JASEM ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://ww.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 22 (10) 1553–1556 October 2018

Properties of Groundnut Shell (A*rachis Hypogaea*) Ash Blended Portland cement

IKUMAPAYI, CM

Department of Civil Engineering, Federal University of Technology, P.M.B. 704, Akure, Nigeria
Email: *mayowaik@yahoo.com*

ABSTRACT: The study of the properties of groundnut shell ash (GSA) obtained at 500ºC revealed that the ash is a pozzolanic material. Its pozzolanicity was studied by Chemical analysis test conducted with the aid of Minipal 4 Energy Dispensing X-ray Fluorescence Spectrometer (EDXRF) as well other physical tests conducted on the material. Hydration behavior of 0%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 12%, 14% and 16% by weight of GSA blended ordinary Portland cement (OPC) was studied through workability measurement, setting time measurement and compressive strength measurement; it was found that at 28 days of hydration the compressive strength value for 12 wt% GSA blended cement concrete was quite comparable to that of concrete made from OPC. However, the highest compressive strength was obtained at 4 wt% GSA replacement with OPC. Chloride Ion penetration of OPC, OPC with 4% GSA and OPC with 12% GSA were then determined using Rapid Migration test. The result showed that application of 12% GSA blended OPC cement in concrete increases the resistance of such concrete to chloride ion penetration.

DOI: https://dx.doi.org/10.4314/jasem.v22i10.03

Dates: Received: 09 September 2018; Revised: 22 October: 2018; Accepted: 30 October 2018

Keywords: Groundnut shell ash, Rapid migration test, chloride ion penetration, compressive strength

Concrete is the most essential sustainable construction material which is widely used all over the world as it provides superior fire resistance, gains strength over time, gives an extremely long service life and capable of being moulded into different shapes (Neville, 2011). The major components of concrete are cement paste and inert materials. Typical Portland cement is a mixtures of tricalcium silicates ($3CaO.SiO_2$), tricalcium aluminates ($3CaO.Al_2O_3$), dicalcium silicates ($2CaO.SiO_2$) and a tetra-calcium aluminoferrite ($4CaO{\cdot}Al_2O_3Fe_2O_3$) in various proportions together with small amounts of magnesium and iron compounds. Sometimes, Gypsum is added to slow the hardening process (Deepa *et al.,* 2010).The temperature at which cement is been manufactured (~1500ºC) and the high energy consumption associating with it pose problem in construction industries. There is also emission of harmful gases which pollute the atmosphere during its production. The production of every ton of Portland cement contributes about one ton of CO_2 in the atmosphere. Small amount of NO_X (NO and NO_2) and CH_4 gases are also emitted (Singh *et al*. 2007). Besides energy consumption and emission of harmful gases, one positive benefit is that calcium hydroxide, one the hydration products during the hydration of cement is a bonus for construction industry especially when allowed to react with pozzolans. This affects the durability characteristics of Portland cement pastes, mortar and concrete (Singh *et al*. 2007).

According to British Standards Institution BS EN 197-1 (2000), pozzolanic materials are natural substances of siliceous or silico-aluminous composition or a combination thereof which do not harden in themselves when mixed with water but, when finely ground and in the presence of water, they react at normal ambient temperature with dissolved calcium hydroxide ($Ca(OH)_2$) to form strength-developing calcium silicate and calcium aluminate compounds which have a low solubility character and possess cementitious properties (Donatello and Cheeseman, 2010). Furthermore, pozolans will decrease the pore size in the concrete and restricts entry of aggressive ions (Setina and Juhnevica, 2013). Pozzolans can be natural or artificial; the natural pozzolans are of volcanic origin, such as volcanic ashes, tuffs and other diatomaceous earths, and agricultural and mine wastes. Artificial pozzolans can be industrial by-product like blast furnace slag, fly ash and silica fume which are available in large quantity or obtained from agriculture based industries. Rice husk ash and sugar cane bagasse ash are well established agro based pozzolans already in use (Soares and Melo, 2015; Hadipramana *et al*, 2016). Research works on Bamboo leaf and locust beans pod ashes are also at high gear (Dwivedia *et al.*, 2006; Ikumapayi, 2016). Also Arum

Email: *mayowaik@yahoo.com*

et al. (2013) reported about the pozzolanicity of some biogenic agricultural wastes such as bamboo leaf ash, coconut shell ash, rice hush ash among others. When these materials are mixed with Portland cement, blended cement or composite cement are obtained. Blended cement many times shows properties (like compressive strength, chloride ion penetration etc.) better than Portland cement provided proper optimization is done (Ikumapayi, 2016). Thus the aim of the research was to investigate some relevant properties of groundnut shell ash (GSA) in term of its suitability as pozzolans. Therefore the effects of replacing cement with GSA at different percentages were investigated on the compressive strength, workability, setting time and chloride ion penetration of the various concrete mixes.

MATERIALS AND METHODS

Materials: Materials used in this research work were (a*rachis hypogaea)* groundnut shells, GSA, sands (fine aggregates), granite chippings (coarse aggregates), OPC (Dangote brand) and water. Good quantity of groundnut shell was obtained and air dried and the ashes were produced by calcinating the shell in a furnace at 500°C for 3hrs (Kreiker, 2014).

Chemical Composition: Chemical Composition of GSA were obtained with the use of Minipal 4 Energy Dispensing X-ray Fluorescence Spectrometer (EDXRF) using MO (white colour) filter and compared with that of OPC. The result of the chemical composition was also compared with the chemical requirement stipulated in ASTM C618-12a.

Workability measurement: Workability was determined in accordance with ASTM C143 (2012) using slump cone and was found to be 45mm for OPC, 49.5 mm for OPC+4 wt% GSA and 45 mm for OPC+12%wt% GSA blended cement. Result for the workability test in detail as well as the result of the compaction factor test obtained using compaction factor apparatus is also presented (Bartos *et al*., 2002).

The compaction factor test indicates small variations in workability over a wide range. The compacting factor or the degree of compaction is measured by the density ratio (i.e the ratio of density actually achieved in the test to density of same concrete fully compacted). Water cement ratio (w/c) ratio of 0.6 was used throughout the experiment.

Compressive Strength and Setting time measurements: OPC/GSA blended cement were mixed with sand and granite using 1:2:4 mix ratio with 0.6w/c ratio. Hydration behavior of 0%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 12%, 14% and 16% by weight of GSA blended ordinary Portland cement (OPC) was studied relative to the compressive strength and the setting time. Concrete steel moulds of 150mm^3 were used for the concrete casting and these cubes were demoulded after one day and stored in water at 27°C at a relative humidity of 100%. The cubes were taken out of water prior to testing and their compressive strengths were determined at 7, 14, 21 and 28days in accordance with BS EN 206-1 (2006). Initial and final setting times for OPC and different GSA percentage replacement was also determined with Vicat apparatus (IS 4031, 1988).

Chloride Ion Penetration test using Rapid Migration Test: A migration cell was set up with a concrete specimen 50mm thick and 100mm in diameter with an applied voltage of 10V.

The volume of the NaCl solution was 750 ml and that of NaOH was 300 ml. After 8 hours the specimen were removed and split and the depth of chloride penetration was determined in one half of the specimen using colorimetric technique in which 0.1N silver nitrate is used as colorimetric indicator (Otsuki *et al.,* 1992). The results of the depth of the chloride ion penetration are also presented and further discussed.

RESULTS AND DISCUSSION

Oxide compositions of GSA and OPC are shown in Table 1 and it indicates that GSA belongs to the group of pozzolanic material because it satisfies most of the requirement specified by ASTM C618 (1996). Addition of Silicon dioxide (SiO_2) plus Aluminium oxide (Al_2O_3) plus iron oxide (Fe_2O_3) is 69.2% which conforms with class C pozzolan, the loss on ignition is 4.0 which is also less than 6.0% maximum requirement and the percentage composition of SO_3 is 6.21% which is not too far from the maximum of 5% specified.

The result of the workability test obtained by slump test indicates that at 12% GSA replacement the concrete from OPC and that of 12% GSA replacement has the same value.

A more accurate workability test done with the use of compaction factor detected 10.23% variation in the workability of 12% GSA and that of OPC. Therefore regarding workability 12% GSA replacement is quite workable. The initial setting and final setting times for OPC and GSA blended cement are shown in Figure 1. The result showed that GSA blended cement took longer time for hydration than OPC.

Table 1. Oxide Compositions

System	Composition (wt%)								
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	LOI*
OPC	21.40	5.03	4.40	61.14	1.35	0.48	0.24	2.53	1.29
GSA	49	12	8.2	5.0	6.74	2.04	9.02	6.21	4.0

LOI-loss on ignition*

Table 2- Measurement of charge passed, current and temperature for various specimen at 30 days

Mix	Testing duration (days)	I_c (mA)	I_p (mA)	I_f (mA)	$[\frac{(I_p-I_c)}{I_c}]$ (100%)	$[\frac{(I_f-I_p)}{I_p}]$ 100%)	T_o (°C)	T_f °C)
OPC	30	5.1	48.5	51.2	851	5.56	25.5	28.5
GSA-4% + OPC	30	9.1	44.2	45.3	3.86	2.94	25.5	29.0
GSA-12% + OPC	30	16.6	45.8	50.6	178	10.48	25.5	29

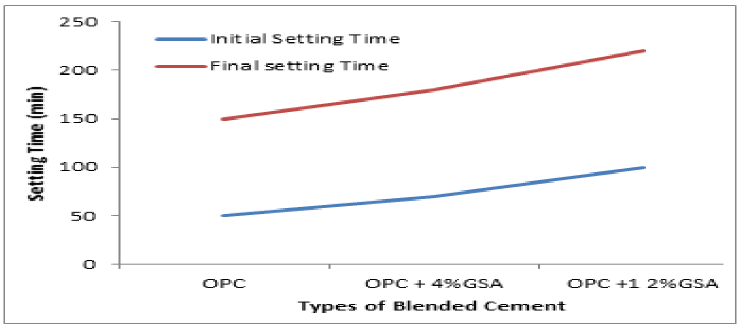

Fig 1.Variation of the setting time with increment in GSA composition

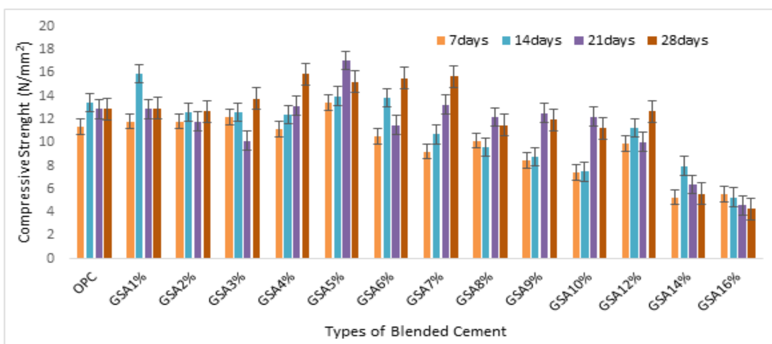

Fig 2. Compressive Strength for different GSA% replacement with OPC at different days

Compressive strength results obtained for different GSA replacement with OPC are shown in Figure 2. The highest compressive strength was obtained at 4% GSA replacement while at 12% GSA replacement the strength obtained was quite comparable with that of concrete made with OPC at 28 days. The results of the depth of chloride ion penetration over time at 30 days are shown in Figure 3. The results show that concrete made with 4% GSA has a better chloride ion resistance than concrete made with OPC and that of 12% GSA gave a better result than 12% GSA. It was also noted during the experiment that after the application of silver nitrate on the surface of each of the specimen; OPC, OPC + 12% GSA and OPC + 4% GSA that the whitish colour silver chloride formed was very sharp in OPC than in the other two specimens .

The current across each cell and the temperature of Nacl solution were recorded during the experiment. Measurements of initial current (I_c), final current (I_f), initial temperature (T_o) and final temperature (T_f) for each specimen are presented in Table 2. The temperature variations for the specimens are not more than 4 °C, this is an indication that Rapid Migration test is able to overcome one of the criticisms of the Rapid Chloride Permeability Test (RCPT) about too much temperature rise during the experiment.

Conclusions: The results show that GSA is a pozzolanic material. It has the ability to increase the compressive strength of concrete; at 4% replacement of OPC with GSA higher compressive strength was obtained. Also the compressive strength of concrete made from OPC and that of 12% GSA are found to be quite comparable. Furthermore, GSA replacement with OPC will improve the resistance of the resulting concrete to chloride ion penetration since the application of both 4% GSA and 12% GSA in concrete has been found to increase its resistance to chloride ion penetration by 25% and 12.5% respectively.

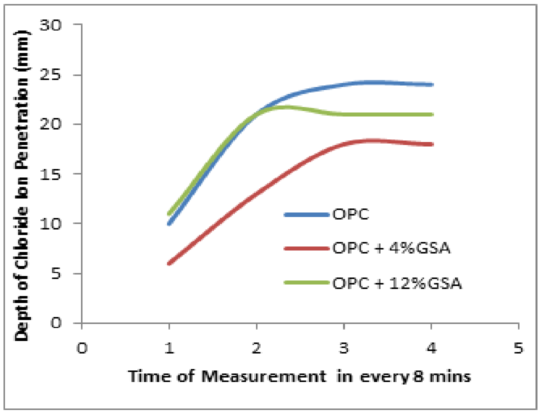

Fig 3. Rate of Chloride Ion penetration over time

REFERENCES

American Society for Testing and Materials (ASTM) (1996). Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete, ASTM C618 - 12a, West Chonshohocken, PA,19428-2959 USA.

Arum C; Ikumapayi CM; Aralepo GO (2013). Ashes of Biogenic wastes-Pozzolanicity, Prospects for use and Effects on Engineering Properties of Concrete. *Mater. Sci. Appl.*, 4; 521-527

ASTMC143/C143M-12 (2012) Standard Test method for Slump of Hydraulic Cement Concrete ASTM International, West Conshohocken, USA

Bartos, PJM; Sonebi M; Tamimi, AK (eds) (2002). Workability and Rheology of Fresh Concrete: Compendium of Tests, Cachan Cedex, France:RILEM.

British Adopted European Standard BS EN 197-1: (2000). Cement. Composition, Specification and Conformity Criteria for Common Cements, United Kingdom.

BS EN 206-1 (2006). Concrete complementary British Standard to BS EN 206-1, Part 1-Method of Specifying and Guidance for Specifier, European Standard published by BSI

Deepa, C; Sathiyakumari K; Preamsudha V (2010). A Tree Based Model for High Performance Concrete Mix Design. *Int. J. of Eng. Sci. Technol.* 2 (9); 4640-4646

Donatello S; Cheeseman CR (2010). Comparison of Test Methods to Assess Pozzolanic Activity, *Cem. Concr. Compos.* 32 (2); 212-127

Dwivedia, VN; Singh, NP; Das, SS; Singh, NB (2006). A New Pozzolanic Material for Cement Industry Bamboo Leaf Ash. *Int. J.Phys. Sci.* 1 (3): 106-111.

Hadipramana J; Riza FV; Rahman I.A; Loon LY; Adnan SH; Zaidi AMA (2016). Pozzolanic Characterization of Waste Rice Husk Ash (RHA) from Muar, Malaysia. *IOP Conference Series: Mater. Sci. Eng.,* 160(1): 012066

Ikumapayi CM (2016). Crystal and Microstructure Analysis of Pozzolanic Properties of Bamboo Leaf Ash and Locust Beans Pod Ash Blended Cement Concrete, *J. Appl. Sci. Environ. Manage.* 20 (4): 943-952

IS 4031; Part 5, (1988) Methods of Physical Tests for Hydraulic Cement: Determination of Initial and final setting times, Indian Standard.

Kreiker J; Andrada C; Positieri M; Gatani M; Crespo EQ (2014). Study of Peanut Husk Ashes Properties to promote its use as Supplementary Material in Cement Mortars, *Rev. IBRACON Estrut. Mater*. 7 (6): 905-912.

Neville AM (2011). Properties of Concrete 5th edition, London: Pearson Education

Otsuki N; Nagataki S; Nakashita K (1992). Evaluation of $AgNO_3$ Solution Spray Method for Measurement of Chloride Penetration into Hardened Cementitious Matrix Materials. *ACI Mater. J.* 89 (6):587-592

Setina J; Juhnevica I (2013). Effect of Pozzolanic Additives on Structure and Chemical Durability of Concrete. *Eng. Proc.* 57: 1005-1012

Singh NB; Das SS; Singh NP; Dwivedi VN. (2007). Hydration of Bamboo Leaf Ash Blended Portland cement. *Indian J. of Eng. Mater. Sci.* 14:69-76

Soares LWO; Melo MAD. (2015). The effect of Rice Husk Ash as Pozzolans in Addition to Cement, *J. Petroleum Sci. Eng.* 131, 80-85