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Case study

Development of low thermal mass cement-sand block utilizing peat soil and effective microorganism

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ABSTRACT

The development of low thermal mass cement-sand block by incorporating peat soil and Effective Microorganism (EM) was studied systematically. In total, seven mixtures of cement-sand block targeted at a 28-days compressive strength of 7 MPa are designed. One control sample is made with a water/cement ratio (w/c) of 0.5, three mixes using 3%, 6% and 10% peat soil replacing sand and three mixes using 10%, 20% and 30% EM replacing water. Modified blocks with 6% of peat soil and 30% of EM are the most optimum blocks to be used in the construction of masonry as they successfully reduced the thermal conductivity of the blocks with the value of 1.275 W/mK and 1.792 W/mK respectively when being compared to the thermal conductivity of the control sample which is 2.400 W/mK. Besides, they are also able to achieve higher strength than the desired compressive strength which is 7 MPa. The compressive strength of the samples with 6% of peat soil is 16.48 MPa at 28-days while 30.39 MPa for samples with 30% of EM. On the other hand, the water absorption rate of samples with 6% of peat soil is 7.6% while 6.1% for samples with 30% EM and both are okay since their rate of water absorption is lower than 20%. In conclusion, the addition of peat soil and EM in the cement-sand mix show promising performance as a low cost material to produce low thermal mass cement-sand block.

1. Introduction

In some climates, high thermal mass buildings have better thermal performance than low mass buildings, regardless of the level of insulation in the low mass building [1]. The most energy is saved when significant reversals in heat flow occur within a wall during the day. So, mass has the greatest benefit in climates with large daily temperature fluctuations above and below the balance point of the building (55 °F–65 °F). For these conditions, the mass can be cooled by natural ventilation during the night, and then be allowed to absorb heat during the warmer day. When outdoor temperatures are at their peak, the inside of the building remains cool, because the heat has not yet penetrated the mass. Although few climates are this ideal, thermal mass in building envelopes will still improve the performance in most climates. Often, the benefits are greater during spring and fall, when conditions most closely approximate the "ideal" climate described above. In heating-dominated climates, thermal mass can be used to effectively collect and store solar gains or to store heat provided by the mechanical system to allow it to operate at off-peak hours. Any solid, liquid or gas that has mass will have some thermal mass. High density materials such as bricks, concrete, glass and marble have high thermal conductivity ranging from 0.51 W/mK to 1.63 W/mK since they require a lot of heat energy to change their temperature. In contrast, material such as plywood, timber and polyurethane have low thermal conductivity ranging from 0.02 W/mK to 0.16 W/mK [2].

Ismail et al. [3] reported a review of previous researches related to the influence of incorporating EM into the cement based

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material. From the review, it is identified that there are two types of EM which is classified as EM product and EM non-product which showed a huge potential as new additives in enhancing the properties of concrete. EM product comes in liquid form and it is widely used in the agriculture sector while EM non-product is not in liquid form and it consists of single colony of bacteria. The introduction of EM in concrete has proved to enhance the mechanical properties of the former but further studies need to be done for better understanding in investigating the mechanism underlies in the microstructure examination of the concrete. That study is also supported by a study conducted by Sato et al. [4], which their objective was to find the solution for the deterioration problem of concrete structures. EM is added as the admixture and they found that by adding EM into the mix, the workability of fresh concrete improves, initial strength increases and carbonation is suppressed almost perfectly when EM is used in concrete. In conclusion, there are no other materials can improve the quality of concrete in so many aspects like EM.

There are several advantages of adding EM into concrete based on previous studies by other researchers. However, no studies conducted to prove that EM could give advantage on the thermal mass of concrete. One of the significant advantages of adding EM into concrete is, it helps concrete to do self-healing when cracks occur [5]. Sierra-Beltran et al. [6] has conducted a study on the performance of strain-hardening cement-based composites with bacteria. The objective of this study is to measure the bonding and durability of concrete patch repair system. Based on the results, it is reported that the usage of SHCC with bacteria as a concrete patch repair material improved the bonding and durability of the material. Another research is conducted by Van Tittelboom et al. [7] where they investigate the alternative material for synthetic polymers that are being used for concrete repair. From the study, it is shown that when the bacteria are protected in silica gel, the cracks are filled completely. In conclusion, the use of biological repair technique is desirable because the mineral precipitation induced is pollution free. There is a research done by Andrew et al. [8], where the objective of the research was to determine the optimum percentage of EM to be added into concrete and to what extend EM is able to enhance the mechanical properties of concrete. From the results, it is found that when 5% of EM is added into the concrete, the compressive, tensile and flexural strength are 143.90%, 25.23% and 19.17% of the design strength respectively. The study concluded that the most economical and optimum percentage of EM to be added into the concrete is 5% as it enhanced the design strength of the concrete. EM in concrete also promotes sustainability to the industry because it is environmental friendly and it will not cause pollution if leakage happens. Other than that, it reduces the risk of Sick House Syndrome.

In Malaysia, most of the peatlands have developed along the coast behind the accreting mangrove coastlines, where sulphides in the mangrove mud and water restrict any bacterial activities. This kind of restriction leads to the accumulation of organic matter, the peat. Peat deposits represent 8% of the total land area of Malaysia, which is approximately 2.6 million hectares of land area [9]. Organic soils have an inhomogeneous and anisotropic structure that differs greatly from inorganic soils, resulting in their peculiar engineering properties which usually not favorable for load-bearing [10]. This type of soil generally contains a very high percentage of organic matters and usually water-logged. Peat soil is generally used to replace the firewood for cooking and heating in Europe, where there are regions that are temperate and boreal. There is diminishing use of peat soil for domestic purposes as peat soil has been used widely in the gas and oil area for cooking and heating fuels during the 20th century. Peat soil is also being used for fueling the electricity as it stimulates the development of large electric power plants. Recently, peat soil has been used to generate electric in small units in the range of 20–1000 kW as carbon and hydrogen contents of the soil are significant to be used as fuel [11].

Previous studies have shown the incorporation of several materials to produce the low thermal mass concrete. Uysal et al. (2004) [12] indicated that the usage of pumice aggregate (PA) as replacement of normal aggregate decreased the thermal mass of concrete up to 46%. Another previous research works proved that by using expanded perlite aggregate (EPA) as replacement of PA and silica fume (SF) and fly ash (FA) as replacement of cement in concrete mixes, the thermal mass can be lowered to about 0.15 W/mK [13]. However, limited research has been done on assessing the thermal insulation property of concrete produced with EM incorporation.

2. Materials and methods

2.1. Materials

An Ordinary Portland cement (ASTM Type 1) sourced locally was used in this study. River sand with size of 600 μ was used as the fine aggregate. It was sieved, washed and dried beforehand.

Peat soil with size of 600 μ was also being used to replace some proportions of river sand as the fine aggregate in the mix. It was sieved and dried beforehand. It was sourced locally from a palm oil plantation area.

Effective Microorganism (EM) was used in this study to replace some amounts of the water in the mix. It was prepared by activating it with sugar solutions called molasses. It was bought from the official supplier of EM in Malaysia.

2.2. Mix proportion design

A control mix, series of peat soil incorporated mortar and EM incorporated mortar were prepared. Water/cement ratio (w/c) was set at 0.5 for all the samples. To investigate the influence brought by peat soil incorporation to the mortar, peat soil was added to replace river sand at a ratio of 3%, 6% and 10% by weight while to investigate the influence brought by EM incorporation to the mortar, EM was added to replace water at a ratio of 10%, 20% and 30% by volume. The details of all the mortar mixtures are listed in Tables 1 and 2.