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Assessing the Effectiveness of Coconut Shell (CS) as Aggregate in Concrete

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Abstract: ***High cost of constructional materials coupled with the clamour to reduce environmental stresses due to excessive usage of natural aggregates has demanded research into the use of alternative materials for construction. Coconut shell is one of the most prevalent agricultural solid wastes in several tropical countries. For coconut shell aggregate to be used efficiently for construction purposes, it is imperative to investigateitsproperties. Therefore, this study examined the effect of coconut shell as fine and coarse aggregate replacement on the behavior of concrete with respect to some vital properties. The coconut shell concrete was designed for characteristic strength of 30MPa with the incorporation of coconut shell as replacement for fine and coarse aggregate at 10%, 20% and 30% of volume fractions respectively. The workability, compressive strength as well as densities and water absorption of 96 cured concrete samples were evaluated at 7, 14, 21 and 28 days and discussed. The results showed that increase in replacement of coconut shell volume fractions yielded increase in workability and water absorption with corresponding decrease in the mechanical properties of the concrete; however 28 day compressive strength of 25 MPa and density of 1874 kg/m^3 was obtained for 30% respective replacement of fine and coarse aggregates.***

Keywords: Coconut shell, lightweight concrete, sustainability, workability compressive strength

1. Introduction

Concrete is the world's most utilized man-made material. Its great resourcefulness and relative low-cost in filling wide range of demands has made it a keen building material [1]. Concrete production is not only a vital source of societal growth, but also a remarkable originator of employment [2]. The unfavorable repercussions of the increase in demand for concrete include depletion of naturally occurring aggregate; degradation of the environment and ecological inequality [3] .The possibility of complete depletion of aggregates resources in the prospective future can therefore not be over-estimated. To arrest this ugly scenario, it has become imperative to conduct research into the use of substitute materials especially industrial and agricultural wastes which can replace traditional ones used in concrete production. In this line, the use of waste materials in construction contributes to conservation of natural resources and the protection of the environment [4].

Coconuts are mainly cultivated in the coastal clays and sands and sporadically distributed in other areas. The shells are regarded as waste and therefore disposed off in large amount which lead to environmental problemsin most of tropical countries particularly in Asia and Africa. Some researchers have concluded that coconut shell can be used for producing lightweight concrete and can be used at different proportion for required concrete strength. In an investigation conducted by [5] it was revealed that the 28th day compressive strength of coconut shell concrete with 25% volume replacement with coconut shell aggregate under full water curing was 21.31MPa equivalent to grade 20 concrete. This makes agricultural wastes concrete ideal for housing and other public buildings if the minimum grade of concrete is achieved since these are generally cheaper than conventional materials. The density of coconut ranges between 550- 650 kg/m^3 and these are within the specified limits for light weight aggregate hence requiring no need for treatment of the coconut shell before use as an aggregate. In addition, better workability is achieved because of the smooth surface of coconut shell aggregate on the concave face of the shells [6]. As part of efforts to make efficient use of locally available materials and also reduce the cost of construction, this study was carried out to examine the behavior of concrete with respective volume replacements of fine and coarse aggregates with coconut shell on the workability, density, absorption and compressive strength of concrete with a view to assessing the suitability of coconut shell concrete as a structural material.

2. Materials

Freshly discarded shells were collected from the local mini market after which they were well seasoned under sun to dry for one week before being crushed. The seasoned coconut shells (CS) were crushed by a mini crusher and were sieved using a 5mm to [7]. The sample passing the sieve was used as replacement for fine aggregates. The CS aggregates used were in saturated surface dry. In order to obtain the coarse aggregates, coconut shells were broken into small chips manually using hammer and sieved through 12.5mm and 4.75mm sieves. Only materials that pass through 12.5mm but retained on 4.75mm sieve were used as replacement for coarse aggregate. Figure 1 shows coconut shells prepared for use as fine and coarse aggregate replacement in concrete.

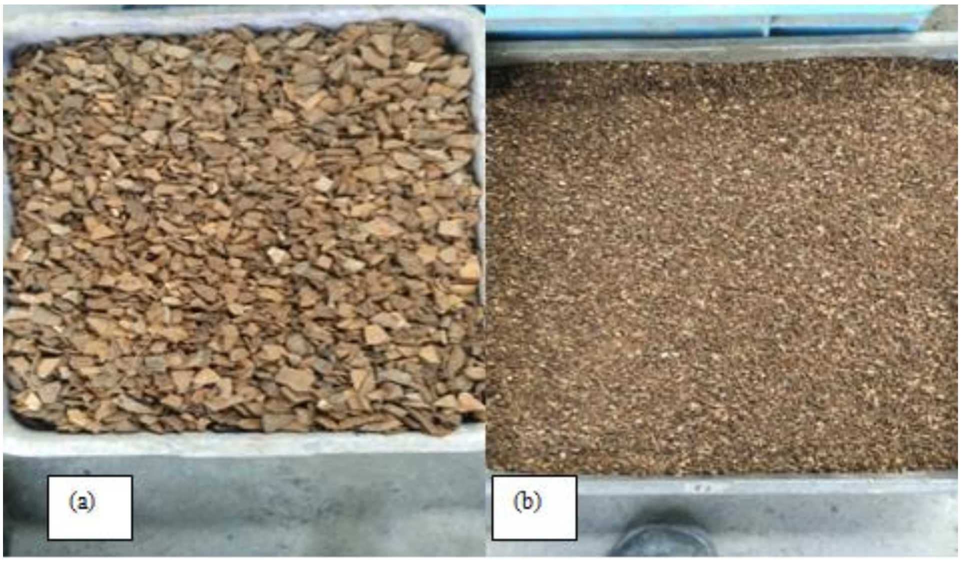

Figure 1: Crushed coconut shell aggregates (a) Coarseaggregate (b) Fine aggregate

The surface texture of the coconut shell is fairly smooth on concave and rough on convex faces. CS aggregates have a relatively high water absorption value nearly 6.71%, compared to the conventional fine aggregate (3%). The physical properties of Coconut shell are shown in Table 1.

Table 1: Physical Properties of Coconut Shell

Physical Properties	Test Results
Specific gravity	1.33
Bulk density (kg/m^3)	800
Shell thickness	2-7mm

Fine aggregate consisting mainly of river sand with a specific gravity of 2.72 was used in this investigation that conformed to the requirement of BS [8] in zone 2 aggregate classification while the coarse aggregates employed was from a crushed mineral rock all obtained in Nigeria. Ordinary Portland cement conforming to ASTM [9] was used throughout and portable drinking from tap water was used which was clean and clear while carrying out this research work.

3. Mix Design

A water cement ratio of 0.45 with a mix design of 1: 1.84: 2.43 for cement fine and coarse aggregates respectively was adopted throughout the experimental program.CS replacement offine and coarse aggregate at 0, 10, 20 and 30% was used**.**The mix design of the control mixture was arrived at using the absolute volume method in ACI 211.1-91 to achieve a compressive strength of 30 MPa at the age of 28 days. Table 2 shows the composition of the constituents materials used.

4. Preparation of concrete

In this research, four series of mixes were produced and utilized.Coarse and fine aggregates were partially replaced with 0%, 10%, 20% and 30% of CSA by volume for control mix and by weight for the other mixes with constant water to cement ratio of 0.45. Immediately after the preparation of mixes, they were covered with hessian bags for 24h to prevent water loss and then demolded after 24 hours of casting, after which they were completely immersed in water in accordance with ASTM [10] C511 until testing at 7, 14, 21 and 28 days. All batches of concretewere homogenized using mechanical mixer in accordance with ASTM [11] C305. Mixing sequences and durations were executed according to standard procedures in ASTM [11].

Table 2: *Mix Proportions of Grade 30 Concrete for various CS replacements*

FA/CA (%)	Cement (kg)	Water (kg)	Fine aggregate (kg)	Coconut shell-FA (kg)	Coarse aggregate (kg)	Coconut shell-CA (kg)
0 %	22.0	9.9	46.39	0	61.5	0
10%	22.0	9.9	41.75	04.64	55.4	6.2
20%	22.0	9.9	37.11	09.28	49.2	12.3
30%	22.0	9.9	32.47	13.92	43.1	18.5

5. Experimental Program

Workability of fresh concrete was determined by a slump test in accordance to procedures prescribed in BS EN [12]. The use of CSA as fine and coarse aggregates revealed better effect on the slump of concrete. Fig. 2. shows result of slump test conducted on mixes of concrete with a replacement of fine and coarse aggregate with CSA. No marked change in workability was evident between the control and 10% CSA replacement of fine and coarse aggregates. There was 75% and 100% increment in workability when the percentage of replacement with CSA was increased from 20 to 30% relative to the control mix as depicted in Fig. 2. This increase in workability may be due to the particle shape of the CSA in which flat shaped CS particles could not have limited the overall movement of particles in concrete thereby increasing the workability to the increase in specific surface resulting from the increase in quantity of CS [13].

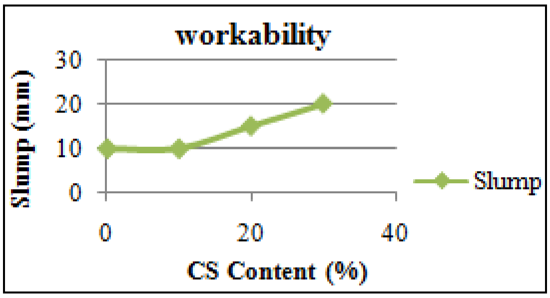

Figure 2: Workability of concrete containing CS as fine and coarse aggregate.

6. Density of concrete

The density of concrete was conducted in accordance with BS EN [14]: Standard Test Method for Hardened concrete Density. A total of 48 number specimens were used for the density test evaluated at 7, 14, 21 and 28 days. Generally, the densities of all specimens containing CS were found to be lower than the control specimen as depicted in Fig. 3. The density of concrete decreases with increase in fine and coarse aggregate replacement with CS. Decreased density could be attributed to direct consequence of specific gravities of materials [15]. Although, all concrete samples containing 10 and 20% CS aggregates weigh more than 2000 kg/m^3, it is important to state that the air dry densities of 30% CS concrete of the typical mixes are within the range of structural lightweight concrete of density less than 2000 kg/m^3[16].This could prove advantageous for construction purposes, as the reduction in concrete density considerably reduces the self-load of a structure and allow for handling of larger precast units.

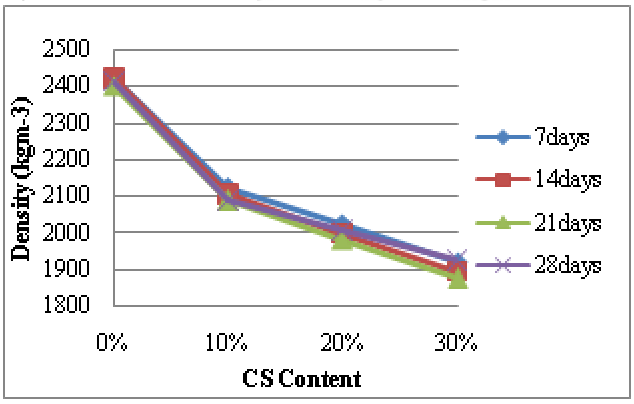

Figure 3: Density of Hardened concrete containing CS as fine and coarse aggregate.

7. Initial Water Absorption

The initial surface absorption test was conducted in accordance with BS 1881 part 208 [17]: Procedure for determination of initial surface absorption of concrete. This test is important for concrete quality because concrete structure need to be impermeable sothat excess water should not be absorbedinto the concrete and corrode the reinforcement. Fig. 4 shows the result of the initial water absorption test of CS concrete as fine and coarse aggregate substitution.

The absorption rate of specimens increased uniformly with the addition of CS replacement from 0% to 30% from 10min to 60 min. For the 30% CS replacement concrete, the absorption rate decreased from 0.871 ml/m²s to 0.449 ml/m²s for 10min to 60min; however it showed highest value compared to other concretes mixes. The absorption at 10 min was higher than 60 min due to the fact that absorption capacity of concrete depends on effective porosity. At 60 min, the pores in the concrete were mostly filled by water. Gunasekaran *et al.* [18] stated that moisture retaining and water absorbing capacity of coconut shell are greater compared to conventional aggregate. Strength and water absorption are dependent on pore structure of the concrete and are inversely proportional to one another, that is, if porosity increases, strength decreases and absorption increases.

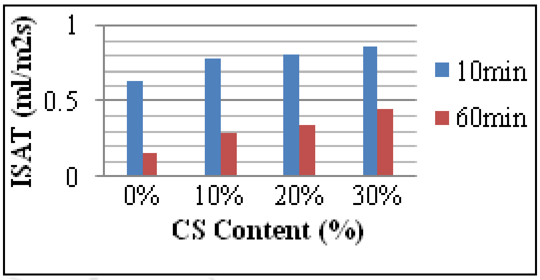

Figure 4: Initial water absorption of concrete containing CS as fine and coarse aggregates.

8. Compressive Strength

Compressive strength evaluation was carried out in accordance with provisions of BS EN [19]: Standard Testing Method for Making and curing specimens for strength tests using sample size 50 x 150 x 150 mm cube. A total No. of 48 samples were fabricated and tested for strength at 7 14 21 and 28 days and the result is depicted in Fig. 5. In general, it was observed that the compressive strength all samples decreases with increase in CS content for all curing regimes. The strength decreased by 50.14% when the replacement of CSA is increased to 30%. The reduction in strength could be due to the increase in surface area of CSA as the replacement is increased hence more cement is needed for proper bonding but as the quantity of cement remains constant, there was no extra bonding and thus this cause reduction in strength [15]. However, 30% replacement of sand and crushed granite by CS in the hardened concrete attained a 28-day compressive strength of 25MPa; equivalent to grade 25 concrete BS 8110 [20]which can be used for structural purposes.

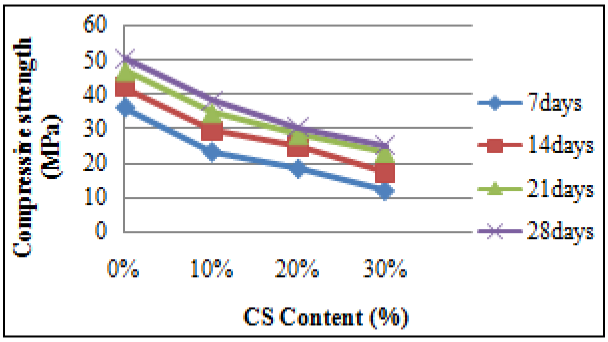

Figure 5: Compressive strength of concrete containing CS as fine and coarse aggregate

9. Conclusions

Coconut Shell (CS) was recycled to substitute fine and coarse aggregates in concrete at 0, 10, 20 and 30% levels of replacement. Workability, density, water absorptionand compressive strength were conducted on the specimens fabricated in conformity with relevant specific standards. Based on the results, it is observed that CS content of 30% is feasible as a light weight structural material in connection with its density reduction and compressive strength characteristics. It is recommended that further study be carried out on the durability mechanism of CS in concrete subjected to harsh conditions.

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Author Profile

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