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Effect of Sulphate Attack on the Strength of Cement Brands Blended with Cassava Peel Ash

Kolawole Adisa Olonade[1] and Abdulwahab Gbenga Abdullah[2]

[1]Department of Civil and Environmental Engineering, University of Lagos, Lagos, Nigeria,
kolonade@unilag.edu.ng
[2]Department of Civil and Environmental Engineering, University of Lagos, Lagos, Nigeria,
ubaydulwahaab@gmail.com

Corresponding Author: kolonade@unilag.edul.com

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***Abstract*— Effect of two sulphate solutions on the strength of blended cassava peel ash (CPA) - cement mortar was investigated. CPA used to replace each brands of the Portland cement at a proportion of 20% by weight. Mortar of mix ratio 1:3 was prepared and 300 small mortar beams were cast and cured in fresh water for 28 days then in 50g/l concentration of sulphate solution of Calcium and Sodium separately for 90 days with the control remaining in fresh water for the periods. The results showed a varying effect of the sulphate solution on the different brands of cement both on the flexural and compressive strength. It was concluded that CPA possessed potential to mitigate effect of sulphate attack on some selected brands of cement.**

***Keywords*— cassava peel ash, concentration, sulphate solution, curing ages**

I. INTRODUCTION

Concrete and mortar are critically important construction materials. While concrete is used as a bulk building material, mortars are used to bind together bricks, stone, or other blocks in masonry-type construction. Concretes and most mortars rely on hydraulic cement binders for their strength and durability (Oss and Padovani, 2003). Over the years, durability issues due to chemical attack on cement-based construction materials have been giving a growing concern. Durability of Portland cement concrete is its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration according American concrete institute (ACI - Committee 201). Sulfate attack – a form of chemical attack - is one of the primary causes leading to deterioration of concrete. Sulfates from sewage water, industrial effluent, sea water groundwater etc. penetrate into the concrete and react with the hydrated cement paste phases leading to the production of secondary phases like gypsum, ettringite or thaumasite which may lead to cracking, spalling or loss of strength (Van Tittelboom and De Belie, 2009).

Industrial waste pozzolans such as fly ash (FA) and silica fume (SF) are already widely used in many countries (Cisse and Laquerbe, 2000) and attempts are being made to produce and use pozzolanic agricultural by-product ashes such as rice husk ash (RHA) and saw dust ash (SDA) commercially in some countries. Mehta and Pirtz (2000) investigated the use of RHA to reduce temperature in high strength mass concrete and found that RHA is very effective in reducing the temperature of mass concrete compared to OPC concrete. Malhotra and Mehta (2004) found that ground RHA with finer particle size than OPC improves concrete properties, including that higher substitution amounts results in lower water absorption values and the addition of RHA causes an increment in the compressive strength. Cordeiro et. al. (2009) carried elaborate studies of Brazilian RHA, rice straw ash (RSA), and demonstrated that grinding increases the pozzolanicity of RHA and that high strength of RHA, RHA concrete makes production of blocks with good bearing strength in a rural setting possible. The use of pozzolanic materials is found in many ancient civilizations. Pozzolans were used to improve the properties of lime, and many structures are still extant as a testament to the durability of lime – pozzolan mortars and concrete (Salau and Olonade, 2012) and (Raheem et.al., 2015). Many of these pozzolans are industrial by-products and considered as waste, so that the resulting benefits in terms of energy savings, economy, environmental protection and conservation of resources are substantial.

Adesanya et. al. (2008) reported that cassava peel constitutes between 20-35% of the weight of tuber, especially in the case of hand peeling. Based on 20% estimate, they said about 6.8 million tonnes of cassava, peel is being generated annually and 12 million tonnes is expected to be produced in the year 2020. They further warned that indiscriminate disposal of cassava peels due to gross underutilization as well as lack of appropriate technology to recycle them is a major challenge, which results in environmental problem. Thus, there is need to search for alternative methods to recycle them

Olonade et. al. (2014) reported that concrete made from blended cement-cassava peel ash possesses relatively low compressive strength, when cured in sulfuric acid and that the Sulfuric acid solution inhibits pozzolanic reaction between CPA and calcium hydroxide to take place, which made the CPA to be inactive in the mixture. They also recommend that more studies on be done on the effect of sulfuric acid solution on cement-CPA concrete cured in fresh water for longer period to allow pozzolanic reaction to take place.

This study assessed the resistance of four different but famous brands of cement in Nigeria blended with cassava (Manihot esculenta) peel ash to two types of Sulphate salt to concrete through strength tests.

II. MATERIALS AND METHODS

A. Materials

Cassava peels were collected and burnt to ashes as recommended by Salau and Olonade (2011). River sand was used as fine aggregates, while cement brands studied were Dangote (D), Lafarge (L), Purchem (P) and Sokoto (S) cements. Calcium and sodium solution of concentration 50g/l were used as sulphate exposure medium, while water medium was used reference.

B. Method

1) Mortar Preparation

Mortar of mix ratio 1: 3 (binder: sand) with cement ratio of 0.5 was batched by weight. Binder contained 20% of volume weight of cement. Normal mortar (0% CPA) was used as reference. Mortar prism of 160 x 40 x 40 mm samples were cast with the cement brands one after the order. The samples were first cured in water for 28 days before they exposed to sulphate attack for a 7, 14, 28, 56 and 90 days.

2) Aggregate Characterization

Properties of the aggregate used (sand) were determined. Specific gravity, Silt content and water absorption were some of the properties determined. Sieve analysis was carried out and the particle size distribution curve for the aggregate was plotted and their corresponding grading properties: coefficients of uniformity, coefficient of curvature and fineness modulus were determined. The characterization of the aggregate was conducted in accordance with the standard procedure of BS 1377 Part 1 and 2.

3) Determination of the Physical and Chemical Properties of the Cement

The chemical compositions of the different brands of cement studied were determined using X-ray florescence spectroscopy. The test was conducted in the Chemical Laboratory of Lafarge/WAPCO Ewekoro, Ogun state, Nigeria. The surface area of the cement brands was determined with Blain meter cell. The densities and the specific gravities of the cements were equally determined in accordance with the (BS 4550).

4) Flexural and Compressive Strength Test

At the expiration of each curing period, the prism was weighed and the flexural strength of the mortar prism was first determined. The amount of force that broke the sample into two halves was recorded as flexural force. Each halves of the prism from flexural testing was used as samples to determine the compressive strength. This was in conformity with the provisions of BS EN 196 -1 (2015).

III. RESULTS AND DISCUSSION

A. Aggregate Characterization

The properties of the aggregates were determined to be properly classified. The results are summarized in Table 1

Table 1: Physical Grading Properties of the Aggregate

Properties	Sand
Specific Gravity	2.66
Silt Content (%)	7.70
Water Absorption (%)	4.10
Fineness Modulus	2.55
Coefficient of Curvature, Cc	1.13
Coefficient of Uniformity, Cu	1.60

The fineness modulus, an index number that represents the mean size of the particles in sand, is within the recommended standard in accordance with ASTM C125 while the water absorption was found to be in consonance with the recommended values given by standard of ASTM C70. The silt content as well falls within the recommended standard. The silt content represents the quantity of sand below the size 4.76 mm present in the sand. A high percentage of the silt content would greatly affect the strength.

The uniformity coefficients (C_u) and coefficient of curvature (C_c) for the fine aggregates were determined and presented in Table 3.1. The fine aggregates have a uniformity coefficients (C_u) of 1.60 and coefficient of curvature or coefficient of gradation (C_c) of 1.13 (Figure 1). As C_u is greater than 1 and C_c is greater than 1 (according to Unified Soil Classification). This indicated that the aggregate was well graded based on Unified Soil Classification.

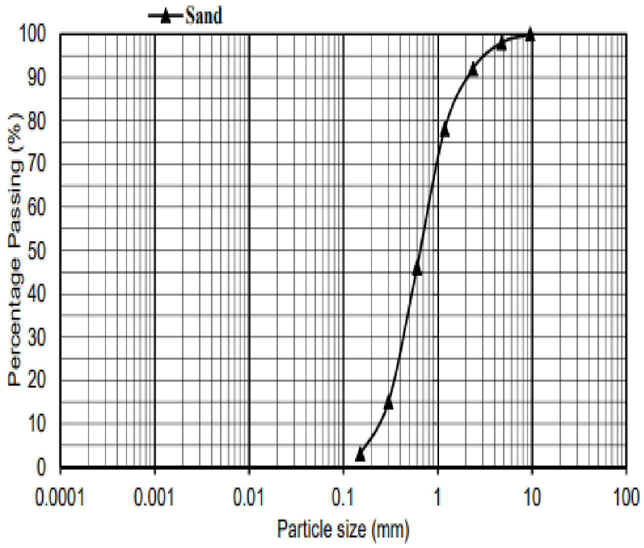

Fig. 1: Particle size distribution curve of the sand

B. Chemical Analysis of the Cements and CPA

The performance of any Portland cement or admixture is highly influenced by its chemical composition. In Table 2, the chemical compounds as well as their percentage chemical composition are shown. The chemical compositions were analyzed with X-Ray Fluorescence spectrometer. The dominant oxides were CaO, SiO_2, Al_2O_3 and Fe_2O_3, but other existing oxide includes MgO, SO_3. Furthermore, other visible alkali oxides are K_2O and Na_2O and oxides of phosphorus, titanium and manganese. Each of the oxides play specific role during cement hydration. A contrary composition of the oxides percentage or a deviation of any oxides in percentages has specified by the standards may lead to expansion of the mortar due to the formation of $Ca(OH)_2$. The specification for the aluminium-oxide according to the British code BS EN 196-2(1995) falls within 2.6-8.0%. All the brands were observed to be within the specification. The presence of the aluminium-oxide contributes to early strength development. From the analysis, Sokoto cement had the highest Aluminium content. The chemical compositions of the ashes showed that cassava peel ash did satisfy the ASTM requirement that the sum of SiO_2, Al $_2O_3$, and Fe_2O_3 should not be less than 70% since the sum gives 72.34% which is support with the studies done by Salau and Olonade (2011).

Table 2: Chemical Composition of the Ordinary Portland Cements and CPA

% Oxides/Parameters	Purechem	Dangote	Lafarge	Sokoto	CPA
SiO_2	19.08	15.77	16.77	19.06	59.72
Na_2O	0.00	0.03	0.02	0.00	0.05
K_2O	0.06	0.34	0.27	0.24	6.82
CaO	60.44	60.53	60.56	60.24	8.42
MgO	1.03	2.25	1.71	2.34	5.22
TiO	0.27	0.22	0.23	0.28	__
P_2O5	0.19	0.45	0.31	0.58	__
Al_2O_3	4.57	4.04	4.40	5.30	11.1
Fe_2O_3	3.13	3.11	2.85	3.35	1.52

SO_3	2.69	1.90	2.00	1.91	2.08
Mn_2O_3	0.05	0.05	0.06	0.13	__
$Ca(OH)_2$	-	-	-	-	__
Blaine	2851	4501	4120	4103	__
LOI	7.04	11.15	10.24	6.20	5.07
Density	3.08	2.82	2.98	3.02	
R45	40.01	2.53	10.09	4.66	
Specific Area (cm²/g)	2107	4737	3965	3571	
Laser Obscuration	2.52	2.41	2.15	2.66	
Span	3.764	3.155	2.941	2.901	
Uniformity	1.201	0.995	0.927	0.918	

C. Effect of Sulphate Attack On Compressive Strength Of Cement Mortar

1) Effect of Calcium Sulphate

Compressive strength of the mortar samples cured in water and calcium sulphate solution is presented in Table 3. A general increase in compressive strength across all the brands of cement can be observed from Figure 1 with ages until 28 days of curing when a general declination in strength sets in except for Sokoto cement, which increased until 56 day before declining. However, for Dangote cement which maintained a consistent increase in strength with the ages (Table 3).

A progressive increase, also, in loss of strength across the ages which were 2.16 N/mm^2 at 7days, 3.79 N/mm^2 at 14days, 3.94 N/mm^2 at 28days, 5.39 N/mm^2 at 56days and 5.78days at 90days. Lafarge cement, like Purechem cement, could be observed to show an initial decrease in loss of strength from 3.18 N/mm^2 at age 7 through age 28 where the strength was more that the corresponding mortal prism in water by 4.25 N/mm^2 rather than loosing strength. Nevertheless, an increase in loss of strength through age 56 at 3.72 N/mm^2 and a very sharp increase in loss of strength through the age 90 of 13.92 N/mm^2, which may be attributed to the effect of the sulphate attack. The loss of strength could be observed in Sokoto cement, as its strength increase progressively across the ages. It was observed from the results that Dangote cement blended with CPA possessed the highest resistance to calcium Sulphate then Sokoto cement blended with CPA.

Table 3: Compressive Strength (N/mm^2) of Portland Cement Brands in Water and $CaSO_4$

Cement	Strength(N/mm^2)						Strength(N/mm^2)				
Brands	Ages of Curing (days) in water						Ages of Curing (days) in water $CaSO_4$				
	7	14	28	56	90		7	14	28	56	90
Purechem	7.18	9.25	9.93	13.65	14.84		6.46	9.10	9.73	9.07	6.12
Dangote	9.86	13.25	13.67	15.58	16.15		7.25	9.10	9.73	10.19	10.37
Lafarge	9.64	9.81	10.1	17.41	20.04		6.46	7.14	14.35	13.69	6.12
Sokoto	11.65	16.58	17.65	19.59	20.76		7.25	9.10	12.93	12.99	12.45

From this results, it can be explained that the initial increase in strength on the mortal samples in calcium sulphate is so because the sulphate attack has not commenced and still finding its way to the mortar matrix while a noticeable decrease in strength is an evidence of the Sulphate attack more resisted by some cement brands than the other. In addition, the loss in strength can be ascribed to the effect of the CPA with which the cement was replaced. It could be observed that the strengths of each brand of the cement at 28 days in the calcium Sulphate were closely comparable to those without CPA and also cured in water, which highlighted the late strength of CPA as an admixture.

2) Effect of Sodium Sulphate

Figure 2 show the relationship between the compressive strength and loss of strength of the four cement brands blended with CPA and ages of curing in Sodium Sulphate respectively. A general increase in strength across all the brands of cement can be observed from the figure with as the ages progress till 56 days of curing when a general declination in strength set in except for Purechem cement which started declining from age 28 days. Purechem cement possessed a compressive strength of 5.83 N/mm^2 at age 7days which continues to increase with the ages till age 28 days to a strength value of 12.19 N/mm^2 (Figure 2). At age 56 days, a declination was observed and also at 90 days with a strength value of 6.39 N/mm^2 and a strength loss of 8.45 N/mm^2.

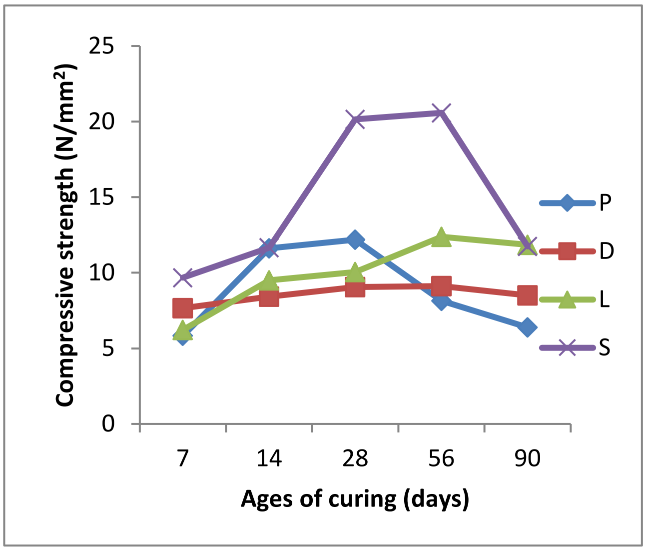

Fig 2.: Compressive strength of Mortar samples cured in Sodium Sulphate at different ages

It could be observed that the strength of Dangote cement blended with CPA rose with ages from 7.66 N/mm^2 with a loss of 2.2 N/mm^2, at 7 days to 9.12N/mm^2 and a loss of strength of 6.46 N/mm^2 at 56 days. Then a declination to 8.51 N/mm^2 at 90 days with an increase in loss of strength of 7.64 as compared with the control. Lafarge cement blended with cement also showed a similar trend through the first 28 days then a declination to a strength of 11.86 with a strength loss of 8.18 N/mm^2. The compressive strength of the Sokoto cement increase as well from age 7 with a value of 9.68 N/mm^2 through age 56 with a value of 20.58 N/mm^2 and a declination of strength at 90 days to 11.75 N/mm^2 yielding a loss of 9.01 N/mm^2.

IV. CONCLUSION

From the study of the effect of Sulphate attack on CPA-Cement Mortal with four different brands of cement and two different solution of Sulphate, it can be concluded that the flexural strength of Dangote cement mortar blended with CPA is the most affected by the Sulphate attack. Sokoto cement blended with CPA showed the greatest average resistant to all the Sulphate solutions. From the X-Ray fluorescence analysis of the cement brands, the oxides and mineral parameters shows the difference in reactivity of the brands. The values of the dicalcium and tri-calcium silicate aided the strength development. The cement brands are differed in properties due to varying percentage composition of CaO and the SiO_2; since these compounds form the raw materials of the calcium carbonate.

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