Strength Characteristics of Lateritic Soils Stabilized with Locally Manufactured and Imported Hydrated Lime

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Abstract: - This research evaluates the use of locally prepared lime to commercial (Imported) lime in stabilization of lateritic soil. limestone samples were collected from Three geographical location which are Ewekoro, Ogun state, Okpella, Edo state and Obajana, Kogi state of Nigeria. Lateritic soil was collected and subsequently stabilized with 3% and 6% of the various hydrated limes. The natural lateritic soil sample was subjected to preliminary tests (Natural moisture content, Specific gravity, Particle size analysis and atterberg's limits), the result of the preliminary test classify the soil into an A-6 lateritic soil. Thereafter, the A-6 lateritic soil was stabilized with the locally prepared hydrated limes as well as a commercial (Imported) lime and the results of unconfined compression, CBR and optimum dry density compared. The locally prepared limes are not inferior to the imported lime as shown in the results of this research.

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Keywords: - *Lateritic Soil, Limestone, Optimum dry density, Stabilization, Unconfined Compression*

1. Introduction

Laterite is a group of highly weathered soils formed by the concentration of hydrated oxides of iron and Buchanan coined aluminium (Thagesen, 1996) .The soil name "laterite" in 1807 in India, from a Latin word "later" meaning brick. This first reference is from India, where this soft, moist soil was cut into blocks of brick size and then dried in the sun. Laterites and lateritic soils form a group comprising a wide variety of red, brown, and yellow, fine-grained residual soils of light texture as well as nodular gravels and cemented soils (Lambe and Whitman, 1979). The application of chemicals such as Portland cement, lime, fly ash, saw dust ash, etc. or the combination of them often results in the transformation of soil index properties which may involve the cementation of particles (Amadi. 2010).

Lateritic soils are widely employed as imported filling material for the prepared sub grade on different kinds of road projects. To enhance durability of such roads, lateritic soils are often stabilized. Some studies have been carried out on geotechnical properties of lateritic soil using stabilizers (Okunade. 2010, Oloruntola *et al*. 2008, Amu *et al* 2011, Okafor and Okonkwo 2009). Generally, soil stabilization is to improve engineering performance of soil. The use of lime stabilization in construction dates back as 5,000 years. The pyramids of Shersi in Tibet were built using compacted mixture of clay and lime. China and India in their long history have used lime stabilization in various ways.

Lime in the form of quicklime (calcium oxide- CaO), hydrated lime (calcium hydroxide- $Ca(OH)_2$, or lime slurry can be used to treat soils. Quicklime is manufactured by chemically transforming calcium carbonates (Limestone- $CaCO_3$) into calcium oxide. Hydrated lime is created when quicklime chemically reacts with water. Hydrated lime reacts with clay particles and permanently transforms them into a strong cementitious matrix. Most lime used in soil treatment is "high calcium" lime, which contains not more than 5 percent magnesium oxide or hydroxide. On some occasions, however, "dolomite" lime is used. Dolomite lime contains 35 to 46 percent magnesium oxide or hydroxide. Dolomite lime can perform well in soil stabilization, although the magnesium fraction reacts more slowly than the calcium fraction according to National Lime Association (2004). It can permanently stabilize fine-grained soil employed as a sub-grade or sub-base to create a layer with structural value in the pavement system. The treated soils may be in-place (sub-grade) or borrowed materials. It can also permanently stabilize sub-marginal base materials (such as clay-gravel, retained on a No. 4 sieve size). Base stabilization is used for new road construction and reconstruction of worn-out roads (Little, 1995).

When lime and water are added to a clay soil, chemical reactions begin to occur almost immediately. If quicklime is used, it immediately hydrates (i.e. chemically combines with water) and releases heat. Soils are dried, because water present in the soil participates in this reaction, and because the heat generated can evaporate additional moisture. The hydrated lime produced by these initial reactions will subsequently react with clay particles. These subsequent reactions will slowly produce additional drying because they reduce the soils moisture holding capacity. If the hydrated lime or hydrated lime slurry is used instead of quicklime, drying occurs only through the chemical changes in the soil that reduce its capacity to hold water and increase its stability.

This paper focuses on the potentials of stabilizing lateritic soil with both locally prepared and commercial imported limes, and comparing the effects of both stabilizing agents on the lateritic soil in relation to the compaction characteristics (OMC and MDD), strength characteristics (CBR and UCS) etc.

Ii Location, Materials And Methods

2.1. Location

Figure 1 shows distribution of limestone deposit in Nigeria, for the purpose of this study, limestone samples were collected in large quantities from three different locations in Nigeria which are Okpella in Edo state, Ewekoro in Ogun state and Obajana in Kogi state.

2.1.1. Okpella, Edo State

Okepella is a clan in Afemailand made popular by large deposit of limestone and many other solid mineral deposit in it soil. Located in the northern part of Edo state in Nigeria. It lies between Latitude 7^{o} and 7.25 ^{o} North and Longitude 6.15^{o} and 6.38^{o} East, covering an area of about 231.2sq.km. To the North and North-East of the clan is Okene local government area in Kogi state, to the West are the Akoko-Edo local government area, villages of Ososo, Oja, Dangbala, Ojirami and Atte. To the south is the Uzairue clan and to the South-West are the north Ibie clans (Okpekpe and the tree Ibies) as shown in Figure 2.

2.1.2. Ewekoro, Ogun State

Ewekoro lies within Ogun state, which is bounded in the west by Benin Republic, in the south by Lagos state, in the north by Oyo state and Osun state, and in the east by Ondo state. It occupies a total area of 323.3 sq.km. Ewekoro is the host of West African Portland Cement quarry and lies between longitude 3°05´E to 3°15´E and latitudes 6°40´N to 6°55´N as shown in Figure 3. Its formation belongs to tertiary-formed Palaeocene and Eocene; and the greater part of the depression is a potential artesian basin where ground water can be sourced. Adegoke *et al*. (1976) outlined the Albran and younger Palaeographic history of Nigeria and summarized the nature and extent of transgressive, regressive phases as well as the nature of the sediment. The geology of Ogun State comprises sedimentary and basement complex rocks, which underlie the remaining surface area of the state. It also consists of intercalations of argillaceous sediment. The sedimentary rock of Ogun State consists of Abeokuta formation lying directly above the basement complex. Ewekoro, Oshosun and Ilaro formations in turn overlie this, which are all overlain by the coastal plain sands (Benin formation).

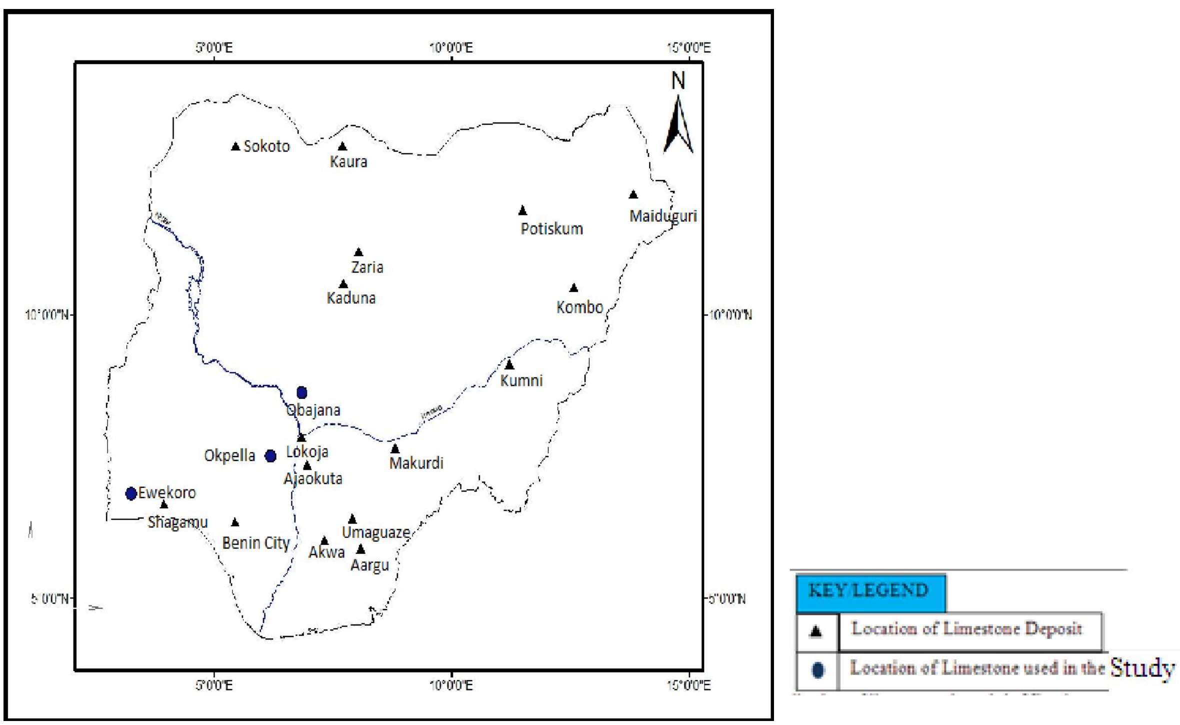

Figure 1: Map of Nigeria showing the Distribution of limestone deposit in Nigeria.

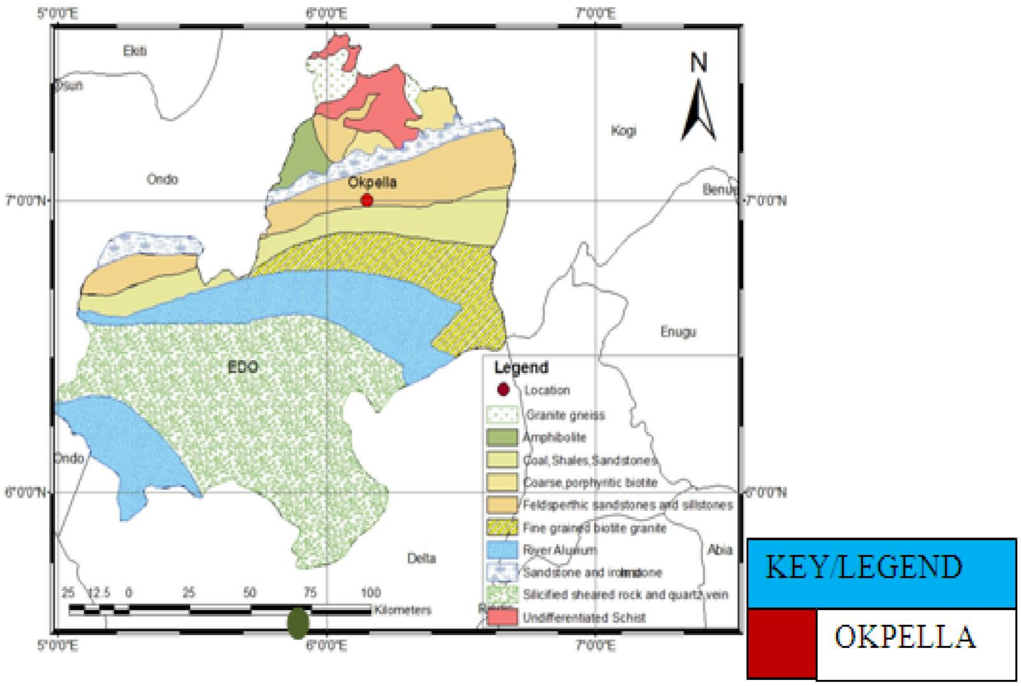

Figure 2: Geological map of Edo State showing the study area (Okpella, Edo State).

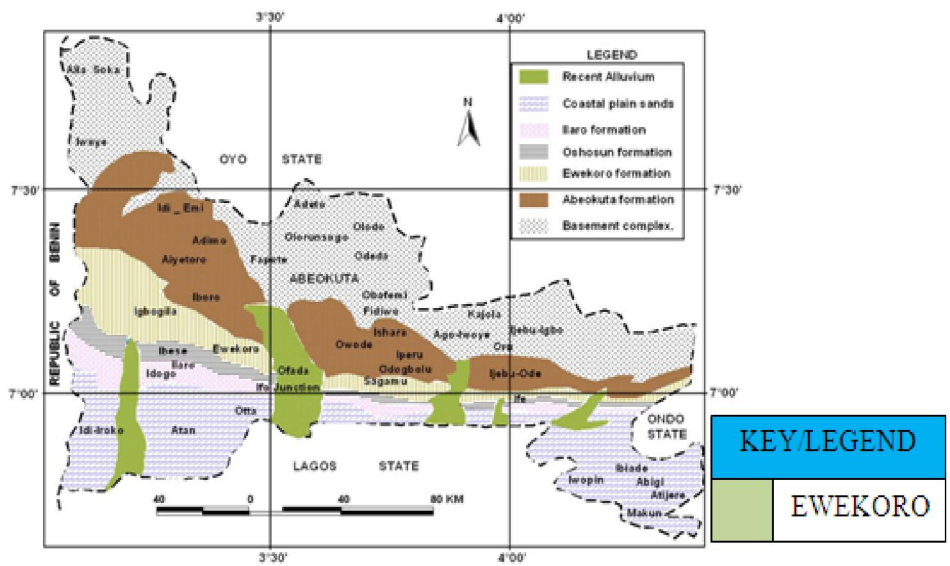

Figure 3: Geological map of Ogun State showing the study area (Ewekoro, Ogun State).

2.1.3. Obajana, Kogi State

The community of Obajana is located next to the site of the cement plant and truck park. Communities downstream include several Fulani migrant settlement (Wuro Gada Buju, Wuro Ardo, Wuro Mashu, and Wuro Jahun) and 'Shagari Town' which is inhabited by Bassa people (on Igbira Land). The original inhibitants of Obajana are the Oworos, who claim to originate from the Yoruba. Obajana is located in Kogi state, North central Nigeria as shown in Figure 4. It is within the geographical co-ordinate of latitude 7.92^0 and longitude 6.43. It is about 22km southwest of lokoja, the state capital and 400km north east of Lagos.

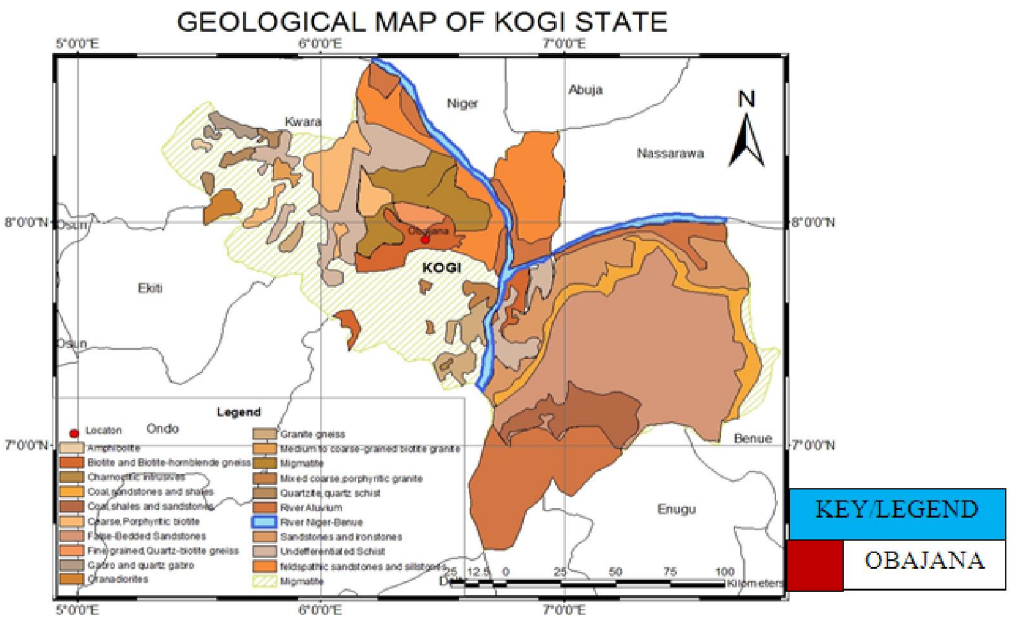

Figure 4: Geological map of Kogi State showing the study area (Obajana, Kogi State)

2.2. Location Of Lateritic Soil Sample

The lateritic soil used for this study was taken from Federal University of Technology, Akure (FUTA) environment, behind Geotechnical Laboratory, along staff quarters. On latitude 07.31^0N and 005.13^0E at an elevation of 405m above mid sea level, 900m from FUTA North gate . The soil sample was a disturbed soil sample taken at a depth between 600mm and 750mm.

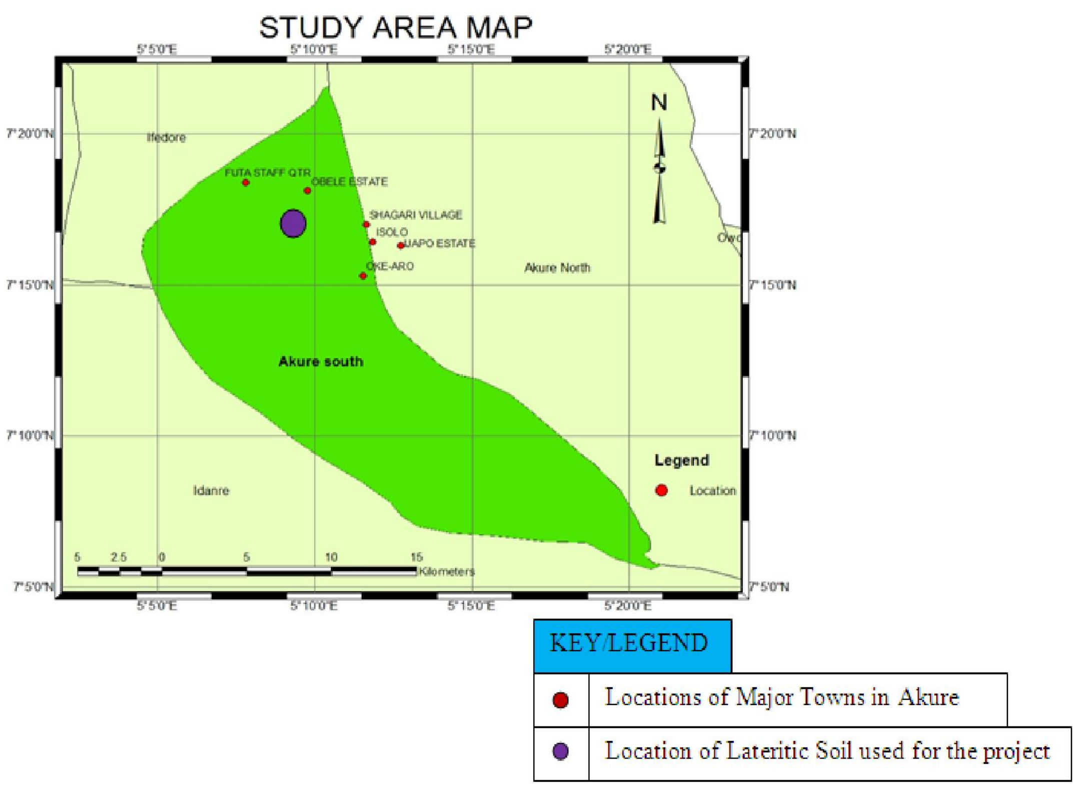

Figure 5: Map of Akure showing the location of Lateritic Soil used (FUTA Staff Quarters)

2.3. Materials

The hydrated lime used as the stabilizing agent were of two types, the first one was procured from a reputable chemical store, the second was locally prepared from three different limestone samples gotten form three different location in Nigeria, which are Okpella, Ewekoro and Obajana. After the hydrated limes has been gotten, it was stored in a cool and dry place away from weather effect. Potable water treated in the laboratory was used for the test carried out during this study.

2.4. Methods

Generally, the procedures used in carrying out the underlisted tests were in accordance to British standard methods (BS 1337) and (ASTM- STP 479) specifications. Test experiment carried out could be grouped into two major categories.

2.4.1 Preliminary Test.

These tests were performed for the purpose of identifying and classifying the soil. These tests were performed on oven-dried samples. They include grain size distribution (Wet Sieving), Sedimentation analysis test, Specific gravity, Moisture content and Atterberg limits.

2.4.2 Stabilization Test

The purpose of these tests was to investigate the strength performance of the soil lime mixture for 0%, 3% and 6% lime. To effectively carry out these tests, the soil was oven dried, pulverized, and divided into batches before each batch was mixed thoroughly with the various hydrated limes to form a uniform colour, water was then added, mixed and then compacted. Tests such as CBR, moisture density, and unconfined compression were performed using the standard proctor compactive energy because this is easily achieved in the field; 0%, 3% and 6% hydrated lime were utilized. The CBR test were soaked for four days with 4.5kg surcharge weights, after which they were tested.

2.5 Local Laboratory Preparation Of Hydrated Lime

(a) Calcination/Heating of the Limestones Samples in a Furnace

10Kg of each of the different limestone samples were placed in a crucible pot and placed in the furnace, which was regulated at 1000^0c for 4 hours. Calcination of the limestones from Obajana, Okpella and Ewekoro was done in Matallurgical and Materials foundry workshop, Federal University of Technology Akure.

Plate 1: Heating of the Limestone Samples in a Furnace

(b) Hydrating/Pulverization of the Limestone Samples

Immediately the limestone samples were removed from the furnace, hydration was done to prevent re-carbonation with the available carbon dioxide present in the atmosphere. The hydration was done in ratio of 1:1, that is, for the equal 10kg of each limestone samples, the equivalent amount of water was added. Pulverization of the hydrated limestone samples was achieved by pounding the limestone inside a gas cylinder with a dropping hammer. The particles that pass through the sieve 212 microns was packed into a polythene bag, tied and thereafter stored in a cool dry place before it was used for the stabilization.

Plate 2: Hydration of the Obajana Limestone Samples with water

III. Results And Discussion

For the purpose of identification, classification and determination of the engineering characteristics of the lateritic soil used for this study, laboratory test were performed on the natural soil sample, the soil sample was then stabilized with hydrated limes, imported and locally prepared limes from three different locations in Nigeria. Below are the results of the respective test carried out on the soil sample.

3.1 Preliminary Soil Classification Results

The summary of the results of the preliminary tests carried on the lateritic soil are presented on Table.

Table 1: The results from the Soil classification test

Natural moisture content (%)	18.7
Liquid Limit (%)	35.5
Plastic Limit (%)	21.5
Plasticity Index (%)	14.0
Specific gravity	2.63
Percentage passing No. 200 BS sieve	55.34
Group Index	5.2

When these values were slotted into the **AASHTO** soil classification system (Highway Research Board Classification System), a soil corresponding to group classification **A-6** was obtained. Thus the soil has 'Fair to Poor' drainage characteristics and a 'Fair to Poor' general rating as a subgrade material.

3.2 Compaction Test Result

The variation in maximum dry density and moisture content with increase in lime content is shown below in Table 2.

Table2: Table Showing the Effect of Lime on the MDD and OMC of the Soil

LIME SOURCE	LIME PERCENTAGE	MAX DRY DENSITY (g/cm^3)	OPTIMUM MOISTURE CONTENT IN (%)
NO LIME	0%	1.84	16.40
EWEKORO	3%	1.74	19.80
	6%	1.68	20.50
OBAJANA	3%	1.72	19.60
	6%	1.63	20.80
OKPELLA	3%	1.71	19.50
	6%	1.66	20.10
IMPORTED	3%	1.66	20.00
	6%	1.70	21.00

These results are consistent with experiments carried out by Balogun (1984), Ola (1978) and Adedimila (1994). It was observed that the addition of lime had considerable effect on the optimum moisture content, increasing it value from 16.40% to 20.50, 20.80, 20.10 and 21.00 for Ewekoro, Obajana, Okpella and Imported limes respectively, with imported lime giving the highest increase due to finnest of its particles (Figure 7).

Its was also observed that lime reduced the maximum dry densities considerably from 1.84g/cm^3 to 1.68, 1.63, 1.66 and 1.70g/cm^3 for Ewekoro, Obajana, Okpella and Imported lime respectively. Ola (1978) attributed this behaviour to the grain size distribution, the specific gravity of the soil and the stabilizer used, which in this case is hydrated lime. Ola (1978) explained further that fine grained soils have a tendency to decrease in maximum dry density. The introduction of lime initially coat the soils to form large aggregates which occupy larger spaces and tends to increase the dry density, but the low specific gravity of lime makes this impossible, since the specific gravity of lime (which is 2.2) is less than that of the soil (which is 2.59) hence, the maximum dry density tends to reduce.

3.3 California Bearing Ratio (C.B.R)

The CBR (Soaked and Unsoaked) result of the soil under study is given in Table 4 for the various soil lime specimens. It can be seen from the table that there is significant increase in the Unsoaked CBR value from 20.35% to 69.69, 70.33, 68.61 and 76.11% for the Ewekoro, Obajana, Okpella and Imported hydrated limes respectively (Figure 15). Also it was seen that for the soaked CBR, the value increased slightly from 9.63% to 23.96, 24.37, 24.07 and 25.67 for the Ewekoro, Obajana, Okpella and Imported hydrated limes respectively Figure 16).

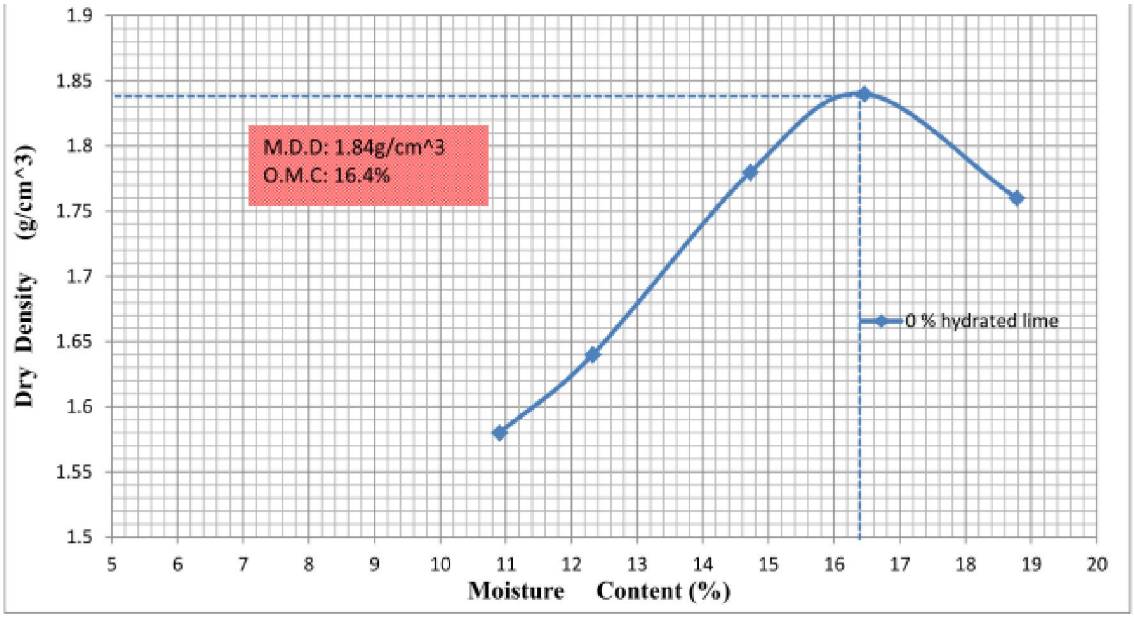

Figure 6: Graph of Dry Density against Moisture Content for 0% Hydrated Lime

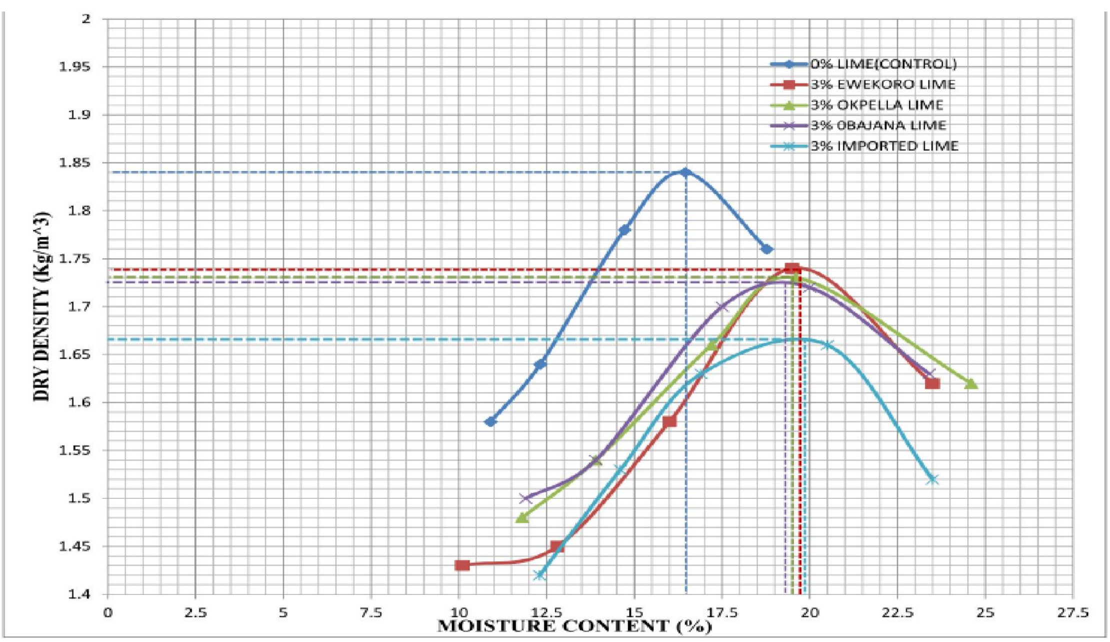

Figure 7: Graph Showing the Combined Graph for 3% Hydrated Limes Used

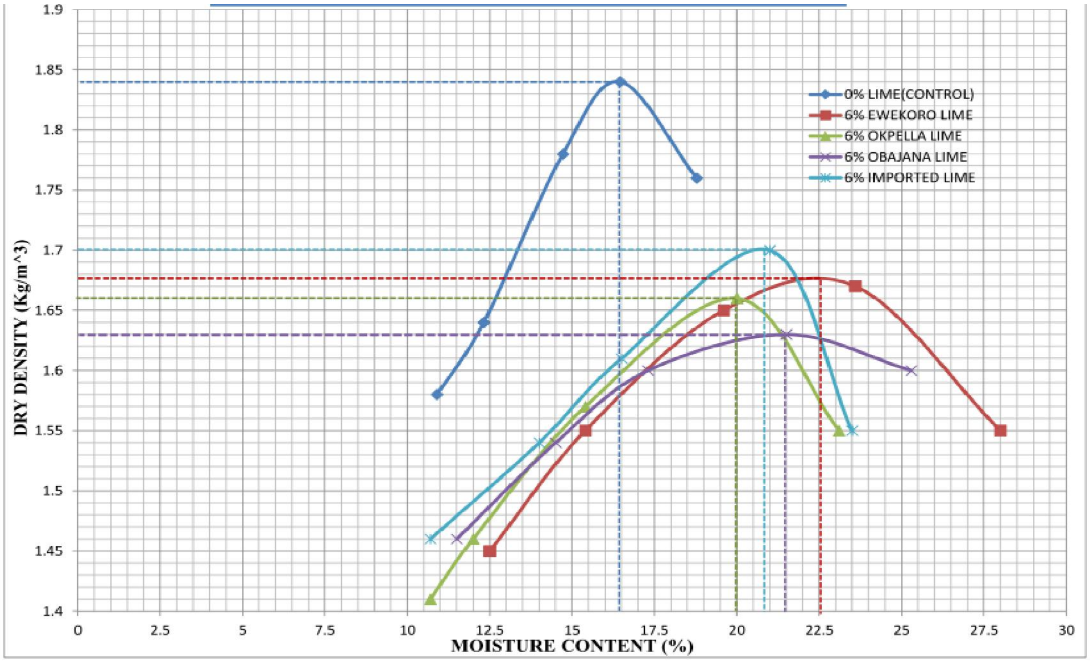

Figure 8: Graph Showing the Combined Graph for 6% Hydrated Limes Used

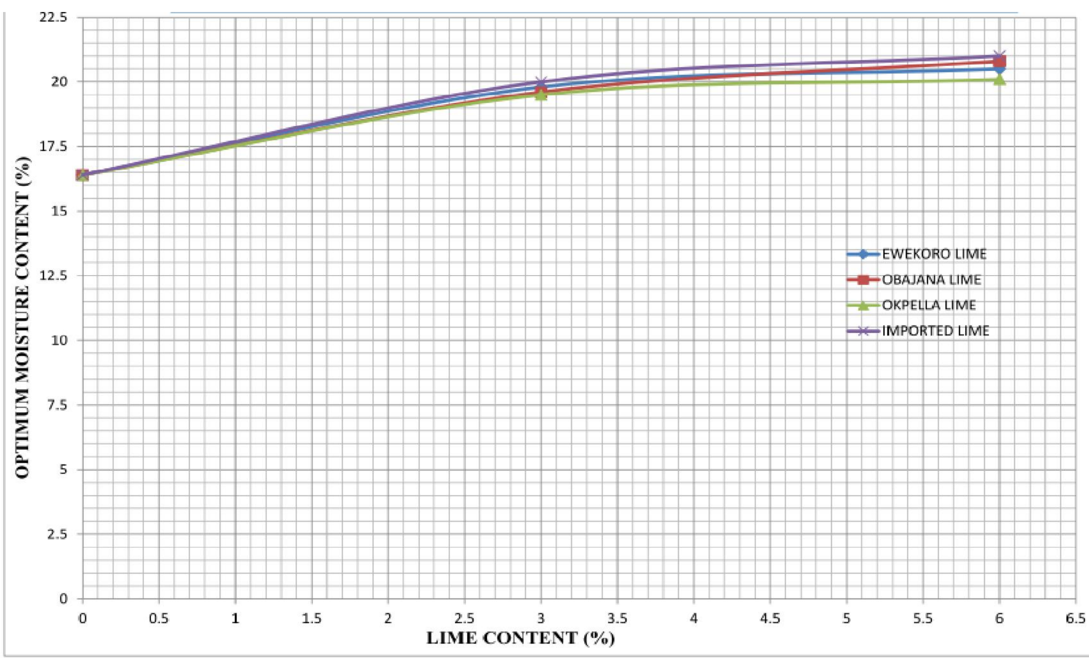

Figure 9: Graph Showing Variation of Optimum Moisture Content with the various Limes

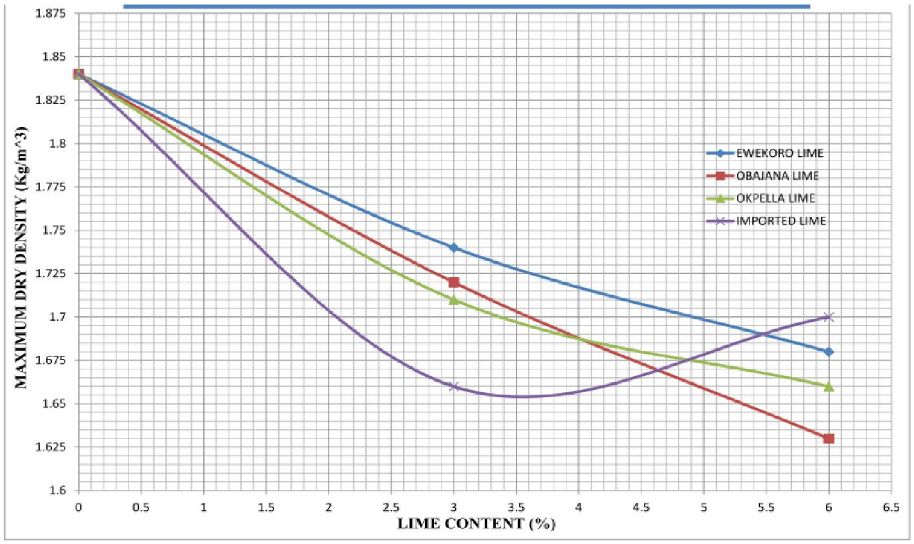

Figure 10: Graph Showing the Variation of Maximum Dry Density with the Various Limes

Table 4: Table Showing the Effect of the Various Hydrated Limes on the California Bearing Ratio (Soaked and Unsoaked) Soil Sample

LIME SOURCE	LIME PERCENTAGE	UNSOAKED CBR (%)	SOAKED CBR (%)
NO LIME	0%	20.35	9.63
EWEKORO	3%	33.53	14.90
	6%	69.69	23.96
OBAJANA	3%	33.08	15.46
	6%	70.33	24.37
OKPELLA	3%	32.27	13.18
	6%	68.61	24.07
IMPORTED	3%	34.16	20.87
	6%	76.11	25.67

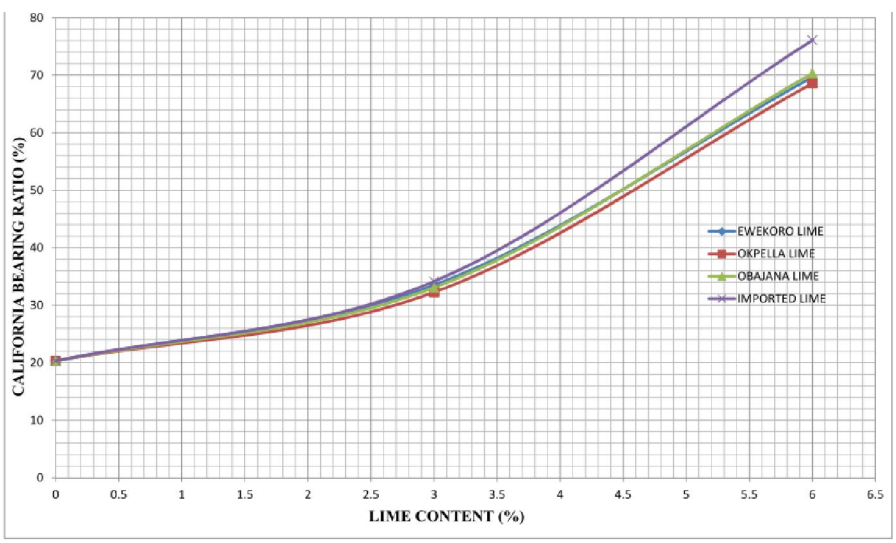

Figure 11: Graph Showing the Variation of Unsoaked CBR with the Various Limes

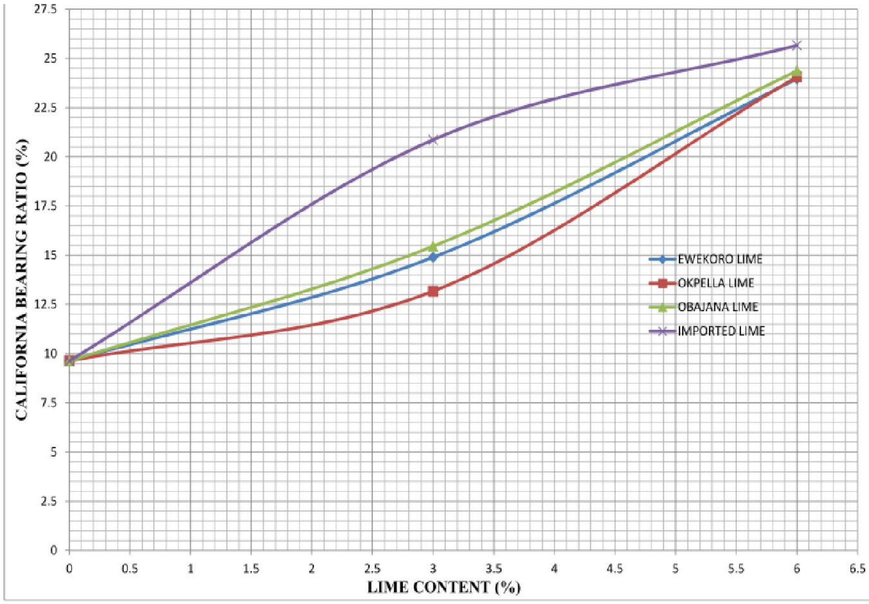

Figure 12: Graph Showing the Variation of Soaked CBR with the Various Limes

3.7 Unconfined Compressive Strength Test Result

The soil attained a compressive strength value above the minimum acceptable value of 103KN/m^2 (150psi), but the imported lime at 6% gives the highest strength of 975KN/m^2, closely followed by Obajana lime at 6% with a compressive strength of 860KN/m^2. Bhatia (1968) suggested that whereas the use of unconfined compressive strength test as a criterion for the design of soil-cement mixes is quite justified in clays and clay soils, it can be very misleading for granular soils. A material with only cohesion and no internal friction shows little increase in strength when tested under confined conditions, whereas a material with internal friction shows considerable increase in strength. This explanation can be extended to soil-lime mixes since the first reaction of the lime is to flocculate and agglomerate the soil particles into granular fractions.

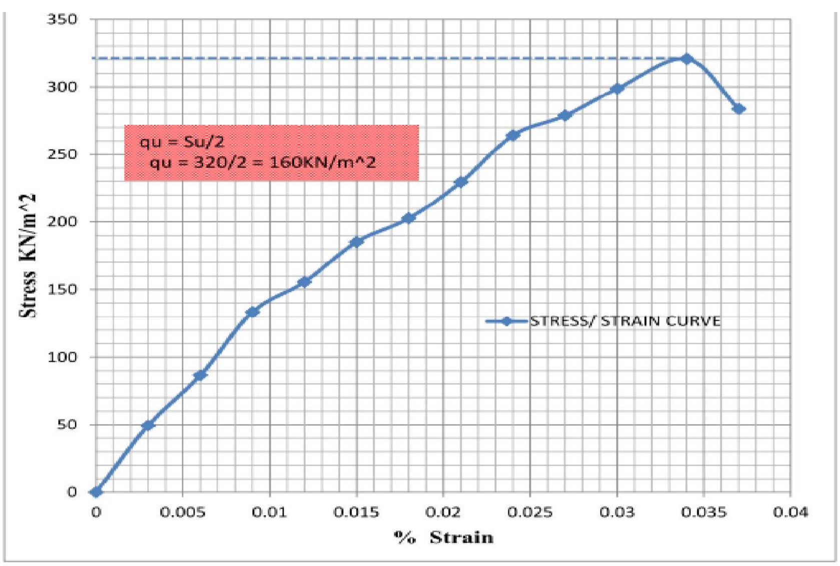

Figure 13: Graph Showing Unconfined Stress/Strain Curve for 0% Hydrated Lime

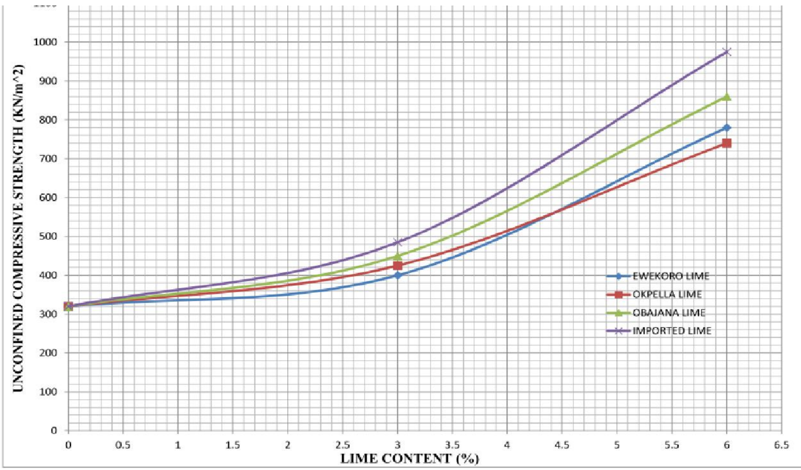

Figure 14: Graph Showing the Variation of Unconfined Compressive Strength with the Various Limes

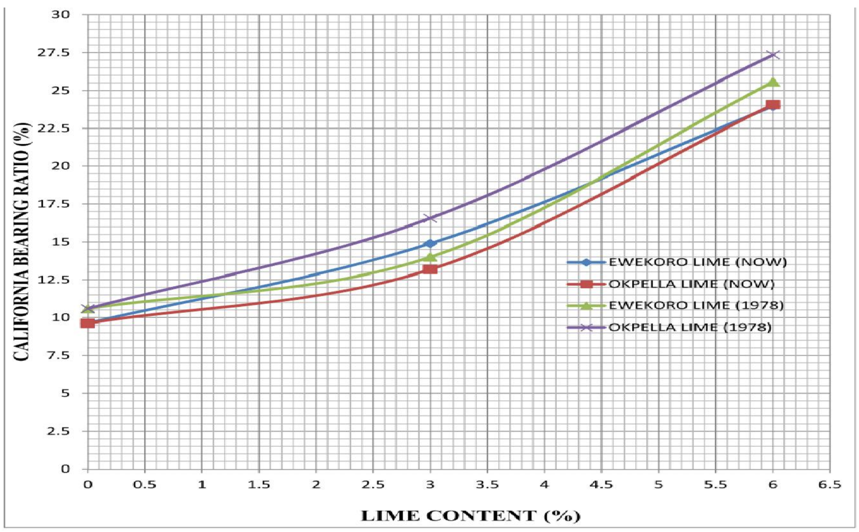

Figure 19: Graph Showing the Comparison of Soaked CBR obtained in 1978 and now

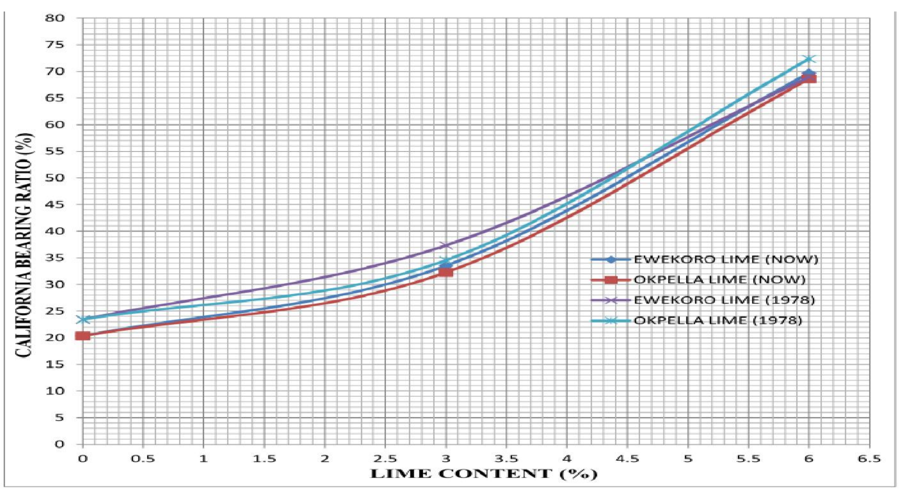

Figure 20: Graph Showing the Comparison of Unsoaked CBR obtained in 1978 and now

Conclusion

The results of soil stabilization with the locally prepared limes shows that despite the non-refinement of these limes as that of the imported lime (For instance no attempt was made to remove the silica or to grind the limes to finer particles), the results shows that they are as good for soil stabilization as the commercial lime used in the tests. The results also confirm that Nigerian limestones are not sensitive to overheating; this is probably because of the low contents of MgO present in these limestones.

In the assessment of the geotechnical properties of the lateritic soil stabilized with hydrated limes, the result shows that the engineering characteristics of the lateritic soil improved considerably upon stabilization. For example, upon addition of the hydrated limes, the liquid limits reduced, the plastic limit increased thereby reducing the plasticity index and modifying the soil making it more workable (this is one advantage of lime stabilization over other methods).

IV. Acknowledgements

The tests were carried out in the Geotechnical and Geo-environmental laboratory of the Department of Civil and Environmental Engineering, Federal University of Technology, Akure, Nigeria. The Authors also appreciate the supervision of a renowned and a seasoned academic in person of Prof. S. A. Ola.

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