The Potentials of Groundnut Shell Ash as Concrete Admixture

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ABSTRACT

Pozzolanic materials have long demonstrated their effectiveness in producing high-performance concrete. Artificial pozzolanas such as rice husk ash have gained acceptance as supplementary cementing materials in many parts of the world. This work evaluates the potentials of groundnut shell ash (GSA) as a partial replacement for ordinary Portland cement (OPC) in concrete. Chemical analysis of the ash was carried out to ascertain whether it possesses pozzolanic or cementing properties and the partial replacement of OPC by GSA was varied from 0% to 70% in the concrete. The compressive strengths of the control and those of other combinations increased with curing age but decreased with increased ash percentage. Though, the strength of the control was higher, replacement of cement with ash up to 30% would be more suitable than others.

Key words: Admixture, groundnut shell ash, cement, concrete, pozzolanic properties, compressive strength

1. INTRODUCTION

Concrete is a composite material which consists essentially of a binding medium, within which are embedded particles or fragments of a relative inert filler in Portland cement concrete, the binder is a mixture of Portland cement, possibly additional cementitious materials such as fly ash and water; the filler may be any of a wide variety of natural or artificial, fine and coarse aggregates; and in some instances, an admixture (Moxie, 2001).

Concrete is presently one of the most popular materials used in building construction and other civil engineering works. When reinforced with steel, it has a higher capacity for carrying loads. Concrete being a heterogeneous material, the quality of the constituents and the proportions in which they are mixed, determine its strength and other properties.

A vast majority of the cement used in construction work is the Portland cement. Portland cement is manufactured by mixing naturally occurring substances containing calcium carbonate with substances containing alumina, silica and iron oxide. Table 1 shows typical chemical compositions of Ordinary Portland Cement (ECO-CARE, 2005).

ASTM C 618-05 defined pozzolana as siliceous or siliceous and aluminous materials which in themselves have little or no cementitious properties but in finely divided form and in the presence of moisture, they react with calcium hydroxide which is liberated during the hydration of Portland Cement) at ordinary temperatures to form compounds possessing cementitious properties. They include pumice, tuffa, volcanic ash, diatomaceous earth, calcined clay, shales, and pulverized-fuel ash (PFA) or fly ash.

Table 1: Chemical composition of typical ordinary Portland cement

Ingredient	**Percentage**
Lime (CaO)	62
Silica (SiO_2)	22
Alumina (Al_2O_3)	5
Calcium Sulphate ($CaSO_4$)	4
Iron Oxide (Fe_2O_3)	3
Magnesia (MgO)	2
Sulphur (S)	1
Alcalies	1
Total	100

By - product mineral admixtures such as fly ash, rice husk ash, and ground granulated blast furnace slag are attracting much attention as materials that not only contribute to improvement of concrete performance (for example, high strength, high durability, and reduction of heat of hydration) but are also indispensable to the reduction of energy and carbon diode generated in the production of cement (Nagataki, 1994).

ASTM C 618-05 specified that any pozzolana that will be used as a cement blender in concrete requires a minimum of 70% for silica, alumina and ferric oxide, and a maximum SO_3 content of 5%. PFA should conform to BS 3892: Parts 1 and 2.

Neville (1995) described rice husk ash as pozzolana. 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 (OPC) concrete. Mbachu and Kolawole (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, Zhang and Malhotra, (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.

In a related work on Bambara Groundnut Shell Ash, Alabadan et al. (2005) reported that substitution of cement with ash 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 120days, 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.

In another study by Ding and Li, (2005), it was shown that a fly ash content of 30 to 50% has the best improving effect on magnesia phosphate cement. Also, Mahmud et al. (2005) reported that with 10 % replacement of cement with Rice husk ash, high workability rice husk ash concrete mixtures in the range of 200-250 mm slump and having 28 days strengths of 80 MN/m^2 can be produced. They concluded that Rice husk ash is just as good as condensed silica fume in producing strength concrete of Grade 80 and can also be produced at a much lower cost the condensed silica fume

The main objective of this study is to investigate the suitability of Groundnut Shell Ash (GSA) as partial replacement for cement in concrete.

2. MATERIALS AND METHODS

The materials used in the tests were Groundnut Shell Ash, ordinary Portland cement (Elephant Brand), Sand (fine aggregate), Chippings (¾ coarse aggregate) and Water. The tools used were wooden moulds (150 mm x 150 mm size), shovels, hand trowels and head pans. The groundnut shells were obtained from a farm in Minna, Niger State.

2.1 Ash Production

The ash was obtained by burning the groundnut shells on an iron sheet in the open air under normal temperature. 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 levels. The burnt ash was passed through a BS sieve (75 microns). The portion passing through the sieve would have the required degree of fineness of 0.063mm and below while the residue was thrown away (Mbachu and Kolawole, 1998).

2.2 Concrete Cubes Production

The batching of the concrete materials was done by volume. The mix proportion used for this work was 1:2:4. The proportions of cement to ash in the concrete were 100:0% as control, 70:30%, 60:40%, 50:50%, 40:60% and 30:70% respectively.

The concrete materials cement, aggregates and ash were mixed by hand with a water/cement ratio of 0.5 by weight. The materials were mixed together thoroughly by stirring to form a uniform mass.

The moulds were cleaned with engine oil to prevent the development of bond between the mould and the concrete and permit easy stripping. The freshly mixed concrete was scooped into the mould. Each mould was filled in three layers with the concrete; each layer was rammed 25 times with a tamping rod. Then the concrete cubes in the moulds were left in the open air for 24 hours. For each of the cement:ash proportions, three cubes of concrete were cast. Therefore, a total of 72 cubes were produced for testing.

Stripping of the concrete cubes from the mould was carefully done after 24 hours of the concrete setting under air. Curing of the concrete cubes was done by complete immersion in a clean fish pond measuring 1.5 m 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 Analysis of Groundnut Shell Ash

Chemical analysis of GSA was carried out at Chemical Laboratory of Nigerian Mining Corporation, Jos. The X-ray Analyzer together with Atomic Absorption Spectrophotometer (AAS) was employed for the analysis except for Sulphur Oxide, Sodium and Potassium Oxide where the Flame Analyzer was used, gravimetric method was employed in the determination of the Carbonate and Hydrogen Carbonate.

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 16 mm diameter round-nosed rod. The overflow is removed. The net mass of the aggregate in the container divide by its volume represents the density.

2.3.3 Compressive Strength Test

Before crushing, the cubes were brought out of the water and kept for about 10 minutes for most of the water to drip off. They were then weighed on a weighing balance and then taken to the 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 0.2 to 0.4 MN/m^2 per second. The compressive strength was reported to the nearest 0.5 MN/m^2.

3. RESULTS AND DISCUSSIONS

3.1 Chemical Analysis of Groundnut Shell Ash (GSA)

The results contained in Table 2 shows that GSA contains some of the elements (oxides) found in both pozzolana and ordinary Portland cement. When compared with the composition of ordinary Portland cement, the percentage of CaO in ordinary Portland cement was higher than that of the Groundnut Shell ash. These compounds are known to have cement properties that would be beneficiary to the concrete. However, the total percentage of Iron Oxide, Silicon Oxide and Aluminum Oxide is less that the minimum of 70% specified by for pozzolanas (ASTM 618, 2005).

Table 2: Results of Chemical Analysis of Groundnut Shell Ash (GSA)

	%SiO_2	**%Al_2O_3**	**%Fe_2O_3**	**%CaO**	**%MgO**
Experimental (GSA)	15.92	6.73	1.93	8.66	6.12
Typical ordinary Portland cement (Table 1)	22	5	3	62	2

3.2 Bulk Density

The results are shown in Table 3 and Fig. 1. From the results it can be seen that for the control (0% ash content) and for each cement: ash ratio, the bulk density decreases with age of curing. This is expected because as the concrete hardens it uses up water in hydration, and the products of hydration occupy less space than the original water and cement (Neville, 1995).

Also the results show that for the same age, the bulk density decreases as the proportion of ash increases. This is expected because ordinary Portland cement has a higher specific gravity than ash.

The analysis of variance result in Table 3 shows that there is a significant difference between the densities obtained for any two cement:ash combinations. Also, there is a significant difference between the control and the other cement:ash combinations. The control had the highest densities followed by the 70:30 % 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.

Table 3: Analysis of Variance for Bulk Densities of Different Cement:Ash Combinations at 5% level of Significance.

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio	F- Probability
Between Group	5	187181.25	37436.25	12.96	2.77
Within Group	18	52013.75	2889.65		
Total	23	239195.0			

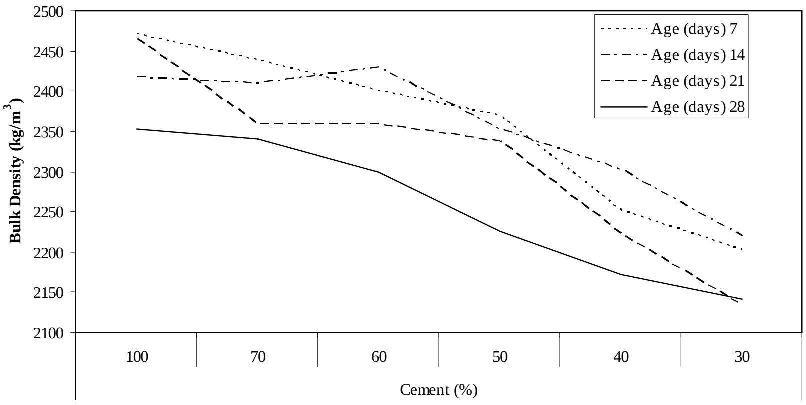

Fig. 1: Bulk Density of Cement/Ash Concrete

3.3 Compressive Strength Test

The results were as presented in Fig. 2. Compressive strength for the control was 16.4MN/m^2, 21.3 MN/m^2, 22 MN/m^2, and 24.3 MN/m^2 for 7, 14, 21 and 28days respectively while it was 12 MN/m^2, 13.5 MN/m^2, 14 MN/m^2 and 16 MN/m^2 for 30% ash replacement. From the results it can be seen that for the control (0% ash content) and for each cement:ash combination, the compressive strength increases as the age of the concrete increases. This is due to hydration of cement. The control had the highest rate of early strength development.

FAO, (1986) reported that cement blended with pozzolanas would produce 65 to 95 % strength of OPC concrete in 28 days. Further, 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) was similar to the pattern of this study. In their study, Sideris and Sarva, (2001) 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.

At age 28 days, the compressive strength was 24.3 MN/m^2, 16 MN/m^2, 12 MN/m^2, 9MN/m^2, 5 MN/m^2, and 4 MN/m^2. The results show that for the same age, the compressive strength decreases as the proportion of ash increases. This is because the ash possesses little cementing properties compared to a Portland cement.

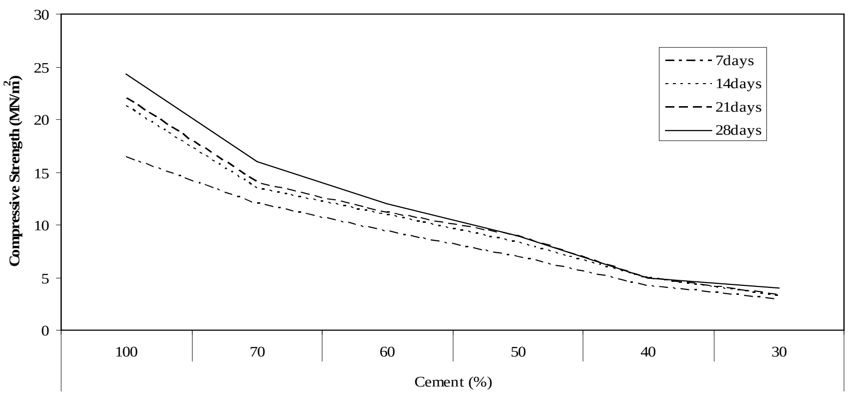

Fig. 2: Compressive Strength of Cement/Ash Concrete

The analysis of variance result in Table 4 shows that there is a significant difference between the strengths obtained for any two cement:ash combinations. Also, there is a significant difference between the control and the other cement:ash combinations. The control had the highest strength followed by the 70:30% cement:ash ratio.

According to BS 8110 (1985), a grade 20 concrete of 1:2:4 mix design without any blending of the cement should have acquired 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 work, OPC/GSA ratio of 70/30 would be suitable for concrete.

Table 4: Analysis of Variance for Compressive Strength Test Results for Different Cement:Ash

Source of Variance	Degree of Freedom	Sum of Squares	Mean Square	F – Ratio	F- Probability
Between Group	5	835.70	167.14	61.68	2.77
Within Group	18	48.76	2.71		
Total	23	884.46			

4. CONCLUSIONS

From the results of the tests carried out in this work, it can be concluded that:
1. Groundnut Shell Ash contains some of the oxides found in pozzolanas and Portland cement.
2. Groundnut Shell Ash up to 30% replacement of ordinary Portland cement in concrete would be acceptable.

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