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Research Article

STRENGTH ASSESSMENT OF COCONUT SHELL AS PARTIAL REPLACEMENT FOR COURSE AGGREGATE IN LIGHT WEIGHT CONCRETE

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Abstract

This research work investigated the physical and chemical properties of coconut shell as an alternative material in light weight concrete, the effect of curing age on the compressive strength of coconut shell concrete and the effect of percentage replacement on compressive strength of coconut shell concrete. Coconut shell were obtained locally and were crushed to an average size of 20mm. Concrete was produced with mix ratio 1(cement):2(fine aggregate):4(coarse aggregate) with a constant water-cement ratio of 0.5, by replacing coarse aggregate volumetrically at 0%, 5%, 10%, 15% and 20% with crushed coconut shells and curing age at four (4) levels 7, 14, 21 and 28 days. The size of specimen used throughout was 100mm x 100mm x 100mm with at least three samples made for each percentage replacement of coarse aggregate. The characteristic properties of materials and coconut shell concrete such as particle size distribution, workability, bulk density, moisture content, specific gravity and compressive strength were reviewed in this study and investigated in the laboratory. The average compressive strength results at 7 days curing with 0%, 5%, 10%, 15%, and 20% are 12.96N/mm^2, 10.16N/mm^2, 7.71N/mm^2, 8.25N/mm^2 and 5.66 N/mm^2 respectively. The average compressive strength results at 14 days curing with 0%, 5%, 10%, 15%, and 20% are 11.47N/mm^2, 11.11N/mm^2, 9.26N/mm^2, 7.22N/mm^2 and 6.85N/mm^{2}respectively. The average compressive strength results at 28 days curing with 0%, 5%, 10%, 15%, and 20% are 14.86N/mm^2, 11.91N/mm^2, 9.72N/mm^2, 8.65N/mm^2 and 6.52N/mm^2 respectively. The average compressive strength results at 28 days curing with 0%, 5%, 10%, 15%, and 20% are 18.51N/mm^2, 14.64N/mm^2, 11.10N/mm^2, 9.22N/mm^2 and 6.84N/mm^2 respectively. The results showed that compressive strength, density and workability of the concretes decreases with increase in coconut shell replacement. Coconut shells can be used as partial replacement for the conventional stone aggregates in concrete production. Therefore, the use of coconut shell aggregate as a replacement in convectional concrete should be encourage in the locality where it is in abundance to enhance environmental cleanliness.

Keywords: Coarse aggregate, Coconut Shell, Compressive Strength Concrete, Workability.

INTRODUCTION

Concrete is one of the most versatile construction materials. It is a widely used construction material that consists of a mixture of cement, aggregates, water and admixtures. Inert granular materials such as sand, crushed stone or gravel form the major part of the aggregates. With more than 10 billion tons of concrete produced annually, it is considered to be the most important building material (Meyer, 2009). To save the natural resources from over extraction of aggregates from rocks and sand from rivers, many agricultural wastes are used in the production of concrete. When these wastes are used in concrete composites, it enables the production of green concrete and helps in the reduction of carbon dioxide (CO_2) emission. As an example, using coal fly ash in concrete production leads to an improvement of fracture toughness and making green concrete, in turn leading to the reduction of CO_2 emission. Literature states that the introduction of supplementary materials into the concrete can be divided generally into six classes, namely industrial wastes (fly ash, silica fume, ground granulated blast furnace slag, metakaolin etc.), nano industrial wastes (nanosilica, nanotitanium, tiania–silica nanosphere, nanoalumina, nanometakaolin, carbon nano tubes etc.), agriculture–farming wastes (bamboo, wheat, barley, corn, olive, banana, sisal, date palm, elephant grass etc.), aquaculture–farming wastes (oyster, periwinkle, mussel etc.), minerals (calcite, diatomite, zeolite, perlite etc.) and dust and powders (limestone powder, brick powder, waste marble dust and powder, waste ceramic powder, ground pumice powder, quartz powder etc.). In line with these alternate materials, coconut shell can be added to the agriculture–farming group, and it has been proven that coconut shell (CS) waste can be used as an aggregate in place of conventional stone aggregate (Kalyanapu *et al.,* 2015). Therefore, there is a growing demand to find alternate materials that can be used as coarse aggregate in concrete. Aggregates made by crushing coconut shells can be effectively used in concrete by partially replacing coarse aggregate up to a certain amount. This will not only reduce the unit weight of resulting concrete made, but also provides an efficient solution to the disposal of coconut shells. Gambhir (2005) reported that coarse aggregate constitutes about 75% to 85% of the concrete matrix. Concrete being one of the major building materials that is used virtually in all aspects of construction and could be delivered to the job site, and be molded in situ or pre-cast to any form or shape, makes it a material of choice in construction. Hence the significance and relevance of coarse aggregate in concrete production in all areas of civil engineering practice and building construction cannot be ignored. Nigeria being a developing country is faced with inadequate provision of physical infrastructure; shelter and related amenities, which are typical factors of under development that need to be addressed through provision of alternative, cheap and affordable materials. In these areas development require the use of cement and other related materials such as coarse aggregate. Technologies which can provide means of upgrading shelter within the scope of the socio economic and cultural

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environment need to be developed (Elinwa, 2003). Currently, research efforts have been geared towards sourcing, development and the use of local alternative construction materials including the possibility of using some agricultural wastes and residues as construction materials. Some investigations made shown that it is possible to produce concrete using agricultural, urban and industrial wastes material, (Shelton and Harper 2002) Kanojia and Jain (2015) also reported that coconut shell has added advantage of high lignin content that makes the composites more weather resistant. The purpose of this research work is to develop a concrete with coconut shells as partial replacement for coarse aggregate. The study of coconut shells will not only provide a new material for construction but will also help in the preservation of the environment in addition to improving the economy by providing new use for the coconut shells. According to Shahiron et al, (2012) the most critical issue in environment protection and natural resource conservation is waste management. Changes in environment and an increase in population are the main causes of the many processes of deterioration which have altered the ecosystem of our planet, including the generation of municipal solid waste.

MMETHODOLOGY

Materials

The cube size of 100x100x100mm was used to conduct the compressive strength test. A sample of specimen which contains 0% coconut shell was also used as control sample. A total of 60 specimens was prepared. Ordinary Portland Cement (OPC) with specific gravity 3.15 f2.3 Granite of 20mm size was used as coarse aggregate with a density, relative density and absorption value of 2375kg/m3, 2.7 and 0.5% respectively ml. The fine aggregate was air dried to obtain saturated surface dry condition to avoid compromising water cement ratio. In this research, river sand was used and sieve analysis was conducted prior to obtain fine aggregate passing through 600µm sieve. The coconut shells was obtained from a local coconut field. The crushed materials was later transported to the laboratory where they were washed and allowed to dry under ambient temperature. The coconut shell used was crushed to a particular size of about 20mm.

Test Procedure

Coconut shell were obtained locally and were crushed to an average size of 20mm. Concrete was produced with mix ratio 1(cement):2(fine aggregate): 4(coarse aggregate) with a constant water-cement ratio of 0.5, by replacing coarse aggregate volumetrically at 0%, 5%, 10%, 15% and 20% with crushed coconut shells and curing age at four (4) levels 7, 14, 21 and 28 days. Absolute weight method of calculation was adopted to determine the quantities of materials required for the production of the specimen cubes. Coconut shell was used to replace coarse aggregate partially at (0, 5, 10, 15 and 20%) in the mix to assess the strength of coconut shell concrete.The batching was carried out by volume batching of the concrete constituents as well as as coconut shell. The ingredients were thoroughly mixed manually. The sand, cement and aggregate were measured accurately and were mixed in dry state for normal concrete. Whereas for coconut shell concrete, first measured quantity of cement and other required ingredients as per mix design. Care was taken to avoid segregation of concrete. Standard timber moulds with internal dimensions of (100mm × 100mm × 100mm) were used. The water – cement ratio used for the casting of the cubes was 0.5. The inner parts of the moulds were smeared and lubricated with engine oil in order to reduce friction, to ensure easy de-moulding and smooth surface finish of concrete. The fresh concrete was placed in the moulds by trowel. It is ensured that the representative volume is filled evenly in all the specimens to avoid accumulation of aggregate, segregation etc. Immediately after thorough mixing, the wet and fresh mixture was used for slump test before being cast into the moulds. The slump mould was filled with concrete in three layers and each layer were tamped 25 times. The concrete in the mould was compacted in 3layers using the rammer (25mm diameter steel rod). Each layer of concrete in the 100mm mould was compacted manually by uniformly distributing at least 25 blows of the rammer across the cross-section of the mould. The essence of the compaction is to reduce the amount of voids in the concrete. The top of each mould was levelled and smoothened and the outside surfaces cleaned. The additional concrete was chopped off from the top surface of the mould for avoiding over sizes etc. Identification marks were given on specimens by embossing over the surface after initial drying. The moulds and their contents were kept in the materials laboratory for 24 hours before de-moulding. Curing been the process of keeping concrete under a specific environmental condition, good curing was typically considered to be in a moist environment which promotes hydration. More specifically, the object of curing was to keep concrete saturated until the original water filled space in fresh cement paste has been filled to the desired extent by the products of hydration of cement. The hardened cubes were remove after 24 hours and taken to the curing tank (BS1881: part 108:1983). Similarly, coconut shells concrete specimens were demoulded after 24 hours of casting and kept in water tank for curing at 7, 14, 21 and after 28 days.

RESULTS AND DISCUSSION

Sieve Analysis

The particle size distribution test result for fine aggregates is presented in Table 1. This was carried out in accordance with BS 812: Part 103, 1989. The particle size distribution graph is shown in Figure 1. The sand is also uniformly graded. Table 1 gives the sieve analysis result carried out on fine aggregate.

Moisture Content

The moisture contents of the aggregates is presented in Tables 2. The natural moisture content of the fine aggregates used is 4.66%.

Specific Gravity

The results of specific gravity of fine aggregate is presented in Table 2. This was conducted in accordance to BS 1330: Part 2: 1995. The results shown in Table 4.3 shows that the fine aggregate have an average specific gravity of 2.64 which agreed with BS 1330: part 2: 1995.

Bulk Density

The bulk density gives information in respect of shape and grading of the aggregate. This is test was performed in accordance to BS 812: Part 2: 1990. Using equation 3.5, the bulk density of the aggregates was calculated and presented in Tables 4. Table 4 gives the compacted bulk density of fine aggregate as 2085.56kg/m^3.

Table 1. Sieve analysis of fine aggregate

Sieve size (mm)	weight of sieve (g)	Weight of sieve + sample retained (g)	Weight of sample retained (g)	Percentage weight retained (%)	Cumulative percentage retained (%)	Percentage passing (%)
4.75	380.00	380.40	0.40	0.07	0.07	99.93
2.36	471.40	478.60	7.20	1.20	1.27	98.73
1.70	371.03	377.20	6.17	1.03	2.30	97.7
1.18	249.0	259.60	10.60	1.77	4.07	95.93
0.60	467.30	550.50	83.20	13.87	17.94	82.06
0.50	360.00	498.20	138.20	23.03	40.97	59.03
0.425	355.8	477.70	121.90	20.32	61.29	38.71
0.212	354.9	478.80	123.90	20.65	81.94	18.06
0.150	246.60	249.70	3.10	0.52	82.46	17.54
0.075	336.80	436.30	99.50	16.58	99.04	0.96
Pan	286.80	292.70	5.90	0.98	100.00	0.00

Weight of sample = 600 g

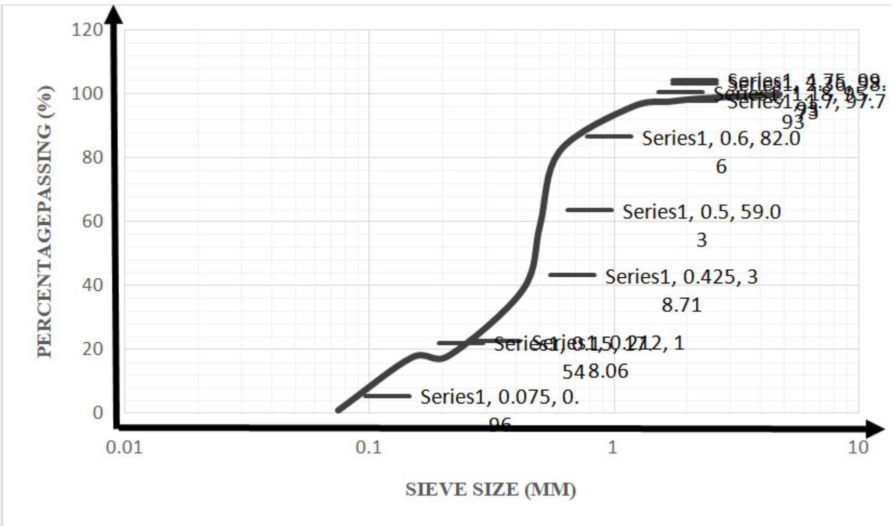

Figure 1. Particle size distribution of fine aggregate

Table 2. Moisture content of fine aggregates (sand)

Details		Readings	
Can number	C1	C2	C3
Weight of empty of can, w_1 (g)	37.20	90.30	115.90
Weight of can + sample, w_2 (g)	759.50	833.50	981.10
Weight of can + oven dried sample, w_3(g)	723.90	802.30	946.7
Moisture Content, Mc (%)	5.19	4.66	4.14
Average Moisture Content, Mc (%)		4.66	

Table 3. Specific gravity of fine aggregate

Details		Readings	
Trials	1	2	3
Weight of bottle, W_1 (g)	291. 70	321.90	284.00
Weight of bottle + dry sample, W_2 (g)	341. 70	371.90	334.00
Weight of bottle + sample + water, W_3 (g)	594.70	573.30	558.40
Weight of bottle + water, W_4 (g)	563.30	542.60	527.40
Specific Gravity, Gs	2.69	2.59	2.63
Average Specific Gravity, Gs	2.64		

Table 4. Bulk Density for fine Aggregate

Details		Readings	
		Compacted	
Trials	1	2	3
Weight of mould, W_1(kg)	0.0248	0.0248	0.0248
Weight of mould + sample, W_3 (kg)	0.0869	0.0877	0.0875
Volume of mould, V (m^3)	0.00003	0.00003	0.00003
Bulk Density (kg/m^3)	2070.00	2096.67	2090.00
Average Bulk density (kg/m^3)		2085.56	

Slump Test Result

The workability of the coconut shell concrete was superb in comparison to normal concrete. The workability here refers to the true slump that was obtained during the slump test. The workability decrease as the percentage of replacement increases. This means that an optimum value of mixing must be obtained in order to obtain better results. The slump test result given in Table 5 shows that there is a decline in the slump value of concrete. Slump value decreases with increase in the percentage of coconut shell.

Table 5. Slump Test Result

Replacement level	Slump (mm)
0%	29
5%	25
10%	21
15%	18
20%	16

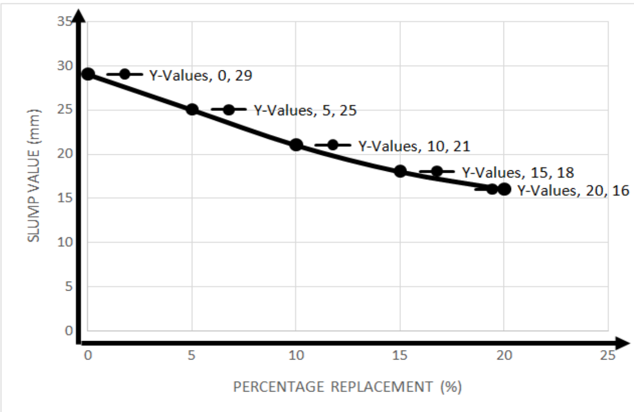

Figure 2. Slump test

Density Test

In all cases, the density of the concrete produced decreased with increase in the percentage replacement of conventional coarse aggregate (granite) with coconut shell.Table 4.6 gives the result for average density of concrete before the crushing of the cube was carried out at each curing ages for the different percentage replacement of coarse aggregate with coconut shell. It was observed thatthe density of the concrete decreased as the percentage of shells increased.

Table 6. Average density of concrete cube before crushing

Days	Average Density of Concrete Cubes (Kg/m^3)				
	0%	5%	10%	15%	20%
7th	2533.33	2433.33	2233.33	2350.00	2350.00
14th	2566.67	2166.67	2166.67	2133.33	2233.33
21st	2466.67	2466.67	2183.33	2300.00	2083.33
28th	2366.67	2150.00	2066.67	2133.33	2050.00

Compressive Strength Test Result

The compressive strength results at 0% replacement shows that the average strength of concrete at 7, 14, 21 and 28 days are 12.96N/mm^2, 11.47N/mm^2, 14.86N/mm^2 and 18.51N/mm^2 respectively. The compressive strength results at 5% replacement shows that the average strength of concrete at 7, 14, 21 and 28 days are 10.16N/mm^2, 11.11N/mm^2, 11.91N/mm^2 and 14.64N/mm^2 respectively. The compressive strength results at 10% replacement presented in table 4.9 shows that the average strength of concrete at 7, 14, 21 and 28 days are 7.71N/mm^2, 9.26N/mm^2, 9.72N/mm^2 and 11.10N/mm^2 respectively. The compressive strength results at 15% replacement presented in table 4.10 shows that the average strength of concrete at 7, 14, 21 and 28 days are 8.25N/mm^2, 7.22N/mm^2, 8.65N/mm^2 and 9.22N/mm^2 respectively. The compressive strength results at 20% replacement presented in table 4.11 shows that the average strength of concrete at 7, 14, 21 and 28 days are 5.66N/mm^2, 6.85N/mm^2, 6.52N/mm^2 and 6.84 N/mm^2 respectively. The results obtained from the partial replacement of normal coarse aggregate with coconut shell aggregate are shown in Tables 4.7, 4.8, 4.9, 4.10 and 4.11. The percentage of coarse aggregate replacement adopted are 0%, 5%, 10%, 15% and 20% using mix ratio 1:2:4. The results show that the compressive strength decreases with percentage increase in the coconut shell aggregate content. It was observed that the concrete compressive strength of the cube specimens increases with increasing age.

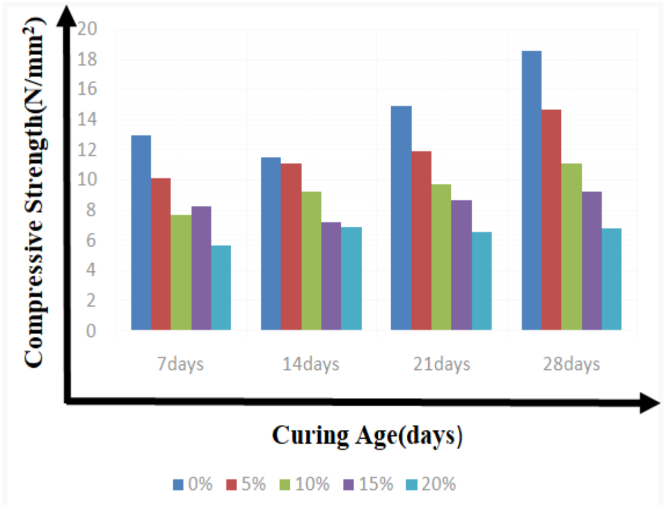

Figure 3. Compressive Strength

Conclusion

The study of the properties of coconut shell aggregate concrete has been carried out through experimentation, analysis and discussions of the suitability of coconut shell aggregate. The experimental results therefore show that coconut shell has the capability of been used as coarse aggregate in lightweight concrete as well as a partial replacement of conventional coarse aggregate in concrete. Therefore, based on investigation the following conclusion can be drawn:

- The compressive strength of coconut shell aggregate concrete at 28day test at 5%, 10%, 15% and 20% replacement were 14.64N/mm^2, 11.10N/mm^2, 9.22N/mm^2, 6.84N/mm^2 which satisfied the requirement of lightweight concrete.
- In all cases the density of the concrete produced decreased with increase in percentage replacement of conventional coarse aggregate (granite) with coconut shell aggregate.
- The strength of concrete is reduced with the increase in percentage of coconut shell.
- Less than 10% replacement of coarse aggregate with coconut shells can be used to produce structural concrete.
- Coconut shells can be used as partial replacement for the conventional stone aggregates in concrete production.

Recommendations

Based on the scope and the results of this research the following are the recommendation for further investigation.

- The use of coconut shell aggregate as a replacement in convectional concrete should be encouraged in the locality where it is in abundance to enhance environmental cleanliness.
- A study of the shrinkage characteristics of coconut shell concrete is recommended.
- A long term durability study of Coconut shell concrete should be investigated.
- There is the need to study the permeability of coconut shell concrete.
- The strength of concrete made from crushed coconut shell should be improved using higher cement content and appropriate admixtures so as to meet the ASTM standard for structural lightweight concrete.

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