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Properties of concrete containing ground palm oil fuel ash as fine aggregate replacement

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Abstract. Environmental degradation resulting from increasing sand mining activities and disposal of palm oil fuel ash (POFA), a solid waste generated from palm oil mill needs to be resolved. Thus, the present research investigates the effect of ground palm oil fuel ash as partial fine aggregate replacement on workability, compressive and flexural strength of concrete. Five mixtures of concrete containing POFA as partial sand replacement designed with 0%, 10%, 20%, 30% and 40% of POFA by the weight of sand were used in this experimental work. The cube and beam specimens were casted and water cured up to 28 days before subjected to compressive strength and flexural strength testing respectively. Finding shows that concrete workability reduces as the amount of POFA added become larger. It is worth to note that 10% of POFA is the best amount to be used as partial fine aggregate replacement to produce concrete with enhanced strength.

1. Introduction

Currently, in modern industrial society, the concrete is expansively used with more than 10 billion tons produced every year [1] Natural sand is prime material used for the preparation of concrete. With the growth in urbanization and industrialization, the demand for sand supply is increased day by-days. Continuous sand mining from the natural environment will cause the depletion of this material in the future generation. The reduction in the sources of natural sand and the requirement for lowering the cost of concrete production tend to find new alternative material to replace natural sand in concrete. In order to resolve these problems, one of the available materials that can be widely found in Malaysia is palm oil fuel ash (POFA). Utilization palm oil fuel ash (POFA) as partial fine aggregate replacement in concrete is seen as one of the steps to reduce the use of natural sand in concrete production.

Palm oil fuel ash (POFA) is an agro-waste ash results from palm oil residues, such as palm fiber and shells. These residues being burned at temperatures of about 800℃ -1000℃ to produce steam for electricity generation in biomass thermal power plants [2]. Malaysia produced about 3 million tons of POFA in 2007 [3]. This production rate is likely to increase due to the increasing plantation of palm oil trees [4]. In practice, this solid waste is dumped near the palm oil mill inside the factory area. This light greyish ash is easy to be carried away by the wind thus creating environmental pollution. Past researcher [5] highlighted that the negative impact of POFA dumping to the environment is evident. Thus, approach of integrating this waste material in concrete production would be able to reduce amount of waste ending at landfill and consumption of natural river sand.

2. Experimental programme

2.1. Materials

The materials used were ordinary Portland cement Type I (OPC), river sand, coarse aggregate, water and Palm Oil Fuel Ash (POFA). The river sand were supplied by local manufacturer nearby. Coarse aggregate used is crushed granite aggregate. Supplied tap water at the laboratory were used for concrete mixing and curing purpose. Palm Oil Fuel Ash (POFA) was supplied from palm oil mill factory located in Ladang Lepar Baru, West Malaysia. The POFA at dumping area as shown in Figure 1 was collected using shovel and then packed tightly in gunny. After that, it is brought to the laboratory for further processing. At the laboratory, the raw Palm Oil Fuel Ash (POFA) was sieved and then ground to obtain finer POFA before it is used as partial sand replacement material. The processed samples of palm oil fuel ash are illustrated in Figure 2.

Figure 1. POFA dumped at palm oil mill.

Figure 2. Ground palm oil fuel ash.

2.2. Mix proportions

The mixes are plain concrete (control specimen) and four mixes concrete containing various POFA content as fine aggregate replacement. The mixing ingredients of control specimen consists OPC, 100% sand, coarse aggregate and water. While the mixing ingredients of POFA concrete are almost same as plain concrete but the sand has been partly replaced with 10%, 20%, 30% and 40% of ground POFA content by weight. The mix proportion of mixes used is tabulated in Table 1.

Table 1. Mix proportion of concrete mixes in kg/ m^3.

Water (kg)	OPC (kg)	C/W	Sand (kg)	Granite (kg)	POFA (kg)
245	350	0.7	980	850	0
245	350	0.7	882	850	98
245	350	0.7	784	850	196
245	350	0.7	686	850	294
245	350	0.7	588	850	392

2.3. Specimen preparation and testing

All the mixes of fresh concrete were casted into standard cubes sized (100 x 100 x 100 mm) and beam specimen size (100 x 100 x 500 mm) then removed from the mould after 24 hours. All specimens were subjected to water curing as illustrated in Figure 3 for 7, 14 and 28 days. Slump test were conducted to determine the concrete mixes workability by following the procedure stated in BS EN 12350 [6]. All testing procedures performed according to BS EN 12390-3:2002 [7] and ASTM 12390 – 5 [8] for compressive strength and flexural strength respectively.

Figure 3. Specimens subjected to water curing.

3. Result and discussion

3.1. Slump test

The result obtained from figure 4 shows that the amount of ground POFA used as partial sand replacement in concrete influences the workability of fresh concrete. The workability of concrete containing palm oil fuel ash (POFA) reduces as the percentage of POFA used in the mix become larger. The slump value for control specimens was the highest and observed to be medium degree of workability. The concrete slump value at 20% and 30% of POFA replacement had given lower workability with 32mm and 29mm respectively as compared to control specimen which is 50mm. The lowest slump value was recorded when 40% POFA is added as partial sand replacement is 27mm. The reduction in concrete workability when larger quantity of POFA is used is likely due to the physical characteristic of POFA which is finer in size compared to sand. The influence of aggregate's physical characteristic on the workability of concrete has been highlighted by past researcher [9]. Finer particle possess larger surface area thus requiring larger amount of water to coat its surface. Another possible explanation is the higher porosity POFA particles absorbing more water as compared to sand. Past researcher [10], noted the presence of pores in unground POFA in contrast to to solid dense river sand causes reduction in the concrete workability. Study elsewhere which investigates the workability of concrete mix containing POFA as partial cement replacement also reported the similar trend of result.

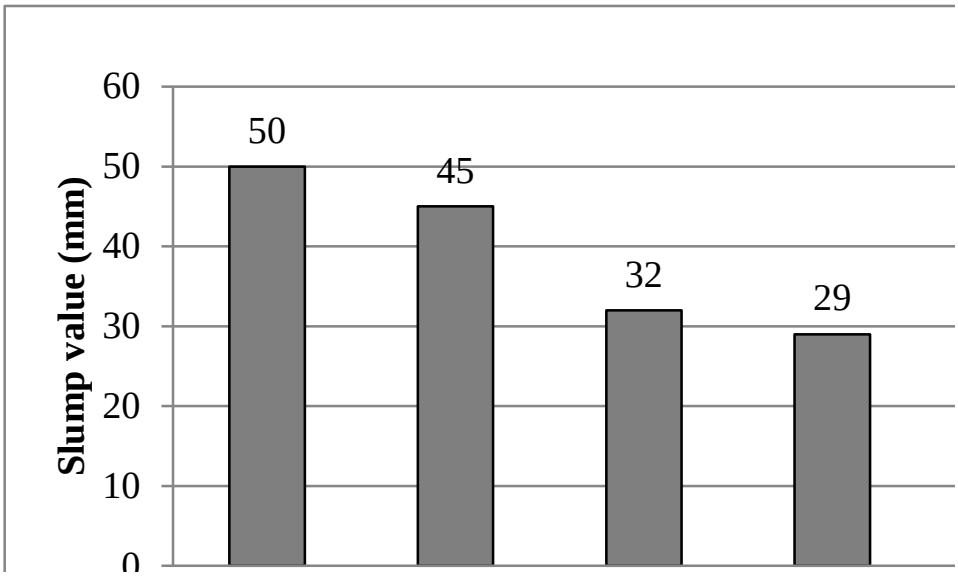

Figure 4. The effect of POFA content on workability of concrete.

3.2. Compressive strength

Figure 5 show the result of compressive strength test of concrete containing POFA. Inclusion of suitable percentage of POFA contributes towards strength enhancement of concrete. All mixes continue to exhibit strength increment as curing age become longer. However, the highest compressive strength was obtained by mix produced using 10% of POFA as sand replacement that exhibit almost 11.31 % higher than control specimens. The increase in compressive strength of 10% palm oil fuel ash (POFA) concrete could possibly due to some factors which is high silica content and high fineness. The chemical reaction between silica from the ash with calcium hydroxide have produced more secondary calcium silicate hydrate gels (C-S-H) in strength development thus improved the concrete strength. According to [11], pozzolanic materials contain high percentage of silica produced more C-S-H gels and reduced the amount of calcium hydroxide that making the concrete stronger, denser and more durable. In addition, high fineness of POFA particle provides a filler effect by filling in the existing voids between sand and aggregate which make the concrete internal structure more packed and contribute to the increment of compressive strength without any chemical reaction [4].

However, a decrease in compressive strength of concrete was observed as the percentage of POFA replacement with sand at 20%, 30% and 40%. In most mixtures, the production of concrete with 40% POFA replacement performed the lowest value compared to control specimens with 14.77MPa. This is because a deficiency in sand will cause the mix of concrete become harsh and contributes to segregation. Increasing in POFA content would increases it fineness. High fineness of POFA particles in the mix will require high water demand due to large surface area of the ash particles. Thus, at constant water-cement ratio, the water are not enough for complete hydration of the cement. And as a result, the quantity of calcium hydroxide $Ca(OH)_2$ will be less, and as a consequence, less secondary calcium silicate hydrate (C-S-H) gel would be produced which plays an important role in making more dense concrete when reacting with the silica contained in the POFA.

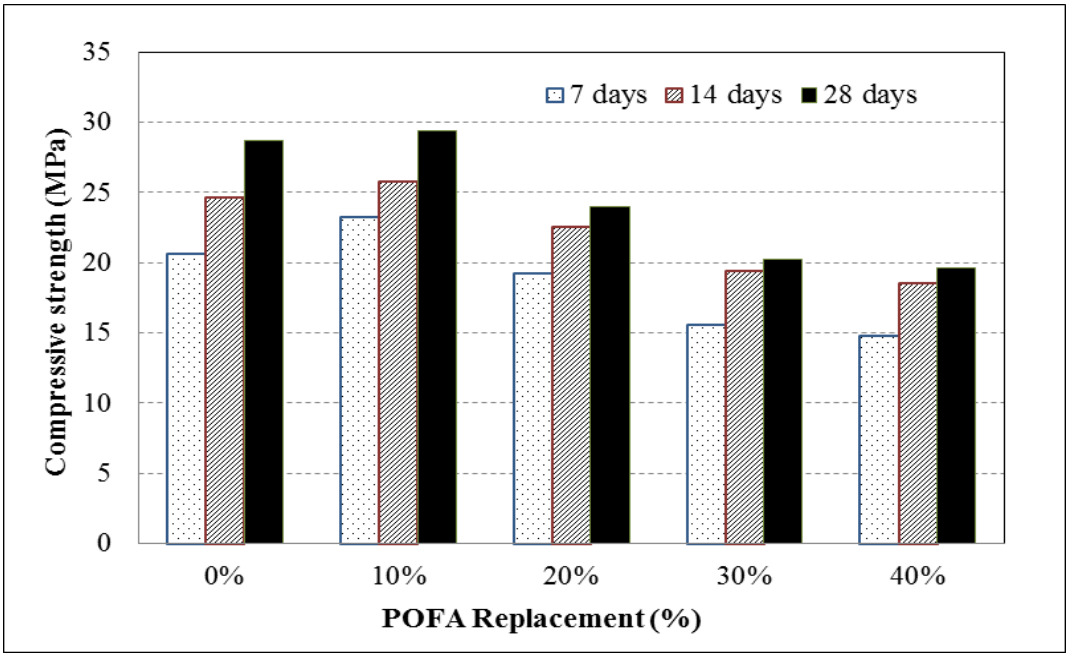

Figure 5. Compressive strengths variation with different percentages of POFA.

3.3. Flexural strength

Figure 6 presents the flexural strength of concrete mixtures containing 0%, 10%, 20%, 30% and 40% of POFA as partial sand replacement. The flexural strength result shows similar trend of the compressive strength. Flexural strength The highest flexural strength was obtained at 10% of sand replacement with POFA that appears to almost 21% higher than control specimens. However, a decreasin trend of flexural strength of concrete can be seen when POFA replacement more than 10%.

The production of concrete with 40% POFA replacement performed the lowest value compared to control specimens with 5.78MPa.

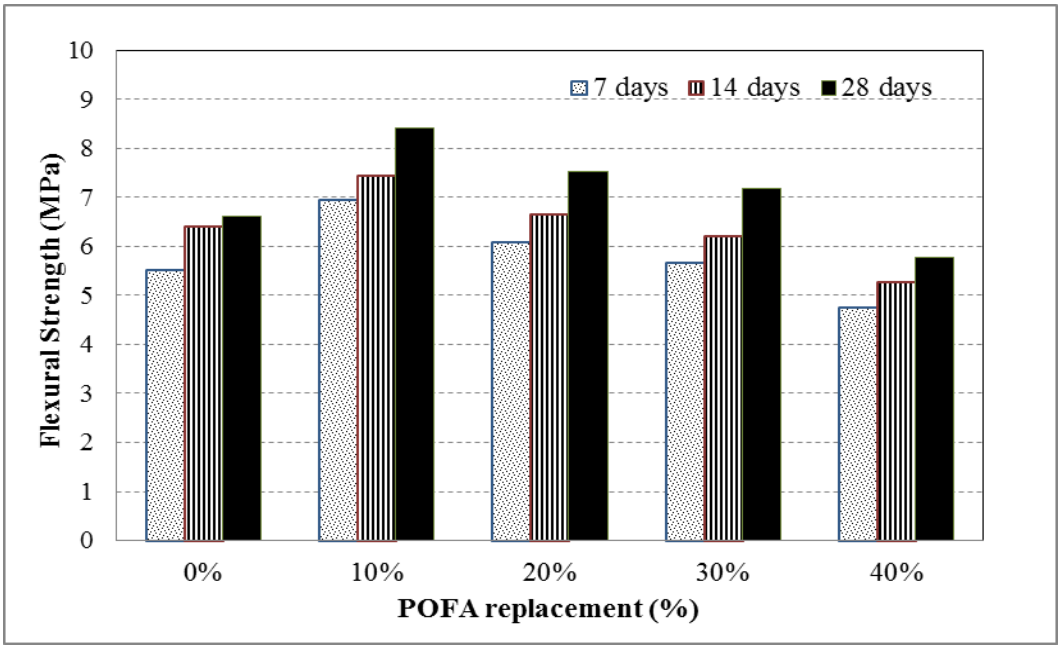

Figure 6. Flexural strength of concrete containing different percentages of POFA.

4. Conclusions

Based on the results obtained from laboratory investigation, it can be concluded that inclusion of suitable percentage of ground POFA as fine aggregate replacement successfully enhances both the compressive strength and flexural strength performance. This finding encourages the use of palm oil waste materials as fine aggregate replacement in concrete, which saves the use of natural sand mined from the river. In addition, amount of palm oil fuel ash disposed at landfill would be reduced thus, assisting the palm oil industry to be more environmental friendly.

5. References

[1] Meyer, C. The greening of the concrete industry. 2009. *Cement and Concrete Composites,* 31, 8, 601-605

[2] Alengaram, J U, Al Muhit, B A and Zamin, M J , 2013. Utilization of oil palm kernel shell as lightweight aggregate in concrete-a review. *Construction. Building. Material*. 38, 161-172

[3] Abdul Awal A S M and Hussin M W. 1997. The effectiveness of palm oil fuel ash in preventing expansion due to alkali–silica reaction. *Cement and Concrete Composites.* 19:367–72

[4] Chindaprasirt P, Homwuttiwong, S and Jaturapittakul C. 2007. Strength and water permeability of concrete containing palm oil fuel ash and rice husk-bark ash. *Construction. Building. Material*. 21:1492–9

[5] Hussin, M W, Muthusamy, K and Zakaria, F. 2010. Effect of mixing constituent towards engineering properties of POFA cement -based aerated concrete. *Journal of Materials in Civil Engineering,* 287-295

[6] BS EN12350 Testing fresh concrete, Compressive strength of test specimens. London. BS EN 12350

[7] BS EN 12390-3 (2009). Testing hardened concrete, Compressive strength of test specimens. London. BS EN 12390-3

[8] BS EN 12390-5 (2009). Testing hardened concrete, Flexural Strength of Test Specimens, London, BS EN 12390-5

[9] Neville, A M (2011). Properties of Concrete (5th Edition).Prentice Hall
[10] Muthusamy, K, and Zamri, N A. 2014. Exploratory study of palm oil fuel ash as partial cement replacement in oil palm shell lightweight aggregate concrete, *Res. J. Appl. Sci. Eng. Technol.* 8(2) 150-152
[11] Jitchaiyaphum. Sinsiri and Jaturapitakkul, 2013. Cellular lightweight concrete containing high-calcium fly ash and natural zeolite. *International Journal of Minerals, Metallurgy and Materials.* 20, 462-471