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THE USE OF GROUNDNUT SHELL ASH AS A PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE PRODUCTION

Mujedu K. A. and Adebara S. A.

[1,]Department of Civil Engineering, Federal Polytechnic, Ede, Osun State, Nigeria.
E – Mail : bayomujedu@yahoo.com; sadebara2006@yahoo.com

ABSTRACT- This project is an experimental investigation on the use of Groundnut Shell Ash (GSA) as a partial replacement for cement in concrete. A total number of Seventy - Two (72) concrete cubes of different percentages of Groundnut shell ash which varies from 0% to 75% at intervals of 15% were produced. Concrete was batched by weight using a mixing ratio of 1: 2: 4 with water-cement ratio of 0.55. The variables considered were percentages of Groundnut shell ash and characteristic strength of the concrete. 150mm x 150mm x 150mm section of concrete cubes were used. Chemical composition of groundnut shell ash (GSA) as well as density and compressive strength of concrete cubes were determined. The results showed that groundnut shell ash is not a good pozzolan with combined SiO_2, Al_2O_3 and Fe_2O_3 of 30.64%. The results also showed that the addition of GSA produces concrete cubes of lower density. Particularly, the density of the concrete cubes decreases as the GSA content increases. The compressive strengths of the control and those of other combinations vary directly with days of curing and inversely proportional to the percentage of Groundnut Shell Ash. The highest compressive strength was 26.82N/mm^2 and 20.10N/mm^2 at 28 days for 0% and 15% groundnut shell ash respectively. Substitution of cement with groundnut shell ash in concrete production was relatively possible not exceeding 15%.

Key words : Groundnut shell ash, cement, concrete, pozzolanic properties, compressive strength, bulk density.

. *INTRODUCTION*

Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravel or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water and chemical admixtures. Concrete is presently one of the most popular materials used in building construction and other civil engineering works. It is strong in compression, as the aggregate efficiently carries the compression load. However, it is weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail. Reinforced concrete solves these problems by adding either steel reinforcing bars, steel fibres, glass fibre, or plastic fibre to carry tensile loads. Thereafter, the concrete is reinforced to withstand the tensile loads upon it.

In Nigeria, like other developing countries, the housing shortage problem is assuming increasing dimensions with the consistent increase in the cost of building materials and this has limited the proportion of Nigerians who can afford to build their own houses to about 25% based on the report of the Nigerian Building and Road Research Institute [1987].

The major component of concrete is cement which is defined as adhesive substances capable of uniting fragments or masses of solid matter to a compact whole, Ghosh [1983]. Cement functions by forming a plastic paste when mixed with water, which develops rigidity (sets) and steadily increases in compressive strength (hardness) by chemical reaction with the water (hydration). When a material increases in strength even when stored under water after setting it, the material is said to be hydraulic, Lea [1970]. Over the years, the price of cement has been increasing, to the extent that the material is now beyond the reach of persons in the low and medium income groups and it is also making it increasingly difficult for governments in developing countries to meet the construction requirements of their housing development plans.

The continuous increase in the price of cement has geared researchers to investigate the viability of some pozzolanic materials as substitutes, which would be used as partial replacement for cement and lower in cost to cement, so that more people can afford to build their houses. Various research works in the recent past had look into the utilization of agricultural wastes that are known to be pozollanas to partially replace cement that is the major component of concrete. Okpalla [1987] showed that at 40% partial replacement of cement with rice husk ash (RHA) produced a concrete with the same strength as plain ordinary Portland cement concrete concrete. Kolawole and Mbachu [1998] examined the influence of coarse aggregate on the drying shrinkage and elastic moduli of concrete with OPC partially replaced with RHA.

Results showed that OPC/RHA concrete cast with quarry granite as coarse aggregate exhibited the least drying shrinkage over time and also gave the highest values of elastic moduli when compared with river gravel. On high performance concrete incorporating rice husk ash as a supplementary cementing material, Malhotra and Zhang [1996] reported that rice husk ash concrete had excellent resistance to chloride ion penetration and higher compressive strengths at various ages up to 730 days compared with that of the control concrete.

Alabadan et al. [2005] reported that substitution of cement with Bambara Groundnut Shell Ash (BGSA) in concrete mix design was possible when not exceeding 10%. Sengul, et al. [2005] reported that there was little reduction in compressive strength up to 40% cement replacement with ground fly ash at 28 days but at 56 and 120 days, however, the compressive strength up to 40% cement replacement by fly ash is almost identical to that of the no fly ash concrete and for one year it was even higher. Raheem et. al [2012] presented a study of the use of saw dust ash as partial replacement for cement in concrete. They concluded that the compressive strength generally increases with curing period and decreases with increased amount of saw dust ash and only 5% saw dust ash substitution is adequate to enjoy maximum benefit of strength gain. Olafusi and Olutoge [2012] investigated the strength properties of corn cob ash concrete. They concluded that concrete do not attain their design strengths at 28 days and the strengths of corn cob ash concrete are dependent on its pozzolanic activities. Mujedu et al. [2014] studied the use of corn cob ash and saw dust ash as a partial replacement for cement in concrete production. They concluded that the compressive strength increases with days of curing and decreases with increased amount of combination of corn cob ash and saw dust ash and only 10% combination of corn cob ash and saw dust ash replacement would be acceptable to enjoy maximum benefit of strength gain.

The partial replacement of cement with groundnut shell ash in concrete production is a welcome development especially in Nigeria. Groundnut shell is an agricultural waste obtained from milling of groundnut. Nigeria contributes about 7 percent of world groundnut production which makes Nigeria the 3rd largest producer of groundnut in the world. In Nigeria, the leading producing states include Niger, Kano, Jigawa, Zamfara, Kebbi, Sokoto, Katsina, Kaduna, Yobe, Adamawa, Borno, Taraba, Plateau, Nasarawa, Bauchi, Gombe and Kwara. It is estimated that over 2million hectares are planted to groundnut in Nigeria [NAERLS, 2010]. The cost of groundnut shell ash when compared with cement is very low due to the availability of groundnut shell in large quantities as agricultural farm wastes. 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 encourage more production.

Moreso, groundnut shell ash production required less energy demand compared with cement production and safe the needed foreign exchange spent on importation of cement or its constituents. The main objective of this study is to investigate the suitability of groundnut shell ash as partial replacement for cement in concrete production. It is expected that these materials would give reasonable results such that an optimum result of their combination for concrete production will be obtained.

2. EXPERIMENTAL PROCEDURE

2.1 Concrete Materials

Materials used in the tests are Ordinary Portland Cement (Elephant Brand) whose properties conform to BS 12, Groundnut Shell Ash (GSA), Sharp Sand (fine aggregate), Crushed Granite (coarse aggregate) of 12mm maximum particle size and Water. The mix proportion was 1:2:4 by weight (cement/groundnut shell ash: fine aggregate: coarse aggregate) with a water / cement ratio of 0.55. The proportions of cement to groundnut shell ash in the concrete were 100:0% as control, 85:15%, 70:30%, 55:45%, 40:60%, and 25:75% respectively.

2.1.1 Preparation of Groundnut Shell Ash (GSA)

The groundnut shell was obtained from the groundnut sellers in Gbongan, Odeomu, Ede and Iwo townships. After the groundnut sellers had removed the groundnut seed from its shells, then the shells was obtained from them free of charge. After obtaining the shell, it was then spread on the floor to sun dried for three weeks (PLATE 1). After sun drying the shell, it was taken into a flat iron sheet in the open air to burn into ashes (PLATE 2). The idea of burning them in a furnace was dropped because it will be time – consuming and uneconomical for most people especially those at the rural areas. The burnt groundnut shell was then grounded and the burnt ash was sieved through British Standard sieve of 75 microns. The portion passing through the sieve would have the required degree of fineness of 63 microns and below while the residue was thrown away, Kolawole and Mbachu [1998].

PLATE 1 : Sundrying of the groundnut shell

PLATE 2: Groundnut shell ash.

2.2 Production of Concrete Cubes

The batching of the concrete materials was done by weight. Table 1 showed the batching information for cube cast. The mixing was done on an impermeable surface free of all harmful materials which could alter the properties of the mix. The required quantity of sand was measured and spread using a shovel to a reasonably large surface area. The quantity of cement to be used was measured and the groundnut shell ash which serves as a partial replacement in part of the cement was also measured, then spread evenly on the sand and the whole contents (sand, cement, groundnut shell ash) were mixed thoroughly with the shovel until the mix appear uniform. The required quantity of granite was also measured and spread evenly on the mixed sand, cement and groundnut shell ash. Water was then added gradually and turned over with shovel until the mix appeared in colour and consistency.

Table 1 : Batching Information for Cubes Cast

Percentage of GSA	GSA (kg)	Cement (kg)	Sand (kg)	Granite (kg)	Water (kg)	Water / Cement ratio
0	0	13.89	27.78	55.56	7.64	0.55
15	2.08	11.81	27.78	55.56	7.64	0.55
30	4.17	9.72	27.78	55.56	7.64	0.55
45	6.25	7.64	27.78	55.56	7.64	0.55
60	8.33	5.56	27.78	55.56	7.64	0.55
75	10.42	3.47	27.78	55.56	7.64	0.55

The cube moulds were cleaned with engine oil to prevent the development of bond between the mould and the concrete and permit easy removing. Each mould was then filled with prepared fresh concrete in three layers and each layer was compacted with tamping rod using twenty five (25) strokes uniformly distributed across the seldom of the concrete in the mould. The top concrete was later smoothened by hand-trowel to level with the edge of the mould and then left in the open air for 24 hours. For each of the cement / ash proportions, three cubes of concrete were cast and therefore, a total of 72 cubes were produced for testing. The concrete cubes were demoulded after 24 hours of the concrete setting under air. They were kept in curing tank measuring 3.0m x 1.5m filled with tap water only for periods of 7, 14, 21 and 28 days respectively.

2.3 Testing

2.3.1 Chemical Composition of Groundnut Shell Ash (GSA)

The chemical composition of groundnut shell ash (GSA) was carried out at Hegada Scientific Services Limited, Samoda, Ibadan in Oyo State. The results were shown in Table 2 and compareit with that of ordinary Portland cement (OPC).

Table 2 : Chemical Composition of Groundnut Shell Ash (GSA)

Oxide	Percentage Composition (%)			
	Sample 1	Sample 2	Average	OPC (BS 12 Ranges)
SiO_2	24.68	23.96	24.32	17 – 25
Al_2O_3	5.24	5.37	5.31	3 – 8
Fe_2O_3	0.80	1.22	1.01	0.5 – 6.0
CaO	9.20	8.65	8.93	60 – 67
MgO	5.40	5.27	5.34	0.1 – 4.0

2.3.2 Bulk Density

For compacted bulk density, the container is filled in three stages, each third of the volume being tamped 25 times with a tamping rod. The overflow is then removed and the density is calculated by dividing the net mass of the aggregate in the container by its volume.

2.3.3 Compressive Strength Test

Before crushing, the cubes were brought out of the water and kept for about 20 minutes for most of the water to wipe off. They were then weighed on a weighing balance and then taken to the digital crushing machine in accordance with BS 1881: Part 116 (1983). The cubes experienced cracks due to failure in their strength as a result of the load applied by the crushing machine. The load on the cube was applied at a constant rate of stress equal to $0.01N/mm^2$ per second. The compressive strength was recorded to the nearest $0.01N/mm^2$.

3. RESULTS AND DISCUSSIONS

3.1 Chemical Composition of Groundnut Shell Ash (GSA)

Table 2 shows the chemical composition of Groundnut shell ashes. The result showed that Groundnut shell ash contains some of the oxides found in both pozzolana and ordinary Portland cement (OPC). These compounds are known to have cement properties that would be beneficiary to the concrete. However, the percentage composition for Calcium oxide (CaO) in Groundnut shell ash was below the minimum value specified by BS 12 (1978) for ordinary Portland cement (OPC) and also the percentage of Magnessium oxide (MgO) had exceeded the maximum value specified by the same code for ordinary Portland cement (OPC). The result also showed that Groundnut shell ash has combined percentages (SiO_2 + Al_2O_3 + Fe_2O_3) of 30.64% which is less than minimum of 70% specified by ASTM 618 (2005) for pozzolanas.

3.2 Bulk Density

Figure 1 below shows the result of the bulk density test. From the result, it can be seen that for the control (0% ash content) and for each cement: ash ratio, the bulk density decreased with days of curing. This is expected because as the concrete hardens, it uses up water in hydration and the products of hydration occupied less space than the original water and cement, Neville [1995].

The results also showed that for the same days of curing, the bulk density decreases as the proportion of ash increases. This is expected because ordinary Portland cement has a higher specific gravity of 3.07 than ash which is 2.02. The control had the highest densities followed by the 85:15% cement: ash combination. This implies that the control aggregate is densely packed and there are fewer voids to be filled by fine aggregate and cement as compared with the other cement: ash combinations.

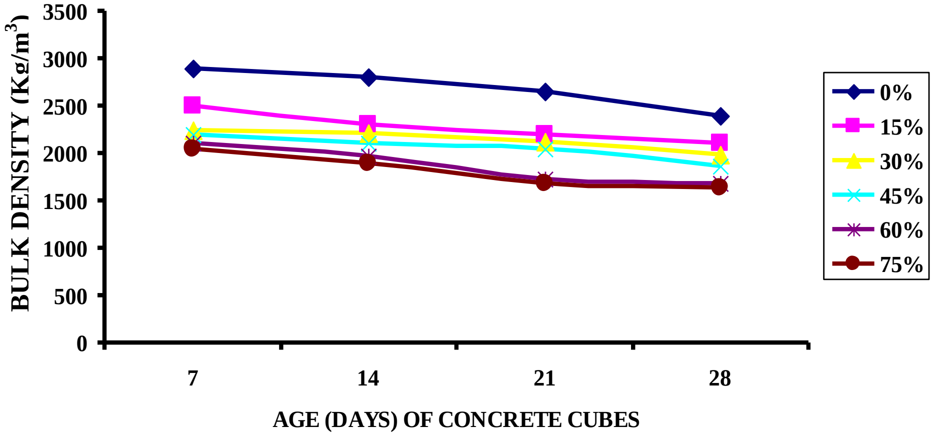

Figure 1 : Bulk Density – Time Characteristics of Concrete Cubes

3.2 Compressive Strength Test

The results of the compressive strength test carried out are shown in Figure 2. It shows that compressive strength increases as the days of curing increases and decreases as the percentage of groundnut shell ash increases. This is due to hydration of cement and ash possesses little cementing properties compared to a Portland cement. The control had the highest rate of early strength development. At 0% ash and 100% cement that served as the control, compressive strength increased from 15.90 N/mm^2 at 7 days to 26.82 N/mm^2 at 28 days that was about 68.68% increment.

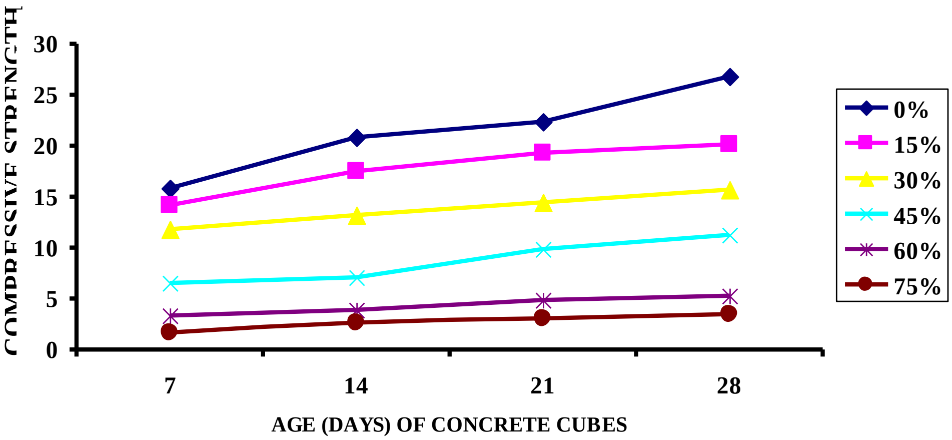

Figure 2 : Compressive Strength – Time Characteristics of Concrete Cubes

Compressive strength of 85:15% cement/ash increased from 14.20 N/mm^2 at 7 days to 22.10 N/mm^2 at 28 days which is about 55.63% increment. The compressive strength for 30% ash replacement were 11.80 N/mm^2, 13.20 N/mm^2,14.40 N/mm^2, and 15.70 N/mm^2 for 7, 14, 21 and 28 days respectively while it was 6.50 N/mm^2, 7.10 N/mm^2, 9.80 N/mm^2 and 11.30 N/mm^2 for 45% ash replacement.

According to BS 8110 [1985], a grade 20 concrete of 1:2:4 mix design without any blending of the cement should have required a strength of 13.5 N/mm^2 within the first seven days of wet curing and 20 N/mm^2 within 28 days. Based on the above and the result obtained from this study, OPC/GSA ratio of 85/15 would be suitable for concrete. FAO, [1986] reported that cement blended with pozzolanas would produce 65 to 95% strength of OPC concrete in 28 days. Also, they reported that their strength normally improves with age since pozzolanas react more slowly than cement due to different composition and at one year about the same strength is obtained. This behaviour was confirmed by Sideris and Sarva, [2001] and Sengul, et al. [2005]. They reported that the replacement of ordinary Portland cement by a pozzolanic material usually has beneficial effects on cement's durability at ages up to 1.5 years. Though, this experiment was extended beyond 28 days, the above may account for the low strength values recorded with the addition of ash in the mixture.

4. CONCLUSIONS

From the results of the tests carried out in this study, it can be concluded that:

i. Groundnut shell ash is not suitable material for use as a pozzolan, since it does not satisfied the requirement for such a material by having a combined (SiO_2 + Al_2O_3 + Fe_2O_3) of 30.64% which is less than 70%.

ii. There exists a potential cost reductions in concrete production using groundnut shell ash as partial replacement for cement.

iii. Groundnut Shell Ash up to 15% replacement of ordinary Portland cement in concrete would be acceptable.

iv. Although the strength of OPC/GSA concrete was lower than that of 100% cement, it can still be used for constructing of light load bearing structures.

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