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Adapting Buildings for Climate Change: Will Indonesian Traditional Houses Shift to Zero Energy Buildings?

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Abstract: *The increase of Surface Air Temperature (SAT) is seen as the major climate change issue in Indonesia. It has significant increasing trend and was parallel with the rate of global average temperature. In this paper, Omah Joglo was investigated toward the adapting building for climate change. It is one of Indonesian traditional houses that still exist in Java Island. There are two parameters in this research to determine the traditional house performance adapting the climate change: indoor thermal quality and environmental impacts of construction materials of building. As result, the indoor temperature always lower than the outer surface of roof with average temperature different 1.2°C. It indicates that the indoor temperature relatively high than the thermal comfort that supposed to be 25.1 to 27.9°C. Maximum average temperature gap was occurred at 11 a.m. where the outer-surface temperature and indoor temperature respectively were 33.1 °C and 31.4 °C. Omah joglo offered a strong in environmental friendly aspect. This can be shown in construction phase in LCA, the material input intensity, carbon dioxide emission and embodied energy respectively were only 409.6 kg/m², 16529 kg-CO_2e and 189593 MJ.*

Keywords: Climate change, Indoor thermal quality, Environmental performance, Traditional house

1. INTRODUCTION

Climate change is growing significantly in Indonesia. In the other side, increasing population has triggered the energy use that ultimately affects the quality of the environment. The increase of Surface Air Temperature (SAT) is seen as the major climate change issue by those anthropogenic driven of greenhouse gas emission. Indonesia in the last decade shows its significant increasing trend of SAT (0.002 °C per year) and this magnitude was parallel with the rate of global average temperature increase as estimated in Intergovernmental Panel on Climate Change (IPCC) is about 0.7 °C in the last century [1].

Energy consumption in buildings approximately 25% of total energy consumed in Indonesia during the period 2000-2012 [3]. The trend shows that the consumption of the building sector was relatively stable with no significant increasing trend as compared to the other sector such as industrial and transportation. However, Indonesia has become one of the three largest emitters of greenhouse gases in the world due to significant release of carbon dioxide from deforestation [4].

Traditional house has known as a result of many aspects of local culture, material resources, and climate as well. There are 34 of traditional houses in Indonesia which have different characteristics from one province to another [5]. Adapting traditional houses for the climate change can play one of the most important roles in becoming net zero-energy buildings and decent for human living besides just become the local heritages.

In this paper, 'Omah Joglo' is an object to investigate in adapting performance toward the climate change occurred in Indonesia. There are two parameters in this research to determine the traditional house performance adapting the climate change: indoor thermal quality and environmental impacts of construction materials and buildings. Indoor thermal quality assessment using the direct temperature measurement and roof thermal distribution analysis. In the other side, the environmental impacts of construction materials and buildings using life cycle assessment (LCA) which inventory analysis based on carbon dioxide emission and energy embodied in 'cradle to gate' phase refers to ICE version 2.0 [6].

2. ROOF THERMAL DISTRIBUTION ANALYSIS

Omah Joglo is a traditional house of D.I. Yogyakarta province and Javanese Island in general. The word 'Omah' means house in Javanese language and 'Joglo' refers to the shape of the roof. Thus the RTTV would be relevant to determine the performance of indoor thermal distribution because the roof has a unique shape (fig.1).

Fig. 1. Omah Joglo where located in Banguntapan, Bantul, D.I. Yogyakarta province.

Joglo roof that has been investigated have geometry characteristics of height, length and width respectively 3.826 m, 9.49 m and 7,662 m. The top roof height is 2.3 m and the lower roof is 1,526 m. Layer of roof covering material has a thickness of 6 mm using clay tile. The x-axis shows the direction of the north wind, the y-axis indicates the direction of the western wind, whereas the z axis shows upward.

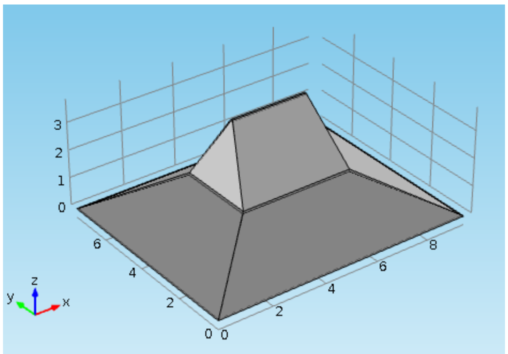

Fig. 2. Roof of Omah Joglo geometry modeling

Temperature average measurement was conducted in the period of the day (8.00 a.m. to 5 p.m.) in August 2017. Roof thermal distribution in this research was comparing between indoor temperature and outer-surface temperature of clay tile roof.

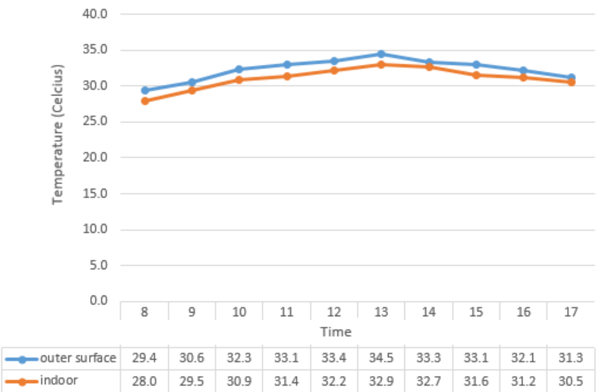

Fig. 3. Temperature average measurement indoor and outer-surface roof.

As shown in figure 3, the maximum average temperature gap was occurred at 11 a.m. where the outer-surface temperature and indoor temperature respectively were 33.1 °C and 31.4 °C. However, the maximum temperature for both outer surface and indoor area was at 1 p.m. The thermal distribution modeling at that time was conducted using COMSOL MULTIPHYSICS software to view a temperature distribution in vertical slice.

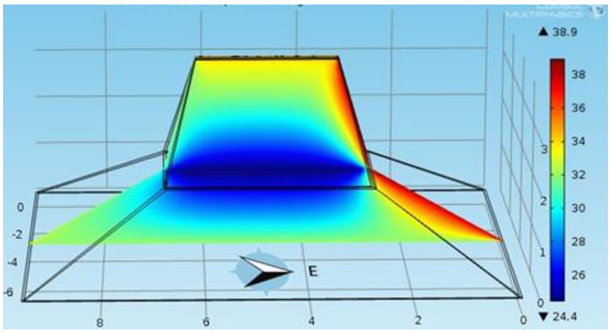

Fig. 4. Thermal distribution of indoor area of roof at 1 p.m.

3. ENVIRONMENTAL IMPACT ANALYSIS

Omah Joglo traditional house is constructed by two main parts including building envelope and roof. The calculation of environmental impact analysis refers to how significant these parts emitted the carbon dioxide and how much was the amount of energy embodied in the construction process.

LCA framework was used in this research to determine environmental impact. It is a method to perform the analysis and evaluation of the potential environmental impact of the system of products or services at all stages of the product life cycle by considering input process until the output associated with supporting materials, energy consumption, product utilization and waste generated [7].

There are 4 stages based on ISO 14040 in order to complete this analysis: (1) goal definition and scope; (2) Inventory Analysis; (3) Impact Assessment; (4) Interpretation.

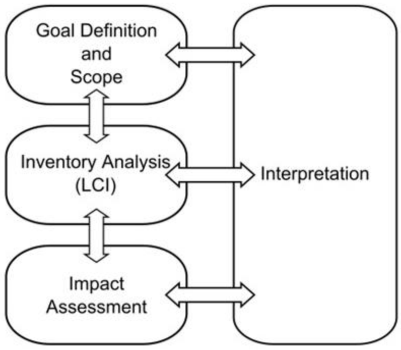

Fig. 5. LCA framework [8]

Goal definition and scope of this assessment is formulated in term of the working plan to quantify the environmental impact that might exist in constructing the building envelope and roof of Omah Joglo. The scope of the study is defined in terms of temporal, geographical and technological coverage, and the level of sophistication of the study in relation to its goal.

Inventory analysis in this context is defining includes setting the system boundaries, designing the flow diagrams with unit processes, collecting the data for each of these processes, performing allocation steps for multifunctional processes and completing the final calculations. Its main result is an inventory table listing or graphic the quantified inputs from and outputs to the environment associated with the function unit in term of $kgCO_2e$ and MJ of energy per kg materials. All data are collected using ICE version 2.0 database.

As shown in table 1, total material input quantity was 73732 kg, meanwhile its intensity per building area 409.6 kg/m^2 assuming the calculation of total area of Omah Joglo including building envelope and roof was 180 m^2.

Table 1. Materials inventory Omah Joglo

No	Materials	Index (per m^2)	Density	Quantity (kg)
1	Clay Brick	140 pcs	3 kg/pcs	50400
2	Cement Plaster	32.95 kg	1506 kg/m^3	3954
3	Sand	0.091 m^3	1400 kg/m^3	15288
4	Glass	-	2579 kg/m^3	266.44
5	Wood	-	705 kg/m^3	1412
6	Paint	0.083 liter	1.2 kg/liter	12
7	Clay tile roof	20 pcs	2 kg/pcs	2400
	Total			73732

Impact assessment in this research is actual modeling results based on the calculation of embodied energy and carbon dioxide emission. Embodied energy indicating the performance of the building's construction process to consume the energy. Carbon dioxide emission refers to the amount of carbon dioxide released. Index number of kg-CO_2 emission and MJ of Embodied Energy were obtained from ICE database version 2.0.

Table 2. Impact assessment of CO_2 emission and energy embodied

No	Materials	kg-CO_2e	MJ Embodied Energy	Index CO_2	Index EE
1	Clay Brick	12096	151200	0.24	3
2	Cement Plaster	2925.96	17832.54	0.74	4.51
3	Sand	77.9688	123.8328	0.0051	0.0081
4	Glass	242.4604	3996.6	0.91	15
5	Wood	0	0	0	0
6	Paint	34.92	840	2.91	70
7	Clay tile roof	1152	15600	0.48	6.5
	Total	16529	189593		

Based on the calculation as shown in table 2, total carbon dioxide emission and embodied energy respectively were 16529 kg-CO_2e and 189593 MJ.

4. RESULT AND DISCUSSION

Omah Joglo based on this research shows that it has two interesting aspects correlated to adaptation performance toward the climate change.

Firstly, roof thermal distribution analysis gave us the figure of how the roof performance to reject the heat from the sun in the noon time. Even though the indoor temperature always lower than the outer surface of roof with average temperature different temperature 1.2ºC, it still indicated that the indoor temperature relatively higher than the thermal comfort that supposed to be 25.1 to 27.9ºC [9]. In the period of measurement, the lowest temperature was occurred at 8.00 a.m. in the morning. However, this existing condition did not fulfill the requirement of thermal comfort. Omah Joglo as a traditional house based on this research was too difficult to optimize the temperature comfort without using the additional air conditioning. In the other side, this emphasizing the energy consumption for air conditioning tools would be necessary for the building. Thus, there should be a reconciliation of energy saving with the thermal comfort optimization.

Secondly, Omah joglo offers a strong in environmental friendly aspect. This can be shown in construction phase in LCA, the material input intensity, carbon dioxide emission and embodied energy respectively were only 409.6 kg/m^2, 16529 kg-CO_2e and 189593 MJ. These numbers, if compared to some general residential buildings in Indonesia (Jakarta and Bandung) in previous study [10] has shown that the traditional house of Omah Joglo has lower value. The residential buildings in Jakarta and Bandung have total material input intensity 2.14 ton/m^2, embodied energy respectively were 54.5 GJ (simple shape), 189.8 GJ (medium shape) and 611.8 GJ (complex shape).

5. CONCLUSION

This research found that the Omah Joglo as a sample of traditional houses in Indonesia has a chance of improvement to be a zero energy consumption buildings if it can deal with the thermal comfort optimization without using a main energy resource from electricity. This traditional house has a good performance in environmental impact which gave the lower number in material input intensity, carbon dioxide emission and embodied energy in construction phase if it compared to residential buildings that exist in Indonesia.

6. RECOMMENDATION

There should be a research to find some alternative techniques to conduct the indoor thermal comfort in Omah Joglo using natural air conditioning equipment in order to minimize the use of energy consumption. This effort would a significant contribution to make Omah Joglo shift to be a zero energy building.

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