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The Potential Use Of Coconut Fibre Ash (CFA) In Concrete

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ABSTRACT
The urgent need to reduce excessive green house emission from the manufacturing process of Ordinary Portland Cement (OPC) has led to an increasing interest in the use of agricultural waste in producing quality construction materials. This study presents an experimental investigation on the strength performance of Coconut Fibre Ash (CFA) with varying dosage. Concrete specimens were cast at 10%, 20% and 30% replacement of OPC. The optimum dosage and performance of Coconut fibre ash based concrete specimens was evaluated by measuring the compressive strength up to 28 days. The outcome of all test properties indicated that the mixtures prepared with 0% CFA in concrete was optimum seconded by that of 10% CFA dosage.
KEYWORDS;- Coconut Fibre Ash, Concrete, Compressive Strength, Slump Test, Ordinary Portland Cement, Specific Gravity Test, Sieve Analysis Test, Pozzolanic Material.

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I. INTRODUCTION

Concrete is a material made from aggregates, cement, water and sometimes admixtures. In ordinary form, concrete contains about 12% cement, 8% water and 80% aggregates by mass. Aggregates and water are from natural resources, only cement must be produced in fabrics, processes which are polluted the environment. According to [1], for producing 1 m^3 of concrete a quantity of 480 kg of CO_2 is liberated in the atmosphere. Because the cement industry is responsible for 5-7% of worldwide emission of CO_2, (which means 1.6 billion tons of carbon dioxide into the atmosphere), in preparing concrete, the cement dosage can be reduced by using mineral additions, strategy that also can contribute to environment protection by preserving the energy and consume the huge quantities of wastes. The building material industry is a domain of interest for using the wastes and researchers have tried to produce new construction materials incorporating wastes. The new generation of building materials is developing on other theories in concordance with the sustainability of environment. According to [2], 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 biomass ash. Coconut shell and husk consist of agricultural wastes and are available in large quantities throughout tropical countries worldwide like Nigeria, Brazil and Ghana. In many countries, coconut shell is subjected to open burning which contribute significantly to CO_2 and methane emissions. Coconut shell is widely used for making charcoal. The traditional pit method of production has a charcoal yield of 25–30% of the dry weight of shells used. The predominant use of coconut husks is in direct combustion in order to make charcoal; otherwise husks are simply thrown away. Over the past few decades, many studies have been conducted for the use of agro waste ashes as a partial replacement of cement in concrete production. [3], discovered that the concrete produced using a particular level of Palm Oil Fuel Ash (POFA) replacement achieved same or more strength as compared to Ordinary Portland Cement (OPC) concrete. No significant strength reduction of concrete is observed up to about 30% replacement of POFA. [4], reviewed that the use of POFA is limited to a partial replacement, ranging from 0-30% by weight of the total cementitious material in the production of concrete. [5], investigated the evaluation of physical and mechanical properties of partially replaced bamboo ash cement mortar. They conducted various tests such as fineness, soundness, drying shrinkage, air entrainment, water absorption, consistency, setting time, chemical composition and observed that bamboo ash is not suitable material for use as a pozzolan. [6] Investigated that high volume palm oil fuel ash concrete, like concrete made with other pozzolanic materials, showed a slower gain in strength at early age. An experimental 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], 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 be successfully replaced by cement and is responsible for higher compressive strengths than normal concrete (keeping quantity of cement constant). Under this study, an experimental investigation on the mechanical, durability and micro-structural performance of Coconut Fibre Ash (CFA) with varying dosage will be conducted. The optimum dosage and performance of CFA based concrete specimens will evaluated by measuring the compressive strength up to 28 days while rate of water absorption tests will be determined after 28-day curing.

II. MATERIALS AND METHODS

2.1 Materials

2.1.1 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 conforming 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.

2.1.2 Coconut Fiber Ash (CFA)

Coconut Fiber Ash is produced from the process of recycling local Coconut Husk and shells extracted from coconut fruits. The fiber and husk are dried and heated in an improvised over for over 10 hours at a temperature below 600 ^{0}C. In this research, CFA passing 425 µm sieve is used. 10%, 20% and 30% of (CFA) will be incorporated as replacement for OPC.

2.1.3 Aggregates

The coarse and fine aggregates used are crushed granite and river sand, respectively from local quarries. Sieve analysis of both CFA and sand was carried out with sieve size No. 4, 10, 40, 100 and 200. The ratio of 1:2:4 were kept constant in all the concrete mixtures. Moreover, all the concrete and mortar specimens were prepared with a w/cm ratio of 0.6 and potable water was used for mixing and curing the specimens.

2.1.4 Water

The water used for the study was obtained from a free flowing stream. The water was clean and free from any visible impurities.

2.2. Specimen preparation

Four concrete mixtures were prepared inside the laboratory using neat OPC and three percentage replacement level (10%, 20% and 30%) of CFA to OPC. The concrete and mortar constituents were weighed in required proportions and mixed in a concrete mixer.

2.3 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. CFA were used to replace OPC at dosage levels of 10%, 20% and 30% replacement by weight of binder. The mix proportions to be used are calculated below:

$$No.of\ Cubes\ per\ Batch = 32\ \ (i.e.Eight\ cubes\ each\ for\ ages\ 7, 14, 21\ and\ 28\ days\ tests)$$

Batch implies Control Mix (0% CFA Replacement),
10% CFA Replacement
20% CFA Replacement and
30% CFA 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 0.6 and this was used to calculate the amount or weight of water required per batch

$$Weight\ of\ water = 0.6 \times weight\ of\ bimder\ (Cement)$$

$$= 0.6 \times 37 = 22.2\ kg$$

2.5 Casting and Compaction of Concrete
The oiled metallic 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.

2.6 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. Once the desired curing period is completed, the specimens were taken out from the curing tank to prepare them for test program.

2.7 Tests
The effect of coconut fibre ash dosage on mortar and concrete specimens was assessed by measuring following mechanical and durability properties:

a. 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.

b. Workability
Slump test and compacting factor 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 mould 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 mould was lifted vertically and the change in height of concrete was measured to the nearest millimetre of 1mm.
The Compacting Factor apparatus was also used to determine the compacting factor values of the fresh concrete in accordance with BS 1881: Part 103 (1983).

c. 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 [8] 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.

1.8 Determination of Water Absorption

Water absorption test was carried out at 28 days only. Concrete cubes were dried in an oven at 110°C for 24 hours and the mass taken was recorded as dry mass (M_d). The mortar cubes were then boiled in water for 2 hours and kept for another 24 hours in the same warm water for the water to penetrate the pores. At the end of 24 hours, the concrete cubes were taken out from the warm water and the mass recorded as wet mass (M_w). Percentage of water absorption was calculated as follows:

$$Percentage\ Water\ Absorption = \left(\frac{M_w - M_d}{M_w}\right) \times 100$$

where

$M_w = Wet\ mass\ of\ concrete\ cube$

$M_d = Dry\ mass\ of\ concrete\ cube$

III. RESULT AND DISCUSSION

3.1 Experimental Mix Design

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

Table 1: Concrete Mix Design

Constituent Materials (kg)	% CFA (Control)	10% CFA	20% CFA	30% CFA
Cement	37.0	33.3	29.6	25.9
CFA	0.0	3.70	7.40	11.1
Fine Aggregate	74.0	74.0	74.0	74.0
Coarse Aggregate	148.0	148.0	148.0	148.0
Water/Cement Ratio	0.6	0.6	0.6	0.6
Total Water (kg)	22.2	22.2	22.2	22.2

3.2 Compressive strength

The compressive strength development in OPC, 10% CFA, 15% CFA and 20% CFA mortar specimens with curing period is shown in table 2.

Table 2: The Compressive Strength Test Result

Amount of Cement (%)	Amount of CFA (%)	Design Strength (N/mm^2)			
		7 Days	14 Days	21 Days	28 Days
100	0	19.45	19.41	19.46	19.51
90	10	16.56	16.00	15.82	16.54
85	20	13.17	12.02	11.41	13.00
80	30	8.70	9.04	10.06	12.65

3.3 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 50mm to 90 mm for the different mix of CFA and OPC. This type of slump is suitable for normal reinforced concrete placed with vibration.

It is found that workability of concrete increases by increasing the percentage of replacement of CFA in concrete.

Table 3: Slump Test Results

Amount of Cement (%)	Amount of CFA (%)	Slump (mm)
100	0	**53.6**
90	10	**61.1**
85	20	**74.0**
80	30	**80.0**

4.4 Particle Sieve Analysis of CFA

The result of the particle sieve analysis conducted on Coconut Fuel Ash (CFA) are displayed on table 4. The result are represented on the particle seize distribution curve shown on figure 2

Table 4: Sieve analysis result table for CFA

Sieve Size (mm)	Percentage Passing
0.6	69.80
0.425	49.70
0.3	30.10
0.212	17.66
0.15	12.55
0.075	8.290
0.063	4.120

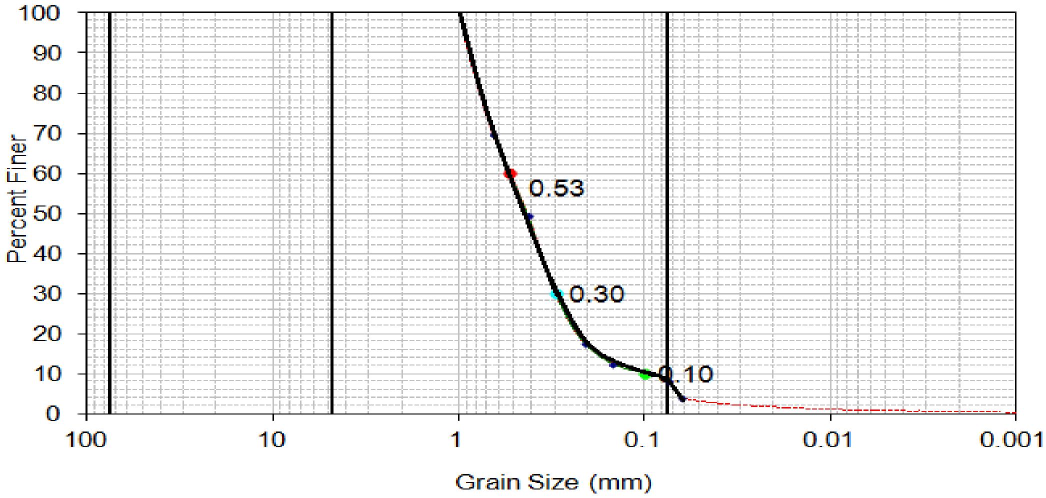

Figure 2: Particle size distribution curve for CFA

3.5 Specific Gravity Test

The specific gravity test was conducted using the relative density bottle method. The result of the test is presented in table 5 to 7

Table 5: Specific Gravity of CFA

Sample Weight (g)	Test A (g)	Test B (g)	Test C (g)
W1	16.62	24.10	20.05
W2	35.42	43.05	40.23
W3	78.58	83.59	79.46
W4	70.97	74.34	71.13
G_S	1.68	1.91	1.70
G_S	1.763		

$$G_s = \frac{(W_2 - W_1)}{\{(W_4 - W_1) - (W_3 - W_2)\}} \qquad 3.1$$

$$Average \ = G_s = \frac{1.68 + 1.91 + 1.70}{3}$$

$G_s = 1.763$

Table 6: Specific Gravity of Cement

Sample Weight (g)	Test A (g)	Test B (g)	Test C (g)
W1	16.62	24.10	20.05
W2	40.71	48.76	42.03
W3	86.29	90.15	85.51
W4	70.97	74.54	71.13
G_S	2.76	2.72	2.89
G_S	2.79		

$$Average \ = G_s = \frac{2.76 + 2.72 + 2.89}{2}$$

$$G_s = 2.79$$

Table 7: Specific Gravity of Sand

Sample Weight (g)	Test A (g)	Test B (g)	Test C (g)
W1	16.62	24.10	20.05
W2	63.44	69.37	65.35
W3	99.30	101.80	99.17
W4	70.97	74.54	71.13
G_S	2.53	2.51	2.62
G_S	2.55		

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

$$G_s = 2.55$$

3.6 Density of Concrete Cubes

The density of the concrete cubes for OPC, 10% CFA, 20% CFA and 30% CFA 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 8

Table 8: Density of Concrete cubes

(x10^3 kg/m^2)	7 days	14 days	21 days	28 days
0% CFA	2.44	2.44	2.62	2.65
10% CFA	2.28	2.42	2.46	2.47
20% CFA	2.32	2.31	2.35	2.38
30% CFA	2.19	2.30	2.28	2.31

4.7 Chemical Composition of Coconut Fibre Ash (CFA)

Table 2 shows the oxide composition of CFA. The CaO content (39.89%) in CFA also shows that it has some self cementing properties.

Table 9: Chemical Composition of Coconut Fibre Ash (CFA)

Oxide	Percentage Composition (%)	OPC (BS 12 Ranges)
SiO_2	5.23	17-25
Fe_2O_3	7.68	0.5-6.0
Al_2O_3	3.17	3-8
CaO	39.89	60-67
MgO	22.76	0.1-4.0
SO_3	1.00	1.0-2.0
K_2O	0.03	
PbO	20.23	

3.7 Water Absorption

The water absorption of CFA presented in Table 10, indicated that the water absorbed by the mortar cube increases as the amount of bamboo ash content increases. The lowest value of 2.18% was obtained with the mix containing 0% CFA while the highest value of 7.35% was obtained for mix containing 30% CFA.

Table 10: Water Absorption Result

CFA (%)	0	10	20	30
Water Absorption (%)	2.18	5.13	6.53	7.35

IV. CONCLUSION

The purpose of this study was to an experimental investigation into the potential use of Coconut Fibre Ash (CFA) in cement based materials. Ordinary Portland Cement (OPC) was replaced with 10%, 20% and 30% CFA using a concrete mix ratio of 1:2:4 and water –cement ratio of 0.6. The concrete cubes where demoulded and cured in a concrete tank full of water for 28 days. Several test where conducted on fresh CFA, fresh and hardened concrete such as Sieve analysis, Specific gravity, Slump Test and Compressive strength test.

5.2 Conclusions

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

1. The use of CFA as a partial replacement for cement exhibits a lower water absorption rate and slower setting time of concrete.
2. Concrete strengths increases with curing age and decreases with increasing percentage of CFA replacement in concrete.
3. The use of CFA will reduce the volume of cement used in light weight concrete, thereby reducing the cost of concrete production.
4. The use of CFA will minimize the environmental issues arising from the disposal of Coconut Fibre Wastes.
5. The CFA which is lighter than OPC and which occupies a greater volume for the same mass of OPC requires additional water in the mix as the quantity of CFA content increases in order to attain to a paste of standard consistency.

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