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Research Article

Effect of mixing ingredient on workability and compressive strength of palm oil clinker lightweight concrete containing palm oil fuel ash

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ABSTRACT

Palm oil industry is one of the important industry that contribute to the country's prosperity. This flourishing industry however also causes environmental problems namely air pollution, soil degradation as well as water pollution due to waste disposal issue. At the same time, intensive cement production and granite mining is damaging the environment and natural habitats. Hence, various efforts have been made by researchers to minimize the effect of pollution including integrating oil palm wastes in construction as building materials. In this study, granite aggregate was fully replaced by palm oil clinker (POC) in lightweight aggregate concrete production. In order to reduce the utilization of cement in concrete, palm oil fuel ash (POFA) was ground to improve its pozzolanic reactivity to partially replace cement in lightweight aggregate concrete. From this investigation, the best performance concrete was attributed by POC LWAC with 20% POFA when the water cement ratio and superplasticizer are 0.45 and 1.0%. Inclusion of water cement ratio and superplasticizer of 0.35 and 0.8% would adversely affects the workability and strength of POC LWAC with POFA.

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1. Introduction

Owing to expensive life nowadays, it is important to produce high quality building materials with cost-effective as an alternative. Utilization of waste materials into construction materials is one of the most efficient methods that can be employed. In Malaysia, there are various potential wastes that can be utilized as alternative materials for building construction especially from the oil palm industry. This industry is more likely to have huge potential due to the fact that Malaysia is the second world's largest palm oil producer. Thus, large quantities of waste produced by this industry and the waste generated is estimated around 80 million tonnes per year and contributes to the highest fraction of total industrial solid wastes in Malaysia (Zafar, 2018). Most of these waste materials are not recycled and disposed to the nearby landfill causes various pollution such as groundwater, water and air contamination (Hosseini and Abdul Wahid, 2013).

Among the potential wastes from this industry are palm oil clinker (POC) and palm oil fuel ash (POFA). According to Mukherjee et al. (2014), 18.5 million tons of POFA were dumped every year without profitable value. POFA which is in the form of fine dust is extremely harmful to the environment and more likely to penetrate deeply into the lungs (Altwair and Kabir, 2010). At the same time, palm oil clinker (POC) is abundantly generated in large quantities from the palm oil industry as well (Abutaha et al., 2017). Similar to POFA, this waste material also contributes towards dumping problem as well as disturbing scenery. Thus, these problems have urged researchers to figure out alternative construction materials such as utilizing palm oil wastes into concrete production. At this point, POFA has been successfully replaced cement in concrete due to its pozzolanic characteristic (Abdul Awal and Warid Hussin, 2011; Alsubari et al., 2018; Lau et al., 2018). Palm oil clinker is suitable to be used as coarse aggregate replacement in lightweight

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aggregate concrete production (Bashar et al., 2014; Kanadasan and Abdul Razak, 2014; Nazmul Huda et al., 2016). However, limited research is available on the performance of lightweight aggregate concrete containing combination of both clinker and palm oil fuel ash as mixing ingredient. The present research investigates the effect of mixing ingredients namely POFA, water cement ratio and superplasticizer on workability and compressive strength of POC lightweight concrete.

2. Materials and Methods

Materials used in this study included a type I Portland cement, tap water, palm oil clinker, sand, palm oil fuel ash, and a high range water reducer admixture. Palm oil clinker was used as sole coarse aggregate. River sand with fineness modulus of 2.31 was used in this experimental work. Palm oil fuel ash (POFA) was employed as partial cement replacement. The amount of high range water reducing admixture used is in the range from 0.8 to 1.2 % by weight of cement in accordance with manufacturer's recommendations. The water to cement ratio used was varied from 0.35 to 0.55 by weight of cement.

A range of mixes consisting of 0%, 20% and 40% POFA has been casted for this research work. To obtain these mixes, it requires carrying out a series of trial and error as recommended by ACI 211 Part 2 (1998). The amount of cement, palm oil clinker and sand were kept constant for all mixes. All the concrete mixes were cast in the form of 100 mm x 100 mm x 100 mm cubes and then subjected to water curing until the testing date. Slump test was conducted to measure the consistency of fresh concrete following the procedure in BS EN 12350: Part 2. The specimens were tested to compressive strength test in accordance to BSEN 12390-3 (2002) at 28 days.

3. Results and Discussion

3.1. Effect of water-cement ratio

Figs. 1 and 2 presents the effect of water-cement ratio towards the workability and compressive strength of POC LWAC containing POFA. As can be observed, the slump values were measured between 30 mm to 90 mm which is categorized in low to medium workability. The highest slump value is denoted by control specimen with water-cement ratio of 0.55. The slump decrease as higher amount of POFA was added. At the water cement ratio of 0.35, the slump workability reduces by 30.7 to 53.8% when 20% and 40% POFA was added. POC LWAC with 40% POFA produces the lowest slump. Similar observation has been made by Wankhede and Fulari (2014) who acquired low slump value when utilizing 0.35 water-cement ratio with the presence of pozzolanic material. Low water-cement usage resulted in insufficient compacted concrete thus produces pores upon hardened. According to Bu and Tian (2014), concrete pores will decrease the compressive strength of concrete. Conclusively, very low water-cement ratio would decrease the overall concrete strength.

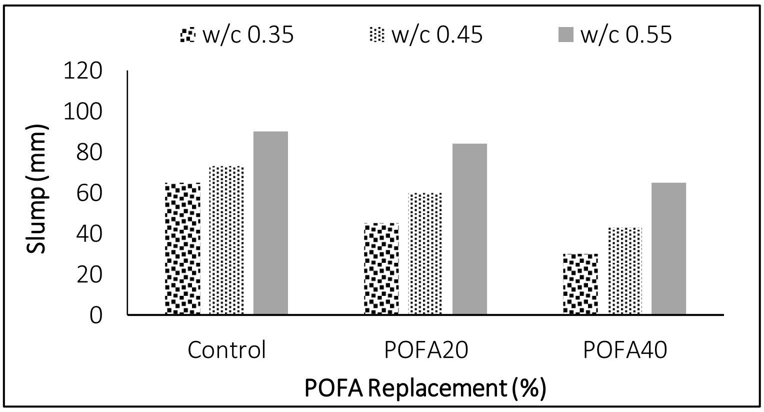

Fig. 1. The effect of water-cement ratio towards workability of POC LWAC with POFA.

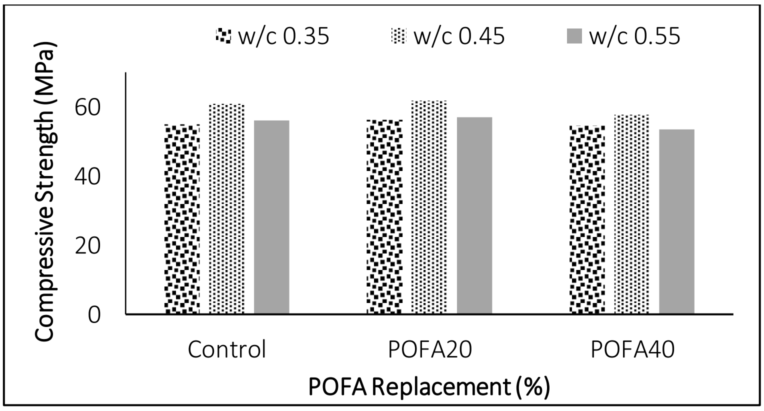

Fig. 2. The effect of water-cement ratio towards compressive strength of POC LWAC with POFA.

Further increase water-cement ratio produces diluted paste that decreases the binding capacity of concrete particles. Diluted paste causes segregation of concrete to occur resulted in coarse aggregates and sand settles at the bottom thus affecting the workability and strength of concrete greatly. These result is in line with the theory stated by Neville (2011). When extra water of more than required is added, it creates pores due to evaporation. Extra water will also cause interfacial transition zone to be formed which will become plane of failure on the concrete strength. Previous researcher, Lee et al. (2014) pointed out that the higher the water-cement ratio, the lower the density and strength. Generally, all mixes produces comparable strength result when water cement ratio of 0.35, 0.45 and 0.55 is employed. Amongst all, water-cement ratio of 0.45 is found to be the optimum water-cement ratio that works well with POC LWAC containing POFA.

3.2. Effect of superplasticizer content

Superplasticizer is one of the most important admixtures in enhancing concrete performance. Addition of superplasticizer resulted in the cement particles highly negative charge so that they repel each other due to the same electrostatic charge. By deflocculating the cement particles, more water is provided for concrete mixing (Neville, 2011). The effect of superplasticizer content towards workability and strength of POC LWAC is presented in Figs. 3 and 4. The slump value measured between 45 mm to 111 mm which is classified in medium to high slump. Unlike water-cement ratio effect, superplasticizer addition produce better slump result. The compressive strength of POC LWAC containing POFA with 0.8 %, 1.0% and 1.2% is between to 48.91 to 61.72 MPa which is also in the range for high strength lightweight aggregate concrete.

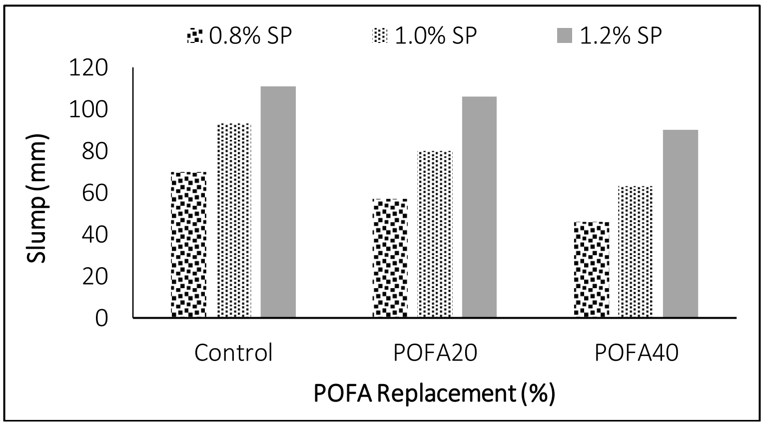

Fig. 3. The effect of superplasticizer content towards workability of POC LWAC with POFA.

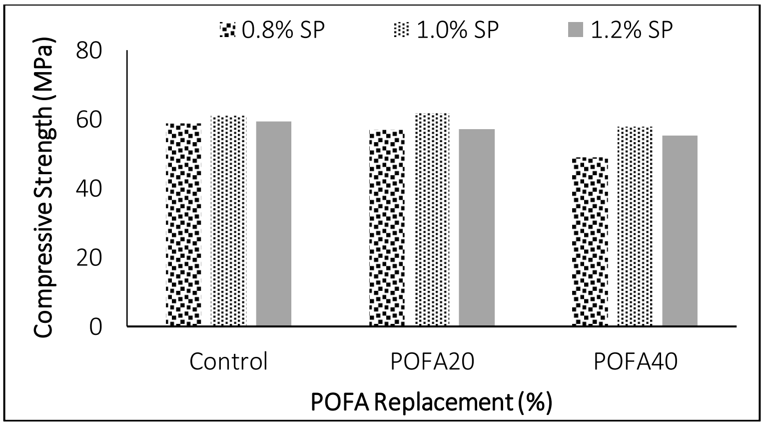

Fig. 4. The effect of superplasticizer content towards compressive strength of POC LWAC with POFA.

In terms of superplasticizer influence, POC LWAC with POFA work efficiently with 1.0% superplasticizer that provides proper dispersion of cement particles. Superplasticizer of 0.8% produces slump and compressive strength slightly lower than 1.0% superplasticizer. This is due to the water reducing admixtures that ensure proper dispersion of the cement particles in concrete thus prevent difficulties during concrete mixing. This result in segregation reduction and hence, lead towards more compact, higher density and higher strength concrete. Other researcher (Muhit, 2013), also managed to produce the highest compressive strength result when utilizing 1% superplasticizer in the concrete production.

Although increment amount of superplasticizer will enhance the compressive strength, there is still an optimum limit for the usage of admixture. When the dosages go beyond this limit, increase in dosage will only reduce the compressive strength. In this case, 1.2% superplasticizer resulted in strength reduction. This phenomenon occurs since over dosage of superplasticizer will cause bleeding and segregation, which will affect the cohesiveness and uniformity of the concrete (Alsadey, 2012). The high-water content may also cause the formation of voids in the concrete and thus porous interfacial transition zone will be formed, which generates a weak bond between coarse aggregate and mortar mix. As a result, compressive strength will reduce when the superplasticizer dosage is beyond the optimum dosage.

4. Conclusions

This investigation reveals that 20% POFA as partial cement replacement in the production of POC LWAC produces the highest strength when the water cement ratio and superplasticizer are 0.45 and 1.0%. The use 0.35 and 0.8% of water cement ratio and superplasticizer is disadvantageous towards POC LWAC with POFA as it produces dry mixes. However, all the samples are in the range for structural application. It is seen that utilization of POC and POFA would produce greener concrete and at the same time assist towards reducing amount of palm oil solid waste dumped at the landfill.

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