

The application of Crude Palm Oil (CPO) within lightweight concrete in passive air conditioning system

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Abstract. Air conditioner (AC) as an active conditioning system is commonly used to absorb heat inside the room or building. However, AC requires relatively large electrical energy. Passive air conditioning system could be seen as an alternative solution to alter the issues mentioned above. Phase Change Material-PCM is able to absorb heat as latent heat that change its form without increasing the temperature. In applications, PCM can be used as mixture on concrete in order to hold the thermal energy from the environment so the temperature inside building can be lower and stable. PCM can decrease thermal conductivity of concrete. Crude Palm Oil (CPO) that can be applied as PCM is added within concrete so that it can have insulating behaviour, decrease the cooling load and electricity energy consumption. In this study, CPO is injected into lightweight concrete with some variation volume to represent its insulating behaviour. Thermal conductivities of lightweight concrete when used CPO volume 0 ml (as control), 2.5 ml, 5 ml, and 7.5 ml are 0,12 W/mK, 0,06 W/mK, 0,07W/mK, and 0,08 W/mK. Thus, the lightweight concrete has better insulating behaviour. This research is expected to be a solution for decreasing cost of electricity energy consumption in buildings.

1. Introduction

The air conditioning system in a room aims to maintain air conditions to meet comfort and health requirements. The air conditioning system includes setting conditions for air temperature, relative humidity, air circulation, and air quality. AC (Air Conditioning) as an active air conditioner can absorb some heat inside the room that caused from the sun and any other heat source. However, AC uses large electrical energy and causes environmental problems. Loekita (2006) shows that cost of electrical energy for air conditioning systems reaches up to 50% - 70% of the overall electricity consumption of buildings.

Passive air conditioning system can be used as a solution in saving energy consumption. Phase-changing materials can store heat as latent heat which can change the form (phase) of a substance without increasing its temperature. In the application, the phase-changing material can be used as a mixture on the walls of the building. The property of this substance allows the heat from the sun not to enter directly to the room because the heat is used to change the phase of the substance inside the wall.

In previous studies, phase-changing materials which is used is coconut oil as mixture of a concrete brick called bataton [1]. The coconut oil solidifies at temperature of 24°C and melts at 26°C. This material is able to reduce the cooling load of the building because it has a relatively low heat conductivity (thermal conductivity) compared to standard concrete brick without the substance. The study proves that



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the mixture of phase change materials can reduce the temperature of the building's inner walls by 3.38 °C. However, there are some obstacles when the experiment of this study will be manufactured into mass production, which are:

- (1) Coconut oil is quite expensive and has limited supply,
- (2) The structural load of the building will be affected due to the bataton brick weight.

So that this study proposes to replace the coconut oil as a phase change material. The bataton as its storage media for the substance will be replaced by other possible brick materials for better construction. Bandung Institute of Technology and Science (ITSB) has an academic program especially the Palm Oil Technology Study Program (TPS) in collaboration with PT Smart Tbk as the largest industry of Crude Palm Oil in Indonesia for field works, research, and human resource development.

Crude Palm Oil (CPO) is an energy source that is very large potential in Indonesia. However, the utilisation of CPO is still very limited. CPO should not only for food and biofuel needs, but it also can be processed for other sector such as cosmetics, medicines and other industrial raw materials. Thus the role of the palm oil industry can provide wider benefits in addition to the existing sector. In the future, palm oil utilisation will not just to meet the needs of biofuels as a substitute for fossil fuel, but also to be developed for energy efficiency purposes.

CPO has phase-changing material characteristics as well. In term of price, CPO price is much lower than coconut oil. Therefore, phase change material that will be used in this study is CPO. A lightweight concrete will be used as a brick material. This brick material is quite light, smooth, has a good level of flatness, and the structural load of the building will be lower.

CPO as phase-changing material can store thermal energy from a building wall so that the building's indoor temperature is more stable and lower. The temperature change outside the building will not have a significant effect on temperature change in the room. The result is to reduce the load of air conditioning system (AC) so that can the energy consumption will be lower. Therefore the decrease of cooling load will have a significant effect on decreasing electrical energy consumption for cooling.

One of the key parameters of phase-changing materials as a mixture of building walls is the value of thermal conductivity. The addition of phase change materials must consider the aspects of advantages and disadvantages so that the saving can be achieved. The choice of phase change materials on building wall materials is very important in order to obtain the benefits and have a significant influence on the thermal conductivity of the walls. This conductivity shows the characteristic of the wall to maintain the temperature stability of the building, so it will reduce the cooling load.

The CPO as a phase change material can be used with lightweight brick for a building walls because CPO has a melting point of 25-50 °C. Generally, this temperature range has good conformity in Indonesia region. The characteristics of the melting point of CPO is better than the melting point of coconut oil. The melting point of CPO shows a better capability to reduce environmental temperature fluctuations for room temperature stability. The addition of CPO to lightweight should not reduce the strength of the lightweight brick. Thus, it is necessary to know the optimal amount of CPO which is added so that lightweight brick has the best thermal conductivity and meets the standard of the building structure.

However, there is no research that recommends how much CPO can be added to light bricks to obtain the best conductivity value. This study is proposed to determine the effect of using CPO in a lightweight brick and to observe thermal conductivity and the strength of lightweight brick.

The contribution of this research in terms of the development of science and technology is to provide an overview of the effect of using CPO as phase-changing materials on the walls of buildings, both in terms of thermal resistance and structural strength. The results of this study are expected to be an option for solutions for:

- (1) The high cost of electricity in active air conditioning systems using AC
- (2) The development of an energy efficient building.

1.1 Air Conditioning System

The air conditioning system is used to regulate and maintain the air condition in a room to create a comfortable and healthy condition. Air conditioning includes setting temperature, relative humidity, air circulation speed, and air quality. One of the main processes in passive air conditioning systems according to S.M. Noerbambang (2011) is cooling which is the process of removing heat from the air in a conditioned room to reduce or maintain air temperature.

Air conditioning (AC) is an active air conditioning device that absorb heat generated by solar heat, lighting, electrical equipment, and the human body. However, based on the research of Loekita (2006), AC requires relatively large electrical energy. The energy needs are increasing as the population increases. So it is necessary to have energy efficiency program for energy conservation and energy diversification (Maritje Hutapea, 2012).

One solution to saving AC energy consumption is by passive air conditioning, which is to apply phase-changing materials to the walls of the building. Phase-changing materials (PCM-Phase Change Material) can store thermal energy as latent heat from the environment so that room temperature is lower and stable (Laila, 2013).

1.2 Cooling Load

Cooling load in a building is defined as energy per unit time that must be removed from the building so that the temperature and humidity in the room can be maintained under conditions according to design and thermal comfort. This amount of energy depends on the heat transfer that occurs between the building and the environment. (Laila, 2013)

Solar radiation as a source of heat from outside is a fairly large sensible heat. The heat from the sun will be transmitted into the room through the building walls by conduction. Walls containing phase change materials have lower thermal conductivity so that they can inhibit the heat transfer. The following is the comparison of the thermal conductivity values of concrete brick according to the Laila study (2013) shown in table 1:

Table 1. Thermal Conductivity of Concrete

No.	Type of Concrete	Thermal Conductivity (W/m.K)
1	non-PCM Concrete	0.683
2	PCM Concrete	0.436

1.3 Phase Change Material (PCM)

Phase-changing materials are materials that can store heat as latent heat, ie heat stored in a substance to change its form from one form to another without increasing temperature. While sensible heat is heat which causes changes in temperature without phase changes. Illustration of latent heat and sensible heat is shown in figure 1.

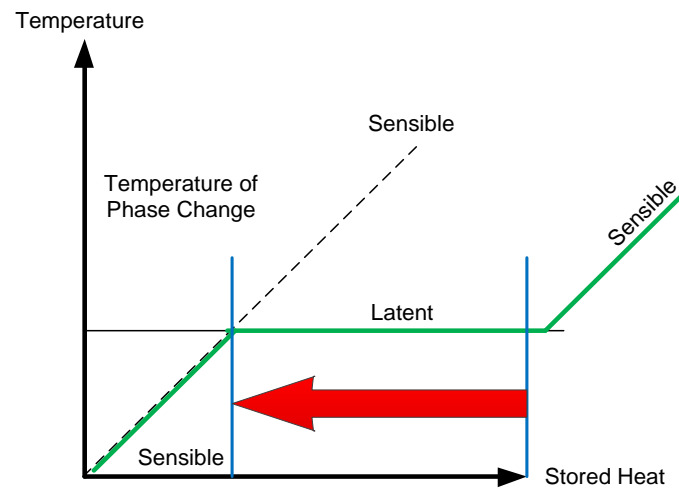


Figure 1. Diagram of pure phase change

1.4 Heat Transfer

Heat transfer is energy that moves due to the temperature difference. There are 3 types of heat transfer [7], which is conduction, convection, and radiation. When there is a temperature gradient in a stationary medium, which may be a solid or a fluid, there is **conduction** to refer to the heat transfer that will occur across the medium. The term **convection** refers to heat transfer that will occur between a surface and a moving or stationary fluid when they are at different temperatures. The third mode of heat transfer is termed thermal **radiation**. All surfaces of finite temperature emit energy in the form of electromagnetic waves.

The rate of heat transfer in the brick occurs by conduction. This value is influenced by the value of thermal conductivity. Thermal conductivity is the ability of a material to transfer heat. Thermal conductivity is proportional to the rate of heat transfer. Low thermal conductivity values resulting in a low rate of conduction heat transfer.

2. Method

The method used in this study is an experimental method with a quantitative approach. Experimental research is a causal research that proves that it is to compare the conditions of object treated with objects that are not treated or before being treated and after being treated. Sugiono (2012: 109) states that experimental research can be interpreted as a research method used to find the effect of certain treatments on others under controlled conditions. The characteristic of experimental research is the existence of variable manipulation, control, random assignment, and treatment.

2.1. Research Location and Variables Observed

This study was to determine the effect of CPO utilisation on thermal conductivity and strength of lightweight brick. In this case the lightweight brick is treated in the form of adding CPO with a certain amount and then observed its effect on thermal conductivity and structural strength. The research was conducted at the ITSB Product Design Workshop, Bandung Fluid Imaging Rock Laboratory, and ITB Center for Infrastructure and Build Environment (CIBE).

The research in the ITSB Product Design Workshop is related to the selection and cutting of light bricks according to the amount permitted by thermal conductivity test kits, hole making, filling CPO in holes and closing holes. Research at the Bandung Rock Fluid Imaging Laboratory is to test the thermal conductivity of light bricks that are not filled with CPO as a control and light brick which is supplied by CPO. While the research at the Center for Infrastructure and Build Environment (CIBE) of ITB is to test the strength of lightweight bricks after being tested for thermal conductivity.

2.2. Research Model

The research begins with conducting a preliminary study to formulate research problems and research objectives. At this stage a library study was also conducted. Literature study aims to obtain reference sources and the basis of theoretical formulas relating to the problems that will be investigated to further serve as the theoretical foundation in conducting research.

Based on the formulation of the research problem and the theoretical basis, as well as the research variables, then the research model was made as a solution model to answer the research objectives. The research model in this study is visualized by figure 2. as follows:

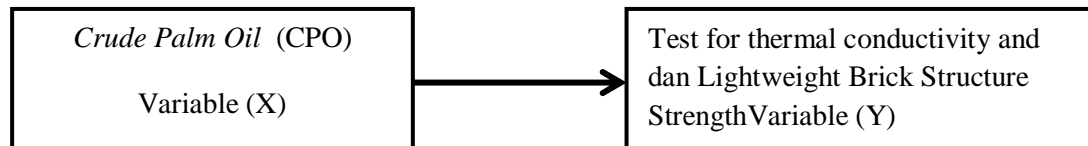


Figure 2. Research Model

2.3. Stages of Research

The stages of research to be explained in this section are the stages of the experimental process for data collection and analysis. The stages of the experimental process are divided into three main parts, namely:

1. Preparation
2. Implementation
3. Analysis

The first step for data collection is preparation. At the preparation stage, there are 2 things that need to be prepared, namely preparing CPO and preparing light brick. Preparations for light brick are:

1. Lightweight bricks will be used for experiments cut to size 10 cm x 5 cm x 4 cm to fit the test of thermal conductivity test. The number of these specimens is 6 (six) pieces which will be used to be treated with 5 (five) pieces and control 1 (one) piece.
2. Lightweight brick that has been cut to certain size, then punched with a diameter of 0.6 cm and a depth of 7 cm. Each specimen is perforated by 4 holes with a distance of 2 cm between holes.

Preparation for CPO is preparing CPO in 5 volume size groups, namely 2.5 ml, 5.0 ml, 7.5 ml, 10.0 ml and 15.0 ml. Each of these sizes is inserted in each light brick. The implementation is done by filling the CPO in the lightweight brick hole evenly. The amount of CPO that is injected into the hole is made 5 variations. Lightweight brick that has been filled with CPO is left until all CPO absorbs into the pores. After that, cover until full of each hole with a mixture of white cement and light brick powder and let it dry.

The next implementation process is testing thermal conductivity. Testing of thermal conductivity was carried out on the control lightweight brick and CPO injected lightweight brick. Testing of thermal conductivity was carried out at the Bandung Rock Fluid Imaging Laboratory with test specimens measuring 10 cm x 5 cm x 4 cm.

After testing thermal conductivity, the strength of the structure is then tested. This structural testing is carried out on the control light brick and lightly treated brick. While the light brick structure strength test was carried out at the ITB Center for Infrastructure and Build Environment (CIBE).

3. Results and discussion

3.1. Effect of CPO Percentage on Thermal Conductivity

Based on measurements of thermal conductivity from 6 rock samples resulting values as in table 2.

Table 2. Thermal Conductivity of Sample

Name of Sample	Thermal Conductivity (W/m.K)	Information
ITSB I.1	0.12 (± 0.01)	Injection 0 ml
ITSB II.1	0.06 (± 0.01)	Injection 2.5 ml
ITSB III.1	0.07 (± 0.01)	Injection 5 ml
ITSB IV.1	0.08 (± 0.01)	Injection 7.5 ml
ITSB V.1	0.14 (± 0.01)	Injection 10 ml
ITSB VI.1	0.15 (± 0.01)	Injection 15 ml

All samples are lightweight bricks whose composition can be considered homogeneous. Each sample carried out a different treatment on the amount of rock filler oil saturation. When filling fluid into the rock, it is made by making injection holes in the sample, then the oil liquid is loaded into the sample.

The ITSB II.1 to ITSB VI.1 samples showed an increase in the value of thermal conductivity which was proportional to the increase in oil injection volume in the sample. This is in accordance with previous studies conducted by Robertson (1988). The thermal conductivity of a rock is influenced by rock composition, porosity and fill fluid in the rock (Robertson, 1988). In this study states that if a rock is saturated with wetting fluid, the value of its thermal conductivity will increase. the value of thermal conductivity of rocks filled with water fluid will be greater than that which is filled with air as shown in figure 3 and figure 4. The image also shows that the smaller the porosity value of the rock as indicated by the greater the value of solidity, the greater the value of thermal conductivity.

However, on the measurement results anomalies occur in the ITSB sample I.1. The sample has a higher thermal conductivity value than the ITSB II.1 sample. But in theory the sample should have the lowest conductivity value compared to other samples. This might be due to differences in porosity. On ITSB II.1 samples to ITSB VI.1 there is an injection hole, which is not possessed by rock samples ITSB I.1. The addition of this injection hole is to result in the addition of porosity values in the sample ITSB II.1 to ITSB VI.1. This is in accordance with Robertson's (1988) study which states that the greater the porosity of feeding rocks will result in smaller thermal conductivity values.

4. References

- [1] Laila, L. (2013). Penggunaan Bahan Berubah Fasa pada Dinding Bangunan dalam Sistem Pengkondisian Udara Pasif. Thesis, Teknik Mesin FTMD ITB.
- [2] Zalba, Belen., Marin, J., Cabeza, LF., Mehling, Harald. (2003). Review on on thermal energy storage with phase change: materials, heat transfer analysis and applications. *Applied Thermal Engineering*, 23, 251-283.
- [3] Loekita S. (2006). Analisis Konservasi Energi Melalui Selubung Bangunan. *Dimensi Teknik Sipil*, 8-12, 93-98
- [4] Hutapea, Maritje. (2012) Kebijakan dan Program Pengembangan Bahan Bakar Nabati. Oral Presentation in Bandung Institute of Technology.
- [5] L.F. Cabeza, A. Castell, C. Barreneche, A. de Gracia, A.I. Fernández. (2011). Materials used as PCM in thermal energy storage in buildings: A review, *Renewable and Sustainable Energy Reviews* Volume 15, Issue 3.
- [6] Baetens, Ruben., Jelle, Bjorn Petter., Gustavsen, Arild. (2010). Phase Change Materials for Building Applications: A State-of-the-Art Review, *Energy and Buildings* **42**:1361–1368
- [7] V.V. Tyagi, S.C. Kaushik, S.K. Tyagi, T. Akiyama.(2011). Development of Phase Change Materials Based Microencapsulated Technology for Buildings: A Review, *Renewable and Sustainable Energy Reviews* **15**:1373–1391.
- [8] B.M. Diaconu and M. Cruceru. (2008). Novel Concept of Composite Phase Change Material Wall System for Year-Round Thermal Energy Savings, *Energy and Buildings*.
- [9] S. M. Noerbambang. (2011). Sistem Pengkondisian Udara. Oral Presentation in Bandung Institute of Technology.

- [10] Khudhair, Amar., Farid, Mohammed. (2003). A review on energy conservation in building applications with thermal storage by latent heat using phase change materials, 45, 263-275.