Direct Research Journal of Public Health and Environmental Technology
Vol. 6, Pp. 52-61, 2021
ISSN: 2734-2182
https://doi.org/10.26765/DRJPHET86135240957
Article Number: DRJPHET86135240957

https://directresearchpublisher.org/drjphet

Full Length Research Paper

Effect of partial replacement of sand with African Elemi (canarium schweinfurthii) in concrete

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Received 16 May 2021; Accepted 25 June, 2021; Published 30 June 2021

ABSTRACT: The safe disposal of waste materials generated on a daily basis by agricultural, industrial, and other similar activities is becoming a major concern in developing countries, including Nigeria. This is a major concern, particularly in terms of health and environmental management. African Elemi seed is one of these materials that are generated and dumped as waste in our environment on a daily basis after utilizing the pulp, and they are not easily decomposed there, making the environment look untidy, especially in areas where this fruit is abundantly available due to a lack of proper waste management techniques. As a result, the importance of proper waste disposal cannot be overstated. As a result, using African elemi as a partial replacement of sand in concrete eliminates waste. This study looked at the physical and oxide composition of African Elemi seed, as well as how it affects the strength development, density, flexural strength, compressive strength, and water absorption of concrete when used in part to replace sand at1,2,3,4,7,14,21,28 and 56days curing at 0%,5%, 10%, 15%, 20%,25%,30%,35% and 40%using 1:1.5:3 mix design at 0.55 w/c ratio. A total of 216 cube specimens of 100mm x 100mm x 100mm were prepared and cured of which crushing test was carried out appropriately. Also,24 beam specimens of 100mm x 100mm x 500mm were prepared and a flexural strength test was carried out after 28 days of curing. The results of this study show that African Eleme seed has a significant effect on the compressive strength, tensile strength, density, and water absorption of concrete. For example, a reduction in density, compressive and flexural strengths were recorded for each increase in A. E. % in the concrete. Optimum compressive and flexural strengths were recorded at 10% replacement of sand with A. E. in the concrete at 56 days the age of curing and were found to be 21.3N/mm^2 and 2.63N/mm^2. These results show that A. E. can be used in non-structural concrete because it met the M15 design strength. Finally, at 10% and 40% replacement levels, the highest and lowest slump values were 40mm and 14mm, respectively, indicating that the workability of concrete decreases as the A. E. percentage in the concrete increases.

Keywords: African Elemi, concrete, compressive and flexural strengths, optimum mix

INTRODUCTION

Concrete is the most widely used material for construction of buildings and other civil engineering structures all over the world. It is obtained by mixing cement, water, aggregates and sometimes admixtures; in the required proportions (Srinivasa *et al*., 2018). Concrete is a composite material that consists essentially of a binding medium in which are embedded particles or fragments of aggregates (Yohanna *et al*., 2019). It can be made to satisfy a wide range of performance specifications, unlike other building materials, such as natural stone or steel, which generally have to be used alone (McGraw-Hill Dictionary of Scientific & Technical Terms, 2003). For most purpose, crushed stones or sand of size less than 4.76mm in diameter are used as fine aggregate in concrete while those with sizes ranging from 19 to 25mm (3/4 or inch) are used as coarse aggregate, but could be as large as 40mm when used in mass concrete (Thomas *et al*., 2019). Li (2011) defined concrete as a material with the following characteristics: economical; an ambient temperature-hardened material; energy efficient, as well as having: the ability to be cast; the ability to work with reinforcing steel; less maintenance required etc. These advantages/characteristics and others have made concrete to be most widely used construction material as noted by Neville and Brooks (2002). These have created an opportunity for the use of agro-waste, industrial waste and related materials as partial replacement of either sand or coarse aggregate in concrete which called for more research on all aggregates replacing materials as this can give more certainty on their utilization in concrete (Jnyamendra *et al*., 2016). One of these materials is African Elemi seed shell.

African Elemi (Canarium Schiweinfurthii bursaraceae) also called 'Atili' in Hausa and 'Ube Okpoko' in Ibo as reported by Yohanna *et al*. (2019) is a fruit of the perennial tree plant which is commonly found in large quantity in Pankshin, Mangu, Jos-south and other local governments areas of Plateau state. It is also produced in similar quantities in other states of the northern and south-eastern Nigeria. The fruit has widespread Geographical distribution throughout Africa as it can be found in Nigeria, Cameroun, Angola and other 12 African countries (Orwa *et al*., 2009). African Elemi plant normally produces its fruits in the rainy season (usually) between April and September. The fruits which are of two varieties-long spirals and short round in shape develop from the flowers. The seeds are embedded in a purplish green pulp (mesocarp) with a desirable sweet but not too sugary taste similar to that of avocado pear. The pulp has oil and is edible. It is the measure source of oleoresin that is used in food, medicine and has a wide range of industrial applications.

The fruits contain single strong oblong-shaped seed (very hard to be broken with hand) which could make it suitable to be used for partial replacement of aggregate in concrete with small projections at the three edges. The average weight of A. E. seed is 5.3g which could also make it a potential material for light weight concrete production. And its average length and thickness are 10-20mm and 5-10mm respectively.). Some of these researches aimed at investigating the strength and durability of concrete with these waste materials while others focused on making the concrete either lighter, more workable, self-compacting etc. without undermining its strength and durability. The overall aim could be: to make the concrete more economical for affordable housing or to solve the problems associated with conservation of natural resources and waste disposal.

From the economic point of view, Adaba *et al.* (2012) reported that reduction of concrete production cost is achieved by reducing the cost of aggregates 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. Also, as way of keeping the environment healthy, some of these wastes have been used by so many researchers and were found to be useful when used in concrete production. Olanipekun *et al*., (2006) conducted a comparative study of concrete properties with coconut and palm kernel. The Strength and Elastic Properties of a Composite Olive Seed/Crushed Aggregate in concrete by Datok and Kamang (1998) which revealed 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/mm^2 (Yohanna et al., 2019). This calls for the need to shift researches towards the use of these locally available waste materials such A. E. seed with the view of solving problems associated with waste disposal/management among others. The seed of African Elemi is an agro-waste. It is a hard mass (which cannot be easily broken with hand) consisting of shell and germ (Agu et al., 2008). The length of African Elemi seed varies between 10-20mm. Its thickness is 5-10mm and its shape is oblong (Maduelosi, 2015). African Elemi seed have shown to have considerable effect on density, compressive strength, and flexural strength when used as partial replacement of coarse aggregate in concrete (Plate 1).

Plate 1: African Elemi Fruit/Seed.

Review of related studies

Some researches carried out on some selected seeds that are considered as waste materials in other to solve the problem of waste disposal are highlighted and the research gaps required to be filled by this research work are pinpointed. These includes: studies on properties of concrete with oil palm shell, palm kernel shell, date seed etc. For example Nimityongskul *et al*. (1995) investigated the structural performance of concrete using palm oil shell (OPS) as light weight aggregate. Other research efforts made by using some selected seeds as partial replacement of aggregate in concrete include; Ibrahim (2001); Yohanna *et al*. (2019) on olive seed shell as full replacement of coarse aggregate in concrete and which he reported that at 100% replacement level, there was 9% increase in the compressive strength of concrete when compared with the concrete with full replacement of coarse aggregate with uncrushed olive seed.

This indicates that concrete with crushed material may have higher compressive strength value and this is the reason why we intend to use African Elemi seed to replace fine aggregate in concrete.

MATERIALS AND METHODS

In other to determine the suitability of all the materials used in this research, the materials were tested in accordance with the various British Standard code specifications. These include: Ordinary Portland cement, Fine Aggregates (Sand and African Elemi seed), Coarse Aggregate (Granite) and Water.

Ordinary Portland cement (OPC)

For the purpose of this research work, the cement used was Ordinary Portland Cement (Dangote brand), grade 42.5, Type 1. It was sourced locally from the Samaru market, Zaria. It was kept in a dry place and later subjected to various physical tests in accordance with BS EN 197-1:2000. These include; specific gravity, consistency, soundness, initial and final setting time and fineness test.

Specific gravity test

Specific gravity test was conducted according to BS 1377-2:1990

Consistency

Consistency test was carried out on the cement paste produced with OPC in accordance with BS 4550:1978, CLAUSE 3.5

Soundness

Soundness of the OPC paste was determined in accordance with BS 4550:1978, Clause 3.7

Setting time

The initial and final setting time of the OPC paste where carried out in accordance with BS 4450:1978, Clause 3.7.

Fineness test

Fineness test was carried out according to BS 4550 (1978) clause 3.3

Aggregates

Fine aggregate (Sand)

The fine aggregate used in this research work was river sand which was sourced locally within Zaria. It was sieved and ensured that only the sand particles that passed sieve size 4.75mm was used in this research work. Sieve analysis was carried out on the sand in accordance with BS 812-103.1:1995 to determine its suitability for used in concrete. The specific gravity, fineness modulus and bulk density were also carried out in accordance with BS812-2:1995.

Fine aggregates (African Elemi crushed seed shell)

Both the physical properties and oxide composition of the A. E. seed were determined as follows:

Physical properties of A. E. Seed

The A. E. seeds used in this research work were obtained in sufficient quantities from Mangu town, Plateau state. It was washed and sundried before taken to Department of Building Technology, A.B.U Zaria for crushing and be made to pass through sieve size 4.75mm to remove those that did not fall under fine aggregates sizes. The specific gravity, fineness modulus, bulk density and sieve analysis test were also carried out on the A. E. seed in accordance with BS812-2:1995.

Oxide composition of A. E. seed

The oxide composition of African Elemi seed was determined by subjecting the sample to chemical composition test in accordance with BS EN 196-2:1995 at the Chemical Engineering Laboratory of the Department of Chemical Engineering, ABU Zaria. This was done by using X-Ray Fluorescence Test (XRF) in which the sample was subjected to test for 30s at the voltage of 45kv and current of 50µA.

Coarse aggregates

Crushed stone of nominal size 20mm, sourced locally from stone dealers in Zaria was used for this research. The sieve analysis test of the coarse aggregate was conducted in accordance with BS 812-103.1:1995. Other important properties of the coarse aggregate which include; Aggregate Impact Value, specific gravity, Aggregate Crushing Value, were determined in accordance with BS 812-2:1995, BS 812-112:1995 and BS 812-110:1995 respectively.

Water

Only portable water, fit for human consumption, which conforms to BS EN 1008:-2002 and sourced from Ahmadu Bello University's water supply was used in preparing the concrete mixes, cement paste and curing of concrete in this research work.

Test on fresh concrete

Workability test

Slump test was carried out to determine the workability of the A.E Concrete in accordance with BS 1881:102, 1983.

Test on hardened concrete

Various tests such as Compressive Strength, Flexural Strength, Water absorption etc. were also carried out accordingly.

Preparation and testing of hardened concrete

Sand was partially replaced with African Elemi crushed seeds in the following order; 0%, (control), 10%, 15%, 20 %, 25%, 30%, 35% and 40%. A total of 216 cube specimens of size 100mm x 100mm x 100mmwere prepared and cured. The crushing test was carried out on the concrete cubes after 1,2,3,4, 7, 14, 28 and 56 days in accordance withBS1881:108:1983. Also, 24 beam specimens of size 100 x 100 x 500mm were prepared and flexural strength test was carried out after 28 days of curingin accordance with BS EN 12390-6 (2003). The mix ratio used in this research is 1:1.5:3 at 0.55 water/cement ratio in other to obtained a 25N/mm^2 concrete of target strength and batching by absolute volume was adopted.

Water absorption test

Water absorption test was carried out on the specimens in accordance with BS 1881, part 122 (1983). The cubes/beam specimens were weighed and immersed in water after which they were brought out and reweighed at intervals of one day until saturation point was achieved.

RESULTS AND DISCUSSION

Physical properties of A. E.

The summary of average results for the physical properties of A. E. seed obtained after subjecting the A. E. sample to different tests in accordance with various B.S codes are shown in (Table 1).

Table 1: Physical properties of African Elemi (A. E).

Bulk Density (loose)	662 kg/m^3
Bulk Density (Compacted)	717 kg/m^3
Specific Gravity	1.05
Moisture Content	10.3%
Moisture Absorption	26.8%
Fineness Modulus	1.63

Oxide composition of African Elemi crushed seed shell

The result obtained after subjecting the A. E. sample to chemical composition test (XRF) in accordance with BS EN 196-2:1995 is shown in (Table 2). It can be seen that the second major oxide after P_2O_5 is SiO_2 (26.01%) which is the major constituent of most inland continental sand.

Properties of sand and coarse aggregate

Table 3 shows the specific gravity of sand and coarse aggregate used in this research falls within the range of 2.5 – 3.0 as specified by BS EN 196-3(2005) hence can be used in structural concrete. Also, both the Aggregate impact value and aggregate crushing value are less than 30% as specified in BS812: Part 3 and BS EN 196-1(1998) respectively.

Sieve analysis

The results of sieve analysis carried out on fine aggregates (sand and A.E) in accordance with BS 882-1992 are plotted on log-graph as shown in (Figure 1). The graph shows how the sand and A. E. particles are distributed.

Properties of cement

The result obtained for the average values of the cement properties such as fineness, specific gravity, initial and final setting time etc. are summarised in (Table 4).

Test on fresh concrete.4.4.1: Workability

The percentage increase in A. E. leads to the decrease in workability of the concrete as shown in (Figure 2). This could be as a result of the porosity nature of the African Elemi seed being lightweight aggregate with greater water absorption capacity. The highest and lowest values of slump at 10% and 40% replacement levels were recorded as 40mm and 14 mm respectively. This implies that the concrete mix with higher percentage of A. E. tends to have lower workably.

Tests on hardened concrete

Density of concrete beams

Figure 3 is the summary of the average result obtained from density test for beams after 28 days hydration. It can be seen that there was an increase in densities with corresponding increase in days of curing. However, decrease in densities with increase in the percentage replacement of sand with A. E. was also noticed. This is in line with Owens *et al*. (2003) observation that reduction of density of conventional concrete can be achieved by

Table 2: Oxide Composition of African Elemi (A.E) crushed seed shell.

Oxide Composition	SiO_2	P_2O_5	K_2O	CaO	MnO	FeO_3	NiO_2	CuO	Na_2O	MgO	Zr_2O_5	Nb_2O_5	M_OO_3
% of Oxide Composition	26.01	58.21	13.13	0.13	0.01	4.25	0.04	0.01	0.05	0.02	0.02	0.08	0.39

AgO	Al_2O_3	$Sb_{22}O_3$	Hf_2O_3	LOI
0.02	0.15	0.01	0.001	18.72

Table 3: Bulk density, specific gravity, aggregate impact and crushing value.

Materials	Bulk density kg/m3	Specific gravity	ACV (%)	AIV (%)
Fine Aggregate (Sand)	1472	2.94	-	-
Coarse Aggregate	1358	2.53	25.4	22

Table 4: Summary of cement properties.

Cement Property	Value	Required BS EN 197-1 (2000)
Bulk density Kg/m^3	1440 (From Literature)	
Specific gravity	3.17	3.15
Fineness	6.2	≤10%
Initial Setting Time	2hr 40min	≥30min
Final Setting Time	3hr 20min	≤10hr
Soundness	1.2mm	≤10mm

Granite) with lightweight materials. The densities for 0%, 10%, 15%, 20%, 25%, 30%, 35% and 40% percentage replacement of sand with A. E. were recorded as 2421, 2354, 2353, 2301, 2248, 2200, 2140 and 2080 Kg/m^3 respectively. This could be as a result of low specific gravity of A. E. compared to conventional fine aggregate (sand).

Flexural strength of A. E. concrete beams

Figure 4 shows the flexural strength development of beams containing 0%, 10%, 15%, 20%, 25%, 30%, 35% and 40% of A. E. as partial replacement of sand in concrete after 28 days of hydration. It can be seen that flexural strengths decrease with increase in percentage replacement of A. E. with 0% (Control), 10% having the highest values of $5.13N/mm^2$ and $2.63N/mm^2$ while 35%, 40% recorded no values. Similar pattern was observed in the case of flexural strength with decrease in densities.

Density of concrete cubes

The result of density of concrete cubes after 7, 21 and 28 days of curing for all replacement levels from 0% to 40% are shown in (Figure 5). As in the case of concrete beams, density of concrete cubes also increases with increase in hydration days from 7 to 28 days and it decreases with increase in percentage replacement of sand with A.E. The densities of all the cubes with replacement levels from 0% up to 40% falls within the range of normal weights concrete which is $1900kg/m^3$ to $2600kg/m^3$ (Clerk, 1993).

Compressive strength

Figure 6 shows the summary of the compressive strength test for various percentage replacements with their corresponding days of curing. The optimal compressive strength of $21.3N/mm^2$ was recorded with 10% replacement of sand with A. E. at 56 days curing. This value is less than $25.8N/mm^2$ which is the highest value of the compressive strength recorded at 0% addition of A.E.

This implies that conventional concrete has more Compressive strength than A. E. concrete. Also, the average value of 2.63 N/mm^2 was recorded as optimal flexural strength at 10% replacement level after 28 days hydration. These values of flexural and compressive strengths are in line with the observation that the flexural strength of concrete falls within the range of 10% to 20%of its compressive strength depending on the type, size and volume of coarse aggregate used (www.aboutcivil.org, Yohanna *et al*. 2019). The result shows an increase in compressive strength with corresponding increase in hydration days for all mixes. However, decreased in compressive strength was

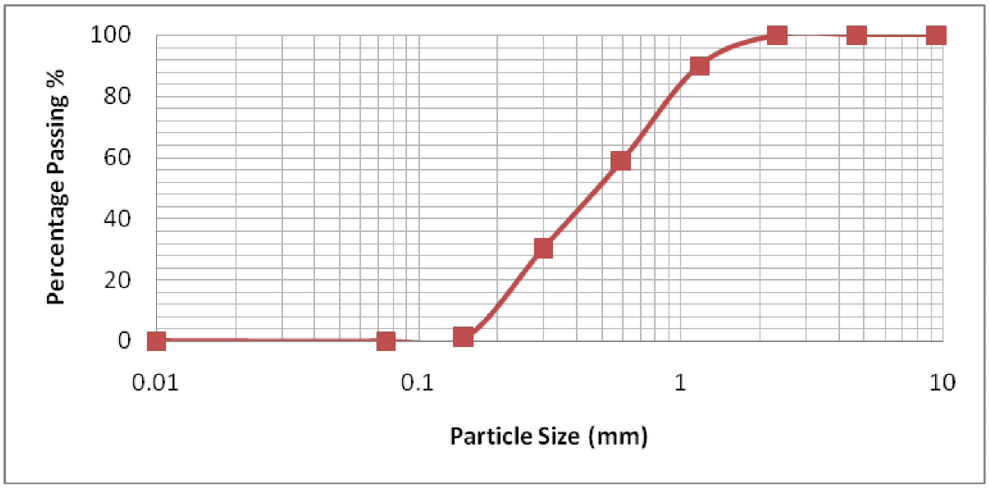

Figure 1: Particles size distribution of fine aggregate (Sand and A. E.).

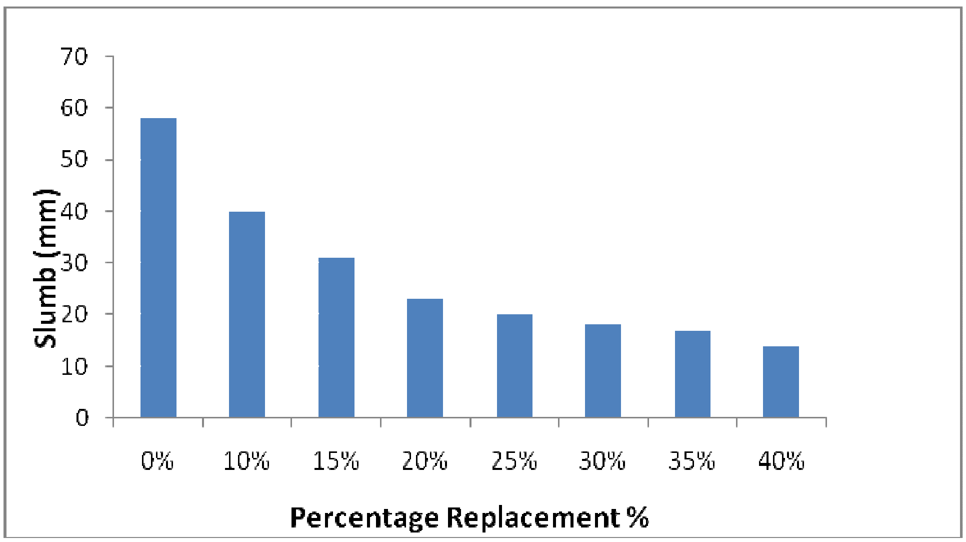

Figure 2: Variation percentage replacement with slump.

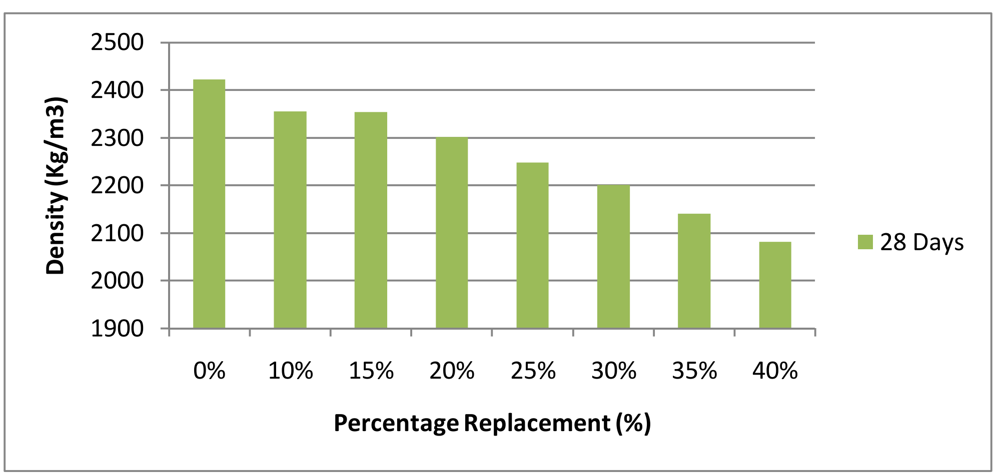

Figure 3: Variation of beam density with percentage replacement.

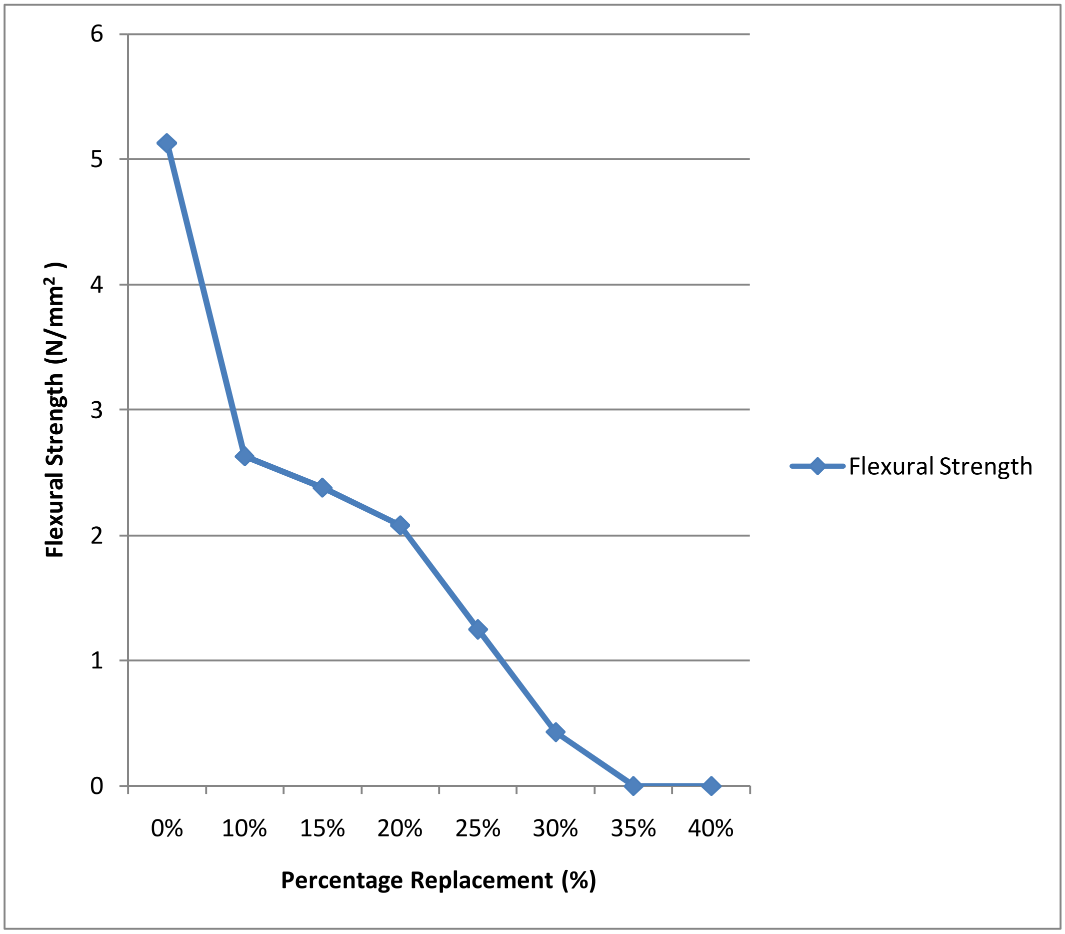

Figure 4: Average Values of flexural strength of beams (N/mm^2) at 28 days curing.

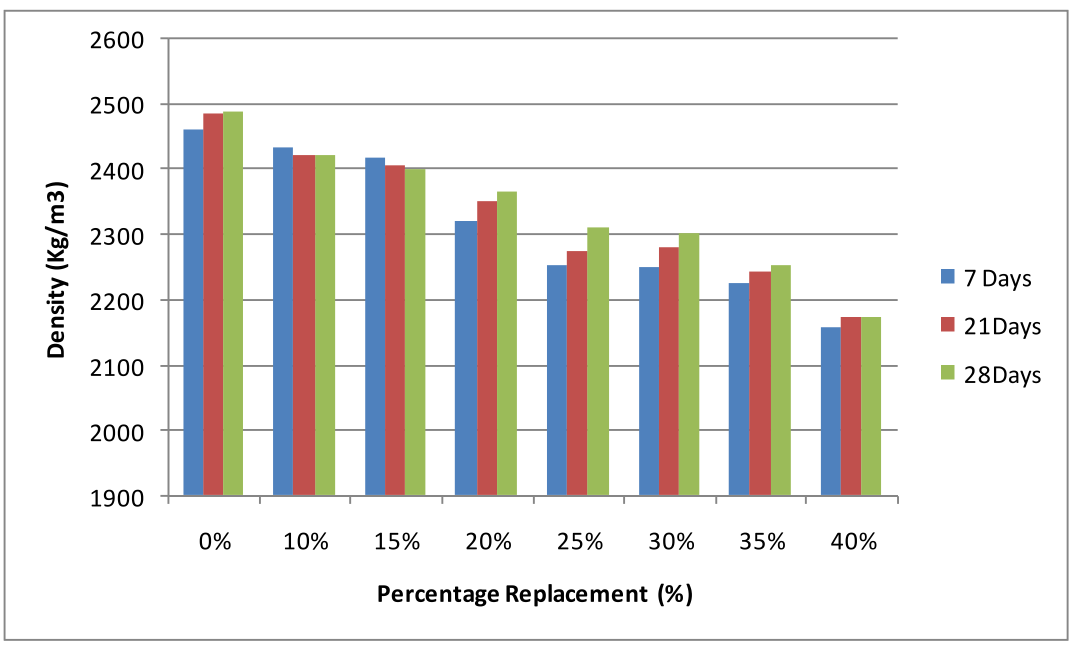

Figure 5: Variation of density of concrete cube with percentage replacement.

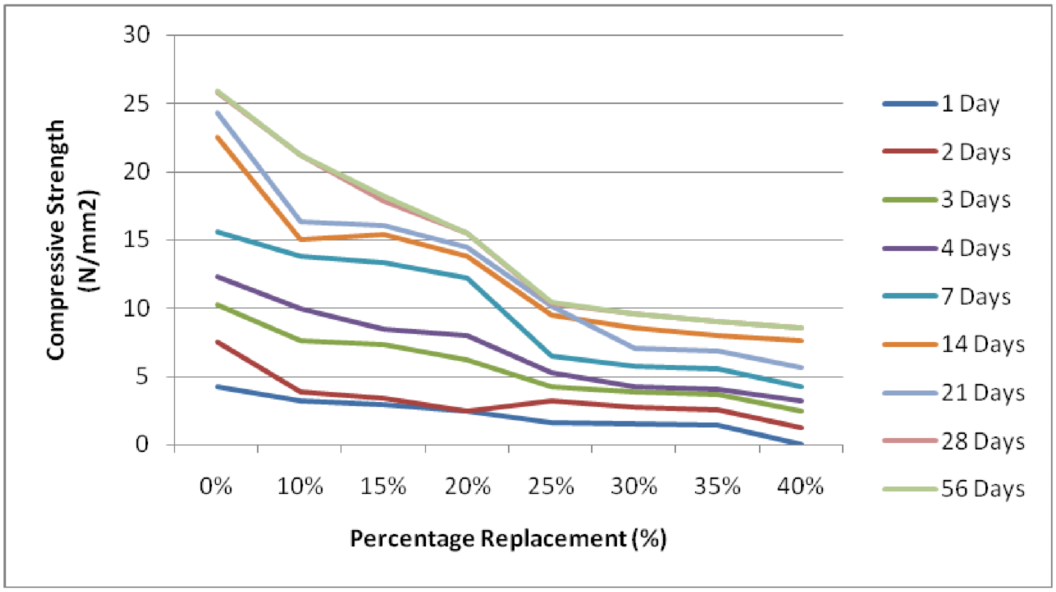

Figure 6: Variation of compressive strength of A. E-concrete with percentage replacement.

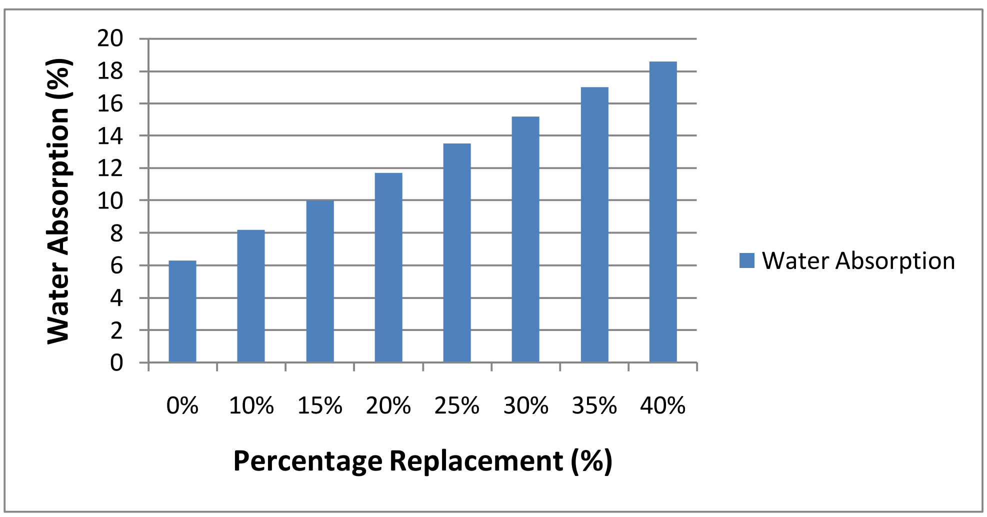

Figure 7: Variation of water absorption of concrete with percentage replacement.

noticed with increase in percentage replacement of sand with A.E. It was also observed that early strength development was achieved at 7 days curing for all cases. This could be as a result of increase in unit weight. Moreover, greater disintegration was noticed at failure for mixes from 30% and above compared to those for 0%, 10%, 15%, 20% and 25%. Also from the result obtained, there was no significant improvement in strength between the compressive strength of concrete cubes at 28 days and 56 days. This indicates that 99% of the target strength is achievable at 28 days curing.

Variation of compressive strength of concrete with percentage replacement of A. E. seed in concrete for different days of hydration is shown in Figure 6 above. The percentage replacement was from 0% to 40% while the curing days shown were shown for all curing days from 1day, 21day to 56days. 0% replacement (Control) recorded the highest value of compressive strength which is 25.9 N/mm^2 at 56 days hydration while 40% replacement recorded the lowest value of compressive strength which is 4.2 N/mm^2 after 7 days hydration. The optimum compressive strength for concrete with A. E.

therefore, was recorded at 10% replacement level at 56 days age of curing as 21.3 N/mm$^{2.}$ It was also observed that compressive strength increase with increase in hydration days while it decreases with increase in percentage replacement of sand with A. E. in the concrete mix.

Water absorption

Figure 7 shows that there was an increase in percentage water absorption for every show how the rate of water absorption of concrete is affected by the present of A. E. seed in the concrete. The result increment of the A. E. seed in concrete with 0% replacement having lowest value of 6.3% and 40% replacement having 18.6% .This could be as a result of the A. E. seed being a light weight aggregate..

Conclusion

Based on the results obtained in this research work, the following conclusions were reached: The physical properties of African Elemi (A.E) were determined as follows: bulk density (loose) 662kg/m^3, bulk density (compacted)717kg/m^3, specific gravity1.05, moisture content26.8%, moisture absorption10.3%, and finesse modulus1.63.Chemical analysis of African Elemi crushed seed shell indicates that it has 18 different oxides with the major ones being Silicon oxide (26.01%), Phosphorus oxide(58.21%), Potassium oxide(13.13%), Iron oxide(4.25%) and Lithium iodide (18.72%) while the minor oxides includes: Aluminium oxide (0.15%),Magnesium Oxide (0.02%), Sodium Oxide (0.04%) etc. The density of concrete containing 0%, 10%, 15% 20%, 25%,30% and 40% A. E. as partial replacement of sand were obtained after 28days of hydration as 2421 Kg/m^3 ,2354Kg/m^3, 2353Kg/m^3,2301 Kg/m^3,2248Kg/m^3, 2200Kg/m^3 2140 Kg/m^3 and 2080Kg/m^3 respectively. The specific gravity of sand was 2.53, specific gravity of A. E. was 1.05, and that of granite was 2.94. Bulk density of Sand was 1472 kg/m^{3,} Bulk density of A. E. was 717 kg/m^3 and that of granite 1358kg/m^3. Aggregate impact and crushing values for coarse aggregate were determined to be 22% and 25.4% respectively. The optimum compressive strength of concrete with A. E. was recorded at 10% replacement level at 56days age of curing as 21.3 N/mm^2 which is close to the target strength of M25. Also, at the same 10% replacement level, optimum value of flexural strength was recorded as 2.63N/mm^2. Both the compressive and flexural strength decrease with increase in percentage replacement of sand with A. E. in the concrete mix. Lastly, both water absorption and workability of the concrete decrease with increase in Percentage of A. E. in the concrete mix.

Concrete sample with 0% replacement recorded lowest value of 6.3% and 40% replacement recorded 18.6% value of water absorption .This could be as a result of high water absorption of the A. E. seed being a light weight aggregate The highest and lowest values of slump where recorded at 10% and 40% replacement levels as 40mm and 14 mm respectively.

Recommendations

(a) Based on the findings of this research work, the following recommendations were drawn: A.E-Concrete can be used where reduction in density is required (Light weight Concrete).

(b) Maximum of 10% replacement of A. E. in concrete is recommended because it recorded the highest values of compressive strength (21.3 N/mm$^{2)}$ and flexural strength (2.63N/mm$^{2)}$ at 56days age of curing and it is very close to the target mix of M25.

(c) The use of African Elemi seed in concrete is therefore recommended because it will help in solving the environmental problems associated with the disposal of this waste.

(d) The value for the compressive strength (21.3N/mm^2) conforms with the requirement of 17N/mm^2 for residential buildings as stated by NRMCA (2003).Therefore it is recommended for non-structural concrete application but cannot be used in structural concrete.

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