ASSESSMENT OF THE EFFECTS OF GUINEA CORN HUSK ASH ON LIME-STABILIZED LATERITIC SOIL

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ABSTRACT

This study assesses the effects of Guinea Corn Husk Ash (GCHA) on lime stabilized lateritic soil. Preliminary tests were carried out on natural soil sample, for the purposes of identification and classification. The soil sample was classified as A-7-5. Hydrated lime was added to the soil sample at varying proportions of 2, 4, 6, 8 and 10% by weight of soil, thereafter, each of the mixes was subjected to atterberg limits tests to get the optimal amount of lime required, which was 10% lime because it was at this amount of lime that the least value of plasticity index was obtained. The guinea corn husk ash was later added to the lime-treated lateritic soil at proportions of 2, 4, 6, 8 and 10%. Each of the mixes was subjected to compaction, California bearing ratio (CBR), atterberg limits and unconfined compressive strength (UCS) tests. Results from these tests showed improvement in soil properties, also, the values of the CBR and UCS increased considerably. It can be concluded that the GCHA performs satisfactorily as a cheap complement for lime in stabilizing lateritic soil.

KEYWORDS*: Atterberg limit; lateritic soil; lime; guinea corn husk ash; soil stabilization*

1.0 INTRODUCTION

According to Ola (1983), laterites are products of tropical weathering with red, reddish brown or dark brown colour with or without nodules or concreting and generally (but not exclusively found) found below hardened ferruginous crust or hard pan. Lateritic soils are generally formed in hot, wet tropical regions of the world with an annual rainfall between 750mm to 3000mm

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(usually in an area with significant dry season) on a variety of different types of rocks with high iron content. The locations on the earth that characterized the condition falls in between 35°S and 35°N. Basically, the following factors influence laterite formation; climate (precipitation, leaching, capillary rise and temperature), topography (drainage), vegetation, parent-rock (iron-rich rocks) and time. Of all these primary factors, climate is considered to be the most important (Owolabi & Aderinola, 2014).

According to Afolagboye and Talabi (2014), lateritic soils are described as the most common pavement material in the tropics and subtropics. They are the most common materials for the construction of earth dams, highways, embankments, airfields, they also serve as foundation materials to support structures in the tropics, where they are mostly used (Gidigasu, 1976). According to Osinubi (1998), it is almost impossible to execute any construction work without the use of lateritic soils. Lateritic soils are mostly used for road construction in Nigeria. Lateritic soil in its natural state generally have low bearing capacity and low strength due to high content of clay. When lateritic soil contains a large amount of clay materials, its strength and stability cannot be guaranteed under load especially in the presence of moisture. Also, when lateritic soil consists of high plastic clay, the plasticity of the soil may cause cracks and damage on pavement, roadways, building foundations or civil engineering construction projects. The improvement in strength and durability of lateritic soil in recent time has become imperative, this has encouraged researchers towards researching into the use of stabilizing materials of a very low cost. These local materials can be classified as either agricultural or industrial wastes (Bello, Ige & Ayodele, 2015).

Ogundipe (2013) defined stabilization as 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 gradation, texture or plasticity or act as a binder for cementation of the soil. Many of these agricultural wastes are pozzolanic in nature due to the presence of high silica content, thus, making them suitable for pozzolana. Pozzolana is defined as siliceous and aluminous materials which in itself possesses little or no cementitious property, but will in finely divided form and in presence of moisture chemically react with Calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. Pozzolanas can be divided into two groups: natural pozzolana such as volcanic ash and diatomite and artificial pozzolana such as calcined clay, pulverized fuel ash and ash from burnt agricultural waste. The addition of pozzolana in the lime-based product has two major advantages, which are; the properties of the lime will be improved and since the costs of pozzolana are generally low, lower than lime; the overall costs of the stabilization project will be low provided factors such as having to transport pozzolana from a far distance to the site where it will be needed does not arise (Tsado, Yewa, Yaman & Yewa, 2014).

1.1 Guinea corn

According to Ndububa and Nurudeen (2015), guinea corn is an essential 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 generally harvested and processed manually for food, leaving the huge volume of residue constituting waste in farm, most of which are flared off in preparation for the subsequent farming season. Guinea corn residue is usually of low bulk density with high moisture content of up to 40% when harvested in partially dried form. The residue ranges from light brown to dark brown colour in the dried form and the particles are light to dark brown colour in the dry form and the particles are high glossy/ lustrums spikelet, very discrete but less particulate in texture. The aim of this study is to assess the effects of guinea-corn husk ash on lime-stabilized lateritic soil.

1.2 Location and Geology of Study Area

Akure, Nigeria, being the study area lies within Longitude 70 18' N and 70 16' N North of the equator and between Latitude 50 09' E and 50 11.50 E of Greenwich meridian. The study area occurred within the pre-cambrian crystalline rocks of the basement complex of southwestern Nigeria. The predominant rock types in the study area are charnockites, granites gneiss and migmatitic rock. In some places in the study, these rocks have undergone deep weathering (Ogunribido, 2011).

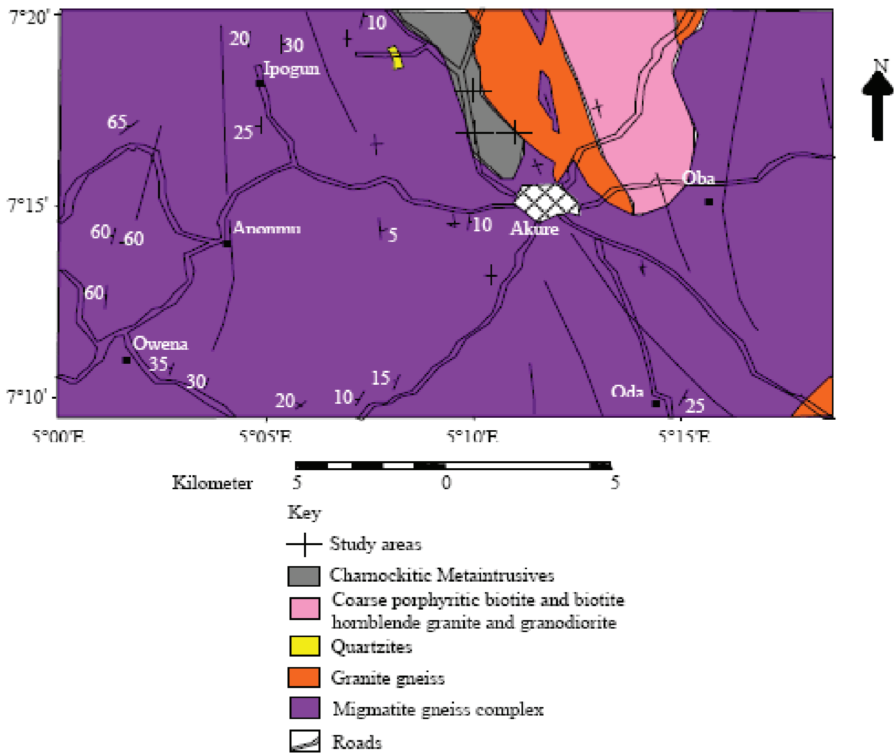

Figure 1. Study Area-Akure, Nigeria (Olutoge, Okeyinka & Olaniyan, 2012)

2.0 MATERIALS AND METHODS

2.1 Materials

Guinea Corn Husk Ash (GCHA)

The guinea corn husk was pretreated so as to ensure that it was purely shaft husk after which it was dried in the sun for three to four days to rid it of moisture. The guinea corn ash was burnt up to a temperature of 600°C using a kiln. It was allowed to cool. The ash gotten was later sieved through 75μm to obtain fine ash.

Lateritic Soil

The lateritic soil sample was collected in Akure at depths representative of soil stratum and not less than 1 metre (1m) below the natural ground level. It was thereafter brought to the Geotechnical Laboratory of the Federal University of Technology, Akure and marked indicating the soil description, sampling depth and date of sampling.

Figure 2. Guinea corn plant

The lateritic soil was air-dried for two weeks to allow for partial elimination of natural water which may affect the analysis, then seived with seive no 4 (4.75 mm opening) to obtain the final soil samples for the tests. After the drying periods, lumps in the sample were pulverised under minimal pressure. Potable water was gotten from the running taps in the laboratory. Hydrated lime was purchased at a licensed chemical store in Akure.

2.2 Methods

The preliminary tests were carried out 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 Guinea Corn Husk Ash (GCHA) was added in proportions of 2, 4, 6, 8 and 10% by weight of soil to the lime-treated soil, thereafter, each of the mixes was subjected to the following tests: Compaction, California Bearing Ratio (CBR), Atterberg Limits and Unconfined Compressive Strength tests.

Atterberg limits test

The Atterberg limits tests were carried out in accordance with the British Standard Methods-BS 1377 (1990). The lateritic soil sample was sieved through 0.425 mm. 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 fixed optimal amount of required lime and varying proportions of 2, 4, 6, 8 and 10% GCHA.

Compaction Characteristics

The proctor standard compaction method was adopted for this study. The test was carried out according to BS 1377 (1990), 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 upon stabilization with lime at optimal amount required and the varying amount of GCHA (2, 4, 6, 8 and 10%).

California bearing ratio (CBR)

The BS 1377 (1990) and BS 1924 (1990) stipulate the procedures to follow in carrying out this test on the natural soil and stabilized samples. However, it was modified in conformity with the recommendation of the Nigerian General Specification, Federal Ministry of Works and Housing (1997), 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 BS 1377 (1990) and BS 1924 (1990) stipulate the procedures for carrying out this test and was adopted for the natural soil sample and stabilized samples respectively. For the stabilized soil mixtures, specimen were prepared by carefully and completely mixing dry quantities of pulverized soil with the fixed optimal amount of hydrated lime required and varying proportions of 2, 4, 6, 8 and 10% GCHA. 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, Federal Ministry of Works and Housing (1997).

3.0 RESULTS AND DISCUSSION

Table 1 shows that the percentage that passed through on No. 200 BS sieve was 36.50%, therefore, suggesting that the soil belonged to one of the following groups; A-4, A-5, A-6 and A-7. It is worthy of note that more than 35% of its sample passed through the No 200 sieve, 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 ≤*LL*-30;16.25≤48.85-30 (18.85). The soil sample therefore falls into the A-7-5 subgroup (Garber and Hoel, 2009). 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 (2000), 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	36.50
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 (OMC) (%)	12.45
Maximum Dry Density (kg/m^3)	1650
Unconfined Compressive Strength (kN/m^2)	190
AASHTO Classification	A-7-5
USCS Classification	CL

In Table 2, chemical composition of GCHA presents a conclusion that the GCHA is pozzolanic and has the same active chemical constituents and properties as that of the hydrated lime, such as CaO, SiO_2, Al2O_3, Fe_2O_3, MgO etc. According to ASTM C618 (1978), if the total sum 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 GCHA equal 79.64%, therefore, the GCHA is pozzolanic. Specific gravity of GCHA is found to be 1.90.

Table 2. Chemical composition of the guinea corn ash and hydrated lime

Elemental Oxide	GCHA (Weight %)	Hydrated Lime (Weight %)
SiO_2	77.46	1.71
Al_2O_3	1.48	0.72
Fe_2O_3	0.70	0.05
CaO	5.40	68.12
MgO	4.64	1.38
SO_3	-	-
K_2O	8.10	0.06
Na_2O	1.00	0.03
P_2O_5	3.23	-

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 GCHA 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**	**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	62.80	51.70
8	42.30	28.30	14.00	1570	16.55	56.88	43.40
10	40.20	27.20	13.00	1548	17.74	50.45	40.70

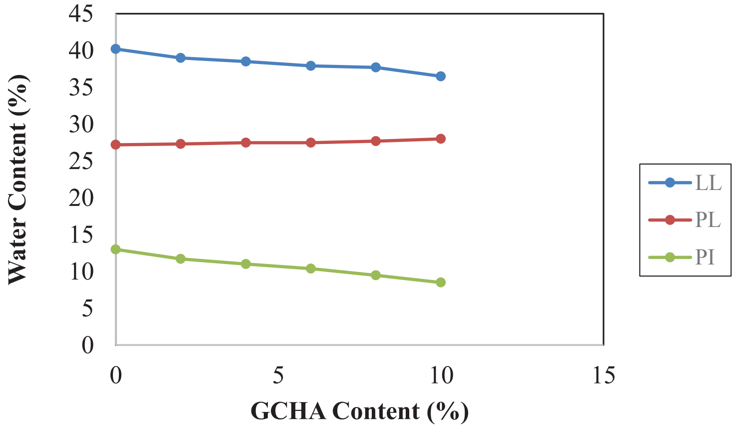

Figure 3. Effects of GCHA on atterberg limits of lime-treated soil

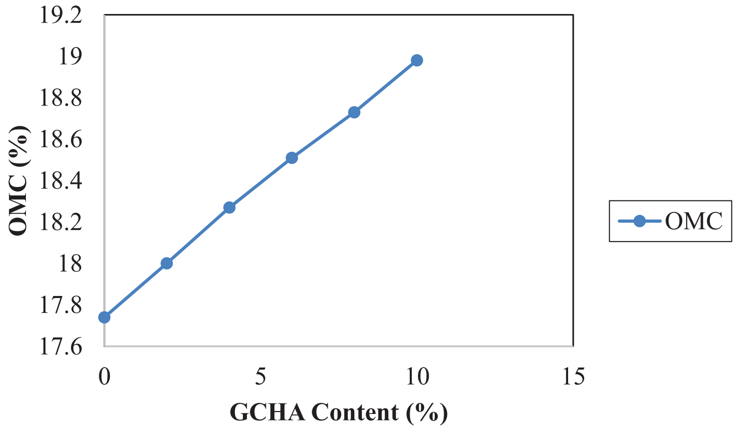

Figure 4. Effects of GCHA on OMC of lime-treated lateritic soil

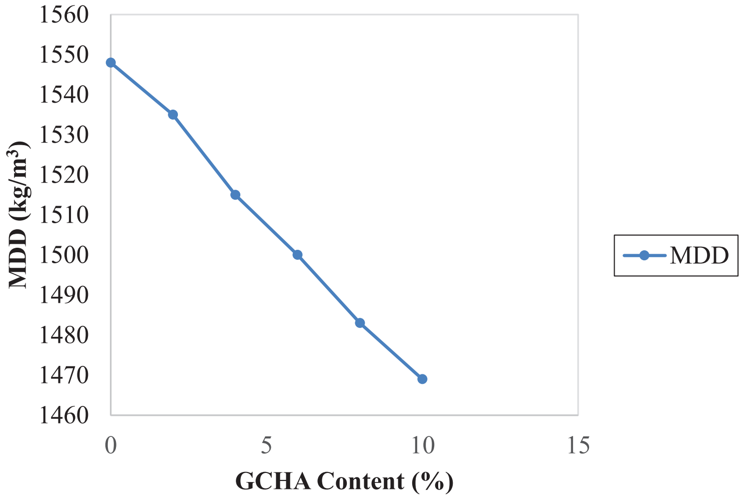

Figure 5. Effects of GCHA on MDD of lime-stabilized lateritic soil

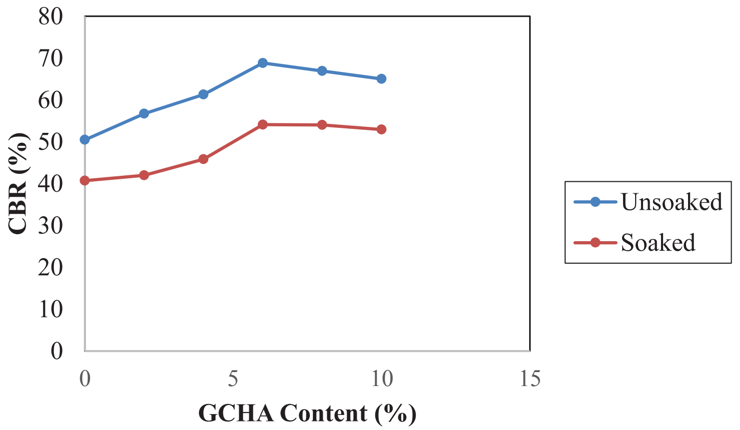

Figure 6. Effects of GCHA on CBR of lime-treated lateritic soil

Effect on Compaction Characteristics

The variations of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) with stabilizer contents are shown in Table 3, Figures 4 and 5. Table 3 shows that with the addition of lime to the natural soil sample, value of MDD decreased from 1650 kN/m^3 at 0% lime to 1548 kN/m^3 at 10% lime. Figure 5 indicates that Maximum Dry Density (MDD) decreases with increase in Guinea Corn Husk Ash (GCHA) content, MDD decreased from 1548 kg/m^3 at 0% GCHA by weight of soil to 1469 kg/m^3 at 10% GCHA. According to Okonkwo (2015), this, may be attributed to the partial replacement of soil with higher specific gravity (2.08) by GCHA with lower specific gravity (1.90). Also, it may be due to the reaction between lime, GCHA and fine fractions of the soil in which they form clusters that occupied larger spaces and invariably increasing their volume with decreasing the maximum dry density (MDD). Also, Table 3 shows increase in the value of OMC as lime was increasingly added to the natural soil sample. OMC value increased from 12.45% at 0% lime to 17.74% at 10% lime. Figure 4 shows that the optimum moisture content (OMC) increased with increase in amount of GCHA added to the lime-treated soil. The rise in OMC with an increase in GCHA may be attributed to the amount of water required in the system to sufficiently lubricate all the particles in the soil-lime and GCHA mixture. OMC therefore continuously increased with increase in GCHA.

California Bearing Ratio

From Figure 6, values of unsoaked CBR increased from 50.45% at 0% GCHA to maximum value of 68.83% at 6% GCHA, while soaked CBR increased from 40.70% at 0% GCHA to 54.10% at 6% GCHA by weight of soil. In both cases, the values started falling at 8% GCHA. 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, Ochepo, Salahudeen and Tijjani, 2015). The reduction in CBR values at 8% GCHA 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).

Atterberg limits

Table 3 shows 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 (Joel & Edeh, 2015). According to Osinubi (1995), 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 lime.

In Figure 3, the addition of GCHA 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 + GCHA (Iorliam, Agbede and Joel, 2012). The addition of the GCHA to the lime-treated soil reduced the plasticity index which is an indication of improvement of soil properties (Basha, Hashim, Mahmud & Muntohar 2005; Iorliam, Okwu & Ukya, 2013). In addition to this, according to the Federal Ministry of Works and Housing (1997), 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 GCHA 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 (Oyediran & Kalejaiye, 2011).

Table 4. Effect of lime on unconfined compressive strength properties of lateritc soil

Lime (%)	7 days (kN/m²)	14 days (kN/m²)	28 days (kN/m²)
0	190	190	190
2	200	229	260
4	230	259	296
6	265	300	339
8	264	292	321
10	248	270	305

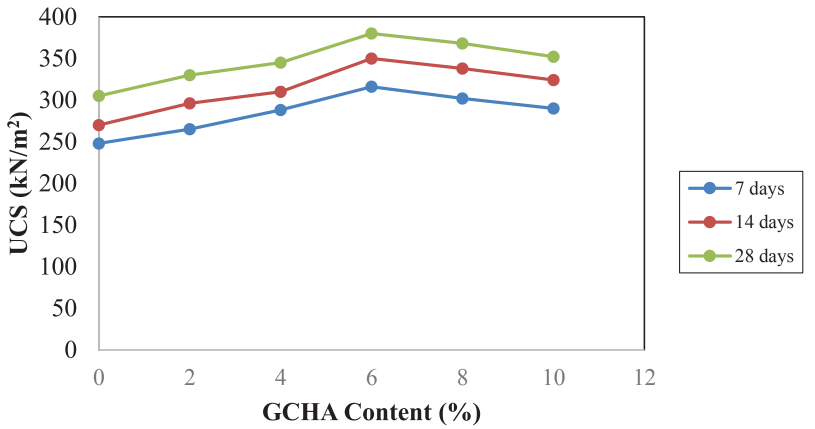

Figure 7. Effect of GCHA on UCS of lime-treated lateritic soil

Unconfined Compressive Strength

Unconfined compressive strength (UCS) is the test commonly used for the determination of the needed amount of additive to be used in stabilization of soil (Ogunribido, 2011). From Table 4, the UCS values increased as more percentages of lime were being added till it got to maximum values of 265, 300 and 339 kN/m² for 7, 14 and 28 days at 6% lime from natural state of 190 kN/m². On reaching these peak values, the UCS started decreasing till it got to 248, 270 and 305 kN/m² at 10% lime content for 7, 14 and 28 days respectively. Figure 7 shows that with the increased addition of GCHA, UCS values increased from

248, 270 and 305 kN/m^2 at 0% GCHA at 7, 14 and 28 days to peak values of 316, 350 and 380 kN/m2 respectively all at 6% GCHA, before declining in values at 8% and 10%. The resultant increase in values of UCS upon the addition of GCHA may be attributed to the formation of cementitious compounds between the CaOH present in the soil and GCHA and the pozzolans present in GCHA. The decrease in UCS values after the addition of 6% GCHA 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, Rahil & Al-Soudany, 2013).

4.0 CONCLUSION

The lateritic soil is classified as A-7-5 using AASHTO classification system and CL using the USCS. Thus, making the soil a poor soil.The optimal amount of lime required is 10%, because at 10% lime the least value of plasticity index was recorded. The addition of guinea corn ash (GCHA) further reduced the plasticity index values from 13% at 0% GCHA to the least value of 8.50% at 10% GCHA, thus, meeting the requirement for use as sub base, since the maximum value of 12% plasticity index is stipulated by clause 6201 of the Nigerian General Specifications, Federal Ministry of Works and Housing (1997) for sub base materials.The maximum dry density (MDD) and optimum dry density (OMC) of lime-treated soil increased and decreased respectively with the addition of the GCHA.Upon the addition of GCHA to the lime-treated soil, the values of unsoaked and soaked CBR improved considerably, from 50.45% (unsoaked CBR) and 40.70% (soaked CBR) to highest value of 68.83% (unsoaked CBR) and 54.10% (soaked CBR) at 6% GCHA, though this value did not meet the recommended 80% CBR value for base course, it met the requirement for sub base.The addition of GCHA to the lime-treated soil improved the UCS values to peak values at 6% GCHA. UCS values also increased with curing ages of 7, 14 and 28 days.It can therefore be concluded that the guinea corn husk ash can serve as cheap complement for lime stabilization.

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