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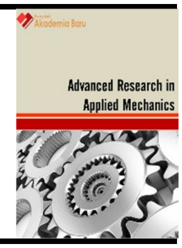

Effect of Thermal Insulation on Building Thermal Comfort and Energy Consumption in Egypt

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ABSTRACT

Building Indoor Environment could be described as one of the most important studying points for designers that must be achieved in highest possible level. While achieving this goal will help in increasing occupant's productivity, satisfaction, economic benefits, and many other sustainability issues. So, and for this highly appreciated importance it became very interesting point of research in developing regions. Hence, the educational building type at Egyptian capital- Cairo was chosen to be a case study for this research as educational buildings have a highly effective weight of thermal comfort and energy consumption. Data of different used materials are used to discuss the trends in thermal comfort were mainly conducted from the Egyptian Energy code. The simulations result from computer based software are used to compare the relation between the insulation materials and thermal comfort. Through the variation of thermal insulation materials in the Egyptian market we are going to study the effect of different thermal insulation materials types and thicknesses on the thermal comfort for the building envelope. Both of literature and computer based studies will be a highly effective way in forming the research methodology. By using software Design Builder, it is paid attention to simulation of the thermal behavior of all accepted types of defined materials in the Egyptian energy code for the building envelope, conducting results and finally commenting these results to get the most suitable insulation material.

1. Introduction

Modern people live at least 90% of their lives in indoor environments doing their normal life activities. So, they must feel comfortable to get the maximum possible benefits of their activities. Studying the indoor thermal comfort depends directly in evaluation on physical elements such as temperature, humidity, air currents, and radiation. Modifying these parameters depends mainly on air-conditions to achieve this indoor comfort. Using air conditioning systems will cause a highly

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increasing in energy consumption. So, it would be profitable if we could reduce the air conditions usage as it is known that energy costs increased all over the world. Thus, we need to study how could we reduce the energy consumption and increase the thermal comfort.

Generally residential buildings type is an effective sector of energy consumers in Egypt as it gets about 40% of the total energy consumption accounted for buildings [1]. So that any effective way of reducing energy demands for this type of buildings will help us to face the highly increasing costs of consumed energy. Educational buildings are an important type of buildings as thermal comfort will be appreciated for students. Studying such building at a city with a high density of population will show the importance of that work. Arab academy for science and technology and maritime transport building was a very good case study because of its location and being an educational building. Egypt's arid weather is known for being hot and dry weather thus, achieving thermal comfort will consume more energy. Using air conditions to control the previous physical parameters of thermal comfort will be much more effective in case of controlling the energy losses for the building environment. To control the ingoing or outgoing energy needs using thick walls with high thermal mass. This wall will be outside ambient temperature conditions modulators and supplier of comfort conditions for building residents with a minimum usage of air conditioning equipment. Thick wall layers will consume much more land area at which land prices in Egypt is expensive. We also need to reduce the thickness of the walls as much as possible to increase the net area of living.

Because of needing to reduce wall thickness and keeping the thick wall layers effect the construction of walls will depend thermal insulation material that gives both benefits. This research uses an accredited software in energy assessment that called Design Builder. Design builder software used to assess the AASTMT building to study the thermal behavior of eight types of materials with different thicknesses. To increase the accuracy of assessment a variation rate of thermal insulation material thickness will be going to be each 2cm as increasing interval step. In this research, thermal comfort and energy consumption will be evaluated with each thickness for each insulation material. Also, the best thickness of each material will be studied in aim of achieving best of thermal comfort and energy consumption.

2. Literature Review

Thermal comfort could be defined on many ways at which all giving almost the same meaning. For example, Thermal comfort is defined as "the state of mind, which expresses satisfaction with the thermal environment" [2]. From that definition, we can see that thermal comfort is a very interdisciplinary field of study, as it involves many aspects of various scientific fields. By looking for ASHRAE Standard 55 -2010 We could also get s definition as "that condition of mind that expresses satisfaction with the thermal environment" [3].

Because there are large variations, both physiologically and psychologically, from person to person, it is difficult to satisfy everyone in a space. The environmental conditions required for comfort are not the same for everyone. However, extensive laboratory and field data have been collected that provide the necessary statistical data to define conditions that a specified percentage of occupants will find thermally comfortable. Thermal comfort could be monitored and maintained through both quantifiable and non-quantifiable parameters. The quantifiable parameters of thermal comfort could be classified in three main categories including air, surface, and human-related factors [4]

2.1 Thermal comfort models

Comfort index-based control has become the tendency of the development of indoor thermal comfort conditions, the lack of definable correlation between thermal sensation and thermal preference question the underlying assumptions of the thermal sensation/comfort models. However, the relation between the thermal environment and the comfort of the people has brought two distinguishable concepts; i. e. a) The heat balance approach. b) The adaptive approach [5].

The beginning of these models was from Houghten and Yaglou [6] who developed the first effective temperature index using empirical methods. Followed by Nevins et al. [7] and McNall et al. [8] who described examples of empirical predictions of thermal sensation ratings. Perhaps the most commonly cited experiments on the human perception of thermal comfort have been performed by Fanger who tried to find a common equation to solve the estimated indoor thermal comfort through prediction models.

Predicted Mean Vote (PMV), Standard Effective Temperature (SET) and others, are empirical comfort index-based models that were developed based physiologically on a steady-state model of thermal exchanges between the human body and the environment. The previously mentioned indices are used for specifying the thermal comfort requirement of a building. The other application is in the commissioning and operation stage of heating, ventilation and air conditioning systems. [9]

2.2 Energy and thermal comfort using simulation tools

The empirical studies part of this research is based on computer simulation and assessment software products. The main software used is DesignBuilder 4.5, which is one of the Building Performance Simulation (BPS) tools that counts more than 389 different tools [10].According to Attia [11], DesignBuilder can be used in all design stages. Furthermore, it has a visual oriented interface that addresses the architects' language.

In this, case study was modelled and edited in Design Builder software. Finally, results were transferred into MS-office software products to be presented as table and charts based.

3. Methodology and Building Model

The simulations, described in the present paper, were performed using the DesignBuilder simulation tool. It allows simultaneous performance assessments of all building issues such as facade and wall construction, window glazing, HVAC systems, controls, indoor air quality, human thermal comfort and energy consumption.

The model used in all simulations included a central module of a college building with a 5 floors distribution of offices and lecture rooms at most of the building rooms' type. As the actual condition of the building all the building data were conducted by the real inspection and collection ways and then it has been used as an input data for the building model, these building layouts and 3-D shape at DesignBuilder is shown in Fig. 1.

The Building input data was verified as the following:

Population density of 0.5 person per square meter for lecture rooms and 0.3 for administrative zones.

Eight types of materials used in the external wall construction as a thermal insulation layer with thickness starting form 2 cm till 20 cm with increasing step of 2 cm.

That used insulation materials as mentioned in Egyptian Energy code was:

Celton, Expanded Polystyrene, Extruded Polystyrene, Perlite, Vermiculite cement, Vermiculite, Polyurethane (U = 0.026 W/m-k), Polyurethane (U=0.045 W/m-k).

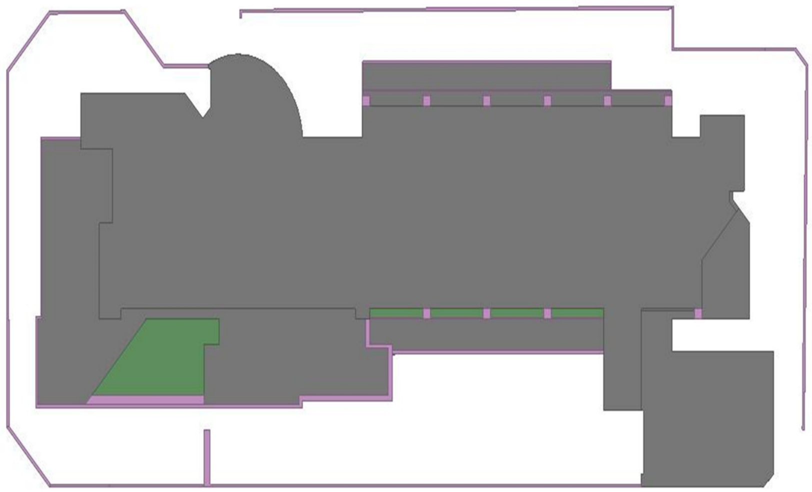

Fig. 1. DesignBuilder plan of AAST building

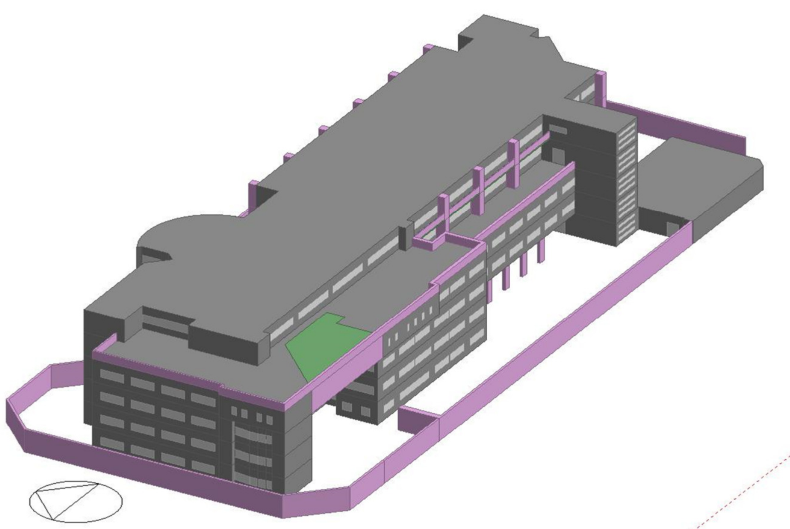

Fig. 2. 3D shape of AAST Building in DesignBuilder

Metabolic rates vary depending on the zone type, at mostly studying standard metabolic rate or light office work metabolic rate.

Minimum fresh air of 12 l/s-person for all buildings. Energy loads varying depending on the type of zone for mainly high usage for computer labs and moderate for office zones and relatively small for lecture rooms. The HVAC used system was split air condition units as the real case condition.

The building construction of the main effective parts was as following:

Table 1
Construction of the most important components of building

	Roof (mm)	Typical slab (mm)	External walls (mm)
Layer No. 1	50 concrete tiles	50 concrete tiles	5 finishing
Layer No. 2	30 plastering	30 plastering	20 gypsums plastering
Layer No. 3	30 sand stones	30 sand stones	30 plastering
Layer No. 4	100 thermal insulation	30 sand stones	Thermal insulation layer
Layer No. 5	30 sand stones	250 concrete slabs	250 wall concrete blocks
Layer No. 6	250 concrete slabs	30 plastering	30 plastering
Layer No. 7	30 plastering	5 painting	20 gypsums plastering
Layer No. 8	5 painting	---------------------------	5 painting finishing

4. Results and Discussion

Thermal comfort effect has been measured in term of the number of discomfort hours. The least value of discomfort will be the best choice at which the relevant thickness must be used in constructing the building to achieve the optimum thermal comfort effect. Energy consumption also an important item at which it's also going to be varying with the variation of thermal insulation materials and thicknesses. Each material with the varied thicknesses will be used to calculate the energy consumption in KWH for the building. This paper has assessed both thermal comfort and energy consumption for even the whole building or for each floor alone. The output results will be shown through the following figures. The results will be shown at which each material effect on thermal comfort comes first and then the relevant energy consumption.

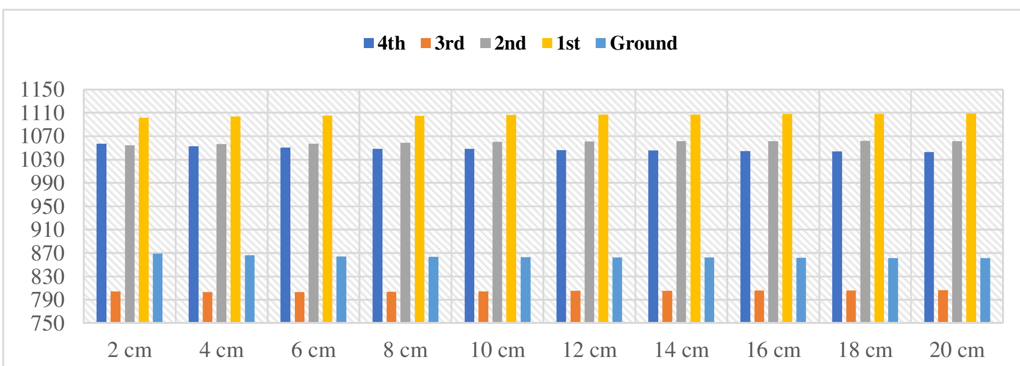

Fig. 3. Discomfort Hours Using Expanded Polystyrene

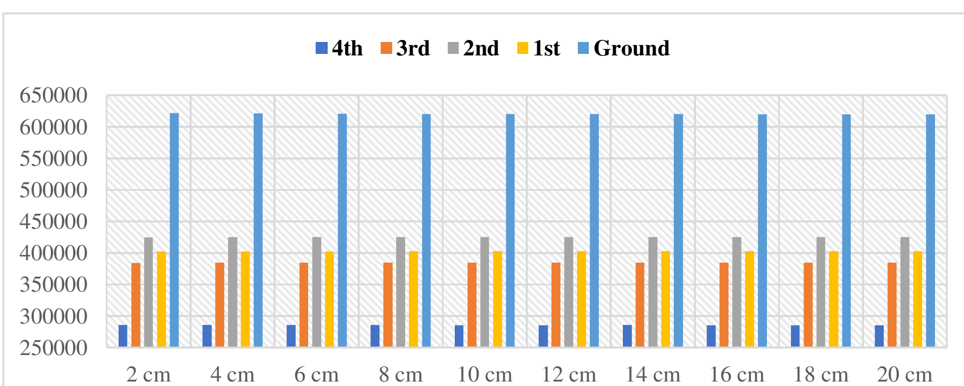

Fig. 4. Energy Consumption Using Expanded Polystyrene

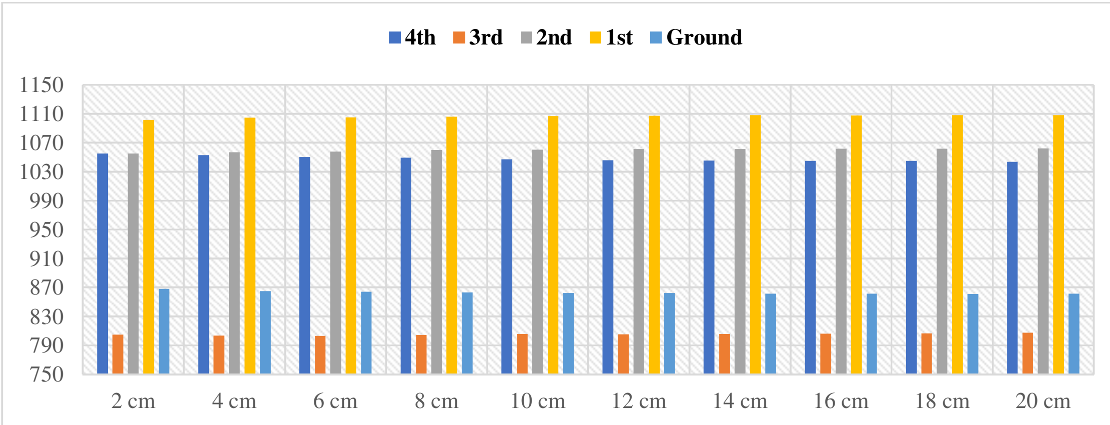

Fig. 5. Discomfort Hours for floors using Extruded polystyrene

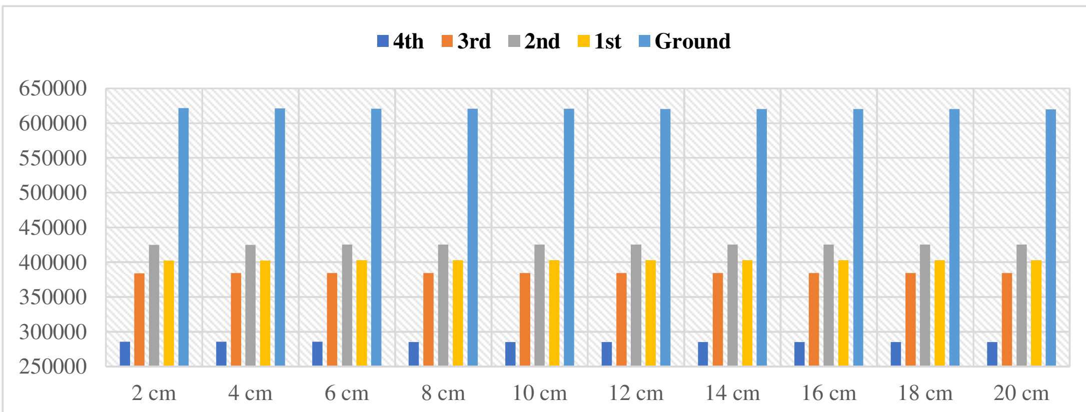

Fig. 6. Energy Consumption Using Extruded Polystyrene

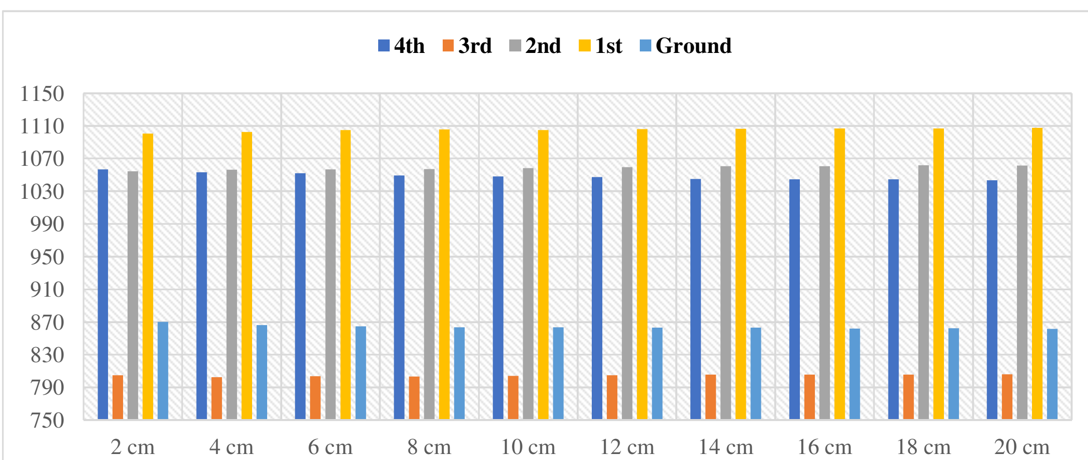

Fig. 7. Discomfort Hours using Polyurethane (0.045)

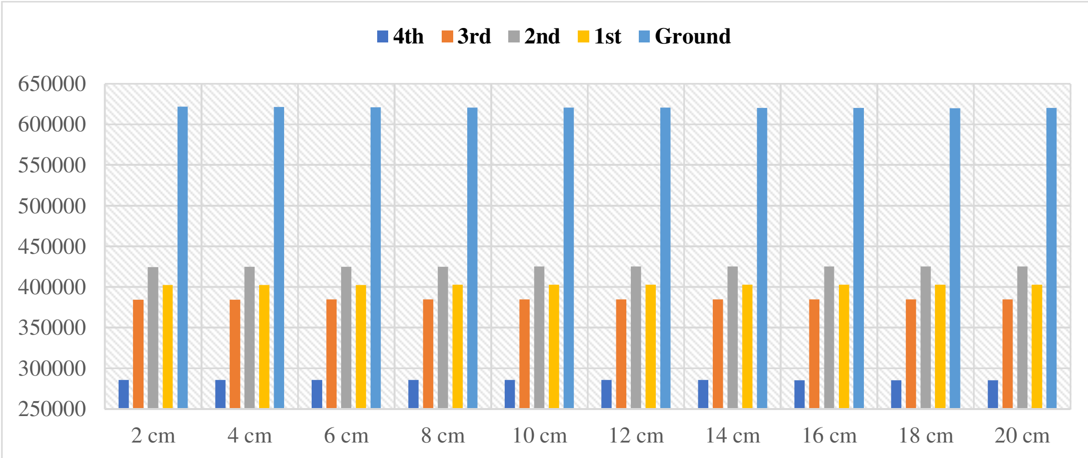

Fig. 8. Energy Consumption using Polyurethane (0.045)

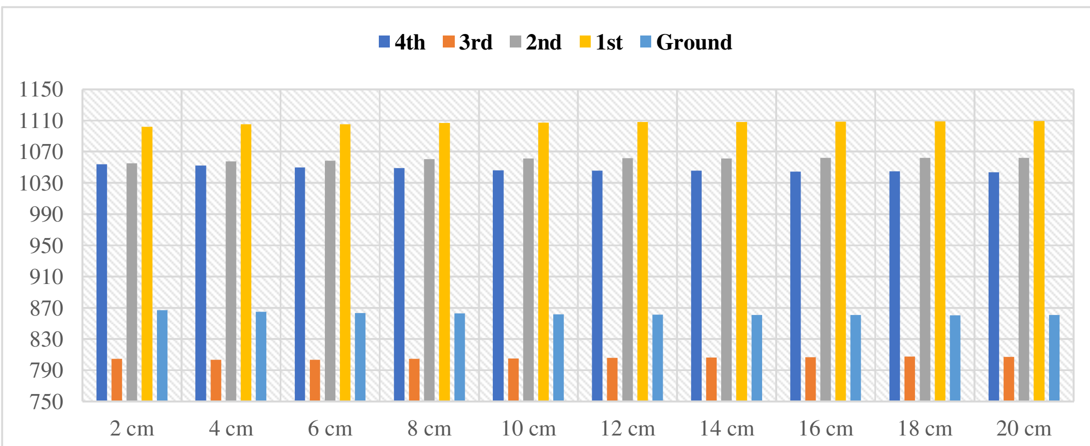

Fig. 9. Discomfort Hours using Polyurethane (0.026)

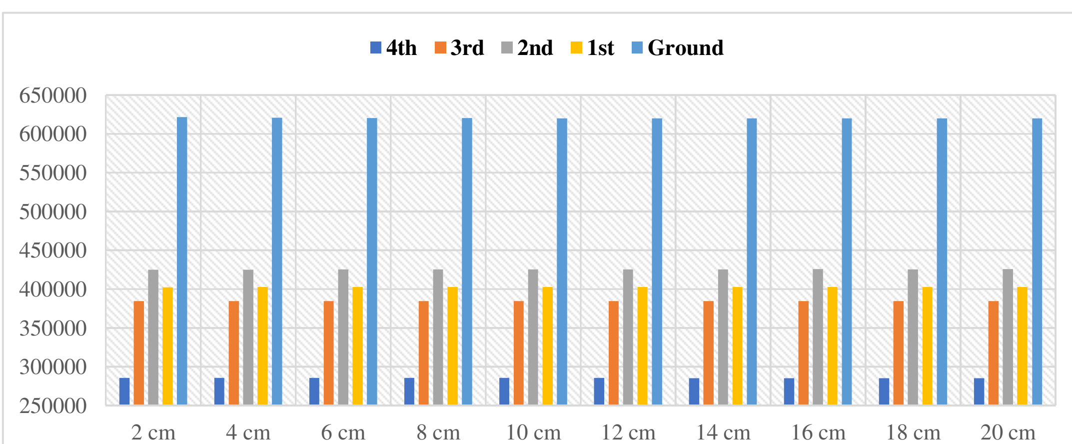

Fig. 10. Energy Consumption using Polyurethane (0.026)

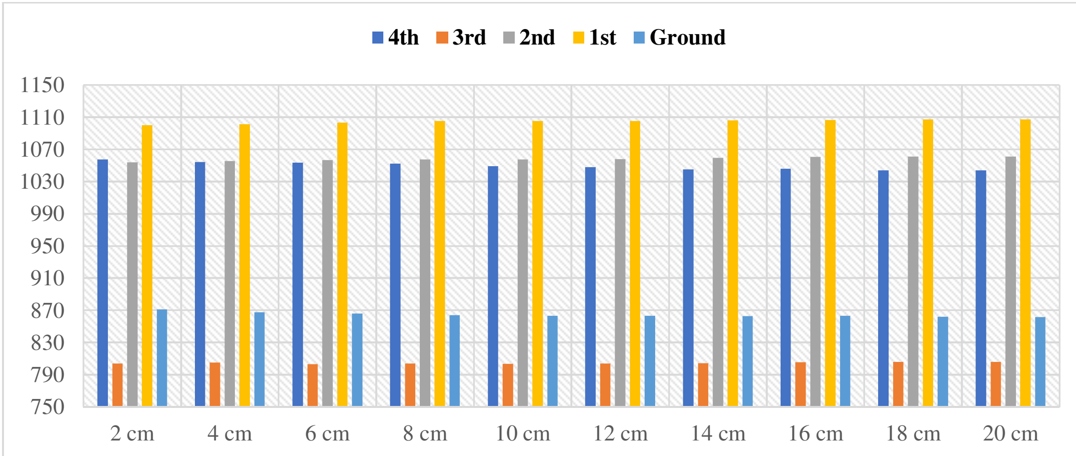

Fig. 11. Discomfort Hours using perlite

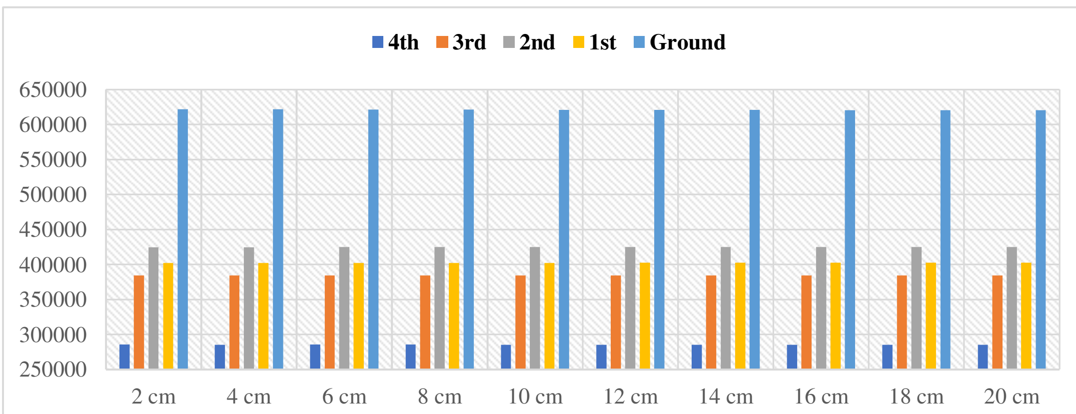

Fig. 12. Energy Consumption using perlite

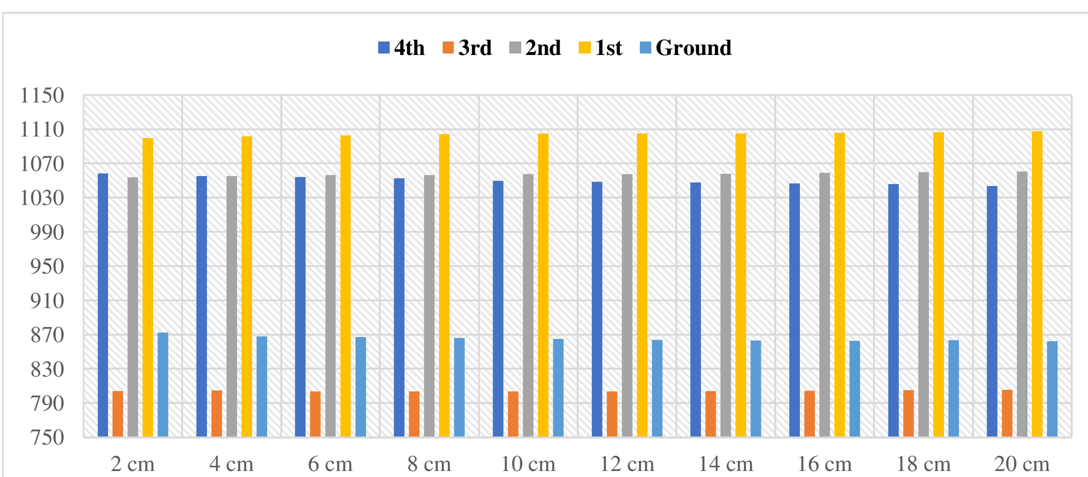

Fig. 13. Discomfort Hours using Vermiculite cement

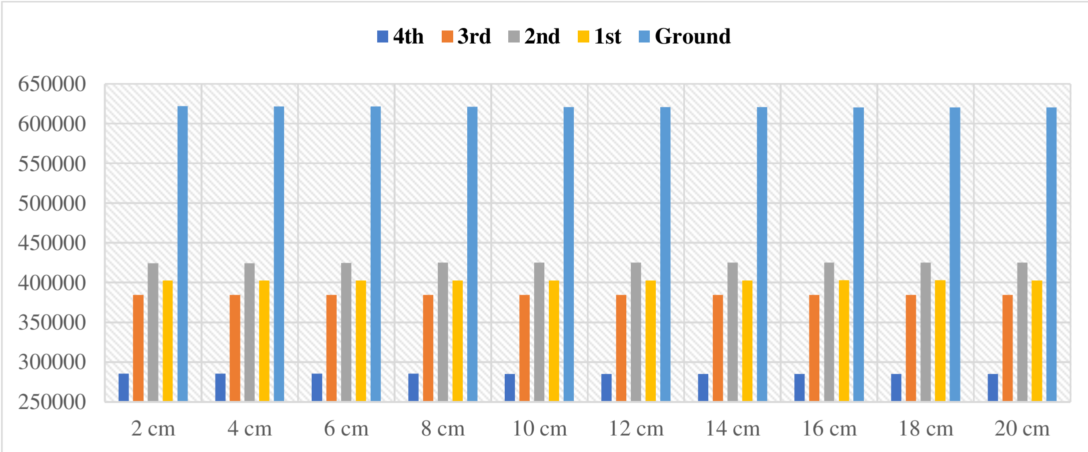

Fig. 14. Energy Consumption using Vermiculite cement

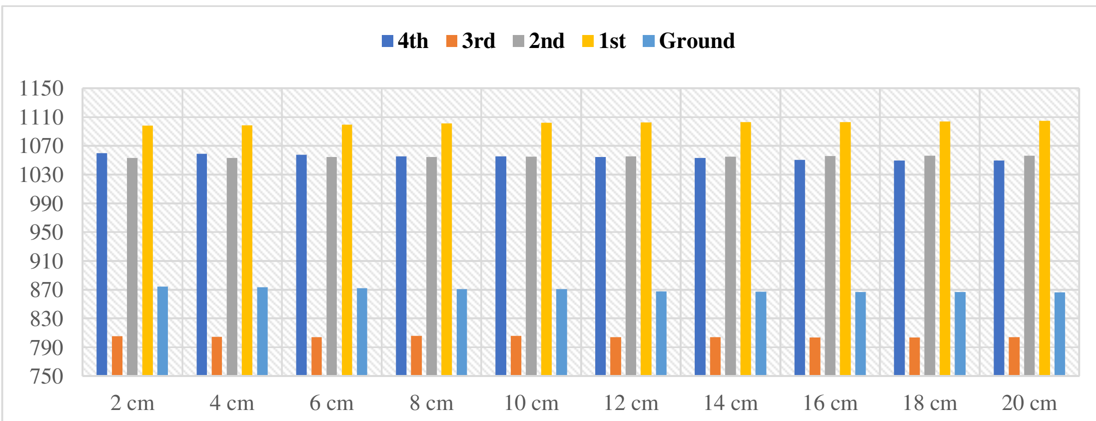

Fig. 15. Discomfort Hours using Vermiculite

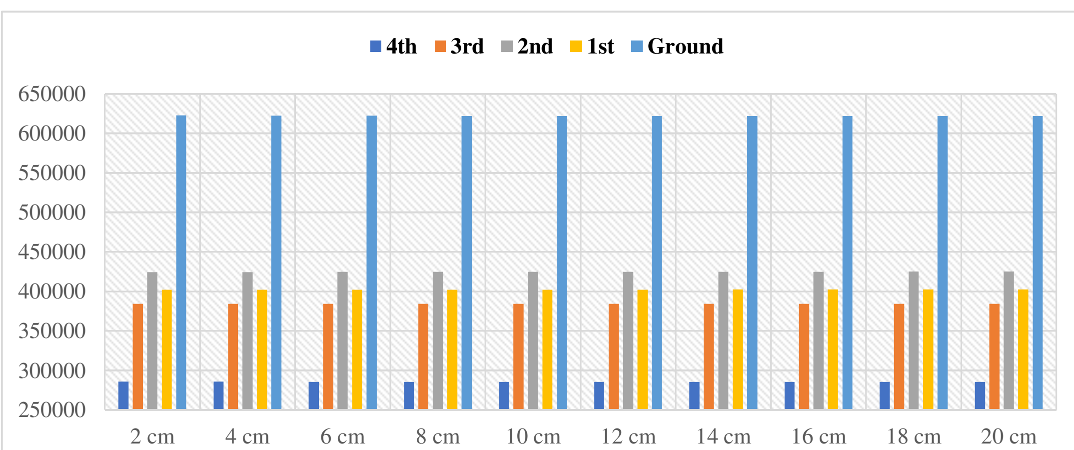

Fig. 16. Energy Consumption Using Vermiculite

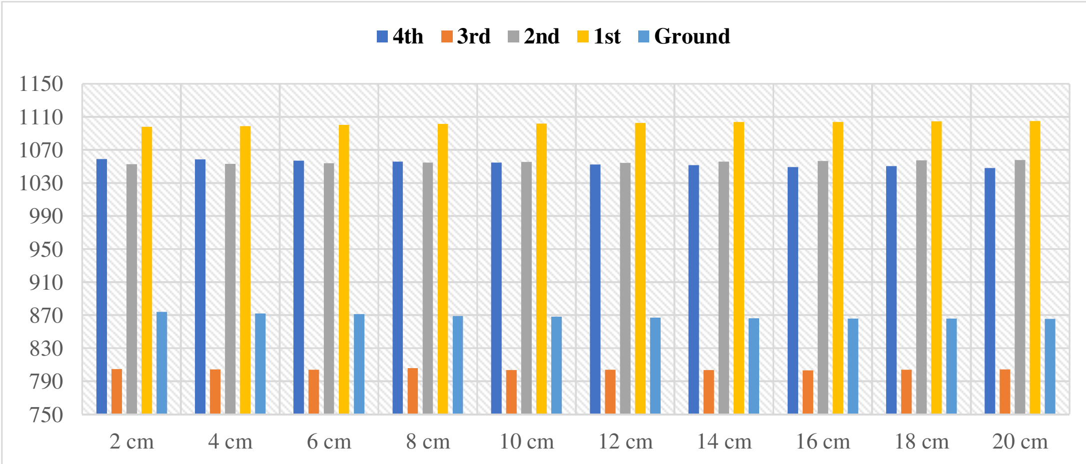

Fig. 17. Discomfort Hours using Celton

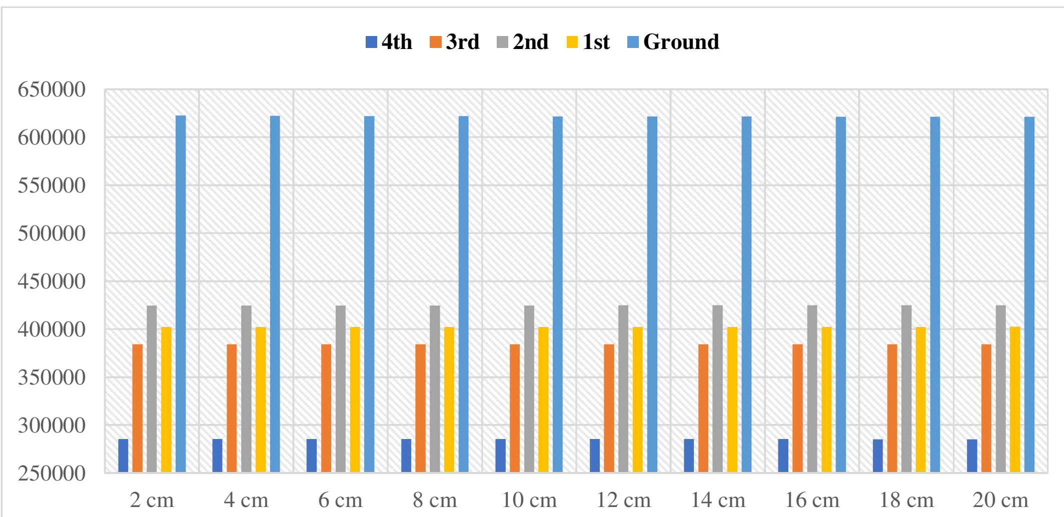

Fig. 18. Energy Consumption using Celton

Table 2 summarizes the optimum thickness of each material for each floor in achieving the highest thermal comfort and the least energy consumption. The table shows also the needed thickness for the whole building to achieve the optimum thermal comfort or energy consumption.

5. Conclusion

This work shows the detailed analysis of indoor thermal comfort and energy consumption for floors or whole building during the year. This was accomplished by taking advantage of the comfort ranges proposed by the methods of analysis of thermal comfort. It was also used in obtaining the possible energy consumption reduction for each floor and for the whole building.

The data represented previously shows that both of fourth floor and ground floor need a thick layer of insulation to achieve the needed target while in first, second, and third floor it will be enough to use thin layer of insulation to achieve its optimum thermal comfort and energy consumption. It also shows that using different thickness for each floor is better that using constant thickness for the whole building. Both of ground and fourth floor need thick layer of insulation. The ground floor needs thick layer because of the effect of surrounding environment of the street while the fourth floor needs it due to the direct facing of sun effect on the roof.

Expanded polystyrene would be the most effective choice for the building to achieve the least value in energy consumption. Vermiculite cement is the best choices to get the best thermal comfort effect. That conclusion comes mainly depending on the values of energy KWH and thermal comfort number of hours. At which the best choice for the whole building will be extruded polystyrene and Polyurethane (0.026) to achieve the least energy consumption depending on the least used thickness of 6 cm. By looking for the thickness only the best choice in thermal comfort will be celton for thickness of 16 cm.

Table 2
Thicknesses in cm to achieve Optimum Energy consumption and thermal comfort

		Ground floor	1st floor	2nd floor	3rd floor	4th floor	Total building
Expanded Polystyrene	Thermal comfort	20	2	2	4	20	8
	Energy Consumption	20	2	8	2	20	18
Extruded Polystyrene	Thermal comfort	18	2	2	6	20	6
	Energy Consumption	20	2	2	2	20	20
Polyurethane (0.045)	Thermal comfort	20	2	2	4	20	8
	Energy Consumption	18	2	2	4	20	20
Polyurethane (0.026)	Thermal comfort	18	2	2	4	20	6
	Energy Consumption	20	2	2	2	18	20
Perlite	Thermal comfort	20	2	2	6	18	14
	Energy Consumption	20	2	2	2	18	20
Vermiculite cement	Thermal comfort	20	2	2	6	20	14
	Energy Consumption	20	2	2	2	20	20
Vermiculite	Thermal comfort	20	2	2	18	18	16
	Energy Consumption	20	2	2	4	18	20
Celton	Thermal comfort	20	2	2	16	20	16
	Energy Consumption	20	6	2	16	20	16

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