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Performance of Alternative Peat Cement Brick as Construction Material

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Abstract: Sustainable Development Goals (SDG) are the strategy for ensuring a more prosperous and sustainable future for all communities. Based on the goals that require actions by all developing countries, the focus is now on evolving and producing building materials that are sustainable by utilizing various types of waste. Open-dumping landfills, greenhouse gas and carbon dioxide emissions, industry demands for sustainable materials, and the downsides of current bricks such as low durability are the issues that need to be resolved. Hence, the production of eco-brick that utilize waste peat soil could be the alternative to minimize these problems. In this study, 60 samples of alternative peat cement bricks were tested for their mechanical properties with various percentages of peat soil replacement starting with 5%, 10%, 15%, and 20%. All laboratory testing such as compressive strength, density, water absorption, UPV, and thermal conductivity was conducted at Universiti Tun Hussein Onn Malaysia Batu Pahat campus and Pagoh Campus. It was observed that bricks with 15% peat soil produced a high-dense brick with the highest compressive strength, and has a minimal defect. Meanwhile, the higher the percentage of peat soil in cement brick, the higher the water absorption rate. Bricks that contain 5% of peat soil recorded the lowest K-value compared to other bricks with peat soil. It can be concluded that peat soil is significant to the mechanical properties of cement brick. This alternative peat cement brick is eligible as a construction material based on standard requirements.

Keywords: Brick, Sustainable Development Goals, Waste Materials, Peat Soil, Construction Material, Sustainable

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1. Introduction

In the year of 2015, 193 countries under the United Nations reached a consensus on the 17 Sustainable Development Goals (SDGs). The SDGs include a wide range of topics that targets society, nature, the economy, and well-being. Some of the SDG targets are directly related to the construction sector such as SDG 9 – Industry, Innovation, and Infrastructure; SDG 11 – Sustainable Cities and Communities, and SDG 15 – Life of Land [2]. In fact, there are numerous developments in construction materials that adopt the green concept of using waste. For example, the production of concrete uses rubber waste, recycled concrete aggregate, waste paper, rice husk, and plastic waste. In order to achieve the targets in the SDGs such as SDG 9 (Industry, Innovation, and Infrastructure), SDG 11(Sustainable Cities and Communities), and SDG 15 (Life and Land), waste peat soil can be incorporated with the production of cement brick. Since ages ago, earth material has been widely used as construction material such as clay, laterite soil, and sand. The utilization of waste peat soil in cement brick could enhance the use of local resources and is low cost.

Current issues such as open-dumping on landfill [2], greenhouse gas and CO_2 emissions [1], industry demand of sustainable building materials, decreasing natural resources [3], and the production of low-quality brick is concerning and it is important for the construction industry to tackle these issues. The utilization of waste materials can contribute to society, the economy, and the environment. Hence, the waste peat soil can be the alternative to produce building materials since it is easily accessible and it is a low-cost material. This study aimed to study the physical properties of peat soil as partial replacement of sand, determine the optimum proportion for the brick mixture, and evaluate the mechanical properties of alternative peat cement brick. There were 60 samples of peat cement bricks that were tested for their mechanical properties such as compressive strength, density, water absorption, UPV, and thermal conductivity. The brick samples have different quantities of peat soil replacement which are 5%, 10%, 15%, and 20%. All laboratory testing was conducted at UTHM Pagoh and UTHM Batu Pahat.

2. Literature Review

According to previous studies, Idris et al., [4] reported that samples consist of up to 6% peat soil able to achieve higher compressive strength than the designed strength of 7 MPa at 28-days with the range of 16.48 MPa – 30.35 MPa. In addition, Idris et al., [4] and Deboucha et al., [5] reported that rate of water absorption for all samples is lower than 20% and increasing curing period improve compressive strength and lowering water absorption. Motamedi et al., [6] in their study concluded that the more the quantity of peat soil, the lower the UPV value. For thermal conductivity, Islam [7] and Idris et al., [4] explained that thermal conductivity of all samples with peat soil achieved a lower k-value (1.275 W/mK – 2.294 W/mK) than the control sample (2.4 W/mK) and cement brick with peat soil have good thermal insulation properties.

3. Materials and Laboratory testing

3.1 Materials

There are two types of material used in this study; raw material and waste material. The waste material which is peat soil was collected at the oil palm plantation at Parit Sulong, Batu Pahat, Johor while raw material such as sand, Ordinary Portland Cement, and water was from the concrete technology laboratory, UTHM Pagoh. Peat soil that was used in this study is collected from a palm oil plantation at Parit Sulong, Batu Pahat, Johor. The peat soil was brought to UTHM's Geotechnical Laboratory and dried in an oven at 105°C for 24 hours. Then, the soil is crushed by using a grinder to obtain it in fine size. Next, the peat soil was sieved to obtain the size of 600 μm using sieve No. 30.

There was a total of 60 samples of alternative peat cement bricks with a size of 215 mm in length, 102.5 mm in width, and 65 mm in height as per MS 76:1972. The percentage of peat soil replacement is 5%, 10% 15%, and 20% including control samples. The brick is then cured for 7 and 28 days and laboratory testing was conducted after the samples had matured. The peat soil was grounded and sieved for a size of 600 μm according to previous works and sieve analysis of sand.

To determine the density of samples containing peat soil, a density test is performed on them after 7 and 28 days of curing. This test is carried out according to BS1881: Part 114: Method for determining the density of hardened concrete. The Vernier caliper and ruler are used to get the sample volume from the brick sample. Next, each sample of brick is weighed to determine its mass and the data was recorded. The density of cured brick is kilogram per cubic meter (kg/m3).

For water absorption, this test is conducted only after the samples have been cured for 7 and 28 days as per BS 1881: Part 122. The weight of the brick was recorded as the initial mass after the sample has cured. The sample then was dried in the oven for 24 hours at 105 ± 5°C of suitable temperature. The sample will be removed from the oven left it to cool down and then submerged in a water tank for 24 hours. The dry mass of the sample is then weighed and recorded. After the weighing procedure is completed, the surface of the samples must be dried using a cloth until there is no water remains on it. Lastly, the brick sample is weighed again, and the percentage values of the results are recorded. Furthermore, UPV test is conducted according to BS EN 12504-4. The transducers were placed precisely opposite one another for optimal performance. The distance between the centres of the transducer faces must be determined, and the pulse velocity may then be estimated by dividing this distance by the transit time of the pulse obtained with the apparatus.

For compressive strength, this test is carried out according to BS EN 12390-3:2002. Three samples of bricks were used to carry out the test after curing or after the samples reach suitable age for testing. The samples were placed on the testing machine in between the platens of a compression testing machine after the sample is removed from the curing tank. The brick sample was subjected to a continuously increasing load until it reached its maximum strength and failed. Lastly, for thermal conductivity, a guarded hot plate which is a steady state method will be conducted for thermal conductivity since it was adopted by British Standard as in BS EN 12667:2001. The sample was placed between two plates, one of which is heated and the other of which is cooled or heated to a lower amount. Next, the temperature of the plates is monitored until they reach a state known as steady state.

4. Results and Discussion

The results and analysis of this study were derived through several experimental procedures on the alternative peat cement brick samples by utilizing peat soil as replacement material in the mix design of a brick. As a replacement for siliceous sand in cement brick, different percentages of peat soil range from 0% to 20%, which is 0%, 5%, 10%, 15%, and 20% in the mixture.

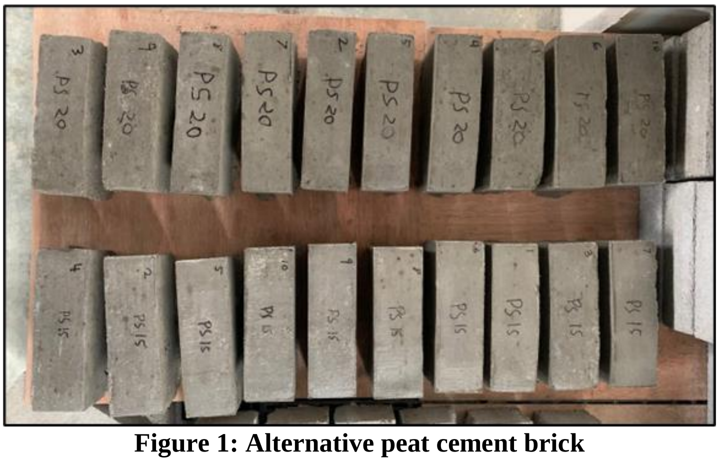

Figure 1: Alternative peat cement brick

The size of peat soil used in this study is based on previous study which is 600 μm and according to the sieve analysis of dry sand from the concrete laboratory. The soil was grounded by a grinder and sieved manually. Based on the result of the sieve analysis, it was observed that the sand from the concrete technology laboratory have various size particles and the highest amount of size is at 600 μm. Thus, the peat soil needs to have the same size to replace the voids left by the sand particles to ensure the brick mixture blend well and to prevent air void. Figures below shows the graph of sieve analysis and peat soil retained on 600 μm mesh.

Figure 2: 600 μm peat soil

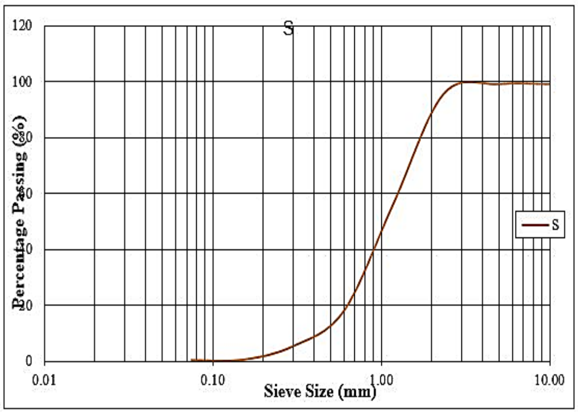

Figure 3: Sieve analysis of sand

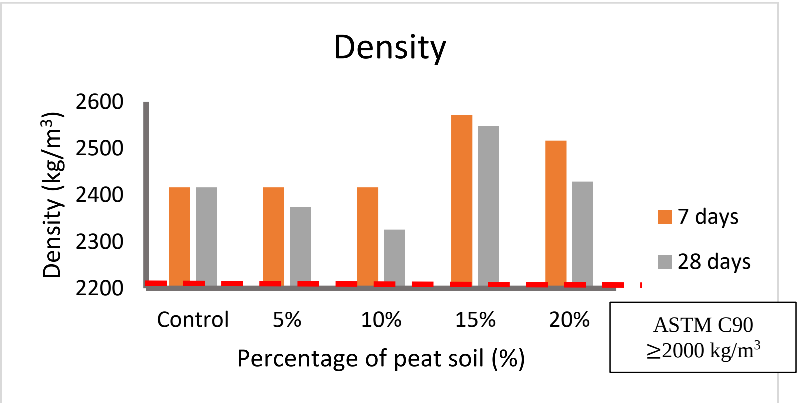

Figure 4: Density

Based on Figure 4, it can be observed that the graph started to fluctuate started from 10% to 20% of peat content. The range of density is between 2300 kg/m3 to 2500 kg/m3 which is considered higher compared to the previous study. According to this finding, the density of the brick sample consists of 15% of peat soil with a 0.6 water-cement ratio recorded the highest density at 7 and 28 days of curing with the value of 2571.43 kg/m3 and 2547.62 kg/m3, respectively. Meanwhile, bricks with the same water-cement ratio of 0.6 for 28 days of curing achieved the lowest density at 2326.19 kg/m3 and 2373.81 kg/m3 with 5% and 10% of peat soil, respectively. Based on ASTM C90-09, concrete masonry units are classified into three types: normal weight (more than 2000 kg/m3), medium weight (1680 – 2000 kg/m3), and lightweight (less than 1680 kg/m3). Thus, bricks with 15% of peat soil are considered normal weight.

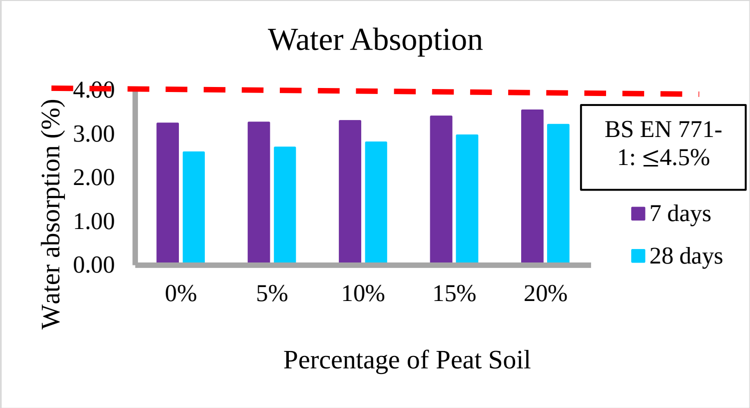

Figure 5: Water absorption

As shown in the Figure 5, the percentage of water absorption for brick samples rises steadily from 3.2% to 3.5% for 7 days of curing and 2.5% to 3.2% for 28 days of curing. Brick samples with 20% of peat soil recorded the highest percentage of water absorption (3.5%) while bricks that contain 5% of peat soil has the lowest percentage (2.6%), excluding the control (0%) samples. It can be seen that the percentage of water absorption increases as the percentage of peat soil increases. The average water absorption in this study is in accordance with BS EN 771-1.

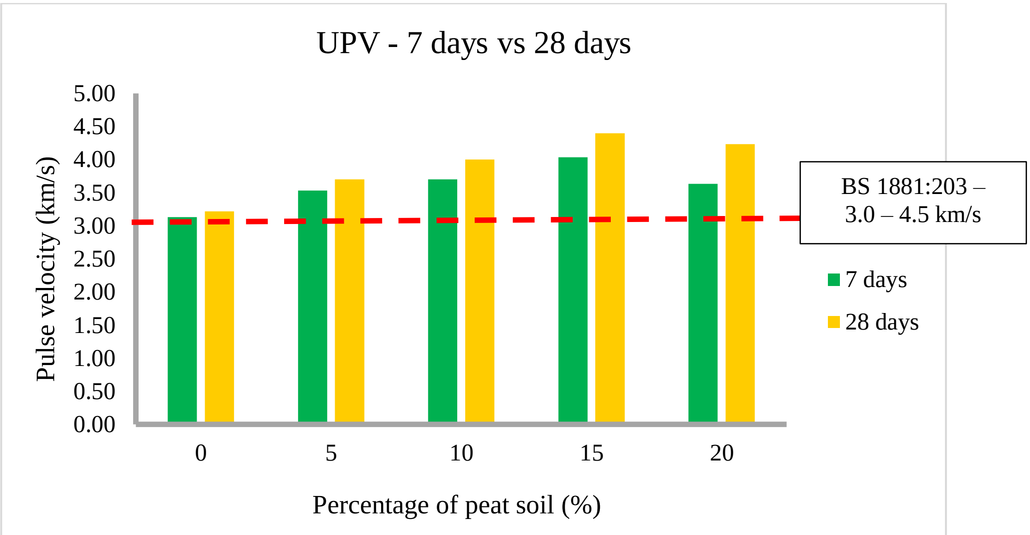

Figure 6: UPV

It was observed in Figure 6 that the pulse velocity was rising steadily with increasing peat soil replacing siliceous sand and then started to decline when the samples contain a maximum of 20% peat soil. Adding 15% peat soil to the mixture, however, has the largest impact on improving the pulse velocity. Furthermore, it can be seen that the maximum pulse velocity at the age of 7 and 28 days with 15% of peat soil substituting siliceous sand is 4.03 and 4.40 km/s, respectively. This depicts that the presence of peat soil in a brick mixture improves pulse velocity. Additionally, the range of pulse velocity in this study is between 3.1 km/s to 4.2 km/s which demonstrated that the brick samples is classified as medium to good, in term of quality ratings.

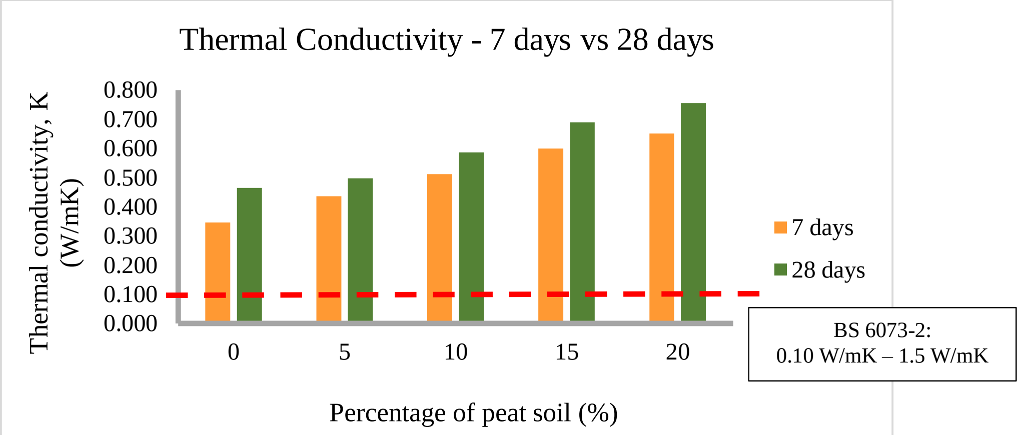

Figure 7: Thermal conductivity

Based on the bar chart illustrated in Figure 7, it was observed that the K-value increased when the percentage of peat soil increased at the age of 7 and 28. Brick samples with 20% peat soil at the age of 7 and 28 days achieved the maximum K-value while bricks with zero content of peat soil recorded a minimum K-value compared to other percentages. This result implies that the age and curing period affect thermal conductivity. Apart from that, bricks with 20% peat soil recorded the highest K-value which is 0.652 W/mK and 0.756 W/mK. This indicates that the presence and quantity of peat soil in the brick mixture affect the heat transfer within the brick sample.

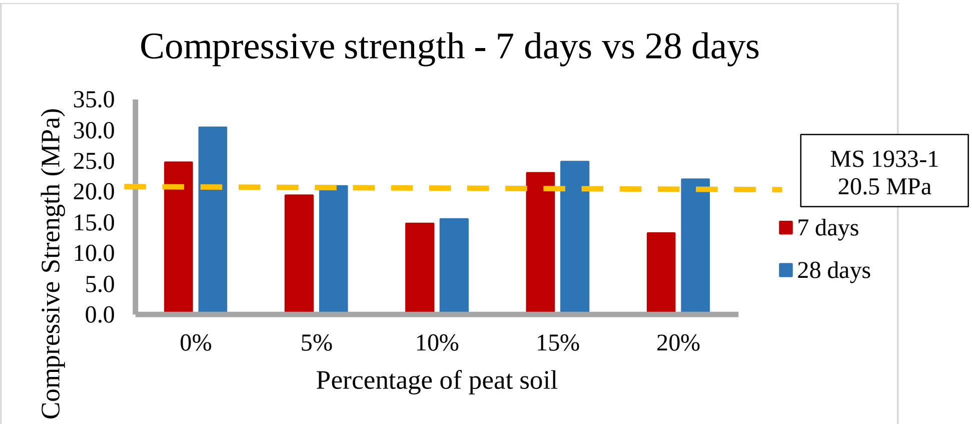

Figure 8: Compressive strength

Based on Figure 8, the bricks' strengths can be seen to fluctuate for both 7 and 28 days of curing. The ratio of replacement materials influences the uneven rise and drop of strength. It can be seen that the strength declines until 10% which recorded the lowest compressive strength with 14.78 MPa and 15.53 MPa. Then, the strength of the brick sample rises by 35% with a peat content of 15% and then dropped again by 11% and 42% when the peat soil in the mixture increased to 20%. In addition, it can be seen that at 28 days, all bricks samples have higher strength compared to bricks cured for 7 days. For instance, brick samples that contained peat soil by 15% at 28 days achieved the highest compressive strength of 24.84 MPa contrasted with the compressive strength of the same mixture at 7 days. This result indicates that 15% of peat soil replacement can improve brick strength. For 15% peat soil, the bricks comply with ASTM C62-17 under severe weather-resistant bricks which require minimum strength of 20.7 MPa, and MS 1933-1 under load-bearing bricks which specify minimum strength of 20.5 MPa.

5. Conclusion

The first objective of this study is to study the physical size of the waste peat soil used in this study. The size of peat soil is 600 μm. The sizing factor is important to ensure the peat soil can blend well with other materials such as sand and cement. Since sand was replaced with peat soil, the size and weight of the peat soil used are suitable for this study. For the second objective, this study aimed to determine the optimum proportion of alternative peat cement brick which is PS15 (15%) due to its achievement of obtaining the highest compressive strength of 24.8 MPa and highest pulse velocity that indicates the brick is good quality. Apart from that, in terms of durability, the control sample obtained better results than samples containing peat soil. Nevertheless, brick samples with peat soil still achieved a lower water absorption rate that satisfied the standard requirement. Similarly, the thermal conductivity of bricks that have peat soil increases but they are still in the allowable range as per standard requirements. However, the density of all brick samples was considered as normal weight but the density value is higher than in previous studies. For this study, it can be deduced that a denser brick produces higher compressive strength with lower volume of air voids. Thus, bricks with 15% peat soil are the optimum proportion for load-bearing application. Apart from that, bricks with 5% - 10% peat soil is suitable for non-load bearing application due to its low rate of water absorption and the ability to absorb heat is also lower compared to 15% - 20%. To conclude, this study has shown that the presence of peat soil affects the mechanical properties of cement brick. In addition, the curing period does affect the performance of this brick. The more the brick matures, the greater the results. Despite the fact that the results were quite distinct from the previous study, this alternative peat cement brick is still applicable for construction such as brickwall for fences, could replace concrete sump, and is beneficial in rural areas since peat soil is easily accessible.

Acknowledgment

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