

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 8, Issue 6, June 2019

The Effect of Thermal Insulation on Building Energy Efficiency in Northern Upper Egypt

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ABSTRACT: Energy saving from fossil fuels is one of the main measures to assess the performance of buildings. Insulation of the building's cover is one of the most well-known ways to increase energy efficiency in buildings. The purpose of this paper is to evaluate the use of thermal insulation materials in increasing energy efficiency in the Upper Egypt region, by studying different types of thermal insulation and its impact on the building's casing. And choose the best materials suitable for this region. The 'design builder' program was used to measure energy efficiency in the building. As a result of the simulation in the four cases the best result in the case of the ceiling, is the use of the double roof, including a 20-cm insulator. The best thermal insulation in the case of the walls is using of single-wall thermally insulated by polyurethane board thickness of 7 cm.

KEYWORDS: Thermal insulation, Energy consumption efficiency, Energy consumption simulation- Environmental simulation program.

I. INTRODUCTION

Today over 50 million buildings consume half of the world's energy. The single largest challenge to enhanced energy efficiency, improved indoor air quality and the streamlined management of buildings is how to use building data effectively.

Egypt aims to improve energy use, increase renewable energy production and reduce greenhouse gas emissions. The construction sector accounts for more than 40% of total energy consumption [1]. Therefore, the building's energy consumption should be rationalized, and the thermal performance of the building is the main factor affecting the energy[2]. Studies in the Arab Republic of Egypt have shown that increasing the temperature of the outside air by one degree Celsius above 35 degrees Celsius results in consumption of 100 MW / hour, so emerged the need to rationalize the uses of energy used in buildings

One possibility to improve the energy efficiency of buildings is to reduce heat gain through the building envelope by internal or external wall insulation [3] [4].

II. BUILDING INSULATION

Insulation is not considered the element most interested in construction work, but is necessary for the performance of the building. Without sufficient insulation, large parts of the energy used to heat or cool in building will be lost. While the majority of insulation in buildings is for thermal purposes, the term also applies to acoustic insulation, fire insulation, and impact insulation (eg for vibrations caused by industrial applications). Often an insulation material will be chosen for its ability to perform several of these functions at once.

III. THERMAL INSULATION

Thermal insulation is used in buildings to achieve thermal comfort for user it minimizes loss or acquisition of unwanted heat and can reduce energy consumption for heating and cooling systems.

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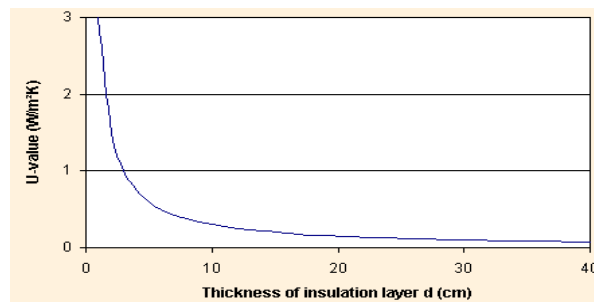
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Building insulation materials are the building materials which form the thermal envelope of a building or otherwise reduce heat transfer. The efficiency of the bulk insulation is usually evaluated by its R value, and R does not take into account the quality of the building or the local environmental factors of each building.

The heat transmission through an element is defined by the air to air heat transmission coefficient U. Reducing the λ -value of a material or increasing the thickness of the insulation layer results in an decreasing U-value. The heat transfer coefficients are composed of a convective and a radiative part. The heat transfer mechanisms are shown in The decrease in the U-value as the thickness of the insulation layer increases. Fig. 1(a) shows Decrease in the U-value with increasing thickness of the insulation layer [5].



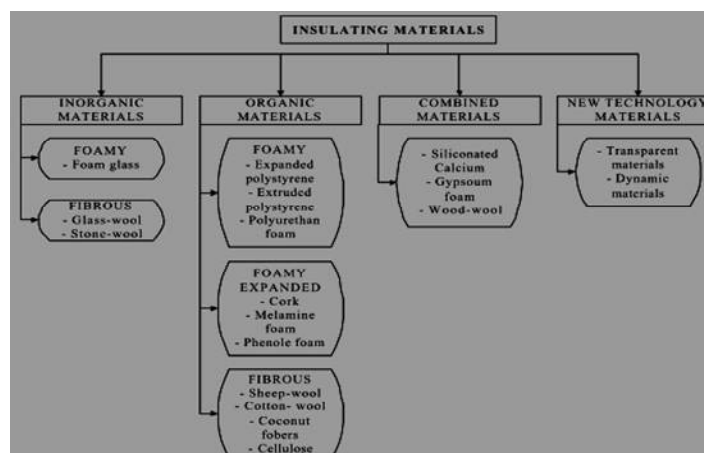
A

Fig. 1 (a) shows Decrease in the U-value with increasing thickness of the insulation layer. [5]

IV. TYPES OF THERMAL INSULATION

There are many forms of insulation, such as bats, hardboards, foam spray, and bulk fillings. The R value of the buffer varies depending on its quality. Better insulation will cost more, but in the long run will contribute to a significant energy saving [6] Insulation may be categorized by its composition (natural or synthetic materials), form (spray foam, and panels), structural contribution (insulating concrete forms, structured panels, and straw bales), functional mode, radiative, convective), resistance to heat transfer, environmental impacts, and more.

Insulation materials can be divided into organic materials, inorganic materials, combined materials, and new technology materials. Fig. 2(a) shows Classification of the insulating materials [7]. Organic materials can be subdivided into natural (cork, cotton, wool) and synthetic (polyurethane rigid foam, polystyrene) materials. (table 1) show properties of insulating materials which applied in this study [8].



C

Fig. 2(a) shows Classification of the insulating materials [7].

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Table 1: material properties of insulating materials which applied in this study. [9]. [10]

insulating material	thermal conductivity (W/m K)	mass density (kg/m ³)
Glass wool (rolls)	0.84	1700
glass fiber wool	0.042	16
Silicon	0.1815	700
Glass fiber board	0.045	
Stone wool(standard board)	0.038	40
Polystyrene	0.032-0.038	18-40
Polyurethane board	0.022-0.028	24
polystyrene, EPS	0.032-0.04	15-30
polystyrene, XPS	0.029-0.038	25-40
polyurethane foam	0.025-0.035	30
foam	0.04-0.055	10-160
mineral fibre	0.035-0.05	15-80
air, motionless	0.0025	1.2

V. ENVIRONMENT SIMULATION PROGRAMS

A computer simulation or a computer model is a computer program that attempts to simulate an abstract model of a particular system.

Computer simulations build on, and are a useful adjunct to purely mathematical models in science, technology [11].

The building needs materials that are efficient under increasing operating conditions. Environmental simulators can help to gain valuable information under these conditions in controlled environment.

Simulation programs are used to create a real modeling process with a range of mathematical formulas. It can be defined as a program that allows the user to monitor a process through simulation without actually performing the operation on the project.

The study will use 'Design Builder program' as a simulation program to simulate the effect of changing the type of thermal insulation on energy consumption in the architecture department at Fayoum University

VI. WHY USING DESIGN BUILDER PROGRAM

Design Builder provides advanced modeling tools in an easy-to-use interface. The same software can be used to develop comfortable, energy-efficient building designs. Design Builder adds significant improvements in LEED system simulations and ASHRAE 90.1 PRM, graphical output of model-generated simulation results and new programming tools to allow the allocation of Energy Plus simulations [12].

The Architectural simulation allow to link with BIM solutions, analyses solar shading, maximize the use of renewable technologies and test facade options all in one place, adjusting as go according to the study requirements.

Key performance indicators such as energy consumption, carbon emissions, thermal comfort, daylight availability and cost can be provided throughout the design process in both naturally ventilated and air-conditioned buildings.

He has been calibrated by many researchers to measure the error rate in the program and found that it does not exceed 3, 1%. [13].

VII. CASE STUDY

The study was applied on the Building of the architecture Department of Architecture at Fayoum University

1- PROJECT DESCRIPTION

It is an educational governmental building located in the city of Fayoum within the northern Upper Egypt.

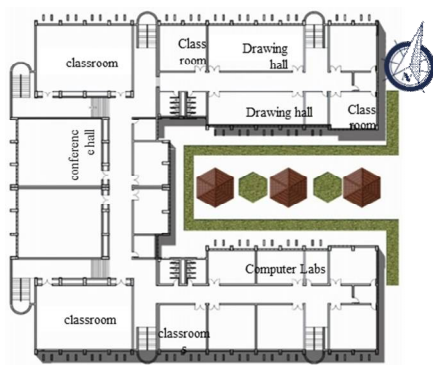
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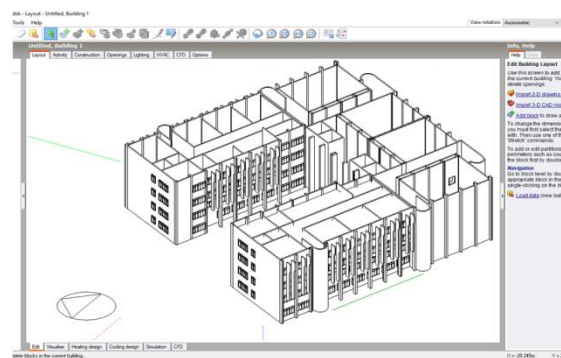
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The number of individuals using the building is approximately 500 students. The number of hours of operation of the building is about 6 hours a day except on Fridays and Saturdays. The building consists of a ground floor and contains a library, office area, and classrooms. The first floor contains the offices of faculty members. The upper second floor has three drawing halls and classrooms Fig. 3 (a) (b) (c)(d), Single translucent glass is used with window openings and wooden doors.



(a)



(b)



(c)



(d)

Fig.3,(a) shows plan of the case study (architecture department building, el Fayoum University). (b) Shows the building of the case study in design builder program window.(c)(d) elevation of the case study (architecture department building, el Fayoum University)

Alternatives to each of the above elements have been identified according to the basic alternative, which was designed by the college builders, in addition to the alternatives of insulation and within the available technological and economic, and what can be used in the existing building and study the effect of each variable with the stability of the other variables according to the basic alternative (Table 2) Fig. 4 (a) (b) (c)(d).

Table (2) alternatives to the facadesof the building in case study.

No. of case	Description		
Roof case			
The existing situation	Roof reinforced concrete 16 cm / Insulation moisture / sand and mortar 8 cm / tile 2 cm		
The first case	The existing situation (single roof) with another thermal	The existing situation + 5 c.m. thermal insulation (Glass wool (rolls), foam, glass fiber wool, Polyurethane board, Glass fiber board, Silicon, Polystyrene, Stone	The existing situation + 7 c.m. thermal insulation (the same thermal insulation material of the first case)

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	insulation	wool(standard board), expanded polystyrene (EPS), Polyurethane, Mineral fiber wool) Foam	
The second case	Double roof with air layer 20 c.m.	The existing situation +new roof thickness10 c.m.+ air layer 20 c.m. + 5 c.m. thermal insulation (the same insulation material of the first case)	The existing situation +new roof thickness10 c.m.+ air layer 20 c.m. + 7 c.m. thermal insulation (the same insulation material of the first case)
Wall cases			
The third case	(single wall (25) c.m). with thermal insulationin walls	The existing situation + 7 c.m. insulation (the same insulation material of the first case)	The existing situation + 7 c.m. insulation (the same insulation material of the first case)
	Double wall (25,12) c.m with thermal insulation	The existing situation + 5 c.m. thermal insulation (the same insulation material of the first case) + wall thickness 12 c.m	The existing situation + 7 c.m. insulation (the same insulation material of the first case) + wall thickness 12 c.m

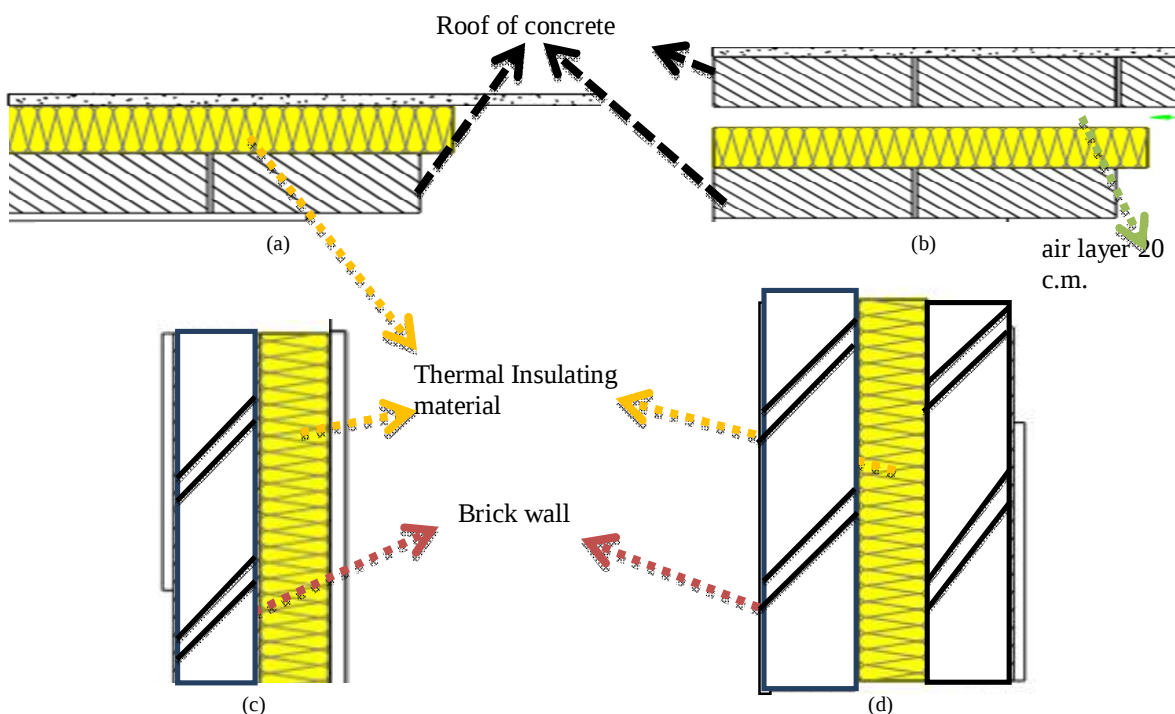


Fig. 4, (a) shows layers of case 1(The existing situation) single roof) with another thermal insulation).(b) Shows, layers of case 2 Double roof with air layer 20 c.m.. (c) Shows layers of case 3(The existing situation) single wall(with thermal insulation), (d) shows layers of case 4(The existing situation) Double wall) with thermal insulation)

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2- SIMULATION RESULT OF STUDY CASE

The study simulated the four cases described in (Table 2) by using (design builder program), and extracted the following results.

a. FIRST CASE

Use heat insulation on the roof of the last floor. Then finish above with sand, concrete and tiles. The simulation result shows Fig. 5(a) that Increase insulation thickness by placing and finishing the insulating material. The results of the simulation show that the percentage of energy savings of up to 5.5%. This savings is very small especially if compared to increased costs. Therefore, increasing thermal insulation thickness with different types does not reduce energy consumption in case of study. Therefore, the study does not recommend applying this condition.

b. THE SECOND CASE

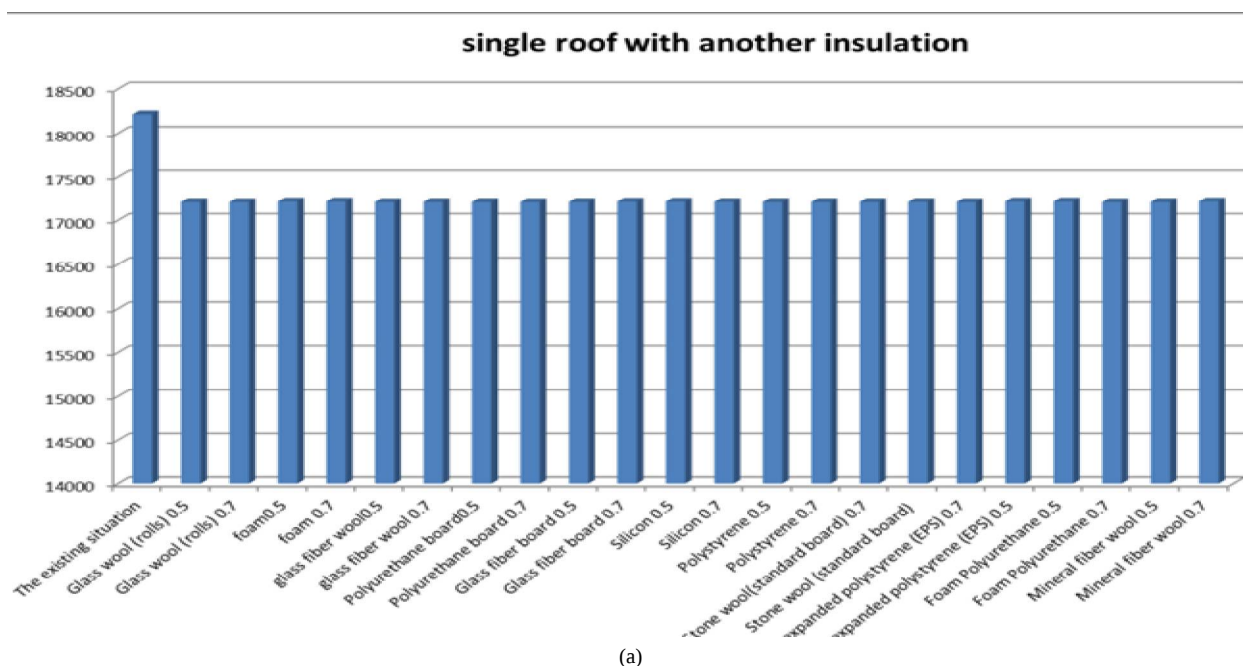


Fig. 5 (a).shows The result of energy consumption simulations in the first case

The use of double roof, including a 20 cm air condenser, is shown using different types of heat insulations with a thickness of 5 cm and a thickness of 7 cm. The result of simulations Fig.6 (a) shows that energy consumption is 22 % lower. This is a good result, but with the use of different insulation materials, energy consumption was reduced by about 2% for all insulation materials and this difference is ineffective. Therefore, the use of double roof with an air insulator, including the use of heat insulation materials does not reduce the energy consumption in the case of study. Therefore, the study recommends the use of a double roof, without an insulator.

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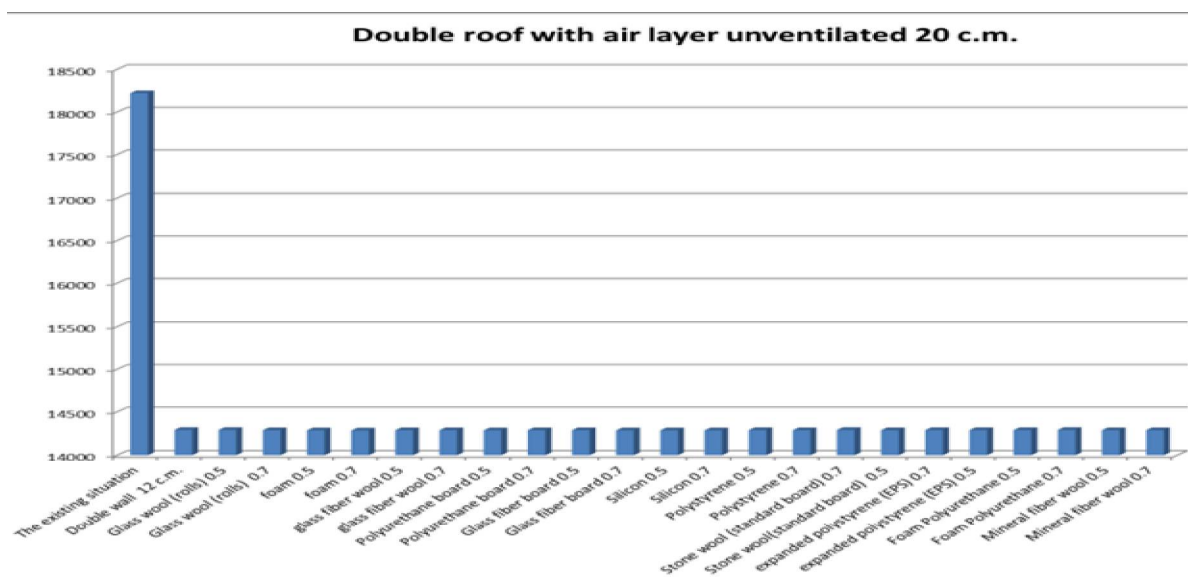
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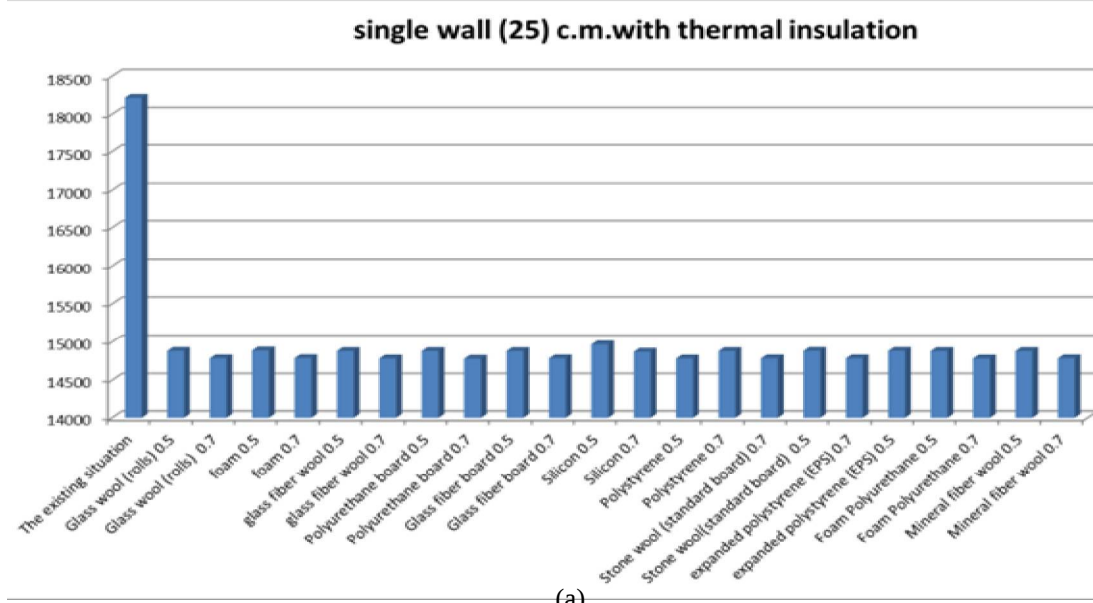
C. THE THIRD CASE

Using of heat insulation on the external walls of the building, from the simulation results Fig. 7(a) that the energy consumption is 18% less than the current state and the use of different insulation materials, the use of insulation thickness of 7 cm better than the use of insulation thickness of 5 cm and the best type of insulation is Polyurethane



(a)

Fig. 6 (a) shows The result of energy consumption simulations in the second case



(a)

Fig. 7 (a) shows the result of energy consumption simulations in the third case

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board with 7cm. Thickness.

For this reason, the study recommends the use of thermal insulation of Polyurethane board of 7 cm thickness as thermal insulation of the walls.

d. THE FOURTH CASE

(The use of a double wall, including thermal insulation, shows that the energy consumption was reduced by approximately 22% with a difference of 2: 3% in the energy consumption results of different types of insulation materials. Fig. 8 (a) The result of the simulation shows that the best insulation material in this case is Polyurethane board thickness of 7 cm.

VIII. EXPERIMENTAL RESULTS

The study concluded with some of results:

1. In First case, the energy consumption was reduced by approximately 5.5% with a difference of 2: 3% in the energy consumption results of different types of insulation materials. This case is uneconomic and the study does not permit its use.
2. In The second case, the energy consumption was reduced by approximately 22 %, but with the use of different insulation materials, the difference is ineffective. Therefore, the study recommends using of a double roof, without an insulator.

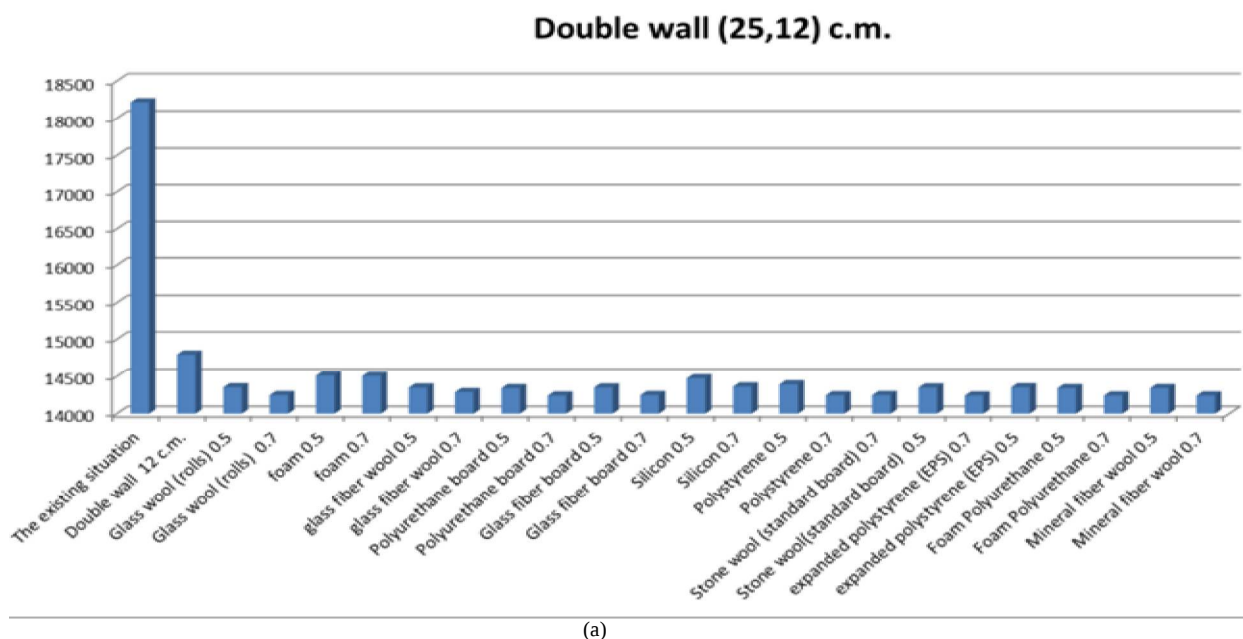


Fig. 8 (a), shows The result of energy consumption simulations in the fourth case

3. In third case, the energy consumption is 18% less than the current state, the use of insulation thickness of 7 cm better than the use of insulation thickness of 5 cm and the best type of insulation is Polyurethane board thickness of 7 cm.

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4. In fourth case, the energy consumption was reduced by approximately 22% with a difference of 2: 3% in the energy consumption results of different types of insulation materials. The best insulation material in this case is Polyurethane board thickness of 7 cm.
5. The amount of energy savings in the fourth case is close to the results of the use of heat insulation materials in the single wall. (The third case) and estimated at about 5% Therefore, the study considers that the use of a double wall, including thermal insulation is not economically feasible and preferably the use of a wall thermally isolated single.
6. As a result of the simulation in the four cases it is clear that the use of the double roof, including a 20-cm insulator without using insulating material is the best result in the case of the ceiling.
7. The use of single-wall thermally insulated by polyurethane board 0.7 is the best thermal insulation in the case of the walls.

IX. CONCLUSION

A study of thermal insulation systems has been conducted on the building of the Faculty of Engineering, el Fayoum University. to become more energy efficient.

Thermal insulation in roof and walls greatly reduces overall energy requirements.

The study simulated the four cases by using (design builder program), First case (Use heat insulation on the roof of the last floor), The second case (The use of double roof, including a 20 cm air condenser), The third case (Using of heat insulation on the external walls of the building), and The fourth case (The use of a double wall, including thermal insulation).

As a result of the simulation in the four cases the best result in the case of the ceiling, is the use of the double roof, including a 20-cm insulator without using insulating material. The best thermal insulation in the case of the walls is using of single-wall thermally insulated by polyurethane board thickness of 7 cm.

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