Comparative Study of Building Envelope Cooling Loads in Al-Amarah City, Iraq

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Abstract. In recent years, the summer season in Iraq has become longer and hotter than before, leading to high cooling loads inside buildings and increased demand for electrical energy. The use of sustainable energy and insulation techniques for building envelopes are reasonable solutions for overcoming harsh weather conditions and reaching acceptable thermal comfort levels. In this study, a survey on more than 60 residential buildings in Al-Amarah City, Iraq, was conducted on 21 July 2018 to examine the nature of the most common construction materials used in the building envelopes. Furthermore, the cooling loads of building envelope elements, e.g. roof, external walls and windows, was calculated using the cooling load temperature difference/solar cooling load/cooling load factor method of ASHRAE. The results were tabulated and compared for each combination of elements. The results showed that reflective glass is the optimal choice for exterior windows. The 'clay–insulation–fired clay bricks–cement mortar' and 'cement mortar–thermo-stone bricks–cement mortar–gypsum mortar' combination layers performed well for roof and external wall installations, respectively. Several recommendations were deduced from this study, which can be used as guidelines for construction authorities in Al-Amarah City and individuals interested in energy-efficient buildings.

Keywords: *building envelope; CLTD/CLF/SCL method; cooling load; comparative study; thermal comfort.*

1 Introduction

Buildings in Iraq suffer from high cooling loads during summer, leading to increased electrical energy demand and shortage of electrical energy supply. This situation is due to the reliance on air-conditioning systems to handle extreme weather conditions and reach thermal comfort levels [1]. Al-Amarah City (the capital of Misan Province, at 31.84° latitude and 47.14° longitude, 320 km southeast of Baghdad, Iraq) is a humid city in Iraq. The temperature reaches 50 °C on many summer days, which may continue until evening. Residential buildings in the city are affected due to the use of relatively high thermal conductivity materials and, in most cases, lack of thermal insulation.

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Many studies have been conducted to reduce the cooling load inside buildings and enhance thermal comfort using different methods applied to building envelope elements (e.g. roof, external walls and windows) [2-5]. Mujtaba, *et al.* [6] simulated the annual energy consumption of a typical residential house located in Basra City, Iraq, using the analysis program e-Quest. The results showed that the cooling load through the roof and walls accounted for more than half of the total load. It was established that the use of thermo-stone bricks can lead to a 5.9% reduction in the total energy consumption. Moreover, the research indicated that the use of insulation for the building envelope reduced the cooling load by 23%. Qussai, *et al.* [7] investigated the use of thermal insulation by covering the exterior wall surfaces of a certain building located in Baghdad with a plate made of reflective aluminum [ANS H35.1 (2001)] and the roof, ground and three walls of one room in the building with a 200-mm polystyrene thermal insulator. The outcomes showed 68 to 70.9% cooling electrical energy savings because of the reduction of heat transferred to the building. Sahar and Yahyah [8] used an evaporative cooling method to cool a building envelope. The building roof was cooled by a ventilated pool in a tunnel, while the external walls were rebuilt using a 10-cm cavity and were cooled using an evaporative cooler. Their study achieved a temperature drop of approximately 10 °C in the interior zone to an average of 31.76 °C, which reduced cooling load levels to less than 88% in comparison with the state of the building before treatment. Similarly, an experimental test on a building envelope (roof and west wall) in Baghdad City revealed that evaporative cooling effectively reduced the exterior envelope surface temperature. Najim and Firas [9] used a mist system for 51 days in May, June and July 2012 (from 8:00 am to 12:00 pm on each test day) and reduced the exterior roof surface temperature by 1.71 to 15.5 °C, which accounted for a 21.3 to 76.6% reduction of heat entering the building in comparison with the original state (1.3 to 18.8 °C of the exterior wall surface temperature).

Several methods using building elements have been used to address the problem of high cooling load. Ibtisam [10] boosted the roof mass by adding covering materials to an existing building to increase the thermal resistance of the roof. Seven thermal insulation materials, namely, reed, reed without air gap, nylon matting, felt, Jnvas, Jnvas stuffed with sawdust and hyper HTS, were added to the exterior surface of the roof. Sheets of gypsum (8.5 mm thickness) and hollow plastic (4.7 mm thickness) were used as a suspended ceiling. It was found that the roof built from perforated bricks and clay tiles had the best performance. Meanwhile, using hollow reed caused a 30% heat reduction. The use of a suspended ceiling reduced the cooling load by 76 to 80% and using hollow plastic sheets also improved the roof’s performance. Saba and Ghada [11] clarified the importance of greening the roof of buildings to minimize the cooling load and produce economic and environmental benefits. They used the

Design Builder software to analyze the advantage of greening the building of the Baghdad University presidency. The results showed the effectiveness of this technique in upgrading the building's energy efficiency. Cooling roof surfaces using buried pipes containing water is a new method for minimizing heat transmission to a conditioned space from the outside of a building in summer [12]. This study considered several parameters, such as the number of pipes per square meter, ratio of pipe diameter to roof thickness (D/W), and inlet pipe water temperature. In accordance with the numerical results of the study, 37.8% heat energy reduction was achieved using three pipes per square meter of the roof, a 0.20 ratio of pipe diameter to wall thickness (D/W), and a water inlet temperature of 30 °C. Atif [13] tested the influence of using white paint on decreasing the cooling load by a roof made of concrete tiles. It was found that this method could save approximately 35% of energy in comparison with the original state.

Another main source of cooling load inside conditioned spaces are the walls, which has led researchers to test different methods for managing the heat gained by walls during the summer season. Nazar, *et al.* [14] have conducted a simulation work on a building to reduce the cooling load using a geothermal cooling system. They used a vertical flat plate with high thermal conductivity that extended to the ground within 3 m and covered the eastern and southern walls. The results showed that the cooling load of the eastern and southern walls was reduced by 13.2% and 12.7%, respectively, when they used the plate only (without insulation). The reduction increased when insulation was added while the heat dissipated to the ground. Haqi [15] developed a numerical model to estimate the thermal response of different wall coverings in Iraq during summer. He used local natural insulations made of palm fiber, local cane matting and local plastic matting to save energy inside a conditioning space. Comparing local plastic matting and local palm fiber matting, the results indicated that local cane matting could reduce approximately 50% of the heat passing through the walls.

Osama, *et al.* [16] used a phase change material (PCM) in building walls and introduced paraffin wax as a common PCM embedded in one of two Iraqi wall models with a 20% volume percentage in the external layer. An external heat source (1000 W) was subjected to the treated and not-treated walls for 6 h. The results showed a temperature decrease of 1.6 °C in the internal surface of the treated walls. Qussai and Bashar [17] used a closed cavity (5 cm) inside an external wall to reduce the heat gain that passes through the space. This method minimized the cooling load by 21.5% and reduced the wall's inner surface temperature by approximately 0.45 °C in comparison with that of a conventional wall. Shen, *et al.* [18] tested three coating types experimentally by applying them to identical buildings; these coating types were applied to investigate their effect on external and internal wall surface temperatures and to determine the annual electricity consumption. The results showed that the exterior and interior surface temperatures could be reduced by up to 20 °C and 4.7 °C, respectively, while the annual electricity consumption was reduced by 116 kWh.

Windows are a source of high cooling load of building envelopes given the conductive and irradiative heat transfer passing through them. The effect of a window depends highly on its area, glazing type, frame type, and orientation. Askar, *et al.* [19] reported the importance of glazing type in improving the window design in order to reduce building electrical energy costs. The study found that a new form of triple-glazing could reduce the direct-beam irradiation transmission to enhance thermal comfort inside the building. Singh and Garg [20] studied the effects of glazed area, orientation and curtain reflectance on building energy consumption for different tropical Indian climates. The results showed that energy consumption is directly proportional to glazed area. The north orientation had minimal energy consumption and a curtained window consumed less energy (6-8%) than a standard window. Sinha, *et al.* [21] examined the thermal and environmental performance of window frame materials. A heat transfer model was applied to three similar frames manufactured using aluminum, polyvinyl chloride (PVC) and wood. In addition, 1 m^2 of window area was covered. The results showed that the wooden window frame was better than the PVC and aluminum ones for thermal and environmental considerations. Moreover, exterior shading devices effectively reduce direct solar radiation on windows; these devices could minimize the cooling load by up to 80% [22]. Palmero-Marrero and Oliveira [23] simulated the effect of horizontal and vertical external louver shading devices on building indoor comfort and energy requirements for different locations using the TRNSYS software. Their study confirmed that horizontal and vertical louver shading devices (with different layouts) lead to comfortable indoor thermal conditions and significant energy savings. To reduce the cooling load, Nazar [24] explored the use of overhang windows in different Iraqi buildings. This author stated that effectiveness of overhangs depends on window height and orientation. The results showed that having overhangs on south windows is important in Iraq (realizing a cooling load reduction of 9%) and that overhangs must be wider on the east and west windows than in the other directions to obtain the same percentage.

The current study aimed to select ideal envelope elements, such as roof, external walls and windows, for different residential buildings. A survey on more than 60 existing residential buildings located in different regions in Al-Amarah City was conducted on 21 July 2018 to study existing building construction patterns. The selection was made by evaluating different element and selecting the optimal element to produce a reduced cooling load. The results were used to develop guidelines that can be delivered to residents and construction authorities in the city. The determination of optimal construction materials contributes significantly to reducing cooling loads in summer, thereby decreasing the electrical energy consumed by air-conditioning systems. Moreover, the use of ideal building materials increases the period in which the indoor temperature can be kept at proper comfort levels and creates a building that is close to a net zero energy building.

2 Calculation Methodology

The cooling load of different residential buildings was estimated using the cooling load temperature difference/solar cooling load/cooling load factor (CLTD/SCL/CLF) method of ASHRAE to compare every element of the building envelope separately. The method uses a set of factors to simulate the external and internal cooling load sources of a building. This study addressed external sources that are related to building envelopes, such as roof, external walls and fenestrations, based on the following set of equations:

Roof cooling load

$$Q_R = A_R * U_R * CLTDcR \, , \tag{1}$$

where,

Q_R: heat gain of the roof (W)
A_R: roof area (m^2)
U_R: overall heat transfer coefficient of the roof ($W/m^2.K$)
$CLTD_{cR}$: corrected cooling load temperature difference of roof (°C)

$$U_R = \frac{1}{R} \quad , R = \sum_i^n \frac{L_i}{k_i} \, , \tag{2}$$

where,

n: number of roof layers
R: thermal resistance of roof layers ($m^2 .K/W$)
L: layer thickness (mm)
k: thermal conductivity of roof layers (W/m. K)

$$CLTD_{cR} = CLTD + (25.5 - t_r) + (T_o - 29.4) \, , \tag{3}$$

$$T_o = t_o - \tfrac{DR}{2} \, , \tag{4}$$

where,

t_r & t_o : indoor and outdoor temperatures, respectively (°C)

T_o : mean outdoor temperature (°C)
DR : daily range $(T_{Max.} - T_{Min.})$

a. External wall cooling load

$$Q_W = A_W U_W CLTD_W \,, \tag{5}$$

where,

A_w : wall area (m^2)
U_w : overall heat transfer coefficient of the external wall ($W/m^2.K$)
$CLTD_{cw}$: corrected cooling load temperature difference of the external wall (°C)

b. Window cooling load

$$Q_{Win.} = A_{Win.}(U_{Win.} CLTD_{CWin.} + SC * SCL)\,, \tag{6}$$

where,

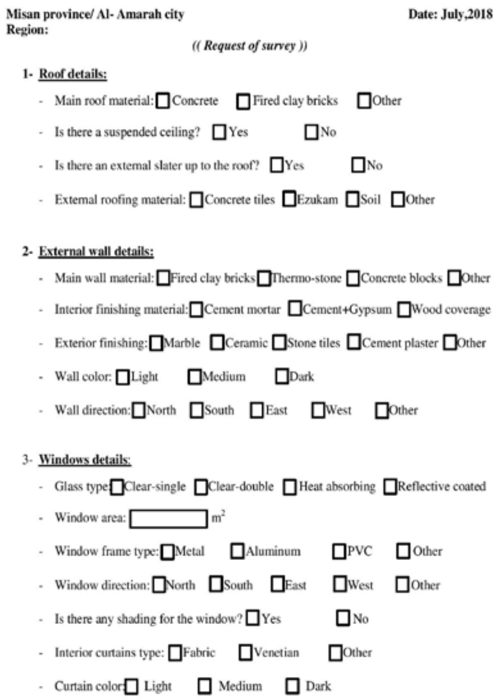
A_{win} : window area (m^2)
$U_{win.}$: overall heat transfer coefficient of the windows ($W/m^2.K$)
$CLTD_{c\ win}$: correction of cooling load temperature difference of windows (°C)
SC : shading coefficient
SCL : solar cooling load factor with or without interior shade (W/m^2)

For the roof and walls, the overall heat transfer coefficient (U) was the main factor in the calculations. This coefficient depends on the thermal conductivity (k) and the thickness (L) of each construction layer. The other factors, namely, element area, orientation, correction of latitude, month and color, were assumed constant to be able to compare the different arrangements of roof and walls with each other. Meanwhile, the shading coefficient (SC) has a major effect on cooling load through the windows.

3 Request of Survey

A survey form was created for different households in Al-Amarah City and distributed randomly across more than 60 locations. The survey was developed to collect information on the building envelope for easy differentiation among the installations. Figure 1 illustrates the form that addressed the main construction materials and building information on construction methods in the city.

On the basis of a set of calculations, a survey was prepared to determine the nature of household construction in the city. The results can guide people and construction authorities in the city toward a construction pattern that will help overcome the city's electrical energy problems. The survey shows that most roofs are built from either high-density concrete (average thickness ≈150 mm) or fired clay bricks (jack arch ceiling typically supported by I-section iron beams, as depicted in Figure 2). Fired clay bricks are commonly used for roof and wall installations given their favorable mechanical properties, wide availability and good market price (Figure 3).



Misan province/ Al- Amarah city **Date: July,2018**
Region:

((Request of survey))

1- **Roof details:**

- Main roof material: ☐Concrete ☐Fired clay bricks ☐Other
- Is there a suspended ceiling? ☐Yes ☐No
- Is there an external slater up to the roof? ☐Yes ☐No
- External roofing material: ☐Concrete tiles ☐Ezukam ☐Soil ☐Other

2- **External wall details:**

- Main wall material: ☐Fired clay bricks ☐Thermo-stone ☐Concrete blocks ☐Other
- Interior finishing material: ☐Cement mortar ☐Cement+Gypsum ☐Wood coverage
- Exterior finishing: ☐Marble ☐Ceramic ☐Stone tiles ☐Cement plaster ☐Other
- Wall color: ☐Light ☐Medium ☐Dark
- Wall direction: ☐North ☐South ☐East ☐West ☐Other

3- **Windows details:**

- Glass type: ☐Clear-single ☐Clear-double ☐Heat absorbing ☐Reflective coated
- Window area: ☐ m^2
- Window frame type: ☐Metal ☐Aluminum ☐PVC ☐Other
- Window direction: ☐North ☐South ☐East ☐West ☐Other
- Is there any shading for the window? ☐Yes ☐No
- Interior curtains type: ☐Fabric ☐Venetian ☐Other
- Curtain color: ☐ Light ☐ Medium ☐ Dark

Figure 1 Survey form.

Figure 2 Fired clay brick roof (jack arch ceiling).

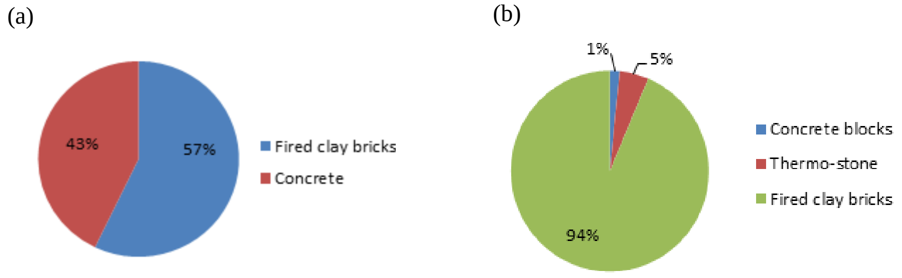


Figure 3 Main materials for (a) roofs and (b) external walls.

Clay (typically mixed with straw) is a traditional material used for roofing given its favorable thermal insulation, low cost and ease of installation in comparison with modern roofing materials, such as concrete tiles and Ezukam, as demonstrated in Figures 4 and 5, respectively. Ezukam is a local roofing material made mainly from felt and fiberglass and covered with a reflective layer; it is used in roof finishing for waterproofing and thermal insulation. It has been used extensively in Iraq over the last 10 years.

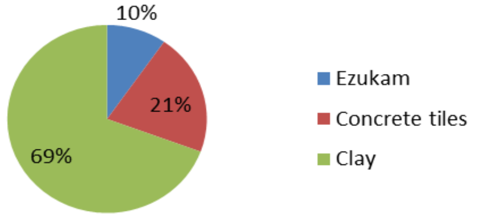


Figure 4 Exterior roofing material.

Figure 5 Popular roofing materials used: (a) Ezukam, (b) concrete tiles, (c) clay.

Figure 6 shows the finishing materials for interior and exterior walls. Cement mortar is used frequently, especially for exterior finishing, because it has good thermal properties and costs less than other materials; several of these materials are used mainly for decorative purposes.

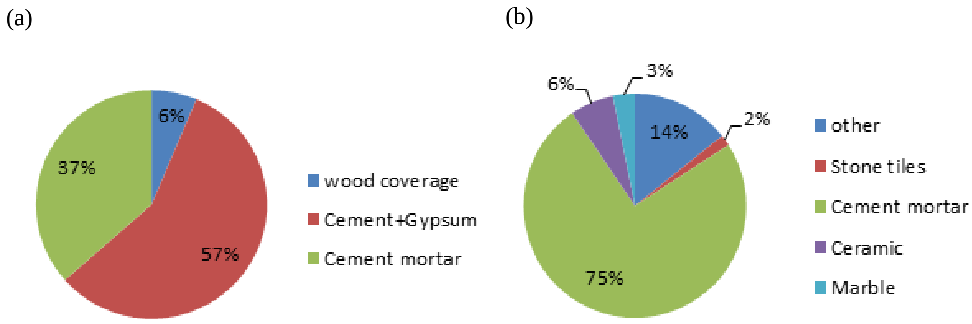


Figure 6 Wall finishing materials: (a) interior, (b) exterior.

The color of exterior elements plays an essential role in reducing cooling load. Light colors reflect solar radiation; consequently, the temperature gained by a building envelope is decreased by 35%. Figure 7 plots the awareness of 72% of the surveyed occupants of this important fact.

In most of the cases, the highest cooling load of buildings comes from windows, where conductive and irradiative heat are transferred into a building. In recent years, residents have been focusing more on window decoration than on window area, frame material and glazing type, which significantly affects building thermal comfort. Most people in Al-Amarah City still use single-clear glass windows, which negatively affect thermal comfort considering their high transmissivity [22]. Figure 8 presents the popular glazing types used for residential buildings in the city.

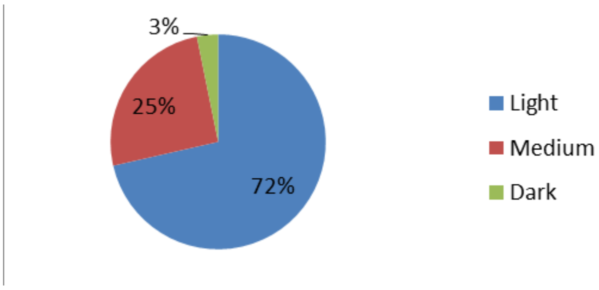


Figure 7 Colors of external walls.

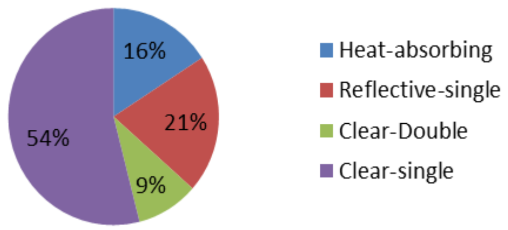


Figure 8 Popular glazing types of windows.

Building orientation also significantly affects heat transfer through windows because most windows are located at the front of buildings; therefore, building orientation must be selected carefully (Figure 9).

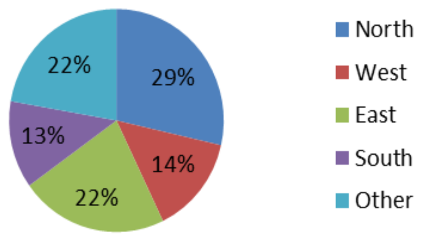


Figure 9 Orientation of residential buildings.

4 Results and Discussion

In general, the standard of living of occupants determines the nature of the household and the type of construction materials used. The economic situation of the occupants of the city is unequal. Most of them are middle- or low-class households. Thus, most materials used for construction are simple. In this study, the results were calculated by comparing the elements (roof, external walls and windows) of the households separately.

To select the optimal construction, the roof and external walls of different households were compared depending on the type of main building layers and the finishing layer materials used in popular construction techniques in the city (Figure 10).

For the windows, only the type of glass was compared in order to simplify the calculations. Other influencing factors, such as window orientation, frame type and existence of shading, were disregarded.

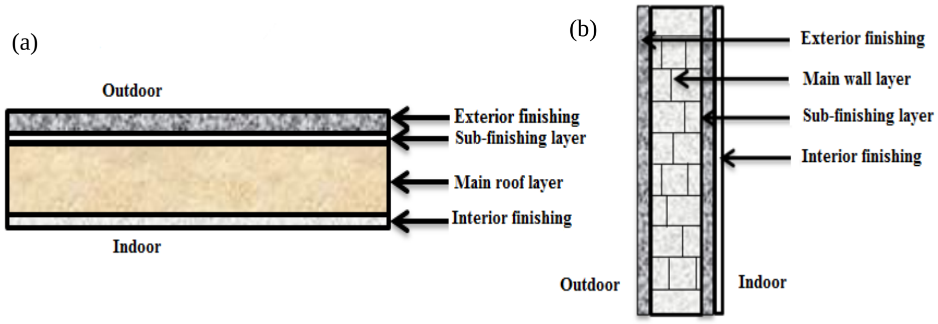


Figure 10 Schematic of the main layers of (a) roof and (b) external walls.

The calculation results can be summarized as follows. This study was conducted in Al-Amarah City, Iraq (31.84° latitude and 47.14° longitude), and all data were estimated on 21 July 2018 at 15:00. The assumptions were as follows: the area of each element (roof, wall and window) was 1 m^2; the daily temperature range was 14 °C; the indoor and outdoor design temperatures were 25.5 °C and 50 °C, respectively.

4.1 Roof Cooling Load

The cooling loads of the different household roofs are summarized in Table 1. The combination of clay–insulation–bricks–cement mortar produces the lowest cooling load given the utilization of clay as the roofing material. The low thermal conductivity, low cost and wide availability of clay are the reasons behind its use in 69% of households.

Modern construction roofing materials, such as Ezukam and concrete tiles, cause high cooling loads. These materials must be supported by additional insulating layers, such as cork, felt and fiberglass, for improved efficiency. However, such addition may increase the cost of roofing. The use of fiberglass with an air gap can be a solution to reducing cooling load through the roof [26]. Moreover, suspended ceilings can decrease the heat gained through roofs significantly and enable considerable energy savings, especially for concrete roofs [27].

The U-values of roof combinations remain high; this issue was noted clearly in all the buildings covered in the present study. Most of the studied roofs had gypsum mortar (L = 2-3 mm, k = 0.72 W/m.K) as a fifth layer; this material is excluded in Table 1 for ease of comparison of the remaining layers. New combinations can be proposed; such combinations can have an additional cork layer (L = 3-5 cm, k = 0.04 W/m.K), which can significantly reduce the overall cooling load (Table 2).

Table 1 Roof layer construction (from outdoor to indoor) [25].

Layer 1 **L (mm)** **k (W/m. K)**	**Layer 2** **L (mm)** **k (W/m. K)**	**Layer 3** **L (mm)** **k (W/m. K)**	**Layer 4** **L (mm)** **k (W/m. K)**	U_{Roof} ($W/m^2.K$)	Q_{Roof} (W)
Clay L = 70, k = 0.25	Insulation (nylon) L = 1, k = 0.049	Fired clay bricks L = 110, k = 0.54	Cement mortar L = 20, k = 1.08	1.912	**96.75**
Clay L = 70, k = 0.25	Insulation (nylon) L = 1, k = 0.049	High-density concrete L = 150, k = 1.49	----------------	2.494	**126.2**
Concrete tiles L = 40, k = 0.85	Felt L = 20, k = 0.35	Fired clay bricks L = 110, k = 0.54	Cement mortar L = 20, k = 1.08	3.058	**154.74**
Ezukam L = 4, k = 0.24	Cement–sand mixture L = 50, k = 1.2	Fired clay bricks L = 110, k = 0.54	Cement mortar L = 20, k = 1.08	3.546	**179.43**
Concrete tiles L = 40, k = 0.85	Felt L = 20, k = 0.35	High-density concrete L = 150, k = 1.49	----------------	4.878	**246.83**
Ezukam L = 4, k = 0.24	Cement–sand mixture L = 50, k = 1.2	High-density concrete L = 150, k = 1.49	----------------	6.25	**316.25**

Table 2 Proposed layer combinations for roofs (from outdoor to indoor) [25].

Layer 1 **L (mm)** **k (W/m. K)**	**Layer 2** **L (mm)** **k (W/m. K)**	**Layer 3** **L (mm)** **k (W/m. K)**	**Layer 4** **L (mm)** **k (W/m. K)**	**Layer 5** **L (mm)** **k (W/m. K)**	U_{Roof} ($W/m^2.K$)	Q_{Roof} (W)
Clay L = 70, k = 0.25	Insulation (nylon) L = 1, k = 0.049	Cork L = 30, k = 0.04	Fired clay bricks L = 110, k = 0.54	Cement mortar L = 20, k = 1.08	**0.786**	**39.77**
Ezukam L = 4, k = 0.24	Cement–sand mixture L = 50, k = 1.2	Insulation (nylon) L = 1, k = 0.049	Cork L = 30, k = 0.04	High-density concrete L = 150, k = 1.49	**1.075**	**54.39**

4.2 External Wall Cooling Load

Table 3 shows that external walls built with thermo-stone bricks as the main building material have a low cooling load. Thermo-stone bricks have excellent thermal properties and insulation behavior; they reduce heat gain by up to 33% in comparison with fired clay bricks and thus are ideal for wall construction [28].

Table 3 Wall layer construction (outdoor to indoor) [25].

Layer 1 **L (mm)** **k (W/m. K)**	**Layer 2** **L (mm)** **k (W/m. K)**	**Layer 3** **L (mm)** **k (W/m. K)**	**Layer 4** **L (mm)** **k (W/m. K)**	U_{wall} **(W/m^2.K)**	Q_{Wall} **(W)**
Cement mortar L = 20, k = 1.08	Thermo-stone bricks L = 240, k = 0.21	Cement mortar L = 20, k = 1.08	Gypsum mortar L= 2, k = 0.72	0.845	**19.94**
Ceramic tiles L = 8, k = 1.38	Thermo-stone bricks L = 240, k = 0.21	Cement mortar L = 20, k = 1.08	Gypsum mortar L = 2, k = 0.72	0.855	**20.18**
Stone tiles L = 50, k = 1.13	Bricks L = 240, k = 0.54	Cement mortar L = 20, k = 1.08	Gypsum mortar L = 2, k = 0.72	1.961	**46.28**
Cement mortar L = 20, k = 1.08	Bricks L = 240, k = 0.54	Cement mortar L = 20, k = 1.08	Gypsum mortar L = 2, k = 0.72	2.065	**48.73**
Marble L = 20, k = 1.6	Bricks L = 240, k = 0.54	Cement mortar L = 20, k= 1.08	Gypsum mortar L = 2, k = 0.72	2.082	**49.14**
Ceramic L = 8, k = 1.38	Bricks L = 240, k = 0.54	Cement mortar L = 20, k = 1.08	Gypsum mortar L = 2, k = 0.72	2.121	**50.06**
Cement mortar L = 20, k = 1.08	Concrete blocks L = 200, k = 1.4	Cement mortar L = 20, k= 1.08	Gypsum mortar L = 2, k = 0.72	5.473	**129.2**

The calculations also show that concrete blocks are a poor choice for wall construction because they produce the highest cooling load among the compared materials given their high thermal conductivity. Exterior finishing materials have approximately the same thermal insulation impact, but the use of internal wall covering materials (such as 10-mm polystyrene thermal insulation) with high thermal resistance can minimize the cooling load of the walls and thus reduce electrical energy consumption by approximately 47% [29].

4.3 Window Cooling Load

Windows are the most critical element of building envelopes. They are important for natural lighting and ventilation of buildings and for decoration. In most Iraqi buildings, the cooling load caused by windows is higher than that of the roof and walls. Solar radiation is transmitted through the windows to the conditioned space in two ways, namely by conduction and by irradiation. The most important factors to be considered in selecting windows for buildings are glass type and frame material. Table 4 lists that reflective glass had the lowest cooling load among all glass types mentioned in the survey. This finding is due to the high shading coefficient of this type and its excellent reflectivity to the incident beam-solar radiation.

Table 4 Cooling load through different glazing types [22].

Glass type	**Shading factor (SC)**	**SCL at 15:00 and E-orientation**	**U_{glass} ($W/m^2 K$)**	**Q_{window} (W)**
Reflective-single	0.45	123	5.48	**99.68**
Double-glazed clear	0.81	123	3.59	**128.35**
Heat-absorbing	0.73	123	5.48	**133.68**
Single-glazed clear	0.94	123	5.48	**159.51**

These considerations are influenced by certain variables, such as building type, window orientation, climate (weather, temperature and wind speed) and microclimate (shading by adjacent buildings and trees).

5 Conclusions and Suggestions

This study involved a survey on the real construction of residential buildings in Al-Amarah City. It examined the cooling load gained from construction elements (roof, walls and windows) and concludes that correct selection of construction materials and other factors can decrease the cooling load of buildings to reasonable levels.

In accordance with the study outcomes, the following recommendations can be made to reduce cooling load through the building envelope and possibly decrease electrical energy consumption.

1. Fired clay bricks supported by I-section iron beams (jack arch ceiling) are preferrable as the main construction materials for roofs.
2. Clay or soil (typically mixed with straw) are the optimal roofing materials among the compared materials. Furthermore, the addition of insulation layers such as cork, fiberglass and felt is necessary for improved roof thermal effectiveness.
3. The use of thermo-stone bricks for external walls, especially on high floors, is an excellent option given their light weight and good thermal properties.
4. The use of a light-colored coating on external building layers (roof and walls) must be emphasized given its high reflectivity, which reduces the cooling load.
5. Covering the interior of the roof and walls using suitable cladding materials with high thermal insulation considerably reduces heat gain.

6. Reflective glass must be used for external windows, with focus on minimizing the window area and framing it using low thermal conductivity materials, such as PVC.
7. The use of passive techniques, such as installing shelters, exterior shading (industrial and/or natural means, such as trees), overhangs and light-colored window curtains, reduces the incident beam-solar radiation on the building envelope.
8. If possible, a north orientation must be selected for buildings for minimal cooling load.

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