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Performance of High Strength POFA Concrete in Acidic Environment

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Abstract

Malaysia as the world's largest exporter of palm oil has been facing problem in disposing palm oil fuel ash, a by-product of palm oil mill since many years ago. The discovery made by researchers of Universiti Teknologi Malaysia last century in revealing the potential of this finely ground waste as a partial cement replacement in normal concrete has stem efforts towards studying the possibility of using it in high strength concrete production. This paper illustrates the durability aspect of high strength concrete produced using POFA of different fineness when exposed to acidic environment. Two POFA concrete mixes with different fineness termed (POFA 45 and POFA 10) at 20% replacement level by weight of cement and an OPC concrete mix functioning as control specimen termed Po was considered in this study. All the specimens were subjected to water curing for 28 days before immersed in the hydrochloric solution having pH 2 for 1800 hours. The progressive deterioration was evaluated through mass changing of the specimens, visual inspection and relative compressive strength determinations. Conclusively, the study found that increase in the POFA fineness enhances the resistance of high strength POFA concrete towards acid attack.

Keywords: Palm Oil Fuel Ash; Different Fineness; High Strength Concrete; Durability; Acidic Environment

1. Introduction

Palm oil is the main product in tropical climate countries and Malaysia is the top producer of it [1]. Annually millions of tons a by-product of palm oil mill known as Palm oil fuel ash (POFA) have been disposed thus giving negative impact to the environment. This factor has stems the effort of researchers to convert this profitless material into a benefitting product. As a result, it is found that this pozzolanic ash can be used to produce normal concrete [2] and lightweight concrete [3] that possess higher strength than the plain specimen.

Looking at the utilization of POFA in high strength concrete research, there has been study conducted on the behaviour of properties of high strength concrete containing POFA in terms of

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compressive strength performance [4] and durability aspect in terms of sulphate resistance as well as drying shrinkage [5]. However, so far none of the researchers has discussed the durability performance of high strength concrete produced using POFA with different fineness when exposed to acidic environment. Therefore, the current study evaluates the effectiveness of the fineness of POFA in two levels termed by POFA 45 and POFA 10, in producing higher strength and more durable concrete in comparison with control specimen termed by Po.

2. Experimental Programme

2.1. Materials

Materials used in this study consisted of POFA, ordinary Portland cement, coarse aggregate, fine sand, superplasticizer and water. A single batch of ordinary Portland cement (OPC) classed ASTM Type 1 was used during the experiments. Coarse aggregate consisting of a single sized 10 mm crushed granite and fine local sand were subjected to oven dry process at the temperature of 110ºC for 24 hours before each of it stored in separate airtight container. Superplasticizer of type F high range water reducer was employed in all mixtures to produce flowing concrete. Supplied tap water was used throughout the study in mixing, curing and others.

The POFA used is a by-product obtained from burning the remaining of extracted palm oil fibers and shells from a palm oil mill owned by Yayasan Pembangunan Johor which is located in State of Johor. The collected ashes were dried in the oven at the temperature of 110°C ± 5 for 24 hours to remove moisture in it before sieved through 300 µm sieve. Then, it was ground to obtain finer ash complying with ASTM C618 – 05 [6] enabling it to be used as partial cement replacement material in concrete. Two types of POFA having different fineness has been produced through grinding process that is POFA 45 having median particle size of 45µm and POFA 10 having median particle size of 10µm. The chemical composition of POFA which is grouped as Class F poszzolan as enlisted in ASTM C618 – 05 [6] and OPC is tabulated in Table 1.

TABLE1: CHEMICAL COMPOSITION OF OPC AND POFA

Chemical Composition	OPC	POFA
Silicon Dioxide (SiO_2)	21.45	48.99
Aluminium Oxide (AL_2O_3)	3.62	3.78
Ferric Oxide (Fe_2O_3)	4.89	3.50
Calcium Oxide (CaO)	60.98	11.69
Magnesium Oxide (MgO)	1.22	0.59
Sodium Oxide (Na_2O)	0.73	0.25
Potassium Oxide (K_2O)	0.51	4.01
Sulphur Trioxide (SO_3)	2.30	2.25
Loss On Ignition (LOI)	1.37	10.51

2.2. Mix Proportion and Testing

Absolute volume mix design was considered to obtain concrete mix proportion. Throughout the study, the total cementitious material content has been kept constant in all the mixes. Since the current study using the same batch of POFA used by previous researcher [7] who manage to produce concrete with higher strength than plain concrete, therefore POFA used to replace the cement was chosen at proportion of 20% by weight of binder. One overall, three mixture has been used in this study whereby the first one identified as POFA 45 consisting POFA that possess a median particle size of 45µm, second mixture, POFA 10 produced using POFA having median particle size of 10µm and the third mixture, PO only uses cement as a

binder which is for reference purpose. The quantity of water, aggregates and superplasticizer used were kept constant for all mixes. The mix proportion is given in Table 2.

TABLE 2: DETAIL OF CONCRETE MIXES

Ingredients	Po Concrete	POFA 45 Concrete	POFA 10 Concrete
Ordinary Portland cement	400	320	320
Palm Oil Fuel Ash	-	80	80
Water	174.5	174.5	174.5
Fine Aggregate	678.7	678.7	678.7
Coarse Aggregate	1090	1090	1090

Prior to the acid resistance test, all the specimens were subjected to 28 days water curing before placed in hydrochloric solution. The pH of the solution was controlled to about 2 throughout the immersion period of 1800 hours similar to the approach used by previous researcher [8]. The compressive strength of concrete was measured before the test and at 1800 hour of exposure. The monitoring of deterioration process of the specimens was followed by a record of visual observations, loss on weight and compressive strength loss.

3. Results and Discussion

3.1. Visual Observation

No much change on the surface of concrete samples containing POFA when exposed to the acid solution, but the damage such as change in colors and corner losses occurred on specimens of OPC concrete due to the effect of the acid as shown in Figures 1 and 2.

Figure 1. Specimens before exposed to acid solution

Figure 2. Specimens after exposed to acid solution

3.2. Loss of Mass

The details on the mass changing of concrete cube specimens at each period of exposure in acid solution are plotted in Figure 3. It is clear that the concrete prepared with POFA10 showed a relatively smaller mass change. Although both the control and POFA45 concrete suffered slight mass losses during the early periods, the overall loss in mass of the control one was, however, much higher.

Although the exposure period is not too long, it seems that the measurement of mass is not a precise test for the evaluation of acid attack of concrete. However, with further period of exposure the subsequent mass loss, particularly in ordinary Portland cement concrete, occurred due to gradual disintegration of the specimens.

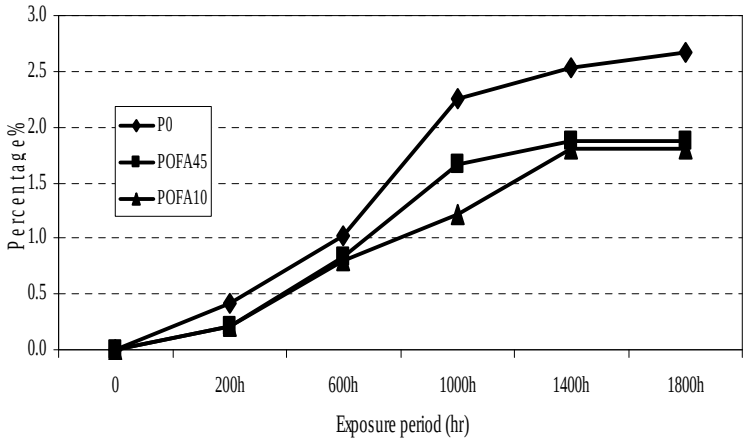

Figure 3. Mass changes in concrete cube specimens

3.3. Relative Compressive Strength

At the end of the mass measurement tests all the specimens were tested for compression to determine the residual strength. Companion specimens (six OPC, six POFA45 and six POFA1 0 concrete cubes), continuously cured in water, and were also tested at the same time, thus, acting as control specimens. The compressive strength result of the cubes exposed in acid 2% hydrochloric solution and the specimens stored in water has been illustrated in the Figure 4. Significant reduction of the strength was observed compared to the specimens that were not replaced with POFA 45 and POFA 10. The compressive strength of P0 concrete at 1800 hours revealed a reduction ratio difference of about 24 % compared to the specimens replaced with 20 % POFA 10 where only 15.9 % reduction on compressive strength.

The better resistance of POFA specimen is expected not only because of the fact that POFA is being identified as a good pozzolanic material [8] but also due to its low CaO content in comparison to the high content of approximately 50% in OPC. Amount of CaO presence in the binder material tend to play significant role in production of Calcium Hydroxide which is susceptible to acid attack finally leading to deterioration of hardened concrete material. This is because acid medium attacks mainly calcium hydroxide and then hydration products in cement matrix which leads to hydrolytic decomposition of hydration cement products followed by degradation of mechanical properties of cement based material [9]. Since POFA contains a small amount of CaO, therefore the amount of CaOH would surely be less in the products of hydration.

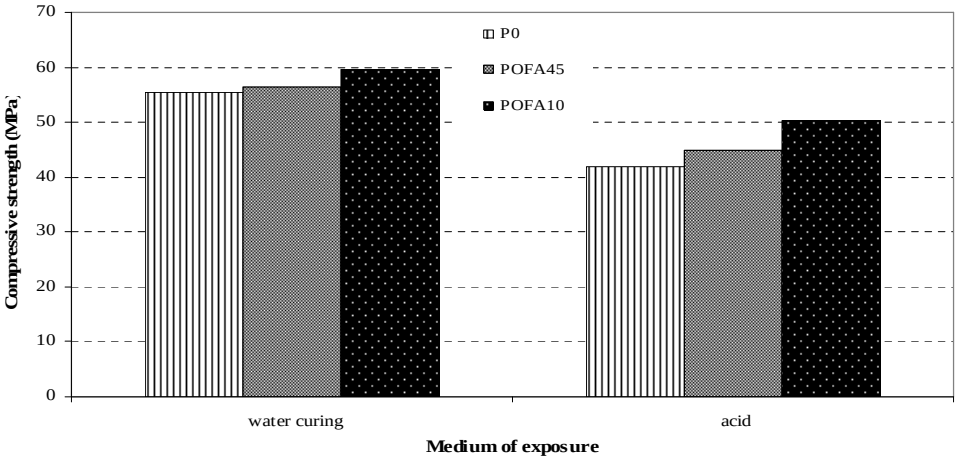

Figure 4. Compressive strength for water cured and acid cured specimens.

4. Conclusion

Based on the experimental study, the following conclusion can be drawn:

The study on durability of POFA concrete examined the performance of POFA high strength concrete exposed to hydrochloric acid solution. It was found that POFA10 concrete has a superior durability compared to POFA45 concrete of similar grade under acid attack. On the other hand POFA45 concrete was found more resistant to deterioration in acid solution than Po concrete.

The investigation has verified that the reduction rate of the compressive strength at 1800 hours was similar at replacement level of 20% POFA to OPC, Although the resistance presented by Po mixed concretes was slightly below those exhibited by POFA45 replaced concretes, concrete replaced by POFA10 showed extreme a promising performance.

The results encourage the use of very fine POFA, as pozzolanic material for partial cement replacement in producing high durable concrete,

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