EFFECTS OF GROUNDNUT HUSK ASH (GHA) IN CEMENT PASTE AND MORTAR

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ABSTRACT

This paper presents the findings of an investigation on the effects 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 °C and sieved through 75 µm sieve after allowing cooling, and characterized. The effects of GHA on cement paste and mortar were investigated at replacement levels of 0, 5, 10, 20, 30 and 40 %, respectively by weight of cement. A total of ninety 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 SiO₂, Al₂O₃ and Fe₂O₃ content of 26.06 %. The drying shrinkage decreased, while consistency, initial and final setting times of cement paste increased with increase in GHA content, where as the flexural and compressive strengths of Mortar decreased with increase in GHA content. However, 10 % GHA replacement was considered as optimum for structural mortar.

Keywords: Cement, Effect, GHA, Mortar, Replacement.

1. INTRODUCTION

The construction industry is heavily reliant on the use of cement-based products (mortar and concrete) as major materials for buildings and other civil engineering works. The strength of mortar or concrete depends on the cohesion of the cement paste, its adhesion to the aggregate particles and to a certain extent on the strength of the aggregates [1]. This therefore indicates the very importance of cement in mortar or concrete production. However, in many developing countries, ordinary Portland cement is an expensive and sometimes scarce commodity and this has contributed to limit the construction of adequate housing in most of these countries. Reference [2] attributed the high cost of ordinary Portland cement to be largely due to the high cost of plant and high energy required in the production, and suggested that a viable means of reducing the cost of cement based
construction is by either reducing the energy costs in the burning of clinker or by increasing the production of pozzolanic cement and pozzolanas for the partial replacement of cement.

The development of supplementary cementitious materials is fundamental to advancing low cost construction materials to be used in the production of self-sufficient shelter especially in developing countries. 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 [3]. According to [1], apart from the cost benefit of use of pozzolanas with Ordinary Portland cement, they enhance the properties of mortar and concrete.

Groundnut husk is a waste from agricultural product which is usually burnt, dumped or left to decay naturally. It constitutes about 25% of the total pod (husk and seeds) mass [4]. However, [5] and [6] have earlier reported the use of Groundnut Husk Ash (GHA) as a supplementary cementing material in concrete. They indicated that GHA has a low silicon dioxide content, and the combined content of oxides of Silicon, Aluminium and iron was less than the minimum of 70% required of a good pozzolana [7]. They also suggested that up to 10% GHA content could be used as a partial substitute of cement in structural concrete. It is on this premise that this research sets out to further investigate the effects of GHA in cement paste and Mortar as a supplementary cementing material.

2. MATERIALS AND METHODS

2.1 Materials

Ordinary Portland cement manufactured in Nigeria as Dangote brand, with a specific gravity of 3.14 was used. The oxide composition 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/m³ and moisture content of 2.50% was used. The particle size distribution of the sand shown in Fig. 1, indicate that the sand used was classified as zone -1 based on [8] 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 [9], where the groundnut husk was burnt to ash and further heating the ash to a temperature of about 600°C in a kiln and controlling the firing at that temperature for about two hours and the ash was allowed to cool before sieving through a 75 µm sieve. The GHA is of specific gravity of 2.12, bulk density of 835 kg/m³, moisture content of 1.60% and grain size distribution is also shown in Fig. 1. A chemical composition analysis of the GHA was conducted using X-Ray Fluorescence (XRF) analytical method and also shown in TABLE 1.

| Table 1: Oxide Composition of OPC (Dangote Brand) and GHA |
|-----------------|-----------|-----------|-------|---------|---------|-------|-------|-------|
| Oxide (%)       | SiO₂      | Al₂O₃     | Fe₂O₃  | CaO     | MgO     | K₂O    | Na₂O  | SO₃   |
| OPC             | 18.0      | 3.10      | 4.82   | 68.37   | 1.48    | 0.35   | 0.32  | 1.82  |
| GHA             | 20.03     | 2.00      | 4.03   | 13.19   | 1.82    | 38.80  | -     | 1.08  |
| Oxide (%)       | V₂O₅      | P₂O₅      | ZnO    | Cr₂O₃   | NiO     | CuO    | SrO   | ZrO₂  |
| OPC             | 0.03      | -         | -      | -       | -       | -     | -     | -     |
| GHA             | 0.03      | 1.90      | 0.08   | 0.03    | 0.01    | 0.10   | 0.20  | 0.22  |
|                 |           |           |       |         |         |       |       |       |
2.2 Methods

2.2.1 Tests on Cement Paste.

Six mixes were used for the determination of Consistency, Setting Times and drying linear shrinkage of GHA-Cement in accordance with [10]. MP-00 is the control mix (0 % GHA) and MP-05, MP-10, MP-20, MP-30 and MP-40 are mixes containing GHA at replacement levels of 5, 10, 20, 30, and 40 %, respectively. Three readings were taken and an average found. The behavior is shown in Fig. 2 - 4.

2.2.2 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. Six mixes were used, M-00 is the control mix and M-05, M-10, M-20, M-30 and M-40 are mixes containing GHA at replacement levels of 5, 10, 20, 30, and 40 %, respectively. The Flexural Strength test was conducted in accordance with [11]. A total of ninety (90) prisms were cast and three prisms tested 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 flexural strength and compressive strength are shown in Fig. 5 and 6, respectively. The 28 day pozzolanic activity index of GHA-Mortar was determined and a pozzolanic index of 62.8 % was obtained.
3. ANALYSIS AND DISCUSSION OF RESULTS

3.1 Groundnut Husk Ash (GHA)

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 [7] 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 \(\text{SiO}_2\), \(\text{Al}_2\text{O}_3\) and \(\text{Fe}_2\text{O}_3\) content of 26.06 %, which is much lower than the minimum value of 70 % in [7] for a good pozzolana, and would therefore be of low reactivity. This is further confirmed by the low 28 day pozzolanic index of GHA-Mortar of 62.8 %. The chemical composition of GHA also indicated a high \(\text{K}_2\text{O}\) content of 38.80 %, which is far higher than 1.2 % limit recommended in cement [12]. The high \(\text{K}_2\text{O}\) content may be a source of disruption in GHA-Mortar and concrete. GHA also showed a \(\text{CaO}\) content of 13.19 %, which indicates that it has some self cementing properties.

3.2 Groundnut Husk Ash (GHA)-Cement Paste

The consistency of GHA-Cement Paste shown in Fig. 2 indicated that water requirement increases with increase in GHA content. The normal consistency of cement paste was 30.0 % while that of GHA-Cement Pastes ranged from 34.5 – 39.0 %, depending on GHA content. The increase in water requirement with increase in GHA content may be due to high porosity as well as high LoI of GHA, consistent with [13] report on rice husk ash-calcium carbide residue as supplementary cementing materials. 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.

![Figure 2: Consistency of GHA-Cement Paste](image)

The setting times of GHA-Cement pastes shown in Fig. 3 showed increase in setting times with increase in GHA content. The initial and final setting times of the cement paste were 46 and 554 minutes, respectively, while that of GHA-Cement pastes ranged from 46 and 600 minutes to 81 and 643 minutes, respectively, with the least and longest times occurring in paste with 5 % and 40 % GHA content, respectively. The results suggested that GHA retards the setting times of cement, and this would be 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 the
dilution of cement with GHA and slower pozzolanic reaction of GHA. This is consistent with early works by [14] and [15].

![Graph showing setting times of GHA-Cement Paste](image)

**Figure 3:** Setting times of GHA-Cement Paste

The drying shrinkage of GHA-Cement Paste shown in Fig. 4 indicated that the shrinkage of GHA-Cement Paste with GHA content up to 10% was same as that of control paste, but the shrinkage of GHA-Cement pastes at replacement levels from 20% and above decreased with increase in GHA content. The decrease in shrinkage may be due to high porosity of GHA particles which absorb more water than cement, leading to reduced shrinkage [16] and [17]. This suggests that GHA-Cement would not be subject to higher movement when put into use compared with control paste.

![Graph showing drying shrinkage of GHA-Cement Paste](image)

**Figure 4:** Drying Shrinkage of GHA-Cement Paste

### 3.3 Flexural Strength and Compressive Strength of GHA-Mortar

The flexural strength of GHA-Mortar shown in Fig. 5 indicated that flexural strength of mortar increased with age of curing but decreased with increase in GHA content. However, the optimum 28 days flexural strength was obtained at 5% GHA content, and the flexural strength of GHA-Mortar at 10% GHA content was same as that of control at 90 days curing. A similar
behaviour was observed with compressive strength of GHA-Mortar shown in Fig. 6. However, GHA content of 10% cement replacement by weight was considered as optimum for structural mortar.

The increase in strength with age of curing is due to hydration of cement and pozzolanic reaction of GHA. The decrease in strength with increase in GHA replacement could be due to the reaction mechanism of GHA, in which dilution of cement and slower strength development from the pozzolanic reaction would be responsible for the reduction in strength [18]. Furthermore, for constant water/binder ratio, the reduction in flow of mortar with increase in GHA content reduced compaction of mortar which may result in reduction in strength of the mortar. However, higher flexural and compressive strengths of mix containing 5% GHA over control mix at 28 days curing and beyond is due to pozzolanic reaction where dilution effect is not significant and the secondary C-S-H compliment the strength from the hydration products.
4. CONCLUSION

i) The GHA is of low reactivity, with a combined $\text{SiO}_2$, $\text{Al}_2\text{O}_3$ and $\text{Fe}_2\text{O}_3$ content of 26.06% which indicate that it does not satisfy the minimum value of 70% (ASTM C618, 2008) for a good pozzolana.

ii) The drying linear shrinkage decreased, while consistency, initial and final setting times of cement increased with increase in GHA content. Therefore GHA can be used as a retarder, suitable for use in hot weather concreting, as well as in mass concreting and long haulage of ready mix concrete.

iii) The compressive and flexural strengths of GHA-Mortar decreased with increase in GHA content. However, 10% GHA is optimum content recommended for production of structural mortar, while GHA content of 20% and above is recommended for non structural mortar.

REFERENCES


