# Groundnut shell ash: a Local Construction Material in Concrete Production

**by**

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**Abstract**

*This research focuses on the use of groundnut shell ash as a partial replacement of cement in concrete production under an environmental friendly environment, it encourages the use of agricultural waste as a construction and building material, optimize the replacement of cement with groundnut shell ash (GSA) and showcase the influence of the groundnut shell in the compressive strength of concrete as an alternative local material that could easily partially or fully replace cement ratio in concrete. Cement in the production of the concrete mix was replaced with 0% of groundnut shell ash (GSA) as control, 5%,10%,15%, 20 and 25% replacement. A total of 100 cubes were cast using G20 concrete mix design of 1:1.5:2, and the cube specimens are tested for their compressive strength after curing for 3 days, 7 days, 21 days and 28 days respectively. Although the result shows that the compressive strength value of all the GSA/OPC blended concrete at 5,10,15, 20 and 25% replacement did not meet the required specification of concrete strength G20 after curing compare to standard or close to the control at 0%, but 5% has the highest level of performance better than the other percentage replacement and would be for the construction light concrete production. Thus the GSA/OPC concrete is considered to be an environmentally pollution frees construction material but not of economic advantage to contractors therefore it can be accepted and considered as a good development in building construction industries.*

***Keywords:*** Groundnut Shell Ash, Local Material, Construction, Concrete,

## 1.0 Introduction

The rising cost of housing and construction material especially cement in developing countries in the world including Nigeria is a major concern. Therefore, Groundnut shell being a total waste in agriculture for decade has resulted for a decade research to ascertain the use of the ash as soil stabilizer in clay brick production, as a fertilizer on soil and in partial replacement of cement (Bokinni, 2008). Due to the impact of the groundnut shell as agricultural waste on the environment it's therefore necessary to use it for sustainable green building material. As early mentioned the groundnut shell being a waste agricultural and plant product it has resulted to a lot of environmental negative factors that result to accumulating of unmanaged wastes especially in developing countries which has continued to create an increasing environmental concern. The wide range of material for used in place of Portland cement in the construction industries has become a great concern for those in the building and construction industries. This been attributed among many factors to the hike in cement, a major component in concrete production that is use in the construction industries (Dauda 2013). To this, the choice and sustainability of a particular material depends mainly on it availability, nature of the project, individual preference, durability, proximity and economic consideration. The Groundnut Shell Ash has been in used for decade in the rural area as a soil stabilizer in the Mud brick making and Mud housing (Zakariya et-al 2005). But the use of this material as a partial replacement of cement cannot be ignored.

The utilization of Groundnut shell will promote waste management at little cost, reduce pollution by these waste and increase the economic base of the farmer when such waste is sold thereby encouraging more production of the material. In zakariya et'al (2004) says material cost accounted for two third of the building production. While Bokinni (2007) observed that material constitute about 65% of the total cost of building. Beside that the quality of any construction work has direct relationship with the quality of materials used for such construction work. In other words, there is an interrelationship between material quality and material behavior. That is why Taylor (2007), was of the view that building pathology depends on the understanding the material physiology to avoid building failure. A question may be asked if at all the groundnut shell has a pazzolanic cement properties. According to Grandawa, et'al (2015) and in Godwin, Et-al (2013), they stated that ''Groundnut shell ash has about 65-80% highly silica content and has been used as super pozzononic in concrete production as partial replacement of cement''. The composition of chemical compound in the groundnut ash make it suitable for application in concrete and mortar as a partial replacement for cement with a measure of succeed achieved. Dauda (2010), point out that the search for alternative binder or cement replacement material led to the discovery of the potentials of using local materials with pazzolanic properties. The use of GSA as a cement replacement as an impact and technical advantages in construction industries which enable a large qualities of cement replacement to be achieved (Hossain 2003). Some other researchers have also done some works in these areas of using waste materials like rice husk and fly ash to replace cement in concrete production.

In a related work of utilizing local construction material, Alabadan et'al, (2006) reported that 30% partial replacement of cement with groundnut shell ash gave better result in the strength of the composite concrete when compared with the controlled value. Zakariya et'al, (2005) in their research on the partial replacement of ordinary Portland cement with bambara groundnut shell ash concluded that there exists a high possibility of bambara groundnut shell ash partially replacing cement in concrete. They further said that at 10% replacement the concrete can be used for light load bearing elements.

Other research conducted in partial replacement of cement in construction includes: the use of rice husk ash and lime to partially replace concrete, the use of rice husk ash in low cost sandcrete block production. Groundnut is produced in large quantity in the northern part of Nigeria. Nigeria is the world third producer of ground nut. Forty percent of groundnut is the shell and are thrown away as wastes.

## 2.0 Materials and Methods

The materials used for this research

**Cement:** Ordinary Portland cement (Dangote) with specific gravity of 3.15 and grade 42.5R was used complying with

Nigeria Standard, which was procured from a local suppliers and use in the experiments in Geidam.

**Aggregates:** 20mm size of coarse aggregates and fine aggregate (river sand) was used. The coarse aggregate was obtained from a local vendor it was washed and dry clean. Likewise, the fine aggregate (river sand) obtain from Geidam river.

**Water:** For preparation of mix and curing of concrete samples, potable water supplied from the reservoir tank well located in the laboratory was used.

**Groundnut shell ash:** The replacing material is the ash found after burning the groundnut shell was obtained from a farm in Degubi, Yobe State. The burned groundnut shell ash was sieve through BS test Sieve 75micron.

## 2.1 Ash Production

The ash was obtained by burning the groundnut shells in perforated steel drum in the open air under normal temperature. The idea of burning them on an iron sheet and the furnace was dropped because they will be time-consuming and uneconomical for most people especially those at the rural levels. The burnt ash was passed through a BS sieve (75micron) the portion passing through the sieve would have the required degree of fineness of 0.063mm and below while the residue was thrown away (Mbachu and Kolawole, 1998).

## 2.2 Setting Time

The initial setting time for OPC and OPC/GSA pastes is very important as such will help to determine the setting time of the OPC and OPC/GSA. To this 2 hours 35 minutes and 3 hours 20 minutes respectively were considered. 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 ASTM C191 (1992), and were in close agreement with the work of (Adole et.al, 2011).

## 2.3 Concrete Cubes Production

The batching of the concrete materials was done by volume. The mix proportion used for this work was 1:1.5:2. The proportions of cement to ash in the concrete were 100:0% as control as a bench mark to compare other result when replace with Cement: GSA, 95:5%, 90:10%, 85:15%, 80:20% and 75:25% respectively. The concrete materials cement, aggregates and ash were mixed by hand with a water/cement ratio of 0.6 by weight. The materials were mixed together thoroughly by stirring to form a uniform mass. Before the casting the concrete paste was subjected to slump test to ascertain it workability. The moulds were cleaned with engine oil to prevent the development of bond between the mould and the concrete and permit easy stripping. 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. Then the concrete cubes in the moulds were left in the open air for 24 hours. For each of the cement: ash proportions, five cubes of concrete were cast. Stripping of the concrete cubes from the mould was carefully done after 24 hours of the concrete setting under air. Then the cubes are weight before immersing in water for curing to determine the concrete water absorption. Curing of the concrete cubes was done by complete immersion in a laboratory water tank of 1.2 m x 1.2m x 1.2m filled with tap water only for periods of 3, 7, 21 and 28 days respectively.

## 3.4 Concrete Water Absorption

The concrete water absorption is importance in production of concrete so as to ascertain the water absorption of the concrete after production this will help in determining the rate at which the concrete will absorb water that will add to the weight of the concrete.

## 3.5 Testing

### 3.5.1 Chemical Analysis of Groundnut Shell Ash

Chemical analysis of GSA was carried out at Chemistry Laboratory of the Science Laboratory department, MIA Polytechnic Geidam, Yobe State. The X-ray Analyzer together with Atomic Absorption Spectrophotometer (AAS) was employed for the analysis except for Sulphur Oxide, Sodium and Potassium Oxide, Carbonate and Hydrogen Carbonate where obtained from already established data.

### 3.5.2 Bulk Density

For compacted bulk density, the cylindrical shape container is filled in three stages, each third of the volume being tamped 25 times with a 16 mm diameter round-nosed rod as in B.A. Alabadan et-al (2006). The overflow is removed. The net mass of the aggregate in the container divide by its volume represents the density.

### 3.5.3 Compressive Strength Test

Before crushing, the cubes were brought out of the water and kept for about 10 minutes for most of the water to drip off. They were then weighed on a weighing balance and then taken to the crushing machine in accordance with BS 1881: Part 116 (1983). The cubes experienced cracks due to failure in their strength as a result of the load applied by the crushing machine. The load on the cube was applied at a constant rate of stress equal to 0.2 to 0.4 $MN/m^2$ per second. The compressive strength was reported to the nearest 0.5 $MN/m^2$.

## 4.0 Result and Discussion

### 4.1 Physical analysis of Groundnut Shell Ash (GSA) and OPC

**Table 1**: Physical Properties of Groundnut Shell Ash with moisture content of 0.43

| S/N | Replacement Ratio | | |
|---|---|---|---|
| | Ordinary Portland Cement | Groundnut Shell Ash | Specific Gravity |
| 1 | 100 | 0 | 3.15 |
| 2 | 95 | 5 | 2.55 |
| 3 | 90 | 10 | 2.55 |
| 4 | 85 | 15 | 2.50 |
| 5 | 80 | 20 | 2.54 |
| 6 | 75 | 25 | 2.36 |
| 7 | 0 | 100 | 1.59 |

Source: Lab Test Research Result 2018

From table 1 above, the Specific gravity of the cement used was 3.15 and the GSA is 1.59 as obtained after the analysis. This value of GSA is greater than 1.54 as reported by Buari et'al, (2013) but less than 1.85 and 1.90 reported by Adole et.al, (2011) and Kamang et.al, (2001) respectively, for GSA and Pulverized Fuel Ash respectively, the specific gravity of the replacement also shows that in 5, 10, 15, 20 and 25% are 2.55, 2.55, 2.50, 2.54 and 2.36 respectively. These values are less than average value of 3.15 for

Portland cement. This means that a considerable greater volume of cementitious materials (GSA) will result from mass replacement. The moisture content is in agreement with value reported by Buari et'al, (2013) which was 0.43%.

### 4.2 Chemical Analysis of Groundnut Shell Ash (GSA) and OPC

The results below in table 2 indicate that GSA contains most of oxides found in ordinary Portland cement. The Calcium Oxide and Silica percentage composition of ordinary Portland cement were higher with 62% and 22% than respectively that of the Groundnut Shell ash with 8.69% and 16.21% for Calcium Oxide and Silica respectively, while the percentage of chemical composition of Potassium Oxide 15.73, Ferrous oxide 1.80, Aluminum Oxide, 5.93, Magnesium Oxide 6.74 and Sulphite 6.21 in GSA are higher than that found in ordinary Portland cement w. The result of the chemical analysis is similar to the works conducted by Alabadan, et 'al (2006), with the total percentage of Iron Oxide, Silicon Oxide and Aluminum Oxide is less than the minimum of 70% specified by for pozzolanonic ASTM C618 (1994).

**Table 2:** Chemical Analysis of Groundnut Shell Ash and OPC

| Constituent | % Composition (GSA) | % Composition (OPC) |
|---|---|---|
| Calcium Oxide (CaO) | 8.69 | 62.00 |
| Potassium Oxide ($K_2O$) | 15.73 | 0.40 |
| Ferrous oxide ($Fe_2O_3$) | 1.80 | 4.60 |
| Silica ($SiO_2$) 16.21 22.00 | 16.21 | 22.00 |
| Aluminum Oxide ($Al_2O3$) | 5.93 | 5.03 |
| Magnesium Oxide (MgO) | 6.74 | 2.06 |
| Sulphite (SO3-) | 6.21 | 1.43 |
| Sodium Oxide (Na2O) | 9.02 | 0.19 |
| I.L | 4.80 | 2.82 |

Source: Lab Test Research Result 2018

## 4.3 Concrete water absorption

Three concrete cubes samples were used for each percentage replacement of cement. From table 3 it was found that the cubes increase by weight of water absorption with time. From the results obtained its was observed that as the percentage replacement of cement increases with GSA the more water the concrete absorb water. However, the result shows that at 25% replacement after 24hrs the highest value of 1.22% compare to the control which has 0.83%. this can be attributed to the high rate of water absorption due to water – binder ratio and pore structure of the GSA replaced concrete.

**Table 3: Water absorption result of GSA concrete at varying percentage cement replacement**

| % replacement | 6Hrs | 12Hrs | 18Hrs | 24Hrs |
|---|---|---|---|---|
| 100:0 (0%) | 0.82 | 0.80 | 0.79 | 0.83 |
| 95:5 (5%) | 0.82 | 0.80 | 0.79 | 0.83 |
| 90:10 (10%) | 0. 95 | 0.86 | 0.82 | 0.84 |
| 85:15 (15%) | 0.93 | 0.84 | 0.82 | 0.85 |
| 80:20 (20%) | 0.83 | 0.72 | .66 | 0.85 |
| 75:25 (25%) | 1.03 | 1.17 | 1.17 | 1.22 |

Source: Lab Test Research Result 2018

### 4.4 Workability

The workability of concrete mixes for different percentages of groundnut shells using slump tests are presented in Table 4. As the percentage of groundnut shell increases, the slump value decreases to very low workability 100 to 40mm as in (Neville 1996). This can be said its due to the water absorptive character of GSA and high fineness (increase surface area). The slump test results show that the control concrete mix indicates a shear slump value of between 100mm and 5% - 25% True shear. This may be due to the high absorption capacity developed as a result of increase in groundnut shell. Low workability concrete can be used in road construction and light weight concrete. The use of groundnut shell in concrete reduces the concrete's workability due to the absorption of part of the mixing water by the groundnut shell. More water is needed to maintain normal workability as groundnut shell is used in concrete or alternatively the groundnut shell should be soaked in water prior to mixing to reduce its tendency of absorbing and reducing the water/cement ratio.

**Table 4** Slump Test Showing at different percentage of GSA.

| % Replacement of GSA in Concrete | Slump value (mm) | Slump Type | Degree of Workability |
|---|---|---|---|
| 0 | 100 | Shear | Medium |
| 5 | 90 | True | Medium |
| 10 | 65 | True | Low |
| 15 | 60 | True | Low |
| 20 | 45 | True | Low |
| 25 | 40 | True | Low |

Source: Lab Test Research Result 2018

## 4.5 Bulk Density

Before the compressive strength test was carried out, the weights of the concrete specimens were taken to assess the bulk density of the concrete cubes. From the table 5 and analyzed shows the decrease in bulk densities of the concrete cubes as the replacement of groundnut shell increases. But at 5% replacement there was an increase in the density which might be due to the fact that at that percentage replacement the weight increased due to the absorption of mixing water by the groundnut shell thereby reducing the water/cement ratio and making the mixture denser thus leading to a specimen of high density. Although there was serious decrease in density as the replacement level is increased but all still satisfy density requirement for lightweight concrete according to BS EN 206 (1).

**Table 5: Bulk Density of Concrete Cube samples before crushing**

| % Of GSA In Concrete Sample | Density ($kg/m^3$) 3 days | Density ($kg/m^3$) 7 days | Density ($kg/m^3$) 21 days | Density ($kg/m^3$) 28 days |
|---|---|---|---|---|
| 0 | 2433.25 | 2415 | 2470.35 | 2490.65 |
| 5 | 2434.4 | 2502.15 | 2444.95 | 2385.45 |
| 10 | 2402.75 | 2392.85 | 2442.3 | 2277.95 |
| 15 | 2436.45 | 2365.05 | 2375.05 | 2382.4 |
| 20 | 2291.45 | 2167.50 | 2302.50 | 2338.25 |
| 25 | 2285.84 | 1998.5 | 2298.65 | 2301.54 |

Source: Lab Test Research Result 2018

### 4.6 Compressive Strength of Samples

The results below as in table 5 shows that Compressive strength for the control indicates that for (0% GSA content) was 18.30N/mm$^2$, 21.99 N/mm$^2$, 23.50 N/mm$^2$ and 26.25 N/mm$^2$ for 3,7,21 and 28 days respectively. For each cement/GSA combination, the compressive strength increases as the age of the concrete increases. This is due to hydration of cement. The control (0% GSA content) had the highest rate of early strength development with 5% GSA/OPC replacement in close contact with consistent rate of strength development as against Buari et.al, (2013) with 10% GSA/OPC replacement in close contact with consistent rate of strength development.

The results also show that their strength improves with age since pozzolanas react more slowly than cement due to variation in their constituents' composition. The pattern of this study was similar to Buari et.al, (2013) they reported that cement blended with pozzolanas would produce 65 to 95 % strength of OPC concrete in 28 days. Further, they reported that the replacement of ordinary Portland cement by a Pozzolanic material usually has beneficial effects on cement durability at ages up to 1.5 years. At age 28 days, the compressive strength was 26.25

N/mm$^2$, 16.50 N/mm$^2$, 14.45 N/mm$^2$, 12.50 N/mm$^2$ and 6.50 N/mm$^2$, for 0, 5, 10, 15 and 20 % GSA content respectively. The results show that for the same age, the compressive strength decreases as the proportion of GSA increases. This is because the GSA possesses little cementing properties compared to a Portland cement, Alabadan, et 'al (2006). As previous described by Bengtsson, et'al (1986) a percentage replacement of 5% with GSA will be adequate for good concrete work.

**Table 4:** Compressive Strength of the Specimens

| % GSA in concrete | Compressive strength N/mm$^2$ 3 days | Compressive strength N/mm$^2$ 7 days | Compressive strength N/mm$^2$ 21 days | Compressive strength N/mm$^2$ 28 days |
|---|---|---|---|---|
| 0 | 18.3 | 21.99 | 23.5 | 26.25 |
| 5 | 15 | 13.8 | 18.05 | 16.5 |
| 10 | 14.2 | 11.15 | 15.1 | 14.14 |
| 15 | 10.45 | 9.85 | 13.2 | 12.5 |
| 20 | 11.95 | 8.98 | 11.56 | 10.65 |
| 25 | 4.75 | 5.2 | 6.95 | 6.5 |

Source: Lab Test Research Result 2018

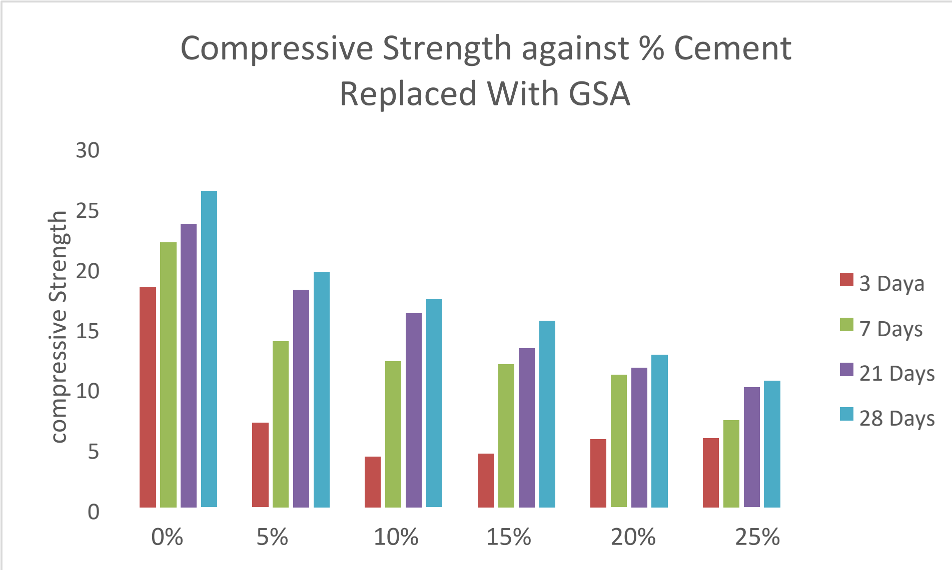


**Figure3** Compressive Strength of the Specimens

## 5. CONCLUSIONS AND RECOMMENDATION

From the results of the tests carried out in this work, it can be concluded that:

1. GSA is a good Pozzolanic material which reacts with calcium hydroxide forming calcium silicate hydrate.

The Pozzolanic activity of GSA increases with increase of time.

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

3 The compressive strength value of the GSA/OPC blended concrete at 5% replacement level performed better and would be acceptable and considered as a good development for construction of masonry walls and mass foundations in low-cost housing in Nigeria.

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