IOP Conf. Series: Materials Science and Engineering **342** (2018) 012098 doi:10.1088/1757-899X/342/1/012098

Effect of palm oil fuel ash on compressive strength of palm oil boiler stone lightweight aggregate concrete

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Abstract. Both palm oil fuel ash (POFA) and palm oil boiler stone (POBS) are by-products which has been continuously generated by local palm oil mill in large amount. Both by products is usually disposed as profitless waste and considered as nuisance to environment. The present research investigates the workability and compressive strength performance of lightweight aggregate concrete (LWAC) made of palm oil boiler stone (POBS) known as palm oil boiler stone lightweight aggregate concrete (POBS LWAC) containing various content of palm oil fuel ash. The control specimen that is POBS LWAC of grade 60 were produced using 100% OPC. Then, another 4 mixes were prepared by varying the POFA percentage from 10%, 20%, 30% and 40% by weight of cement. Fresh mixes were subjected to slump test to determine its workability before casted in form of cubes. Then, all specimens were subjected to water curing up to 28 days and then tested for its compressive strength. It was found out that utilizing of optimum amount of POFA in POBS LWAC would improve the workability and compressive strength of the concrete. However, inclusion of POFA more than optimum amount is not recommended as it will increase the water demand leading to lower workability and strength reduction.

1. Introduction

Globally, urbanization was driven by increasing numbers of population growth. Rapid urbanization was seen to put high pressure on building and infrastructure expansion. The continuously growing construction activities leads to higher demand for non-renewable resources such as aggregates from the environment to be used in the production of construction building materials such as cement and concrete. Aggregate being one of the materials which continuously extracted from the hills for concrete production is depleting from the face of the earth. One of the researcher, Hainin et al [1] has stated that the extensive use of aggregate would cause depletion of local aggregate supply. At the same time, the cement production which consumes a huge amount of limestone and releases greenhouse gas causes environmental degradation. The negative impact of cement production to the environment has been highlighted by Meyer [2]. Realizing the importance of preserving the natural non-renewable resources for a cleaner and healthier environment, various attempts have been made by researchers in order to identify waste materials that have potential to replace the existing precious natural raw materials. Utilizing locally available industrial by-products as partial aggregate or cement replacement would reduce the construction material cost and decrease amount of waste dumped at the landfill.

In relation to that, Malaysia being one of the world largest palm oil producers also generates increasing amount of by-products which disposed as waste. Palm oil boiler stone (POBS) and palm oil boiler ash are waste produced after the incineration of oil palm shell, fruit bunch and oil palm fibres to produce electricity for the palm oil mill. Palm oil boiler stones are big solid chunks that formed in the incinerator as a result of incineration process. These rock like material are usually dumped as waste. As for palm oil fuel ash, it appears in form of greyish ash. Normally it is dumped at open environment within the palm oil mill vicinity and easy to be carried by the wind thus causing air pollution. The pollution caused by the ashes has been pointed by past researchers [3, 4]. It is seen that integrating these unwanted waste materials as mixing ingredient in concrete would reduce high dependency on natural aggregate and cement as well as reduce amount of wastes disposed to the environment. Therefore, the present research looks into the effect of palm oil fuel ash (POFA) as partial cement replacement towards workability and compressive strength of palm oil boiler stone lightweight aggregate concrete.

2. Methodology

2.1. Materials

Ordinary Portland cement from a single source was used as binder throughout the experimental work. River sand was utilized as fine aggregates. For mixing and curing purpose, clean tap water was used. No granite aggregate is used. Palm oil fuel ash (POFA) which is a by-product obtained by burning of fibers, shells and empty fruit bunches was obtained from nearby palm oil mill in the state of Pahang, West Malaysia. At the laboratory, the ash was dried in an oven at 105 ± 5 °C for 24 h to remove moisture. The ash was sieved through using 300 μm sieves to remove impurities. After the sieving process, palm oil boiler ash was ground to sufficient fineness to be used as partial cement replacement. The palm oil boiler stone (POBS) was obtained from palm oil mill at Pahang. The stone was also dried in an oven at 105 ± 5 °C for 24 h to remove moisture. It was then crushed using jaw crusher to reduce its size before used as coarse aggregate replacement. .

2.2. Mix Proportion and Testing

The concrete in this experiment is designed to achieve a compressive strength of 60 N/mm^2 at 28 days of curing age. Five concrete mixes consists of 0%, 10%, 20%, 30% and 40% POFA by weight of cement were prepared. Concrete mix with 0% POFA was act as control specimen. The slump test is essential in order to produce fresh concrete with good consistency. This test was conducted according to BS EN 12350-2 [5]. To determine the concrete strength, compressive strength test was conducted according to BS EN 12390-3 [6]. The mixes were prepared in form of cubes with size of 100mm x 100mm x 100mm and subjected to water curing for 28 days.

3. Results and discussion

3.1. Workability

Figure 1 demonstrates the influence of various percentage of POFA as partial cement replacement towards the workability of POBS LWAC. From the graph, it was observed that the workability of POBS LWAC with POFA was reasonably satisfactory within the expected range. The slump values of POBS LWAC with different percentage of POFA mixtures were measured between 23 and 97 cm. Slump with POBA replacement between 10 to 30% produces true slump with a medium degree of workability which normally applied for normal reinforced concrete. The best slump is best denoted by POBS LWAC with 10% POFA replacement. The slump flow increase by 4% from control mixes with 97 mm. Similarly Zeyad et al [7] reported that the normal consistency of OPC concrete is lower than that of the concrete with POFA. Inclusion of more than 10% POFA reduces concrete workability. Workability becomes lower as more POFA is used as partial cement replacement. The lower slump result is due to porous particle of POFA that absorbs more water compared to OPC when it is utilized more than the optimum amount. In addition, the high carbon content of the POFA also contributes to lower workability of mix. On overall, addition of POFA at suitable amount would produce concrete mix with the targeted workability.

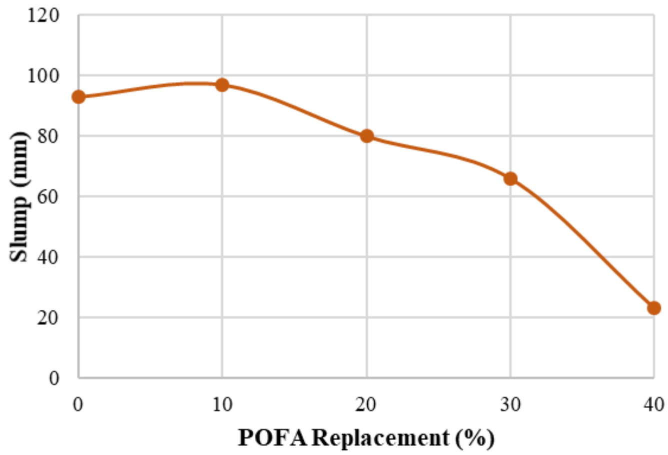

Figure 1. Effect of POFA content on workability of lightweight aggregate concrete mix.

3.2. Dry Density

Figure 2 shows the influence of various percentage of POFA as partial cement replacement towards the density of POBS LWAC the age of 28 days. Generally, the dry density of POBS LWAC with POFA for all percentages falls in the range for LWAC. In this research, 10% POFA replacement in POBS LWAC shows the highest dry density. This is due to the pozzolanic reaction from POFA that produces larger amount of C-S-H gel causing the concrete to be more compact finally producing concete with higher dry density. Studies by [8, 9] have proved that the pozzolanic additives reduce porosity and increase the dry density of concrete. However, when a higher amount of POFA is utilized than optimum amount it produces concrete with lower dry density. This is due to porous POFA particle that absorbs high water when it is utilized of more than optimum amount in the concrete mix. As a result, the mix becomes dry and hard to be compact thus causing segregation. Improper compaction resulted in honeycomb that trapped inside concrete paste, leading to low dry density.

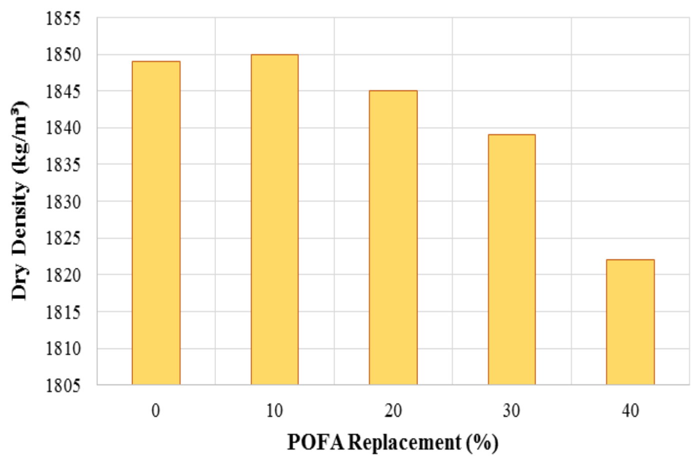

Figure 2. Dry density of lightweight aggregate concrete containing various percentage of POFA.

3.3 Compressive Strength

Figure 3 shows the variation of POC LWAC compressive strength with POFA percentage at the age of 28 days. It can be observed that all the samples excluding POBS LWAC with 40% POBA replacement attained 28 days strength above 60 MPa which in the range for high strength concrete (HSC). HSC is often used in the construction of high load bearing columns and also to produce precast concrete products. The strength gain of the POBS LWAC with POBA is superior to that of the control POBS LWAC when cement is replaced with 10% POFA. The pozzolanic reaction due to presence of POFA generates secondary C-S-H gel which makes the total C-S-H gel in the blended cement lightweight aggregate concrete is higher than control specimen. Unreacted fine POFA also act as filler that fill in the pores inside the concrete structure makes the concrete denser and stronger.

It is also observed that the compressive strength of concrete containing more than 10% POFA replacement were lower than control specimen. The compressive strength of concrete continues to drop as larger amount of POFA is used as partial cement replacement. This is happening due to the porous characteristic of POFA particle as compared to cement. When POFA is used more than the optimum amount, drier mix and difficult to be compacted is produced resulting in a formation of concrete with larger amount of voids as compared to specimen with lesser amount of ash content. Similarly, previous researcher [10, 11] noted the decreasing strength of concrete when POFA used exceeded the optimum amount. Conclusively, utilization of POFA at 10% as partial cement replacement contributes towards strength enhancement of high strength lightweight aggregate concrete.

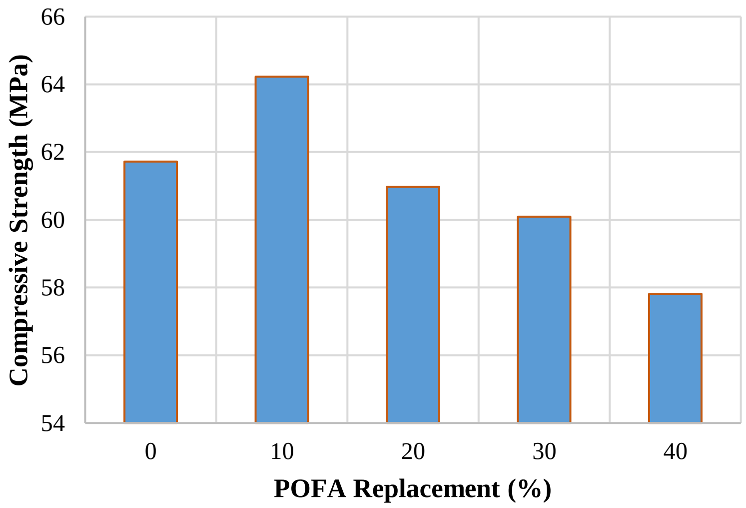

Figure 3. Compressive strength of lightweight aggregate concrete at 28 days.

4. Conclusion

The present findings show that palm oil fuel ash can be used as partial cement replacement to produce palm oil boiler stone lightweight aggregate concrete exhibiting higher compressive strength than the plain specimen. Success in utilizing palm oil fuel ash in lightweight concrete production would reduce the amount of cement used and contribute towards cleaner environment.

Acknowledgments

The authors would like to acknowledge the help and co-operation received from the lecturers and technical staff of Universiti Malaysia Pahang in conducting the experimental work. The financial support received from Universiti Malaysia Pahang through grant RDU1703109 is gratefully acknowledged.

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