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Evaluation of the Effect of Lime and Cement on the Engineering Properties of Selected Soil in a University in Southwestern Nigeria.

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ABSTRACT
Soil stabilization means alteration of the soils properties to meet the specified engineering requirements. Methods for the stabilization are compaction and use of admixtures. Lime and Cement was commonly used as stabilizer for altering the properties of soils. This project focuses on the effect of Cement and Lime on selected engineering properties of lateritic soils in Ladoke Akintola University of Technology, Ogbomoso, Nigeria. In order to study this effect, fresh laterite was obtained and tested for its index and geotechnical properties. Afterwards, the soil sample was altered with additives proportions which includes 0%, 2.5%, 5%, 7.5%, and 10% of both cement and lime replacement by dry weight. On examination laterite, it was discovered that the laterite can be classified as good. After carrying out the engineering properties on the sample, it was observed that the maximum dry density reduced with increase in the lime content and for cement content at 2.5 and 10% but increases at 5-7.5%. Also, the optimum moisture content increased for increasing lime content and fluctuates for increasing cement content. However, an increase in the California Bearing Ratio (CBR) was noticed for increase in cement but a low effect for lime addition. It was therefore concluded that lime and cement modifies the chemical property of the tested soil with cement the most suitable.
Keywords: *admixtures, engineering properties, CBR.*

INTRODUCTION
Laterite soil is a compressible soil with large quantity of clayey material and low bearing capacity to resist load. The laterite soil is said to be weak because of low density due to its compression. The problem associated with weak lateritic soil is its inability to resist loads due to its compressibility when load is applied on it. Laterite soil may be improved through the addition of chemical additives which ranges from lime, fly ash, Portland cement, cement kiln dust etc. these additives can be used with a variety of soils to help improve their native engineering properties. The effectiveness of these additives depends on the soil treated and the amount of additive used. This report contains the distinguishing properties between the use of lime and cement as soil stabilizers, so also, varying the moisture contents of test samples in percentages of optimum moisture contents contained during the procedure.
The term 'stabilization' is the process whereby the natural strength and durability of a soil or granular material is increased by the addition of a stabilizing agent. . In addition, it may provide a greater resistance to the ingress of water. There are many types of stabilizer that can be used, each with their own advantages and disadvantages. The type and quantity of stabilizer added depends mainly on the strength and performance that needs to be achieved. Soil stabilization occurs when lime, fly ash, cement or bentonite clay is added to a reactive soil. The resulting pozzolanic reaction between these materials and the soil develops a durable and stable bond between molecules in the soil. This reaction can provide for long lasting stabilization of clay based soils. This study is aimed at evaluating the effect of lime and cement on the engineering properties of a lateritic soil sample collected in Ladoke Akintola University of technology (LAUTECH), Ogbomoso, Nigeria.
"Soil stabilization means the improvement of stability or bearing power of the soil by the use of controlled compaction, proportioning and/or the addition of suitable admixture or stabilizers. Stabilization processes are very complex because many parameters come into play. The knowledge of soil properties can help to better consider what changes, the economic studies (cost and time), as well as production and construction techniques to use. The simplest process consists of taking soil and drying it in open-air. More elaborate processes can include heat treatment or mixing soil with ordinary Portland cement, lime, etc". [8].
Stabilization is the process of mixing a stabilizer, for example cement, with a soil or imported aggregate to produce a material whose strength is greater than that of the original unbound material. The use of stabilization to improve the properties of a material is becoming more widespread due to the increased strength and load spreading ability that these materials can offer. Stabilization technology is extremely relevant for heavily trafficked pavements where its' benefits are beginning to be appreciated.

Methods of Soil Stabilization
Mechanical Stabilization
Mechanical stabilization consists of compacting the soil to affect its resistance, compressibility, permeability and porosity. The soil is mechanically treated so that maximum air can be eliminated and this contributes to an increase in its density. With mechanical stabilization, the particle size distribution constituting the material is not affected, but its structure is changed because the particles are redistributed [5, 11]. Mechanical stabilization is widely used in road construction and requires a prior analysis of the soil to determine the optimum water content for better soil compressibility.
Physical Stabilization
Physical stabilization consists of modifying the properties of soil by intervening with its texture (granulometry treatment, heat (dehydration or freezing) or electric (electrosmosis) treatments that lead to the drainage of the soil and thus confer new structural properties to it) [5, 11]. It also involves the introduction of synthetic fibers or fibers originating from plants, animals and

minerals into the soil. This method is used when there are reasons not to affect the particle size distribution of the soil or if the material is sensitive to movements induced by factors such as water action, thermal expansion etc. These movements can then be countered by a frame made of fibers. The armature acts at a macroscopic level (on grain aggregation), and not at the level of individual grains [5].

Chemical Stabilization

Lime Stabilization

The word "lime" originates with its earliest use as building mortar and has the sense of "sticking or adhering." Lime can also be referred to as sticky substance (birdlime) smeared on branches to catch small birds [7].

These materials are still used in large quantities as building and engineering materials (including limestone products, concrete and mortar) and as chemical feedstocks, among other uses. The rocks and minerals from which these materials are derived, typically limestone or chalk, are composed primarily of calcium carbonate. They may be cut, crushed or pulverized and chemically altered. "Burning" (calcination) converts them into the highly caustic material *quicklime* (calcium oxide, CaO) and, through subsequent addition of water, into the less caustic (but still strongly alkaline) *slaked lime* or *hydrated lime* (calcium hydroxide, $Ca(OH)_2$), the process of which is called 'slaking of lime'.

Cement Stabilization

Cement used in construction is characterized as hydraulic or non-hydraulic. Hydraulic cements (*e.g.,* Portland cement) harden because of hydration, chemical reactions that occur independently of the mixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble. Non-hydraulic cements (*e.g.* gypsum plaster) must be kept dry in order to retain their strength.

Portland cement clinker is a hydraulic material which shall consist of at least two-thirds by mass of calcium silicates ($3\,CaO{\cdot}SiO_2$ and $2\,CaO{\cdot}SiO_2$), the remainder consisting of aluminium- and iron-containing clinker phases and other compounds. The ratio of CaO to SiO_2 shall not be less than 2.0. The magnesium oxide content (MgO) shall not exceed 5.0% by mass.

The main reaction in a soil/cement mixture comes from the hydration of the two anhydrous calcium silicates (3CaO. SiO_2 (C_3S) and 2CaO. SiO_2 (C_2S)), the major constituents of cement, which form two new compounds: calcium hydroxide (hydrated lime called portlandite) and calcium silicate hydrate (CSH), the main binder of concrete [Tremblay, 1998; Billong *et al*, 2008]. The reaction is as follows (Equation 1):

$$\text{Cement} + H_20 \rightarrow CSH + Ca\,(OH)_2 \qquad (1)$$

Unlike lime, the mineralogy and granulometry of cement treated soils have little influence on the reaction since the cement powder contains in itself everything it needs to react and form cementitious products. Cement will create physical links between particles, increasing the soil strength; meanwhile lime needs silica and alumina from clay particles to develop pozzolanic reactions [6, 12].

Generally, the hydration reactions of cements are faster than those of lime, but in both cases, the final strength results from the formation of CSH [6]. Other chemical materials such as gypsum, asphalt and bitumen can be also used.

METHODOLOGY

Samples Collection

Lateritic Soils

It was suggested that the soil be collected from a single borrowed pit to avoid interference of results, samples will be collected from borrow sites, packed in a polythene bags, pre-treatment will be done on it in the laboratory and placed in a tray and passed through riffle box for representation of all particle sizes.

Cement and Lime

Cement Lime to be used will be purchased in the local market and stored effectively to prevent moisturisation.

Soil Sample preparation

The lime and cement used have uniform physical properties where addition will allow for identification of the effect of water content, texture, constituent etc and also the modification of soil properties. The sample was air-dried to remove the moisture and also pulverized by mallet for separation of particles.

Determination of Engineering Properties of collected sample

In order to identify, classify and determine the effect of chemical stabilizers on lateritic soils, tests were carried out on the laterites in accordance to BS 1377[3]. The following tests were carried out in the Ladoke Akintola University of Technology, Ogbomoso (LAUTECH) Civil Engineering geotechnical laboratory;

i. Sieve analysis
ii. Compaction
iii. Atterberg's limit test
iv. California bearing ratio test

Laboratory experiments on samples

The proportions include 0%, 2.5%, 5%, 7.5%, and 10% of both cement and lime replacement by dry weight for the soil samples used for the aforementioned tests.

RESULTS

Results of various tests carried out on samples collected from the borrow pit (behind Architecture Studio, LAUTECH, Ogbomoso). The summary of the results are presented in the tables and charts in this chapter and all respective datasheets and calculations for each tests are presented in the appendices.

Sieve Analysis

The result of the sieve analysis of the sample is presented in table 1 and curve in Fig. 1. It shows the percentages by mass, of soil passing and retained in the individual sieves of varying sizes. This helps to ascertain the percentages of silt, sand and gravel in the lateritic soil, as well as help to determine the AASHTO classification of the soil as shown in Table 2

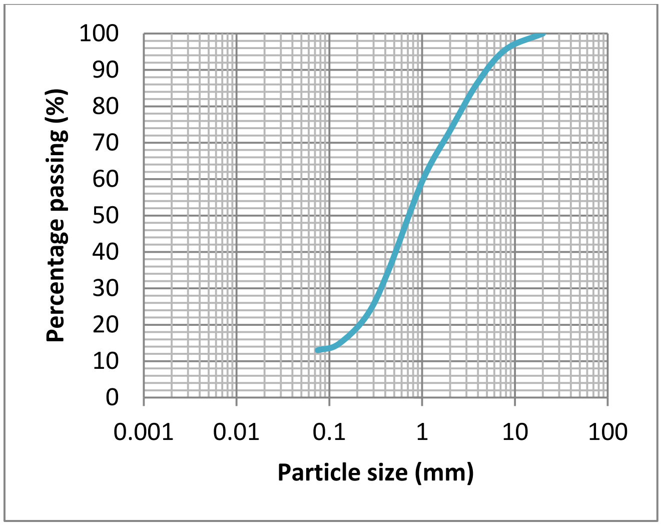

Figure 1: Sieve Analysis Curve

Table 1 Sieve Analysis Result for Natural Soil

ASTM Sieve Number	Sieve Diameter (mm)	Mass Retained(g)	Cumulative Percentage Retained (%)	Percentage Passing (%)
¾ in	20.0	0.00	0.00	100
5/6 in	8.0	13.0	4.33	95.67
No. 5	4.0	27.0	13.33	86.67
No. 10	2.0	40.0	26.66	73.67
No 18	1.0	42.0	40.66	59.34
No. 40	0.425	75.0	65.66	34.34
No 60	0.250	36.0	77.60	22.34
No 120	0.125	23.0	85.33	14.69
No 200	0.075	5.0	87.00	13.00
< No 200	< 0.075	39.0	100.00	0.00

Table 2: Silt, Sand and gravel Distribution

SILT-CLAY	**SAND**			**GRAVEL**		
	Fine	Medium	Coarse	Fine	Medium	Coarse
13%	7%	28%	25%	20%	7%	0%

Atterberg's Limits

The result of the liquid limit, plastic limit and plastic index carried out on the lateritic unstabilized and stabilized soil samples are in presented in Table 3 and 4 and Fig 2 and 3, with subsequent addition of cement and lime on the basis of percentage replacement by mass of 0%, 2.5%, 5.0%, 7.5% and 10.0%.

Table 3: Summary of Atterberg's limits test for 0% - 10% lime

Lime Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
0	23.4	15.90	7.50
2.5	24.8	17.48	7.32
5.0	25.5	18.66	6.84
7.5	27.8	21.47	6.33
10.0	28.0	21.96	6.04

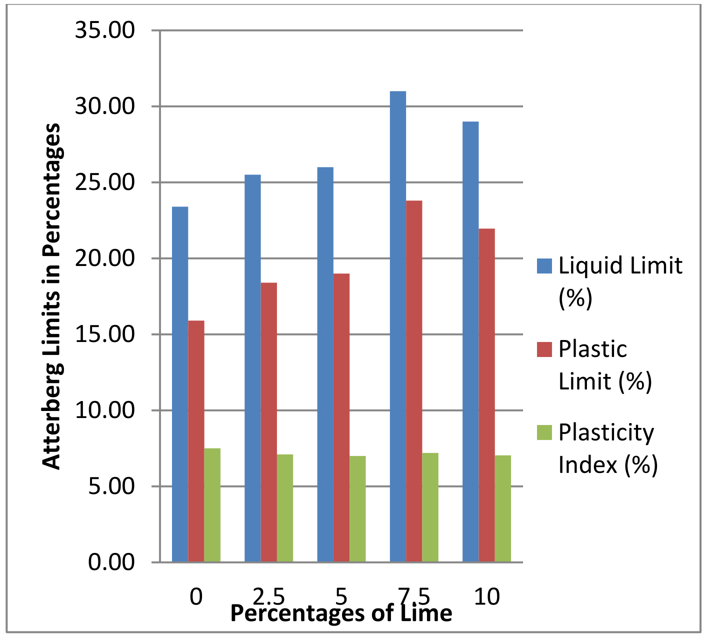

Figure 2: Chart representation of Atterberg's Limit of the soil for 0-10% lime

Table 4: Summary of Atterberg's limits test for 0% - 10% cement

Cement Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
0	23.40	15.90	7.50
2.5	25.50	18.40	7.10
5.0	26.00	19.00	7.00
7.5	31.00	23.80	7.20
10.0	29.00	21.96	7.04

Table 5 Comparison between the Maximum Dry Densities (MDD) for the two additives from 0% - 10% using BS compaction Energy

Additives (%)	**MDD (g/cm^3) Lime**	**MDD (g/cm^3),Cement**
0	1.98	1.98
2.5	1.98	1.96
5.0	1.94	1.98
7.5	1.95	2.05
10	1.91	1.98

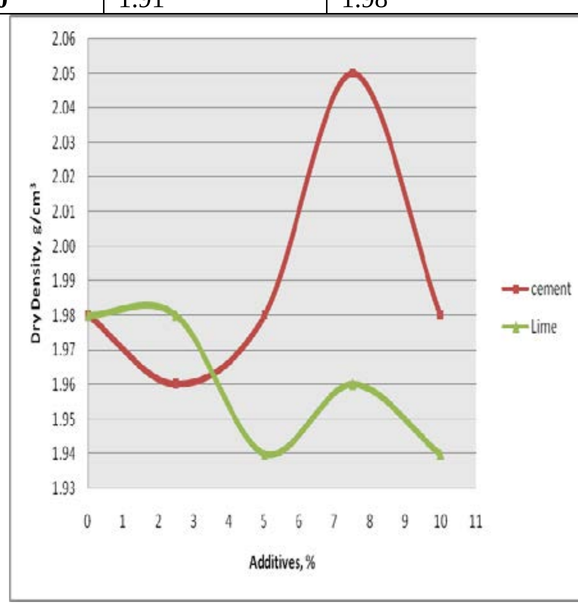

Figure 4 Graphical Comparison between the MDDs for of 0% - 10.0% lime and cement additives

Table 6 Comparison between the Optimum Moisture Contents (OMC) for the two additives from 0% - 10% using BS compaction Energy

Additives (%)	OMC (%), Lime	OMC (%), Cement
0	12.55	12.55
2.5	13.99	13.50
5.0	14.06	10.27
7.5	11.50	10.25
10	14.56	14.70

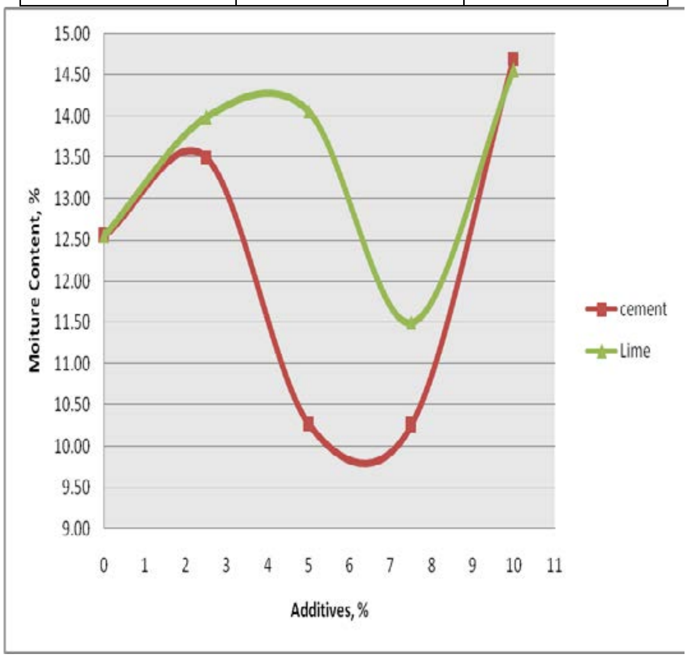

Figure 5 Graphical Comparison between the OMCs for of 0% - 10.0% lime and cement additives

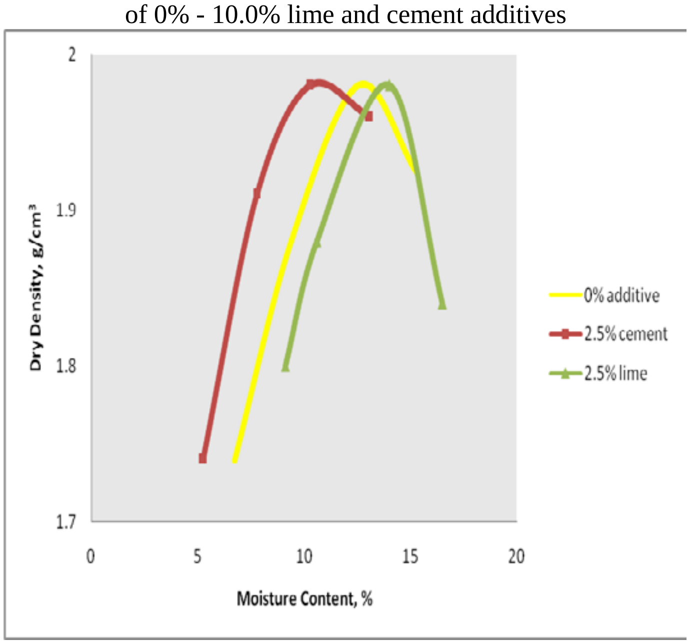

Figure 6 Chart showing the comparison between the 0%, 2.5% cement and 2.5% lime

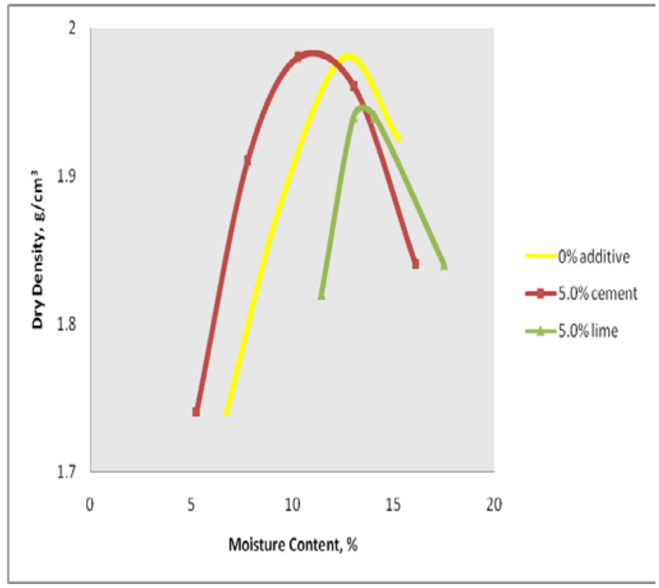

Figure 7 Chart showing the comparison between the 0%, 5.0% cement and 5.0% lime

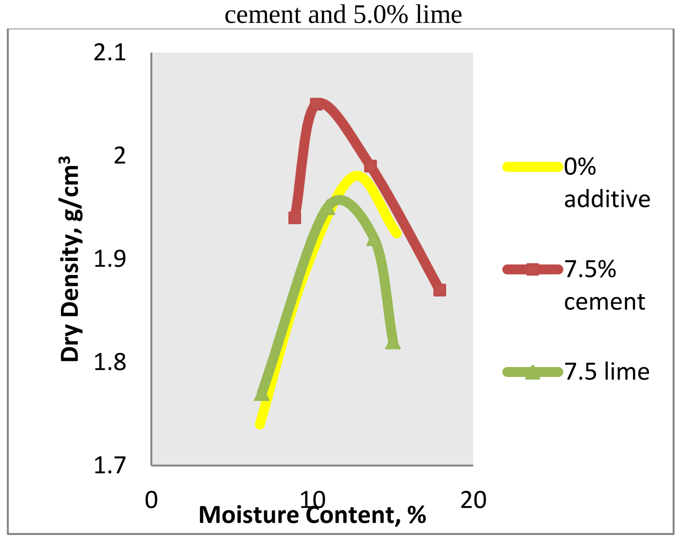

Figure 8 Chart showing the comparison between the 0%, 7.5% cement and 7.5% lime

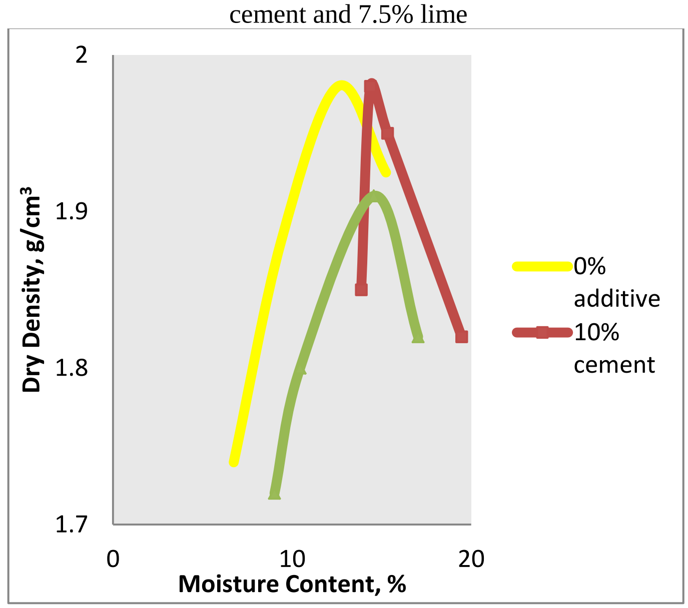

Figure 9 Chart showing the comparison between the 0%, 10% cement and 10% lime

California Bearing Ratio (CBR)

The lateritic soil was prepared by static compaction and therefore stabilized with Lime and Cement on the basis of percentage replacement by mass at 0%, 2.5%, 5.0%, 7.5% and 10.0% for both cement and lime. Therefore, the summary of results obtained is as follows in Table 7 and Table 8 respectively

Table 7: Result of California Bearing Ratio using the BS method for Cement additive.

Cement Content (%)	0%	2.5%	5.0%	7.5%	10%
CBR (%)	6.28	4.06	29.48	53.16	6.06

Table 8: Result of California Bearing Ratio using the BS method for Lime additive.

Lime Content (%)	0%	2.5%	5.0%	7.5%	10%
CBR (%)	6.28	7.57	7.46	6.32	2.80

DISCUSSION

Sieve Analysis

Based on the sieve analysis that was carried out on the natural lateritic soil, the summary of results shows the percentage by mass of sample passing through ASTM sieve No. 200 is not greater than 35%, therefore making it a suitable subgrade material

Atterberg Limits

The addition of lime and cement in 2.5, 5.0, 7.5 and 10% to the samples caused changes in the liquid limits and plastic limits of the sample, which are shown in Table 3 and 4 respectively. The plasticity indices decreased from 7.50 to 6.04 and 7.50 to 7.04 for lime and cement respectively. These reductions in plasticity indices are indicators of soil improvement.

The addition of lime and cement to sample produced a corresponding increase in the LL and PL of the soil as seen in Table 3 and 4, thus causing a decrease in the PI which is in conformity with Rowlands et al [9]who stated that increase in liquid limit values shows that the soil sample is clay mineral dependent

The reduction in the swell potential is as a result of the cation exchange which occurs when Ca^{2+}ions from the lime and cement replace weaker cations in the soil, thereby causing a better sealing of the voids by the agglomeration of the particles[1].

Compaction Test

The unstabilized Optimum Moisture Content (OMC) for the sample is 12.55% with Maximum Dry Density (MDD) of 1.98g/cm^3. The addition of lime in 2.5, 5.0, 7.5 and 10.0% by weight of sample generally increased OMC and decreased MDD of the sample. The OMC increased from 12.55 to 14.56% in the sample. The MDD decreased from 1.98 to 1.91g/cm^3. However, the addition of cement in 2.5, 5.0, 7.5 and 10.0% by weight sample also increased the OMC from 12.55 to 14.70%. The MDD is highest at 7.5% as 2.05g/cm^3 which is a general indication of soil improvement. The increase in OMC is probably due to the additional water held within the flocculent soil structure due to excess water absorbed as a result of the porous property of the stabilizers. The opinion of Das [4] revealed that a change down in dry density might occur due to both the particle size and specific gravity of the soil and stabilizer.

The effect of the additives on the laterite MDD shows an increase as shown in Table 5 and 6 and Fig 4-9 which can be linked to the additional water needed to enable the pozzolanic soil-additives reactions necessary for the stabilization process [10]

The increase in the MDD can be seen as a result of the increasing additive particles that were ready to perform the exchange of cations with the soil particles, thus filling up the voids spaces and densely packing the soil particles together [1].

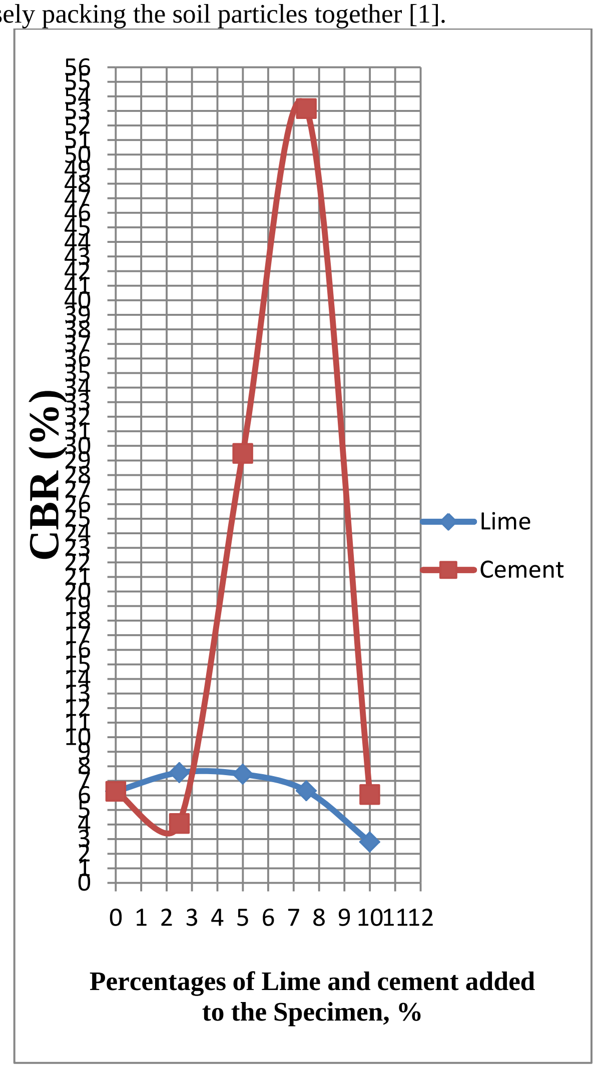

Figure 10 Graphical Comparison between the CB values of Lime and Cement additives

Decreases in density are directly attributed to the flocculation/aggregation and the formation of weak cementitious products, as flocculation/aggregation of the soil offers greater resistance to densification at a given level of compactive effort resulting in the reduction of MDD.

Decrease in OMC as was attributable to the absorption capacity of the stabilizer due to its porous properties, Increase in OMC as in table 6 can be attributed to the hydration effect and the affinity for more moisture during the modification process.

California Bearing Ratio

The CBR values of the soil sample increases from 6.26% to

53.16% with cement additive while the maximum value for CBR attained is 7.57% at 2.5% lime addition. The considerable increase in strength with cement is due to the binding action of high percentage cement, causing a considerable increase in the cohesion of the silt and clay particle within the sample. The opinion of Watson [13] revealed that lime will only be effective with materials which contain enough clay for a positive reaction to take place and that attempt to use Lime as a binding material will not be successful.

CONCLUSION

The following conclusions are drawn from the present study:

- The engineering properties of the natural lateritic soil sample show that sample is classified as A-2-4 (0) according to the AASHTO Unified Soil Classification system, ratified as ASTM D2487.
- The Atterberg's' limit test also shows that the addition of both cement and lime reduces the plasticity indices of the sample which are indicators of soil improvement.
- The maximum dry densities of the cement-stabilized soil reduced at 2.5% and then later increases at 5% and 7.5% but reduced at 10% while the maximum dry densities of the lime-stabilized soil reduces as the percentage addition of lime increases and it was maximum at 2.5%.
- It is also observed that the California Bearing Ratio increases with increase in Cement addition but was noticed to have optimum strength at 7.5%, causing a considerable increase in the cohesion of the silt and clay particles within the sample. However, Lime shows a little increase in the CBR strength due to the presence of minimum clay content as shown in the particle size distribution and has the maximum strength at 2.5%.

RECOMMENDATION

Based on the result of the laboratory, these recommendations are made

i. Cement is a suitable treatment additive for lateritic soil having high percentage of sand particularly when added in percentages between 5% and 7.5% in extreme cases of high water infiltration. However, lime is suitable for treating lateritic soil with high clay and silt contents.

ii. More samples having high content of clay can be collected and treated with lime and cement to improve the engineering properties of the soil in order to affirm the (i) above.

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