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# Assessment of Groundnut Shell Ash (GSA) as Admixture in Cement Paste and Concrete

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**Abstract**
This paper assesses the effect of Groundnut Shell Ash (GSA) as admixture on cement paste and concrete. The GSA used was obtained by controlled burning of groundnut shell in an incinerator to a temperature of 600°C and after cooling was sieved through a 75µm sieve and characterized. The effects of GSA on cement paste were investigated for addition of 0, 1, 2, 3, 4, 5 and 6 %, respectively by weight of cement. The slump of fresh 1:2:4 concrete mixes with 0.55 water cement ratio and GSA in the order above was determined and a total of one hundred and five 150 mm cubes of hardened concrete tested for compressive strength at 1, 3, 7, 28 and 56 days of curing in accordance with standard procedures. Also the resistance of concrete to specimen exposed to 2.5% concentration of sulphuric acid solution was investigated. The result of the investigations showed that GSA was predominantly of calcium oxide (24.10 %), potassium oxide (21.90 %) and a combined $SiO_2$, $Al_2O_3$ and $Fe_2O_3$ content of 29.04 %. The addition of GSA in cement or concrete decreased drying shrinkage, slump and water absorption, but increased consistency, initial and final setting times and could be used as a retarder. Also GSA addition showed increase in compressive strength, with an optimum of 4% GSA. The use of GSA in concrete also offered a better resistance to sulphuric acid environment. Therefore up to 4% GSA is recommended as a retarding admixture and strength improver in normal and sulphuric acid environments.

Keywords: **Acidic environment, admixture, cement paste, concrete, Groundnut shell ash**

## 1. Introduction

Global research trends in materials development have been that of sourcing for alternatives necessitated by the high cost of conventional materials, difficulties in accessing fund for construction/ building development, the need to recycle agricultural waste materials for construction, the need to maintain ecological balance and the challenges of housing amongst many other reasons. These alternatives to conventional materials include use of pozzolanas as substitutes to cement and as mineral admixtures. In many developing countries the demand for building construction materials such as Ordinary Portland cement and admixtures is high to meet the infrastructure needs of the citizens. However, the production of these products requires capital intensive plants and expertise, with consequent high cost in addition to increase in the prices of traditional building materials to the common man due to inflation. To lessen material and construction cost to affordable rate, many research works have been directed towards utilization of cheap and readily available local materials such as industrial and agricultural by products as substitute of aggregate or binder in infrastructure construction [1].

Industrialization in developing countries has resulted in an increase in agricultural output and consequent accumulation of unmanageable waste. Groundnut shell is a waste from agricultural product which is usually burnt, dumped or left to decay naturally. It constitutes about 25 % of the total pod (shell and seeds) mass [2] and may be a nuisance to both health and environment when not properly disposed, these may create large amounts of waste byproducts that must be transported away and stored in landfills. The pollution arising from such waste is a cause of concern for many developing nations such as Nigeria [1]. However, studies reported by [3], [4], [5], etc on use of groundnut shell ash (GSA) as partial substitute of cement in mortar and concrete work have shown that inclusion of the material in the matrix not only lowers the cost of the concrete but also offers a large potential as a cost-effective alternative to current disposal method of waste. They also suggested that up to 10 % GSA content could be used as a partial substitute of cement in structural concrete and mortar.

The use of admixture in concrete is necessary in situations where there is a need to enhance the properties of either fresh or hardened concrete or both for a particular purpose. In most situations the realization of such improvement can only be achieved effectively and more rapidly when appropriate admixtures are used. The choice to investigate into the use of groundnut shell ash as admixture in cement paste and concrete may serve as a cheaper alternative to that of conventional admixtures, with a consequent reduction in the cost of construction and also as a means of addressing the environmental pollution caused by the accumulation of the waste.

## 2. Materials and Methods

### 2.1 Materials

Ordinary Portland cement manufactured in Nigeria as Dangote brand with a specific gravity of 3.15 was used. The oxide composition of the cement is shown in Table 1. Sharp sand from River Kumayan, Kumbutso Local Government Area, Kano State, Nigeria, with a specific gravity of 2.57 and bulk density of 1632 kg/m$^3$ 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 [6] grading limits for fine aggregates. The coarse aggregate is crushed granite of nominal size of 20 mm with a specific gravity of 2.67 and bulk density of 1562 kg/m$^3$. The particle size distribution is also shown in Fig. 1.

Groundnut shell was sourced from Barama, Mubi North Local Government Area, Adamawa state, Nigeria. The Groundnut Shell Ash (GSA) was obtained by burning the groundnut shell to a temperature of about 600 $^o$C in an incinerator and controlling the firing at that temperature for about two hours, the ash was allowed to cool and ground before sieving through a 75 µm sieve. The GSA is of specific gravity of 2.35, bulk density of 445 kg/m$^3$, moisture content of 1.42 % and grain size distribution is shown in Fig. 1. A chemical composition analysis of the GSA was conducted using X-Ray Flouresence (XRF) analytical method and shown in Table 1.

### 2.2 Methods

#### 2.2.1 Tests on Cement Paste.

Seven mixes were used for the determination of Consistency, Setting Times and drying linear shrinkage of GSA-Cement in accordance with [7]. MP-00 is the control mix (0 % GSA), and MP-01, MP-02, MP-03, MP-04, MP-05 and MP-06 are mixes containing GSA additions of 1, 2, 3, 4, 5 and 6 %, respectively. Three readings were taken and an average found. The behavior is shown in Fig. 2 - 4.

#### 2.2.2 Concrete mix Proportion

Prescribed concrete mix of 1:2:4 and water-cement ratio 0.55 was used to assess the effect of GSA as admixture in concrete. Seven mixes were used, ACM-00 is the control mix and ACM-01, ACM-02, ACM-03, ACM-04, ACM-05 and ACM-06 representing mixes with addition of GSA of 1 % to 6 %, respectively.

Table 1: Oxide Composition of OPC (Dangote Brand) and GSA

| Oxide (%) | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $K_2O$ | $Na_2O$ | $SO_3$ | $TiO_2$ | MnO | BaO |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OPC | 18.0 | 3.10 | 4.82 | 68.37 | 1.48 | 0.35 | 0.32 | 1.82 | 0.35 | 0.03 | 0.16 |
| GSA | 22.00 | 2.00 | 5.04 | 24.10 | 3.00 | 21.90 | - | 1.05 | 1.70 | 0.42 | 0.57 |
| | | | | | | | | | | | |
| Oxide (%) | $V_2O_5$ | $P_2O_5$ | ZnO | $Cr_2O_3$ | NiO | CuO | SrO | $ZrO_2$ | L.o.I | | |
| OPC | 0.03 | - | - | - | - | - | - | - | 1.27 | | |
| GSA | 0.05 | 1.08 | 0.12 | 0.04 | 0.02 | 0.14 | 0.30 | 0.43 | 4.36 | | |

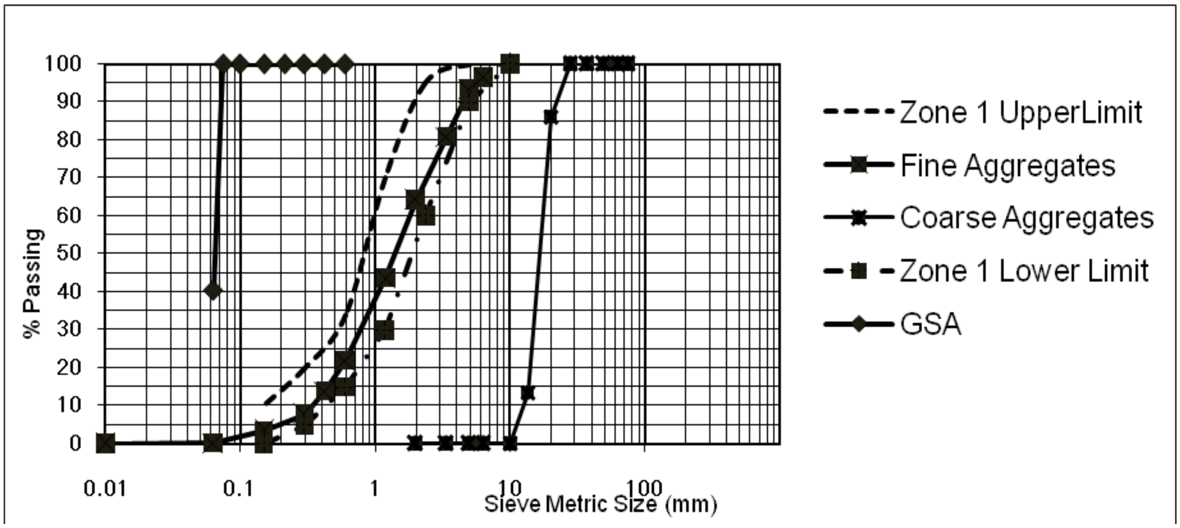


Fig. 1: Particle Size Distribution of GSA, River Sand and Coarse Aggregate

2.2.3 Slump of GSA- Concrete

The workability of fresh Concrete with GSA addition was determined in accordance with [8] using the mixes stated above and the results are shown in Fig. 5

2.2.4 Compressive strength test on GSA-Concrete

The compressive strength of Concrete with addition of GSA was carried out in accordance with [9] for the prescribed concrete mix of 1:2:4 and water-cement ratio 0.55. A total of one hundred and five (105) 150 mm cube specimens were cast and cured in water for 1, 3, 7, 28 and 56 days, respectively and at the end of every curing regime, three samples were crushed using the Avery Denison Compression Machine of 2000 kN load capacity and at constant rate of 15 kN/s and the average taken. The compressive strength behaviour is shown in Fig. 6.

2.2.5 Test of GSA-Concrete in Sulphuric Acid.

This was carried out using crushed samples of the cube from the compressive strength test at 28 days curing for the seven mixes. Three pieces of crushed samples for each percentage addition of GSA were taken and weighed before exposure in 2.5% concentration of sulphuric acid ($H_2SO_4$) solution. The test ran for 28 days with weight retained taken at 7days intervals. At the end of every 7th day, the samples were removed cleaned and left to dry before weighing to obtain the weight at the end of that regime. The behaviour of GSA-Concrete resistance to sulphuric acid environment was determined in terms of weight retained and is shown in Fig. 7.

### 2.2.6 Water absorption test of GSA-Concrete

This test was done in accordance to [10] using GSA-Concrete cubes of the seven mixes. A total of twenty one (21) samples were cast and after 28 days curing tested in triplicate for an average. The behavior is shown in Fig. 8.

## 3. Discussion of Results

### 3.1 Cement and Groundnut Shell Ash

The oxide composition of groundnut shell ash (GSA) indicate a combined $SiO_2$, $Al_2O_3$ and $Fe_2O_3$ content of 29.04 % which is much less than that specified by [11] for pozzolana and shows that is not a good pozzolana. The CaO content (24.10 %) in GSA also shows that it has some self cementing properties. The oxide composition of GSA also indicated a high content of $K_2O$ (21.90 %) which may be a source of disruption in cement and concrete matrix. The chemical composition of the cement is satisfactory and has met the [12] standard.

### 3.2 Groundnut Shell Ash-Cement pastes

Normal consistency of cement with addition of GSA increases with increase in GSA content as shown in Fig. 2. More water is required for wetting the particles as the total surface area of the particle is increased [13]. Furthermore, since GSA has a less specific gravity than the OPC, a large volume of water may be required to properly wet excess volume of GSA added to the mix to produce GSA-cement gel and this could lead to increase in consistency of the GSA-cement paste, consistent with [14] explanation on OPC-Sawdust ash cement composites.

The setting times of GSA-cement increased with increase in GSA content as shown in Fig. 3. This behavior may be due to the presence of potassium oxide ($K_2O$) which hinders complete combination of lime and causes setting anomalies or negative effect on setting [15]. It may also be due to the possibility of formation of magnesium silicate ($MgSiO_3$) which is known to be a retarder thereby causing delay in the setting time of cement [16]. The reaction of GSA with cement and water may be as presented in equations (1) to (5).

$$Ca(OH)_2 + SiO_2 \rightarrow CaSiO_3 .H2O \quad (1)$$

$$MgO + H_2O \rightarrow Mg(OH)_2 \quad (2)$$

$$Mg(OH)_2 + SiO_2 \rightarrow MgSiO_3 . H_2O \quad (3)$$

$$K_2O + H_2O \rightarrow 2KOH \quad (4)$$

$$2KOH + SiO_2 \rightarrow K_2SiO_3 + H2O \quad (5)$$

The drying shrinkage of GSA-Cement paste shows a decrease in linear drying shrinkage with percentage addition of GSA as shown in Fig. 4. This may be due to the presence of calcium oxide and potassium oxide which hydrates, reducing the water content and this would be useful in cold weather concreting without problems of cracking since increase in percentage addition of GSA reduces linear shrinkage of the concrete [17].

### 3.3 Slump of GSA-concrete

The slump of concrete decreased with increase in addition of GSA content as shown in Fig. 5. This may be due high loss on ignition of GSA to that of cement and also may be due to high specific surface of GSA for constant water content [18].

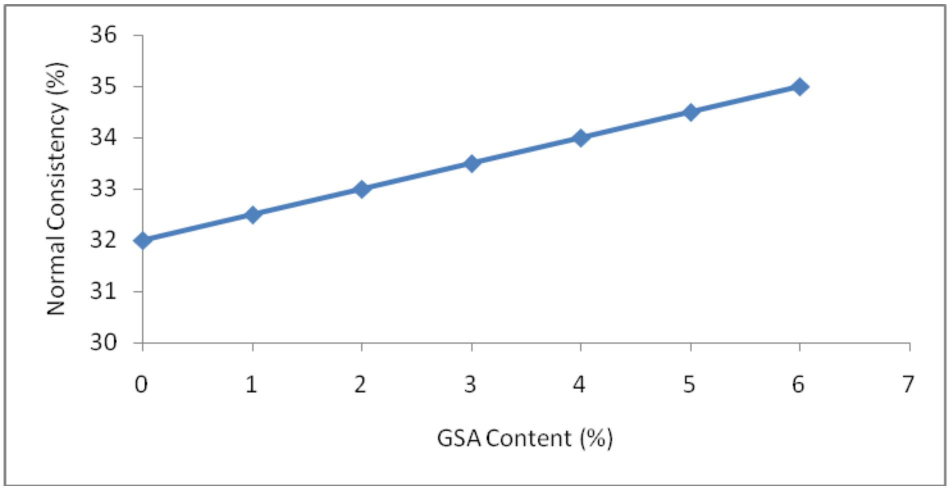


Fig. 2: Normal Consistency of GSA-Cement Paste

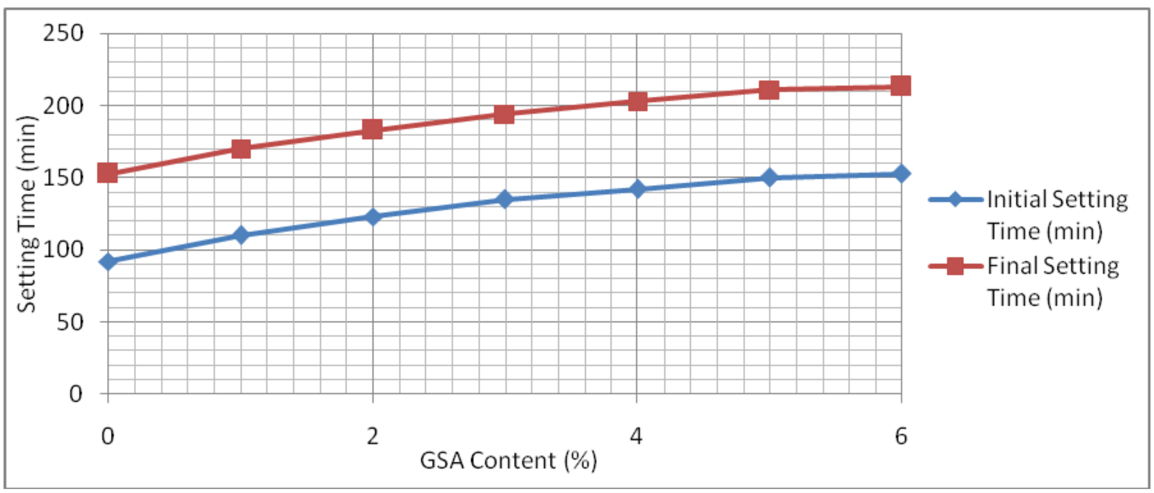


Fig. 3: Setting Times of GSA-Cement Paste

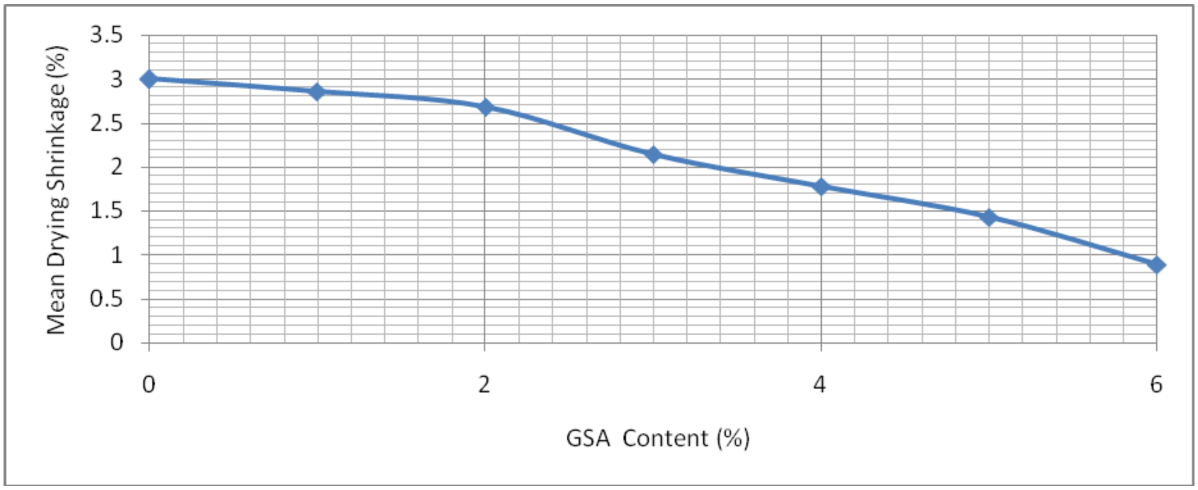


Fig. 4: Drying Shrinkage of GSA-Cement Paste

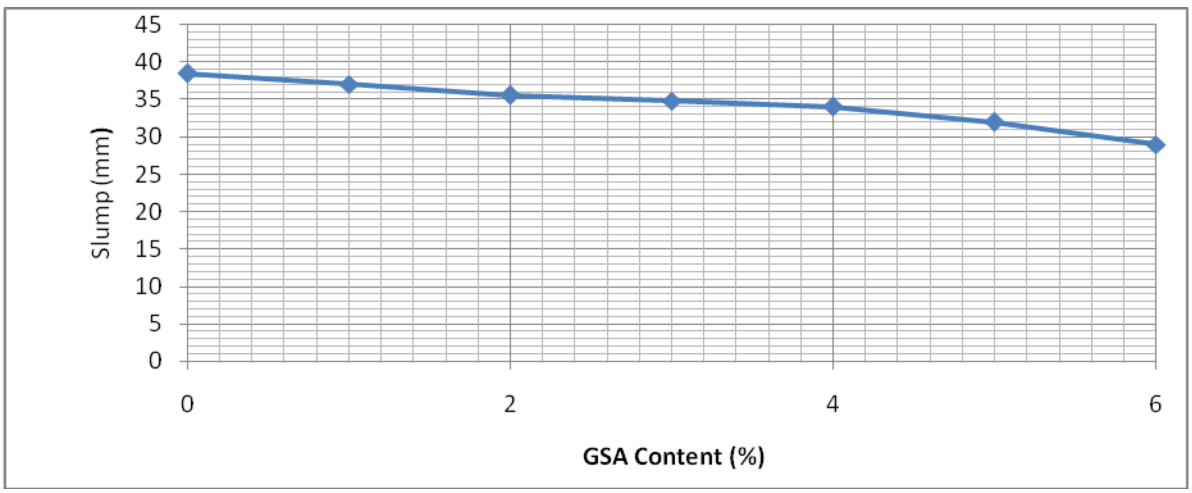


Fig. 5: Slump of GSA-Concrete

3.4 Compressive Strength of GSA-concrete

The compressive strength of GSA-concrete showed that compressive strength increased with curing age and also increased with addition of up to 4% of GSA. Further increase in addition of GSA showed a decrease in compressive strength of the concrete as shown in Fig. 6. The increase in compression strength with curing age is due to hydration of cement and GSA, while increase in compressive strength with addition of GSA up to 4% may be due to formation of additional calcium silicate hydrates from the pozzolanic reaction of GSA. The reduction in compressive strength with addition of GSA of 4% and above may be due to saturation of the cement mix with oxides of $K_2O$ and MgO in GSA which form composites that may inhibit the formation of strength giving calcium silicate hydrates from cement hydration, consistent with [19] report on sawdust ash in concrete.

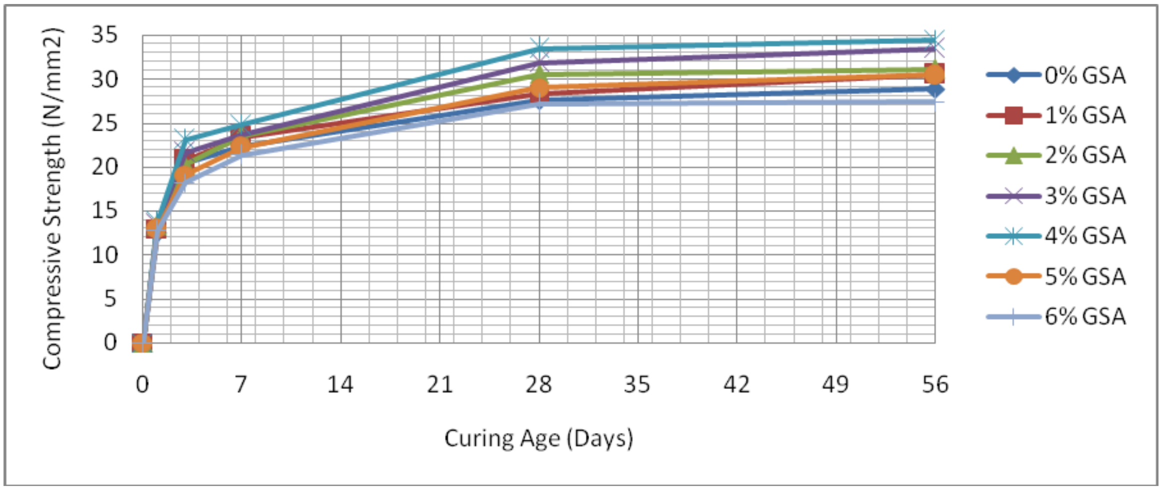


Fig. 6: Compressive Strength Development of GSA-Concrete.

3.5 Effect of Sulphuric Acid on GSA-concrete.

Fig. 7 shows the weight retained of GSA-Concrete specimens exposed to sulphuric acid environment. The weight of concrete retained decreased with increase in exposure duration but increased with increase in GSA content up to 4 % with a maximum weight retained at 28 days of 83.4% compared to 82.4% for the control specimens. The improvement in resistance to sulphuric acid of GSA up to 4 % in concrete could be attributed to pozzolanic reaction of GSA with the lime in the paste matrix; consequently it reduced the lime present in its free format which usually reacts with many chemicals causing concrete degradation [19]. Also the additional calcium silicate hydrates formed from GSA pozzolanic reaction improved the concrete pore structure with greater impermeability than that of Ordinary Portland cement concrete, and would slow down the penetration of water and chemicals into the concrete. However, at high percentage addition of GSA above 4%, the other GSA oxides such as phosphorus oxide and potassium oxide will inhibit further formation of $CaSiO_4$ hydrates and may lead to the formation of void in GSA-Concrete due to the formation of potassium silicates that displaced more calcium oxide in cement, with a consequent reduction in resistance to sulphuric acid aggression.

3.7 Water Absorption of GSA-Concrete

The water absorption of GSA-Concrete decreased with increase in GSA addition as shown in Fig. 8. This may be due to the presence of phosphorous (v) oxide in GSA, which is known to be an effective drying and dehydrating agent [17].

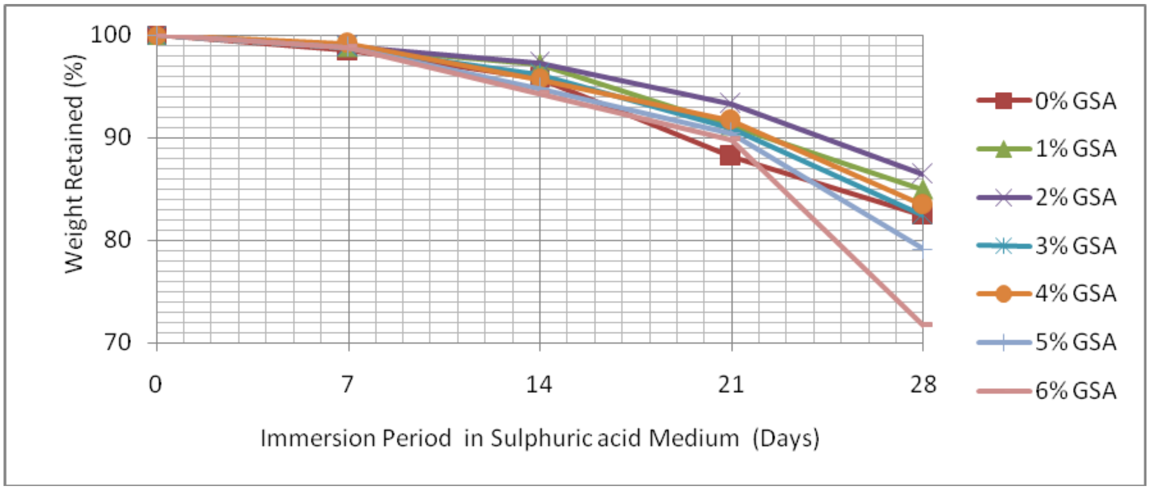


Fig. 7: Weight of GSA-Concrete retained after exposure in Sulphuric acid solution.

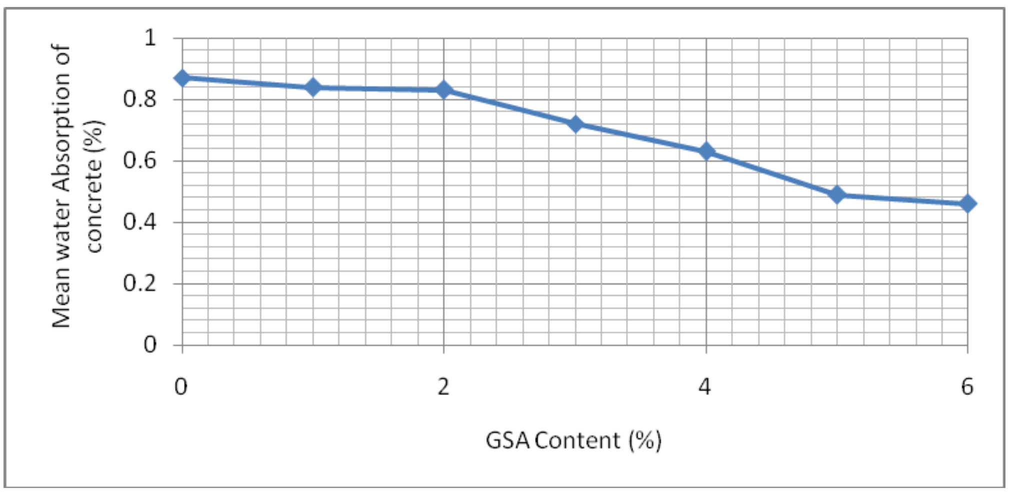


Fig. 8: Water Absorption of GSA-Concrete

## 4. Conclusions

i) Groundnut Shell Ash addition decreased drying shrinkage, but increased the consistency and setting times of cement paste, and could be used as a retarder.

ii) GSA addition also decreased the workability and water absorption of concrete.

iii) GSA addition of up to 4 % increased the compressive strength and resistance of concrete exposed to sulphuric acid environment.

iv) Caution should be applied in the used of GSA as admixture in concrete to avoid alkali silica reaction from GSA with some aggregates.

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