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AN INVESTIGATION INTO THE USE OF GROUNDNUT SHELL AS FINE AGGREGATE REPLACEMENT

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Abstract

The suitability of groundnut shell as a constituent material in concrete was investigated by replacing proportions by volume of fine aggregate (river sand) with groundnut shells. Physical properties of cement, groundnut shells and aggregates were determined. Concrete cubes measuring 150x150x150mm were cast. Groundnut shells were used to replace fine aggregate at 0, 5, 15, 25, 50 and 75% replacement levels. The effects of the groundnut shells on the workability of fresh concrete were determined by the slump and compacting factor value tests. Compressive strengths and density values of the concrete cubes were evaluated at 28 days at different percentage replacement levels obtaining a range of values of 34.37, 40.59, 21.33, 17.78, 12.44, 7.56N/mm^2 and 2402.96, 2533.33, 2349.62, 2215.30, 2121.48, and 1854.81Kg/m^3 respectively. Increase in percentage of groundnut shells in the cubes led to a corresponding reduction in densities of the cubes and compressive strength values. At a replacement value of 25% and above, of fine aggregate with groundnut shells; lightweight concrete was produced which could be used where low stress is required. Hence groundnut shells can be used for the production of lightweight concrete.

Keywords: groundnut shell, lightweight, aggregates, concrete, compressive strength

1. Introduction

Concrete is a composite building material that is obtained by a proportional mix of aggregates, water and a binder. This mixture, when cast into forms, demolded and cured, hardens into a rock-like material by a chemical reaction between the binder and water. The flexibility in use of concrete, and its adaptability to environmental conditions make concrete suitable for applications in almost all civil engineering and building structures [1]. Despite these attributes, Concrete still has a characteristics weight which presents problems and complications in construction usually resulting to high cost of construction of underlying sections. The introduction of lightweight concrete has to a large extent solved the attendant problems in concrete constructions. Various lightweight concrete have been formulated through different technical approaches, these are:

I. Inclusion of air voids into the concrete mix.
II. Omission of fine aggregate phase.
III. Replacing the normal natural aggregates with lightweight aggregates.

In the third approach, natural lightweight aggregate such as expanded slag, pumice, scoria, and perlite, industrial, and agricultural wastes have been used. Other wood waste such as splinters and shavings, suitably treated chemically have been used to make non-load bearing concrete with a density of 800 and 1200Kg/m^3 [2]. Apart from being advantageous to construction, the use of these alternative aggregates reduces the over dependence on the conventional aggregates (river sand and crushed rock) which is increasingly becoming expensive, limited and gradually degrading the natural habitat and causing ecological imbalance [3]. Several comprehensive studies during the past years have dealt with the subject of aggregate supplies and needs and the possible use of waste materials as aggregates for concrete. Critical shortage of natural aggregate for concrete is developing in many regions. The needs for better methods of solid waste disposal and probably energy conservation have contributed to the increased interest in this technology [4]. The use of agricultural waste products such as periwinkle shells and quarry dust, groundnut shells etc. as replacement for conventional aggregates could reduce the cost of construction and helps take care

(a) Plate A

(b) Plate B

of energy and disposal problems. Periwinkle shell is a form of lightweight aggregate which can be used as partial replacement material for sand. In some parts of Nigeria, periwinkle shells are used as conglomerate in the production of concrete [5]. Quarry dusts are either lightweight or high density aggregates. Quarry dust material intended for use as fine aggregate should be defined as material less than 4mm size unless it is to be used in asphalt [5].

Groundnut botanically belongs to Araches hypo Gaea Linn of leguminous family. Groundnut is a self pollinated; annual and herbaceous legume crop. A complete seed of groundnut is called pod and contains one to five kermils which develops underground in a needle like structure called peg which grow into the soil and then converts into a pod. Groundnut has taproot system which has many nodules, present in root and lateral roots. These nodules contain Rhizobium bacterial, which are symbiotic in nature and focus atmospheric nitrogen. Outer layer of groundnut is called groundnut shell: The shell constitute about 25-35% of the pod. The seed accounts for the remaining portion (65-75%).

Nigeria is one of the foremost producers of groundnut in the world, producing up to about 2.699 million metric tonnes in 2002 and 1.55 million metric tonnes in 2008. Groundnut shell is found in large quantities as agricultural farm wastes in Northern parts of Nigeria such as Sokoto, Kebbi, Zaria, Borno and Yobe States.

Over the years, groundnut shell constitutes common solid waste especially in the developing part of this world. It's potential as a useful engineering material has not been investigated. The utilization of Groundnut shell will promote waste management at little cost, reduce pollution by these waste and increase the economic base of the farmer when such waste are sold thereby encouraging more production [6].

2. Materials and Methods

2.1. Cement

Locally produced cement manufactured by Dangote Cement Company Plc. and obtained from the open market at Samaru, Zaria was used for the experiment. The cement was subjected to some physical tests in accordance with BS 4550 [7]. The results are shown in Table 2.

2.2. Fine aggregates

Naturally occurring river sand, obtained in Zaria, all passing 4.75mm BS sieve was used in this experiment. The fine aggregate was subjected to particle size distribution test and is as shown in Figure 1. Some physical tests were also performed on fine aggregate sample and the results are displayed in Table 2.

2.3. Coarse aggregate

Crushed stones sourced from a quarry in Samaru, Zaria having a maximum size of 25mm was used for this research. Various physical tests performed on coarse aggregate sample are displayed in Table 2. Figure 1 also shows the particle size distribution of the coarse aggregate.

2.4. Groundnut shells

The groundnut shells were obtained from Zaria city as a waste from a household which uses groundnut for oil making. The shells (shown in Plate A) were sun dried and then ground using rice milling machine to reduce it to sizes conforming to fine aggregates as specified in BS 882 [8] (see Plate B). Some physical tests performed on groundnut shells sample are displayed in Table 1. Figure 1 shows the particle size distribution of the groundnut shells fine.

Table 1: Masses of constituents for groundnut shell replacement for one mix batch.

Groundnut shell replacement (%)	Cement (kg)	Sand (kg)	Gravel (kg)	Groundnut shell (GS) (g)
0%	4.536	9.072	13.608	0.00
5%	4.536	8.616	13.608	76.68
15%	4.536	7.708	13.608	230.01
25%	4.536	6.802	13.608	383.40
50%	4.536	4.535	13.608	766.50
75%	4.536	2.267	13.608	1149.9

Table 2: Properties of the materials.

Material	Properties	Specifications
Cement	Consistency: 0.31 Setting times: Initial setting time = 123 minutes Final setting times = 195 minutes Soundness: 2.5mm	30–35% [7] > 45 minutes [7] < 10 hours [7] < 10mm [7]
Fine aggregate (sand)	Specific gravity: 2.67 Bulk density: 1505.5kg/m3	
Coarse aggregate	Specific gravity: 2.68 Bulk density: 1554kg/m3	
Groundnut shells	Bulk density: 254.55kg/m^3 Absorption: 1.61	
Water	Density: 1000kg/m^3	

2.5. Water

The water used was clean tap water free from any deleterious substances and impurities and was collected from the tap in the Concrete Laboratory of Department of Civil Engineering, Ahmadu Bello University, Zaria. The water is portable; it therefore satisfies the specification requirement for water according to BS 3148 [9].

2.6. Batching, mixing and casting of concrete cubes

Batching by volume approach was adopted in this research work. A mix ratio of 1:2:3 (by weight of cement: fines: coarse) with a water cement ratio of 0.5 and a targeted strength of 30N/mm^2 was used. The percentage replacements of fine aggregate (sand) with groundnut shells were 0, 5, 15, 25, 50 and 75% by volume of the fine aggregate to determine the effects of different proportions of the groundnut shell on some properties of concrete. Table 1 presents the calculated masses of constituent materials for all mixes. The 0% replacement served as control for other mixes. Workability tests using the slump and compacting factor was carried out. Concrete cubes were cast using steel moulds of sizes 150mm × 150mm × 150mm. The moulds were assembled and lubricated prior to casting for easy removal of cubes; machine vibration was used during the casting. The concrete cubes were demolded 24 hours after casting and were cured for 28 days in water at room temperature. The cubes were surface dried and weighted to obtain their densities prior to testing and the compressive strength of the cubes was obtained by crushing with the universal testing machine located in the Concrete Laboratory, Department of Civil Engineering, Ahmadu Bello University, Zaria.

3. Results and Discussion

The results obtained from physical tests carried out on the materials used are given in Table 2. The consistency obtained was 31%, this value falls within the range of 30–35% for ordinary Portland cement as specified by [10,2]. Initial and final setting times as prescribed in BS 12 [10] for ordinary Portland cement is taken as greater than 45mins and less than 10hrs respectively. The values of 123 and 195 minutes obtained fall within the specified limits for ordinary Portland cement, therefore the setting times conform to standard. The soundness value obtained (2.5mm) falls within the specification of soundness value for ordinary Portland cement of not greater than 10mm as specified in BS 12 [10]. Based on the results obtained on the cement sample, implies that the cement used is an ordinary Portland cement.

Kosmatka et al [11] specifies that the bulk density of aggregates commonly used in normal concrete ranges from about 1200 to 1750Kg/m^3. The values obtained

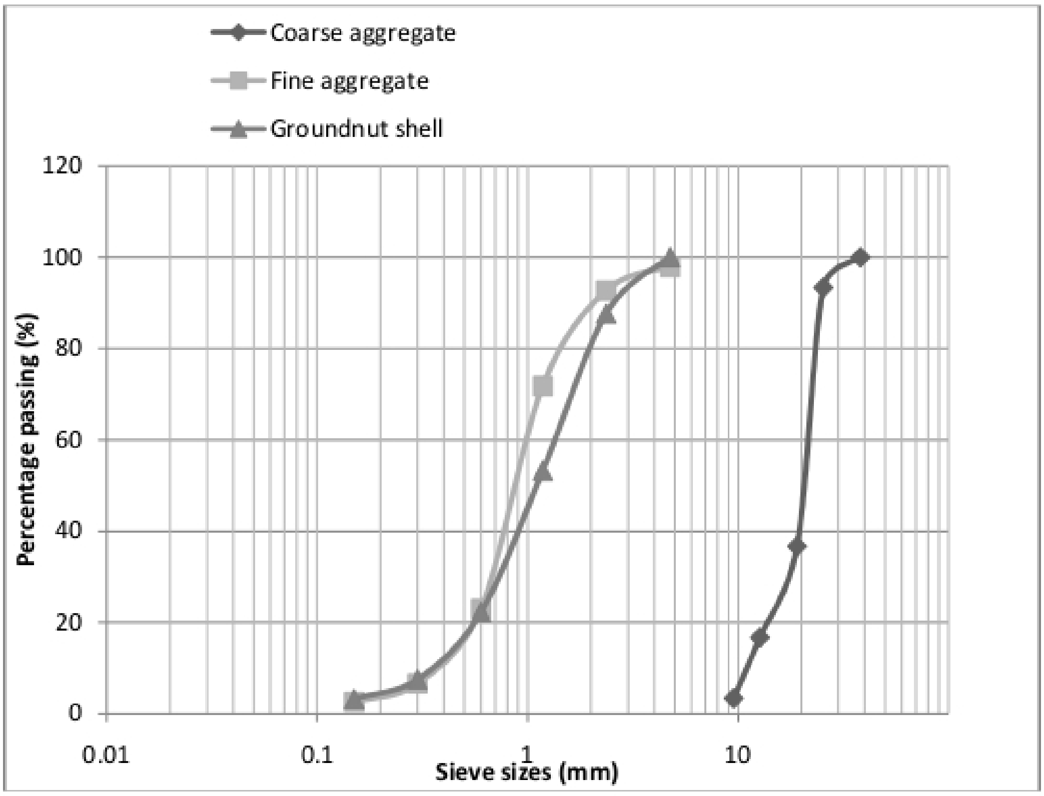

Figure 1: Particle size distribution curve for aggregates and groundnut shells fines.

for both fine and coarse aggregates falls within the limits as specified by Kosmatka et al, [11]. The bulk density of groundnut shell is lower than the accepted values for lightweight aggregates of 750–1100kg/m^3 as specified by Jackson and Dhir [12]. The majority of natural aggregates have specific gravity between 2.5 and 3.0 as specified by Jackson and Dhir [12]. The specific gravities of 2.67 for fine aggregate and 2.68 for coarse aggregates obtained in this research work falls within the specified standard stated by Jackson and Dhir [12]. The aggregates therefore satisfy the requirement for use in concrete making.

Table 2 also shows the result of absorption test for the groundnut shells. The water absorption was found to be 1.61%. This value is lower than the maximum of 2.5% as specified by ASTM C128 [13] which make the groundnut shell suitable for use as fine aggregate under normal construction conditions.

Figure 1 show the grading of aggregates and groundnut shells fine used in this study. The grading of an aggregate defines the proportion of particles of different size in the aggregate bulk. The size of aggregate particles normally used in the concrete usually varies from 37.5mm to 0.15mm. BS 882 [8] specifies that the majority of fine aggregates should be smaller than 4.76mm while coarse aggregates should be greater than 5mm. 97.9% of fine aggregates passed the 4.76mm sieve, 100% of ground groundnut shells passed the 4.76mm sieve, 100% of coarse aggregates passed 38.10mm sieve and were retained in the 4.76mm sieve. Hence the aggregates have satisfied the above BS 882 [8] specification.

3.1. Workability

The workability of concrete mixes for different percentages of groundnut shells using slump and compacting factor tests are presented in Table 3. The slump test results show that the control concrete mix indicates a medium slump value of between 50–100mm [14]. But as the percentage of groundnut shell increases, the slump value decreases to very low workability 0–25mm [14]. This may be due to the high absorption capacity developed as a result of increase in groundnut shell. Low workability concrete can be used in road construction and light weight concrete. The compacting factor test results also follow the trend of low to very low workability 0.85–0.78 [14] as the groundnut shell was increased. The use of groundnut shell in concrete reduces the concrete's workability due to the absorption of part of the mixing water by the groundnut shell. More water is needed to maintain normal workability as groundnut shell is used in concrete or alternatively the groundnut shell should be soaked in water prior to mixing to reduce its tendency of absorbing and reducing the water/cement ratio.

Figure 2: **Pls supply figure 2!!!!!**

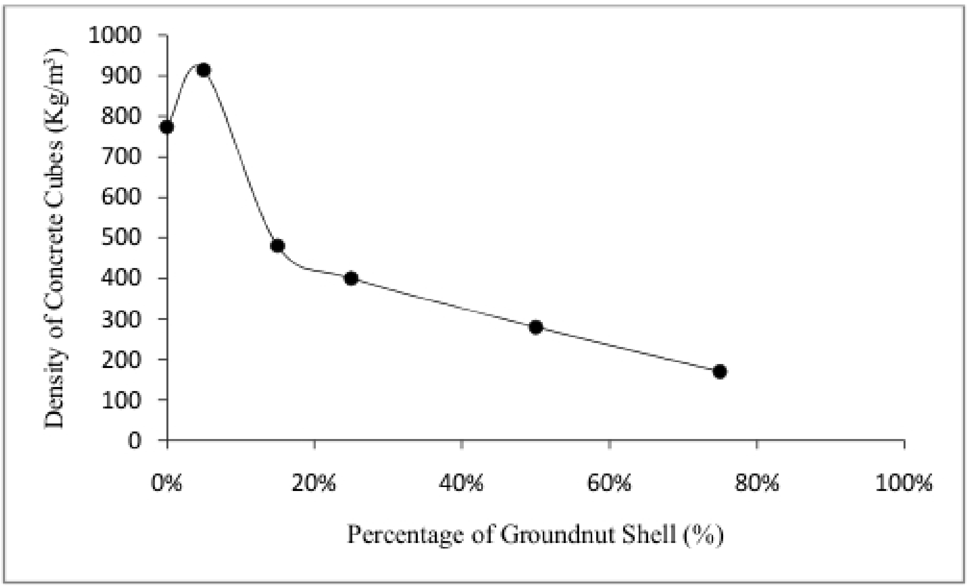

Figure 3: Variation of cubes density with groundnut shell percentage.

Table 3: Properties of fresh concrete batches using compacting factor and slump tests.

Groundnut shell replacement (%)	Compacting factor	Slump value (mm)
0	0.88	52.0
5	0.89	34.0
15	0.88	20.0
25	0.82	15.0
50	0.78	5.0
75	0.75	5.0

Table 4: Density and compressive strength of concrete cubes.

Samples	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)
0%	2402.96	773.33	34.37
5%	2533.33	913.33	40.59
15%	2349.62	480.00	21.33
25%	2215.30	400.00	17.78
50%	2121.48	280.00	12.44
75%	1854.81	170.00	7.56

3.2. Density

Before the compressive strength test was carried out, the weights of the concrete specimens were taken to assess the density of the concrete cubes. Figure 3 shows the decrease in densities of the concrete cubes as the replacement of groundnut shell increases. But at 5% replacement there was an increase in the density which might be due to the fact that at that percentage replacement the weight increased due to the absorption of mixing water by the groundnut shell thereby reducing the water/cement ratio and making the mixture denser thus leading to a specimen of high density. Although there was serious decrease in density as the replacement level is increased but all still satisfy density requirement for lightweight concrete according to BS EN 206–1 [15].

3.3. Compressive strength

From the values obtained for the strength of the concrete specimens and as shown in Figure 4, it can be seen that the strength of concrete decreases with an increase in groundnut shell percentage. It was observed that during soaking the concrete cubes containing more groundnut shell i.e. 50 and 75% replacements may have absorbed more water which led to low workability of the concrete mixtures and this contributed to the low compressive strength at these replacement levels. Also, the low density of the groundnut shell as compared to that of the fine aggregate it was used to replace may also have contributed to the low strength of the concrete. Although, the concrete cubes containing groundnut shell exhibited compressive strength values for light weight concrete according to BS EN 206-1 [15].

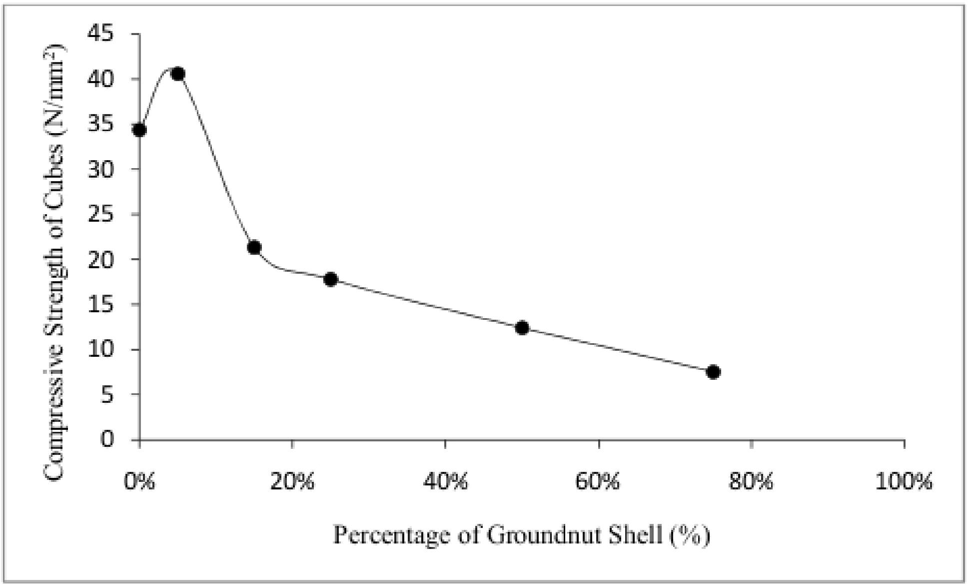

Figure 4: Variation of compressive strength with percentage of groundnut shells.

4. Conclusions and Recommendations

- Based on the physical tests carried out on the cement sample, Dangote cement used in this study is an ordinary Portland cement.
- The aggregates satisfy the requirements for use in concrete based on their grading, bulk densities and specific gravities which conform to standards.
- Based on the rate of absorption and particle size distribution of the groundnut shells, groundnut shells are suitable for use as fine aggregate replacement.
- It can also be concluded that the use of groundnut shell in concrete reduces the concretes workability due to the high absorption of water by the groundnut shell.
- The densities and compressive strength of concrete decreased with an increase in groundnut shell; it is therefore possible to replace sand with groundnut shell in the production of light weight concrete.
- Concrete containing groundnut shell could be used in non-load bearing panels where structural strength is not of importance. It can be used as; non load bearing partition walls, floor panels, noise barriers etc.

Based on the above the following recommendations are made:

- Pre-wetting of the groundnut shell could enhance workability of the concrete and ease of mixing.
- The concrete should not be used in areas exposed to water and water logging since moisture affects the weight and strength.

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