Acid Resistance of OPS Lightweight Concrete with Unground POFA as Partial Fine Aggregate Replacement

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Abstract— Oil palm shell (OPS) and Palm oil fuel ash (POFA) is a waste material generated in palm oil mill. This waste material generally dumping at open field area causing health hazards and environmental pollution problems. Due to its abundance and characteristics, many researchers have evaluated its potential as a construction material. The objective of this research is investigating the effect of unground palm oil fuel ash (POFA) content as partial fine aggregate replacement towards durability of oil palm shell lightweight aggregate concrete in acidic environment. Five types of mixes consisting 0%, 5%, 10%, 15% and 20% unground POFA as partial fine aggregate replacement were prepared in form of cubes were used for this research. After the specimens were water cured for 28 days before immersed in hydrochloric acid solution for 1800hr. The durability of specimens was evaluated by measuring the weight loss and compressive strength at end of testing period. The result shows that specimen containing 10% unground POFA experience the least mass loss of all. Utilization of unground POFA at suitable amount enhances the concrete durability through filler effect that promotes the densification of concrete internal structure. However, use of unground POFA beyond the optimum amount causes the concrete to experience higher mass loss and higher deterioration.

Keywords—Oil Palm Shell Lightweight Aggregate Concrete, Unground Palm Oil Fuel Ash, Durability, Acid Resistance, Mass Loss,

1. INTRODUCTION

Malaysia being one of the key players in palm oil industries generates a large amount of solid wastes. Indonesia and Malaysia are the dominant palm oil production countries, manufacturing 86% of global supplies making them the premier POFA producers. The plantation of palm oil tree achieved 3.8-million-hectare land per year and expected to rise up 5 million hectares by 2020 [1]. Massive production of oil palm product in Malaysia raises a problem to the waste management. Oil palm shells (OPS) and palm oil fuel ash (POFA) wastes are generated in increasing quantity throughout the years along with the expanding palm oil industry. Annually, it was estimated that the total production of POFA was 2.6 million tonne [11] and OPS is about 5.3 million tonne [4]. Disposal of OPS as oil palm mill waste creates the environmental issue due to storage problems and land pollution of the surrounding fields. Furthermore, the improper handling of POFA as a waste could lead to health risk hazard [5]. Success using these wastes in production of products would be one of the ways to reduce quantity of waste disposed.

At the same time, the demand for natural granite and river supply are rising owing to increasing in concrete production to cater the need of the growing construction industries. Excessive harvesting of these non -renewable aggregates destroys the habitat of flora and fauna which leads to their extinction in future. The exploration of hills to obtain aggregate changes the landscape of the area from green area to a barren one tend to create other problems such as erosion, reduced water quality and air quality. Uncontrolled river sand mining also disturbs the aquatic life in the river and lowers the water quality. Preventing these activities which the concrete industry relies on for the supply of raw material from taking place is impossible. However, introducing alternative materials to reduce the usage of these non-renewable resources would be reduce the high dependency of concrete industry on these resources. In relation to that, the freely available waste materials namely OPS and POFA has been used to produce granite free concrete with lower amount of river sand. The present investigation explores the effect of unground POFA to the compressive strength and acid resistance of oil palm shell lightweight concrete.

2. METHODOLOGY

A. 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) complying with MS 522:Part 1:2003 was used for preparing all the specimens involved in the experiment. The type of sand used in natural river sand 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 unground palm oil fuel ash (POFA) were supplied by nearby palm oil mills in the state of Pahang, East Coast Malaysia. Oil palm shells and unground POFA were collected and packed in gunny before brought to the laboratory for concrete preparation work as per shown on figure 1.

Figure 1: Unground POFA and oil palm shell packed in gunny at the dumping area of oil palm mill.

B. Specimen Preparation.

Two types of mixes were used in this experimental work. The control specimen of Grade 30 which 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 (POFA). The weight of sand was substituted with unground POFA 5%, 10% 15% and 20%. All the mixing ingredient content is kept constant except for the unground POFA. The preparation of the concrete specimens were done in accordance to BS 1881-125-1986. Firstly, oil palm shell(OPS), unground palm oil fuel ash (POFA)and sand was blended early in a mixer. Next, the water was gradually added with superplasticizer into the mix. Then, the cement was added and the remaining water was poured into the mixer. The mix is mixed well to ensure it become a homogeneous mix. All the fresh mix are placed in mould 100mm x 100mm x 100mm, compacted and covered with wet gunny sack. The next day, the samples were demoulded and immersed in water tank.

C. Testing Procedure.

The effect of unground palm oil fuel ash content on the concrete strength is determined through compressive strength test. The test was conducted to concrete samples at 28 days. The compressive strength test were carried in accordance to BS 1881-116-1983. The acid resistance were conducted following the experimental method by () . The effect of unground POFA as partial fine aggregate replacement on acid resistance of concrete were evaluated by immersing the specimens in acid hydrochloric (HCl) solution. All the specimen have been continuously immersed in the HCl solution for the duration up to 1800 hours. The weight of the specimen has been taken every 100 hours to monitor any changes in term of weight. At the end of immersion period, the specimens were tested for their compressive strength.

3. RESULT AND DISCUSSION

A. Compressive Strength

Fig. 2 illustrates the compressive strength of OPS lightweight concrete at 28 days. It can be observed that the use of certain percentage of unground POFA able to increase the strength of OPS lightweight aggregate concrete.

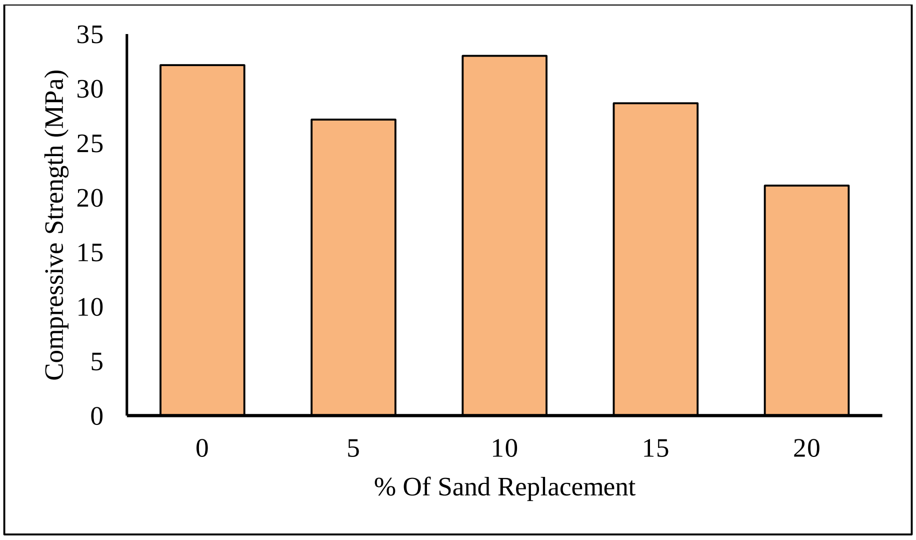

Figure 2: Compressive strength of OPS LWAC with various percentage of unground POFA replacement.

Compressive strength test results are presented in Fig. 3. Compressive strength of OPS LWAC with various unground POFA content mixtures 5%, 10%, 15% and 20% was 27.14 N/ mm2, 33.01 N/mm2, 28.66 N/mm2 and 21.09 N/mm2 respectively as compared to 32.14 N/mm2N/mm2 of control concrete mixture. This result is quite similar with the research from [12] and [13] where the optimum strength of OPS LWAC is achieved at certain percentage of sand replacement. At 28 days curing age, OPS LWAC with 10% of unground POFA as sand replacement achieved compressive strength comparable to that of control concrete mixture. The use of unground POFA which is finer than natural sand, enables the ash contribute towards concrete internal structure densification by filling in the existing void in concrete. More than that, utilization of unground POFA beyond than 10% causes the concrete strength to reduce. This probably attributed to the characteristic of fine POFA possessing higher specific area than sand thus requires more water to coat the POFA particles. As a result, the concrete mix becomes drier, more difficult to be mixed and to be compacted when quantity of POFA used is increased. Finally, the concrete exhibit lower strength due to lack of bonding between particle and existence of more voids in the hardened concrete. These condition is shown by the OPS LWAC specimen with 20% replacement of unground POFA as sand replacement.

B. Acid Resistance

Fig. 3 illustrated the mass loss result of OPS lightweight aggregates concrete (LWAC) with unground POFA when immersed in hydrochloric solution up to 1800 hours. Generally, all specimens' experiences higher mass loss value as the immersion period becomes longer. According to [5], the leaching of calcium hydroxide causes the mass loss in concrete and turn out to be more disintegration along with increment of immersion period. The result shows that the percentage of unground POFA used influences the mass loss value of the concrete. Concrete containing 10% unground POFA exhibit the lowest total mass value of all mixes containing POFA and control specimen. Meanwhile, concrete produced using 20% unground POFA exhibit total mass loss. At the end of mass loss observation, all the concrete specimen were subjected to compression test to measure its strength.

As can be seen in Fig. 3, the deterioration range of the specimens in this testing is 23% to 33%. OPS lightweight aggregate concrete 10% unground POFA as partial fine aggregate replacement exhibit the most minimum strength deterioration value of all. The ability of concrete sample with 10% of unground POFA replacement withstand with the acidic attack are related to the filler effect provided by the unground POFA which contributed to the densification process and makes the concrete stronger. This condition makes the durability of concrete with unground POFA in acidic environment is higher compared to plain concrete. Specimens containing 15% and 20% unground POFA exhibit higher deterioration level than the optimum mix and control specimen. This is probably due to the insufficient water content during the mixing stage that causes disruption in the hydration process and difficulties in compaction making these concrete have more voids and demonstrate lower resistance to acid attack. Conclusively, the use of optimum amount of unground POFA as partial fine aggregate replacements successfully enhances the acid resistance of OPS lightweight aggregate concrete.

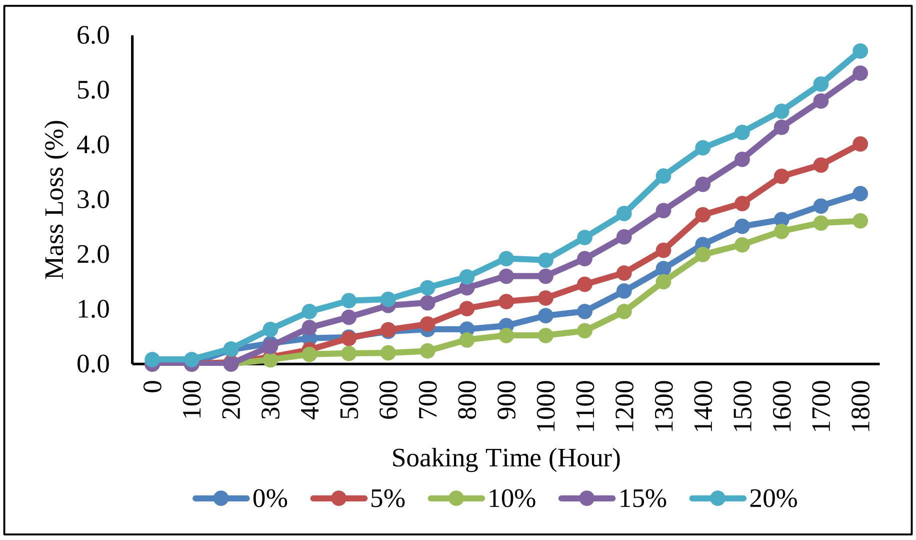

Figure 3: Mass loss percentage of specimens that have been immersed in HCl solution for 1800 hours.

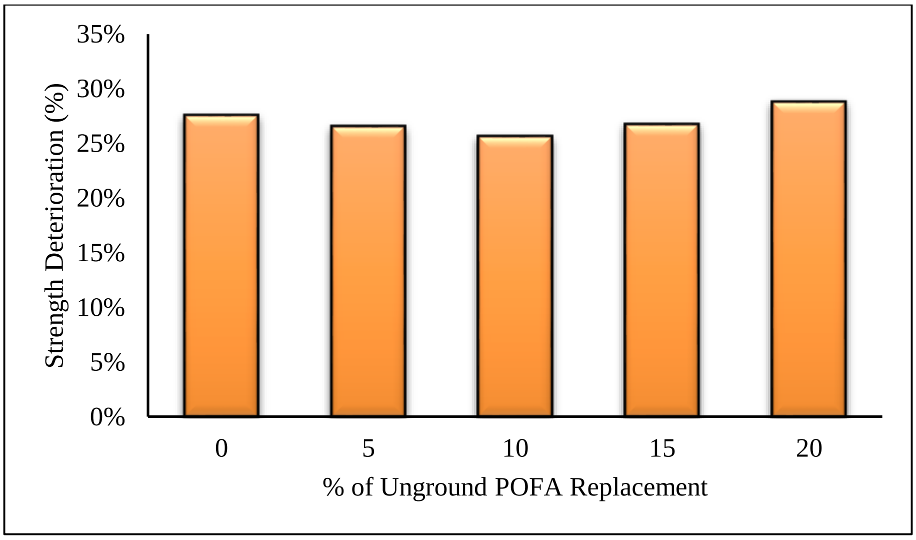

Figure 4: Strength deterioration of specimens after immersed in HCl solution for 1800 hours

4. CONCLUSION

The results demonstrate that integrating suitable percentage of unground POFA as partial fine aggregate replacement increases the compressive strength and the resistance of OPS lightweight concrete to acid attack. The effect of using optimum contents of unground POFA, as sand partial replacement of OPS LWAC has better resistance to acid than control concrete. The mass loss is reduced for the specimen immersed in hydrochloric acid after 1800 hours than control specimen due better densification of concrete sample contain 10% amount of unground POFA. Likewise the strength deterioration of concrete with 10% of unground POFA after 1800 hours immersion in hydrochloric acid is the lowest among the other sample including the control sample. Success in using these wastes in concrete production would be able to reduce the use of natural aggregate and river sand

REFERENCES

[1] MPOB Malaysian Oil Palm Statistics 2016 – Economics and Indsurty Development Division (Malaysia, Bangi: Malaysia Palm Oil Board). (2016).

[2] BS1881-125-1983.Testing concrete – Part 116: Methods for determination of compressive strength of concrete cubes.(1991).

[3] Ul Islam, M. M., Mo, K. H., Alengaram, U. J., & Jumaat, M. Z. Durability properties of sustainable concrete containing high volume palm oil waste materials. *Journal of Cleaner Production*, *137*, 167–177. http://doi.org/10.1016/j.jclepro.2016.07.061 (2016).

[4] Sabil, K.M., Aziz, M.A., Lal, B., Uemura, Y., Effects of torrefaction on the physiochemical properties of oil palm empty fruit bunches, mesocarp fiber and kernel shell. Biomass Bioenergy 56, 351 - 360. 2013.

[5] Mohammad M.U.l, Kim H.M., U. A.J. Alengaram, M.Z. Jumaat. Mechanical and fresh properties of sustainable oil palm shell lightweight concrete incorporating palm oil fuel ash. Journal of Cleaner Production. Volume 115, Pages 307 – 514. (2016),

[6] Huber, B., Hilbig, H., Mago, M. M., Drewes, J. E., & Müller, E. Comparative analysis of biogenic and chemical sulfuric acid attack on hardened cement paste using laser ablation-ICP-MS. *Cement and Concrete Research*, *87*, 14–21. http://doi.org/10.1016/j.cemconres.2016.05.003 (2016).

[7] Ul Islam, M. M., Mo, K. H., Alengaram, U. J., & Jumaat, M. Z. Durability properties of sustainable concrete containing high volume palm oil waste materials. *Journal of Cleaner Production*, *137*, 167–177. http://doi.org/10.1016/j.jclepro.2016.07.061 (2016).

[8] Xiao, J., Qu, W., Li, W., & Zhu, P. Investigation on effect of aggregate on three non-destructive testing properties of concrete subjected to sulfuric acid attack. *Construction and Building Materials*, *115*, 486–495. http://doi.org/10.1016/j.conbuildmat.2016.04.017 (2016).

[9] A. M. Neville, Properties of Concrete (5th Edition).Prentice Hall. Pages 68. (2011).

[10] BS1881-125-1986.Testing concrete – Part 125: Methods for mixing and sampling fresh concrete in the laboratory. (1989).

[11] J.U. Hassan, M.Z. Noh, Z.A. AhmadEffects of palm oil fuel ash composition on the properties and morphology of porcelain palm oil fuel ash composite.Jurnal Teknologi.Volume 70 no(5) (2014)

[12] Muhammad Nazrin Akmal, A. Z., Muthusamy, K., Mat Yahaya, F., Mohd Hanafi, H., & Nur Azzimah, Z. Utilization of fly ash as partial sand replacement in oil palm shell lightweight aggregate concrete. *IOP Conference Series: Materials Science and Engineering*, *271*(1). http://doi.org/10.1088/1757-899X/271/1/012003.(2017).

[13] Muthusamy, K., Mohamad Hafizuddin, R., Mat Yahaya, F., Sulaiman, M. A., Syed Mohsin, S. M., Tukimat, N. N., Chin, S. C. Compressive strength performance of OPS lightweight aggregate concrete containing coal bottom ash as partial fine aggregate replacement. *IOP Conference Series: Materials Science and Engineering*, *342*(1). http://doi.org/10.1088/1757-899X/342/1/012099 (2018).

[14] S, E. A. (2017). A huge number of arti fi cial waste material can be supplementary cementitious material (SCM) for concrete production e a review part II. Journal of Cleaner Production, 142, 4178–4194. http://doi.org/10.1016/j.jclepro.2015.12.115