Thermal Performance Simulation of Residential Building in Tropical Climate Case Study: Housing in Bandar Universiti, Malaysia

Ratna Dewi Nur'aini[1]

[1]*Department of Architecture, Universitas Muhammadiyah Jakarta, Indonesia*
ratnadewina@ftumj.ac.id ; ratnadewina@gmail.com

ABSTRACT

Malaysia is one of country in with tropical climate that many people using air conditioning system to get indoor thermal comfort level. Computer simulation is one of method to predict the thermal performance of building. This paper focused on the thermal analysis of one storey row residential building at Bandar Universiti, Seri Iskandar, Perak, Malaysia. The objectives of this research were to investigate thermal performance of a residential building in tropical climate by Ecotect software simulation and to compare between ceramic roof, metallic roof and green roof due to temperature reduction. This research has focused on single storey terrace houses in Bandar Universiti, Seri Iskandar, Perak, Malaysia. The building model was row house for single family (livingroom-diningroom and master bedroom) and simulated using Autodesk Ecotect Analysis 2011 software. Metal roof has highest range of maximum and minimum compared with clay roof, concrete roof, and green roof. The lowest indoor air temperature was reached under green roof. Green roof can reduce indoor temperature from outdoor air temperature more and longer than clay roof, concrete roof, and metal roof. The result of simulation analysis indicated that green roof could reduce indoor temperature more than other roof types. This study suggests that green roof can be used in residential building in tropical climate.

Keywords: ceramic roof, computer simulation, green roof, metallic roof, residential building.

1. Introduction

Malaysia is one of country with tropical climate that is passed thermal equator denote the highest annual average temperature, World Climate Map[9]. The majority of people were using air conditioning system to get indoor thermal comfort level, 75% of Malaysian used air conditioning to improve indoor thermal comfort of their house, Yacouby et al.,[10]. Residential buildings in Malaysia were significant cooling requirements due to high intensity of heat transmission through the building envelope, especially for low rise buildings that roofs represented 70% of heat gain, Yacouby et al.[10], so keeping the cool home become important.

Computer simulation is not new method to predict a thermal performance of building. Modeling and simulation become very important to make decision process in building design, Yin et al.[11]. Ecotect analysis software is a comprehensive concept to detail sustainable building design tool, offers a wide range of simulation and building analysis that can improve performance of existing buildings and new building designs, Autodesk Ecotect Analysis[1]. In this study, Ecotect software is used to generate model behavioral data and predict thermal performance in a residential building including difference temperatures. Ecotect software was simple to run building simulations easy and accurate, Bakar & Abdullah[2], the tools set guidance quickly and reliably, Yin et al.[11]. The objectives of this research were to investigate thermal performance of a residential building by Ecotect software simulation and to compare four types of roof material due to temperature reduction.

There were some factors that affect the thermal performance of residential building such as orientation, weather, envelope material, and HVAC system, Yin et al.[11]. This research analysed some roof materials due to temperature reduction.

Ecotect was one software that assisted building designer to make a right decision. It was a three dimensional building analysis program that analysed some factors of building performance, Yin et al.[11], including thermal performance. Ecotect Analysis offered a wide range of simulation and building energy analysis functionality that could improve performance of buildings. Ecotect was one of tools that thermal performance analysis was simple, almost accurate, visually responsive, and informative graphical, Sadafi et al.[6]. Generally, Ecotect Analysis could analyse building energy, thermal performance, water usage and cost evaluation, solar radiation, daylighting, shadows and reflections, Autodesk Ecotect Analysis[1]. This research used Autodesk Ecotect Analysis 2011 to analyse thermal performance of residential building.

2. Material and Methods

2.1. Weather data

Air temperature, solar radiation and wind conditions were included in weather data. It was used to predict historical data for the site of building. Weather data file of Kualalumpur was obtained from EnergyPlus webpage, Weather Data[8], was used to perform

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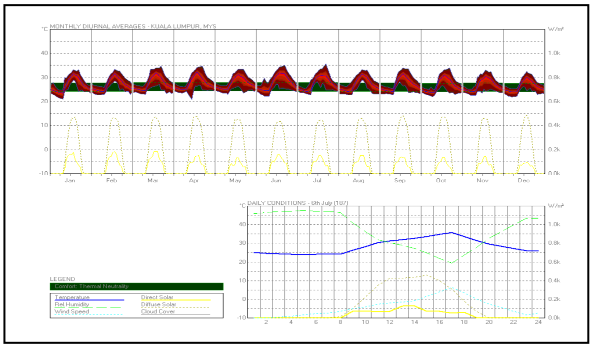
simulation in Ecotect software. In this study, weather data of Kualalumpur represented weather data of Bandar Universiti according data from Malaysian Meteorological Department that both of them had nearly the same weather (Malaysian Meteorological Department[8]. Figure 1 presented the weather data of Kualalumpur that was presented by weather tool.

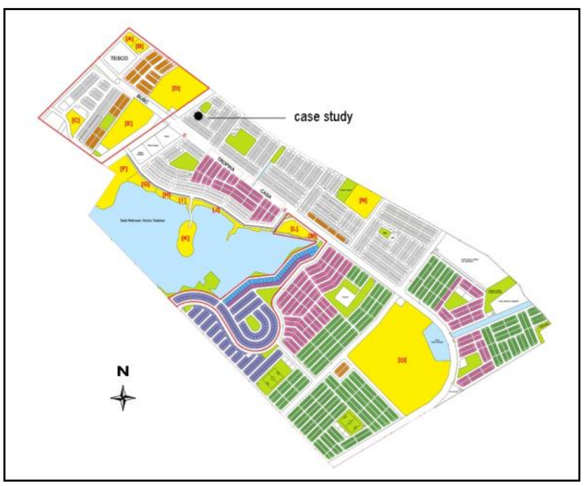


Source: Autodesk Ecotect Analysis[1]

Figure 1: Weather data of Kualalumpur

2.2. Case study

This research has focused on single storey terrace houses in Bandar Universiti, Seri Iskandar, Perak, Malaysia which was located at latitude 4°36’08.05"N and longitude 100°98’59.84"E (Map of Bandar Universiti[5]. Location could be shown in Figure 2.



Source: siteplan Bandar Universiti[7]

Figure 2: Siteplan of Bandar Universiti

Each house was Northeast-Southwest facing with length about 13m, wide about 6m, and height about 6m. It consisted some rooms i.e. livingroom, diningroom, master bedroom, two bedrooms, kitchen, and two bathrooms. The perspective and floor plan of house could be shown in Figure 3 and Figure 4.

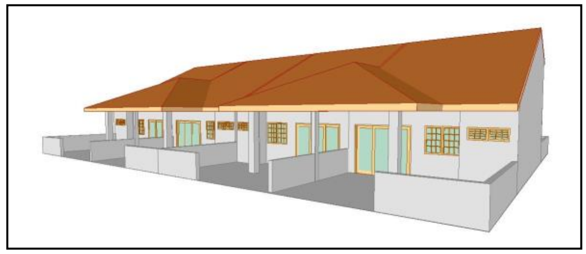


Figure 3: Perspective of the house

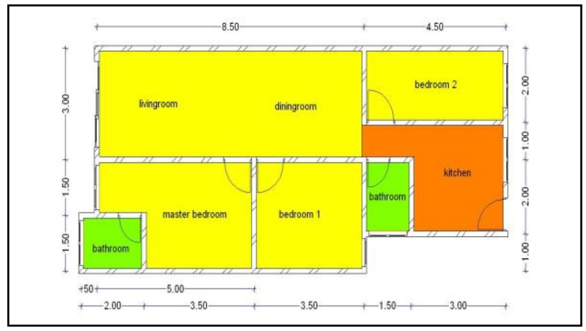
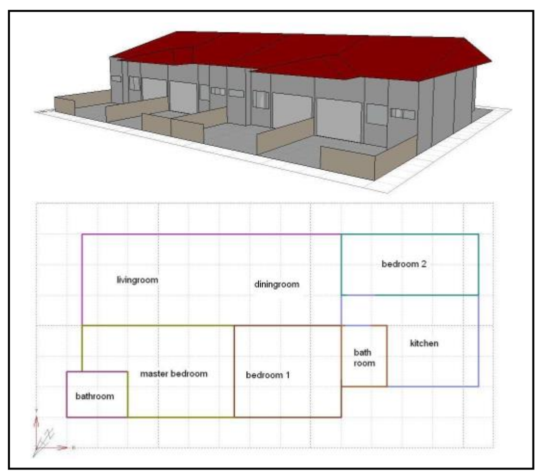


Figure 4: Floor plan of the house

2.3. Building model

The building model was row house for single family. The model for simulation was built using Autodesk Ecotect Analysis 2011 software. The analysis was carried out on one storey row house, whose geometry was presented in Figure 5. The livingroom-diningroom and master bedroom of the house were analyzed, where usually air conditioning and fan were placed.



Source: Autodesk Ecotect Analysis[1]

Figure 5: Modeling with Autodesk Ecotect Analysis 2011 software

Floor area of livingroom-diningroom was 25.5m^2, with a glass sliding door and no window. Floor area of master bedroom was 12.75m^2, with a timber door and double glass window. Materials of building were chosen from Ecotect library. The property values of materials were calculated from Ecotect material property. Tabel 1 displays the description of building materials that was simulated. Bare roofs (clay roof, concrete roof, metal roof) and green roof were compared. Green roof layer consisted of vegetation, soil, and wood pine.

Table 1: Material Description of Building

Element	Description	Thickness	U-value W/m^2.K
Floor	100mm thick concrete floor plus 10mm ceramic tiles.	110mm	2.900
Wall	100mm brick with 10mm plaster both of sides.	120mm	1.770
Ceiling	10mm suspended plaster board ceiling with 150mm joists as air gap.	160mm	0.500
Door	Triple pane of glass sliding door with aluminum frame. *Case I (living-dining room)*	15mm	5.356
	40mm thick hollow core plywood door. *Case I (living-dining room)* *Case II (master bedroom)*	40mm	2.310
Window	Double pane of glass window with timber frame. *Case II (master bedroom)*	15mm	2.900
Clay roof	50mm clay tiles plus 75mm air gap plus 10mm plaster.	135mm	3.100
Concrete roof	6mm asphalt cover plus 150mm concrete plus 10mm plaster.	166mm	0.896
Metal roof	1mm zinc.	1mm	7.140
Green roof	50mm vegetation plus 100mm soil plus 25mm wood pine.	175mm	0.420

Source: (Autodesk Ecotect Analysis, 2011)

2.4. Ecotect simulation

Simulations were divided in two cases. Cases I was conducted to calculate inside temperatures in livingroom-diningroom due to change with clay roof, concrete roof, metal roof, and green roof. Case II was the same work but conducted in master bedroom. Both of rooms were set as natural ventilation system. Then respectively could be calculated temperatures difference.

3. Results and Discussions

Outdoor air temperatures data were obtained from weather data of Kualalumpur in Figure 2. the outdoor air temperatures profile on the hottest day (6th july) were redrawn as detail in Figure 6 which are around 24-35.7°C, in early morning at 7am gradually increase as the sun rise. The outdoor air temperatures during the day were generally high and reached maximum 35.7°C at 4pm. Then, temperatures decreased to the lowest 24°C at 4am.

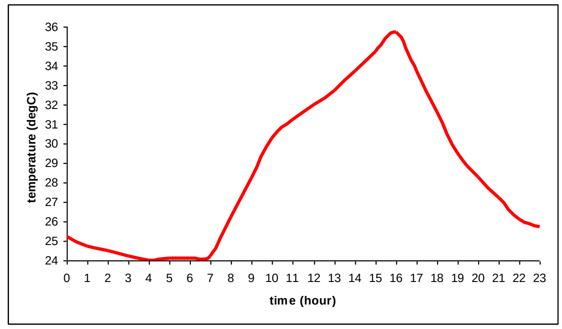


Figure 6: Outdoor temperatures profile on hottest day

Indoor temperatures profile on the hottest day (6th july) were presented in Figure 7. In Case I, indoor temperatures profile of livingroom-diningroom due to clay roof, concrete roof, metal roof and green roof. The highest indoor temperature 32.4°C was reached at 4pm with metal roof. The lowest indoor temperature 30.1°C was at 4-7am with green roof. In Case II, indoor temperatures profile of master bedroom due to clay roof, concrete roof, metal roof and green roof. The highest indoor temperature 31.7°C was reached at 4pm with metal roof. The lowest indoor temperature 29.7°C was at 4-7am with green roof. In both of cases, indoor temperature due to clay roof and concrete roof are almost similar.

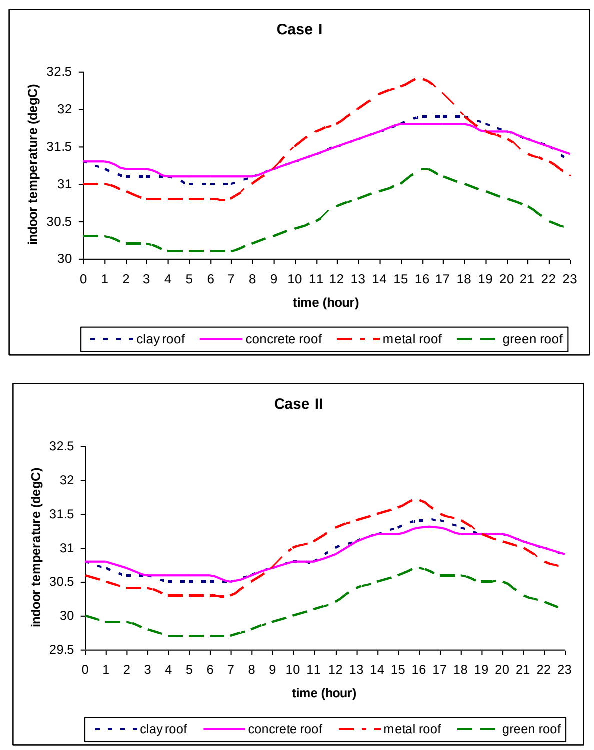


Figure 7: Indoor temperature with different roof type

Both of graphics show indoor temperatures due to metal roof were highest at day but not at night. It could describe that metal roofs affect hot at day but cool at night. While with green roof, indoor temperatures were lowest for all time.

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Temperature differences of outdoor and indoor due to four roof types could be shown in Figure 8 and Figure 9. The positive values described outdoor temperature higher than indoor temperature. Otherwise, the negative values showed outdoor temperature lower than indoor temperature. Graphic of case I presented temperature differences due to clay roof, concrete roof, metal roof, and green roof in the living-dining room, case II in the master bedroom.

In case I, temperature differences of green roof were positive values at 11am-6pm while other roof types at 12am-5pm. In case II, temperature differences of green roof were positive values at 10am-6pm while other roof types at 11am-6pm. According both of cases, it described that green roof could reduce indoor temperature from outdoor temperature longer than other roof types.

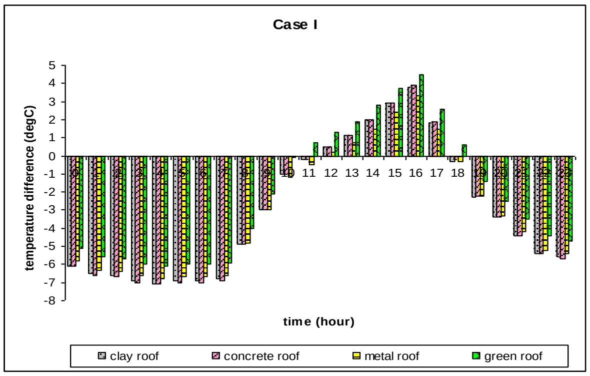

Figure 8. Temperature differences of outdoor and indoor due to four roof types in case I

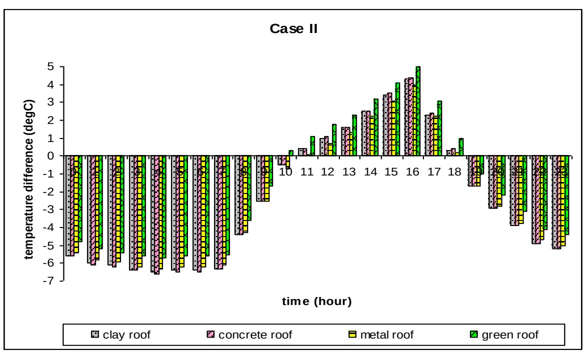

Figure 9. Temperature differences of outdoor and indoor due to four roof types in case II

In detail, the values of temperature differences at daytime (11am-6pm) could be shown in Figure 10 and Figure 11.

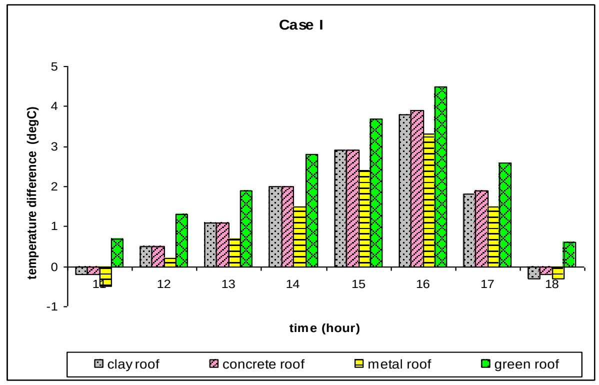

Figure 10. Temperature differences at daytime due to four roof types in case I

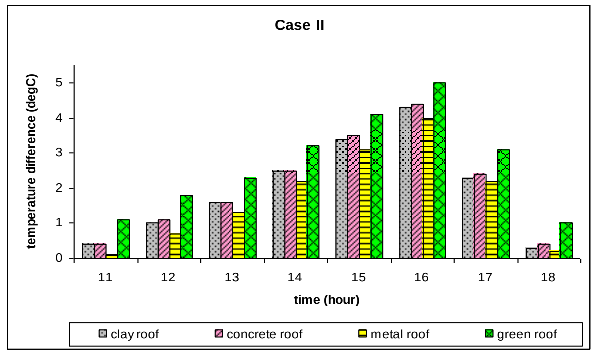

Figure 11. Temperature differences at daytime due to four roof types in case II

Both of graphics show green roof had highest temperature differences compared with other roof types. It described that green roof could reduce indoor temperature more than clay roof, concrete roof, and metal roof for all time. Although the temperature difference between green roof and other roof was not big, but according to previous experimental research, Ismail et al.[3], it still presented the positive cooling effect.

4. Conclusion

Ecotect can be a useful simulation tool that only needs simple geometry in modeling phase and produces representative graphics for presentation. It can be considered to predict thermal performance of building, whenever the building materials change, it will automatically recalculate new results.

Through the thermal analysis, building materials have significant effect to the indoor air temperatures. The green roof on residential building can reduce indoor air temperatures highest compared with clay roof, concrete roof, and metal roof during the hottest day. The highest indoor air temperature was reached under metal roof. It can describe that metal roof affect hot at day. Metal roof has highest range of maximum and minimum compared with clay roof, concrete roof, and green roof.
The lowest indoor air temperature was reached under green roof. Green roof can reduce indoor temperature

from outdoor air temperature more and longer than clay roof, concrete roof, and metal roof. Indoor air temperature under clay roof and concrete roof are almost similar.

According to the result of simulation in this study have shown that green roof contributes to the thermal performance of residential building in tropical climate. This study also suggest that green roof can be installed in residential building.

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