constant power density for a long period of time [28]. However, the power density of energy harvesters depends on the operating conditions. The interest in study of energy harvesting devices is increased recently due to the reductions in the power consumption of the electronics devices, advancement in wireless data transmission and miniaturization of devices. Hence, energy harvesting device can provide a good power supply for any electronics device which is independent of time. However, these applications are limited due to amount of power that can be harvested [29]. Among the different types of renewable energy, this study focuses on harvesting solar and kinetic energy. The kinetic energy sources completely depend on the motion of the host structures, which can be vibration [30, 31], rotation, or a linear motion. In the case of vibration energy harvesters, the power density is directly proportional to the vibration frequencies [29]. Walking energy as a sort of kinetic energy usually is wasted during day, while can be harvested, recovered and converted into electrical power to supply the electronic devices. This study aims to focus on harvesting kinetic energy of walking people to supply lighting system of pedestrian walkways.

Regarding the study of Vanz and Karakiewicz [32], and to achieved the aim of the study, four conditions are considered to review, including type of energy, type of technology for harvesting energy, service provided by the renewable energy technologies and context, in order to organized the data. The conceptual framework, variables and hypothesis are achieved at the end of this section. This study is kinetic energy of walking and solar energy. Therefore, these two energy sources are described in the following sub-sections.

2.1 Kinetic Energy Harvesting

Regarding the increasing of development and economic growth and subsequently, increasing of energy consumption and new electronic applications, other energy sources are needed to cover this demand, rather than fossil fuels. Energy harvesting can be an option to solve this problem [27]. Furthermore, harvesting energy is one of the most promising techniques in response to the global energy problem without depleting natural resources. Many scholar has defined "Energy Harvesting" [33–35]. Energy harvesting is an economically practical, environmentally friendly, and technically feasible alternative to batteries as a power source [26, 36, 37].

Kinetic, thermal, solar sources or electromagnetic radiation sources are employed for energy harvesting. Energy harvesting is a sustainable method to generate electrical energy [38]. An energy harvesting system usually includes an energy conversion device such as a piezoelectric element, energy harvesting circuit and control, and an energy storage unit. Generally, a lower voltage, and higher current for better power efficiency are preferred for energy harvesting circuit design [26]. As ambient energy sources are unstable and varying with time, the harvested power from an energy transducer also changes with time. As a result, an energy transducer is often unable to directly power the application unit or charge the energy storage buffer due to the different level of output voltage of an energy transducer and the energy storage buffer or the application unit. In order to mitigate the voltage gap, a power converter is usually used as the interface circuitry between energy transducers and energy storage buffers [39].

The history of energy harvesting dates back to before the invention of the internal combustion engine, the power grid, or batteries. For instance, wind turbine farms and hydroelectric plants are as results of windmills and water wheels improvement. Moreover, small electrical generators were used in radios and flashlights in the 1940s, which operated by hand cranking. Other latest examples is the bicycle dynamo and lever-driven mobile phone chargers [40, 41]. Energy of water flow in oceans and rivers are also harvested [42], through a device uses the traveling vortices in water to strain piezoelectric polymers [27]. The renewable energies selected for this study is kinetic energy and solar energy, particularly from body motion, which is explained in the following sections.

The kinetic energy is transferred to a mass where several transduction techniques can be employed to transform it to electrical energy [27]. The kinetic or inertial energy harvesting also known as vibration power generators, converts movement, mainly in form of vibrations, into electrical energy [35]. The basic model of kinetic energy harvesters was first developed by Williams and Yatus [43, 44]. These devices are typically designed to match their natural resonant frequency with the energy source to maximize the power output [27]. Transducers that can be used to convert the vibration energy into electrical energy include piezoelectric elements, electromagnetic coils, and electrostatic devices [35], which are discussed in the next section. The challenges for energy harvesting is maximizing the available electrical power from the ambient energy found in the application environment [34]. Since vibration power generators are mainly resonant systems, the maximum power is generated when the resonant frequency of the generators matches ambient vibration frequency [44]. There are different types of vibration energy for harvesting, such as human motion or ocean wave (Table 1).

Kinetic energy harvesters, also known as vibration power generators, extract electrical power by employing one or a combination of different mechanisms including piezoelectric, electromagnetic, electrostatic or by using magnetostrictive materials [45]. Many scholars have studied the application of harvesting vibrational energy in various systems including medical implants systems [46]; self-powered sensor devices [47–51]; portable, wearable, ubiquitous computing systems [40, 52, 53]; used in monitoring system on vibrating machinery [54, 55]; remote or embedded monitoring system [56]; wireless sensor networks for structural health monitoring in automotives, aerospace systems and civil structures such as buildings and bridges [43, 57–62]. Among the different types of kinetic energy, vibration energy of body is

Table 1 The different types of kinetic energy that can be converted to electricity

Type of kinetic energy		Conversion mechanism
Human motion	**Human activities** such as relaxing, walking, and cycling, writing with a pencil, reading a book, and opening a door)	The kinetic (motion) energy that can be harvested by a mobile device with an Internet of Things applications form Factor [63]
	Walking	Coupling by direct straining of, or impacting on, a piezoelectric element has been applied to human applications. The average gait walking human of weight 68 kg, produces 67Wof energy at the heel of the shoe [64]
		Convert extra energy of walking motion into electrical energy by a harvesting floor is designed with piezoelectric material [65]
	Movement of the human wrist	A microgenerator that is capable of harnessing the kinetic energy produced by the movement of human wrist [64]
	Pedal lights for bicycles	Electromagnetic rotational generator used in self-powered pedal lights for bicycles [64]
Harvest strain from beam elements in critical structures		A sensor system that is powered by converting structural stresses into electrical power via piezoelectric transducers [66]

selected for this study. Body motion is a source of energy which is typically wasted, can be used for producing energy to run the mechanical or electronic device. The self-winding wristwatch mechanism is as the most well-known examples of energy harvesting from body motion that evolved from being entirely mechanical to use a hybrid approach which uses a miniature electromagnetic generator to charge a battery [27]. Harvesting of body motion energy is described in the following section.

2.2 *Walking Energy Harvesting*

Body motion has a high kinetic energy content due to the relatively abrupt movements, acceleration fluctuations, and rather large displacements. The human body is also an alternative energy source that can provide power densities under 1 W/kg, 1 W/L or 1 mW/cm^3, (1mW of power in a volume of 1 cm^3). By decreasing power consumption of electronic devices, the available power density levels of 1 mW/cm^3 or 1 mW/g would be an interesting supply option for low-power applications. Assuming a frequency of 1 Hz, similar to human walking, estimated power density limits for piezoelectric transduction during human walking can be as high as 343 mW/cm^3 theoretical value (19 mW/cm^3 practical value). Therefore, it seems reasonable to generate power from body motion with power densities on the order of mW/cm^3. However, human-based generators are still an unexploited source of kinetic energy [27].

The history of harvesting body motion dates back to invention of Abraham-Louis Perrelet, a French scientist, in 1770. He designed a completely autonomous, self-winding pedometer watch that power from harvesting energy of arm movements [26]. Generally, one of the first investigations on energy generation from the human body was conducted by Starner in 1996 [67]. The report included analysis for available power from body heat (0.2–0.3 W on the neck, 0.6–1.0 W on the head, and 3–5 W on the entire body surface), respiration (~1 W for breathing, ~ 0.8 W from chest movement), blood pressure (~1 W), and activities, such as typing (0.007–0.02 W), bicep curls exercising (~20 W), arm lifting (~60 W), and walking (~70 W). There are some studies examined the power outputs generated from some activities, such as cranking, shaking, and pedaling, as well as the comfort of sustained generation. In 1999, Jansen and Stevels [68] reported power generation levels using lever-driven generators (~6 W), crank-driven generators (~21 W), and bicycle pedaling (~100 W). Another study [69] concluded that 28 W power on average can be generated the from sustained one-hand cranking for 30 min that 14 W could be converted into electricity when assuming a conversion mechanism efficiency of 50%. Other studies stated that the peak power from cycling and rowing is 600 and 800 W respectively, though it would be dropped to near 20% after 5 min of continuous activity [27].

There are some examples of harvesting kinetic energy of body by using piezoelectric generators. One of the first attempts to harness heart motion for electric generation belongs to a patent granted in 1969 to Wen H. Ko described. It was a piezoelectric device produced a 4 V output voltage and 160 μW of power to run an electrical implant such as a cardiac pacemaker. Impact forces have also been harvested through implementing piezoelectric materials. For instance, a linear impact-based generator was suggested by Renaud, Sterken [70] in order to harness limb motion with an estimated power output of 40 μW. Platt and et al., also employed piezoelectric generators in Prosthetic knee implants [46, 71], which the prototype was capable of producing 850 μW of continuously regulated power. Piezoelectric devices on the knee location can be an interesting option due to the high forces, up to three times higher than body weight. Another study by Feenstra et al., reported that backpack straps as locations for piezoelectric stacks can generate 176 μW of power when walking on a treadmill with a 40 lb load. However, the maximum power output is expected to be 400 μW [72]. Moreover, muscle-powered piezoelectric generation was developed by Lewandowski et al., The forearm muscle, the dorso-lateral muscle on the trunk, and the calf muscle are capable to produce power outputs of 8 μW, 54 μW, and 690 μW [73]. Moreover, other technologies, such as Zinc oxide nanowires have also been suggested for energy generation [74, 75]. Gao et al., reported that flexible substrates would enable using of piezoelectric nano arrays for bendable power sources in implantable biosensors with power densities of 100–200 μW/cm^2 [76]. Also, nanowires stimulated by ultrasonic waves would able to produce power densities approximately to 83 nW/cm^2 [77].

However, human based generators require active generation in order to produce sufficient a power output for power-hungry devices such as notebook computers. On the other hand, passive generations, with a lower power output, energize low-power electronic applications, sufficiently, including some medical devices. Therefore, energy harvesting from body motion has the potential to power some biomedical applications and other low-power devices [27].

Walking as a sort of body motion is the oldest and most efficient, affordable, and environmentally-friendly form of transportation. Moreover, walking is about more than transportation and helps to build strong communities. Walking is also great exercise and an easy way to improve your mental and physical health [78]. Daily activity of walking can generate significant power [67]. Harvesting kinetic energy of the human body including walking energy is one of the methods of providing electricity for low-powered devices through implementing energy harvesting technologies, which in the individual has the potential to become a generator. As a consequence, in this model the user becomes the producer as well as the consumer of the service [32]. The frequency of the human movements is less than 10 Hz [79]. Step frequencies for the walking is tested by Romero-Ramirez [34], which differs rather linearly from 1.2 to 2.2 Hz when considering 1.4 m/s as the average walking speed. The results demonstrate that high energetic locations such as the ankle and knee, reveal larger accelerations [34]. During walking at average speeds, the upper body located generator can produce power densities near to hundreds of μW/cm^3. Whereas, the leg location can provide 10 times higher power densities for linear generators [34].

Niu et al., investigated biomechanical motion for energy harvesting from walking at the joints [80]. The analysis of a 1 Hz gait cycle (two steps per second on average) revealed the possibility of energy harvesting from movements of the elbow, knee, and ankle. Li et al., in 2008 presented energy harvesting by a knee brace when the limbs decelerated, which generated an output power near to 5 W [77]. Design of generators based on linear motion have also been explored. According to estimation of Von Buren et al., a generator with a 1 g proof mass is capable to produce 200 μW [81]. Other studies stated that if these generators locate on the lower limbs rather than on upper body positions, four times more power would be produced [27, 82]. In order to find the most proper technology for harvesting walking energy and the best position of harvester, the different types of walking energy harvesting technologies are introduced, and different locations of harvesters are discussed. The kinetic energy of footstep during walking as a sort of renewable energy resources is selected for this research. Since, the main function of the pedestrian walkway is providing a space for walking of people, thus footstep energy of people who walk across the walkway can be considered as a significant source of energy. Generally, kinetic energy of footstep during walking is mostly wasted, while, this energy can be harvested and through implementing energy recovery technologies, can be reused to generate electrical power. The study aims to capture most of the force of footstep and discharge it in the form of power, which is then either stored or used in real time situations for lighting. Hence, the study focuses on harvesting of the walking energy of through the employed system in floor.

2.3 Solar Energy Harvesting

The sun is the most abundant renewable energy source in the World. The solar energy, received by the Earth in an hour is greater than the consumed energy in a year. Photovoltaic materials are used to generate green energy from the largest energy source. Increasing solar cell production is considerably promising method for a cleaner world and many countries are well aware of it. The largest solar power generator is Germany followed by Italy, Czech Republic and France. Photovoltaic effect was first observed by Alexandre-Edmond Becquerel in 1839. The word "photo" is a Greek word used for light and "voltaic" named after Alessandro Volta, a pioneer in the study of electricity. The sunlight beam contains photons, with different amount of energy related to the different wavelengths of the solar spectrum. When a photovoltaic material is exposed to sunlight, photons may be reflected, absorbed or transmitted. The ability of materials to absorb photons and convert into electricity is known as photovoltaic effect [83, 84]. When the photon is in violation or in contact with the solar panel, solar panels will absorb photons in some degree. Not all photons are absorbed by the solar panels because it depends on the type of semiconductor materials used to produce the solar panels. Photon energy at certain levels is able to dissolve the bonding electrons from atoms to produce electricity [85]. The basic building block of PV technology is the solar "cell." Multiple PV cells are connected to form a PV "module," the smallest PV component sold commercially [84]. The standalone photovoltaic system is shown in Fig. 1 [86]. The proportion of sunlight energy is significant for the conversion efficiency of a PV cell which converts sunlight energy to electrical energy. The efficiency of PV energy is important to make PV

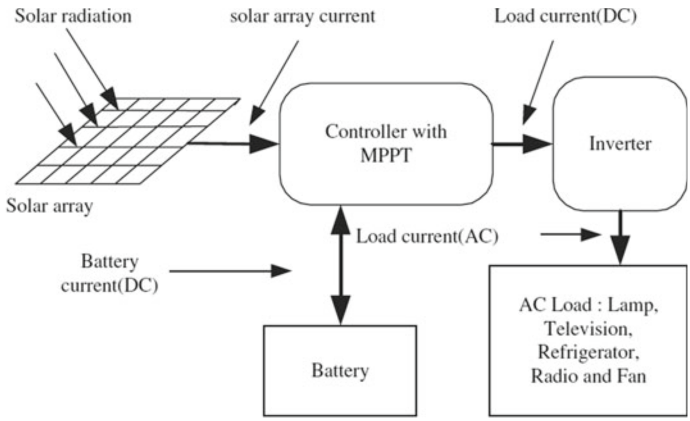

Fig. 1 Standalone photovoltaic system [86]

energy competitive with more traditional sources of energy, such as fossil fuels [84]. The different types of technologies for harvesting solar energy are described in the following section.

3 Kinetic Energy Harvesting Technologies

A typical power harvesting system for self-powered sensor nodes and micro sensors includes an external energy source, a transducer to convert energy from external energy to electric power, a harvesting circuit to optimize the harvesting efficiency and a storage battery or a load circuit. As aforementioned, this research focuses on harvesting electric power from solar power, and walking vibrations due to the reason of optimal sizing of the hybrid system. In comparison to possible energy sources, mechanical vibration is the potential power source that can be easily accessed through adopting microelectromechanical systems (MEMS) technology [87–89]. Different types of technologies is used for harvesting kinetic energy of walking and solar power which are described in the following sub-sections.

Study of energy harvesting has recently gained attention in order to power portable electronic devices [64, 90]. Walking as the main motion in normal human lives considerable vibration energy for harvesting [63]. Walking is an economical energy harvesting approaches [91]. Romero et al., estimated that 1 mW/cm^3 power could be produced from human walking that this level of power would energize low-power applications [92, 93]. The idea of harvesting energy from human motion is based on the fact that the amount of energy used by the body per day, is 1.07×107 J [94], an amount equivalent to around 800 AA (2500 mAh) batteries [95]. Kinetic energy harvesters, also known as vibration power generators, extract electrical power by employing one or a combination of different mechanisms including piezoelectric, electromagnetic, electrostatic or by using magnetostrictive materials [45]. Human activities as energy sources [91] also are harvested by employing these transduction methods [67, 90, 92]. In order to maximize power output, the resonant frequency of a harvester (fr), should match the dominant frequency of motion (fm) [63]. Generally, motion energy availability increases as fm increases [96]. The different mechanisms for converting kinetic energy to electrical power are described as follows:

Piezoelectric Transduction. The piezoelectric effect is described as a mechanism of electrical energy generation in which particular materials become electrically polarized when subject to mechanical stress. These materials deform once exposed to an electric field. There are many forms of piezoelectric materials including single crystal such as quartz, piezoceramic such as lead zirconate titanate (PZT), thin film and polymeric materials such as Polyvinylidenefluoride (PVDF).

Electromagnetic Transduction. Electromagnetic induction is described as a mechanism of the electricity generation in a conductor placed within a magnetic field and usually takes the form of a coil. The electricity is generated by either changes in the magnetic field or the relative movement of the magnet and coil. The velocity of the relative motion, the strength of the magnetic field, and the number of turns of the coil are effective on the amount of generated electricity.

Electrostatic Transduction. Electrostatic transduction is another mechanism of electricity generation by employing the relative movement between two dielectrically isolated electrodes as capacitors. These plates are charged by either periodic connection to a voltage source or the employing electrets. The harvested energy is provided through the work, which is done between the plates against the electrostatic force [97].

Magnetostrictive Materials. Magnetostrictive materials also used to extract electrical energy from ambient vibration. These materials deform when placed in a magnetic field and conversely if strained can induce changes in a magnetic field. Magnetostrictive materials can be used independently but generally are employed in piezoelectric-magnetostrictive composites. Such composites were originally intended for use in magnetic field sensors but have been recently evaluated for use in energy-harvesting applications [45, 64]. Table 2 indicates the properties, advantages and disadvantages of the different mechanisms.

3.1 Different Types of Kinetic Energy Harvesters

Several harvesters are under development and different ways of harvesting motion energy, including inertial energy harvesters, integrating a piezoelectric system, the technology of electrostatic generators based on electroactive polymers (EAPs), or electromagnetic energy harvester. Generally, devices on the order of 1 cm^3 were reported to produce from less than 1 μW up to ~ 1 mW for generators operating at frequencies close to walking [32]. Inertial forces have been used for energy generation either inside shoes [101], within the shoe sole [32, 52, 102], that harvest energy from footfalls or mobile phone chargers integrated in backpacks[103] or phones [104].

Table 2 Comparisons of different mechanisms of kinetic energy harvesters

Type of transduction	Properties	Advantages	Disadvantages
Piezoelectric transduction	– Employ active materials to generate a charge when mechanically stressed [98] – Vibrations are directly converted into a voltage output by using an electroded piezoelectric material [64] – The power output achieved in the compressive mode can be improved by increasing the piezoelectric element's thickness or by using multi-layer stacks [64] – Supply electrical devices with very low average power requirements (lower than one Watt) [99]	– Offer wireless and lower maintenance [99] – The piezoelectric material is small in size, and high in power density [65] – Simple structure [45] – No external voltage source [45] – Compatible with Microelectromechanical systems (MEMS) [45] – High output voltage [45] – No mechanical constraints needed [45] – Flexibility of the design and geometry [32] – The ability of easily meshing into hybrid materials [33]	– Low output current: Produce relatively high output voltages but only at low electrical currents [45, 64] – The piezoelectric properties vary with age, stress and temperature [64] – Poor mechanical properties [45]: The piezoelectric material will lose its piezoelectric properties effectively becoming de-polarized [64] – Temperature is also a limiting factor with piezoceramics due to the Curie point [64] – Charge leakage [45] – The capacitor has poor power storage characteristics because of its quick discharge time, causing the electrical output of such circuitry to switch on and off as the capacitor charges and discharges [87] – The energy generation from piezoelectric material has a low efficiency that is insufficient to drive a wireless module [65] – The resonant frequency of piezoelectric structure is lower than the frequency of environment and causing low generating efficiency [65] – Thin films have poor coupling [45] – High output impedance [45]

(continued)

Table 2 (continued)

Type of transduction	Properties	Advantages	Disadvantages
Electromagnetic Transduction	– Employ electromagnetic induction arising from the relative motion between a magnetic flux gradient and a conductor [64] – Generation of electric current in a conductor located within a magnetic field [97]	– Has a wide spectrum of applications due to simplicity in the method and comparative cost effectiveness [100] – Comparatively high output current levels are achievable at the expense of low voltages (typically < 1 V) [64] – No external voltage source [45] – No mechanical constraints needed [45]	– Requires rigorous optimization to extract the maximum amount of energy [100] – Difficult to integrate with MEMS fabrication process[45]: There are problems with the assembly and alignment of sub-millimetre scale electromagnetic systems [64] – Poor performance in micro-scale [45] – Low output voltage [45]

(continued)

Table 2 (continued)

Type of transduction	Properties	Advantages	Disadvantages
Electrostatic Transduction	– Exploits the relative movement between two dielectrically isolated electrodes (capacitor) [97]	– Easy to integrate with MEMS fabrication process [45] – High output voltage (>100 V) [45] – For heel-strike devices the most promising technology seems to lie with EAPs (electrostatic generators based on electroactive polymers), which have a high power-to-weight ratio [95]	– Low output current [45] – The energy extracted is comparatively low [100] – Needs an initial voltage applied across the device (external voltage source) or pre-charged electret needed [45, 100] – Mechanical constraints needed [45] – High output impedance [45]
Magnetostrictive Materials	– These materials when placed in a magnetic field and it can induce charges in magnetic fields when it is strained [45]	– Ultra high coupling coefficient [45] – High flexibility [45]	– Non-linear effect [45] – May needs bias magnets[45] – Difficult to integrate with MEMS fabrication process [45]

Gorlatova et al., focused on inertial energy harvesters and studied human physical parameters when harvesting walking energy. They showed that the taller half of the participants, harvested more power than the shorter half (around 20%). Moreover, the average power for going downstairs is significantly higher than for going upstairs. As their measurements demonstrate, for prolonged activities, average absolute deviation of the acceleration, frequency of motion, and the average power vary considerably over time due to the physiological parameters changes [63].

Several scholars attempted to harvest body motion by piezoelectric generators. Generally, an 68 kg individual walking at 1 Hz with a 5 cm vertical displacement produces 67 W of power [105]. For instance, Antaki et al. [106] examined a piezoelectric generator that harvest the energy of foot fall during walking in order to power artificial organs. Their prototype produced 150–675 mW for walking, though up to 6.2 W could be expected from a person with 75 kg weight. Another example is a generator located inside the shoe using the bending of piezoelectric materials, which developed by Kymissis et al. [52]. Kymissis et al. [52] presented two different piezoelectric designs. The first configuration was made of a stack of Polyvinylidine-fluoride (PVDF) sheets shaped, similar to a shoe sole, which the outside layers were stretched, while the inner layers were compressed. This product produced ±60 V with an average power output of 1.1 mW. Their second design, was a configuration that harness the heel strike using a unimorph strip, including a steel spring bonded to a PZT piezoelectric material sheet. It generates up to 150 V voltages and up to 1.8 mW power outputs [27]. Other studies could generate a power output of 1.3 mW using the PVDF stack, and 8.4 mW using two back-to-back unimorphs [30]. Nia, Zawawi [107] compared the different technologies located on the body for converting energy of body motion during walking to electrical energy studied by several scholars. [64, 80, 90, 92, 95, 108–112]. As a consequence, according to Riemer and Shapiro, the most power output refers to the technology of EAPs for heel-strike devices [95].

Moreover, the harvesters located within the pavement are reviewed by [32, 65, 95, 113–116]. Accordingly, Nia, Zawawi [107] concluded that harvesters located on the body are dependent on the location of the generator and average of the acceleration, frequency of motion, and the power vary, significantly. Therefore, to gain a consistent output, implementing the harvester within the pavement slab is a better choice. They also concluded that among the different types of kinetic energy harvesting technologies, the piezoelectric transduction is more suitable for harvesting low frequencies energies such as walking energy [80, 109]. Thus, this study selected piezoelectric transduction for generating electricity by exploiting the mechanical strain of footsteps during walking. The strain effects typically, utilizes the deformation within the system and employs active materials [79]. Harvesting kinetic energy of the human body including walking energy is one of the methods of providing electricity for low-powered devices through implementing energy harvesting technologies, which in the individual has the potential to become a generator. As a consequence in this model the user becomes the producer as well as the consumer of the service [32]. The strain effects typically, utilizes the deformation within the system and employs active materials. Due to the high energy density and compact size, piezoelectric transductions is an effective and suitable conversion mechanism [79]. Since the output power of the piezoelectric elements is relatively low, energy storage devices are needed to accumulate the energy and energy harvesting circuits are employed to transfer the electrical energy from the sources to the storage devices. Hence, a piezoelectric energy harvesting system includes three parts: the energy source, the energy harvesting circuit, and the energy storage device [35]. Consequently, this research aims to focus on harvesting kinetic energy of footsteps during walking through the pavement equipped with the piezoelectric materials. The output power is used for lighting system of pedestrian walkway, which are discussed in the following sub-sections.

3.2 *Piezoelectric Energy Harvesters*

Piezoelectricity, originates from the Greek word "squeeze or press". The piezoelectric effect was discovered by Pierre and Jacques Curie in 1880 [24, 117]. In a micro scale device, the effect can be used in a sensor and a micro-generator [24]. It is the ability of some materials especially crystals and certain ceramics to generate an electric potential in response to applied mechanical stress [45]. As a result of polarization, electrical charges are distributed on the surface of the electroded ceramic. A mechanical force, causes mechanical expansion and compression in the thickness, separates the centers of positive and negative electrical charges and generates the array of dipoles [117]. The generated charges are dependent on the material property, geometries, and the volume reduction. The volumetric changes may reach in the range of 4% [24, 118]. However, an optimal external impedance causes the maximum output power [35]. Basically, piezoelectric energy harvesting system is divided into three parts: the energy source, the energy harvesting circuit, and the energy storage device [35].

The sizing factor determines which system is appropriate for particular applications. Piezoelectric systems, have a better action in smaller size. Piezoelectric energy harvesting are preferable options due to some of their unique properties, including higher energy density, simple structure, and low cost [26]. Moreover, the piezoelectric method does not need a separate and initial voltage source, hence is easily incorporated in compact systems [39]. However, the power harvested from the piezoelectric system is rather low. As aforementioned, the dissertation selected piezoelectric transduction. There are several reasons for the main focus of the proposed work on piezoelectric sensor technology. The first reason of this selection is that the electromagnetic effect has already been recently explored in the form of Pavegen technology, a successful tile that harvests energy from footsteps through an electromagnetic system and generates a current by moving a magnet inside a coil. The second reason refers to the flexibility of the design and geometry of the piezoelectric technology, compared to the Pavegen electromagnetic technology. The technology is used in the form of sensors that are small in scale, needs fewer components and less force applied to operate them. Moreover, the small size of piezoelectric sensors and limited physical space occupied for the generation is a desirable properties of this technology

[32]. Additionally, piezoelectric materials have been studied for producing power from small-scale vibrations like footsteps. For these market challenges, piezomaterials offer the desired functionality that can be easily meshed into hybrid materials. Although, the type and magnitude of the applied stimulus determines the producing power, piezomaterials, generally, produce a broad range of voltages. Furthermore, they can respond to any type of physical stimulus including tensile force, torsion, and pressure. Moreover, piezoelectric system do not have a minimum requirement for producing a response. Piezoelectric transducers embedded into the pavements have the potential to harvest the waste mechanical energy as well as to store it in electronic capacitor [33]. Finally the piezoelectric transducer is considered a potential choice when compared with electromagnetic and electrostatic transducers due to its high energy density [119].

A piezoelectric energy harvester consists of a piezoelectric element and is connected to a storage circuit system. A piezoelectric micro-generator requires a larger volume of piezo material. The piezo layer number also is a factor in the structure design that affects the complexity of the fabrication and control circuit system [24]. du Plessis et al. [55] mentioned that the key advantage of the bimorph piezoelectric energy harvesting configuration is the low compliance of the system compared to the stack configuration. The bimorph can be tuned by altering the design geometry or with external masses to achieve a specific structural frequency [35]. The modes of piezo polarization, affects the generator structure [24].

In this study, a pavement slab consists of piezoelectric structured is considered which an exerted mass of body M apply forcing function F (t) on a piezoelectric element. In this model, a layer of piezoelectric material with polarization poled along the thickness direction is considered. The electric field is generated through the direction of thickness of the piezoelectric layers. In this mode, a force is applied in the same direction as the poling direction. The details are described in the following sections.

3.3 Piezoelectric Materials

As aforementioned, this study mainly focused on piezoelectric energy harvesting. Piezoelectric materials are available commercially and are widely used for energy harvesting applications due to their high energy density, simple structure, and high frequency response. Piezoelectricity is a material property involving a mutual coupling between mechanical strain / stress and electrical field / charge. The piezoelectric effect happens only in non-conductive materials. Piezoelectric materials are divided into two main groups including crystals and ceramics. Originally, crystals made from quartz were used as a material for piezoelectric transducers. The piezoelectric single crystal has much higher coupling than the ceramic counterpart such as PZT, thus a smaller force is needed to generate enough power [26]. Nevertheless, in the early 1950s, quartz crystals replaced by piezoelectric ceramic as the primary transducer material. The ceramic piezo materials are common products for a piezo actuator, sensor and micro-generator [24]. Commonly, the materials used for piezoelectric power generation are Lead zirconate titanate (PZT), polymer polyvinylidene fluoride (PVDF) [120], and macro-fibre composite (MFC) [121]. PZT and PVDF are the most popular piezoelectric ceramics and piezoelectric polymer, respectively, which both are used for commercial products. In general, PZT-based energy harvesters are more efficient in converting mechanical energy to electrical energy due to their higher electromechanical coupling coefficient [35]. Furthermore, the elastic modulus of PZT is approximately 25 times greater than PVDF. Thus, with the same geometric dimensions and boundary conditions, a PZT beam would have a higher resonant frequency than the PVDF one. However, the fragility of PZT-based transducers causes damaging easily. Also, PZT will lose a significant fraction of its piezoelectric properties once over-strained, even without any visible cracking [122]. Nevertheless, it is possible to solve the problem of brittleness of PZT by using fiber geometries and embedding them in epoxy to form advanced composites, as other researchers have done [51, 54, 55, 121, 123, 124]. PZT-based flexible composite materials are more durable than piezoceramic specimen which are brittle. They have become more predominant in the application of vibration suppression. These composites include physical flexibility which cause to install them onto arbitrary shape structures, easily [117].

Due to the small displacement and high force output of piezoelectric material, a monolithic piece is rarely used directly as a device. Moreover, the generated strain of a piezoelectric material is small, even under high field. Likewise, piezoelectric material, especially ceramics such as PZT, is rather hard and needs a great stress to be strained, well. Therefore, piezoelectric materials are often laminated into multilayer structures [125] or made into fibers to enhance their strength [121]. The multilayer structure also provides a higher current-to-voltage ratio than a monolithic device with the same thickness, which is preferred by the power electronic circuit efficiency. However, the efficiency of the piezoelectric material is related with irreversible energy loss during the conversion process [26].

3.4 Fundamentals and Mathematics of Piezoelectricity

The conversion of the energy is dependent on the piezoelectric coupling coefficient, (kij), and the capacitance of the piezoelectric material (Cp). The polarization of the material in three dimensional space is indicated by subscripts 'i' and 'j' in the coupling coefficient [29]. The electrical polarization is proportional to the applied strain. Piezoelectric materials has two mode of the operation including 33 mode and 31 mode. Piezoelectric generators typically work in either 33 mode or 31 mode [45]. The operation called d31 mode, a voltage is generated when a mechanical stress is applied to a layer of piezoelectric material in the longitudinal direction and parallel to polarization. In this mode the generated voltage tries to return the piece to its original thickness. In 31 mode, the applied strain is in three directions and electric field is only in the one direction. Likewise, in d33 mode a voltage is generated when a stress is applied to the layer in a transverse direction and perpendicular to polarization in this mode, the generated voltage attempts to return the piece to its original length and width. In the 33 mode, both the applied field and electric field is in the three directions. Most of the piezoelectric energy harvesters use 33 mode, due to the higher coupling coefficient in 33 mode [29]. Piezoelectric transducers in a cantilever beam configuration commonly work in d31 mode [35, 48, 54–56, 58, 59, 61, 119, 126]. While, piezoelectric stacks usually work in d33 mode [71]. Figure 2 shows longitudinal and transverse generators operational modes [24]. The piezoelectric energy harvesters in the study uses 33 mode.

IEEE Standard on Piezoelectricity (1987) is an essential document in piezoelectricity research developed by several researchers [127–131]. As Fig. 3 shows and according to Homami [24] the piezoelectric parameters are as follows:

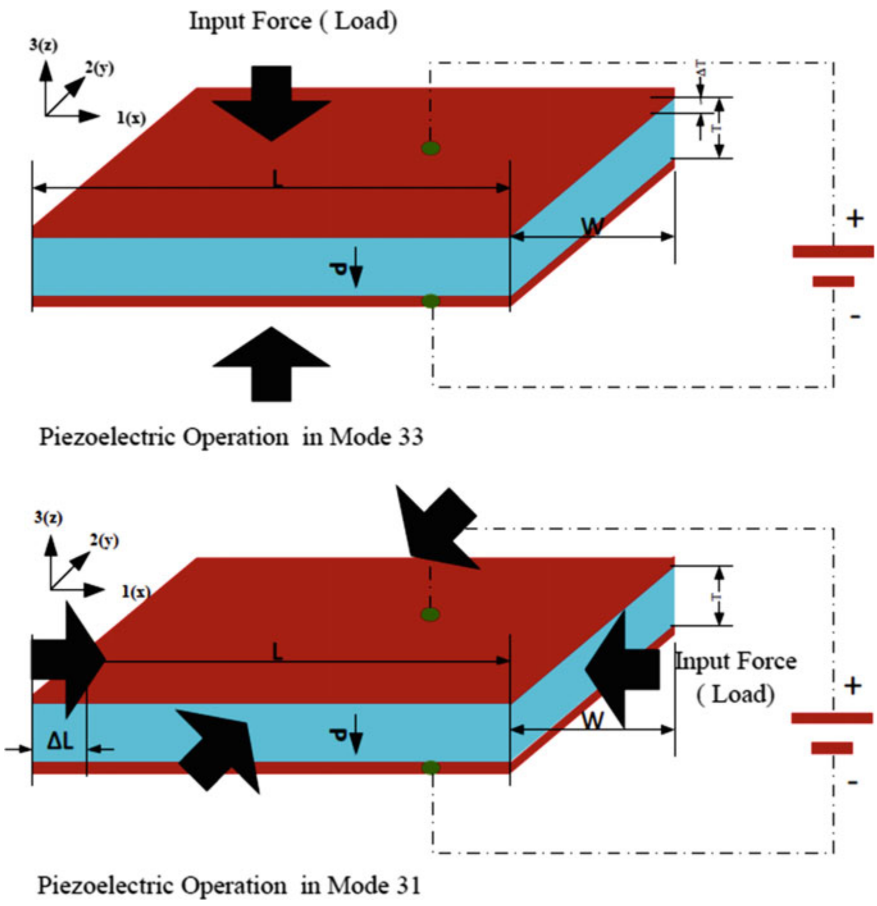

Fig. 2 Two operation mode of piezoelectric material [24]

	Mode 33	*Mode 31*
Voltage	$V = \frac{g_{33} \times F \times T}{W \times L}$	$V = \frac{g_{31} \times F}{W}$
Charge	$q = d_{33} \times F$	$q = \frac{d_{31} \times F \times L}{T}$
Displacement	$\Delta T = d_{33} \times V$	$\Delta L = \frac{d_{31} \times L \times V}{T}$ $\Delta W = \frac{d_{31} \times W \times V}{T}$

Fig. 3 Piezoelectric operation modes formulations [24]

- Permittivity (ε) or relative dielectric constant, is a measure of the polarizability of the material
- Piezoelectric charge constant (di) or strain constant is a measure of the electric charge induced in response to a mechanical stress, or the achievable mechanical strain when an electric field applied.
- Piezoelectric voltage constant (gi) defines the ratio of electric field strength E to the effective mechanical stress T.
- Elastic constant (si) is a measure of the ratio of relative deformation S to the mechanical stress T.
- Frequency constant (Ni) corresponds to half the speed of the sound wave propagating in the ceramic body.
- Mechanical quality factor (Q) characterize the sharpness of the resonance of a piezoelectric body (resonator) and is primarily determined from the 3 dB bandwidth of the series resonance of the resonating system.
- Coupling factor (k) is a measure of effectiveness of the piezoelectric effect (not the efficiency). It describe the ability of a piezoelectric material to transform electrical energy into mechanical energy and vice versa [24, 132]. Materials with higher (k) can have higher conversion rates. The common modes of piezoelectric material operation, 31 mode and 33 mode, have different values of coupling factors. The (k) factor in 33 mode is higher than 31 in typical cases. d33, d31, g33 and g31 are not significant factors to change the rate of voltages or charges between modes [24].

The power is generally related to the force (F) and its displacement (x) [26]. Its average power is given by Eq. 1:

$$P = \frac{1}{T} \int_{0}^{T} F x dt \tag{1}$$

Where, "D" is Electric Displacement, "E" is applied Electric Field (V/m) and "ε" is Permittivity (F/m), "S" is the Strain, "s" is mechanical compliance (m2/N) and "T" is the stress (N/m2), based on the ANSI/ IEEE 176 notation, the equations with coupling effect are shown in Eqs. 2 and 3 as follows:

$$\mathbf{S} = [\mathbf{s}]\mathbf{E} \times \mathbf{T} + [\mathbf{dT}] \times \mathbf{E} \tag{2}$$

$$\mathrm{D} = [\mathrm{d}] \times \mathrm{T} + [\varepsilon \mathrm{T}] \times \mathrm{E} \tag{3}$$

3.5 Energy Harvesting Circuitry

A key component of any micro-scale energy harvesting system is the power converter circuit. The maximum output power of the micro-scale energy transducers is small. Therefore, the power converter should be carefully designed to extract as much power as possible from the transducer, boosts the output voltage to an appropriate level and transfer it to the storage buffer [39]. The overall circuit diagram of the entire process is shown in Fig. 4 [133]. Piezoelectric operation can be described by the circuit that has two parts, a mechanical and an electrical equivalent circuit. The general form of the emulated circuit of the piezo generator is shown in Fig. 5 that presents the mechanical and electrical circuits [24].

Energy harvesting circuits could be categorized into three types based on their energy flow patterns including passive, semi-passive and active. A passive circuit, such as a diode rectifier, always transfers power from the piezoelectric devices to the energy storage unit (rechargeable batteries or supercapacitor). The semi-passive circuit uses a passive component, such as an inductor, to temporarily store and return part of the energy back to the piezoelectric devices during each cycle. The active energy harvesting circuit, utilizes bi-directional inverters and circulates part of energy back and forth between the piezoelectric device and the energy storage cell in each energy conversion cycle. Hence, in most cases at least two switches have to be used in

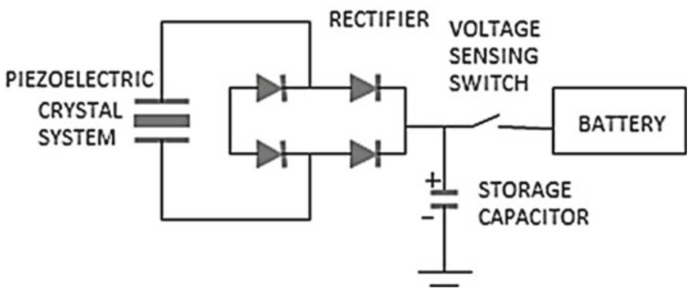

Fig. 4 Circuit diagram of whole process [133]

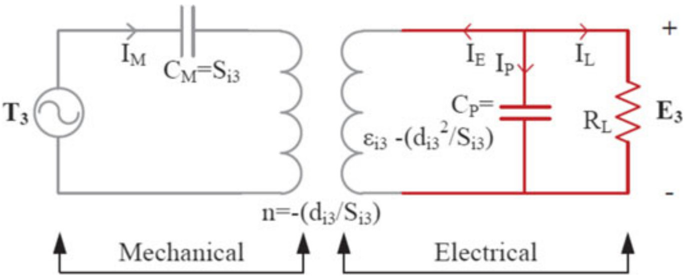

Fig. 5 An emulated piezoelectric circuit [24]

the active circuit. The active energy harvesting is as an effective approach that control the voltage or charge of a piezoelectric device to maximize power conversion without modification of the mechanical system [26]. PZT materials are often used for active control [134]. The active energy harvesting circuit potentially could achieve better performance. The active energy harvesting improves the performance much more for a smaller force. Experimental study also confirms that active energy harvesting outperforms the traditional diode rectifier circuit by a large margin [26].

Generally, when the dominant frequency of excitation is much lower than the fundamental resonance frequency of the energy conversion device, quasi-static mechanical excitation happens. Human motion is usually much slower than the resonance frequency of energy harvesting devices. For example, the frequency of walking or running is usually between 1 and 10 Hz, whereas, piezoelectric bimorphs have resonance frequencies of a few hundreds of Hertz. Quasi-static energy harvesting usually has a low frequency and a high force input, which generally needs a mechanical impedance-matching structure for its optimal performance. Theoretically, the active energy harvesting is appropriate for quasi-static applications, due to its higher energy output and better electromechanical coupling [26]. Two schemes of piezoelectric energy harvesting circuits are one-stage and two-stage circuit. A basic energy harvesting circuit, also named a one-stage energy harvesting circuit contains a conventional diode bridge rectifier and an energy storage device. Due to the alternating current source, an AC-DC rectifier is needed, such as a diode bridge rectifier. In order to harvest the power from varying exciting sources, another scheme is used called a two-stage harvesting circuit [35] or synchronized switch harvesting [99] (Figs. 6 and 7). Firstly, the capacitor Co is charged. When the voltage of the capacitor Co reaches the optimal voltage Vrect-opt, the converter starts working. The switch is controlled to switch on or off in order to keep the voltage across the capacitor Co optimal [35].

Although, more power can be harvested via the one-stage energy harvesting circuit by choosing an optimal energy storage device voltage, two-stage harvesting circuit is more adaptive. The power consumption in the control system is a problem since the DC-DC converter in the two-stage scheme consumes a part of harvested energy. It leads to cancel out the benefits of the harvesting efficiency from the use of the two-stage energy harvesting [35]. Consequently, one of the key aspects of energy

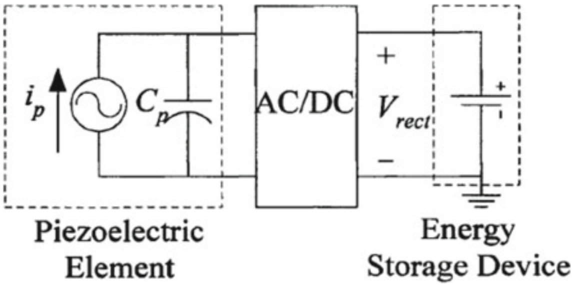

Fig. 6 One-stage energy harvesting circuit [35]

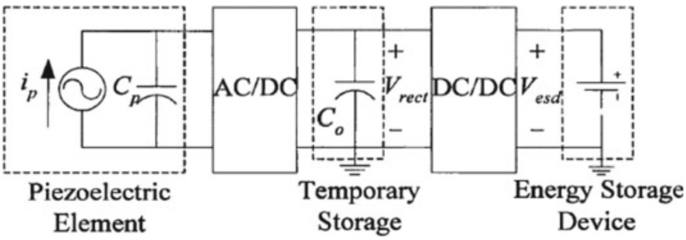

Fig. 7 Generalized two-stage piezoelectric energy harvesting circuit [35]

harvesting is how to extract energy from an electrical network [117]. The efficiency of the energy harvesting is dependent on the power transfer in the system [29]. The design consideration determines how to construct high efficiency energy conversion devices that minimize conversion loss. Therefore, the use of switching systems is introduced to decrease the power loss and increase the power efficiency of the device [117].

3.6 Energy Storage Technologies

Due to the low power harvested from the piezoelectric elements, energy storage devices are required in order to accumulate the energy for periodic use [35]. Battery storage increases the flexibility of system control [135]. The efficiency could be possibly improved by increasing the storage device voltage [35].

Prior researches on energy harvesting used the traditional electrolytic capacitors as energy storage devices [30, 35, 50, 61, 67, 136, 137]. Due to the low energy density of traditional capacitors, rechargeable batteries with higher energy density were replaced [87, 121, 123, 124]. Sodano, Inman [121] showed that a 40 mA nickel metal hydride (NiMH) rechargeable battery can be completely charged in less than one hour under the vibration of a typical vibrating machine. The batteries are a finite source of energy, and require be replacing or recharging, frequently. The batteries are capable of delivering high power density. However, they can perform only for a short period of time [29]. The life time of the battery is a problem for a long life system. Additionally, voltage of battery drop gradually, that is not acceptable for some of the circuits [24]. The leakage resistances of the energy storage devices is the dominant factor that influences the charge/discharge efficiency in the piezoelectric energy harvesting system. Super-capacitors are alternative energy storage devices [35] in energy harvesting systems [138, 139]. It can be concluded that the super-capacitors are appropriate choice and more attractive than the rechargeable batteries to store the energy in the piezoelectric energy harvesting system [35]. Super-capacitor is an electrochemical double-layer capacitor with higher energy density. They do not have the problems of rechargeable batteries including rate-capacity and aging problems. Hence, super-capacitor is an attractive option to be used in micro-scale energy harvesting systems. However, there are some undesired characteristics of super-capacitors. The output voltage of a super-capacitor linearly changes with its energy capacity. Moreover, super-capacitors usually have a significantly higher leakage power loss than batteries [39]. Therefore, the choice of energy storage element is dependent on the temporal profile of power consumption by the load. Finally, it is feasible to integrate both a super-capacitor and a rechargeable battery to form a hybrid energy storage mechanism [39, 139, 140]. Moreover, the scholar who studied hybrid systems, suggested the battery bank, which is usually of the lead-acid type, to store extra electrical energy, to regulate system voltage and to supply power to load in case of low wind speed or low solar conditions. However, most storage systems are not ideal and have some losses during charging, discharging and during storage periods [141].

4 Solar Energy Technologies

Since the discovery of photovoltaic effect by Becquerel, several researchers studied and worked on various photoactive materials and methods of making photovoltaic cells. The first solar cell was developed at Bell Laboratories [142], which was silicon based inorganic solar cell with power conversion efficiency of 6%. The highest power conversion efficiency for inorganic solar cells, which reported recently is 24.7% [143]. The initial PV devices converted about 1–2% of sunlight energy into electric energy [84, 143, 144]. The different types of photovoltaic materials described by Vatansever, Siores [84] are as follows:

- **Inorganic photovoltaic materials**. Silicon is the best example for inorganic photovoltaic material. It is the most common material that absorbs light and creates electron–hole pairs. The basis of all inorganic PV cells are two fundamental processes of PV effect, including light absorption and charge separation.
- **Organic photovoltaic materials**. Semiconducting polymers with proper bandgaps, absorption characteristics and physical properties are used to fabricate organic photovoltaic materials.

- **Dye-sensitized photovoltaic materials**. The dye-sensitized solar cells (DSSC or DSC) are thin film photovoltaic materials. The first DSSCs were studied by Gerischer et al. in late 1960s, who showed that organic dyes can generate electricity at oxide electrodes in electrochemical cells [145].
- **Tandem cell photovoltaic materials**. Tandem solar cells (TSCs) are developed to overcome some drawbacks of conventional solar cells. Each active material used in a solar cell can only convert certain wavelength of the light to electricity. To achieve better photon absorption efficiency, two or more active materials with different bandgaps are linked to built-up a TSC. Two or more heterojunction solar cells are deposited on top of each other to create a TSC. The maximum efficiency for organic tandem solar cells consisting of two sub cells is around 14% [146].
- **Hybrid photovoltaic materials**. Both organic and inorganic nanostructures are combined and named as "hybrid solar cell" (HSC). Organic materials absorb light as a donor and transport holes while inorganic materials act as an acceptor to transport electrons.
- **Photovoltaic fibre attempts**. There are a significant number of approaches to produce solar cells in fibre form. Konarka Technologies, Inc. was the first one who announced and patented the idea of producing a flexible photovoltaic fibre via a continuous process in 2005 [147]. They have used an electrically conductive fibre core, which passes through a titania (TiO^2) suspension and thus coated with the interconnected nanoparticles. The interconnected nanoparticle coated fibre is dried and passed through a dye solution and dried again. The dried fibre is then passed through a polymeric electrolyte and thus coated with the transparent electrode.

In order to design an accurate hybrid system, using PV panels, the hourly solar radiation data is necessary. The output power of each photovoltaic panel, with respect to the solar radiation power, can be calculated by Eq. 4:

$$\text{PPV (t)} = \text{PR, PV} \times (\text{R/Rref}) \times [1 + \text{NT (Tc\_ Tref)}] \quad (4)$$

where PPV (t) is the power generated by each PV panel at time t, PR,PV is the PV rated power, R is the solar radiation in (W/m^2), Rref is the solar radiation at reference conditions and set usually as 1000 (W/m^2), Tref is the cell temperature at reference conditions and set usually as 25 °C, NT is the temperature coefficient of the photovoltaic panel and it equals -3.7×10^{-3} (1/°C) for mono and polycrystalline silicon [148, 149]. In order to install photovoltaic module/array, optimizing the tilt angle of the panel is required. In term of components, generally, hybrid PV system includes PV generator, diesel generator and/or battery system [135]. The challenges and deficiency of previous technologies is discussed in the following section.

5 Conclusion

The different types of system for harvesting renewable energies was reviewed in the paper. The case studies of piezoelectric harvesting that presented above, demonstrated initial design applications of energy harvesting technologies in urban spaces, and each mainly to focus on a specific aspect of the overall design, such as "aesthetic" (Crowd Farm), or context of implementation (Tokyo), or energy output (Pavegen). These examples have investigated awareness of the users about the production of energy and its use. The missed opportunity is the relationships between all of these conditions in order to fully visualize and exploit the potentials user interaction with energy production in space. The opportunity relies on the understanding of possible urban design scale implementations considering the benefit of harvesting energy from pedestrian footfalls [32].

There are a large number of optimization methods for renewable energy system, while a few of them have discussed multi-objective optimization of hybrid renewable energy system by using heuristic algorithm [150]. The case studies of energy harvesting by piezoelectric-photovoltaic materials, shows different approaches far away from the idea of this study. For instance, the patent of "Hybrid Energy Conversion Device" includes layers of PV and piezo sensors [151], while for harvesting optimum energy, it is better to arrange piezoelectric sensors in the floor to harvest kinetic energy of walking people and PV panels at top of the roof. The study propose a walkway according to the best location of sensors to harvest most energy from both sources. The piezoelectric materials have to be designed regarding the mechanism of walking. The PV panel have to be located and tilted according to the solar radiation. As the system sizing is important in the design of hybrid renewable energy system, there is a gap in study of the optimum sizing of a hybrid piezoelectric-photovoltaic system.

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