Malaysian Journal of Civil Engineering 27 Special Issue (1):170-177 (2015)

PERFORMANCE OF AERATED CONCRETE INCORPORATING BY-PRODUCT FROM AGRO-INDUSTRY IN SULPHURIC ACID

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Abstract: The challenge of utilisation of sustainable, durable and cost effective building materials leads civil engineering researcher in rich agro-industrial country such as Malaysia to find suitable building materials alternatives. This paper illustrates the aspect of sustainability of cellular lightweight concrete composed of POFA and PFA at the percentage of 30% and 20% respectively when exposed to sulphuric acid for duarability test.The mix of POFA and PFA used on weight replacement of cement and concrete OPC perforemance considered as a control sample taken in this research. All samples were subjected to the curing in water for 28 days before the immersion in sulphuric acid having with a pH value of 1 to 2160 hours. The progressive deterioration was evaluated by the change in mass of the samples and visual inspection decisions regarding the compressive strength. The study showed that 30% POFA and 20% PFA improves the strength of aerated concrete attack by sulphuric acid.

Keywords: *Palm oil fuel ash; pulverise fuel ash; aerated concrete; durability; sulphuric acid*

1.0 Introduction

According to Sumathi *et al.* (2008), some of the countries in the world have palm oil plants but Malaysia is ranked as the world’s largest producer of palm oil. Therefore, it is predicted that bigger quantity of Palm oil fuel ash (POFA) will be discarded as environmental pollution waste in the future unless this material is processed for other application. Innovation of new product through integration of this freely available waste would be one of the solutions to sustainably use this environmentally degrading by-product into beneficial material so as to meet up the housing needs and housing demands of the people at a very minimal cost of construction.

Incorporation of pozzolanic waste materials to partially substitute Ordinery Portland Cement (OPC) in aerated concrete to produce wall system would reduce the cost and improve the performance of the concrete. Furthermore, the environmental threat sequel to disposal of these wastes to landfills will be curtailed (Mehmannavaz *et al*., 2014a).

Looking at the utilization of POFA and pulverise fuel ash (PFA) in aerated concrete research, there has been study conducted on the behaviour of strength properties and density (Hussin and Abdullah, 2009; Mehmannavaz, *et al*., 2014a; Mehmannavaz *et al*., 2014b; Bhutta, 2013) but there isn't study in term of durability aspect in sulphuric acid. However, the researchers have discussed the durability performance of aerated concrete containing POFA and PFA as replacement of OPC. Therefore, the current study evaluates the effectiveness of the aerated concrete containing POFA and PFA in sulphuric acid.

2.0 Materials and Methods

2.1 Materials

Cement: Ordinary Portland Cement (OPC) of Tasek CorporationBerhad –Malaysia Cement Industry has used during the study. The OPC was used classified as Type I Portland Cement according to ASTM standard (ASTM C 150 – 05, 2005).

POFA: Palm oil fuel ash (POFA) used is obtained from Kahang palm oil mill in Kluang Johor, Southern state of Malaysia. The material was ground using a modified Los Angeles abrasion test machine having 8 stainless bars, each of which is 12 mm diameter and 800 mm long in order to acquire finer particles (Abdul Awal and Abubakar, 2011; Hussin and Abdul Awal, 1996).

PFA: Pulverize fuel Ash (PFA) is a by-product of the combustion of pulverized coal in thermal power plants. The material was obtained at the power plant dust collection systems from the exhaust gases of fossil fuel power plants. PFA was supplied by Sultan Abdul Aziz Generation Station Kapar, located from Klang, Selangor, Malaysia. In this research, PFA, Class F which is low calcium PFA under (ASTM C 618 – 12A, 2012), "Standard Specification for Coal Fuel Ash and Raw or Calcined Natural Pozzolon for Use in Concrete" was used.

Fine aggregate: In this study bottom ash was used for aerated concrete and sand was used for OPC as control.

Superplasticizer: The superplasticizer trade name SIKAMENT NN and high range water reducing admixture was used in this study as chemical admixture, according to (ASTM C494/C494 M – 05, 2005). This material belongs to the group of Sulphonated Naphthalene Formaldehyde condensates (SNF) in dry powder form.

Aluminum powder: The aluminum powder Y250 was used during the study as the gaseous agent to insert the porosity within the mass of aerated concrete.
Table 1 and Table 2 illustrated chemical combination and physical properties of OPC, POFA and PFA.

Table 1: Chemical combination of OPC, POFA and PFA

Chemical combination (%)	OPC	POFA	PFA
SiO_2	16.40%	63.70%	53.60%
Al_2O_3	4.24%	3.68%	26.60%
Fe_2O_3	3.53%	6.27%	5.36%
CaO	68.30%	5.97%	7.28%
K_2O	0.22%	9.15%	1.30%
P_2O_5		4.26%	1.51%
MgO	2.39%	4.11%	0.67%
CO_2	0.10%	0.10%	0.10%
SO_3	4.39%	1.59%	0.63%
Cl		0.50%	
TiO_2		0.30%	1.94%
Mn		0 < LLD	0 < LLD
Na		0 < LLD	
Mno	0.15%		
Ti	0 < LLD		
SrO			0.33%
BaO			0.20%
Zr			0 < LLD

Table 2: Physical properties of OPC, POFA and PFA

Physical properties	OPC	POFA	PFA
Specific gravity	3.15	2.42	2.62
Particle retained on 45µm sieve	4.58	4.98	6.92
Median particle d10	-	1.69	-
Median particle d50	- -	14.58	-
Blaine fineness (cm^3/g)	3999	4935	3205
Soundness (mm)	1.0	2.0	-
Strength Activity Index (%)			
At 7days	-	80	84
At 28 days	-	84	92

2.2 Mix Proportion and Testing

The perforemance evaluation of aerated concrete with pozzolanic materials in acid environment was tested. Cubes of the dimensions (100 x 100 x 100 mm) comprising of two sets of mixed namely aerated concrete with pozzolanic materials and OPC concrete as a control are casted and subjected to water curing in the laboratory over 28 days. The experimental work begins when specimens are immersed in sulphuric acid solution with pH value of; 1. In order to determine the extent of the material durability towards sulphuric acid attack, the weight loss of the samples involved in the testing was examined. The tests are taken every two weeks beginning from the time that was immersed in sulphuric acid solution, prepared using 0.5% sulphuric acid of 98% concentration. The pH of the solution is controlled at every 2 week after remove the specimen. Figure 1 shows a pictorial view of acid sulphuric attack and pH test in progress. The quantity of water, aggregates and superplasticizer and the mix proportion are shown in Table 3.

Figure 1: A pictorial view of acid sulphuric attack and pH test in progress

Table 3: Detail of mixes

Materials	OPC	Aerated concrete
OPC (kg/m^3)	600	300
POFA (kg/m^3)	--	180
PFA (kg/m^3)	--	120
Bottom Ash passing 1.18 mm (kg/m^3)	--	600
Sand Passing 2.36 µm (kg/m^3)	1200	--
Water (kg/m^3)	276	276
Aluminum Powder (kg/m^3)	--	3.6
Superplasticizer (kg/m^3)	2.4	2.4

3.0 Results and Discussion

3.1 Visual Observation

The visual appearance of aerated concrete and OPC concrete specimens are shown in Figure 2. The surface conditions of these specimens were observed.

Figure 2: Appearance of specimens after immersed in 5% sulphuric acid solution

Figure 2 shows the specimens after 2160 hours exposure in sulphuric acid. Aerated concrete did not show any change in dimension and remain structurally intact without visible cracks on the surface. In case of OPC specimens there was a high change of dimension and decomposition with associated visible cracks on the surface. Additionally, OPC specimen's experience some soften and brittle surface texture. As seen in Figure 2, there was no change observed on the surface of aerated concrete while OPC concrete showed significant surface deterioration after 2160 hours exposure in 5% sulphuric acid solution.

3.2 Loss of Mass

The details on the mass changing of concrete cube specimens at each period of exposure in sulphuric acid solution are plotted in Figure 3. It is clear that the aerated concrete prepared with POFA and PFA showed a relatively smaller mass change. Although the control OPC concrete suffered mass losses during the early periods, the overall loss in mass of the control OPC was much higher than aerated concrete containing POFA and PFA.

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 OPC concrete, occurred due to gradual disintegration of the specimens.

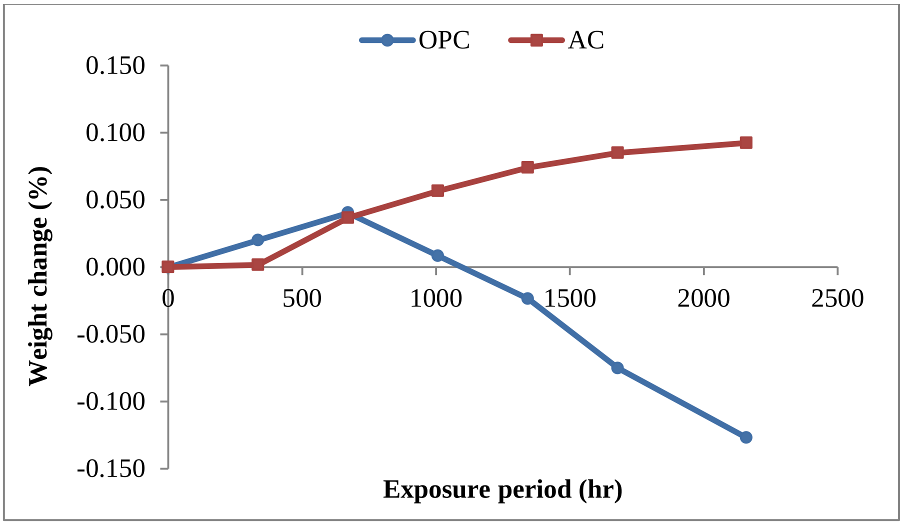

Figure 3: Mass changes in concrete cube specimens

3.3 Relative Compressive

At the end of the mass measurement tests all the specimens were tested for compression to determine the residual strength. Companion specimens (3 controls OPC and 3 aerated concrete containing PFA and PFA), 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 5% sulphuric acid solution and the specimens stored in water has been illustrated in the Figure 4. Significant reduction of the strength was observed in the OPC control sample were exposed to acid sulphuric compared to the aerated concrete specimens containing POFA and PFA. The compressive strength of OPC concrete at

2160 hours revealed a reduction ratio difference of about 72% compared to the specimens replaced with POFA and PFA where only 38% reduction on compressive strength.

The better resistance of aerated concrete containing POFA and PFA is expected not only because of the fact that POFA and PFA are being identified as a good pozzolanic material (Abdul Awal and Shehu, 2013; Balakrishnan *et al*., 2013) but also due to its low Calcium oxide (CaO) content in comparison to the high content of approximately 68% 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 (Ariffin *et al*., 2013). Since POFA and PFA contain a small amount of CaO, therefore the amount of Calcium hydroxide (CaOH) would surely be less in the products of hydration.

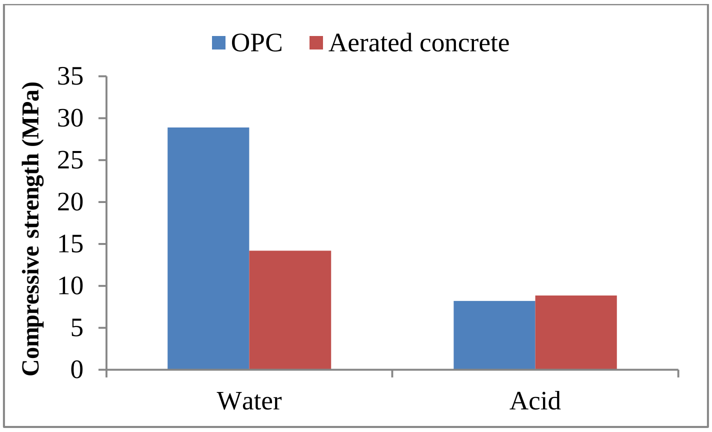

Figure 4: Compressive strength for water cured and acid cured specimens

4.0 Conclusions

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

1. Tests on durability of aerated concrete containing POFA and PFA concrete examined the performance of POFA and PFA demonstrate a good durability compared to specimens without POFA and PFA exposed to sulphuric acid attack.

2. On the other hand, aerated concrete with POFA and PFA was found more resistant to deterioration in acid solution rather than OPC concrete.

3. The investigation has verified that the reduction rate of the compressive strength at 2160 hours in OPC control specimens was higher than the aerated concrete containing POFA and PFA.

4. All results encourage the use of POFA and PFA, as pozzolanic materials for partial cement replacement in producing high durable concrete was very useful.

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