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Federal University of Technology, Minna, Nigeria

Suitability of Periwinkle Shell as Partial Replacement of Bida Natural Stone in Concrete Production

Alhaji, B.
Department of Civil Engineering, Federal University of Technology, PMB 65, Minna, Nigeria

ABSTRACT
The suitability of periwinkle shells as partial replacement of Bida natural stone in concrete production was investigated in this study, physical and mechanical properties of the periwinkle shells, Bida natural stone and sand were determined. The concrete specimens that were used for this research work are 150mmx150mm150mm concrete cube for compressive strength, three number of specimens were cast and cure for 7, 21 and 28days. Concrete cubes were prepared using proportion of 0:100, 10:90, 20:80 30:70, 40:60, 50:50 periwinkle shells to Bida natural stone by weight as coarse aggregate, The mix ratio used here is 1:2:4 and the w/c ratio of 0.55% was adopted as a standard for the experiment. Slump test were conducted on fresh concrete to examined the workability of the concrete, dry density and compressive strength test were carried out on the hardened concrete. The bulk density of periwinkle shells was found to be 603.10kg/m^3 while that of Bida natural stone was 1625kg/m^3. The concrete cubes with periwinkle shells 50:50 proportion is lighter and have lower compressive strength compared to those with lesser percentage replacement. Optimum compressive strength at 28days of curing are 26.8N/mm^2, 19.93 N/mm^2, 16.61 N/mm^2, 11.23 N/mm^2, 8.48 N/mm^2 and 6.97N/mm^2 at 0, 10, 20, 30, 40, and 50% respectively. Workability and the compressive strength decrease with periwinkle shells content. From this study, it can be concluded that periwinkle shell can be used as partial replacement of Bida natural stone in cocrete construction work especially in place were gravel is in short supply and periwinkle shell are readily available. It can be safely recommended that Periwinkle shells can be a very good substitute for Bida natural stones in concrete works, but the percentage replacements should not exceed the 20% threshold.

Keywords: Bida natural stone, mechanical properties, Periwinkle shells, compressive strength

1.0 INTRODUCTION

Concrete is a construction material composed of cement, aggregate, and water with or without chemical admixture (Bamigboye *et al*, 2016). As the concrete hardens, water content in the cement begins to be reduced it fluidity and concrete hardens with time (age). The concrete has to be sufficiently workable to be able to complete the chemical reaction of the paste. This is continuous until the required strength is attained, where the thickness of the concrete is small and the concrete dry out quickly, there may be little gain in strength with age (Krishna, 2015). Aggregate in concrete is made up of two types; the fine and coarse aggregate. Fine aggregate is generally natural sand and is graded from particle of 5mm in size down to the finest particles but excluding dust. Coarse aggregate is natural gravel or crushed stone usually larger than 5mm and usually less than 16mm in ordinary structure (Olufemu *et al*, 2009). Cement is a binder, a substance that sets and hardens independently and can bind other materials together. The most important uses of cement are as an ingredient in the production of mortar in masonry and of concrete, a combination of cement and aggregate to form a strong building material.

Water is an essential component of concrete. Combination of water with a cementitious material will lead to a cement paste by the process of hydration, the cement glues the aggregates together, fills voids within it and allows it to flow more freely. Less water in the cement paste will yield a stronger, more durable concrete, whereby more water will give a freer-flowing concrete with a higher slump (Olugbenga, 2014).

Periwinkle shells are small greenish blue marine snails with spiral conical shell and round aperture. The average winkle lives three years and grows to a shell height of 20mm, but largest recorded winkle grew to 52mm, they are common in the riverine areas and coastal
regions of Nigeria where they are used for food (Adewuyi, 2008).

Bida Natural natural stone (BNS) is a by-product of the Precambrian decomposition, transportation and deposition of rocks of the Bida trough (Basin) which is an extension of Inllumedin basin, which stretches through Niger Republic to Mali in West Africa. Bida basin is in Northern Nigeria, and is delimited to the North East and South West by Basement Complex, Alhaji (2016). According to McCurry (1989) Northern Nigeria is underlain by gneisses, migmatites and metasediments of Precambrian age which have been intruded by series of granitic rocks of late Precambrian to lower Paleozoic age. These rocks have been variably metamorphosed and granitised through at least two tectono-metarmophic cycle hence, they have been largely converted to magnitites and grante-gneiss.

2.0 Significant of the study

The inflationary trend in the Nigeria economy escalated the cost of building materials to the extent that many of the conventional building materials are no longer affordable for construction of low cost housing. Cost of construction in the south-south zone is the highest. Thus, alternative lightweight options are adopted, the growing concern of resource depletion and global pollution has challenged many researchers and engineers to seek and develop new materials relying on renewable resources. In addition, the periwinkle shell, which are regarded as waste ordinarily posed environmental nuisance in terms of its unpleasant odour and unsightly appearance in a dumping 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. It is on this note that this research work is carried out to achieve the better understanding the effect of partial replacement Bida natural stone with periwinkle shell in lightweight concrete, to arrive at the optimum replacement level of the waste.

3.0 MATERIALS AND METHOD

3.1 Materials

The raw materials used for this experiment are: Ordinary Portland cement (binder), Sharp sand (fine aggregate), Bida natural stone and Periwinkle shell (coarse aggregates), and Potable water.

3.1.1 Ordinary Portland cement

The most common, widely used and most recommended cement is the Ordinary Portland Cement (OPC). This cement was used for this research work. It was purchased from a store opposite **the University's main campus gate.** The cement were produced in accordance with NIS 87:2004: Part 1 and classified as CEM 1 of the standard.

3.1.2 Fine Aggregate

The natural sharp sand used were extracted behind the male hostel Gidan Kwano campus of the Federal University of Technology, Minna. The sample collected were air dried inside the civil engineering laboratory to enhance a better concrete production, the sharp sand was cleaned, well graded in accordance with the set requirements by ASTMC 114, standard specification of aggregate for conventional concrete.

3.1.3 Coarse Aggregates

a) Bida Natural Stones

The size of the stones used in this research work was 5mm to 14mm nominal size gotten from Bida town, Niger state. The aggregate was passed through a set of sieves to know their actual sizes. The aggregates that pass through BS sieve 20mm and retained on BS sieve 14mm to 5mm werused for the research work.

Plate I: Bida natural stone

b) Periwinkle Shells

Periwinkle shells are small greenish-blue marine snails with spiral conical shell and round aperture. The periwinkle shells used for these experiments are gotten from Badagry, Lagos state. The Periwinkle shells that pass through BS sieve 20mm and retained on BS sieve 14mm to 5mm were used for the research work.

Plate II: Periwinkle Shells

3.1.4 Portable Water

Water used for this research was obtained from a borehole behind Civil Engineering Laboratory in Gidan Kwano, Federal University Minna, free from algae, spirogyra and other biological substances. Commonly, water suitable for drinking is fit for making concrete.

3.2 Methods

Aggregate characterization involves the determination of physical and mechanical properties of the aggregates. These tests include sieve analysis test, specific gravity, bulk density, aggregate impact value, aggregate crushing value. The mechanical test conducted on fresh and hardened concrete are slump test, dry density and compressive strength test respectively.

3.2.1 Specific Gravity Test

Specific gravity is defined as the ratio of the density (weight per unit volume of a substance) of substance to the density of water. This test was conducted in accordance with BS EN 12620 (2008).

3.2.2 Sieve Analysis Test

Sieve analysis test was carried out to determine the particle size distribution of aggregate used in concrete mix. Well graded aggregate contains aggregate sizes ranging from the smallest to the largest, while poorly graded aggregate contain particles of the same size. Well graded aggregate produce concrete of higher strength. Total weight of coarse and fine aggregate is 1000g and 500g respectively.

The ASTM guideline for sieve analysis 1985 edition and procedures recommended by lamb, 1951 were used; the method employed for the determination of particle size distribution is the dry sieve analysis.

3.2.3 Bulk Density Test

Bulk density is defined as actual mass of sample that would fill a unit volume of container. It depends on particle size distribution and shape of the particles. It converts quantities by mass to quantities by volume. This test was conducted in accordance with BS 8121 part 2: 1975 uncompacted and compacted bulk density tests were carried out.

3.2.4 Aggregate Impact Value (AIV) Test

The aggregate impact value test is used to determine the impact of a sample of coarse aggregate, degradation may take place if the aggregate is weak and this will lead to a change in grading or production of excessive and undesired fines.

3.2.5 Aggregate Crushing Value (ACV) Test

The aim of this test is to determine the aggregate crushing values of a coarse aggregate, aggregate should be strong enough to resist crushing under loading. If the strength of aggregate is weak then failure is inevitable. The strength of aggregate is accessed by the means of aggregate crushing value test.

3.3.1 Production of Concrete for Compressive strength

The sample was thoroughly mixed manually until the required homogeneity was achieved; the standard iron moulds of 150×150×150 mm^3 were used. The moulds were lubricated with engine oil in other to reduce friction and to enhance removal of cubes from the moulds, they were then filled with fresh concrete in three layers and each layer was tamped 25 times.

3.3.2 Curing of Cubes

This is the usual means of applying water to the cubes to ensure adequate hydration to reduce the porosity to a level such that the design strength and durability can be attained. The method of curing used for this research was total immersion method of the cubes in water for specific age of 7, 21 and 28 days from the day of demoulding the cast concrete (BS EN 12620 (2008)).

3.3.3 Crushing Test

Crushing is the practice of placing the concrete cubes in the crushing machine in other to determine the compressive strength of the cubes. The the compressive strength test reading was taken after the cube has failed in accordance with (BS 1881:1983).

Procedure

The cubes (3 no.) of each replacement for crushing were removed from curing tank and the water was allowed to dry off in the air, each cube was then weighed and placed one at a time in the crushing machine, the machine was switched on and loaded to crush the cube. The crushing machine continues to compress the cubes till the cube failed immediately the red pointer stopped and black pointer returned and the reading is recorded. For this research work, five (5) different concrete mixes with coarse aggregate partially replaced with 0%, 5%, 10%, 15%, and 20% respectively were cast. Three cubes were tested for compressive strength at selected ages of 7days and 28days and the values were recorded. The same procedure was repeated for 7, 21 and 28days respectively. The compressive strength (f_{cu}) was calculated using relation below.

$$f_{cu} = \frac{load(N)}{Area of cubes(mm^2)} \times 1000$$

4.0 RESULTS AND DISCUSSION

4.1Aggregate characterization

4.1a Result

Table 1. Physical properties of constituent materials

Parameters	Sand	Bida gravel	Periwinkle shell
Specific gravity	2.46	2.64	1.19
Compacted bulk Density	1625kg/m^3	1729kg/m^3	603.10kg/m^3
Uncompacted bulk Density	1542kg/m^3	1628kg/m^3	496.15kg/m^3
Coefficient of uniformity(C_u)	5	1.5	1.45
AIV	-	23.14	49.73
ACV	-	22.61	39.43

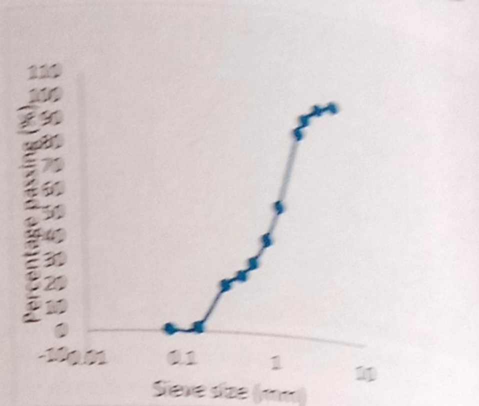

Figure 1: Fine aggregate Sieve Analysis Graph

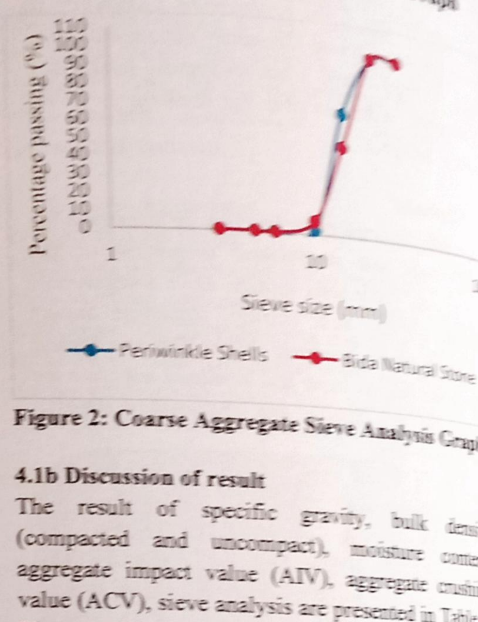

Figure 2: Coarse Aggregate Sieve Analysis Graph

4.1b Discussion of result

The result of specific gravity, bulk density (compacted and uncompact), moisture content, aggregate impact value (AIV), aggregate crushing value (ACV), sieve analysis are presented in Table 1. The specific gravity of Bida natural stone, Periwinkle shell, fine aggregate are 2.46, 2.64 and 1.19 for sharp sand, Bida natural stone and Periwinkle shells respectively. These value obtained fall within the limit for natural aggregate with the limit for natural aggregate with the range of 1.3-3.0 and 2.6-2.7 respectively. It implies that aggregate can be conveniently use for construction work (concrete) without much need for mix proportioning adjustment (Naville, 1995). The specific gravity of periwinkle shell is 1.19, which is very low compared with that of natural aggregate. This in an indication that periwinkle shell is much lighter than most natural aggregate and can therefore be suitable for light weight concrete. However this value is close to the value obtained by Abdullahi *et all*, (2017) who reported that the specific gravity of coconut shell is 1.32 and can be conveniently use for light weight concrete.

Sieve analysis: figure 1 and 2 shows the particle size distribution curve for the aggregates. The result of percentage passing BS sieves shows that the sand is sartisfies the grading requirement forv overall and mediun grading as specified in BS 812: Part 1 (1985) which implies that the sand can be used convimniently for concrete work without much trial mix. Figure 2 shows a smooth curve which is an indication that the aggregate contain particle size in good proportion. Hence the soil is considered to be well graded. The coefficient of uniformity (C_u) for periwinkle shell and Bida natural stone amount to 1.45 and 1.5 respectively this value is within the range of 1-3 specified by Arora, (2009) wchh is an indication that the shell is suitable for concrete work. Also that of sand is 5 whch is greater than 3, hence the sand is well greaded.

The bulk density result shows 1628kg/m³ uncompacted and 1729kg/m³ compacted for Bida natural stones, which classified Bida natural stones as normal weight aggregate, it is also shows 496.15kg/m³ uncompacted and 603.1kg/m³ compacted for periwinkle shells which is classified as light weight aggregate, it also goes further to show for 1542kg/m³ uncompacted and 1625 kg/m³ compacted for sand.

The uncompacted bulk density of periwinkle shell is 496.15kg/m³, this is similar to that of Agbede and Manasseh (2009) who reported that periwinkle shell has a bulk density of 515kg/m³ and can be used as light weight aggregate in concrete work. Also the compacted and uncompacted bulk density of sand are1625 kg/m³ and 1542kg/m³ which agree with the value of 1602kg/m³ and 1468.46kg/m³ report by Abdullahi *et all* (2017)

4.2 Concrete properties

4.2a Result

Table 2: Result of slump test

% replacement	Mix ratio	Slump trials 1	2	3	Ave. slump	Slump type
0	1:2:4	52	47	50	49.6	True
10	1:2:4	33	37	29	33	True
20	1:2:4	18	14.5	16	16.17	True
30	1:2:4	0	0	0	0	Zero
40	1:2:4	0	0	0	0	Zero
50	1:2:4	0	0	0	0	Zero

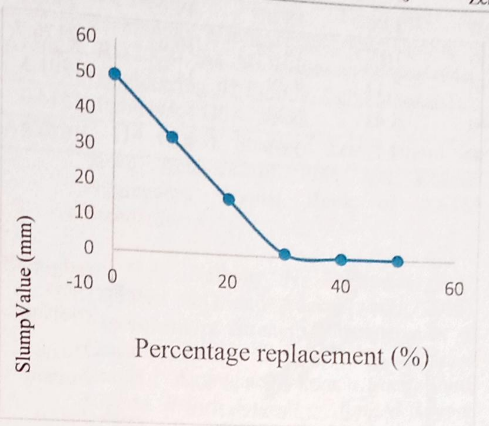

Figure 3: Slump Test result

4.2b Discussion of result

The result of slump is presented in Tables 2. and figure 3. From the result of slump, it shows that workability of concrete reduced with increasing periwinkle shell content. This could be attributed to the texture and shape of the shell, because pervoius research has shown that rough texture, angular and elongated aggregate will required more water to produce workable concrete than a smooth and rounded aggregate. Hence reduction in workability observed in this research work is a true reflection of the physical properties of material constituent explained above. Thus, mix with 10% and 20% replacement gave a true slump and these mix with 30%, 40% and 50% provided a zero slump, meaning that the effect of admixtures toward workability was proportional to the shell content.

4.2c Result

Table 3: Compressive strength of concrete after 7, 21 and 28 days curing/Dry density at 28 day

% replacement	7 days crushing (N/mm²)	21 days crushing (N/mm²)	28 days density crushing (N/mm²)	Dry at 28 days curing(kg/m³)
0	14.82	23.29	26.80	2538.7
10	12.67	18.01	19.93	2306.0
20	10.77	14.28	16.61	2176.7
30	7.11	9.79	11.23	1901.3
40	5.43	6.88	8.48	1514.0
50	4.12	5.61	6.97	1610.3

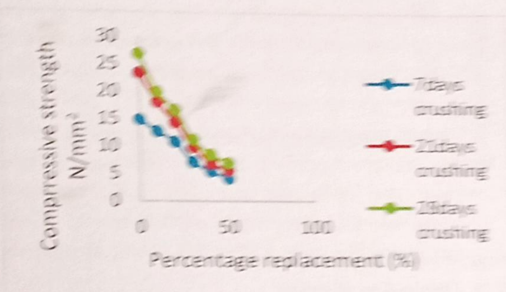

Figure 4: Compressive strength after 28 days curing

4.2d Discussion of result

The result of dry density and compressive strength are as shown in Table 3. Dry density of the concrete is within the range of 1610.3-1901kg/m³ and 2306.0- 2538.7kg/m³ for mix 30%-50% and mix 0%-20% respectively. However, based on the research reported by Agede and Manasseh (2009) who stated that those concrete with dry density between 300 – 800kg/m³ can be classified as low density concrete, while those between 960-1300kg/m³ are moderate strength concrete and the once having density in the range of 1350-1900kg/m³ are structural light weight concrete . Normal weight concrete are these with density of 2200-2600kg/m³ (Agede and Manasseh, 2009). Hence the concrete with mixes 30%, 40% and 50% with dry density of 1901.3, 1724.0 and 1610.3 can be classified as light weight concrete. And the mixes 0%, 10% and 20% can be classified as Normal weight concrete.

Compressive strength: the strength increases as the curing age increases (Table 3. And Fig 4). This is primarily due to the fact that concrete hardening is caused by chemical reaction between cement and water which continues for a long period of time and consequently, concrete get stronger with age (Gambhir, 2004). The range of value of compressive strength for normal strength concrete is 20N/mm²-40N/mm². It was also observed that the strength decreases along the increment of the periwinkle shell, this behaviour is also a true reflection of the result obtained from physical analysis such as lower value of bulk density, aggregate crushing value and aggregate impact value which shows that periwinkle is a weaker aggregate, thus the substitution of which leads to a reduction in the strength of the concrete. However, the result of percentage replacement at 20% with compressive strength of 19.93N/mm² is very close to the lower limit of normal strength concrete is the optimum replacement and can be used for structural purpose such as reinforced concrete slab, beam, column and foundation with minimum adjustment in the factor of safety. But where a higher strength is required then 10% replacement can be considered.

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Results of this research work conducted have been within the limits of experimental accuracy, upon which various deductions were made, following the behavioural characteristics of both fresh and hardened concrete made from different proportion of Bida natural stone to Periwinkle shells.

Deductions include:

1. The result of physical and mechanical of Periwinkle shells has shown that is suitable as partial replacement for Bida natural stone in concrete production.
2. Workability of the concrete decreased with increasing content of Periwinkle shells in concrete.
3. The strength development at 10% replacement of periwinkle shell to 90% Bida natural stone proportion was satisfactory with a cube strength

of 19.93N/mm^2 and appreciably close the strength concrete made using convenctional aggregate. Concrete produced with 20% replacement periwinkle shell to 80% Bida natural stone offers a cube strength value of 16.61N/mm^2, which can be employed where lower strength is required.

4. It can be also be deduced from the result of dry density that this concrete can be classified as structural light weight concrete.

5.2 Recommendations

From the results obtained in this research work with the conclusion drawn, it is therefore recommended that;

1. Periwinkle shells can be used as a partial replacement of gravels especially in places where gravels are in short supply and Periwinkle shells are in abundance. This practice will mitigate the environmental problem since their decaying rate is insignificant.
2. Concrete should be properly cured to the achieve properties of design strength, durability and long lasting serviceability.
3. It can be safely recommended that Periwinkle shells can be a very good substitute for Bida natural stones in concrete works, but the percentage replacements should not exceed the 20% threshold.

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