GROUND NUT HUSK ASH (GHA) AS A PARTIAL REPLACEMENT OF CEMENT IN MORTAR

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ABSTRACT
This paper examines some properties of Ordinary Portland Cement (OPC) and Groundnut Husk Ash (GHA) mortar. The GHA was used as a partial replacement of OPC. The replacement levels of 0%, 2%, 4%, 6%, 8% *and 10% ash were used. The chemical analysis of the ash carried out ascertained its pozzolanic properties. The initial and final setting times of the paste were* 95 *minutes and* 11 *hours respectively. These are higher than* 45 *minutes and 10 hours respectively for plain OPC. The pozzolanic mortar gave compressive strength in the range of 3.45 N/mm^2 for 0% ash to* 2.69 *N/mm^2 for 10% ash at* 28 *days curing period surpassing the minimum strength of 2.5 N/mm^2 Specified for sandcrete blocks [I]. The density and water absorption capacity of the mortar decreased as the percentage of ash increased. OPC/GHA mortar is recommended for production of sandcrete blocks in hot weather climate. Further research on the permeability and durability are also recommended.*

1.0 INTRODUCTION

Efforts at mass housing delivery at affordable rates to low-income earners have not been successful due to the high cost of cement. A way out is replacing a proportion of cement with cheap and available pozzolanic materials. ASTMC618[2] defined pozzolana as siliceous or siliceous and aluminous materials 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 which is liberated during the hydration of Portland cement at ordinary temperatures to form compounds possessing cementitous properties". Pozzolanas 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[3]. By-products mineral admixtures such as fly ash, rice husk ash and ground granulated blast furnace slag 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 [4].

Groundnut is an important cash crop produced in large quantity in Nigeria. The production of ground nut reached its peak in Nigeria during the period of 1969 to 1971, when approximately 1.7 million tonnes of the pods were produced from an area of 1.8 million hectares[5]. The utilization of groundnut husk will promote waste management at little cost, reduce pollution by these wastes and increase the economic base of farmers when the waste is sold thereby encouraging more production.

This study investigated the engineering properties of groundnut husk ash as a material for mortar production. The results showed that the values of normal consistency increased as the percentage of ash increased. The initial and final setting times of the pozzolanic paste were 95 minutes and 11 hours respectively. This means that pozzolanas reduced the setting times of mortar when compared to ordinary Portland cement with values of 45 minutes and 10 hours respectively [6].

The results of the compressive strength test showed that the mortar was suitable for low cost housing. However, the trend showed that ash replacement level of more than 10% is not recommended. The results of water absorption showed reduction as the percentage of ash increased. Further research on the permeability and durability of pozzolanic mortar is recommended.

2.0 MATERIALS AND METHODS

The laboratory programme was designed to determine compressive strength, density and water absorption capacity of cement-GHA mortar. Parameters that affect strength such as GHA constituent, consistency and setting times were also determined.

Cement replacement levels of 2%, 4%, 6%, 8% and 10% by weight were investigated with 0% GHA as control. The control mix proportion (i.e. ratio of cement to sand) of 1:5 was adopted.

2.1 Materials

The materials for this study included sand, cement, groundnut husk ash and potable water. The sand was obtained from Bayara River near Bauchi town. The cement was Ashaka Brand produced in Gombe State, Nigeria. Groundnut husk was obtained from local groundnut oil mills in Bauchi metropolis. Samples collected were burnt up to 600^oC using a kerosene vaporization burner kiln at the Industrial Design Programme of the Abubakar Tafawa Balewa University, Bauchi. The temperature was monitored by a pyrometer until a required level was attained. 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 GHA

The ash was analyzed using Atomic Absorption Spectrometer (AAS) to determine its suitability as a pozzolana. The chemical analysis was conducted at the Geological Survey of Nigeria office at Barnawa, Kaduna.

2.3 Consistency and setting times of the Pozzolanic Paste

The vicat apparatus was used to determine the consistency and setting time of the pozzolanic paste in accordance with BS 12. The water cement ratio that gives a plunger penetration of 5 to 7mm above the bottom of the mould is the standard consistency. The Initial Setting Time (1ST) is the time taken from mixing with water until the paste has stiffened for the needle to penetrate not deeper than 5mm above the bottom of the mould. The Final Setting Time (FST) is determined by replacing the needle with annular attachment. The FST is the time from mixing with water to when the needle makes an impression on the surface but another cutting edge fails to do so.

2.4 Compressive Strength Test

The compressive strength test of the mortar cubes were performed using a mould of 50mm x 50mm x 50mm in accordance with ASTM C 109[7]. 72 cubes were cast for replacement levels of 0%, 2%, 4%,6%,8%, and 10% 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.

2.5 Density Test

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

Table 1: Chemical Analysis of GHA

Constituent	**S_1O_2**	**AL_iO_3**	**Fe_20_3**	**CaO**	**MgO**	**T_1O_2**	**MnO**	**P_2O_5**	**S**	**SO_3**	**L.O.1**	**Others**
% by weight	51.54	22.45	2.40	15.63	1.20	0.13	0.05	0.60	0.38	0.94	3.98	0.70

Note: L.O.I. denotes loss on ignition

2.6 Water Absorption Test

Water absorption test was conducted in accordance with BS 1881, Part 122 [8]. It was carried out in conjunction with compressive strength test. After 28 days of curing, the specimens were weighed and immersed in water. They were brought out and re-weighed at intervals of 1 day, 2 days, 3 days, 4 days, 5 days and 6 days when saturation point was achieved. The water absorption capacity was the increase in mass measured as percentage of dry mass.

3.0 RESULTS AND DISCUSSION

3.1 Chemical Analysis

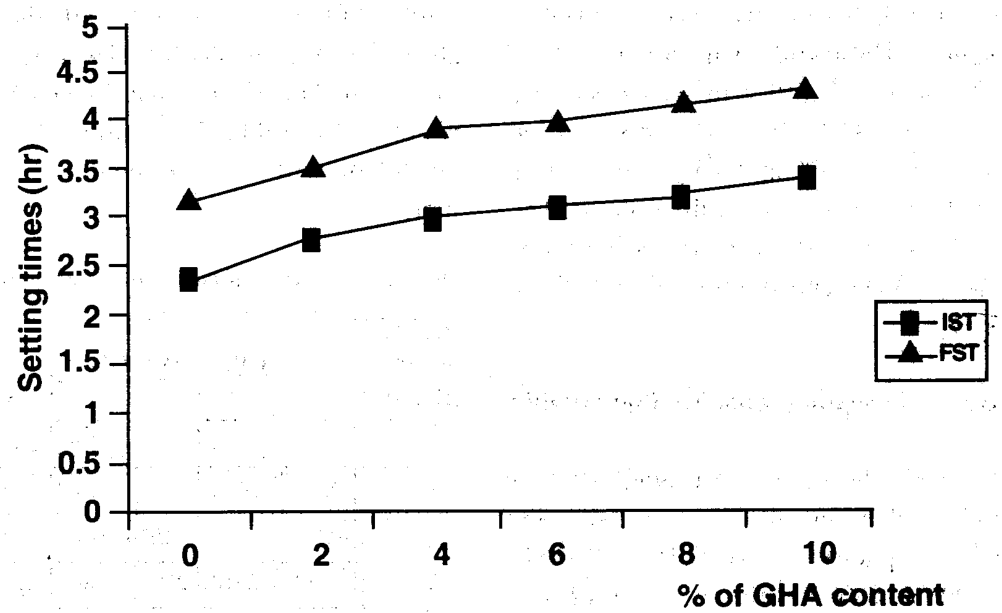
The result of the chemical analysis is shown in Table 1. The total combined content of silica, alumina and ferric oxides was 76.39%. ASTMC 618 [9] specifies that any pozzolana that will be used as a cement blender in concrete requires a minimum of 70% for silica alumina and ferric oxide. Hence GHA is suitable as a pozzolana. Also, SO_3 content of 0.94% met the maximum content of 5% specified in the same ASTMC 618. The ash was adjudged a suitable pozzolana.

3.2 Consistency and Setting Times of the Pozzolana Paste

The result of the standard consistency and setting times of the pozzolana paste are shown in Table 2 and Figure 1. The values of normal consistency increased with the increase of the proportion of the GHA content. This further confirmed the GHA as possessing pozzolanic property [10]. From the table, it is seen that the Initial Setting Time (IST) and Final Setting Time (FST) increased with increase in GHA content. This is because the more the ash content, the less the amount of tricalcium illuminate (C_3A) which is responsible for quick set and the more times required for pozzolanic paste to set. The value of the ISTs were 140 minutes, 165 minutes, 180 minutes, 188 minutes, 195 minutes and 206 minutes for 0%, 2%, 4%, 6%, 8%, and 10% respectively. But the IST for OPC is 4 minutes according to BS 12. This is 95 minutes more than the value for 0% ash content. If this difference were subtracted from the results, the IST of the pozzolanic paste *would* be 70 minutes, 85minutes, 93 minutes, 100 minutes and 111 minutes for 2%, 4%,6%,8%, and 10% respectively. The average IST is 95 minutes. The FSTs were 117 hours, 3.50 hours, 3.92 hours, 4 hours, 4.20 hours, and 4.33 hours for both 0%, 2%,4%, 6%,8%, and 10% ash respectively. The BS 12 specified 10 hours as final setting time of OPC. This is 6.83 hour less than the value for 0% GHA. If this difference were added to our result, the FST of the pozzolanic pastes would be 10.33 hours, 10.75 hours, 10.83 hours, 11.03 hours and 11.16 hours for 2%,4%,6%,8%, and 10% ash respectively. The average FST is 11 hours. It shows that pozzolanas reduced the setting times of the mortar. This is useful in hot weather concreting.

Table 2: Setting Times of the Pozzolanic Mortar

Ash Cement (%)	Initial Setting Time (IST)	Final Setting Time (FST)	W/C Ratio
0	2 hrs 20 mins	3 hrs 10 mins	0.31
2	2 hrs 40 mins	3 hrs 30 mins	0.33
4	3 hrs 00 mins	3 hrs 55mins	0.34
6	3 hrs 0.8 mins	4 hrs 00 mins	0.36
8	3 hrs 15 mins	4 hrs 12 mins	0.38
10	3 hrs 26 mins	4 hrs 20 mins	0.4



ı. 1: Setting Times of Pozzolanic Mortar.

3.3 Compressive strength of the pozzolanic mortar

The results of the compressive strength test' is shown in Table 3 and presented graphically in Figure 2. The compressive strength decreased as percentage of GHA ash increased. The highest strengths of 3.45 N/mm^2, 3.04 N/mm^2, *2.84 N/mm^2* and 2.69 N/mm^2 at 28 days curing periods were added for 0%, 2%, 4%, 6%, 8%, and 10% ash content respectively. The Nigerian Standards Organization specified a minimum compressive strength of 2.5 N/mm^2 for sandcrete blocks.

Therefore, the compressive strength of the pozzolanic mortar is adequate for block production. However, the trend of the compressive strength shows that replacing cement with more than 10% groundnut husk ash will not give required strength for block production.

Table 3: Compressive Strength of the Pozzolanic Mortar (N/mm^2)

Curing Period(Days)	Gha Content (%)					
	0	2	4	6	8	10
7	2.36	2.29	2.27	2.27	1.93	1.80
14	2.74	2.69	2.42	2.31	2:28	2.10
21	3.04	2.96	2.89	2.84	2.80	2.72
28	3.45	3.31	3.21	3.04	2.84	2.69

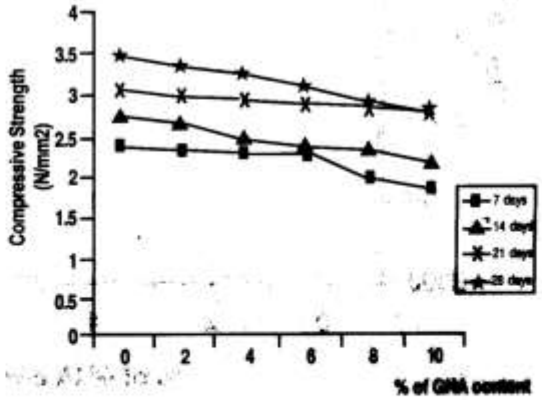


Fig. 2: Comressive Strength of Pozzolaic Mortar with different GHA Contents and Curing Days.

3.4 Density of the pozzolanic mortar

The density test results are shown in table 4 and Figure 3. The average densities of 2301kg/m^3, 2287kg/m^3, 2260kg/m^3, 2248kg/m^3, 2227kg/m^3 and 2152kg/m^3 were observed for 0%, 2%, 4%, 6%, 8% and 10% ash content respectively. The densities slightly decreased as ash percentage increased. This shows that as the higher the GHA content, the higher the weight of the mortar.

3.5 Water absorption capacity of pozzolanic mortar

The water absorption test results are shown in Table 5 and Figure 4. The average water absorption capacities were 9.41%, 9.19%, 9.06%, 8.61 %, 8.46% were observed for 0%, 2%, 4%, 6%, 8% and 10% ash at saturation point, which was on the sixth day. Water absorption capacity decreased as ash percent increased. This means that the GHA reduced water permeability. It is anticipated that the pozzolana will improve the durability of the mortar.

Table 4: Densities of a Pozzolanic Mortar (Kg/m^3)

Curing period (Days)	GHA Content (%)					
	0	**2**	**4**	**6**	**8**	**10**
7	2296	2276	2215	2208	2152	2144
14	2305	2286	2264	2260	2252	2168
21	2307	2272	2257	2236	2232	2164
28	2313	2310	2294	2287	2270	2133

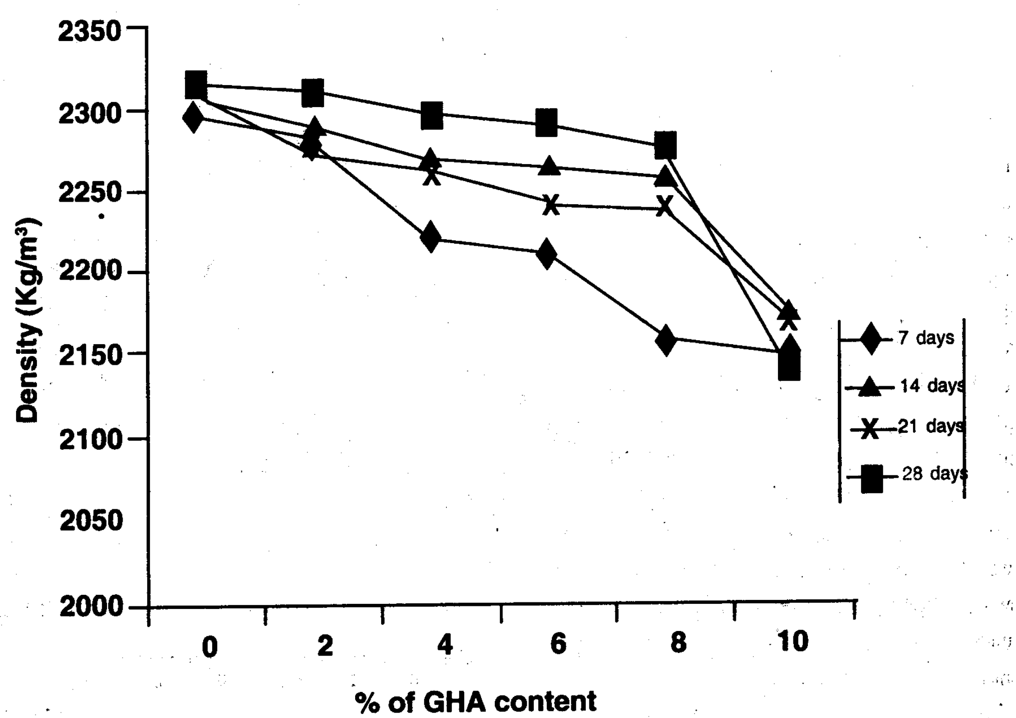


Fig. 3: Density of Pozzolanic Mortar with different GHA Contents and Curing Days.

Table 5: Water Absorption Capacity of the Pozzolanic Mortar (%).

Curing period (Days)	GHA Content (%)					
	0	**2**	**4**	**6**	**8**	**10**
1	8.46	8.31	8.26	7.62	7.28	7.26
2	8.76	8.72	8.46	8.05	7.57	7.54
3	8.95	8.90	8.66	8.21	8.19	7.66
4	9.17	8.86	8.41	8.32	7.75	7.17
5	9.41	9.19	9.05	8.61	8.45	7.83
6	9.41	9.19	9.06	8.61	8.46	7.83

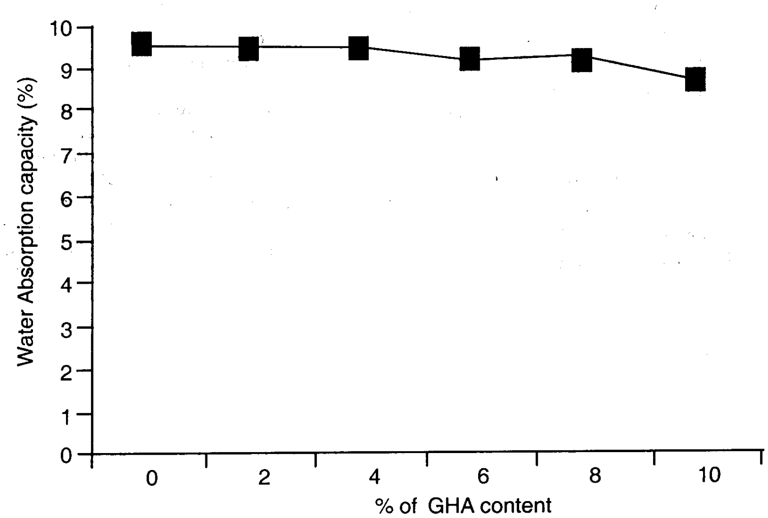


Fig. 4: Water Absorption Capacity of Pozzolanic Mortar.

4.0 CONCLUSION

Groundnut husk was burnt up to 600°C using a kerosene vaporization burner. The ash was allowed to cool, then grounded and sieved through 212 microns sieve. The chemical analysis of the ash gave favourable result for use as pozzolana.

The GHA was used to replace cement. The replacement levels of 0%, 2%, 4%, 6%, 8%, and 10% were used. The mix proportion for the control mortar was 1:5 (ratio of cement to sand). The IST and FST of the pozzolanic paste were 95 minutes and 11 hours respectively. This means that the ash reduced the setting time of the mortar, which is useful in hot weather concreting. The compressive strengths were 3.31 N/mm^2 for 2 % and 2.69 N/mm^2 for 10% ash at 28 days curing period. These are above the specified minimum of 2.5N/mm^2 for sandcrete blocks. However, the trend of the results showed that substitution of more than 10% ash would give strength less than *2.5* N/mm^2 and is not recommended. The density decreased as the percentage of ash increased.This is because groundnut husk ash is lighter than concrete. The water absorption capacity also decreased with increasing ash content. It is anticipated that groundnut husk ash will improve the durability of mortars. There is need to conduct further research on permeability an durability of GHA mortar.

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