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Application of Palm Oil Fuel Ash as Source Material for Geopolymer Concrete Production

Yabefa B.E.[1], Jonathan B. J. [2] and Orumu S. T. [3*]

[1,2]Department of Agricultural, Environmental Engineering

[3]Department of Civil Engineering
Niger Delta University Wilberforce Island, Amassoma, Bayelsa State

*Corresponding author details: Orumu S. T.; solorumu@yahoo.com

ABSTRACT

This experimental study examined Palm Oil Fuel Ash (POFA) application as geopolymer binder source material for concrete production. Palm oil residues where sourced from Ogbia in Bayelsa State, cleaned and calcined in an uncontrolled temperature, ground, and sieved through 75 microns BS sieve. Chemical analysis carried out on the POFA using X-ray fluorescence. Sodium silicate and sodium hydroxide mixture in a ratio of 2:5 was used as an activator. Tests carried out on the concrete so produced include compressive, splitting tensile and flexural strengths at 7, 14, 21 and 28 days. It was shown from the results that, combined acidic oxide of POFA was 72.61% which can be grouped under class F pozzolan. The utmost compressive, splitting tensile and flexural strengths obtained for 28 days are 25.23N/mm2, 5.13N/mm2, 3.14 N/mm2 respectively. The strength increased with increase in curing days. Hence, using POFA as source material for geopolymer concrete production had good strength development.

Keywords: geopolymer concrete; palm oil fuel ash; concrete strength properties

INTRODUCTION

Concrete is a blend of cement, sand, granites and water. In the construction industry, concrete is the most desired construction materials for its outstanding structural characteristics. Cement is normally used as the binder in concrete, hence, it is significant to the economic and social wellbeing of the society. Cement production comes with serious challenges due to the emission of greenhouse gases such as carbon dioxide (CO2) which causes global warming. The production of cement causes about 10% of world's total CO2 emissions (Johnson & Gonzalez, 2013). Hence, based on these adverse effects associated with PLC production, construction workers have been encouraged to reduce the volume of cement used in concrete by either wholly or partial replacement with pozzolans which can be obtained locally in the environment (Tangchirapat, 2007). Much work has been done on application of local materials like fly ash, RHA, PSA etc. with pozzolanic properties as partial replacements for cement in concrete. Malhotra et al., (2005) described pozzolanasas materials that have less or without binding properties independently, but their particle sizes are reduced to finer sizes, when exposed to moisture, they can bond with calcium hydroxide at ambient temperatures to create the required properties of cement.

Experimental results from some researchers on POFA reveal that, the properties of POFA incorporated PLC concrete looks like the properties of the normal concrete. In the study, cement was replaced partially by POFA in different percentages such as 10%, 20% and 30%, where the strength was not significantly affected due to the pozzolanic properties of POFA.

In another study, Sukantapree et al., (2002) also presented that, application of POFA as supplement to PLC is possible in construction works. According to Ahmad et al., (2008), POFA is a very useful agro waste produced by calcining the residues that are obtained through the production of palm oil, such as, empty fruit brunches, shells, palm fibers etc. This ash contains silica that enables it to behave as a pozzolan to create a strong concrete.

Awal and Hussin (1997) presented that POFA can suppress the effect of expansion as a result of alkali-silica reaction and enhances resistance against sulfate attack, which was also confirmed by (Tangchirapat, 2007). It is a useful agro-waste material that is commonly available in most African countries. Therefore, this study is aimed at investigating the strength properties of POFA based geopolymer concrete, since, literature is sparse on the strength properties of POFA based geopolymer. Geopolymer binder is formed by activating aluminium and silica containing source material with an alkaline activator.

MATERIALS AND METHOD

Residues from palm oil extraction as shown in plate 1 were collected from a local industry in Ogbia, dried and calcined in an uncontrolled environment to form the POFA used in this study. Plate 1 show palm oil residues from which POFA was produced. The chemical analysis of POFA using X-ray Fluorescence was carried out in White House Laboratory, Effurun, Warri, Delta State and the results are presented in Table 2.

PLATE 1: Palm oil residues

TABLE 1: Chemical Analysis of POFA

Components	% Composition
Silicate oxide (SiO_2)	54.01
Aluminium oxide (Al_2O_3)	13.60
Ferrous oxide (Fe_2O_3)	5.1
Calcium oxide (CaO)	10.82
Pottasium oxide (K_2O)	2.62
Magnesium oxide (MgO)	2.89
Sodium oxide (Na_2O)	1.21
Lead oxide (PbO)	0.13
Copper oxide (CuO)	1.02
Loss on Ignition (LOI)	3.92

Combination of Na_2SiO_3 and NaOH was used as activator. The NaOH concentration was 8M, the ratio of Na_2SiO_3 to NaOH was 2.5 which was based on the findings by Hardjito et al., (2004) and Olivia *et al.,* (2017) in similar findings. The solution of Na_2SiO_3 (Na_2O = 15.10%, SiO_2=30.21%, and H_2O=54.89% by mass) was purchased from a local supplier. The POFA has a specific gravity of 2.3 and it can be classified under class F ($SiO_2 + Al_2O_3 + Fe_2O_3 = 72.71$). River sand and granites bought from the Amassoma market were used in the study. specific gravities of sand and granites are; 2.53 and 2.66 respectively. The mix proportion used in the study is shown in Table 2.

TABLE 2: Mix Properties of constituents for POFA based geopolymer concrete

Grade of GPC concrete	M25
Palm oil fuel ash (POFA) kg/m³	408
Sand(kg/m³)	612
Granites(kg/m³)	1346.4
Sodium silicate (Na_2SO_3) kg/m³	103
Sodium hydroxide (NaOH) kg/m³	41
Extra water (H_2O) kg/m³	41
Liquid to binder ratio	0.8
Ratio of mix proportions	1:1.5:3.3

The concrete specimen was cast in moulds of 100mm cube, 100mm × 200mm cylinder, and 100mm × 100mm × 500mm beam, and allowed for a rest period of 24 hours before they were demoulded and cured at 60°C for 6 hours, and kept in the laboratory under room temperature. The compressive, splitting tensile and flexural strength at 7, 14, 21 and 28 days were tested.

Plate 2 presents the fresh mixture of the geopolymer concrete.

PLATE 2: Fresh geopolymer concrete

RESULTS AND DISCUSSIONS

Compressive Strength

This was tested using the UTM as provided in BS. 1881. Part 116: 1989. The average strength for the sample for each testing day is presented in Table 3 and illustrated in Figure 1. The result showed that, compressive strength increased as the curing period increased. The compressive strength ranged from 14.33N/mm² for 7 days to 25.23N/mm² for 28 days respectively. The compressive strength had 76.06% increment after 28 days of curing, which was up to the designed characteristic strength of the concrete.

TABLE 3: Compressive Strength

S/N	Curing Duration (Days)	Compressive Strength readings N/mm²	Average Compressive Strength N/mm²
1	7	14	14.33
		15	
		14	
2	14	15.5	15.83
		16	
		16	
3	21	21	20.00
		19	
		20	
4	28	26	25.23
		25.7	
		24	

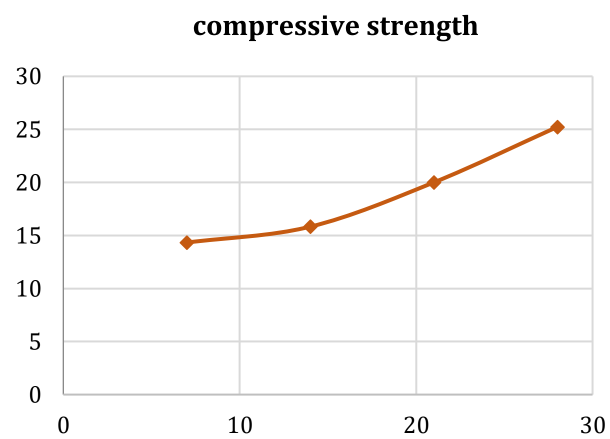

FIGURE 1: Compressive strength development with curing duration

Splitting Tensile Strength
This is used in determining the ability of the concrete to withstand tensile loading. The result shows that, there was an increase in strength as the curing days increased. Table 4 shows that, the splitting tensile strength of the samples at 7, 14, 21, and 28 days are 2.72N/mm², 4.52N/mm², 4.70N/mm², 5.13N/mm² respectively. It was revealed that the strength had an increase of 88.6% from 7 to 28 days. Figure 2 presents the relationship between splitting tensile strength and curing duration.

TABLE 4: Split Tensile Strength

S/No.	Curing Duration days	Splitting tensileStrength (N/mm²)	Average splitting tensile strength (N/mm²)
1	7	2.66	2.72
		2.85	
		2.66	
2	14	4.52	4.52
		4.70	
		4.33	
3	21	4.52	4.70
		4.70	
		4.89	
4	28	5.07	5.13
		5.07	
		5.25	

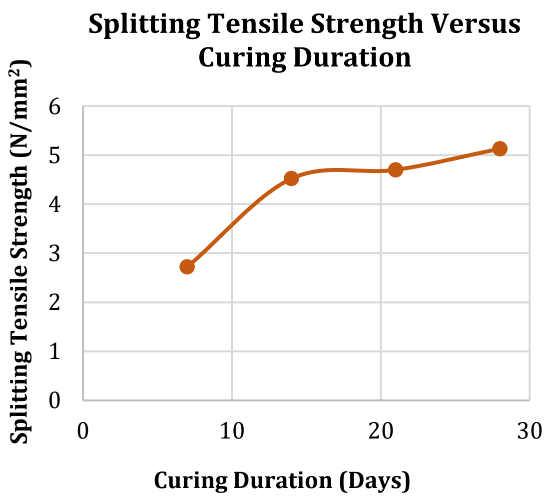

FIGURE 2: Splitting tensile strength development

Flexural Strength of POFA based Geopolymer Concrete Beams
The result of POFA based geopolymer concrete as presented in the Table 5 indicates an increase in the flexural strength as curing duration increases. The highest strength of 3.14 N/mm² was observed and recorded for 28 days of curing and minimum strength of 1.30N/mm was observed and recorded after 7 days of curing. The result of the flexural strength is also illustrated in Figure 3 below. It was revealed that the flexural strength had an increase of 141% from, 7 to 28 days of curing.

TABLE 5: Flexural strength for POFA based geopolymer concrete

S/No.	Curing Duration	Flexural strength (N/mm²)	Average flexural strength (N/mm²)
1	7days	1.24	1.30
		1.43	
		1.25	
2	14days	1.53	1.61
		1.65	
		1.65	
3	21days	2.91	2.63
		2.35	
		2.62	
4	28 days	3.54	3.14
		2.43	
		3.44	

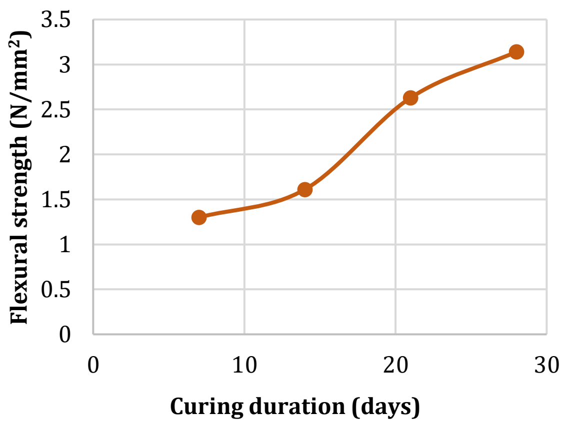

FIGURE 3: Flexural strength development with curing age

CONCLUSIONS
The conclusions below are drawn from the findings of this study;

- POFA can be grouped under class F ash with combined acidic oxide of 72.71%, hence can be applied as geopolymer source material for concrete production.
- The mechanical properties increased generally with increase in curing days from 7 – 28 days.
- The maximum compressive, split tensile and flexural strengths are; 25.23N/mm², 5.13N/mm², 3.14 N/mm²respectively.

RECOMMENDATION
The following recommendation are proposed

- Other mix ratio needs to be studied to see if High Strength concrete HSC can be achieved using the POFA based geopolymer concrete
- Other variants of POFA as a base for geopolymer concrete needs to be prepared and investigated to achieve better qualities in terms of strength and durability
- A comparative Benefit cost analysis between POFA Geopolymer concrete and Portland Limestone Cement Concrete is an area to be looked into, in order to see if it could be used to completely replace cement.

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