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Optimum Building Wall Thickness under Actual Weather Conditions for Kirkuk City

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A R T I C L E   I N F O

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A B S T R A C T

The aim of the present study is to obtain the optimum wall thickness of the buildings from four different wall thickness sizes that which selected as 48, 32, 24, and 16 cm used for building room. The dimension of 6×4×3 m, built by a common brick insulated for all sides except south wall. For this purpose, an energy simulation has been conducted by preparing a computer programmer and was executed by Matlab software. The two days in different weather conditions on 2016, first on 30/12, and other 01/07 for a constant indoor temperature at 23ºC. The results showed that the inner surface temperature was more stability against to the weather change for both climate conditions. In addition, the thick wall 48cm needs more energy consumption than other three types of walls about twice that 16cm thickness in a cold climate. The wall thick was more active for energy saving in a hot climate, and obverse, where the thin wall has more energy saving in a cold climate. The energy analyzing for both climates showing that the optimum wall thickness about 30 cm and the rate of energy consumption were estimated about 500 W.

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السمك الامثل لجدار البناية تحت ظروف الطقس الحقيقي لمدينة كركوك

الخلاصة

تهدف الدراسة الحالية الحصول على سمك مثالي للبناية وذلك من خلال اختبار أربعة انواع مختلفة لسمك لجدار وبقياسات 48، 32، 24 و16 سم. هذا الجدار يستخدم في بناء غرفة ذات ابعاد 6 × 4 × 3 م، والتي بنيت بالطابوق الاعتيادي ومعزول حراريا من جميع الجوانب باستثناء الجدار الجنوبي. ولهذا الغرض فقد تم استخدام برنامج ماتلاب لمحاكاة استهلاك الطاقة ليومين وبظروف الطقس المختلفة في عام 2016 والتي تم اختيار 30/ 12 و 1/ 7 للطقسين البارد والحار على التوالي، وبثبوت درجة حرارة داخل الغرفة عند 23 ºC.. أظهرت النتائج بأن درجة حرارة السطح الداخلي كانت لها أكثر استقراريه بالرغم تغير المناخ خلال فترة المحاكات في كلا الظرفين المناخيين المختبرين. بالإضافة إلى ذلك فأن الجدار ذي السمك 48 سم يحتاج إلى استهلاك أكثر للطاقة من انواع الثلاثة الأخرى وبحوالي ضعف للسمك 16 سم في المناخ البارد، اما في المناخ الحار فان الجدار السميك يكون أكثر قابلية لحفظ الطاقة بعكس الجدار الاقل سمكاً لحفظ الطاقة في المناخ البارد. من تحليل استهلاك الطاقة للمناخين تبين بان السمك الامثل هو 30 سم واستهلاك الطاقة تقدر بحدود 500 واط.

1. INTRODUCTION

Energy consumption at the present time has become a priority and cannot be dispensed with, where the cost of producing energy in continuous increasing, this calls for interesting in rationalizing energy. There are numerous studies which were performed on the saving energy in the buildings. Beach [1] investigated the method of improving the thermal performance of the building by adding insulation to the advantage of comfort conditions inside the building in the Canadian homes. The results appear that the optimum insulation thickness has been obtained from a relationship between surrounding temperature and annual cost that which depends on fuel consumption and insulation thickness. Mahlia et al. [2] developed a correlation between thermal conductivity and the thickness of insulation materials for building the wall. The result showed that they were found a relation of the optimum of insulation which obeys a polynomial function and it may be very well practiced in a calculation of the optimum thickness of insulation. Zhu et al. [3] determine the optimum and energy saving for different types of external insulation wall for four cities that which has a typical weather and compared the results with Chinese energy-saving standard, the results that which obtained from this study make sure that the optimum thickness of the insulation was depended on the city weather. Mishra et al. [4] investigated the optimum thickness of thermal insulation which used to reduce heat loss through external walls and roof by using degree-day (DD) method for calculating heating and cooling loads requirement. The

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Nomenclature

Bi	Biot number
h	convection heat transfer coefficient, (W/m^2 ^{o}C)
H	height, (m)
I	solar intensity, (W/m^2)
K	thermal conductivity, (W/m ^{o}C)
l	wall thickness, (m)
L	length, (m)
N	number of nodes
Q	energy consumption, (W)
R	thermal resistance, (m^2 ^{o}C/W)
T	time of iteration, (sec)
T	temperature, (^{o}C)
U	wind speed, (m/sec)
W	width, (m)
X	node width, (m)

Greek symbol

Α	thermal diffusivity, (m^2/sec)
ε	emissivity

Subscripts

I	inner surface
o	outer surface

results showed that the optimum thickness of the thermal insulation layer varies between 14.46 to 20.77 cm, and the annual energy saving varies between 500.03 to 1014.27 Rs/m^2. Fertilli [5] studied the optimum thickness of four different building walls stone, brick, concrete, and bims which are used in Turkish building construction, from the results, when using insulation thickness between 0.0 – 17.9 cm leads to saving 0-235 \$/m^2 of energy. Basrawi et al. [6] studied the optimum thickness of wall insulation materials for building under the transient case,results showed that the fiberglass urethane was most efficient for cost saving. Nyres et al. [7] presented that mathematical model consists technical and economic optimum thickness of thermal insulation layer of an external wall. The numerical results showed the optimum thickness of the thermal insulation layer (polystyrene) is about 9 cm, based on a current price in Serbia (2013). Kaynakli et al. [8] studied an optimization of insulation thickness used for external walls, the optimization calculation based on sol-air temperature for four different regions. The economic optimum thickness has been performed by degree-day for each region. The economic optimum of insulation thickness has been performed on the four degree-day regions. The authors claiming an optimum insulation thickness obtained vary between 0.9 to 7.5 cm for heating and 0 to 3.2 cm for cooling depending on cities.

The aim of the present study is the determination of optimum wall thickness for building in Kirkuk city without using thermal insulation layer and through comparison of four wall thickness 48, 36, 24, and 16 cm. The simulation of energy on the building is performed by using actual weather in two different conditions cold and hot climates. The principle of comparative is based on the temperature distribution within the wall and energy consumption to conditions at constant indoor temperature.

2. MATHEMATICAL MODEL

The energy is transferred through the walls into inside any building geometrical form by conduction heat transfer. The limitation of transferring energy to/out the building depends on the thermal resistance when the temperature difference is constant. Where thermal resistance defined as [9]:

$$R = \frac{x}{kA} \tag{1}$$

The optimum wall thickness of the wall was obtained by simulating energy on the room shown in Fig. 1, under transient condition. First, assume the room was insulated completely, except south wall. The second constant physical properties for building material. The temperature distribution within the wall has been calculated by using one-dimensional transient heat equation. The finite difference on the wall section shown in Fig. 2, where it was divided into ***(N)*** division, where

$$N = \frac{1}{x} \tag{2}$$

The one-dimensional transient heat conduction will be applying to the Fig. 2 as a governing equation to determine the temperature distribution [9]:

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t} \tag{3}$$

Equation (3) has been solved by finite difference method, where for constant physical properties and by applying the boundary and initial conditions to the equation, and it has become

$$T(t,N) = \frac{\left[2T(t-1,N+1) + 2Bi_o(t) \times To(t) + 2\varepsilon I \frac{\Delta x}{k} + (M - 2Bi_o(t) - 2)T(t-1,N)\right]}{M} \tag{4}$$

$$T(t,N) = \frac{[T(t-1,N+1) + T(t-1,N-1)]}{M} + \left(1 - \frac{2}{M}\right)T(t-1,N) \quad \text{for } 0 < N \le N-1 \tag{5}$$

for node *N* = 0

$$T(t,N) = \frac{[2T(t-1,N-1) + 2Bi_i \times Tr + (M - 2Bi_i - 2)T(t-1,N)]}{M} \quad \text{for } N = N \tag{6}$$

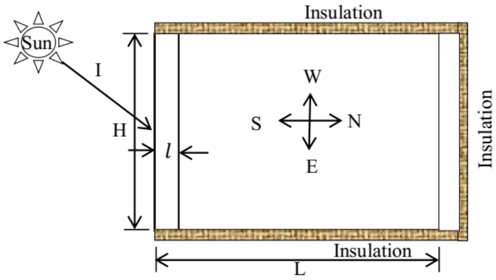

Fig. 1. The illustration of room module.

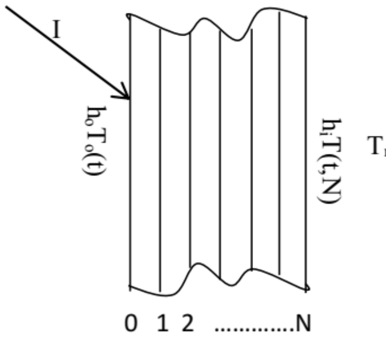

Fig. 2. the illustration of boundary conditions and distribution of nodes on the south wall.

where

$$Bi_o(t) = \frac{h_o(t)\,H}{k} \tag{7}$$

The outside convection heat transfer coefficient which was calculated based on the wind speed [10]:

$$h_o(t) = 5.4 + 4.1U \tag{8}$$

$$Bi_i = \frac{h_i\,H}{k} \tag{9}$$

$$M = \frac{x^2}{\alpha\,t} \tag{10}$$

The parameter M must be restricted according to

$$M \geq \begin{cases} 2[Bi_o(t)+1] \\ 2 \\ 2[Bi_i+1] \end{cases} \tag{11}$$

To ensure convergence of numerical solution, the M must be the higher values from above values, and Eqs. (5) to (7) are solved simultaneously by preparing a program and proceeding through Matlab software.

3. RESULTS AND DISCUSSION

The amount of energy transferring to/out the building is limited through many parameters that which has been related to the building material and walls dimension. For this purpose, a module of a building has been selected as shown in Fig. 1 of common brick four wall section geometry shown in Fig. 3. The physical specifications present in the Table 1. The energy analyzing has been conducted for this room under two different actual weather conditions in Kirkuk city for 2016, first, on January 31, 2016, which is the coldest month and the second, on 1st July 2016 which is the hottest month in Iraq, Table 2 shown the details of parameters that which used for executing the program. Energy analyzing in both heating and cooling seasons depended on a constant room temperature of 23 ºC. From the results of the simulation shown in Figs. 4 and 5 observed that inner surface temperature of wall thickness 48 cm was little-effect with change of weathers, unlike to thin wall 16 cm, where it was inner surface temperature has been rapidly changing with the weather, also from these two figures observed similarity in outer surface temperature for all wall thicknesses.

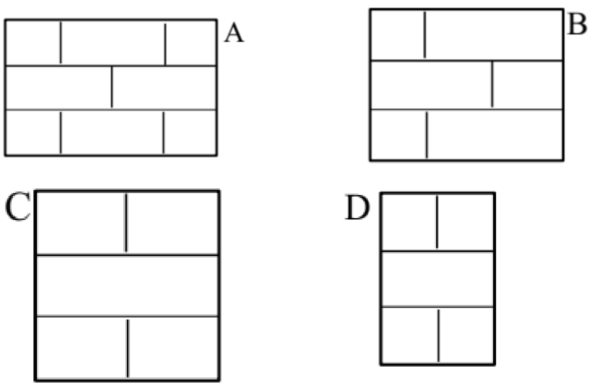

Fig. 3. Cross-section for wall thickness. (a) 48 cm thick, (b) 36 cm thick, (c) 24 cm thick, and (d) 16 cm thick.

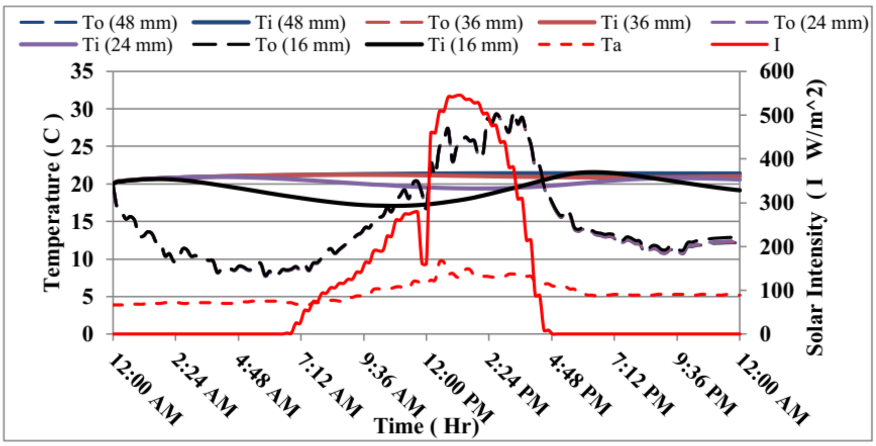

Fig. 4. The hourly variation of Inside and outside surfaces temperatures for four wall types in cold climate on the 31/12/2016.

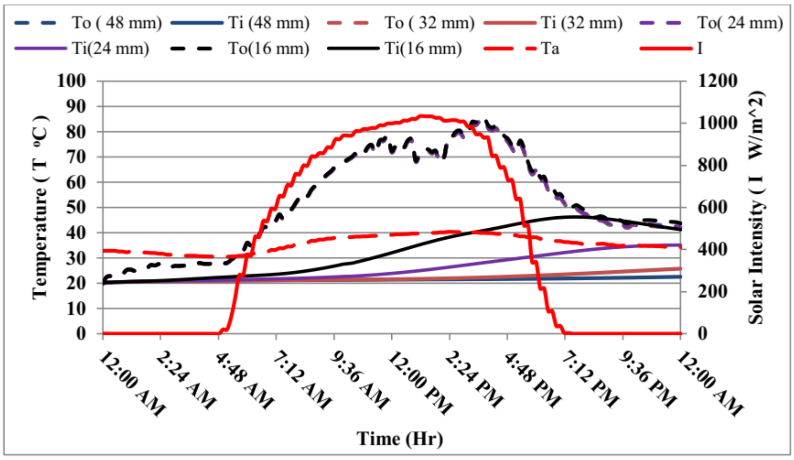

Fig. 5. The hourly variation of Inside and outside surface temperatures for four wall types in the hot climate on the 1/7/2016.

Table 1
Physical properties of building materials that which used.

Type of building material	Density (kg/m^3)	Specific heat (J/kg°C)	Thermal conductivity (W/m °C)	Thermal diffusivity (m^2/sec)	Emissivity
Common brick [10]	1600	840	0.69	5.200×10^{-7}	0.96
Cement mortar [11]	1860	780	0.72	4.963×10^{-7}	0.63

Table 2
Parameters which have been used for simulation.

x (m)	*t* (sec)	Indoor temperature (°C)	*hi* (W/m^2 °C)	Initial Temperature (°C)
0.02	300	23	5	20

In other hand, when comparing the energy consumption (*Q*) from the room through the south wall were present in Fig. 6. The amount of *Q* during cold climate was less than hot climate overall and the amount of Q was inverse between heating and cooling processes. Where the higher *Q* was obtained during the summer season, especially at *l* =16 cm and it is about 1975 W during 24 hr., while the minimum of *Q* was obtained at *l* = 32 mm and it is about 208 W, and it contributes to rationalizing rate about 9.5 times than *l* = 16 cm. While in the heating process the maximum *Q* was obtained at *l* = 48 cm, that due to the insensitivity of the wall with the weather change, contrary to the *l* =16 cm where it was needed to the minimum *Q*, where the Q_{16}/Q_{48}) is about 48.5%.

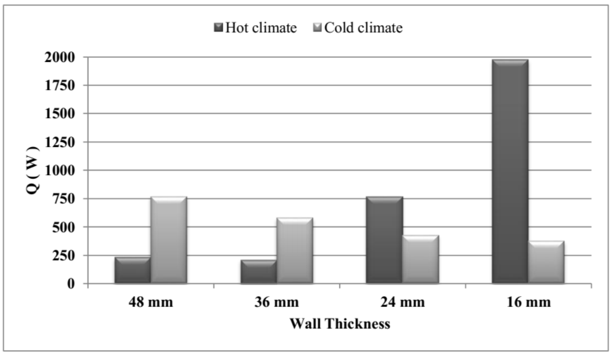

Fig 6. Energy consumption for four types of wall in both cold and hot climates (2016).

From analyzing results observing that energy consumptions are varying with the (*l*) and seasons by a large amount and to fixing these variations as shown in Fig. 7, where two relations of wall thickness against for two climates have been intersected at the mid of wall thickness of 36 and 24 cm, where it is about 28 cm and it was considered an optimum wall thickness for building in Kirkuk city.

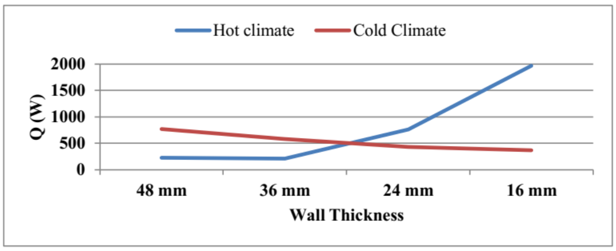

Fig. 7. Energy consumption against wall thickness for hot and cold.

4. CONCLUSIONS

From the results obtained from energy simulation on the typical room under two different weather conditions could be summarized as:

1. The energy consumption for the thick wall in a hot climate has been less than the thinner wall and vice versa in the cold climate
2. The optimum wall thickness in these weather conditions was (28 mm) which gives stability to energy consumption during heating and cooling cases and it is about (500 W).

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