Feasibility study of the use of Groundnut Shells as Fine Aggregates in Light weight Concrete Construction

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Abstract—Issues bothering on sustainability in our society today have generated a lot of curious interest among researchers. The need to optimize the use of scarce resources, reduce cost of construction, and reduce environmental pollution has necessitated the research into many waste materials that pose a lot of threat to the environment. One of these waste materials is groundnut shell which is abundant in Northern Nigeria and which is normally left to rot and pose an environmental nuisance. This research therefore sought to use groundnut shell as a partial or full replacement as fine aggregate in light concrete panels with the ultimate aim of reducing the amount of these waste products in our environment and also indirectly increasing groundnut production if the research is successful. This is because farmers will not only sell the groundnuts but also will sell the waste products. 63 concrete samples were casted using groundnut shell replacements of 0%, 10%, 20%, 30%, 50%, 70%, 100% and tested for 7days, 14days and 28 days for compressive strength tests. The density of the various samples measured and swelling tests were also carried out. From the results of the laboratory tests the density of the cubes ranged from 830kg/m^3 for cubes with only groundnut shells to 2160kg/m^3 for cubes with only sand as fine aggregates. The average compressive strength range for 0% ground shell to 100% ground shell was 5.83N/mm^2 to 0.9N/mm^2 at 7 days, 8.07 to 0.5 N/mm^2 at 14 days and 10 to 0.6 N/mm^2 at 28 days while moisture absorption increased from 0.47 to 2.04%. The strength results indicate that groundnut shell panels cannot be used for structural purposes but will be suitable for non-load bearing partition walls. Replacements of 30 to 70% had suitable strength and can be used for this purpose. It is recommended that further research to be carried out to determine its acoustic and thermal properties.

Index Terms—Groundnut shell, compressive strength, light weight concrete

I. Introduction

Alexander and Mindess [2] and Neville [12] consider concrete as an artificial conglomerate comprising fragments (aggregates) that are held together by a cementing phase. Concrete is a composite building material basically obtained by a proportional mix of aggregates, water and a binder. The composite matrix when cast into forms and cured, hardens into a rock-like material by a chemical reaction between water and the binder material. This material, overtime acquires desirable properties such as improved and increased strength, toughness, fire resistance, compactness and durability. These stated properties are all affected by so many factors such as type of aggregates, proportions of coarse and fine aggregates, type of binder, amount of water, method of curing etc. which is based on desired properties. The flexibility of concrete and its easy adaptability to environmental conditions make concrete suitable for applications in almost all structures (Mtallib and Ibrahim [13]). Concrete varies in weight from high density to light weight concrete depending on the weight component materials, mainly fine and coarse aggregates and amount of air entrained. It's therefore, classified based on its density into lightweight, normal weight and high density concrete. Besides water and soil, aggregates are the most abundantly used materials worldwide. With the worlds growing population, the optimal use of land space has edged the building industry into construction of high rise and other structures whose efficiency is increased by using lightweight components which are produced with lighter and tougher materials to lockdown problems associated with use of high density concrete in mega construction. These problems basically have to do with the reduction of the overall weight of the structure as this will help save cost on the size and geometry of beams and foundations. This can be achieved using structural light weight concrete

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(LWC) which is considered by ACI Committee 211[1] to be concrete which has a compressive strength in excess of 17.2N/mm^2 at 28 days of curing and an equilibrium weight not exceeding 1842kg/m^3. Chandra and Berntsson [9] stated that light weight concrete has been used successfully since ancient Roman times. The dead load to be carried by a building is always far in excess of the imposed load and as such researchers have over the years made several attempts to produce concrete using substitute materials for partial replacement of coarse aggregates in concrete in an attempt to produce light weight concrete. Bai and Basher [6]; Berra and Ferrara [5] and Kayali and Hague [11] have identified some of the benefits of LWC in addition to its light weight to include improved durability properties, low coefficient of thermal conductivity and a higher fire rating. Hanson [10] stipulated that lightweight concrete can be produced basically in 3 ways. These include the use of lightweight aggregate such as expanded clay, sawdust, foamed slag, groundnut and palm kernel shell; by entraining air using hydrogen peroxide and by using only coarse aggregates (Hanson [10]). Table 1 shows the different classifications of light weight aggregates. Coarse aggregates are used only in the casting of the concrete.

Table 1: *Classification of some Light Weight concretes and their densities*

Types of lightweight concrete	Density (kg/m3)
No fines (normal concrete aggregate)	1600-1930
No fines (light weight aggregate)	885-1200
Clinker	1050-1600
Foamed slag	965-1600
Expanded clay	800-1770
Pumice	725-1126
Sawdust	645-1290
Cellular or aerated	400-1600
Vermiculite	480-960

Source: Short [15]

II. Materials and Methods

The groundnut shells used for the study were sourced locally from farmers in the Sabongari area of Kaduna state Nigeria. Groundnut shell was first planted in South Africa, mainly Brazil and spread to other part of America, Asia, and northwestern Argentina and then brought to West Africa by the Portuguese in the 16th century. The shells were washed clean to remove any dust or mud impurities and then dried. Ordinary Portland cement was obtained from the local market while river sand passing through sieve no 4.75mm was used as fine aggregate. The cement used for this experiment is locally produced by Dangote Cement Company Plc. For this experiment, naturally occurring river sand was used passing through a BS sieve of 4.75mm which was obtained from the market. This was obtained from a groundnut stall along the railway line as an agricultural waste in the study area. The water used in the process of carrying out this experiment, was clean tap water free from any deleterious substances and impurities and was collected from the tap in the Concrete Laboratory of Department of Building, Ahmadu Bello University, Zaria. The water is portable satisfying the specification requirement for water according to BS 3148. The compacted bulk density test was conducted in accordance to BS 812-2 [7]. The specific gravity of the aggregate was determined using a pyclometer in accordance to BS 812-2 [7].

A mix ratio of 1:3 was used for cement and aggregate and a water cement ratio of 0.75 was used as groundnut absorbs more water. The quantities were determined using the absolute volume method. The materials were mixed on a metal platform in the department of Building concrete lab. The sand was first measured using a scale and poured on the platform, then the measured cement was poured next after which the measured groundnut shell was poured and all materials mixed together. Water was measured and gradually added. After thorough mixing, the concrete was casted. The concrete casting was done in a metallic cube of dimension 100mm x 100mm x 100mm. After mixing, the fresh concrete was poured into the metallic cubic mould in three different layer with each layer tamped 25 times using a tapping rod. The cubic mould was then filled with fresh concrete and leveled using a hand trowel. This procedure was repeated for all the mixes of fresh concrete made. Concrete cubes were de-moulded after 24hours and arranged for curing (Plate1).

The concrete cubes were cured using the sprinkling method. The cubes were arranged on the floor and covered with a fiber sack. The sack helps to reduce the rate of evaporation and keep the curing environment completely moist. Water was continually sprinkled on the concrete twice to three times daily for a maximum period of 28days as tests were being conducted on the cubes after every 7days.

Table 2*: Composition by weight of cubes with different percentages of groundnut shell, sand, water and cement*

Col A	Col. B	Col C	Col D	Col E	Col F
0 %	5.25	0.00	18.20	3.96	27.41
10 %	5.25	0.26	16.40	3.96	25.87
20 %	5.25	0.52	14.56	3.96	24.29
30 %	5.25	0.78	12.74	3.96	22.73
50 %	5.25	1.30	9.10	3.96	19.61
70 %	5.25	1.82	5.46	3.96	16.49
100 %	5.25	2.60	0.00	3.96	11.81

Col A: Column A is percentage groundnut replacement
Col B: Column B is Weight of cement in kilograms
Col C: Column C is weight of cement in kilograms
Col D: Column D is Weight of fine aggregate in kilograms
Col E: Column E is weight of water in kilograms

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Col F: Column F is Total weight of a cube



Plate 1: Sample of cubes casted and ready for curing and Testing

III. Results and Discussion

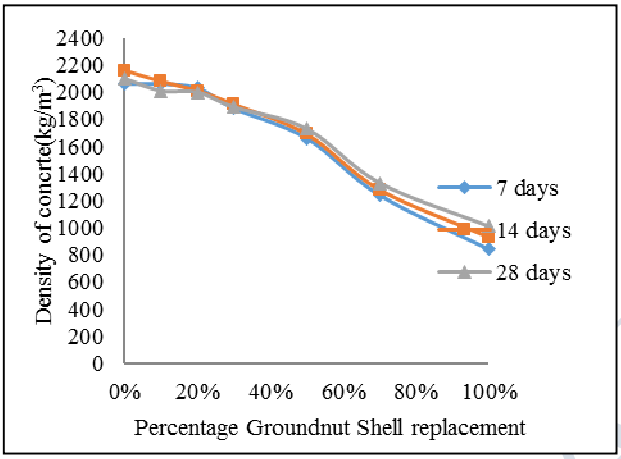


Fig. 1: Variation of Density with percentage ground replacement for cubes tested at 7, 14 and 28 days

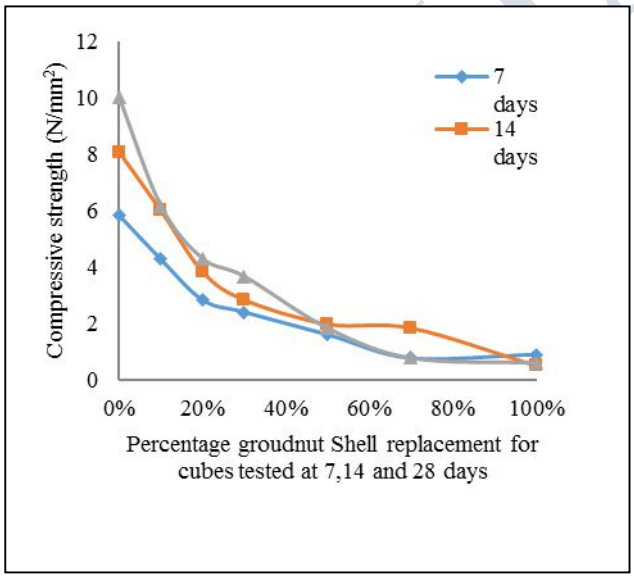


Fig. 2: Compressive strength of cubes with varying percentages of groundnut shell replacement for cubes tested at 7, 14 and 28 days

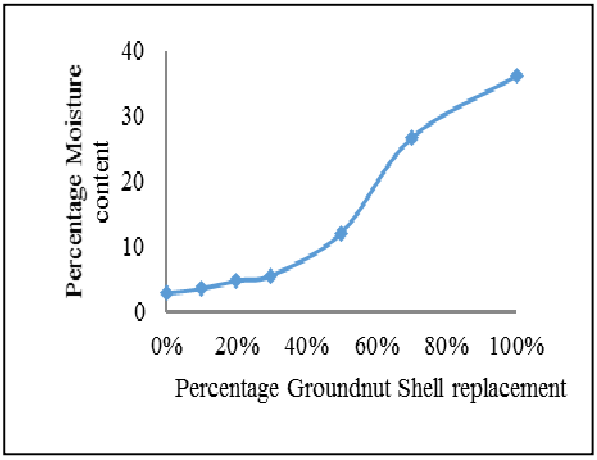


Fig. 3: Moisture content variation for various percentages of groundnut shell replacement

a) Bulk Density Of Aggregates

The bulk density obtained from the fine aggregate, sand was 1816.30kg/m^3 and that of groundnut shell was obtained as 257.78kg/m^3. The bulk density of groundnut shell is low indicating it's a light weight aggregate and suitable in the production of light weight concrete (Portland Cement Association, [14]]. This implies that the combination of groundnut shell and sand will produce concrete of very low density hence light weight concrete.

It should be noted that due to the low density of both aggregate, the concrete to be produced would be of low strength. This led to the use of low cement-sand ratio of 1:3 in order to improve concrete strength and increase bonding property of cement and groundnut shell.

b) Specific Gravity of Aggregates

The specific gravity of groundnut shell was gotten as 0.6 and that of sand was gotten as 2.6. These aggregates can be used for light weight concrete as they fall within the acceptable range (Short [15]

c) Density of Concrete Cubes

The density of concrete cubes from 30% to 100% indicate light weight as it falls within the range of 400-1950kg/m^3 for light weight concrete and density of concrete cubes from 0% to 20% indicate normal weight concrete as the range is below 2400kg/m^3 (Neville [12]). The density of all the cubes decreased as the percentage of groundnut shells was varied from 0-100% for all the cubes at different curing ages as shown in Fig. 1.

d) Compressive Strength of Concrete

The test for compressive strength was carried out according to BS 1881 part 116 [8]. The cubes were produced cured and crushed after 7days, 14days and 28days using a crushing machine. 6 cubes of each mix were crushed and their failure load was determined and recorded. From the results of the tests it was observed that the strength of concrete cubes increases with age of curing. At 28 days of curing the compressive strength of concrete cubes of 10% to 100% groundnut shell concrete cannot be used as structural light weight concrete because its compressive strength is below 17N/mm^2 but can be used as insulating concrete since its compressive strength ranges between 0.7 to 7N/mm^2 (ASTM standard C330-77). As the percentage of groundnut shell is increased, there is a corresponding decrease in the compressive strength of concrete as seen in Fig. 2. An increase in the percentage of groundnut shell resulted in a corresponding decrease in the strength of concrete.

e) Moisture Content and Absorption Capacity

The moisture and absorption capacity of the concrete was carried out after the 28 days of curing the concrete. A sample of each cube mix was measured and each value recorded, each samples were placed in the oven at a temperature of 105°C for 24 hours and the weight of each cube samples were also recorded. These cube samples were soaked in water for 24 hours and the saturated weight were recorded. These cubes were dried and the final air dried weights were recorded. From the results of the moisture content and water absorption capacity of concrete cubes showed that an increase in the percentage of groundnut shell will lead to a corresponding increase in the moisture content absorption of the concrete cubes as shown in Fig. 3. The high water absorption of the concrete will also affect the density and compressive strength of the concrete.

IV. Conclusion

The partial replacement of sand with groundnut shell in the production of lightweight concrete as observed from the experimental program carried out showed positive prospects. The varying percentages of groundnut shell used in replacing sand has indicated that a lightweight concrete can be produced and can be used as non-load bearing concrete or insulated lightweight concrete due to the low compressive strength and density of the sample cubes produced. The various acceptable percentages of groundnut shell that can be used to replace sand in order to produce lightweight concrete are in the range of 30-70% as they fall within the range of densities accepted for lightweight concrete. 30% groundnut shell replacement achieved a compressive strength of 3.67N/mm2 and a density of 1890kg/m3 after 28days of curing. Its density indicates that it is a lightweight concrete and its strength indicates that it can be used as a non-load bearing lightweight concrete or an insulated lightweight concrete.

The analysis on the specific gravity of groundnut shell used was 0.6 and that of sand was 2.6 therefore implying that both materials can be used for light weight concrete. In addition the bulk densities were 257.78kg/m3 for groundnut shells and 1816.3kg/m3 and these fall within the acceptable ranges for fine aggregates.

V. Recommendations

From the study lightweight concrete produced with groundnut shells should only be used for lightweight skating and light weight partitions. It is not recommended in areas prone to abrasion or excessive moisture absorption.

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