Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

Advances in Applied Science Research, 2012, 3 (4):2283-2287

ISSN: 0976-8610
CODEN (USA): AASRFC

stability of groundnut shell ash (GSA)/ordinary portland cement (OPC) concrete in Nigeria

T.C. Nwofor and S. Sule

Department of Civil and Environmental Engineering, University of Port Harcourt, P.M.B 5323, Port Harcourt, Rivers State, Nigeria

---

ABSTRACT

This study investigates the use of considerable volume of groundnut shell ash as the partial replacement for cement in concrete production. A total of 100 specimens of the GSA/OPC concrete was cured in cubes of 100mm dimension for 7, 14, 21 and 28 days and the compressive strength and density determined. The percentage replacement of Ordinary Portland Cement (OPC) varies to the control (0% replacement) about 40%. The results generally show a decrease in density and compressive strength as the percentage replacement with GSA increases suggesting less hydration with cement. Based on a general analysis of the results as well as the logical comparison to the acceptable standard, a percentage replacement of 10% is suggested for sustainable construction, especially in mass concrete constructions.

Key words: Compressive strength, groundnut shell ash, ordinary Portland cement, concrete

---

INTRODUCTION

The continuous increase in the price of Portland cement is attributed to the insufficient production rate of the raw materials when compared with the demand rate in the construction industries. During and after the harvest of groundnut, the shell is regarded as waste product which when accumulated in large quantity in a particular area will constitute an environmental hazard.

Therefore the utilization of groundnut shell ash reduces the environmental problem resulting from the accumulation of the shells in a large quantity in a particular area. In recent times, the knowledge of natural pozzolanas materials use as partial replacement for cement has increased substantially. The literature is reach and various research papers are available [1-9] which have indicated various advantages in the use of pozzolanas in concrete production. However, it has been shown that the hydration process of concrete is slowed down by the addition of these substitutes [10-11] and again the early stage strength is reduced in comparison with normal ordinary Portland cement concrete (OPC). At present time, issues related to environmental conservation have gained importance, hence the utilization of these waste materials that are available in our environment is now necessary [12-14]. In related works, rice husk ash, fly ash, volcanic ash etc have been used as partial replacement for cement in concrete work.

Replacement level of 0-50% was carried out by [4] and comparing the strength property with [15] which recommends that cement partially replaced with pozzolanas should reach a compressive strength of 65 to 95% of the control specimen (i.e. 0% substitutions) in 28 days and hence an optimum replacement of 20% recommended. Also another researcher [5] in his results demonstrated that the replacement of ordinary Portland cement (OPC) with volcanic ash presented a good tendency of pozzolonic activity and the resulting concrete very adequate for construction of masonry walls and simple foundations. Therefore in this present research, the idea of using groundnut shell ash (GSA) as partial replacement for cement in concrete work is investigated.

MATERIALS AND METHODS

The materials used in this project were groundnut shell ash, sand (fine aggregate), gravel (coarse aggregate), cement and water. The good quantity of ground shell is readily gotten form the northern part of Nigeria. The groundnut shell ash is assumed to be pozzolanas since it has chemical constituent of certain elements found in good pozzolans and ordinary Portland cement (OPC). The groundnut shell ash used in this work is well grained into fine particles.

The groundnut shell obtained from Kano State, Nigeria as a major groundnut producing area in Northern Nigeria was then thoroughly cleaned and dried for chemical pretreatment in order to remove impurities from the shell. The next stage is to heat the treated groundnut shell in an electric muffle furnace at a temperature of 500^{o}C to 600^{o}C for 4 hours in order to produce the groundnut shell ash. The result is then tested to determine the particle size distribution of the ash in accordance with British standard institution [16], which would pass 75microns sieve.

In order to reveal it's composition, the analysis of the GSA and the mixed concrete design are conducted at the structural laboratory of the Department of Civil and Environmental Engineering, University of Port Harcourt. The mix ratio used is 1:2:4 at different nominal replacement of OPC with GSA and water cement ratio of 0.55 by weight. The replacement levels of 0% to 40% by weight of GSA in the mass proportioning was used to prepare the fresh concrete mix which are then placed into the test cube moulds of 150mm x 150mm x 150mm. For each replacement level, twenty test cubes were cast.

In preparing for the compressive strength test, the test cubes were brought out of the moulds after 24hours and then put in a curing tank containing clean water to cure for 7, 14, 21 and 28 days respectively.

RESULTS AND DISCUSSION

3.1 Chemical Analysis of Ground Shell Ash (GSA)

Chemical analysis was carried out on samples of GSA and ordinary Portland cement (OPC) to reveal and compare their composition, and the result shown in table 1. The percentage composition of the constituent compounds in the GSA is compared to that of typical ordinary Portland cement (OPC). The results show that GSA contains most of the compounds known to have binding properties necessary for concrete work. The percentage composition of CaO found in the GSA was found to be less than that in the OPC. The total percentage of iron oxide (Fe_2O_3) silicon dioxide (SiO_2) and aluminum oxide (Al_2O_3) is found to be less than the minimum of 70% specified for pozzolanas by ASTM C618 (American Society for Testing and Material) [17]. However, the percentage content of magnesium oxide was found to be much higher than the minimum recommended.

Table 1: Chemical composition of GSA/OPC

Constituent	% Composition (GSA)	% Composition OPC
Ferrous oxide (Fe_2O_3)	1.80	4.65
Silica (SiO_2)	16.21	22.00
Calcium Oxide (CaO)	8.69	62
Aluminum Oxide (Al_2O_3)	5.93	5.03
Magnesium Oxide (MgO)	6.74	2.06
Sodium Oxide (Na_2O)	9.02	0.19
Potassium Oxide (K_2O)	15.73	0.40
Sulphite (SO_3^{2-})	6.21	1.43

3.2 Particle Size Distribution

Sieve analysis was carried out on 300mgrams of river sand sample. The fine aggregate passed through 5mm sieve as recommended. Before the sand was used it was dried to remove the moisture content so that it will not increase the water content in the concrete mix and the results shown in table 2. The result revealed the sand sample was well graded falling into zone 2 near border of zone 1, which is very appropriate for concrete work in accordance with

British Standards Institutions (BS) test sieves [18]. The fineness modulus of the sand was found to be 3.15, which makes the sand sample a rather coarse one.

Table 2. Particle Size Analysis on Fine Aggregate Sample

Sieve		*Mass on (g)*	*% on sieve*	*% retained*	*% passing*	*Zone (2) limits*	*Max. on sieve permitted (g)*
5.00mm		12	4	4	96	90-100	-
2.36mm	No.7	54	18	22	78	75-100	200
1.18mm	14	60	20	42	58	55-90	100
600.00µm	25	66	22	64	36	35-59	75
300.00µm	52	63+	21	85	15	8-30	50
150.00µm	100	39	13	98	2	0-10	40
Tray		6	2	-	-	-	
				315			

+Needed dividing as it exceeded the maximum permitted on sieve.
Zone = zone 2, near border of zone 1.
Fineness modulus (FM) 315 ÷ 100 = 3.15 (rather coarse)

The crushed rock (coarse aggregate) was also subject to gradation test. The coarse aggregate used was angular shaped gravel and has a minimum size of about 10mm. before the aggregate was used it was dried so that its moisture content will not affect the result of the experiment. The result of the sieve analysis is shown in table 3, on the sample of coarse aggregate with average size of 20mm slowed a well graded sample with a fineness modulus of 6.54.

Table 3: Particle Size Analysis on Coarse Aggregate Sample

Sieve	Mass on	% on	% ret.	% passing	BS limit (20mm)
37.5mm	-	-	-	100	100
20	60	4	4	96	95-100
10	765	51	55	45	30-60
5	600	40	95	5	0-10
2.36	75	5	100	0	-
	1500		254		
			+400		
			654		

Fineness modulus (FM) 6.54 ÷ 100 = 6.54

3.3 Specific Gravity
The specify gravity test conducted on the materials revealed the specific gravity of GSA as 2.23. This value is less than the value for cement which is 3.15 but however, it falls within the recommended range of 1.9 and 2.4 for pulverized fuel ash [19]. It was also found out that the specific gravity of sand and granite was found to be 2.62 and 2.51 which are very close to the values seen in literature [20].

3.4 Bulk Density Test
The compacted bulk density test was performed for each material by filling the container in three stages and each third of the volume being temped 25 times with a 16mm diameter rod and the overflow removed. The density of the material would then be obtain by dividing the net mass of the material by its volume. The compacted density of the GSA was found to be 678kg/m^3 which shows that the material is a lightweight material. The whole ideal of bulk densities is to show how dense the particles are packed. This value for GSA is much less then the value for OPC.

3.5 Compressive Strength Test
Compressive strength test was carried out to determine the strength of the concrete at various ages. The concrete was placed in a curing tank filled with water and left to cure for 7, 14, 21 and 28 days for a total of 100 specimens for percentage replacement of cement of 0%-40%. The dried concrete cubes were tested by crushing under compressive load in the compressive machine. The failure load were recorded and the compressive strength of each concrete cubes was found, as shown in table 4.

$$\text{Note that compressive strength} = \frac{\text{Failure load (N)}}{Area\ of\ cube\ (mm^2)} \qquad (1)$$

It was generally noticed that the workability of the GSA/OPC concrete decreases as the percentage of GSA is increased. Also the density of the specimens also decreased as the percentage of GSA increased as it was clearly seen that the density decreased from 2412kg/m^3 of 0% replacement to about 2190kg/m^3 at 60% replacement (see table 4 and 5).

Table 4: Summary of compressive strength (F_c)N/mm^2 and density (kg/m^3) results

GSA % content	Curing days							
	7		14		21		28	
	Density	F_c	Density	F_c	Density	F_c	Density	F_c
0	2412	10.10	2422	14.63	2430	22.01	2380	25.58
10	2284	6.50	2285	8.05	2278	13.21	2284	17.98
20	2303	5.80	2314	7.08	2325	11.45	2301	15.90
30	2206	3.40	2220	5.20	2221	8.01	2231	11.20
40	2190	2.01	2198	3.46	2205	5.23	2220	7.50

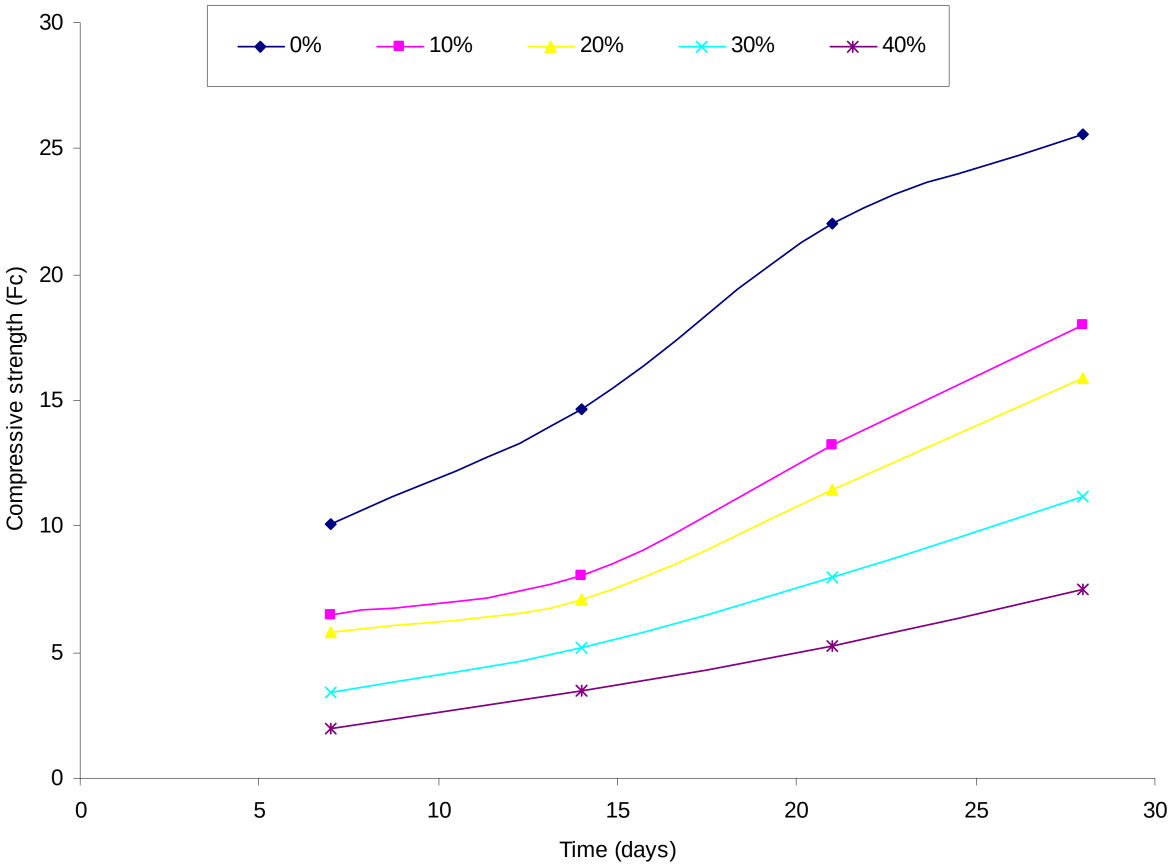

Figure 1:General comparison of compressive strength of GSA/OPC Concrete

A general comparison of compressive strength of the GSA/OPC concrete against the age of concrete is displayed in figure 1. The compressive strength of the control specimen (i.e. 0% GAS) increase from 10.10N/mm^2 at 7 days to about 25.58N/mm^2 at 28 days. That of 10% GSA and 98% OPC increased from 6.50N/mm^2 at 7 days to about 17.98N/mm^2 at 28 days. Considering the summary of results displayed in table 4, the results show a general increase of strength with age of GSA/OPC concrete but a decrease in strength with increase in percentage substitution with GSA. This is because of the less hydration of cement as the GSA possess less cementing property than the OPC. A compressive strength value of 25.58N/mm^2, 17.98N/mm^2, 15.90N/mm^2 and 11.20N/mm^2 were obtained for replacements levels of 0%, 10%, 20% and 30% respectively. As previous described [15], a percentage replacement of 10% with GSA will be adequate for good concrete work.

The general trend of the result obtained in this work is also similar to that obtained in [4] where Rice husk ash (RHA) was used as partial replacement for OPC. Again comparing the results with recommendation of ASTMC 618 [17] for a 28 days strength for concrete, a percentage replacement level greater than 10% may not be adequate for quality concrete work.

CONCLUSION

The results show that the compressive strength value of the GSA/OPC concrete ranged from 29% at 40% replacement level to about 70% at 10% replacement level of the compressive strength of the control (0% GSA replacement) at the 28th day. It can be concluded that a good tendency for pozzolanic activity especially for percentage replacement less than 10%. Base on previous research which is focused on looking for alternatives for OPC concrete, the GSA/OPC concrete is considered as a good development for construction of masonry walls and mass foundations. At this point, we note that groundnut shell which is a by-product from agricultural waste cheaper than ordinary Portland cement and available in large qualities in many northern states of Nigeria, the utilization of this product in concrete work would therefore reduce the effect of this agricultural waste acting as an agent of environmental pollution.

REFERENCES

[1] Alabadam, B.A.; Njoku, C.F. and Yusuf, M.O, *Agricultural Engineering International: the CIGR Ejournal*, **2006**, Manuscript BC 05 012, vol.VIII.
[2] American Standard for Testing Materials, Specification for fly ash and raw or calcium natural pozzolana for use as a mineral admixture in Portland cement concrete. *ASTMC* **2005**, 618-78.
[3] Dashan, I.I. and Kamang, E.E.I., *Nigeria Journal of Construction Technology and Management* **1999**, 2(1), 22-28.
[4] Nwofor, T.C and Eme, D.B., *Journal of Chemical, Mechanical and Engineering Practice*, **2010**, vol.1, Nos. 2 & 3, pp.42-47.
[5] Olawuyi, B.J. and Olusola, K.O., *Civil Engineering Dimension*, **2010**, vol.12, no.1, pp.23-28.
[6] Malhotra, V.M., and Mehia P.K., High-performance, high-volume fly ash concrete, Ottawa, 2002, pp.101.
[7] Vargas, Jose A., A Designer's view of fly ash concrete, USA, **2007**.
[8] Olawuyi, B.J. An Evaluation of the performance Characteristics of volcanic-Ash/Ordinary Portland cement laterized concrete, Thesis proposal for MPhi/Ph.D. Department of Building Obafemi Awolowo University, Ile-Ife, **2008**.
[9] Elinwa, AU. and Mahmood, Y.A., *Cement and Concrete Composites*,**2002**, vol.24, no.2, pp.219-222.
[10] Malhotra, V.M., Zhang, M.H., Read, P.H. and Ryell, J., Long-term mechanical properties and durability characteristics of high-strength/high-performance concrete incorporating supplementary cementing materials under outdoor exposure conditions, ACI J. **2000**, Issue, 97, pp.518-525.
[11] Swamy, R.N., Ali, A.R.S. and Theodorakopoulos, D.D., *ACI J*., **1983**, pp.414-423.
[12] Md. Safiuddn, Mohd Zamin Jumaat, Salam, M.A., M.S. Islam and R. Hashim , *International Journal of Physical sciences*, 2010, vol.5(13), pp.**1952-1963**.
[13] Xue, Y. Hou Zhu S, Zha, J., *Construction and Building Materials*, **2009**, 23:989-996.
[14] Aubert J.E, Husson B. Sarramone, N., *J. Hazardous Mater*, **2006**, 136:624-631.
[15] Bengtsson, C.P. and Whilken, J.H., Farm Structures in tropical climates: A textbook for structural Engineering and Design. FAO/SIDA Cooperative Programme. Rome: Food and Agricultural Organization, **1986**.
[16] British Standards Institution, Specifications for pulverized fuel ash for use with Portland cement in concrete. London,**1997**, BS 3892: I.
[17] American Society for Testing and Materials, Specifications for pozzolanas. ASTM International, USA, ASTM C618, **1978**.
[18] British Standards Institution, Methods of testing for soils for Civil Engineering purposes. London, **1990**, pp.1377.
[19] Neville, A.M., *Properties of concrete, fourth edition* (low priced edition), England: Pearson Education Asia Publishing Limited, **2000**.
[20] Tyler, H.A., *Science and Materials Level III, England:* Van Nostrand Reinhold Company Ltd., Berleshire, **1980**.