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Effect of Guinea Corn Husk Ash as Partial Replacement for Cement in Concrete

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Abstract: *This paper reports an investigation on Guinea Corn Husk Ash (GCHA) as partial replacement of Ordinary Portland Cement (OPC) in concrete. The percent replacement levels by weight were 5%, 10%, 15%, 20% and 25% in 1:2:4 concrete mix with 0.65 water - cement ratio. The chemical constituents of the GCHA were* SiO_2 *(78.19%),* Al_2O_3 *(1.36%),* Fe_2O_3 *(0.84%), CaO (3.34%), MgO (3.76%),* K_2O *(7.67%),* $P_2 O_5$ *(2.95%) and* Na_2O*,* TiO_2*, SrO, Cl, MnO,* $S0_3$ *in trace quantities. Since* SiO_2*,* Al_2O_3*, and* Fe_2O_3 *have a combined constituent percent in excess of 70% (i.e. 80.39%), GCHA meets the requirement of a pozzolana in accordance the relevant standards. The GCHA concrete gave compressive strength in the range of 9.5* N/mm^2 *for 25% ash and 26.3* N/mm^2 *for 5% ash at 28 days curing period. The 5% value was higher than that of plain concrete which was 25.5*N/mm^2*. The trend shows that 10% GCHA should not be exceeded for a competitive value for compressive strength. The density of GCHA-cement concrete slightly reduced with increase of GCHA, for example it reduced by 2.27% for 25% ash at 28days curing. However it slightly increased at 5% replacement level again. Further work on the Water Absorption Capacity, permeability and durability parameters of GCHA-cement concrete is recommended.*

Keywords*: Cement, Guinea Corn Husk Ash, Pozzolana, Compressive strength*

I. Introduction

The high cost of cement remains a big challenge to affordable housing for many. The Nigerian government recently launched a Mortgage Refinance scheme to produce ten thousand houses for its citizens [1]. A way out is replacing a proportion of cement in concrete with cheap and available pozzolanic materials from agro wastes. The analysis of the Guinea Corn Husk Ash (GCHA) showed that a combination of its chemical constituents qualified it as a pozzollana [2]. Pozzolanas are "siliceous or siliceous and aluminous material which in themselves have little or no cementitous properties but in finely divided form and in the presence of moisture they can react with calcium hydroxide (CaO) which is liberated during the hydration of OPC at ordinary temperatures to form compounds possessing cementitous properties" [3]. Lea [4] further reported thus: "Pozzolana have the characteristics of combining with the free lime liberated during the hydration process of OPC to produce stable, insoluble calcium silicates thus reducing the process of mortar and concrete attacks from sulphates, salts and chlorides. Pozzolana can be divided into two groups: natural Pozzolana such as volcanic ash and diatomic and artificial Pozzolana such as calcite clay, pulverized fuel ash and ash from burnt agricultural wastes such as rice husk, guinea corn husk and locust bean husk. The addition of Pozzolana in either a lime or OPC based product has a number of advantages: the costs of Pozzolanas are usually low and certainly well below that of lime or OPC. Also, Pozzolanas like fly ash, rice husk ash and ground granulated blast furnace slag have been found to contribute to improvement of concrete performance (for example; high strength, high durability and reduction of heat of hydration) as well as reduction of energy and carbon dioxide generated in the production of cement [5]. Extensive work has been carried out on Rice Husk Ash (RHA) - cement composites: In a paper presentation [6], it was shown that at w/c ratio of 0.30 and OPC replacement of 20%, RHA mortar resulted in higher compressive strength compared to the control for both water cured and uncured cubes, and improvements in durability properties. Equally, according to another report [7], at 20% RHA replacement level, compressive strength and porosity of cement mortar showed better result over plain mortar.

According to a paper [8], the optimum RHA replacement level was 15% in concrete blocks. However, 10% RHA replacement level was reported as the optimum strength for cement paste in another one [9]. Also the presence of RHA and cement kiln dust in cement pastes improved the resistance of the mortar to sulfuric acid attack [10].

In the case of Palm Kernel Shell Ash (PKSA) Concrete, it was reported that the compressive strength did not exceed that of plain concrete. The results showed that 10% of the PKSA in replacement for cement was 22.8 N/mm^2 at 28 days [11].

Guinea corn is an important food crop produced in large quantity in the savannah belt of Nigeria and West Africa. It ranks amongst the three major grain crops growing particularly in the northern states of Nigeria. Guinea corn is mostly harvested and processed manually for food, leaving the large volume of residue constituting waste in the farm, most of which are flared off in preparation for subsequent farming season. Plates 1 and 2 at the end of the paper show in closer details the Guinea corn fruit at harvest, comprising the seed, husk and straw. Plate 3 shows the mass harvest by the local people when separated from the straw.

The Guinea corn or sorghum residue like any other organic waste is heterogeneous varying in bulk density, moisture content, particle size and distribution depending on the mode of handling. It is usually of low bulk density with high moisture content of up to 40% when harvested from the farm in partially dried form. The residue ranges from light brown to dark brown colour in the dry form. The particles have a high glossy/lustrums spikelet, very discrete but less particulate in texture.

This paper presents an investigative study in determining the chemical composition of GCHA and the compressive strength of concrete made from partial replacement of cement with GCHA at 5% to 25% replacements. The cube samples were cured for 7, 14, 21 and 28days respectively before crushing. Preliminary engineering properties like density and consistency were also determined.

II. Materials and Methods

All the materials used for experiment were procured from the immediate environment. The relevant standards were used in the conducting the experiments.

2.1 Materials

The materials for this study included Sand, Cement, Guinea Corn Husk Ash (GCHA) and water. Guinea Corn husk was obtained from Bullun village in Kafin Madaki, Ganjuwa Local Government Area of Bauchi State, Nigeria. It constituted a large part of the post harvest wastes from guinea corn processing. They are usually piled up in heaps after the guinea corn seed is extracted and later burnt or fed to livestock by the locals.

The sand was obtained from Bayara River near Bauchi town. The OPC was procured from Ashaka Cement Works in Gombe state of Nigeria. Samples of Guinea Corn Husk (GCH) collected were burnt up to 600^0C using a kiln fuelled by kerosene at the Industrial Design Programme of the Abubakar T/Balewa University Bauchi. The ash was allowed to cool before grinding to a very fine texture and then allowed to pass through 212 microns sieve.

2.2 Chemical Analysis of GCHA

The GCHA was analyzed to determine its suitability as a pozzolana. The chemical analysis was conducted at the Lafarge Cement Plant in Ashaka, Gombe State, Nigeria. The Atomic Absorption Spectrometer (AAS) was used for the analysis.

2.3 Workability Tests of the wet GCHA-Cement Concrete

The Compacting factor test was conducted in accordance with British Standard BS 1881: Part 103 [12]. Slump test was also conducted using the relevant cone for measurements. The tests were conducted in accordance with British Standards [13].

2.4 Compressive Strength Test

The compressive strength test was conducted in accordance with British Standards [14]. The 1: 2: 4 mix ratio was adopted. The ratio was that of OPC (with levels of GCHA), fine aggregate and coarse aggregate. The cubes were cast for replacement levels of 0%, 5%, 10%, 15%, 20%, and 25% and cured for 7 days, 14 days, 21 days and 28 days respectively. For each mix, 3 cubes were crushed to obtain the average strength. The compressive strength is the ratio of the weight of cube and the cross sectional area.

2.5 Density Test

This was carried out before crushing of the cubes. At the end of each curing period, the mortar cubes were weighed using an electric weighing machine balance. Density is calculated as mass of mortar cube (kg) divided by volume of mortar cube (m^3) and expressed in kg/m^3.

III. Results and Discussion

3.1 Chemical Analysis

The result of the chemical analysis showing the chemical composition of GCHA is presented in Table 1 and Fig. 1. The total combined content of silica, alumina and ferric oxides was 80.374%. ASTM C618 [15] specifies that any pozzolana that will be used as a cement blender in concrete requires a minimum 70% of combined silica, alumina and ferric oxides. Hence GCHA is very suitable as a pozzolana. Also the very low SO_3 content of 0.494% is far from the maximum acceptable content of 5% specified in the same ASTM C618. The SiO_2 percent composition of 78.126 is higher than all the values derived from pozzolanas earlier reviewed in a

Report [16]. These were Acha Husk Ash (AHA), Bambara Groundnut Husk Ash (BGHA), Bone Powder Ash (BPA), Groundnut Husk Ash (GHA), Rice Husk Ash (RHA) and Wood Ash (WA). Also the CaO percent of 3.338 was higher than 0.84, 1.70 and 1.36 obtained from Acha Husk Ash (AHA), Groundnut Husk Ash (GHA) and Rice Husk Ash (RHA) respectively. These are all grown within the same environment. This quality has the potential of giving up GCHA as a better pozollana for concrete. It however exhibited that quality optimally at 5% replacement.

3.2 Workability

The result of the Compacting factor test is shown in Table 2 and Fig. 2. The values increased with the increase of the proportion of the GCHA content and peaking at 15% content. This further confirmed the GCHA as possessing pozzolana property. The Compacting factor values can be categorized as low (0.85) and medium (0.92) in accordance with European Standard [17].

The Slump test results are also in Table 2 and Fig. 2.The slump values increased with increase in GCHA proportions except at the 5% replacement. All the values fall within the medium range of slump (35mm – 75mm) in accordance with BS 1881 [18]. According to ENV 206 [19], only the 5% replacement was in the S1 classification (10mm – 40mm) while the remaining were in the S2 classification (50mm – 90mm).

3.4 Compressive strength of the GCHA-cement Concrete

The results of the compressive strength test is shown in Table 3 and presented graphically in Fig. 3. The compressive strength decreased as percentage ash increased, however the 5% GCHA replacement concrete presented an exception. The strength value increased over the plain concrete before decreasing at the other higher replacement levels. It is apparent that a 5% replacement level will produce the optimum strength. However the trend of the compressive strength shows that replacing cement with more than 10% GCHA will not give required strength for strong concrete that is capable of bearing heavy load. Reports on Corn Cob Ash (CCA) Cement Concrete [20] on the effect of admixtures, showed that compressive strength improved by 9.99% with accelerator, by 29.1% with plasticizer and by 14.2% with water reducer and retarder.

3.5. Density of the GCHA-cement Concrete

The results of the density test are shown in Table 4 and Fig. 4. The densities slightly decreased as ash percentage increased especially at 21days and 28days curing periods. However 5% GCHA presented higher density over plain concrete, thereby once more signifying the optimum strength derivable at that replacement level. Specific gravity of GCHA was 1.76

IV. Conclusion

Guinea corn husk was burnt up to 600^0C using a kiln. The ash was allowed to cool, then grinded and sieved. The chemical analysis of the ash gave favourable result for use as pozzolana.

The GCHA was used to replace cement at 5% - 25% levels. The consistency of the wet mixes fell within the low and medium classifications. The Compressive strengths declined with increase in GCHA levels except for the 5% level that presented a marked increase, thereby suggesting that the best mix for strength is that of 5% level. The density values showed similar trend though with far lower drop at values beyond the 15% level. It can conveniently be concluded that the GCHA is a good pozzolana for concrete and at 5% - 10% optimum replacement levels can produce very strong concrete. Admixtures may be added to improve performance and further work on parameters like setting times, water absorption capacity, permeability, durability on concrete and mortars made from GCHA replacements is suggested.

Table 1: Chemical Composition of GCHA

Constituent	% by weight
SiO_2	78.192
Al_2O_3	1.345
Fe_2O_3	0.837
CaO	3.338
MgO	3.757
SO_3	0.494
K_2O	7.674
Na_2O	0.249
$P2O_5$	2.946
Mn_2O_3	0.081
TiO_2	0.180
Cl	0.061
Cr_2O_3	0.000
SrO	0.020

Table 2: Workability Results of wet GCHA-cement Concrete

Workability	% Replacement					
	0	5	10	15	20	25
Compacting Factor	0.77	0.87	0.93	0.93	0.88	0.89
Slump (cm)	4.80	3.60	5.00	5.80	6.30	4.90

Table 3: Compressive Strength of the GCHA-cement Concrete (N/mm^2)

Curing period (Days)	GCHA Content (%)					
	0	5	10	15	20	25
7	11.45	14.96	11.41	9.85	7.98	6.01
14	18.52	20.00	15.70	10.86	6.12	6.90
21	24.0	24.33	18.43	12.33	8.25	8.47
28	25.5	26.27	23.51	13.93	9.70	9.51

Table 4: Densities of the GCHA-cement Concrete (Kg/m^3)

Curing period (Days)	GCHA Content (%)					
	0	5	10	15	20	25
7	2439	2514	2475	2399	2391	2388
14	2428	2534	2423	2382	2377	2377
21	2439	2402	2391	2391	2387	2381
28	2428	2432	2399	2393	2389	2376

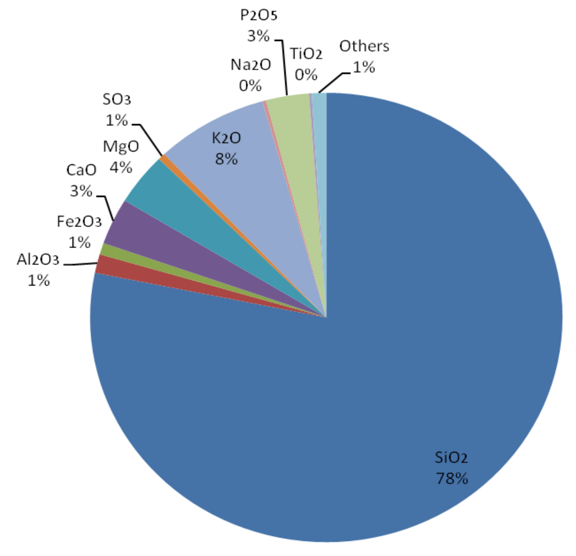

Fig. 1: Percent Chemical constituents of GCHA

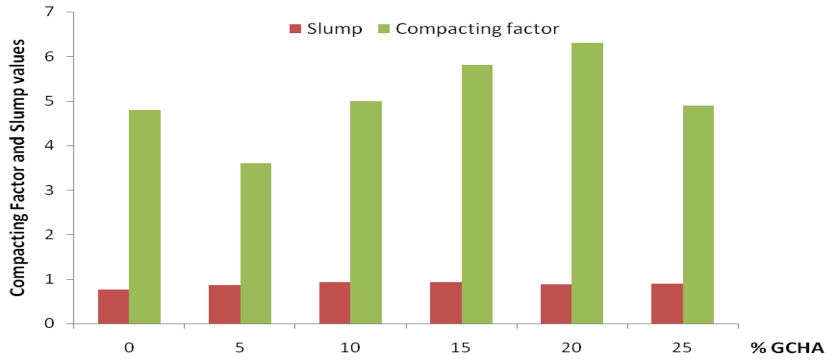

Fig. 2: Compaction Factor and Slump Results of GCHA-cement Concrete

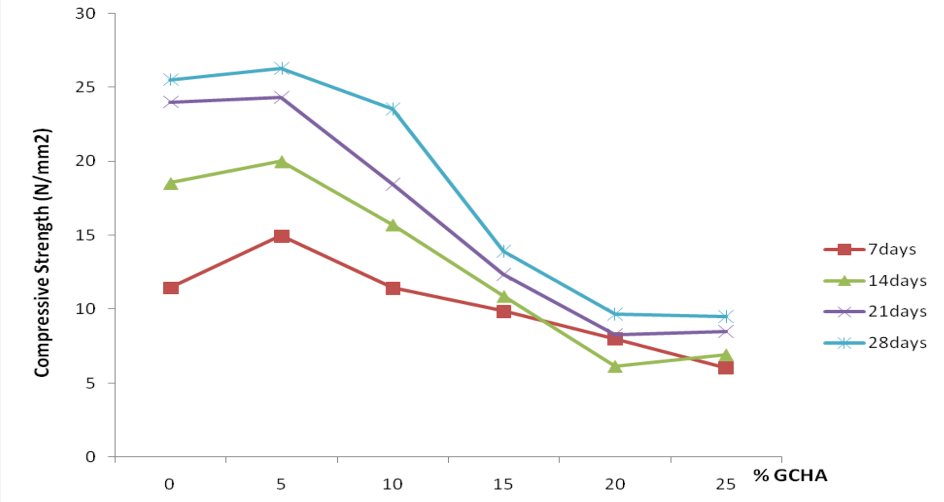

Fig.3: Compressive Strength of GCHA-cement Concrete

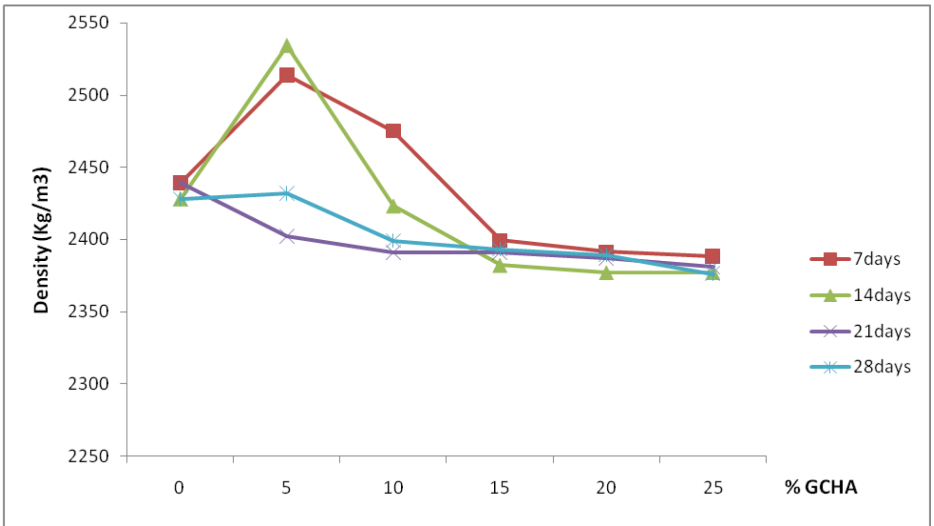

Fig.4: Density of GCHA-cement Concrete

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Appendix

Plate 1: A bunch of harvested Guinea corn

Plate 1: Guinea corn fruit showing the seed (white) and husk (brown)

Plate 2: Guinea corn separated from the Husk and Straw (around the corn)