Properties of Rice Husk Ash Concrete with Periwinkle Shell as Coarse Aggregates

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ABSTRACT: This research is aimed at investigating the properties of concrete made from 20% Rice Husk Ash (RHA) and 80% ordinary Portland cement (OPC) using granite in one part and periwinkle shell (PS) in varying proportion in the other, as coarse aggregates. A prescribed mix of 1:2:4, cement, fine and coarse aggregates respectively with water cement ratio of 0.56 was adopted. The mix was further adjusted by replacing the coarse granite with periwinkle shell in partial replacement of the coarse aggregate varied at 0, 30, 40, 50 and 100 percentages. The constituents were mixed manually then cast into steel moulds of size 150 x 150 x 150 mm for compressive strength tests, while cylinder mould measuring 80 mm diameter x 250 mm long was used for the splitting tests. All specimens were de-moulded after 24 hrs, cured in water by immersion and then crushed at 3, 7, 28, 56 and 90 days respectively. Results showed that the density of RHA concrete with periwinkle shell in partial replacement of granite is less than normal (granite) concrete. Compressive strength and splitting tensile tests results decreased with increase in the periwinkle shell (PS) content. However concrete mix of 20% RHA and 30% PS, other than the cost savings accrued due to the replacement of the conventional materials leads to concrete with minimum strength of 20 N/mm^2 at 90 days.

KEYWORDS: rice husk, ash, periwinkle shell, compressive strength, split tensile strength

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I. INTRODUCTION

Gross inadequacy in housing delivery in Nigeria has mainly been attributed to the excessive increase in the cost of conventional building materials, especially cement (Achuenu, 1999). In view of this, researchers have been looking at various ways of addressing this problem. Part of the solution to the high cost material could be in the utilization of locally available materials that can partially or even totally replace cement, in concrete production and still achieve the desired results. Established pozzolanas from agricultural wastes such as Rice Husk Ash (RHA), Millet Husk Ash (MHA), Corn Cob Ash (CCA) etc., have been utilized up to 20% partial replacement of cement in production of concrete (Ikpong and Okpala, 1992). RHA as admixture in partial replacement of cement is reported to be 5% (Aboshio et al., 2009) with strength increase of about 14% of the 28day strength of normal concrete.

Zhang and Malhotra (1996), reported that Rice Husk Ash contains a high percentage of silica, usually over 80%. Nehdi et al., (2003) and Ganesan et al., (2008) hence justified its used in partial replacement for RHA to achieve a desirable optimum strength in concrete. To further investigate modified concrete, an understanding of the characteristics of RHA-PS concrete will go a long way in addressing challenges of high cost of materials as well as improve the strength which is essential for building considerations.

Beside the direct savings in concrete cost from such replacement, RHA has been particularly known to improve concrete durability (Zhang and Malhotra, 1996) and its ability to withstand aggressive media (Ganesan, et al., 2008).

Low cost of concrete could also be achieved by totally or partially replacing the traditional granite coarse aggregate with alternatively cheaper materials such as ‘’Marmara’’, Coco nut shells, Oysters shells etc. (Oyetola and Abdullahi, 2006).

This study thus seeks to investigate the strength properties of RHA together with PS concrete with a view to understanding its behaviour for structural application and possibly recommending it as a cost effective concrete constituent material.

II. METHODOLOGY

A. Materials

The binders used in this study were Ordinary Portland Cement (3x) (OPC), manufactured by Dangote and Rice Husk Ash (RHA). The Rice Husk was obtained from local farmers in Kura Local Government Area of Kano State Nigeria, while the ash was then obtained by burning the Rice

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Husk at a controlled temperature of 700°C for 3 hours. The ash was then cooled and sieved through 75 µm. Naturally occurring clean sand, free from impurities, was used as the fine aggregates. Sieve analysis was conducted in accordance to BS 882 (1992) on the fine aggregates to determine its grade zone for mix design purpose.

Granites with aggregates crushing value of 24% for 12mm and 22% for 20mm aggregates were used together with Periwinkle Shell. The crushed granite was obtained from a standard quarry site of Abduljalil Hajaig and Sons Ltd, while the PS was obtained from Sabon-Gari Central Market of Kano State. The PS was first washed and dried to remove all unwanted particles before been subjected to tests (such as sieve analysis, aggregate impact value, bulk density, specific gravity).

The water used for mixing and curing was potable water from the Civil Engineering Laboratory of Bayero University Kano and met ASTM C1602-12 specification of water for use in concrete mixtures.

B. Methods

1). Batching

The Normal concrete was produced based on mix of 1:2:4 for cement, sand and coarse aggregate respectively. RHA-PS concrete were made from RHA partially replacing OPC at 20% and with PS also partially replacing coarse aggregate at 0%, 30%, 40%, 50%, and 100% respectively as shown in Table 1 with water-cement ratio of 0.56 which was obtained from the mix design and an adjusted water-cement ratio of 0.62 to maintain uniform workability of the mixes. Twenty-One (21) concrete cubes were cast for each curing age using 150mm x 150mm x 150mm metal moulds for both normal and RHA-PS concrete. A total of 105 concrete cubes were cast, de-moulded after 24hours and then immersed in water for curing ages of 3, 7, 28, 56 and 90days respectively.

2). Experimental Procedures

A mix of 1:2:4 was used, with a constant water cement (W/C) ratio of 0.56 for the control mix and 0.62% W/C representing 10% addition to the W/C for the mix with 20% of RHA to improve on the workability of the fresh concrete, this is because the RHA absorb much water.

The volume of materials required for the experiment and casting of the cubes were obtained by the absolute volume method (AVM), which assumes that the volume of compacted concrete is equal to the sum of the absolute volumes of all the ingredients as given in Equation (1). Workability of fresh concrete was determined in accordance to BS EN12350-2 (2009).

$$\text{Absolute volume} = \frac{\text{Mass of material}}{\text{Material specific gravity}} \qquad (1)$$

Table 1: Mix Proportion of the Sample Specimens (1:2:4) for 1 m^3.

Percentage mix (%)	W.C (kg)	Cement (kg)	RHA (kg)	Fine (kg)	Coarse (kg)	P.S (kg)
A (RHA 0%, PS 0%)	0.56	315	0	630	1260	0
B (RHA 20%, PS 0%)	0.62	249.6	62.4	624	1248	0
C (RHA 20%, PS 30%)	0.62	248	62	620	1147	93
D (RHA 20%, PS 40%)	0.62	247.78	61.94	619.4	1114.92	123.88
E (RHA20%, PS 50%)	0.62	247.5	61.88	618.76	1082.83	154.69
F (RHA 20%, PS 100%)	0.62	231.2	57.8	578	0	1156
G (RHA 0%, PS 100%)	0.62	291	0	582	0	1164.6

Casting of the concrete cubes were then carried out immediately after the workability test, to determine compressive strength of the remaining mixes at the various curing ages earlier represented. The moulds were lubricated to allow for easy removal of the concrete when fully set. Fresh concrete was filled into the 150mm x 150mm x 150mm moulds in three (3) compacted layers using a tamping rod with twenty-five blows per layer. They were de- moulded after 24hrs and immerses in water for curing for 3, 7, 28, 56 and 90days. At the end of each curing period, three specimens for each mixture were tested for compressive strength and the average was recorded.

3). Compressive Strength Test

The compressive strength of the concrete mixes were determined using Avery Denison compressive machine at a loading rate of 0.05 N/s. The compressive strength was taken as the maximum compressive load the cube can carry per unit areas. The test was carried out after 3, 7, 28, 56 and 90 days of curing ages.

The compressive test was conducted in accordance with BS EN 12390-3 (2009) using Avery Denison Testing Machine of 600kN load capacity and the average taken. The summarized calculations of the quantities required for concrete cubes specimens are presented in Table 2. The compressive strength was calculated as follows.

$$\text{Compressive strength} = \frac{F}{A} \qquad (2)$$

where:
F is the load at failure in Newton and A is the area of a cube which is 150 mm x 150 mm = 22,500 mm^2

Table 2: Summary of Materials Required for Compressive Strength of the Three Specimens Considered (0.078m^3).

Percentage mix (%)	W.C (kg)	Cement (kg)	RHA (kg)	Fine (kg)	Coarse (kg)	P.S (kg)
A (RHA 0%, PS 0%)	4.59	8.19	0	16.38	32.76	0
B (RHA 20%, PS 0%)	3.63	6.49	1.62	16.22	32.45	0
C (RHA 20%, PS 30%)	3.61	6.45	1.61	16.12	29.82	2.42
D (RHA 20%, PS 40%)	3.61	6.44	1.61	16.10	28.99	3.22
E (RHA20%, PS 50%)	3.60	6.44	1.61	16.09	28.15	4.02
F (RHA 20%, PS 100%)	3.37	6.01	1.50	15.03	0	30.06
G (RHA 0%, PS 100%)	4.24	7.57	0	15.13	0	30.28

4). Splitting Tensile Strength Test

The splitting tensile strength of concrete was done in accordance with BS EN12390-6 (2009). The mixing was done manually and cast in steel cylinder moulds of 8cm diameter and 25cm length and cured in water for 3, 7, 28, 56 and 90days respectively. A total of 126 cylinders were tested and at the end of every curing regime, 21 cylinders were crushed with the longitudinal axis of the sample placed horizontally.

The test was carried out using Avery Denison Testing Machine of 600kN load capacity and the average taken. The split tensile strength was calculated using equation (3)

$$\text{Split Tensile Strength} = \frac{2 \times F}{\pi \times l \times d} \qquad (3)$$

where:
d is the diameter of the cylinder = 8 cm = 80 mm
l is the height of the cylinder = 25 cm = 250 mm
F is the load at failure
π is $\frac{22}{7}$

III. RESULTS AND DISCUSSION

A. Properties of Aggregates

Comparing the percentage passing in Table 3 for fine aggregates, it can be seen that the data in the table fit the limit set for zone 3 with fineness modulus of between 2.78 to 1.71. A plot of the data showing also the limit of the zone is represented in Figure 1.

Particles size distribution for the Periwinkle shells ranged from 6.30 to 25.0 mm maximum size. A total of 89.42% by weight of the periwinkle shells were retained on 14.0 mm sieve while 10.58% were retained on 10.0 mm sieve.

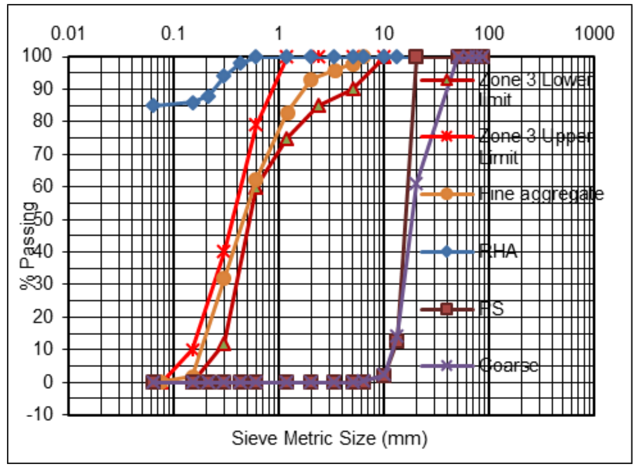

Figure 1: Particles Size Distribution Curve for Fine Aggregate.

Tables 3, 4, 5 and 6 show summary of results of the tests on sieve analysis for fine aggregate, coarse aggregate (granite), and RHA while the results obtained from preliminary tests on materials are recorded in Table 7.

Table 3: Sieve Analysis Test Result of Fine Aggregate.

Particle Description	Sieve Diameter (mm)	Cumulative Passing %
	10	100.00
	6.3	99.89
	5.0	97.80
	3.4	95.80
	2.0	93.00
	1.2	82.70
Coarse	0.6	62.40
Medium	0.3	31.90
	0.15	1.70
	0.063	0.19
Clay or Silt	Pass 63 microns	0.00

Table 4: Sieve Analysis Test Result of Rice Husk Ash.

Particle Description	Sieve Diameter (mm)	Cumulative Passing %
Coarse	0.6	100.00
Medium	0.425	98.00
	0.3	94.00
	0.212	88.00
Fine	0.15	86.00
	0.063	85.00
clay or Silt	Pass 63 microns	0.00

Table 5: Sieve Analysis Test Result of Coarse Aggregate.

Particle Description	Sieve Diameter (mm)	Cumulative Passing %
	50	100.00
	20	61.05
	13.2	14.40
	10	2.25
	6.3	0.35
	5.0	0.00
	3.4	0.00
clay or Silt	Pass 63 microns	0.00

Table 6: Sieve Analysis Test Result of Periwinkle Shell.

Particle Description	Sieve Diameter (mm)	Cumulative Passing %
	20	100.00
	13.2	12.67
	10	2.09
	6.3	0.24
Fine	5.0	0.00
clay or Silt	Pass 63 microns	0.00

Table 7: Summary of Standard Tests on Materials

Material property	Result obtained	Standard range	Standard	Remark
Fine aggregate zone	3	1 – 4	BS EN 933-1	Acceptable
Aggregate crushing value (%) (Granite)	22.03	≤ 30 %	BS EN 12620	Acceptable
Aggregate crushing value (%) (PS)	27.47	≤ 30 %	BS EN 12620	Acceptable
Specific gravity of cement	3.17	3.1 - 3.2	BS 4550-3	Acceptable
Specific gravity of fine aggregate	2.56	2.3–2.9	BS EN 12620	Acceptable
Specific gravity of Rice Husk Ash (RHA)	2.15	2.0–2.2	BS EN 12620	Acceptable
Specific gravity of Periwinkle Shell (PS)	2.25	1.0–2.4	BS EN 12620	Acceptable
Specific gravity of coarse aggregate	2.64	2.3–2.9	BS EN 12620	Acceptable
pH of water for casting	8.3	6.5 – 8.5	BS EN 1008:2002	Acceptable
pH of water for curing before immersion	8.34	6.5 – 8.5	BS EN 1008:2002	Acceptable

B. Workability Test Result

Figure 2 presents results of slump for various concrete mixes considered in the study. Mixes with 20% RHA and PS 50% and beyond gives zero slump. It can be observed from Figure 2 that the workability reduces in the concrete mix containing RHA compared to that of the conventional concrete (control) as also reported by Umoh and Olusola, (2012). This could be attributed to the fineness of the RHA and its high-water absorption potentials. It was also observed that the workability of the concrete mix containing PS decreases with increase in PS content. This is in line with the findings of Adewuyi and Adegoke, (2008).

This may be attributed to the likely trap of water molecules in the pores of the periwinkle shells and thereby further reduce the workability in concrete. When RHA-PS are contained in a mix, the combined effect of both RHA and PS becomes high i.e. zero slump.

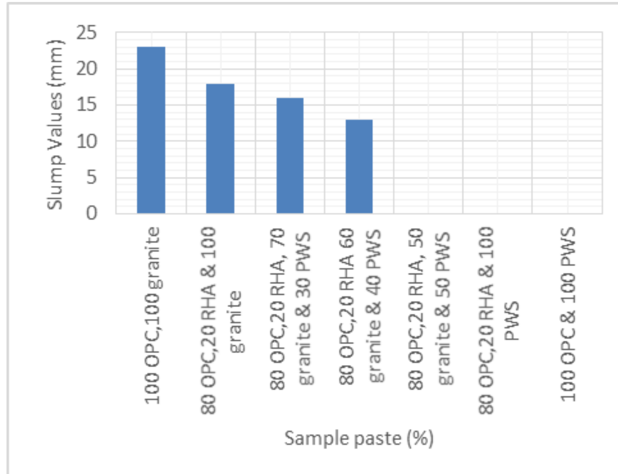

Figure 2: Bar Chart of the Workability Test Results.

C. Compressive Strength and Density of RHA with PS

Mean compressive strength result and densities of concrete cubes cured at 3, 7, 28, 56 and 90 days are presented in Table 9 and 10 respectively.

The compressive strength development of mixes containing RHA and PS is presented in Figure 3. It indicated that compressive strength increased with curing age and decreased with 20% RHA which is in line with other submission (Aboshio et al; 2009) and further decreases with increase in PS content.

The increase in compressive strength with curing age can be attributed to the cementitious products formed as a result of hydration of OPC with pozzolana incorporated in the mix (Adesanya and Raheem, 2010). The decrease in compressive strength with increase in RHA and PS content may be due to reduction in OPC content and the dilution effect of OPC and formation of weaker C-S-H gel as a result of pozzolanic reaction of RHA (Ogork et al., 2014).

The results at 3 days showed a decrease in strength from 11.36 N/mm^2 for control to 8.81 N/mm^2, 7.73 N/mm^2, 7.03 N/mm^2, 5.28N/mm^2, 0.84 N/mm^2, and 1.6 N/mm^2 for the rest of the RHA and PS content respectively. Similar trend was observed at 7, 28, 56 and 90 days as shown in Figure 3.

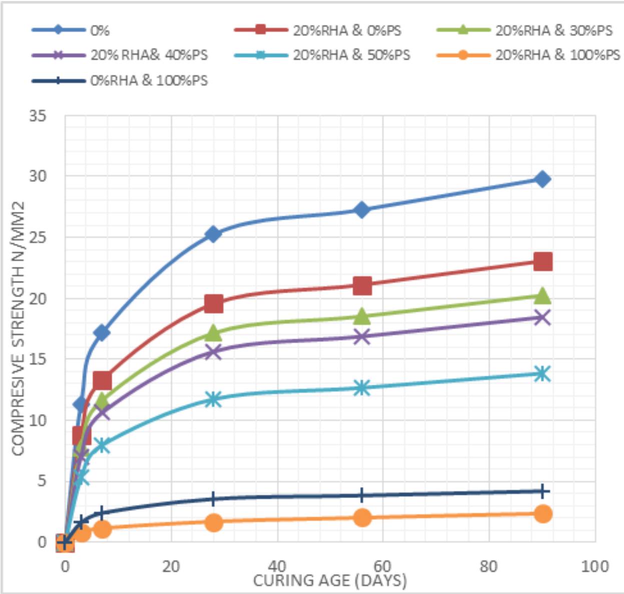

Figure 3: Compressive Strength Test Result.

This result is in line with previous findings that concrete containing pozzolanic materials gained strength slowly at early curing age (Adesanya and Raheem, 2010). The recommended RHA and PS content for production of light weight concrete can be adjudge to be sample B (20%RHA & 30%PS) an average of 28days compressive strength of 17.16 N/mm^2.

This is because further increase in the PS content tends to reduce the compressive strength. It is also observed that sample F (20%RHA & 100%PS) had the lowest compressive strength of 1.70 N/mm^2 at 28days and not up to the minimum strength of 20 N/mm^2 for structural applications. This is because both the RHA and PS tend to lower the strength and that is evident in the results. However, these would be suitable in construction where much strength is not necessarily needed at the initial stage as stated by (Olutoge et al., 2012). Moreover, when these mixes are combined, the compressive strength reduced further than the individual specimens.

Table 8: Bulk Density of Coarse Aggregate, PS and RHA.

Sample	Granite Bulk density of coarse Aggregate (kg/m^3)	PS Bulk density of periwinkle Aggregate (kg/m^3)	RHA Bulk density of rice husk ash Aggregate (kg/m^3)
A	1575.19	516	712
B	1583.97	590	740
Average bulk density (kg/m^3)	1579.58	553	726

The densities of mixes given in Table 8 showed that for the same age, the density was decreasing steadily as the percentage of PS content increased in the mix. This may be due to a higher specific gravity (3.17) of OPC than RHA (2.15) and that of granite (2.64) and PS (2.25). Also, the density of mix with various RHA and PS content decreased with increase in curing age. This is because as the concrete hardens it uses up water in hydration, and the products of hydration occupy less space than the original water and cement (Neville, 2006).

However, all the density values are within the limit of normal weight concrete (2000-2600kg/m^3) in accordance to BS EN 206-1 (2000).

D. Splitting Tensile Strength

The summary of the result of mean splitting tensile strength test is as presented in Figure 4. It can be seen from Figure 4 that the splitting tensile strength increased with increase in curing age and decreased with increase in RHA and PS content. The decrease in splitting tensile strength with increase in RHA content is similar to that presented for the compressive strength and can be attributed to dilution effect of OPC and formation of weaker C-S-H gel as a result of pozzolanic reaction of RHA (Ogork et al., 2014).

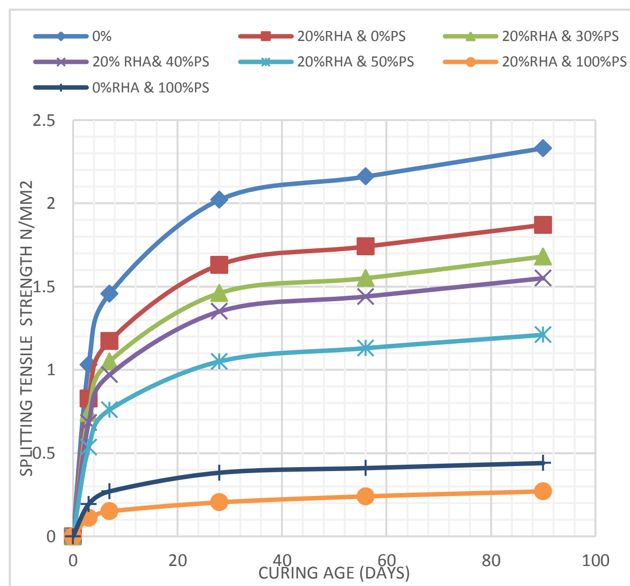

Figure 4: Splitting Tensile Strength Result.

IV. CONCLUSION

In this study, engineering properties of locally sourced RHA- PS concrete were assessed in the laboratory and the following conclusions were drawn from the result obtained:

i. The workability of 20 % RHA-PS concrete decreases with increase in PS content.

ii. Compressive strength and the splitting tensile strength for the various mixes considered increases with increase in curing age and decrease with increase in PS content for 20% RHA.
iii. The optimum content of 20%RHA-PS concrete is at 30%PS content which was found to have at 28 days strength of 18.53 N/mm^2 and 20.24 N/mm^2 at 90days of curing.
iv. Concrete with 100% PS (PS Concrete) as coarse aggregate was found to have at 28days strength of 3.55 N/mm^2 and 4.19 N/mm^2 at 90 days. Similar trend goes for the splitting tensile strength at 28 days strength of 0.69 N/mm^2 and 0.73 N/mm^2 at 90 days.

It is recommended that concrete of 20% RHA and 30% PS could be used for structural purposes since its strength at 90 days meets the minimum 20 N/mm^2 required for such purpose.

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