Towards a Sustainable Touristic Buildings in Egypt Using Innovative Wall Materials

Mahmoud Yasser Ouf $^1$, Mohamed M. Mahdy $^2$, Sheriff Ibrahim $^2$ and Nabil ashry$^3$

$^1$ Department of engineering, Egyptian armed forces, Egypt  
$^2$ Architecture Engineering Department, Military Technical College, Egypt  
$^3$ Architecture Engineering Department, Shoubra Engineering, Egypt

E-mail: tigerenoo.mtc@gmail.com

Abstract: By the unprecedented development witnessed by the world in the field of construction, especially in the tourism sector in Egypt, as well as the efforts of the engineering department of the Egyptian armed forces to make a boom in all standards in the fields of construction. Therefore, it is necessary to search for building materials that are both environment and economy efficient to raise the standard of occupants’ life of these facilities, which represented in thermal comfort and all necessities to enjoy the accommodation and the convenience of the intended future operation and maintenance. The objectives of the research are: 1) to evaluate the materials used in the construction of the walls in touristic buildings in the coastal areas of Egypt; 2) to choose the suitable and the economic materials, which is compatible with the surrounding environment, whereas maintaining the level of indoor environmental quality (IEQ) in the buildings; and 3) to proof of this compatibility computationally and geometrically by comparing simulation results with experimental results of these new materials. The Methodology of this research followed the comparative analysis of the simulation results of using traditional Egyptian building materials and innovative ones used in the construction of walls (red bricks and light bricks). Pros and cons were identified according to: savings in construction’s initial cost, providing internal thermal comfort, and reducing electric loads. The study showed the advantages of each type of brick and the benefits gained from it in the near term and the revelation in 2080 (based on the projected climate changes) and calculate the amount of reduction in thermal loads and savings of running costs and other advantages acquired. Moreover, the research showed that light bricks needed to use less reinforcing steel in construction, which was founded to be a fair compromise to compensate its high price.

Keywords: Sustainable buildings; Wall materials; Energy efficiency; Climate change; Performance simulation.
1. Introduction

The building sector has a direct impact on the social, environmental and economic aspects [1, 2]. It consumes 19% of the global energy consumption and 50% of global electricity that is needed for construction and operation of buildings, which leads to 33% of total carbon dioxide emissions through the whole life cycle of buildings [3, 4]. These emissions have the major responsibility of the global climate change, especially the rise in temperatures [5, 6]. Accordingly, the deliberate design of buildings is not only a form and aesthetic concept, but also a holistic process that includes a precise choice of the building materials can minimize the energy consumption of buildings and implementing passive design strategies [7, 8]. These strategies opt to decrease the heat gain through the building envelope (walls).

Moreover, these strategies can have a direct influence on the energy performance of buildings that are being considered one of the important aspects, which needs a precise attention [9, 10]. From this point of view, this research will introduce two different materials of wall constructions of a case study building: the first material is the traditional red brick wall; the second uses light block wall construction. Furthermore, comparisons between the two materials were conducted to proof the effect of the wall material on minimizing the indoor air temperature and increasing the savings in construction materials by decreasing the structural loads of buildings.

Therefore, the aim of this research is to demonstrate the advantages of using light blocks made of sand, lime, cement and water added to the amount of aluminum powder compared to ordinary bricks and the impact on the building, people and the environment in terms of construction costs and thermal comfort. The aim will be clarified through comparative and analytical methodology, showing the results of the case study simulation and ending with conclusion and discussion.

2. Methodology

2.1 Case study

This project is Residential compound named village of Brigadier General Tulip is located in the north coast, EL OMAYED, consists of different types of buildings. Villa model B, as shown in Fig.1, was selected as a case study to perform the structural and environmental analytical studies using two types of walls: 1) using red brick walls and other using light bricks (unreinforced Autoclaved aerated concrete). The building consists of ground, first floor, and roof as shown in Fig. (1) and Fig. (2).

![Perspective view of the case study Villa](image)
2.2 Structural studies and economic studies

The structural analysis of the various structural elements of the statical system is (flat slab) with marginal beam & column system, the building is totally designed to resist the vertical and horizontal loads acting on it and according to Egyptian Standard. In order to perform the structural analysis, the software; ETABs 2016, and SAFE 2016 were used. The structural data used in this study as shown in Table 1. The structural study comprises: 1) design of reinforced concrete columns and reinforced walls, and 2) design of reinforced concrete slabs and beams. Based on the structural analytical study, a comparison is conducted for the case study using light block walls and red brick wall to distinguish the amount of saving in the plain concrete and reinforced concrete resulted from the decrease of the dead load when using light brick walls as shown in Table 2.

![Figure 2: Ground and first floor plans](image)

**Table 1: structural data**

| Item                                             | Value   |
|--------------------------------------------------|---------|
| Bearing capacity of soil                         | 1.50 kg/cm² |
| Common Live load                                 | 200 kg/m²  |
| Live load in balcony, bathroom and kitchen       | 300 kg/m²  |
| Common flooring cover                            | 200 kg/m²  |
| Flooring cover at roof                           | 200 kg/m²  |
| Density of walls                                 | 550 kg/m³  |
| Density of plastering mortar                     | 1800 kg/m³ |
| Density of plain concrete                         | 2200 kg/m³ |
| Density of reinforced concrete                    | 2500 kg/m³ |

**Table 2: Economic comparison between using light block and red brick**

| Items of Comparison                              | Light Block | Red Brick |
|--------------------------------------------------|-------------|-----------|
| Quantity of Plain concrete/ m³ (kg)              | 19.3        | 80.2      |
| Quantity of saving Plain concrete/ m³ (kg)       | 60.9        |           |
| Percentage of saving                             | 75.93 %     |           |
| Quantity of Reinforced concrete / m³ (kg)        | 34.95       | 42.5      |
| Quantity of saving Reinforced concrete / m³ (kg) | 7.55        |           |
| Percentage of saving                             | 17.7 %      |           |
Density of plain concrete: 2200 kg/m³  
Density of reinforced concrete: 2500 kg/m³  

| Columns and Beams |  |
|-------------------|--|
| Quantity of Reinforced concrete / m³ (kg) | 22.38 |
| Quantity of saving of Reinforced concrete / m³ (kg) | 5.62 |
| Percentage of saving | 25.11 % |

| Floors and Beams |  |
|------------------|--|
| Quantity of Reinforced concrete / m³ (kg) (in ground floor) | 40 |
| Quantity of saving of Reinforced concrete / m³ (kg) | 10 |
| Percentage of saving | 25 % |
| Quantity of Reinforced concrete / m³ (kg) (in first floor) | 42 |
| Quantity of saving of Reinforced concrete / m³ (kg) | 9.70 |
| Percentage of saving | 23.09 % |
| Quantity of Reinforced concrete / m³ (kg) (in roof) | 9.6 |
| Quantity of saving of Reinforced concrete / m³ (kg) | - |
| Percentage of saving | - |
| Percentage of saving in the three floors | 48.09 % |

2.3 Environmental analytical studies
The climatic analytic studies of the case study building were done using DesignBuilder Software specializes in developing high-quality, easy-to-use simulation software that helps to quickly assess the environmental performance of new and existing buildings as shown in Fig.3. DesignBuilder’s advanced building performance simulation tools minimize modeling time and maximize productivity as a result of considerable investment in user interface technology and an uncompromising approach to software design. Models either imported from BIM or built quickly within DesignBuilder provide fully integrated performance analysis including energy consumption and thermal comfort, HVAC, daylighting, cost, design optimization, CFD, BREEAM/LEED credits, and reports complying with several national building regulations and certification standards. DesignBuilder software is distributed globally by a network of international partners.

Figure 3: Case study and Design Builder interface

3 Results
The simulations were performed using the selected case study building using two groups of wall construction: 1) the typical red brick wall; and 2) the delta block walls. Each group of construction
comprises three different orientations for the case study building, which are 45°, 90 °, and 135 ° orientations. Each orientation is simulated three times using the weather data files for three different scenarios that are 2020, 2050, and 2080 to predict the impact of the climate change on the thermal behavior of the building.

Based on the simulation output results of the peak high temperature month August, the typical red brick wall results in an indoor temperatures in the orientations of 450, 900, and 1350 in the periods of 2020, 2050, and 2080 are (32.18 ºc, 31.71 ºc, and 32.18 ºc), (33.95 ºc, 32.15 ºc, and 33.20 ºc), and (35.73 ºc, 33.95 ºc, and 35.79 ºc) as shown in Fig.2. Whereas, the typical delta block wall results in an indoor temperatures in the orientations of 45, 90 , and 135 in the periods of 2020, 2050, and 2080 are (31.65 ºc, 30.71 ºc, and 31.68 ºc), (33.26 ºc, 31.59 ºc, and 33.20 ºc), and (33.29 ºc, 32.47 ºc, and 33.20 ºc) as shown in Fig.5. The differences in the indoor temperature between the use of traditional red brick wall and delta block are as follows and as shown in Fig.6:

a) For the simulation period 2020, the light blocks performs better than the traditional red brick wall in all the orientations in the peak month, such that the indoor temperature using delta blocks results in decreasing the indoor temperature by 0.53 ºc, 1.00 ºc, and 0.5 ºc for the orientations 450, 900 , and 1350 respectively.

b) For the simulation period 2050, the delta blocks performs better than the traditional red brick wall in all the orientations in the peak month, such that the indoor temperature using delta blocks results in decreasing the indoor temperature by 0.69 ºc, 0.56 ºc, and 0.78 ºc for the orientations 450, 900 , and 1350 respectively.

c) For the simulation period 2080, the delta blocks performs better than the traditional red brick wall in all the orientations in the peak month, such that the indoor temperature using delta blocks results in decreasing the indoor temperature by 2.44 ºc, 1.48 ºc, and 2.59 ºc for the orientations 450, 900 , and 1350 respectively.

Figure 4: Indoor temperature of red brick wall with different orientations and same period
Figure 5: Indoor temperature of red brick wall with different orientations and same period

Figure 6: Indoor temperature of red brick wall and light block with different periods
4. Conclusion and Discussion

This study aims to spotlight on the advantages of using a light block in wall construction rather than using the traditional red brick wall construction method. The study introduced both comparative and analytical methodology. An economic comparison was conducted based on structural study of the case study using light block in wall construction one time and use the red brick in the other. This comparison illustrates that the light block decreases the dead loads and in turn decrease the structural burden on the structural elements such as foundations, slabs, beams and columns. This minimization in the structural load resulted in minimizing the amount of plain concrete and reinforced concrete in the cubic meter. The percentage of savings in reinforced concrete when using light block instead of red brick in wall construction are 17.7 %, 25.11 %, and 48.09 % in foundations, columns and beams, and slabs respectively. Moreover, based on the simulation performed using Design builder software, in three climatic period scenarios 2020, 2050, 2080, the use of light weight block resulted in reduction of the indoor air temperature in the three periods ranging from 0.5 ºc to 2.59 ºc. Although, this reduction in the air temperature is still beyond the thermal comfort zone which is between 20 ºc and 30 ºc, but this slight reduction will have its impact of the reduction of the thermal loads and in turn decrease the electricity consumption in both cooling in summer and heating in winter results in saving costs and resources.

References

[1] U. Berardi, "Sustainability assessment in the construction sector: rating systems and rated buildings," Sustainable Development, pp. 411-424, 2012.
[2] S. Mahmoud, T. Zayed, and M. Fahmy, "Development of sustainability assessment tool for existing buildings," Sustainable Cities and Society, vol. 44, pp. 99-119, 2019.
[3] IPCC, "Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change," Switzerland2014.
[4] L. Gustavsson, A. Joelsson, and R. Sathre, "Life cycle primary energy use and carbon emission of an eight-storey wood-framed apartment building," Energy and Buildings, vol. 42, pp. 230-242, 2009.
[5] M. Fahmy, H. El-Hady, M. Mahdy, and M. Abdelalim, f., "On the green adaptation of urban developments in Egypt; predicting community future energy efficiency using coupled outdoor-indoor simulations," Energy and Buildings, vol. 153, pp. 241-261, 2017.
[6] M. J. Holmes and J. N. Hacker, "Climate change, thermal comfort and energy: Meeting the design challenges of the 21st century," Energy and Buildings, vol. 39, pp. 802-814, 2007.
[7] M. Fahmy, M. M. Mahdy, and M. Nikolopoulou, "Prediction of future energy consumption reduction using GRC envelope optimization for residential buildings in Egypt," Energy and Buildings, vol. 70, pp. 186-193, 2014.
[8] D. J. Sailor, "A green roof model for building energy simulation programs," Energy and Buildings, vol. 40, pp. 1466-1478, 2008b.
[9] S. H. A. Aleem, A. F. Zobaa, and H. M. A. Mageed, "Assessment of energy credits for the enhancement of the Egyptian Green Pyramid Rating System," Energy Policy, vol. 87, pp. 407-416, 2015.
[10] S. Mahmoud, and Zayed, T., "An Integrated Sustainability Assessment Tool Framework," in Proceedings of the 2nd World Congress on Civil, Structural, and Environmental Engineering (CSEE’17), Barcelona, Spain, 2017, pp. 1-8.