Utilization of Beeswax/Bentonite as energy storage material on building wall composite

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Abstract. The combination of building materials and PCM is an efficient way to increase thermal energy storage capacity in building components. In this study, a study of the use of beeswax/bentonite PCM on the concrete walls of the building had been carried out. This investigation intended to ascertain the amount of concrete compressive strength if coarse aggregates were replaced in part by PCM beeswax/bentonite. The use of PCM-beeswax in the concrete has not been able to increase the strength of concrete. Even worse, their existence proof to decreased the compressive strength of PCM mixture concrete. Heat absorption test shows that PCM beeswax/bentonite is capable of decreasing the concrete temperature up to 6.67% compared to concrete without PCM. It also means that the PCM proposed in this study shows great potential for application as a phase change material in lightweight concrete.

1. Introduction

In the world of construction, a common material used in conventional building materials include bricks, steel frame concrete, cast concrete, cement plaster, and insulation to reduce the AC load in the building. The use of phase change material, capable of storing latent-energy, is an efficient way to reduce energy consumption in buildings [1].

Heat energy can be stored and taken in the form of internal energy changes from materials as sensible heat, latent heat, and thermo-chemistry or a combination of them. Insensible heat storage systems, energy is stored by increasing the temperature of the material. This system utilizes heat capacity and changes in the temperature of materials during the process of heat absorption and release. The amount of energy deposited inside the system depends on the specific heat of the media, changes in temperature and mass of media used. Latent heat storage works based on heat absorption or releases when the storage material undergoes a phase change from solid to liquid or from liquid to gas or vice versa [2]. In thermochemical systems, energy absorbed or released takes place during the process of changing molecular bonds due to chemical reactions and the process that takes place is entirely reversible.

Among these techniques, latent heat storage utilizing PCM has attracted researchers due to its superiority in storing high energy and small temperature changes. The mechanisms of latent heat storage
obtained through a solid-solid, solid-liquid, gas-solid, and gas-liquid transformation phase. However, solid-liquid systems, superior economically attractive for use in thermal energy storage systems.

The combination of building materials and PCM is an efficient way to increase thermal energy storage capacity in building components. Concrete is a material generally used for building infrastructure, and public facilities which gain increasing popularity along with the times, therefore the selection of concrete as the primary raw material for building construction is significant. Several things had been a significant consideration in the making of concrete, i.e., the price is relatively low, easy to apply, high compressive strength, and excellent resistance to environmental factors.

Currently, the research concerning the integration of Phase Change Material (PCM) in the concrete mixture, gain more popularity. Benz et al. [3], analyzed the use of Phase Change Materials in concrete technology. Biwan et al. [4] conducted a study of Paraffin/diatomite composite phase change cement-based composite material for thermal energy storage. Rongda et al [5] conducted a study on Preparation, Mechanical and Thermal Properties of Cement Expanded Perlite Based Composite Phase Change Material to Improving Buildings Thermal Behavior Boards. Ahmad Hasan et al. [6], conducted a study of the Effect of Phase Change Materials (PCMs) Integrated into a Concrete Block on Heat Gain Prevention in a hot climate.

Many studies have conducted studies on the effect of using PCM on concrete compressive strength and thermal effects of concrete [7–11]. In another study, Hamdani [12] has conducted an experimental study of mechanical properties of concrete containing beeswax/dammar gum as phase change material for thermal energy storage. In this study, utilization of beeswax/bentonite PCM on the concrete walls of the building was carried out. This study aimed to ascertain the amount of concrete compressive strength if coarse aggregates were replaced in part by PCM beeswax/bentonite.

2. Material and methods
The test object used is a concrete cube measuring 15 cm x 15 cm x 15 cm. The total number of cubes is 24, for testing concrete characteristics, testing compressive strength, flexural strength, concrete testing carried out at the age of 7 and 28 days. The cement selected for this study was type I Portland cement, while the coarser aggregate earned from asphalt mixing plane. The powdery aggregate is beeswax and bentonite.

Several stages of material testing were carried out to analyze coarse aggregate sieves, bentonite, and beeswax, including assessing of the specific gravity and impregnation of coarse aggregates and fine aggregates, and the examination of organic content on coarse aggregates and fine aggregates, and also slump test.

In this study, the concrete is mix according to the Indonesian National Standard Method SK.SNI.T-15-1990-03. The concrete compressive strength designed to withstand more than 20 MPa. The curing process also carefully designed so that the next hydration process does not experience any intervention. If any, the concrete becomes subjected to cracks due to the rapid loss of water. This treatment is not only intended to obtain high compressive strength concrete but is also dedicated to improve the quality of the concrete durability, water resistance, wear resistance, and dimensional stability.
Figure 1. Concrete-PCM thermal performance testing device.

The PCM concrete thermal performance test device is carried out in a room designed, as shown in Figure 1. PCM concrete samples are 200 mm x 200 mm x 20 mm, placed at the top of the test chamber measuring 200 mm x 200 mm x 200 mm, with walls made of wood. For heat sources, a 250 W power lamp is used, placed at a distance of 320 mm above the sample. To maintain a uniform and stable temperature used a hollow cover of PVC material covered with a transparent sheet so that the heat source can reach the sample.

3. Result and discussion

The test result reveals that the fine aggregate sample with a saturated specific gravity (SSD), the average is 2.77 and can be classified as a normal aggregate because the value is still within the allowable limit of 2.2-2.7. Water absorption (absorption) obtained from the test results is 1.46%. This figure shows that the aggregate ability to absorb water from a dry state to face dry saturation is 1.46% of the aggregate dry weight itself. Beeswax density is 0.76.

The coarse aggregate density test finds out that the average density (SSD) is 2.64 and can be classified as an average aggregate since the value is still within the allowable limit of 2.2-2.7. Water absorption obtained from the test results is 1.20%, which mean, that the ability of the aggregate to absorb water from a dry state to face dry saturation is 1.20% of the aggregate dry weight itself. The results of the concrete compressive strength testing of various components of beeswax in the mixture shown in Figure 2-3.
Figures 2 and 3 portray that the addition of beeswax in the mixture reduces the compressive strength of the concrete, this phenomenon originated by the nature of beeswax, which has not been able to replace sand as fine aggregate.

The test results of the ability of PCM composites to absorb heat, as shown in Figure 3-4. This test uses a sample measuring 200mm x 200mm x 20mm. The sample used consisted of standard concrete (without PCM), and concrete-30% beeswax.

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Thermal performance tests for beeswax PCM-based concrete walls were successfully carried out. The picture above shows the temperature profile in a concrete wall without PCM and uses PCM-beeswax. Figure 4.a shows the temperature difference in the concrete test chamber without PCM with the inner surface of the concrete being 6 °C while in Figure 4.b shows the temperature difference of the concrete test chamber using PCM-beeswax with the surface in the concrete is 5.6 °C. It turned out that the effect of adding PCM-beeswax to the concrete caused a decrease in temperature of 0.4 °C or decreased by 6.67%. This result shows that PCM-beeswax is able to absorb heat and act as thermal storage material. The thermal absorbance conducted in this research also shows a similar result to what H.D Yun already conducted using Strontium-based PCM [13].

4. Conclusion
There are several results as key findings to wrap up the whole discussion of this research, i.e., the use of PCM-beeswax in the concrete has not been able to increase the strength of concrete, even worse; their existence reduced the compressive strength of PCM mixture concrete. However, the PCM proposed in this study shows great potential to be applied as a phase change material mainly to make relatively lightweight concrete. Unfortunately, the PCM mixture is not suitable for use as building main structures. On the other hand, the effect of adding PCM-beeswax to concrete has a good effect as a heat absorbent, where the temperature absorbed is about 6.67%.

References
[1] G Li and X Zheng 2016 Thermal energy storage system integration forms for a sustainable future. Renewable and Sustainable Energy Reviews 62 736–57.
[2] A Sharma, V V Tyagi, C R Chen and D Buddhi 2009 Review on thermal energy storage with phase change materials and applications. Renewable and Sustainable Energy Reviews 13(2) 318–45.
[3] D P Bentz and R Turpin 2007 Potential applications of phase change materials in concrete technology. Cement and Concrete Composites 29(7) 527–32.
[4] B Xu and Z Li 2013 Paraffin/diatomite composite phase change material incorporated cement-based composite for thermal energy storage. Applied Energy 105 229–37.
[5] R Ye, X Fang, Z Zhang and X Gao 2015 Preparation, mechanical and thermal properties of cement board with expanded perlite based composite phase change material for improving buildings thermal behavior. Materials 8(11) 7702–13.
[6] H Ahmad, K A Al-Sallal, H Alnoman, Y Rashid and S Abdelbaqi 2016 Effect of phase change materials (PCMs) integrated into a concrete block on heat gain prevention in a hot climate. Sustainability (Switzerland) 8(10).
[7] H-B Yang, T C Liu, J-C Chern and M-H Lee 2016 Mechanical properties of concrete containing phase-change material. Journal of the Chinese Institute of Engineers 39(5) 521–30.
[8] P Bamonte, A Caverzan and N Kalaba 2017 Lamperti Tornaghi M. Lightweight Concrete Containing Phase Change Materials (PCMs): A Numerical Investigation on the Thermal Behaviour of Cladding Panels. Buildings 7(2) 35.
[9] L K Sahu, D Mondloe and A Garhewal 2017 A review on thermal and mechanical properties of concrete containing phase change material. International Research Journal of Engineering and Technology (IRJET) 04(05) 2154–65.
[10] A D’Alessandro, A L Pisello, C Fabiani, F Ubertini, L F Cabeza and F Cotana 2018 Multifunctional smart concretes with novel phase change materials: Mechanical and thermo-energy investigation. Applied Energy 212(1) 1448–61.
[11] H Paksoy, G Kardas, Y Konuklu, K Cellat and F Tezcan 2017 Characterization of Concrete Mixes Containing Phase Change Materials. IOP Conference Series: Materials Science and Engineering 251(1).
[12] H Umar, S Rizal, M Riza, T Meurah and I Mahlia 2018 Mechanical properties of concrete containing beeswax/dammar gum as phase change material for thermal energy storage AIMS
[13] H D Yun, K L Ahn, S J Jang, B S Khil, W S Park and S W Kim 2019 Thermal and Mechanical Behaviors of Concrete with Incorporation of Strontium-Based Phase Change Material (PCM). *International Journal of Concrete Structures and Materials* **13**(1).