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Physical and Mechanical Properties of Compressed Earth Brick (CEB) Incorporation with Palm Oil Fuel Ash (POFA) as Cement Replacement

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Abstract: Malaysia is the largest palm oil producer where palm oil fuel ash (POFA) is a solid waste that were difficult to remove but the waste can be used to solve solid waste problem. POFA is a pozzolanic material that can replace Ordinary Portland Cement (OPC) in order to produce high strength and low-cost bricks. Replacement of POFA can be considered as environmentally friendly. Palm oil fuel ash (POFA) was used as a component in compressed earth brick (CEB) in this study to replace cement. The purpose of this study was to determine the density, water absorption and compression strength of CEB. The dimension of CEB produced was 250 mm x 125 mm x 100 mm and the mix ratio is 1:4:4 for cement, sand and soil respectively. 0%, 5%, 10%, 15%, and 20% from cement content are the five types of percentages used. A total of 60 pieces of CEB was produced. CEB was given a 7-day and 28-day curing process before the test. The test conducted were density test, water absorption and compressive strength test. The results showed that CEB specimens with 10% POFA had the maximum density and compressive strength after 28 days, with values of 2099.4 kg/m^3 and 3.4559 N/mm^2, respectively. The CEB specimen with 0% POFA for 28 days had the lowest rate of water absorption which is 9.5% and it is in compliance with MS 76: 1972 that allowable 15% of water absorption for an earth brick. Therefore, as a result of findings, solid waste such as POFA was identified to be suitable materials in part of construction. However, more research is needed in term of chemical composition and other aspects to improve the understanding before it can be used in brick manufacture.

Keywords: Palm Oil Fuel Ash, Compressed Earth Brick, Pozzolanic Materials, Solid Waste

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1. Introduction

Nowadays, bricks are considered as one of the most sought-after building materials for a variety of civil engineering projects all over the world. Bricks are currently mostly made of clay and sand mixed with a binder in the proper proportions [10]. Earth blocks stabilized with various chemicals are widely used to make bricks. However, the properties of bricks vary depending on the composition of the bricks. Due to the economics of the building industry, there is a demand for quick and cost-effective construction. The conventional construction approach is slow and inefficient, thus it can no longer fulfil the contractors' construction budget [4]. Furthermore, there is a growing demand for eco-friendly building construction in order to lower down energy emissions and carbon footprint [13].

The compressed earth block, is a modern replacement for the moulded earth block. A compressed earth block (CEB) is a form of building material constructed mostly from damp soil compacted under high pressure into blocks [13]. It is also known as a pressed earth block or a compressed soil block. By using a mechanical press, compressed earth blocks are created from a mixture of reasonable dry inorganic subsoil, non-expansive clay, and aggregate. The raw or stabilized soil for compressed earth block (CEB) is slightly moistened, poured into a press with or without stabilizer, and compacted using a manual or automated press [7].

Blocks that have been stabilized with a chemical binder such as Portland cement are known as compressed stabilized earth blocks (CSEB) or stabilized earth blocks (SEB) [7]. In addition, compressed earth brick (CEB) is a more convenient, low-cost, and environmentally beneficial type of brick than conventional bricks. Other than that, CEB also takes shorter time to produce than conventional bricks. CEB is compressed at high pressure to make blocks that can be easily installed, whereas conventional bricks must be dried and burned, which might take longer time [8]. A small amount of Ordinary Portland cement (OPC), that works as a stabilizer for the soil combination, is added to the CEB mixture to improve its properties. Nonetheless, the usage of OPC will raise the carbon footprint of CEB manufacturing. As a result, there has been an increase in demand for supplemental cementitious materials with low environmental impact [1].

Palm oil fuel ash (POFA) is a solid waste by-product of the palm oil industry produced as ash from the combustion of palm oil husk and palm kernel shell used as fuel in palm oil mill steam boilers. Because palm oil is the principal ingredient in biodiesel production, the by-product of palm oil fuel ash tends to rise year after year, although POFA application remains limited. Because of its pozzolanic properties, POFA can be used not only as a cement alternative, but also to make strong and long-lasting concrete [11]. Replacement of POFA as cement replacement can be categorized as eco-friendly because cement emits a lot of CO2 during its manufacturing from fossil fuel combustion, which can harm human health and pollute the air. [12] Therefore, there are many researchers that did their studies on the use of solid waste as partial construction materials [14 – 15].

Palm oil fuel ash (POFA) was used in this study with percentage of 0%, 5%, 10%, 15% and 20% as substance to replace cement in manufacturing CEB. POFA is solid waste that contains pozzolanic materials that can replace OPC as binder in bricks. The dimension of CEB produce is 250 mm x 125 mm x 100 mm with ratio of mixture is 1:4:4 which is cement: sand: soil. After conducted the test, the data was analyses to determine the physical properties and compressive strength of CEB with incorporation of POFA as cement replacement material.

2. Materials and Methods

The physical properties and compressive strength of CEB incorporating with POFA were investigated in the laboratory, which included density, water absorption and compressive strength. The data of density, water absorption and compressive strength had been analysed.

2.1 Materials

The materials used in this study are Ordinary Portland Cement (OPC), sand, laterite soil, palm oil fuel ash (POFA) and water. Ordinary Portland Cement (OPC) used in this study was Holcim cement brand manufactured by San Minguel Corp. The specifications of the cement are accordance to the ASTM C 150. As for Palm Oil Fuel Ash (POFA), it was collected at Kilang Sawit Muar Berhad that located at Johor. POFA was in wet condition upon collected, hence it was needed to oven-dried in the oven for 24 hours at 105 ºC in order to remove all the moisture content. After been oven-dried, POFA then sieved passing 90 µm to remove the coarse particles. Higher fineness of POFA helps the pozzolanic properties to be greater [2]. Laterite soil was supplied from Aymas Hardware at Parit Raja, Johor. The laterite soil will be oven dried and crushed to the correct grain size particle before used. Sand is made of crushed rock that has fine and sized fractions maximum up to 5mm. Sand also one of the main materials in the manufacture of compressed earth brick. To ensure that the sand is free of any unwanted particles, the sand will be sieved passing 2.36mm. Sand was provided by Advance Material Laboratory, FKAAB.

2.2 Methods

Compressed earth brick (CEB) was designed in compliance with ARS 674:1996 [9] which have dimensional tolerances for special blocks with length, width and height that is not more than 4mm, 3mm and 5mm respectively from common dimension. The study prepared two types of CEB specimen with dimension of 250 mm x 125 mm x 100 mm (length x width x height). The mix proportion for POFA is 0%, 5%, 10%, 15% and 20%. The number of specimens to be tested was 60 specimens and been cured for 7 days and 28 days by air-curing process. After 7 days and 28 days, the specimens were evaluated for density test, water absorption test and compressive strength test in compliance with the specifications of BS 3921:1985 [6], MS 76: 1972 [9] and ASTM C140 [5].

Table 1: Mix design of a CEB

Mix Designation	Cement (kg)	Sand (kg)	Soil (kg)	POFA (kg)	w/c
CEB0	0.4	1.92	2.13	0	0.6
CEB5	0.38	1.92	2.13	0.02	0.6
CEB10	0.36	1.92	2.13	0.04	0.6
CEB15	0.34	1.92	2.13	0.06	0.6
CEB20	0.32	1.92	2.13	0.08	0.6

3. Results and Discussion

The value of density, water absorption and compressive strength of CEB are used to determine its performance in this study. Several tests were carried out in order to obtain the result of its performance which is density test to gain the density value, water absorption test to obtain the rate of water absorption value and compressive strength test to obtain the compressive strength value of CEB.

3.1 Density

Based on Figure 1, it can be concluded that addition of POFA in CEB shows a good pozzolanic reaction as the reading started to increase when there was mixture of POFA. However, higher percentage of POFA tend to lower the density value of CEB as the rate of hydration also reduced. Furthermore, a high amount of POFA mixed in bricks might result in a drop of average density because an excessive amount of POFA at a fixed cement content can result in the formation of voids. Air voids tend to lower down the strength of CEB other than its density. Other than that, longer time of curing affected the density value of CEB as the value on 28 days was higher than 7 days. The condition of CEB for 28 days was denser than 7 days due to the pozzolanic activity that has fully began as the strength gained at the age of 28 days. Figure 1 below shows the density value obtained based on the testing of specimens for 7 days and 28 days.

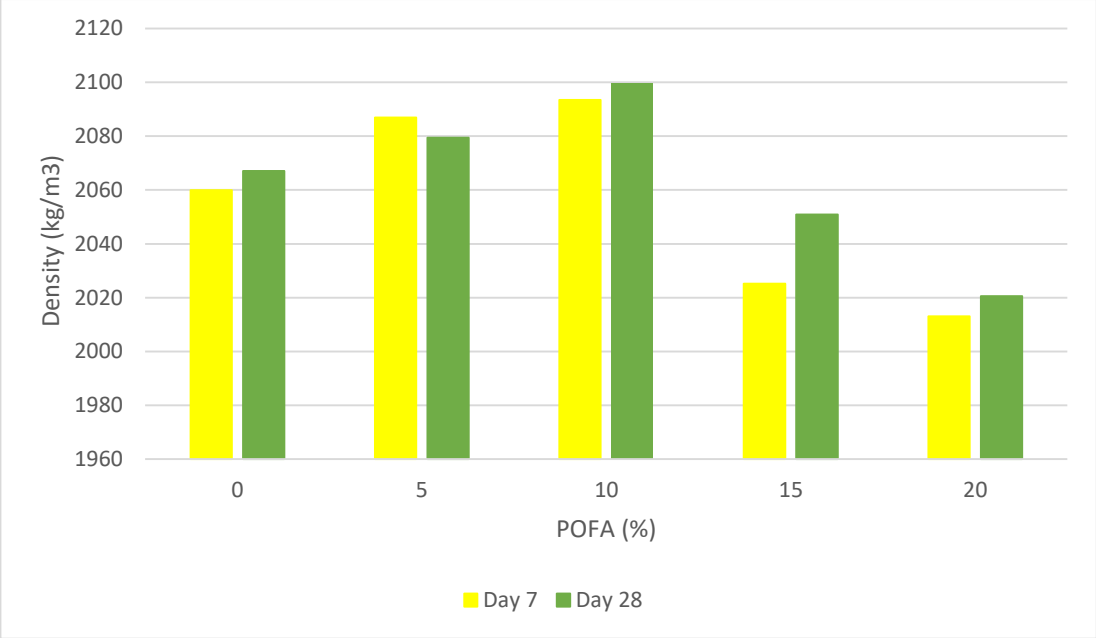

Figure 1: Density of CEB for 7 days and 28 days

3.2 Water absorption

Figure 2 below shows that there was increasing in water absorption value in CEB for both 7 days and 28 days whereas this can be concluded that higher amount of POFA tend to increase the value of water absorption of CEB. This prove that the rate of water absorption increases as the content of POFA grows, because the rate of water absorption rose as the amount of pozzolan increased. The pozzolan reaction contribute in reducing the pores in CEB and the increasing of water absorption was likely due to the increment of porosity in CEB. Between 7 days and 28 days, there was a slight differences of water absorption value. However, the data obtained is compliance to the MS 76: 1972 which is 15% is the allowable water absorption for an earth brick. Figure 2 below shows the water absorption value obtained based on the testing of specimens for 7 days and 28 days.

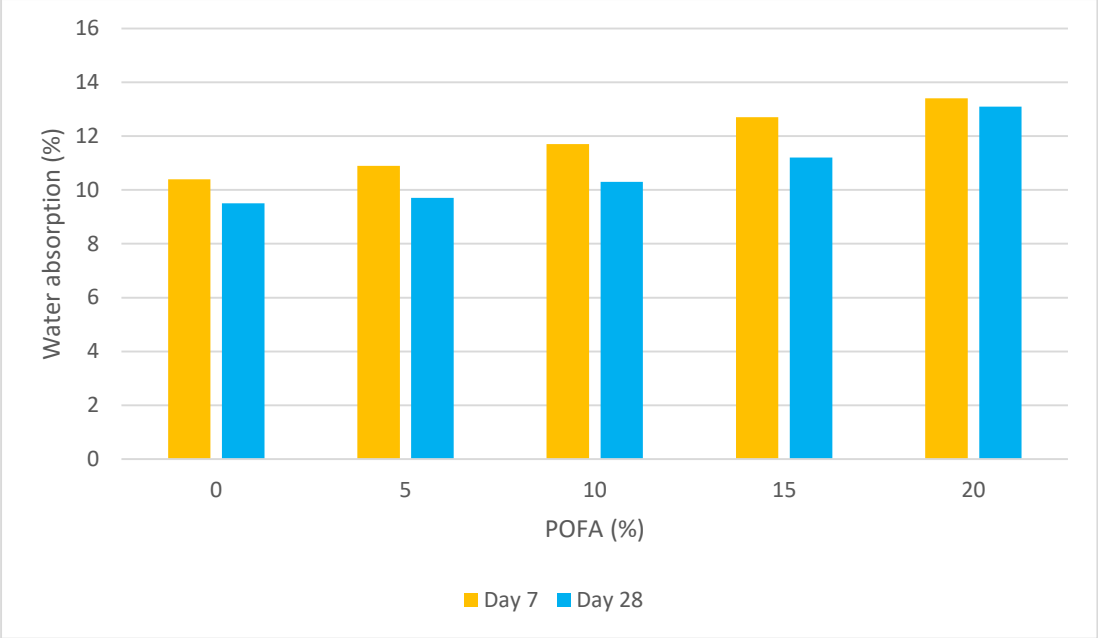

Figure 2: Rate of water absorption of CEB for 7 days and 28 days

3.3 Compressive strength

Based on the data obtained in Figure 3, short period of curing may affect the decreasing in mix designation as there was slight differences in data for 7 days and 28 days. Other than that, decreasing of mix designation was due to excessive amount of POFA that distracts the amount of cement hydration formed due to immoderate pozzolan particles surround the cement particles. Thus, this resulted to lower strength of bricks. Figure 3 below shows the compressive strength value obtained based on the testing of specimens for 7 days and 28 days.

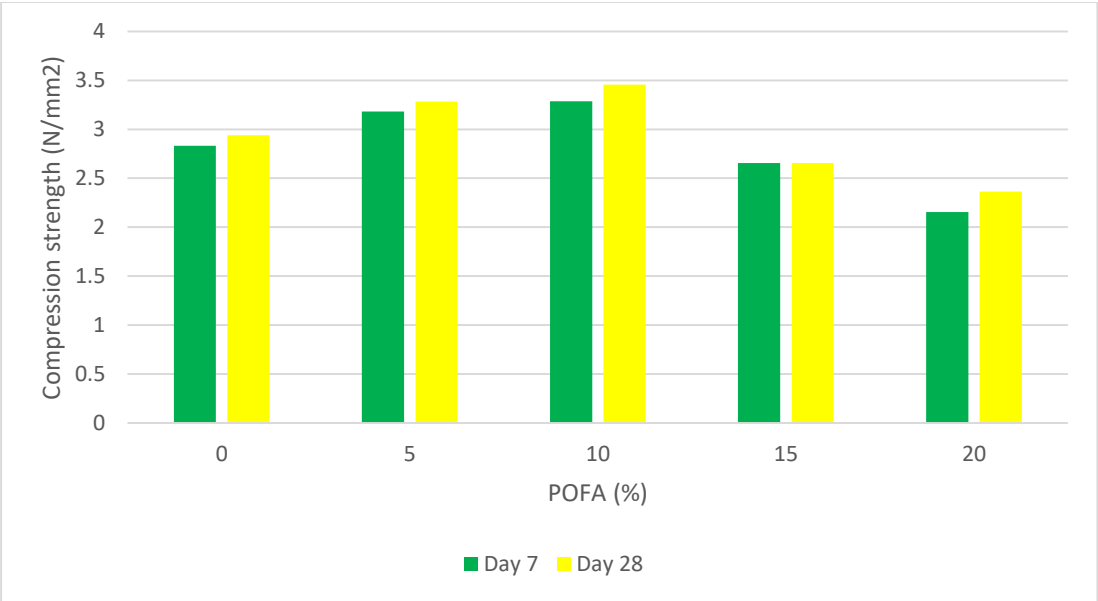

Figure 3: Compressive strength of CEB for 7 days and 28 days

4. Conclusion

For bricks improvements, there are many studies had been done to increase the strength, durability and performance of bricks itself. Some improvement that had been done are by using different brick ratio in order to find the high quality of CEB. Then, more test been conducted to determine the optimum percentage of POFA replacement in CEB. Other than that, various water cement ratios also can be tested to find the best mix percentage of POFA in CEB. The finding for this study revealed that POFA have potential to be green materials in CEB but not exceeding 10% of addition. This is because higher amount of POFA can affect the instability of density, water absorption and compressive strength of CEB. The ratio for the best mix designation of CEB is 10% for density and compressive strength while 0% for water absorption. Hence, it can be concluded that the value of density and compressive strength increased while the water absorption decreased with 10% addition of POFA in CEB.

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