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# Potential Use of Groundnut Shell Ash as Soils Strength Enhancer

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## Abstract
*This research investigates the potential use of groundnut shell ash (GSA) as soils strength enhancer. The GSA was used as admixture on selected soil samples from four different locations and samples were named T1, T2, T3 & T4. The tests carried out on the samples include Atterberg limit, sieve size analysis, soil hydrometer, compaction and California bearing ratio (CBR), X-ray fluorescence (XRF). Sieve size analysis, soil hydrometer test, Atterberg limit test were used to classify soil samples' properties and classification was done as per AASHTO soil classification system. Sample T1 was classified as A-6, samples T2, T3 and T4 were classified as A-4. GSA was added to the soil samples; 2, 4, 6, 8, 10 and 15% of GSA by weight of soil samples. Compaction test and California bearing ratio (CBR) were carried out on soil samples with added GSA. Results from XRF showed that* $SiO_2 + Al_2O_3 + Fe_2O_3 = 25.61\%$*. For GSA to be classified as pozzolan,* $SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70\%$ *as per ASTM C618 – 08. Therefore, GSA cannot be classified as pozzolan as it does not meet requirement stipulated in ASTM C618 but rather as inert pores filler. Based on the results from compaction and CBR, the study showed that 4-8% of GSA was found to have improved and enhanced the strength of the soil samples.*

**Keywords:** CBR, compaction test, sieve size analysis, GSA, pozzolan

## Introduction
Groundnut belongs to the leguminous family that are of South America origin mostly Brazil. China and India contribute over two-third of global output. Nigeria, Sudan, Senegal, Argentina, South Africa etc. are other important producers (Nautiyal, 2002). Oriola and Moses (2010) reported that Nigeria contributed less than 10% of world groundnut production output which makes it the (third) 3rd largest producer in Africa. The disposal of agricultural waste is one of the major challenges confronting developing nations. African countries are commodity-exporting countries and predominately into farming and thus humongous amount of wastes are generated from agricultural related farming activities. Wastes from agro-industries are majorly divided into two and namely (i) agricultural and forestry, and (ii) agro-allied industrial activities (Yusuf, 2017).

In recent time, the use of agricultural residues for various civil/structural engineering works had received attention around the world, as studies on this is not new or recent neither is the nuisance generated from agricultural produce recent. Researchers have investigated the possibilities of utilizing this and other agricultural residues for civil/structural engineering works. In concrete production, Corn Cob Ash (CCA), Acha Husk Ash (AHA), Bambara Groundnut Shell Ash (BGSA), Peanut Shell Ash (PSA), Rice Husk Ash (RHA), Palm Oil Fuel Ash (POFA), Groundnut Shell Ash (GSA), Bagasse Ash (BA) and Wood Ash (WA) were used as a partial replacement for cement or fine aggregate (Alabadan *et al.*, 2006; Chatveera and Lertwattanaruk, 2014; Ige *et al.*, 2017; Joel, 2010; Oyedepo and Olukanni, 2015; Sokolova *et al.*, 2018).

In a study carried out by Batari *et al.* (2017), the authors investigated the possibilities of using BA to improve the strength of cement stabilized black cotton soil. They discovered that 5% BA and 8% cement to be optimum proportions needed to make significant impact on the California bearing ratio

(CBR), Unified Compressive Strength (UCS) as well as Maximum dry density (MDD) and Optimum Moisture Content (OMC) of black cotton soil meant for sub-base in a flexible pavement. Pourakbar and his team investigated the possibilities of using alkali-activated agro-waste as soil stabilizer; POFA was used as a binder. Regardless of the types of activators, increase in the content of POFA in the activation process to 15% leads to increase in the UCS value (Pourakbar *et al.*, 2015). Incorporation of agricultural wastes such as RHA and POFA as soil stabilizers have the tendency to absorb more water than landfill soil and also help to increase the durability and compressive strength of stabilized soil (Rahmat *et al.*, 2014). Kharade *et al.* (2014) studied the influence of Sugarcane Bagasse ash (SCBA) on black cotton soil, the black cotton soil was partially replaced with SCBA at different proportions of 3, 6, 9 and 12%. CBR, MDD, OMC and UCS parameters of each proportions were investigated. The authors established 6% as the optimal value for SCBA to produce acceptable results in terms of CBR, MDD, OMC and UCS. Fly Ash (FA), RHA, BA & RSA (Rice Straw Ash) were also found to improve the soaked CBR, increase the load bearing capacity and dramatically reduced the dry density of clayey soil meant for lower layer of road construction (Anupam *et al.*, 2013). Chittaranjan *et al.* (2011) successfully used agricultural wastes such as SCBA, RHA and GSA to improve the strength of weak sub-grade soil. In an experimental research carried out by Oriola and Moses (2010) on the use of GSA as black cotton soil stabilizer, the outcome of the research showed that there was no significant improvement in the CBR and UCS parameters of tested black cotton soils. RHA was used to improve the CBR strength properties of lateritic soil for the sub-grade purpose (Okafor and Okonkwo, 2009). Palm Kernel Shell Ash (PKSA) provided stability to asphaltic pavement (Edeh *et al.*, 2014, 2012; Komolafe and Osinubi, 2019). FA and RHA were also used to stabilize black cotton soil (Yadu *et al.*, 2011). FA and Groundnut Shell Powder (GSP) admixture can also be used to improve the engineering properties of weak soil (Taksande *et al.*, 2011). RHA was used to improve the California Bearing Ratio (CBR) and Unified Compressive Strength (UCS) of lateritic soil (Alhassan, 2008; Alhassan and Mustapha, 2007; Behak, 2017; Choobbasti *et al*., 2010; Rahman, 1987). In a review on the use of agricultural wastes to modify some geotechnical properties of sub-grade soils, Afolayan *et al.* (2019) established that POFA, PKSA, RHA, SA, SSP (Sea Shell Powder) are effective sub-grade soil modifiers and can also be used as traditional soil stabilizers. Onakunle *et al.*, (2019) used ceramic waste dust up to 30% to reduce to the barest minimal the liquid limit, plastic limit, plasticity index, optimum moisture content as well as to increase the maximum dry density and California bearing ratio of lateritic soil from Agbara, located in South-west zone of Nigeria.

Alabadan *et al.*, (2006), Alhassan (2008), Chittaranjan *et al.*, (2011), Edeh *et al*., (2012), Okafor and Okonkwo, (2009) and Yadu *et al.*, (2011) concluded that reactive pozzolanic properties of these agricultural residues were responsible for the role they played either as a partial replacement of cement in concrete or as stabilizing agents in weak soils.

This research will serve dual purposes of significantly reducing pollution associated with indiscrimate disposal of agro-residue wastes and utilization of GSA as soils strength enhancer.

## Materials and Methods

Soil samples were collected from four different locations within the University of Ibadan environment, Oyo State, Nigeria and soil samples were labelled as T1, T2, T3 & T4. The borrow-pits considered are at a depth of 1.0 meter. The coordinates of each soil samples are as shown in Table 1. The properties of the soil samples collected are as shown in Table 2.

The groundnut shell used were collected dry from Shaki and Ogbomoso, all from Oyo state in Nigeria and burnt in an electric furnace to a temperature of between 600˚- 650˚C and for a burning duration of 45 minutes. Groundnut Shell Ash (GSA) sample were taken to private laboratory in Ibadan called HEGADA scientific services limited were X-ray Fluorescence test was carried out to determine the oxides compositions of the GSA. The result of the GSA oxide composition is as shown in Table 3.

**Table 1.** Locations of the soil samples.

| Samples Code | Coordinates of the locations |
|---|---|
| Sample T1 | 7.43516ºN & 3.89279ºE |
| Sample T2 | 7.43850ºN & 3.89631ºE |
| Sample T3 | 7.43483ºN & 3.89235ºE |
| Sample T4 | 7.43465ºN & 3.89240ºE |

The laboratory tests carried out on soil samples include particle size distribution, Atterberg limit test, soil hydrometer test, compaction test and California bearing ratio (CBR) (BS 1377-2, 1990; BS 1377-4, 1990). Strength properties of the soil were studied by adding 2, 4, 6, 8, 10 and 15% of GSA by weight of soil samples. Particle size distribution, Atterberg limit test and soil hydrometer test were used to classify the soil samples as per AASHTO soil classification systems (AASHTO, 1986). To determine optimum moisture content (OMC) and maximum dry density (MDD) for each sample, standard proctor compactive energy was used for all compaction test as found in British Standard (BS) codes of practice (BS 1377-4, 1990). This involved energy derived from a hammer of 2.5kg mass falling through a height of 30cm in a mould of 1000cm$^3$ and 2360cm$^3$ for compaction and California bearing ratio (CBR) respectively. Hammer of the same weight and dropping through the same height were used for these purposes.

## Results and Discussion

The preliminary geotechnical properties of the soil samples are as presented in Table 2. Soil classification was done as per AASHTO soil classification system and as such soil sample T1 is classified as A-6 while soil samples T2, T3 and T4 are classified as A-4.

**Table 2.** Properties of studied soil samples

| Properties | T1 | T2 | T3 | T4 |
|---|---|---|---|---|
| Natural Moisture Content (%) | 20.43 | 18.4 | 17.8 | 18.3 |
| Liquid limit, LL (%) | 34.2 | 23.55 | 19.6 | 22.9 |
| Plastic limit, PL (%) | 20.55 | 16.04 | 12.66 | 15.07 |
| Plastic Index, PI (%) | 13.65 | 7.51 | 6.94 | 7.83 |
| AASHTO soil classification | A-6 | A-4 | A-4 | A-4 |
| CBR- Unsoaked | 8.3 | 9.9 | 10.4 | 9.2 |
| Colour | Reddish-Brown | Brown | Brown | Brown |

These classifications showed that soil sample T1 has high volume change properties with a change in moisture content and very poor drainage characteristics. While samples T2, T3 and T4 have poor drainage as well but not as poor as soil samples T1, but the drainage characteristic is fair to poor and it is susceptible to volume change just like soil sample T1. The characterizations of soil samples were done as per (AASHTO, 1986). The colour of the GSA after cooling was creamy-white. The result of oxides composition/pozzolanic properties of GSA is as presented in Table 3.

**Table 3.** Oxides present in Groundnut Shell Ash (GSA)

| Oxides | Groundnut Shell Ash (%) |
|---|---|
| $SiO_2$ | 18.42 |
| $Al_2O_3$ | 5.98 |
| ZnO | 0.071 |
| $Fe_2O_3$ | 1.21 |
| MnO | 0.127 |
| $Na_2O$ | 2.75 |
| $K_2O$ | 10.87 |
| MgO | 4.72 |
| CaO | 1.78 |

It was observed that the values obtained for oxides composition of GSA support those that was obtained by Alabadan *et al.*, (2006). Alabadan *et al.*, (2006) classified GSA as pozzolan after studied later strength gain in partially replaced concrete with GSA. For GSA to be classified as a pozzolan, $SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70\%$ as per (ASTMC618-08, 2008). Therefore, GSA does not meet the requirement of a pozzolanic material as stipulated in ASTM C618.

**Effect of addition of groundnut shell ash on soil samples**

*Compaction characteristics*

Compaction is the process of increasing the density of soil by removing the air voids present in the soil through mechanical means. The main aim of soil compaction is to establish the soil's optimum moisture content and maximum dry density (Craig, 1992).

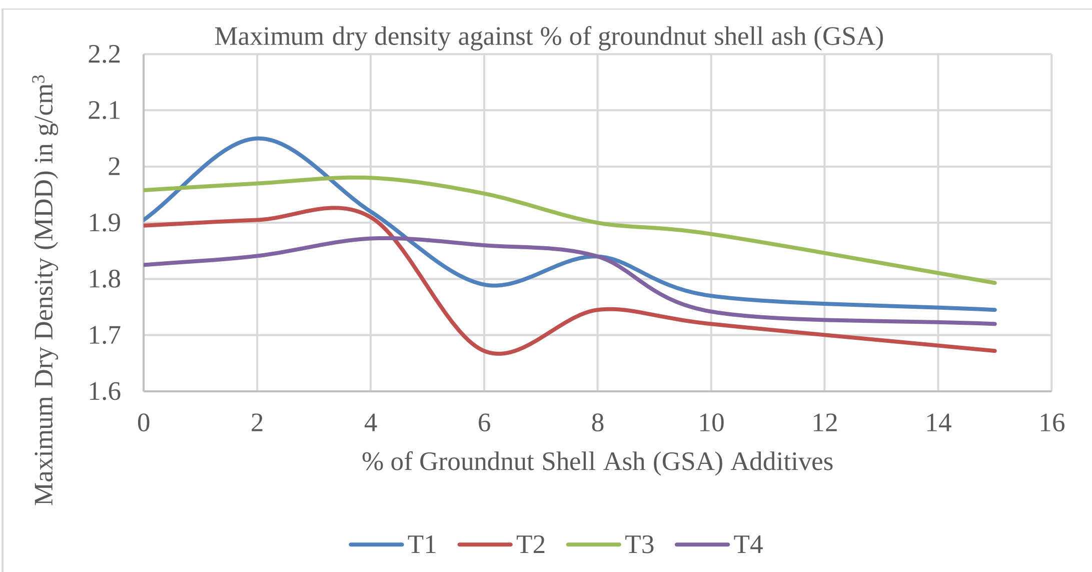


**Figure 1.** Graph of Maximum Dry Density against the per cent of Groundnut Shell Ash (GSA)

The dynamic compaction of soil samples was used to determine the maximum dry density (MDD) and optimum moisture content (OMC) of the soil samples. Figure 1 showed an increase in the value of MDD up to 4% GSA, subsequent addition of GSA does not increase the value of MDD, and increase in MDD is an indicator of improvement. Samples with 4% GSA showed a better MDD than all reference samples without GSA. The increase in MDD is due to the ability of GSA to fill the pores within the soil particles leading to a marginal increase in dry density, and subsequent decrease in MDD could be as a result of displacement of soil particles by GSA. The result obtained is similar to that obtained by Oriola and Moses (2010) and Moses (2008) when GSA was unsuccessfully used to stabilize black cotton soils. The result from UCS showed a positive trend in term of strength development owing the agglomeration and flocculation of soil-GSA particles as well ability of GSA to fill pores in between coarse aggregate.

Ordinarily, soil particles are known to have higher specific gravity than GSA and hence, leads to lower dry density. Edeh *et al.*, (2012) and Moses (2008) stated that an increase in MDD indicated increase in soil compactness which helps to determine a reduction in susceptibility to settlement and also indicate stiffness, stability and strength of materials. Figure 2 showed a general decrease in the value of OMC up to 4% GSA and the subsequent addition of GSA does not decrease the OMC. At 8% GSA, while all other soil samples maintained a gentle increment in OMC, sample T2 and T1 witnessed sharp increment and decrement in their OMC. For good soil, the lower the OMC, the better its workability (Lambe and Whitman, 1969). It can be seen clearly that maximum dry density (MDD) decreases while optimum moisture content (OMC) increases and vice-versa (Rahman, 1987).

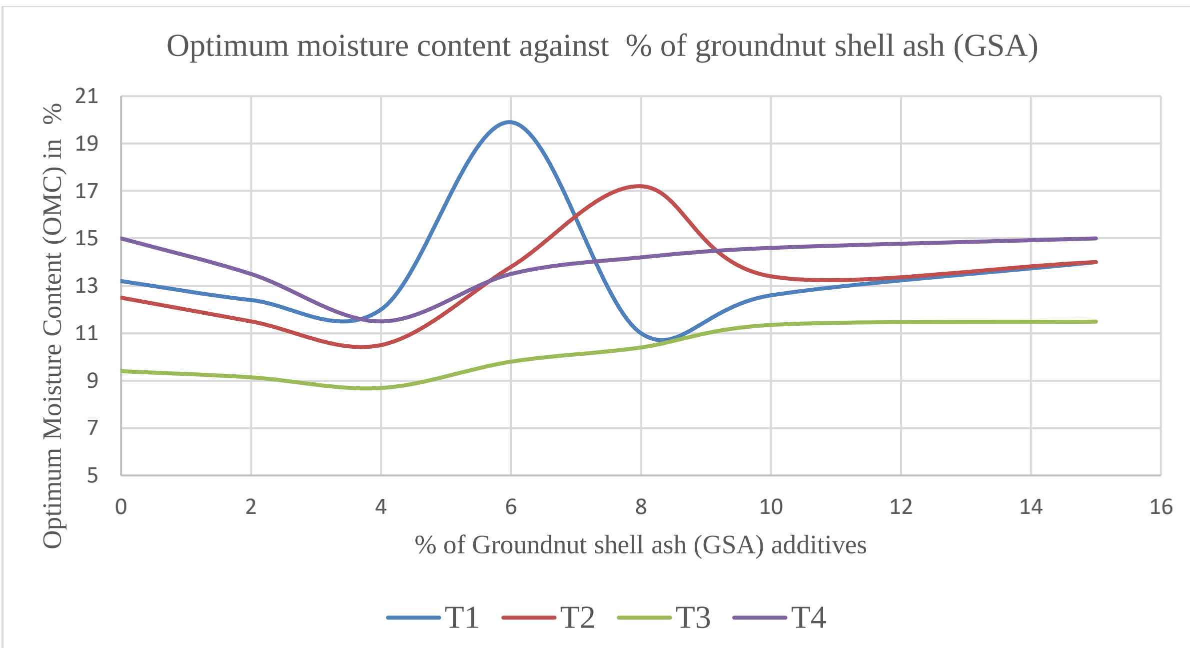


**Figure 2.** Graph of Optimum Moisture Content (OMC) versus % of groundnut shell ash (GSA)

*California bearing characteristics*

Bearing capacity and strength of a compacted soil is measure by CBR. Values from CBR are used to design base and sub-base material for pavement. Arguably, CBR is one of the commonest tests used to measure the strength of stabilized soils (Lambe and Whitman, 1969). It can be deduced from Figure 3 that as percentage GSA additives increases, so thus the California Bearing Ratio (CBR) increases till it started falling from 10%. There is an initial decrease in CBR at 2% of GSA which can be attributed to anomalies behaviour of GSA as inert pores filler (with exception to sample T4). From CBR results, it is obvious that increase in CBR is subjected to increase in the percentage of added GSA.

The CBR is used to determine the strength of the subgrade. 8% of GSA content gave the highest improvement of CBR for the soil samples (with exception to sample T3 which has its peak of CBR at 6% GSA). One of the plausible reasons behind the increase in CBR may be due to the ability of GSA to fill the pores within the soil particles and serves as strength bearer. Oriola and Moses (2010) and Moses (2008) achieved similar results when they used GSA to achieved marginal increment in CBR values of black cotton soil due to flocculation of GSA-soil particles and closing-up of the voids between soil aggregates. The decrease in CBR above 8% GSA content may be ascribed to the displacement of the soil particles by a lower specific gravity material i.e. GSA.

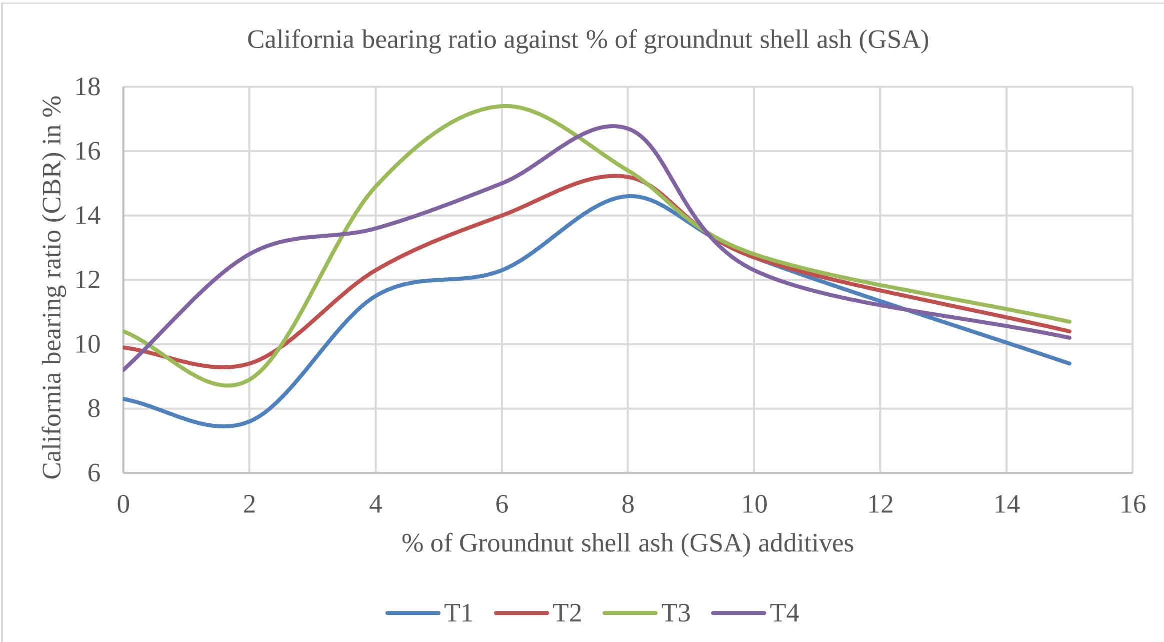


**Figure 3.** Graph of California Bearing Ratio (CBR) versus % of groundnut shell ash (GSA)

## Conclusion

Conclusively, the following can be deduced from the laboratory study of the soil samples with the various percent of GSA additive.

i. Based on the results from sieve analysis, soil hydrometer and Atterberg limit tests, sample T1 is classified as A-6, samples T2, T3 and T4 are classified as A-4 in accordance with AASHTO soil classification system.
ii. Results of oxides composition from XRF and requirement stipulated in ASTM C618-08 showed that Groundnut Shell Ash (GSA) cannot be classified as pozzolana but rather as inert pore filler based on results from compactions and CBR as well as previous research studies.
iii. Addition of GSA to the soil samples showed that there was strength gained between 4% and 8% of GSA by weight of soil samples based on results from compaction tests and California bearing ratio.

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