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Strength Characteristics Of Concrete Made With Rice Husk Ash As Partial Replacement Of Cement Using Periwinkle Shell As Coarse Aggregate

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Abstract

This research is aimed at determining the strength characteristic of rice husk ash /ordinary Portland cement/(RHA /OPC) concrete using periwinkle shell as aggregate. Three mix proportions of 1:1:2, 1:2:4 and 1:3:6 with water/cement ratio of 0:7 were used. The level of percentage replacement of cement with RHA varied with percentage replacement of 0, 30, 40 and 50 adopted in the course of the work. The mix proportion where properly cured and crushed at 7, 14,21and 28 days respectively.

RHA was determined to have a specific gravity of 2.07 with bulk density of 726kg/m^3 while the specific gravity of periwinkle shell was determined to be 2.07 with average bulk density of 553kg/m^3 and was therefore classified as light weight aggregate. Compressive strength test taking on the cubes cast shows strength values decreasing with increase in RHA content and increasing with age. Values of compressive strength obtained at the 28th day hydration period ranges between 3.64-17.96N/mm^2 for all mixes. These values though are low, but still fall within the minimum standard for lightweight concrete specified by[24,3] and were therefore recommended for use as lightweight concrete in masonry concrete, lean concrete bases, simple foundations for masonry work and insulating concrete.

Key words: Rice husk ash, Periwinkle shell, Compressive strength, Lightweight Concrete.

1. Introduction

The high inadequacies in housing delivery in Nigeria have mainly been attributed to the excessive increase in the cost of conventional building materials especially cement [1]. This high cost has also contributed to the non-realization of adequate housing for urban and rural dwellers in Nigeria.

This is why it is exigent to find ways of utilizing locally available building materials for construction purposes. Part of the solution to the high materials cost could be in the form of materials that can partially or even totally replace cement, and still achieve the desired properties since the cost of cement is many times more than the cost of other ingredients. Hence, the investigation into the possible utilization of materials, which are cheap, but of similar properties/quality as cement could be of vital importance. Low cost of concrete can also be achieved by totally or partially replacing the coarse aggregate since it equally constitutes a substantial cost.

Research findings have shown the benefits and potentials of using Rice Husk Ash (RHA), which is an agricultural waste material that could be used in blending cement as a cost saving measure without compromising standards [10, 26, and 23].

In this work, Rice Husk Ash (RHA) is used to partially replace cement and periwinkle shell is used as coarse aggregate. The incorporation of RHA as a partial replacement of ordinary Portland cement (OPC) results to changes in three factors namely: water-cement ratio, aggregate-cement ration, and cement type [11]. When Rice Husk Ash (RHA) is introduced into concrete, water requirement increases [6 and 23], While the cement content decreases (as part of the cement is replaced with RHA) resulting in an increase in the ratio of water content to cement content [13]. [18] reports that different types of cement are made by varying their chemical composition and/or their fineness. Silica with lime forms the essential cementing compound of Portland cement. [25, 26] reports that Rice Husk Ash contains a high percentage of silica, usually over 80%.

[17 and 9] justified the possibility of the partial replacement of cement with certain proportions of RHA to achieve a desirable optimum strength of concrete. Rice Husk as a waste material is abundant in Nigeria, but before considering the advantage and further improvement on the disadvantage of using Rice Husk Ash as a partial replacement of cement, a better understanding and study of the characteristics of concrete made with RHA is essential, particularly the strength characteristics as will be dealt with in this work. This study of RHA products is seen in light of the above as being essential in aiding the housing need at affordable cost.

Periwinkle shell (PS) has been found to be a good lightweight material for concrete production. PS can be used to either partially or totally replace aggregates in concrete, yet achieve the desired properties [16and 15].

The continuous dumping of Rice Husks and Periwinkle shell has resulted and constituted nuisance and waste problems in villages and towns in Nigeria, so adopting them as concrete material will provide an out let for the wastes. From the forgoing therefore, it is expected that if Rice Husk Ash and periwinkle shell can find considerable application in building construction, it will spontaneously reduce the cost of building in Nigeria.

2. Statement of Problem

One of the major problems facing effective delivery of a large number of development projects is the incessant increase in price of building materials including cement and aggregate [1]. Also according to [24] cost wise all concretes depend primarily on two factors; namely cost of material and cost of labour. Labour cost, by way of form works, batching, mixing, transporting and curing is nearly same for good concrete and bad concrete. Therefore attention should mainly be directed to the cost of materials particularly the cost of cement which is many times more than the cost of other ingredients in concrete. It is therefore imperative that a much cheaper building material be developed to enhance the construction of low cost buildings in the most economical manner for residential, institutional, commercial and social purposes. One of such ways is by partially or fully replacing the cement and coarse aggregate contents in concrete to produce a concrete that will possess all the properties and characteristics of a good concrete consistent with strength and durability. Such alternative materials as previously studied to mention a few include sawdust, palm kernel shell, olive seed, Raffia palm, lateritic soil, Rice Husk and Periwinkle shell to either partially or fully replace aggregate(s) in concrete [7,14,8, 16 and 21]. And Rice Husk Ash, Pulverised Fuel Ash (PFA), saw-dust ash, corn ash and so on to partially replace cement [12, 5, and 20].
The problem is that none of the previous researchers have attempted to study the characteristic of concrete made by replacing both the cement content and coarse aggregate at the same time. This research will be a major breakthrough in Nigeria particularly in the Niger Delta area because the research materials Rice husk and Periwinkle shell are waste materials, which are abundant in the area waiting for disposal. Such concrete therefore will be unprecedentedly very cheap as a construction material.

3. Objectives of the Study

1. To establish the compressive strength of concrete made with PS and OPC-RHA at varying proportions of replacements of cement with Rice Husk Ash.
2. To establish the optimum RHA contents from tests, that will achieve the strength and durability standards for the concrete.
3. To establish a mathematical model relating the strength of the concrete to the PS/OPC-RHA content required to achieve this stipulated value.

4. Research Methodology

The methods adopted in this research work are essentially by extensive laboratory experimentation and entails preparing and testing of fresh and hardened concrete specimens. However, a detail review of past-related works was also adapted using test books, journal, periodicals and Internet.
The rice husk used in this research was obtained from Markurdi in Benue State of Nigeria. The husk was burnt in an electric furnace, which allows for accurate monitoring of the burnt temperature. The burning temperature was maintained within the range of 650^{0}C to 700^{0}C as this is the thermal level that produces highly reactive amorphous ash [11]. The husk was burnt in a rectangular mild steel vessel of dimensions 900 × 650 fabricated from a mild steel 1mm thick.
The vessel was loaded with the husk and burnt in the furnace for 2hours, after which the processed husk was withdrawn from the furnace and heaped on a metal tray. Subsequent processed husk were piled on a heap to ensure that the combination of the required temperature and its duration is sufficient to ash the processed husk but not high enough to produce crystalline ash, which is much less reactive than amorphous ash [11]. Also, [25] notes that not only the temperature but also the duration of husk burning determines the crystallinity or other wise of the ash produced.

The heap of processed husk was left to stand for 17 to 20 hours during which period about 80% of the heap turn into ash. The ash was carefully separated from the charcoal and the lather refired in the furnace for about 30 minutes and subsequently heaped for another 17 to 20 hours, within which period it turns in to ash. In all the mixes made, ordinary Portland cement (OPC) was used together with coarse aggregate as control samples. Later, the cement was partially replaced with RHA and the coarse aggregate totally replaced with periwinkle shell (PS). Suitability and functional characteristics of the RHA, cement and PS was determined by carrying out varying laboratory test. Three types of mixes of 1:2:4, 1:3:6 and 1:1:2 (cement/RHA: sand: shell) was used while partial replacements of cement with 0%, 30%, 40% and 50% (by volume of cement) of RHA as recommended by [11] was adopted. Batching by absolute volume of materials was used in this work because of the different specific gravity of the materials.
Water/cement ratio of 0.7 was adopted. The method of mix design used was that published by the Department of The Environmental, United Kingdom. Using each of the above mixes, a total of 144 cubes were cast varying the RHA contents for the water/cement ratio of 0.7 and testing for compressive strength after curing for 7, 14, 21 and 28 days.
The results obtained were subsequently used in the analysis and discussions in this study.

5. Results and Interpretation

5.1 Properties of Rice Husk Ash (Rha)

Table 1. Sieve Analysis of Rice Husk Ash

Sieve size (μm)	% Passing
212	100
150	86.7
75	70.5

Grading of the Rice Husk Ash used in this research work, as shown in table 1 shows that all pass a 212μm sieve size and up to 70.5% by weight passes through a 75μm sieve size. The average specific gravity of RHA was found to be 2.07. This is lower than that of cement with mean specific gravity of 3.15 [18]. The average bulk density of RHA was found to be 726kg/m^3, which is also lower than that of cement with mean bulk density of 1440kg/m^3 [18].

5.2 PROPERTIES OF PERIWNKLE SHELL

Table 2.1. Results of Specific Gravity Test of Periwinkle Shell

Test	Bottle 1(g)	Bottle 2(g)
Wt of bottle only	602	602
Wt of bottle + water (P_1)	1602	1605
Wt. Of oven dried sample in air (W_1)	262	262
Wt. Of S.S.D sample (W_2)	288	288
Wt. Of bottle + water + S.S.D (P_2)	1761	1766
GS. On oven dried basis	2.03	2.11

Table 2.2 Result of Bulk Density Calculation for Periwinkle Shell.

	Kg
Wt of cylinder (W_1)	4.65
Wt of cylinder + uncompacted sample (W_2)	8.25
Wt of cylinder + compacted sample (W_3)	8.78
Wt of uncompacted sample (W_2-W_1) = W_4	3.60
Wt of compacted sample (W_3-W_1) = W_5	4.13
Bulk density of uncompacted sample =W_4/Volume of cylinder (V)	514kg/m^3
Bulk density of compacted sample =W_5/V	590kg/m^3

The apparent specific gravity of the shell was found to be 2.07 (Table 2.1), which is between 1.0 and 2.4 specified by the code for lightweight aggregates [2]. The shell has loose and compacted bulk densities of 515Kg/m^3 and 590Kg/m^3 respectively (Table 2.2). This places the material within the range of bulk densities for lightweight aggregates which vary from 300 to 1100Kg/m^3 [18]. Hence the periwinkle shell can be classified as a lightweight aggregate.

5.3 HARDENED CONCRETE

Table 3. Compressive Strength Development with the hydration period of 7,14,21 and 28 days for all mixes

			7 days	14 days	21 days	28 days
Mix Proportion	W/C Ratio	RHA% Replacement	Compressive Strength N/mm	Compressive Strength N/mm	Compressive Strength N/mm	Compressive Strength N/mm
1:01:02	0.7	0	4.06	13.24	15.32	17.96
		30	3.7	6.74	8.62	8.74
		40	3.05	6.52	6.8	7.2
		50	2.62	5.64	6.08	6.7
1:02:04	0.7	0	3.53	11.28	11.86	11.92
		30	2.15	4.5	6.64	7.9
		40	2.01	3.58	4.06	6.38
		50	0.8	3.12	3.88	4.08
1:03:06	0.7	0	3.28	6.62	7.98	8.9
		30	2.07	6.22	6.64	6.82
		40	1.81	3.5	4.64	5.68
		50	1.2	2.9	3.46	3.64

The results of the development of compressive strength with the hydration period of 7,14,21 and 28 days for all mixes are given in Table 3, while figures 1 to 3 present the variation of compressive strength with hydration period for the various mixes. In addition, figures 4 to 6 present the variation of compressive strength with percentage of RHA replacement for the various mixes. The table and figures indicated that:

1. Strength development continued to increase With hydration period

2. The continual increase in strength as hydration progressed and at an increasing rate, may be taken to indicate that no noticeable deterioration of the concrete had occurred within the 28-day test period.

3. The rate of strength development of PS/OPC-RHA concrete is slow as compared to that of conventional concrete at the initial stage of hydration. This could be due to the fact that initially RHA act as fillers. As the cement hydrates, lime ($CaCOH_2$) is produced. The RHA then react with the lime produced to form the calcium silicate, which reduces the porosity of the concrete, this reduction in porosity leads to increase in strength of concrete.

4. Compressive strength of PS/OPC-RHA concrete decreased with increasing RHA content in all the mixes with the mix having 0% replacement of RHA content having a higher strength, followed by that with 30% RHA content as indicated in table 3.

5. Considering the results compressive strength for the three mixes (mix 1:1:2, mix 1:2:4 and mix 1:3:6) shown in the table 3, the compressive strength of mix 1:1:2 has higher strength value for each percentage of RHA replacement than that of the other mixes and the compressive strength of mix 1:2:4 is higher than that of mix 1:3:6. This could be linked to that the high aggregate cement ratio of mix 1:3:6 to that of 1:2:4 and 1:1:2 respectively. [4] specified that aggregate cement ratio of 2.4-3.0 gives optimum strength above which the strength will be inversely proportional to the aggregate cement ratio. So increasing

aggregate cement ratio (as was the case in mix 1:3:6 having aggregate cement ratio of 9) reduces the strength of the concrete.

6. The compressive strengths obtained at 28-days of hydration period for the 3 mixes and various percentage of RHA replacement as shown in table 4.1 are less than that obtained by [4] who had strengths between 16 and 19.78N/mm^2 at 28days and the values are also less than 21N/mm^2 which is the minimum strength at 28 days for conventional concrete [22].

This low strength is attributed to several factors which are as follows:

i. Degree of compaction of the concrete, which was less since the concrete was compacted manually. The entrapped air voids reduces the strength of concrete, as it is not possible to expel all air from the concrete even in fully compacted concrete [19].

ii. The presence of enclosed voids within the confines of the periwinkle shell, which reduces its density and the density of the concrete. The density of concrete is known to be a function of aggregate pore space. [19] reports that the presence of these voids reduces the strength of lightweight concrete.

iii. The large amount of the periwinkle shell content in the mixes. Although the volumetric proportion of the shell in the mix increases the modulus of elasticity but reduces the strength of the concrete.

iv. The high water content ratio of 0.7 used in the mix. The strength of fully compacted concrete is inversely proportional to the water/cement ratio [19].

7. [24] specified the strength of lightweight concrete as varying from 0.3 N/mm^2 to 40N/mm^2. The [3] recommends that at the 28th day, strength of at least 17N/mm^2 is required for structural lightweight concrete, between 7 and 14N/mm^2 for masonry concrete, and between 0.7 and 7N/mm^2 for insulating concrete. Furthermore the Indian standard IS: 456-1978, recommends the compressive strength at 28th days of between 5 - 7.5N/mm of concrete may be used for lean concrete bases and simple foundations for masonry walls and the compressive strength of concrete lower than 15N/mm^2 should not be used in reinforced concrete.

Based on the above recommendations, the following can be deduced:

i. PS/OPC-RHA Concrete is a lightweight concrete.

ii. PS/OPC-RHA Concrete of mix 1:1:2 with 30%, 40% and 50% of RHA replacement content would be adequate for masonry concrete, lean concrete bases and simple foundations for masonry walls. PS/OPC-RHA concrete of mix 1:2:4 and 1:3:6 with 30% and 40% of RHA replacement content would be adequate for lean concrete bases and simple foundations for masonry walls, while the 50% RHA replacement content of the two mixes will be good for insulating concrete.

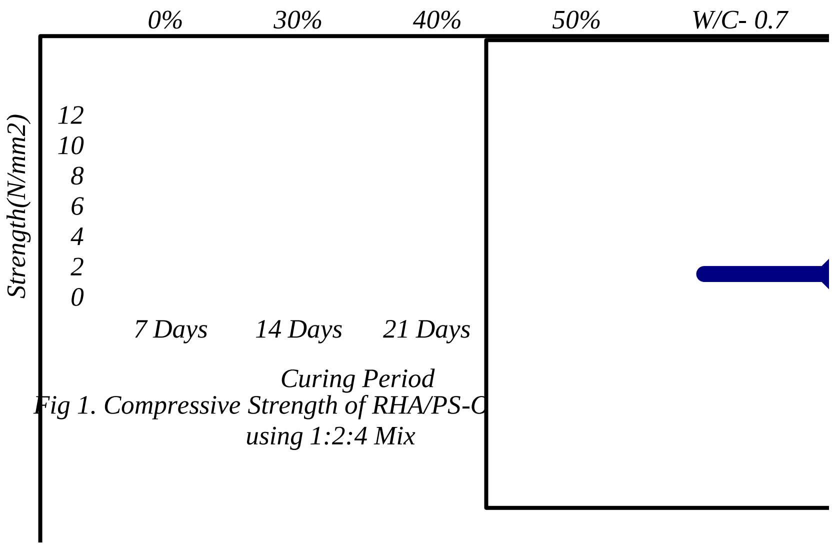

Fig 1. Compressive Strength of RHA/PS-C using 1:2:4 Mix

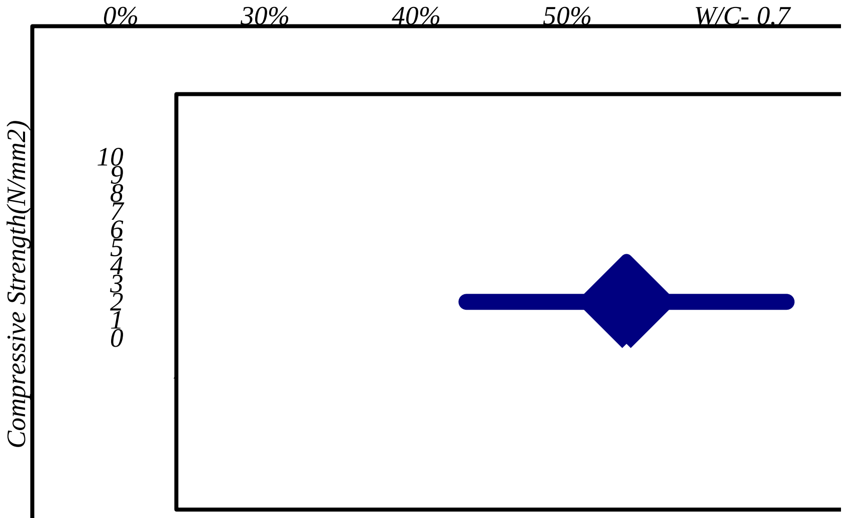

Fig 2. Compressive Strength of RHA/PS-OPC Concrete using 1:3:6 Mix.

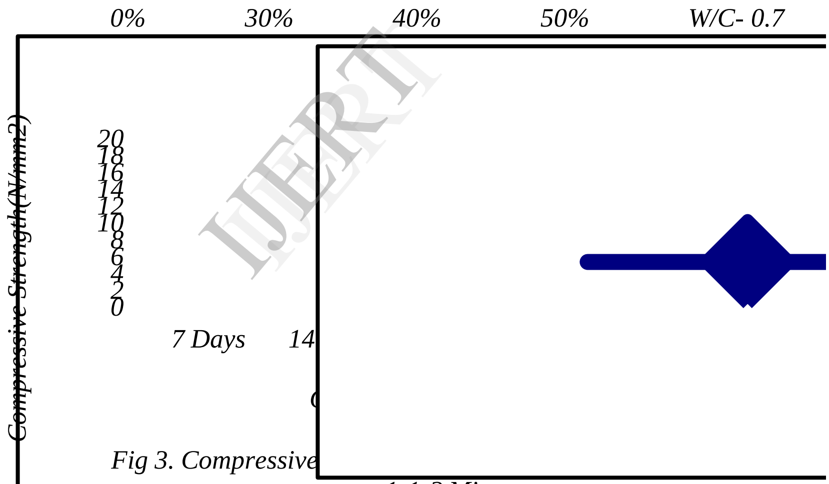

Fig 3. Compressive

1:1:2 Mix.

Table 4. Result of Correlation Test 1

Mix proportion	% Replacement	Multiple R	R Square
1:1:2	0	0.918703	0.844016
	30	0.950736	0.903899
	40	0.941041	0.885558
	50	0.880107	0.774589
1:2:4	0	0.953208	0.908605
	30	0.959496	0.90632
	40	0.957184	0.916201
	50	0.957864	0.917504
1:3:6	0	0.983868	0.967996
	30	0.990958	0.981998
	40	0.929393	0.863771
	50	0.932740	0.870004

TABLE 5.Results of Correlation Test 2

Mix proportion	Multiple R	R^2
1:1:2	0.974065	0.948802
1:2:4	0.905844	0.820553
1:3:6	0.992910	0.985870

5.4 Relationship between the Curing Period and Compressive Strength of RHA/PS-OPC Concrete.

Considering the result of correlation test 1 (table 4), the various correlation coefficient (R) of over 0.9 shows that there is high positive linear relationship between the curing period/age and compressive strength of RHA/PS-OPC concrete. Secondly, the coefficient of determination $R^2 \geq 0.9$ which implies that 90% of the variation in the values of the variables Y (compressive strength) may be accounted for by the linear relationship with the variable X (curing period) of the various mixes of RHA/PS-OPC concrete.

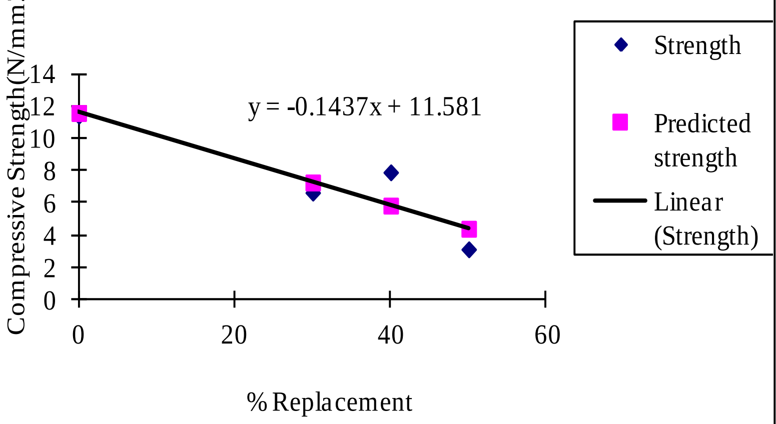

Fig 4. Line Fit Plot for % Replacement against Compressive strength at the 28th day for RHA/PS-OPC Concrete (1:2:4 Mix)

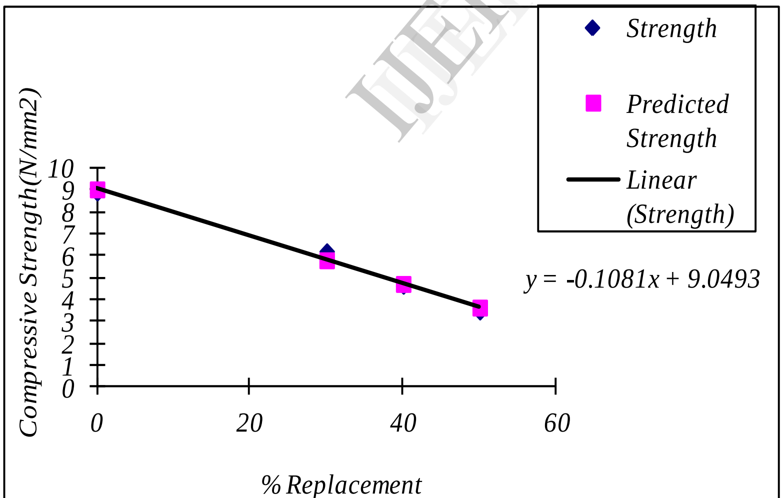

Fig 5. Line Fit Plot for % Replacement against Compressive Strength at the 28th day for RHA/PS-OPC Concrete(1:3:6 Mix)

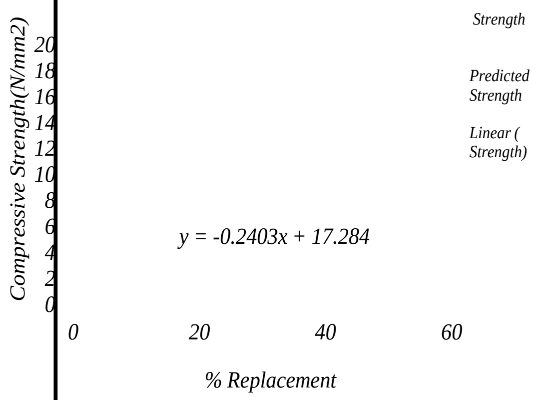

Fig 6. Line Fit Plot for % Replacement against compressive Strength at the 28th Day for RHA/PS-OPC Concrete(1:1:2 Mix)

5.5 Relationship between the % Replacement of RHA and Compressive Strength of RHA/PS-OPC Concrete.

Considering the results of correlation test 2 (Table 5), the various correlation coefficients (R) of over 0.9 shows that there is a high negative linear relationship between the percentage replacement of RHA with OPC and compressive strength of RHA/PS-OPC concrete. This means that the higher the % replacement the lower the compressive strength of RHA/PS-OPC concrete.

Secondly, the coefficient of determination $R^2 > 0.8$ implies that over 80% of the variation in the values of the variables Y (compressive strength) may be accounted for by the linear relationship with the variable X (% Replacement) of the various mix proportion of RHA/PS-OPC concrete.

Regression Model for RHA/PS-OPC Concrete (mix 1:1:2; 1:2:4 AND 1:3:6).

Given that Y = compressive strength of RHA/PS-OPC concrete (N/mm^2)

X=% Replacement of RHA with OPC in RHA/PS-OPC concrete.

Y = -0.1437X + 11.581 **(1: 2: 4 mix)**

Y = - 0.1081X + 9.0493 **(1: 3: 6 mix)**

Y = -0.2403X + 17.284 **(1:1:2 mix)**

The regression plot for the above models are shown in fig.4 – 6

6. Conclusions and Recommendations

(A). Based on the result of experiments carried out to determine the strength characteristics of concrete made with rice husk ash as partial replacement of cement using periwinkle shell as coarse aggregate, the following conclusions are drawn:

1. The burning temperature of rice husk was limited to between 650 – 700^{0}C so as to produce silica that is amorphous (non – crystalline) and highly reactive.
2. The Rice Husk Ash has an average specific gravity of 2.07 and an average bulk density of 726Kg/m^3. These values are less than the mean specific gravity and bulk density of ordinary portland cement, which is 3.15 and 1440Kg/m^3 respectively.
3. The sieve analysis of RHA indicates that it has similar particle size distribution as Ordinary Portland Cement (OPC), which it partially replaces in concrete.
4. To attain good level of workability, concrete mixes containing RHA and PS requires more water content with increasing quantity of RHA and PS.
5. The periwinkle shell used has a specific gravity of 2.07, loose and compacted bulk densities of 515Kg/m^3 and 590Kg/m^3 respectively, which classifies it as a lightweight aggregate.
6. The sieve Analysis of the periwinkle shell showed that it could be used in concrete to replace conventional coarse aggregate of size distribution not greater than 20mm.
7. The value of the compressive strength continues to increase with age, though the rate of increase in strength is low at the initial age, And the 28 days compressive strength for all the concrete mix at the various percentage replacements is of RHA was in the range of 3.64-17.96N/mm^2.
8. The result of the compressive strength test on the hardened concrete was found to depend on the following:

i. The aggregate /cement ratio of the mix
ii. The percentage replacement of R H A with cement.
iii.The physical characteristics of the periwinkle shell e.g., its bond capacity, water absorption and porosity.

(B). Concrete made with rice husk ash as partial replacement of cement and periwinkle shell as coarse aggregate (PS/OPC – RHA concrete) can be used as a light weight concrete for construction work, particularly for construction of masonry walls, lean concrete bases, simple foundations and as insulating concrete. Also, with greater consideration on the mix design and proper site supervision, it can be used for structural lightweight concrete.

(C). Its incorporation in the building industry is anticipated to lead to not less than 50% savings on the cement and coarse aggregate cost used in construction work. This makes it a source of local raw material for the construction industry, which will enhance the provision of low cost housing thereby furthering the realization of adequate housing for urban and rural dwellers in Nigeria.

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