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Comparative Analysis of Coconut Husk Ash (CHA) with Ordinary Portland Cement (OPC) to Determine the Pozzolanic Property of Coconut Husk Ash (CHA)

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ABSTRACT

This research was conducted to develop new kinds of pozzolana from recycled materials. The study investigated the suitability of Coconut Husk Ash (CHA) as a pozzolana. Series of tests were carried out to determine the pozzolanic properties of Coconut Husk Ash (CHA) as compared with Ordinary Portland Cement (OPC). Tests conducted include: chemical analysis of CHA and OPC, particle size analysis of sand, specific gravity of CHA, OPC and sand, Bulk density of CHA, OPC and sand. To determine the pozzolanic nature of CHA, comparative chemical analysis was conducted on samples of CHA and OPC in the Chemistry Lab of the University of Lagos. Test results revealed that CHA when compared with OPC possesses slight amount of pozzolanic properties and showed some similarities in specific gravity and bulk density tests, hence may be used to partially replace OPC in sandcrete block production. The study therefore submits that Coconut Husk Ash is slightly pozzolanic and may be used as partial replacement for Ordinary Portland Cement (OPC) in sandcrete block production.

Key words: Coconut Husk Ash (CHA), Ordinary Portland Cement (OPC), sand.

INTRODUCTION

The need to add value to wastes and the use of cement replacement materials for cheaper sandcrete blocks were the grounds for this work that aims at the comparative analysis of CHA with OPC to determine the pozzolanic nature of CHA and its suitability of being used as partial replacement for OPC.

Chaatveera B. and Nimityongskul P. (1994) submitted that Coconut Husk Ash cannot be utilized as pozzolana while Corn Cob Ash and

Peanut Shell Ash can be classified as F and N pozzolana respectively. [8]

E. B Oyetola and M Abdullahi in their work on Rice Husk Ash (RHA) submitted that 20% is the optimum replacement level of Ordinary Portland Cement with RHA. This is so because it is the cheapest block that met the minimum compressive strength required for sandcrete blocks at 28 days. [5]

A. Fragata, H. Paiva, A. L. Velosa, M. R. Veiga and V. M. Ferreira submitted that flat construction glass is a material with a high percentage of amorphous silica, favouring pozzolanic reactivity. This property was evaluated using a chemical test based on the standard EN 196-5 - Methods of testing cement - Part 5: Pozzolanicity test of pozzolanic cement. The results obtained by this test indicate the material's capacity to react with calcium hydroxide, forming hydrated calcium alumino-silicates. [3]

B. A. Alabadan; M. A. Olutoye, M. S. Abolarin and M. Zakariya examined Ordinary Portland Cement (OPC) and Bambara Groundnut Shell Ash (BGSA) concrete and concluded that a partial replacement of Ordinary Portland Cement with about 10% Bambara Groundnut Shell ash in concrete is acceptable. [9]

EXPERIMENTAL DESIGN / METHODOLOGY

For the purpose of this work, CHA sample was prepared and subjected to various tests alongside OPC. Burham Cement was adopted for the OPC.

PREPARATION OF THE ASH SAMPLE

The following procedures outlined below were used in the production of the Coconut Husk Ash:

i. Collection of Coconut Husk from source (Epe, Lagos State, Nigeria).

ii. The husks were Sun dried in the open field for 7 days.

iii. The dried husks were burnt in a gas kiln at the Federal Institute of Industrial Research, Oshodi (FIIRO), at an average temperature of 1000°C, using cooking gas as the combustion medium.

iv. After allowing the burnt products to cool off, it was then collected and sieved using sieve size 600μm.

v. The materials passing the 600μm sieve were used for the practical work.

LABORATORY TESTS

Series of laboratory tests were performed in order to determine the pozzolanic properties and the durability characteristics of using recycled materials (CHA) as partial replacement for OPC. Tests conducted include: chemical analysis of Coconut Husk Ash (CHA) and Ordinary Portland Cement (OPC), particle size analysis of sand, specific gravity test of CHA, OPC and sand [2], Bulk density test of CHA, OPC and sand [2].

Chemical Analysis of CHA and OPC

Samples of the Coconut Husk Ash (CHA) and Ordinary Portland Cement (OPC - Burham cement was used) were taken to the Chemistry Laboratory of University of Lagos for chemical analysis. The chemical compositions were determined and the results will be discussed in the proceeding section.

Particle Size Distribution of Sand

This experiment was carried out in the soil laboratory of Civil Engineering Department, University of Lagos, Akoka. It involved the use of British sieves, mechanical sieve shaker, and weighing balance with sensitivity of 0.1g. About 200g of the sand sample was weighed on the balance and introduced into the sieve. The stack of sieves were arranged in order of decreasing known diameters of 6.3mm, 5.0mm, 3.35mm, 2.0mm, 1.18mm, 600μm, 425μm, 300μm, 212μm, 150μm, 63μm and a pan placed after the last sieve. With the stack of sieves firmly clamped to the mechanical shaker, the shaker was switched on and allowed to vibrate the sand sample. After sieving, the sand particles retained on each sieve (including any material cleaned from mesh) was weighed and expressed as a percentage of the weight of the total sample.

Specific Gravity Test

The specific gravity of a material is defined as the ratio of the weight or mass of a given volume of that material to the weight or mass of an equal volume of water. It is represented by the symbol G_s. This test was carried out on samples of CHA, OPC and sand respectively in the soil lab, Civil Engineering Department, University of Lagos.

About 20g of each sample (CHA, OPC and sand) was introduced into a 50ml density bottle and weighed to obtain m_2. The sample was thoroughly mixed with 40ml of water in the density bottle and the outside of the bottle wiped dry. The bottle was then filled to the brim with water and weighed to obtain m_3. The sample was thrown away and only water was introduced into the bottle and weighed to obtain m_4. The specific gravity was calculated using the formula:

Mass of bottle $= m_1$
Mass of bottle + dry sample $= m_2$
Mass of bottle + sample + water $= m_3$
Mass of bottle + water $= m_4$

$$G_s = \frac{\text{Mass of sample}}{\text{Mass of same volume of water}} = \frac{m_2 - m_1}{(m_4 - m_1) - (m_3 - m_2)}$$

Bulk Density Test

The bulk density of a soil sample is defined as the density of the complete soil sample (i.e. solids and voids). Un-compacted bulk density tests were performed on the CHA, OPC and soil samples in the concrete lab of Civil Engineering Department, University of Lagos. A cylinder 155mm diameter and 134mm high was weighed when empty to obtain m_1. It was then filled with the sample and weighed to obtain m_2. The difference is the weight of the sample. The bulk density was expressed as the weight of the sample divided by the volume of the sample.

Mass of empty cylinder $= m_1$
Mass of cylinder + sample $= m_2$
Mass of sample $= m_3$
Volume of cylinder $= V$
Bulk density $= \frac{m_3}{V}$

RESULTS AND DISCUSSIONS

The results of the various tests carried out on the CHA, OPC and sand samples are presented in both tabular and graphical form, and discussed in the preceding sections.

Chemical Analysis of CHA and OPC

Table l shows the chemical compositions of Coconut Husk Ash (CHA) and Burham cement (OPC). The total percentage composition of iron oxide (Fe_2O_3 = 0.002%), Silicon dioxide (SiO_2 = 3%) and Aluminum Oxide (Al_2O_3 = 1.2%) for CHA was found to be 4.2%. This value is below the required value of 70% minimum for pozzolanas [7] which indicates that CHA has little pozzolanic property. It is also below the value gotten for Burham cement (25.86%). The value of 4.2% gotten for CHA is lower than the value obtained in [5] for Rice Husk Ash (73.15%) and as such the Rice Husk Ash is more pozzolanic than Coconut Husk Ash. Also this value 4.2% is less than the 37.27% obtained in [9] for BGSA. This implies that CHA may not be a very good pozzolana.

Table 1 Chemical Composition of Coconut Husk Ash (CHA) and Burham cement (OPC)

Constituents	% Composition of CHA	% Composition of Burham cement (OPC)
SiO_2	3.0	18.72
Al_2O_3	1.2	6.2
Fe_2O_3	0.002	0.94
CaO	5.0	62.32
MgO	0.0002	1.62
SO_3	0.02	1.1
Na_2O	1.14	0.34
Total Organic Carbon (TOC)	0.42	1.7
Moisture content	1.09	0.0

The moisture content for CHA was found to be 1.09% while that of cement gave 0%. This value is less than 12% maximum as required for pozzolanas [7]. The TOC was found to be 0.42% which means that the CHA still contains very little unburnt carbon and the presence of the carbon may slightly affect the pozzolanic activity of the ash. The unburnt carbon it-self is not pozzolanic and its presence serves as filler to the mixture. The value obtained is less than 17.78% obtained in [5] for RHA and also less than the value for Burham cement (1.7%). Fly ash produces greater unburnt carbon compound compared to coconut husk ash reported in [7], though one may not readily conclude that CHA is more pozzolanic than fly ash and RHA.

The magnesium oxide (MgO) content was found to be 0.0002%. This satisfies the required value of 5% maximum as reported in [7], but this value is less than the value obtained for Burham cement (1.62%) which implies that CHA is less pozzolanic compared to Burham cement. This value of 0.0002% is less than 1.18% obtained in [5] for RHA and 3.33% obtained in [3] for crushed waste glass. It is also less than 2.5% obtained in [7] for fly ash and 4.72% obtained in [9] for

BGSA. This implies that CHA is far less pozzolanic compared to all the above.

The Sulphur Oxide (SO_3) content was found to be 0.02%. This satisfies required value of 5% maximum as reported in [7], but this value is less than the value obtained for Burham cement (1.1%) which implies that CHA is less pozzolanic compared to Burham cement. This value of 0.02% is less than 0.9% obtained in [7] for fly ash and 6.4% obtained in [9] for BGSA. This implies that CHA is less pozzolanic compared to all the above.

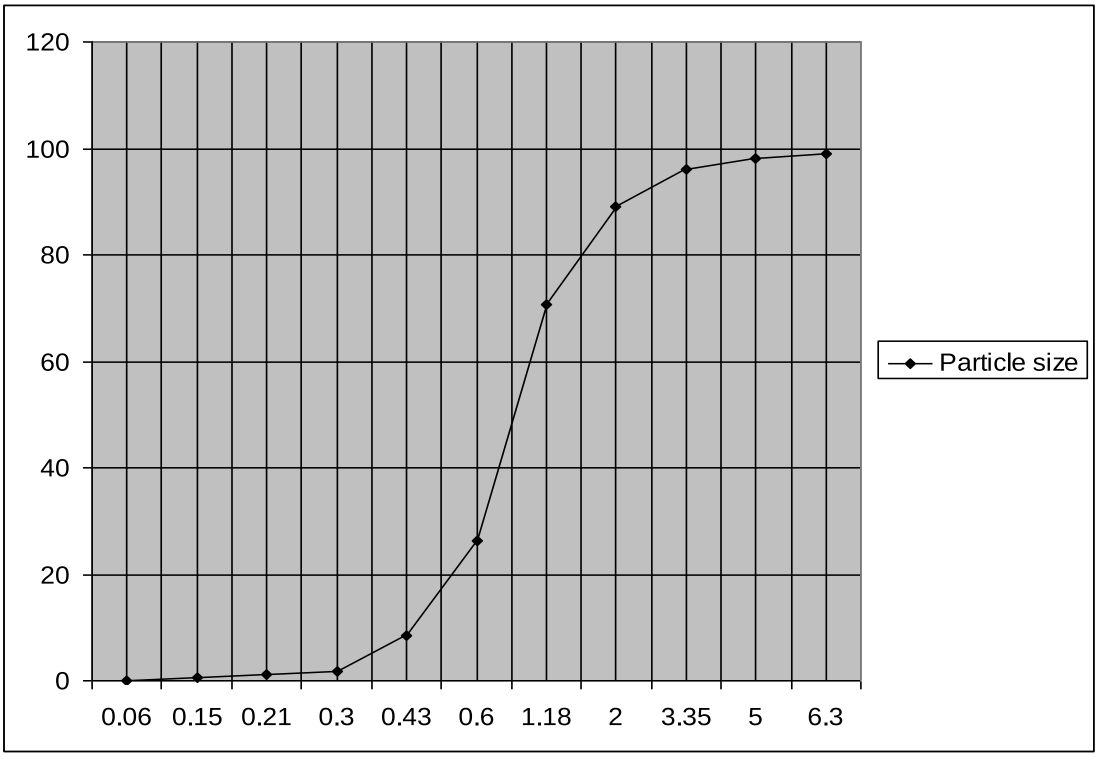
The Calcium oxide (CaO) - the major pozzolanic compound - was found to be 5.0% which is less than the value of 62.32% obtained for Burham cement. This implies that CHA is not as pozzolanic as Burham cement but exhibits slight pozzolanicity.

Particle Size Analysis

Table II shows the result of the particle size analysis performed on the sand sample, and the particle distribution curve is shown in Fig 1.

Table II: Particle Size Analysis of sand sample

Sieve Size [mm]	Weight of Sample Retained [g]	% of Sample Retained	% of Sample Passing
6.30	2.3	1.15	98.85
5.00	1.4	0.70	98.15
3.35	4.2	2.10	96.05
2.00	14.2	7.10	88.95
1.18	36.5	18.25	70.70
0.60	88.9	44.45	26.25
0.425	35.5	17.75	8.50
0.30	13.5	6.75	1.75
0.212	1.2	0.60	1.15
0.150	1.2	0.60	0.55
0.063	1.1	0.55	-



Particle size (mm)

FINE	MEDIUM	COARSE	FINE	MEDIUM
	SAND			GRAVEL

Fig. 1 *Particle size distribution curve*

The sand was obtained from natural source by dredging from the Ogun riverbed, Lagos, Nigeria. The results obtained complied with the grading limit of zone 1 and therefore are suitable for construction work.

Specific Gravity Test

Table III shows the result for the specific gravity test of CHA, OPC and sand. The specific gravity of CHA was found to be 2.17. This value is close to the value of 2.12 for Acha Husk Ash, and in [5] was reported a value of 2.13 for rice husk ash. The value is within the range for pulverized fuel ash (pfa), which is between 1.9 and 2.4 as reported in [6]. The value of the specific gravity of CHA is, however, less than the value for OPC, which is 2.90. Further, the specific gravity of sand was found to be 2.67. The value obtained falls within the limit for natural aggregates with value of specific gravity between 2.6 and 2.7 as reported in [6].

Table III Specific Gravity of CHA, OPC and Sand

	CHA	OPC	Sand
Mass of density bottle, sample and water (m_3) [g]	92.0	91.4	89.7
Mass of density bottle and sample (m_2) [g]	52.2	48.2	47.2
Mass of density bottle and water (m_4) [g]	81.2	78.3	77.2
Mass of density bottle (m_1) [g]	32.2	28.2	27.2
$(m_2 – m_1)$ [g]	20.0	20	20.0
$(m_4 – m_1)$ [g]	49.0	50.1	50.0
$(m_3 – m_2)$ [g]	39.8	43.2	42.5
$(m_4 – m_1)$ - $(m_3 – m_2)$ [g]	9.2	6.9	7.5
Specific gravity of the particles $G_s = (m_2 - m_1)/((m_4 - m_1) - (m_3 - m_2))$	2.17	2.90	2.67

Bulk Density Test

Table IV shows the result of the un-compacted bulk densities of CHA, OPC and sand. The un-compacted bulk density of Coconut Husk Ash (CHA) was found to be 553.4 kg/m^3 while a value of 1422.9 kg/m^3 was obtained for OPC which indicates that CHA is lighter than OPC. A compacted bulk density of 740 kg/m^3 was obtained for Acha Husk Ash, and a value of 460 kg/m^3 was obtained for Rice Husk Ash as reported in [5].

Test result indicates that these materials are lightweight materials. Bulk density depends on how densely the particles are packed. The Silica in pozzolanas can only combine with Calcium Hydroxide when it is in a finely divided state. Pozzolana in this state have uniform particles which cannot be packed very closely consequently leading to a low un-compacted bulk density.

Table IV: Bulk Density of CHA, OPC and Sand

Un-compacted Bulk Density	CHA	OPC	Sand
Weight of empty cylinder (w_1) (kg)	14.2	14.2	14.2
Weight of empty cylinder + weight of loose materials (w_2) (kg)	15.6	17.8	17.7
Weight of loose materials (w_3) (kg)	1.4	3.6	3.5
Volume of Cylinder (V) (m^3)	0.00253	0.00253	0.00253
Un-compacted Bulk density (w_3/V) (Kg/m^3)	553.4	1422.9	1383.4

The un-compacted bulk density of the sand was found to be 1383.4 kg/m^3. This value is reasonably close to the value given for bulk density before excavation for sands and sandy soils which ranges from 1650 kg/m^3 to 1850 kg/m^3 as reported in [5]. The difference in these values is due to sample disturbance.

CONCLUSIONS

From the various tests conducted on CHA/OPC samples as presented in the various sections, the following conclusions are made:

- The Coconut Husk Ash (CHA) produced by burning the husk in a gas kiln is slightly pozzolanic and therefore might be suitable as a partial replacement for Ordinary Portland Cement (OPC) in non-load bearing sandcrete block production;
- The Specific gravity and Un-compacted bulk density of Coconut Husk Ash (CHA) were found to be 2.17 and 553.4 Kg/m^3 respectively;
- Coconut husk is available in significant quantities as a waste product, hence if utilized for construction purposes would go a long way in reducing the quantity of wastes in our environment.

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