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EXPLORATORY STUDY OF PERIWINKLE SHELLS AS COARSE AGGREGATES IN CONCRETE WORKS

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ABSTRACT

This paper reports the exploratory study on the suitability of the periwinkle shells as partial or full replacement for granite in concrete works. Physical and mechanical properties of periwinkle shells and crushed granite were determined and compared. A total of 300 concrete cubes of size 150 x 150 x 150 mm^3 with different percentages by weight of crushed granite to periwinkle shells as coarse aggregate in the order 100:0, 75:25, 50:50, 25:75 and 0:100 were cast, tested and their physical and mechanical properties were determined. Compressive strength tests showed that 35.4% and 42.5% of the periwinkle shells in replacement for granite was quite satisfactory with no compromise in compressive strength requirements for concrete mix ratios 1:2:4 and 1:3:6, respectively. This corresponds to savings of 14.8% and 17.5% for 1:2:4 and 1:3:6 concrete mixes, respectively.

Keywords: periwinkle shells, mechanical properties, concrete, compressive strength, cost analysis, coarse aggregates.

INTRODUCTION

The overall relevance of concrete in virtually all civil engineering practice and building construction works cannot be overemphasized. 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. These include the use of by-products and waste materials in building construction. 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 concrete, these are mostly confined to naturally occurring aggregates, manufactured aggregates, and aggregates from industrial by-products.

With the global economic recession coupled with the market inflationary trends, the constituent materials used for these structures had led to a very high cost of construction. Hence, researchers in material science and engineering are committed to having local materials to partially or fully replace these costly conventional materials. Numerous achievements have been made in these regards and the subject is attracting attention due to its functional benefit of waste reusability and sustainable development. Reduction in construction costs and the ability produce light-weight structures are added advantages. Ndoke [1] assessed the performance of palm kernel shells as a partial replacement for coarse aggregate in asphalt concrete, while Falade [2] investigated the suitability of palm kernel shells as aggregates in light and dense concrete for structural and non-structural purposes. For instance, sludge from water treatment, industrial and domestic wastewater has been found very suitable as partial economic replacement for cement in concrete works [3] and also in the production of building bricks [4]. Other similar efforts in the direction of waste management strategies include structural performance of concrete using oil palm shell (OPS) as lightweight aggregate. In addition, other materials explored in partial replacement for concrete aggregates include cow bone ash, palm kernel shells, fly-ash, rice husk, and rice straw as pozzolanic materials. The use of coconut husk ash, corn cob ash and peanut shell ash as cement replacement has also been investigated [5].

Civil engineering practice and construction works in Nigeria depend to a very large extent on concrete. Concrete is one of the major building materials that can be delivered to the job site in a plastic state and can be molded insitu or precast to virtually any form or shape. Its basic constituents are cement, fine aggregate (sand), coarse aggregate (granite chippings) and water. Hence, the overall cost of concrete production depends largely on the availability of the constituents. In Nigeria, a 50kg bag of cement is sold at almost uniform price with slight deviations in every state of the federation and fine aggregates are readily available. However, the cost of concrete is directly proportional to the cost of crushed stones or local gravels, which increases from the north to the south. Cost of construction in the Niger Delta areas especially the south-south zone is highest. Thus, alternatives lightweight options are adopted for non-load bearing walls and non-structural floors in buildings.

Periwinkles (*Nodilittorina radiata*) 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 20 mm, but the largest recorded winkle grew to 52 mm. 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

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lightweight concrete is required for non-load bearing walls, non-structural floors, strip footings and other non load-bearing structural elements. It is worth stressing that coarse aggregate usually takes about 60% of the overall self-weight of normal weight concrete, thereby determining the quantity of reinforcement required to resist forces acting on the structural member. Although there are records of long use of the shells as concrete aggregates, little or no effort has been made to verify the strength and properties of the concrete made these materials and economic benefits derivable [6].

This paper therefore studies the physical properties of periwinkle shells with respect to the requirements for coarse aggregate and lightweight concrete. The compressive strengths of cubes made with varying percentages of shells for coarse aggregates are evaluated to determine the optimum percentage replacement without compromising strength. The economic implication of lightweight concrete made of periwinkle-shell blended coarse aggregates is also investigated.

MATERIALS AND METHODS

Selection of materials

The choice of ordinary Portland cement for this experiment conforms to the requirements of BS12. River sand used for this study was obtained from Oba River in Ogbomoso and is free from deleterious materials. Crushed granite was purchased from a quarry site at Orile-Igbon area of Ogbomoso and periwinkle shells were obtained in sufficient quantities from Aleshinloye market in Ibadan 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.

Mix proportions and casting of concrete cubes

Batching operation by volume approach was adopted in the study. Preliminary mixes of 1:2:4 (cement : fines : coarse) and 1:3:6 were investigated with water/cement ratio of 0.60 and 0.55, respectively. The fine aggregate used was sharp sand. Cast iron mould of size 150 x 150 x 150 mm^3 was used for casting. The mould was assembled prior to mixing and properly lubricated for easy removal of hardened concrete cubes. Concrete cubes were prepared in percentage by weight of crushed granite to periwinkle shells as coarse aggregate in the order 100:0, 75:25, 50:50, 25:75 and 0:100 ranging zero to full replacement for crushed granite by periwinkle shells. The mixture was properly turned with shovel until it reached a plastic state which was fed into lubricated cast iron moulds. Water curing method was adopted in this project. The specimens were made in accordance with BS 1881 [7].

The molded concrete cubes were given 24 hours to set before demoulding. They were then immersed into a large curing tank in order to increase the strength of the concrete, promote hydration, eliminate shrinkage and absorb heat of hydration until the age of test. Cubes prepared were cured for 3 days, 7 days, 14 days, 21 days and 28 days. The cubes were weighed before testing and the densities of cubes at different time of testing were measured. Prior to testing, the specimens were brought out of the curing tank, left outside in the open air for about 2 hours before crushing. The compressive strengths of the cubes were tested in accordance to BS 1881[7] using universal testing machine.

RESULTS AND DISCUSSIONS

Properties of aggregates

The chemical properties of periwinkle shells were not considered in this paper, however, they are calcareous in nature and can bind easily with cement products. Characteristic shape factor of the periwinkle shells used in the experiment defined as the ratio of the maximum length to diameter was 3.23 (coefficient of variation of 8.92 %). The average moisture content and bulk density periwinkle shells were 1.44% and 1243 kg/m^3, respectively. The bulk density of crushed granite was 2860 kg/m^3. The particle size distribution of fines, crushed granite and periwinkle shells is shown in Figure-1. The uniformity coefficient for periwinkle shells is greater than 4.0, which implies that the material is suitable for concrete works and its coefficient of curvature of 1.75 lies within the required range of value of 1.0 and 3.0. The S-shaped curve of sand (fine aggregates) shows that it is well graded.

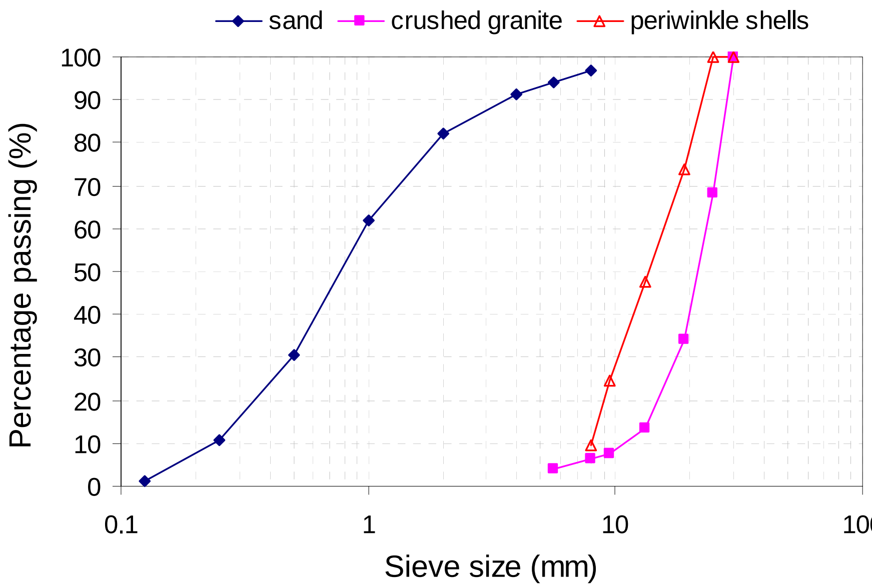

Figure-1. Particle size distribution of aggregates.

Workability

The workability of concrete batches for different percentages of periwinkle shells using slump test is shown in Table-1. First, workability is inversely proportional to the aggregate/cement ratio. For example, workability is lower for concrete mix 1:3:6 than that of 1:2:4 for every trial. It is also obvious that workability of concrete reduces as the percentage of periwinkle shells increases. This can be attributed to the fact that since the granite is denser than periwinkle shells and the replacement is by weight, the specific surface area increases periwinkle contents increase.

Table-1. Workability of concrete batches using slump test.

Periwinkle shell: granite	0:100	25:75	50:50	75:25	100:0
Slump 1:2:4 mix (mm)	18	15	10	8	5
Slump 1:3:6 mix (mm)	15	11	8	5	2

Compressive strength

The compressive strengths of concrete cube specimens for different percentages of periwinkles are shown in Figures 2 and 3 for concrete mixes 1:2:4 and 1:3:6, respectively. For each mix, compressive strength decreases as periwinkle shells content increases (as percentage of granite chips decrease).

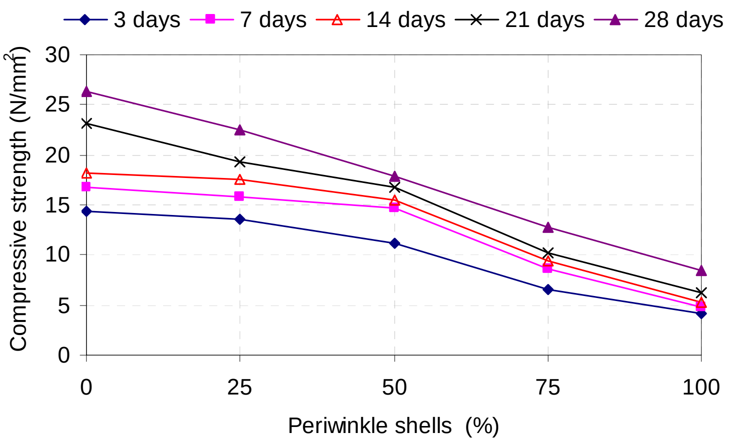

Figure-2. Compressive strengths variation with different percentages of periwinkle shells in coarse aggregates for mix 1:2:4

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The compressive strength is maximum for specimens with 100% granite and minimum when periwinkle shells content is 100%. The main explanation is that as the quantity of periwinkle shells increases, the proportion of cement paste becomes insufficient to make effective bond with the coarse aggregate, because of its higher effective surface area. It can be further stressed that the minimum 28-day cube strength values of 21 N/mm^2 and 15 N/mm^2 expected for concrete mixes 1:2:4 and 1:3:6 could still be achieved with 35.4% and 42.5% periwinkle shells inclusion, respectively.

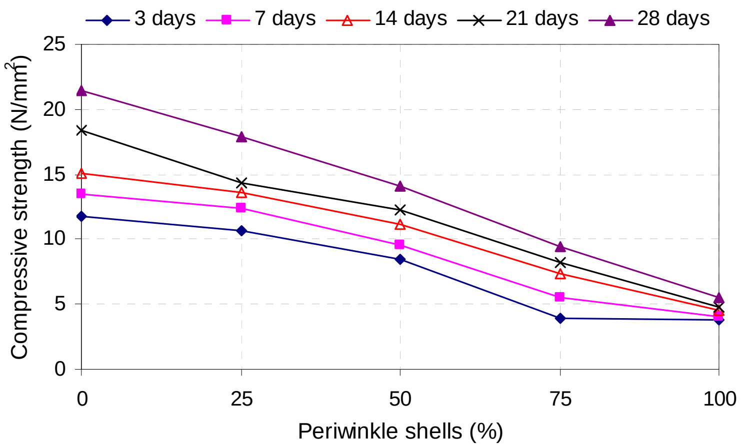

Figure-3. Compressive strengths variation with different percentages of periwinkle shells in coarse aggregates for mix 1:3:6

Density of specimens

The density of concrete can be used to classify different mixes considering the 28-day density of the periwinkle granite concrete cubes. Figure-4 shows that the density reduces as percentage inclusion of periwinkle shells increases. The minimum densities corresponding to 100% periwinkle shells are 1481~1605 kg/m^3 and 1508~1728 kg/m^3 for concrete mixes 1:2:4 and 1:3:6, respectively. These fall within the range of lightweight concrete. However, it is also apparent that partial replacement for crushed granite with periwinkle investigations up to 50% for the two mixes can still be regarded as normal weight concrete (>2000 kg/m^3).

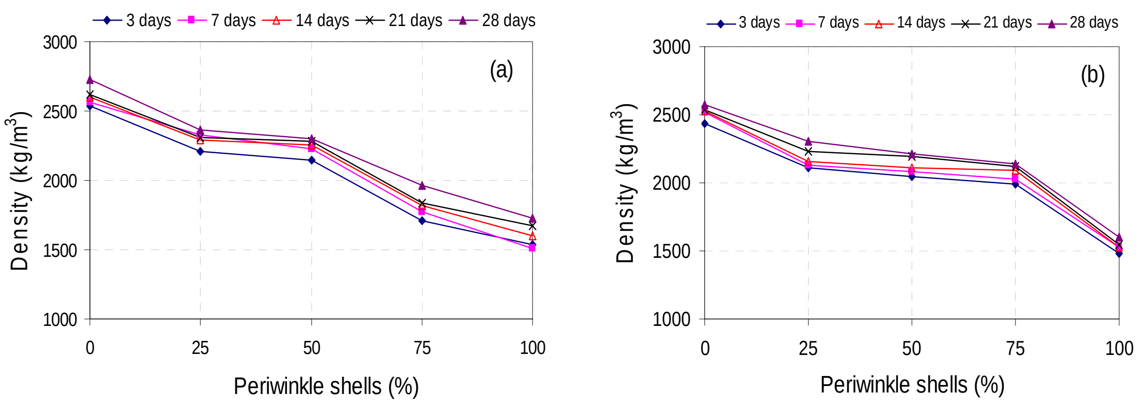

Figure-4. Density of cubes for different percentages of periwinkle shells in coarse aggregates for concrete mixes (a) 1:2:4 and (b) 1:3:6

Cost analysis

The production costs of 1m^3 concrete with 100% crushed granite (no replacement with periwinkle shells) and 35.4% periwinkle shells plus 64.6% granite were comparatively evaluated for 1:2:4 mix. Likewise, cost estimates were made for 1:3:6 concrete mix of 100% crushed granite and that of 42.5% periwinkle shell plus 57.5% granite. The analyses were based on existing market costs of the constituent materials and workmanship in the Niger Delta region where periwinkle shells are in abundance. Cost savings of about 14.8% and 17.5% can be made on 1m^3 of 1:2:4 and 1:3:6 concrete mixes using 35.4% and of 42.5% periwinkle inclusion, respectively.

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CONCLUSIONS

The following conclusions can be made from this study:

- The strength of periwinkle shell concrete is determined based on the properties of the shells and various percentage replacements;
- Concrete with 35.4% and 42.5% periwinkle shells inclusion can still give the minimum 28-day cube strength values of 21 N/mm2 and 15 N/mm2 expected for concrete mixes 1:2:4 and 1:3:6, respectively;
- Concrete having up to 50% periwinkle shells inclusion can still be regarded as normal weight concrete; and
- Savings of about 14.8% and 17.5% can be achieved by adopting 35.4% and 42.5% periwinkle inclusion for 1:2:4 and 1:3:6 concrete mixes, respectively.

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