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Research Article

Exploratory Study of Palm Oil Fuel Ash as Partial Cement Replacement in Oil Palm Shell Lightweight Aggregate Concrete

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Abstract: In Malaysia, issue of environmental pollution resulting from disposal of Palm Oil Fuel Ash (POFA) which is a by-product from palm oil mill has initiated research to incorporate this waste in Oil Palm Shell (OPS) lightweight aggregate concrete production. The current study investigates the effect of palm oil fuel ash content as partial cement replacement towards compressive strength OPS lightweight aggregate concrete. Several OPS lightweight aggregate concrete mixes were produced by replacing various percentage of POFA ranging from 10, 20, 30, 40 and 50%, respectively by weight of cement. All the mixes were cast in form of cubes and then subjected to water curing until the testing date. The compressive strength test is conducted in accordance to BSEN 12390 (2009) at 7 and 28 days. From the results, it was observed that the combination of appropriate POFA content would enhance the compressive strength of OPS lightweight aggregate concrete. Specimen produced using 20% POFA as partial cement replacement exhibit higher value of compressive strength than that of control OPS lightweight aggregate concrete. However, mixes consisting POFA up to 50% is also suitable for structural application.

Keywords: Compressive strength, oil palm shell lightweight aggregate concrete, palm oil fuel ash, partial cement replacement, water curing

INTRODUCTION

Owing to the low density of lightweight aggregate concrete that is in the range of 300 to 1850 kg/m^3, this material is suitable for a wide range of purposes such as block production, panels, sound barrier walls and floating structural. The use of lightweight aggregate concrete results in reduction of total dead load of the building, leading to savings in supporting structures and foundation as the member can be narrower due to the decreased dead load and finally rewarding the constructor with lower construction cost. At the same time, concern towards sustainable and cleaner environment has driven researchers to integrate available waste material in lightweight concrete production which is more economic. As a result, lightweight aggregate concrete which produced by utilizing various kind of industrial waste as aggregates replacement (Ibrahim *et al*., 2013; Zega and Di Maio, 2011) are becoming popular nowadays.

As in Malaysia, palm oil industry which is the major agro-industry in this country has been generating large amount of waste which becomes one of the main contributor to the nation's pollution problem (Teo *et al*., 2006). Oil Palm Shell (OPS) and Palm Oil Fuel Ash (POFA) produced from the industry has been dumped in the vicinity of palm oil mill. Improper disposal of the vast quantity of POFA which has been produced may contribute to environmental problem in future (Megat Johari *et al*., 2012). Similarly, dumping oil palm shell in open area to biodegrade may take long time and consume more space to be allocated for the disposal of this by-product which would increase the cost of palm oil mill in managing this waste. Thus, these problems have driven researchers to figure out possible solution such as utilizing palm oil by product in concrete production.

So far, OPS has been successfully incorporated as coarse aggregate replacement in lightweight concrete (Mannan and Ganapathy, 2001; Shafigh *et al*., 2012) and POFA being a pozzolanic material has been used as a partial cement substitute to produce various types of concrete (Awal, 1998; Sata *et al*., 2004; Megat Johari *et al*., 2012). However, uses of POFA as partial cement replacement in production of OPS lightweight aggregate concrete making yet to be explored. It is anticipated that formulation of OPS lightweight aggregate concrete integrating POFA to substitute the use of cement partially would produce a greener concrete and assist palm oil industry to be more environmental friendly.

In this research study, the effect of Palm Oil Fuel Ash (POFA) content as partial cement replacement towards compressive strength of oil palm shell

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Fig. 1: Oil palm shell collected from the factory

Fig. 2: Processed oil palm shell

Fig. 3: Palm oil fuel ash collected from the palm oil mill

Fig. 4: Processed palm oil fuel ash

lightweight aggregate concrete were investigated through experimental study.

The work has been conducted at laboratory of Faculty of Civil Engineering and Earth Resources, University Malaysia Pahang. The present study discusses the performance of various concrete mixes in terms of compressive strength.

METHODOLOGY

The materials used were Ordinary Portland Cement (OPC) complies with the Type 1 Portland cement as in ASTM C 150-05 (2005), river sand, oil palm shell, palm oil fuel ash, potable water, and super-plasticizer. Both Oil Palm Shell (OPS) and Palm Oil Fuel Ash (POFA) collected from a palm oil mill factory located in Felda Lepar Hilir in the state of Pahang, Malaysia used as coarse aggregate and partial cement replacement respectively. The Oil Palm Shell (OPS) is processed to remove foreign particles such as dried fibres. The processed Palm Oil Fuel Ash (POFA) was ground to be fine fulfilling the requirement in ASTM C 618-05 (2005) which enables it to be used as partial cement replacement material. Both original and processed samples of oil palm shell and palm oil fuel ash are illustrated in Fig. 1 to 4, respectively.

Two types of mixes has been used in this experimental work that is plain oil palm shell lightweight aggregate concrete (control specimen) and oil palm shell lightweight aggregate concrete containing POFA as partial cement replacement material. The control mix consist 100% ordinary Portland cement. Then, five mixes of oil palm shell lightweight aggregate concrete consisting various content of palm oil fuel ash as partial cement substitute have been used in this investigation. The total cementitious material content has been kept constant in all the mixes except for the variation in the percentage of palm oil fuel ash used. The proportion of cement content replaced ranged from 0 to 50 with 10% interval. All mixes were cast in cubes (100×100×100 mm) and then subjected to water curing until the testing date. The specimens were subjected to compressive strength test in accordance to BSEN 12390-3 (2009) at 7 and 28 days.

RESULTS AND DISCUSSION

Figure 5 displays the compressive strength of OPS lightweight aggregate concrete that has been produced using various percentage of POFA as partial cement replacement. It can be seen that addition of ash tends to influence the strength exhibited by the concrete material. The achievement of highest strength gain for OPS lightweight aggregate concrete integrating POFA as partial cement substitute is possible only when right amount of this pozzolanic material is added. As can be observed, inclusion of POFA up to 30% replacement results in development of material of higher strength than control specimen. However, integration of 20% POFA assist towards achievement of the highest compressive strength in comparison to other mixes.

Similar to the findings by Massazza (1993), the strength of specimen decreases when too much of POFA that function as partial cement replacement integrated in the concrete mix. Evidently, replacement of 40 and 50% POFA causes the strength of concrete to decrease since the amount of Portland cement was greatly reduced. The lower content of calcium oxide in POFA which is crucial for strength development tends to limit the use of this ash as partial cement replacing material. Initially, lower content of calcium oxide reduces the early strength development due the lower amount C-S-H gel produced through hydration process. Then, the smaller amount of calcium hydroxide produced from hydration process is also not sufficient for complete pozzolanic reaction to take place which also lead to the formation of lower amount of secondary C-S-H gel. This provides explanation as for why not all POFA replacement levels could produce lightweight aggregate concrete having higher strength than control

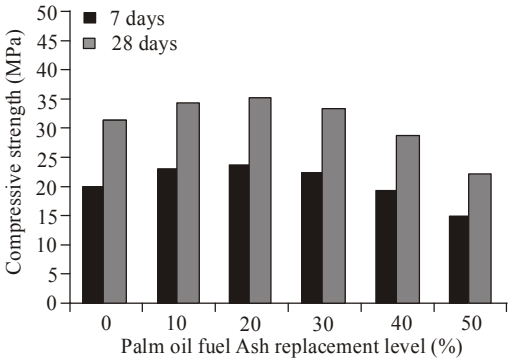

Fig. 5: Effect of palm oil fuel ash content on compressive strength of OPS lightweight aggregate concrete at the age of 7 and 28 days

specimen. The inferior performance of lightweight aggregate concrete consisting too high POFA content compared to plain specimen is due to the formation of lower quantity of total amount of C-S-H gel that is principally responsible for the strength performance of concrete. Since, the minimum requirement for lightweight concrete to be used for structural application is 17 MPa (Neville, 2005), OPS lightweight aggregate concrete containing POFA as partial cement replacement up to 50% is still suitable to be used as structural concrete.

Conclusively, only a certain percentage of POFA could replace OPC to act as partial cement replacement material so that an exclusive combination of blended cement could be produced creating a win-win situation between the two materials finally producing an end product having better properties than the existing one. The creation of another alternative construction material combined with POFA is expected to reduce the quantity of cement in lightweight aggregate concrete production as well as able to decrease the quantity of waste material dumped at landfill; which results in more environmental friendly industry.

CONCLUSION

This investigation reveals that there is a promising potential for the use of palm oil fuel ash as partial cement replacement in oil palm shell lightweight aggregate concrete production. Replacement of palm oil fuel ash which is around 20% would be able to produce lightweight concrete suitable for structural application.

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