Characteristics Strength and Durability of Groundnut Shell Ash (GSA) Blended Cement Concrete in Sulphate Environments

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ABSTRACT: *The study investigates the characteristics strength performance and durability of Groundnut Shell Ash (GSA) blended cement concrete exposed to sulphate environments. The principal characteristic measured was the compressive strength of Ordinary Portland Cement (OPC) concrete and OPC/GSA concrete at varying substitution levels of 0%, 5%, 10% and 15% after curing in water and three chemical solutions ($MgSO_4$, $NaSO_4$ and Ca_2SO_4) of varying concentrations of 0.5%, 1.5% and 2.5% each at 56 day hydration period. The results showed that the OPC/GSA concrete performed best in these chemical solutions, especially at 10% GSA replacement which exhibited a convincing increase in compressive strengths above that obtain with the use of Ordinary Portland cement. The study concluded that OPC/GSA concrete having showed resistant to calcium sulphate, magnesium sulphate and Sodium Sulphate media would perform better in environments or soils containing these sulphates. ($MgSO_4$, $NaSO_4$ and Ca_2SO_4).*

Key words- *Blended cement concrete*, *Compressive strength*, Concentration, *Groundnut shell Ash*, *Sulphates.*

1.0 Introduction

Cement concrete is the most widely used building material due to its satisfying performance in strength requirements and its ability to be moulded into a variety of shapes and sizes. Construction industry relies heavily on cement for its operation in the development of shelter and other infrastructural facilities [1]. However, Pozzolanic materials have long demonstrated their effectiveness in producing high performance concrete. Artificial pozzolanas such as rice husk ash have gained acceptance as supplementary cementing materials in many parts of the world [2] . In recent times, many waste materials like fly ash periwinkle shell ash, and ashes produced from various agricultural wastes such as palm oil waste, rice husk ash, corncob ash, millet husk ash, groundnut husk ash have been tried as pozzolanas or secondary cementitious materials. These supplementary cementing materials play an important role when added to Portland cement because they usually alter the pore structure of concrete to reduce its permeability, thus increasing its resistance to water penetration and water related deterioration such as reinforcement corrosion, sulphate and acid attack.

Therefore the utilization of groundnut shell ash reduces the environmental problem resulting from the accumulation of the shells in a large quantity in a particular area.

With these reasons, this work evaluates the characteristics strength performance of groundnut shell ash (GSA) as a partial replacement for ordinary Portland cement (OPC) in concrete, the durability aspects of concrete, including resistance to chemical attack in an exposure to sulphate environments(which results in volume change, cracking of concrete and the consequent deterioration of concrete). Concrete durability is defined as the capability of concrete to resist deterioration from freezing and thawing, heating and cooling, the action of chemicals such as deicers and fertilizers, abrasion, or any other environmental exposure [3].

In this study, groundnut shell ash (GSA) was used as secondary cementitious materials. Various percentages of GSA (0%, 5%,10%,15%.) were used to produce the concrete and GSA/OPC concrete's characteristics performance were measured after curing in three chemical solutions ($MgSO_4$, Na_2SO_4 and $CaSO_4$) of varying concentration of 0.5%,1.5% and 2.5% at 56 day hydration periods by conducting Compressive tests on the hardened concretes.

The choice of the percentage concentration of chemicals used as curing media was based on a similar research carried out by [4-7].

2.0 Materials and Method

The materials used in this project were groundnut shell ash, sand (fine aggregate), granite (coarse aggregate), cement and clean water as the curing medium. The concrete comprised of ordinary Portland cement (OPC), groundnut shell ash. (G.S.A), fine aggregate, coarse aggregate and water at design proportions.

Groundnut shell used for this research was sourced from Ogbomosho L.G.A. of Oyo State. The shells was collected in bags and transported to Ibadan and later moved to the Federal institute for Industrial research (FIIRO) Lagos, where the burning and grinding were carried out. Consequently, the ashes were collected in bags and were taken to the Concrete and Structural Laboratory of the Department of Building, Federal Polytechnic, Ede. The sieve analysis, moisture content and the specific gravity were carried out on GSA at the Soil Mechanics Laboratory of the Department of Building, Federal Polytechnic, Ede. The results of physical analysis, sieve analysis and chemical properties of GSA are presented in TABLES 1, 2 and 3 respectively.

The Coarse aggregate used was granite stone. It was of high quality and free of deleterious organic matter and the 20mm maximum sieve size were used. Also, the fine aggregate used was white sand obtained from river with 4.75mm maximum sieve size. Before the sand was used it was dried to remove the moisture content so that it will not increase the water content in the concrete mix. Dangote brand of Ordinary Portland Cement was used as the main binder. It conforms to type 1 cement as specified by [8].

2.1 Mixes

A concrete mix of ratio 1:2:4 was adopted for the production of concrete cubes at water / cement ratio of 0.6. Cement content was replaced at 5%, 10%, 15% and 20% with GSA. The adopted substitution levels was based on previous similar works conducted by[9-10] .which recommends between 10%- 40% as the most suitable replacement level for Blended concrete. The moulds used were cleaned with black engine oil to prevent the development of bond between the mould and the concrete. The freshly mixed concrete was scooped into the mould. Each mould was filled in three layers with the concrete; each layer was rammed 25 times with a tamping rod. 150mm x 150mm x 150mm cubes were produced for the tests. A total of 80 cubes were cast. Concrete cubes were stripped from the mould carefully after 24 hours of the concrete setting under air. All the cubes were cured in water for hydration period of 21, 28 and 56 days respectively. Average of three cubes was crushed for each test. The results of the analysis are shown in TABLES 4, 5, 6 and Figs. 1, 2, 3, 4

2.2 Setting Time

Values obtained as initial setting time for OPC and OPC/GSA pastes were 2 hours 35 minutes and 3 hours 20 minutes respectively. Final setting time values were obtained for OPC and OPC/GSA pastes as 3 hours 20minutes and 4 hours 22 minutes. The setting time values obtained were within the recommended range of 30 minutes to 10 hours stipulated by [11].

2.3 *Curing Condition*

Curing condition of concrete influence its hydration process. For full hydration of binder and strength development in the concrete the continuous, longer and moist curing is required. In this work, the Initial curing condition which affects the Sulphate resistance of concrete or mortar were carefully done in curing tank with samples totally immersed in the curing mediums.

2.4 Compressive Strength Test

Before crushing, the cubes were brought out of the water and kept for exact1y 30 minutes for the water to drip off. They were then taken to the crushing machine in accordance with [12] .The cubes were crushed a result of the load applied by the crushing machine and the reading were taken.

$$\text{Compressive Stress} = \frac{\text{Applied Load (N)}}{\text{Cross sectional Area of specimen (mm}^2\text{)}}$$

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3.0 Results and Discussions

3.1 Physical and Chemical Analysis of Groundnut Shell Ash (GSA)

Table 1: Physical Properties of Groundnut Shell Ash

Moisture content	0.42%
Specific gravity	1.54

Table 2: Result of specific gravity of G.S.A

Sample Weight	Test A	Test B
W1	25.60	25.30
W2	60.12	59.59
W3	80.20	80.10
W4	68.24	68.00
G	1.54	1.55

$$S.G = \frac{(W2-W1)}{(W4-W1)-(W3-W2)}$$

Where: W1= weight of empty flask W2= weight of flask + cement

W3= weight of flask + cement + water W4= weight of flask + water

Average= 1.54

The specific gravity of the GSA (1.54) was less than that of the OPC (3.15) it replaced, this means that a considerable greater volume of cementitious materials will result from mass replacement.

Table 3: Chemical Analysis of Groundnut Shell Ash and OPC

Constituent	**%** Composition (GSA)	**%** Composition (OPC)
Ferrous oxide (Fe_2O_3)	1.80	**4.60**
Silica (SiO_2)	16.21	**22.00**
Calcium Oxide (CaO)	8.69	**62.00**
Aluminum Oxide (Al_2O_3)	5.93	**5.03**
Magnesium Oxide (MgO)	6.74	**2.06**
Sodium Oxide (Na_2O)	9.02	**0.19**
Potassium Oxide (K_2O)	15.73	**0.40**
Sulphite (SO_3-)	6.21	**1.43**
I.L	4.80	2.82

Table 4: Compressive Strength of OPC and OPC/GSA Cured in Water and 0.5%, 1.5% and 2.5% $CaSO_4$ **at 56 days of hydration.**

Description	Compressive Strength In (N/mm^2)			
	water	**0.5% $CaSO_4$**	**1.5% $CaSO_4$**	**2.5% $CaSO_4$**
CN_0	**24.33**	**21.78**	**21.88**	**22.00**
CN_5	**19.40**	**13.73**	**18.00**	**16.40**
CN_{10}	**21.84**	**20.99**	**21.56**	**22.90**
CN_{15}	**16.89**	**18.00**	**19.69**	**16.31**

CN_0, CN_5, CN_{10} and CN_{15} are; 0%, 5%, 10% and 15% GSA replacements

The above result indicates OPC/GSA concretes performed better in **CaSO4** solution at 58 days of hydration as the strength of blended concrete at 10% replacement increase from 21.84 N/mm^2 to 22.90 N/mm^2. The OPC concrete does not show major reduction in strength, but performed less at hydration period. Also, the result indicates that OPC/GSA at 10% replacement and OPC concrete Cured in **$CaSO_4$** solution of 2.5% concentrations, gives relatively similar compressive strength.

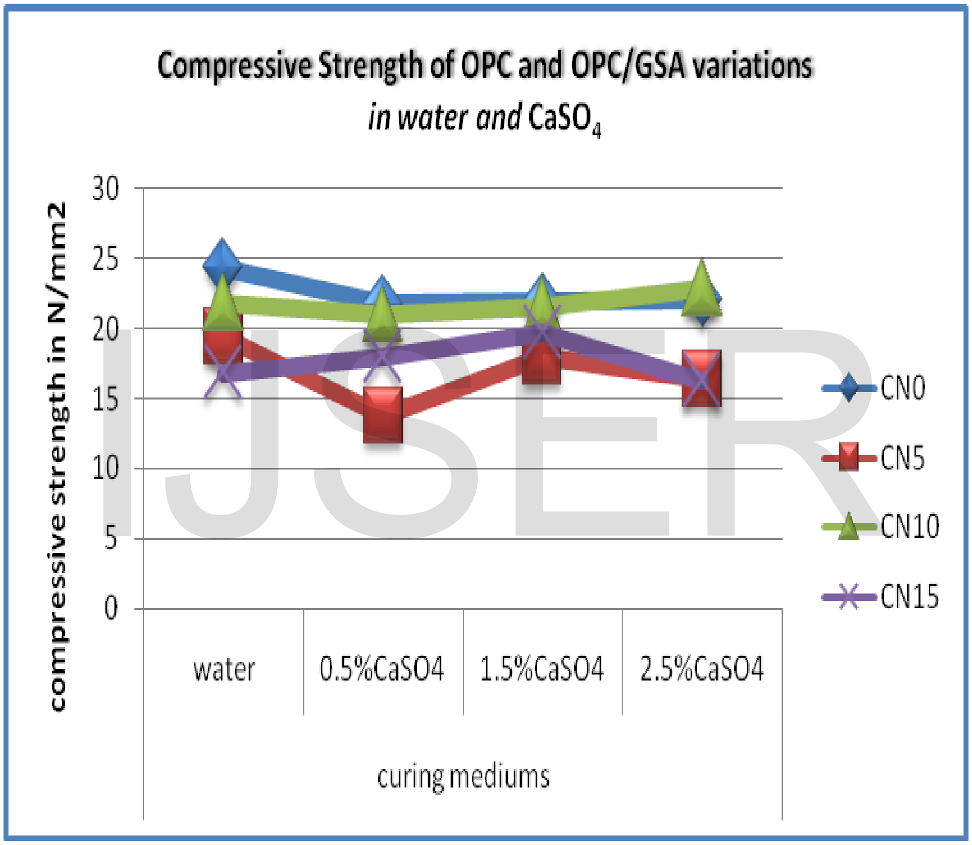

Figure 1: Showing *compressive strength variations of samples in water and* $CaSO_4$ *at 56th day*.

Table 5: Compressive Strength of OPC and OPC/GSA Cured in Water and 0.5%, 1.5% and 2.5% Solution of Na_2SO_4 **at 56 days of hydration.**

Description	Compressive Strength In (N/mm^2)			
	Water	**0.5%** $\mathbf{Na_2SO_4}$	**1.5%** $\mathbf{Na_2SO_4}$	**2.5%** $\mathbf{Na_2SO_4}$
$\mathbf{CN_0}$	**24.33**	**20.40**	**22.67**	**23.24**
$\mathbf{CN_5}$	**19.40**	**14.48**	**15.87**	**16.04**
$\mathbf{CN_{10}}$	**21.84**	**20.87**	**21.98**	**22.72**
$\mathbf{CN_{15}}$	**16.89**	**18.44**	**19.02**	**20.49**

CN_0, CN_5, CN_{10} and CN_{15} are; 0%, 5%, 10% and 15% GSA replacements

The result above shows OPC/GSA blended concrete performed better in $\mathbf{Na_2SO_4}$ solution, with compressive strength of 22.72 N/mm^2 over that of OPC/GSA concrete cured in water, with 21.84 N/mm^2. The OPC concrete in $\mathbf{Na_2SO_4}$ solution shows little strength loss, with 24.33 N/mm^2 and 23.24 N/mm^2 in water and sodium sulphates medium respectively.

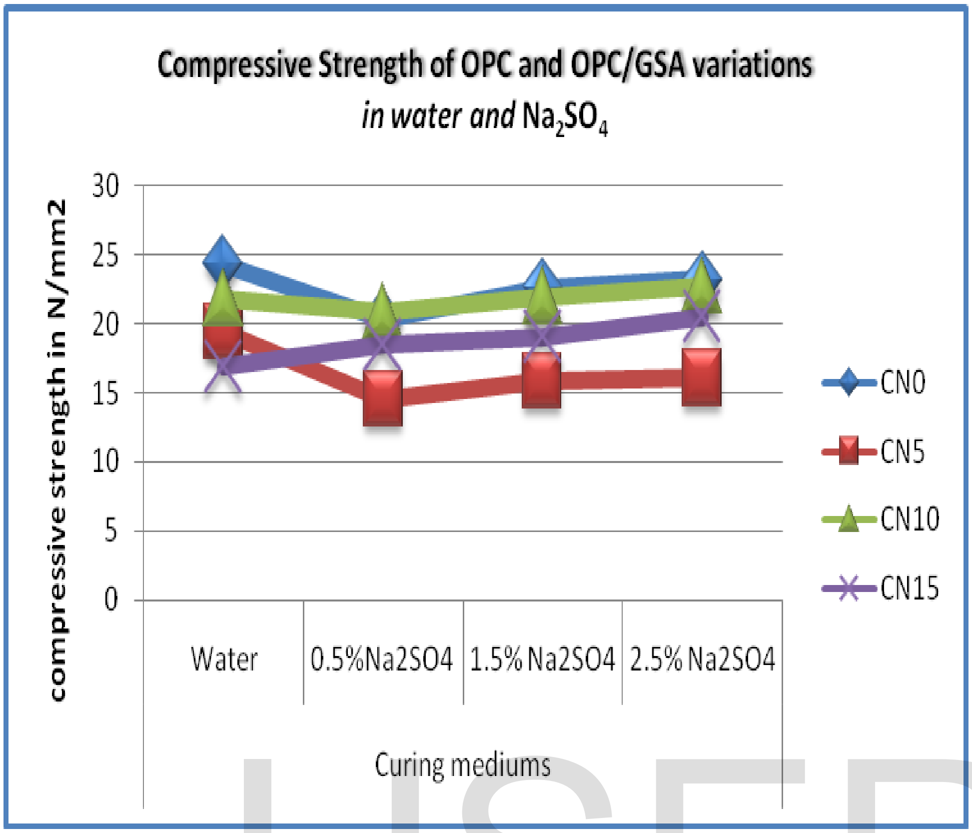

Figure 2: Showing *compressive strength variations of samples in water and* Na_2SO_4 *at 56th day*.

Table 6: Compressive Strength of OPC and OPC/GSA Cured in Water and 0.5%, 1.5% and 2.5% Solution of $MgSO_4$ **at 56 days of hydration.**

Description	Compressive Strength In (N/mm^2)			
	water	**0.5% $MgSO_4$**	**1.5% $MgSO_4$**	**2.5% $MgSO_4$**
CN_0	**24.33**	**19.60**	**19.48**	**18.44**
CN_5	**19.40**	**17.82**	**16.27**	**14.71**
CN_{10}	**21.84**	**19.13**	**19.89**	**22.11**
CN_{15}	**16.89**	**16.78**	**16.70**	**16.71**

CN_0, CN_5, CN_{10} andCN_{15} are; 0%, 5%, 10% and 15% GSA replacements

The result in table above shows loss in compressive strength of OPC concrete cured in MgSO4 solution over that of OPC concrete cured in water. The OPC/GSA concrete shows no sign of strength loss, rather there was increase in its value at 10% GSA replacement. This may be attributed to the reaction between magnesium sulphate solution and cement paste forming gypsum (CaSO4 – 32H2O) and Ettringite (3CaO – Al2O3 – 3CaSO4 – 32H2O).

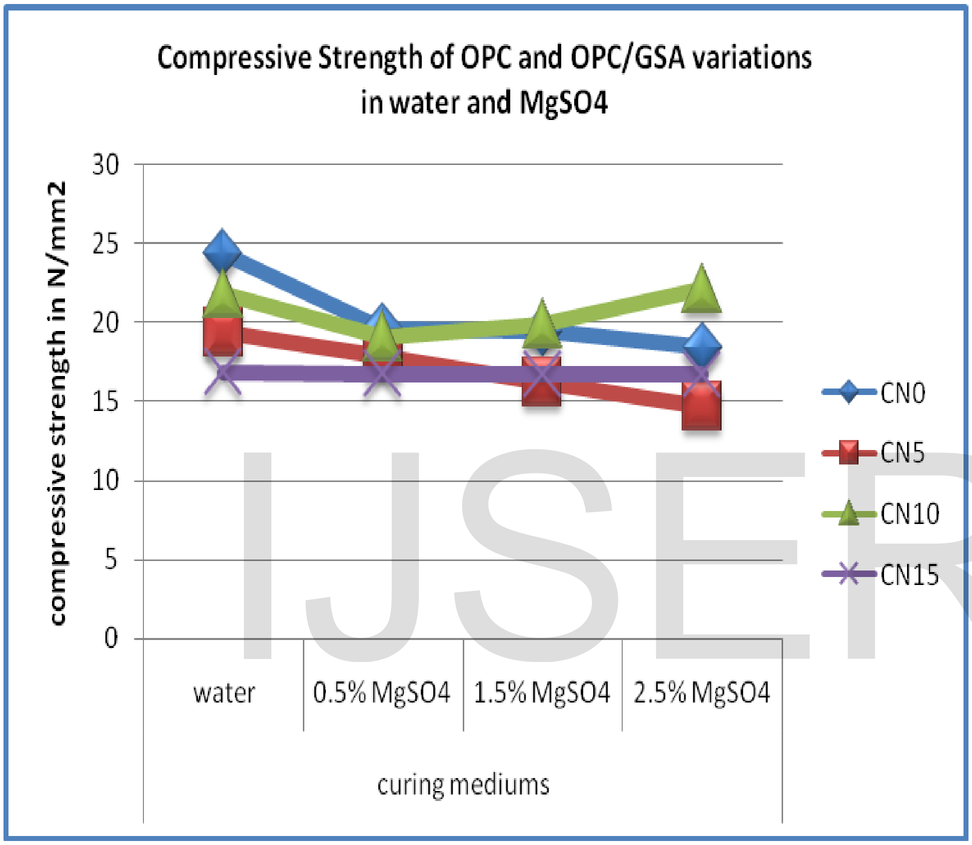

Figure 3: Showing *compressive strength variations of samples in water and* $MgSO_4$ *at 56th day*.

Table 7: Results of slump test on concrete with GSA partial replacement (1:2:4 mixes)

OPC/GSA	0%	5%	10%	15%
Slump 1:2:4 mix (mm)	30	23	18	15

The table above shows that the slump decreases with increasing %GSA replacement.

Table 8: Splitting Tensile Test Result for the Concrete (1:2:4) at water curing medium

Samples	GSA%	21days	28days	56days
TN_0	0%	2.01	2.57	3.13
TN_5	5%	1.86	2.46	2.94
TN_{10}	10%	1.64	2.11	2.76
TN_{15}	15%	1.15	1.99	2.66

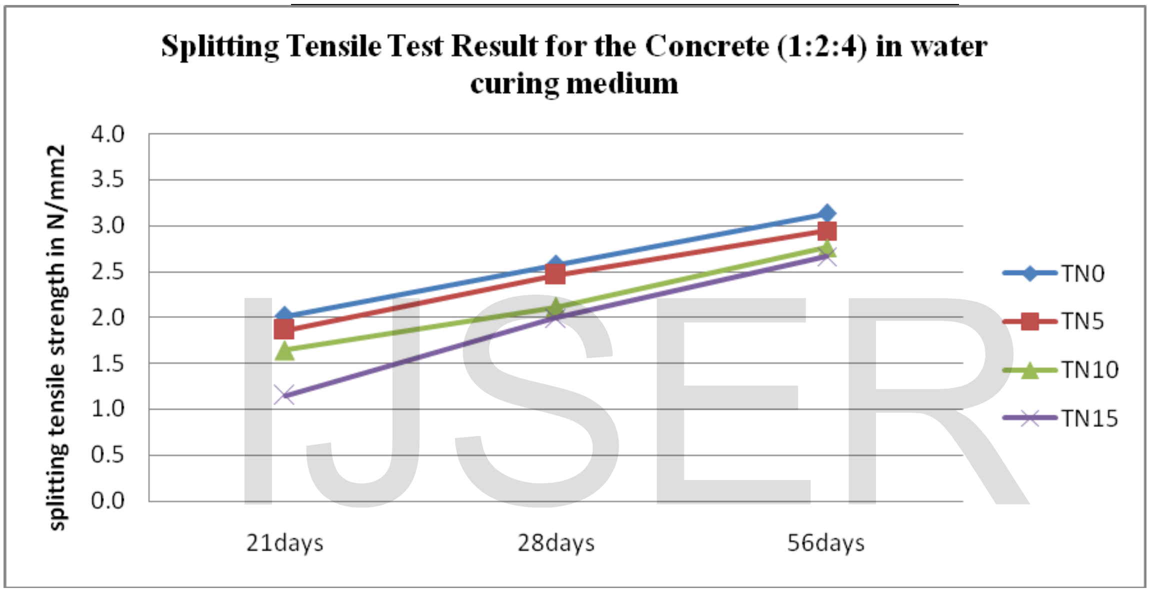

Figure 4: Showing Splitting Tensile Strengths Variation with Different Percentages of GSA in Concrete with mix 1:2:4

4. Conclusions

From the result of the tests and analysis carried out, the following conclusions were drawn:

- The Groundnut Shell Ash blended cement concrete haven proven resistance to magnesium sulphate, sodium sulphate and calcium sulphate media and would perform better in soils containing these media (**$MgSO_4$, Na_2SO_4, $CaSO_4$.**).
- The specific gravity of the GSA was less than that of the OPC it replaced, and thereby affects the slump values of OPC/GSA blended concrete as its Slump values decreases with increasing GSA replacement.
- The compressive strength value of the GSA/OPC blended concrete at 10% replacement level performed better and would be acceptable and considered as a good development for construction of masonry walls and mass foundations in any sulphate environment.

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