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Using polystyrene foam to reduction the cooling load by Auto desk Revit software

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Abstract
Roof insulation is one of the most important strategies to reduce the electricity consumption in the building which leading cost savings and reduce the emission of gases that pollute the environment directly. Therefore, building information modeling took great interest in recent years in the world in terms of the design simulation of the buildings and choose the best design. This study aimed to evaluate the effect of various types of building roof materials on the cooling load. This study involved in selecting a particular building type (factory building) and the effect of the cooling load by using a various metal deck roofing with and without insulation. The cooling load requirement for the building was calculated by using Auto desk Revit software. The results indicated that roof insulation is one of the most important strategies to reduce the cooling load and enhanced the electricity consumption in the building. The twenty percent reduction in the space cooling leading cost savings and reduce the emission of gases that pollute the environment directly.
Keywords: *Cooling load, Insulation strategy, Polystyrene Foam insulation, Autodesk Revit software.*

1. Introduction

Air-conditioning is a process that simultaneously conditions air; distributes it combined with the outdoor air to the conditioned space; and at the same time controls and maintains the required space's temperature, humidity, air movement, air cleanliness, sound level, and pressure differential within predetermined limits for the health and comfort of the occupants, for product processing, or both [1].

Air-conditioning System consists of components or equipment connected in series to control the environmental parameters. An air-conditioning system, by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) definition is a system that must accomplish four objectives simultaneously. These objectives are to control, air temperature, air humidity, air circulation; and air quality. The cooling is typically done using a simple refrigeration cycle, but sometimes evaporation is used, commonly for comfort cooling in buildings and motor vehicles. In construction, a complete system of heating, ventilation and air conditioning is referred to as "HVAC". Cooling load is the rate of heat which must be removed from the space to maintain a specific space air temperature and moisture content [2]. The parameters affecting cooling load calculations are numerous, for example, the outside air temperature, the humidity ratio, the number and activity of people and etc. These parameters are often difficult to precisely define and always intricately interrelated. Many cooling load components vary in magnitude over a wide range during a 24 hr period. These cyclic changes in load components are not often in phase with each other. Each must be analyzed to establish the maximum cooling load for a building or zone. Moreover effects of thermal accumulation also involve in calculating procedure. Therefore various models and assumptions are developed. The estimated results at the specific time of calculation are normally expected and not the exact ones [3]. Insulation of building envelopes, both opaque and transparent, is an important strategy for building energy conservation. Insulation of walls, roof, attic, basement walls and even foundations is one of the most essential features of energy efficient homes. In addition, as glass is a poor insulator, insulating transparent envelopes, windows and skylights, significantly reduces heat loss and gain during the winter and summer [4]. The insulation strategy of a building needs to be based on a careful consideration of the mode of energy transfer and the direction and intensity in which it moves. This may alter throughout the day and from season to season. It is important to choose an appropriate design, the correct combination of materials and building techniques to suit the particular situation. This study focused on reducing the electrical consumption for various environmental conditions by optimizing the cooling load of a building. The issue in this research is that of enhancement the cooling performance by mean of using insulator. The paper is organized as follows: Section II shows the roofs effect on the cooling load. Section III indicates the polystyrene foam insulation. Section IV describes the case study. Section V discusses the new method of simulation by using Autodesk Revit software. Section VI illustrates the simulation results and section VII summarizes the conclusion.

2. The roofs effect on the cooling load

In tropical countries, including Malaysia, Iraq, which is characterized by its climate heat and long-term drought during the summer season or during the year, the roof ceiling is the most important elements affecting the thermal environment inside buildings because it receives large amounts of solar radiation. For buildings in equatorial regions with warm and humid climate such as Malaysia, the roof has been said to be a major source of heat gain. Solar protection of the roof remains one of the main concerns in the thermal design of buildings in the region [5]. Previous studies have shown that in Malaysian building, roof has a huge impact on the thermal performance of the whole building [6]. Due to its geographical location, Malaysia receives the sun directly overhead most of the day throughout the year. Therefore, major heat gain of Malaysian houses comes from the roof. According to previous studies, around 87% of heat transfer from the roof to occupant is through radiation process, whereby only around 13% of heat is transferred through conduction and convection [7], as illustrated in figure (1). The radiant heat received by the occupants in a space can be measured as mean radiant temperature (MRT). The mean radiant temperature (MRT) is the area-weighted average of all the surface temperatures in a room, and is affected by the position of the person in relation to the various surfaces. The larger the surface area and the closer to the person, it will have more influence to an occupant's MRT. This explains why the roof plays an important role in determining the overall MRT of the building, which will have a direct impact on the thermal comfort level of the occupants. According to Peng Chen [8], the thermal radiation of roof largely depends on the composition materials.

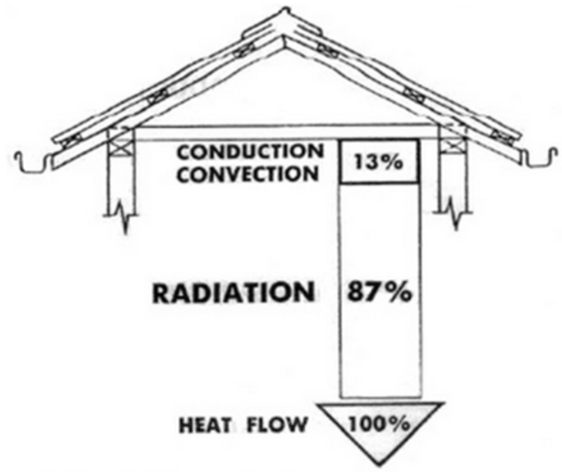

Fig 1 Thermal radiation from roof into interior [7].

2.1 Roof Materials

The heat gain through the outer shell of the structural section of the building consists of a total transmitted amounts of heat in the state of stability (which arise from differing degrees air temperature inside and outside building) and the unstable situation (resulting from variation of solar radiation falling on the roofs of the building density) and complicated heat transfer process through the roof of having heat capacity (whose value depends on both the amount of conductivity makes them part of the stored heat (Thermal, specific heat and density of the components of the roof) [9]. Transmitted through it, where the vagaries of the degree of heat to the outer surface of the roof section does not appear rapidly fluctuations .Similar to the degree of the inner surface temperature of the roof section, which means that the construction materials of which the outer roof section will increase of the value of the thermal resistance of the roof itself and thus will increase the amount of delay time to the heat transfer through it, which requires the use of air-conditioning equipment throughout the hours per day to absorb the thermal loads on arrival and reduce the degree of air space temperature to that level specified in advance, which means that the electric power consumption for the purposes of running the air conditioning equipment is linked to the amount of heat transmitted through the roof of the building, reduce that heat will lead to reduce the period of operation of air conditioners and thus reduce the amount of electrical energy consumed for air conditioning purposes. Optimizing roof materials can play a vital role in lowering down the heat built up in both air-conditioned spaces and naturally ventilated spaces. Also to achieve a better thermal performance of the roofs, it is desirable to have a multi-layered roof comprising materials of different thermo physical properties. It can be concluded that the most important physical property of a roof is the thermal conductivity, which must be as low as possible. The common roofing systems and materials used in Malaysian residential developments, clay tiles with double sided aluminum foil and plasterboard ceiling is able to produce the optimum thermal performance in relation to Mean Radiant Temperature [6]. This is followed by concrete tile roofing system with double sided aluminum foil and plasterboard ceiling, and lastly metal deck roofing system with double sided aluminum foil, rockwool as insulation materials and plasterboard ceiling.

2.2 The angle of inclination in roof

Hasan [10], mentioned that by increasing the angle of inclination of the roof the amount of heat leaking from the roof of the apartment building can achieve greater savings in electrical energy consumed. For the purpose of the annual air-conditioning when we make concrete roof inclined at an angle of 5 degrees from the horizon .The biggest saving achieved was when the roof was the leaning directed towards the north where the amount of energy savings of 11% per year, followed by facing towards the north-east and then north-west a little difference, while avoiding routing towards South, east and west and south to the negative impact. The fact that the sunlight received by the building surfaces are larger than the effect on the temperature of the environment (Shadow), the temperature change of the internal space of the building, was influenced by the increase in the degree of inclination roof .This affect more in reducing the energy required in conditioning the building, while the effect of the surface of the building guide change (summer and winter), since the change is a courier to note that. The rate of change in the external boundary layer temperature of the roof of the building change in hourly manner per day depending on how much sunshine that part of the roof was exposed [11]. Figure 2 shows the angle of inclination in roof.

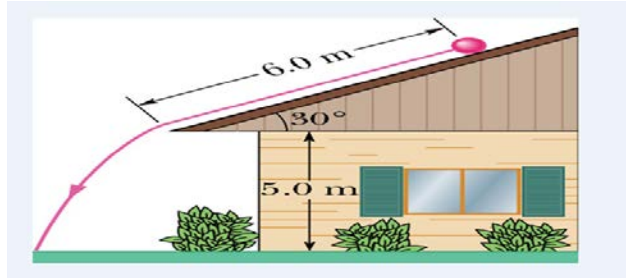

Fig 2 The angle of inclination in roof [12]

3. Insulation

Insulation is one of those ubiquitous techniques that are always around, always impinging on our work, social and domestic activities and yet for most of the time is hardly noticed. Insulation is a passive product; once installed, it works efficiently, quietly and continually, usually out of sight, enclosed within a structure or a casing or under cladding.

3.1 Polystyrene Foam insulation

Polystyrene is a petroleum-based plastic made from the styrene monomer. Most people know it under the name Styrofoam, which is actually the trade name of a polystyrene foam product used for housing insulation. Polystyrene is a light-weight material, about 95% air, with very good insulation properties and is used in all types of products, available either as EPS (Expanded Polystyrene, produced from polystyrene beads) or as XPS (directly Extruded Polystyrene). EPS and XPS foam boards have been widely used for many decades in the construction and building industry. Tailor-made for thermal and acoustic insulation needs and easy-to-use in all types of buildings, they offer a versatile and cost-effective insulation solution. Polystyrene foams are durable materials, designed to offer superior, constant insulation performance over their entire service life of more than 50 years.
Recent studies have demonstrated that building insulation is the most cost-effective way to significantly alleviate the global warming effect of

greenhouse gases by drastically reducing CO2 emissions.

Buildings insulated with polystyrene foam boards achieve optimum levels of energy efficiency, meeting the most stringent pieces of relevant legislation, including the EU Directive 2002/91/EC on the energy performance of buildings. The use of polystyrene foam reduces significantly heat losses and related CO2 emissions from heating and/or air conditioning, thus contributing strongly to mitigate the effects of global warming. Polystyrene foam boards have no global warming potential: they contain no ozone-depleting substances, and deliver optimal energy efficiency at an affordable price [13].

4. Case study

Case study in this project is a simple factory building consists of two floors .Ground floor is a production space and the first floor is the factory's offices. The dimensions of the factory (10m*30m) and has in ground floor productive machine (lathe - Dril - milling) (4 of each type). We have assumed that the factory building located in town of Batu Pahat, Johor and the latitude and longitude (1.854262835, 103.08965206). Figures 3 and 4 show the floor details of the building.

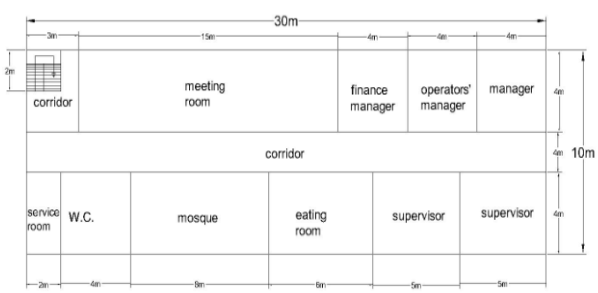

Fig 3 First floor (Administrative Area)

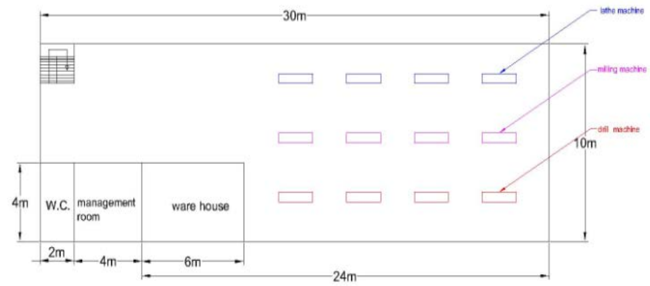

Fig 4 Ground floor (Production Area)

4.1 Roof and wall layers

The interior walls of the factory building consist of gibson board either the exterior walls will be from bricks. The roof layers are consisted of metal deck, polystyrene foam (three thicknesses 1.6, 5 and 10 mm respectively) and aluminum sheet. Figure 3.7 shows the roof layers.

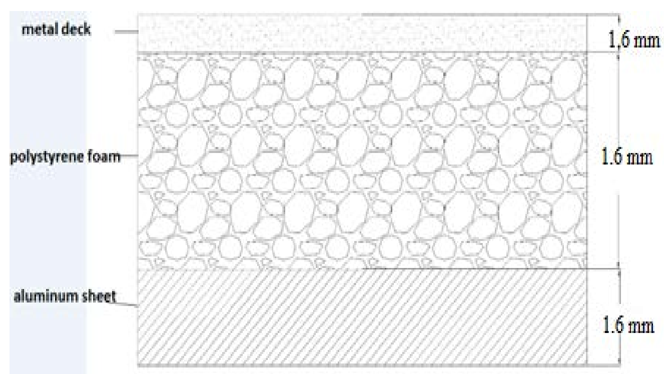

Fig 5 Roof layer with polystyrene foam

5. Method

The main objective of the study is to investigate the effects of roof insulation on the cooling load of a factory building. The following are performed:

i. Simulate the cooling load for the model factory with metal deck roofing with and without insulation. Insulating material is consisted of Polystyrene foam and aluminum sheet where polystyrene foam was in various thicknesses (1.6, 5 and 10 mm).

ii. The resulting in cooling load is compared as for part (i). The cooling load calculations are performed using Autodesk Revit software.
Figure 6 shows 3D model of the factory building and the roof details without using the insulating material while figure 7 shows 3D model of the factory building by using the insulating material.

Fig 6 The roof of the factory building without the insulating material

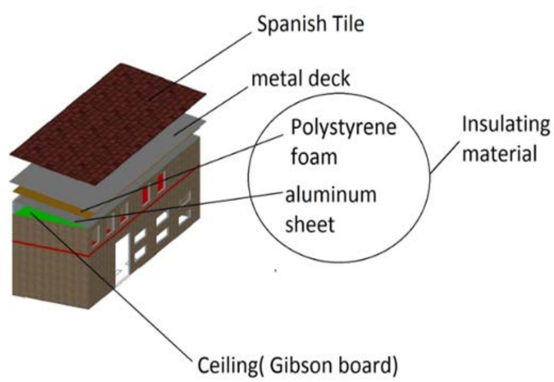

Fig 7 The roof of the factory building with insulating material

6. Simulation

6.1 Building element model

Many of settings apply to the Energy Analysis for Autodesk Revit feature to perform energy analysis using conceptual masses or building elements in this project. The energy analysis was performed by using building elements. Energy Analysis for Autodesk Revit using building elements is intended to provide insight into potential building energy use given more detailed information typically available at later stages in the design process. Create building elements i.e. walls, roofs, floors, windows etc. (room/space elements are optional), define energy settings (especially location and building type) and submit a whole building energy simulation to the Autodesk Green Building Studio web service.

6.2 simulation results

The results of simulation were for cooling load estimation for both cases of roof with and without insulation, are presented in graphical forms. Comparisons of results between the two cases of study i.e roofing with and without insulation were carried out.

6.2.1 Cooling load saving

This section presents the result and analysis of the cooling load of the factory building in both cases with and without insulation showing the effects of the outdoor design and insulation in the overall cooling load of the building. Figure 8 below presents the results of the cooling load of the factory building without insulation (A) and with using insulation (B), (C) and (D).

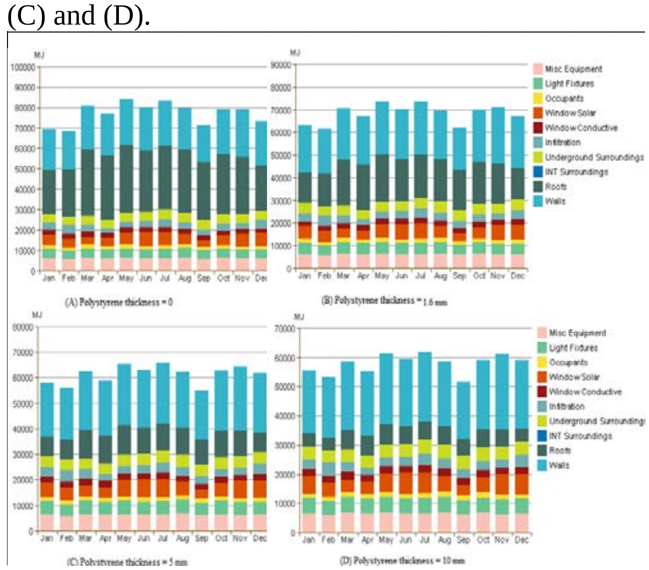

Fig 8 Building monthly cooling load for roof with and without insulation.

The results indicated that the cooling load without insulation was high and ranged between 68500 and 83900 MJ, while for roof with insulation ranged between 51500 and 73500 MJ in three cases of using polystyrene foam as insulation in the roof of factory building. Moreover, there was a difference in the cooling load from month to month. This difference is a natural result of the different temperatures and relative humidity during the year, although the difference in temperature was small, but the relative humidity has had the greatest influence in the cooling load. Table 1 shows the amount of cooling load with and without insulation.

Table 1: The building cooling load for roof with and without insulation

Month	Cooling load without insulation kJ	Cooling load with use insulation KJ (polystyrene thicknes = 1.6 mm)	Cooling load with use insulation KJ(polystyrene thicknes = 5 mm)	Cooling load with use insulation KJ(polystyrene thickness = 10 mm)
Jan.	69,063,480.4	63,008,493.5	58,029,275.8	55,527,169.3
Feb.	68,554,096.6	61,383,345.2	55,845,051.3	53,135,735.4
Mar.	80,680,759.2	70,521,696.4	62,454,474.6	58,457,215.7
Apr.	76,962,903.3	66,930,663.5	59,016,478.3	52,632,534.4
May	83,977,613.1	73,514,341.9	65,319,624.9	61,272,603.2
Jun.	79,931,217.4	70,350,015	62,969,951	59,332,544.1
Jul.	83,211,839.6	73,273,464.6	65,702,839.8	62,010,164.4
Aug.	79,429,187.9	69,628,345.6	62,108,956.7	58,429,489.3
Sep.	71,065,030.1	61,975,311.3	54,975,028.9	51,541,647.5
Oct.	74,425,791.3	69,990,779	62,755,604.9	59,184,683.8
Nov.	79,060,040.8	73,139,968.1	62,799,002.9	60,946,686.8
Dec.	73,247,539.3	66,897,984.3	61,770,739.3	59,206,669.7

6.2.2 Effect of insulation on roof heat transmission/cooling load

The result and analysis of the cooling load of the building with the roof with and without insulation is as shown in figure 9.

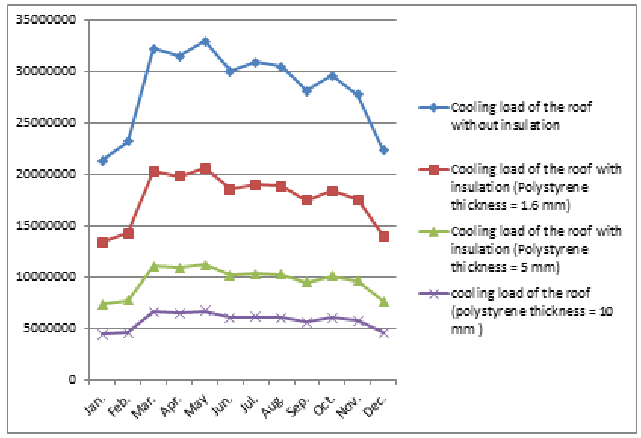

Fig 9 Cooling load of the roof with and without insulation (Joules)

The results indicated the significant impact of insulator use in the roof on the cooling load. This means reducing the heat gained and transmission from the roof into the factory building. It seems very clear the big difference among the readings that show the effect of insulation to reduce the heat transmission through the roof and thus reducing the overall cooling load of the factory building.

On the other hand, the use of roof insulation of different thickness of 1.6 mm, 5 mm and 10 mm had resulted approximately 10.41, 17.86 and 18.718% reduction of electricity consumption respectively as a result of reduced heat transmission into the factory building. Table 2 shows the amount of the cooling load of the roof with and without insulation.

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Table 2: Cooling load of the roof of the factory building with and without insulation.

Month	Cooling load of the roof without insulation (KJ))	Cooling load of the roof (polystyrene thickness = 1.6)	Cooling load of the roof (polystyrene thickness = 5mm	Cooling load of the roof (polystyrene thickness = 10 mm)
Jan.	21469690	13551110	7474931	4489044
Feb.	23249520	14371560	7826609	4672666
Mar.	32359790	20350470	11191610	6711871
Apr.	31620910	19865280	10935950	6562518
May	33029220	20656820	11336090	6791127
Jun.	30066220	18650310	10188010	6092113
Jul.	30933150	19092750	10400060	6211071
Aug.	30485270	18892140	10314890	6168087
Sep.	28164120	17498630	9569091	5725141
Oct.	29689200	18518090	10143620	6072651
Nov.	27833160	17601800	9733176	5852068
Dec.	22361940	14012460	7706115	4621698

6.2.3 The effect on the cooling load - the electricity consumption with and without insulation

This section presents the result and analysis of the cooling load on the electricity consumption with and without insulation. Figure 10 below presents the results of the electricity consumption of the factory building without insulation (A) and with using insulation (B), (C) and (D).

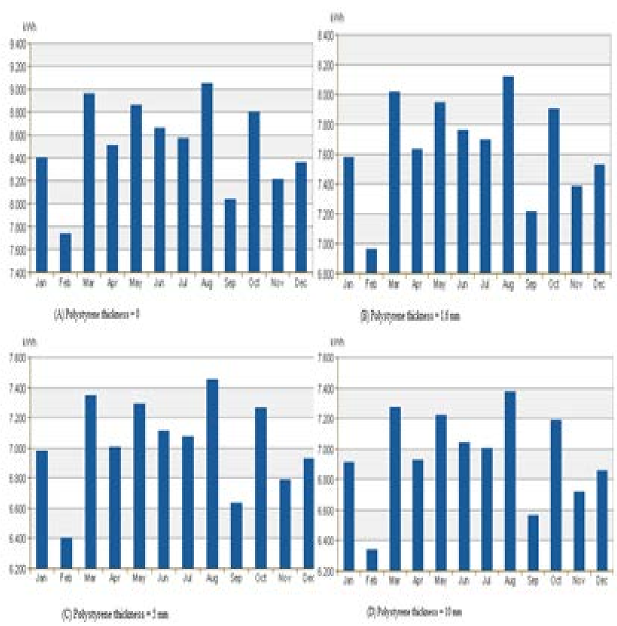

Fig 10 Monthly electricity consumption with and without insulation.

The results indicated that the electricity consumption without insulation was high and ranged between 7735 - 9050 kWh, while for roof with insulation it ranged between 6960 - 8117 kWh (Polystyrene thickness = 1.6 mm) , 6402 - 7452 kwh (Polystyrene thickness = 5 mm) and 6340-7353 kwh (Polystyrene thickness = 10 mm) . Moreover, there was a difference in the electricity consumption from month to month. This difference was a natural result of the different temperatures and relative humidity during the year, although the difference in temperature was small, but the relative humidity has greater influence in the cooling load and thus leads to reduced electricity consumption. Table 3 shows the amount of electricity consumption with and without insulation.

Table 3 : The amount of electricity consumption with and without insulation.

Month	Electricity consumption without insulation (kwh)	Electricity consumption (kwh) P0lystyrene thickness = 1.6 mm	Electricity consumption (kwh) P0lystyrene thickness = 5 mm	Electricity consumption (kwh) P0lystyrene thickness = 10 mm
Jan.	8403.65	7576.59	6980.16	6913.48
Feb.	7735.6	6958.96	6401.61	6338.53
Mar.	8955.7	8017.83	7350.42	7272.78
Apr.	8505.57	7629.3	7004.6	6931.44
May	8859.02	7946.46	7295	7219.12
Jun.	8660.51	7758.59	7113.46	7038.83
Jul.	8567.21	7698.93	7077.86	7006.13
Aug.	9048.2	8116.96	7452.12	7353.36
Sep.	8040.13	7218.52	6633.18	6565.44
Oct.	8801.59	7903.32	7260.66	7186.71
Nov.	8212.01	7384.8	6789.26	6721.2
Dec.	8356.17	7525.54	6924.99	6857.94

Figure 11 presents electricity consumption saving for each month. The area under curve in figure 4.4 (B) represents the saving in electricity consumption, which range from 776.64 to 937.87 kWh when the thickness of polystyrene was 1.6 mm, from 1333.99 to 1605.28 kwh when the thickness of polystyrene was 5 mm and lastly from 1397.o7 to 1694.84 kwh when the thickness of polystyrene was 10 mm. This indicated that the significant impact of insulator use in the roof on the cooling load as a result, reduce electricity consumption and save money. Moreover, this increase in the provision of electricity consumption increases with the thickness of insulation user.

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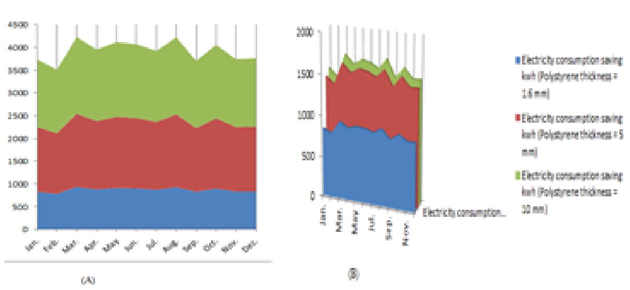

Fig 11 Electricity consumption saving (kWh).

6.2.4 Cost and Saving

This section presents the results and analysis of the cost and saving for the factoty building with and without insulation. Figure 12 below presents the results of the cost (a) and the saving (b) of the factory building with and without insulation.

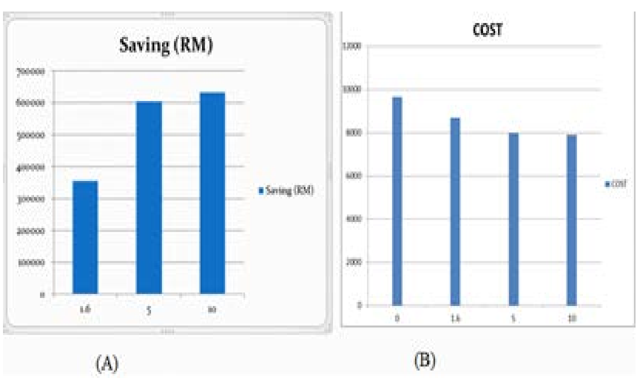

Fig 11 Annually Cost and saving of the factory building with and without insulation.

The results indicated the significant impact of insulator use in the roof on the cost and saving money. It is clear that cost less than with the use of the insulation in the roof and this decrease increased with the increase in thickness of insulation.On the other side, the savings in money will increase with each case decrease in the cost. On the other words, the use of insulation of different thickness of 1.6 mm, 5 mm and 10 mm had resulted approximately 355000,603000 and 632000 RM saving in money annually respectively as a result of reduced the cost of each case.

7. Conclusions

For buildings in equatorial regions with warm and humid climate such as Malaysia, the roof has been said to be one of the major sources of heat gain. Solar protection of the roof remains one of the main concerns in the thermal design of buildings in the region.
The reduction in the cooling load by using insulating material in the roof is very important as a means to reduce the electrical energy consumption to cool the space and hence cost saving. Many types of material had been used as insulation with defferent thickness. In this paper, a new software has been used to simulate the model of building to calculate the cooling load of a simulated factory building for 12 month in Batu Pahat district, Malaysia in 2013 by using Autodesk Revit software. The performance of the polysryrene foam was investigated and analyzed as an insulation with three thickness by using Autodesk Revit software. The simulation results proved useful information for roof insulation and proposed a tool i.e simulation program for estimation of the cooling load in factory building. On the other hand, building information modeling took great interest in recent years in the world in terms of the design simulation of the buildings and chooses the best design. Therefore, the use of software has emerged one of the most important for the simulation, this study showed that the facts about the impact of insulated roof by using the Autodesk Revit software.

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