Effect of Raffia Palm Ash (RPA) on the Compressive Strength of Concrete

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Abstract:- The urgent need to source for an ecofriendly construction materials to replace the existing non-ecofriendly ones, has led to massive interest in the use of agricultural wastes as substitute for cement in concrete. Hence, this study presents an experimental investigation on the mechanical, durability and microstructural performance of Raffia Palm Ash (RPA) with varying dosage. Mortar and concrete specimens were cast at 10%, 20% and 30% replacement of ordinary Portland Cement (OPC). The optimum dosage and performance of RPA based concrete specimens was evaluated by testing the compressive strength for 7, 14, 21 and 28 days. The outcome of all test indicated that the mixtures prepared with 0% RPA replacement in concrete was the highest seconded by that of 10% RPA dosage.

***Keywords**:- Coconut Fibre Ash, Concrete, Compressive Strength, Slump Test, Ordinary Portland Cement, Pozzolanic Material.*

I. INTRODUCTION

Concrete is the second largest material used by man mainly for construction works [1]. Its usage is second only to that of water, an important component needed to promote the hydraulic action of cement, a principal binder in concrete [1]. Apart from water and cement, other constituents of concrete include aggregates (coarse and fine) as well as admixtures. Portland cement, water, sand, and coarse aggregate are proportioned and mixed to produce concrete suited to the particular job for which it is intended. The process of cement production is highly energy consuming and is one of the major sources of carbon dioxide emission to the atmosphere [1].

The need for affordable building materials in providing adequate housing for the teaming populace of the world has become the major concern of researchers. The cost of conventional building materials continue to increase as the majority of the population continues to fall below the poverty line. This thereby necessitates the need for alternative local materials as total or partial replacement for cement in concrete. The search has led to the discovery of the potentials of industrial by-products and agricultural wastes as cementitious materials. The utilization of agricultural waste products in cement production is an environmentally-friendly method of disposal of large amounts of materials that would have constituted pollution to land, water and air [2].

According to Sooraj [3] for concrete production, the reduction of cement content in concrete can be achieved by utilization of supplementary cementitious materials such as fly ash, blast furnace slag, natural pozzolans, and biomas ash. Raffia palm (Raphia Hookeri) is the largest palm in Africa and is restricted to the tropical rainforest, the ideal ecological condition for its growth. It is one of the most economically useful plants in Africa.

[4] proposed the use of Palm Oil Fuel Ash (POFA) as partial replacement ranging from 0-30% by weight of the total cementitious material in the production of concrete. [5] carried out an experimental research on the strength performance of concrete using Portland pozzolana Cement and Sugarcane Bagasse Ash (SCBA). They observed that the finely grounded SCBA can successfully replaced cement and is responsible for higher compressive strengths than normal concrete (keeping quantity of cement constant) [6] developed mathematical models for predicting the compressive strength characteristics of Sugar Cane Bagasse Ash Concrete (SCBAC) using Scheffe's (5, 2) polynomial. A study was conducted to investigate the acid resistance of concrete containing Sugar Cane Straw Ash (SCSA) by [7]. He used SCSA to partially replace Portland cement by weight of binder in order to prepare SCSA concrete. [8] conducted an investigation into the strength properties of Palm Kernel Shell Ash concrete. The main objective of their work was to alleviate the challenges of scarcity and high cost of construction materials used by the construction industry in Nigeria and Africa in general, by reducing the volume of cement usage in concrete works. [3] studied the effect of Palm Oil Fuel Ash (POFA) on the strength properties of concrete. In his work, the strength properties such as compressive strength, flexural strength and split tensile strength were studied, and compared with that of concrete containing 100% ordinary Portland Cement (OPC) as control. The experimental results revealed that POFA is an excellent pozzolanic material which can be used as cement replacement in concrete. It was recommended that the optimum replacement level of OPC by POFA is 20% for a good strength in compressive test.

Under this research work, an experimental investigation on the compressive strength performance of Raffia Palm Ash (RPA) with varying dosage was conducted. The optimum dosage and performance of RPA based mortar and concrete specimens was evaluated by measuring the compressive strength up to 7, 14, 21 and 28 days while rate of water absorption and rapid chloride permeability tests will be determined after 28-day curing in water.

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II. MATERIALS AND METHODS

A. Materials

- *Cement*

The type of cement selected for this research work is ordinary Portland cement (OPC). There are various brands available in the Nigerian Building material Markets such as Dangote, BUA, Unicem, Elepahnt Cement (Which is of two grades: 42.5 for Supaset and 32 for ordinary one). Elephant Supaset is a Portland Limestone Cement conforming2 to the Nigerian cement standards NIS 444-1: 2003 & EN 197-1:2011 specifications will be used in all the four concrete and mortar mixtures.

- *Raffia Palm Ash*

Raffia palm ash is a material produced from the process of recycling local Raffia palm or from burning local palm dead fronds which is obtained from Uli Anambra State in the eastern region of Nigeria.

The local palm ash is produced from wastage by process of heating the raw material in an oven for 7 hours. The local palm firewood is first produced which turn into local palm coal and after burning the wastage together with those from the straw we get the Raffia palm ash.

In this research, Raffia palm ash passing 425 µm sieve is used. 10%, 15% and 20% of palm ash (RPA) will be incorporated as replacement of OPC.

- *Aggregates*

The coarse and fine aggregates used are crushed granite and river sand, respectively from local quarries. The grading of fine aggregates was conforming to BS 882 (1992).

Sieve analysis of both RPA and sand was carried out with sieve size No. 4, 10, 40, 100 and 200. The ratio of 1:2:4were kept constant in all the concrete mixtures. Moreover, all the concrete and mortar specimens were prepared with a w/cm ratio of 0.4 and potable water was used for mixing and curing the specimens.

- *Water*

The water used for the study was obtained from a free flowing stream. The water was clean and free from any visible impurities. It conformed to BS EN 1008:2002 requirements.

B. Specimen preparation

Four concrete mixtures were prepared inside the laboratory using neat OPC and three percentage replacement level (10%, 15% and 20%) of Raffia palm ash to OPC. The concrete and mortar constituents were weighed in required proportions and mixed in a concrete mixer.

C. Mix proportions of concrete specimens

The proportioning by weight was used in this research. The cement-aggregates ratio used in this work is 1:2:4. RPA were used to replace OPC at dosage levels of 10% , 15% and 20% replacement by weight of binder. The mix proportions to be used are calculated below:

$No. of\ Cubes\ per\ Batch$

$= 32\ (i.e. Eight\ cubes\ each\ for\ ages\ 7, 14, 21\ and\ 28\ days$

Batch implies Control Mix (0% PKSA Replacement),

10% RPA Replacement

15% RPA Replacement and 20% RPA Replacement

$Size\ of\ each\ Cube = 150\ mm \times 150\ mm \times 150\ mm$

$Size\ of\ each\ cube = 150mm \times 150mm \times 150mm$

$Volume\ of\ one\ Cube = 150^3 = 3.375 \times 10^{-3} m$

$Volume\ of\ 32\ cubes = 32 \times 3.375 \times 10^{-3} = 0.108\ m^3$

To account for wastage, it was factored by 1.2

$Volume\ of\ the\ Batch = 0.108 \times 1.2 = 0.130\ m^3$

$The\ ratio\ to\ be\ used\ in\ this\ research\ is\ 1:2:4$

$= cement: Sand: Coarse\ Aggregate$

$Volume\ of\ Cement = \frac{1}{7} \times 0.108 = 0.0154\ m^3$

$Standard\ Weight\ of\ Concrete = 2400\ kg/m^3$

Therefore:

$Weight\ of\ cement\ in\ one\ Batch = 2400 \times 0.0154$

$= 37.03kg \cong 37kg$

$Similarly:$

$Volume\ of\ sand = \frac{2}{7} \times 0.108\ m^3 = 0.031\ m^3$

$Weight\ of\ sand = 2400 \times 0.031 = 74.4\ kg$

$Volume\ of\ Coarse\ Aggregate = \frac{4}{7} \times 0.108\ m^3 = 0.062\ m^3$

$Weight\ of\ sand = 2400 \times 0.062 = 148.11\ kg$

The water to binder ratio adopted in the course of this research was 0.5 and this was used to calculate the amount or weight of water required per batch.

$Weight\ of\ water = 0.5 \times weight\ of\ bimder\ (Cement$

$= 0.5 \times 37 = 18.5\ kg$

D. Casting and Compaction of Concrete

The oiled plastic moulds, free from any foreign material were arranged close to the platform. The concrete was simultaneously filled in the moulds approximately 150mm thick and each layer was compacted on compacted table using tamping rod. The surplus on the mould was stripped off and leveled by hand trowel. The specimens were packed neatly to maintain proper hydration of the cement.

E. Curing

After casting, placing, compacting and finishing operation, all specimens were covered with a plastic sheet till demoulding. The specimens were remolded after 24 hours and immersed in water in a water tank for 28 days. This was done in accordance with BS 1881: part 111, 1983. Once the desired curing period is completed, the specimens were taken out from the curing tank to prepare them for test program.

F. Tests

The effect of Raffia palm ash dosage on mortar and concrete specimens was assessed by measuring following mechanical and durability properties:

➢ *Chemical Composition*

Chemical composition analysis for PA: to determine the mineralogical analysis of PA, chemical composition analysis for PA was determined for silica, Ca, K, Mg, Na, Al, Fe. Loss on Ignition was done as per standard method.

➢ *Workability*

Slump test was conducted on the fresh concrete to determine their ease of mixing, placement and compaction. The slump test was used to test the workability of the concrete. A slump cone mold of diameters 200mm and 100mm, and height 300mm was filled with concrete in three layers of equal volume. Each layer was compacted with 25 strokes of a tamping rod. The slump cone mold was lifted vertically and the change in height of concrete was measured to the nearest millimetre of 1mm.

➢ *Compressive Strength*

Compressive strength was assessed at the ages of 3, 7, 14, 28 days of curing on 150 mm cube mortar specimens, as per BS 1881: Part 116 (1983) and tested by means of compression testing machine at standard loading rate.

The sample was weighed before being put in the compressive test machine. The machine automatically stops when failure occurs and then displays the failure load. Two specimens were tested at each age from each mix and their average reading is reported.

➢ *Density of Concrete*

The concrete cubes where dried and weighed using a weighing balance prior to crushing at 7, 14, 21, 28 days. The weight obtained was divided by the volume on one cube to obtain results for the concrete densities.

III. RESULTS AND DISCUSSION

A. Experimental Mix Design

The result of the concrete mix design are shown in table 1.

Table 1: Concrete Mix Design

Constituent Materials	0% RPA (Control)	10 % RPA	20 % RPA	30 % RPA
Cement (kg)	34.0	30.6	27.2	23.8
RPA (kg)	0.0	3.40	6.80	10.2
Fine Aggregate (kg)	68.0	68.0	68.0	68.0
Coarse Aggregates (kg)	136.0	136.0	136.0	136.0
Water/Cement Ratio	0.6	0.6	0.6	0.6
Total Water (kg)	20.4	20.4	20.4	20.4

B. Compressive strength

The compressive strength development in OPC, 10% RPA, 20% RPA and 30% RPA mortar specimens with curing period is shown in table 2.

Table 2: The Compressive Strength Test Results

Amount of Cement (%)	Amount of RPA (%)	Design Strength (N/mm^2)			
		7 Days	14 Days	21 Days	28 Days
100	0	11.34	18.52	20.60	22.54
90	10	8.28	15.10	16.75	19.32
80	20	6.58	12.34	13.61	16.45
70	30	5.38	11.30	11.97	14.36

The highest early strength development was noted in mortar specimens prepared with 100% OPC, followed by 10% RPA, 20% RPA and 30% RPA specimens respectively. The 7-day compressive strength of OPC, 10% RPA, 20% RPA and 30% RPA mortar specimens was 11.34, 8.28, 6.58 and 5.38 N/mm^2, respectively. The 28-day strength development was found to be also highest in 100% OPC specimens and lowest strength was achieved in both 20% and 30% PA specimens having marginal difference. The 28-day compressive strength of OPC specimens was 22.54 N/mm^2 which is about 14.3%, 27% and 36% more than that of 10% RPA, 20% PA and 30% PA specimens, respectively.

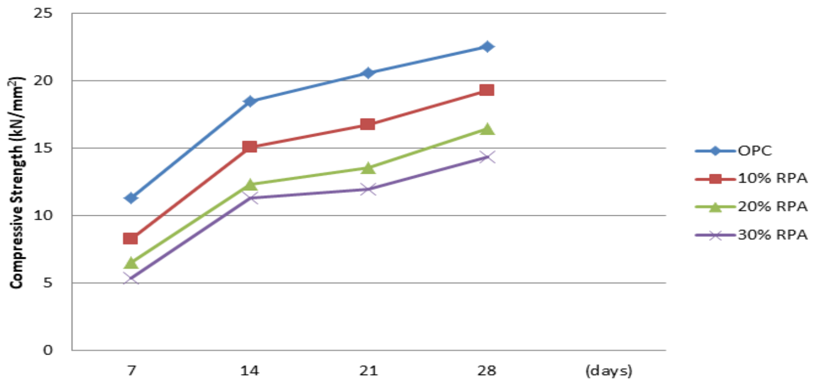

Fig. 1: Compressive strength development in all mortar mixtures.

C. Slump cone test

A high quality concrete is one which has appropriate workability in the fresh condition. Basically, the greater the measured height of slump , the improved the workability will be , indicating that the concrete flows easily but at the same time is free from segregation the slump achieved at the rate of 30mm to 40 mm for the different mix of RPA and OPC. It is found that workability of concrete increases by increasing the percentage of replacement of RPA in concrete.

Table 3: Slump Test Results

Amount of Cement (%)	Amount of RPA (%)	Slump (mm)
100	0	**43.6**
90	10	**42.1**
80	20	**36.0**
70	30	**30.0**

D. Fineness Test

Based on the finite test, the fineness of RPA was measured by sieving it on standard sieve. The proportion of RPA of which its particle sizes are greater than 90 micron os determined as 0.8%.

E. Particle Sieve Analysis of RPA

The result of the particle sieve analysis conducted on Raffia Palm Ash (RPA) are displayed on table 4. The result are represented on the particle seize distribution curve shown on figure 4.

Table 4: Sieve analysis result table for RPA

Sieve Size (mm)	Percentage Passing
0.6	100.00%
0.425	54.66%
0.3	28.37%
0.212	13.40%
0.15	7.06%
0.075	2.81%
0.063	0.77%

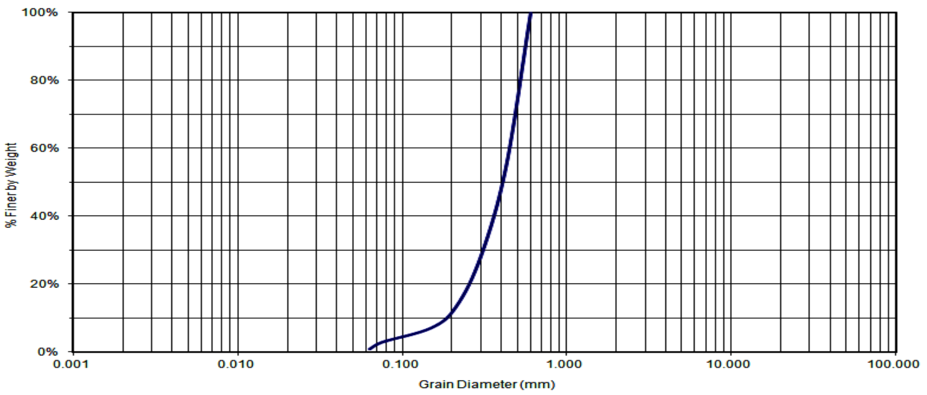

Fig. 2: Particle size distribution curve for RPA

Table 5: Specific Gravity of RPA

Sample Weight (g)	Test A (g)	Test B (g)
W1	22.70	23.20
W2	32.80	33.31
W3	77.90	77.75
W4	73.10	72.80
G_S	1.91	1.96
G_S	1.93	

$$G_s = \frac{(W_2 - W_1)}{\{(W_4 - W_1) - (W_3 - W_2)\}} \qquad 4.1$$

$$Average = G_s = \frac{1.91 + 1.96}{2}$$

$$G_s = 1.93$$

F. Density of Concrete Cubes

The density of the concrete cubes for OPC, 10% RPA, 20% RPA and 30% RPA where determined after curing in the water tank for 7, 14, 21 and 28th days by measuring the mass and dividing the value by the volume of one cube (150mm x 150mm x 150mm). The results are shown in table 6.

Table 6: Density of Concrete cubes

($x10^3$ kg/m^2)	7 days	14 days	21 days	28 days
0% RPA	2.44	2.47	2.53	2.55
10% RPA	2.43	2.45	2.48	2.52
20% RPA	2.40	2.41	2.46	2.49
30% RPA	2.40	2.42	2.44	2.45

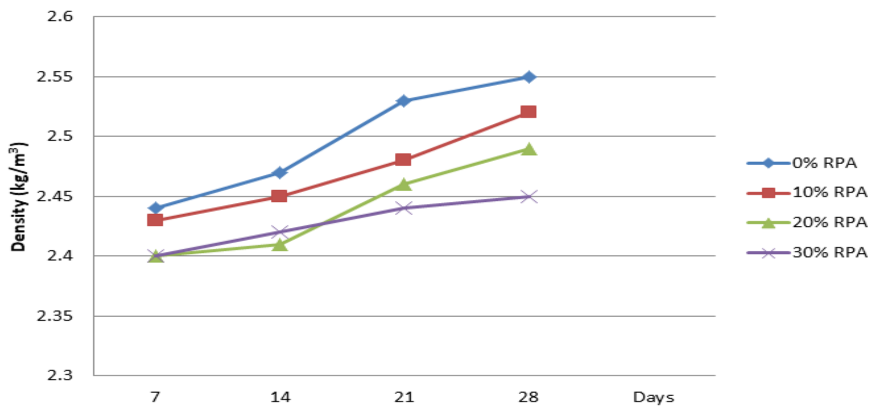

Fig. 3: Densities (x103kg/m3) of various RPA contents

IV. CONCLUSION

Based on the findings from this study, the following conclusions can be arrived at;

- The use of RPA as a partial replacement for cement exhibits a lower water absorption rate and slower setting time of concrete.
- Concrete strengths increases with curing age and decreases with increasing percentage of RPA replacement in concrete.
- The use of RPA will reduce the volume of cement used in concrete, thereby reducing the cost of concrete production.

The use of PKSA will minimize the environmental issues arising from the disposal of Raffia Palm Wastes.

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