Mansoura Engineering Journal

Volume 41 | Issue 4 Article 13

6-29-2020

Effect of Wall Insulation on Energy Performance of Healthcare Buildings (Case Study Inpatient Rooms in Egyptian Liver Hospital)

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Recommended Citation
Elnahas, Shymaa E.; El-Maadawy, Ahmed E.; and El-Gazawi, Lamis S. (2020) "Effect of Wall Insulation on Energy Performance of Healthcare Buildings (Case Study Inpatient Rooms in Egyptian Liver Hospital)," *Mansoura Engineering Journal*: Vol. 41 : Iss. 4 , Article 13.
Available at: https://doi.org/10.58491/2735-4202.3112

Mansoura University
Faculty of Engineering
Mansoura Engineering Journal

Effect of Wall Insulation on Energy Performance of Healthcare Buildings Case Study Inpatient Rooms in Egyptian Liver Hospital

تأثير عزل الحوائط على أداء الطاقة بمباني الرعاية الصحية دراسة حالة فراغات الاقامة بمستشفي الكبد المصري

Shymaa E. Elnahas, *Ahmed E. El-Maadawy* and Lamis S. El-Gazawi

KEYWORDS:
Inpatient rooms, Wall Insulation, Energy Efficiency in Hospitals

الملخص العربي:- **أصبحت مفاهيم التصميم المستدام والمباني الخضراء غير المستهلكة للطاقة منتشرة عالميا، وأصبح التوجه العام للدولة هو توفير الطاقة في المباني، فالمباني التي تحقق الاستدامة هي الحل الامثل لتحقيق كفاءة الطاقة في مباني الرعاية الصحية المستهلكة بصورة كبيرة للطاقة وفقا لتقارير وزارة الكهرباء والطاقة المصرية، وذلك لتحقيق أفضل بيئات استشفاء. حيث يهدف البحث لدراسة تأثير عزل الحوائط الخارجية لفراغات الاقامة لتحقيق كفاءة الطاقة في مباني الرعاية الصحية ، حيث تختبر الدراسة تأثير الحوائط الخارجية لفراغات الاقامة بمبني مستشفى الكبد المصري علي تحسين اداء الطاقة داخل المبني باستخدام برامج المحاكاة Autodesk Revit and Green Building Studio)) ، فتظهر الدراسة مدي تأثير مواد البناء والعزل علي أداء الطاقة داخل المبني ، يوصي البحث باستخدام الحوائط المزدوجة المعزولة من الطوب واستخدام تشطيبات خارجية كالرخام والجرانيت المعزولة بمواد عزل حراري لتساهم في تقليل استهلاك الطاقة بالمبني .**

Abstract— **Green building and sustainable design are worldwide concepts in architecture. Also, the general trends of the state are focus on energy conservation in buildings, so sustainable buildings are the best choice to achieve energy efficiency in healthcare buildings which greatly use energy according to reports from the Egyptian ministry of electricity and energy. This paper reports on a research that utilized simulation techniques for identifying the most efficient material for external wall of inpatient spaces. This research aims to study the impact of external wall material of inpatient rooms on achieving energy efficiency in healthcare buildings. The research examines the impact of wall materials of inpatient spaces in Egyptian liver hospital to improve the performance of energy by using simulation programs Autodesk Revit and Green Building Studio. Results demonstrated that properties of building walls effect on building energy use. Use of insulated double wall from burn clay block in inpatient spaces of Egyptian liver hospital reduced energy use intensity from [797 to 771] MJ/sm/yr and saved 42000 Egyptian pound per year. The study results of this paper demonstrated the need for insulation of external wall for inpatient spaces to save energy in healthcare buildings.**

Received: (11 October, 2016) - accepted: (26 December, 2016)
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I. INTRODUCTION

After the problem of energy that faces the world, there has been a general trend to save energy. According to the report of the Egyptian ministry, healthcare buildings are one of the most intensive energy use buildings (1). Heat loss or gain from building envelope has a major share in waste of energy, so it is essential to save energy by selecting the proper thermal properties of building walls that play a major role in determining the energy consumption patterns and comfort conditions in enclosed spaces. Strategies of installing insulation in wall achieve energy saving and high performance healing environments, so it's an environmental friendly strategy which has the ability to reduce environmental impact and carbon dioxide concentration (2). This research aims to find out the potential of reducing energy consumption of buildings through the proper selection of wall construction materials and wall surface material. The research examines the effect of the thermal properties of various wall combinations of inpatient rooms on the annual required energy for heating and cooling in healthcare buildings. The research focuses on arriving to the most efficient wall building materials and the most efficient finishing material having a significant effect on the amount of energy consumed by buildings. It is worth mentioning that many previous studies have confirmed the benefits of improving the envelope thermal properties on the consumed energy of buildings. Fang et al. 2014 (3) investigated the effect of wall insulation on the thermal performance of two types of constructed test rooms in China on the hot climate in Chongqing. They concluded that the well-insulated room reduces the required cooling energy by up to 23% compared with the other un-insulated normally constructed room. Thormark (2006) (4) reported that improving the thermal insulation of the building envelope will considerably reduce the energy required to operate the building. Mishra et al. (2012) (5) estimated the optimum thickness of wall insulation materials to reduce the energy consumption of buildings in India in Dehradun which climatic condition is moderate cool winters, warm summers, rainy monsoons and a balmy spring taking into consideration the cost of insulation and energy over the life time of the building. The results of the simulation study carried out by Yoshimi et al (2011) (6) concluded that covering the external walls with vegetation results in reducing the heat gain and loss and consequently lowering the required heating and cooling loads of buildings. Almujahid et al. (2013) (7) examined the thermal performance of real test walls with three different combinations in the arid climate of Riyadh City with the aim of finding out the effect of wall materials on a building thermal behavior. In all studies, there is strong consensus that appropriate treatment of the building envelope is imperative in attaining both comfortable living and working environments, as well as reducing the energy consumption.

1.1. The Problem

Healthcare buildings consume considerable amount of energy. In the same time, most of external wall of inpatient spaces which represent the most significant part of external surfaces of these buildings are not insulated, so they have a major share in waste of energy in these buildings.

1.2. The Aim of Research

This research aims to examine the effect of wall material and insulation wall strategies of inpatient rooms on improving the energy performance of healthcare buildings by using simulation programs to reach an ideal healing environment.

1.3. Energy Efficiency in healthcare buildings

A healthcare building aims to provide best healing environments for patients. The challenge is to reduce energy use without effecting negatively on healing environments quality. Energy efficiency not only saves energy but also enhances the other design goals important to healthcare facilities to contribute to an environmentally conscious building design, and improve the bottom-line performance of the healthcare facility.

II. METHODOLOGY

The study's methodology based on simulation research strategy which tries to recreate some aspect of the physical environment in one of a variety mode, from a digital simulation software to real scale conditions imitation (8). This study investigates the energy performance and cooling loads of Egyptian Liver Hospital with design alternatives of inpatient spaces wall materials by using digital building performance simulation software.

2-1 Case study design

Project title	Egyptian Liver Hospital

Figure 1: Egyptian Liver Hospital (9)

The Egyptian Liver Hospital at Mansoura was selected to be the case study as Dakahlia Governorate Mediates provinces of northern and central Delta to be center to serve the people of other provinces

Site

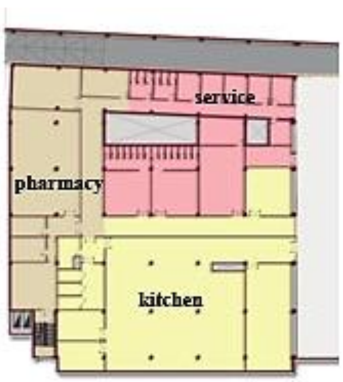
Figure 2: Satalite Map for Egyption Liver Hospital (Goole Earth 2016)

Located 20 km from Mansoura city and 45 km from Damietta

Basic information

✓ Project overview	
Egyptian liver hospital provides medical care for liver patients', liver Hospital building consists of two phases, first phase was built and operated. The second phase is not yet completed.	
✓ Site area	15454 m2
floor area	5756 m2
✓ Type	Liver hospital
Owner	Association of liver patient care
✓ Case study description	
First phase consists of basement and four floors. Ground floor and first includes radiology administration, operations, intensive care digestive system and emergency. Third and fourth floor include inpatient spaces.	

Basic information



Pharmacy

Service

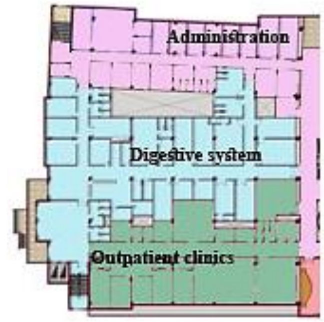
kitchen

Figure 3: Basement floor *(9)*

Labs

Outpatient clinics

Figure 4: Ground floor (9)

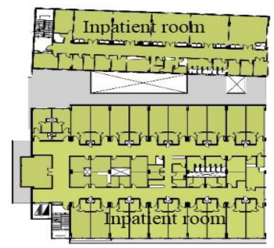


Administration

Digestive system

Outpatient clinics

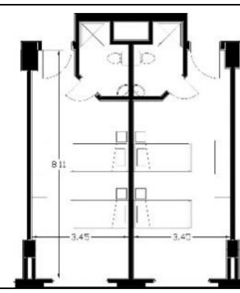
Figure 5: First floor (9)



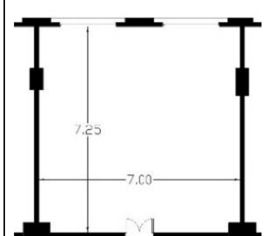
Inpatient room

Figure 6: Second floor and Third floor (9)

2.2 Inpatient rooms parameters



Design A



Design B

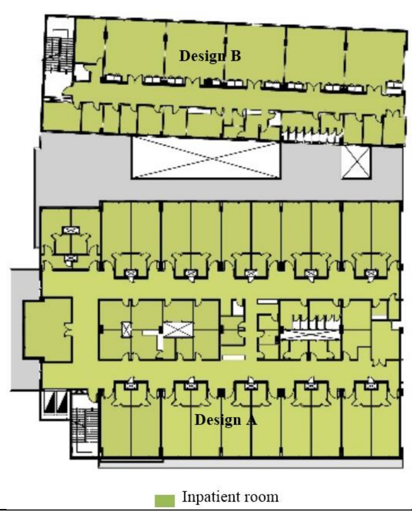


Figure 7: Inpatient units' plan design

There are two models of inpatient spaces. Inpatient rooms with design A is in second floor and third

floor which half of them take the north-east orientation, and the other group take the south-west orientation. Its width 3.45 m and the depth 8.11m with 3.85m height. Inpatient spaces with design B also located in second and third floor, and they take the south west orientation. Its width is 7 m, and its depth is 7.25 m. Inpatient spaces with design A and B have the same external wall material which consist of .25 m of burnt clay brick with .02 m cement, and the external surface material finish is off white plastic paints. floor structure consists of .30 m of reinforced concrete slab and finish surface of material is vinyl sheets. Window glazing consists of .006 m single pane glass with .78 heat gain coefficient. WWR value is 25 %. Inpatient space achieves thermal comfort by using central mechanical HVAC system.

There are two models of inpatient spaces. Inpatient rooms with design A is in second floor and third floor which half of them take the north-east orientation, and the other group take the south-west orientation. Its width 3.45 m and the depth 8.11m with 3.85m height. Inpatient spaces with design B also located in second and third floor, and they take the south west orientation. Its width is 7 m, and its depth is 7.25 m. Inpatient spaces with design A and B have the same external wall material which consist of .25 m of burnt clay brick with .02 m cement, and the external surface material finish is off white plastic paints. floor structure consists of .30 m of reinforced concrete slab and finish surface of material is vinyl sheets. Window glazing consists of .006 m single pane glass with .78 heat gain coefficient. WWR value is 25 %. Inpatient space achieves thermal comfort by using central mechanical HVAC system.

TABLE 1
PARAMETERS OF INPATIENT ROOMS ENVELOPE MATERIAL FOR EGYPTIAN LIVER HOSPITAL.

External envelope materials		
Exterior wall	Thickness	.30 m
	Resistance	.54(m². k/W)
	Thermal mass	36.88 KJ/k
	structure	.005 m plastic paint
		.02 m mortar
		.25 m burnt clay brick
		.02 m mortar
		0.005 m plastic paint
window	Window size	25% WWR
	Glazing	Single glass
	SHG	.78
	Shading	Without shading device
floor	Thickness	.40 m
	Resistance	0.52 (m2. k/W)
	Thermal mass	47.7 KJ/k
	Structure	.02m Vinyl sheets
		.02 m mortar
		.06 m sand
		30cm reinforced concrete
Ceiling	Ceiling for third floor	
	Thickness	.5 m
	Resistance	0.63(m2. k/W)
	Thermal mass	62.02 KJ/k
	Structure	.02 m Mosaic title
		.03 m mortar
		.06 m sand
		.07 m mortar
		.02m damp proofing
		.30 m reinforced concrete
		Gypsum board sheets and titles .60*.60 m
	Ceiling for second floor	
	Thickness	.40 m
	Resistance	0.52 (m2. k/W)
	Thermal mass	47.7 KJ/k
	Structure	.20 m Vinyl sheets
		.02 m mortar
		.06 m sand
		.30 m reinforced concrete
		Gypsum board sheets and titles. 60*.60 m

2.3 Simulation domains

Simulation of energy consumption of Egyptian Liver Hospital are conducted using alternatives of external wall material and external finish material for inpatient spaces in this hospital. In Egypt, common external wall materials are concrete blocks and common burnt brick. It is used either with or without cement plaster as an external finishing surface. The external walls of buildings are usually made of 200mm concrete blocks or 25 cm of common burnt brick or 20 cm of hollow blocks whereas internal walls are made of 100mm, 120mm or 150mm concrete blocks or common brick. Thermal insulation is not usually used as part of the walls construction materials due to its high initial cost in addition to the lack of awareness of its benefits in reducing the heating and cooling energy requirements. For increasing the thermal resistance of external wall materials, some improvements make on the wall material. This includes making double wall with various thicknesses and installing insulation material. Simulation domains of wall material type, thermal insulation and external finish of external walls of inpatient room of case study are described as shown in figure 8.

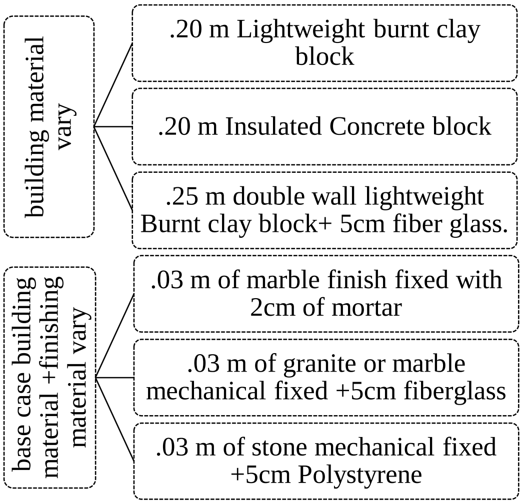


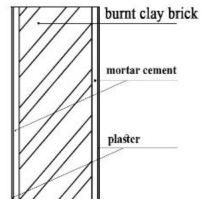
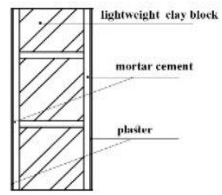
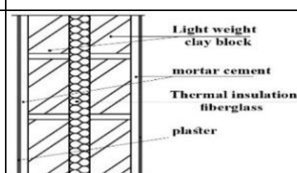
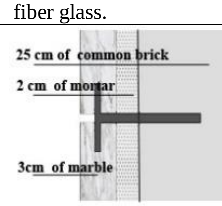
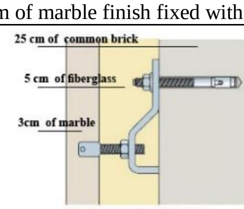
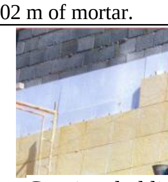
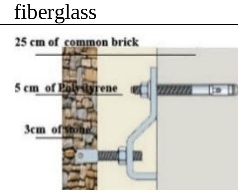
Figure 8: Domain matrix.

TABLE 2
SIMULATION DOMAINS PROPERTIES.

	External wall properties		
	Structure	**Th m**	**K W/m. K**
Case 1	plastic paint	.005	.51
	Mortar	.02	.72
	Light weight burnt clay block	.20	.27
	Mortar	.02	.72
	Plastic paint	.005	.51
Case 2	plastic paint	.005	.51
	Mortar	.02	.72
	Insulated Concrete block	.20	.17
	Mortar	.02	.72
	Plastic paint	.005	.51
Case 3	plastic paint	.005	.51
	Mortar	.02	.72
	Light weight burnt clay block	.10	.27
	fiber glass insulation	.05	.019
	Light weight burnt clay block	.10	.27
	Mortar	.02	.72
	plastic paint	.005	.51
Case 4	marble	.03	2.9
	Mortar	.02	.72
	Common brick	.25	.54
	Mortar	.02	.72
	plaster	.005	.51
Case 5	Marble or granite	.03	2.9
	Fiberglass insulation	.05	.019
	Common brick	.25	.54
	Mortar	.02	.72
	plaster	.005	.51
Case 6	limestone	.03	2.9
	Polystyrene - Expanded	.05	.035
	Bitumen	.005	.016
	Common brick	.25	.54
	Mortar	.02	.72
	plaster	.005	.51

Note ; (k) donated to Thermal Conductivity (W/m. k) which defined as the property of a material to conduct heat. (10)

TABLE3
EXTERNAL WALL INSTALLING.

	External wall
Base case	  Burnt clay brick
	.25 m burnt clay brick
Case 1	  ghtweight burnt clay block
	.20 m Lightweight burnt clay block
Case 2	 Insulated concrete block
	.20 m Insulated Concrete block
Case 3	  Insulated double wall
	.25 m double wall lightweight Burnt clay block+ 5cm fiber glass.
Case 4	  Marble cladding
	.03 m of marble finish fixed with .02 m of mortar.
Case 5	  Granite cladding
	.03 m of marble or granite mechanical fixed +.05 m fiberglass
Case 6	  Stone cladding
	.03 m of stone mechanical fixed +.05 m Polystyrene.

The following table provide details about the assumptions used during energy analysis for healthcare building. These assumptions are based on ASHRAE standards**.**

TABLE 4
ASSUMPTIONS USED DURING SIMULATION PROCESS.

Parameter	Value
Occupancy Schedule	**Health**
People/100 sq. M.	**10**
People Sensible Heat Gain (W/person)	**73**
People Latent Heat Gain (W/person)	**59**
Lighting Load Density (W/sq. M.)	**12.9**
Equipment Load Density (W/sq. M.)	**12.7**
Infiltration Flow (ACH)	**0.1**
Outside Air (ventilation air) Flow Per Person (liters per second)	**13**
Outside Air (ventilation air) Flow Per Area (cubic meters per hour per square meter)	**3.7**
Unoccupied Cooling Set Point (C)	**29.4**

2.4. Simulation software

The research examines energy performance and annual carbon emission of tested hospital along alternative wall material of inpatient spaces in this hospital. Energy simulation required detailed data of building type, location, thermal properties of model project phase and HVAC system. The study depends on Building Information Modeling (BIM) and energy-analysis software to simulate it. These are Revit Autodesk and Green Building Studio software. Revit® BIM software is specifically built for Building, Information and Modeling (BIM), and Green Building Studio is energy-analysis software. Revit software includes features for architectural design, MEP, structural engineering and construction. Revit is a single software application that supports a BIM workflow from concept to construction. Revit is used to design models with precision, optimize performance and collaborate more effectively (11). Green Building Studio enables architects and designers to perform whole-building analysis and optimize energy consumption. It works toward carbon-neutral building designs earlier in the process. Cloud-based energy-efficiency software helps teams achieve sustainable building designs faster and more accurately with powerful energy- and carbon-analysis tools. (12). This simulation study is done under these building performance factors.

TABLE 5
BUILDING PERFORMANCE FACTORS.

building performance factors	
location	*Al Mansoura, Egypt*
Weather station	*1247177*
Outdoor temperature	*Max 41 °c min 3 °c*
Floor area	*5.760*
Exterior wall area	*2.533*
Average lighting power	*13.02*
People	*576*
Exterior window ratio	*.25*
Electrical cost	*.84 p*

III. RESULTS

Improving thermal properties of external wall can help to solve problem of energy consumption and reduce of cooling loads and carbon emission. the choice of wall material which was enhanced by insulation is depend on an accurate result of digital simulation of these cases and its impact on energy performance of tested hospital. Total energy use intensity values expressed in (MJ/sm/yr). Annual electricity use expressed in kwh, and fuel use expressed in MJ and energy cost expressed in pound.

3. 1. Base case

- Parameters of base case

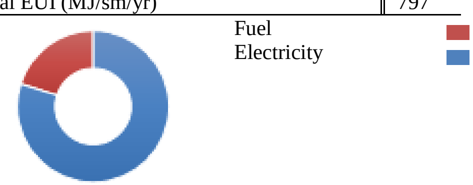
TABLE 6
PROPERTIES OF EXTERNAL WALL FOR BASE CASE.

Properties of inpatient room external wall material		
External wall	Thickness (m)	0.30
	Resistance (m². k/W)	0.54
	Structure	.005m plaster
		.02Mortar
		.25 m common brick
		.02 m Mortar
		.005 m plaster

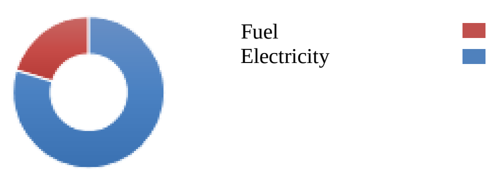
TABLE 7
ENERGY ANALYSIS RESULTS FOR BASE CASE.

Energy Analysis Results

Energy use intensity		
	Electricity EUI (kwh/ sm /yr.)	177
	Fuel EUI (MJ/sm/yr)	161
	Total EUI (MJ/sm/yr)	797



Life cycle energy use		
	Life cycle Electricity Use (million kwh)	30
	Life cycle Fuel Use (million MJ)	27
	Life cycle energy cost	



Annual carbon emissions		
	Electricity use (metric tons /yr)	236
	Fuel use (metric tons /yr)	46
	Net co2(metric tons /yr)	282

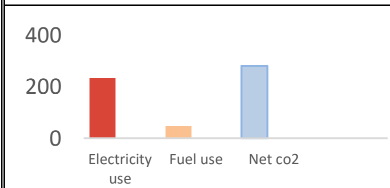


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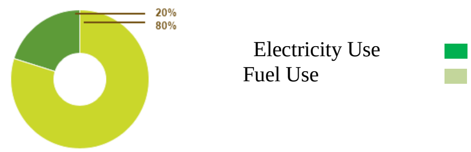
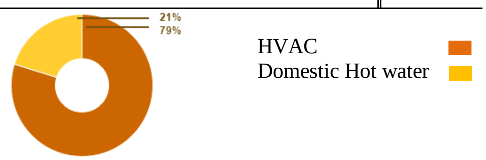
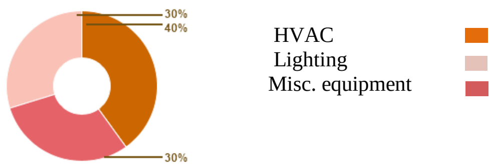
TABLE 7: continued

Annual energy use	Electricity Use (million kwh)	1
	Fuel Use (million MJ)	.9
		
Energy Use Fuel	HVAC (million MJ)	.74
	Domestic Hot water (million MJ)	.19
		
Energy Use Electricity	HVAC (million kwh)	.40
	Lighting (million kwh)	.30
	Misc. equipment (million kwh)	.30
		

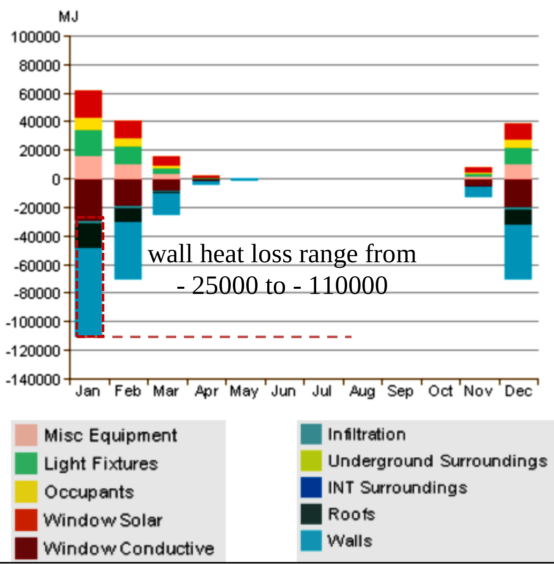


Figure 9: Case 1 monthly heating loads.

The largest negative value for January is walls as shown in figure 9. Therefore, heat loss from conduction through walls represents the largest single monthly demand for heat in January. However, Miscellaneous Equipment (which includes plug loads, computers, office equipment, and so on) reduces the demand for heat, as we notice the demand of wall heat loss range from -25000 to -110000 MJ, so it is needed to examine anther alternatives of wall materials to determine the material which achieve energy efficiency in this hospital.

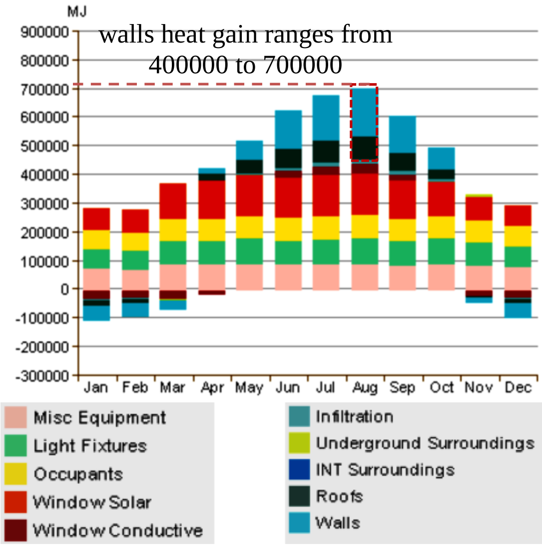


Figure 10: Case 1 monthly cooling loads.

The largest cumulative cooling loads occur in August, with the greatest contribution from walls which heat gains ranges from -400000 to 700000. Therefore, we should improve the wall thermal properties by reducing their thermal conductivity and investing in improvements to the wall insulation that can achieve more energy saving. Energy simulation parameters were selected to focus on studying the performance associated thermal transmittance through external walls of inpatient rooms in hospital. The largest value of monthly heating loads and monthly cooling load largest value is walls, so walls material and its thermal properties have effective impact on energy consumption of this building as shown in this chart in figure 11 that discusses electricity consumption which has the large value in August with the greatest contribution from walls in this month.

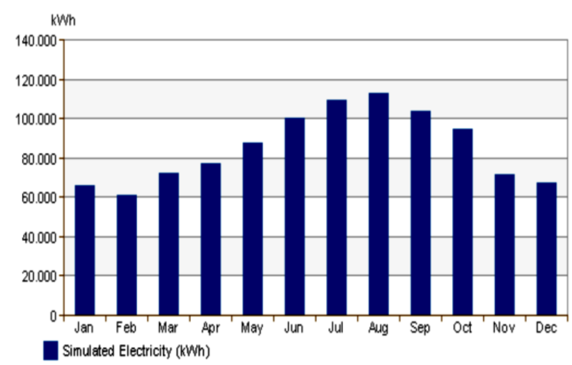


Figure 11: Base case Monthly Electricity use.

This chart displays the hospital estimated electricity usage by month. As the building uses air conditioning, electricity usage increases during the hotter months of the year.

TABLE 8
Energy analysis results

1) cases		2) Base	3) External wall material			4) External finish material		
		0	5) 1	6) 2	7) 3	8) 4	9) 5	10) 6
Description		**.25 m burnt clay brick.**	.20 m lightweight burnt clay block.	.20 m Insulated Concrete block.	.25 m double wall LW burnt clay block +5cm fiberglass.	.03 m of marble finish fixed with .02 m of mortar.	.03 m of marble or granite mechanical fixed + fiberglass.	.03 m of stone mechanical fixed +.05 m Polystyrene.
Energy use intensity	Electricity EUI(kwh/sm/yr)	**177**	175	175	175	176	177	177
	Fuel EUI (MJ/sm/yr)	**161**	150	146	141	155	143	145
	Total EUI (MJ/sm/yr)	**797**	779	775	771	789	778	780
	Sensitivity analysis	**0 %**	2.25%	2.76%	3.26%	1.03%	2.38%	2.13%
Life cycle energy use	Life cycle(Kwh) Electricity Use	**30.664**	30.250	30.205	30.213	30.305	30.246	30.250
	Life cycle (MJ) Fuel Use	**27.902**	25.893	25,173	24.271	26.666	24.443	24.773
	Life cycle energy cost (Million p)	**32.270**	31.453	31.245	31.042	31.678	31.110	31.190
Annual energy Use	Electricity Use (million kwh)	**1.022**	1.008	1.006	1.007	1.010	1.008	1.008
	Fuel Use (million MJ)	**.930**	.863	.839	.809	.889	.814	.826
	Annual energy cost (Million p)	**1.076**	1.048	1.041	1.034	1.055	1.037	1.039
Energy Use Fuel	HVAC (million MJ)	**.7373**	.671	.647	.617	.697	.624	.635
	Domestic Hot water (million	**.193**	.192	.192	.192	.191	.191	.190
Energy Use Electricity	HVAC (million kwh)	**.409**	.399	.399	.399	.401	.401	.401
	Lighting (million kwh)	**.305**	.304	.303	.303	.303	.302	.301
	Misc equipment (million kwh)	**.302**	.300	.299	.299	.300	.298	.299
Net Co2 (metric tons/yr)		**282**	276	273	272	274	273	274

Notes: Electrical cost .84 Egyptian Pound Conversions: 1.0 Kwh=3.6 MJ3413 BTU

- Case 0: .25 m of common brick with plastic finish, thermal resistance 0.54 m2. k/W
- Case 1: .20 m lightweight burnt clay block with plastic finish, thermal resistance 0.54 m2. k/W
- Case 2: .20 m Insulated Concrete block with plastic finish, thermal resistance 1.25 m2. k/W
- Case 3: .25 m double wall LW burnt clay block+.05 m fiberglass, thermal resistance 3.44 m2. k/W
- Case 4: Base case + .03 m of marble finish fixed with .02 m of mortar, thermal resistance 3.44 m2. k/W.
- Case 5: Base case + .03 m of marble mechanical fixed +.05 m fiberglass, thermal resistance 3.22 m2. k/W.
- Case 6: Base case + .03cm of stone mechanical fixed +.05 m Polystyrene, thermal resistance 3.20 m2. k/W

continued on the next page

TABLE 8: CONTINUED

Monthly heating loads

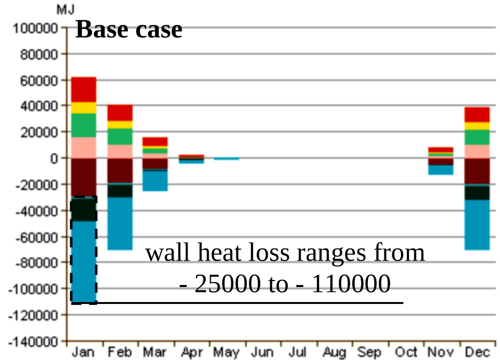


Figure 12: Base case monthly heating loads

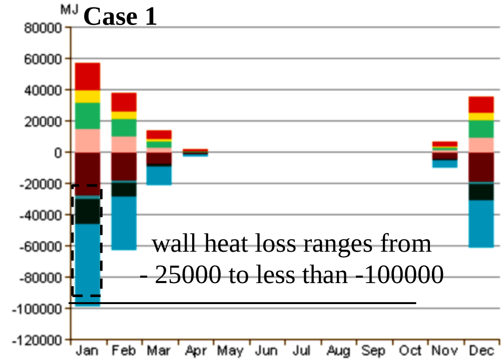


Figure 13: Case 1 monthly heating loads

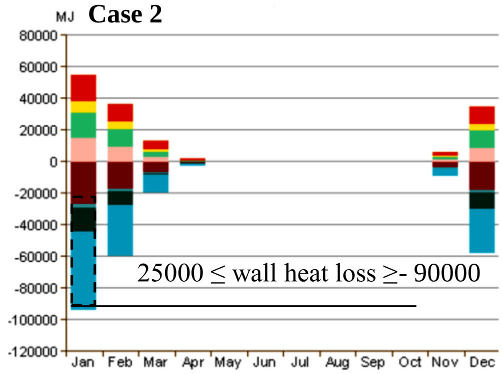


Figure 14: Case 2 monthly heating loads

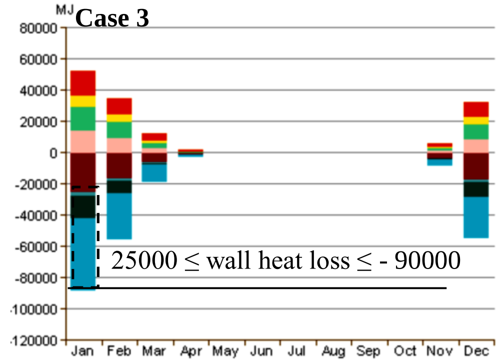


Figure 15: Case 3 monthly heating loads.

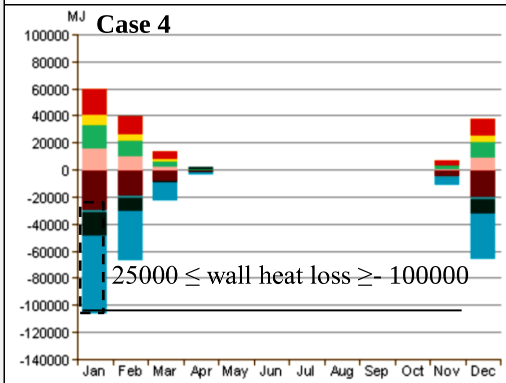


Figure 16: Case 4 monthly heating loads.

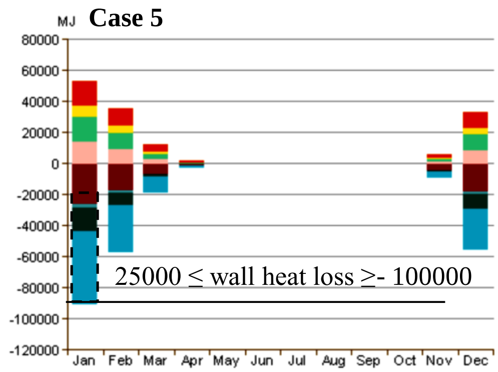


Figure 17: Case 5monthly heating loads

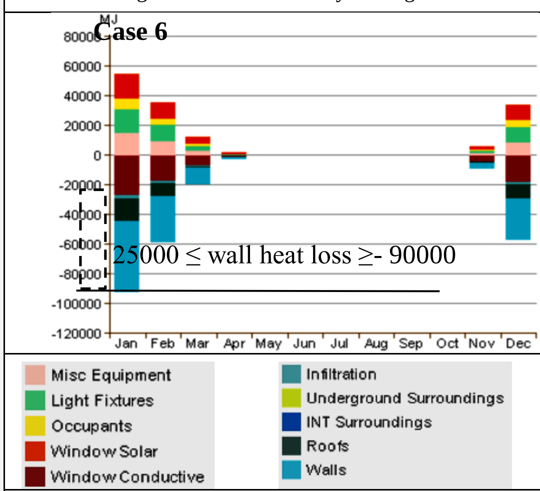


Figure 18: Case 6 monthly heating loads.

The largest negative value for January is walls. In base case heat loss ranges from -25000 to -110000 on the other hand case 3 has the most positive impact in reducing heat loss from walls. Its value ranges from -25000 to -90000. Case 4 does not have a noticeable impact in reducing of heating loads comparing with base case heating loads

TABLE 9
DIFFERENCE BETWEEN MONTHLY COOLING LOADS.

Monthly cooling loads

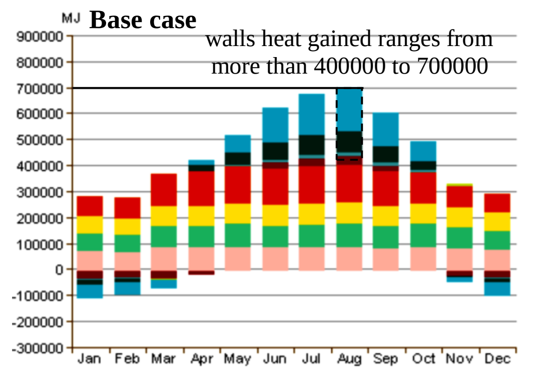


Figure 19: Base case monthly cooling loads.

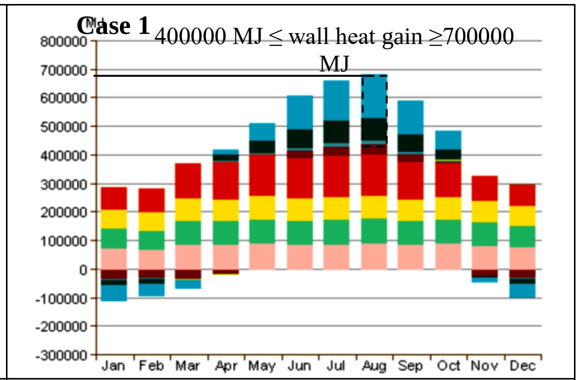


Figure 20: Case 1 monthly cooling loads.

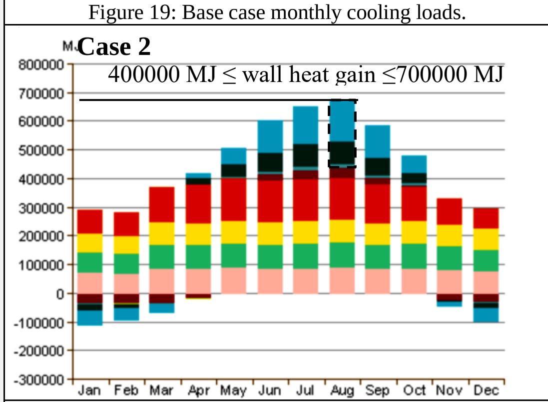


Figure 21: Case 2 monthly cooling loads

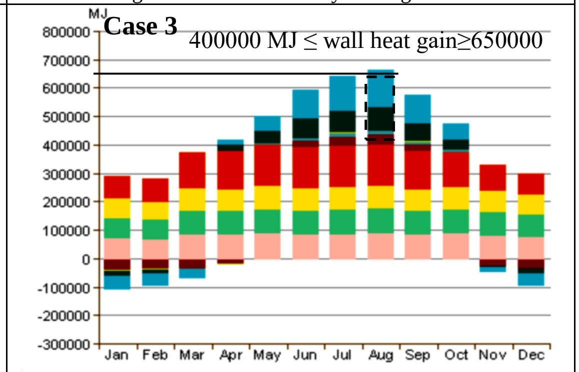


Figure 22: Base case monthly cooling loads

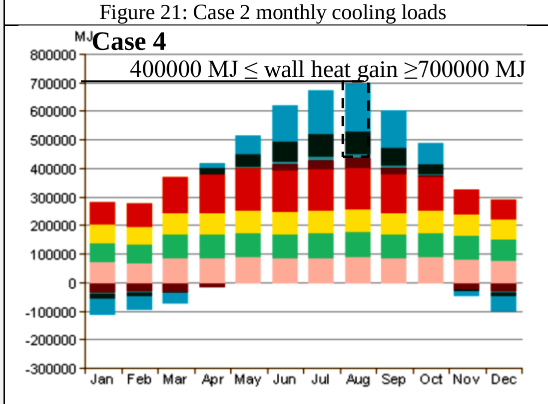


Figure 23: Case 4 monthly cooling loads.

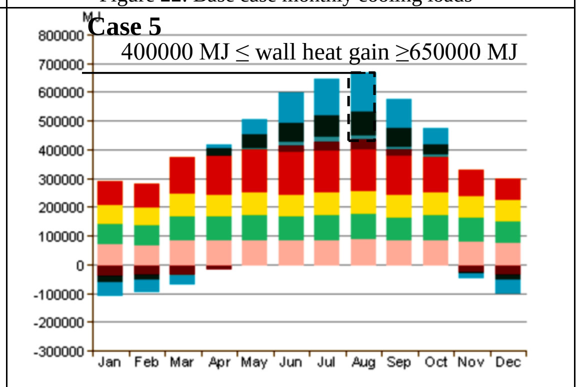


Figure 24: Case 5 monthly cooling loads.

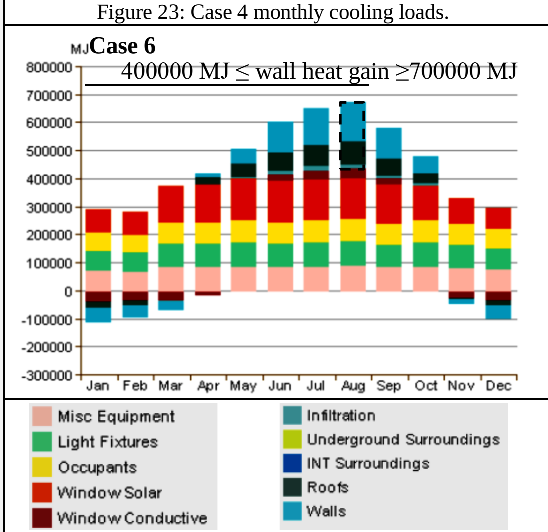


Figure 25: Case 2 monthly cooling loads.

In base case, cooling loads in August which has the largest contribution from walls range from more than 400000 to 700000. However, in case 3 and case 5 heat gain ranges from 400000 to 650000, on the other hand case 4 and case 1 do not have noticeable impact in reducing of cooling loads comparing with base case cooling loads.

IV. Discussion

i. Impact of external wall insulation on Total energy use intensity

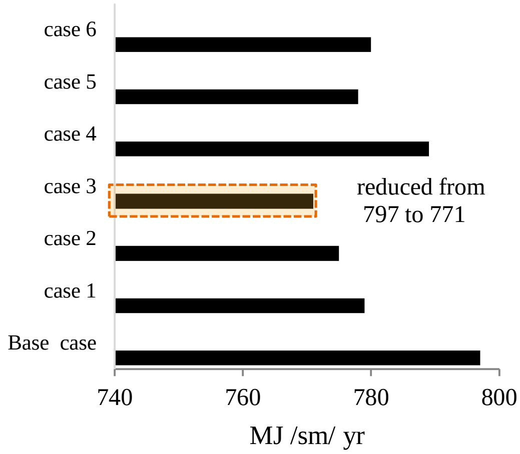


Figure 26: Total energy use intensity.

Case 3 and case 2 have less value of total energy use intensity, on the other hand case 4 doesn't have a noticeable impact in energy performance due to its thermal conductivity and resistance.

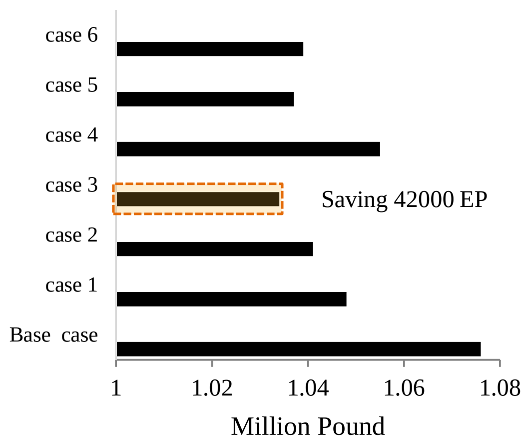


Figure 27: Total annual energy cost.

i. Impact of external wall insulation on annual energy cost

ii. Case 3 has the least cost of annual energy cost. It reduced costs from 1.76 to 1.34 million pound achieving 42000 Egyptian pound saving.

iii. Annual carbon emissions

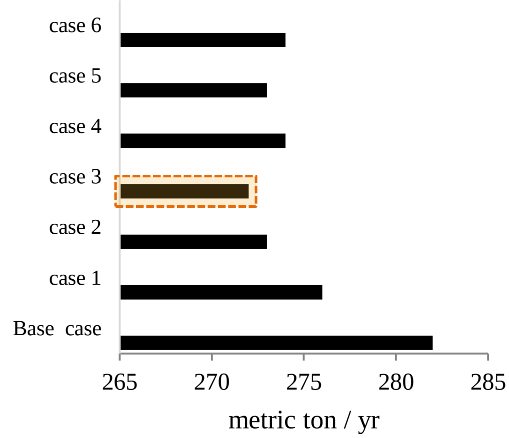


Figure 28: Annual carbon emissions.

Case 1 has the largest value of net co² on the other hand case 2, case 3 and case 5 have the minimum value. Case 1 has maximum carbon emission and it is due to high energy use, and on the other hand case 3 have the minimum value of net co² and it is due to energy use. In case 4, case 5 and case 6, they consume energy more than case 1 ,but they have carbon emissions less than other cases and close to cases 2 and case 3 as their finishing surface materials consist of natural materials which do not consume a lot of energy in their production comparing with the energy consumed to produce the rest of building material (13) .

V. Conclusion and Recommendations

This research presents a detailed simulation – based study of mutual impacts done by different wall material of external wall on energy performance for one of critical building type. Results of this study demonstrated that thermal properties of wall building materials have a significant role in determining the thermal behavior of buildings. Use of double wall from Lightweight Burnt clay block enhanced with fiber glass was found to be the most efficient among alternatives as it reduced energy use intensity in this hospital from 797 to 771 MJ/sm/yr and reduced annual energy cost to save 42000 per year. Using of marble finish fixed with mortar without thermal insulation does not have a noticeable impact on reducing building energy use, however use of marble or granite enhanced with thermal insulation have a positive impact on reducing energy use from 797 to 778 MJ/sm/yr and saved 39000 per year. So, using of digital simulation software is a good tool to compare wall material impact on energy performance and shows the ability to improve energy performance in building. The research proofs that using of insulated wall for inpatient spaces of healthcare building instead of uninsulated walls reduce building energy use and reduce cooling loads.

This research recommended to:

- Using wall insulation techniques to improve energy efficiency and reducing carbon emissions

- Using double insulated walls because they have high value of resistance from concrete and common brick.

Using marble or stone which fixed mechanical with thermal insulation having also a positive effect on energy efficiency of tasted building and have less carbon emission comparing with other building materials.

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