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Effects Of Guinea Corn Husk Ash And Lime Mixtures On Lateritic Soil For Highway Construction

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***Abstract*— This study investigates the effects of guinea corn husk ash and lime mixtures on lateritic soil for highway construction. Preliminary tests were carried out on the soil for the purposes of identification and classification. The guinea corn husk ash was added to the soil sample at varying proportions of 2, 3 and 4 percentages by weight of soil and the lime was added to the soil sample at varying proportions of 4, 6 and 8 percentages by weight of soil. Each of these mixes was subjected to engineering tests; compaction, California bearing ratio (CBR) and unconfined compressive strength (UCS) test. The results of these tests showed that GCHA and lime improved the soil properties. It can be concluded that the guinea corn husk ash and lime modified the poor soil sample into being suitable for subbase to reduce failures in highway pavements.**

Keywords*— *atterberg limit, lateritic soil, lime stabilization, cattle bone ash, soil stabilization

I. INTRODUCTION

Failure in the highway pavement structure is mostly caused by environmental factors, overloading and substandard construction materials. The need to improve the engineering properties of highway construction materials for the overall performance of the pavement structure is imperative, hence this study. Soil stabilization is the alteration of one or more soil properties, by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties. Soils may be stabilized to increase strength and durability or to prevent erosion and dust generation. 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 or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil (Department of the army, the navy, and the air force, 1994). It is therefore necessary to use the properties of waste materials such as guinea corn husk ash to determine its effectiveness on lateritic soils and thus reduces the cost of highway construction.

Guinea corn is an important food crop produced in large quantity in the savannah belt of Nigeria and West Africa. It ranks amongst the three major grain crops growing particularly in the northern states of Nigeria. Guinea corn is mostly harvested and processed manually for food, leaving a large quantity of residue as waste product which is burnt in preparation for the next farming season. In Nigeria, 1.5 million tonnes of guinea corn husk is produced annually, while in Kaduna state, about 92,000 tonnes of guinea corn was produced in 2007 (Alhassan, 2008). Guinea corn husk ash GCHA is an agricultural waste obtained from milling of Guinea corn and the husk is the protective outer covering shell or coating of a seed and extracted from the Guinea corn as shown in fig 1.1. About 10 million tonnes of guinea corn husk is generated annually in the world (Alhassan, 2008). The ash is categorized under Pozzolana with about 60 – 65 % of Si, about 29 % of A and 3.5 % of iron oxides; the silica is substantially contained in amorphous form, which can react with the CaOH (Medega *et al.,* 2014).

Lateritic soils are one of the essential soils used in highway pavement construction and they have been extensively used in roadways, embankments and retaining walls due to the excellent improvement after compaction. Unstable soils can create significant problems for the pavements and it is difficult to work with soils containing significant levels of silt or clay having varying geotechnical properties like; swelling and becoming plastic in the presence of water, shrinkage when dry, expand when exposed to frost (Ankit *et al.,* 2013). Soil stabilization is the process of changing the properties of soils either by mechanical or chemical means in order to enhance the engineering quality of the soil. Lateritic soil modification is the addition of a modifier (cement, lime, etc.) to the laterite to change its index properties, while stabilization is the treatment of soil to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification (Osinubi and Bajeh, 1994). Soil stabilization using lime is essential to ensure the stability of soil, so that it can successfully sustain the load of the superstructure in cases of soil which are highly active. Hydrated limes have been considered excellent stabilizers for the improvement of different soils and have been extensively used in the past decades (Portelinha *et al.,* 2012). The geotechnical behaviour of lime or cement treated soils depends on physical and chemical properties of soils, in which are directly related with soil formation conditions and mineralogical composition of the matrix rock (Kennedy et al., 1987; Consoli et al., 2009). Although most soils can be lime stabilized, some soils are more easily stabilized than others (National Lime Association, 1991). Therefore, the effect of guinea corn husk ash to lime-stabilized lateritic soil has a major role in the future of the construction industry due to the shortage and increase in price of cement.

The objectives of the research include;

a) Determining the geotechnical properties of lateritic soil and characterize GCHA.

b) Modifying the lateritic soil with GCHA and lime at varying percentages.

c) Evaluating the effects of GCHA and lime on the geotechnical properties of lateritic soil

Fig 1. *Guinea Corn Husk*
Source: Akinloye *et al.*, 2014

II. Materials

This study was conducted at the concrete and soil laboratory of the Department of Civil Engineering, Afe Babalola University, Ado-Ekiti, Ekiti state, Nigeria. The GCHA, laterite and lime was used according to the predefined proportions and according to the relevant standards.

A. Lateritic Soil

The lateritic soil sample was obtained from Ifaki, Ekiti state. The sample was collected in its disturbed state from a depth of (1.5 m). It is reddish in colour.

B. Guinea Corn Husk Ash

The guinea corn husk used was gotten from Mokwa, Niger State. The burning of the guinea corn husk to form the ash was carried out at Federal Polytechnic, Ado - Ekiti. The guinea corn was burnt, ground and sieved through sieve No. 200 to obtain fine ash.

C. Hydrated Lime

The hydrated lime used was a white powder and was purchased in a 25 kg bag from Ado-Ekiti, Nigeria. The hydrated lime was kept safe in the bag to prevent contact with moisture and any other external material of deleterious effects.

D. Water

The water used was from available water in the laboratory. The water did not have any substance that might affect the chemical reaction between the compounds of lime and GCHA.

III. Methods

This section includes all laboratory methods used for this study. The preliminary tests include: Atterberg limits (plastic limit, liquid limit, shrinkage limit and plastic index), sieve analysis (dry and wet sieving) and specific gravity. The engineering tests include; compaction, California bearing ratio and unconfined compressive strength were carried out on the soil sample to determine its properties and they are described below:

A. Atterberg Limits Test

300 g of the sieved soil sample was weighed and poured on a glass plate. Water was poured into the sample and was mixed thoroughly until the soil mass became plastic enough to be easily moulded with fingers. The plastic soil mass was left for enough time to allow water saturate throughout the soil mass. 8 g of plastic soil was taken to make a ball and rolled between fingers on the glass plate with sufficient pressure into a thread till the thread became 3 mm. The soil was remoulded to a uniform mass and rolled again. The process of rolling and remoulding was continued until the thread started crumbling at a diameter of 3 mm. The crumbled threads were placed in moisture cans for moisture content determination. The test was repeated twice with fresh soil samples. The soil with the moisture cans was weighed and placed in the oven for 8 hours at 105 °C. The dried soil sample was weighed and recorded. The plastic limit was then taken as the average of the moisture contents.

B. *Liquid Limit*

300 g of sieved soil sample was mixed thoroughly with water on a glass plate to form a uniform paste. A portion of the paste was placed in the cup of the casagrande apparatus and spread where the cup rests on the base with few strokes with a spatula. The soil in the cup was trimmed to a depth of 1 cm at the point of maximum thickness and returned the excess back to the glass plate. The soil was divided by the strokes of the grooving tool through the centre so that a sharp groove of proper dimension is formed. The handle was rotated at the rate of about two revolutions per second. The number of blows was counted until the two halves of the soil sample came in contact at the bottom of the groove at a distance of 10 mm. The number of blows required to close the groove was recorded and about 10 g of soil sample was taken from the cup for water content determination. The procedure was repeated for at least 2 more times for blows between 10 and 40.

C. *Shrinkage Limit*

300 g of soil sample was mixed thoroughly with water using a palette knife until the mass becomes homogenous. The soil paste was placed in the dish slightly above the sides of the mould with the help of a spatula. The dish was gently tapped on a firm surface, to allow the paste flow towards the edge it the paste is compacted and all entrapped air is brought to the surface. The excess soil paste was removed with a straight edge and all soil on the outside of the dish was wiped off. The mould with the soil paste was placed in the oven maintaining the temperature of 105 °C to 110 °C. After drying, the mould with the soil was allowed to cool down and the mean length of the soil bar was measured.

D. *Sieve Analysis*

1000 g of soil sample was poured in a pan and water was poured into it to give its characteristics. The soil was steered to remove void and the soaked soil was left for 24 hours. After soaking, the soil was poured from a pan through a 4.75 µm sieve to rinse it. The rinsing was done until the liquid which was discharged through the receiver was clear. The sample residue on the sieve was dried and weighed it for the dry sieving.

E. *Dry Sieving*

The soil sample was weighed and poured into the top sieve which has the largest sieve screen opening. Each lower sieve in the column has smaller openings than the one above with a round pan as a receiver. The column of sieves was shaken for a period of 10 minutes in a mechanical shaker. After the shaking was completed, the material retained on each sieve was weighed.

F. *Specific Gravity*

The empty cylinder was weighed as (W1). About 200 g of air dried soil sample that has been sieved was taken into the cylinder using a funnel. Weight the cylinder and soil (W2) and 300 g of water was poured into the cylinder to allow the soil soak. The cylinder was stirred using a glass rod to remove the entrapped air and was left for about 2 hours. The cylinder was wiped clean and dried and the weight of the bottle and its content (W3) was determined. The cylinder was emptied and washed thoroughly, then the cleaned cylinder was filled completely with distilled water and was weigh (W4). The empty cylinder also was weighed after drying

G. *Compaction Test*

The proctor standard compaction method was adopted for this study. The soil sample was thoroughly dried in air. The mould was assembled and filter paper was inserted and greased as shown. The mass of soil sample and each of the additives i.e. 2, 3 and 4 % for GCHA and 4, 6 and 8 % for lime of 3000 g was calculated and placed in a mixing pan and broken up into smaller particles. The empty mould was weighed and the height, diameter and volume were determined. All the moisture cans were weighed and labelled before the experiment. The appropriate mass for the soil sample and the additives (2 and 4 %) for GCHA and lime respectively was weighed and mixed thoroughly. Water was added to the sample with 2 % of 3000 g (240 ml) and mixed thoroughly. The wet sample was divided into five equal parts for five layers. Each layer was gently compacted with 10 blows with the rammer dropping freely from a height where it makes the “click” sound. The blows were distributed uniformly over the surface of the layer being compacted. After the specimen was compacted, the collar was removed from the mould and a straight edge was used to level the compacted sample at the top. The filter paper was removed from the base and the mould with sample was weighed using a weighing balance to the nearest gram. A spatula was used to remove approximately 10-15 g of sample from the top and bottom section of the test specimen for moisture content determination. The samples were placed in moisture cans, weighed and oven dried at 105 °C for 8 hours. The wet sample was removed from the mould and was reassembled then greased. This procedure was repeated with 2 % addition of water (60 ml) to the wet sample until the weight of the mould drops. After cooling, the moisture can and dried sample was weighed and the moisture content was determined. The whole procedures were repeated for compaction and moisture content determinations for the remaining predefined proportions.

H. *California Bearing Ratio (Unsoaked)*

The soil sample was thoroughly dried in air. The OMC for the compaction test was used to find the ml of water required for the sample using each of the additives i.e. 2, 3 and 4 % for GCHA and 4, 6 and 8 % for lime of 6000 g of sample. The empty mould was weighed and the height, diameter and volume were determined. The mould was assembled with the collar on the base plate and a filter paper was inserted and grease. Five moisture cans was weighed before the experiment and label them. The samples were poured in a mixing tray and the large soil particles were broken. Water was added from the OMC obtained from the compaction test 20.7 % of 6000 g and mixed thoroughly. The wet sample was divided into five equal parts for five layers. Moisture content samples were taken after mixing in two moisture cans. Each layer was compacted gently with 62 blows with the rammer dropping freely from a height where it makes the "click" sound. The blows were distributed uniformly over the surface of the layer being compacted. The collar and base plate was removed and the compacted soil was carefully levelled to the top of the mould by means of a straight edge. The mould and the specimen were weighed using a weighing balance to the nearest gram. The mould was placed on the lower plate of the testing machine with the top face exposed. A kg surcharge weight was placed on the surface of the mould and the plunger was set so that full contact was established between the surface of the specimen and the plunger. The stress and strain gauges were set to zero and the readings of the load at penetrations of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4, 4.5, 5, 5.5, 6.0, 6.5 and 7.5 mm was taken at 40 seconds interval. The plunger was raised and the mould was detached from the loading equipment. The samples were oven dried at 105 °C. The dried samples were weighed and recorded. These procedures were repeated for CBR and moisture content determinations for the remaining predefined percentages OMC (20.3 %, 22.4 %) of 6000 g.

I. Unconfined Compressive Strength Test

The soil was air dried. The aggregate was mixed thoroughly and was reduced to a suitable size for testing with a mortar and wooden pistol. The soil sample and the additives of 400 g were mixed in a bowl with their various predefined OMC for water content (20.7, 20.3, and 22.4 %). The casting mould was greased and locked at the bottom with the stopper. The casting mould was filled halfway with the wet sample and suppressed with the suppressor lever. A layer of wet sample was poured at the top and compacted with 20 blows. The casting mould was removed from the machine and turned over. A layer of wet soil was poured at the bottom and was compacted with 20 blows. The casting mould was removed and placed on an extruder to remove the compacted sampleThe sample was left to air dry for 24 hours. The exact length, diameter of the top and bottom of the specimen was measured and the average measurements were recorded. The specimen was placed carefully on the compression device and centered between the lower and upper plates. The plunger was set so that full contact was established between the surface of the specimen and the plunger. The stress and strain gauges were set to zero. The loading was started and the readings were taken until the load values decreased or remained constant with increasing strain. At this point, the sample was considered to be at failure. These procedures were repeated for the remaining samples of the predefined OMC.

IV. RESULTS AND DISCUSSION

A. Preliminary Test

The preliminary tests include the sieve analysis, Atterberg limits test and specific gravity. Table 1.1 shows that in the sieve analysis 36.68 % of the soil sample passed the No 200 mm sieve according to Garber and Hoel (2009), materials more than 35 % passing through sieve No 200 is said to be fair to poor and belongs to the following class the soil sample A-4, A-5, A-6 and A-7 soil. The liquid limit of the soil is 64 % and was classified using the AASHTO classification system for granular materials belonging to A-5 and A-7 class. It was further sub grouped using its plasticity index 26 % as A-7-5 groups. The value for the specific gravity of the soil sample is 2.5 and according to Das (2000) most clay minerals have specific gravity values that falls within a general range (1.6 - 2.9) are classified as halloysites.

TABLE I. SUMMARY OF THE PRELIMINARY TEST RESULTS

Property	Description/values
Natural moisture content	22.6
Percentage passing sieve No. 200	36.68
Specific gravity	2.5
Liquid limit (%)	64
Plastic limit (%)	38
Plasticity index (%)	26
Unsoaked CBR (%)	3
Maximum Dry Density (mg/cm^3)	1.71
Unconfined Compressive strength (kN/)	157.35
AASHTO Classification	A-7-5
USCS Classification	CL

B. *Compaction Test*

Table II shows the engineering properties result for compaction test of dry density and moisture content on the soil sample at percentages 0, 2, 3 and 4 % for GCHA and 0, 4, 6, and 8 % for lime. Figure 4.1 shows the relationship between the dry density and moisture content of the control natural soil sample and it shows the point where it dropped and figures 4.2, 4.3 and 4.4 shows the relationship between the dry density and moisture content of the varying percentages of 2, 3 and 4 % for GCHA and 4, 6, and 8 % for lime and the point where they dropped. The compaction test on the control natural soil sample has its maximum dry density (MDD) as 1.71 mg/cm^3 with the optimum moisture content (OMC) of 22.6 % while at the varying percentages of 2, 3 and 4 % for GCHA and 4, 6, and 8 % for lime have MDD of 1.82, 1.86 and 1.76 mg/cm^3 with corresponding OMC of 20.7, 20.3 and 22.4 % respectively. The to the highest value of 1.86 mg/cm^3 indicates an increase in the values from 1.71 mg/cm^3 improvement in the soil properties (Lambe and Whiteman, 1979). The result shows that the highest MDD and lowest OMC was obtained was at 3 and 6 %

of GCHA-lime and it therefore proves that the higher the MDD the lower the OMC.

TABLE II. SUMMARY OF COMPACTION TEST FOR GCHA-LIME AT VARYING MIXED RATIOS

0%		2:4		3:6		4:8	
Dry density (mg/cm³)	Moisture content (%)	Dry density (mg/cm³)	Moisture content (%)	Dry density (mg/cm³)	Moisture content (%)	Dry density (mg/cm³)	Moisture content (%)
1.58	16.2	1.59	15.6	1.64	13.5	1.63	19.4
1.61	19.0	1.65	17.2	1.69	15.3	1.73	21.3
1.67	20.6	1.71	18.4	1.73	17.3	1.76	22.4
1.71	22.6	1.79	19.7	1.79	19.1	1.73	23.0
1.59	25.6	1.82	20.7	1.86	20.3	-	-
-	-	1.75	24.3	1.75	23.4	-	-

C. California Bearing Ratio Test

The results of the CBR on table III shows the summary of the unsoaked values for the varying GCHA-Lime of percentages 0, 2, 3 and 4 % for GHA and 0, 4, 6, and 8 % for lime on the lateritic soil. The CBR test on the control lateritic soil at 0 % has its CBR value as 3 % and 2, 3 and 4 % for GHA and 4, 6, and 8 % for lime as 9, 12 and 8 %. The values for unsoaked increased from 3 % at 0 % GCHA-Lime to maximum value at 12% by weight of the soil. The increase in values of California Bearing Ratio (CBR) upon the addition of GCHA may be attributed 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 (Sadeeq et al., 2015). The values started falling at 4 % of GCHA and 8 % lime. The maximum CBR value obtained was at 3 and 6 % GCHA-Lime with CBR value 12 % as shown in figure 4.7. The reduction in CBR values at 4 % GCHA and 8 % may be due to excess GCHA and lime that was not mobilized in the reaction, therefore, reducing bond in the lime-GCHA-soil (Ogunribido, 2011).

TABLE III. SUMMARY OF UNSOAKED VALUES FOR VARYING GCHA-LIME AT OPTIMUM POINTS

Laterite content (%)	GCHA content (%)	Lime content (%)	CBR values (%)
100	0	0	3
94	2	4	9
91	3	6	12
88	4	8	8

D. Unconfined Compressive Strength

The results of the compressive strength test are shown in table IV which shows the relationship between the shear strength and the percentages of addition of GCHA and Lime. This test is commonly used for the determination of the amount of additive to be used in stabilization of soil (Ogunribido, 2011). The Unconfined Compressive Strength (UCS) at control soil sample is 157.35 kN/m^3 while the varying percentages at 2, 3 and 4 % of GCHA and 4, 6 and 8 % Lime are 201.35, 357.14 and 320.40 kN/m^3. From table 4.6, the Unconfined Compressive Strength (UCS) values increased as more percentages of GCHA and lime were being added till it got to maximum value 357.14 kN/m^3 at 3 % GCHA and 6 % lime. At this peak point value, the UCS started decreasing at 4 and 8 % of GCHA-lime content with the value at 320.40 kN/m^2. The result shows that with the increased addition of GCHA and lime, UCS values increased from 157.35 kN/m^2 at 0 % to peak value 357.14 kN/m^2 before declining to 320.40 kN/m^2 at 4 and 8 % GCHA-lime. The increase in the values of the Unconfined Compressive Strength (UCS) upon the addition of GCHA and lime may be due to the formation of the cementitous compounds between the CaOH present in both the GCHA and lime and the pozzolans present in GCHA. The decrease in the UCS values after the addition of 3 % and 6 % GCHA-lime may be due to the excess GCHA introduced to the soil and therefore forming weak bonds between the soil and the cementitious compounds formed (Fattah et al., 2013).

TABLE IV. UNCONFINED COMPRESSIVE STRENGTH TO GCHA-LIME MIXED RATIO

Unconfined compressive strength (kN/m2)	GCHA-Lime mixed ratio (%)
157.35	0
201.35	2:4
357.14	3:6
320.40	4:8

V. CONCLUSION

In view of the result analyzed and based on the discussion of the outcome of the project on the effect of guinea corn husk ash and lime mixtures on lateritic soil for highway construction, the objectives of this project was achieved and leads to the following conclusions:

a) *The classification of the lateritic soil was determined by the preliminary tests such as Atterberg limits (PL, LL, SL and PI), sieve analysis (wet and dry) and specific gravity as an A-7-5 using AASHTO classification system. Thus making the soil a poor soil.*

b) *The A-7-5 soil was modified by introducing guinea corn husk ash (GCHA) at 2, 3 and 4 % and lime at 4, 6 and 8 % respectively.*

c) *The effects of GCHA and lime on lateritic soil was evaluated and the results summarized as follows:*

- *The Atterberg limits test, sieve analysis and the specific gravity all conform to the standard specifications (ASTM).*
- *The optimum percentage for compaction of GCHA and lime on the*

lateritic soil sample was at 3 and 6 % GCHA-Lime with MDD as 1.86 mg/cm3 and OMC as 20.3 % respectively.

- *The optimum percentage for California bearing ratio (CBR) of GCHA and lime on the lateritic soil sample was at 3 and 6 % GCHA-Lime with the CBR value at 12 %.*
- *The optimum percentage for Unconfined Compressive Strength (UCS) of GCHA and lime on the lateritic soil sample was at 3 and 6 % GCHA and Lime as 357.14kN/m2*
- *It can be concluded that the guinea corn husk ash and lime modified the poor soil sample into being suitable for subbase to reduce failures in highway pavements*

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