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Effect of Cement and Groundnut Shell Ash in Stabilizing Clayey Soil

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ABSTRACT

The effects of cement and groundnut shell ash (GSA) in stabilizing clayey soil were investigated in this study. Cement, GSA and their combinations were used as soil stabilizers at various percentages (0%, 5%, 10%, 15%, 20% and 25%) to improve the strength of locally available highly compressible clayey soil obtained within the premises of Federal Polytechnic Ede. The laboratory tests carried out on soil samples were Sieve analysis, atterberg limit test, compaction, and california bearing ratio tests. The experiment was performed using only GSA, only cement and using combination of cement and GSA. The test results show that the combination of GSA and Cement reduced the liquid and plastic limits. It increased the shrinkage limit, MDD and OMC. Also, GSA and Cement (at 20% optimum replacement level) increased the values of CBR of the clayey soils at 2.50 and 5.00 penetrations respectively. It is concluded that Cement-GSA combination can be used as alternative to modify and stabilize problematic soil to bring about soil with improved geotechnical properties, and also mitigate the environmental pollution of groundnut shell.

Keywords: Cement, Clayey Soil, Groundnut Shell Ash, Stabilization.

1. INTRODUCTION

Pavements having the least thickness are found to be the most economical. This can be achieved only when the underlying soil has greater strength. If the soil is weak, then there will be increase in the thickness of the pavements. So for such unsuitable soil, it is necessary to stabilize them in the most economic and effective way (Tijani *et al.,* 2020; Afsal, 2013). Clay soils can be altered to enhance their engineering capabilities. According to past studies, stabilizing a soil reduces its flexibility, makes it easier to deal with, and enhances its compressive strength and load-bearing capabilities (Tijani *et al.,* 2017; Patel, 2015; George and Karibo, 2014; Dhakal, 2012; Moses, 2008; Indiana, 2002). These improvements are the result of several chemical processes that take place when a stabilizer is present (Shankar *et al.,* 2015).

Alternative methods, such as stabilizing the problematic soil with locally available materials are required as a result of expensive cost of replacing and removing problematic soils. The most typical additives used in stabilizing soil are those produced industrially, like cement, and lime (Adetoro and Dada, 2015). Ola (2013) reported that bitumen, lime, or cement are good soil stabilizers. However, due to the high cost of stabilizing soil using these additives, locally available, potentially affordable materials from agricultural and solid wastes such as palm kernel shell ash, GSA, sawdust ash, locust beans pod ash, rice husk ash and sugarcane bagasse ash have been utilized to stabilize soil (George and Karibo, 2014; Cokca, 2011; Moses, 2008; Alhassan and Mustapha, 2007; Osinubi and Stephen, 2007; Medjo and Riskowiski, 2004; Osinubi and Eberemu, 2005). These materials have been found to improve the characteristics of deficient soils and meet geotechnical civil engineering design criteria.

Groundnut shell is considered as a waste product that is gathered in huge amounts after it has been harvested (Nwofor and Sule, 2012). As a result, the use of GSA lessens the environmental issue caused by the shells' large-scale accumulation in a given location. With more than 20 million hectares of groundnuts being grown each year throughout the world, groundnut shell is a byproduct of groundnut milling that is used in agriculture. Nigeria, which is the greatest producer of groundnuts in West Africa, produces around 7% of the world's production of groundnuts and 39% of that of Africa, ranking Nigeria as the third-largest producer in the world. Groundnut is mainly planted in the northern part of Nigeria (RMRDC, 2005). Kano, Katsina, Kaduna, Jigawa, Sokoto, Zamfara, Kebbi, Adamawa, Bauchi, Yobe, Borno, Benue, Plateau, Taraba, Nasarawa, Abuja, Kogi, Niger, and Kwara are the primary groundnut producing states (Ajeigbe *et al.,* 2005). About 48.8 million tonnes of groundnuts were produced globally in 2019 on 29.6 million hectares. Also, in 2019, Nigeria produced about 4.4 million tonnes of groundnut in about 3.9 million Hectares of Land while China's was 17.1 million tones and India was put at 6.7 million tonnes (FAO, 2021).

The GSA is a suitable pozzolanic substance that can replace industrial soil stabilizer additives more effectively. Pozzolana has been produced from GSA, which contains about 8.66% calcium oxide (CaO), 1.93% iron oxide (Fe_2O_3), 6.12% magnesium oxide (MgO), 15.92% silicon oxide (SiO_2), and 6.73% aluminum oxide (Al_2O_3) (Alabadan, 2006). ASTM C168 stipulates GSA major oxides ($Al_2O_3 + Fe_2O_3 + SiO_2$) to be 70% and above for class F pozzolan. However, if the oxides are lesser, they are classify as class C pozzolan. The finding of the study by Krishna and Beebi (2014) concluded that the GSA and polypropylene fiber reinforced soil can be thought of as a suitable ground improvement technique, particularly in engineering projects on weak soils where it can substitute for deep/raft foundations while also cost- and energy-saving. The Potentials of GSA for stabilizing the soil in Ekiti State, Nigeria, were examined by Adetoro and Dada (2015). On a soil sample stabilized with 2% to 10% GSA, tests for particle size distribution analysis, Atterberg limits, compaction, and CBR were performed. It was concluded that GSA-stabilized soil increased the coarse soil particles by cementing them. A drop in the MDD value was observed with increased in GSA content but an increase in the OMC and CBR values.

The duo of GSA and Portland cement can provide calcium, which is the main component required for stabilizing a clay soil. However, the two stabilizers are different in terms of their chemical characteristics, how they react when water is present, the products that result from that reaction, and how much they cost. Hence, the use of GSA and cement in stabilizing clay soil is the focus of this research work. This will help in reduction of stabilization of soil using costly stabilizers (which makes them economically unattractive as stabilizing agent) and help in managing groundnut wastes properly.

2. METHODOLOGY

2.1 Collection and Preparation of Materials

The groundnut shells used for this research were obtained from Ede, Osun State. It was obtained and sundried for two weeks. Samples were burnt into ash by open air burning in a metal container. After cooling, the burnt groundnut shell was pulverized in a mortar and pestle, and the ashes were sieved through a 75µm British sieve size. This is in line with ASTM C1240 (2004) and Mujedu *et al.* (2014). The area where the clayey soil was collected (at the back of Entrepreneurship Department of Federal Polytechnic Ede) is well renowned for being a good supply of clay-containing soils. In order to preserve uniformity and to restrict the diversity of clay composition, random soil samples were obtained close to one another. The ordinary Portland cement used was obtained from local suppliers in Ede, Osun State of Nigeria and has properties conforming to the ASTM C150 (2004) specification for Ordinary Portland Cement.

2.2 Experimental Test Procedures

2.2.1 Chemical Composition

The GSA was taking to the laboratory at OAU, Ile Ife for analysis to detect elements present in the ashes. The model of the equipment used is TEFA ORTEC automatic X-ray F (Phillips PW-1800). Each sample was crushed with an electric crusher and then pulverized for 60 seconds using Herzog Gyro-mill (Simatic C7-621). Pellets were prepared from the pulverized sample, first by grinding 20 g of each sample with 0.4 g of stearic acid for 60 seconds. After each grinding, the gyro-mill was cleansed to avoid contamination. 1 g of stearic acid was weighed into an aluminium cup to act as binding agent and the cup was subsequently filled with the sample to the level point. The cup was then taken to Herzong pelletizing equipment where it was passed at a pressure of 200 kN for 60 seconds. The 2 mm pellets were added into a sample holder of the x-ray equipment (Phillips PW-1800) for analysis.

2.2.2 Sieve Analysis

In order to ascertain the soil's particle size distribution, a sieve analysis test was performed according to ASTM D6913 (2009). A representative sample of 500 g of soil passing through sieve of 4.75 mm was taken, and then the mass of the sample was determined accurately, a stack of sieves was prepared and then shaken by mechanical sieve shaker for 5 minutes. Each sieve with soil sample retained was measured and recorded. The percentage retained and proportion of the soil sample was also determined. The percentage retained was calculated from equation 1.

$$\%\ \text{Retained} = \frac{\text{Weight of sieve}}{\text{Total weight}}\ \text{X}\ 100\% \quad (1)$$

2.2.3 Atterberg Limit

Atterberg test was employed to determine the critical water contents of a fine-grained soil. It consist of liquid limit, shrinkage limit, and plastic limit at 0, 5, 10, 15, 20, and 25% of Cement, GSA, and combination of both Cement and GSA. It was performed according to ASTM D4318 and ISO/TS 17892-12: 2004.

Liquid Limit

The sample of clay soil that passed through a 0.425 mm sieve was weighed and recorded as 200 g. The soil sample was then mixed with a little amount of distilled water to make a smooth, homogenous paste. The test was performed according to ASTM D4318.

Plastic Limit

The experiment was performed according to ASTM D4318. When the soil could be rolled into an ellipsoidal mass without clinging to the hands, a soil sample was taken. Distilled water was then added, and the soil moisture sample was weighed before being put in an oven for 24 hours. The same procedure was used to determine the water content for each trial.

Shrinkage Limit

Petroleum jelly was applied to an aluminum shrinkage dish to prevent soil from adhering to it and creating cracks when it dried. The dish was filled in three levels by adding around one-third of the necessary wet soil and tapping it on a solid surface until no visible air bubbles were left. The soil was spread evenly around the surface of the dish with a spatula after repeating this process with the second and third layers. The soil and dish's combined mass were measured. The soil was poured in the dish and placed in an oven for at least 24 hours, or until it dried to a uniform mass and lightened in color. The dried dish was taken out of the oven, and the equation 2 was used to calculate the % shrinkage. The experiment was performed in accordance with ASTM D4318.

$$\text{Percentage Shrinkage (\%)} = \left\{1 - \frac{\text{dry length}}{\text{Wet length}}\right\} \text{ x } 100\% \qquad (2)$$

2.2.4 Compaction

A laboratory experiment was conducted to evaluate the ideal moisture content and maximum dry density of the soil sample in accordance with ASTM D1557 (2021). In order to do this, three equal layers of damp soil were placed into the mould, with each receiving 25 blows from a 2.5 kg rammer that was dropped from a height of 310 mm above the soil. A little soil sample was obtained from the top and bottom of the mould after the soil had been removed to determine the soil's water content. After continuously adding 150 ml of water to the soil until the soil weight and mould fell, the method was repeated. The weights of container only, wet soil and container, dry soil and container were recorded and water content and dry unit weight were determined from the equations 3 and 4.

Weight of water = (weight of wet soil + container) – weight of dry soil container
Weight of dry soil = (weight of dry soil + containers) – weight of container

$$\text{WaterContent} = \frac{\text{weight of water}}{\text{weight of drysoil}} \text{x } 100\% \qquad (3)$$

$$\text{Dry unit weight} = \frac{\text{100 x wet unit weight}}{\text{100+water content}} \qquad (4)$$

2.2.5 California Bearing Ratio

The soil sample's CBR test was performed in the laboratory in accordance with ASTM D1883 (2021). The cement content was varied during the tests as earlier stated. The procedure was repeated with GSA as replacement of cement and the same procedure for the mixture GSA and cement mixed in equal proportion. The penetration and load value were measured and documented.

2.2.6 Production of Clayey Brick with 15% Groundnut Shell Ash

Bricks are small building components that are frequently produced from fired clay and bound with mortar. The first step in making bricks was crushing and grinding the raw materials in a separator and a jaw crusher. The blend of materials used for each batch was then picked and filtered before going through one of three brick shaping processes (extrusion, molding, or pressing), the first of which is the most adaptable and hence the most common. After the production, the bricks were dried to remove excess moisture that could otherwise cause cracking during the burning process. The bricks were cured for 7, 14, 21, and 28 days and compressive strength was determined in accordance with ASTM C109 (2020). Although, this is beyond the scope of this research, but we want to test if there is going to be any effect as a result of addition of GSA, hence, one proportion was pick (15%).

3. RESULTS AND DISCUSSION

3.1 Chemical Composition of Groundnut Shell Ash

The result of chemical composition of GSA is presented in Table 1. The major chemical composition of GSA was potassium (K) having the concentration value of 17.016%. Iron which is responsible for strength and soundness are present in considerable amount (2.21%). The percentage composition of calcium which usualy contributes to strength attainment was obtained to be 7.6%. It was noted that potassium compound is the major impurity present in the ash obtained.

Table 1: Chemical Composition of Groundnut Shell Ash

Elements	Conc. Value	Conc. Error	Unit
K	17.016	± 0.0155	Wt.%
Ca	7.600	± 0.102	Wt.%
Ti	0.1105	± 0.0061	Wt.%
Mn	3110	±22	Ppm
Fe	2.2081	±0.101	Wt.%
Ni	18	±2	Ppm
Zn	71	±9	Ppm
Cu	182	±11	Ppm
As	8	±0.6	Ppm
Rb	22	±3	Ppm
Sr	11	±2	Ppm
Se	19	±2	Ppm
Zr	102	±12	Ppm
V	34	±4	Ppm

3.2 Sieve Analysis

Figure 1 shows the result of sieve analysis of the soil sample. The soil sample was observed to be silt clay soil which exhibit reddish brown colour and is characterized by 10% gravel, 31% silt and 59% clay. According to AASHTO Soil Classification, the soil sample falls within A-7-6 group

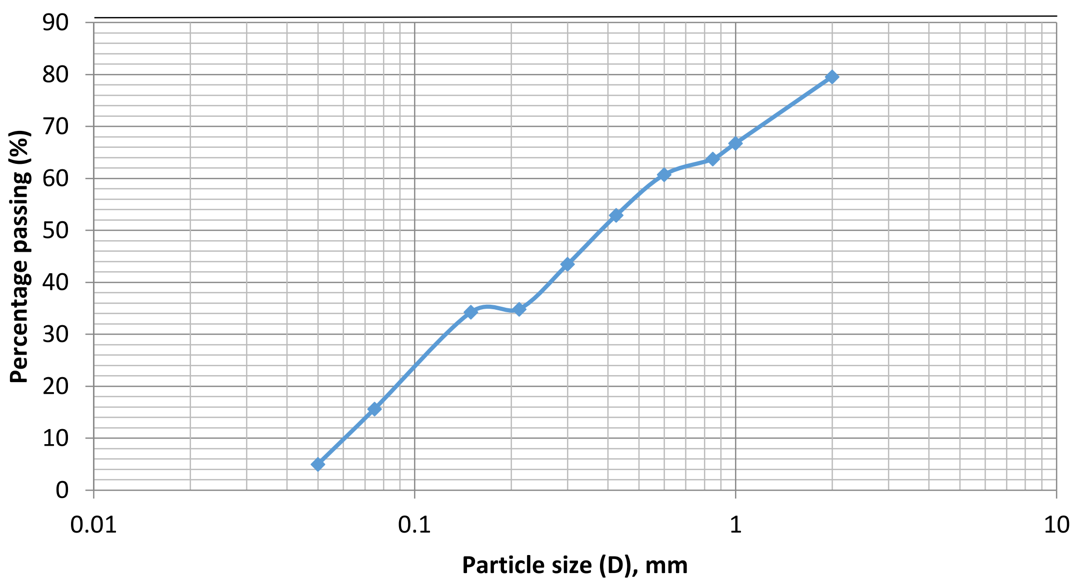

Figure 1: Sieve Analysis of the Soil Particles

3.3 Atterberg Limit Result

The Atterberg limit results as shown in Table 2 indicated that the L.L. and P.L. increased as the percentage of GSA and cement increased. Addition of cement (0- 25%) has the greatest effect on the soil sample (i.e 24.44 to 62.61%) while addition of combination of GSA and cement significantly improve LL and PL of the soil (24.44 to 58.28%). The LL and PL increased upon the addition of GSA up to 25% and upon the addition of the combination of GSA and cement, the results revealed a critical increase in LL from 24.44% to 62.25% and 15.02% to 42.70% respectively at 10% and later decreased above 10%. The plasticity index of the soil sample as shown in Table 3 showed a general improvement with the addition of 10% GSA and cement. The GSA and cement content increased, which raised the clayey soil's liquid and plastic limits. This is in agreement with the findings of Ijimdiya (2014), and this could be due to the increase in silicate and aluminum ions which in the presence of water reacted with available sulphate to form the sulphate attack phenomenon and this formation led to increase in volume and plasticity of the soil. The corresponding shrinkage limits also reduced with an increase in GSA and Cement.

Table 2: Atterberg Limit for Cement, GSA and GSA + Cement

	Cement			**GSA**			**GSA + Cement**		
	L.L.%	**P.L.%**	**S.L.%**	**L.L.%**	**P.L.%**	**S.L.%**	**L.L.%**	**P.L.%**	**S.L.%**
0%	24.44	15.02	5.60	24.44	15.02	5.60	24.44	15.02	5.60
5%	57.06	43.50	5.30	50.28	43.50	5.30	59.58	41.90	5.00
10%	66.33	44.36	4.60	55.23	42.36	4.60	62.25	42.70	4.88
15%	62.82	44.55	2.50	55.61	44.55	2.50	58.69	42.59	3.94
20%	62.81	45.55	2.00	57.45	41.55	2.00	58.53	42.36	3.36
25%	62.61	45.65	1.67	58.23	41.45	1.67	58.28	41.42	3.04

Table 3: Plasticity Index for Cement, GSA and GSA + Cement

	Cement	**GSA**	**GSA + Cement**
	P.I.%	**P.I.%**	**P.I.%**
0%	9.42	9.42	9.42
5%	13.56	6.78	17.68
10%	21.97	12.87	19.55
15%	18.27	11.06	16.10
20%	17.26	15.90	16.17
25%	16.96	16.78	16.86

3.4 Compaction

From the result obtained from compaction test as shown in Figures 2 - 4, increase in the combination of GSA and cement caused an increase in the maximum dry density and an increase in the optimum moisture contents. The use of additives (such as GSA and cement) reduces the free silt, clay fraction, and coarse materials' quality with wide surface areas, which is why the optimal moisture content increased (Adetoro and Dada, 2015). The clayey soils increased in weight when mixed with various percentages of GSA. This is similar to the findings of Gajera and Thanki (2015) who reported the addition of GSA brought an improvement in the compaction parameters.

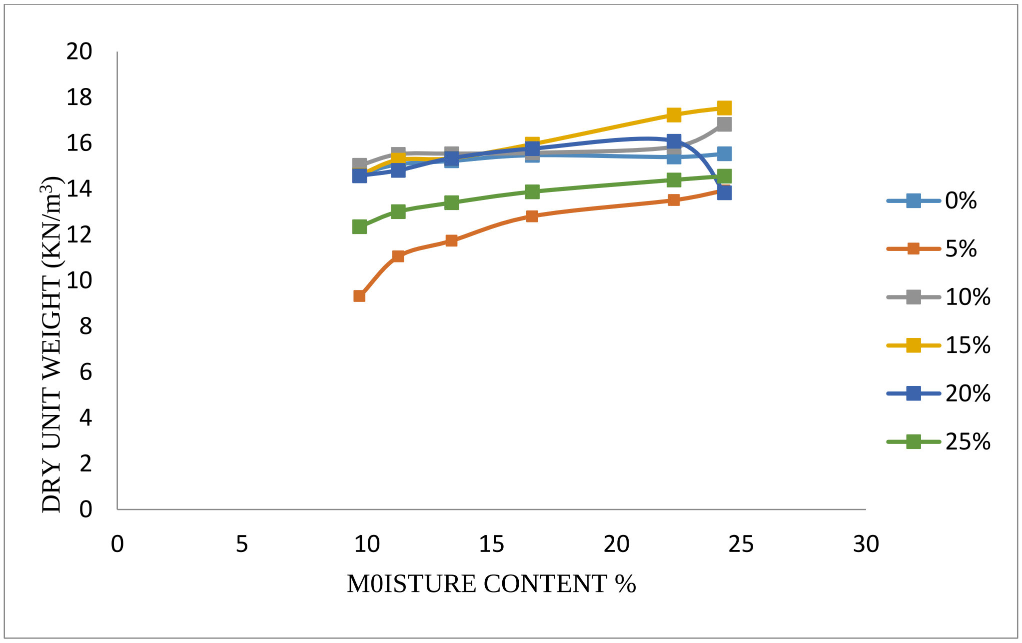

Figure 2: Compaction Test Curve for GSA

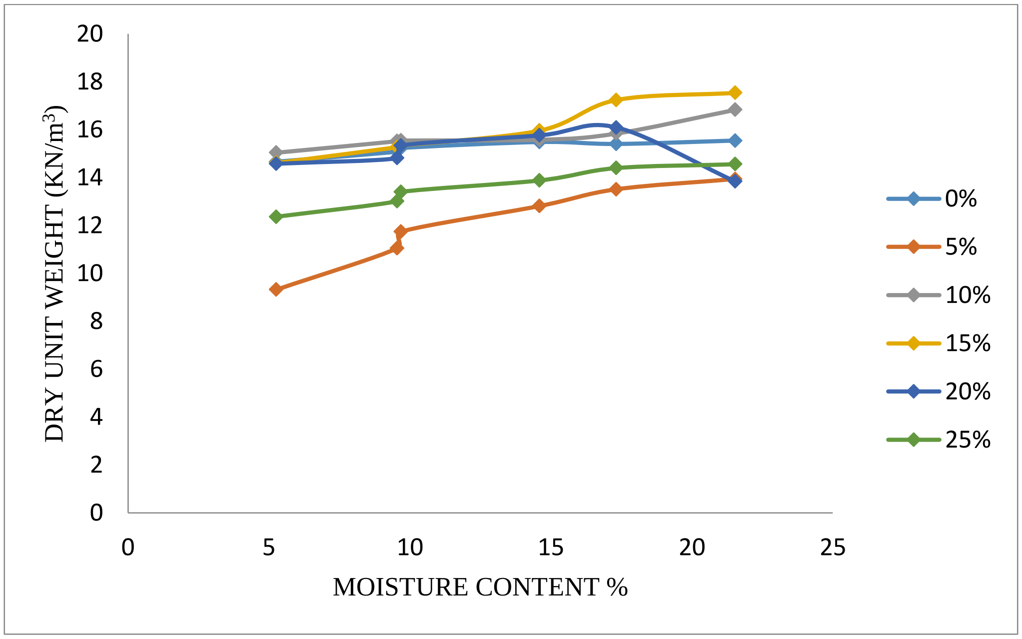

Figure 3: Compaction Test Curve for Cement

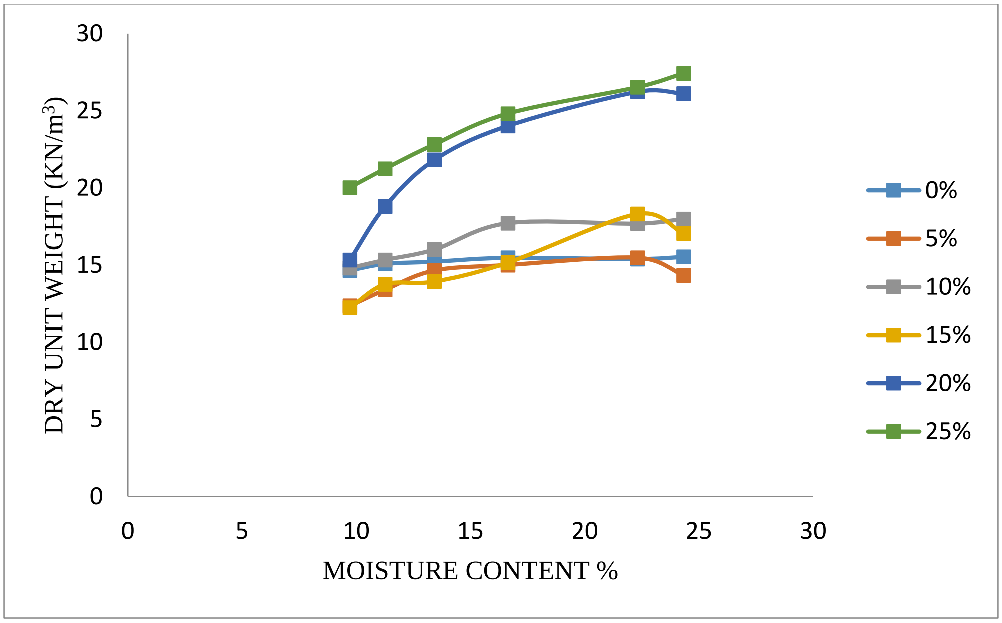

Figure 4: Compaction Test for GSA and Cement

3.5 California Bearing Ratio

According to the CBR results as shown in Figures 5 - 7, the samples' CBR values were higher when in the range of their ideal moisture content and maximum dry unit weight. Furthermore, the results from the graphs shows GSA and cement increases in the values of the CBR of the clayey soils at 2.50 and 5.00 penetrations respectively. The CBR value increment could be attributed to gradual formation of cementitious compound between the GSA and calcium hydroxide present in the soil. These findings is similar to that of Adetoro and Dada (2015) and Gajera and Thanki (2015).

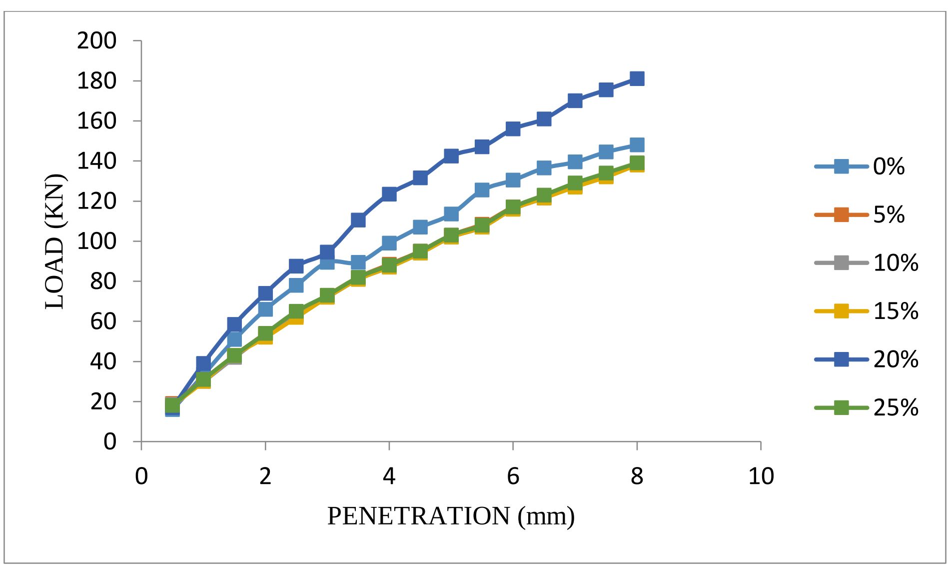

Figure 5: California Bearing Ratio Curve for Cement

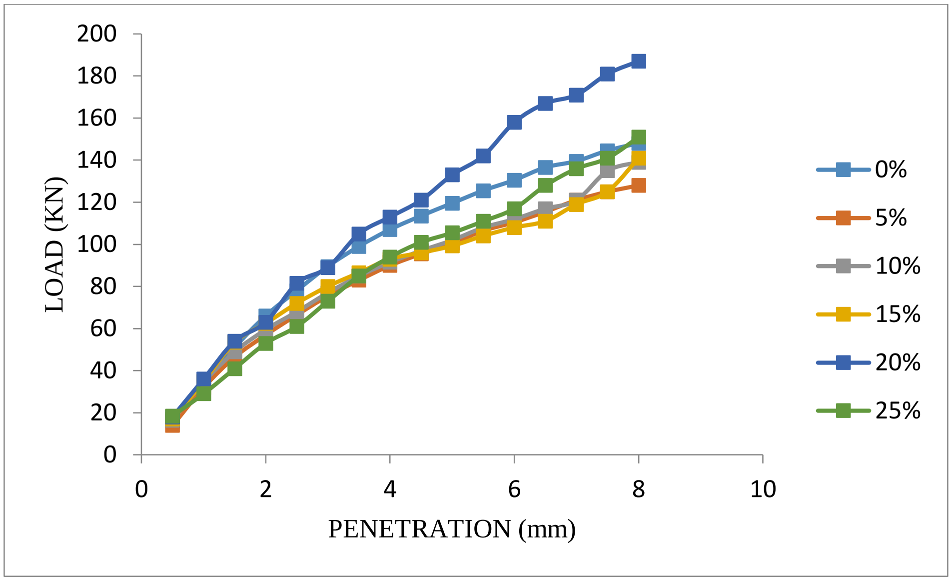

Figure 6: California Bearing Ratio Curve for GSA

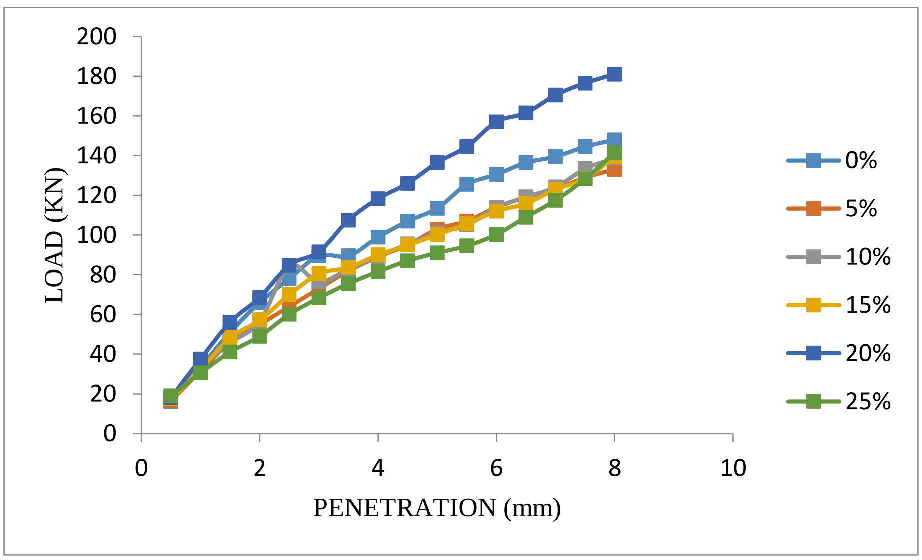

Figure 7: California Bearing Ratio Curve for GSA and Cement

3.6 Compressive Strength

Figure 8 shows the result of compressive strength of the brick made with 15% GSA. The result shows the compressive strength of the bricks increased with an increase in the numbers of days of curing. Although, this is beyond the scope of this research, but we want to test if there is going to be any negative effect on the compressive strength as a result of addition of GSA, hence, one proportion was used (15%). The compressive strength obtained was lower than 2.0 N/mm^2 specified for non-load bearing walls by NIS (2004) but higher than the specification (1.65 N/mm^2) of NBRRI (2006).

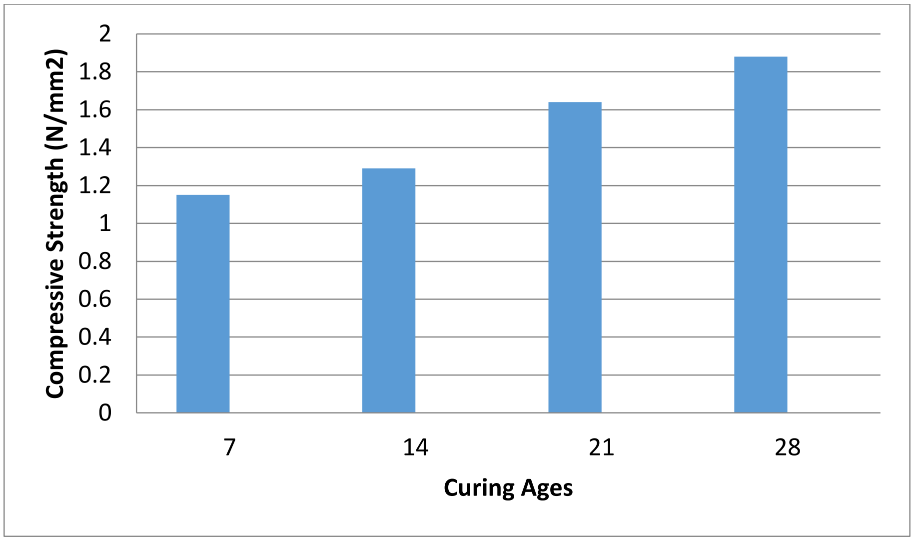

Figure 8: Compressive Strength Curve for 15% GSA

4. CONCLUSION

The study investigated the effects of cement and groundnut shell ash (GSA) in stabilizing clayey soil. Cement, GSA and their combinations were used as soil stabilizers at various percentages (0%, 5%, 10%, 15%, 20% and 25%) to improve the strength of locally available highly compressible clayey soil. It was observed that clayey soil used for the experiment was plastic in nature when no stabilizing agent was added. Additions of stabilizing agents (GSA and Cement) increases plastic limit, liquid limit, the maximum dry density and the optimum moisture content, CBR values of clayey soil, weight of the soil and decreases the shrinkage limit. Cement and GSA can be used as a good economic alternative in stabilizing clayey soil. The GSA can also serve as alternative to modify and stabilize problematic soil such as clayey soil and bring about shale with improved geotechnical properties. It is recommended that GSA should be used as an admixture with a more potent stabilizer to reduce cost of stabilization and environmental pollution associated with groundnut shell wastes.

REFERENCES

AASHTO (American Association of State Highway and Transportation Officials). Standard Specification for Transportation Materials and Methods of Sampling and Testing (14th ed.), USA: Washington DC, 1986.

Adetoro, A. E. and Dada, O. M. (2015). Potenial of Groundnut Shell Ash for Stabilization of Ekiti State Soil, Nigeria. *Journal of Multidisciplinary Engineering Sciences and Technology*, 2: 2301-2304.

Afsal, K. (2013). Potentials of Treated Contaminant Soil as a Sustainable Stabilizing Admixture. *International Journal of Sustainable Materials and Structural System*, 1(2): 188 - 200.

Ajeigbe, H. A., Waliyar, F., Echekwu, C. A. and Ayuba, K. (2005). A Farmer's Guide to Groundnut Production in Nigeria. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Alabadan, B. A. (2006). The Potentials of Groundnut Shell Ash as Concrete Admixture. *Agriculture Engineering International*, 8: 1-8.

Alhassan, M. and Mustapha, M. M. (2007). Effect of Rice Husk on Cement Stabilized Laterite. *Leonardo Electronic Journal of Practices and Technologies*, 2: 47 - 58.

ASTM (American Society for Testing and Materials). (2004). Standard Specification for Atterberg Limit Test. *D4318,* West Conshohocken, PA, USA.

ASTM (American Society for Testing and Materials). (2004). Standard Specification for Ordinary Portland Cement. *C150,* West Conshohocken, PA, USA.

ASTM (American Society for Testing and Materials). (2004). Standard Specification for Pozzolanic Activity. *C1240,* West Conshohocken, PA, USA.

ASTM (American Society for Testing and Materials). (2009). Standard Specification for Particle-Size Distribution (Gradation) of Soils, Using Sieve Analysis. *D6913,* West Conshohocken, PA, USA.

ASTM (American Society for Testing and Materials). (2020). Standard Specification for Compressive Strength Test. *C109,* West Conshohocken, PA, USA.

ASTM (American Society for Testing and Materials). (2021). Standard Specification for California Bearing Ratio. D1883, *West Conshohocken, PA, USA.*

*ASTM (Ameri*can Society for Testing and Materials). (2021). Standard Specification for Compaction Test. *D1557,* West Conshohocken, PA, USA.

Cokca, E. (2011). Stimulation of Contaminant Migration through a Soil Layer Due to an Instantaneous Source. *Computer Applications in Engineering Education,* 19(2): 385-398.

Dhakal, S. K. (2012). Stabilization of Very Weak Subgrade Soil with Cementitous Stabilizers. Thesis for Master of Science in Civil Engineering, Civil and Environmental Engineering, Louisiana State University. https://digitalcommons.lsu.edu/gradschool_theses/67

FAO. (2021). FAO Stat. Retrieved May 13, 2021 from http://www.fao.org/faostat/en/#data/QC

Gajera, N. V. and Thanki, K. R. (2015). Stabilization Analysis of Black Cotton Soil by using Groundnut Shell Ash. *International Journal for Innovative Research in Science and Technology*, 2(1): 158-162.

George, R. O., and Karibo, P. (2014). Stabilization of Nigerian Deltaic Clay (Chikoko) with Groundnut Shell Ash (GSA). *International Journal of Engineering and Technology Research,* 2(6): 1 - 11.

Ijimdiya, S. (2014). Effect of Groundnut Shell Ash on the Particle Size and Plasticity Characteristics of Black Cotton Soil. *Nigerian Journal of Materials Science and Engineering,* 5(1): 68-72.

Indiana Department of Transportation. (2002). Design Procedures for Soil Modification or Stabilization. Office of Geotechnical Engineering 120 South Shortridge Road Indianapolis, Indiana. 46219; 2002

Krishna, T. M. and Beebi, S. S. (2014). Soil Stabilization by Groundnut Shell Ash and Waste Fiber Material. *International Journal of Innovations in Engineering and Technology*, 5(3): 52-57.

Medjo, E. and Riskowiski, G. (2004). A Procedure for Processing Mixtures of Soils, Cement and Sugar Cane Bagasse. *The Journal of Scientific Research and Development*, 3: 1 - 5.

Moses, G. (2008). Stabilization of Black Cotton Soil with Ordinary Portland Cement Using Bagasse Ash as Admixture. *International Journal of Research in Engineering,* 5(3): 107-115.

Mujedu, K. A., Adebara, S. A. and Lamidi, I. O. (2014). The Use of Corn Cob Ash and Saw Dust Ash as Cement Replacement in Concrete Works. *The International Journal of Engineering and Science*, 3(4): 22-28.

NBRRI (Nigerian Building and Road Research Institute) (2006). NBRRI Interlocking Block Making Machine. *NBRRI Newsletter*, 1(1): 15-17.

Nwofor, T. C. and Sule, S. (2012). Stability of Groundnut Shell Ash/Ordinary Portland Cement Concrete in Nigeria. Advanced Applied Science Research, 3(4): 2283-2289.

Ola, S.A. (2013). Essentials of Geotechnical Engineering. 1st Ed. University Press Plc, Ibadan. Pg 471.

Osinubi, K. J. and Eberemu, A. O. (2005). The Use of Blast Furnace Slag Treated Laterite in the Attenuation of Groundwater Contaminants. *Proceedings of the Nigerian Material Congress, Zaria, Nigeria*. Pp. 28-35.

Osinubi, K. J. and Stephen, A. T. (2007). Influence of Compactive Efforts on Bagasse Ash Treated Black Cotton Soil. *Nigerian Journal of Soil and Environmental Research,* 7: 92-101.

Patel, M. P. (2015). Scientifically Surveying the Usage of Terassil Chemical for Soil Stabilization. *International Journal of Research in Advent Technology,* 3(6): 77 - 84.

RMRDC (Raw Materials Research and Development Council, Nigeria). (2005). Federal Ministry of Science and Technology – Agriculture.

Shankar, A. U. R., Lekha, B. M. and Goutham, S. (2015). Evaluation of Lateritic Soil Stabilized with Arecanut Coir for Low Volume Pavement. *Journal of Transportation Geotechnics*, 2: 20-29.

Tijani, M. A. and Olawale, S. O. A. (2020). Investigation of Flexible Pavement Failure along Ede – Akoda Road, Osun State, Southwestern Nigeria. *LAUTECH Journal of Civil and Environmental Studies,* 4(1): 1-9.

Tijani, M. A., Akinleye, M. T. and Jaiyeoba, K. F. (2017). Engineering Properties of Laterites Obtained in Ede, Southwestern Nigeria. *International Journal of Engineering and Advanced Technology,* 7(1): 160 – 162.