A Dynamic Thermal Simulation in New Residential Housing of Lakhiayta City in Morocco

Karima El Azhary[1], Najma Laaroussi[1](✉), Mohammed Garoum[1], Khalid El Harrouni[2], and Majid Mansour[2]

[1] Materials Energy and Acoustics Team (MEAT), Mohammed V University in Rabat, EST de Salé, Salé, Morocco
najma.laaroussi@um5.ac.ma
[2] Ecole Nationale d'Architecture, Medinat al Irfane, Rabat, Morocco

Abstract. The aim of this study is to get the most optimal energy efficient heating and cooling material combinations that would result to an energy saving buildings. The regulatory requirement limits of thermal characteristics of residential building's envelope were stated by the TRCM. It is mandatory to respect the thermal transmittance, also known as U-value of external walls that should not exceed 1.20 W/m^2 K and the annual savings in heating and cooling range is 40 kWh/m^2/year in the climate area represented by Casablanca. The simulation results were analyzed to find the combination of parameters yielding the lowest energy consumption and to define potential energy savings for this residential building located in this climate zone.

Keywords: Building simulation · Heating and cooling · Comfort Thermal regulation

1 Introduction

The residential energy consumption remains high and it's increasing overtime in Morocco due to the growth of population and the urbanization [1]. The Moroccan government establishes an ambitious program to reduce residential energy consumption and carbon emissions by building new smart houses. The program aims to achieve 1.2 Mt/year of energy consumption reduction in the building sector by 2020 and decreasing greenhouse gas (GHG) emissions by about 4.5 Mt/year. Therefore, the Moroccan government has introduced a thermal regulation for building envelopes. The implementation of the thermal regulation of construction in Morocco (TRCM) focuses on improving thermal performance and reducing the requirement of buildings in heating and cooling [2].

The need for reducing the energy consumption used for heating or cooling buildings has motivated many studies with the aim at improving the thermal performance of construction. The field of construction and building materials and their application in new works provides an international dissemination of research and development. The description and resulting graphics for a Moroccan public administration building and the complete description of all buildings and simulation results can be found in [3].

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The effect of the insulation of the roof and the facades on the cooling energy of a typical house villa situated in hot and arid climate zone like Marrakech was studied in [4]. The results showed that the insulation of the roof is essential for the Marrakech climate as it resulted in reducing the needs for cooling of almost 40%.

Sick et al. [5] used dynamic building simulations performing sensitivity analysis for the influence of various parameters on the heating and cooling demands of different building types in Morocco. In [6], the effect of using three different external wall constructions on the energy consumption, energy cost and the comfort in Egypt. The simulations results showed different performance for each specification across the climatic zones. Gueddouch et al. [7, 8] have developed a dynamic model of the building based on equivalent circuit model with the aim of evaluating the energy consumption of a typical building in Morocco.

Benhamou and Bennouna [9] carried out an experimental study of the thermal performance of an underground heat exchanger for the air conditioning of a well-insulated house located outside of the city of Marrakech. The coupling of a direct thermal calculation with an optimization algorithm to achieve the identification of the thermal characteristics of a building structure was presented in [10], the proposed optimization model was verified and validated against experimental results obtained from a wooden structure with a heated wall.

The renovation of social housing which provides an interesting opportunity for reducing energy consumption and increasing the comfort of residents has been studied by Gagliano et al. [11]. The improvement of thermal insulation of the building envelope and the use of renewable energy sources have been proposed and have led to energy savings and increased interior comfort. For various cities in Morocco, Guechchati et al. [12] studied the impact of passive design parameters on energy consumption for annual cooling and heating in villas according to regions.

Thus, the energy consumption in Morocco's residential sector is growing. The most efficient way to satisfy this demand on energy is to introduce energy-efficiency measures in new buildings.

In this work, a series of energy simulations were performed for the residential housing located in new city (Lakhiayta) in the suburbs of Casablanca. The residential building was simulated as a case study, by using DesignBuilder [13] by applying different insulations and wall compositions in comparison with the ordinary walls using conventional materials in this climatic zone.

2 Methodology and Parameterization

The studied building is being investigated and modelled using the simulation software DesignBuilder [13], which is the transient simulation of systems, including multi-zone buildings to develop comfortable and energy-efficient building designs from concept to completion. The simulations concern the building and its equipment, including control strategies, occupant behavior and energy systems, thus allowing the correct calculation of heat transfer coupled with thermal storage within the building structure like walls and ceilings.

The building type is a simple standard multi-storey residential building and as shown in Fig. 1. The model of apartments is schematized in the Fig. 2.

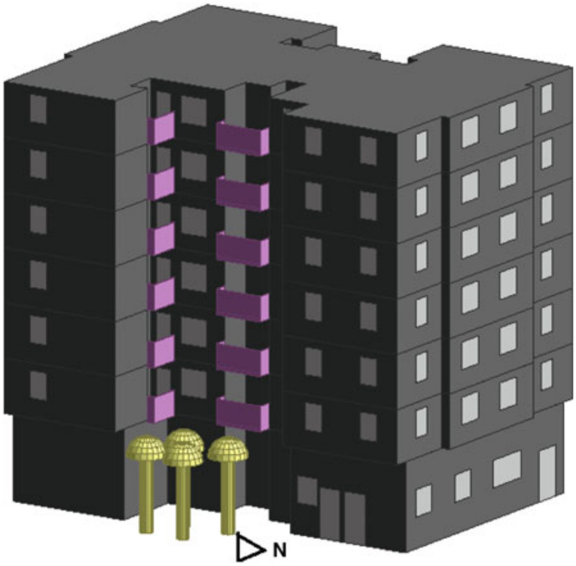

Fig. 1. The view of residential housing (R + 6)

Fig. 2. The typical plan for a flat in the building

The simulation model is made up of 14 thermal zones, two zones for each one of the upper floors representing the four apartments with 60 m^2 of surface, one zone modelling the ground floor is reserved for commercial stores and parking lots and one zone for the staircase.

We estimated that about 5 people live in an apartment. The construction design is documented in Table 1 according to building practice in Morocco. Table 2 gives the U-value corresponding to variation of thickness of polystyrene. The characteristic areas and the volume of building are summarized in Table 3.

Table 1. The design characteristics of construction

Building element	Without insulation U (W/m^2K)	With insulation U (W/m^2K)	U_{TRCM} (W/m^2K)
External wall	1.96	1.33–0.97 (Table 2)	$U \leq 1.20$
Roof	2.04	0.54	$U \leq 0.75$
Floor plate	1.60	1.60	No requirement
First floor intermediate	2.13	0.4	No requirement
Window-to-wall ratio (WWR)	15%		
Windows	Simple glazing, g = 0.86 U = 5.89 (W/m^2K)	Double glazing, g = 0.7 U = 3.09 (W/m^2K)	$U \leq 5.8$
Orientation of building	Sud-Ouest		

Table 2. The U-value corresponding to variation of thickness of polystyrene

Insulation thickness (cm)	2	3	4	5	6
External wall U (W/m^2K)	1.33	1.23	1.12	1.05	0.97

Table 3. The characteristic sizes of construction

Orientation	South	West	North	East	Sum
Gross area (m^2)	300	362.1	259.5	362.1	1283.7
Window area (m^2)	48.7	43.5	48.7	47.7	188.7
WWR facade (%)	16.23	12	18.76	13.17	≈15
Floor area (m^2) without staircase	1426.4	Volume (m^3) without staircase		3993.92	

The Table 4 describes the simulated interior conditions of the building. The dwellings are used by five persons from 17:00 to 07:30 and by 3 persons otherwise as shown in Table 4. Ventilation rate including infiltration is 36 m^3/h per person, corresponding to an air change rate between 1 and 0.4 h^{-1}. All internal gains sum up to 4533 kWh per dwelling per year, evenly distributed. External shading (50%) is used during summer.

Table 4. The interior conditions as simulated for the building

Interior conditions	Week		Week-end	
	7:30–17:00	17:00–7:30	7:30–17:00	17:00–7:30
Occupancy (persons)	3	5	5	5
Ventilation rate including infiltration	Distributed according occupancy			
External shading during summer	50%		50%	
Interior gains sum up	Distributed according occupancy			
Set point temperature heating (°C)	20			
Set point temperature cooling (°C)	24			

3 Results

The parameter variations of the building simulations are the insulation and the type of windows. The construction method used in the simulations was modified by adding layers from 2 to 6 cm of insulation external walls, without changing the construction technique. The increasing of the thickness of the insulating layer of polystyrene decreases the U-value of external walls in the building as shown in Table 2.

3.1 Prescriptive Approach

The minimum technical specifications for thermal performance of buildings in Morocco were set by the TRCM according to the climatic conditions [2]. Then, the prescriptive approach of TRCM was setting technical specifications to be respected by climate zone (roofs, exterior walls, floors and windows).

The recommended setting for zone 1 with a 15% WWR is given in Table 1 and the maximum values to be respected are presented. When introducing the thermal parameters of the envelope referred in Table 1, it shows non-compliance for the not insulated building in the reference case and for the insulated external walls with 2 and 3 cm of thickness (Table 2).

3.2 Performance Approach

The performance approach was setting maximum limits for heating and cooling (kWh/m^2/year) in relation to internal reference temperature (20 °C for heating and 24–26 °C for cooling) [2].

The climate data for the studied Moroccan location were used in this project. The data are available in the software DesignBuilder. The results are displayed as the annual delivered energy for heating, cooling, lighting, cooking and specific electricity (refrigerator, TV, computer).

The following results are generated for the studied building:

– The specific heating and cooling energy demands for heating to 20 °C and cooling to 24 °C room temperatures, respectively.

– The solar heat gains for building in kWh/m^2 for year.
– The number of hours with room temperature exceeding 24 °C during summer without cooling and lower than 18 °C during winter without heating.

In order to evaluate the heating and cooling loads of the building the set points are fixed to 20 and 24 °C, respectively.

The total energy consumption obtained for the reference case is 53.94 kWh/m^2/year, exceeding the requirement of the TRCM which is 40 kWh/m^2/year (for Zone 1). This consumption includes heating and cooling energy.

The most dominating consumption is cooling energy, about 45.06 kWh/m^2/year. However, the heating energy is very low (8.08 kWh/m^2/year). It's clear that the cooling load is a significant part of total consumption as shown in Table 5.

Table 5. The specific heating and cooling energy of the building

Insulation thickness (cm)	Annual solar heat gain (kWh/m^2)	Annual cooling energy demand (kWh/m^2)	Annual heating energy demand (kWh/m^2)	Total annual consumption energy (kWh/m^2)
Without insulation (reference case)	Simple glazing 33.68 (46.22)	45.06	8.88	53.94
2	Double glazing 33.68 (27%)	38.05 (16%)	4.03 (55%)	42.08 (22%)
3		37.06 (18%)	3.55% (60%)	40.61 (25%)
4		36.50 (19%)	3.09 (65%)	39.59 (27%)
5		36.10 (20%)	2.81 (68%)	38.28 (29%)
6		35.21 (22%)	2.49 (72%)	37.70 (30%)

There is significant difference in cooling energy demand between the reference case and the case using insulation in building. Although, the observed difference was between 55 and 72% for heating energy consumption and not exceeding 22% for cooling energy demand.

The results in Fig. 3 show that the use of the double glazing reduced the solar heat gains by 25%.

The monthly indoor air temperature in the conditioned building is ranging between 19 and 24 °C with the external temperature disorders reaching the peak on July and the lowest level on January as shown in Fig. 4.

The unconditioned building is ventilated during summer when the ambient air temperature is lower than the room air temperature. The difference between the indoor temperature and the external dry bulb temperature is varying and is at the maximum difference on July.

Applying the thermal insulation for building envelope, the results in Fig. 5 show that a significant decrease in heating and cooling demand has been achieved compared to the reference case. The insulation is of major importance in heating energy demands exceeding 55%. The effect on cooling energy demands is small and is reduced by approximately 22% when adding an insulation layer of 6 cm thickness.

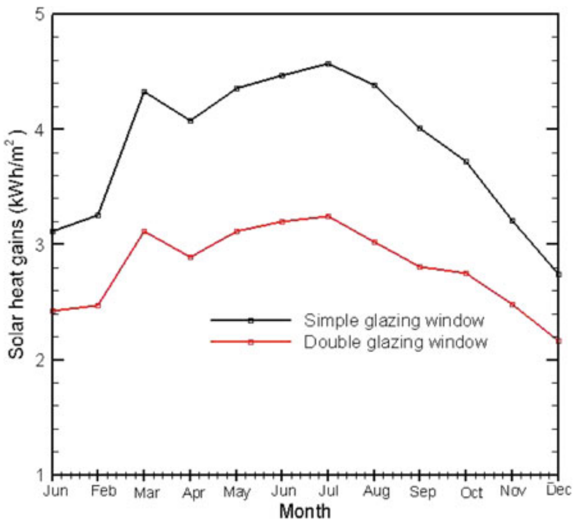

Fig. 3. Comparison of solar heat gains in the building for used of simple and double glazing

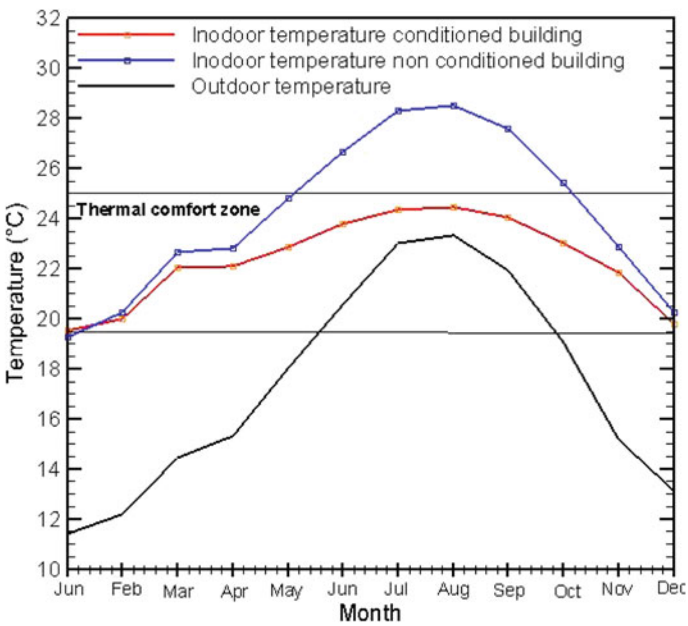

Fig. 4. Mean monthly air temperatures for interior and exterior of the building

By turning off heating and cooling in the simulation, we can count the hours beyond certain room temperatures considered to limit the comfort region.

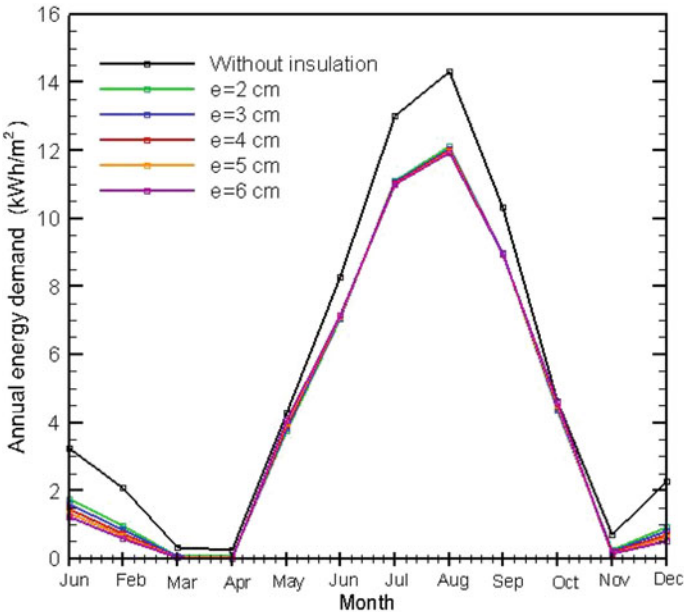

Fig. 5. Annual sum of the cooling and heating energy consumption in building for different thickness of insulation of the external walls

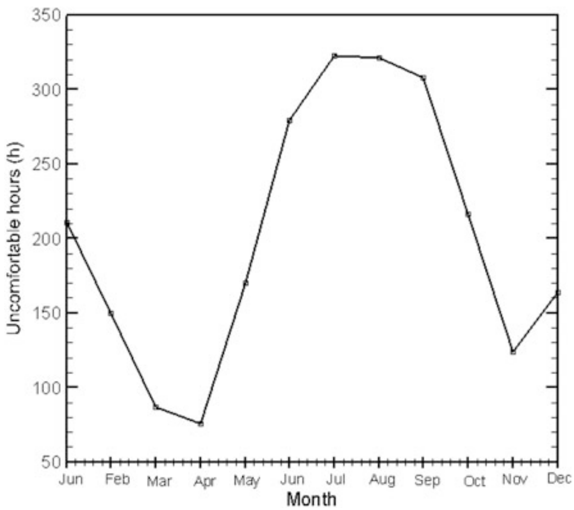

Fig. 6. Monthly number of uncomfortable hours without heating and cooling

The results are shown in Fig. 6. It is observed that Casablanca regions may show high cooling and little heating demands. The observation of the unconditioned building in Fig. 6, reveals the numbers of hours with uncomfortably low or high temperature, respectively in good accordance with heating and cooling demands in the conditioned building (Fig. 5).

4 Conclusion

In this paper, dynamic simulations were carried out with DesignBuilder software on a typical building located in the Casablanca region. The simulations resulted in a significant reduction which reaches 30% of the final total energy consumption for heating and cooling energy compared to the reference case. Results indicate that thermal regulation of buildings in Morocco has a considerable effect on heating and cooling load.

The insulation parameters have the greatest influence in the heating energy demand which is reduced until 72% for 6 cm of insulation of the external walls.

Due to Moroccan regulation, the energy consumption of buildings has to be reduced of the current and this objective could be reached if we build based on these principles and adapting existing buildings.

The regulation aims at allowing improvement to the thermal performance of the building envelope with only little extra costs.

References

1. Ministère de l'Habitat, de l'Urbanisme et de l'Aménagement de l'Espace: Immobilier 2020: Eléments de prospective. N° du dépôt légal: 2011 MO 2633, ISBN:978-9954-30-538-6, p 178
2. Thermal Regulation of Construction in Morocco (TRCM), National Agency for the Development of Renewable Energy and Energy Efficiency (ADEREE) (2014)
3. Sick F, Schade S (2010) Report on TRNSYS Simulations for establishing a Morocco Building Energy Code, Report prepared by order of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, D-65760 Eschborn, Germany
4. Sobhy I, Brakez A, Benhamou B (2014) Modélisation dynamique d'une maison typique à Marrakech et propositions pour améliorer ses performances énergétiques, 3 ème AMT, Agadir, Morocco
5. Sick F, Shade S, Mourtada A, Uh D, Grausam M (2014) Dynamic building simulations for the establishment of a Moroccan thermal regulation for buildings. J Green Build 9:145–165
6. Fahmy M, Mahdy MM, Nikolopoulou M (2014) Prediction of future energy consumption reduction using GRC envelope optimization for residential buildings in Egypt. Energy Build 70:186–193
7. Gueddouch T, Saad A, Hmidat A (2016) Analysis of the influence of Moroccan thermal regulation on energy consumption of a typical apartment located in Morocco. Int J Appl Eng Res 11(5):3458–3461 (ISSN: 0973-4562)
8. Gueddouch T, Saad A (2014) Modeling of a building with the aim of the evaluation of its energy consumption: application to a typical building in morocco. Int J Comput Sci Eng 2 (2):1–5
9. Benhamou B, Bennouna A (2013) Energy performances of a passive building in marrakech: parametric study. Energy Procedia 42:624–632
10. Bouache T, Ginestet S, Limam K, Lindner G, Bosschaerts W (2013) Identification of thermal characteristics of a building. Energy Procedia 42:280–288

11. Gagliano A, Nocera F, Patania F, Capizzi G (2013) A case study of energy efficiency retrofit in social housing units. Energy Procedia 42:289–298
12. Guechchati R, Moussaoui MA, Mezrhab A (2014) Evaluation des besoins d'une bâtiment dans différentes ville du Maroc, 3ème Congres de l'Association Marocaine de Thermique, AMT2014, Agadir, Maroc, 21–22 Avril
13. DesingBuilder software, version 3