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Investigation into the use of Raffia Palm Ash (RPA) in Cement-based Material

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Abstract: *The production of cement releases a lot of greenhouse gases to the atmosphere, thereby leading to global warming and climate change. This study evaluated the potential use of the Raffia Palm Ash (RPA) in cement-based materials. RPA was produced from Raffia hookeri by incinerating the dried wastes such as the logs, the leaves, the fronds, the straws and the jute, excluding the seeds. Ordinary Portland cement (OPC) was replaced in a concrete mix ratio of 1:2:4 and water-cement ratio of 0.6. A total of forty-eight concrete cubes, three cubes per experimental point(0%, 10%, 20% and 30% RPA replacement of Ordinary Portland cement) were made and cured, submerged in water, in a concrete tank for 7, 14, 21, and 28 days ,respectively; and then tested for their compressive strength. Other tests conducted were sieve analysis tests, specific gravity test, fineness test and slump test. It was observed that the compressive strength decreased progressively with increased substitution of OPC with RPA. The same goes for the slump test. The 100% OPC concrete gave the highest compressive strength value of 22.54 N/mm2 at the 28th day. For the substituted mixes, the compressive strength tests results gave the optimum value of 20N/mm2 for 10% RPA replacement of OPC at the 28th day. By this result, RPA can be used potentially as a substitute for cement in cement-based materials to minimize the environmental problems associated with the disposal of the Raffia palm waste and global warming associated with cement production.*

KEYWORDS: *Raffia Palm Ash, cement, compressive strength, Concrete, global warming*

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1. INTRODUCTION

Concrete is the most versatile heterogeneous construction material and the impetus of infrastructural development of any nation (Olafusi and Olutoge, 2012; Umeonyiagu, 2019a). It is a composite, inert material comprising of a binder (e.g. cement), mineral filler (body or aggregates) and water (Oyenuga, 2001).The word concrete comes from the Latin word "concretus" (meaning compact or condensed). During the Roman Empire, Roman concrete was made from quicklime, pozzolana and an aggregate of pumice. An analysis of mortar from the Great Pyramids showed that it contained 81.5 per cent calcium sulphate and only 9.5 per cent carbonate. The durability and other characteristics of concrete depend upon the properties of its ingredients, proportions of the mix, method of compaction and other controls during placing, compaction and curing (Gambhir, 2005; Dzasu and Ayegba, 2010).

The usage of concrete is second only to that of water, an important component needed to promote the hydraulic action of cement, a principal binder in concrete. Apart from water and cement, other constituents of concrete include aggregates (course and fine) as well as admixtures. The process of cement production is highly energy consuming and is one of the major sources of carbon dioxide emission to the atmosphere. Carbon dioxide, (CO_2), which is a greenhouse gas, contributes about 65% of global warming (Mo, et al., 2016; Blaszczynski and Krol, 2015). The need for affordable building materials in providing adequate housing for the teaming populace of the world has become the major concern of the 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 search for alternative local materials as total or partial replacement for cement (Adesanya and Raheem, 2009; Akinwumi and Aidomojie, 2015). The search has led to the discovery of the potentials of using 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 (Raheem, et al., 2017) According to Sooraj (2013), 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. The use of waste materials in concrete has led to considerable improvements in concrete performance, green environment, construction savings and working conditions (Amadi and Osu, 2018; Ikponmwosa, et al., 2017; Al-Kutti, et al., 2018).

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; the leaves are used for shelter and the stem produces palm sap, which is drank as beverage (Ndon, 2003). Raffia palms (*Raphia*) are a genus of about twenty species of palms. Raffia plants are generally found in the tropical zones and more precisely in tropical Africa, and especially Madagascar and Nigeria, with one specie also occurring in Central and South America (Musset, 1933). In Nigeria, palms especially raffia palms (*Raffia hookeri*) are basically tapped for the production of palm wine. A typical tall *Raffia hookeri* gets to a height of 15m and are remarkable for their compound pinnate leaves, the longest in the plant kingdom (Akpabio, et al., 2001). The leaves of *Raffia hookeri*, often split lengthwise, are used to make mats, baskets and other articles. The midribs and petioles of the leaves (Raffia bamboo or bamboo) are used for poles, rafters, ladders, furniture and cross-bearers in canoes. Plate (1) shows a Raffia palm tree (*Raffia hookeri*).

Plate 1: Raffia palm tree (*Raffia hookeri*) at the middle

Many works have been carried out on the Raffia palm, among which is the use of the Raffia bamboo as main reinforcement in the concrete (Kankam, 1997). No work has been carried out on the suitability of Raffia Palm Ash in cement or concrete-based materials.

Over the past few decades, many studies have been conducted on the use of agro-waste ashes as a partial replacement for cement in concrete production.

Karim, et al., (2011) 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 reduction in concrete strength was observed up to about 30% replacement with POFA. Safiuddin, et al., (2010) concluded that the use of POFA was limited to partial replacement, ranging from 0-30% by weight of the total cementitious material in the production of concrete. Mujedu, et al., (2018) investigated the 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 was not suitable for use as a pozzolan.

Awal and Abubakar (2011) found that high volume Palm Oil Fuel Ash concrete, like concrete made with other pozzolanic materials, showed a slower gain in strength at the early age. A study to investigate the acid resistance of concrete containing Sugar Cane Straw Ash (SCSA) was done by Obilade (2018). He used SCSA to partially replace Portland cement by weight of binder in order to prepare SCSA concrete. Nawkhare, et al., (2018) carried out a research on the strength performance of concrete using Portland pozzolana cement and Sugar Cane Bagasse Ash (SCBA). They observed that the finely grounded SCBA can successfully replace cement and is responsible for the higher compressive strengths than normal concrete (keeping quantity of cement constant). Umeonyiagu (2019b; 2019c) produced the mathematical model for the prediction of the compressive strength characteristics of concrete made with Sugar Cane Bagasse Ash (SCBA). Al-Kutti, et al., (2019) studied the potential use of Date Palm Ash in cement-based materials. Date Palm Ash was found to have great potentials and it may be effectively utilized as a construction material, thus reducing the CO_2 emission into the atmosphere and minimizing the cost of construction without compromising the service life of the structures (Al-Kutti, et al., 2019).

II. MATERIALS AND METHODS

2.1 Materials

2.1 Materials

(i) Cement

The type of cement selected for this research was the ordinary Portland cement (OPC). There are various brands available in the Nigerian Markets such as Dangote, BUA, Unicem, Elephant Cement (which are of two grades: 42.5 for Supersets and 32 for ordinary one), etc. Elephant superset was used in all the concrete and mortar mixtures. The cement conformed to the Nigerian cement standards, NIS 11:1974; NIS 439: 2000; NIS 444-1: 2003 and also to the specifications of EN 197-1:2011.

(**ii**) Raffia Palm Ash (RPA) .

The raw materials used were the dried parts (wastages) of the *Raffia hookeri* such as the logs, the leaves, the fronds, the straws and the jute excluding the seeds, obtained from Uli, Anambra State in the Eastern region of Nigeria. The Raffia Palm Ash (RPA) was produced from these wastages by the process of incineration in an improvised oven for 7 hours. Raffia Palm Ash passing through 425 µm sieves were used. 10%, 20% and 30% of Raffia Palm Ash (RPA) by weight of the cement were incorporated as replacements for OPC. Plate(2) shows the raw materials (wastages) from the Raffia palm *(Raffia hookeri)*.

(a.) Raffia palm jute

(b.) Raffia palm fronds

(c.) Logs

(d.) processed and dried Raffia palm waste

Plate(2) Raw materials for the RPA

(iii) Aggregates

The coarse and fine aggregates used were crushed granite from the local quarries, and river sand, respectively.

The grading of fine aggregates conformed to BS 882:1992. Sieve analysis of both RPA and sand were carried out with sieve sizes No. 4, 10, 40, 100 and 200.

(iv) Water

The water used for the research was obtained from a free flowing stream. The water was clean and free from any visible impurities. It conformed to BS 3148:1980 and BS EN 1008:2002 requirements.

2.2 Methods

Slump test was conducted on the fresh concrete to determine the workability of the concrete based on BS EN 12350 Part 2:2000 requirements. A slump cone mould of diameters 200mm and 100mm, and height 300mm was filled with concrete in three layers of equal height. 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 millimeter.

Plate(3)Incineration of the Raffia wastes Plat(4) RPA got from the incineration of Raffia wastes

The concrete and mortar constituents were batched by weight in required proportions and mixed in a concrete mixer. The concrete mix ratio used in this work was 1:2:4 with a water-cement ratio of 0.6.The batch quantities are shown in Table 1

Table 1: Concrete batch quantities

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 Aggregate (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

The required concrete specimens were made in threes in accordance with the methods specified in BS 1881: 108: 1983 and BS EN 12390 Part 2: 2000. RPA was used to replace OPC at dosage levels of 10%, 15% and 20% by weight of binder. Oiled plastic cubic moulds, of dimensions 150 x 150 x 150mm, free from any foreign material were arranged close to the platform. 12390

The concrete was simultaneously filled in the moulds, and each layer was compacted on compaction table using tamping rod. All specimens were covered with plastic sheets till demoulding. The specimens were demoulded after 24 hours and immersed in a tank full of water for 7, 14, 21 and 28 days. This was done in accordance with BS 1881: Part 111:1983 and BS EN

Part 2. 2000. Once the desired curing period was completed, the concrete cubes were dried and weighed using a weighing balance prior to crushing at 7, 14, 21, 28 days. The weights obtained were divided by the volume of one cube to obtain results for the concrete densities. The testing of the cubes was done in accordance with BS 1881: Part 116:1983 and BS EN

12390 Part 3: 2009, using the Universal testing machine.

III. RESULT AND DISCUSSION

3.1. Compressive Strength

The compressive strength development in OPC, 10% RPA, 20% RPA and 30% RPA mortar specimens with curing periods are shown in Fig. 5. The highest early strength development was noted in mortar specimens prepared with 100% OPC, followed by 10% RPA, 20% OPC and 30% RPA specimens. The 7-day compressive strengths of OPC, 10% RPA, 20% RPA and 30% RPA mortar specimens were 11.34, 8.28, 6.58 and 5.38N/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% RPA specimens, having marginal difference. The 28-day compressive strength of OPC specimens was 22.54N/mm^2 which is about 14.3%, 27% and 36% more than that of 10% RPA, 20% RPA and 30% RPA specimens, respectively.

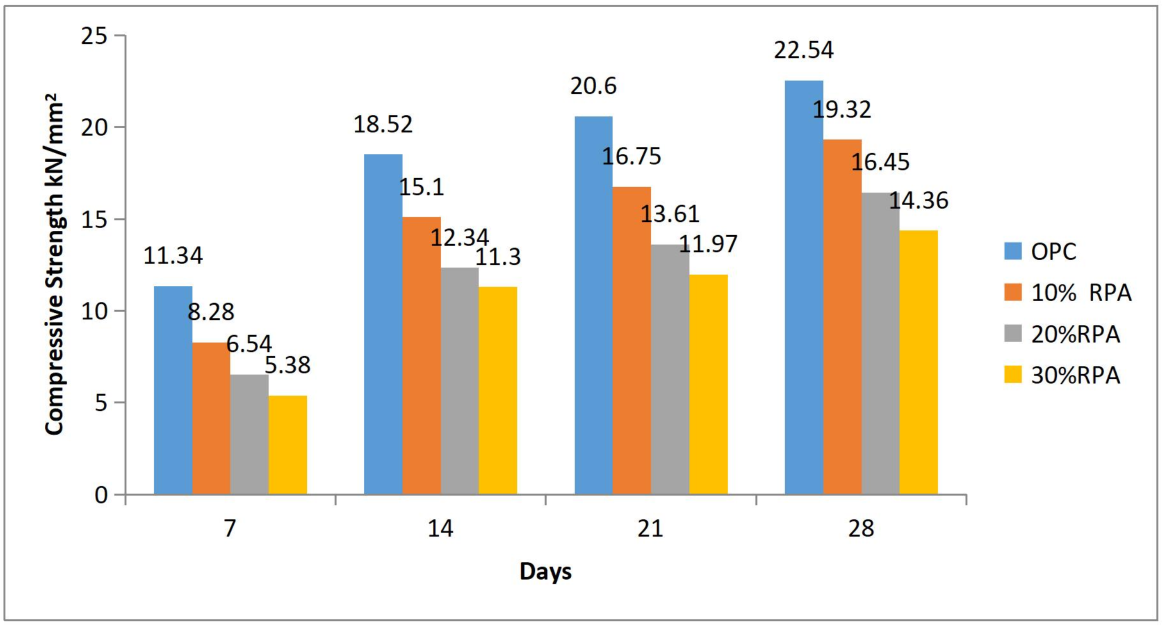


Fig. 1 Compressive Strength Developments In All Concrete Mixtures

3.2 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 more improved the workability will be, indicating that the concrete flows easily and at the same time is free from segregation. The slump achieved was at the value 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.

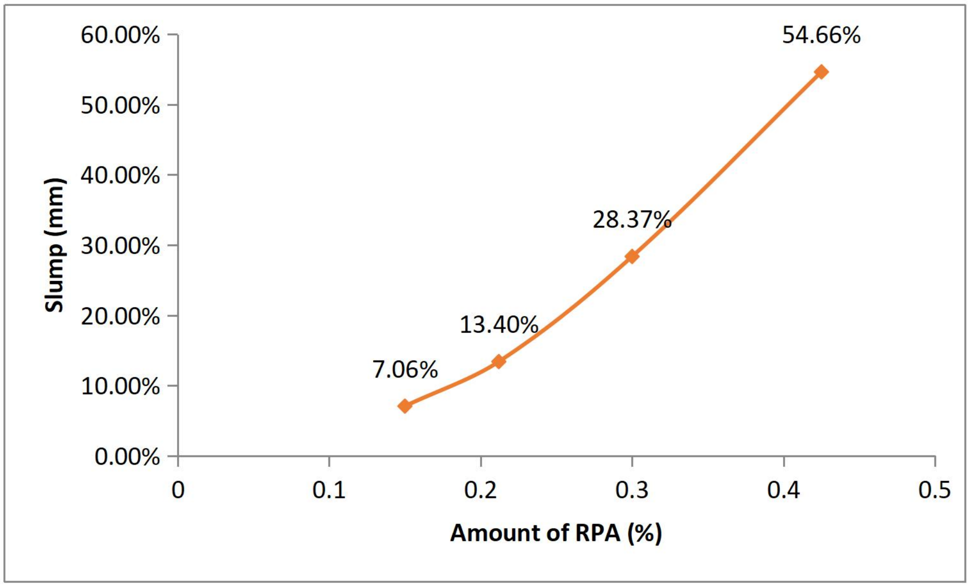


Fig. 2: Slump test results

3.3 Fineness Test

Based on the fineness 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 was determined as 0.8%.

3.4 Particle Sieve Analysis of RPA

The result are presented on the particle seize distribution curve shown on Fig. 3

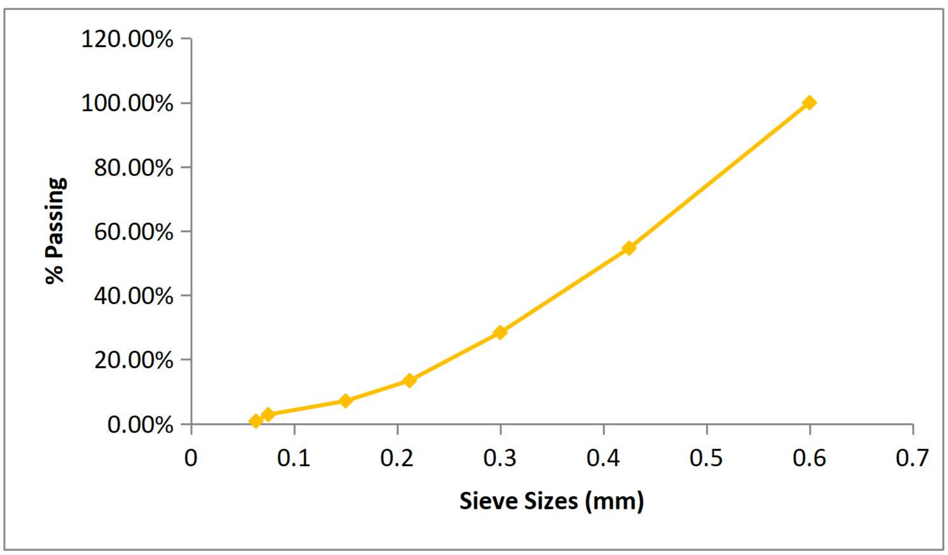


Fig. 3: Particle size distribution curve for RPA

Table 2: Specific Gravity of RPA

Sample weight	Test A (g)	Test B (g)
W_1	22.70	23.20
W_2	32.80	33.31
W_3	77.90	77.75
W_4	73.90	72.80
Gs	1.91	1.96

$$G_s = \frac{(W_2 - W_1)}{\{(W_4 - W_1) - (W_3 - W_2)\}} \quad (1)$$

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

$$G_s = 1.93$$

3.4 Densities of Concrete Cubes

The density of the concrete cubes for OPC, 10% RPA, 20% RPA and 30% RPA were 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 Fig (4)

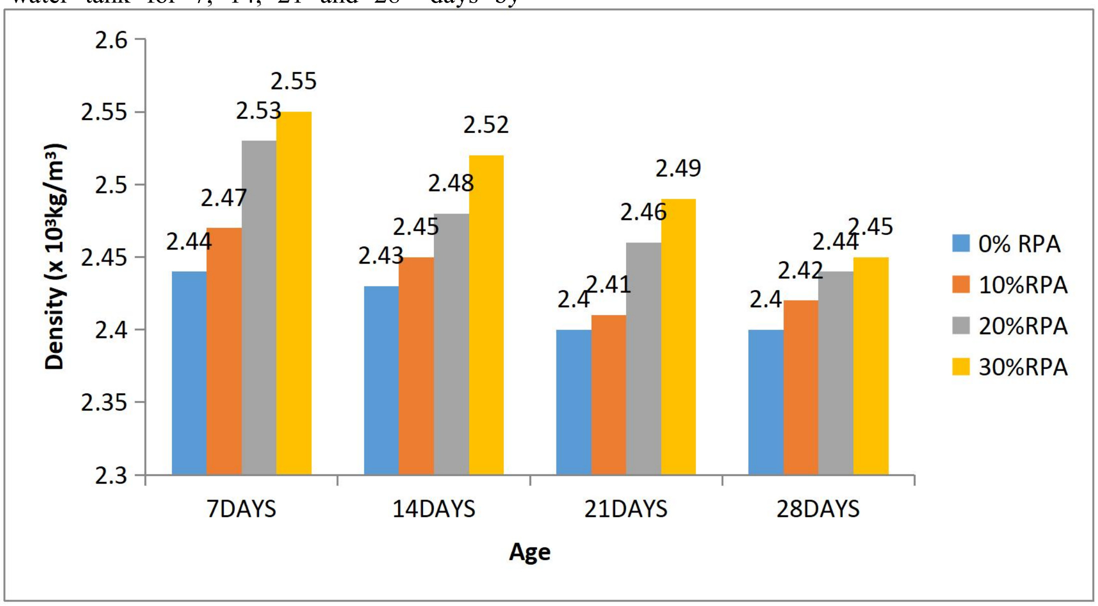
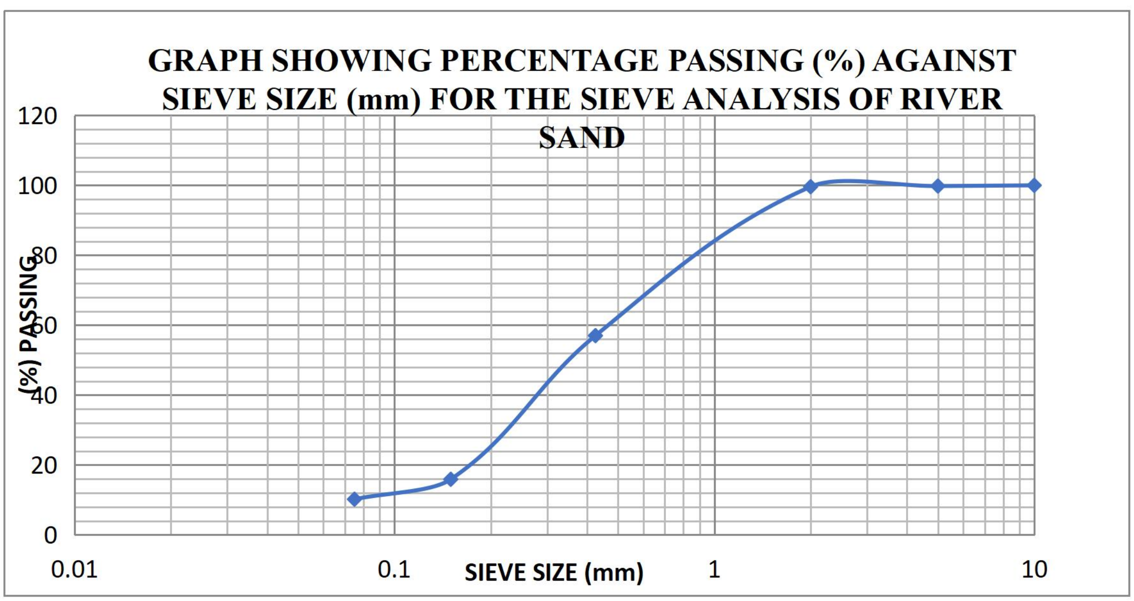


Fig. 4:Densities (x10^{3}kg/m^3) of various RPA contents



Concrete Cost Analysis

The proportioning by weight was used in this research. The concrete mix ratio used was 1:2:4. RPA were used to replace OPC at dosage levels of 10%, 20% and 30% by weight of binder. The concrete cost is calculated below

Table3a: Cost of Concrete materials including Ordinary Portland Cement (OPC) per

Constituent material	Mix ratio	Weight per m^3	Unit cost per kg (Naira)	Total cost per m^3 (Naira)
OPC Cement	1	343	52	52 x 343 = 17836
Fine Aggregates	2	686	6	6 x 686 = 4116
Coarse Aggregates	4	1372	24	24 x 1372 = 32928
Water	0.5	171.5	0	0
Total		2572.5		54880

Table3b cost of binder produced with 10% replacement of OPC with RPA in Naira

Constituent material	Mix ratio	Weight per m^3 (kg)	Unit cost per kg (Naira)	Total cost per m^3 (Naira)
OPC	9	307.7	52	52 x 307.7 = 16052.4
10% RPA	1	34.3	4	4 x 34.3 =137.2
Total	10	343		16189.6

Table3c cost of binder produced with 20% replacement of OPC with RPA in Naira

Constituent material	Mix ratio	Weight per m^3 (kg)	Unit cost per kg (Naira)	Total cost per m^3 (Naira)
OPC	8	274.4	52	52 x 274.4 = 14268.8
20% RPA	2	68.6	4	4 x 68.6 = 274.4
Total	10	343		14543.2

Table3d: cost of binder produced with 30% replacement of OPC with RPA in Naira

Constituent material	Mix ratio	Weight per m^3 (kg)	Unit cost per kg (Naira)	Total cost per m^3 (Naira)
OPC	7	240.1	52	52 x 240.1= 12485.2
30% RPA	3	102.9	4	4 x 102.9 = 411.6
Total	10	343		12896.8

Table 4 Percentage Savings by partial replacement of OPC with RPA per m^3 of concrete

Binder Material	Cost per m^3 of Concrete	Amount saved (Naira)	%Savings
0%	17836	0	0
10%	16189.6	1646.4	9.23
20%	14543.2	3292.8	18.4
30%	12896.8	4939.2	27.69

IV. CONCLUSION

The purpose of this study was an investigation into the potential use of Raffia Palm Ash (RPA) in cement-based materials. Ordinary Portland Cement (OPC) was replaced with 10%, 20% and 30% RPA using a concrete mix ratio of 1:2:4 and water –cement ratio of 0.6.

4.1 Conclusions

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

1. Concrete strength increased with curing age and decreased with increasing percentage of RPA replacement in concrete.

2. The use of RPA reduced the volume of cement used in concrete, thereby potentially reducing the cost of concrete production, emission of the greenhouse gases into the atmosphere; and potentially helping in curtailing global warming and climate change. Reduced cost of construction would arise from the use of locally available agricultural waste materials such as RPA and enhance infrastructural developments.

3. The use of RPA would minimize the environmental issues arising from the disposal of Raffia Palm Wastes.

4.2 Recommendation

1 Cement should be substituted with RPA in concrete at about 10% the original weight of the binder for equivalent normal concrete to mitigate the effects of global warming and high cost of building materials

2 Subsequent studies on concretes with the replacement of cement with RPA, concrete should be allowed to cure for 90 days, by which pozzolanic activity of the ash is believed to have been concluded; and chemical analysis of the ash should be carried out to determine the oxide compositions.

Further tests on the tensile and flexural properties of concrete made from partial replacement with RPA should be conducted

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