Effect of Unground Palm Oil Fuel Ash as Partial Sand Replacement on Compressive Strength of Oil Palm Shell Lightweight Concrete

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Abstract. Concern towards degradation of environment due to increasing use of natural sand in construction industry and dumping of solid wastes from palm oil industry namely palm oil fuel ash and oil palm shell has lead towards the development of environmental friendly concrete. The present study investigates the effect of unground palm oil fuel ash as partial sand replacement towards workability and compressive strength of oil palm shell lightweight aggregate concrete. Two types of mixes were used. Control specimen was prepared using 100% natural sand. Another type of mix were prepared by integrating 5%, 10% and 15% unground palm oil fuel ash by weight of sand. The concrete mixes workability were investigated by conducting slump test in accordance to standard. All specimens were made in form of cubes (150mm x150mm) and water cured up to 28 days. The compressive strength test was carried out in accordance to BS EN12390: 3 at 1, 4, 7 and 28 days. The finding shows that integration of 10% unground palm oil fuel ash contributes to the enhancement of oil palm shell lightweight aggregate concrete properties. Success in using unground POFA as partial sand replacement in concrete production would reduce quantity of ash disposed as waste and save the consumption of natural river sand.

1. Introduction

Malaysia is one of the largest palm oil producers in the world. Throughout the year, as the demand for palm oil continues to increase, the palm oil industry also flourishes in the country. Total exports of oil palm products rose 2.9% to 23.97 million tonnes in 2017 from 23.29 million tonnes exported in 2016 [1]. At the same time, the palm oil processing mills are generating many types of wastes namely palm oil fuel ash (POFA), clinker, oil palm shell (OPS), empty fruit bunch and others. As the palm oil industry continues to grow, more waste are generated and need to managed. Annually, the estimated total production of POFA was 2.6 million tonne in Malaysia [2]. According to Teo et al. [3], approximately 4 MT of OPS were generated yearly by Malaysian palm oil mills. Both oil palm kernel shell (OPKS) and palm oil fuel ash (POFA) were thrown as waste, consuming larger area for dumping purposes and causes environmental pollution. Other researchers Mohammad et al. [4] and Kim et al. [5] have reported the pollution problem caused by palm oil wastes dumping. Thus, it is seen that,

converting this waste material into construction products would reduce amount of by-product disposed as waste and contributes to the environment cleanliness.

At the same time, the development of construction industry has resulted in the increase of natural sand use in construction. Based on the report by Department of Minerals & Geosciences of Malaysia [6], the sand mining activity in Malaysia has increased from 24.471 million tonne in 2008 to 34.341 million tonne in 2015. Excessive sand mining activity causes destruction of natural habitats, soil erosion and reduced river water quality. Previous researcher Ashraf et al. [7] has pointed out that environmental problems occur when the rate of extraction of sand, gravel and other materials exceeds the rate at which natural processes generate these materials. Discovery of other alternative material to reduce the use of natural sand would be able to preserve environment and contribute to sustainable construction. Realization on the environmental problems caused by the above-mentioned industrial activities, the present research investigates the potential of using palm oil fuel ash as partial sand replacement in oil palm shell lightweight aggregate concrete production. Many researchers, Mohammad et al. [4], Kim et al. [5], Teo et al. [8], Shafigh et al. [9], Jumaat et al. [10] and Ming et al. [11] have investigated the properties and potential of oil palm shell lightweight aggregate concrete. However, research on the use of palm oil fuel ash as partial sand replacement in this type of concrete are not found in the literature so far. Thus, the present research aims to investigate the effect of integrating unground palm oil fuel ash as partial sand replacement in oil palm shell lightweight concrete.

2. Methods

The experimental works were divided into three stages. Firstly, materials needed were obtained and processed ready for use. Then, in the second stage, the concrete specimens were prepared for testing. At the third stage, the concrete specimens were tested in accordance to the standard.

2.1. Materials

The material used in this experiment are cement, sand, water, water reducing admixture, oil palm shell and palm oil fuel ash from the palm oil mill. Ordinary Portland cement (OPC) was used for preparing all the concrete specimens involved in the experiment. The type of sand used in natural river sand with specific gravity of 2.77 obtained from the nearby supplier. Tap water at the laboratory was used for concrete mixing and curing work. Both solid wastes oil palm shell (OPS) and palm oil fuel ash (POFA) were supplied by nearby palm oil mills in the state of Pahang, East Coast Malaysia. Oil palm shells were packed in gunny as shown in Figure 1 before brought to the laboratory for concrete preparation work. The specific gravity of palm oil fuel ash used is 2.21. Figure 2 illustrates the image of natural sand and palm oil fuel ash used in this experimental work.

Figure 1. OPS collection from the palm oil mill.

Figure 2. Sand (left) and palm oil fuel ash (right).

2.2. Concrete Specimen Preparation

Two types of mixes were used in this experimental work. The control specimen of Grade 30 produced using 100% natural sand was used as reference specimen. Another type of mix were prepared using various percentage of unground palm oil fuel ash (UPOFA). The weight of sand was substituted with 5%, 10% and 15% of UPOFA. All the mixing ingredient content is kept constant except for the unground palm oil fuel ash (UPOFA). Table 1 tabulates the mix proportion of plain concrete. The preparations of the concrete specimens were done using a clean drum mixing machine. Firstly, oil palm shell (OPS), unground palm oil fuel ash (UPOFA) and sand was blended in the mixer. Next, the water was gradually added with small amount of superplasticizer onto the mix. Then, the cement was added and the balance of water was poured to the mixer until the concrete are ready and homogeneous. The fresh mix are placed in the cube mould, compacted before covered with wet gunny and left overnight. The next day, the demoulded samples were placed in water tank for curing purpose.

Table 1. Details of 1m³ control mixes.

Materials	Quantity (kg)
Cement	500
Oil Palm Shell	300
Water	225
Sand	700

2.3. Testing

In order to determine the concrete workability, the freshly prepared mixed were immediately subjected to slump test. The slump test were conducted following the procedure in BS EN12350-2 [12].The effect of unground palm oil fuel ash content on the concrete strength is determined through compressive strength test. The concrete samples were tested at various curing ages up to 28 days. The compressive strength test were carried in accordance to BS EN 12390-3 [13]. Scanning Electron Microscopy analysis were conducted on UPOFA and sand used in this research to justify the effect of the particles on the results obtained.

3. Results and discussion

3.1. Workability

Figure 3 illustrates the result of slump test conducted on mixes containing various percentage of unground POFA. Evidently, inclusion of POFA as partial sand replacement affects the workability of concrete. As higher percentage of unground POFA replaces the sand in the mix, the concrete mixture becomes stiffer thus resulting in lower slump value. Mixture containing 15% POFA replacement is categorized as very low workability compare with the control specimen 0% POFA that have high workability. The workable mix of control specimen as shown in Figure 4 changed to be stiffer mix with the inclusion of 15% of ash as can be observed in Figure 5. One of the contributing factors is the finer size of POFA particles with specific gravity of 2.21 having larger surface area than sand with specific gravity of 2.77, which increases the mixing water requirement resulting in the lower workability. Aggregate characteristic is one of the factors that influence concrete workability [14]. A similar trend result is observed when the waste material that is used as partial sand replacement in concrete is smaller size than sand [15].

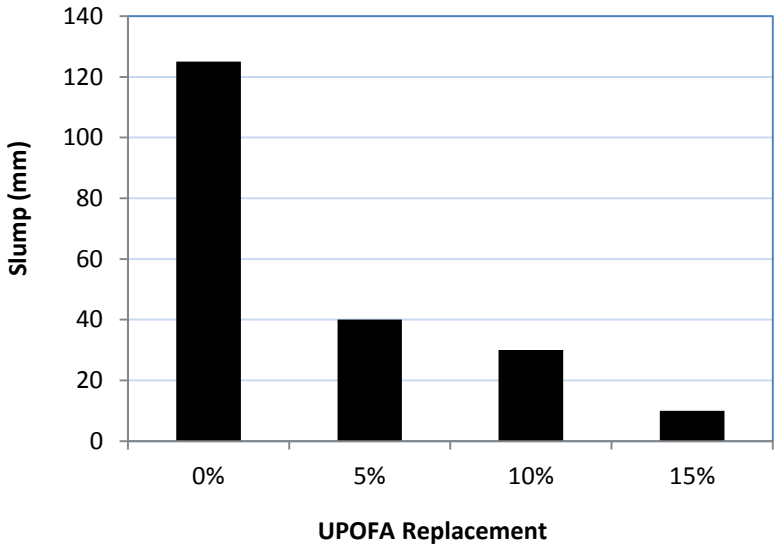

Figure 3. Slump test result

Figure 4. Slump of plain concrete mix

Figure 5. Slump of mix with 15% UPOFA

3.2. Compressive Strength

Figure 6 illustrates the compressive strength result of oil palm shell lightweight aggregate concrete containing unground palm oil fuel ash up to 28 days. Generally, all mixes exhibit continuous strength increment throughout the curing age. The amount of UPOFA added in the concrete mix affect the strength performance of concrete. The result also indicates that inclusion of unground POFA content at 10% able to produce concrete with enhanced strength than control specimen. The use of UPOFA which is finer as illustrated in Figure 7 than natural sand shown in Figure 8, enables the ash contribute towards concrete internal structure densification by filling in the existing void in concrete. Utilization of 15% UPOFA causes the concrete strength to drop. This probably attributed to the characteristic of fine UPOFA possessing higher specific area than sand thus requires more water to coat the UPOFA particles. As a result, the concrete mix becomes drier, more difficult to be mixed and to be compacted when quantity of UPOFA used is increased. Finally, the concrete exhibit lowers strength due to lack of bonding between particle and existence of more voids in the hardened concrete. Similar pattern in increase and drop in concrete strength depending on quantity of waste materials used as partial sand replacement were reported by Singh and Siddique [16].

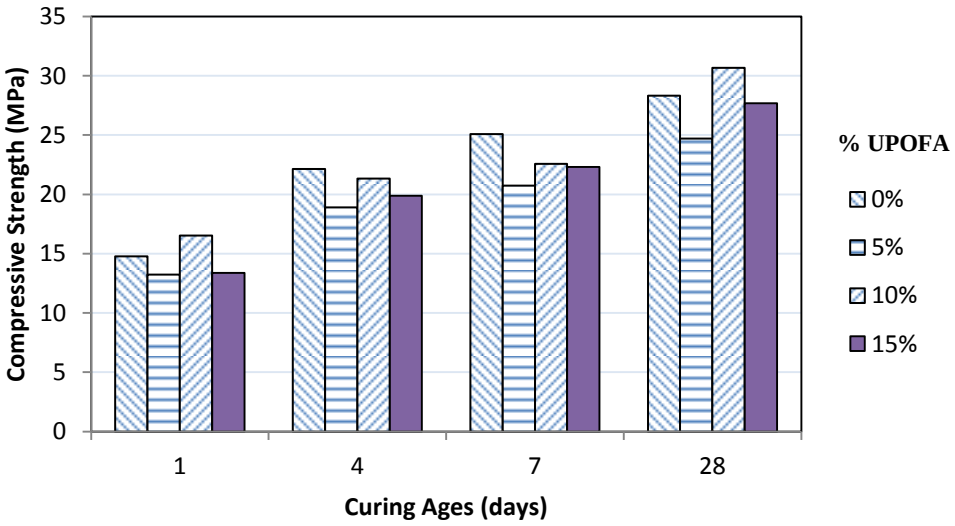

Figure 6. Compressive strength test result

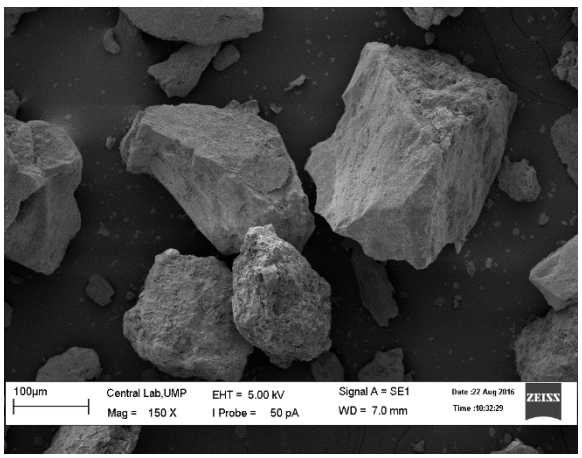

Figure 7. Unground POFA

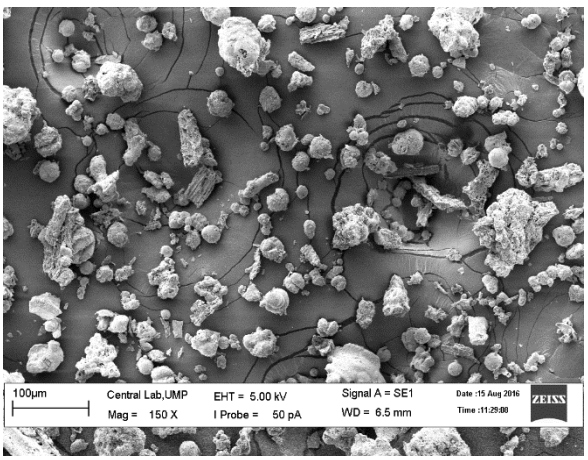

Figure 8. Natural river sand

4. Conclusion

The finding shows that use of 10% unground palm oil fuel ash able to produce concrete with strength higher than control specimen. The recent discovery on the potential of unground POFA as partial sand replacement in concrete is anticipated to reduce amount of POFA disposed as waste and reduces the dependency of concrete industry on natural river sand supply.

5. References

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