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Research Article

The effect of Groundnut Shell Ash on Road subgrade stabilization

***Nkwocha Samuel, Chiemela Chijioke and Chukwudi EU Prince**

Civil Engineering Department, Federal Polytechnic Nekede Owerri, Nigeria

*Corresponding Author Email: snkwocha@fpno.edu.ng

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Abstract

Road infrastructure is essential for economic development and societal connectivity, making the durability and stability of road subgrades a priority in construction. Traditional methods for stabilizing road subgrades rely heavily on materials like cement or lime, which can be expensive and environmentally taxing. This research investigates the potential of groundnut shell ash (GSA), an agricultural by-product, as an eco-friendly and cost-effective stabilizing agent for subgrade materials. Groundnut shell ash, derived from the combustion of groundnut shells, presents a promising alternative due to its mineral-rich composition, including silica, which may enhance the mechanical and chemical properties of subgrade soils. The study involved collecting subgrade samples from problematic spots on Umukoto Road in Nekede, Imo State, Nigeria, and stabilizing them with varying percentages of groundnut shell ash (2%, 4%, 6%, 8%, and 10%). Laboratory tests, including compaction and California Bearing Ratio (CBR) tests, were conducted to evaluate the changes in soil properties, such as density, moisture content, and compressive strength. Initial findings demonstrate that GSA enhances the soil's compaction characteristics and improves load-bearing capacity, suggesting its viability as a stabilizing agent. This research contributes to sustainable road construction practices by offering insights into using GSA as a low-cost, environmentally friendly solution for subgrade stabilization. The study's outcomes are anticipated to advance knowledge on alternative stabilization methods, with implications for promoting sustainable waste utilization in road infrastructure development.

Keyword: Ground Nut Shell (GSA), Soil Stabilization, California Bearing Ratio.

INTRODUCTION

Road infrastructure is a vital component of a nation's development, serving as the lifeline for economic activities and societal connectivity. Ensuring the durability and stability of roads, particularly their subgrades, is imperative to enhance their performance and longevity (Abiodun, 2013). Traditional methods of subgrade stabilization often rely on the use of cement, lime, or other chemical additives, which can be expensive and environmentally impactful (Talal and Gabriel, 2020). In pursuit of sustainable and cost-effective alternatives, researchers have turned their attention to exploring unconventional materials, such as agricultural by-products, for their potential in enhancing subgrade properties (Adama and Sofoluwe, 2018).

One such promising material is groundnut shell ash (GSA), a residue derived from the combustion of groundnut shells. Groundnut cultivation, a significant agricultural activity in many regions, generates a substantial quantity of shells as by-products (Ibrahim and Hassan, 2020). The disposal of these shells poses environmental challenges, making their utilization in road construction an attractive proposition (Osinubi, 2000). This research aims to investigate the effect of groundnut shell ash on the stabilization of road subgrade materials, exploring its potential as a viable and eco-friendly alternative.

The utilization of agricultural by-products in construction materials has gained attention in recent years due to its dual benefit of waste management and material enhancement. Groundnut shell ash, being rich in silica and other minerals, exhibits properties that could positively influence the engineering characteristics of subgrade soils. As we delve into this study, our focus lies in assessing the physical, chemical, and mechanical changes that occur in road subgrade materials when stabilized with groundnut shell ash.

Understanding the influence of groundnut shell ash on road subgrade stabilization holds significant implications for sustainable road construction practices (Salahudeen, 2017). This research seeks to contribute to the ongoing discourse on environmentally conscious infrastructure development by providing insights into the effectiveness of groundnut shell ash as a potential stabilizing agent. As we embark on this exploration, the anticipation is that the findings will not only expand the knowledge base but also offer practical solutions for enhancing the performance and resilience of road subgrades.

Road infrastructure plays a pivotal role in fostering economic development and societal connectivity. The stability and durability of roads, particularly the subgrade, are critical factors in ensuring their long-term performance. Traditional methods of subgrade stabilization, often involving costly additives like cement or lime, pose economic and environmental challenges. In the pursuit of sustainable and cost-effective alternatives, the exploration of unconventional materials, such as agricultural by-products, emerges as a promising avenue (Olarewaju and Ige, 2020).

One such by-product under investigation is groundnut shell ash (GSA), derived from the combustion of groundnut shells. The disposal of groundnut shells, a by-product of groundnut cultivation, poses environmental concerns, making the utilization of groundnut shell ash in road construction an appealing prospect. This research endeavours to examine the influence of groundnut shell ash on road subgrade materials, with a focus on its potential as an eco-friendly stabilizing agent (Krishna and Beebi, 2021).

Objectives of Study

The main objective of this research work is to assess the impact of groundnut shell ash on the compaction characteristics and CBR of road subgrade materials. While the specific objectives are:

a. To prepare groundnut shell ash samples and characterize its properties.
b. To collect subgrade samples and characterize its properties.
c. To carryout stabilization on the subgrade material and determine the optimum replacement of groundnut shell ash
d. To access the performance benefits and potential risks of using subgrades stabilized with locally made materials.

MATERIALS AND EXPERIMENTAL METHOD

Materials

The following materials were used in this research work:

a. **Subgrade material:** Subgrade materials samples will be collected from bad spots along Umukoto Road in Umudibia Autonomous Community, Nekede Owerri West LGA Imo state Nigeria.
b. **Groundnut shell ash:** The groundnut shell ash used in the study for stabilization will be obtained locally from a groundnut post-harvest farm.

Methods

The laboratory investigation procedure was developed to explore the suitability of GSA for stabilizing problematic soils such as those commonly found in Nigeria. The first step of this activity was to identify potential locally available materials for subgrade stabilization. The testing set out to determine the advantages and disadvantages of using the GSA as a stabilizing material in conjunction with the common problematic soils found in Nigeria.

Chemical Stabilization

Chemical stabilization was carried out by addition of groundnut shell ash to the natural soil samples at proportions of 2%, 4%, 6%, 8% and 10% by weight of the natural soil sample. Various test was performed during this project on concrete and aggregate and they include;

a. Sieve Analysis

The sieving method adopted was dry sieving and a sample size of about 705g was used for the subgrade material. The results from the sieve analysis were plotted in graph to represent the grading curves and was classified.

b. Calculations/Materials proportioning by Weight

c. This refers to determining the quantity in weight of each constituent in the material mix. All the materials are weighed using a weighing balance. The 152mm diameter x 178mm height cylindrical mould was used

i. Volume of specimen

$$\text{volume of sample} = \frac{\pi D^2}{4} H = \frac{\pi(152)^2}{4} * 178 = 3229959.37\text{mm}^3 = 0.00323\text{m}^3$$

ii. Density of specimen

The density of subgrade materials is a function of the aggregate shape and mineralogy, size and grading, degree of compaction or aeration and the specimen. The compacted bulk densities of the aggregates are between 1407 Kg/m^3 to 1867 Kg/m^3 Therefore, density = 1637kg/m^3

Density = $\frac{\text{Mass}}{\text{Volume}}$

Therefore, Mass = Density x Volume
Mass = 0.00323 x 1637 = 5.3kg

Including a 10% waste, the weight of a mould would be 5.3 X 1.1 = 5.83kg
Take weight = 6kg
Based on the mass, the different sample proportion can be obtained in Table 1

Table 1. Sample Proportion by Mass

Mix no	% Replacement	Subgrade	Groundnut Shell Ash
SBG	0	6	0
SBG - C_2	2	5.58	0.12
SBG - C_4	4	5.16	0.24
SBG - C_6	6	4.74	0.36
SBG - C_8	8	4.32	0.48
SBG - C_{10}	10	3.90	0.6

d. Production of Specimen

i. The floor surface was cleaned, wetted and dried to prevent loss of the water and prevent excess water being added into the mix. Batching of the materials was done by weight using a weighing balance of 50kg capacity. The inside surface of the mould was coated lightly with medium viscosity oil and then placed on a clean, level and firm surface. The mould is made of metal.
ii. Mixing of the constituents was done manually using a hand trowel. The production process involved collection of the subgrade material which was left to dry, the groundnut shell ash was mixed to a constant colour. Water was finally added and the mixing continued until the colour of the material was uniform. The mixture was then loaded into the moulds it was compacted manually in layers.
iii. A total of 6 mix was made. Each specimen prepared was tested for compaction and was taken to the CBR machine for the penetration test.

e. Compaction Test

The following procedures were adopted to conduct a compaction test on the sample:
i. Obtain about 3 kg of soil.

ii. Pass the soil through the No. 4 sieve.
iii. Weight the soil mass and the mould without the collar (W_m).
iv. Place the soil in the mixer and gradually add water to reach the desired moisture content (w).
v. Apply lubricant to the collar.
vi. Remove the soil from the mixer and place it in the mould in 3 layers or 5 layers depending on the method utilized (Standard Proctor or Modified Proctor). For each layer, initiate the compaction process with 25 blows per layer. The drops are applied manually or mechanically at a steady rate. The soil mass should fill the mould and extend into the collar but not more than ~1 centimetre.
vii. Carefully remove the collar and trim the soil that extends above the mould with a sharpened straight edge.
viii. Weight the mould and the containing soil (W).
ix. Extrude the soil from the mould using a metallic extruder, making sure that the extruder and the mould are in-line.
x. Measure the water content from the top, middle and bottom of the sample.
xi. Place the soil again in the mixer and add water to achieve higher water content, w.

f. CBR Test

A compaction test is conducted on the soil using the optimum moisture content in order to obtain the maximum dry density. Spacer disc is placed over the base plate at the bottom of mould and a coarse filter paper is placed over the spacer disc. The penetration plunger is brought in contact with the soil and a load of 4kg (seating load) is applied so that contact between soil and plunger is established. Then dial readings are adjusted to zero. Load is applied such that penetration rate is 1.25mm per minute. Load at penetration of 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 7.5, 10 and 12.5mm are noted.

RESULTS AND ANALYSIS

Results

The following results were obtained after the successful completion of the laboratory practical on the materials

a. Sieve Analysis Results

The results of sieve analysis test for the subgrade material are presented in Tables 2 while the gradation chart for the subgrade material is shown in Figure 1.

Table 2. Grain size distribution of subgrade material

Sieve Size (mm)	Mass of Soil Retained (g)	Percentage of Soil Passing (%)
2.36	20	97
1.18	15	95
0.6	70	85
0.425	79	74
0.3	85	62
0.212	93	49
0.15	95	35
0.075	144	15
Pan	103	0

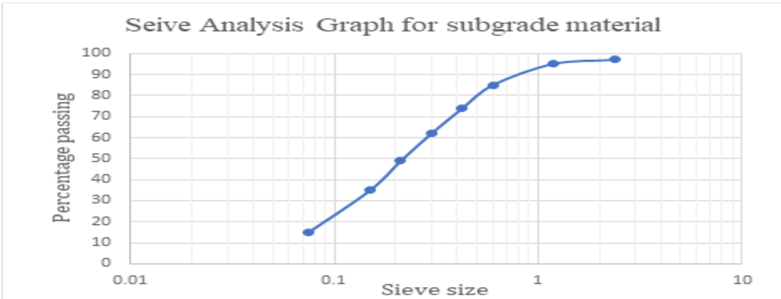

Figure 1. Gradation curve for subgrade material

Percentage passing sieve size 2mm = 96%
Percentage passing sieve size 0.425mm = 74%
Percentage passing sieve size 0.075mm = 49%
From the Fig 4.1, the values of D_{10}, D_{30}, and D_{60} for river sand are gotten and computed to get values for Coefficient of uniformity, (C_u) and Coefficient of gradation, (C_c) for both river sand.
D_{10} = 0.06
D_{30} = 0.14
D_{60} = 0.30

$$\text{Coefficient of uniformity, Cu} = \frac{D60}{D10} = \frac{0.30}{0.06} = 6$$

$$\text{Coefficient of gradation, Cc} = \frac{(D30)^2}{(D60 \times D10)} = \frac{(0.14)^2}{(0.30 \times 0.06)} = 1.09$$

b. Liquid Limit and Plastic Limit Test Result

The result of the liquid limit and plastic limit test are given in Table 3. While the graph is presented in Figure 2.

Table 3. Liquid Limit and Plastic Limit Test Result

	LIQUID LIMIT				**PLASTIC LIMIT**	
Container Number	**1**	**2**	**3**	**4**	**1**	**2**
$\mathbf{Wt.\ of\ can, M_1\ \ (g)}$	16	15.9	15.8	16.2	16	16
$\mathbf{Wt.\ of\ wet\ soil + can, M_2\ \ (g)}$	68	47	42	50	56	47
$\mathbf{Wt.\ of\ dry\ soil + can, M_3\ \ (g)}$	48	36	34	42	46	39
$\mathbf{Wt.\ of\ dry\ soil, M_4 = M_3 - M_1\ \ (g)}$	32	20.1	18.2	24	30	23
$\mathbf{Wt.\ of\ moisture, M_5 = M_2 - M_3\ \ (g)}$	20	11	8	8	10	8
No. of blows, N	14	19	24	29		
$\mathbf{Water\ content, w = \frac{M_5}{M_4} \times 100\ \ (\%)}$	62.5	54.7	44	33.3	33.3	34.8
Average plastic limit					34.1	

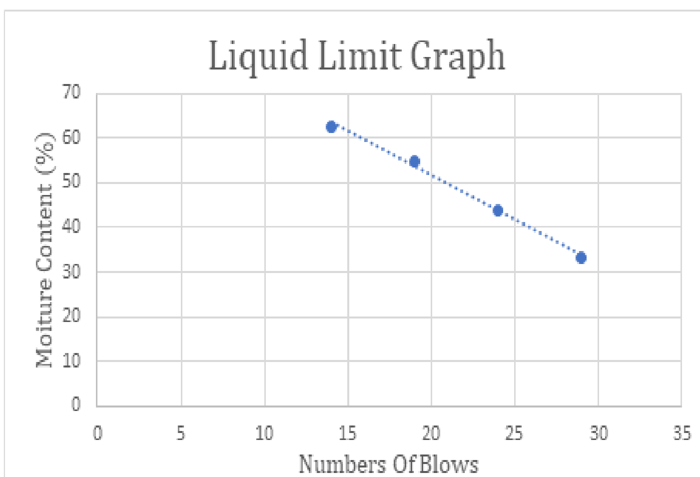

Figure 2. Liquid Limit Graph

Liquid Limit, LL = 42%
Average Plastic limit, PL = 34.1 %
Plastic index, PI = LL – PL = 42 – 34.1 = 7.9%

c. Compaction and CBR Test Results

The summary of the compaction and CBR test result obtained for the different mixes are presented In Table 6, Figure 3, Figure 4, Figure 5 and Figure 6

Table 6. Compaction and CBR Test Result

Mix no	Maximum dry density (g/cm^3)	Optimum moisture content (%)	Soaked CBR value (%)	Unsoaked CBR value (%)
SBG	1.77	18.6	3.8	13.9
GSA-2	1.92	15	5.8	25.5
GSA-4	1.91	15	12.7	46.5
GSA-6	1.90	16	15.9	54.7
GSA-8	1.97	16	18.2	56.2
GSA-10	2.03	16	15.5	55.3

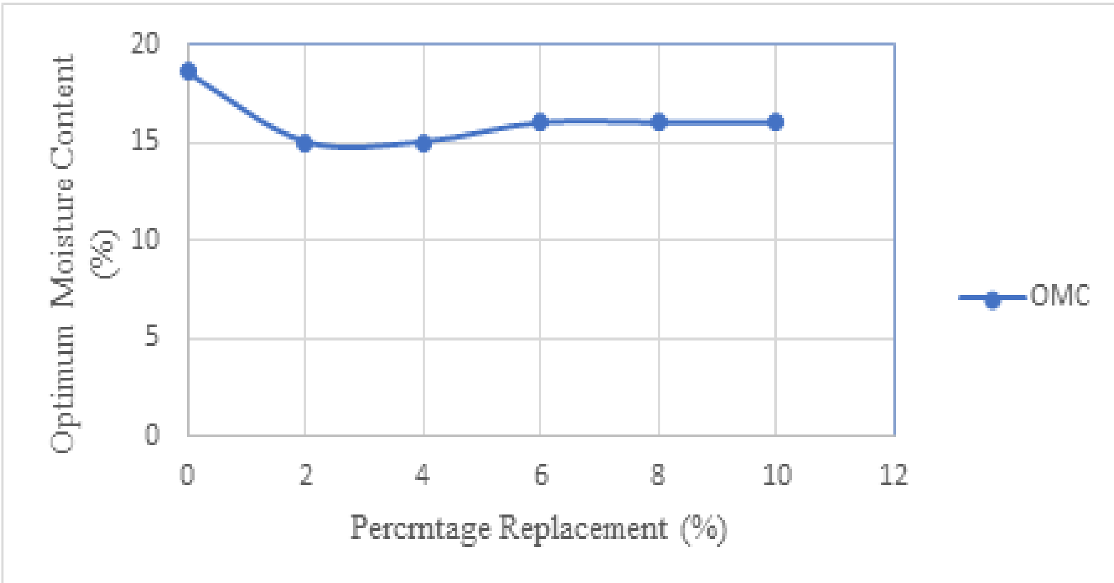

Figure 3. Optimum Moisture against Percentage Replacement

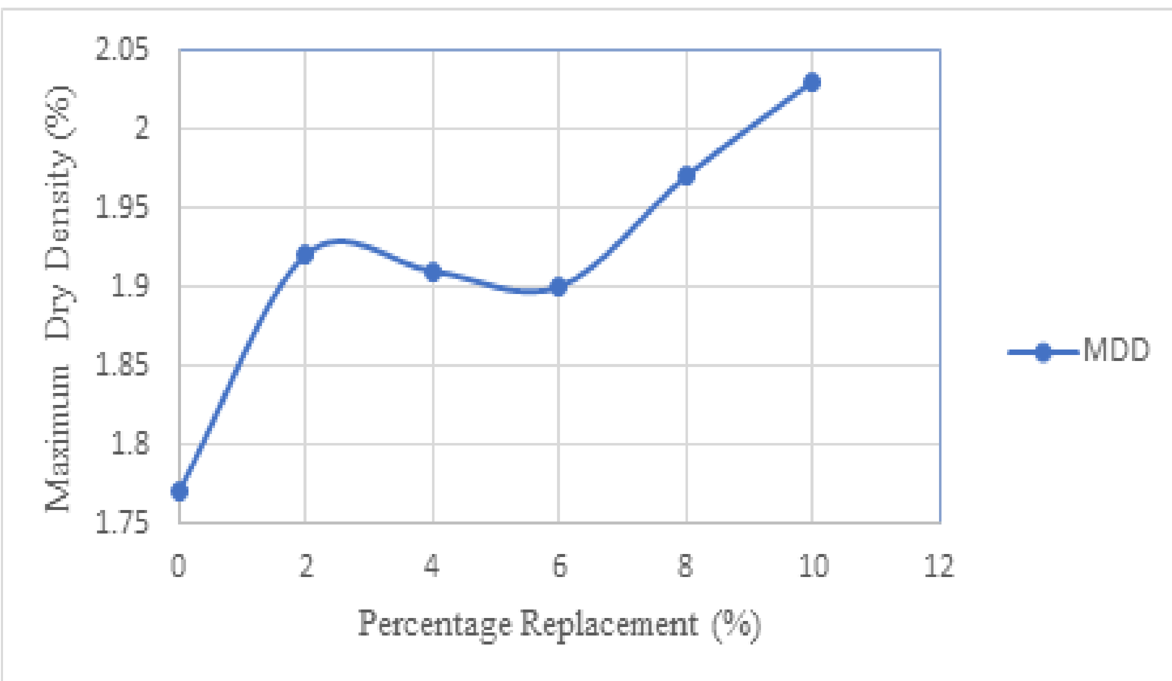

Figure 4. Maximum Dry Density against Percentage Replacement

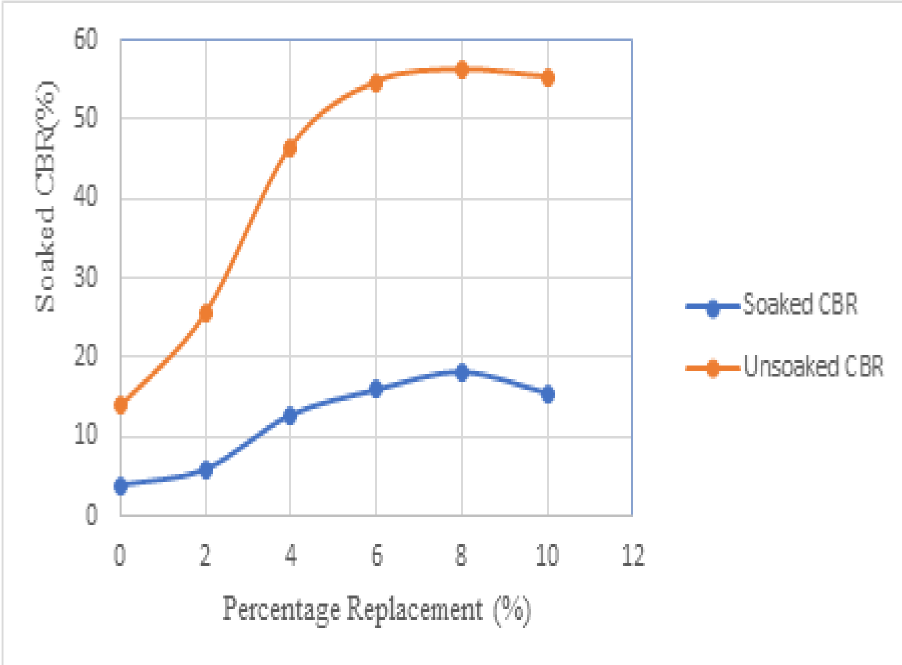

Figure 5. Soaked CBR against Percentage Replacement

ANALYSIS OF RESULTS

The analysis of the results is given below

a. Sieve Analysis and Consistency Limit Results

From the values presented in the sieve analysis and consistency limit test, the AASHTO classification of the subgrade material is classified A-7

b. Bulk Density Test Results

The values for bulk density of subgrade material and groundnut shell ash have values representing for material used in road construction. Values of the bulk density of the materials obtained may vary, however, owing to the nature and properties of the parent materials.

c. Analysis of Compaction and CBR test

From Table 6, Figure 3, Figure 4, Figure 5 and Figure 6, it is observed that the value OMC reduced at 2% groundnut shell ash replacement, it maintained the same value for 4%, then there was a slight increase at 6% replacement and the value was maintained at 8% and 10% replacement. The value of the MDD kept increased at 2% groundnut shell ash replacement, slightly reduces at 4% and 6% replacement, and then increases afterwards at 8% and 10% replacement. The value of the CBR kept increasing from 2% groundnut shell ash replacement, got to its peak value of 18.2% (soaked) and 55.3% (unsoaked) at 8% groundnut shell ash replacement, and then reduces afterwards.

CONCLUSION

After the successful completion of this work, the following conclusions are made:

a. The replacement of groundnut shell ash has a positive improvement in the properties of the subgrade material.

b. The maximum value of MDD was gotten as 2.03g/cm^3 at 10% groundnut shell ash replacement. While the maximum value of CBR was obtained as 18.2% (soaked) and 56.2% (unsoaked) at 10% groundnut shell ash replacement.

c. After the peak values of the CBR were obtained, further increment in the percentage replacement of the subgrade material with river sand and palm ash led to a corresponding reduction in the CBR values.

RECOMMENDATIONS

The following recommendation are made:

a. Groundnut shell ash are adequate materials to be used in stabilization of subgrade material in road projects.

b. Optimum replacement percentage of 8% for groundnut shell ash can suitably be used for subgrade stabilization.

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