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Effect Of Particle Size Of Groundnut Husk Ash (Gha) In Cement Paste And Mortar

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Abstract--This paper presents an investigation on the effects of particle size of Groundnut Husk Ash (GHA) in cement paste and Mortar as a supplementary cementing material. The GHA used was obtained by controlled burning of groundnut husk to a temperature of 600 ^{o}C and sieved through sieve 425, 150 and 75 µm, respectively after allowing cooling, and characterized. The effects of particle size distribution of GHA in cement paste and Mortar was investigated at 10 % replacement by weight of cement. A total of sixty 40 mm x 40 mm x 160 mm GHA-Mortar prisms made with 1 : 3 (cement : sand) and 0.5 water-cement ratio were tested for flexural and compressive strengths at 3, 7, 28, 60 and 90 days of curing. The results of the investigations showed that GHA was of low reactivity, with a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 26.06 %. The consistency of GHA-Cement pastes decreased, while shrinkage increased with more fine GHA particle size distribution, where as there was no significant relationship between setting time and particle size of GHA. The flexural and compressive strengths of GHA mortar increased with increase in fine GHA particle size and the finest particle size distribution of GHA used was the most suitable for use as partial substitute to cement

Ke words: *Groundnut Husk Ash, Particle Size, Cement Paste, Mortar*

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INTRODUCTION

The manufacture of Portland cement is the third largest carbon dioxide (CO_2) producer and accounts for over 50 % of all industrial CO_2 emissions (for every 1 ton of cement produced, 1.25 tons of CO_2 is released in the air) and 1.6 tons of natural resources is consumed to produce 1 ton of cement [1]. This indicates that cement manufacture is not environmentally friendly and is expensive. This calls for the use of sustainable binders such a pozzolanas which have been identified as cheaper supplementary cementing materials fundamental to advancing low cost construction materials with the main benefits of saving natural resources and energy as well as protecting the environment through the use of the main mineral admixtures [2]. According to [3], the use of various ashes as potential replacement of cement in mortar and concrete production has attracted the attention of researchers because of its potential to reduce or totally eliminate the classification of ashes as waste materials polluting the environment and also reduce the quantity and consequently the cost of cement applied in concrete works. Apart from the cost benefit of use of pozzolanas with Ordinary Portland cement, they enhance the properties of mortar and concrete [4].

Groundnut husk is a waste from groundnut pod which is usually burnt, dumped or left to decay naturally. It constitutes about 25 % of the total pod (husk and seeds) mass [5]. Due to the growing environmental concern and the need to conserve energy and resources, efforts have been made to properly burn the ash and to examine the ash so produced with a view to utilizing it for useful purposes. For instance, [6], [7] and [8] have reported on the use of Groundnut Husk Ash (GHA) as a supplementary cementing material in concrete. They indicated that GHA is of low reactivity, and the combined content of oxides of silicon, aluminium and iron was less than the minimum of 70 % required of a good pozzolana [9]. They also suggested that up to 10 % GHA content could be used as a partial substitute of cement in structural concrete. Reference [10] also studied the durability of GHA-Concrete exposed to acidic environments. Their report suggested that GHA improved the resistance of concrete exposed to sulphuric acid environment, but not in nitric acid. However, the research on influence of GHA in concrete so far reported does not include the effect of particle size of GHA on the properties of mortar or concrete. This paper therefore sets out to investigate the effect of particle size distribution of GHA on the properties of cement paste and mortar.

MATERIALS AND METHODS

MATERIALS

Ordinary Portland cement (Dangote brand), with a specific gravity of 3.14 was used. The chemical composition analysis of the cement is shown in Table 1.

Sharp sand from river Challawa, Kano, Nigeria, with a specific gravity of 2.62, bulk density of 1899.50 kg/m^3, moisture content of 2.50 % was used. The particle size

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distribution of the sand shown in Fig. 1, indicate that the sand used was classified as zone -1 based on [11] grading limits for fine aggregates.

Groundnut husk was sourced from Yakasai village, Kano State, Nigeria. The Groundnut Husk Ash (GHA) was obtained by a two-step burning method [12], where the groundnut husk was burnt to ash and further heating the ash to a temperature of about 600 ^oC in a kiln and controlling the firing at that temperature for about two hours and the ash was allowed cooling before sieving using sieve 425, 150 and 75 µm, respectively.. The GHA is of specific gravity of 2.12, bulk density of 835 kg/m^3, moisture content of 1.60 % and grain size distribution is shown in Fig. 1. A chemical composition analysis of the GHA was conducted using X-Ray Flouresence (XRF) analytical method and shown in Table 1.

METHODS

TESTS ON CEMENT PASTE

Four mixes were used for the determination of consistency, setting times and drying linear shrinkage of GHA-Cement in accordance with [13]. Mix MFP-00 is the control mix containing 0 % GHA while Mixes MFP-01, MFP-02 and MFP-03, are mixes containing 10 % GHA passing through sieve 425, 150 and 75 µm, respectively. Three readings were taken for each mix of each test and an average found. The results are shown in Fig. 2 - 4.

Table 1: Oxide Composition of OPC (Dangote Brand) and GHA

Oxide (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	TiO_2	MnO	BaO
OPC	18.0	3.10	4.82	68.37	1.48	0.35	0.32	1.82	0.35	0.03	0.16
GHA	20.03	2.00	4.03	13.19	1.82	38.80	-	1.08	0.68	0.20	0.31
Oxide (%)	V_2O_5	P_2O_5	ZnO	Cr_2O_3	NiO	CuO	SrO	ZrO_2	Cl	L.o.I	
OPC	0.03	-	-	-	-	-	-	-	-	1.27	
GHA	0.03	1.90	0.08	0.03	0.01	0.10	0.20	0.22	0.26	8.02	

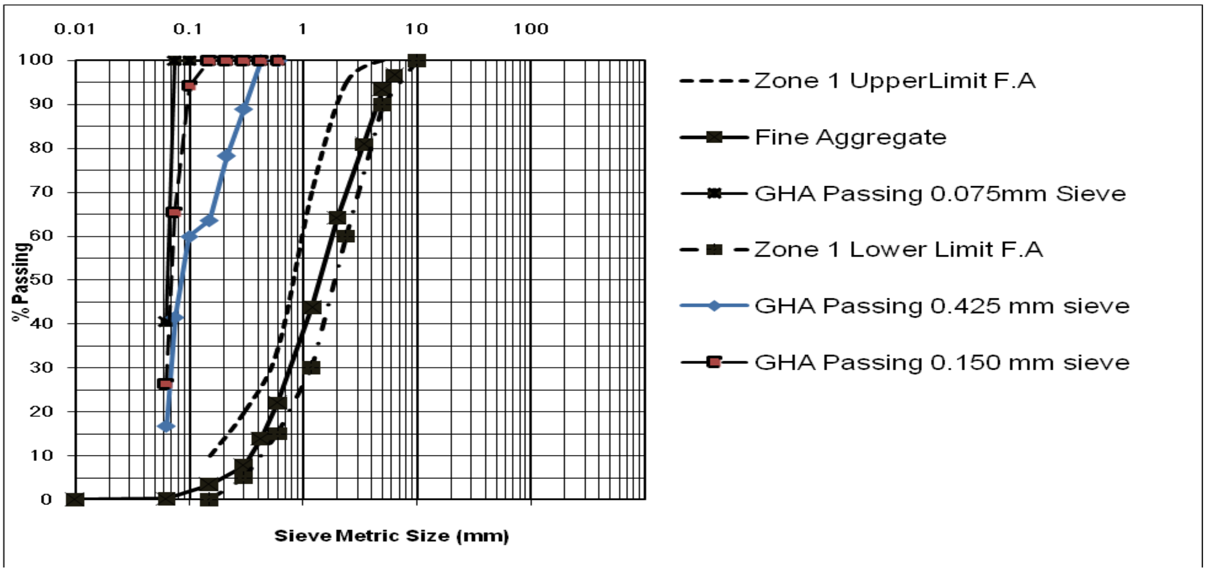

Fig. 1: Particle Size Distribution of GHA and River Sand

TESTS ON GROUNDNUT HUSK ASH (GHA)-MORTAR

Mortar of 1: 3 (GHA-Cement: Sand) mix with a water-cement ratio of 0.5 was used to prepare 40 mm x 40 mm x 160 mm prism specimens to determine the Flexural and Compressive Strengths of GHA-Mortar cured in water for 3, 7, 28, 60 and 90 days. Four mixes were used, MF-00 is the control mix and MF-01, MF-02 and MF-03 are mixes containing 10 % GHA passing through sieve 425, 150 and 75 µm, respectively. The Flexural Strength test was conducted in accordance with [14]. A total of sixty (60) prisms were cast and tested in triplicate for an average for each curing regime using the Avery Denison Universal Testing Machine of 600 kN load capacity at a rate of loading of (50 ± 10) N/s.

Samples of 40 mm x 40 mm x 40 mm were prepared from the crushed samples (half prisms) from the flexural strength test and tested for compressive strength using the Avery Denison Universal Testing Machine. The results of flexural strength and compressive strength are shown in Fig. 5 and 6, respectively.

ANALYSIS AND DISCUSSION OF RESULTS

GROUNDNUT HUSK ASH (GHA)

The grain size distribution of GHA obtained by sieving through 425, 150 and 75 µm sieves, respectively shown in Fig. 1 indicate that GHA obtained through 425 and

150 µm sieves, are of coarse grains with only 41.6 and 65.41 %, respectively passing 75 µm sieve size recommended in [9] for use for pozzolanas. The physical properties of GHA showed that it has a specific gravity of 2.12 and a Loss on Ignition (LoI) value of 8.02 %, which is within [9] acceptable limit of 10 % for Class N pozzolana. This therefore indicated that the GHA was properly burnt. However, the chemical composition of GHA indicate a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 26.06 %, which is much lower than the minimum value of 70 % [9] for a good pozzolana, and would therefore be of low reactivity. The chemical composition of GHA also indicated a high K_2O content of 38.80 %, which is far higher than 1.2 % limit recommended in cement [15]. The high K_2O content may be a source of disruption in GHA-Mortar and concrete matrix. GHA also showed a CaO content of 13.19 %, which shows that it has some self cementing properties.

GROUNDNUT HUSK ASH (GHA)-CEMENT PASTE

The consistency of GHA-Cement paste for 10 % GHA replacement using GHA obtained through sieve 425, 150 and 75 µm, respectively (mixes MFP-01, MFP-02 and MFP-03) and control cement paste (MFP-00) indicated that consistency of GHA-Cement pastes were greater than that of control paste and increased with increase in sieve aperture as shown in Fig. 2. The normal consistency of cement paste was 30.0 % while that of GHA-Cement Pastes at 10 % GHA replacement using GHA obtained through sieves 425, 150 and 75 µm, respectively were 42, 40 and 35 %, respectively. This implied that there was decrease in water requirement of GHA-Cement paste with more fine GHA particle size distribution to achieve normal consistency. This behavior may be due to the more porous nature of coarse grains of GHA which absorb free water from the mix [16]. The higher water requirement for GHA-Cement paste above control may be due to high porosity as well as high LoI of GHA [17]. It may also be due to lower specific gravity of GHA than cement, that is, higher volume of GHA compared to OPC of same weight would require more water to form paste.

The setting times of GHA-Cement pastes shown in Fig. 3 showed that there was no significant relationship between setting time and particle size distribution of GHA. The initial setting times of GHA-Cement paste for 10 % GHA replacement using GHA obtained through sieve 425, 150 and 75 µm, respectively were constant at 47 minutes as shown in Fig. 3, as opposed to that of control paste of 46 minutes. The final setting times of the GHA pastes ranged from 600 – 604 minutes, as against 554 minutes for control paste. Thus, GHA-Cement paste at 10 % GHA extended setting times of cement paste, and would be useful as a retarder suitable for use in hot weather concreting, as well as in mass concreting and long haulage of ready mix concrete. The delay in setting times of GHA-Cement paste was due to lower cement content and slower pozzolanic reaction of GHA [18] and [19].

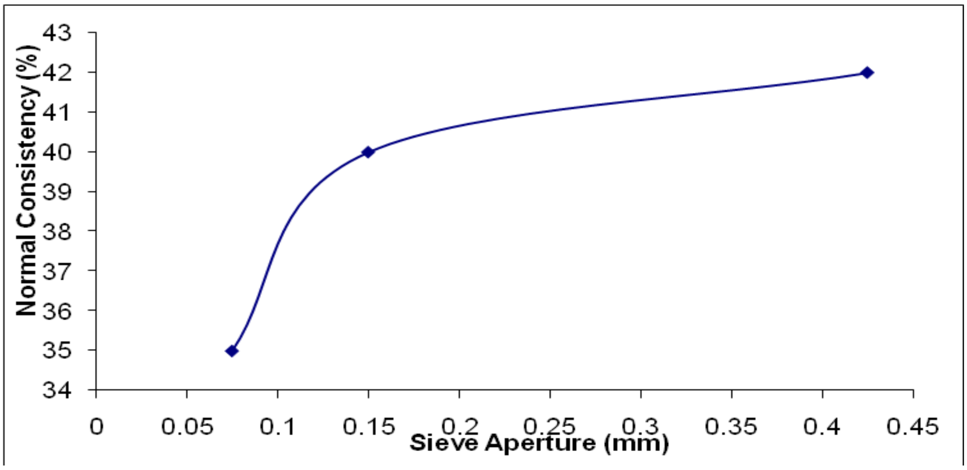

Fig. 2: Consistency of GHA-Cement Paste of GHA Passing Through Different Sieve Aperture

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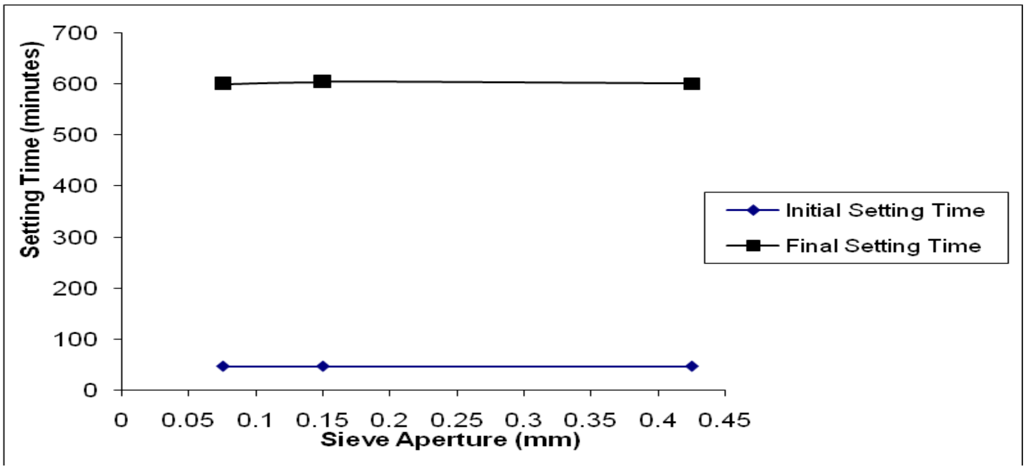

Fig. 3: Setting Times of GHA-Cement Paste of GHA Passing Through Different Sieves Aperture.

The linear shrinkage of GHA-Cement Paste at 10 % GHA of the three GHA mixes (MFP-01, MFP-02 and MFP-03) and that of control (MFP-00) shown in Fig. 4, indicated that shrinkage increased for GHA-Cement paste with more fine GHA particle size distribution. The increase in shrinkage may be due to pore refinement of the matrix and may also be due to higher porosity of coarse particles of GHA which absorb more water than cement and finer GHA particles, leading to reduced shrinkage [1] and [20]. It was however observed that the shrinkage of finer GHA was same as that of control.

FLEXURAL STRENGTH AND COMPRESSIVE STRENGTH OF GHA-MORTAR

The flexural strength and compressive strength of GHA mortar at 10 % replacement using GHA obtained through sieve 425, 150 and 75 µm, respectively, shown in Fig. 5 and 6, respectively showed that there was increase in strength with more fine GHA particle size distribution (Mixes MF-01 to MF-03) consistent with [1] report on fineness of RHA in concrete.

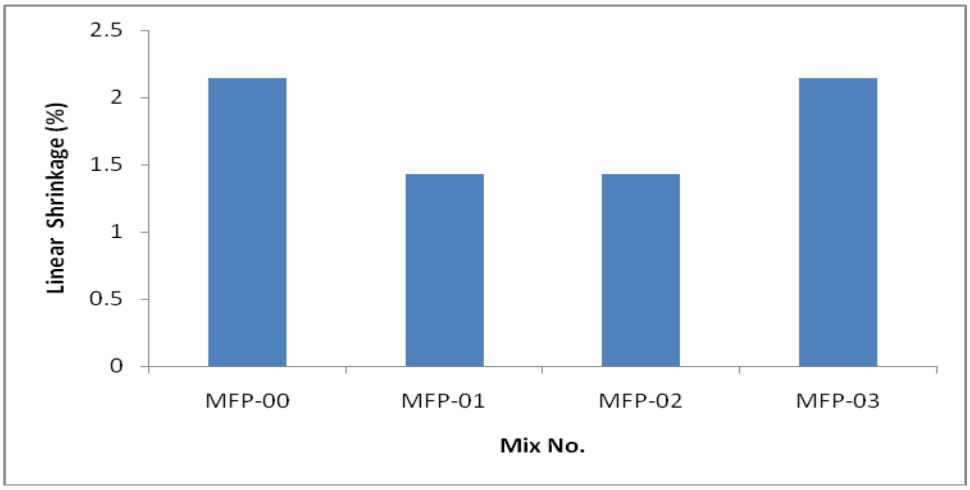

Fig. 4: Drying Linear Shrinkage of GHA-Cement Paste of GHA Passing Through Different Sieves Aperture

The increase in strength with more fine GHA particles size distribution was more significant at early age up to 7 days of curing than at mature ages [21] and was due to increase in specific surface of the fine GHA particles. However, the 28 days strength of mortar at 10 % replacement with GHA of the different fineness was lower than control mortar (MF-00).

It was generally observed that the finest particle size of GHA used produced GHA-Cement Paste (MFP-03) and mortar (MF-03) with properties closely similar to that of control and could be considered as the best fineness of GHA for use as partial substitute to cement.

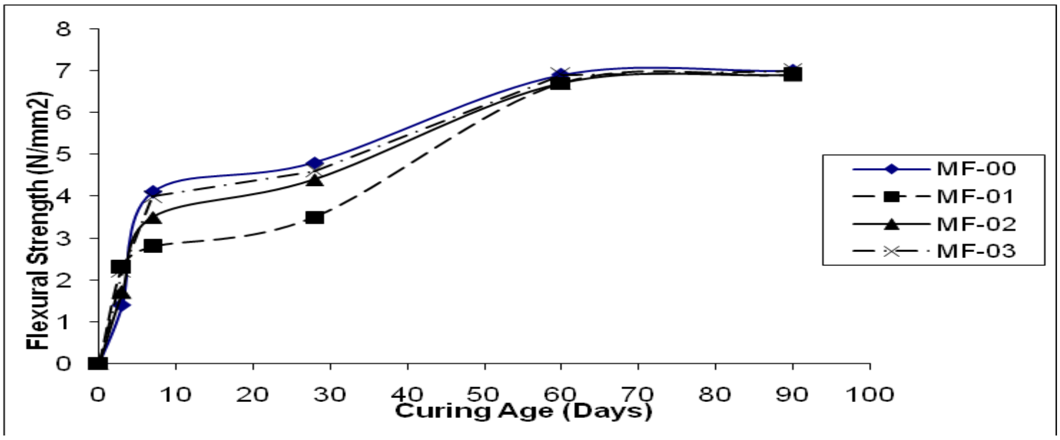

Fig. 5: Flexural Strength of GHA-Mortar of GHA Obtained Through Different Sieves

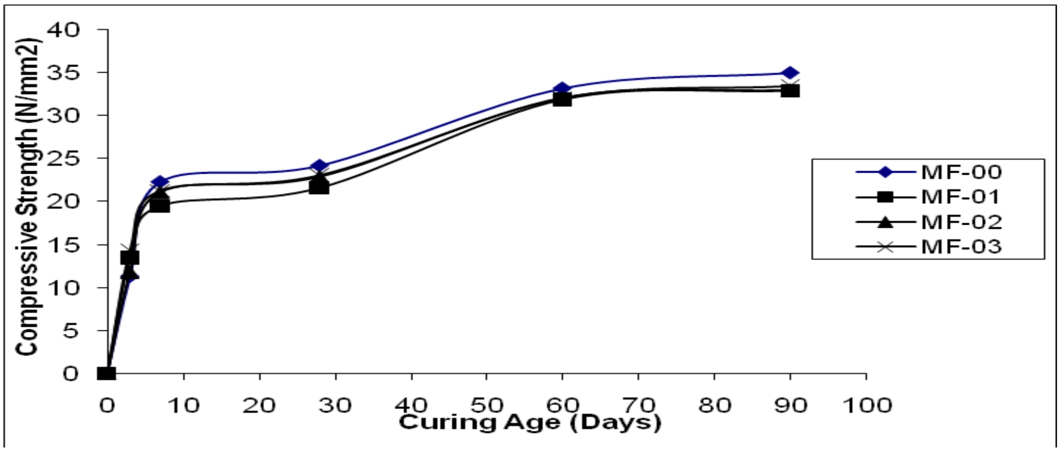

Fig. 6: Compressive Strength of GHA-Mortar of GHA Obtained Through Different Sieves

CONCLUSION

i. The GHA is of low reactivity, with a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 26.06 % which indicate that it does not satisfy the minimum value of 70 % (ASTM C618, 2008) for a good pozzolana.

ii. Consistency of GHA-Cement pastes were greater than that of control paste and decreased, while shrinkage increased with more fine GHA particle size distribution, where as there was no significant relationship between setting time and particle size distribution of GHA.

iii. The flexural strength and compressive strength of GHA mortar increased with more fine GHA particle size distribution.

iv. The finest particle size distribution of GHA used produced cement Paste and mortar with properties closely similar to that of control and could be considered as the best fineness of GHA for use as partial substitute to cement.

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