Energy Optimum Building Wall From a Mixture of Papercrete and Local Soil in Tropical Humid Area

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Abstract. Paper waste is today's problem in urban areas. It is important to utilize papercrete waste as the raw material of building materials. This research explored the relationship between papercrete wall and the energy produced.The problem of this research was to obtain a simple house wall optimally against overheating and embodied energy. The wall materials used papercrete and local soil. The research location was in Surabaya. The method of wall production was mixing paper and local soil and adhesive i.e. cement that was compacted and molded. The research variable was walls thickness and the measurement of embodied energy was unit value of embodied energy of material. The value of overheating was obtained by using Archipak simulation program on building simulation model with dimension 6 x 6 m. Energy optimization was carried out on variables. The results revealed wall of papercrete and local soil in simulation building model; wall thickness of 8 cm was energy optimal wall to embody energy and overheating. That was one of the principles of green design.

Keywords: papercrete, soil, simulation, embodied energy, cooling energy

1. Introduction

The world's current problems are waste increase and natural resource depletion. Those problemsare closely related to the development of public consumption. This paper focused on paper waste. The problem of paper waste will be reduced if the waste is utilized as the basic materials of building materials. Waste processing can be done by reuse or recycle. To date researchers mostly investigated the development of research on waste processing into building materials [1]

The focus of this research is to discuss the building wall using the basic materials of paper waste. In the field of wall building construction of paper called papercrete [2]. The composition of the papercrete wall used consists of paper as raw materials plus local soil. Addition of soil increases the resistance to climate and material density [3]. The adhesive materialsare cement and lime. The block-making process of the papercrete wall uses a compacting process and is dried in a natural way. This is similar to the process of making compressed earth blocks [4].

The purpose of the study was to investigate the potential of this papercerete wall to the energy it produced. The wall of the building in question was a wall of buildings in simple house. The energy discussed here is cooling energy and embodied energy. The research problem is how the condition of simple house wall is right to produce optimum energy against overheating and embodied energy.

The method used simulation and optimization by using model of simple building type 36 which had a width of 6 m; width 6 m and height 3 m. This building is widely developed in Indonesia. This study was conducted in Surabaya. The variable used wall thickness of building. Optimization of embodied energy with climate needs to be done [5]. In this research, energy optimization was done on overheating and embodied energy in the model.

The result of this research is simple wall thickness design using paper composition and soil that is energy efficient. Besides, the results of this study show the use of papercrete wall not only solve the problem of paper waste and problem in the field of construction alone but also on the development of the energy field. So using papercrete and soil as a wall material is part of the concept of green design and green material.

2.Methods

This paper conducted a study of wall construction materials consisting of papercrete and local soil. The composition adhesive used cement. This was carried out so that the composition had hardness and density. Activities undertaken were: simulation model of building design that using walls of papercrete and local soil. The building had efficient energy to overheating and embodied energy. While embodied energy was energy used building materials for the production process from the search of natural resources to be building materials. Here is the research thinking flow (Figure 1).

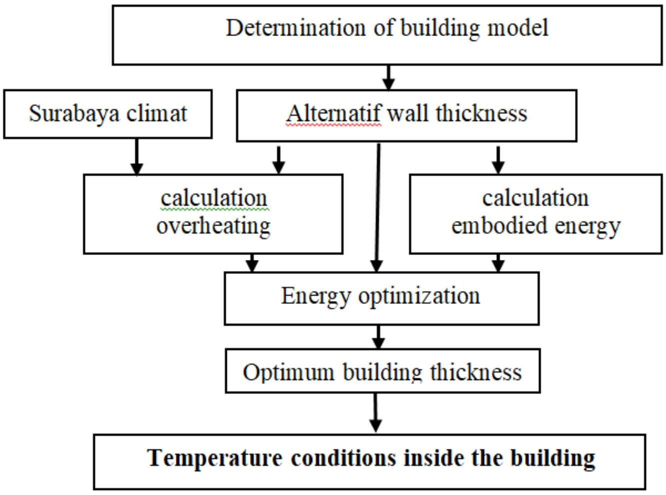


Figure1. the thought line of the study

The dimensions of the building model were determined according to the size of the modest house. So the dimension of simulation building model used with size 6 x 6 x 3 m (see figure 2). Alternative wall design was done to obtain optimal temperature conditions. For that alternative of different wall thickness was made. Thickness of the wall was a variable of research. The condition of the wall can be seen in Figure 3. While the wall plan variables can be seen in table 1.

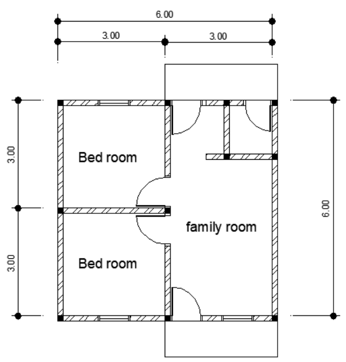


Figure 2. Plan of model building type 36

Front elevation of model Back elevation of model

Figure 3. Plan and elevation of model

Calculation of overheating used archipak program. As the variable was wall thickness that was 8 cm, 11cm and 16 cm and they had code W8; W11 and W16 (see table 1). Embodied energy calculation was done by multiplying the width or volume of the building material with the embodied energy value per unit of each building material.

3. Discussion

3.1. Overheating

Overheating describes uncomfortable thermal conditions above and below comfortable thermal conditions. The determination and calculation of overheating requires data about thermal properties of materials. The thermal properties obtained by using Archipak software can be seen in table 1.

Table 1. Thermal property of papercrete mix soil walls

No	Wall Thickness	U-value	Admitance	Time lag	Decrement factor
1	8 cm	5,53	5,76	1	0,97
2	11 cm	5,52	5,92	1,35	0,94
3	16cm	5,51	6,24	1,89	0,88

Results of calculations with Archipak

Table 2 shows the cooling energy and overheating of papercrete and soil for a year from each model with different wall thickness. The location of the calculation was in Surabaya. The model with the thickest wall had the smallest cooling energy and smallest overheated. While model with the thinnest walls have the greatest cooling energy and greatest overheated. In terms of cooling energy and overheated, models with thick walls were the best wall, because the energy was lower.

Table 2. Cooling energy and overheated

No	code	Wall thickness	Cooling kWh/years	Overheating K.h/years
1	W8	8 cm	18029	10037
2	W11	11 cm	17652	10285
3	W16	16cm	16604	9354

Results of calculations with Archipak

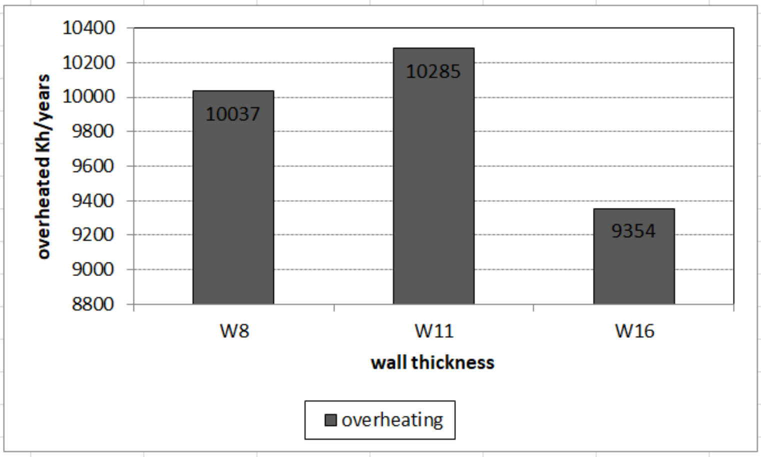
Table 3 shows the maximum and minimum energy in Surabaya. In this table the minimum energy value was in July. While the maximum energy value was in October. July was the coldest month, while October was the hottest month.

Table 3. Energy maximum and minimum of model

No	Code	minimum			maksimum		
		Cooling kWh/bln	Overheated K.h/bln	month	Cooling kWh/bln	Overheated K.h/bln	month
1	W8	1324	579	July	1721	1182	October
2	W11	1293	588	July	1682	1207	October
3	W16	1232	506	July	1595	1127	October

Results of calculations with Archipak

In this study energy that used as main energy was overheating. Figure 4 shows that the highest overheatingwas in the W11 building model, i.e.building with wall thickness of 11 cm where as the lowest overheating was found in the building model W16. The building had a wall with a thickness of 16 cm. Comparison of cooling load between building W8 with W11 was not significant that was2%. The comparison between lowest and highest cooling loads in all three buildings was 931 Kh/years or 10%.This shows that the difference in overheating of W8 dan W11of walls was not significant.



Results of calculations with Archipak

Figure 4. Cooling energy on differents wall

3.2. Embodied Energy

The process of production materials from raw materials into finished materials is called embodied energy [7]. The main building material used in this research was the composition of the papercrete and the soil around. Each material had a different embodied energy. There were two types of embodied energy in this research that was embodied energy total and embodied energy per m^2 of building. Materials used for the building model with embodied energy per unit can be seen in Table 4.

Table 4 embodied energy per unit

Materials	Embodied energy perunit
Papercrete and soil	32855 MJ/m^3
Roof	251 MJ/m^2
floor	5250 MJ/m^3
Wood door	388Mj/m^2

Source: Lawson [9]

Table 4 shows that the values per unit of embodied energy in each material were different. The units were based on volume, weight and area of materials. Each building model had different embodied energy depending on the volume or weight of the material used. The volume of material and building area could reduce the value of embodied energy [8].

Compositions of the papercrete and soil had influenced value of embodied energy in the building model. This was due to the weight and volume of both materials is relatively large. The embodied energy value of each building model was calculated based on the multiplication of the area or volume of the building material with the embodied energy per unit value. The result of calculation of total Embodied Energy from each building can be seen in Figure 5. The building had the highest thickness wall had the highest total embodied energy i.e. W16 which had wall thickness 16 cm.

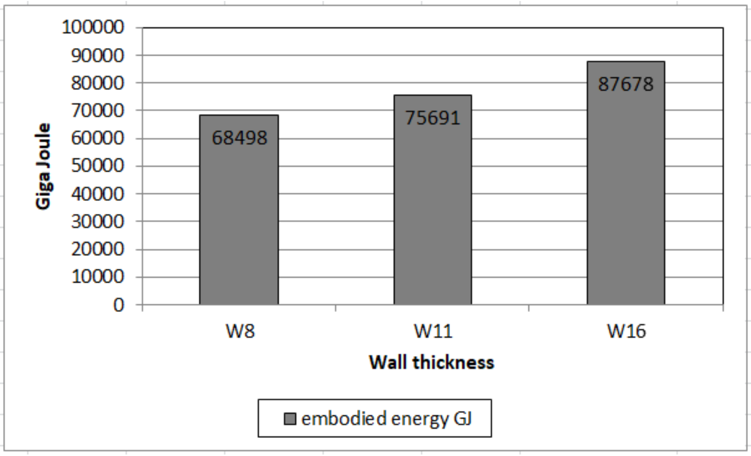


Figure 5. Embodied total energy on different walls

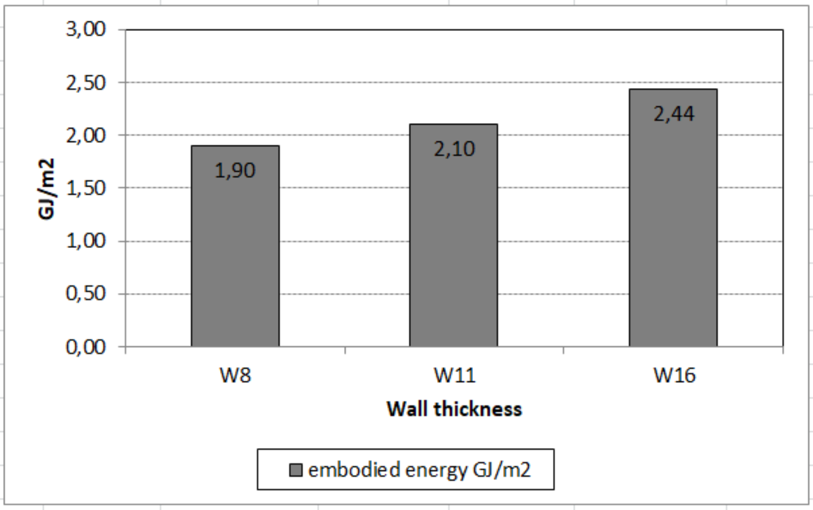


Figure 6. Embodied energy per m^2 on different wall

Figure 6 shows value of the embodied energy per m^2 of the building. Buildings with thinner walls contained the lowest embodied energy per m^2. This condition was equal to the value of total embodied energy (figure 4). Where, the lowest embodied energy was owned by the building with the thinnest wall (W8). The cause of same condition between total embodied energy and embodied energy per m^2 because both had the same building area. In this case a good embodied energy was owned by building model with a wall thickness of 8 cm (W8).

3.3. Optimization

The condition of each building model had different energy value between cooling energy with embodied energy. There were building models that had low embodied energy but they had high cooling energy. Besides that there were also models that had high-embodied energy but cooling energy was low. Therefore, it is necessary to optimize the all energy in each building model. The energy optimization required data about yearly cooling load and embodied energy per year. The value of cooling energy and embodied energy can be seen in Figures 3 and 6.

Energy optimization was carried out by looking at the energy position of the building model against the value of cooling energy and embodied energy. The optimization process used the percentage graph of energy. The percentage comparison of energy can be seen in table 5.

Table 5. Embodied energy and overheated model

Model	Embodied energy GJ/m2	overheated Kh/years
W8	1,90	1182
W11	2,10	1207
W16	2,44	1127
average	2,15	1172

Figure 7 shows an application of energy in the graph. There was a combined difference of embodied energy and overheating in each model. The W8 and W11 models were low embodied energy models. Furthermore, the W8 and W11 models were chosen most optimally. Criteria to determine the condition in the room were embodied energy. The lower embodied energy of the room became more efficient in materials. Therefore, among the lower W8 and W11 models the embodied energy was W8 (see Figure 7). However, in reality the embodied energy W11 was higher than W8 namely 10,5%. This shows that the wall with the composition of mixture of papercrete and soil with 8 cm thick was the optimal wall in overheating and embodied energy.

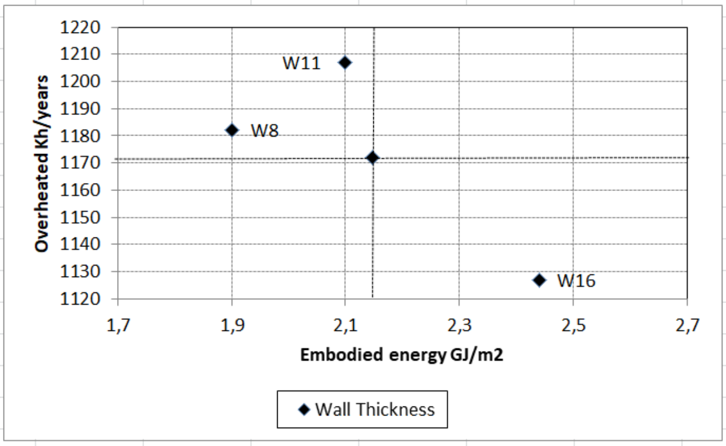


Figure 7. Optimization of overheated and embodied energy

3.4. Indoor Temperature

Based on table 3 shows overheating conditions of W8 (wall with 8 cm thick) in the hottest and coldest month i.e. July and October. Condition of indoor temperature in those months can be seen in figure 8. In October, the hottest indoor temperature was at 4pm, at 35.1 C^O. The coldest indoor temperature was at 6 pm at 26.8 C^O. The hottest temperature in July was 32.6 C^O occurred at 4 pm. The coldest temperature occurred at 7 pm at a temperature of 24.9 C^O.

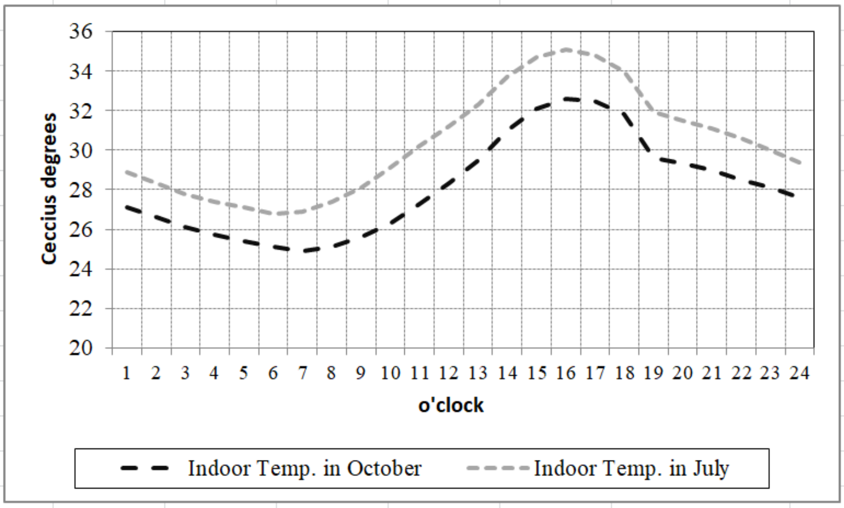


Figure 8. Indoor temperature conditions of wall with 8 cm in July and October

4. Conclusion

In this study optimum results in overheating and embodied energy were not on the wall papercrete only but from the composition of the mixture of concrete paper with soil.

Thickness of the wall from composition of mixture papercrete and soil affected the value of material thermal properties. Cooling energy building was affected by thickness of the wall and climatic conditions around.

The wall that had the optimum energy in this study was a wall with a thickness of 8 cm. The walls had relatively low overheating and the lowest embodied energy compared to wall thickness of 11 cm and 16 cm. Optimum energy was not always present in buildings with walls that had the lowest embodied energy and the lowest cooling energy, but they must be balanced.

The highest indoor temperature occurred in October and the lowest indoor temperature minimum occurred in July. In those months the maximum indoor temperature occurred at 4pm.

The papercrete mix soil wall absorbed the water so it needed to be protected on the bottom of the wall. Its top was quite protected with cantilever of building.

5. References

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