"A Comparative Study on the Cost Effectiveness of AAC Blocks and Conventional Bricks in Residential and Public Building Construction"

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ABSTRACT: The selection of suitable building materials is an important factor in achieving economical, energy-efficient, and sustainable construction. Conventional materials such as red bricks are widely used in residential and public buildings because of their availability and established construction practices. However, their use can contribute to environmental impacts and may provide limited thermal insulation compared with modern walling materials. The increasing demand for energy-efficient buildings has therefore encouraged the use of alternative materials such as Autoclaved Aerated Concrete (AAC) blocks.

This study evaluates the cost effectiveness and environmental performance of AAC blocks in comparison with conventional red brick masonry. The research considers important parameters such as material cost, labour requirements, construction time, energy consumption, thermal performance, and environmental impact. The performance of the two wall systems is assessed for residential and public/commercial buildings to determine their suitability as sustainable construction alternatives.

AAC blocks are lightweight and possess better thermal insulation properties, which can reduce heat transfer through the building envelope. Improved thermal performance can consequently decrease the energy required for heating and cooling, resulting in lower operational costs over the service life of a building. In addition, the reduced weight of AAC masonry may contribute to savings in structural components, transportation, and handling.

The study indicates that the adoption of AAC block wall systems can provide significant economic and energy-related benefits. The analysis suggests that initial construction costs can potentially be reduced by approximately **14.3% for residential buildings and 9.4% for commercial/public buildings**. Similarly, energy consumption and associated operational costs may be reduced by approximately **23.6% and 24.6%**, respectively. These findings demonstrate that AAC blocks can be a viable alternative to conventional red bricks for modern building construction.

Therefore, the use of AAC blocks can contribute to the development of more economical, energy-efficient, and environmentally responsible buildings. The study highlights the importance of selecting construction materials based not only on their initial cost and availability but also on their long-term energy performance, environmental impact, and overall life-cycle benefits.

Keywords: AAC Blocks, Red Bricks, Cost Effectiveness, Energy Efficiency, Thermal Performance, Sustainable Construction, Building Materials, Building Envelope.

INTODUCTION: Thermal comfort and energy efficiency are two of the main approaches to reduce energy consumption in buildings. Buildings need to have a heating and a cooling system to reach the thermal comfort zone to occupy any space. Building envelope is one of the main factors that affect the indoor thermal comfort (Hashemi, 2015). Figure 1 is a representation of the sources of heat leakage in buildings by component . Walls and windows are considered the main source of heat leakage in a building (Duanmu, 2017).

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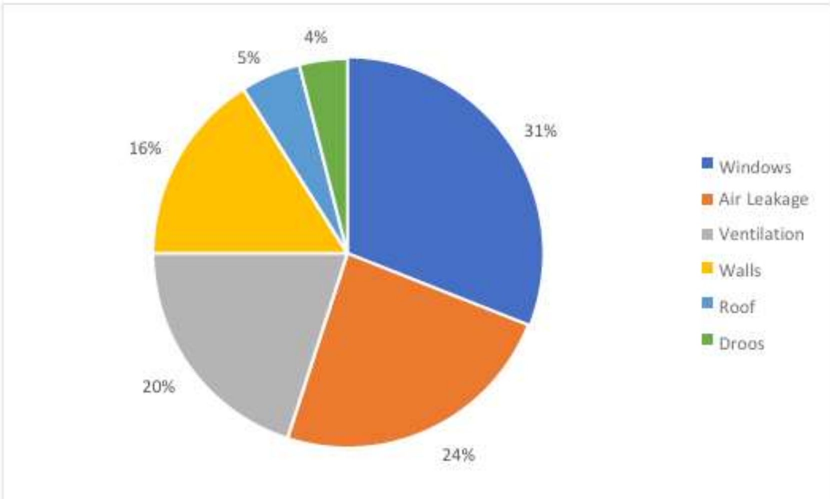

Figure: Sources of air leakage in buildings (Duanmu, 2017)

The air leakage through these sources cause the building in thermal discomfort for the occupants which leads to increase in demand to the heating and the cooling systems which increase the energy consumption of the buildings as well. Figure 2 demonstrates the total percentages of energy consumption in buildings. (CAPMAS, 2018).

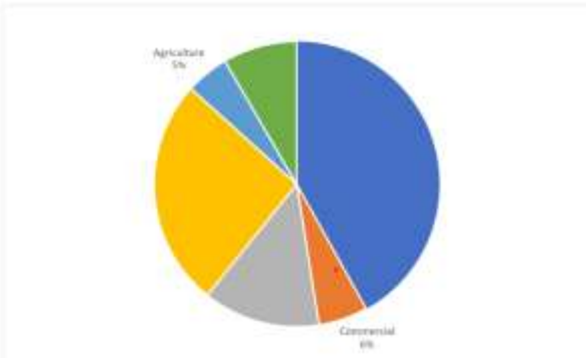

Figure 2: Energy consumption (CAPMAS, 2018)

The use of unsustainable building materials affects the environment and causes damages to it and causes an increase in the cooling and heating loads due to indoor thermal discomfort as shown in Figure 2. Building materials emits a lot of carbon dioxide (CO_2). There has been a strong evidence that the global climate is warming (Azouz, 2017). This change in the climate globally is due to number of factors, such as the greenhouse gases and others. Climate change must be addressed to avoid escalation of the problem and causing more harm to the environment. The CO_2 emission is one of these and it is affecting our environment negatively (Azouz, 2017). Furthermore, the construction industry is sharing a significant portion of this impact due to the huge emissions of CO_2 throughout the process of manufacturing and implementing the construction building materials. In addition, the construction works has been dominated by the use phase of the structure which accounted to almost 90% of the total environmental impacts which is being released by the construction works (Elattar, 2014).

The use of building materials in the construction industry has a significant effect on the cost and the environmental quality of the building experience. The construction sector is taking a good portion of the economy; however, there is a shortage in the sustainability of the buildings. The building sector has increased, the percentage of the total number of buildings constructed from 2006 till 2017 has reached 45.6% (Barakat, 2018).There are some efforts to improve the sustainability of the building sector and the materials used which will improve, consequently, the quality, affordability, sustainability and experience of the built environment (El-Kabbany, 2013). Knowing that the concept of go-green is one of the main topics that of great concern to the researchers worldwide, it shows its significance. In the past few decades, a lot of changes have happened to the construction industry which changed that way we see the environment. Some of these changes affect how we target to solve environmental problems or should solve it. Building envelop is one of the major and significant factors that contributes in these environmental issues. Additionally, the construction and finishing phase is becoming a crucial aspect of the shift to green buildings and design. Since these issues are diverse and have many different dimensions regarding the impact on the environment, the need for deeper analysis on the effect of building envelops on the energy consumption and total construction initial cost is significant (Azouz, 2017).

There are some initial considerations towards energy conservation by using more uncommon building envelops. In the residential areas, a double wall red brick with air gap is usedwhich will decrease the energy consumption more than the traditional single wall system, but it still is not sufficient to make a huge difference. However, the traditional building materials are yet being used.

THE OBJECTIVES TO REACH THE MAIN GOALS OF THIS RESEARCH ARE

Identify the main wall systems that are being used in the new capital

- Calculate the total brick and glass quantities of each building and compute the percentagesof savings in the total initial construction costs.

- Calculate the U-Value and the average weighted U-Value of each wall system
- Simulate the two buildings on a thermal performance tool- Design Builder

LITERATURE REVIEW:

Lumia, 2017 The need to reduce the greenhouse gasses and energy consumption in the building sector are major issues that needs to be solved. The Passive house and net zero emission buildings are concepts that are being introduced to the building sector. These concepts inspire the need to reduction of the heat that is being transfer from the building envelope to the indoor interior space. Currently, the building sector is moving towards the energy efficient designs that includes many factors. These factors are not only exclusive to the thermal transmission of the heat or the thermal performance of the building but also the reduction in the use of materials that consumes a lot of energy during the production and in the use phase.

Palumbo, 2015 The need for criteria to enhance the building sector is spreading widely in many countries worldwide in order to decrease the environmental impacts, energy consumption and cost. There are many certificates that evaluate the building and consider to which level of Green it is as mentioned. Building materials choice is a key factor in this evaluation. There are many buildings that applied this concept of going Green in both the design phase of theproject and the construction phase. There are international and national Green certificates. LEED is one of the international certificates that evaluate the performance of the building.

A. Mohamed, 2011 There are some requirements by the LEED for the existing buildings to be certified. There are some initiatives to change homes into more sustainable buildings. LEED for homes is one of these initiatives that works in the residential buildings industry.

Sakr, 2017 shows a comparison between Code-home and LEED Home 2009 as a way to reflect energy savings in green buildings due to reduction in energy consumption. This comparison shows that the initial cost of the Code home is less than the LEEDhome; however, the energy consumption of the code home is higher than that of the LEED home.

Marincic, 2014 Wall systems are different and there are many types of blocks that are being used widely as a construction material. The choice of wall system differs from one project to another according to the project concept and budget (see section 2.6). There are some blocks that are used widely in Egypt in both the residential and the commercial projects which are clay bricks, Hollow blocks, and other concrete blocks. Each one of these has its own uses and properties whichmeans that the local situation guides which brick to be used.

El-Kabbany, 2013 Besides, the development of new building materials contributes to the environment a lot since their use will reduce the energy demand of the building, reduction of the waste generation, beneficial health, environmental aspects and the embodied energy as well. The use of new materials is increasing nowadays. There are some other building materials that are being used commercially but they are not common such as Autoclaved aerated concrete, Non- autoclaved aerated concrete, Cellular lightweight concrete and straw bale.

El-Kabbany, 2013 The field of green buildings, eco-friendly environment and sustainable construction are gaining a lot of interest in the research field and the construction industry in Egypt. This is due to the gap between the energy consumption, the rapid urbanization and high pollution rates. The realchallenge is how to promote and raise people awareness towards the use of new building materialsfor the benefit of the environment. Still the construction sector doesn't remarkably change on the common practice level which lead to shortage in the movement towards sustainability and sustainable materials. However, there are some projects that started to be more aware of the problem and consider the long-term benefits of the introduction of new building materials. In addition, there are many factors that influence the move towards sustainable construction such as the design strategy, the choice of materials, the selection of the best techniques for construction,and minimizing energy consumption

El-Nadi, 2016 To illustrate, this depend on thewalls, windows, floors and roofs of buildings and their ability to impede any heat loss or gain froma building to the environment. These sources are accounted to 50% of energy loss in the commercial and residential buildings in Egypt. So, insulated walls will have a less U-Value than walls which are poorly insulated, which means to design an energy efficient building, the exteriorof the building is very important. This element affects the performance of a building in many factors. These factors include natural ventilation, heat transfer, residence well-being, and filteringdaylighting.

Krivak, 2013 Furthermore, the type of building structure varies, and each building structure has its own thermal transmittance value. Table 10 shows the different types of building structures and their corresponding thermal value.

Wanas, 2012 shows the thermal properties regarding the most commonly used building materials which is Bricks in Egypt. The heat transfer values for the common wall building materials has been a subject to the researchers in the past years. The data for the heat transfer of the exterior walls can be estimated since the U-value of materials are known or can be measured. It lists some properties for the building materials including the density, heat capacity, and thermal conductivity.

SIMULATION WORK

FINANCIAL ANALYSIS

Construction Materials cost

Detailed area calculations for each building that has been used in the simulation were conducted. These calculations included the initial costs of each building material such as bricks, mortar, paint, concrete, and steel. The cost estimation of each building, residential and commercial, was divided into two main segments. The first section included the structural cost of each wall system (Red brick and AAC). This section contained the concrete and steel construction costs for the footings, columns, beams, slabs and cores. The difference in cost between each wall system is due to the lightweight of the AAC blocks which decreases the dead loads on the buildings. The second section is the construction initial costs of each brick itself and the finishing materials as well from mortar and paint.

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Each building was divided into zones, then calculating the total area of each zone and the wall parameter to get the wall areas added to them a percentage of waste. After summing all the areas up of each building using the plans, sections and elevations, costs of each item are calculatedto provide a total cost of each building using a specific wall system. Then, the total cost of each building was subtracted to get the difference between each wall system initial construction cost. This comparative cost analysis gives the percentage of savings in each item's initial cost as well as the percentages of savings in the total cost of the buildings.

Table: Prices of Building Materials (Ministry of Housing, 2019)

Type	Item	Unit	Price (LE)	Unit Price (M2)	Notes
	AAC Blocks	M3	1032	15-30	25cm,IncludingTaxes And transportation
	Red Brick	M3	750	25-28	25cm, Including Taxes, And transportation
Construction	Cement	Ton	950	--	--
	Steel	Ton	12500	--	--
	Concrete	M3	--	320	The Military provides the cement, water and Labor cost
	Mortar (Exterior)	M2	--	45	--
	Mortar (Interior)	M2	--	22	--
Finishing	Paint (Economic Matt, Interior)	Gallon	115	25.5	2-3coats,Jotun
	Paint (Fenomastic, Matt, Interior)	Gallon	240	25.5	2-3coats,Jotun
	Primers (Economic)	10 Liters	150	19.5	2coats,Jotun
	Primers	10 Liter	180	18.5	Fenomastic
	Base	15Kilo	90	6	3 coats, Jotun prefix
Fenestration	Glass 1	M2	--	200	Single clear
	Glass 2	M2	--	500	Double Reflective

MODELS DEFINITION

Two different buildings with different functions were used in the simulation, one residential and the other is commercial according to the avaliable plans. The master plan of each building zones is presented in the next section. Simulation models are adjusted according to these master plans using detailed architectural plans, elevations and sections. HVAC systems, orientations, window to wall ration (WWR) were selected for each building and applied for both the traditional and the unconventional building envelope

Building 1- Residential Model

The first site location is in area which a residential complex. The masterplan of this area is divided into four main parts as shown in the Figure 37. The highlighted part is the one that was used in the simulation and it is about 1225 m2 per floor. This building is a multistory residential complex where each floor has seven apartments with three different area and prototypes. The first prototype (P1) is a three-bedroom apartment which is approximately 140m2 and each floor has four flats of this area. The areas of each zone of this prototype are demonstrated in the Table

Figure : Site location 1 Masterplan

Table : Prototype 1 Area

Typical Building Zones(P1)	Floor areas(M2)	Wall perimeter (ML)	Wall Areas (M2)
Reception	35.4	25.7	70.675
Kitchen	12.35	13.4	36.85
Gues ttoilet	3	5	13.75
Bedroom1	22.26	13.7	37.675
Master bedroom	21.73	16.7	45.925
Master bathroom	4.86	4.5	12.375
Dressing room	5.67	9.6	26.4
Bed room 2	16.4	12.1	33.275
Lobby space	12.1	--	--
Bath room	7.37	4.4	12.1

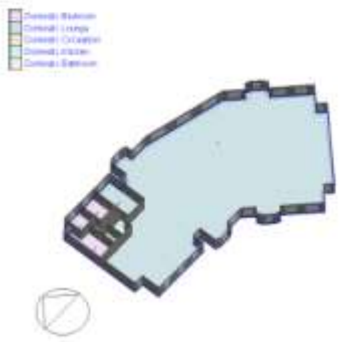
Table : Prototype 2 Areas

Typical Building Zones(P2)	Floor areas (M2)	Wall perimeter (ML)	Wall Areas (M2)
Reception	30.75	19.1	52.525
Kitchen	10.15	11	30.25
Bedroom1	16.3	14.3	39.325
Master bedroom	18.4	13.9	38.225
Lobby1	3.6	7.6	20.9
Balcony1	3.12	4.6	5.045
Balcony2	2.66	1.9	1.52
Lobby2	6.3	--	--
Bath room	6.6	7.3	20.075

Table : Prototype 3 Areas

Typical Building Zones(P3)	Floor areas (M2)	Wall perimeter (ML)	Wall Areas (M2)
Reception	30	19.6	53.9
Kitchen	9.6	9.35	25.7125
Guest toilet	2.125	2.95	8.1125
Lobby1	13.52	15.6	42.9
Bedroom1	14	8.7	23.925
Master bedroom	22.6	15.1	41.525
Master bathroom	4.8	6.8	18.7

Dressing room	5	2	5.5
Bedroom2	18.5	14.2	39.05
Lobby2	5.7	--	--
Bathroom	4.9	6.4	17.6



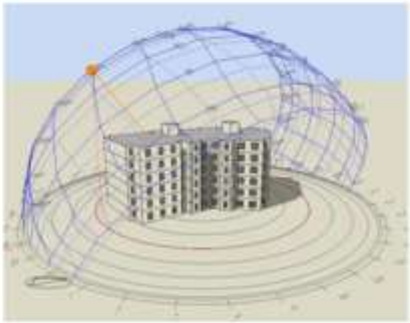


Figure : Typical Residential Floor Plan **Figure : Simulated Residential Model**

Building 2- Commercial Model

The second site location is in the commercial hub area which consists of cinema complex, mall complex, hyper markets, car agencies and banks which is around 82100 m2. The masterplan of this area is shown in Figure 8. The highlighted part is the Mall that was used in the simulation and it is around 3990 m2 per floor. This building is a two-story building consists of different commercial spaces and uses.

Figure : Site Location 2 master plan

Table : Commercial building area

Building Zones per floor	Floor areas (M2)	Wall perimeter (ML)	Wall Areas (M2)
Commercial zones	3000	462.4	2775
Storage room	80.94	39.8	238.8
Toilets	124	55	330
Services/food preparation	85	41.2	247
Circulation/corridor	505.89	361.5	2169
Cores	196	84	504
Internal walls	--	188	1128

Partitions	--	300	1800
Extra partitions	--	121	726

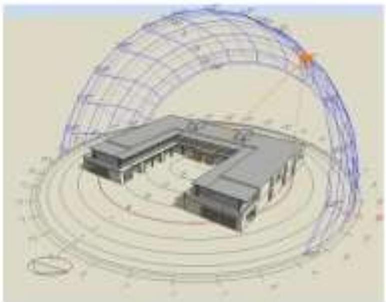



Figure : Simulated Model for Commercial Building Figure: Floor plan for commercial building

RESULTS AND ANALYSIS

This chapter represents the finidings and results of each wall system after carrying out each simulation. It is divided into three sections as follows:

I. Finaincial study of each building (residential and commercial) using the two building systems (Red Brick and AAC Blocks) and a comparison of the results.
II. Simulation results from the original building wall systems and the alternative wall systems from two sities.

The studies done on each wall sytem simulations revealed that one of the main building components that leaks heat is the wall system. Also, the fenestrations were indicated as one of the reasons for the increase in energy consumption due to the leakage of heat flow from the outdoors to indoors. The total energy consumption of the original wall systems, Red brick wall systems, is higher than the alternative wall systems, AAC blocks. This difference in energy consumption is around 23.6% for the residential model and 24.6% for the commercial model.

The second part is the financial analysis which includs the initial construction cost of each wall system.

FINANCIAL ANALYSIS

For the financial analysis part, some equations were used based on the Net Present value (NPV). The cost of the wall systems used in simulation were compared to the long-term investments over a period of 14 years (see section 3.4.1). The interest rate which is 15.57% as well as the electricity tariff were assumed to be fixed over this period of analysis. The benefits of this analysis is to show the difference between investing a small amount of money as an intial cost which in this case the Red brick wall systems and investing larger amount of money which is in this case the AAC blocks but gaining on the long run. The equations used to calculate the long- term investment in the four wall systems are as follows (Mahdy, 2016):

$S1 = D1 \times (1 + i) N$ & $S2 = (1 + i)N-1 / (i \times D2)(3)$

Where

S1 & S2 = Money after N amount of time RS

D1 &D2 = Difference between the costs RS

N = Number of investment years in bank Number

I = Interest Rate of the bank %

Savings in Steel and Concrete

Steel and concrete are two of the main components in any building skeleton. The savings in steel and concrete reduces the over all initial construction costs as mentioned

CONCLUSION

This study has conducted an analysis of the effect of different wall systems and fenestrations on the indoor environmental quality. A comparison between the traditional clay brick and AAC wall systems was conducted to evaluate their performance to the standards. In the simulation four different wall systems were used, two of the original wall systems in two buildings. The simulation was done based on the recommendations of the EREC taking into account the WWR, shading, glass types and SHGC. Also, a financial analysis was conducted to evaluate each of the four simulated wall systems and determine the most cost-effective wall system regarding the initial cost and the running cost. Based on the building envelops used, the environmental conditions and weather data files, building finishing materials, and other simulation parameters taken in consideration in this study, a summary of all the findings with conclusions can be stated and categorized into two categories.

CONCLUSIONS OF THE CONSTRUCTION PHASE

1. AAC blocks takes less mortar due to fewer number of joints because of the size of the block is larger. AAC blocks are much durable than the clay brick and less time consuming.

2. The study revealed that the savings in the construction components such as cement in mortar, concrete, steel, labor, and finishing materials compensate for the extra cost of the AAC blocks.
3. AAC blocks initial construction cost is less than that of red bricks.

RECOMMENDATIONS FOR FUTURE WORK

This section summarized some recommendations and potentials for future work. The simulation results showed some differences in the level of emissions using different wall systems; however, there are some limitations in the simulations of the results. There are some recommendations to overcome these limitations in the future:
Some other parameters should be adjusted in the simulation process to give clearer data such as detailed schedules for lighting in relation with occupancy.

- Using different lighting control units, level of luminance, and dimming controllers in relation with the natural light amount and energy consumption.
- The effect of fenestrations coatings and orientation on the energy efficiency and the effect ofdouble reflective glazing on red bricks performance.
- The effect of different fenestration types on the performance of the red brick with respect tothe AAC blocks.
- The effect of using a single brick with insulation materials on the cost and the thermal performance of the building.
- The calculations of the energy consumption may be conducted to include the level of each flat instead of the building as a whole.
- The interaction between the building envelopes and indoor air quality should be taken in consideration in the simulations. Enhancing the simulation programs to include life cycle cost analysis and to include more
- exchange in data between different tools. This would provide the user with a tool to evaluate different aspects in different phases.
- The effect of protective coatings on the thermal performance is recommended in future work.
- The effect of other types of plastering on the thermal performance of AAC blocks needs to be studied especially the use of ready mix plastering on the durability of the blocks.
- The acoustic and thermal performance of AAC blocks for different zones such as building close to airports should be conducted.
- Further testing on the effect of reducing the aluminum powder and cement content on the AAC blocks and their mechanical properties.
- Most of the sectors are considering sustainability; however, new building wall systems are not that popular.

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