Properties of palm oil fuel ash cement sand brick containing pulverized cockle shell as partial sand replacement

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Abstract. Environmental pollution caused by the disposal of solid wastes generated from both palm oil industry and cockle shell trade has motivated researches to explore the potential of these wastes. Integrating these wastes in production of construction material is one of the ways to reduce amount of waste thrown at dumping area. Thus, the present investigation investigates the performance of palm oil fuel ash (POFA) cement sand brick containing pulverized cockle shell as partial fine aggregate replacement. All mixes used contain 20% of POFA as partial cement replacement. Total of six mixes were prepared by adding a range of pulverized cockle shell that is 0%, 10%, 20%, 30%, 40% and 50% as partial sand replacement. The mixes were prepared in form of brick. All the water cured samples were tested for compressive strength and flexural strength until 28 days. Findings show that brick produced using 20% pulverized cockle shell exhibit the highest compressive strength and flexural strength also the lowest water absorption value.

1. Introduction

Malaysia as one of the world largest palm oil producers generates a large amount of by product known as palm oil fuel ash (POFA). This light ash which color ranges from whitish to greyish is disposed at dumping site within the factory area and creates pollution. About 4 million tonnes of (POFA) is produced annually [1]. The abundance of this solid waste initiated researches to discover the potential of this waste. As a result, Abdul Awal [2] found that POFA contains high silica content, leading it to be classified as a pozzolanic material thus enabling it to be used as partial cement replacement material in concrete. Further research also discovers that integration of POFA as partial cement replacement in i.e. high strength concrete [3], aerated concrete [4] and lightweight aggregate concrete [5] successfully enhances the blended cement properties as compared to plain concrete. Still with the huge availability of POFA in this country, varieties of construction material containing POFA need to be produced to reduce amount of ash disposed as waste.

Other than palm oil industry, cockle trade also generates cockle shell waste which has impact on the environmental quality. In practice, the shells of cockles are cracked open to acquire the edible meat. The shells are thrown as waste at dumping site. Another researcher, Boey et al [6] stated that this fishery waste causes stinking smell and unappealing view to the community surrounding. Report by Department of Fisheries [7] highlighted that the cockle trade is growing compared to the year before. As the industry continues to flourish, it is foreseen that more cockle shell would be disposed in larger amount which in turn will pose negative impact to the nearby area. Therefore, integrating this waste for production of construction material such as cement sand brick would contribute towards cleaner environment. Thus, in this research, the effects of using different percentage of pulverized cockle shell as partial sand replacement in POFA cement sand brick were investigated. The properties of this newly developed POFA cement sand brick containing pulverized cockle shell are determined.

2. Methodology

2.1. Materials

Cement, river sand, water, palm oil fuel ash and cockle shells are among the materials used in specimen preparation. Ordinary Portland cement was used throughout the experimental work. River sand was obtained from the nearby local supplier. Tap water was used for brick mixing and curing process. POFA was supplied by a local palm oil mill located in the state of Pahang, East Coast of Peninsular Malaysia. Cockle shell wastes were collected from a dumping area in the state of Perak, West Coast of Peninsular Malaysia. Figure 1 and 2 illustrates the collection process of both POFA and cockle shell respectively.

At the laboratory, both wastes were processed before ready to be used for brick production. POFA was sieved and ground to be fine fulfilling the requirement in ASTM C618-16 [8] in order to be used as partial cement replacement. Figure 3 depicts original POFA and after it was ground to be fine ash. Cockle shells were ensured to be free from debris. Then, it pulverized into small particles using crushing machine. Figure 4 shows appearance of cockle shell waste before and after it was processed to be fine as sand. The chemical composition of the cockle shell is tabulated in table 1. The calcium oxide content is high in cockle shell causing to appear in whitish colour. Previous researchers also noted that the high content of calcium oxide in cockle shell [9, 10].

Figure 1. Palm oil fuel ash is packed in gunny sack

Figure 2. Cockle shell collecting process

Figure 3. Palm oil fuel ash before and after grinding

Figure 4. Cockle shell before and after processing

Table 1. Chemical content of pulverized cockle shell

Chemical Composition	Percentage (%)
Calcium Oxide (CaO)	67.28
Silicon Dioxide (SiO_2)	0.50
Sodium Oxide (Na_2O)	0.42
Iron Oxide (Fe_2O_3)	0.27
Aluminium Oxide (Al_2O_3)	0.19
Strontium Oxide (SrO)	0.19
Sulphur Trioxide (SO_3)	0.14
Magnesium Oxide (MgO)	0.07
Phosphorus Pentoxide (P_2O_5)	0.04
Potassium Oxide (K_2O)	0.03
Chlorine (Cl)	0.03
Manganese Oxide (MnO)	0.02
Titanium Oxide (TiO_2)	0.02

2.2. Specimen Preparation and Testing

Six types of mixes were used to prepare specimens in form of brick (210 x 100 x 65)mm for the experiments. All mixes contains 20% POFA as partial cement replacement by weight of cement. Twenty percent of POFA has been selected to replace the cement partially since results from previous studies [3, 4, 11] indicates that replacement of 20% gives the optimum strength of concrete. Plain cement sand brick produced using 100% river sand was used as control specimen. The rest of the mixes contain various percentage of crushed cockle shell from 10% up to 50% as partial fine aggregate replacement.

The mixing process was carried out using mechanical mixing machine to acquire uniform mixture. Then, the mixes were placed in timber brick mould as shown in Figure 5. All the specimens were covered with wet gunny sack and left overnight. The next day, it is demoulded (Figure 6) and immersed in water tank until the testing age. All the specimens after demoulded were immersed in water tank until the testing age. Both compressive strength test and flexural strength were conducted at 7 and 28 days. Water absorption test were conducted at 28 days. All tests were conducted in accordance to ASTM C55 [12].

Figure 5. Casting of brick specimen

Figure 6. Brick samples ready to be water cured

3. Results And Analysis

3.1. Mechanical Properties

Both compressive strength and flexural strength of POFA cement brick specimens containing various percentage of crushed cockle shell is presented in Figure 7 and Figure 8. Generally, all specimens exhibit continues strength increment as the curing age become longer due to the application of water curing. Water curing ensures the undisturbed hydration process for continuous generation of calcium silicate hydrate (C-S-H) gel which fills in the voids, resulted in denser and stronger brick. It is important to highlight that integrating suitable amount of pulverized cockle shell as partial sand replacement also successfully increases the strength of POFA cement sand brick.

Brick produced using 20% and 30% pulverised cockle shell exhibit significant strength improvement compared to all other mix. Incorporation of 20% of pulverized cockle shell as partial sand replacement produces brick with the highest strength value at all curing age. This positive contribution is probably due to the filling effect of this fine waste material. Similar observation has been highlighted by Shettima et al. [13] when solid waste known as iron ore tailing were integrated as partial fine aggregate replacement in concrete. Although inclusion of more crushed cockle shell would be able to reduce larger amount of natural river sand used which makes the material more environmental friendly, the utilization of this waste material in the mix need to be limited. This is because; too much of pulverized cockle shell which is 50% replacement in the mix causes apparent drop in the compressive strength. Nevertheless, looking from the point of industrial application, brick containing 50% of pulverized cockle shell still can be used for certain application in construction project.

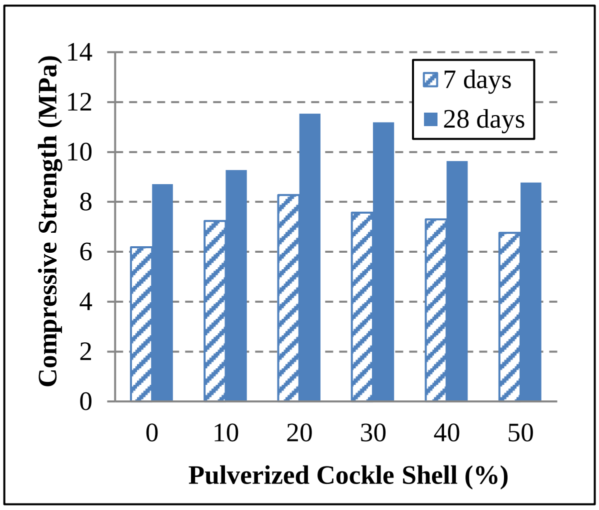

Figure 7. Compressive strength result

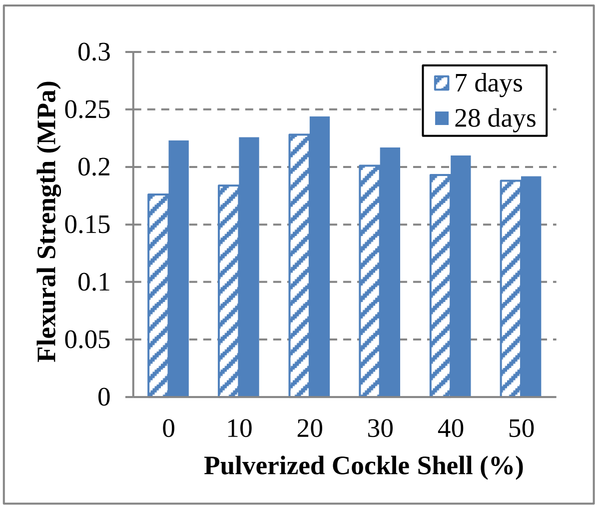

Figure 8. Flexural strength result

3.2. Water Absorption

The water absorption results presented in Figure 9 indicate that inclusion of pulverized cockle shell does affect the percentage of water absorbed by the brick. On overall, incorporation of pulverized cockle shell up to 50% able to reduce the percentage of water absorbed by the specimens. However, the best performing mix with the lowest percentage water absorbed is the one containing 20% pulverized cockle shell replacement by weight of sand. This is likely due to role of fine particles of crushed cockle shell that fill in the existing voids making it denser resulting lower water absorption. The encouraging result is probably owing to the filling ability of finer particles of pulverized cockle shell which assist the specimen to be denser and absorb less water. It is evident from the SEM image that pulverized cockle shell (Figure 10) is finer than the river sand (Figure 11). On overall, the content of crushed cockle shell used and its fineness is one of the factors that influence the compactness of brick which determine the water absorption of the material. The positive contribution of waste material such as fly ash when used as partial fine aggregate replacement that results in lowering the water absorption has been reported by [14].

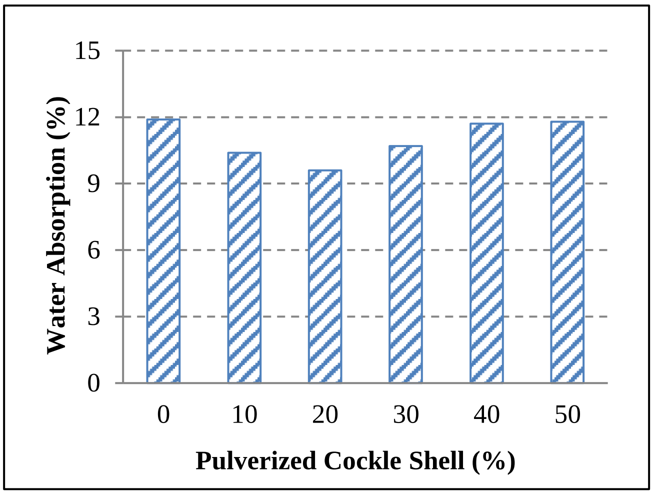

Figure 9. Water absorption result at 28 days

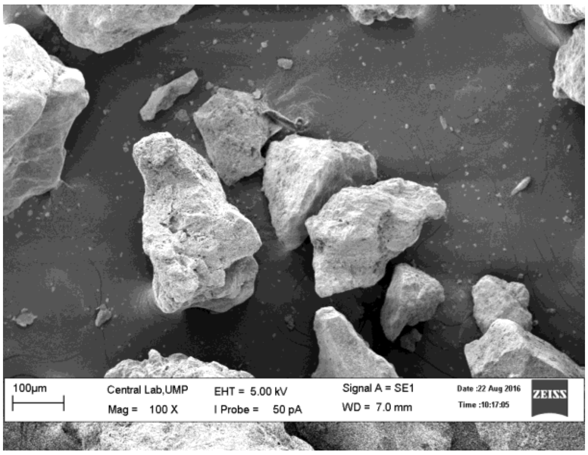

Figure 10. SEM image of river sand size

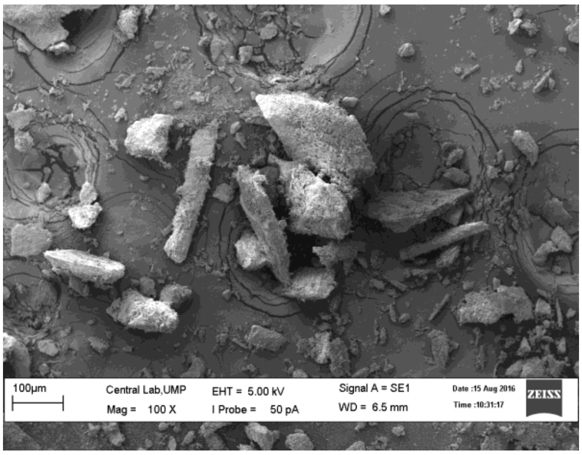

Figure 11. SEM image of crushed cockle shell size

4. Conclusion

The experimental work carried out shows that cockle shell is suitable to be used as a partial sand replacement in POFA cement sand brick. Integration of 20% of cockle shell replacement produces POFA cement sand brick with enhanced compressive strength and flexural strength. Inclusion of finely crushed cockle shell causes the cement brick become more compact. This is due to the filler effect of the fine particles of cockle shell which filled the void inside the brick. As a result, POFA cement sand brick containing 20% cockle shell exhibits lower water absorption. Conclusively, another locally made environmental friendly cement sand brick containing lesser cement and natural river sand is possible to be produced for the use in construction industry. Pollution issue related to disposal of palm oil fuel ash and cockle shell at dumping site also can be reduced.

Acknowledgements
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