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The Influence of Palm Oil Fuel Ash (POFA) on the Mechanical Properties of Portland Limestone Cement Concrete

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Abstract

This experimental study involves the investigation of how the strength properties of Portland Limestone Cement concrete is influenced by the palm oil fuel ash. The characterization of the POFA was done in this study. The percentage replacement with POFA were 0%, 5%, 15%, and 20%. The mix ratio and water/binder ratio considered are 1:2:4, and 0.5 respectively. The various tests done on the samples include; compressive, splitting tensile, and flexural strengths. The result showed that, the specific gravity of PLC, POFA were; 3.13 and 2.19 respectively. The highest concrete strengths of 44.12, 3.51 and 4.36 N/mm^2 for compressive, splitting tensile and flexural strengths respectively were obtained at 10% replacement in 28 days curing period. The study revealed that, POFA has good properties that makes it suitable to be used as a partial replacement for PLC to produce light weight concrete for less expensive structural applications.

Keywords: *Concrete, P OFA, compressive strength, tensile strength, flexural strength*

1. INTRODUCTION

The durability of concrete has been considered to be a vital point of concern in construction works around the globe. Hence, much work has been done by different scholars across the globe to improve the strength characteristics and ability of concrete to resist against sulfate attacks by using pozzolanic materials. The most conventionally used pozzolanas are blast furnace slag, fly ash, metakaolin etc. Again, there are still more intensive investigations in search of locally available materials from agro-wastes to be used as pozzolans which are more environment friendly including corn cob ash (Adesanya 2001).

The increasing cost of things in Nigeria and around the world has also increased the cost of all construction materials to an extent that, most of the conventionally used materials cannot be easily reached for the construction of low cost houses. Therefore, it is a necessity to produce low cost construction materials which can be durable but using locally available materials and simple technology (Soneye et al., 2016). The application of such materials can also serve as a source of income to some persons who may engage in the production of such materials, which may also reserve the level of foreign exchange. Most researchers have encouraged the use of naturally

occurring materials as replacement for the conventional construction materials to reduce the cost of construction works (Soneye et al., 2016).

Concrete can be described as a construction material that is highly demanded, and it is a extensively used construction material in Nigerian and around the globe for construction works/projects. It is one of the main building materials that can be transported to the construction site in a plastic condition, which can be precast or molded in an almost infinite number of shapes. Its primary ingredients are water, cement, and fine and coarse aggregates (sand and granites). So, the availability of the ingredients has a huge impact on the total cost of making concrete (Adewuyi et al., 2008). Crushed stone or gravel in Nigeria are directly proportional to the price of concrete, and they rise from north to the south. Construction costs are higher in the Southern part of Nigeria, hence, researchers have suggested that, for non-load bearing walls and non-structural floors in structures, lighter alternatives can be used (Adewuyi et al., 2008)

The POFA is an agricultural waste that is produced from palm oil fruit while processing palm oil, which has many economic and environmental benefits. According to Sukantapree et al. (2002), POFA can be used in building projects as an addition to PLC. The wastes from the manufacturing of palm oil, (i.e. palm fibers, empty fruit brunches, shells, etc.) are calcined to create POFA, a very beneficial agricultural waste, according to Ahmad et al. (2008). Because it includes silica, this ash can act as a pozzolan to produce concrete that is strong. The qualities of POFA-incorporated PLC concrete appear to be similar to those of regular concrete, according to experimental findings by some researchers. The POFA's pozzolanic qualities allowed it to be used in place of cement in varying percentages for concrete production. POFA can increase resistance against sulfate attack and inhibit the effect of expansion caused by the alkali-silica reaction, according to Awal and Hussin (1997). Therefore, this study aimed to evaluate the influence of POFA on the strength properties of concrete when used as substitute for cement in concrete production.

2. MATERIALS AND METHOD

The POFA that was used as the substitute for the PLC in this work was produced from residues of palm oil extraction that were obtained from a dumpsite in a local industry in Ogbia town. The materials were dried before they were calcined in an uncontrolled environment. The Portland Limestone Cement (PLC) used in this study was the Dangote brand of cement which conforms to the requirements of BS12. The river sand and granites used in the study were obtained from local dealers in Amassoma, Bayelsa State. The batching of materials was done by weight using the weighing balance. Then, concrete samples of 100mm cube, 100mm by 100mm by 500mm beams, and 100mm by 200mm cylinders were prepared and cured at 7, 14, 21 and 28 days before the test. The POFA was used as a substitute for cement in different percentages ranging from 5 - 20% in steps of 5. The mix ratio used for the study was 1:2:4, and water to binder ratio was 0.5. The concrete samples were prepared in accordance with BS 1881.

3. RESULTS AND DISCUSSION

The preliminary test result for specific gravity SG and fineness modules FM of the samples showed that, the SG of PLC, POFA, sand and granites were; 3.13, 2.19, 2.65 and 2.72 respectively, the fineness modules for PLC, POFA and sand are; 2%, 2.58% and 2.5%. Table 1 presents the XRD analysis of POFA that was carried out in White House Lab. Effurun, Delta State.

Table 1: Analysis of POFA

Composition	%
SiO_2	54.0
Al_2O_3	14.0
Fe_2O_3	5.0
CaO	11.0
K_2O	3.0
MgO	3.0
Na_2O	1.0
PbO	0.13
CuO	1.0
LOI	4.0

3.1 Compressive Strength

Compressive strength was tested with the Universal Testing Machine in accordance with BS. 1881. Part 116: 1989. The average test results are shown in Table 2 and illustrated in Figure.1. It was revealed from the result that, the strength increased with respect to the number of curing days from 7 - 28 days. Again, the strength increased as the percentage of POFA replacement increased from 5 - 10% and decreased thereafter as the replacement increased to 20% in all curing days. The compressive strength at day 28 for samples with 0 to 20% of POFA are 41.20, 41.45, 44.12, 40.30, 38.50N/mm^2 respectively. The compressive strengths of samples with 10% replacement had the highest strengths which ranged from 38.13N/mm^2 – 44.12N/mm^2 for 7 - 28 days respectively. There was 15.7% increment of the compressive strength after 28days of curing. this was also confirmed by Aiswarya et al., (2017) in a similar study.

Table 2: Compressive strength result

S/NO.	**% POFA**	**Compressive Strength (N/mm^2)**			
		7days	**14days**	**21days**	**28days**
1.	0%	34.1	35.01	38.67	41.2
2.	5%	35.8	37.21	38.89	41.45
3.	10%	38.3	38.96	40.11	44.12

4.	15%	33.95	34.67	37.89	40.30
5.	20%	30.34	32.23	36.11	38.50

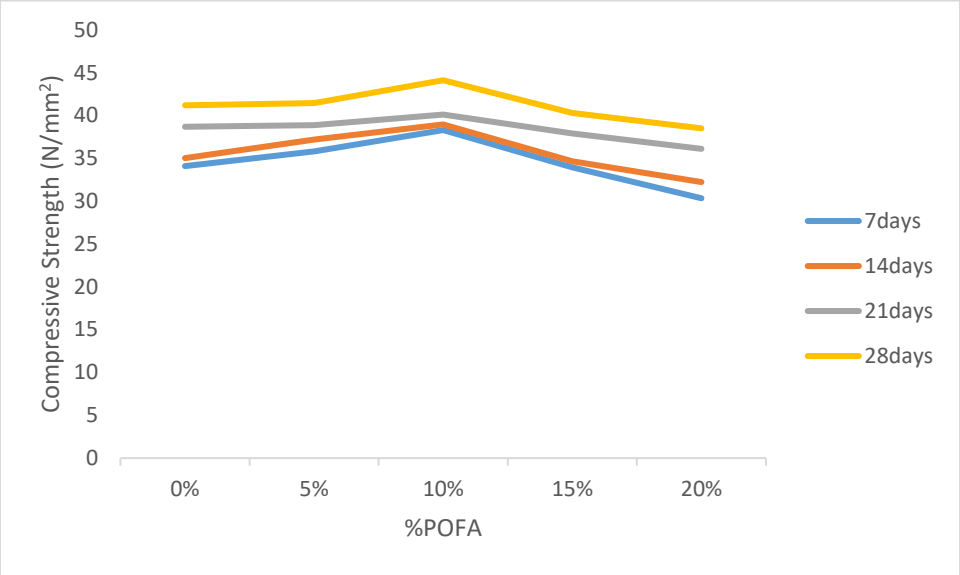

Figure 1: Influence of %POFA on the compressive strength of PLC concrete

3.2 Splitting Tensile Strength

This test was done to evaluate the tensile load bearing capacity of the concrete samples. The result for the tensile strength test is shown in Table 3, and Figure 2 gives an illustration of it. It was revealed that, splitting tensile strength increased as the number of curing days increased from 7 to 28 days. Also, it increased as the percentage replacement increased from 5 to 10% and decreased thereafter as the replacement increased to 20% in all curing days. The splitting tensile strength at day 28 for samples with 0 to 20% of POFA are 3.45, 3.22, 3.51, 3.48, 3.10N/mm^2 respectively. The splitting tensile strengths of samples with 10% replacement had the highest strengths which ranged from 2.95N/mm^2 – 3.51N/mm^2 for 7 - 28 days respectively.

Table 3: Splitting tensile Strength test result

S/NO.	% POFA	Splitting Tensile Strength (N/mm^2)			
		7days	14days	21days	28days
1.	0%	2.75	2.85	3.01	3.46
2.	5%	2.80	2.86	2.98	3.22
3.	10%	2.95	3.00	3.16	3.51
4.	15%	2.76	2.94	3.01	3.48
5.	20%	2.45	2.56	2.88	3.10

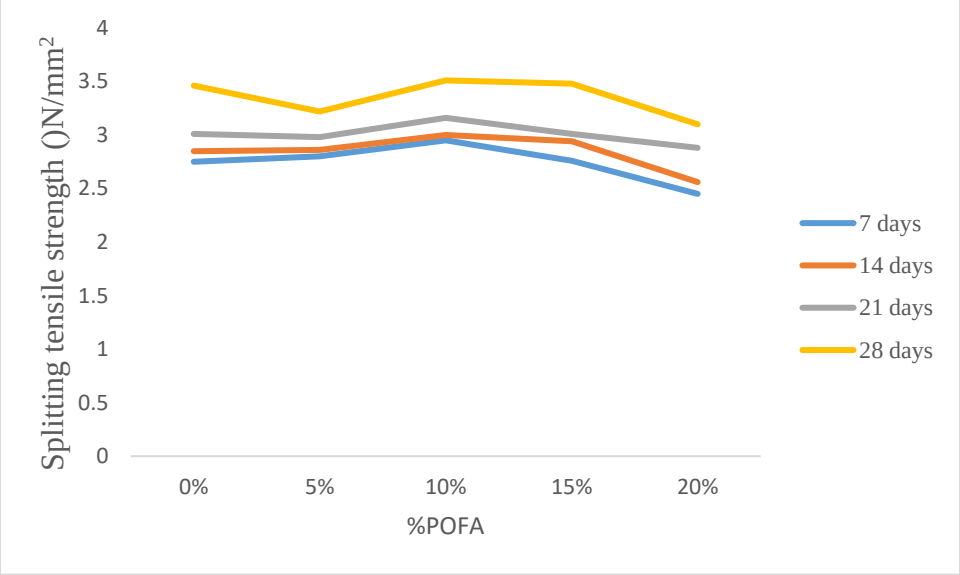

Figure 2: Influence of %POFA on the splitting tensile strength of PLC concrete

3.3 Flexural Strength

The ability of the concrete beam sample to resist failure due to bending is related to the flexural strength the sample. The test result is presented in Table 4 and demonstrated in Figure 3. The result showed that, strength increased as the number of curing days increased from 7 to 28 days. The Flexural strength increased as the percentage replacement increased from 5 to 10% and decreased thereafter as the replacement increased to 20% in all curing days. The flexural strength at 28 days for samples with 0 to 20% of POFA are 4.12, 4.20, 4.38, 4.22, 4.00 N/mm^2 respectively. The highest flexural strengths were obtained in samples with 10% replacement which ranged from 4.10N/mm^2 – 4.38N/mm^2 for 7 - 28 days respectively.

Table 4: Flexural Strength test result

S/NO.	%POFA	Flexural Strength (N/mm^2)			
		7days	14days	21days	28days
1.	0%	3.90	3.90	4.00	4.12
2.	5%	3.95	4.0	4.06	4.20
3.	10%	4.10	4.15	4.21	4.38
4.	15%	3.88	3.99	4.11	4.22
5.	20%	3.84	3.87	3.98	4.00

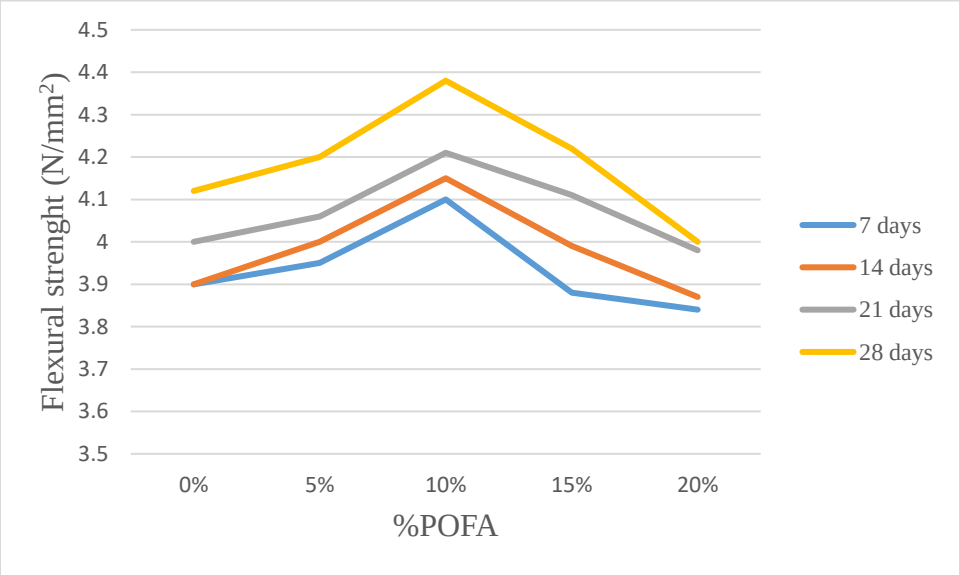

Figure 3: Influence of %POFA on the flexural strength of PLC concrete

4. CONCLUSION

The following conclusions were made at the end of this study;

i. The specific gravity of PLC, POFA are; 3.13, 2.19 respectively while the specific gravity of fine and coarse aggregates is; 2.65 and 2.72 respectively, the fineness modules for PLC, POFA are; 2%, 2.58%.
ii. As the percentage of POFA increased in the mixture, the strength started reducing, however, the highest strength of the concrete was obtained at 10 %POFA replacement. The concrete strength also increased with increasing curing duration.
iii. The percentage inclusion of PSA in the concrete also enhanced the splitting tensile and flexural strength of the concrete.
iv. The use of POFA as partial replacement for PLC in concrete production did not only reduce the cost of concrete but a source of pollution control in the environment.

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