Characteristics of Concrete Produced With Periwinkle and Palm Kernel Shells as Aggregates

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Abstract

We assess the suitability of palm kernel shell (PKS) and periwinkle shell (PS) as partial or full replacement of fine and coarse aggregates respectively, in concrete production. First, the physical properties of PKS and PS were determined. Then concrete was produced using varying percentage replacements of 0%, 25%, 50% and 100% of fine and coarse aggregates, with PKS and PS respectively. The samples were cured for 7, 14, and 28 days. Tests to determine its compressive strength, tensile strength, abrasion resistance and water absorption capacity we conducted. Results showed that the compressive strength and tensile strength of the samples with 25% of its aggregate replaced with PKS and PS are very close to the values of the control samples but there was huge difference when the samples of 50% and 100% replacement were compared with the control sample. However the concrete samples produced with 50% and 100% replacement levels, showed more resistance to abrasion when compared with the control sample. It was concluded that the compressive strength of concrete produced with partial or full replacement of fine and coarse aggregates with PKS and PS, has inverse relationship with the quantity of PKS and PS. It is recommended that maximum of 25% replacement level of PKS and PS as fine and coarse aggregates respectively can be used in concrete production.

Keywords: Aggregates, Concrete, Palm Kernel, Periwinkle, Properties, Shell

INTRODUCTION

Affordability of building materials has been a major concern in the construction industry, in the bid to provide adequate housing for the ever increasing populace of the world especially those in the developing countries like Nigeria, The cost of building material has always been on a sharp rise and as this increase in price continues, majority of the population continues to fall below the poverty line. This means that the need to search for local materials as alternatives for the construction of functional but low-cost building has become a necessity.

Concrete which is the major building construction material is a combination of cement, fine and coarse aggregates and water, which are mixed in a particular proportion to get particular target strength. The cement and water react together chemically to form a paste, which binds the aggregate particles together. The mixture sets into a rock-like solid mass, which has considerable compressive strength but little resistance in tension. (Agbede and Manasseh, 2009)

The overall relevance of concrete in virtually all building construction works and civil engineering practice cannot be overemphasized. The growing concern of resource depletion and global pollution has challenged many researchers and engineers to seek and to develop new materials relying on renewable resources. These include the use of by-products and waste materials in building construction. (Adewuyi and Adegoke, 2008).

Many of these by-products are used as aggregate for the production of lightweight concrete. Although there has been much research conducted on the structural performance of lightweight aggregate in concrete, these are mostly confined to naturally occurring aggregates, manufactured aggregates, and aggregates from industrial by-products. Attempts have equally been made by various researchers to reduce the cost of its constituents and hence total construction cost by investigating and ascertaining the usefulness of materials which could be classified as agricultural or industrial waste. Some of these wastes include sawdust, pulverized fuel ash palm kernel shells, slag, fly ash etc. which are produced from milling stations, thermal power station, waste treatment plants etc.

Periwinkles shells (PS) are waste products obtained from Periwinkles, Periwinkles are small greenish-blue marine snails with spiral conical shell and round aperture. The average periwinkle lives three years and grows to a shell height of 20 mm, but the largest recorded periwinkle grew to 52 mm. They are univalve gastropods of the phylum Mollusca. The genera consist of *Tympanotonus Pachymelania* and *Merceneria*. The two species of Periwinkle commonly found in the estuarine habitat and benthos of the Niger Delta are *Tympanotonus fuscatus* and *Pachymelania aurita. T. fuscatus* occurs in the littoral habitat e.g. Mangrove swamps and *P. aurita* colonized the sub-tidal and mud beaches (Olaniyan, 1975, Dambo, 1985; Dambo 1993). They are common in the riverine areas and coastal regions of Nigeria where they are used for food. The hard shells, which are regarded as wastes ordinarily posed environmental nuisance in terms of its unpleasant odour and unsightly appearance in open-dump sites located at strategic places, are now being considered as coarse aggregates in full or partial replacement for expensive, unaffordable or unavailable crushed stones or local washed gravels. This is a usual practice among the average residents of these areas especially where lightweight concrete is required for non-load bearing walls, non-structural floors, strip footings and other non-load-bearing structural elements.

Palm kernel shell (PKS) is the hard endocarp of palm kernel fruit that surrounds the palm seed. It is obtained as crushed pieces after threshing or crushing to remove the seed, which is used in the production of palm kernel oil (Olutoge, 1995). PKS is light and can be ideal for substitution as aggregate in the production of concrete. Olutoge (1995) in his investigations into the physical properties of rice husk ash, sawdust and palm kernel shell, found their bulk densities to be 530kg/m^3, 614kg/m^3 and 740kg/m^3 respectively. He concluded that these materials had properties which resembled those of concrete materials.

MATERIALS AND METHOD

The study entails laboratory investigation details of the materials and methods used in the research are presented as follows:

Materials

The materials used in this research are: Ordinary Portland cement (OPC), Periwinkle shell (PS), Palm kernel shell (PKS), fine aggregate (sand), coarse aggregate and water.
Details of the types and nature of these materials are as follows:

Cement

The cement used for the study was the OPC manufactured by Dangote Cement Company in Nigeria. It was obtained from local dealers in Zaria and recently supplied and used throughout the production of cubes specimens. Tests were undertaken so as to ensure that it complies with the British standards BS 12 (1996) and EN 197-1 (2000).

Palm kernel shell

The Palm kernel shell (plate I) used was obtained from Umuohia-Agu village, palm oil mill in Ngor-opkala, Local Government Area of Imo State. The PKS was washed to remove oil and other form of impurities, after which it was sun dried and then crushed to fine aggregate size passing through 4.75mm sieve.

PLATE I: Palm Kernel Shell (left), crushed palm kernel shell (middle), Periwinkle Shell (right).

Periwinkle shell

Periwinkle shells (plate I right) were obtained in sufficient quantities from Mile 1 market in Port-Harcourt where they were dumped after the removal of the edible portion. Impurities such as soils and other dirt were removed and the shells were sun dried. Only the shells passing through 19.0mm sieve was used for this study.

Fine aggregates

The fine aggregate used in this research work were clean and air dried river sand which was obtained within Zaria It was sieved with a 5mm B5 112 (1971) sieve, so as to remove the impurities and larger aggregates. Before, the fine aggregate was used; it was subjected to sieve analysis in accordance to the BS 933 Part 1 (1997).

Coarse aggregates

The coarse aggregates used were crushed granite stones obtained from single quarry site along Zaria - Sokoto road. Preliminary tests were carried out on these materials in accordance to the appropriate British Standards such as BS 812 (1990).

Water: Water used for producing concrete was clean fresh water, fit for drinking and free from injurious impurities.

Apparatus: The apparatus used for experiment were; crushed value testing machine, aggregate impact testing machine, weight scale, head pan, BS Standard test sieves, trowels, psycnometer, Wheel Barrow, mixing board, 100mm x 100mm x 100mm cube mold, taping rod, Electric Oven, sack.

METHODS

The various individual constituents used for the production of concrete use for the study and the concrete samples were subjected to various tests, details of those tests are presented are as follows

Aggregates Physical Properties Tests

a. Bulk density:

For the purpose of this research work, the bulk density of the **PKS**, **PS**, sand and gravel was determined at air dry condition in accordance to BS 812 (1975).

A cylindrical mould with height of 180mm and diameter of 110mm was first weighed and then filled with aggregate gradually using a hand scoop and was filled in three equal layers with each layer was tamped with 25 strokes of a 25mm standard rammer. The top was levelled and the weight of the mould and compacted aggregate was determined this was done for fine aggregate (sharp sand) and coarse aggregate (gravel) respectively.

b. Aggregate grading

The particle size distribution of the various constituents used in the production of concrete, used for the study, was determined, summary of the steps are as follows:

One (1) kilogram of each sample (PKS, PS, sharp sand and gravel) were weighed and poured gradually into the arranged stack of sieve. The PS and Coarse aggregate were graded by passing it through BS sieves of sizes 20mm, 10mm and 4.75mm, while the PKS fine aggregate was also graded by passing through BS sieve of 4.75mm, 2.36mm, 1.18mm, 600µm, 300µm and 150 µm. The weight retained in each sieve obtained and summed together and compared with the weight of the sample before sieving in order to get weight retained at each sieve and weight passing from each sieve and the percentage passing at the beginning of the analysis.

c. Specific gravity:

The specific gravity of **PKS**, **PS,** fine aggregate and coarse aggregate was determined in accordance to the provisions of BS 812 -2 (1975) and BS1377 (1990), then, equation 1 was used to determine the Specific gravity.

$$S_g = \frac{[B-A]}{(D-A) - (C-B)]} \; g/m^3 \qquad \textbf{(i)}$$

Where A = weight of psycnometer
B = weight of psycnometer + sample
C = weight of psycnometer + sample + water
D = weight of psycnometer + water
S_g = Specific gravity

d. Moisture content test & water absorption test

Apparatus used are: Aggregate sample, water, plastic container and weighing scale.

Samples "A" of PKS, PS, fine aggregate and coarse aggregate were weighed respectively and was recorded as W1 for each. The Samples were dried in an oven at 105^{o}C for 24 hours. The weight after 24 hours was measured and recorded as W2 for each. Sample "B" of the same weight soaked in water inside plastic containers for 24 hours. The sample weighed after 24 hours was measured and recorded as W3. The moisture content and absorption capacity of the aggregate were computed using the following relationship:.

$$\text{Moisture content} = \frac{\text{Airweight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100 \qquad (2)$$

E. WATER ABSORPTION TEST

Small samples of PKS, PS, fine aggregate and coarse aggregate was put into the plastic bowls, 250ml was poured into each bowl and was allowed to soak for 24 hours. The samples were extracted by means of filtration and the water was measured and the readings were recorded. The results of the test are shown in chapter four.

Mechanical Properties of Aggregate

a. Aggregate Impact Value: The toughness (impact value) of the aggregates (PS and Gravel) was determined in accordance with BS812: part 3 (1975).
Apparatus: BS test sieves of sizes 14mm, 10mm and 2.36mm.Weighing scale, An aggregate impact testing machine, 15mm standard rammer, Cylinder steel cup (100mm diameter and 50mm height).

B. AGGREGATE CRUSHING VALUE

The Aggregate Crushing Value test was

Procedure used were

a. Part of the aggregate passing 13mm sieve and retained on 10mm sieve were collected.
b. The aggregate sample was dried in an oven at 105 $\pm$ 5^{0}C for four hours and allowed to cool.
c. The cylindrical cup was filled with the given aggregate sample in three layers. Each of the layers was tamped twenty five times with a standard rammer. And the net weight of the filled measure was found.
d. The cylinder was filled with the aggregates in the compression testing machine and a load of 400KN (40tons) was applied through the plunger, the load was applied at the rate of 40KN $\pm$ 4KN per minute.

e. The loads were released and then the weight of fine passing through 2.36mm sieve that was produced was measured.

Apparatus used were: Aggregate sample BS Test of Size 14mm, 10mm and 2.36mmm
A 150mm diameter by 135mm high metal cylinder, 15mm diameter by 600mm length standard rammer, Steel plate, Plunger, Oven, Compression testing machine and Weighing scale.

Precautions taken were:

i. Error due to parallax was avoided during readings.
ii. Two tests were carried out from which an average was taken.
iii. Load was applied at the rate of 40KN $\pm$ 4KN per minute.

Concrete Production

A. Concrete Mix Design

Mix design of 1:2:4 with a W/C ratio of 0.6 was used and the quantities were determined using the absolute volume method. The method involves the following steps:

a. Computing the total volume of concrete required.
b. Adding waste (normally 15%)
c. Computing absolute volume
d. Absolute volume of material(AV) $= \frac{\text{Ratio of material in mix x density of material}}{\text{Specific gravity x 1000}}$ (3)
e. Computing total absolute volume
f. Determining the quantities in kilograms per cubic matter of concrete.

Quantity of material (Kg/m^3) $= \frac{\text{Ratio of material in mix x density of material}}{\text{Total absolute volume}}$ (4)

g. Determining the quantities of materials in kilogram for the total volume of concrete required.

Table 1: Specific gravity and density of material used in this research

Materials	Specific Gravity	Density [Kg/m^3]
Cement	3.15	1440.0
Sand	2.66	1681.4
Gravels	3.20	1660.8
Water	1.00	1440.0
PKS	1.15	877.20
PS	1.73	619.90

Workability Test

The degree of workability of the concrete mixes was determined by slump test.

The slump test

The test was conducted in accordance with B.S.1881. This test was conducted to ascertain the slump assumed while designing the concretes.

Storage of specimens:

The normal concrete and the specimen concrete cube specimens were kept in the laboratory for 24 hours after which they were demoulded and the cubes were exposed to air for drying. After the cubes were kept outside sacks. In accordance to the method of curing adopted which is sprinkling method

Testing of Hardened Concrete

Destructive methods of testing were used in this study. This included compressive strength test for cubes. Test carried out on the hardened concrete were the determination of the density of the hardened concrete, and compressive strength.

Density of Concrete

The density in kg/m^3 was determined by air-drying the cured cubes, weighing and computing the density using the relationship;

$$Density\ of\ concrete = \frac{\text{Mass of cube (kg)}}{\text{Volume of cube } (m^3)} \qquad (5)$$

Compressive strength test

The test was conducted according to BS 1881. Here, a total of 48 concrete cubes of 100mm x 100mm x 100mm dimension, were crushed at saturated surface dry condition using the hydraulic crushing machine. The failure load was divided by the cross-sectional area of the specimens to obtain the strength.
The test was carried out by crushing the cube in a crushing machine at 7, 14 and 28days respectively. Three samples of cubes were crushed for 0%, 25%, 50%, and 100% each of the ages. This was accomplished by subjecting the cubes to systematic increase in load using a motorized hydraulic compression machine of 1100km (250,000 1b) capacity. The failure load was recorded from which the compressive strength of the cubes were determined using the relationship below. The test was carried out in the Department of Building, Ahmadu Bello University.

$$\text{Compressive strength (N/mm}^2) = \frac{P}{A} \qquad (6)$$

Where,

P = load at failure

A = Cross-sectional are of specimen (mm)

Tensile strength test

The splitting test was used to establish the tensile strength of the sample specimens. It does not require other equipment than that needed for the compression test, and gives an approximately similar value of the "true" tensile strength of concrete (Neville, 2007). Thus In this study, a destructive testing method was adopted, using concrete cylinder at 7, 14, 28 days of curing. The test was conducted in accordance with BS 1881 (1970). The 100mm diameter x 200mm long cylinder was loaded along the length until the cylinder split. The cylinder concrete used for tensile strength test is shown in plate II.

PLATE II: Cylinder concrete used for tensile strength test

Abrasion resistance

The Abrasion resistance test was undertaken so as to check the level of resistance to wearing of concrete produced with PS and PKS as replacement of coarse aggregate and fine aggregate respectively. Details are as follows:

Apparatus: Concrete cube samples, Wire brush, Scale, Weights,

Procedure
The normal concrete (control) cubes and concrete cubes with PS and PKS were removed from the sack After 28 days of curing, a total of 12 cubes were used .i.e. 3 cubes for each percentage replacement and for the control samples the cubes were air dried for a period of one (1) to (2) hours, each cube was marked with a permanent marker then weighed and the weight was recorded. Then, a load of 3500g was loaded on the brush and tired with a rubber and each cube was brushed 60 times and also the time was recorded for the period of brushing each cube. Besides that, all the cubes were measured again (re weight) and the

final reading or second reading was recorded. After which the differences were computed and recorded.

RESULTS AND DISCUSSION

Data Presentation

The result of test performed on PS and PKS and also on Coarse aggregates (gravel) and Fine aggregate (sand) to determine their properties as follows; bulk density, specific gravity, water absorption capacity, moisture content, impact value, aggregate crushing value, compressive strength, tensile strength and abrasion test. Tests results were compared and discussed.

Physical Properties of Aggregates

The physical properties of the individual constituents used in producing concrete for this research work were first and foremost established and the details of the result is presented in Table 2

Table 2: Summary of the physical properties of the aggregates

Properties	**Periwinkle Shell (PS)**	**Gravel**	**Palm Kernel Shell (PKS)**	**Sand**
Specific gravity	1.73	3.20	1.15	2.66
Bulk density	619.90	1660.8	877.20	1681.4

Table 3: Fine Aggregate Sieve Analysis for sand.

Sieve Size	**Weight retained (g)**	**Weight passing (g)**	**Percentage passing (%)**
4.75 mm	35.97	464.03	92.81
2.36 mm	260.00	204.03	43.97
1.18 mm	47.91	156.12	76.52
600 µm	90.00	60.12	38.51
300 µm	32.17	33.95	56.47
150 µm	15.97	17.98	52.96
Pan	17.97	0	0

Table 4: Fine Aggregate Sieve Analysis for PKS.

Sieve Size	**Weight retained (g)**	**Weight passing (g)**	**Percentage passing (%)**
4.75 mm	86.69	413.31	82.66
2.36 mm	66.20	347.11	84.00
1.18 mm	69.66	277.45	79.93
600µm	189.00	88.45	31.88
300 µm	77.03	11.42	12.91
150 µm	8.63	2.79	24.43
Pan	2.27	0	0

Aggregate Sieve Analysis for PS &Gravel

For the PS the material used was those retained in 13 mm sieve because of the shape of the PS, this was also adopted for the gravel samples

Water absorption & Moisture content

Table 5: Absorption Capacity of materials

Samples	Initial Weight before immersion (g)	Final Weight after immersion (g)	Weight gained (g)	% of water absorbed
1. Gravel	100	109	12	9
2. Sand	100	110	10	10
3. PS	100	125	25	25
4. PKS	100	112	12	12

Table 6: Moisture content

Materials	Moisture content in (%)
PKS	37.12
PS	0

Mechanical Properties of Aggregates

The tests carried are presented in Table 4. Aggregate crushing value test and impact value test.

Table 7: Mechanical Properties of the aggregate

Properties	PS aggregate	Gravel
Impact values	65%	25%

Fresh concrete

Four concrete mix samples were used with content water/cement ratio of 0.6 and a nominal mix proration of 1:2:4, the mix samples are:

A = Cement: 100% Sand and Gravel (control sample)
B = Cement: Sand: Gravel with 25% replacement with PKS and PS respectively
C = Cement: Sand: Gravel with 50% replacement with PKS and PS respectively
D = Cement: 100% PKS and PS – as fine and coarse aggregates respectively.

SLUMP TEST

Result obtained from workability test are in the Table 8.

Table 8: Workability test result.

Mix	W/C ratio	Slump
A (control)	0.6	5
B (25%)	0.6	3
C (50%)	0.6	0
D (100%)	0.6	0

Harden Concrete

DENSITY

The weight of the concrete cubes were taken in the airy dry condition and the density was obtained using the relationship stated in chapter three. The result are presented in Table 9.

Table 9: Weight and Density of cube Samples at 7 days

Mix	**Volume [*m^3*]**	**Average weight [*kg*]**	**Average density [*kg/m^3*]**
A (control sample)	$1.00x10^{-3}$	2.44	2440
B. 25% PS & PKS	1.00×10^{-3}	2.12	2120
C. 50% PS & PKS	1.00×10^{-3}	1.98	1980
C. 100% PS & PKS	1.00×10^{-3}	1.38	1380

Table 10: Weight and density of cube samples at 14 days

Mix	**Volume [*m^3*]**	**Average weight [*kg*]**	**Average density [*kg/m^3*]**
A (control sample)	$1.00x10^{-3}$	2.46	2460
B. 25% PS & PKS	1.00×10^{-3}	2.11	2110
C. 50% PS & PKS	1.00×10^{-3}	1.74	1740
D. 100% PS & PKS	1.00×10^{-3}	1.41	1410

Table 11: Weight and density of cube samples at 28 days

Mix	**Volume [*m^3*]**	**Average weight [*kg*]**	**Average density [*kg/m^3*]**
A (control sample)	$1.00x10^{-3}$	2.56	2560
B. 25% PS & PKS	1.00×10^{-3}	2.16	2160
C. 50% PS & PKS	1.00×10^{-3}	2.05	2050
E. 100% PS & PKS	1.00×10^{-3}	1.45	1450

Table 12: Compressive strength test result

Sample	**W/C**	**Compressive strength (N/mm^2)**		
		7days	14days	28days
A (control sample)	0.60	8.65	16.80	20.00
B 25 % PS &PKS	0.60	9.67	10.90	18.50
C 50 % PS &PKS	0.60	6.70	9.30	12.00
D 100 % PS &PKS	0.60	2.70	3.75	9.50

TENSILE STRENGTH

The tensile strength of concrete produced by replacing coarse and fine aggregate with PS and PKS respectively with that of the normal concrete (control sample), was determined so as to assess the suitability of using the PS and PKS to produce concrete.

Table 13: Tensile strength test result

Sample	**W/C**	**Tensile strength (N/mm^2)**		
		7days	14days	28days
A (control sample)	0.60	0.43	0.72	0.80
B 25 % PS &PKS	0.60	0.48	0.71	0.76
C 50 % PS &PKS	0.60	0.41	0.67	0.72
D 100 % PS &PKS	0.60	0.32	0.32	0.33

ABSORPTION CAPACITY

Table 14: Absorption capacity of concrete cubes produced

Samples	**Initial Weight before immersion (kg)**	**Final Weight after immersion (kg)**	**Weight gained (kg)**
A. control	2.460	2.462	0.002
B. 25%	2.08	2.12	0.04
C. 50%	1.78	1.82	0.04
D. 100%	1.36	1.42	0.06

ABRASION TEST

Samples	**Initial Weight before abrasion [*kg*]**	**Final Weight after abrasion[*kg*]**	**Weight loss[*kg*]**
A. Control	2.373	2.372	0.001
B. 25%	2.760	2.740	0.020
C. 50%	1.790	1.786	0.004
D. 100%	1.380	1.375	0.004

DISCUSSION

Results obtained are discussed under the following headings:

Specific Gravity

As it can be observed from Table 2 and Figure 1, the specific gravity of PS is 1.73, while that of gravel, which is the coarse aggregate used as a control, is 3.20. When the Specific gravity of the two materials is compared, it can be observed that there is a wide difference between the two values. The Specific gravity of gravel is almost twice as much as that of PS. In other words PS has Specific gravity which is 45.94% lower than that of gravel (coarse aggregates). On the other hand, when the materials used as fine aggregates are related, it can be seen that PKS Specific gravity is 1.15 as against sand with 2.66. In this case, also, there is a difference of 57%. . PKS has a Specific gravity which is approximately 57% lower than that of sand. According to Clarke & Cookie (1992) if the percentage difference is less than 5 it can be regarded as negligible. But in these two cases, the difference between the specific gravity of sand (fine aggregates) and gravel (coarse aggregates), on one hand, and PKS and PS,(serving as full or partial replacement of fine and coarse aggregate), on the other hand, the difference in each case, is very wide (50%). Thus in both cases, they do not conform to Clarke's (1992) conclusions of neglecting the difference as they are by far, greater than 5%.

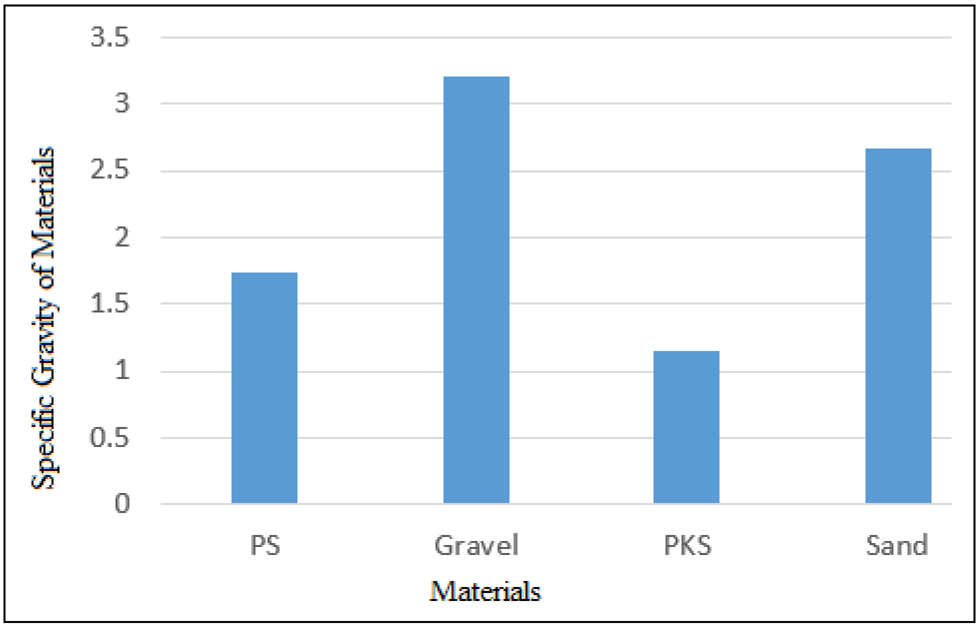

Figure 1: Specific gravity of materials used for concrete production

Specific gravity is the ratio of the mass per cubic meter of the aggregate to the mass of the same volume of water at the stated temperature. It is used in the batching of the mix. Thus when and where the specific gravity is low, for a particular material, it implies that more of such materials will be needed, in the production of concrete.

Sesha (2014) classified aggregate with specific gravities ranging from 2.5 - 2.7 as normal weight. From the data and analysis PS and PKS can be classified as lightweight materials as they fall below this classification.

Bulk Density

Looking at Table 2, the Bulk density of PS is 619.90kg/m^3 while that of gravel is 1660.8 kg/m^3. Also the PKS is 877.20 kg/m^3 as compared to the Bulk density of sand which is

1681.40 kg/m^3. Figure 2 depicts the difference in the values of Bulk density between the four different constituents used in the study, as aggregates.

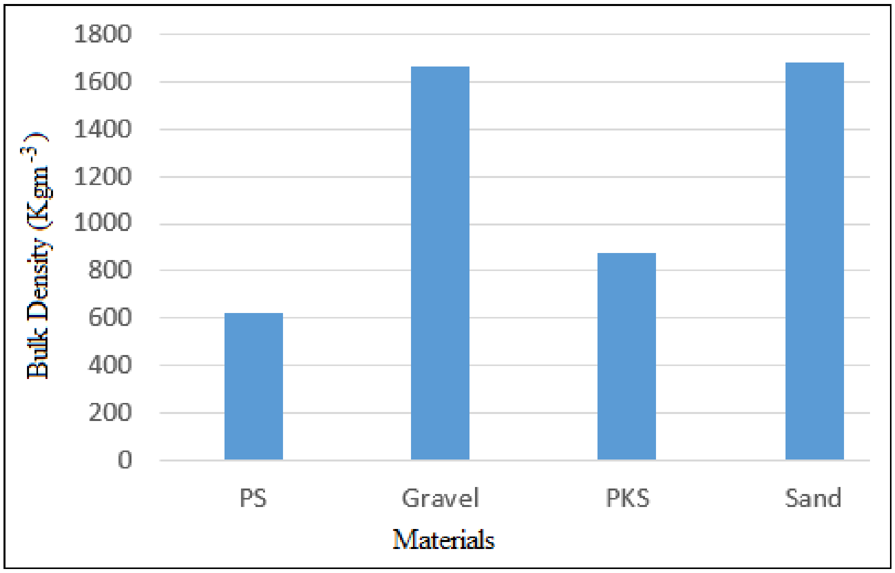

Figure 2: Chart of bulk density of material used for concrete production

Thus the bulk density of Gravel is 62.67% greater than that of PS while the Bulk density of sand is 47.83% greater than that of PKS .Aggregate of a given specific gravity having low bulk density means that there is lose packing. Therefore, when the two physical properties are considered, it can be said that the gravel is denser than PS and Sand denser than PKS.

Bulk density is the weight of aggregate held by container of unit volume when filled or compacted under different condition (Shetty, 2009 and Duggal, 2012). The low value of PKS and PS in relation to the control samples, sand and gravel, could be due the texture and shapes of the sample specimens – PKS and PS. The implication of this is: concrete produced with these two materials as fine and coarse aggregates, respectively, is that the strength of concrete produced with this material, may be relatively lower in strength and more of such materials are required compared to situation when sand and gravel are used in the production of concrete.

Water absorption

According to (Neville & Brooks 2010), the important requirement for a dry normal aggregate, is that it must have compacted bulk density of not less than 1200 kg/m^3 it can be inferred that the bulk densities of PKS and PS are lower than the required bulk density for the production of normal concrete . But according to Sesha (2014) this type of material (aggregates) falls under ultra-light weight aggregate, Balamurali (2014) classification also conforms to this assumption of classifying PKS and PS as ultra-light weight aggregates, for it values falls within the ranges of aggregates used for non -structural members and insulating materials. This shows that PKS and PS can be used in production of such materials stated based on BS812 (1975) which recognises two degrees of compaction, Loose and Compacted PS & PKS can be considered as loosely compacted materials.

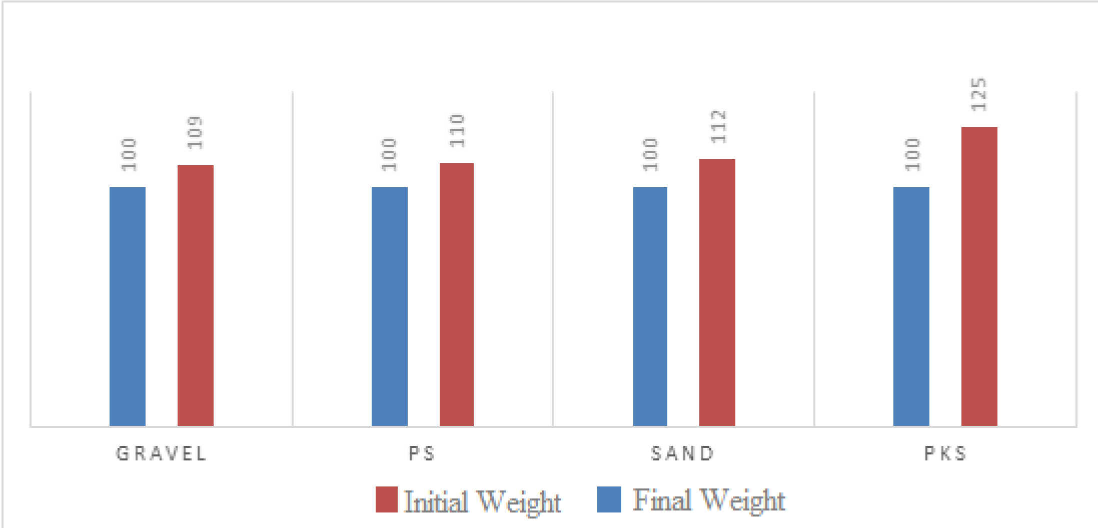

Figure 3: Water absorption chart for specific gravity of materials used for concrete production

Form Table 5 it is seen that PS and PKS absorbed more water when compared to Gravel and sand respectively, which means concrete produced using these materials have more tendency to absorb water at a higher rate when compared to the conventional concrete.

Impact values

From the results the PS has low resistance to impact when compared to that of gravel. From the result impact value of the PS shows that the aggregate used is not for wearing surface but can be used for other structural element. As stated by Shetty (2009), wearing surface aggregates were required to have maximum impact values of 30% while other concrete aggregates are to have maximum values of 45%. The aggregate impact values followed the stipulation of BS 812 part 3: 1975.

Workability

Result of Slump test shows that all the various samples have slump below 25mm, based on Gambhir,(2006) classification, it means the mixes have low workability. This could be due to the nature of the aggregates; for the fact that both the sample specimens that were used as fine and coarse aggregates, PK and PKS, respectively, have rough texture. In view of the fact that workability relates to the ease with which a given set of materials can be mixed into concrete and subsequently handled, transported and placed with minimum loss of homogeneity, concrete with such type of workability, will, most likely, exhibits internal friction between particle and particle or may not overcome the frictional resistance offered by the formwork surface or reinforcement contained in the concrete with just the amount of compacting efforts forthcoming (Arthur 2007)

Hardened Concrete

Density of concrete

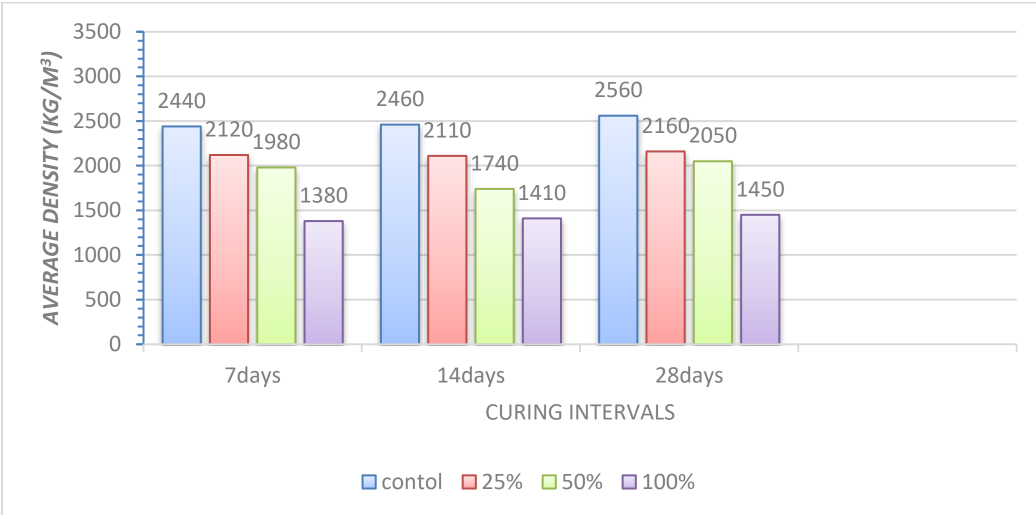

Figure 4: Density of concrete cube sample used at their different curing intervals.

Density obtained from concrete mix sample A. (control) ranges from (2560-2440) kg/m^3 with average of 2500 kg/m^3. Concrete of sample B. (25%) ranges from (2160-2120) kg/m^3 with average density of 2140 kg/m^3. The concrete sample C. (50%) ranges from (1980-2050) kg/m^3 with average density of 2015 kg/m^3. Concrete of Sample D. (100%) ranges from (1380-1450) kg/m^3 with average density of 1415 kg/m^3. It can be observed clearly from Figure 4, which the more the quantity of material replaced the lower the density of the concrete produced reduces. Thus, there is inverse relationship between the density of concrete produced with full or partial replacement of fine and coarse aggregates with PKS and PS, respectively.

Based on the aforementioned observations, only the control sample meets the generally assumed density for concrete. Glenn Elert (2000) noted that “typical density of concrete is 2300 kg/m^3” but "Volume generally assumed for the density of hardened concrete is 2400 kg/m^3” it was also stated that densities ranging from 1750–2400 kg/m^3 is classified as light weight concrete, while some experts like Neville (2007) and Gupta & Gupta (2006) classified concrete as follows;

- **a.** Super heavy weight (density greater than 2500 kg/m^3)
- **b.** Heavy weight (2500 kg/m^3)
- **c.** Normal weight concrete (density of 1899 to 2499kg/m^3)
- **d.** Light weight (density below 500kg/m^3)

Looking at this closely, the results obtained from concrete samples with 25% replacement has an average density of 2140 kg/m^3 which can be classified as normal concrete.

Compressive Strength of Concrete

Conventionally concrete mix of 1:2:4 is expected to have a target strength of 25N/mm^2 and is expected to have gained 2/3 of its estimated target strength after seven days of curing, which is about 16.66N/mm^2 and this accounts for 66.66% of the expected strength but from the chart none of the sample achieved the expected strength, the control sample A. had a compressive strength of 8.65 N/mm^2 which is 34.60% B. 25% had 9.67 N/mm^2 which is 38.68%, C. 50% had 6.7 N/mm^2 which is 26.8% and D. 100% had 2.7 N/mm^2 which is 10.8% of the target strength. At 14 days the control sample A. had a compressive strength of 16.8 N/mm^2 which is 67.2% B. 25% had 10.90 N/mm^2 which is 43.6%, C. 50% had 9.3 N/mm^2 which is 37.2% and D. 100% had 3.7 N/mm^2 which is 14.8% of the target strength. After 28 days control sample A. had a compressive strength of 20 N/mm^2 which is 80% B. 25% had 18.5N/mm^2 which is 74%, C. 50% had 12.0N/mm^2 which is 48% and D. 100% had 2.7 N/mm^2 which is 38% of the target strength.

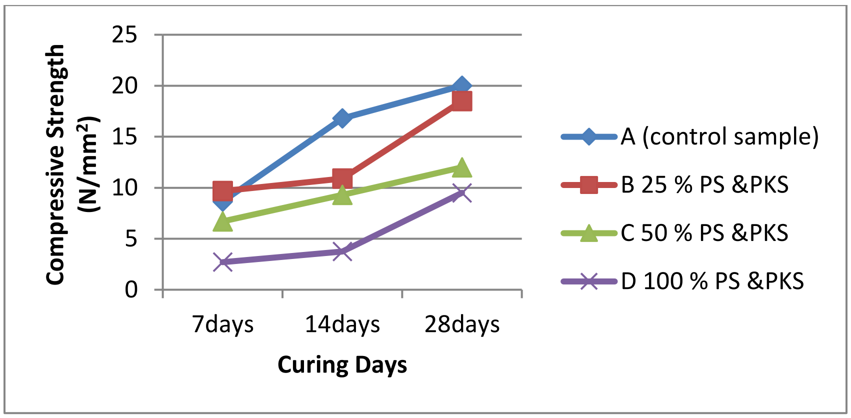

Figure 5: Compressive strength of concrete produced at different days of curing

From the results it can be observed that after 28 days of curing the control sample had a compressive strength of 20N/mm^2, which is 20% lower than the expected of 25m/mm^2 .this drop in the compressive strength might be as a result of the method of curing adopted for the purpose of this research work. When the compressive strength of control sample is compared with that of the 25% replacement, it can be observed that they are close; in fact, the compressive strength of control sample after 7 days of curing is less than that 25% partial replacement of PKS and PS. Besides that, at 28 days of curing the control sample and that of sample specimen (concrete made with PKS and PS) have the following compressive strength: 20N/mm^2 and 17.50 N/mm^2. Thus the compressive strength of sample specimen represents 87.5% of the control. The compressive strength of concrete gives an idea of the quality of concrete as such, the compressive strength is used by designers, specifers and users of concrete as quality index (Mehta & Monteiro 2007).

Tensile strength

From Figure 6 it can be observed that the tensile strength of sample A (control) ranges from 0.43 to 0.80 N/mm^2, sample B 0.48 to 0.76 N/mm^2, sample C(50%) ranges from 0.41

to 0.72 N/mm^2, sample D. ranges from 0.32 to 0.33 N/mm^2. The difference of between the tensile strength of the samples with 25% and 50% replacement is relatively narrow and consistence with the age of the concrete as it increase unlike the 100% replacement which has a wide difference when compared with the control sample. It can be observed that as the volume of the percentage replaced increases the tensile strength decreases. Also completely replacing the aggregates would produce a concrete with very low tensile strength, which means concrete produced using PKS and PS as full replacement for sand and gravel respectively would have very low tensile strength. Thus there is inverse relationship between the tensile strength and the quantity of PKS and PS, used as full or partial replacements of fine and coarse aggregates in concrete production.

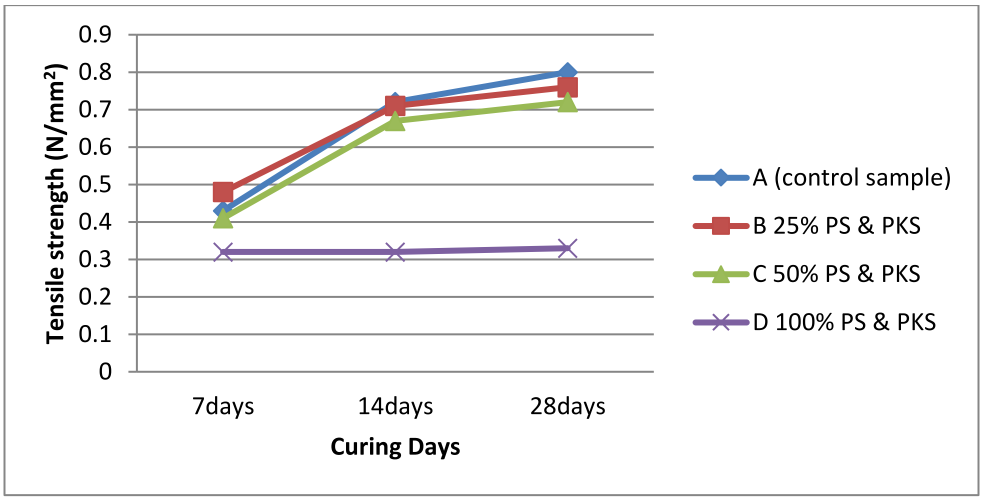

Figure 6: Chart of tensile strength of concrete produced at different days of curing

Water Absorption Capacity

From Table 14 the difference in absorption rate in kg when compared with the control sample is 0.038 kg for 25% and 50% replacement and 0.058 for 100% replacement. It can be observed that concrete produced with PS and PKS as replacement of gravel and sand has more tendency to absorb water when compared with conventional concrete. The high absorption of water of concrete specimen may be due to the use of PKS and PS as partial or full replacement of fine and coarse aggregates. This becomes very clear when the control sample is compared with 100% replacement of aggregates with the normal fine and coarse aggregates. Thus the higher the quantity of PKS and PS, the less the water absorption capacity. This is to be expected because use of PKS and PS, leads to increase in pores in between the particles of the concrete matrix due to the nature of the surface texture of PKS and PS.

Abrasion Test

From the results obtained it indicates that concrete produced with 25% partial replacement of normal fine and coarse aggregates, lost more weight compared to other samples. The difference between that sample B (25%) replacement and the control sample A is 0.019 kg while when compared with samples C and D the difference is 0.003 kg this shows that there is low difference margin between the value of the control sample and the concrete sample specimen produced with partial or full replacements of normal fine and coarse aggregates with 50% and 100% replacement with PS and PKS. This also implies that the abrasion resistance increase with increase in the quantity of PKS and PS. Thus there is direct relationship between the wearing resistance with the quantities of PKS and PS.

SUMMARY

In this study various tests were undertaken to evaluate the characteristics of PS and PKS, assess the properties of concrete produced with PSK and PS as partial or full replacement of normal aggregates and establish their suitability as a possible replacement of both fine and coarse aggregates in concrete production. Highlights of the major findings are as follows:

The Specific gravity of PS and PKS are 1.73 and 1.15 as against the Specific gravity of sand and gravel, (controls) which are 2.66 and 3.20. Thus The Specific gravity of PS and PKS are lower than the normal aggregates by 57% and 46% respectively. Also the Bulk density of PS and PKS are 619.90kg/m^3 and 877.20 kg/m^3 respectively. These values represent 62.67% and 47.83% less than the Bulk density of gravel and sand respectively.

The concrete produced with partial or full replacement of fine and coarse aggregates with PKS and PS have average density of 2440 kg/m^3, 2120 kg/m^3, 1980 kg/m^3 and 1380 kg/m^3 for 0%, 25%, 50% and 100%. While the compressive strength for 0%, 25%, 50% and 100% are 20 N/mm^2, 18N/mm^2, 12N/mm^2 and 9.50N/mm^2. The tensile strength for 0%, 25%, 50% and 100% are 080 N/mm^2, 0.76 N/mm^2, 0.72 N/mm^2 and 0.33 N/mm^2 respectively.

CONCLUSION AND RECOMMENDATIONS

PS and PKS can be classified as light weight aggregates because of their low density and specific gravity. Besides that they are loosely compacted and have higher rate of water absorption capacity when compared with the conventional aggregates. Replacing the conventional aggregates with PS and PKS would give low workability and had more water absorption capacity. They can, however, be used for production of light weight concretes. The difference in compressive strength of concrete cube produced with 25% replacement of conventional aggregates with PS and PKS was not much. Thus based on the results of the study, it was concluded that complete replacement of the normal aggregates with PS and PKS would produce concrete with low compressive and tensile strengths, low resistance to wearing and concrete with relatively, tendency to absorb water compared with the conventional concrete. However, the materials (PKS and PS), have the potentials to be used as aggregates for concrete production but for partial replacement of the normal aggregates of up to 25%. Based on the research findings, the following recommendations are made:

a) PKS and PS should be used as partial replacement of fine and coarse aggregates, respectively, in concrete production it should however, not exceed 25% partial replacement.
b) The use of PKS and PS as fine and coarse aggregates respectively, in the production of concrete structure should be restricted to non-structural concrete.

c) Research should be carried out on the durability properties of concrete produce with PSK and PS as partial replacement of aggregates in concrete production; most especially exposure to chemically aggressive environment.
d) Research should be undertaken on the possibilities of using PS and PKS in concrete production considering lower replacement quantities e.g. 5- 20 %.
e) Research should be carried out on effects of admixture on concrete produced using PS and PKS as replacement for conventional aggregates.

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