Durability Performance of Palm Oil Fuel Ash Cement Based Aerated Concrete in Marine Environment

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Abstract

The ever popular issue on environmental preservation and sustainability all over the world has lead towards the innovation of new materials from either industrial or agricultural waste. Malaysia being one of the leading producers of palm oil has been conducting numerous researches to discover the various potentials of by-products generated by palm oil mills. The current findings revealed that palm oil fuel ash (POFA) produced in the mills can be used for producing a new alternative lightweight construction material known as POFA cement based aerated concrete having enhanced strength than specimen produced using 100% ordinary Portland cement. Since, the performance this material in marine environment is unknown, this paper presents and discusses the result on the strength performance of this lightweight concrete upon exposure to sea water for one year. The concrete cubes were prepared and subjected to water curing for 28 days before immersed in sea water. The compressive and flexural strengths of the specimens were tested at 3, 6 and 12 month following the procedures stated in BS 1881: Part 116 and ASTM C293-79 respectively. The study found that integration of POFA as partial cement replacement in aerated concrete enhances the performance of concrete in sea water environment.

Keywords: palm oil fuel ash, partial cement replacement, aerated concrete, durability, marine environment

1 INTRODUCTION

Malaysia being the world largest palm oil producers in the year 2006 [1] which is also predicted to maintain its lead position over the next one and a half decade [2], has been generating abundant by-product known as palm oil fuel ash (POFA) from the palm oil industry. This material which is produced from combustion of extracted palm oil fibers and palm oil shells in palm oil mill has been dumped at the landfill [3] thus causing environmental pollution. The continuous increase in the palm oil production is expected to result in larger amount of POFA thrown as waste unless solutions found to recycle this material.

Since end of 20th century, concern towards preservation of clean environment has initiated research on this material leading to discovery of this ash as a pozzolanic material [4] suitable to be used as constituent in concrete production. From that time onwards, efforts taken to produce concrete using this waste has result in several types of concrete such as normal concrete [5] and high strength concrete [6] that exhibits enhanced strength and durability upon utilization of this ash as partial cement replacement material. To date, attempt made by replacing 20% of cement with POFA in aerated concrete mix has results in a development of newly modified concrete known as POFA cement based aerated concrete exhibiting enhanced strength and durability against acidic environment than the plain aerated concrete [7, 8]. However, this product which is suitable for non load bearing application [9] is unknowns its performance when placed in marine environment. Therefore, this paper would be discussing the behavior of this agro blended cement based aerated concrete upon exposure to marine environment.

2 METHODOLOGY

2.1 Material

Palm oil fuel ash used throughout this study was collected from a local palm oil mill situated in the area of Bukit Lawang, Johor. The ashes were sieved passing 300 micrometer sieve so that the finer ash can be separated from the coarse type. Then, the fine ash is ground to produce fine ash complying to the requirement in ASTM C 618 – 05 [10]. Based on the chemical analysis conducted, this ash can be classified as class F pozzolan in accordance to ASTM C618 – 05 (2005). A single batch of ordinary Portland cement that complies with the ASTM 150 [11] was used throughout the experimental programme. Oven dried river sand was sieved passing 600 micrometer sieve before kept in closed container. Aluminium powder type Y250 was used as gas foaming agent. Superplasticizer is also added in all concrete mix to increase the workability. Clean tap water has been used throughout the experiment.

2.2 Mix Proportion

The effect of POFA content towards the durability of aerated concrete in marine environment was studied by placing the specimens consisting of control specimens and specimen produced using POFA as partial cement replacement. POFA incorporated into aerated concrete mix is as a direct replacement for ordinary Portland cement on weight basis. Control specimens were formed using 100% OPC known as OPC aerated concrete and a mix of OPC/POFA prepared by replacing 20% of cement with ground POFA. The mix proportion used to produce POFA cement based aerated concrete is tabulated in Table 1.

Table 1 : Mix Proportion of POFA aerated concrete

Material	**Details**
Ordinary Portland cement%)	80
Palm Oil Fuel Ash (%)	20
Sand Fineness (µm)	Passing 600
Water Dry Mix Ratio	0.24
Aluminium Powder (%)	0.30
Superplasticizer (%)	0.75

2.3 Experimental Programme

The study is conducted at the jetty of Marine Police Station situated on the Johor Straits. Specimens consisting of OPC and POFA aerated concrete cubes (70.6 x 70.6 x 70.6 mm) and prisms (40 x 40 x 160 mm) are placed under the jetty to be exposed to sea water with alternate wetting and drying cycles due to tidal fluctuations. Specimens involved in this study are earlier subjected to water curing for 28 days in the laboratory before being exposed to sea water for 1 year. Another set of specimen are left in water curing, to be used as a control sample in this study. The tests for determination of compressive strength of cubes and flexural strength of prisms were carried in accordance to BS 1881 :Part 116 [12] and ASTM C293-79 [13].

3. RESULT AND DISCUSSION

3.1 Effect of Marine Environment

It is well known that normal concrete once submerged in sea water will face reduction in compressive strength value. The present study compares the performance of OPC and POFA aerated concrete submerged in sea water for one year. In general, no physical deformation is detected on the specimens placed in marine environment throughout the experimental study. From samples directly taken out from the sea, there is a lot of mud and marine organism covering both OPC and POFA specimens. On the other hand, no deterioration is detected except for the appearance of whitish colour on some parts of both specimens. Furthermore, the fillings in of the mud in the existing pores of this highly porous structure and the marine growth have caused increase in the weight of this lightweight concrete. In addition, the variation in the colour of the specimens subjected to sea water curing with the one in tap water at the curing age of 6 months and 1 year can be clearly seen in Fig. 1 until 4. All specimens placed in marine environment change colour to become darker brown as the curing age become longer in contrast with control specimen both OPC and POFA placed in plain water that does not show any colour change.

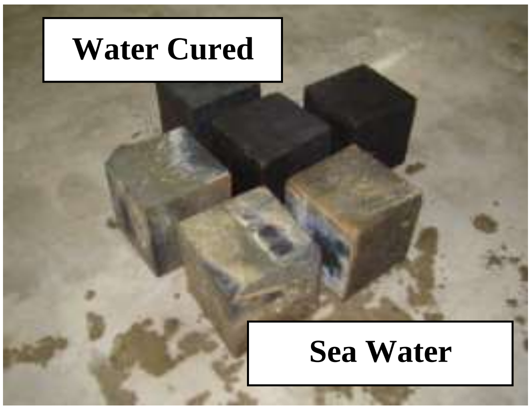

Figure 1 : 6 month water cured POFA cubes with sea water cured specimens

Figure 2 : 1 year water cured POFA cubes with sea water cured specimens

Figure 3 : 6 month water cured OPC cubes with sea water cured specimens

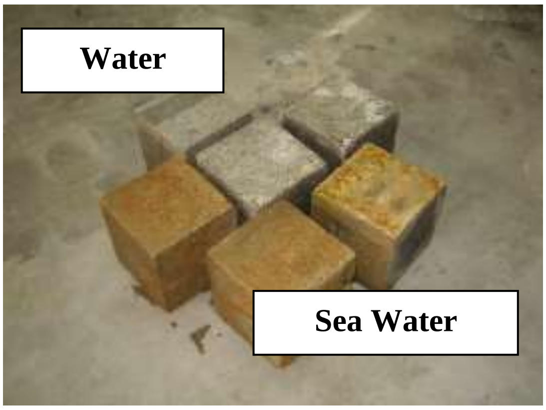

Figure 4 : 1 year water cured OPC cubes with sea water cured specimens

3.2 Strength Performance

Specimens are subjected to compressive strength test in order to evaluate the influence of POFA towards performance of aerated concrete mix. The variation on the strength performance of OPC and POFA specimen placed in sea water with the one placed in plain water can be observed in Fig. 5 to 8. The results indicate that specimens exposed to sea water exhibit decline in both compressive strength and flexural strength, as the exposure period become longer in contrast with specimen placed in plain water where strength is seen to continue increasing. It is interesting to note that the strength degradation for this lightweight concrete is somewhat very fast and significant in comparison with the result of normal concrete presented by [14]. This is believed to be due to the physical characteristic of normal concrete which is rather well compacted and dense creating difficulties for penetration of sea water in contrast to highly porous aerated concrete that allows easy diffusion of sea water thus exposing it to faster deterioration. In general, the present finding is consistent with [15] who found that the effect of marine environments on concrete is that there is decrease in its compressive strength and the loss increases with age of exposure.

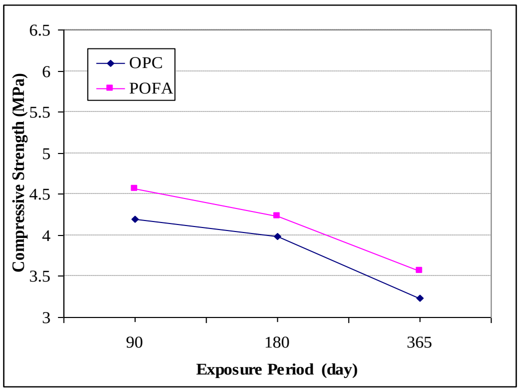

Figure 5 : Strength performance of OPC POFA specimen cured in tap water for 1 year

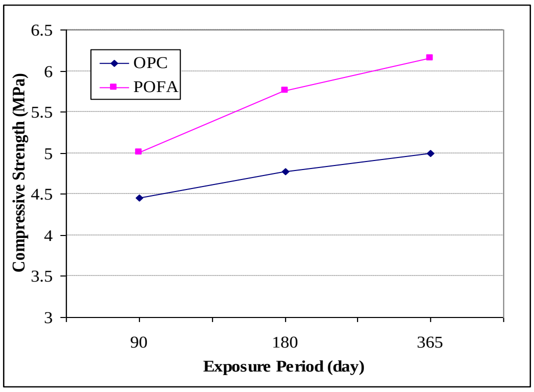

Figure 6 : Strength performance of OPC and OPC and POFA specimen exposed to sea water for1 year

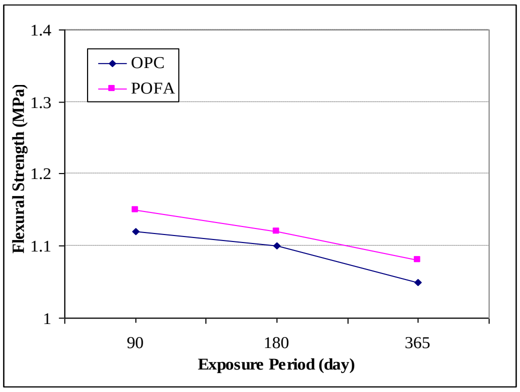

Figure 7 : Flexural strength of OPC and POFA specimen exposed to sea water for year year

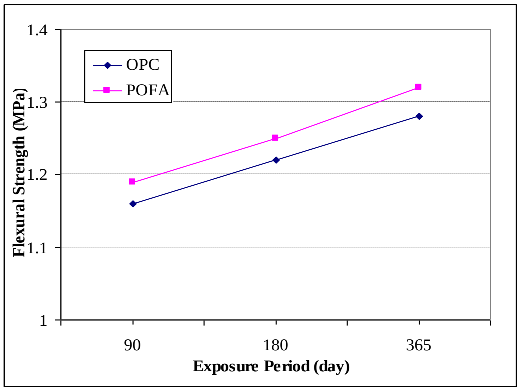

Figure 8 : Flexural strength of OPC and POFA specimen cured in tap water for 1 year

Comparing the performance of OPC and POFA specimens, apparently POFA aerated concrete exhibits lower reduction in the strength as compared to OPC specimens. In other words, the performance of POFA aerated concrete was better as compared to OPC specimens. This is because the pozzolanic reaction which has taken place during 28 days initial water curing before the specimens are placed in sea water. This has made the content of calcium hydroxide in this material lower. The additional calcium silicate hydrate gel produced has filled up the pores forming a denser concrete thus making it more resistant towards sea water attack in comparison with control specimen that does not undergo pozzolanic reaction. Actually, the reduction of hydrated lime in the concrete has a significant resistance towards sea water attack because it has been reported by [16] that leaching of calcium hydroxide is the main weakening effect towards the hardened material. In general, it can be deduced that utilization of POFA as partial cement replacement material is able to improve the resistance of aerated concrete towards sea water attack.

4. CONCLUSION

Based on the experimental results and discussion, it can be concluded that the durability performance of aerated concrete in sea water environment can be improved through inclusion of POFA as a partial cement replacement material. Application of water curing for this blended cement material has promoted the pozzolanic reaction that leads to refinement of the pore structure as well as decreasing the calcium hydroxide content that is susceptible to any aggressive agent. On overall, the result encourages the use of POFA for production of durable lightweight concrete for the use in marine environment.

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