Mechanical Properties of Mortar Incorporating Guinea Corn Husk Ash (GCHA) as Partial Replacement of Cement

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Abstract- This study investigates the effect of using Guinea Corn Husk Ash (GCHA) as partial replacement for cement in mortar production. Guinea corn husk ash (GCHA) was incorporated into the mix in various proportions for cement replacement at 0%, 2%, 4%, 6%, 8% and 10%. A total of seventy-two cubes were cast in a mould of size: 0.1m x 0.1m x 0.1m, and then cured in water. The Slump test was carried out on fresh mortar in accordance with BS EN 12350-2 (2009). The hardened specimens were tested for compressive strength at 0, 3, 7, and 28 days and water absorption test in accordance with BS EN 12350-2 (2009)and BS 1881-122 (2011) respectively. The results showed that the compressive strength of the mortar increases up to 4% replacement level before it begins to decrease with an increase in GCHA replacement. There is a significant increase in mortar strength at all percentage replacement levels as the curing age increases. The compressive strength of mortar with4% GCHA yielded the highest value of compressive strength at 28 days. The research has also shown an increase in slump and water absorption of mortar as the percentage of GCHA increases. To achieve optimum strength of mortar incorporating GCHA, it is concluded that the percentage replacement should not exceed 4% replacement of cement.

Indexed Terms- Mortar, Guinea-Corn Husk Ash, Compressive Strength, Water Absorption, Aggregate

I. INTRODUCTION

The production of cement, one of the main components of mortar, has a significant impact on the environment due to its high carbon dioxide emissions and energy consumption [1]. The use of alternative materials to replace cement in mortar production has become a topic of interest in recent years to reduce the environmental impact of cement production [2]. One such material is agricultural waste such as guinea corn husk ash, which is a pozzolana and readily available and has the potential to be used as a partial replacement for cement in the production of mortar.

Guinea corn is a common cereal crop in Africa, and its husk is an agricultural waste product that is often burned or discarded [3], which can significantly impact our climate by contributing to greenhouse gases. The use of guinea corn husk ash (GCHA) as a partial replacement for cement in the production of mortar and concrete has been investigated in previous studies. Oyedepo et al., [4] investigates the potential of using guinea corn husk ash (GCHA) as partial replacement for cement in mortar at 0%, 5%, 10% 15%, and 20%. The study found that as the percentage of GCHA in the mortar increases, there was an increase in compressive strength up to 10% replacement before the strength starts to decrease. A decrease in density was also observed. However, the water absorption capacity and porosity of the mortar increased with the in the percentage of GCHA. Afolayan et al., [5] investigated the effect of adding GCHA to concrete mixture on the compressive strength of the resulting concrete. The researchers found that the addition of GCHA to the concrete mixtures resulted in an increase in the compressive strength of the concrete at early ages (7 and 28 days) but a decrease in strength at later ages (56 and 90 days). Odeyemi et al., [6] investigated the effect of guinea corn husk ash (GCHA) as a partial replacement of cement in mortar. The study involved testing the compressive strength, water absorption, and density of the mortar with varying levels of

GCHA replacement (0%, 10%, 20%, 30%, and 40%). The results showed that the compressive strength decreased as the GCHA replacement level increased, with the 10% replacement level showing the highest compressive strength. The water absorption of the mortar also increased with increasing GCHA replacement level. However, the density of the mortar decreased with increasing GCHA replacement level. The study concludes that GCHA can be used as a partial replacement of cement in mortar, with the optimal replacement level being 10%.The compressive strength of mortar is an essential property that determines its suitability for construction purposes. These studies have shown that the use of GCHA as a partial replacement for cement has the potential to improve the strength properties of mortar and can reduce the negative impact of these waste materials in our environment.

Several other researchers studied the use of other materials as substitutes for cement in mortar. Khan et al., [2] carried out a study that evaluate the effect of different levels replacement of cement with marble powder (0%, 5%, 10%, and 15%) on the mechanical and durability properties of mortar. They found that the addition of marble powder up to 10% improved the mechanical and durability properties of mortar, including increased compressive strength, flexural strength, and tensile strength, as well as decreased water absorption and porosity. Afolayan et al., [7] carried out a research that utilizes bagasse ash as partial replacement of cement in mortar production. The study showed that up to 15% replacement of cement with bagasse ash did not significantly affect the compressive strength of the mortar, but increased water absorption and decreased workability. The authors suggested that bagasse ash could be used as an eco-friendly alternative to cement in mortar production, which could help to reduce environmental pollution and waste disposal problems. Afolayan et al. [8] investigated the use of groundnut shell ash (GSA) as a partial replacement for cement in mortar production. The GSA was obtained by burning groundnut shells and grinding them into a fine powder. Mortar mixes were prepared with different proportions of GSA and cement, and their compressive strength, water absorption, and density were tested. The results showed that up to 10% replacement of cement with GSA did not significantly affect the compressive strength of the mortar, but increased water absorption and density. This study suggests that GSA can be used as a partial replacement for cement in mortar production, potentially leading to environmental and economic benefits. Tariq et al., [9]studied the use of metakaolin as a partial replacement for cement in mortar production. The authors discuss the properties and benefits of metakaolin, as well as the effects of its use on the properties of fresh and hardened mortar. They also review previous studies that have investigated the use of metakaolin in mortar production, and discuss the potential for further research in this area. The study concludes that the use of metakaolin as a partial replacement for cement in mortar production can lead to improved strength, durability, and sustainability of the resulting mortar.

There is limited research on the use of GCHA as a partial replacement for cement in mortar production and its effect on compressive strength. This study investigates the effect of using GCHA as a partial replacement for cement on the compressive strength of mortar. The compressive strength of the mortar produced using different percentages (0%, 2%, 4%, 6%, 8% and 10%) of GCHA as a replacement for cement is tested. This study provides valuable information on the use of GCHA as a partial replacement for cement in mortar production, which could reduce the environmental impact of cement production.

II. MATERIALS AND METHODS

a. Materials

The following materials were used for the purpose of this research work: Ordinary Portland Cement (OPC), Fine Aggregate, Guinea Corn Husk Ash (GCHA), and water.

Cement: The hydraulic binder used for this research work was the Ordinary Portland Cement (OPC) of the Dangote 42.5N brand, which complies with BS 12 (1996) [11]. It was obtained from Danbare Market in Kano, Kano state, Nigeria.

Fine Aggregate: For this research work, the fine aggregate used was obtained from Janguza town, Kano state. Sieve analysis and specific gravity tests were carried out per BS 812 (1995) [12].

Guinea Corn Husk Ash (GCHA):The Guinea Corn Husk used in this research work was obtained from Janguza market in Kano and burnt in a rotary kiln at 600^oC at mechanical engineering department in BUK. The preparation process for the Guinea Corn Husk Ash used as a partial replacement of cement in mortar involves the following steps:

1. Collecting waste Guinea Corn Husk: (GCH) The waste guinea corn husk shown in Figure 1was collected from Janguza market, Kano. These waste materials were sourced from various villages in Tofa local government area of kano state.
2. Cleaning: All debris were handpicked from the waste material to ensure it is completely free from other external material.
3. Burning and Grinding: The GCH material was incinerated in a rotary kiln at a temperature of 600^oC for about two hours to ensure the material is burnt completely. The ash was collected, grinded into powder and sieved through a 150µmsieve size. The ash particles passing was used in the mortar production process.Only the guinea corn husk ash material that passes through the 0.0015mm sieve(Sieve No. 100) was used for the research.

Figure 1: Guinea Corn Husk

Water: The water used for this research work was obtained from the Civil Engineering Laboratory of BUK, and it meets the specifications of BS EN 1008 (2002) [13].

b. Methods

i. Test on cement

The following tests were carried out on the cement material: Specific gravity as per ASTM C188-17 (2017) [14], initial and final setting time tests were conducted as per BS EN 197-1 (2011) [15].

ii. Test on Fine aggregate

The tests carried out on the fine aggregates used in this research work are: specific gravity as specified in BS 812-1995 [12], sieve analysis per BS 812-103.2 [16], and bulk density per BS 812-3 (1989) [17]. The bulk density is found to be 1602kg/m^3while the specific gravity of the fine aggregate is 2.61. The classification of the fine aggregate used in this research iszone-1 based on BS 882 - Part 2 (1992) [18] classification

iii. Mixing Design

The proportions of cement, fine aggregate, water and guinea corn husk ash (GCHA)obtained from the mix design were presented in Table 1.

Table 1: mix proportion of each material from the mix design

Mix	OPC (g)	GCHA (g)	Fine Agg. (g)	Water (g)
A (0% GCHA)	630.72	-	4200	346.90
B (2% GCHA)	618.11	12.61	4200	339.96
C (4% GCHA)	605.49	25.23	4200	333.02
D (6% GCHA)	592.88	37.84	4200	326.08

E (8% GCHA)	580.26	50.46	4200	319.14
F (10% GCHA)	565.65	63.07	4200	311.11

iv. Compressive Strength Test on Mortar

According to the requirements of BS EN 12390 Part 3 (2009) [19], specimens of hardened mortar containing various percentages of guinea corn husk ash at 0%, 2%, 4%, 6%, 8% and 10% subjected to a compressive strength test. The 72 samples produced were cured in water tanks at the Civil Engineering Department laboratory, BUK. The compressive strength of the samples was tested after a period of 0, 3, 7, and 28days of curing. A total of 18 cube samples were tested for each curing period using the Avery Universal Testing Machine with a capacity of 2000 KN in the concrete laboratory of the Civil Engineering Department, BUK. The compressive strength of each sample was determined using the formula below:

$$\text{Compressive Strength } (N/mm^2) = \frac{\text{Normal Load (N)}}{\text{Area of Specime (mm 2)}} \times 100 \qquad (1)$$

v. Water Absorption Test on Mortar

The water absorption test was conducted as per BS 1881-Part 122 (2011) [20]. A total of 18 samples were dried in an oven for 72 hours at the concrete laboratory of the Department of Civil Engineering BUK. After removing the samples from the oven, it was allowed to cool for 24 hours. The samples were weighed and immediately immersed in water for 24 hours. Upon removal, the excess water was wiped off with a cloth and the samples were weighed again. The water absorption of each sample is calculated using the below formula.

$$\text{Water absorption } (\%) = \frac{\text{Weight of sample immersed in water} - \text{Weight of dry sample}}{\text{Weight of dry sample}} \times 100 \qquad (2)$$

III. RESULTS AND DISCUSSION

a. Preliminary Test Results

Preliminary tests carried out on cement and fine aggregate materials are presented in Table 1 and Table 2, respectively. The results obtained have satisfied the specifications with the relevant code recommendations.

Table -1: Test results on Cement

Test	Test Result	Specification	Code
Specific Gravity	3.15	3.10 – 3.16	ASTM C188-17 (2017) [14]
Initial setting time of Cement	70 min	should not be less than 45 minutes	BS EN 197-1 (2011) [15]
Final setting time of cement	390 min	should not be more than 6.5 hours	BS EN 197-1 (2011) [15]

Table 2 presents the physical and some mechanical properties of the materials used in this study. The tests give an idea on the properties of the materials and will definitely be reflected when materials are mixed in the mortar production.

Table 2. Physical and mechanical properties of fine aggregate

Test	GCHA	Fine aggregate	Specification
Water absorption (%)	6	9	ASTM D570
Bulk Density (kg/m^3)	361	1602	BS 812-3 (1989) [17]

Specific Gravity	1.76	2.61	BS 812-103 (1995) [12]

b. Slump Test Result
Figure 2 shows the result of slump tests carried out on fresh mortar mix of 0-10% guinea corn husk ash replacement. The result revealed that the slump increases as the percentage of GCHA increases. The maximum increase of 20% was observed at 8% replacement when the slump increased from 7.8mm to 9.5mm. The finding shows that mortar containing GCHA has more ease of handling and placement than the control sample. The high cohesive ability of guinea corn husk ash in binding with other materials may have led to the increase in slump.

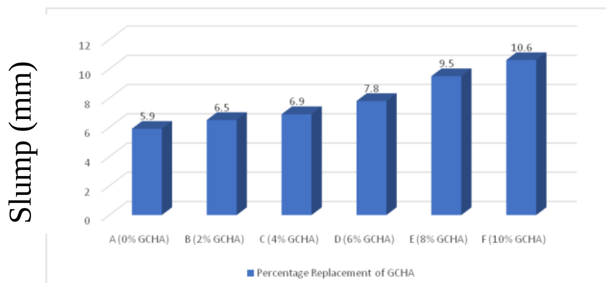


Figure -2: Slump at percentage addition of GCHA

c. Compressive Strength Test Result of Mortar
Figure 3 shows the results of the compressive strength test carried out on mortar containing guinea corn husk ash. The result showed an increase in compressive strength with an increase in curing age and the addition of GCHA at 4%. This agrees with Oyedepo et al., [4], Afolayan et al., [5], and Odeyemi et al., [6]. High increase in strength was observed at 4% replacement, while a decrease in strength was observed from 6% to 10% replacement. At 28 days, a maximum increase in compressive strength of 7.5% was observed at 4% addition of GCHA when compared to the control. The strength increased from 9.73N/mm^2 to 10.46N/mm^2. Further increases in GCHA result in a decrease in mortar strength. The hydration of cement leads to an increase in compressive strength as the curing period increases. The presence of excess GCHA in the mixture may have hindered the inter-particle bond between the cement particles and aggregates, which is why the compressive strength decreased with the addition of GCHAfrom6-10% when compared to the control mix.

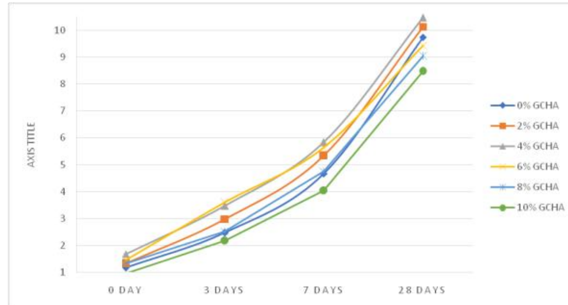


Figure -3: Compressive strength against curing age of mortar

d. Density
Figure 4 shows the density reduction of mortar cube samples that contains guinea corn husk ash. The result shows a decrease in the weight of mortar with an increase in guinea corn husk ash material but significant increase was observed as the curing days increases. At 28-daysof curing, a maximum decrease of 2.7% was observed at 10% replacement, when the weight was reduced from 2068.3 kg/m^3 to 2014.7 kg/m^3. This agrees with Oyedepo et al., [4] and Odeyemi et al., [6]. The decrease in density is a result of reduction in cement content added to the mix.

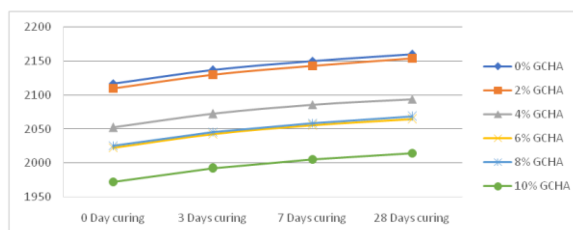
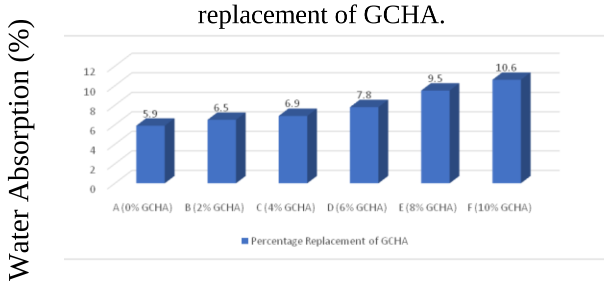


Figure -4: Weight of mortar with different percentage replacement levels of GCHA

e. Water Absorption of Mortar
From Figure 5, it can be shown that an increase in GCHA content increases the water absorption rate of the mortar. A maximum increase of 10.25% was observed at 8% addition of GCHA when the rate of water absorption increases from 7.8% to 9.5%. This result agrees with the findings ofOyedepo et al., [4] and Odeyemi et al., [6]. This is due to the ability of guinea corn husk ashto react with calcium hydroxide to form additional cementitious compounds that creates a more porous and interconnected network of voids within the mortar.

Figure -5: Water absorption vs percentage replacement of GCHA.



CONCLUSION

From the findings of this research work, the addition of guinea corn husk ash to the fresh mortar mix increases its workability (slump). A decrease in density of mortar and an increase in water absorption rate of mortar was observed from this study. A 7.5% increase in the compressive strength of the hardened mortar was observed by adding4% guinea corn husk ash (GCHA).Further increase in GCHA resulted in a decrease in compressive strength of the mortar. As a result, the optimum value of cement percentage replacement level with guinea corn husk ash in mortar should be maintained at 4%.

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