Suitability of Periwinkle Shell as Partial Replacement for River Gravel in Concrete

Olufemi Isaac AGBEDE and Joel MANASSEH

Department of Civil Engineering, University of Agriculture, Makurdi Benue State, Nigeria
E-mail(s):femiagbede2002@yahoo.com, manassehjoel@yahoo.com

Abstract

The suitability of periwinkle shells, a small gastropod sea snail (mollusk), as a replacement of river gravel in concrete production was investigated. Physical and mechanical properties of the shells and well-graded river gravel were determined and compared. Concrete cubes were prepared using proportions of 1:0, 1:1, 1:3, 3:1 and 0:1 periwinkle shells to river gravel by weight, as coarse aggregate. Compressive strength tests were carried out on the periwinkle gravel concrete cubes. The bulk density of the periwinkle shells was found to be 515 kg/m^3 while that for river gravel was 1611 kg/m^3. The aggregate impact values for periwinkle shells and river gravel were 58.59 % and 27.1 % respectively. Concrete cubes with periwinkle shells alone as coarse aggregate were lighter and of lower compressive strengths compared to those with other periwinkle: gravel properties. The 28-day density and compressive strength of periwinkle were 1944 kg/m^3 and 13.05 N/mm^2 respectively. Density, workability and the compressive strength of periwinkle concrete increased with increasing inclusion of river gravel. From this study, it can be concluded that periwinkle shells can be used as partial replacement for river gravel in normal construction works especially in places where river gravel is in short supply and periwinkle shells are readily available.

Keywords

Periwinkle; Gravel; Aggregate; Concrete.

Introduction

Concrete is a combination of cement, fine and coarse aggregates and water, which are mixed in a particular proportion to get a particular 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. Concrete remove any has tremendous versatility because of its initial fluid state. It may be poured into a mould, and it is compacted by vibration or ramming to entrapped air. The mixture sets within a few hours for the mould or formwork to be removed. It is ideal for use in foundation where the load that is to be carried is wholly compressive. But in bending, tension could develop at low loads. The lack of resistance to overcome tensile strength is overcome by providing steel bars at appropriate places. The resulting composite structure is called reinforced concrete.

In heterogeneous materials like concrete, quality of the constituent proportions in which they are mixed determine the strength and properties of the resulting products. A good knowledge of the properties of cement, aggregates and water is required in understanding the behaviour of concrete. In ordinary structural concrete, the aggregates occupy about 70 to 75 % of the volume of the hardened mass. There are two types of aggregates namely fine and coarse aggregates.

Fine aggregate is generally natural sand and is graded from particles 5 mm in size down to the finest particles but excluding dust. Coarse aggregate is natural gravel or crushed stone usually larger than 5 mm and usually less than 16 mm in ordinary structure.

Periwinkle shells are obtained from periwinkle. Periwinkles are marine molluscs (gastropods) with thick spiral shells. As they grow, gastropod shells follow a mathematically regular pattern. Thus, as they increase in size, they retain their basic form. The mollusc produces this spiral shape by continually adding shell to the edge, coiling around an imaginary axis running straight through the shell. The resulting shell becomes a strong compact home for the mollusc inside. The major families of periwinkle include the Litorinae family. They are common in the North America and European shores and are widely distributed in the littoral drifts and sand banks. The major species available in the lagoon and mudflats of Nigeria's Niger Delta, between Calabar in the east and Badagry in the west, are *Tympanostomus spp.* and *Pachmellania spp.* Over the years, large quantities of periwinkle shells have accumulated in many parts of the country such as Bori, Western Ijaw, Burutu, Agoro, Ogalaga and Lotugbene. [1]

Periwinkle shells have been used by the people of the coastal states e.g. Rivers State of Nigeria for over 30 years as conglomerate in concrete reinforcement. These shells have been used for many purposes e.g. for homes, soak-away, slabs and road construction. The cost of these shells was more than 10 times cheaper than that of gravel as at the time of this study.

Crushed oyster shells, an industrial waste, were substituted for fine aggregate in concrete [2]. The investigation revealed that oyster shell did not cause reduction in the compressive strength of concrete at 28 days. Furthermore, it was reported that development of compressive strength was faster as substitution rate of oyster shell increased.

Periwinkle shells concrete is prepared almost the same way the gravel concrete is prepared with a difference of using periwinkle shells in place of river gravel. Sea sands are often extensively fine and the grading of any new sand should be carefully checked. According to [3] sea-dredged coarse aggregate may have a large shell content, which may not have any adverse effect on concrete strength but may reduce its workability where there is a large shell content. The shell content of particles larger than 5 mm can be determined by hand picking, using an amendment of the method in [4].

For low and medium strength workable concrete, smooth round gravels are usually to be prepared, but for high crushing strength or flexural strength, concrete made with angular and rough or crystalline crushed rock e.g. granite, carboniferous limestone may demonstrate a benefit for all workable concrete, natural rounded sands are preferable to crushed stone fines [5]. Thus aggregate surface texture influences the bond between aggregate and the cement paste in hardened concrete.

It has been shown that periwinkle shells can be used as a partial replacement for granite in normal construction works and that the strength development in periwinkle-granite concrete is similar to those of conventional granite concrete [1]. River gravel is a conventional building material which has been largely used with or without granite. It is usually cheaper than granite but round and smooth in appearance. The objective of this study is to investigate if periwinkle shells can be used as a replacement of river gravel in concrete so as to explore how this waste material can be safely disposed in a meaningful way.

Materials and Methods

Ordinary Portland cement from Dangote cement factory in Gboko, Benue State of Nigeria was used as binding agent together with River Benue sharp sand and washed gravel. The periwinkle shells were collected from the stock dumped at Kono Boue in Khana Local Government Area of Rivers State in Nigeria, where they were discarded after the removal of the edible portions. Impurities such as soil and other dirt were removed and the shells sun-dried. Clean water obtained from public water supply was used for mixing the concrete.

The mix was designed using the absolute weight method. Physical and mechanical properties of periwinkle shells and river gravel were investigated through the following tests: specific gravity test, bulk density, slump and aggregate impact value tests. Cube crushing tests were also carried out to determine the compressive strengths of periwinkle-gravel concretes. Sieve analysis was carried out using sieves arranged in decreasing size of opening and placed on a shaker in order to differentiate samples of the aggregate into fractions. The coefficients of uniformity, curvature and gradation were determined.

For the aggregate impact value test, air-dried aggregates were sieved to obtain the 12.70 mm - 9.52 mm fraction and dried at a temperature of 105°C for 4 hours and then cooled to room temperature. The 7.6 cm diameter test cylinder was filled with aggregates in three equal layers, 25 strokes were given to each layer with 22.9 cm metal tamping rod. The top of the cylinder was levelled off with the tamping rod. The whole sample was placed in a cup, fixed firmly in position on the base of the impact machine and 25 blows of the tamping rod were applied. The sample was subjected to 15 blows by allowing the hammer to fall freely. The crushed aggregate was sieved on a 2.40 mm sieve and the percentage passing by weight was determined. The impact value was expressed as a percentage of fines passing the 2.40 mm sieve to the total weight of the sample.

Also the slump test apparatus was cleaned and the wider surface was placed on the steel plate and supported with legs. The apparatus was filled in four layers with concrete; each layer received 25 blows from a sixteen millimetre tamping rod. The top was smoothened with a float. The apparatus was gently and sprightly lifted and placed on the plate near the concrete. The difference in height gave the slump value.

Mixing of the concrete was done mainly by hand with the aid of a shovel. The fine aggregate was first poured to the ground on a particular spot where it was mixed with cement.

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Coarse aggregate was then added and also thoroughly mixed. This was followed by adding some quantity of the required clean tap water. The remaining water was then added after a short time of mixing. The whole constituents were mixed until an even paste was obtained.

Square moulds were cleaned and oiled before each casting. Concrete cubes of 150 mm were produced. Batching of materials was by weight with a nominal mix proportion of 1:1.5:3. Coarse aggregate for the project was a mixture of river gravel and periwinkle shells at specified proportions; 0:1, 1:0, 1:1, 3:1 and 1:3 of periwinkle shells to river gravel. Water/cement ratio of 0.5 was used.

Remoulding of the cubes was done between 18 hours to 24 hours after casting. The hardened cubes were transferred immediately into the curing tank. Curing was done at normal temperature. Depending on the level of curing, the cubes were removed at the end of 7, 14 or 28 days from the day of casting and dried at room temperature for 2 hours before testing.

Compressive strength tests were carried out on the cubes in a 1560 kg capacity ELE electro hydraulic pump powered testing machine. All the tests were carried out at the same rate of loading.

Results and Discussions

Figure 1 shows the grain size analyses for periwinkle shells, river gravel and sharp sand.

Table 1 summarizes the results of the slump test for a water cement ratio of 0.5 and a mix proportion of 1:1.5:3. Workability of periwinkle - gravel concrete measured by slump for the periwinkle - gravel mix ratios of 0:1, 1:0, 3:1, 1:3, 1:1 are 80, 35, 45, 70, 62 mm respectively. Therefore, the periwinkle concrete had lower workability compared to gravel concrete. The workability of periwinkle gravel concrete reduced with increasing periwinkle content.

Table 1 also showed that the 28-day density of the periwinkle-gravel concrete reduced with increasing periwinkle content. The density of concrete can be used to classify the different concrete mixes [1].

Table 1. Workability and Density of Periwinkle-Gravel Concrete

Periwinkle-Gravel Mix	Slump (mm)	Density (kg/m^3)
0:1	80	2508
1:3	70	2311
1:1	62	2164
3:1	45	2128
1:0	35	1944

The reduction in workability with increasing periwinkle content could be attributed to the texture and shape of the shells, as rough-textured, angular and elongated aggregates will require more water to produce workable concrete than smooth and rounded aggregates. However concrete aggregates that are rough-textured and angular such as periwinkle shells would be expected to have good bonding properties with cement paste and hence improve the properties of concrete, especially in members subjected to tensile loading.

For the periwinkle shells uniformity coefficient, Cu; coefficient of curvature, Cc and coefficient of gradation, Cg were found to be 1.14, 0.98 and 1.1 respectively. For the river gravel, the corresponding values were found to be 1.1, 0.9 and 1.04 respectively.

The uniformity coefficient of the periwinkle shells was 1.14 indicating its suitability for concrete works because it is within the range of 1 and 3 recommended by [6]. The coefficient of gradation Cg was found to be 1.1, which suggests that the sample was well graded since its Cg is between 0.5 and 2.0 as recommended by [7]. The average moisture content of the sun-dried periwinkle shells was 1.1% while that of the gravel was 0.87%.

The bulk density of the periwinkle shells and river gravel was 515 kg/m^3 and 1611 kg/m^3 respectively. The low bulk density of periwinkle shells suggests that lighter concrete can be produced from them. The aggregate crushing value (ACV) was 59.6% and 27.1% for periwinkle shells and river gravel respectively. The ACV values suggest that periwinkle shells are not suitable for normal dense concrete because a maximum ACV value of 30% was recommended for normal dense concrete [8]. The values also suggest that river gravel is more adequate for concrete and can withstand more load than periwinkle shells.

Those with density between 300 and 800 kg/m^3 can be classified as low density concrete while those between 960 and 1300 kg/m^3 are the moderate strength concrete and the ones having density value in the range of 1350 to 1900 kg/m^3 are structural light weight concrete. Normal concrete are those with density of 2200 to 2600 kg/m^3. Therefore periwinkle-gravel concrete of 1:0 can be classified as structural lightweight concrete while the other mixes can be classified as normal weight concrete.

The economy of substituting periwinkle shells for gravel in lightweight concrete would therefore recommend it in cast-in-place structures due to less dead load making foundation less expensive. This will also lead to savings in production and man hours because member sizes will also be reduced [9].

Figure 2 summarizes the compressive strength results for 7, 14 and 28 days respectively. Compared to the results obtained by [1] the 28 day strength for the periwinkle-gravel concrete was 13.05 N/mm^2 instead of 12.12 N/mm^2 obtained for periwinkle-granite concrete. Periwinkle-gravel concrete with 3:1 aggregate ratio had compressive strength of 14.71 N/mm^2 instead of 14.78 N/mm^2 for periwinkle-granite concrete. The 28 day strength for periwinkle-gravel concrete also increased with increasing gravel content. With an aggregate ratio of 1:1, the periwinkle-gravel concrete had strength of 16.30 N/mm^2 instead of 13.52 N/mm^2 obtained for periwinkle-granite concrete. The differences in the compressive strength in the two studies can be attributed to the differences in the mix ratios, aggregate type and nature of the periwinkle shells and water/cement ratio (0.5 instead of 0.8).

However this study has shown that periwinkle-granite concrete would be stronger than periwinkle-gravel concrete since the strength obtained for the former are almost the same for the latter though the concrete mix used in the periwinkle-granite concrete was 1:2:4 instead of 1:1.5:3 that was used in this study. This is probably due to the smooth and rounded texture of gravel compared with the angular and rough textured granite.

Conclusions

The study could lead to the following conclusions:

- Periwinkle shells can be used as a lightweight aggregate in concrete works. Its bulk density of 515 kg/m^3 resulted in concrete with lower weight. Hence lower dead loads in concrete construction.
- The workability of periwinkle-gravel concrete is reduced with increasing content of periwinkle shells.
- The strength development in periwinkle-gravel concrete is similar to those of conventional gravel concrete.

- Periwinkle-gravel concrete mixes of 0:1, 1:3, 1:1 and 1:3 can be classified as normal weight concrete, those having periwinkle-gravel ratio 1:0 are structural lightweight concrete.
- The foregoing suggests that periwinkle shells can be used as a partial replacement for river gravel in normal construction works especially in places where gravel is in short supply and periwinkle shells are readily available. This will help in reducing the threat these shells pose to our environment since their decaying rate is insignificant.

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