Investigation into the Effects of Groundnut Shell Ash as Partial Replacement of Cement Mortar in Compressive Strength and Durability of Cement Mortar

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Abstract: This study examines the effects of groundnut shell ash as partial replacement of cement in mortar. The GSA used in this study is an agricultural product. The groundnut shell was collected from Zaria city market of Kaduna state. The Ash used was obtained by burning the groundnut shell in an open place, and then calcinated at 600^0C. A mix ratio 1:3 grade was used to produce ranging from 0% to 20 % by weight, with water cement ratio of 0.55 for each replacement 3 samples were casts and the averages were obtained at (70.6 x 70.6 x 70.6mm). For compressive strength, it was observed that the percentage of groundnut shell ash (GSA) increased from 0% to 20%, the compressive strength of the cement mortar initially increased and then decreased across all the curing ages (7,14,21 and 28 days). Specifically, the strength increased from 11.83N/mm^2 at 0% GSA to 16.22 N/mm^2 at 5% GSA at 28 days curing ages, beyond 5% replacement, the compressive strength began to decrease progressively up to 20% GSA at 11.22 N/mm^2, 8.45 N/mm^2, and 7.65 N/mm^2 at 10%, 15% and 20% respectively. The maximum compressive strength value obtained from the partial replacement of GSA was 16.22N/mm^2 at 5% replacement, the XRF, summed up 100% which is higher than the standard value and qualifies to be a Class N Pozzolan. The water absorption of the cube for GSA replacement from 0% to,20% are 2.90 and 4.72 respectively, it was observed that the water absorption increases as the percentage replacement increases; this may be attributed to increase in pores spaces in the cement mortar as GSA percentages increases. Specific gravity of fine aggregate found to be 2.50, GSA was gotten to be 2.45 and that of cement found to be 3.13.

Keywords: XRF, GSA Compressive strength, and Water Absorption.

1. INTRODUCTION

In recent advancement in civil engineering has been made in the research of alternative materials to replace cement. This effort aims to reduce the environmental impact of concrete production, while also improving strength and durability of concrete structures. Cement is one of the major components of mortar production, but its manufacturing process contributes significantly to global co_2 emissions. Many researchers have investigated the use of materials such as rice husk ash, groundnut shell ash, banana peel ash and yam peel ash as replacement of cement. Biwoye and Naallah, (2017), reported that the present society has shown increasing interest in the use of new materials in place of traditional products. The search for alternative binders or cement replacement materials has continued in the last three decades. From the economical, technological and ecological points of view, cement replacement materials play an undisputed role in the construction industry. Small amounts of inert fillers have always been acceptable as cement replacement. Ramsharat., et al (2017), stated that the utilization of waste by-product in concrete has garnered positive regarding the cost

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saving and conversion of natural resources. Therefore, waste materials such as rice husk, groundnut shell, and sesame husk ash have contributed to the pollution in the environment and there is need for them to be converted into useful materials to minimize the effect of their pollution to the surrounding environment. Sulaiman et al., (2022), stated that the use of supplementary cementing material (SCM) in the production of concrete is very essential where there is a need to modify the characteristics of concrete. Groundnut shell ash (GSA), an agricultural waste product, has shown potential as a pozzolanic material that can improve mortar properties.

This research work aims to determine the effects of groundnut shell ash as partial replacement of cement in compressive strength and durability of cement mortar. To achieve this goal, the properties of the constituent materials were determined. Also, the effect of groundnut shell ash (GSA) on compressive strength and water absorption at different percentages of 0%, 5%, 10%, 15% and 20% of cement mortar were investigated. The XRF test was carried out to determine chemical composition.

2. MATERIALS AND METHODS

2.1 Materials

The materials used in this study were cement, fine aggregate, water and groundnut shell Ash.

2.1.1 Fine Aggregate

Fine Aggregate (naturally occurring river sand) obtained from Zaria local government Kaduna State was used throughout the research work. Adequate quantity of sand was used and ensured that the sand was clean and dry before used.

2.1.2 Cement

Ordinary Portland cement (OPC) obtained from Dangote Cement with brand with 42.5N grade shop in gwargwaje market which was used throughout the research work; its properties were also found to be in conformity to BS 12(1996).

2.1.3 Groundnut Shell Ash (GSA)

The groundnut shell ash used in this in this research work was sourced from zaria city market Kaduna State were collected air-dried, and burned at 600^0c for 3-4 hours. The resulting ash was cooled and sieved through a 200mm sieve to remove unburnt residues. And also, XRF test was carried out to determine chemical composition.

2.1.4 Water

Also, the water used throughout the research works was sourced from municipal water that is drinkable and has no definite taste, odour or oil presence from the main Laboratory of the Department of Civil Engineering Nuhu Bamalli Polytechnic, Zaria which is in conformity with BS EN 1008:2002.

2.2 Methods

The laboratory tests carried out during this study is in accordance with standard codes.

2.2.1 Consistency Test of Cement

The consistency test was carried out in accordance with BS EN196-3:1995 specification.

2.2.2 Setting Time of Cement

The tests were carried out in accordance with BS EN 196-3:2016 specification.

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2.2.3 Soundness of Cement Paste

The tests were carried out in accordance with BS EN 196-3:1995 specification.

2.2.4 Sieve Analysis (Fine aggregate)

The tests were carried out in accordance with BS 812-103 part 1:1985 specification.

2.2.5 Specific Gravity of Aggregate

The test was carried out in accordance with BS 812 part 2:1995 specifications.

2.2.6 Mix Design

The mix design used for this study is 1:3 with a well graded fine aggregate.

$$\frac{wc}{1000}+\frac{C}{1000SGc}+\frac{FA}{1000SGf}=1m^2 \qquad 3.3$$

Where: SG cement=Specific gravity for cement

SG fine = Specific gravity for fine aggregate

Mortar mix proportion

Table 1: Mortar mix proportion

GSA %	Cement (g)	GSA (g)	Fine Aggregate (g)	Water (g)
0	1.3136	0	3.9421	0.7228
5	1.24792	0.06568	3.9421	0.7228
10	1.18224	0.13136	3.9421	0.7228
15	1.11656	0.19704	3.9421	0.7228
20	1.05088	0.6568	3.9421	0.7228

2.2.7 Compressive Strength Test

The cubes specimens for compressive strength tests were 70.6mm x 70.6mm x 70.6mm mortar specimens after weighing was crushed in accordance with BS EN 12390-1:2000 for 7,14,21, and 28days curing period. For each test, 3 cubes were tested and the average results were calculated.

Table 2: Average Compressive Strength of mortar cubes at various curing ages

Sample	7 days	14 days	21 days	28 days
Groundnut shell ash content %	Compressive Strength N/mm^2	Compressive Strength N/mm^2	Compressive Strength N/mm^2	Compressive Strength N/mm^2
0	8.05	8.46	11.63	11.83
5	15.00	14.69	15.71	16.22
10	13.67	9.57	12.95	11.22
15	6.83	8.46	8.66	8.45
20	6.84	8.05	7.95	7.65

2.2.8 Water Absorption

The test was performed in accordance with BS EN 1015-18:2002. A total of 3 cubes samples of size 70.6mm x 70.6mm were casted and cured for 28 days in water, the samples were oven dried at 105^0c ± 5^0c until constant weight (w_1) is obtained and cool in a desiccator. Immerse the specimen in clean water for 24 hours. Remove the specimens

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from water, wipe surface gently, and weight again (w_2).

$$WA=\frac{w2-W_1}{W1}\times 100$$

Table 3: Average water absorption for mortar cubes

Percentage of groundnut shell ash (GSA)	Average Water absorption (%)
0	2.90
5	3.26
10	4.26
15	4.44
20	4.72

3. RESULTS AND DISCUSSION

3.1 Specific Gravities Test for Cement, groundnut shell Ash, and Fine Aggregate

The specific gravity of the cement, groundnut shell ash and sand used were 3.13, 2.45 and 2.50.

Table 4: Specific Gravity of Materials

S/N	Materials	Average specific gravity
1	Cement	3.13
2	Groundnut Shell Ash	2.45
3	Fine Aggregate	2.50

3.2 Chemical Composition of GSA

The chemical composition tests were carried for the elements that characterize the nature of GSA which includes Silicon dioxide (SiO_2), Aluminum oxide (Al_2O_3), Iron oxide (Fe_2O_3) , Potassium oxide (K_2O), Calcium oxide (CaO), Magnesium oxide (MgO) and Sulfur trioxide (SO_3). However, the percentage composition for calcium Oxide (CaO) in groundnut shell ash (GSA) was below the minimum obtained in cement and also the percentage of potassium oxide (K_2O) has exceeded the optimum value obtained in cement.

Table 5: X-ray fluorescence analysis of Cement in comparison to Groundnut Shell Ash.

Oxide	GSA (%)	Cement (%)
SiO_2	33.54	17-25
CaO	29.61	60-67
K_2O	17.11	0.1-3
MgO	6.0	0.1-4.0
Al_2O_3	5.32	3-8
Fe_2O_3	3.55	0.5-6.0
Na_2O	1.54	0.1-3
P_2O_5	0.99	0.1-0.5
SO_3	0.75	1-3
Alkalis	1.59	0.2-1.3

3.3 Sieve Analysis for Fine Aggregate

Figure1. Shows the variation of percentage passing against sieve size which indicates the particle size distribution of fine aggregate used in the research, the results used where presented. It was observed that the fine aggregate used belong to zone 1 in accordance with BS 882 (1992) for grading limit zone for fine aggregate.

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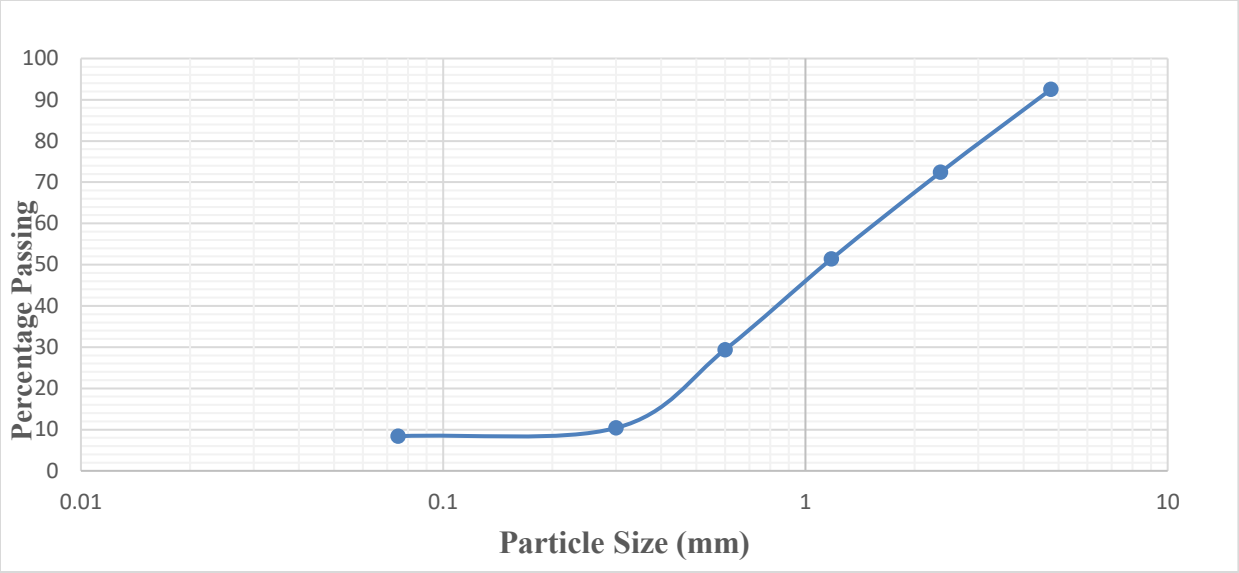

Figure 1: Particle Size Distribution of Fine Aggregate

3.4 Consistency

The result of consistency test carried out on cement paste is presented in Figure 2. It was observed that the normal consistency of cement paste incorporated with GSA increases with an increase in quantity of GSA content. This implies that the GHA has higher water demand for its hydration. The satisfied the requirement, (BS EN197-1: 2000) states that for a cement to be classified as an Ordinary Portland Cement, the standard consistency should have a range of 26 % - 33 %.

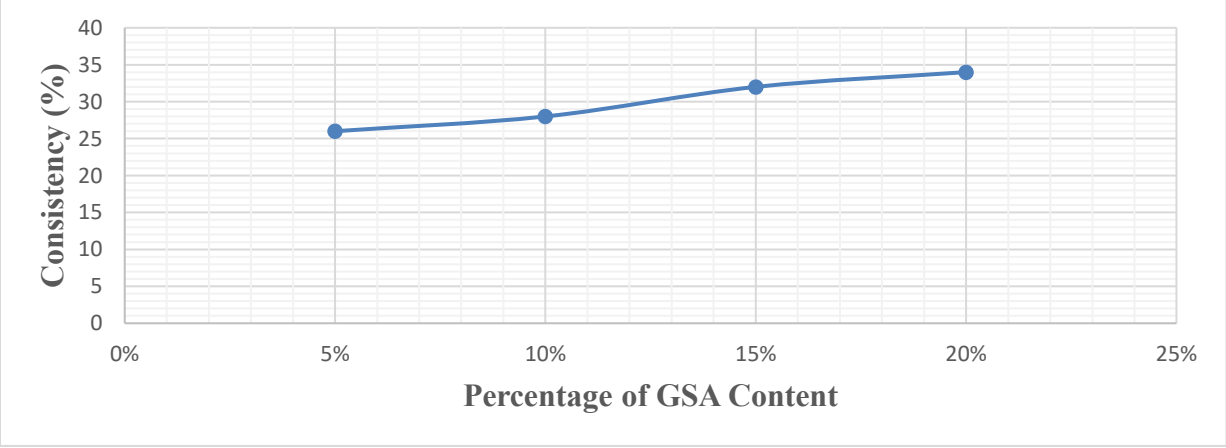

Figure 2: Consistency against percentage of GSA content

3.5 Initial Setting Time

The result indicates that the initial setting time increases with increase in the percentage of GSA. This implies that the heat of hydration is increases due to increase of carbon content. BS EN197-1 (2000) requires

that the initial setting time of an OPC should be greater than 45mins, From Figure 3. The initial setting time is 90minutes.

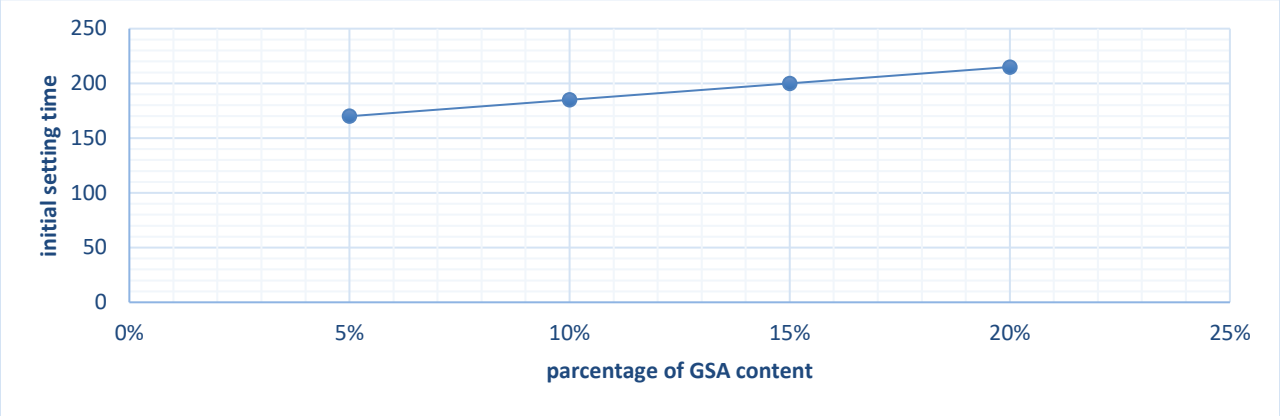

Figure 3: Initial Setting Time against Percentage of GSA content

3.6 Final Setting Time

The result indicates that the final setting time increase with increase in the percentage of GSA. This implies that the heat of hydration increases due to increase of carbon content. BS EN197-1 (2000) requires that the final setting time should be less than 10hrs. From Figure, the final setting time is 140 minutes.

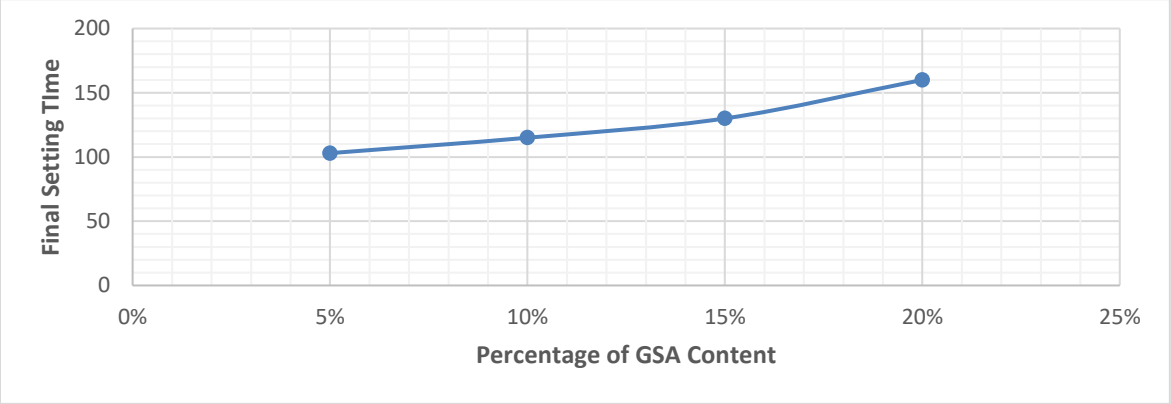

Figure 4: Final Setting Time against Percentage of GSA-Content

3.7 Soundness

From the test carried out, it was found that the soundness obtained is within the tolerance limit which is shown in Figure 4. Therefore, GSA does not have negative effect on soundness, and this implies that it is a cementations material without recourse to delayed expansion. The purpose for conducting soundness test is to check the possible risk of expansion in concrete due to duration of uncombined calcium oxide and/or magnesium oxide. BS EN197-1(2000) specifies that the result of soundness test should be less than or equal to 10mm.

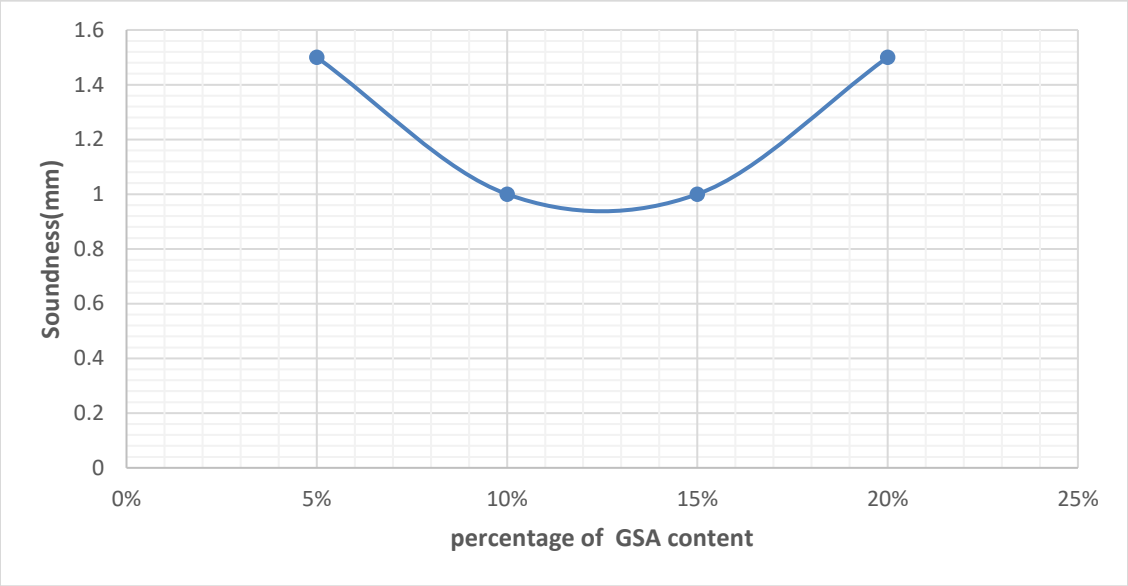

Figure 5: Soundness against Percentage of GSA-content

3.8 Compressive Strength

From the table, it was observed that the percentage of groundnut shell ash (GSA) increased from 0% to 20%, the compressive strength of the cement mortar initially increased and then decreased across all the curing ages (7,14,21 and 28 days). Specifically, the strength increased from 11.83N/mm^2 at 0% GSA to 16.22 N/mm^2 at 5% GSA at 28 days curing ages, indicating an improvement in strength level. This increase at 5% replacement suggests that a small quantity of groundnut shell ash contributed to the pozzolanic reaction, filling the voids and improving the bond between the particles, which enhanced the strength of the mortar. However, beyond 5% replacement, the compressive strength began to decrease progressively up to 20% GSA at 11.22 N/mm^2, 8.45 N/mm^2, and 7.65 N/mm^2 at 10%, 15% and 20% respectively. This reduction in strength at higher replacement levels could be attributed to the dilution effect. Also, higher ash content may introduce more unreacted particles and increase porosity, thereby weakening the mortar structure.

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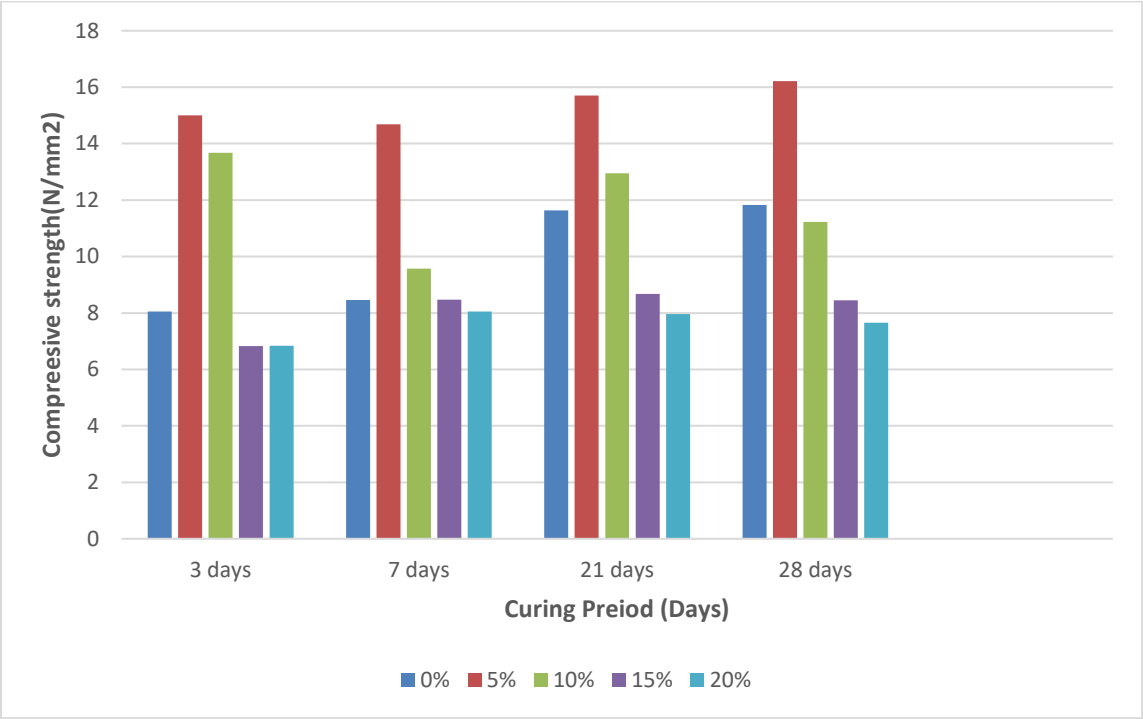

Figure 6: Compressive Strength against curing age.

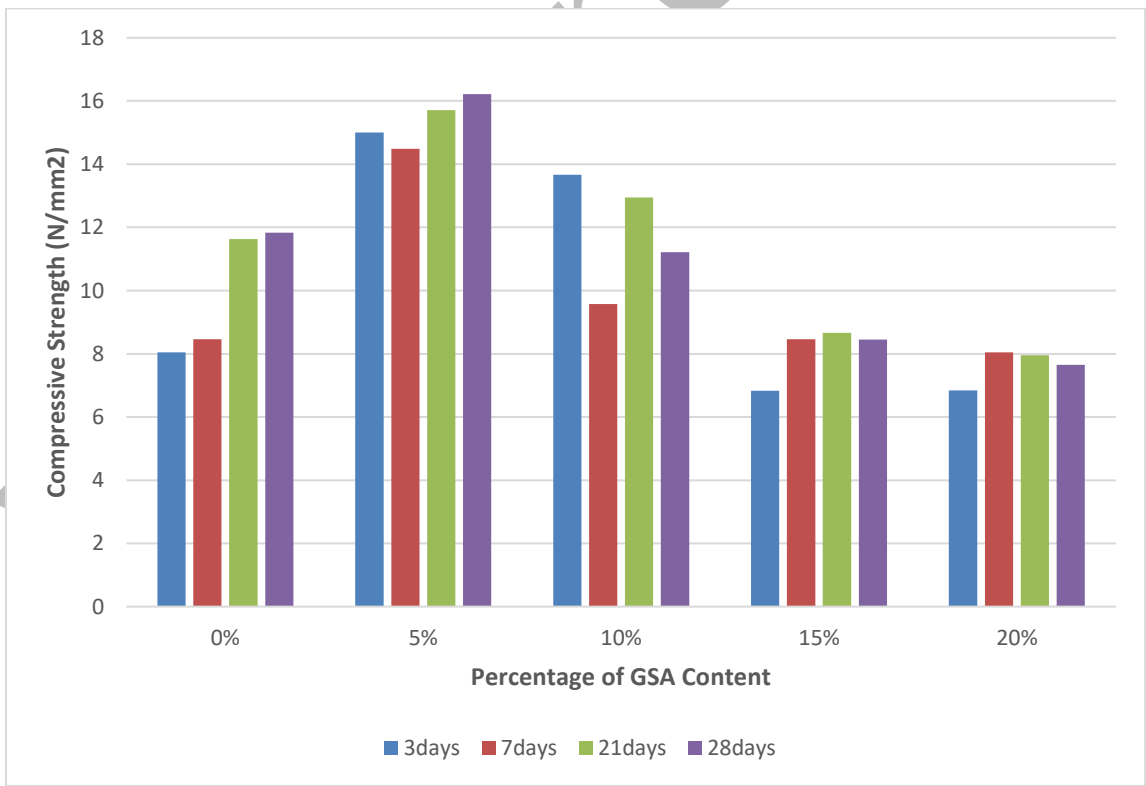

Figure 7: Compressive Strength of Cement with GSA content.

3.8 Water Absorption

The result shows that the percentage of groundnut shell ash (GSA) increased from 0% to 20%, the water absorption of the mortar also increased from 2.90% to 4.72%. This indicates that incorporating more GSA in the mix tends to increase the porosity of the mortar. It was observed that the increase in water absorption can be attributed the less dense nature and more porous of GSA than cement.

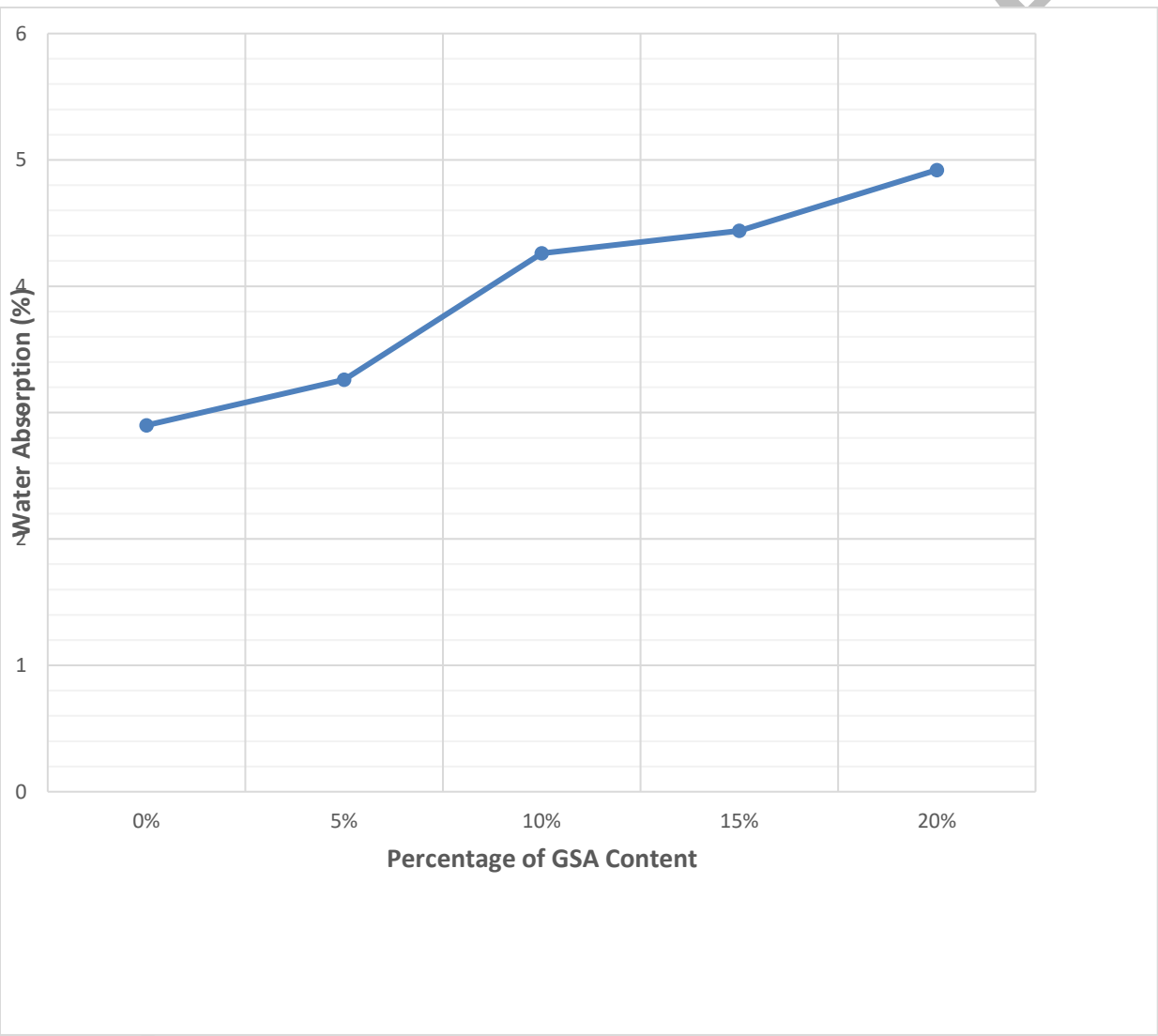

Figure 8: Water Absorption against Percentage of GSA Content

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Based on the work carried out, the following conclusions were made;

i. The specific gravity of fine aggregate found to be 2.50 which conforms to the requirement of BS 1881 part 3 which recommends the standard maximum value of 2.65 of fine aggregate, specific gravity for cement found to be 3.13, and according to BS EN 196-3(2005), cement should have the specific gravity of 3.1 - 3.16, therefore the result obtained as 3.13 shows that is a good cement. And specific gravity for GHA found to be 2.45.

ii. It has been observed that the result for 5% and 10 % replacement GHA-Cement has increase in compressive strength of mortar, which is all greater than the control specimens.

iii. GSA can be used as a partial replacement for cement; higher percentage may adversely affect durability, as higher water absorption can lead to increased permeability and vulnerability to moisture related deterioration.

iv. The optimum value for compressive strength is at 5 %, beyond which the strength of the cement mortar decreases with increasing GSA content.

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