Cost benefit analysis of optimum thickness for selected insulation materials for building walls in Malaysia

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Abstract: - This study estimated the cost savings potentially achieved by installing different insulation materials, each of its optimum thickness, in the walls of a building, taking the Chancellery office building of University Kebangsaan Malaysia as the test bed for simulation studies. IES (Integrated Environmental Solution) software was used to model the office building and for thermal performance and cost benefit analysis. This study found that by introducing insulation of optimal thicknesses varying between 2 and 4 cm, a reduction in cost of energy consumption of between 32 and 35% over the cost of energy consumption with no insulation can be achieved.

Key-Words: Cost benefits analysis, Thermal insulation, Optimum insulation thickness, Building simulation, Life cycle analysis, Insulation thickness.

1 Introduction

As population increases, improved energy demand for the future is easily predicted, which however, raises the level of comfort as times people spend inside buildings improved. It has shown that the demand for quality buildings increases with respect to the office buildings [1]. Although the energy consumed in office buildings was 10-12 times higher compared to residential buildings, which is around 70-300 kw/h/m^2 annually, for office buildings (yang et al. 2008). Saidur et al. (2009) has reported that office building air conditioners had the highest energy consumption of 57% followed by lighting (19%), lifts, pumps, and other equipment, 18 and 6% respectively. A large number of the buildings in Malaysia are fitted with air conditioned systems due to the dynamic tropical conditions in Malaysia, which alternates between humid and hot climates. In many tropical countries, the use of air condition is conventional for space cooling, which raises the energy consumption as well as equipment levels thereby subjecting the business sectors with no alternative but high electricity costs [2]. The energy consumption for air conditioned system is minimized by insulation. Thermal insulation is therefore the alternative choice which is cost effective for energy reduction. However, the cost of insulation is directly proportional to the insulation thickness. Therefore an optimum determination of the insulation thickness via cost analysis is unavoidable by researchers [3]. Bolatturk (2008) carried out some analysis on the use of insulation for external wall buildings. The results showed that maximum insulation thickness ranges from 2-17 cm, payback duration 1.3-4.5 and energy savings 22-79%. In Denizli Turkey, Dombayci [4] found that using expanded polystyrene as an insulation material with insulating thickness decreased energy consumption by 40.6% and reduced the discharge of CO_2 and SO_2 by 41.53%, while the source of energy was coal. This study was undertaken to evaluate the cost benefit analysis and energy consumption via insulation material installation for air conditioned buildings walls in Malaysia.

2 Modeling the office building for energy consumptions

IES <VE-Pro> (Integrated Environmental Solution) was used to model the office building located at Bangi, Malaysia.The geographic coordinates of Malaysia lies at Latitude 3.12^{o}N; longitude 101.55^{o}E with variable temperatures, and high humidity. The Malaysians' hottest time is around March which is 27.8^{o}C [6].As it shown in Fig.1, the annual weather data, maximum dry-wet bulb 34.90 ^{o}C and 26.50 ^{o}C respectively.

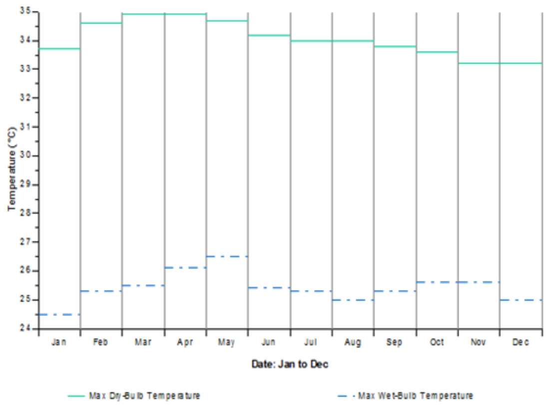

Fig.1. Annual dry-wet bulb temperature, Kuala Lumpur, Malaysia

2.1 An overview of the case study building

The propose building chosen is Chancellery office building, an iconic landmark in UKM (Universiti Kebangsaan Malaysia) which is located at Bangi, Malaysia. The selected building is a typical six-storied office building which contains assignable 12239 square meter of instructional space including office spaces, lobby, meeting rooms and restaurants.

2.1.1 Energy analysis, IES<VE-Pro>Software

To integrate the building design process and fulfill the experimental requirements for this study, IES was the program of choice for simulation study. Based on existing office building the model has been created to evaluate the energy consumption of selected building (as shown on **Figs 2-3**).Weather data in these formats is available for a large number of sites worldwide. The summary on the data input for energy audit are as follows, data weather and sites location, building construction, specific variation profiles of casual gain, ventilation and set points, light and office equipments internal gain from occupants and cooling system setting. Equipment for all applicants for annual energy consumption was calculated from the simulation analysis. The annual energy consumption and energy intensity for this project is 211.593(Mwh) and 173 kwh/m^2 respectively. Of the total electricity consumption, 58% of building energy consumption is from a space conditioning which includes space cooling and ventilation followed by lighting 21%, other equipment, 21% respectively (**Figs 4-5**).

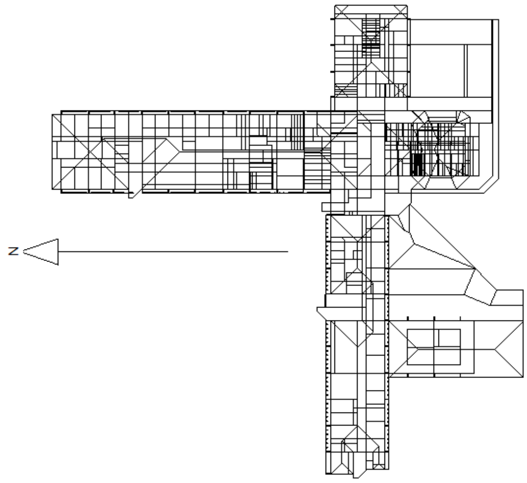

Fig.2. Building site plan

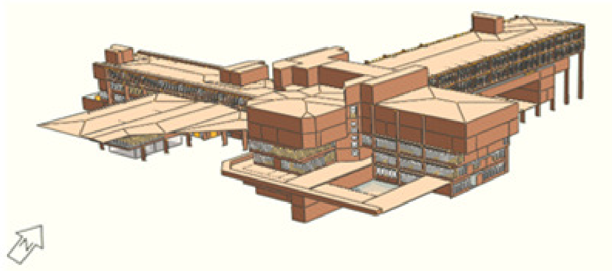

Fig.3. 3D view of the Chancellery office building model developed in IES< VE-PRO> 6.2.0.1

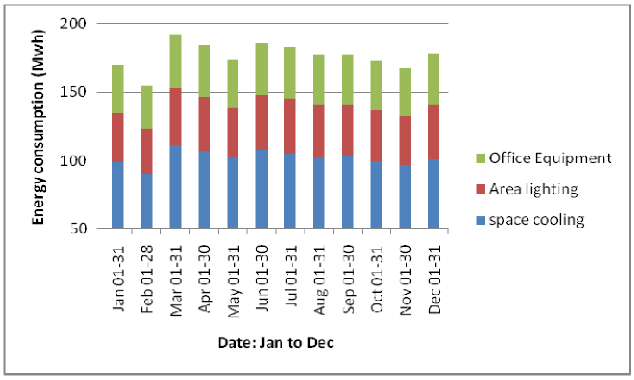

Fig.4. Results of the IES run on Chancellery building energy performance for the base case

ISBN: 978-1-61804-052-7

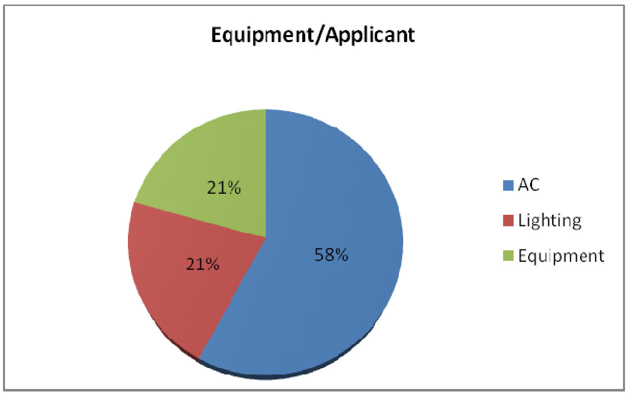

Fig.5. Total energy consumption by all equipments and their breakdown

2.1.2 Optimum insulation thickness and the energy savings

Thermal insulation is the alternative choice in order to lower the heat flow from outside to inside. Non-linear relation between the thermal conductivity and optimum insulation thickness of selected insulation materials for building wall found out by Ref [3].

Electricity tariff is a function of the optimum insulation thickness as well as the cost of material insulation, lifetime of the buildings, inflation and discount rate and air conditioner performance coefficient. The total cost of energy consumption the building can be calculated (C_{TE}) by the following equation calculated as follows:

$$C_{TE} = E \times C_E \qquad [1]$$

Where E is energy consumption (KWh), C_E is the electricity tariff rate. For the life time of N years, it is necessary to know the present value (PV) which is depends on the electricity tariff (C_E) and inflation rate (IR).

$$PV = C_E ((1+IR)^n - 1) / IR (1+IR)^n) \qquad [2]$$

Table.1 Essential input data

Description	Value
Annual energy consumption (Mwh/year)	2117.593 (Mwh/year)
Life cycle period (N)	5
Electricity Tariff (CE)	0.312 (MYR/kWh)
Inflation rate (i)	3.50%
Present value (PV)	4.51
Total heat transfer area (A)	12239 m

Table.2 Data of Insulation Materials

Type of insulation	Thermal Conductivity (W/m° C)	Density `kg/m^3	Cost RM/m^3
Extrude polystyrene	0.029	35	210
Rock wool	0.034	100	202

The total cost of insulation (C_{ins}) which is necessary for the cost benefit analysis, can be calculated by the following equation:

$$C_{Tins} = AxC_A \qquad [3]$$

To calculate the enrgy saving over the life cycle priod, Where C_{ins} is the cost of insulation material per unit volume in\$/m^3, A is the surface area of insulation material in m^2, x the insulation thickness in m. The total savings are the net savings from the total cost of energy without insulation minus of the total cost of energy for cooling with insulation and minus the total cost of insulation. Thus the equation becomes:

$$T_s = (C_{TEun} - C_{TEins}) - C_{ins} \qquad [5]$$

3 Results and discussions

Results of simulation shows that energy consumption was reduced which reduces the cost due to increased insulation thickness. However, a linear insulation increase costs was observed as well as insulation thickness, which is an indication that total cost was not linearly correlated with the insulation thickness .The total cost saving increases with increasing the thickness of insulation until it reaches the optimum thickness where the total cost saving start to drop . **Figs. 6-8** illustrates that using extrude-polystyrene and rock wool as the insulation materials will save 60135.68 RM and 59590.82 RM respectively at the optimum thickness. Table 3 showed selected insulation materials in different thickness and energy consumption. The result suggests that extrude polystyrene (saving 60135.68 RM in 5 years) compared to rock wool. The extrude-polystyrene has the lower thermal conductivity compared to rock wool that means higher thermal resistance and therefore less consumption and more cost saving.

Table 3 Different insulation thickness and energy consumption for each insulation material

Thickness (m)	Annual Energy consumption (MWh)		Total cost saving (RM)	
	Polystyrene	Rockwool	Polystyrene	Rockwool
0.02	2064.32	2067.122	59092.85	56533.48
0.04	2052.30	2054.658	60135.68	59590.82
0.06	2046.82	2048.794	51983.78	53363.38
0.08	2043.72	2045.375	40484.62	43694.69
0.1	2041.62	2043.141	27570.02	32358.00

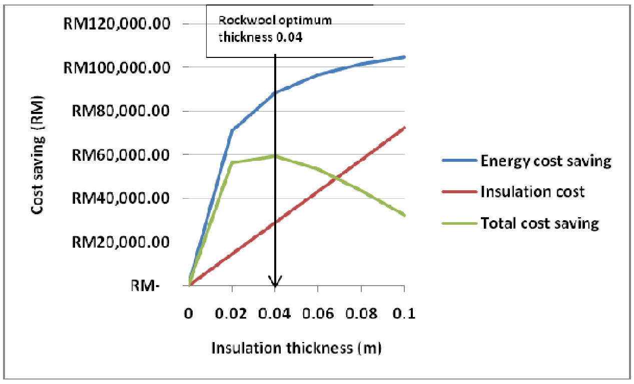

Fig.6. Effect of insulation thickness on cost saving (5 years lifecycle-Rockwool)

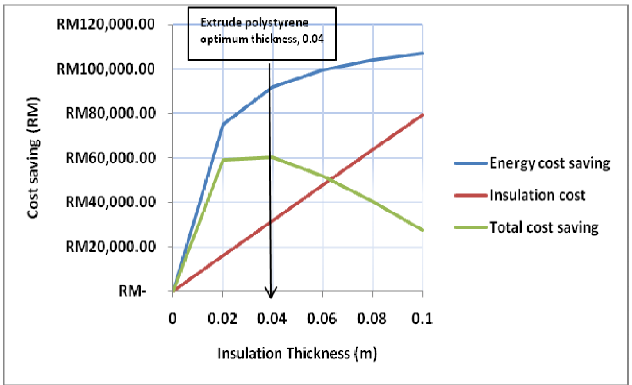

Fig.7.Effect of insulation thickness on cost saving (5 years lifecycle-Polystyrene)

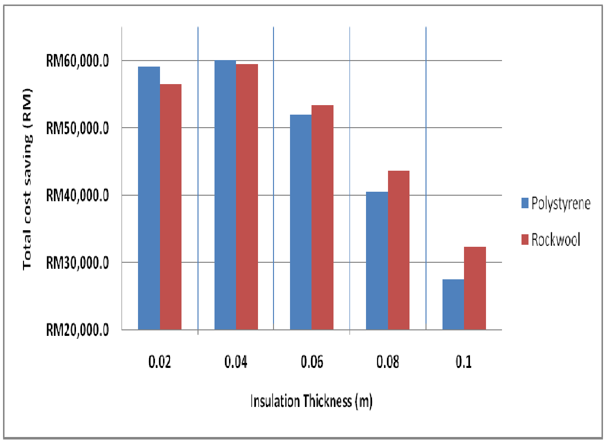

Fig.8 Costs saving comparision between extrude polystyrene and rockwool

4 Conclusion

This paper analysed the cost saving achieved by installing different insulation materials, each of its optimum thickness, in the walls of a building. In this study, the optimum insulation thicknesses of extrude polystyrene and rock wool on external walls of buildings were calculated based on annual cooling loads by using IES software. The optimum insulation thickness, the amount of energy saved, and the total cost saving are calculated using life-cycle cost analysis over the lifetime of 5 years. This study found that by introducing insulation of optimal thicknesses varying between 2 and 4 cm, a reduction in cost of energy consumption of between 32 and 35% over the cost of energy consumption with no insulation can be achieved. Extrude-polystyrene at its optimum thickness, 4 cm will save 60135.68 RM which is higher than rock wool with the same thickness of insulation.

ISBN: 978-1-61804-052-7

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