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Research Article

Effect of Neem Seed Ash on the Geotechnical Properties of Lateritic Soil

Tijanee Sharifdeen Adebayo*, Abdulrauf Kabir

Department of Civil Engineering, Federal Polytechnic Offa, Offa, Nigeria

Abstract

The impact of Neem Seed Ash (NSA) on the geotechnical properties of three clay soil samples classified as MH and CH by the Unified Soil Classification System is investigated in this study. The results of preliminary testing indicated moderate plasticity and load-bearing capacity, with natural moisture levels ranging from 7.2% to 9.38%, specific gravities from 2.66 to 2.75, and California Bearing Ratio (CBR) values from 13.42% to 19.8%. According to ASTM C618's Class C classification, NSA's pozzolanic content of 52.01% was determined by chemical analysis. The engineering properties of the soils were significantly improved by NSA integration. As the NSA content rose, the specific gravity decreased, demonstrating the admixture's decreased density. Indicating improved soil workability and decreased plasticity, Atterberg limits showed a significant decline: liquid limits decreased from 37% to 12%, plastic limits from 27% to 11%, and the plasticity index from 14% to 2%. The maximum dry density increased to 2.37 g/cm^3 at 6% NSA substitution, according to compaction tests, and the optimal moisture content decreased from 16% to 9.6%, indicating increased compaction efficiency. With 8% NSA replacement, the CBR values increased dramatically, reaching 44.1%, indicating a notable improvement in strength. These findings confirm that NSA is an effective stabilizing agent for difficult clay soils, enhancing their mechanical properties and potentially reducing environmental impacts and building costs. The study supports the use of NSA as an economical and environmentally friendly additive for stabilizing geotechnical soil.

Keywords

Neem Seed Ash, Lateritic Soils, California Bearing Ratio, Maximum Dry Density, Fly-ash

1. Introduction

Lateritic soil with remarkable engineering features is frequently sought after by contractors building various engineering constructions [1, 2]. In actuality, it is often difficult to identify such soils, especially since many construction sites are predominantly made up of lateritic soil, some of which are known to have high clay content in their native state. Engineers all throughout the world have frequently expressed concern about this issue. To overcome this issue, different strategies are available; one option is to scarify the current soil and immediately replace it with a brought-in material, or to stabilize the existing soil in place. However, given the financial elements of site logistics, haulage distances, and the transportation of imported components, scarification and substitution with foreign resources may not always be cost-effective and may frequently increase building costs. Unlike stabilization, cost is reduced while achieving sustainability [3]. Soil stabilization is essentially the process of changing the soil's properties by applying chemically reactive

*Corresponding author: tijaneesharifdeenadebayo@gmail.com (Tijanee Sharifdeen Adebayo)

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chemicals. This improves the soil's engineering qualities, both physical and chemical. Chemical soil stabilization alters the soil's consistency, swelling properties, grain size distribution, unconsolidated compressive strength (UCS), and California bearing ratio (CBR) [4, 5]. Numerous research have recently been undertaken on the use of chemical additives such as cement, lime, and fly ash in the treatment of clay-rich [6-8].

Despite these outstanding results, the cost of using this traditional addition is substantial, as are the environmental effects it produces during manufacturing. As a result, researchers face the difficult task of investigating alternate methods for soil stabilization. The global surge in urban populations has led in an increase in trash production across all aspects of human activity [9]. Careless trash disposal is quickly becoming a major concern in Nigeria, with agricultural waste accounting for the majority of the waste generated [10-12]. According to Agamuthu [13], around 998 million tonnes of agricultural waste are produced each year. These findings have prompted academics to focus further on converting these minerals for usage as a soil augmentation resource in building. However, initiatives aimed at achieving environmental sustainability have prompted the investigation of various sustainable materials (agricultural waste materials) as effective alternatives for improving lateritic soil, as opposed to traditional approaches that use cement and lime for soil improvement [9, 14, 15].

Numerous research have shown that agricultural waste is an effective substitute for traditional materials in improving soil quality [16-19]. Agricultural waste refers to the byproducts produced during the production and handling of unprocessed agricultural products such as fruits, vegetables, livestock, poultry, dairy products and crops. Neem Seed Husk is a by-product of the industrial processing of Neem Seed for oil extraction and fertilizer manufacturing [20-22]. To make neem-based fertilizer, first extract neem oil, and then use the resultant cake to make organic fertilizer. A little portion of seed husk is crushed and used into fertilizer, while the majority goes to waste [23, 24]. However, neem seed husk waste causes disposal challenges in neem oil processing plants, resulting in severe ecological and environmental contamination when discarded, causing serious threats to human health and other living species [25-28]. This demands the utilization of neem seed husk waste.

2. Materials and Methodology

2.1. Laterite

This was taken from three different areas in AjaseIpo village, packaged, and ramped to keep its natural moisture content for measuring purposes. The samples were collected from AjaseIpo town using GPS coordinates (latitude: 8.2333, longitude: 4.8167) at a depth of 900mm after the overlying soil was removed. The natural moisture content was determined using FMWH (2000) criteria for road construction.

2.2. Neem Seed

The neem seed husk was received from Yammfy Farms Nigeria Limited, located on Offa-Ilemona Road in Offa, Kwara State, Nigeria. Following collecting, the husks were carefully placed in sack bags, properly sealed, and tagged for onward transport to the laboratory. Inside the lab, the husks were rigorously cleansed to remove any impurities or pollutants. They were then sun-dried for 24 hours to ensure complete moisture removal. The remaining contaminants were then manually chosen, and the husks were cut into smaller fragments of around 2.00 mm in size. The prepared Neem Seed Husk underwent controlled calcination at temperatures ranging from 700 ℃ to 900 ℃. The obtained Neem seed Ash (NSA) was then ground into finer particles that could pass through a 63 mm sieve and was kept in a cool, dry place for later use.

2.3. Sample Preparation

Laterite soil samples were oven-dried for 24 hours at 60 ℃ to preserve their clay mineral properties. To modify the laterite soil, varying volumes of Neem Seed Ash (NSA) were injected at rates of 2%, 4%, 6%, 8%, and 10% (by weight). The ingredients were thoroughly mixed to ensure close mixing. The mixed samples were allowed to cure for 48 hours before being remixed to achieve a uniform consistency for testing..

2.4. Testing Experiment

Specific gravity, Atterberg limits, compaction, particle size distribution (sieve analysis), and California Bearing Ratio (CBR) were among the laboratory experiments conducted on soils and Neem Seed Ash (NSA) stabilized soils. Neem Seed Ash was used to stabilize clay soil in compliance with BS 1924 guidelines.

3. Results and Discussion

3.1. Preliminary Test Results on Soil Samples

Table 1 summarizes the results of the preliminary geotechnical tests, such as natural moisture content, specific gravity, Atterberg limits, compaction, and CBR, which were conducted only on clay soil.

Table 1. Results of Preliminary Test on Soil Samples.

Properties	Soil 1	Soil 2	Soil 3
Natural Moisture Content	8.4	9.38	7.2
Grain Specific Gravity, Gs	2.66	2.71	2.75
Liquid Limit (LL)%	33	37	35
Plastic Limit (PL)%	27	27	21
Plasticity Index (PI)%	6	10	14
Sand	34.29%	36.79%	17.12%
Silt	58.49%	44.23%	60.34%
Clay	7.2%	18.98%	22.54%
Effective Diameter, (D10) mm	0.054	0.023	0.019
Coefficient of Uniformity (Cu)	20	15	18
UCSC Soil Classification	MH	MH	CH
AASHTOSoil Classification	A-6	A-6	A-7-6
Maximum Dry Density (g/cm^3)	2.33	2.39	1.40
Optimum Moisture Content (%l)	16	13.5	7.1
California Bearing Ratio (%)	19.8	17.1	13.42

The natural moisture levels of soil samples A, B, C are 8.4%, 9.38%, and 7.2%, indicating that all the soil samples are relatively dry. The specific gravity of the soil is recorded at 2.66 for soil sample 1, 2.71 for soil sample 2, and 2.75 for soil sample 3; these figures suggest that all soil samples possess moderately high specific gravity. Upon compaction of the soil samples, soil sample 1 exhibits a Maximum Dry Density of 2.33 with an optimum moisture content (OMC) of 16%, soil sample 2 presents a Maximum Dry Density of 2.39 at an optimum moisture content (OMC) of 13.5%, while soil sample 3 reflects a Maximum Dry Density of 1.40 with an optimum moisture content (OMC) of 7.1%. This indicates that the soil possesses considerable weight per unit volume under compression, which is beneficial for load-bearing structures.

The Unified Soil Classification System identifies the three soil samples as MH (Sandy Silt), MH (Sandy Silt), and CH (Clayey Silt), while the AASHTO classification categorizes them as A-6, A-6, and A-7-6, respectively. The soil samples show a Liquid limit from 33 to 37%, a Plastic limit from 21 to 27%, and a Plasticity index from 6% to 14%. All of this suggests that every soil sample exhibits moderate plasticity.

3.2. Chemical Composition of Neem Seed Ash (Nsa)

The chemical analysis tests were done to determine the oxide composition of Neem Seed Ash (NSA). This was carried out at Rolab research Centre Ibadan.

Table 2. Oxides Cmposition of NSA.

Chemical Constitutients	Neem Seed Ash (NSA) (%)
SiO_2	36.5
Al_2O_3	3.37
Fe_2O_3	12.14
CaO	18.08
MgO	3.2

Chemical Constitutients	Neem Seed Ash (NSA) (%)
K_2O	9.45
Na_2O	0.05
SO_3	2.09
Loss on Ignition (LOI)	7.50

Table 2 showed the chemical composition of Neem Seed Ash (NSA). The chemical constituents include Calcium oxides (CaO), Potassium oxides (K_2O), Silica (SiO_2), Alumina (Al_2O_3) and Ferric Oxide (Fe_2O_3) amongst others and Loss on Ignition (LOI) as 36.5%, 3.37%, 12.14%, 18.08%, 3.25, 9.45%, 0.05%, 2.09% and 7.50% respectively. From Table 2, the pozzolan content (i.e. combination of SiO_2+ Al_2O_3 +Fe_2O_3) of Neem Seed Ash (NSA) is 52.01% which is greater than 50% specified for Class C pozollan. Thus, the Neem Seed Ash (NSA) meets the requirement for Class C pozzolan.

3.3. Specific Gravity

The specific gravity of the Neem Seed Ash (NSA) is 2.35. The specific gravity of the mixes of soil samples with the Neem Seed Ash are shown in Table 3 and Figure 1. There was reduction in specific gravity of mixes of soil sample 1 from 2.66 to 2.53, Soil Sample 2 from 2.71 to 2.55 and soil sample 3 from 2.75 to 2.63. It was observed that there is significant reduction in the specific gravity of all the soil samples as the Neem Seed Ash Content increases.

Table 3. *Result for specific gravity test.*

Test	Specific Gravity (Gs)				
% NSA Replacement	0%	2%	4%	6%	8%
Sample 1	2.66	2.61	2.63	2.59	2.53
Sample 2	2.71	2.65	2.62	2.58	2.55
Sample 3	2.75	2.79	2.68	2.72	2.63

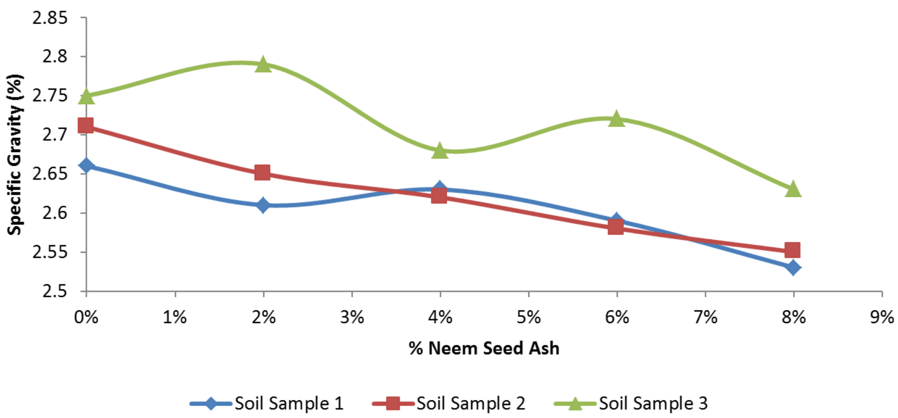

Figure 1. *Specific Gravity of Modified Soil Samples.*

3.4. Atterberg Limit Test

The Atterberg limit tests which include the liquid limit tests, plastic limit tests and plasticity index tests are carried out in accordance with BS 1377. The Atterberg tests were done for the three natural soil samples 1, 2 and 3 which are regarded as 0% and also for the stabilized (addition of Neem Seed Ash) soil samples at an increment of 2%, 4%, 6% and 8% for soil sample 1, 2 and 3 as shown in Table 4, Figure 2 and Figure 3.

Table 4. *Result of Atterberg Limits Tests.*

Test	Atterberg Limit (%)														
Sample	1					2					3				
% Replacement	0%	2%	4%	6%	8%	0%	2%	4%	6%	8%	0%	2%	4%	6%	8%
Liquid Limit	33	23	20	21	12	37	29	25	23	12	35	21	21	26	18
Plastic limit	27	19	18	14	11	27	24	16	19	11	21	17	16	21	16
Plasticity index	6	4	2	7	1	10	5	9	4	1	14	4	5	5	2

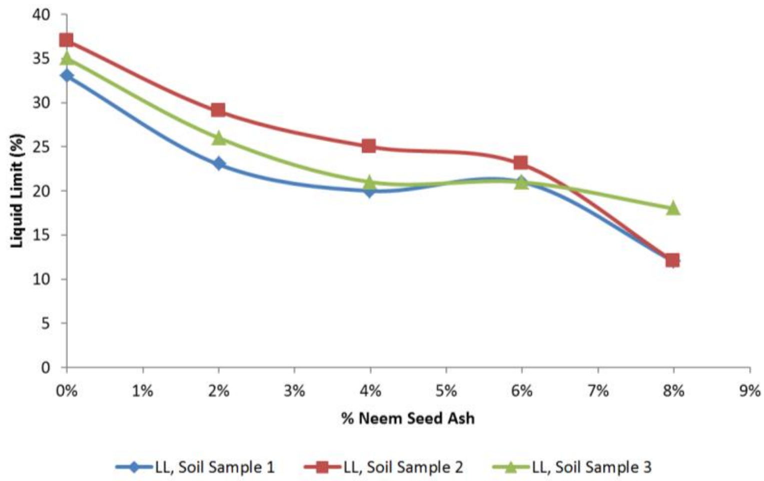

Figure 2. *Liquid Limit of Modified Soil Sample.*

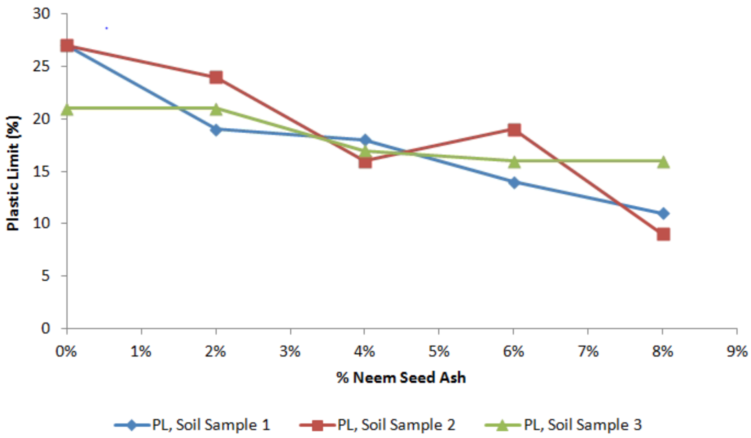

Figure 3. *Plastic Limit of Modified Soil Sample.*

Neem Seed Ash (NSA) changes the Atterberg limits of the soils. An increase in NSA from 0%-8%, the liquid limit, plastic limit and plasticity index of all soil samples reduces from 37% to 12%, 27% to 11% and 10% to 1%. The reduction in plastic index is expected because Neem Seed Ash (NSA) are cohesion-less material. Thus an inclusion of Neem Seed Ash (NSA) reduces the Atterberg limits of the clay soils. Thus, this is an indication there is an improvement in the consistency of the soil.

3.5. Compaction

In determining the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), the compaction test was performed on the soil samples andmodified soil samples using the Standard Proctor test compaction method. The average value of the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are shown in Table 5 and presented in Figure 4 and Figure 5 respectively.

Table 5. *Result of Compaction test.*

Sample	Sample 1		Sample 2		Sample 3	
% Neem Seed Ash (NSA) Re-placement	**MDD (g/cm3)**	**OMC (g/cm3)**	**MDD (g/cm3)**	**OMC (g/cm3)**	**MDD (g/cm3)**	**OMC (g/cm3)**
0%	2.33	16	2.39	13.5	1.40	8.2
2%	2.34	11.0	2.43	11	1.48	7.9
4%	2.35	11.5	2.21	13	1.58	7.6
6%	2.37	9.6	2.37	9.8	2.13	7.1
8%	1.53	11.0	2.10	7.1	1.58	7.2

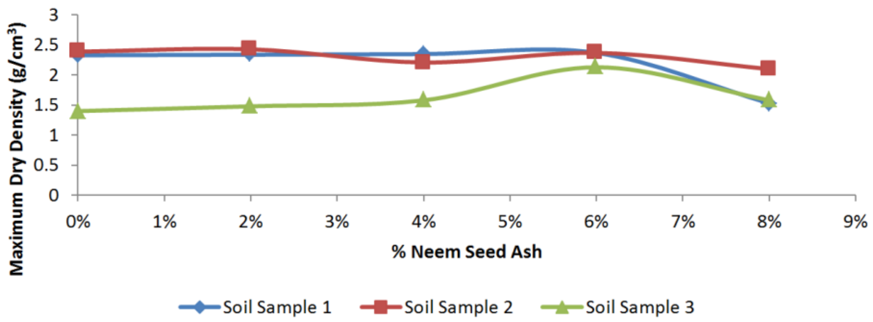

Figure 4. *Maximum Dry Density (MDD) of Modified Soil Samples.*

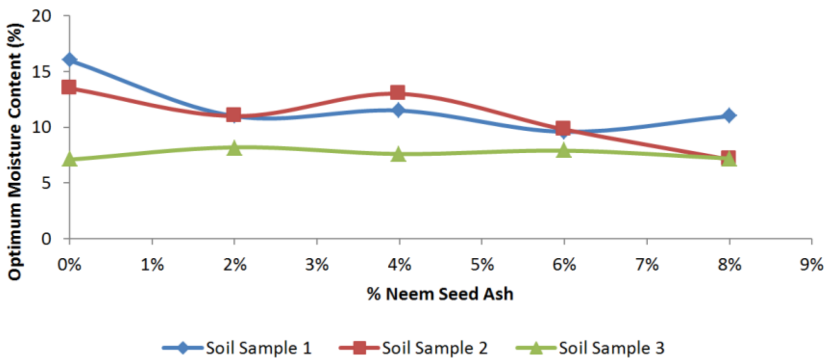

Figure 5. *Optimum Moisture Content of Modified Soil Samples.*

Neem Seed Ash (NSA) changes the compaction characteristics of the soils. An increase in NSA from 0%-8%, the maximum dry density of all soil samples increases up to 6%Neem Seed Ash (NSA) replacement, but beyond 6% it reduces. Similarly, the optimum moisture content (OMC) of all soil sample reduces as the Neem Seed Ash content increases in the soil mixes. The reduction in maximum dry density is attributed to the fact that Neem Seed Ash (NSA) is a cohesion-less material and of low specific gravity. Also, the addition of Neem Seed Ash (NSA) reduces the optimum moisture content (OMC) because the surface area and water absorption rate of the soil samples are diminished. Thus, increase in the maximum dry density (MDD) and reduction in the optimum moisture content (OMC) is a pointer there is an improvement in the mechanical properties of the modified clay soil.

3.6. California Bearing Ratio

The average value of the soaked California Bearing Ratio (CBR) test results are shown in Table 6 and presented in Figure 6.

Table 6. Result of CBR Test.

	1	2	3
% NSA Replacement	**CBR Value (%)**	**CBR Value (%)**	**CBR Value (%)**
0%	19.8	17.1	13.42
2%	29.4	26.6	22.5
4%	32.5	34.0	34.2
6%	34.6	35.2	36.4
8%	38.3	44.1	36.9

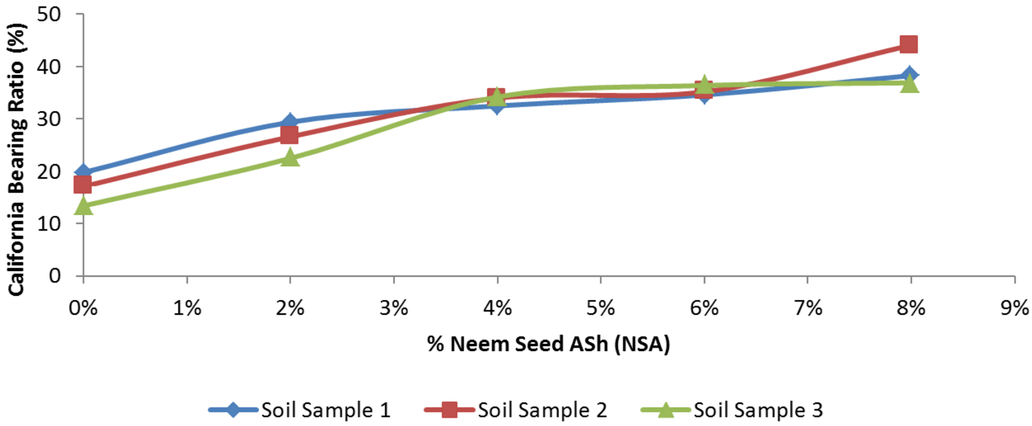

Figure 6. California Bearing Ratio of Modified Soil Sample.

Neem Seed Ash (NSA) changes the California bearing ratio (CBR) of the soils. An increase in NSA from 0%-8%, the California bearing ratio (CBR) of all soil samples increases The increase in California bearing ratio (CBR) is attributed to the fact that Neem Seed Ash (NSA) is made up of coarser material and its pozzolanic reaction. Thus, increase California bearing ratio (CBR) in is a pointer there is an improvement in the mechanical properties of the modified soil samples.

4. Conclusion

This study examines the impact of Neem Seed Ash (NSA) on the geotechnical characteristics of three soil samples collected from various sites. The three soil samples examined in this study were categorized as MH, MH, and CH according to the USCS soil classification system. The materials vary from sandy silt to clayey silt with high plasticity according to general classification. The results from the chemical composition test indicate that the Neem Seed Ash (NSA) is classified as Fly-Ash type C according to ASTM C618. Furthermore, it was demonstrated that incorporating Neem Seed Ash (NSA) admixture enhanced the engineering characteristics of the clay soils. The plasticity index, including liquid limits, plastic limits, and plastic index, decreases. The decrease in the plasticity index indicates that the soil characteristics and its operability have been enhanced. The OMC decreases, while the values of MDD and CBR rise.

In conclusion, Neem Seed Ash can act as effective alternatives to amend and stabilize troublesome clay soils, thereby aiding in lowering construction expenses, minimizing environmental risks, and ultimately enhancing the geotechnical characteristics of clay soils.

Abbreviations

MH	Silty Clay
CH	High Plasticity Clay
CBR	California Bearing Ratio
NSA	Neem SeedAsh
ASTM	American Society for Testing and Materials
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
FMWH	Federal Ministry of Works and Housing
BS	Bristish Standard
Gs	Specific Gravity
LL	Liquid Limit
PL	Plastic Limit
PI	Plasticity Index
D_{10}	Effective Diameter
C_u	Coefficient of Uniformity
UCSC	Unified Soil Classification System
AASHTO	American Association of State Highway and Transportation Officials

Conflicts of Interest

The authors declare no conflicts of interest.

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