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Simulation Studies on Heat Absorption of Container Green Roof Design Using BIM

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Abstract:In meeting the needs of the users for temporary buildings or houses, the use of containers in the construction industry has become one of a trendy contemporary solution. Due to its structure readiness and low cost advantage, containers are well used as commercial kiosks, office space and home shelter. However, containers are often associated with thermal problems related to indoor temperature increment especially in tropical region. Due to that, several thermal insulation techniques are introduced, mostly are indoor insulation panel cladding type. However, the physical condition of the container, especially the roof may determine the heat absorption level of the building. Based on a simulation study using Autodesk Revit Building Information Nodelling (BIM) software, this paper reports how types of roof design and green roof application may reflect on container's heat absorption. A flat and curved roof were chose to be simulated based on standard 20ft x 40ft size of container where both were tested with and without the green roof application. The result shows that curved roof surface with green roof do produce a better heat absorption quality.

Keywords: Heat Absorption, Indoor Thermal Condition

1. Introduction

In the construction industry today, container construction is one of the practical alternatives for conventional building in architecture to fulfill human needs for emergency shelter, housing, workplace, or recreational facilities. The container building has simplicity and has the ideal strength to fullfill the needs. As the world is now promoting sustainable approach in all sectors, the construction industry also has opt for various alternative techniques due to limited resources and tryng to minimize the negative impact to the environment. Hence, reuse shipping container has become one of the popular approach of providing shelters. The container building is not limited to its

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manufacturing or modular features, but it relates to strength, robustness, structural availability, mobile, and low cost. The standard container size set by the International Standards Organization (ISO) is 20 feet wide and 40 feet long [1].

Meanwhile, the green roof was originally used as a firewall structure. In Germany in the 20th century there was a modern green roof, where plants were installed on the roof to minimize the harmful effects of solar radiation on the roof structure [2]. The green roof, known for its deep substrates and various cultivation as "intensive" green roofs, requires great care and investment. Green roofs are "intensive", having the appearance of a conventional level garden. In addition, it is an active use of space and has a higher aesthetic value compared to the extensive green roof, which has shallow soil and low soil cover [3].

In additon, green roofs provide ecosystem services in urban areas, including improved storm-water management, better regulation of building temperatures, reduced urban heat-island effects, and increased urban wildlife habitat. Benefits of green roofs have three main categories: storm water management, energy conservation, and urban habitat allocation. Growth medium is important for plant growth and can even help with stormwater retention, where the ecosystem services come from three main components: plant, substrate (growth medium), and membrane [4].

At the same time, global warming is currently becomes a general awareness around the world. Heat island effect is one of the major contributor to global warming problem. It occurs due to factor of higher temperature in the city center compared with rural areas or nearby suburban. This phenomenon occurs in connection with the high density of buildings and structures that can absorb sunlight or solar radiation, the use of very high heat absorbing the material, the lack of green space and the characteristics of the urban canyons and the production of anthropogenic heat [5].

The city's thermal balance depends on the material used as the building envelope and urban structure. The material absorp the solar and infrared radiation, thereby removing part of accumulated heat through convective and radiative processes to atmospheric elevations. Thus, the technical characteristics of the materials used determine the high level of energy consumption and the comfort of individual buildings. Many studies have been conducted to better understand the optical and thermal properties of the materials as well as their impact on the city's climate [6].

2. Research Background

Shipping container building can be economical, durable, fast to construct, portable, and can be used for many applications including post-disaster housing or military operations and housing. Although aesthetic are important for architect and designers, shipping container cannot be viewed as building block if efficiency and economics are driving the project [1].

Generally, the container can only last for 10 to 30 years and can be more than that if maintained properly [7]. Based on Table 1 shows the size of the container in the market. For Malaysia usually used for building is 20 feet and 40 feet. Meanwhile, Figure 1 shows the shipping container dimension and thickness shipping container wall respectively.

Table 1: Size of Container in Market (Evegreen Marine Corp)

Model	Length (m)		Width (m)		Height (m)		Volume (m^3)
	Internal mesurement	External measurement	Internal mesurement	External measurement	Internal mesurement	External measurement	
20 feet	5.898	6.058	2.352	2.438	2.385	2.591	33.1
40 feet	12.032	12.192	2.352	2.438	2.385	2.591	67.5
40 feet High cube	12.032	12.192	2.352	2.438	2.698	2.896	76.2
45 feet High cube	12.556	13.716	2.352	2.438	2.698	2.896	86.1

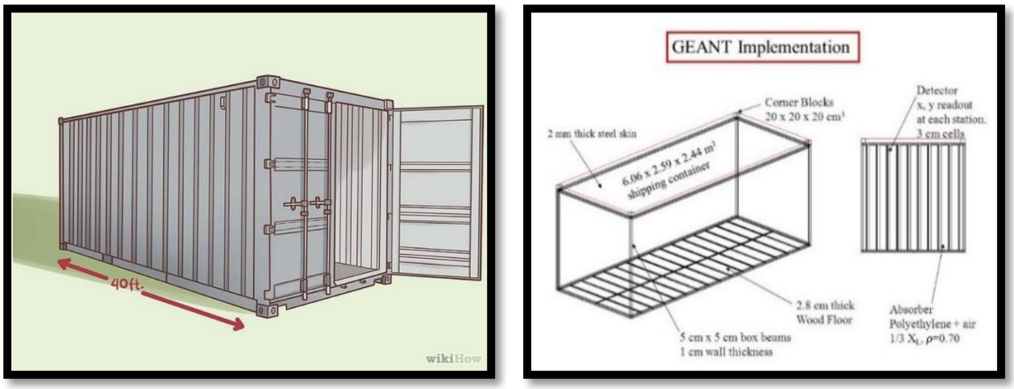


Figure 1: Dimension Shipping Container and Implementation Thickness Shipping Container (Evergreen Marine Corp.)

There are many types of roof systems that can be set up even though the shipping containers come with flat roofs, such as shed, hip and gable type depending on likings for the style, insulation requirement and cost. Many people think that flat roof is enough. A shed is sloped roof, simple, cheap and easy to build. A conventional hip and gable rooftops can also be secured on top of the container within a shortest possible time [7].

According to [8] also, heat transfer into the building envelope can be slow if the roof is double and coated roofs, next can maintain a consistent temperature. In addition, adding a roof to a container obviously does not save money at first, but can ultimately save a huge amount of operational energy bills. To have a better look, the plasterboard is mounted on a metal roof from the bottom surface.

2.1 Green Roof Concept

The concept of green roofs is able to control the building from the solar part, controlling the temperature and movement of the wind and humidity either inside or outside the building. Surface runoff reduction can also be used with green roofing methods as well as being said to be temperature storage.

a) Extensive Green Roof

Extensive green roof has a thin growth medium. The coating thickness is between 75-150mm and weighs 75-150 kg / m². Thus they can be supported by specially designed light structures, making them economical. However, thin layers of media do not support water storage. Therefore, plants must be selected for durability and drought tolerance [8].

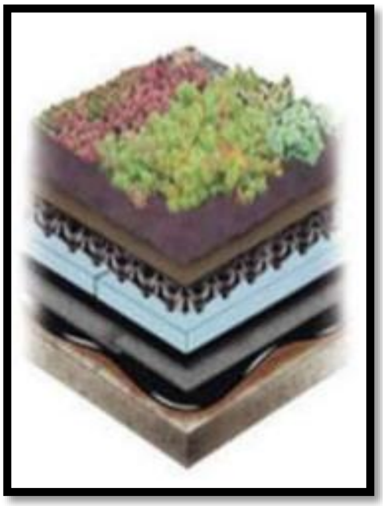


Figure 2: Extensive Green Roof [9]

b) Intensive Green Roof

Intensive green roof has a thickness of between 200-300 mm and can weigh up to 240 kg / m². Increased thickness allows greater planting, but the roof structure should be heavier to accommodate the additional load [3].

Figure 3: Intensive Green Roof [9]

Based on Table 2, the overall characteristics of green roofs and the general advantages of different green roof types are summarized.

Table 2: Classification of green roof according to type of usage and construction factors [10]

Features	Extensive	Intensive
		
Maintenance	Low	High
Irrigation	No	Regurlarly
Plant communities	Moss, Sedum, Herbs and Grasses	Lawn or Perennials, Shrubs and Trees
Height	60-200 mm	150-400 mm on underground garages > 1000 mm
Costs	Low	High
Use	Ecological protection layer	Park like garden

Green roofs are to be considered environmentally benign as well as to meet long-term client expectations, then selection of efficient green roof components are extremely important [11]. Depending on the location and requirements, green roofs generally comprise of several components as listed in Figure 4.

Figure 4: Cross Section of a Green Roof [9]

2.2 Building Information Modelling (BIM)

Building Information Modelling (BIM) is a digital software that creates a 3D representation of a building, which is layered with additional project information. It is sometimes referred to as a “5D representation of a building”, where the 4th and 5th dimensions are time and cost. For example, using a BIM model, an architect could simulate how the wind would flow around and through a building, and how that ventilation and wind velocity might change if the building’s shape or surface material is changed. Other additional information that can be modeled in BIM includes component details and specifications, materials, structural loads, air flow, water flow, spatial relationships and scheduling information [12]. Building Information Modelling is best used to analyze how a whole bunch of complex variables work together, and it streamlines the communication process between various parties involved in the design of a building. The process makes it easier to design a better buildings as BIM increases efficiency in the design process and sustainable design.

Revit Autodesk Platform for Building Information Modelling (BIM) is a document design system that supports the design of drawings and schedules required for building projects [13]. BIM only provides information on project design, quantity scope, and phases as and when required. Whereas for this Revit model it provides information on 2D and 3D views, the table of contents from the database model as well as information on building projects and coordinates [13]. In addition, Revit helpsto minimize model repetition and reduce the time taken to produce construction drawings while improves overall document accuracy for clients. There are five (5) classes of elements in this software namely host, components, annotations, views and datum. These elements work together in characterize every building components modelling developed in Revit. Therefore, the building model can be customizedto the designer’s creativity and requirements.

3.0 Methodology

The raw data preparation in Revit Autodesk is very important in this case study. It is to produce a building model based on the data obtained from survey results and observations on pre-study and weather data collected from the Meteorology Weather and Climate data. Initially, to create a model grid in this Revit software, raw data such as container office building dimensions were included in the layout such as the height of the building height of the datum, the length and physical width of the building according to the standard size of the container 40 ft, followed by the identification of the characteristics of materials used on the container building elements such as the roof and the walls.

This model was analyzed in three different places which is based on Meteorology Malaysia. Ten (10) areas in the country that experience heat waves were identified at level 1; Muar, Kepong, Maran, Kinta, Kuala Kangsar, Hulu Perak, Sik, Kota Setar, Kubang Pasu and Chuping. These areas experience daily maximum temperatures of up to 35 degrees Celsius up to 36.9 degrees Celsius for at least 3 consecutive days. As the research aims on the most extreme heat effect to the container green roof, Kepong (Kuala Lumpur), Chuping (Perlis) and Muar (Johor) were chose as the environment setting to be analyzedas the areas were recorded as the top three highest temperature from the list..

The purpose of these data setup is to produce quantities of distribution and intensity of radiation on various forms of mass. In addition, measurements for extensive green roof layers are based on studies [2], where each layer for green roofs has different thermal conductivity values, thicknesses and materials. Table 3 shows the thermophysical properties of the green roof different layers that will be used in analysis.

Table3: Thermophysical Properties of The Green Roof Different Layer [2]

Layer	Thickness (m)	Material	Thermal Conductivity (W/(mk))	Density (kg/m3)	Specific Heat (J/kgK)
Vegetation	0.200	Perenial vegetation			
Soil substrate	0.150	Lapillus, compost	0.33	582	1000
Filter sheet	0.001	Polypropylene	0.22	910	1900
Drainage, storage and ventilation element	0.002	Polypropylene	0.380	950	2300
Air (inside the drainage element)	0.023	Air	Thermal resistance – 0.16 (m2 KJ/W)		
Retention felt	0.004	Polypropylene	0.220	910	1900
Roof Covering	0.001	Copper	380	8900	382
Osb board	0.015	OSB	0.130	630	2200
Insulation	0.120	EPS	0.035	25	1470
Roof Slab	0.050	Fire wood	0.120	550	2700

4.0 Result and Discussion

i) Analysis Data for Flat Roof Without Green Roof and With Green Roof on Shipping Container at Each Location in Malaysia

Figure 5 and Table 4 below shows the total cumulative insolation on surface for flat roof without green roof and with green roof on shipping container at each location in Malaysia. The average values shown indicate that buildings with flat roof (with green roof) are higher than flat roof without green roof at each location. Thecontainer with green roof in the area of Chuping Perlis showed a heat acceptance of 269 kWh/m^2 compared to without green roof of 228 kWh/m^2. InKepong, Kuala Lumpur,the average value of 261 kWh/m^2 was with green roof, while without green roof, it was 225 kWh/m^2. Whereas in Muar, Johor area, the result showed an average total value for without green roof 243 kWh/m^2 and an increase of 261 kWh/m^2 on green roof. These data shows different heat acceptance level in different areas which may influenced by its surrounding settings

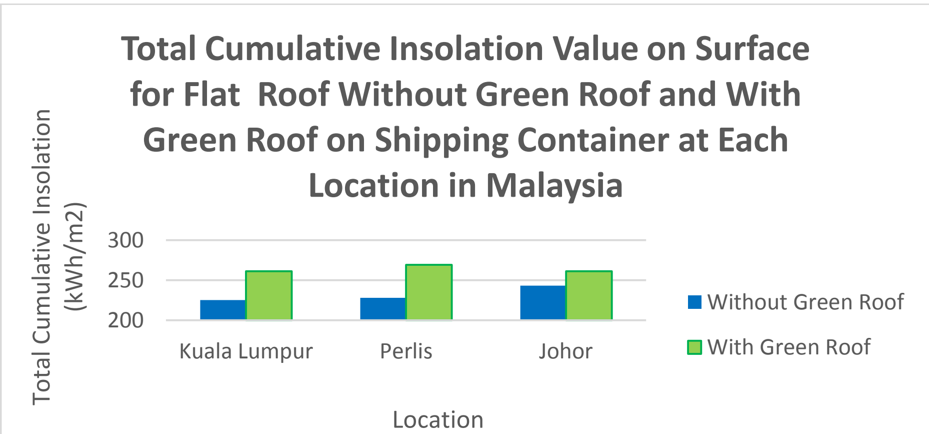
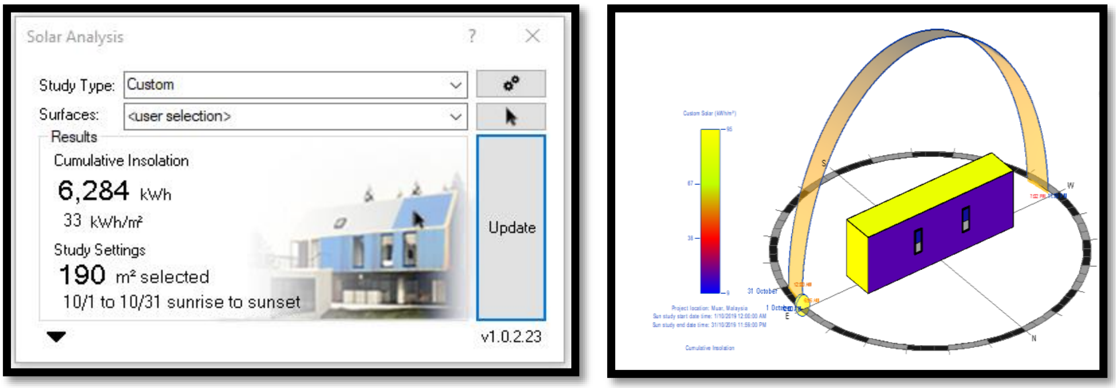


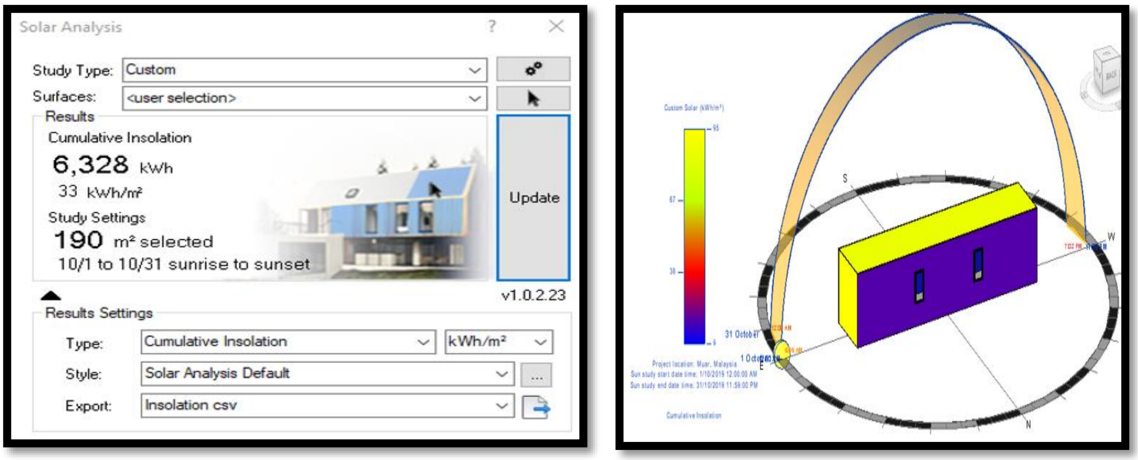
Figure 5: Different of Total Cumulative Insolation on Surface for Flat Roof without Green Roof and with Green Roof on Shipping Container at Each Location in Malaysia

Table 4: Total Cumulative Insolation on Surface for Flat Roof without Green Roof and with Green Roof on Shipping Container at Each Location in Malaysia

Location	Total Cumulative Insulation on Flat Surface without Green Roof (kWh/m^2)	Total Cumulative Insulation on Flat Surface with Green Roof (kWh/m^2)
Kuala Lumpur	225	261
Perlis	228	269
Johor	243	261



(a) Flat Roof without Green Roof



(b) Flat Roof with Green Roof

Figure 6: Illustration of An Analysis and Results of An Analysis of a Flat Roof Container Building In Johor

ii) Analysis Data for Curved Roof Without Green Roof and With Green Roof on Shipping Container at Each Location in Malaysia

Figure 7 and Table 5 shows the total cumulative insolation on surface for curved roof without green roof and with green roof on shipping container at each location in Malaysia. Based on the results, Perlis was still effectives in the heat treatment for the curved roof with green roof which was recorded 286 kWh/m^2 as the flat roof with green roof. The value for the curved roof was recorded higher than the flat roof. In Kuala Lumpur, was also produced a high total cumulative insolation for buildings with green roof of 273 kWh/m^2 and even for buildings without green roof slightly varying at 268 kWh/m^2. Meanwhile, in Johor a building without a green roof produces 245 kWh/m^2 then an increase of 259 kWh/m^2 to a building with a green roof. Due to the materials and thickness of the roof, it shows that that container buildings with green roof indicate higher value of their total cummulativr insolation than container buildings without green roof.

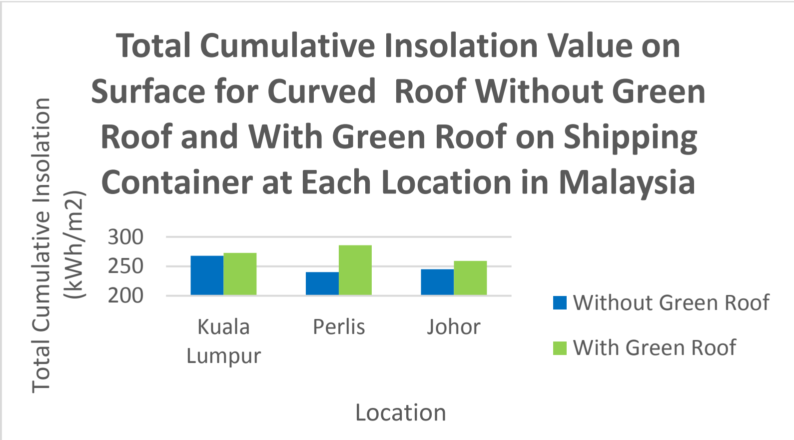
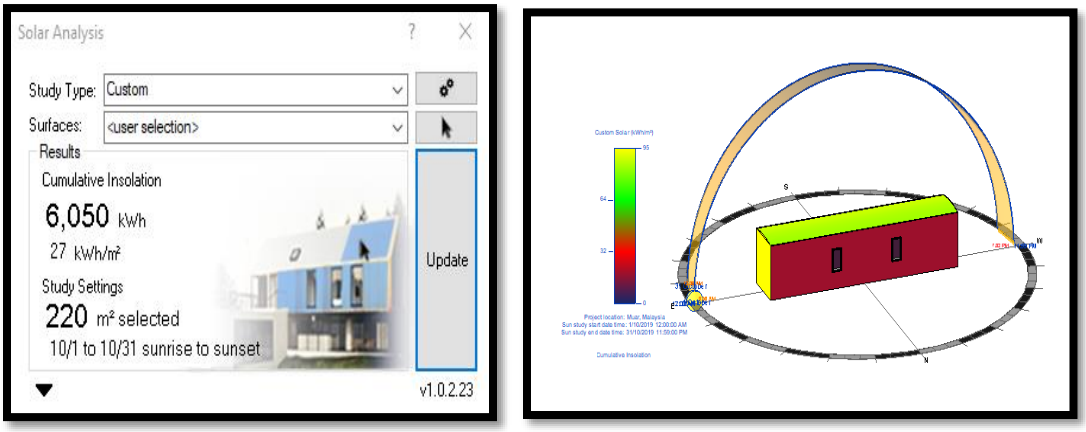


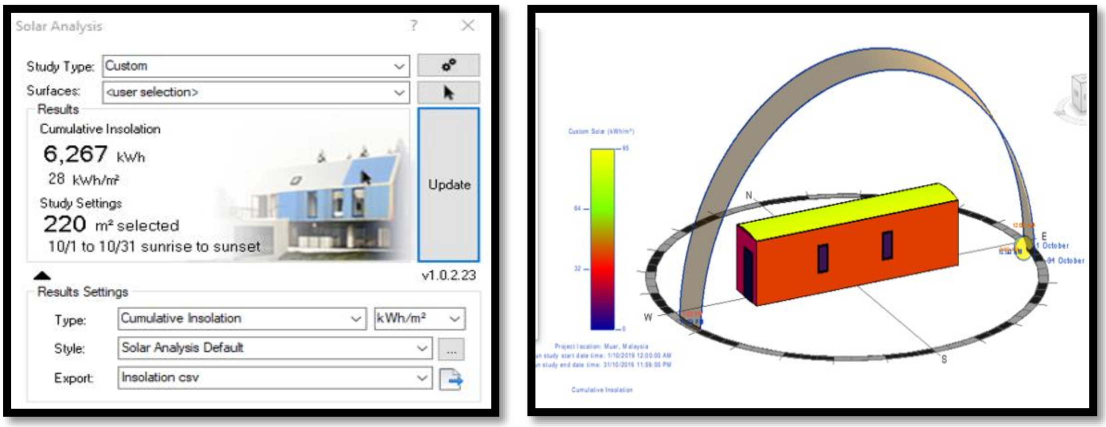
Figure 7: Different of Total Cumulative Insolation on Surface for Curved Roof without Green Roof and with Green Roof on Shipping Container at Each Location in Malaysia

Table 5: Total Cumulative Insolation on Surface for Curved Roof without Green Roof and with Green Roof on Shipping Container at Each Location in Malaysia

Location	**Total Cumulative Insulation on Surface without Green Roof (kWh/m^2)**	**Total Cumulative Insulation on Surface with Green Roof (kWh/m^2)**
Kuala Lumpur	**268**	**273**
Perlis	**240**	**286**
Johor	**245**	**259**



(a) Curved Roof without Green Roof



(b) Curved Roof with Green Roof

Figure 8: Illustration of an Analysis and Results of an Analysis of a Curved Roof Container Building in Johor

Based on the findings, the data show that the insolation value of a roof with a green roof is higher than a roof without a green roof. However the differences value between areas in Perlis, Kuala Lumpur and Johor is interesting. The differences may happened due to the intense of local heat from the sun penetration differences between these areas [5]. This indicates that the green roof absorbs more heat on the exterior of the building, in addition to the possible factor in terms of the thickness of the green roof.

The findings also show curved roof with green roof has higher insolation value than on flat roof with green roof. Though curved roof has different angle along its curvy line, the overall surface is larger than a flat roof. The fact may cause insolation level to be higher of curved roof where it may allows larger heat absorption at surface. The findings supported earlier researches on roof shape potential in causing indoor heat built up [14].

5.0 Conclusion

As conclusion, we can determine that roof may still be the major influencer for heat penetration for buildings in tropical area. Therefore, it may still become the major element to be considered in design process and even in any renovation strategy to provide better indoor thermal condition. From the studies done, the curved roof without Green Roof shows the highest average insolation value compared to the flat roof without Green Roof. This is because, as the roof gets longer or wider, the rate of sunlight absorption in the building decreases. Additionally, the roof with Green Roof shows different results in each area, where data in Kuala Lumpur and Perlis show that Curved Roof with green roof is higher than average in Johor where Flat Roof with green roof is higher high average value.

The intensity of the sun varies depending on the brightness of the sun and the angle at which the sun absorbs the surface of the earth. Therefore, the more perpendicular the sunlight is to the surface, the warmer the surface of the building. Therefore, to reduce heat transfer to buildings, roof design is one of the best mediums to reduce heat flow. So the second objective of this simulation study was achieved. Hence, determining the location of the direction of the sun's position and the design of the building's roof is important. As if these two factors are properly applied, the heat absorption into the container will be reduced.

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