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STUDY THE ECONOMICAL AND OPTIMUM THERMAL INSULATION THICKNESS OF BUILDING WALLS FOR ENERGY SAVING IN IRAQ

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ABSTRACT: - In hot climatic countries such as Iraq, a great amount of energy is consumed in air-conditioning. Environmental effect of energy consuming and the increasing cost of energy, give special interest in order to overcome the day by day increasing energy demand. Therefore the optimum insulation thickness for building was studied in this work to reduce the energy losses in three different climatic city of Iraq; Mosul, Baghdad and Basrah. Cork was used as an insulation material in present work. The optimization based on ten years life cycle cost analysis. As a result; significant energy saving is gained; saving of 10573 IDper square meter (about 10$/m^2) of the wall in Basrah can be obtained annually when the optimum insulation thickness is applied.

KEYWORD: Energy saving, optimum thickness of insulation, degree day.

1- INTRODUCTION

High oil prices, decreasing supply of fossil fuel and their significant environmental pollution call for efficient energy use. The air conditioning in building sector is the highest energy consumer area. The optimum thickness of insulation has been calculated for heat losses from external walls only, in fact walls and roof insulation can save up to 77% of energy [1]. The optimum insulation thickness is that thickness of insulation material in which energy saving is maximum and the total cost is minimum. In order to take the cost change of both the energy and the insulation material, the value of optimum insulation thickness was calculated by using life cycle cost analysis. The literature review predate the scope of this paper is given as follows: Ahmet [2] estimated the heating energy required in building in winter using the degree hours method based on human comfort levels. Farhanieh [3] studied the effect of the using of a proper insulation on the energy saving in Iranian building using integrative modeling for insulation. Ozden [4] studied the environmental impact of optimum insulation thickness in building of Turkey. Subhash [5] discussed the energy saving in different type of Indian building by using optimum insulation thickness with suitable insulation material. Ahmed [6] presented the important climatic data in Iraq for sustainable building design.

2- RESEARCH DATA AND CALCULATION PROCEDURE

In Iraq, the common structure of the wall is 24 cm of brick and an external 2 cm cement layer, the total thermal resistance for this wall type had been determined to be 0.42 $\mathrm{m^2C/W}$. Where the insulation can be applied internally and followed by thin layer of decorating or for safety from fire; as most the insulation material is flammable. The insulation can be also applied externally as some type of the insulation comes with a finished surface. In this study cork ($k = 0.039\ (W/m.C)$) was used as an insulation material, the price of the insulation material is$80000\ (ID/m^3)$.Cooling losses in building occur through

external walls, roof, floors and windows. The heat loss from window is not taken into account and optimum thickness of insulation has been calculated based on heat losses from external walls only.
The heat flux loss from the external wall is:

$$q = U\,.\,\Delta T (1)$$

Where:
$q$is heat transfer per unit area (W/m^2).
$U$is the overall heat transfer coefficient for an external wall with a layer of insulation (W/m^2.^{o}C).

$$U = \frac{1}{R_i + R_w + R_{in} + R_o} \quad (2)$$

$R_i$and$R_o$are the thermal resistance of inside and outside room air, respectively. $R_w$is the thermal resistance of external wall and R_{in} is the thermal resistance of insulation layer.
Let's:

$$R_{in} = \frac{x}{k} \quad and \quad R_t = R_i + R_w + R_O \quad (3)$$

So $$U = \frac{1}{R_t + \frac{x}{k}} \quad (4)$$

The annual heat flux lossq_A, $\left(\frac{h.W}{m^2}\right)$ can be determined using degree days, DD.

$$q_A = 24\,.\,DD\,.\,U \quad (5)$$

The energy requiredE_A,$\left(\frac{h.W}{m^2}\right)$ to substitute the heat flux losses is found by dividing the annual heat loss to the coefficient of performance (COP) of the cooling device

$$E_A = \frac{24\,.\,DD\,.\,U}{COP} = \frac{24\,.\,DD}{\left(R_t + \frac{x}{k}\right).\,COP} \quad (6)$$

The annual energy flux costE_c, (ID/m^2):

$$E_c = E_A, * f_c, \quad (7)$$

Where: f_c $\left(\frac{ID}{h.kW}\right)$is the electricity cost.

$$E_c = \frac{0.024\,.\,DD.\,f_c}{\left(R_t + \frac{x}{k}\right).\,COP} \quad (8)$$

The life cycle cost analysis was considered in this work. The annual energy cost was evaluated in present value based upon the present worth factor (PWF). Where: the PWF [7] is a function of the interest rate I and the inflation rate g.

$$PWF = \frac{1 - (1 + r)^{-N}}{r} \quad (9)$$

Where:
N is the lifetime and it had been taken 10 years for this study.

$$r = \frac{(I - g)}{(1 + g)} \quad when\ (I > g) \quad (10)$$

So the total cost of cooling of an insulated buildingE_{ct}, $\left(\frac{ID}{m^2}\right)$ is given by:

$$E_{ct} = PWF \times E_c + i_c \times x \quad (11)$$

Where: i_c is the insulation cost ID/m^3 and x is the thickness of insulation

$$E_{ct} = PWF \times \frac{0.024\,.\,DD.\,f_c}{\left(R_t + \frac{x}{k}\right).\,COP} + i_c \times x \quad (12)$$

The optimum insulation thickness x_o(meter) is obtained by optimizing the total cooling cost of an insulated building(E_{ct}).

$$x_o = 0.155\sqrt{\frac{PWF.DD\,.f_c\,.k}{i_c\,.COP}} - k\,.R_t \tag{13}$$

The parameters used in this equation are given in Table (1).
Energy saving(E_s), (ID/m^2) can be calculated by:

$$E_s = E_{no\,i} - E_{ct} \tag{14}$$

Where: $E_{no\,i}$ and E_{ct} are the total cooling costs of building when insulation is not and is used, respectively.
Payback period for the insulation material can be calculated by:

$$Payback\ period = \frac{i_c \times x_o}{E_s} \tag{15}$$

3- RESULTS AND DISCUSSION

Optimum insulation thickness, energy saving and payback period for a lifetime of 10 years for three cities in Iraq are shown in Table (2). From Table (2); the insulation thickness required for Basrah which it's the hotter city in Iraq is the highest since it has the highest cooling degree day, the lowest insulation thickness was in Mosul which it is one the coldest cities of Iraq and so Baghdad in between, Figure (1).

Figure (1) shows the optimum insulation thickness increased with the increasing of degree day. Obviously the thicker the insulation, the lower running cost of energy but also required much building cost and vice versa. Therefore, the total cost is minimizing until a particular value of insulation thickness in which a maximum saving amount is obtained as shown in Figure (2).

As can be noted though the optimum insulation thickness is the highest in Basrah but the saving amount is the highest, thus the saving amount increased with the increasing of degree day. See Figure (3).

So it is very important to use the insulation in the hot climate region which has the higher degree day, therefore this investigation has been made for cooling purpose as the Iraq has number of hot days higher than cold days, which make the insulation an urgent issue as the saving amount is high.

4- CONCLUSION

In this work the optimum insulation thickness of external walls and the energy saving in three climatic zones of Iraq have been investigated. It was found that the payback period is too short due to the efficient saving. The maximum amount of saving was10573 ID/m^{2}yearover a life time of ten years, thus the optimum insulation thickness should be applied to the buildings in Iraq.

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Table (1): Parameters used in the optimum insulation thickness calculation.

Parameter	value
Cooling degree day (DD) of Mosul	2676(7)
Cooling degree day (DD) of Baghdad	3393(7)
Cooling degree day (DD) of Basrah	3807(7)
Inflation rate (g)	0.025(8)
Interest rate (I)	0.04(8)
Electricity cost	25 (ID/kW.h) (9)
COP	2.6(10)

Table (2): Optimum insulation thickness, saving value and payback period for the selected area

City	Optimum insulation thickness (m)	Saving value (ID/m^2)	Payback period (year)
Basra	0.046	10573	0.35
Baghdad	0.043	9034	0.38
Mosul	0.036	6457	0.45

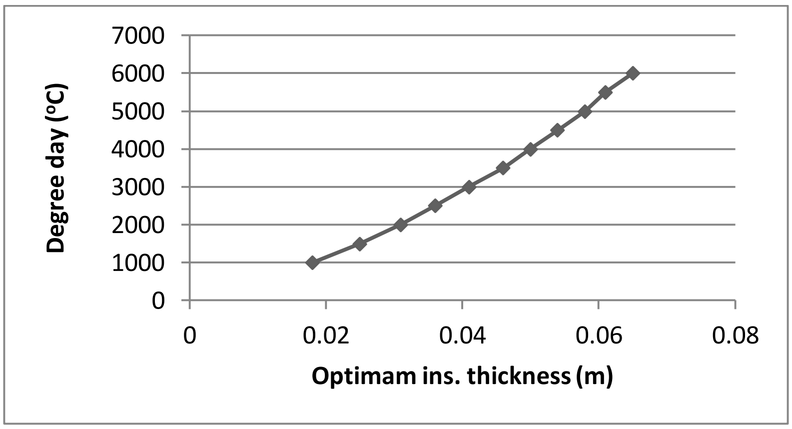

Figure (1): Effect of degree day on insulation thickness.

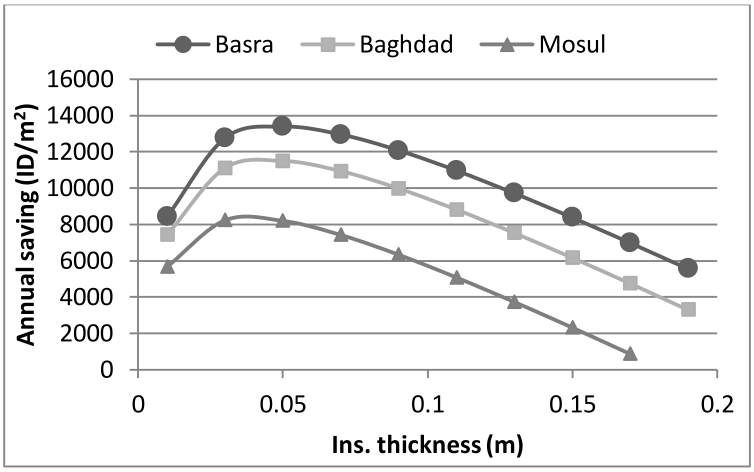

Figure (2): Effect of insulation thickness on annual saving.

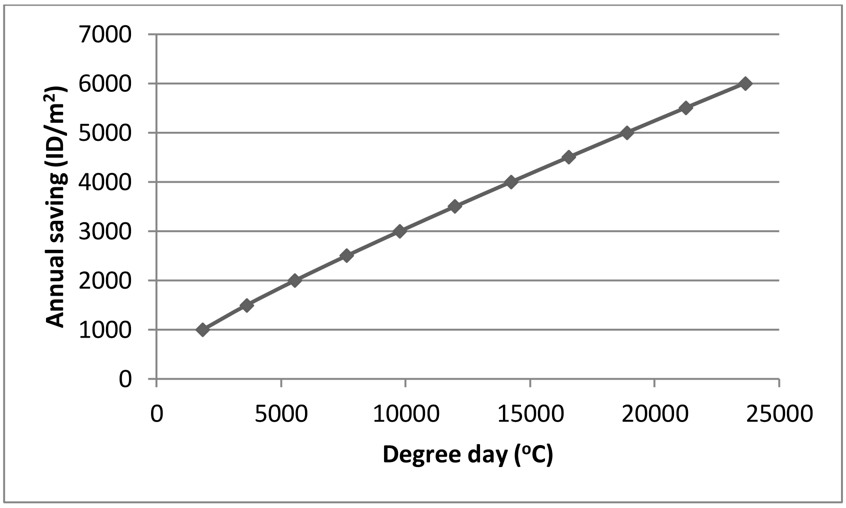

Figure (3): Effect of degree day on annual saving.

دراسة الظروف المثلى و الاقتصادية لسمك الجدران العازلة لتوفير الطاقة في العراق

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الخلاصة

في الدول ذات المناخ الحار مثل العراق, كمية كبيرة من الطاقة تستهلك للتكييف. الأثر البيئي لاستهلاك الطاقة وتكاليف الطاقة المتزايدة, يعطي اهتمام خاص من اجل التغلب على الطلب المتزايد بشكل اليومي للطاقة. ولهذا تم دراسة سمك العزل الأمثل للأبنية في هذا العمل للحد من الخسارة في الطاقة لثلاثة مدن عراقية مختلفة مناخيا: الموصل وبغداد والبصرة. حيث تم استخدام الفلين كمادة عازلة في هذا العمل. الدراسة بنيت على تحليل التكاليف لدورة حياة أمدها عشرة سنين. النتائج توضح إن هناك مقدار كبير من الطاقة يمكن توفيرها, مقدار 10573 دينار عراقي لكل متر مربع من الجدران (حوالي 10 دولار لكل متر مربع) يمكن توفيره في مدينة البصرة عند تطبيق سمك العزل الأمثل.

الكلمات الدالة: حفظ الطاقة، العزل الأمثل للأبنية، درجة حرارية باليوم.