Prospect of Lateritic Sand and Periwinkle Shell as Aggregates in Concrete.

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***Abstract*—This study investigates the potential usefulness of periwinkle shell as an alternative replacement of coarse aggregate in concrete work. The mechanical properties of concrete with fine and coarse aggregates components fully and partly replaced with lateritic sand and periwinkle shell was investigated. A working sample of one hundred and thirty five concrete cubes of 100mm dimensions were produced and cured in water for 7, 14 and 28 days. The fine aggregates and coarse aggregates were replaced with lateritic sand and periwinkle shells respectively at 10%, 20%, 30%, 40% and 100%. The mix proportions adopted for this work was 1:1½:3, 1:2:4 and 1:3:7 with water/cement ratio of 0.65. the results indicates that through partial replacement the concrete composed of up to 20% of lateritic sand and periwinkle shell developed a higher compressive strength for the curing ages of 7, 14, and 28days independent of the mix ratios than concrete containing lateritic sand and periwinkle shell at 100% full replacement.The study therefore recommends that 20% lateritic sand and periwinkle shell replacement for fine and coarse aggregate in concrete is suitable for use as low strength lightweight concrete.**

***Index Terms*—Compressive strength, lateritic sand, laterized concrete, periwinkle concrete, periwinkle shell.**

I. INTRODUCTION

Shelter is one of the three basic necessities of life. It has been reported that housing deficit in Nigeria stands at 17 million. This translate to over 65 million out of the over 167 million either living in overcrowded homes or without shelter. The World Bank predicted that N59.5 trillion will be needed to bridge housing deficit [1]. With dwindling revenue from oil, Nigerians' major source of foreign earning, it will be a herculean task to bridge the current housing deficit in the near future. Another factor that contributes to the huge housing deficit is the persistent ever increasing prices of concrete materials such as river sand, granite and cement.

Sourcing for an alternative building materials has been the focus of researches in building materials development worldwide to evolve conventional materials [2]. The evolution of alternative aggregate materials is believed to be key to promoting research in low-cost construction materials. A number of attempts have been made to provide local alternatives to the use of river sand and granite/washed stone as fine aggregate and coarse aggregates respectively in conventional concrete. Laterite has been used in part as alternative material for the replacement of sand in concrete to produce what is now referred to as laterized concrete [3]. Recent developments in the building construction industry have witnessed increase in the use of locally available sandy laterite generally referred to as 'sharp-sharp sand' from borrow pits for block moulding and concrete works[4-6]. Some combine the sandy laterite with quarry dust[5]. The prospect of periwinkle shell as substitute for coarse aggregate in concrete has also been investigated [7-9].

It will be interesting to combine the result of the knowledge from previous findings on the prospects of lateritic sand and aggregate from periwinkle in a single study to investigate the structural characteristics of the concrete. Hence, in this current study, attempts have been made to replace either wholly or partially the aggregate components in the production of concrete with lateritic sand and periwinkle shell for the purpose of evaluating their effects on the structural characteristics of the resulting concrete.

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II. LITERATURE REVIEW

Partial or total replacement of concrete component has been the direction of research on alternative building materials development. One of such is laterized concrete. Laterized concrete as defined by Osunade [10] is concrete in which the fine aggregate component is lateritic soil. Characteristics of laterized concrete have been widely investigated and recommendations are in support of laterite as suitable for use in the construction industry. Laterite containing up to 40% clay content was recommended for laterized concrete [11]. Furthermore, Adepegba [12], recommended 25% substitution of sand with laterite in concrete at a mix ratio not exceeding 1:1½:3 (cement: sand/laterite: granite) with a water/cement ratio of 0.65 to achieve high strength and workability. Joshua *et al*.[4] reported a study where lateritic soil was used as partial substitute for the conventional fine aggregate (local river sand) in steps of 10% to 60% in the production of Sandcrete blocks. The results indicated an approximately negative linear strength curve with increasing replacement with lateritic soil. The maximum strength occurs at 20% laterite content.

The suitability of periwinkle shell for coarse aggregate in concrete production has been previously investigated. Periwinkles (Nodilittorinaradiata) are small edible greenish blue marine gastropods. The shell varies from 20 mm to 52 mm long. Periwinkle shells hitherto are regarded as wastes and often disposed at strategic dump sites were they constitute environmental nuisance on account of its unpleasant odours and unsightly appearance. The prospect of periwinkle shells as alternative to the often expensive or unavailable coarse aggregates (crushed stones or local washed gravels) has been investigated [13]. Concrete produced from total replacement of coarse aggregate with periwinkle shells were reportedly light (1944kg/m^3) and the compressive strengths at 28days lower (13.05N/mm^2) when compared with concrete with partial coarse aggregate replacement. Osarenmwinda and Awaro [7] reported that concrete with different proportion of periwinkle shell mixes had compressive strength between 14.00 N/mm^2 and 25.67 N/mm^2 at 28 days of age. Amaziah *et al.*[9] also examined the characteristics of crushed periwinkle shell (CPWS) as substitute for coarse aggregate in concrete. Result indicates that the compressive strength decreased with increased percentage replacement of the river sand with CPWS. At 50:50 CPWS:River Sand proportion for the 1:2:4 mix, an average cube strength of 18.67N/mm^2 was recorded. Thus CPWS partly replaced with river sand is suitable for light weight concrete.

The prospects of other materials as fine or coarse aggregate substitute, wholly or partly in concrete have been investigated. Yang *et al.*[14] investigated the properties of concrete comprising crushed Oyster shells as substitute for fine aggregates. The result revealed that compressive strength development was faster as substitution rate of Oyster shell increased [14].

Abubakar and Abubakar[15] investigated Coconut shell aggregate concrete with 1:2:4, 1:1½ :3, and 1:3:6 mix ratios with a maximum compressive strength of 8.9, 11.2, 13.1, and 16.5 respectively using 1:1½ :3mix proportion.

III. RESEARCH METHOD

A. Materials

Ordinary Portland cement (grade 32.5) with the trade name “Elephant Cement” fully certified by the Standard Organization of Nigeria (SON, 2003) and in compliance with BS EN 197-1[16] was used for the research. Physical checks conducted on the cement bag indicated that they were properly sealed and stalked above the floor, eliminating the problem of loss of strength resulting from improper storage.

The fine aggregate used was river sand often referred to as “sharp sand” and meets the specification in BS EN 12620 [17] provision for reference sand. The lateritic sand used are those with sharp sand content of about 60% used in the manufacture of sandcrete block by commercial block makers in Lagos state.

The range of size of granite used was those that passed through 20mm BS sieve and that of the fine aggregate through 5mm BS sieve. The periwinkle shell used was purchased from a supplier in Lagos.

B. Experimental Investigation

B1. Preliminary Investigation

a. Sieve Analysis

In this section sieve analysis was carried out. According to Neville*et al.* [20], Sample grading or sieve analysis is the grading or distribution of aggregates into fractions each containing particles of the same size. The purpose of carrying out sample grading was to determine the proportion of various sizes of particles in the aggregate so as to ascertain whether the particle distribution is in compliance with recognized standards. In grading the aggregates, the dry sieve analysis method was adopted. The particles was allowed to pass through several sieves with openings of known sizes by shaking, using a mechanical sieve shaker. The test was carried out for all the aggregates according to standard procedures (BS 812: Section 103.1: 1985 and BS 1377: 1975), [21].

The percentage passing (finer) and the cumulative percentage of soil that was retained was calculated using the expression below:

Percentage retained on any sieve

$$= \frac{Weight\ of\ soil\ retained}{Total\ weight\ of\ soil}$$

$$= \frac{w1-w2}{W} \times 100 \qquad (1)$$

Where w_2 = weight of sieve + soil (g)

w_1 = weight of sieve (g)

w = total soil weight (g)

Percentage passing = 100 – cumulative percentage of soil to be retained

b. Bulk Density

Bulk density of a material is the weight of a material held by a container of unit volume when filled or compacted under defined condition. The bulk density of a material is affected by factors such as the amount of compaction effort used in filling the container and the amount of moisture present. The apparatus used for this test include cylinder of a known volume, weighing balance and tampering rod. The test was done in accordance to BS 812: Part 2: 1975 specifications [22].

c. Relative Density/ Specific Gravity of soil samples

The relative density is the ratio of mass of aggregate dried in an oven at 100°C to 110°C for 24 hours to the mass of water occupying a volume equal to that of the solid including the impermeable pores. The relative densities of the samples used for this research work was done in accordance with the procedures in BS 812: Part 107 [23].

The mass of the samples used was well saturated and surface-dried aggregates, and the samples have their surfaces dried while the accessible pores were full of water. The relative density was calculated for a typical soil sample as follows:

$$\text{Relative density} = \frac{A}{A-(B-C)} \qquad (2)$$

Where;

A = mass of a sample that was saturated and surface-dried aggregate.

B = mass of vessel with the sample and topped up with water.

C = mass of vessel full of water.

d. Moisture Content Test

Moisture content is the water in excess of the saturated and surface-dry condition of the moisture content of the fine and coarse aggregate were determined by means of the oven-dried drying method according to BS 812: Part 109: 1990 [22]. Known weight of aggregate was oven-dried for 24 hours at a temperature above 100°C (105°C), the weight was then taken after drying to determine the weight of water evaporated and that of the dry soil

The moisture content was calculated as follows:

Total moisture content (%) of the dry mass of aggregate $= \frac{Y-X}{Z-X} \times 100 \qquad (3)$

Where,

X = mass of an air-tight container,
Y= mass of the container and sample
Z = mass of the container and sample after drying to a constant mass.

B2. Workability Test

To ensure that the concrete was of good workability, the slump test was carried out. This was done for each mix i.e. the respective partial replacement of sand with lateritic sand and granite with periwinkle shell (10%, 20%, 30%, 40% and 100%). The test was done in accordance with the requirements of B.S. 1881: Part 102: 1983 [18].

B3. Compressive Strength Test

Compressive strength is the maximum stress sustained by the specimen, that is the maximum load registered on the testing machine divided by the cross sectional area of the specimen [10].

The compressive strength is the most important factor which determines the overall quality of concrete. The compressive test was carried out on three cube specimens for each of the percentage replacement (10%, 20%, 30%, 40%, 100%) corresponding to the hydration period of 7, 14 and 28 days. The procedures for testing and crushing were carried out in accordance with B.S. 1881: Part 116: 1983.

The formula used for the determination of the compressive strength in N/mm^2 is

$$\text{Compressive strength} = \frac{Load}{Area} \qquad (4)$$

Where,

Load = load to be recorded from compressive testing machine
Area = L^2 = Surface area of cube
L = length of cube.

B4. Proportioning, Mixing and Curing

Batching by weight was employed. The fine and coarse aggregate component of concrete were replaced with 10%, 20%, 30%, 40% and 100% respectively using lateritic sand and periwinkle shell. The concrete ingredients were mixed in 1:1½:3, 1:2:4, 1:3:7 ratios respectively. The materials were then mixed thoroughly before adding the prescribed quantity of water at 0.65 water/cement ratio and then mixed further to produce fresh concrete. The mixing was done manually using hand tools. The freshly mixed concrete was then filled into 100mm x 100mm x 100mm moulds in approximately 50mm layers. Eeach layer was compacted with 35 strokes of the tamping rod comprising steel bar of 16mm diameter and 60cm long, with bullet pointed lower end. The concrete was leveled off with the top of the mould and the specimen stored under damp sacking for 24 hours in the laboratory before de-moulding and storing in water at 27±2^{o}C for the required curing age. A total of 135 cubes of Lateriwinkle Concrete (concrete with lateritic sand and periwinkle shell as aggregate) cubes were made.

Testing of the hardened cubes were carried out after 7days, 14days and 28days, respectively using a compression testing machine. The cube sample was placed between hardened steel bearing plates on a compression machine and load applied as specified in BS1881 [17]. The sample was wiped off from grit and placed centrally with load applied steadily to destruction and the highest load reached was determined. This is used to compute the compressive strength which is the ratio of the highest load to the cross sectional area of the sample expressed in N/mm^2. Three samples were used for each test and the average results adopted as the compressive strength.

IV. RESULTS AND DISCUSSION

a. Sieve Analysis

The results of the sieve analyses was presented and plotted on a grading curve. The sieve analysis and grading curve of the river sand and lateritic sand is shown in Table 1 and 2, and figure 1 and 2 respectively. The fineness modulus of river sand and lateritic sand is 2.71 and 2.72 respectively, which falls between the recommended limit of 2.6 - 2.8 classification for medium sand and thus suitable for making good concrete. The sieve analysis result further shows that the percentage of clay in the sample is below 40%.

Table 1: Sieve Analysis result for the Fine Aggregate (Sand) used.

Sieve size	Weight Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
4.75mm	2	0.4	0.4	99.6
2.36mm	4	0.8	1.2	98.8
1.18mm	11	2.2	3.4	96.6
600µm	84	16.8	20.2	79.8
300µm	194	38.8	59.0	41.0
150µm	152	30.4	89.4	10.6
75µm	42	8.4	97.8	2.2
Receiver	11	2.2	100.0	0.0

Fineness modulus-2.71

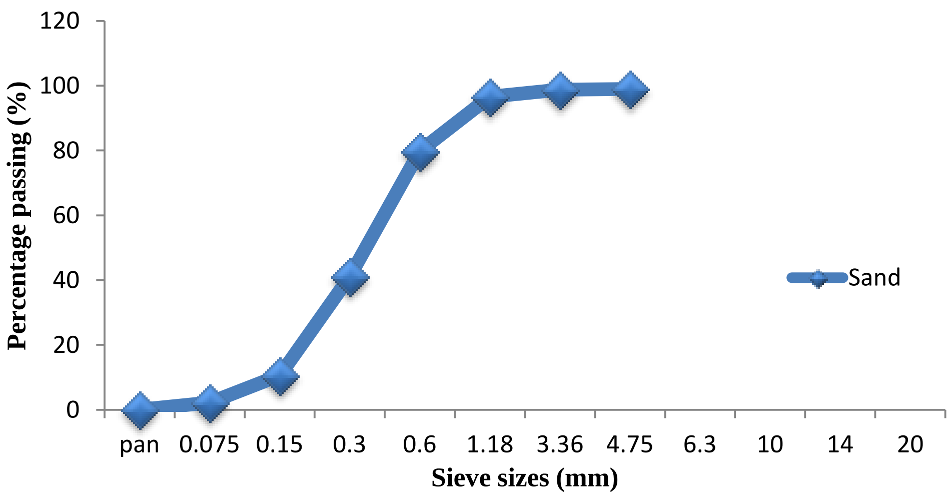


Figure 1: Particle size distribution of fine aggregates (sand)

Table 2: Sieve Analysis result for the Fine Aggregate (Lateritic sand) used.

Sieve size	Weight Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
4.75mm	0	-	-	100.0
2.36mm	10	2.0	2.0	98.0
1.18mm	40	8.0	10.0	90.0
600µm	93	18.6	28.6	71.4
300µm	87	17.4	46.0	54.0
150µm	200	40.0	86.0	14.0
75µm	67	13.4	99.4	0.6
Receiver	3	0.6	100.0	0.0

Fineness modulus-2.22

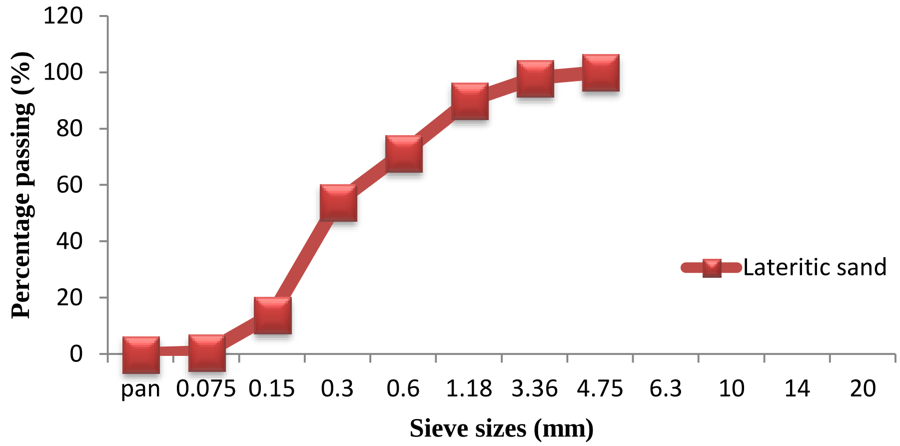


Figure 2: Particle size distribution of fine aggregate (Lateritic sand)

The coarse aggregate used were crushed granite (5mm-20mm size) obtained from a commercial supplier in Lagos, while periwinkle shell were bought in bags from the market. Table 3 and 4 and figure 3 and 4 respectively shows the sieve analysis and grading curves for crushed gravel and periwinkle shell respectively.

Table 3: Sieve Analysis result for the Coarse Aggregate (Granite) used.

Sieve size	Weight Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
37.5mm	—	—	—	—
28mm	—	—	—	—
20mm	465	15.5	15.5	84.5
14mm	1620	54.0	69.5	30.5
10mm	665	22.2	91.7	8.3
6.3mm	225	7.5	99.2	0.8
Receiver	25	0.8	100.0	0.0

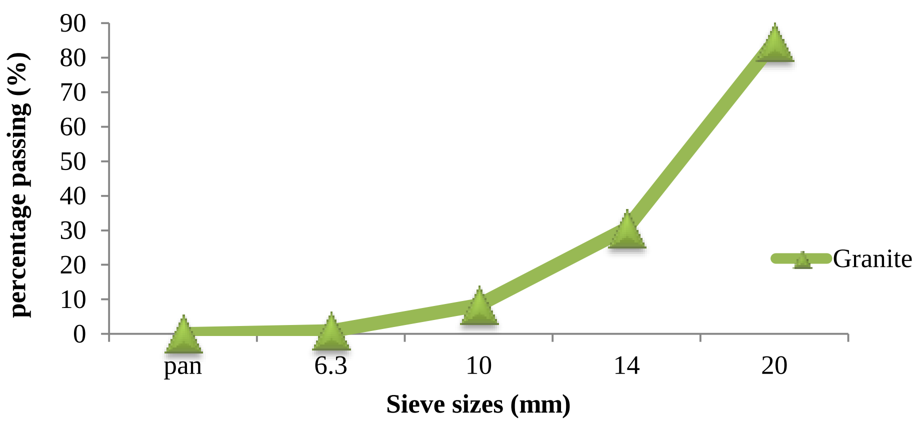


Figure 3: Particle size distribution of coarse aggregate (granite)

Table 4: Sieve Analysis result for the Coarse Aggregate (Periwinkle Shells) used.

Sieve size	Weight Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
37.5mm	—	—	—	—
28mm	—	—	—	—
20mm	350	11.7	11.7	88.3
14mm	1050	35.0	46.7	53.3
10mm	1120	37.3	84.0	16.0
6.3mm	410	13.7	97.7	2.3
Receiver	70	2.3	100.0	0.0

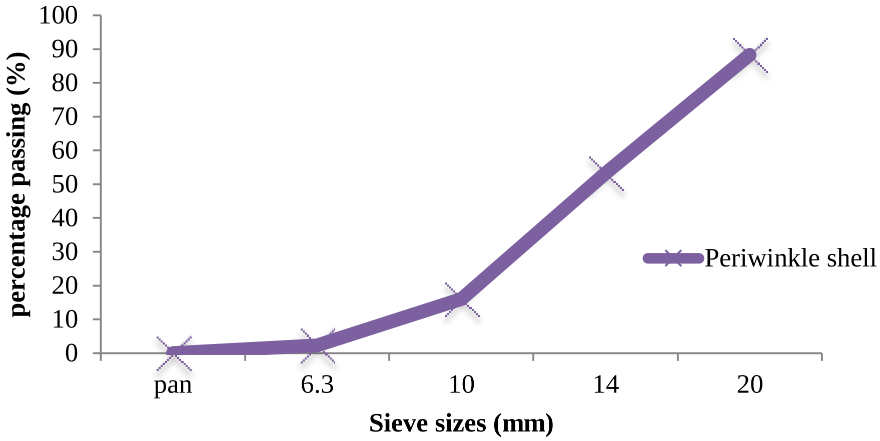


Figure 4: Particle size distribution of coarse aggregate (Periwinkle shell)

Physical properties of the constituent materials are presented in Table 5.

Table 5: Summary of Physical properties of constituent materials.

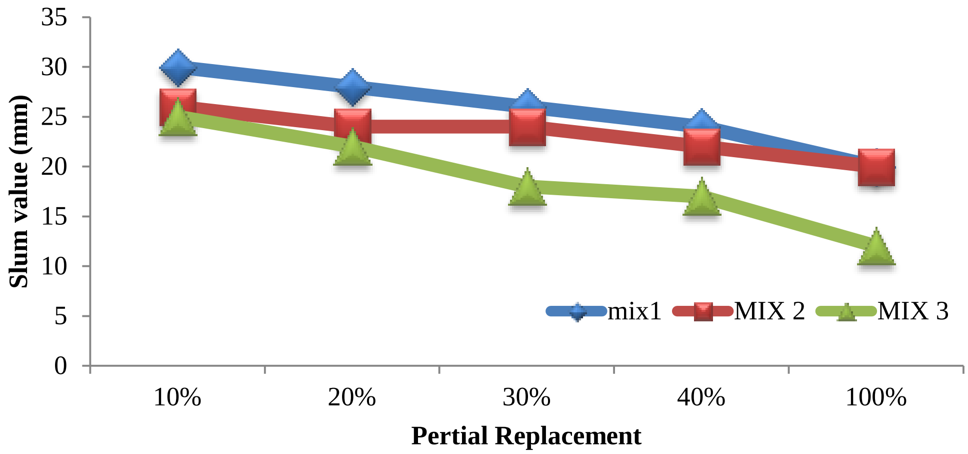
Materials	Properties				
	Specific Gravity	Bulk density (kg/m^3)		Moisture Content (%)	Sieve Analysis (mm)
		Compacted	Uncompacted		
Sand		1.458	1.337	7.80	0.6 to 5
Lateritic sand	2.54	1.375	1.226	15.79	0.6 to 5
Crushed granite	2.64	1.792	1.287	2.76	5 to 20
Periwinkle shell	2.30	1.649	1.394	11.65	5 to 20

b. Workability of concrete

The workability of concrete for both full and partial replacement with lateritic sand and periwinkle shell was done using slump test [18] and the result is presented in Table 6. The result indicates that first; workability is inversely proportional to the aggregate concrete mix ratio. That is to say that the lower the mix design, the higher the workability. Workability is lower for concrete mix 1:3:7 than that of 1:2:4 and 1:1½:3 for every trial. Furthermore, concrete with full lateritic sand and periwinkle shell as aggregate has lower workability compared to that of partial replacement irrespective of the mix ratios. This can be attributed to the fact that partly replaced concrete is denser than the full concrete replacement. The slump decreases as the mix ratios increases. This means that the concrete becomes less workable (stiff) with increase in the mix ratio, hence there is a high demand for water to maintain the same workability level as the control.

Table 6: workability test results for the three different mix ratios.

S/N	Percentage Replacement	Water/cement Ratios	Slump Value (mm)		
			(1: $1^1/_2$: 3)	(1:2:4)	(1:3:7)
1	10	0.65	30	26	25
2	20	0.65	28	24	22
3	30	0.65	26	24	18
4	40	0.65	24	22	17
5	100	0.65	20	20	12



Mix1= 1: $1^1/_2$: 3 Mix 2= 1:2:4 and Mix 3= 1:3:7

Figure 5: Comparison of slump test for different mixes

c. Compressive strength

The results of the compressive strength at the hydration period of 7, 14 and 28 days for all the percentage replacement are presented in Table 7. The results indicate that the compressive strength of concrete generally increases irrespective of the percentage replacement as the curing age increases. This is consistent with general literature on the behavior of concrete with age. Between 10% and 20% lateritic sand and periwinkle shell replacement, It was observed that compressive strength of concrete increases. This is in tandem with Joshua *et al.*[4]. However, as the percentage replacement increases beyond 20%, there was a reduction in the strength development irrespective of the mix proportion but do not follow a definite pattern as shown in figures 6-8.

Table 7: Compressive Strength mix ratios

Mix ratio	Percentage Replacement	Compressive Strength N/mm² 7days	14days	28days
$1{:}1^1/_2{:}3$	10	12.27	18.20	23.13
	20	13.07	19.47	24.07
	30	11.27	16.93	20.93
	40	10.00	15.00	19.13
	100	5.20	6.93	8.80
1:2:4	10	11.20	17.40	21.20
	20	11.93	18.00	21.80
	30	10.80	15.00	20.20
	40	9.20	13.53	17.80
	100	4.40	6.10	7.87
1:3:7	10	9.07	10.70	17.07
	20	10.00	11.40	18.42
	30	8.40	11.07	17.73
	40	7.50	10.07	16.07
	100	3.90	5.40	6.87

Figure 6 explains the variation of compressive strength using $1{:}1^1/_2{:}3$ mix proportions corresponding to 7, 14 and 28 days hydration period at various level of percentage replacement of fine and coarse aggregate with lateritic sand and periwinkle shell. The 28 days compressive strength for 20% lateritic sand and periwinkle shell replacement recorded a maximum strength of 24.1N/mm^2.This is higher compared to 16.5N/mm^2 obtained in Abubakar and Abubakar[15] study for the same mix proportion using coconut shell as substitute for aggregate in concrete.

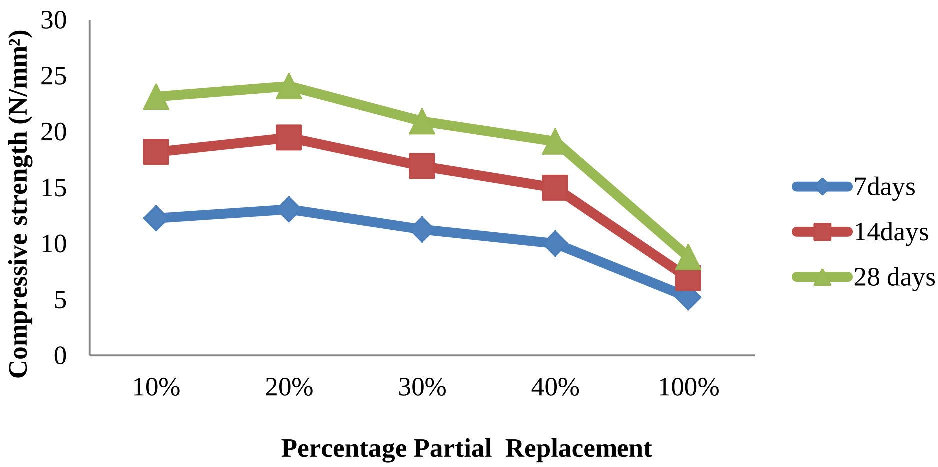


Figure 6: Variation of compressive strength for $1{:}1^1/_2{:}3$ mix at various curing ages with varying percentage replacement of fine and coarse aggregates with lateritic sand and periwinkle shell.

Figure 7 explains the variation of compressive strength using 1:2:4 mix proportions corresponding to 7, 14 and 28 days hydration period at various level of percentage replacement of fine and coarse aggregate with lateritic sand and periwinkle shell. The 28 days compressive strength for 20% lateritic sand and periwinkle shell replacement recorded a maximum strength of 21.8N/mm^2.This value satisfy the requirement for normal weight concrete which is stipulated to be 21N/mm^2 (Akaninye and Olusola

[19]. This is higher than 15.1 N/mm^2 obtained in Abubakar and Abubakar[15] study for the same mix proportion using coconut shell as substitute for aggregate in concrete and 18.67N/mm^2 recorded for a 50:50 Crushed Periwinkle Shell:River Sand proportion for the 1:2:4 mix [9]. This result also compare favourably with Osarenmwinda and Awaro[7] investigation of the potentials of periwinkle shell as coarse aggregate for concrete. Result of that study revealed that concrete produced. with different cement:sand:periwinkle mixes had compressive strength values ranging from 14.00 N/mm^2 to 25.67 N/mm^2 at 28 days of age.

Figure 8 presents variation of compressive strength using mix design practiced commonly on many construction sites. This is 1:3:7 mix proportion comprising one part cement, three part fine aggregate (river sand) and seven part coarse aggregate (washed gravel or granite). Various levels of percentage replacement of fine and coarse aggregate with lateritic sand and periwinkle shell were tested at 7, 14 and 28 days curing period respectively. The result as presented in figure 7 indicated a maximum strength of 18.42N/mm^2 at 20% lateritic sand and periwinkle shell replacement. This is higher than 11N/mm^2 reported in Abubakar and Abubakar[15] for coconut shell aggregate for same duration of curing using 1:3:6 mix proportion. This value satisfies the requirement of 17N/mm^{2}for low strength lightweight aggregate concrete [5].

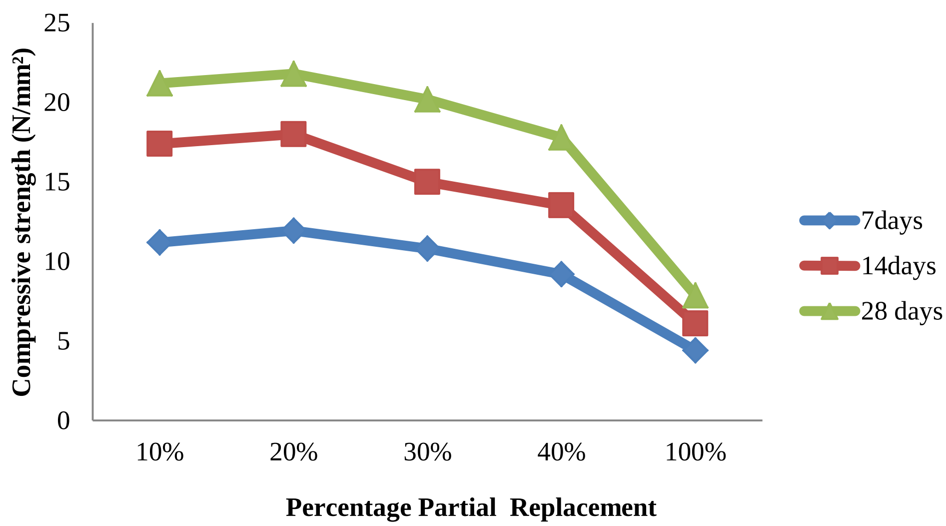


Figure7**:** Variation of compressive strength for 1:2:4 mix at various curing age with varying percentage replacement of fine and coarse aggregates with lateritic sand and periwinkle shell.

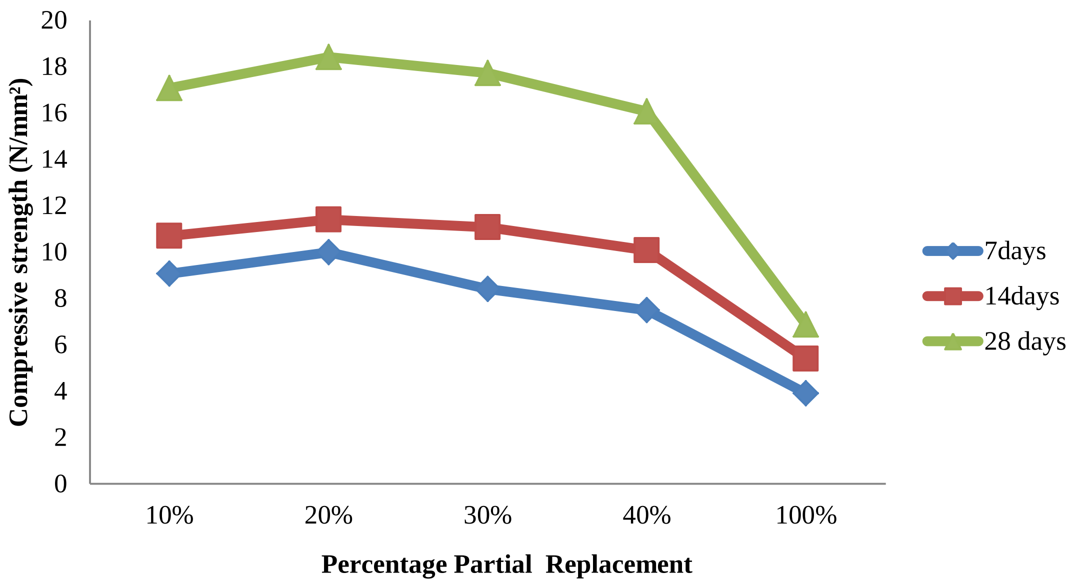


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Figure8: Variation of compressive strength for 1:3:7 mix at various curing ages with varying percentage replacement of fine and coarse aggregates with lateritic sand and periwinkle shell.

V. CONCLUSION

The strength of concrete containing lateritic sand and periwinkle shell as replacements increases gradually to its peak at 20%, irrespective of the mix ratios. After this percentage replacement, the strength begins to decrease. The results of the research work shows that concrete containing lateritic sand and periwinkle shell as partial replacement up to 20% develop a higher compressive strength for the curing ages of 7, 14, and 28 days irrespective of the mix ratios than concrete containing lateritic sand and periwinkle shell alone (i.e 100% replacement). This shows that lateritic sand and periwinkle shell is limited in use and cannot be fully substituted for river sand and gravel/granite in structural concrete. However, it satisfies the minimum strength requirement and therefore suitable for low strength lightweight concrete used for aesthetic purposes. For example, it may be used in parapet walls, window sills, garden ornaments among others.

Further studies should be concentrated on the utilization of other waste shells aggregate as coarse aggregates in concrete so as to further proffer solutions to problems associated with waste generation.

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