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Effects of Groundnut Husk Ash on Lime-Stabilized Lateritic Soil

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Abstract: *This study assesses the effects of groundnut husk ash (GHA) on lime-stabilized lateritic soil. Preliminary tests were carried out on the natural soil sample for the purposes of identification and classification. The soil sample was classified as A-7-5, hence, necessitating stabilization. The soil sample was thereafter mixed with lime at percentages of 2, 4, 6, 8 and 10. These were later subjected to atterberg limit tests to get the optimum amount of lime, which was 10% because the least value of plasticity index was recorded at this state. GHA was added to the lime-treated soil sample at varying proportions of 2, 4, 6, 8 and 10%. The mixes were subjected to compaction, California bearing ratio (CBR), atterberg limits and unconfined compressive strength (UCS) tests, in so doing, the values of the CBR and UCS increased considerably, upon the addition of lime alone to lateritic soil, both soaked and unsoaked CBR values increased from 5.5% and 9.5% to 40.70% and 50.45% and when GHA was further added soaked and unsoaked CBR values further rose from 40.70% to 49.94% and 50.45 to 65.42%. It can be concluded therefore that the GHA performs satisfactorily as a cheap complement for lime in soil stabilization.*

Keywords: Atterberg limits, Groundnut husk ash, Lateritic soil, Lime stabilization, Soil stabilization

1. INTRODUCTION

According to Akintorinwa *et al*. [1], road transportation is an important element in the physical development of any society because it controls the direction and magnitude of development. Good roads promote the economic growth of a nation by creating enabling atmosphere for the distribution of goods and services. A good network of roads will reduce haulage and reduce accidents, thereby minimizing human and material losses. The rate of road failures in Nigeria, in recent times, has assumed an alarming proportion. Several factors are said to be the causes of failures of our road pavements; prominent among such factors are geological, geomorphological, geotechnical, road usage, construction practices and maintenance culture [2]. Of particular interest to this study is the geological factors as highlighted by [2], is the nature of soils- laterites. According to Ola [3], laterites is defined as the product of tropical weathering with red, reddish brown and dark brown colour, with or without ferruginous crust or hard pan. Fundamentally soils having a ratio of silica to sesquioxide ($SiO_2/Fe_2O_3+Al_2O_3$) which are less than 1.33 are regarded as laterites, between 1.33 and 2.00 are regarded as lateritic soil and those above 2.00 are non-lateritic soils. Though, this definition is not convenient from the engineering point of view especially due to lack of adequate laboratory facilities. Most lateritic soils in their natural states generally have low bearing capacity and low strength due to content of clay. When lateritic soil contains large amount of clay materials its strength and stability cannot be guaranteed under load especially in the presence of moisture, hence, the need of stabilization [4]. According to Ogundipe [5], Stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include the blending of soils to achieve a desired gradation, texture or plasticity, or act as a binder for cementation of the soil.

The two most commonly used stabilizers for expansive clays are cement and lime. Lime stabilization are commonly restricted to warm to moderate climates since lime stabilized soils are susceptible to breaking under freezing and thawing. The action of lime can be generally reduced to three fundamental reactions: alteration of water film surrounding the clay minerals; flocculation of the soil particles and reaction of lime with soil components to form new chemical compounds [6]. There is no direct hydration to form cementitious compounds in lime stabilization, instead, we have the physical and chemical components to the reaction of lime with clay. The physical reaction is one of cation absorption where calcium first replaces any other ion present as a base exchange ion. This process is followed by flocculation into coarse particles, which produced an immediate increase in strength [7].

2. MATERIALS

Lateritic Soil: The soil sample was obtained at existing burrow pit along Ifaki – Iworoko –Ekiti road, behind Hajaig Operational Office, by using the method of disturbed sampling at 1.2m depth from the natural earth surface to avoid contacts with organic soil/matter. It was thereafter taken to the soil laboratory, Afe Babalola University, Ado-Ekiti (ABUAD) and marked, indicating the soil description, sampling depth and date of sampling. The lateritic soil was air-dried for two weeks to allow for partial elimination of natural water content which may affect the analysis, then sieved with Sieve No 4 (4.75mm opening) to obtain the final soil samples for the test. After the drying period, lumps in the samples were pulverized under minimal pressure.

Hydrated Lime: The hydrated lime used for this study was bought from a chemical store in Ado-Ekiti.

Ground-Nut Husk Ash: The ground-nut husk was obtained from a groundnut vendor at Awedele, Ado-Ekiti, Nigeria. The groundnut husk was collected, air-dried and burnt under atmosphere conditions. The residue obtained after burning was the ash that was also collected and taken to the Soil Laboratory of the Afe Babalola University, Ado-Ekiti. The ash was then sieved using sieve no. 200 (0.075mm) to meet the requirements of both British Standard 1924 [8] and ASTM C618 [9]. The chemical composition of ground-nut husk ash and hydrated lime were determined at the Petroleum Reservoir Engineering Laboratory of the Afe Babalola University, Ado-Ekiti.

3. METHODS

The preliminary tests were performed on the natural lateritic soil sample for the purpose of identification and classification, thereafter, the engineering tests such as california bearing ratio tests, unconfined compressive strength tests and compaction tests were performed on the natural soil sample. Hydrated lime was added to the soil sample in proportions of 2, 4, 6, 8 and 10% and were later subjected to atterberg limits tests, to detect the optimal amount of lime required which is the amount of lime added where the least value of plasticity index is recorded. The Ground-nut Husk Ash (GHA) was added in proportions of 2, 4, 6, 8 and 10% by weight of soil to the soil stabilized with lime at separate amounts of 2, 4, 6, 8 and 10% respectively. Thereafter, each of the mixes were subjected to the following tests: Compaction, California Bearing Ratio (CBR), Atterberg Limits and Unconfined Compressive Strength tests. Generally, the laboratory tests were performed on the natural soil and stabilized soil in accordance with British Standard 1377 [10] and British Standard 1924 [8] respectively.

Atterberg limits test

The Atterberg limits tests were carried out in accordance with the British Standard Methods 1377 [10]. The lateritic soil sample was sieved through 0.425mm. Materials that were retained on the sieve was discarded and not used for the test. The soil sample was oven-dried for at least 2 hours before the test. For the stabilized specimens; the tests were carried out on the soils mixed with lime alone and on soils with the optimal amount of required lime and varying proportions of 2, 4, 6, 8 and 10% GHA.

Compaction Characteristics

The proctor standard compaction method was adopted for this study. The test was carried out in accordance with British Standard 1377 [10] with the purpose of determining the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils. The soil mixtures (with or without additives) were thoroughly mixed with various moisture content and allowed to equilibrate for 24 hours before compaction. The first aspect of the compaction test involved determining the compaction properties of the natural soil sample. At the second stage, tests were performed to determine the proctor compaction properties of soil sample stabilized with lime at optimal amount required and the varying amounts of GHA (2, 4, 6, 8 and 10%).

California bearing ratio (CBR)

The British Standard 1377 [10], stipulates the procedures to follow in carrying out this test. This, was however modified in conformity with the recommendation of the Nigerian General Specification, Federal Ministry of Works and Housing [11], which stipulates that specimens be cured for six days unsoaked, immersed in water for 24 hours and allowed to drain for 15 minutes before testing.

Unconfined Compressive Strength (UCS)

The British Standard 1924 [8] stipulates the procedure for carrying out this test and was adopted for the natural soil sample. For the stabilized soil mixtures, specimen were prepared by carefully and completely mixing dry quantities of pulverized soil with the optimal amount of hydrated lime required and varying proportions of 2, 4, 6, 8 and 10% GHA. The needed amount of water was determined from moisture-density relationships for stabilized-soil mixtures was subsequently added to the mixture. For each of the mix, three specimens were prepared as stipulated by the Nigerian General Specification, [11].

4. RESULTS AND DISCUSSIONS

Table 1 shows that the percentage that passed through No. 200 BS sieve was 52.50%, therefore, suggesting that the soil belonged to one of the following groups; A-4, A-5, A-6 and A-7. Having more than 35% of soil sample to pass through the No 200 sieve connotes that the soil sample therefore fell into the silty or clayey group with generating rating of fair to poor. The liquid limit of the soil is 48.85%, thereby, falling into the A-5 and A-7 groups. The value of the plasticity index is 16.25%, the soil therefore falls into the A-7 group. For soil sample to be classified into the A-7-5 subgroup; plasticity index $\leq LL - 30; 16.25 \leq 48.85 - 30\ (18.85)$. The soil sample therefore falls into the A-7-5 subgroup [12]. Furthermore, the specific gravity of the soil sample is 2.08, the soil can be said to belong to the halloysite group, according to Das [13], soils that possess specific gravity value within the range of 1.69-2.9 are classified as halloysites.

Table 1: Summary of the preliminary tests results

Property	Amount
Natural Moisture Content (%)	21.85
Percentage passing sieve No. 200 (%)	52.50
Specific gravity	2.08
Liquid limit (%)	48.85
Plastic limit (%)	32.60
Plasticity Index (%)	16.25
Unsoaked CBR (%)	9.50
Soaked CBR (%)	5.50
Optimum Moisture Content (%)	12.45
Maximum Dry Density (kg/m^3)	1650
Unconfined Compressive Strength (kN/m^3)	1650

Property	**Amount**
AASHTO Classification	A-7-5
USCS Classification	CL

In Table 2, chemical composition of GHA presents a conclusion that the GHA is pozzolanic and has the same active chemical constituents and properties as that of the hydrated lime, such as CaO, SiO_2, Al_2O_3, Fe_2O_3, MgO etc. According to ASTM C618 [14], if the total sum by weight percentage of SiO_2, Al_2O_3 and Fe_2O_3 of a material is equal or greater than 70%, the material can be said to be pozzolanic. The sum total of SiO_2, Al_2O_3 and Fe_2O_3 of the GHA equal 76.39%, therefore, the GHA is pozzolanic and according to the same standard, the pozzolan belonged to class C pozzolan.

Table 2: Chemical composition of the GHA and hydrated lime used for the study.

Elemental Oxide	**GHA (wt %)***	**Hydrated Lime (wt %)**
SiO_2	51.54	1.71
Al_2O_3	22.45	0.72
Fe_2O_3	2.40	0.05
CaO	15.63	68.12
MgO	1.20	1.38
SO_3	0.05	-
K_2O	-	0.06
Na_2O	0.04	0.03
P_2O_5	0.60	-
LOI	3.05	-

*Source: [15]

Table 3 shows effects of lime on soil properties, with increasing addition of lime to soil values of liquid limit and plasticity index reduced. The least value of plasticity index-13% was recorded at 10% lime content. Therefore, the optimum lime requirement was 10%, further addition of the GHA was done to the soil sample which was treated with 10% lime.

Table 3: Effects of lime on soil properties

Lime (%)	**LL (%)**	**PL(%)**	**PI (%)**	**MDD (kg/m³)**	**OMC (%)**	**Unsoaked CBR (%)**	**Soaked CBR (%)**
0	48.85	32.60	16.25	1650	12.45	9.50	5.50
2	47.25	31.35	15.90	1630	13.50	20.65	11.35
4	46.40	31.00	15.40	1605	14.30	35.75	25.65
6	43.80	29.00	14.80	1587	15.40	40.60	29.50
8	42.30	28.30	14.00	1570	16.55	45.20	34.60
10	40.20	27.20	13.00	1548	17.74	50.45	40.70

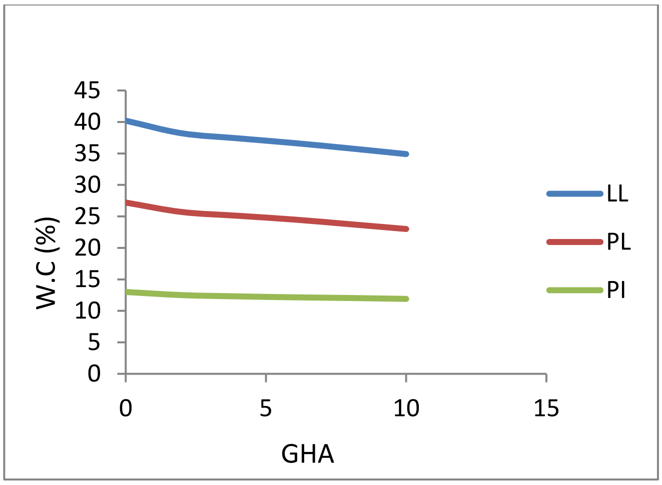

Figure 1. Effects of GHA on atterberg limits of lime-treated lateritic soil

From Table 3, the addition of lime to the lateritic soil sample resulted to the decrease in the values of liquid limit and plasticity indices of the soil sample. The trend observed with the lime can be attributed to agglomeration of fine clay particles into coarse, friable particles by a base exchange with the calcium cations from lime displacing sodium or hydrogen ions, with a subsequent dewatering of the clay fraction of the laterite, referred to as cation exchange reaction [16].

According to Osinubi [17], the reduction in the plasticity is attributed to the change in soil nature (granular nature after flocculation and agglomeration) and the modified soil as crumbly as silt soil, which is characterized by low surface area and low liquid limit because of the plastic nature of the time. In Fig. 1; the addition of GHA to the lime-treated lateritic soil sample further reduced the liquid limit values and its plasticity index values. This, may be attributed to the higher release of Ca^{2+} and Si^{2+} cations with increased lime+GHA [18]. The addition of the GHA to the lime-treated soil reduced the plasticity index which is an indication of improvement of soil properties [19]. In addition to this, according to the Nigerian General Specifications [11], subgrade or fill material is expected to have a liquid limit value of less than 50% and plasticity index should be equal or less than 30%, while for sub base, liquid limit is expected to be equal or less than 30% and plasticity index should be equal or less than 12%. With the addition of GHA to the lime-treated soil, the plasticity index of the soil reduced to a level where it can be adequately used for sub base in Nigerian roads since soils with plasticity index higher than 12% are not suitable for use as sub base materials for roads in Nigeria [20].

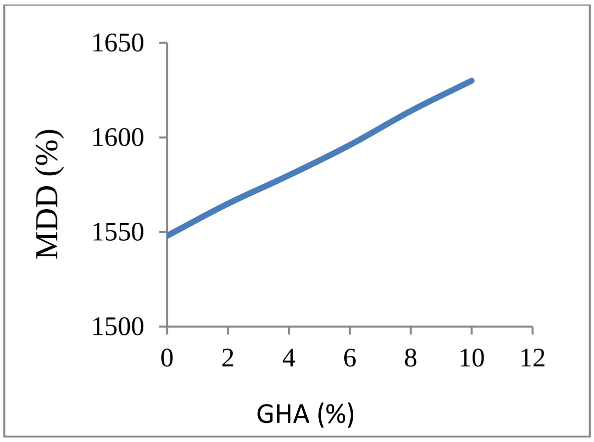

Figure 2. Effects of GHA on MDD of lime-treated lateritic soil

From Table 1, the maximum dry density (MDD) of the lateritic soil sample at its natural state was 1650 kg/m^3. From Table 3; the addition of lime to the soil sample resulted to gradual decrease of value of MDD from 1650 kg/m^3 at 0% lime (natural state) to the lowest value of 1548 kg/m^3 at 10% lime. Also, from Figure 2, the addition of ground-nut husk ash (GHA) to lime-treated soil led to the increase in value of MDD from 1548 kg/m^3 at 0% GHA to highest value of 1630 kg/m^3 at 10% GHA. According to Iorliam *et al.* [18], increase in MDD may be as a result of the combined action of lime and GHA, GHA released more silica, lime released Calcium Oxide that caused the flocculation and agglomeration of clay particles. This flocculation-agglomeration process results in floc formation. The enlarged particle size causes the void ratio to increase. This increase in void ratio reflects the decrease in maximum dry density. The variation of OMC with increase in GHA in the soil-lime mixture can be seen in Figure 3. The increase in OMC with increase GHA in the lime-treated soil may be attributable to the decrease in the quantity of free silt and clay fraction and coarser materials with larger surface areas were formed (these processes need water to take place). This connotes that aside the water needed to take place, more water was needed in order to compact the soil-lime-GHA mixtures [21].

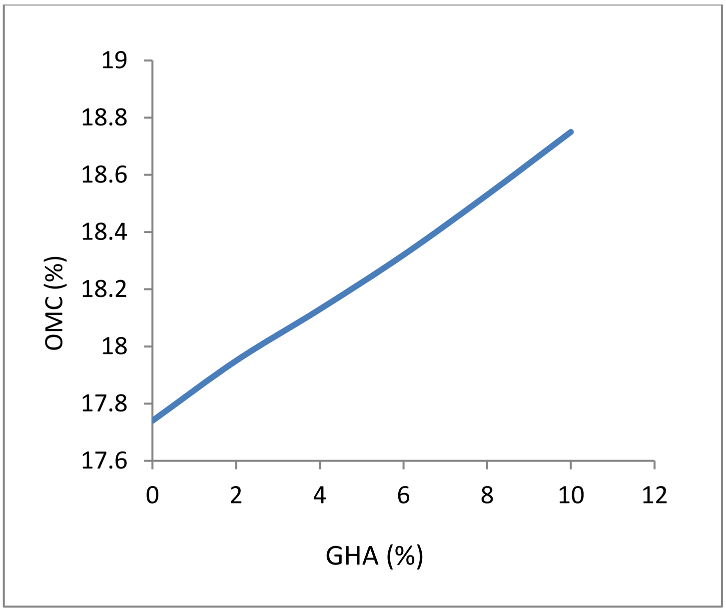

Figure 3. Effects of GHA on OMC of lime-treated lateritic soil

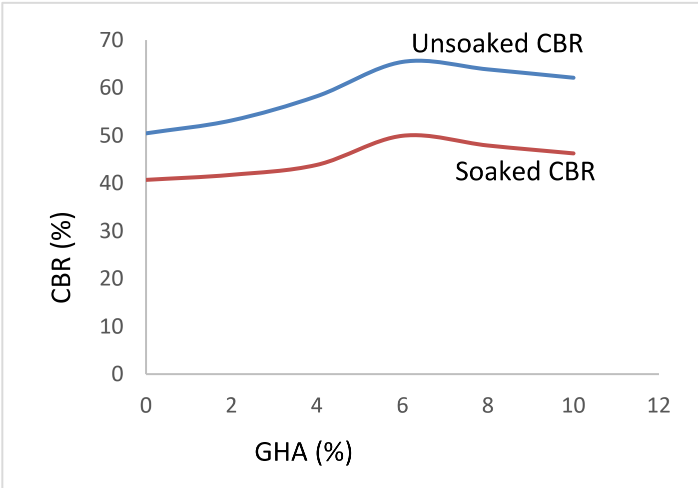

Figure 4. Effects of GHA on CBR of lime-treated lateritic soil

Table 3 shows that with the addition of lime to natural soil CBR values of both unsoaked and soaked soil increased appreciably. Unsoaked and soaked values at 0% lime, were 9.5% and 5.50% respectively, these increased to maximum values of 50.45% and 40.70% both at 10% lime. Increase in CBR may be due to the cation exchange and pozzolanic reaction of lime [16]. Figure 4 shows that the addition of GHA to the lime-treated lateritic soil further increased the CBR values of both unsoaked and soaked values from 0% GHA at 50.45% and 40.70% to 65.42% and 49.94% both at 6% GHA respectively. This increase could be due to the presence of adequate amounts of calcium required for the formation of Calcium silicate hydrate (CSH) and Calcium aluminate hydrate (CAH), which are the major compounds responsible for strength gain [22]. The reduction in CBR values at 8% GHA may be due to excess GHA and lime that was not mobilized in the reaction, therefore, reducing bond in the lime-GHA-soil [23].

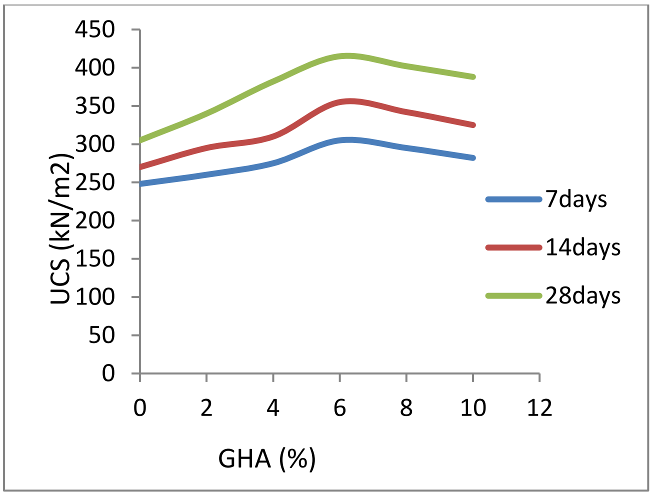

Figure 5. Effects of GHA on UCS of lime-treated lateritic soil

From Figure 5, at 7 days, UCS increased from 248 kN/m^2 at 0% GHA to peak value of 305 kN/m^2 at 6% GHA before decreasing in values. At 14 days, UCS increased from 270 kN/m^2 at GHA 0% to value of 355 kN/m^2 at 6% GHA, after which values started decreasing, at 28 days, UCS increased from 305 kN/m^2 at 0% GHA to peak value of 415 kN/m^2 at 6% GHA, afterwards, values decreased.

The improvement in value of UCS upon addition of lime to soil may be attributed to soil-lime reaction, which results in the formation of cementitious compounds that binds soil aggregates. This strength improvement also increased with age. The introduction of the GHA into the lime-treated soil further increased the UCS. The increase in value of UCS was observed from 0% to 10% GHA. This may be due to the utilization of readily available silica and alumina from GHA by the calcium from the lime to form cementitious compounds that binds the soil aggregates. It was also observed that the UCS increased with curing age at the specified lime content (10%). This may be due to the pozzolanic reaction between the lime and GHA resulting in the formation of more cementitious compounds [24].

5. CONCLUSION

This analysis of the effects of groundnut husk ash on lime stabilized lateritic soil was carried out compliance with BS 1377 [10] and BS 1924 [8].

Based on AASHTO classification, the soil sample was classified into subgroup A-7-5, a poor soil.

The groundnut husk ash (GHA) chemical composition clearly shows that the groundnut husk ash is pozzolanic.

The addition of lime to natural soil reduced the liquid limit and plasticity index values; the addition of groundnut husk ash further reduced the values of liquid limit and plasticity index, an indication of soil improvement.

The optimum amount for required lime is 10%, because the least value of plasticity index (13%) was recorded at this point, while the optimum amount of groundnut husk ash required is 6% because maximum strength values were recorded at this point.

The addition of hydrated lime to natural soil increased the strength properties-such as California bearing ratio (CBR) and Unconfined compressive strength (UCS) of the soil and the addition of groundnut husk ash further increased the strength values of the soil.

It can therefore be concluded that groundnut husk ash can adequately serve as a cheap complement for lime in soil stabilization.

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