OPTIMIZATION OF PARTIAL REPLACEMENT OF CONCRETE COARSE AGGREGATE WITH CRUSHED *CANARIUM SCHWEINFURTHII* (ATILI) SEED SHELL

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Abstract
Environmental concerns arising from the exploitation of conventional coarse aggregates (mainly crushed rocks) and the need to provide more sustainable alternatives; the need to manage and utilize agricultural wastes having suitable properties one of which is canarium schweinfurthii (atili) seed have led to many research efforts aimed at addressing such concerns and issues. This research work assessed the use of atili seed shell (CASS) as partial replacement of conventional coarse aggregates with the aim of studying the physical properties of CASS; studying the effect(s) of the partial replacements on some selected properties of concrete and determining the optimum replacement. Selected construction properties of the aggregates used were determined and compared. Seven mixes were prepared using design mix ratio of 1:2:4 and water cement ratio of 0.55. The seven mixes were produced with different percentages of crushed granite to CASS as coarse aggregate in the order 100:0, 85:15, 80:20, 75:25, 50:50, 25:75 and 0:100 and were used to produce 100x100x100 mm concrete cubes and 100x100x500 mm beams which were then immersed in ordinary water for maximum of 28 days after demoulding. The findings of this study show that the use of crushed atili seed shell as partial replacement for conventional aggregate had considerable effect on the density, compressive strength and flexural strength of concrete. A reduction in the density of concrete was recorded with each percentage increase of replacement of the conventional aggregate with crushed atili seed shell thus following a similar pattern with the compressive and flexural strengths. Concrete beams containing 0%, 15%, 20%, 25%, 50%, 75% and 100% after 28 days of hydration recorded average densities of 2433, 2367, 2333, 2283, 2073, 2050, 1900 kg/m3 respectively. The compressive strength of concrete containing 15%, 20%, 25%, 50%, 75% and 100% crushed atili seed shell (CASS) as partial/full replacement and cured over a period of 28days showed no decline. The compressive strength test and flexural strength test carried out on the concrete specimens showed that the concrete containing 15% CASS produced the optimal compressive and flexural strengths of 18.16N/mm2 and 2.47N/mm2 respectively. This compressive strength meets the minimum requirement of 17N/mm2 for residential concrete as stated by NRMCA (2003).

***Key words**: Optimization, Partial, Replacement, Canarium Schweinfurthii, Shell*

INTRODUCTION

According to Li (2011), Concrete is a manmade building material that looks like stone. The word “concrete” is derived from the Latin concretus, meaning “to grow together.” Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. Alternatively, we can say that concrete is a composite material that consists essentially of a binding medium in which are embedded particles or fragments of aggregates. The simplest definition of concrete can be written as concrete = filler + binder. Li (2011) also noted concrete as being: economical; an ambient temperature-hardened material; energy efficient, as well as having: the ability to be cast; excellent resistance to water; high-temperature resistance; the ability to consume waste; the ability to work with reinforcing steel; less maintenance required. These advantages/characteristics and others have made concrete to be the most widely used construction material as noted by Neville and Brooks (2002) and as a result, efforts have been made by researchers towards the reduction of its production cost. These research efforts are crucial to the drive towards provision of affordable housing for low income earners especially in developing countries due to the relatively high cost of conventional construction materials mainly concrete and steel (largely due to energy and importation costs). These efforts have also promoted the utilization of industrial and agricultural

wastes in the production of concrete owing to its ability to consume wastes; this in turn will assist in the management of wastes and the conservation of energy and natural resources.
According to Adefemi , Nensok , Ka'ase and Wuna (2013), the reduction of concrete production cost is achieved by reducing the cost of coarse aggregate and cement since concrete 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 these constituents. Fine aggregates (mainly sand) are readily available. Dashan and Kamang (1999) observed that the cost of cement can be reduced through the use of agro-industrial waste or pozzolanas. Adefemi et al (2013) observed that the cost of concrete is directly proportional to the cost of crushed stones or local gravels thus, alternatives lightweight materials are adopted for non-load bearing walls and non-structural floors in buildings. Some of these alternative materials include Palm Kernel Shell, Olive Seed and Periwinkle Shell which can be used to fully or partially to replace coarse aggregate in concrete production. Research efforts made in this direction include among others: investigation of the suitability of Palm Kernel shells as aggregates in light and dense concrete for structural and non-structural purposes by Falade (1992), assessment of the performance of palm kernel shells as partial replacement of coarse aggregate in asphalt concrete by Ndoke (2006), while Olanipekun et al (2006) carried out a comparative study of concrete properties using coconut shell and palm kernel shells as coarse aggregates, exploratory study of date seed as partial replacement for coarse aggregate in concrete production carried by Adefemi et al (2006) which showed significant compressive strength increase in concrete with 75%, 50% and 25% date seed content when compared to that with 100% date seed content, Datok and Kamang (1998) studied the Strength and Elastic Properties of a Composite Olive Seed/Crush Aggregate Concrete which showed that 1:1:2 concrete having 30% uncrushed olive seed content with water-cement ratio of 0.5 had a 28-day compressive strength of 10.95 N/mm2. Ibrahim (2001) studied the use of crushed olive seed shell as full replacement for coarse aggregate in concrete and observed that at full replacement there was a 9% increase in the 28-day compressive strength of the concrete with crushed olive seed in comparison to the concrete with uncrushed olive seed. Other similar efforts in the direction of waste management strategies include structural performance of concrete using Oil Palm Shell (OPS) as lightweight aggregate (Nimityongskul and Daladar, 1995), Topcu and Canbaz (2007), investigated the use of Crushed Tiles as Aggregate in concrete production while Sekar, Ganesan and Nampoothiri (2011) carried out similar work to that of Topcus and Canbaz on the Strength Characteristics on Utilization Of Waste Materials As Coarse Aggregate In Concrete using broken tiles and broken glass pieces as coarse aggregate which showed that the concrete made of waste ceramic tile aggregate produced similar strength in compression as conventional concrete while the compressive strength of concrete cubes made with ceramic insulator and glass concrete were found to be 16% and 26.34 % lesser respectively than that of conventional concrete . In the light of the aforementioned research efforts towards the utilization of industrial and agricultural wastes in concrete production for more cost effective housing delivery; energy and natural resource conservation, this research seeks to examine the optimization of crushed canariun schweifurthi (atili) seed as a partial replacement for coarse aggregate in concrete.
"Atili" (Canarium schweinfurthii bursaraceae) is the fruit of the perennial tree plant also called "atili" tree. In Nigeria, the fruit is called 'ube okpoko' in Ibo and "atili" in Hausa. The fruit is commonly found in large quantity in Pankshin, Plateau State of Nigeria and is also produced in similar quantities in other states of the northern and south-eastern Nigeria.
The plant produces its fruits in the rainy season (usually) between the months of April and September. The flowers grow in clusters at the end of the twigs and are small and dark green in colour. The fruits which are of two varieties-long spirals and short round in shape develop from the flowers. The fruits contain single triangular-shaped seed with small projections at the three edges. The seeds are embedded in a purplish green pulp with a desirable sweet but not too sugary taste similar to that of avocado pear. The pulp is of oily consistency and edible. The weight of the fruits ranges from 3.5 to 9 g with a predominant average weight of about 5.3 g. The fruit is very hard; the seed is cooked and yields oil, sometimes used as a substitute for shear butter (Agu, Ukonze and Uchola, 2008).

MATERIALS AND METHODS

MATERIALS

Cement

Cement is a binder, a substance that sets and hardens and can bind other materials together.
ASTM C 150 defines portland cementas a hydraulic cement produced by pulverizing clinkers consisting essentially of hydraulic calcium silicates, and a small amount of one or more forms of calcium sulfate as an interground addition. Clinkers are 5- to 25-mm-diameter nodules of a sintered material that is produced when a raw mixture of predetermined composition is heated to high temperatures (Mehta & Monteiro, 2006).
Ordinary Portland Cement (OPC) Dangote brand of grade 42.5, manufactured by Dangote Cement factory, which conforms to Type 1 cement as specified by BS 12 (1978), was used for this research.

Fine Aggregate

The fine aggregate used in this research is river sand sourced from within Jos. It was made to pass through a sieve size of 4.75mm. The fine aggregate also used had a fineness modulus (FM) of 1.61, a specific gravity of 2.62, a bulk density of 1510kg/m3 and a percentage of voids of 5.3%.

Coarse Aggregate (Crushed Granite)

Coarse aggregate used in this research is crushed gravel, with a nominal size of 12.7mm. The specific gravity of the gravel was determined to be 2.56, and the bulk density was determined to be 1449kg/m3 and having a percentage of voids of 7.8%.
The coarse aggregate (gravel) particles were passed through a series of standard sieve sizes starting with a 20mm sieve.

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Coarse Aggregate (CASS)

The atili seeds employed in this study was obtained in sufficient quantities from Pankshin Town, Plateau State, where they were stockpiled, sun-dried and washed by rain. They were hand-crushed using rocks and sieved to remove unwanted materials. The crushed atili seed shell was passed through sieve no 4 (4.75µm size) to remove the crushed seed shells that do not fall under the coarse aggregate zone.

Water

Portable water fit for drinking was used for this research work.

METHODS

Sieve analysis, Aggregate impact tests, Specific gravity tests, Bulk density and Void ratio tests were carried out on the aggregates to help in their classification. The workability of concrete produced with crushed Atili seeds was determined using slump test. A concrete mix of ratio 1:2:4-12.7 (Cement: Fine Aggregate: Coarse Aggregate) was adopted for the production of 100 x100 x 100 concrete cubes and 100 x100 x 500 concrete beams using a water-cement ratio of 0.55. Seven mixes were produced containing 0%, 15%, 20%, 25%, 50%, 75% and 100% of CASS replacement of the coarse aggregate (gravel).

Batching by absolute volume was adopted and a total of 63 cubes and 21 beams were cast, and subsequently cured in water for 7days, 21days and 28days.

MIX DESIGN

Absolute Volumes

Table 1: Bulk Densities, Specific Gravities and Total Absolute Volumes Of Batches

Bulk Density of Materials	
Cement	1440kg/m^3 (obtained from literature)
Fine Aggregate (sand)	1510kg/m^3
Coarse Aggregate (gravel)	1449kg/m^3
Coarse Aggregate (CASS)	635kg/m^3
Specific Gravity of Materials	
Cement	3.15 (obtained from literature)
Fine Aggregate (sand)	2.62
Coarse Aggregate (gravel)	2.56
Coarse Aggregate (CASS)	1.30
Total Absolute Volumes	

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Batch Containing 0% CASS	4.603m^3
Batch Containing 15% CASS	4.619m^3
Batch Containing 20% CASS	4.604 m^3
Batch Containing 25% CASS	4.588 m^3
Batch Containing 50% CASS	4.506 m^3
Batch Containing 75% CASS	4.433m^3
Batch Containing 100% CASS	4.357m^3

Table 2: Quantities of Materials Required Per M^3 of Concrete

Replacement Level	**Cement**	**Sand**	**Gravel**	**CASS**
0% (Control)	313kg	656kg	1259kg	-
15%	313kg	656kg	1067kg	82kg
20%	313kg	656kg	1007kg	110kg
25%	314kg	658kg	947kg	138kg
50%	320kg	670kg	643kg	282kg
75%	325kg	681kg	314kg	430kg
100%	331kg	693kg	-	583kg

PRESENTATION AND DISCUSSION OF RESULTS

PHYSICAL/MECHANICAL PROPERTIES OF CASS

Table 3: Physical/Mechanical Properties of CASS

Physical properties	**CASS**

Specific Gravity	1.30
Moisture Content	10.09%
Moisture absorption	20.61%
Bulk Density (compacted)	635kg/m^3
Bulk Density (loose)	578kg/m^3
AIV	43.5%

WORKABILITY
Table 4: Workability (Slump)

Workability (Slump)	
Percentage Replacement (%)	**Slump (mm)**
0	62
15	35
20	27
25	25
50	23
75	16
100	10

There was reduction in the workability of the concrete mixes as the percentage of the CASS content increased. This is attributable to the nature of CASS being a lightweight aggregate. CASS being more porous and having a greater absorption capacity will absorb more of the mixing water than the gravel. The implication of this is that the mix containing more CASS will have a lower workability as observed from the slump. Table 4 above gives the slump values for the various mixes.

CONCRETE TESTS
CUBE TESTS

Density of Cubes

The results obtained from the density test for cubes, shows that there was a decrease in the density of the concrete cubes with every increase in the percentage replacement of the gravel with CASS as coarse aggregate at all ages. This falls in line with the observation by Owens and Newman (2003) that the density of concrete can be reduced by replacing dense natural aggregates either wholly or partially with lightweight aggregates. The variation of cube densities with the percentage of replacement is given in figure 1.

From the results obtained, only the concrete containing 100% CASS can be considered as lightweight concrete in terms of density. Lightweight concrete is defined by Clark (1993) as having an air dry density not exceeding 2000kg/m^3 but can be as low as 400kg/m^3, depending on the material used compressive strength can vary between 1 and 65N/mm$^{2.}$ The concrete samples containing 0%, 15%, 20%, 25%, 50% and 75% having densities between 1900-2600kg/m^3 fall within the category of normal weight concrete.

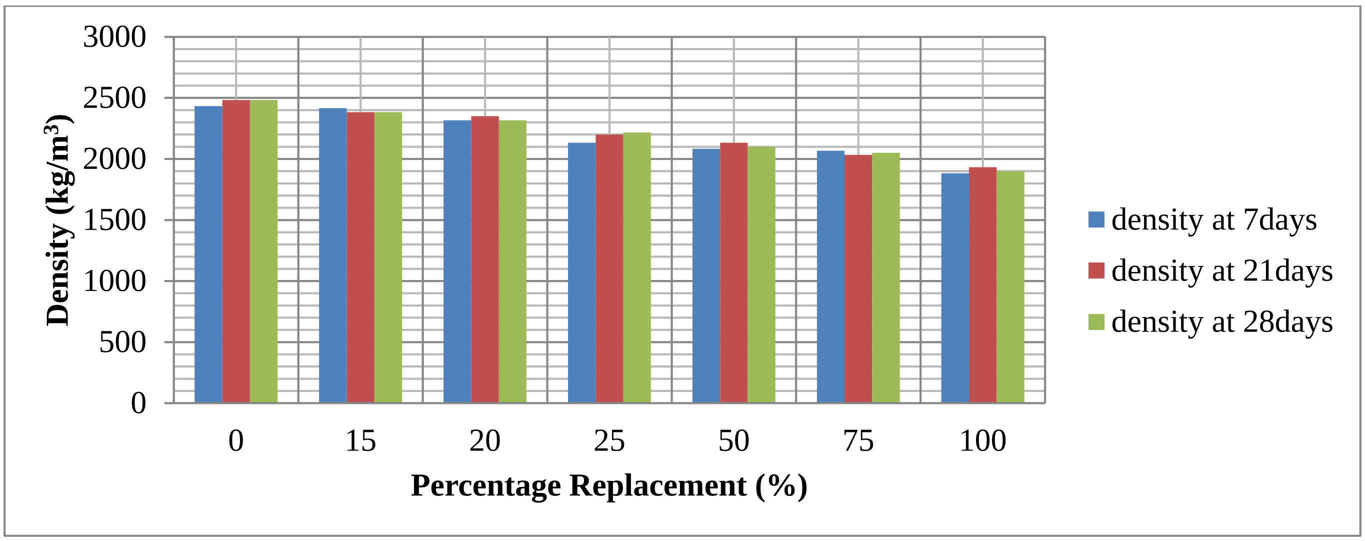

Figure 1: Chart Showing the Variation of Density of with Percentage Replacement after 7, 21 and 28days Hydration

Compressive Strength

The compressive strength development after hydration period of 7, 21, and 28days for concrete cubes containing 0%, 15%, 20%, 25%, 50%, 75%, 100% CASS are given in table 16. The results show an increase in the average compressive strength with hydration period/age in all cases, however, the rate of strength gain was greater and more consistent in the concrete containing 0% CASS than in the other cases. The results also show a decrease in the average compressive strength as the percentage replacement increases; this also implies a decrease in the average compressive strength as the average density decreases in all cases. This compares positively with the observation of Hanson (1964) who conducted some experiments where the expanded fines of 1ightweight concrete were replaced by an equal ‘volume of river sand. The total amount of cement was varied to give a strength range of 3 to 6 kips per square inch. It was found that, in general, the structural properties were improved, but this improvement was achieved only with a considerable increase in unit weight.

The strengths recorded after 7day hydration period showed that in all the cases a high early strength was development. It is 57% in the concrete containing 0% CASS (control) and ranged from57.1% to 87% in concrete containing CASS.

The optimal 28day compressive strength of 18.16N/mm2 was recorded from the concrete containing 15% CASS as this meets the minimum compressive strength requirement for residential concrete of 17N/mm2. NRMCA (2003) noted that compressive strength requirements can vary from 17Mpa (17N/mm2) for residential concrete to 28Mpa (28N/mm2) and higher in commercial structures. Figure 2 gives a chart showing the variation of the compressive strength with the percentage of replacement while figure 3 is a chart showing the variation of compressive strength with density.

The concrete samples containing 50, 75 and 100% CASS showed greater disintegration at failure than the samples containing 0, 15, 20, and 25% CASS. The difference in the mode of failure is attributable to the surface texture of crushed Canarium Schweinfurthii (atili) seed shell which is smoother than that of the crushed granite and will therefore produce a weaker bond with the cement paste.

The failure of the concrete samples containing high percentage of CASS was observed to be largely as a result of the breakdown of bond between CASS and the cement paste.

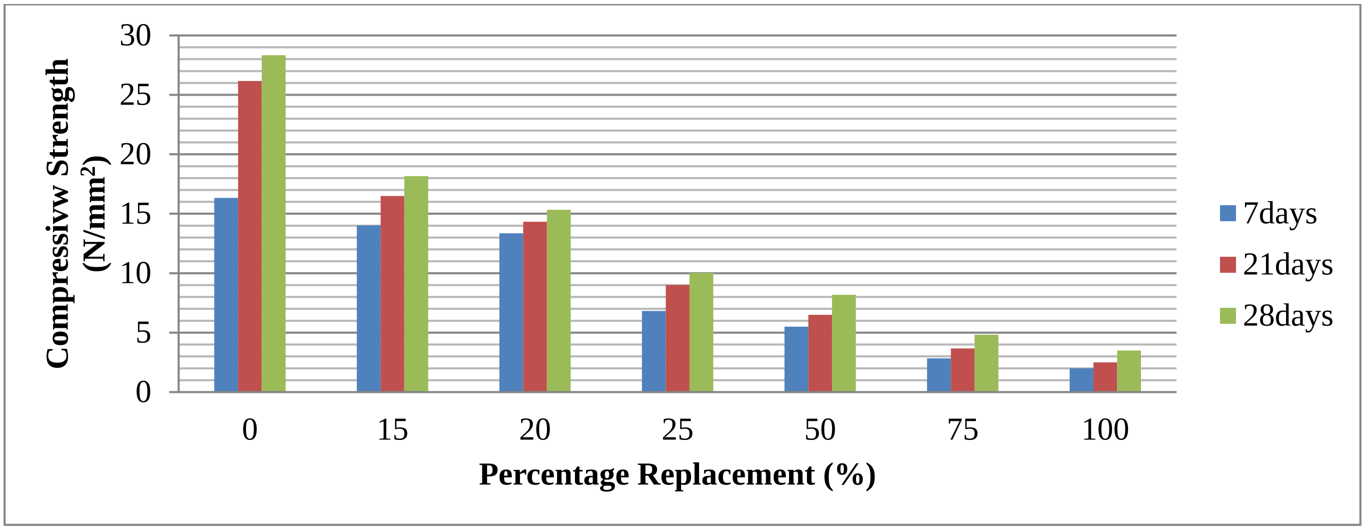

Figure 2: Chart Showing the Variation of Compressive Strength with the Percentage of Replacement

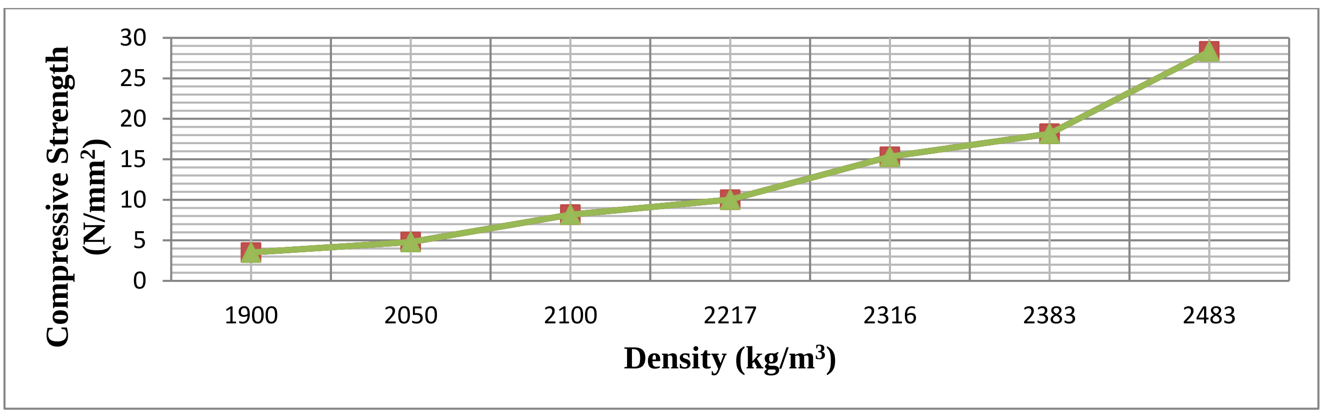

Figure 3: Chart Showing the Variation of Compressive Strength with Density after 28days Hydration

BEAM TESTS

Density of Beams

Table 15: Average Density of Beams

Hydration Days	Density of Beams (kg/m^3) Replacement Level (%)			
	0	**15**	**20**	**25**
28	2433	2367	2333	2283

	Density of Beams (kg/m^3)		
Hydration Days	**Replacement Level (%)**		
	50	**75**	**100**
28	2073	2050	1900

The densities of the concrete beams followed the same pattern as those of the concrete cubes. The results obtained from the density test for beams also shows that there was a decrease in the density of the concrete cubes with every increase in the percentage replacement of the gravel with CASS as coarse aggregate at all ages. The densities were determined to be: 2433, 2367, 2333, 2283, 2073, 2050 and 1900 kg/m^3 for concrete beams containing 0, 15, 20, 25, 50, 75, 100% CASS. This also falls in line with the observation by Owens and Newman (2003) that the density of concrete can be reduced by replacing dense natural aggregates either wholly or partially with lightweight aggregates. The average densities of beams are given in table 5 above.

Flexural Strength

Table 6: Average Flexural Strength of Beams

	Flexural Strength (N/mm^2)			
Hydration Days	**Replacement Level (%)**			
	0	**15**	**20**	**25**
28	5.24	2.47	2.18	1.33

The flexural strength development after hydration period of and 28days for concrete beams containing 0%, 15%, 20%, 25%, given in table. The flexural strengths of beams containing 50%, 75% and 100 CASS were quite low and no reading was recorded by the testing machine. The results show a similar pattern as that of the compressive strength. There was a decrease in the flexural strength as the percentage replacement increased; this also implies a decrease in the flexural strength as the density decreases in all cases. This also compares favourably with the observation of Hanson (1964) who conducted some experiments where the expanded fines of 1ightweight concrete were replaced by an equal ‘volume of river sand. The total amount of cement was varied to give a strength range of 3 to 6 kips per square inch. It was found that, in general, the structural properties were improved, but this improvement was achieved only with a considerable increase in unit weight.
The optimal 28-day flexural strength of 2.47N/mm2 was recorded from the concrete containing 15% CASS. This value is 13.6% of the average compressive strength of 18.16N/mm2 for the concrete containing 15% CASS. This is in line with the observation that the flexural strength of concrete is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used (www.aboutcivil.org). Table 18 gives the flexural strength of beams after 28days hydration.

CONCLUSION

Crushed canarium schweinfurthii (atili) seed shell having a specific gravity of 1.31: loose bulk density of 578kg/m3 and compacted bulk density of 635kg/m3; moisture content of10.09% and water absorption20.61% capacity of is a lightweight aggregate. Although crushed canarium schweinfurthii (atili) seed shell is a lightweight aggregate, only the concrete containing 100% CASS can be considered as a lightweight concrete having an air dry density not exceeding 2000kg/m3 and not lower than 400kg/m3 as defined by Clark (1993). The findings of this study show that the use of crushed atili seed shell as partial replacement for conventional aggregate had considerable effect on the density, compressive strength and flexural strength of concrete.
The compressive strength of concrete containing 15%, 20%, 25%, 50%, 75% and 100% crushed atili seed shell (CASS) as partial/full replacement and cured over a period of 28days showed no decline. After 28 days of hydration, the concrete containing 15% crushed atili seed shell recorded the optimal compressive strength of 18.16N/mm2 and and flexural strength of 2.47 N/mm2. This finding shows that it can be used for residential construction because it meets the minimum compressive strength requirement of 17N/mm2 for residential concrete as stated by NRMCA (2003).

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