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An Investigation into the Chloride and Sulphate Resistance of Concrete and Mortars Containing Palm Oil Fuel Ash

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ABSTRACT

An investigation was carried out into the chloride and sulphate resistance of concrete and mortar containing palm oil fuel ash (POFA) as partial replacement for cement. POFA was used to partially replace Portland cement by 0, 10, 20, 30, 40 and 50% by weight of binder in order to prepare POFA concrete and mortars.The chloride resistance of POFA concretes at various mixes towards chloride attack was investigated by placing concrete cubes inside 3 per cent Sodium Chloride (NaCl) solutionand tested for mass change after 2, 4, 6, 8 and 10 weeks of immersion.The durability of POFA Mortar Bars at various mixes towards sulphate attack was investigated by immersing mortar bars in magnesium sulphate solution and tested for mass change after 1, 5, 9, 13 and 15 weeks of immersion. Results revealed that POFA concrete with 10% by weight replacement of cement had the best resistance towards chloride ingress and mortar bar with 10% POFA exhibited the best resistance towards sulphate attack. It is recommended that application of POFA in the right dosage would enhance the chloride and sulphate resistance of concrete and mortars.

KEYWORDS: *chloride resistance, concrete, mortar, palm oil fuel ash, sulphate resistance.*

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I. INTRODUCTION

Many researchers have studied the compressive strength and durability of concrete and mortar. Theirstudies had revealed that that their compressive strengths and sulphate resistance are improved when ground palm oil fuel ash was used to partially replace cement in concrete or mortar mixes. Chindaprasirt et al. (2008) studied the ability of POFA mortar to resist the chloride ions penetration; the results showed that the chloride resistance of mortar was improved substantially by POFA. The improvement in POFA mortar and concrete was due to pozzolanic reaction where the hydration products react with the silica contained in POFA. The aim of this research work is to investigate the chloride and sulphate resistance of concrete and mortars containing palm oil fuel ash.

II. MATERIALS AND METHODS

Materials

The Palm Oil Fibres used for this study was sourced from local palm oil producers in Obaagun, Nigeria. The Fibres were burnt to ashes in specially prepared drums under controlled air. The resulting ashes were sieved using 600µm sieve. The chemical analysis of the ash was carried out using X-ray Fluorescent Analyser in Lafarge Cement WAPCO Nigeria Plc, Sagamu, Nigeria. The Ordinary Portland Cement (Dangote Brand) used was obtained from local suppliers. Sharp sand was collected from the drains and was sieved using 5mm size sieve.

Methods

The Chloride resistance of POFA concretes at various mixes towards chloride attack was investigated using 100 x 100 x 100 mm concrete cubes with varying percentages of POFA replacing Ordinary Portland Cement(OPC) from 0% to 50% prepared and cured after 24 hours from casting for 14 days. They were then stored in drying room for 28 days. After the conditioning period, they were placed inside 3 per cent Sodium Chloride (NaCl) solution. The concrete cubes were brought out and tested for mass change after 2, 4, 6, 8 and 10 weeks of immersion. After each interval, the concrete cubes were placed in fresh sodium chloride solution until the subsequent measurement.

The durability of POFA Mortar Bars at various mixes towards sulphate attack was investigated by testing mortar bars following the procedures outlined in ASTM C 1012-04. The variations in the mass of mortar bars (25 x 25 x 25 mm sizes) after exposure to sulphate solutions were observed. The mortar bars were made using 1 part of cement to 2.75 parts of sand by mass. A water-cement ratio by mass of 0.485 was used. Six sets of mortar bars were produced by replacing OPC with POFA at 0, 10, 20, 30, 40 and 50% levels. The specimens were demoulded after 24 hours and thereafter placed inside magnesium sulphate solution. Each litre of sulphate solution was prepared by dissolving 42.35g of Magnesium Sulphate (MgSO4) in 900ml of distilled water to obtain 1.0litre of solution. The mortar bars were brought out and tested for mass change after 1, 5, 9, 13 and 15 weeks of immersion. After each interval, the mortar bars were placed in fresh sulphate solution until the subsequent measurement.

III. RESULTS AND DISCUSSION

Chemical Composition of POFA

The chemical composition of POFA is shown in Table 1. The total amount of SiO_2, Al_2O_3 and Fe_2O_3 is 76.04% for POFA which is more than70%, requirement which a good pozzolan for manufacture of blended cement should meet (Shihembetsa and Waswa-Sabuni, 2002; Pekmezci and Akyuz, 2004). The requirements of ASTM C 618 for a combined SiO_2+Al_2O_3+Fe_2O_3 of more than 70% was also satisfied (Siddique, 2004). Thus, POFA is a suitable material for use as a pozzolan. The presence of Silica, Alumina and Iron is responsible for the formation of cementitious products when they react with lime in the presence of water.

Table 1 Chemical Composition of Palm Oil Fuel Ash (POFA)

Chemical Constituents	Percentage Composition %
SiO_2	69.46
Al_2O_3	3.68
Fe_2O_3	2.90
CaO	1.63
MgO	0.51
SO_3	0.55
Na_2O	0.06
K_2O	3.91
P_2O_3	1.47
LOI	9.91

Resistance of POFA Concrete to Sodium Chloride Penetration

The results of the penetration of Sodium Chloride (NaCl) solution into POFA concrete cube specimens are presented in Table 2. The details of the percentage change in mass of concrete cube specimens at each period of immersion in sodium chloride solution is plotted in Figure 1. All the concrete cubes experienced gain in mass as a result of the penetration of chloride solution into the concrete. After 10 weeks immersion in chloride solution, the percentage increase in masses of 0%, 10%, 20%, 30%, 40% and 50% of POFA concretes were 1.6%, 1.4%, 2.5%, 2.9% 3.7% and 4.9% respectively. It can be seen that after 10 weeks exposure to sodium chloride solution, the gain in mass of the control cube was higher than the gain in the mass of the 10% POFA concrete bars. The 50% POFA concrete cubes experienced the highest penetration of chloride revealed by the percentage gain in mass of 4.9% after 10 weeks immersion in sodium chloride solution. Thus, the inclusion POFA of not more than 10% improved the resistance of the concrete cubes towards chloride attack. This improvement in concrete resistivity towards chloride ingress is due to the pozzolanic reaction of POFA that improves the interfacial bonding between the aggregates and the pastes resulting in impermeable and dense concrete (Weerachat et al., 2009; Isaia et al., 2003; Zhang and Malhotra, 1996). The migration of chloride ions through POFA concrete was much lower than OPC concrete due to the production of more calcium silicate hydrates resulting in a highly impermeable matrix that prevents or slows down the chloride transport (Bamaga et al., 2010). It is worthy of note that the POFA replacement of cement beyond 10% promoted higher permeability of chloride solution due to the presence of larger pores resulting in low micro-filling in the concrete.

Resistance of POFA Mortar Bars towards Sulphate attack

The results of the reaction of POFA mortar bar specimens with Magnesium sulphate (MgSO4) solution are presented in Table 3. The details of the percentage change in mass of mortar bar specimens at each period of exposure in sulphate solution is plotted in Figure 2. All the mortar bars experienced gain in mass as a result of the expansion of the mortar bars. After 15 weeks immersion in magnesium sulphate solution, the percentage increase in masses of 0%, 10%, 20%, 30%, 40% and 50% of POFA mortars were 9.4%, 8.9%, 9.8%, 12.1% 12.4% and 14.4% respectively. It can be seen that after 15 weeks exposure to sulphate solution, the gain in masses of the control mortar bars were higher than the gain in masses of the 10% POFA mortar bars. The 50% POFA mortar bars experienced the biggest expansion as revealed by the percentage gain in mass of 14.4% after 15 weeks exposure to MgSO4 solution. Thus, the inclusion of POFA of not more than 10% improved the resistance of the mortar bars towards sulphate attack. The formation of C-S-H gel made the mortar bars to be denser and more resistant towards sulphate attack. This is in agreement with the findings of some previous researchers (Abdul Awal, 1998 andHussin et al., 2009) who stated that the integration of POFA as partial cement substitute enhances concrete durability towards sulphate attack.

Table 2 Sodium Chloride Penetration into POFA Concrete

Percentage POFA (%)	Effect of NaCl on	Duration of Immersion in Sodium Chloride (Weeks)					
		0 Week	2 Weeks	4 Weeks	6 Weeks	8 Weeks	10 Weeks
0	Mass (g)	2635.9	2667.5	2672.8	2675.4	2675.4	2678.1
	Change (g)		31.6	36.9	39.5	39.5	42.2
	% Change		1.2	1.4	1.5	1.5	1.6
10	Mass (g)	2486.7	2511.6	2514.1	2514.1	2516.5	2521.5
	Change (g)		24.9	27.4	27.4	29.8	34.8
	% Change		1.0	1.1	1.1	1.2	1.4
20	Mass (g)	2352.5	2404.3	2406.6	2409.0	2409.1	2411.3
	Change (g)		51.8	54.1	56.5	56.6	58.8
	% Change		2.2	2.3	2.4	2.4	2.5
30	Mass (g)	2203.9	2256.8	2259.0	2263.4	2263.6	2267.8
	Change (g)		52.9	55.1	59.5	59.7	63.9
	% Change		2.4	2.5	2.7	2.7	2.9
40	Mass (g)	2184.3	2243.3	2247.6	2256.4	2258.6	2265.1
	Change (g)		59.0	63.3	72.1	74.3	80.8
	% Change		2.7	2.9	3.3	3.4	3.7
50	Mass (g)	2134.8	2213.8	2222.3	2224.5	2230.9	2239.4
	Change (g)		79.0	87.5	89.7	96.1	104.6
	% Change		3.7	4.1	4.2	4.5	4.9

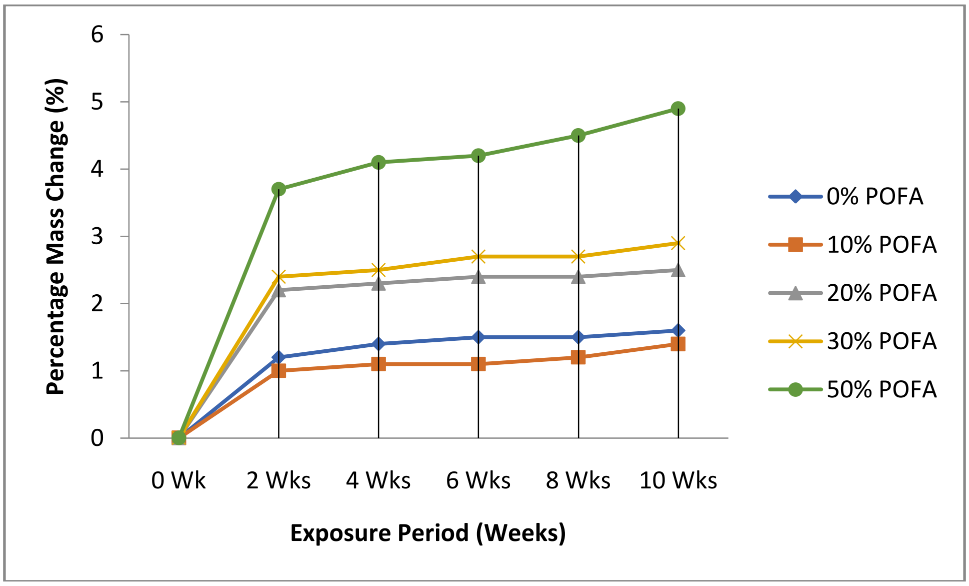

Figure 1: Effect of Sodium Chloride on POFA Concrete

Table 3: Reaction of POFA Mortars with Magnessium Sulphate

Percentage POFA (%)	Effect of $MgSO_4$ on	Duration of Immersion in Magnesium Sulphate (Weeks)					
		0	1	5	9	13	15
0	Mass (g)	433.9	469.5	472.5	473.0	473.0	474.7
	Change (g)		35.6	38.6	39.1	39.1	40.8
	% Change		8.2	8.9	9.0	9.0	9.4
10	Mass (g)	434.6	468.5	471.1	472.0	472.4	473.3
	Change (g)		33.9	36.5	37.4	37.8	38.7
	% Change		7.8	8.4	8.6	8.7	8.9
20	Mass (g)	404.2	439.8	442.2	443.4	443.4	443.8
	Change (g)		35.6	38.0	39.2	39.2	39.6
	% Change		8.8	9.4	9.7	9.7	9.8
30	Mass (g)	362.9	401.4	403.9	405.0	405.1	406.8
	Change (g)		38.5	41.0	42.1	42.2	43.9
	% Change		10.6	11.3	11.6	11.6	12.1
40	Mass (g)	347.8	386.4	389.5	389.9	390.6	390.9
	Change (g)		38.6	41.7	42.1	42.8	43.1
	% Change		11.1	12.0	12.1	12.3	12.4
50	Mass (g)	345.4	390.6	394.1	394.8	396.1	397.9
	Change (g)		45.2	48.7	49.4	50.7	52.5
	% Change		12.3	13.3	13.5	13.9	14.4

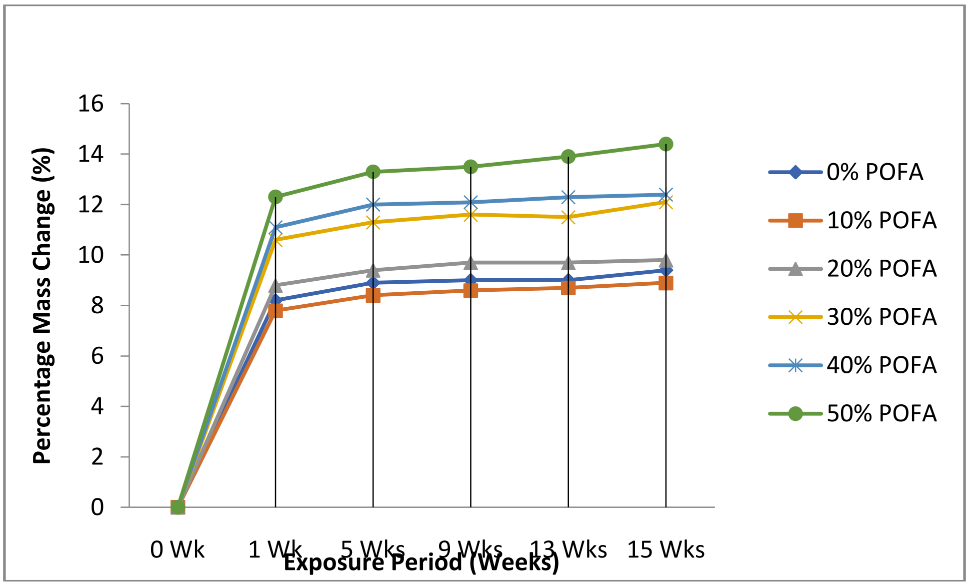

Figure 2: Effect of Magnesium Sulphate Attack on POFA Mortars

IV. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from this research work:

Palm Oil Fuel Ash (POFA) satisfied the requirements for a good pozzolan as it has a combined SiO_2 + Al_2O_3 + Fe_2O_3 of more than 70%.

The POFA concrete with 10% by weight replacement of cement had the best resistance towards chloride ingress as it experienced the least percentage gain in mass upon immersion in sodium chloride solution.

The mortar bar with 10% POFA exhibited the best resistance towards sulphate attack as it experienced the least percentage gain in mass upon immersion in magnesium sulphate solution.

The following recommendations can be drawn from this research work:

Incentives should be given to farmers to cultivate more Oil Palm to guarantee the availability of Palm Oil Fuel Ash.

Further studies on this subject matter are suggested.

REFERENCES

[1]. Abdul Awal, A.S.M. (1998). A Study of Strength and Durability Performances of Concrete Containing Palm Oil Fuel Ash. PhD Thesis. UniversitiTeknologi Malaysia.

[2]. ASTM C 618-03(2003). Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete.

[3]. ASTM C 1012-04(2004). Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution.

[4]. Bamaga, S., Ismail, M.A. and Hussin, M.W. (2010). Chloride Resistance of Concrete Containing Palm Oil Fuel Ash. Concrete Research Letters. 1(4), 158-166.

[5]. Chindaprasirt, P., Homwuttiwong, S. and Jaturapitakkul, C. (2008). Strength and water permeability of concrete containing palm oil fuel ash and rice husk-bark ash. Construction and Building Materials. 21(7), 1492-1499.

[6]. Hussin, M.W., Ismail, M.A., Budiea, A. and Muthusamy, K. (2009). Durability of High Strength Concrete Containing Palm Oil Fuel Ash of Different Fineness. Malaysian Journal of Civil engineering. 21(2). 180-194.

[7]. Isaia, G.C., Galstaldini, A.L.G. and Moraes, R. (2003). Physical and pozzolanic action of mineral additions on the mechanical strength of high performance concrete. Cement and Concrete Composites. 25(1), 69-76.

[8]. Pekmezci B.Y. and Akyuz, S. (2004). Optimum Usage of a Natural Pozzolan for the Maximum Compressive Strength of Concrete. Cement and Concrete Research, 34, 2175-2179.

[9]. Shihembetsa, L.U. and Waswa-Sabuni, B. (2002). Burnt Clay Waste as a Pozzolanic Material in Kenya. Journal of Civil Engineering. JKUAT, 7, 21-28.

[10]. Siddique, R. (2004). Performance Characteristics of High-Volume Class F Fly Ash. Concrete. Cement Concrete Research, 34(3), 487-493.

[11]. Weerachart, T., Chai, J. and Kraiwood, K. (2009). Compressive Strength and Expansion of Blended Cement Mortar Containing Palm Oil Fuel Ash. Journal of Materials in Civil Engineering, ASCE. 21(8), 426-431.

[12]. Zhang, M.H. and Malhotra, V.M. (1996). High performance concrete incorporating rice husk ash as a supplementary cementing material. ACI Material Journal. 93(6), 629-636.

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