DETERMINATION OF CONCRETE STRENGTH PRODUCED WITH CEMENT PARTIALLY REPLACED WITH PALM FROND ASH

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ABSTRACT

Most of the infrastructural inadequacies in the country is caused by lack or high cost of construction materials. On the other hand production of cement is responsible for the emission of 0.9 tons of CO_2 to the atmosphere. Therefore, this study examines the reuse of palm frond ash which is an agricultural waste as a partial replacement for cement in the production of concrete, which will help to reduce the over cost of concrete production and the pollution of the environment. The results obtained from the aggregate testing was used for mix design of 25N/mm^2 targeted strength giving mix ratio of 1:2.4 with 0.5 W/C ratio. The mix was calculated for 20%, 40%, 60%, and 80% replacement of cement with palm frond ash. The properties of the aggregates, fresh and hard concrete was determined and compared with normal concrete. It was observed that specific gravity of the palm frond ash which is 2.68 was lower than that of the cement 3.08 which contributed immensely to the overall light weight of the concrete. The slump values ranged from 28% 25% 20% 12% and 5% at the replacement of cement by 20 to 80% palm frond ash respectively, this indicates a reduction in the workability of the concrete. Strength of the concrete decrease with the introduction of palm frond ash into the concrete mix. The highest compressive strength of the concrete that was achieved for the Palm Frond Ash concrete is 18.67N/mm^2 at 20% replacement and 28days curing; while highest flexural strength of the concrete which is 3.484KN/m^2 was achieved after the 28days curing at the 20% replacement with the palm frond ash. At 80% replacement of cement with palm frond ash it was observed that the concrete disintegrated in the tank before the testing days therefore the optimum replacement of cement by palm frond ash recommended is 20% and because of the light weight of the concrete it can be used for high rise buildings were reduction of weight is important.

Keywords: *Concrete, Concrete Strength, Partial replacement, Palm Frond Ash, Cement*

1.0 INTRODUCTION

Housing, like most basic human needs that is in far shorter supply than demand in practically every country of the world.

It is pertinent to say that man cannot do without shelter as it is arguably the most important need of man. The issue of inadequate housing system in Nigeria cannot be over emphasized (Punch, 2012).

Over the years concrete has become a very important material used in building construction; therefore issues that surmounts the optimization and production of the composite should be taken seriously. According to Kawade (2013), Concrete are attractive for use as construction materials, due to its advantages such as built-in-fire resistance, high compressive strength and low maintenance.

Concrete is a composite material made up of cement, aggregates, water and admixture. Nevertheless, cement as one of the components of concrete requires high level of energy in its production processes and also impacts negatively on the environment. It is known that there are several causes of global warming, including CO_2 from cement. Approximately 5% of total CO_2 emission is released to atmosphere, with about 0.7–1.1 ton of CO_2 being emitted for every ton of cement production. (Sooraj V.M., 2013). Also Badur and Chaudhary (2008) noted that about 7% $C0_2$ is released into the atmosphere during cement production, which has a negative influence on ecology and threatens the future of human beings arising from global warming.

Concrete is the world's leading material for providing housing units and cement production is both significantly energy consuming and environmentally damaging in production, consequently the use of concrete in buildings is becoming more problematic in developing countries because of the ever-rising cost of ordinary Portland cement, which is made even worse by Nigeria's already high and increasing population.

The scarcity of cement has made it (incumbent) on researchers to find a cheaper, dependable and durable substitute material that can be used to partially replace the cement content for concrete production, hence this study.

It is a fact that raw materials from earth resources are scarce, notwithstanding in the meantime the demand for cement is increasing globally as a result of economic and population growth, therefore there is the need to find alternative materials which must require minimal energy for production and be of benign environmental impact as well as cost effective.

The most common and readily available Pozzolanic material that can be used to partially replace cement without economic implications are "agro based wastes", notable ones being Acha husk ash (AHA), Bone powder ash (BPA), Palm oil fuel ash (POFA), Palm kernel shell ash (PKSA), groundnut husk ash (GHA), Rice husk ash (RHA), banana leaves ash, sawdust, periwinkle shell ash (PSA).

This research is based on the use of palm frond ash (PFA) as a partial substitute for cement in concrete. Plant ash is the powdery residue that remains after plants are burned; chemically the ash is alkaline (pH > 10) and composed primarily of calcium carbonate and, secondarily, most often, of potassium chloride (interestingly, alkaline derives from the Arabic word meaning plant ashes).

Robert, 2012 noted that one of the major problems of developing countries is improper management of vast amount of waste generated by various human activities. Therefore this work will add in optimization of the palm frond which is a waste to an impactful use.

The following are some of the reason for which this research is important;

i. This work, when finished would hopefully help to provide an option for reducing the overall cost of producing concrete, thus bringing housing and other forms of concrete construction works to a cheaper and affordable rate.
ii. This work will suggest ways to further research improvements to the use of local raw materials as cement replacement. A possible economic gateway for ordinary farmers
iii. The economic benefit of agricultural waste will be exposed through this work. A potential for better waste management resulting in a cleaner environment in the third world.
iv. By minimizing the cost of housing construction, the cost of rent will automatically reduce, thereby making cost of living more affordable.
v. Since a large demand has been placed on building material industry especially in the last decade owing to the increasing population that causes a chronic shortage of building materials, the civil engineers have been challenged to convert the industrial wastes to useful building and construction materials.

The core objective of this project is to do a comparative analysis between the strength characteristics of concrete produced with palm frond ash as partial replacement for cement and that concrete produced with cement only.

The specific objectives of the work are as follows:

i. To determine the effect of palm frond ash in the setting time of concrete
ii. To study the physical and mechanical properties of the concrete
iii. To determine the optimum percentage of palm frond ash replaced in concrete that makes the tensile strength of concrete maximum.
iv. To introduce this concrete as a cheaper alternative to existing products.

This work is based on determination of the strength characteristics of concrete produced with palm frond ash as a partial replacement for cement. To achieve several laboratory tests will be carried (such as cement test (setting time), specific gravity of aggregate, particle size distribution test, compressive and tensile strength test of concrete etc.) to ascertain the properties of the concrete. The properties of the concrete produced with partial replacement of cement with palm frond determined in this research will be limited to the following percent replacements 0%, 20%, 40%, 80% replacements.

2.0 MATERIALS AND METHODOLOGY

The methodology of this work encompasses the various methods by which the objective of this research will be achieved. The various test carried out are explained in details here; test on cement, aggregates and test on green and hardened concrete.

The materials that will be used to actualize the objectives of this project and where they will be gotten from are stated below. The materials includes Cement, Fine aggregate, Coarse aggregate, Water, and Palm frond ash.

Ordinary Portland cement (Dangote Brand) was used throughout this research work. The fine and Course Aggregate used are sharp sand and Granite, it will be gotten from Amawom River at

Ikwuano State. Water that is clean, colorless, odorless, free from dirt or unwanted chemical that may affect the properties of concrete. It must conform to NIS 87:2004. The pozzolan to be used for this project is palm frond ash.

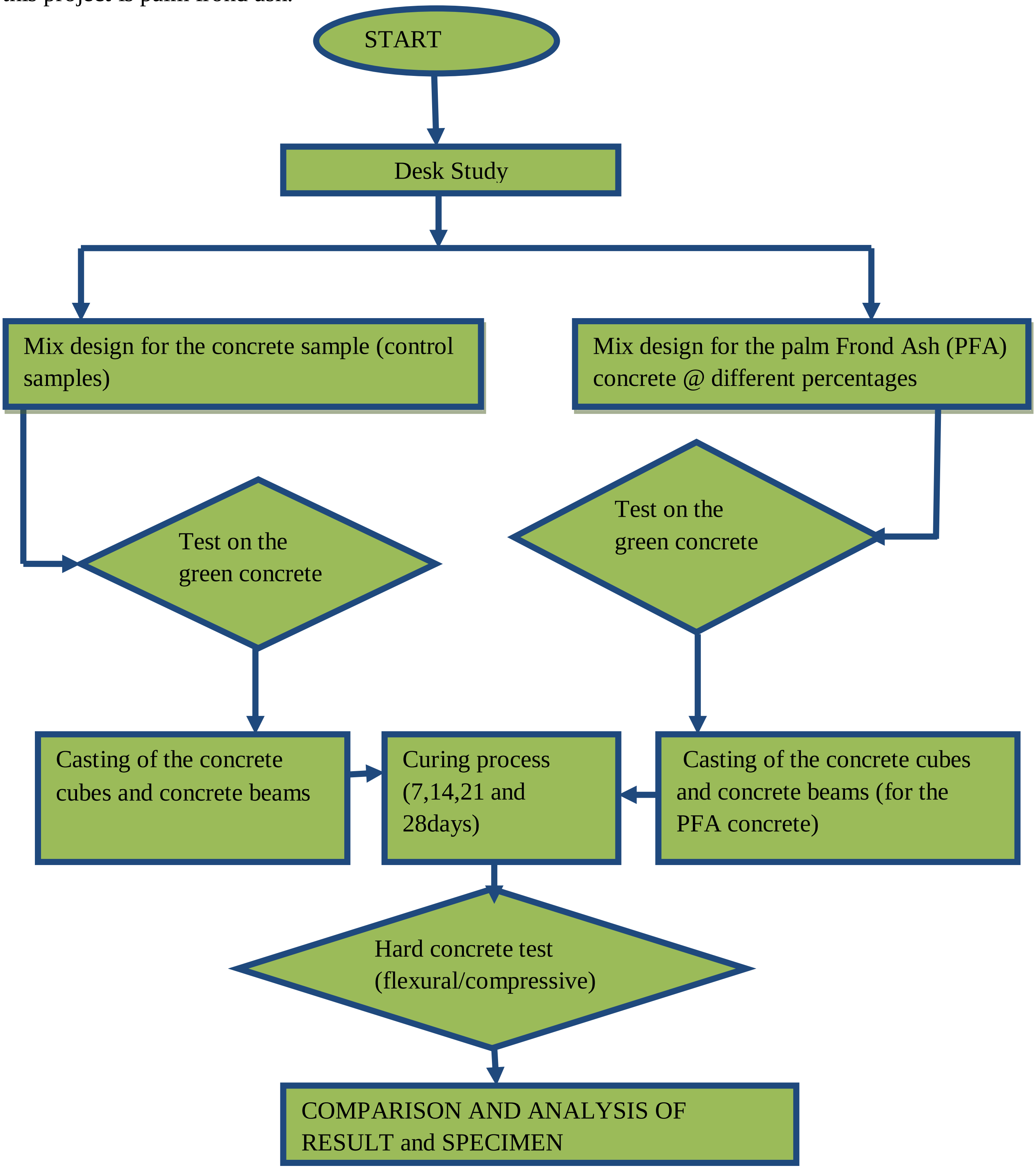


Fig 1: Methodology for Experimentation

2.1 Sand Preparation

The sand (fine aggregate) used for this study will be prepared in accordance to BS 1377: Part 2:1990. After the collection of the sand it will be air-dried and sieved through 10mm B.S test sieve to remove cobbles. The figure below shows the processes taken for the preparation of the fine aggregate used for the study.

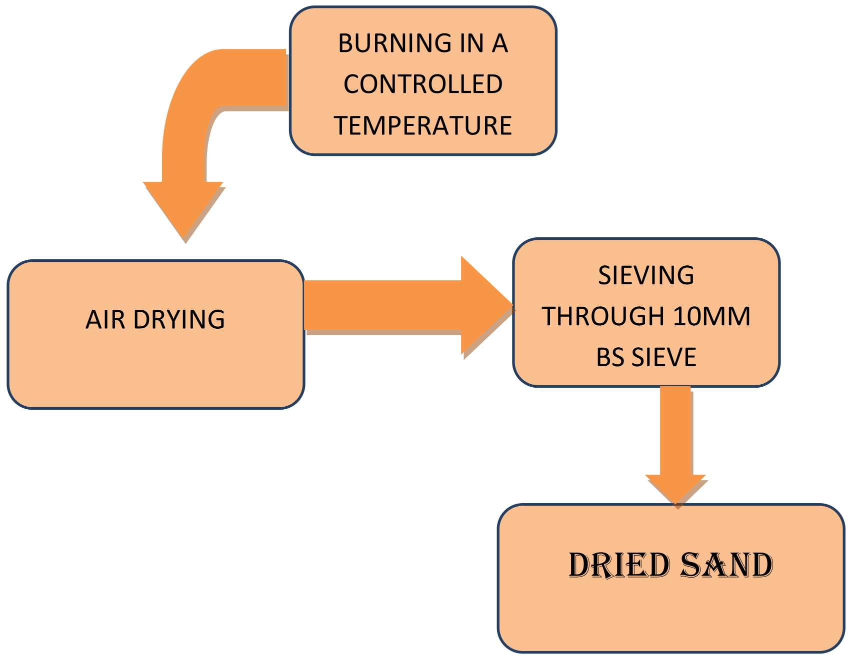


Fig 2: Fine aggregate preparation

2.2 Coarse Aggregate Preparation: The coarse aggregates used for the study is purchased from Umuahia in Abia state. The maximum aggregate size of 20mm. The granite coarse aggregate is then washed of dust and air dried the bigger pebbles were sieved off using the 80mm B.S test sieve.

2.3 Preparation of the Palm Frond Ash (PFA)

After the collection of the sample it will be dried for some days, the sample would be burnt at an uncontrolled degree of temperature. Open field burning would be employed so as to be able to control it and go close to it. The burning would occur bit by bit as the burning pan carry. The palm fronds would be placed in such a way as to allow oxygen to pass through. By this, less time would be spent on burning and more than 95% will be burned. After burning some impurities will mix with the ash burnt sample, which will lead to sieving the ashes using 600µm sieve. Particles retained on the 600µm sieve would be discarded while the rest would be stored in an airtight cement bag.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 6 Issue 4, April 2019
ISSN (Online) 2348 – 7968
www.ijiset.com

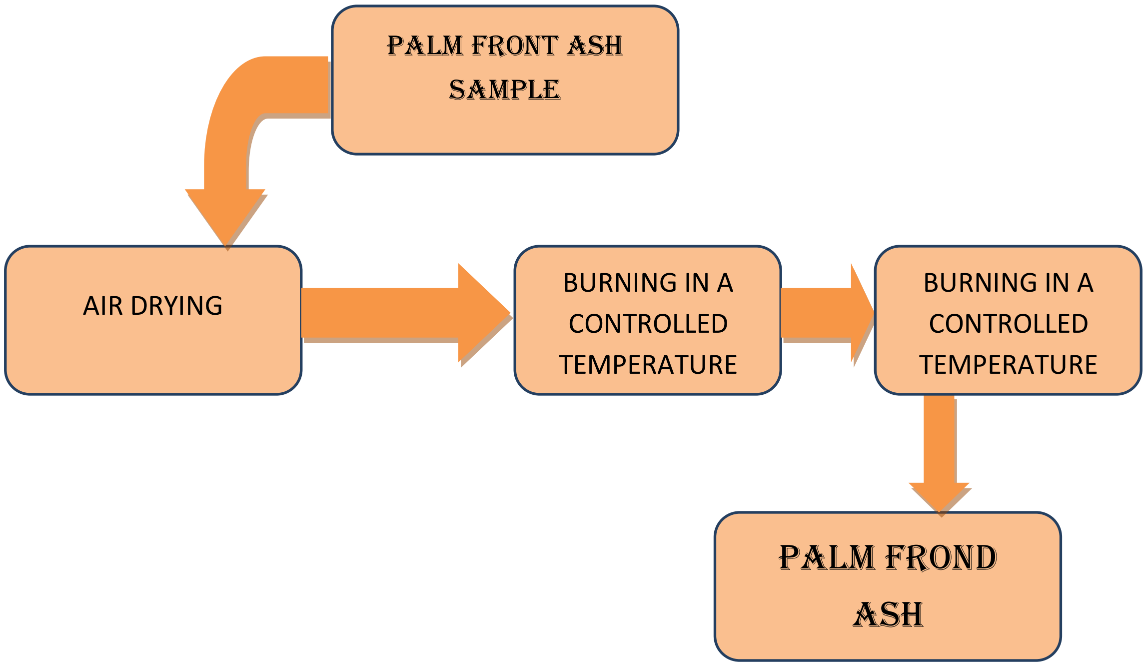


Fig 3: Palm frond Ash preparation

3.0. PRESENTATION, ANALYSIS OF RESULTS AND DISCUSSIONS

From the results obtained from the various experiment carried out in the cause of this work analysis and calculation were deduced as follows

Table 1: Summary of the design for Concrete Cube (Compressive Strength)

Percentage of palm frond Ash	Water (m^3)	Cement (Kg)	Palm frond Ash (PFA)(Kg)	Fine aggregates (Kg)	Coarse Aggregate(Kg)
0%PFA	6.37	8.5	0	21.24	42.48
20%PFA	6.37	6.37	2.12	21.24	42.48
40%PFA	6.37	6.37	4.25	21.24	42.48
60%PFA	6.37	4.25	6.37	21.24	42.48
80%PFA	6.37	2.12	8.5	21.24	42.48

Table 2: Summary of the design for Concrete Beam (Flexural Strength)

Percentage of palm frond Ash	Water (m^3)	Cement (Kg)	Palm frond Ash (PFA)(Kg)	Fine aggregates (Kg)	Coarse Aggregate(Kg)
0%PFA	12.74	21.24	0	42.48	84.96
20%PFA	12.74	16.99	4.25	42.48	84.96
40%PFA	12.74	8.5	12.74	42.48	84.96
60%PFA	12.74	12.74	8.5	42.48	84.96
80%PFA	12.74	4.25	16.99	42.48	84.96

3.1 Particle Size Distribution Analysis for Aggregates:

Sieve analysis with respect with material (Sand, Aggregate and Cement) weight and specific gravity was performed in accordance with BS 1377: PART 2:1990 specification.

As presented below, the particles size properties of the fine aggregates is as follows: C_u = 5.5, C_c = 1.03, FM = 3.9. According to Arora, (2009) a well graded soil will have a coefficient of curvature of 1 to 3, and a uniformity coefficient of 6 or more, the result below shows that the soil is a well graded soil. Holtz, (1981) noted that the Finest Modulus FM of a soil used for concrete falls within 2-4; therefore the fine aggregate is suitable to be used. Figure 5 shows the particle size properties of the coarse aggregates, the range of the finest modulus for coarse Aggregates is given as 6.50 to 8, while the Coarse Aggregate used in this study has FM of 7.6 therefore it falls within the accepted range.

From results in figures 4 and 5, the uniformity coefficient and fineness modulus calculated.

Uniformity coefficient $C_u = \frac{D_{60}}{D_{10}} = \frac{0.44}{0.08} = 5.5$

Coefficient of curvature $C_c = \frac{{D_{30}}^2}{D_{60} \times D_{10}} = \frac{0.19^2}{0.44 \times 0.08} = 1.03$

%fine= $\frac{11}{500} \times 100 = 2.2\%$

Finest Modulus for Fine Aggregate $= \frac{cummulative\ percentage\ passing\ the\ sieves}{100} = \frac{391.52}{100} \cong 3.9$

Finest Modulus for Coarse Aggregate $= \frac{cummulative\ percentage\ passing\ the\ sieves}{100} = \frac{756.76}{100} \cong 7.6$

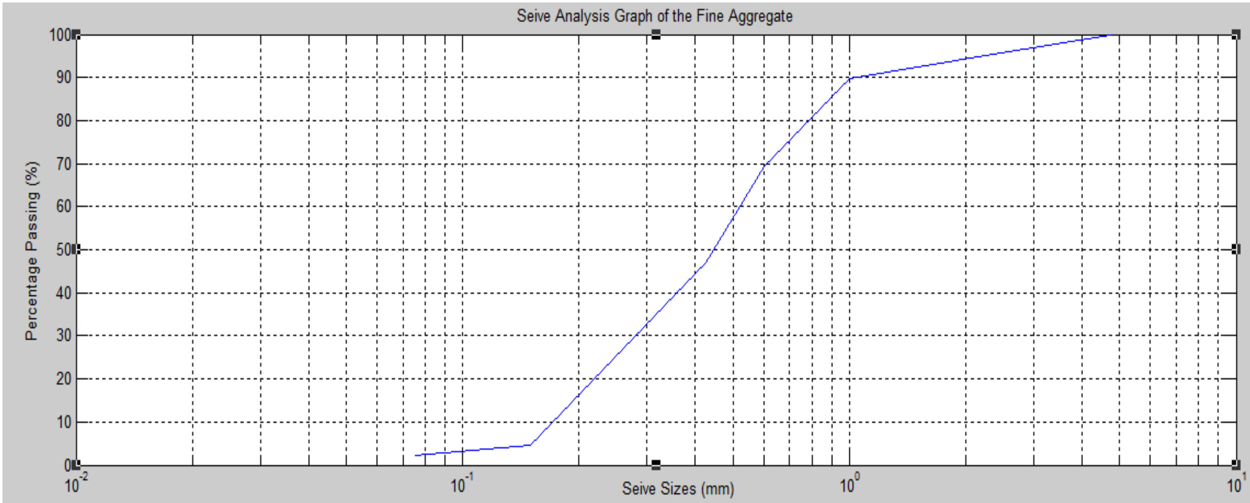


Fig 4: Particle Size Distribution curve of Fine aggregate

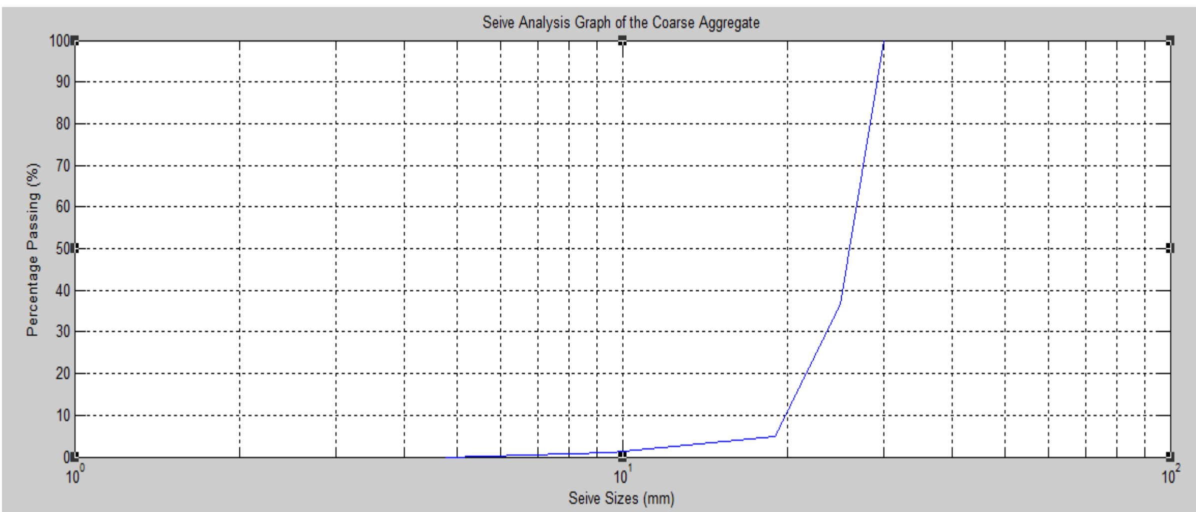


Fig 5: Particle Size Distribution curve of Coarse Aggregate

3.2 Specific Gravity Test Results

The specific gravity of Sand, Coarse Aggregate and Glass Coarse Aggregate and Dangote Cement (to determine on relative paraffin value for the OPC (Dangote) was carried out at room temp thus yielding the following results.

From table 3, 4, 5 and 6, the specific or unit weight of sand having an average of 2.61 and coarse aggregate 2.59. The specific gravity of the Palm Frond Ash was obtained as 2.68 and the cement as 3.08, discrepancies between the specific gravity of the cement and that of the Palm Frond Ash will lead to the reduction of the overall weight of the concrete. The specific gravity of the sand and the coarse aggregates falls within the accepted criterion.

Table 3: Specific Gravity of fine aggregate (Sand)

Sample	Wt of bottle(g) M_1	Bottle +sample(g) M_2	Bottle+sample+H_20(g) M_3	bottle+H_20(g) M_4	Specific gravity $\frac{M_2-M_1}{(M_4-M_1)-(M_3-M_2)}$ (g/cm^3)
A	409.20	439.20	674.44	656.37	2.51
B	408.98	438.95	676.20	658.62	2.42
C	408.45	438.54	676.64	656.90	2.91

Average Specific Gravity $G_s = \frac{A+B+C}{3} = \frac{2.51+2.42+2.91}{3} = \frac{7.84}{3} = 2.61$

Table 4: Specific Gravity of Coarse aggregate (Granite)

DESCRIPTION	SAMPLE A	SAMPLE B
Mass of Air Dried Sample (A)	2938.4	2323.5
Mass of Basket + Sample in Water (B)(g)	2145.19	1751.5
Mass of Basket in Water (C) (g)	333.0	328.7
Mass of Oven Dried Sample (D) (g)	2908.7	2293.8
$G_s = \frac{A}{A-(B-C)}$	$\frac{2938.4}{2938.4-(2145.19-333)} =$ **2.6091**	$\frac{2323.5}{2323.5-(1751.5-328.7)} =$ **2.5797**
Average Specific Gravity g/cm^3	2.59	
Water Absorption = $\frac{100(A-D)}{D}$	$\frac{100(2938.4-2908.7)}{2908.7}$ =**1.02 %**	$\frac{100(2323.5-2293.8)}{2293.8} =$ **1.29%**
Average Water Absorption	1.16%	

Table 5: Specific Gravity of Palm Frond Ash (PFA)

Sample	Wt of bottle(g) M_1	Bottle +sample(g) M_2	Bottle+sample+ H_20(g) M_3	bottle+$H_2$0(g) M_4	Specific gravity $\frac{M_2-M_1}{(M_4-M_1)-(M_3-M_2)}$ (g/cm^3)
A	592.5	1345.6	2023.6	1552.4	2.67
B	592.5	1347.5	2025.6	1551.3	2.69

Average Specific Gravity $G_s = \frac{A+B}{3} = \frac{2.67+2.69}{2} = \frac{5.36}{2} = 2.68$

Table 6: Specific Gravity of Dangote Cement

DESCRIPTION	SAMPLE A	SAMPLE B
Mass of empty bottle(W1) (g)	30.5	28.5
Mass of bottle +cement (W2) (g)	52.1	48.9
Mass of bottle + cement + kerosene (W3)	86.2	84.8
Mass of bottle + kerosene (W4) (g)	69.2	70.2

Mass of bottle + water (W5) (g)	78.8	78.5
SPof kerosene= $\frac{W_4-W_1}{(W_5-W_1)}$ =	0.80	0.83
SP of Cement $\frac{W_2-W_1}{(W_3-W_1)-(W_5-W_1)}$ =	2.92	3.24
Average specific gravity	3.08	

3.3 Cement Consistency Test

The result of the various test carried out in accordance to BS 1881 part 125 on the cement is presented as follows;

Table 7: Cement Consistency Test

DESCRIPTION	Specification	% Replacement				
		0%	**20%**	**40%**	**60%**	**80%**
Weight of cement(g)	Minimun200g	400g	400g	400g	400g	400g
Weight of water(g)	Minimum50g	103g	125g	135g	145g	160g
Initial setting time	Minimum 45 Mins	140mins	125mins	150mins	165mins	180mins
Final setting time	Maximum 600mins	285mins	265mins	320mins	335mins	395mins

Table 8: Fineness of Cement

Fineness of cement using BS sieve NO. 170	
Weight of sample	100g
Fineness of cement	2%

3.4 Density of Concrete

The densities of the concrete as shown in the table below reduced as the percentage of the palm frond ash increase this is probably because of the variation in the specific gravity of the palm frond ash and that of cement. It was also observed that the density increase with the increase in the curing days which shows the water absorption capacity of the concrete.

Table 6: Bulk density of Fine aggregate (sand)

S/NO	Observation and calculation	Determination no.		
		1	**2**	**3**
1	Mass of empty mould +base plate(g)	2346	2346	2346
2	Mass of mould +base plate+compacted soil(g)	4051	4031	4036
3	Mass of compacted soil M, = (2)-(1) (g)	1705	1685	1690

4	Bulk density, $\rho = \frac{M}{V}$(g/ml)	1..7	1.69	1.69
	Average bulk density, (g/ml)	1.69		

Table 7: Bulk density of coarse aggregate (granite)

S/NO	Observation and calculation	Determination no.		
		1	**2**	**3**
1	Mass of empty mould +base plate(g)	2346	2346	2346
2	Mass of mould +base plate+compacted aggregatel (g)	3751	3781	3796
3	Mass of compacted soil M, = (2)-(1) (g)	1405	1435	1450
4	Bulk density, $\rho = \frac{M}{V}$(g/ml)	1..4	1.44	1.45
	Average bulk density, (g/ml)	1.43		

Table 8: Average Densities of the Concrete Cubes

% replacement	**Days of Curing and Densities of the concrete (kg/m^3)**		
	7Days	**14Days**	**28Days**
0	2495.8	2551.11	2584.80
20	2473.74	2478.03	2524.44
40	2441.48	2465.18	2503.70
60	2409.88	2429.26	2482.96
80	the concrete disintegrated in the tank before the testing day		

3.5 Fresh Concrete Slump Test Results Analysis

This test on the fresh concrete was formed before setting and its result was deduced for the concrete having its cement partially replaced by the Palm frond Ash.

It was observed from the slump test that the slump decreased upon the inclusion of palm frond ash as partial replacement of OPC. Therefore, it can be inferred that to attain the required workability, mixes containing palm frond ash will required higher water content than the corresponding conventional mixes.

The OPC (0% replacement) had a slump value of 75mm. These values decreased as the palm frond ash was increased in proportion.

This trend is similar to the one found by other researchers (Raheem A.A, Olasunkanmi, &Folorunso, 2012 and Marthong.C. 2012). The workability (effort required to manipulate a concrete mixture with a minimum of segregation) of fresh concrete depends on the water content in the mix. This would be disadvantageous for large construction works involving the partial replacement of cement with palm frond ash as the cost of more water would increase the overall costs of materials.

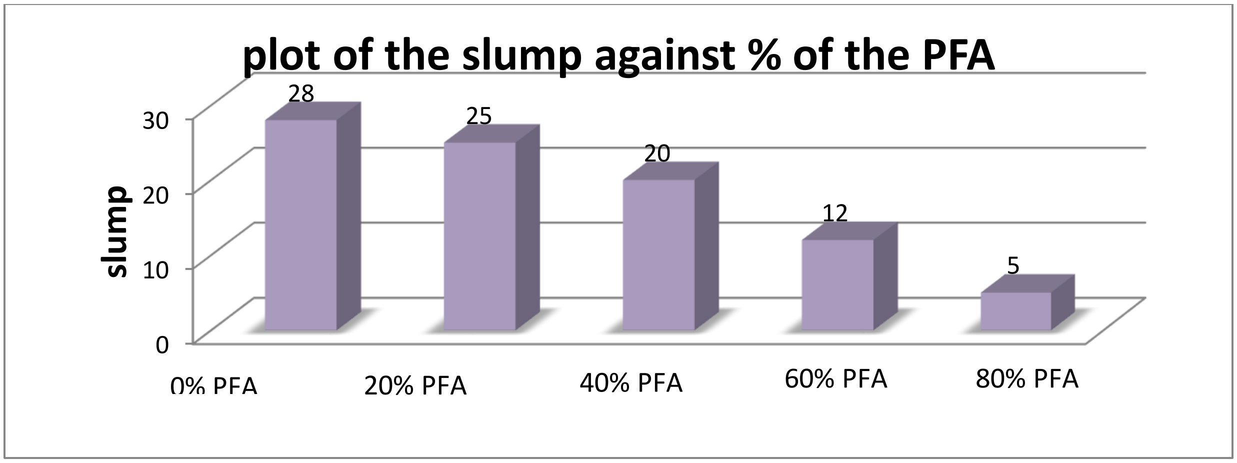
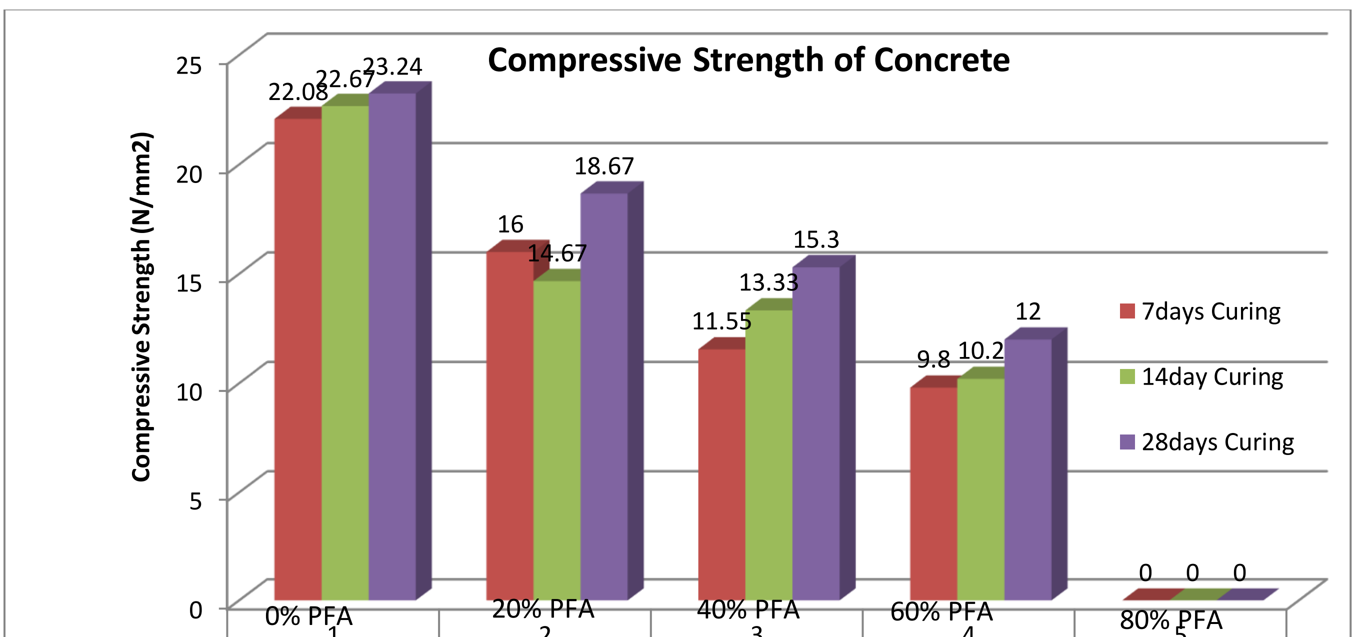


Fig.6: The Result of the Slump Test Showing the workability of the concrete

3.6 Compressive Strength of Concrete after 7, 14, and 28 Days Curing

The concrete was crushed after curing and its load and the compressive strength calculated using the expression as:

$F_{cu} = \frac{crushing\ load(N)}{surface\ area(mm^2)}$ for the mean crushing load.



	1	2	3	4	5
7days Curing	22.08	16	11.55	9.8	0
14day Curing	22.67	14.67	13.33	10.2	0
28days Curing	23.24	18.67	15.3	12	0

Fig 7: Compressive Strength of Palm Frond Ash Concrete at 7, 14 and 28 Days Curing (N/mm^2)

From the result above, the compressive strength of the concrete increased progressively with the increase in the curing days but no strength was achieved at the 80% replacement of cement with palm frond Ash because the concrete disintegrated before the test could be achieved that is to say that beyond 60% replacement of cement with palm frond Ash reasonable strength is not guarantee. The highest compressive strength of the concrete that was achieved for the Palm Frond Ash concrete is 18.67N/mm^2 at 20% replacement this was achieved at 28days curing. Also at the increase in the percentage of the palm frond ash the compressive strength of the concrete reduced. At the increase in the curing days the compressive strength of the concrete increase by 16.7%.

3.8 Flexural Strength of Concrete after 7, 14, and 28 Days Curing

For varying replacement of PFA, the weight of the hard concrete and applied load are tabulated below for respective number of curing days. The flexural strength of concrete was also calculated for various percent replacement of cement as shown in the tables below;

Volume of each concrete beam = 0.010125m^3

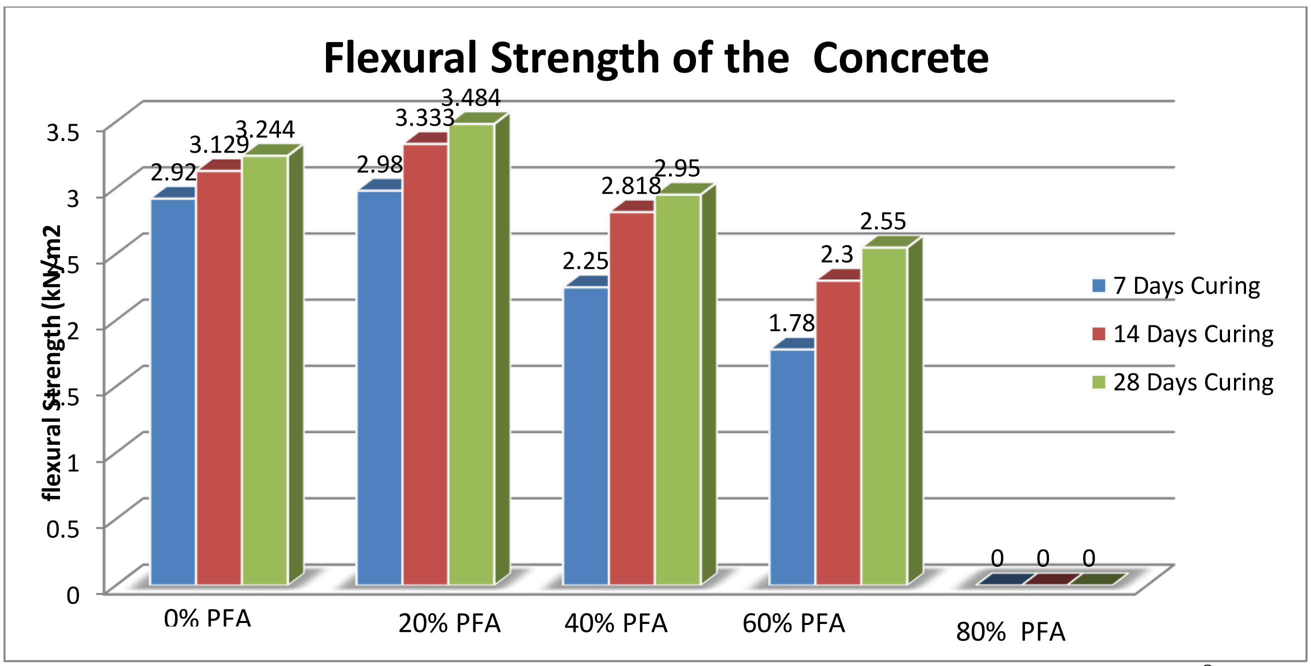


Figure 8: Flexural Strength of Palm Frond Ash Concrete at 7, 14 and 28 Days Curing (KN/m^2)

The tensile strength of concrete is usually 10% of the compressive strength of the concrete which is clearly shown by the results obtained from the study. Flexural strength of the concrete increase at the 20% replacement of the concrete with the palm frond ash by 2.05% at the 7day curing. The highest flexural strength of the concrete which is 3.484KN/m^2 was achieved after the 28days curing at the 20% replacement with the palm frond ash. While the flexural strength of the reduced progressively after the replacement with 20%. The concrete flexural strength at 80% replacement of the cement with palm frond ash did not give any value because the sample disintegrated in the curing tank before the test on the hard concrete could carried out.

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