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Simple Energy-Efficient House Wall Material Selection In a Humid Tropical Area — Case Study in Surabaya

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Abstract. The large variety of alternative wall materials currently promises improved construction and comfort in buildings. The use of energy-efficient compounds has received less attention, particularly with respect to simple buildings. Energy in this case involves both cooling and embodied energy types. This research analyzes the use of various types of materials in simple houses. The study aims to determine which types of wall material can save energy. The research problem involves determining the type of materials that are efficient in terms of both cooling and embodied energies.

The research method used simulation and optimization. The location of the study was Surabaya, Indonesia. The simulation model employed a simple house of type 36. Wall materials analyzed comprised red bricks, hollow blocks, earth compresses, lightweight bricks and papercrete blocks. Cooling energy calculations involved the use of Archipak software. Optimization was performed on both cooling and embodied energies of the building model.

This study determined the type of material that is energy efficient with respect to both cooling and embodied energy types in a simple house of type 36 in the humid tropics.

Key Word: type wall material; building type 36; cooling energy; embodied energy; optimization

I. INTRODUCTION

At present, the development of wall building materials in Indonesia is relatively rapid. Growth in expenditure for construction in Indonesia has been estimated as 5.2 percent in 2014–2019 [8]. This growth makes it easy for architects, civil engineers and interior experts to choose materials with the function and aesthetics of the building to suit their tastes. Such alternative wall types promise users improved construction and building aesthetics. The use of energy-efficient building materials has received significantly less attention, particularly for simple buildings. Further, physical comfort in buildings has received even less focus.

Inside a building, there are two influential energies—operational and embodied [1]. In this study, the discussion focuses on efficiency in terms of operational energy in buildings, namely cooling energy [4] and energy for the process of making building materials, ranging from raw to finished materials, referred to as embodied energy [5]. This research uses simulations with building models. Simulation provides the ability to study and overcome difficult scientific approaches [2]. Energy operational costs can be reduced by using simulations [4]. For this reason, several types of building material are used as research variables. Wall materials comprise red brick, concrete brick, compressed earth block (CEB), lightweight concrete and papercrete. Such materials can be used for the building of simple homes in Indonesia.

The purpose of this study is to determine the most appropriate materials for buildings walls, with a focus on efficient characteristics regarding both cooling and embodied energies. The research problem is to obtain the characteristics of wall building materials and choose the ideal building material with respect to cooling and embodied energy types. As a simple model home simulation, a building with a size of 6 x 6 x 3 m (commonly referred to as a simple house of type 36) was chosen. The research was carried out in Surabaya, Indonesia. The selected wall building material will be a proposal for the production of such materials for use in simple houses in Indonesia. Therefore, the selected wall building material will be measured with respect to indoor building temperature.

II. METHOD

The main research problem is associated with the characteristics of both cooling and embodied energies of the material. Therefore, a program and method are required that can calculate the characteristics of the building material. The research approach is provided in Figure 1.

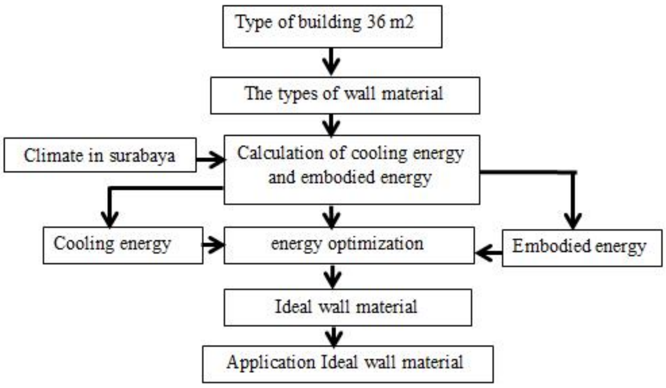


Figure 1: Research approach.

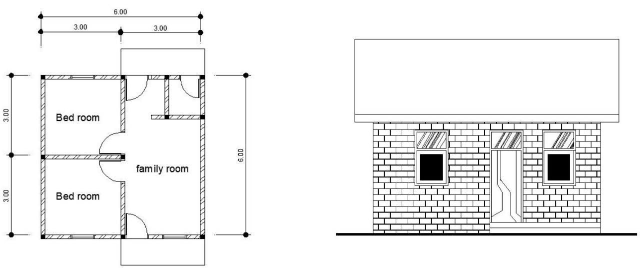
In Figure 1, the type of wall materials is a variable from the study, namely red brick wall, hollow block; compressed earth block (CEB); lightweight concrete and papercrete. Calculation of cooling energy used the Archipak program, supported by climate data in Surabaya. Regarding the calculation of building embodied energy, a unit price of per unit energy embodied was used. Both of these energies are calculated based on the area or volume of materials of type 36 buildings.

Optimization of both cool and embodied energy types from each wall variable was performed using the X and Y axis graphs. The optimization method is used to select the most optimal variables. In this case, the most important aspect to consider is the condition of cooling energy in the room; this factor was compared to embodied energy. Ideal variable walls are a type of wall material that have optimal cooling and embodied energies. Furthermore, the building with the selected wall material type was applied and indoor temperature was then measured.

III. DISCUSSION AND RESULTS

3.1 Simulation model

The study used a type 36 building as a simulation model. This building type is widely used for simple homes in Indonesia. Building plans are provided in Figure 2. In this study, wall thicknesses for all variables were found to different. The wall thickness of the variables is as follows: redbrick wall 12 cm; Hollow block 10 cm; CEB 10 cm; Lightweight concrete 8 cm and papercrete 10 cm.



Plan facade

Figure 2: Plan and facade of a simple home model.

3.1.1 Cooling Energy

Calculation of cooling energy required data from the city of Surabaya. This city has highest and lowest daily mean temperatures of 34^{0}C and 24^{0}C, respectively. Humidity in the city averages 64% annually. Further, width and height data of wall conditions also determine the value of cooling energy. The initial calculation involves determining the wall material's thermal properties. Table 1 provides the calculation of the thermal properties of the wall variables using the Archipak program.

TABLE 1 THERMAL PROPERTIES OF VARIABLE WALLS

Wall Material	U-value (w/m²K)	Admitance (W/m²K)	Time lag (jam)	Decrement factor
Red brick 12 cm	2,52	4,15	4,46	0,6
Hollow block 10 cm	2,17	2,85	2,37	0,9
Compressed Earth Block 10 cm	2,33	4,28	5,85	0,4
Lightweight concrete 8 cm	2,38	2,05	2,48	0,9
Papercrete 10 cm	3,27	4,12	2,34	0,8

Source: Archipak software

Cooling energy of each wall variable can be calculated using the thermal properties of each wall variable. The yearly cooling energy can be observed in Figure 3.

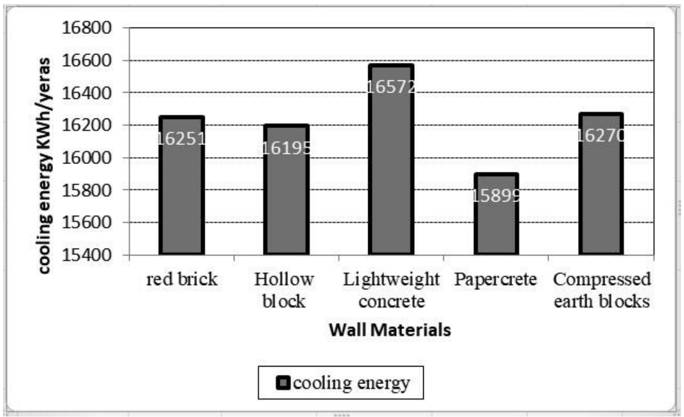


Figure 3: Cooling energy from each wall variable.

Figure 3 demonstrates that the lightweight concrete wall has the highest cooling energy value, while the lowest cooling energy is illustrated by the papercrete wall. The difference in cooling energy between walls constructed with either lightweight concrete or papercrete is 673 Kwh (4.23%). Red brick, hollow block and CEB have relatively similar cooling energies. Values for cooling energy of lightweight and papercrete walls were found to be the most suitable for all varieties of wall.

3.1.2 Embodied energy

Embodied Energy is influenced by the area, weight, volume of wall and material unit value. Unit value can be seen in table 2. Value of embodied energy per unit of the material is different. The following embodied energy values for each material are shown in Figure 4.

TABLE 2: EMBODIED ENERGY PER UNIT OF MATERIALS

Materials	Embodied Energy/unit		
	MJ/m^2	MJ/m^3	MJ/kg
Redbrick 12 cm		5170	
Hollow Block 10 cm			0,94
Lightweight concrete 8 cm		3,18	2
Papercrete 10 cm		4700	2
Compression earth blocks 10 cm			0,8
Plestered		890	
Roof tile	251		
floor		5250	
Door/window	388		

In Figure 4, the most interesting observation is for the red brick and papercrete walls. Both have relatively high differences in embodied energy. The difference is 1.4 GJ/m^2 (82.35%); the energy difference is relatively high. The difference between the embodied energy value between hollow block and lightweight concrete, papercrete and CEB is not particularly high, at 2–16%. Thus, redbrick wall has the highest energy embodied compared to other walls examined.

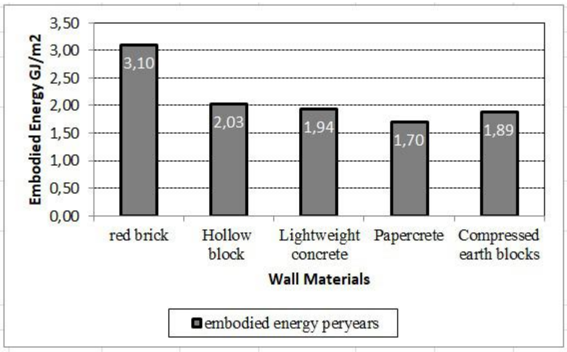


Figure 4:. Embodied energy of each variable wall

3.2 Optimization

To obtain optimal wall variables, X and Y axes were used. The X axis is embodied energy GJ/rm2, while the Y axis is the cooling energy KWh / years. The field between the X and Y axes is divided into four zones. The best zone is where both cooling and lowest energies are embodied. In Figure 5, the best zone can be seen to be produced by both papercrete and hollow block walls. The worst zone was found for red brick walls. In the best zone, the most ideal wall is made from papercrete. Hence, papercrete walls appear to be the most suitable for building simple homes in Indonesia.

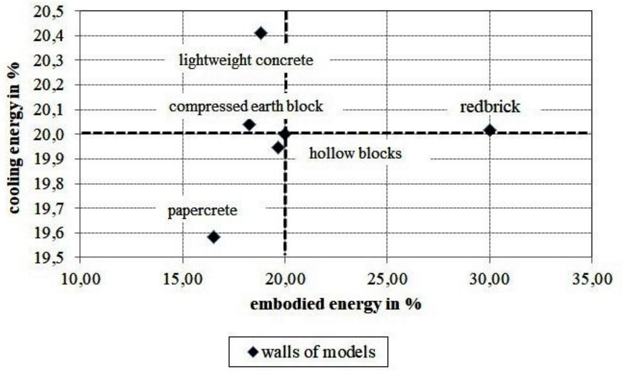


Figure 5: Optimization of all wall variables.

It is important to determine temperatures inside buildings made with paper concrete walls—indoor temperatures in the hottest and coldest months in Indonesia are displayed in Figure 6. November is the hottest month, while July is the coldest.

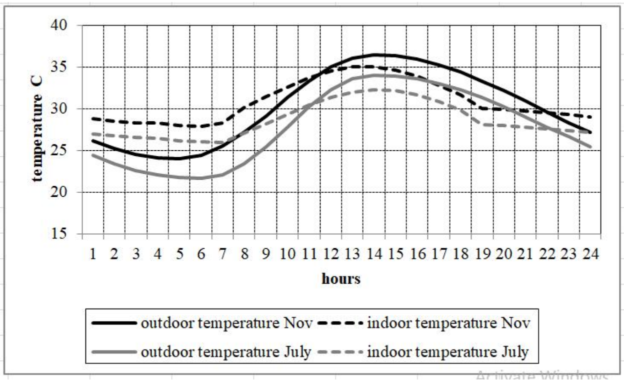


Figure 6: Indoor and outdoor temperatures of papercrete walls.

Figure 6 demonstrates that papercrete walls can decrease outdoor temperatures in the daytime when the temperature is high. At night, it can warm the room when the outdoor temperature decreases. This ability was observed both in the hottest and coldest months.

IV. CONCLUSIONS

In this study, papercrete walls were found to be the most efficient in terms of both cooling and embodied energy types. Such walls had the lowest values for both cooling and embodied energies among all walls examined. Currently, paper walls have not been used for simple house walls in Indonesia.

Red brick walls are widely used in simple homes in Indonesia. This material has the highest cooling energy compared to a hollow block wall, lightweight concrete, papercrete and CEB. For this reason, reduction in the use of red bricks in simple buildings is recommended.

The most prominent energy difference of all building materials was found for embodied energy, while with respect to cooling energy, the energy ratio of all materials was found to be relatively similar. Therefore, the volume and thickness of building walls are important factors to consider. Papercrete walls are suitable for humid tropical climates. Such walls can adapt to the outside climate so that residents in the building can feel more comfortable. Walls can decrease indoor temperatures during the day and increase such temperatures at night.

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