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Stabilization of Lateritic Soil Using Hydrated Lime and Calcium Carbide Residue

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ABSTRACT
Soil stabilization means alteration of the soils properties to meet the specified engineering requirements. Hydrated lime and calcium carbide residue were used to stabilize lateritic soil collected from a location in Maikunkele suburb of Minna, Niger State. The two additives were proportioned 0%, 5%, 10%, 15%, and 20% of dry weight. From the results, the soil is classified as A-2-4 (0). The maximum dry density reduced with increase in the lime content and for Calcium Carbide content at 5% and 20% but increases at 10-15%. Also, the optimum moisture content increased for increasing lime content and reduced with higher lime content. The combination of hydrated lime and calcium carbide residue increased the CBR from 30% to 136%, and UCS from 475 kN/m^2 to 2803 kN/m^2 after 7 days curing. The optimum strength of stabilized soil was obtained at 15% hydrated lime and 10% calcium carbide residue addition respectively. The use of calcium carbide residue and hydrated lime will provide an effective way of disposing the former and lead to in road construction.

Keywords: *Admixtures, Calcium carbide residue, California bearing ratio, Hydrated lime, Stabilization.*

1 INTRODUCTION

Laterite is both a soil and a rock type rich in iron and aluminum and is commonly considered to have formed in hot and wet tropical areas. Nearly all laterites are of rusty-red coloration, because of high iron oxide content. They developed by intensive and prolonged weathering of the underlying parent rock. Tropical weathering (laterization) is a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. The majority of the land areas containing laterites are between the tropics of Cancer and Capricorn (Wikipedia.org)

Laterite has commonly been referred to as a soil type as well as being a rock type. This and further variation in the modes of conceptualizing about laterite (e.g. also as a complete weathering profile or theory about weathering) has led to calls for the term to be abandoned altogether. At least a few researchers specializing in regolith development have considered that hopeless confusion has evolved around the name. Material that looks highly similar to the laterite occur abundantly worldwide (Bourman, 1993).

Stabilization of soil is the process of changing one or more soil properties through mechanical or chemical means, to produce soil with improved and desired engineering properties. According to the American Society for Testing and Materials (ASTM), the main purpose of soil stabilization includes increasing the strength of an existing soil to enhance its load bearing capacity, permeability improvement and enhancement of soil resistance to the process of weathering and traffic usage among others ASTM (2014). Soil stabilization achieves a number of objectives that are important in obtaining a long-lasting structure from locally available earth materials, including better mechanical characteristics; better cohesion between particles which reduces the porosity and changes in volume due to moisture fluctuations; and improved resistance to rain, wind, and erosion. Soil stabilization techniques include mechanical, physical and chemical stabilization. The choice of building materials in the society has been influenced by availability and cost (Sergio, 2008). As a result of the high cost of construction materials in most developing countries, owning a house is relatively difficult. In order to solve this problem, it is necessary to explore new ways of producing building materials from locally available materials at low cost. Laterite soil consists of high plastic clay; the plasticity of soil may cause cracks and damage on building foundations, pavement, highway or any other construction projects. It is therefore important, to understand the behavior of laterite soil and thus figure out the method of soil stabilization. In this research, hydrated lime and calcium carbide was used as the stabilizing agents for the soil.

Lime stabilization technology is an attractive stabilization technique most widely used in geotechnical and geo-environmental applications when the project requires improvement of the local soil. Bell (1996) reported that many types of lime has been successfully used as soil stabilizing agents for many years. However, the most widely used and best performing limes in soil stabilization is the quicklime (CaO) and hydrated ($Ca(OH)_2$) lime. While both quick and hydrated limes are capable of providing calcium ions (Ca^{2+}) in sufficient amount, the primary ingredient necessary for stabilizing clay soil, differ slightly in the mode of reaction in the presence of water (Chou, 1987).

Engineering properties of lateritic soil

Geotechnical characteristics and performance of lateritic soils as well as their reactions to different stabilizing agent may be interpreted in the light of all or some of the following parameters;

i. Genesis and pedological factors (parent material, climate, topographic. vegetation. period of time in which the weathering process have occured).
ii. Degree of weathering (decomposition, sesqioxide enrichment and clay size content, degree of leaching)
iii. Position in the topographic level
iv. Depth of soil in the profile

Particle Size Distribution

This may provide the following information

i. The Compatibility Characteristic
ii. Permeability
iii. A rough idea of information characteristic of the soil mass. Texturally laterites soils are very variable and may contain all fraction, Sizes, boulders, cobbles, gravel sand, silt and clay as well as Concretionary rocks. Quarzitic gravels, which are formed from the alteration of quartz rich parent - rocks, one generally well graded with 20% of silt and clay size fraction. Concretionary laterites have a higher content of fines ranging between 35% to 40% (Charman, 1988).
iv. Swellability

2 METHODOLOGY

Lateritic Soils

The soil sample was collected from a borrowed pit, packed in a polythene bags, test was carried out on it in the laboratory, shake through mechanical sieve shaker machine before each soil retained was weighed and recorded.

Lime and Calcium carbide

Lime was purchased in the local market and Calcium carbide from a welder located at the mechanic village in Maikunkele, Local Government area of Minna.

Soil Sample Preparation

The physical properties of lime and Calcium carbide used were different, adding the additives is to identify the effect of constituents, changes that occur in the soil properties texture and water content of the sample. It was dried in the open air, and grinded into fine particles, and was made to pass through the B.S sieves.

2.1 Subsection

Determination of Engineering Properties of collected sample

To determine the effect of chemical stabilizers on lateritic soils, tests were carried out on the laterites in accordance to BS 1377. Sieve analysis, Compaction, Atterberg limit test and California bearing ratio test was carried out.

Laboratory experiments on samples

The laboratory experiments were conducted in accordance with B.S 1377 (1990). The engineering properties of the soil were determined using percentage of admixtures ranging from 0% 5% 10% 15% and 20% respectively.

3 RESULTS AND DISCUSSION

The results of the sample collected are represented in the tables and charts.

Sieve Analysis

The result of sieve analysis of the sample is presented in Chart 1 and Figure 1. It shows the percentages by mass, of soil passing and soil retained.

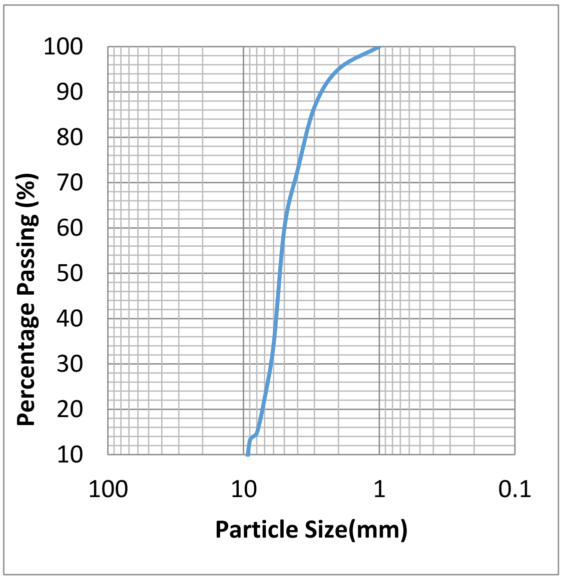

Figure 1: Sieve Analysis

Table 1: Sieve Analysis for Natural Soil

Sieve Size (mm)	Mass Retained	% Retained (%)	Cum Retained (%)	%Passing (%)
5	54	18	18	82.0
3.35	24	8.0	26	74.0
2.36	19.20	6.40	32.4	67.6
2.0	13.70	4.57	36.97	63.03
0.85	11.10	3.70	40.67	59.33
0.60	8.2	2.73	43.07	56.93
0.425	5.1	1.70	45.10	54.90
0.30	5.70	1.90	47.0	53.0
0.15	4.40	1.47	48.47	51.53
0.075	2.1	0.70	49.17	50.83

Atterberg Limits

Summary of Atterberg test carried out for liquid limit, plastic limit and plasticity index are presented in Table 2 and 3 and Figure 2, based on the percentage replacement by mass at 0%, 5%, 10%, 15% and 20%

Table 2: Atterberg limits test from 0% - 20% Lime

Lime Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
0	46.8	31.7	15.50
5	49.5	34.86	14.84
10	51.0	37.32	13.90
15	55.6	42.94	12.88
20	55.4	42.80	11.50

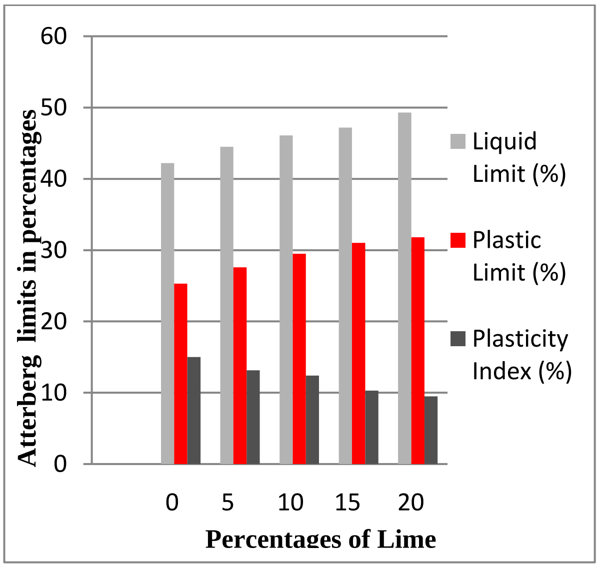

Figure 2: Atterberg Limit test for 0 - 20% Lime

Table 3: Atterberg limits of samples with 0% - 20% Calcium carbide residue

Calcium Carbide (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
0	42.20	25.30	15.50
5	44.50	27.60	13.15
10	46.10	29.50	12.40
15	47.20	31.02	10.30
20	49.30	31.80	9.50

Tale 4: MDD of samples with 0-20% Lime and Calcium Carbide residue

Additives (%)	MDD (g/cm^3) Lime	MDD (g/cm^3) Calcium Carbide
0	1.95	1.95
5	1.94	1.97
10	1.98	1.94
15	1.93	1.99
20	1.90	1.91

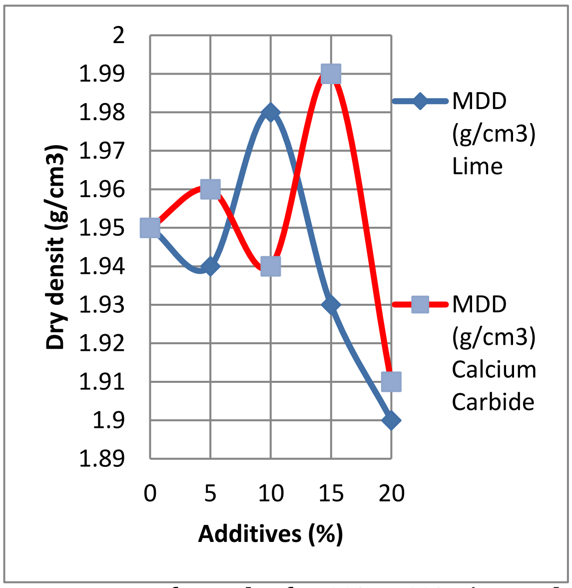

Figure 3: MDD of samples for 0% - 20% Lime and Calcium carbide additives

Table 5: Optimum moisture contents of samples stabilized with 0 - 20% additives

Additives (%)	OMC (%) Lime	OMC (%) Calcium Carbide
0	24.10	24.10
5	27.88	26.7
10	28.12	21.5
15	23.00	25.0
20	29.10	28.33

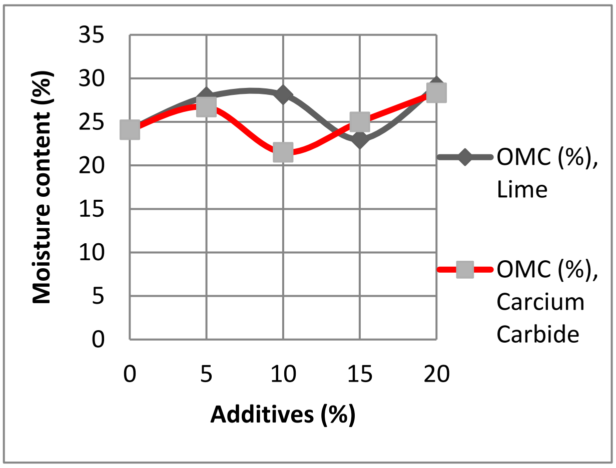

Figure 4: Moisture content of soil stabilized with for 0% - 20% Lime and Calcium Carbide

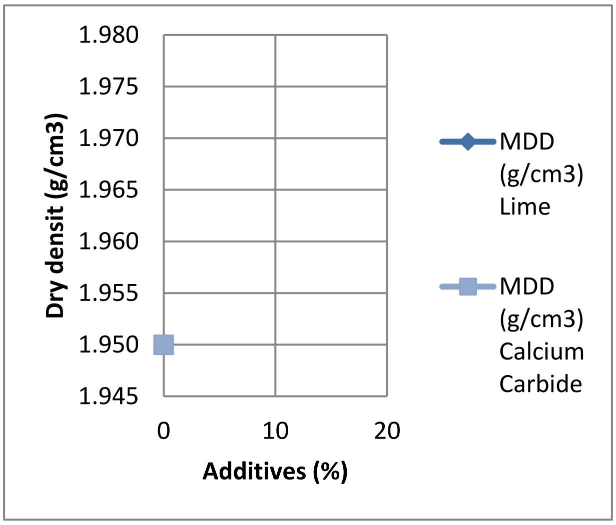

Figure 5: Dry density of soil stabilized with 0% Lime and Calcium Carbide

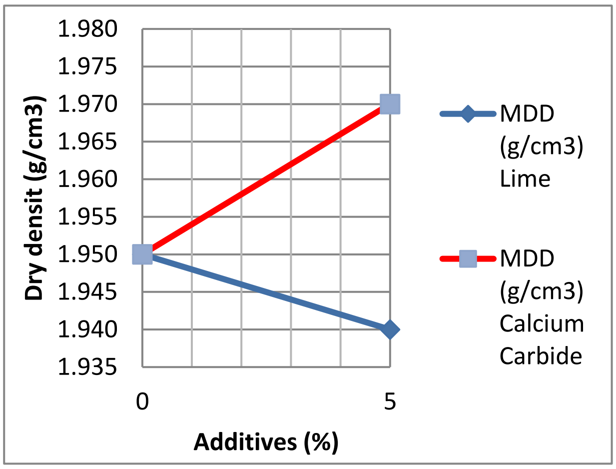

Figure 6: Dry density of soil stabilized with 0% - 5% Lime and Calcium Carbide additives

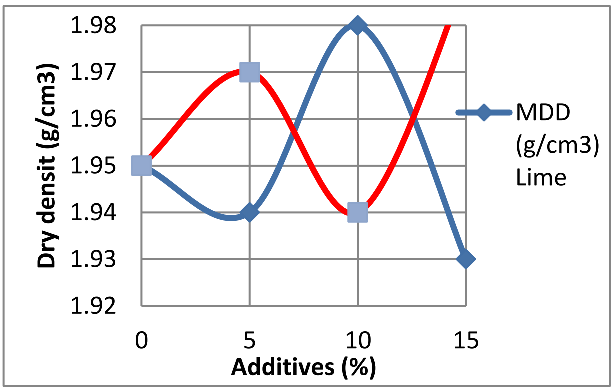

Figure 7: Dry density of soil stabilized with 0% - 10% Lime and calcium carbide

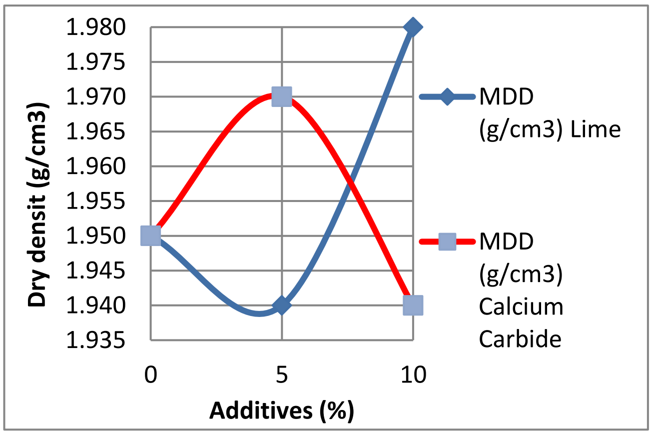

Figure 8: Dry density of soil stabilized with 0% - 15% Lime and Calcium Carbide

California bearing ratio (CBR)

The lateritic soil was stabilized with Lime and Calcium Carbide with percentage replacement by mass at 0%, 5%, 10%, 15% and 20% for both Lime and Calcium Carbide. Hence, the results are represented in the Tables 6-8 and Figure 9.

Table 6: California Bearing Ratio of samples stabilized with Calcium Carbide

Calcium Carbide (%)	0	5	10	15	20
CBR (%)	29.9	18.2	50.4	62.5	60.3

Table 7: California Bearing Ratio of samples stabilized with Lime

Lime content (%)	0	5	10	15	20
CBR (%)	29.9	42.2	58.3	91.1	82.8

Table 8: California Bearing Ratio of samples stabilized with Lime and calcium carbide residue

Lime content (%)	0	5	10	15	20
CBR (%)	30	55	85	145	121

Particle size distribution

The test was carried out to determine the particle size distribution of the soil as the sieves were arranged in descending order. The percentage by mass of sample passing through ASTM sieve No. 200 is greater than 35%, therefore making the sample a fine grained soil.

Atterberg Limits

Varying percentages of Lime and Calcium Carbide at 5%, 10%, 15% and 20% to the samples, cause changes in the liquid limits and plastic limits of the soil. The plasticity index decreased from 15.50% to 11.50% for lime, while 15.50% to 9.50% for Calcium Carbide respectively.

As the lime and Calcium carbide is added to the soil, there is an increase in liquid limit and plastic limit with decrease in plasticity index.

Compaction Test

For unstabilized sample, the optimum moisture content (OMC) is 24.10% with maximum dry density (MDD) of 1.96g/cm^3. The addition of lime at 5%, 10%, 15% and 20% by weight of sample increased the optimum moisture content from 24.10% to 29.10% for lime and 24.10% to 28.33% for calciuin carbide residue. A change which occurs down in dry density might be due to the particle size and specific gravity of the soil and the stabilizer.

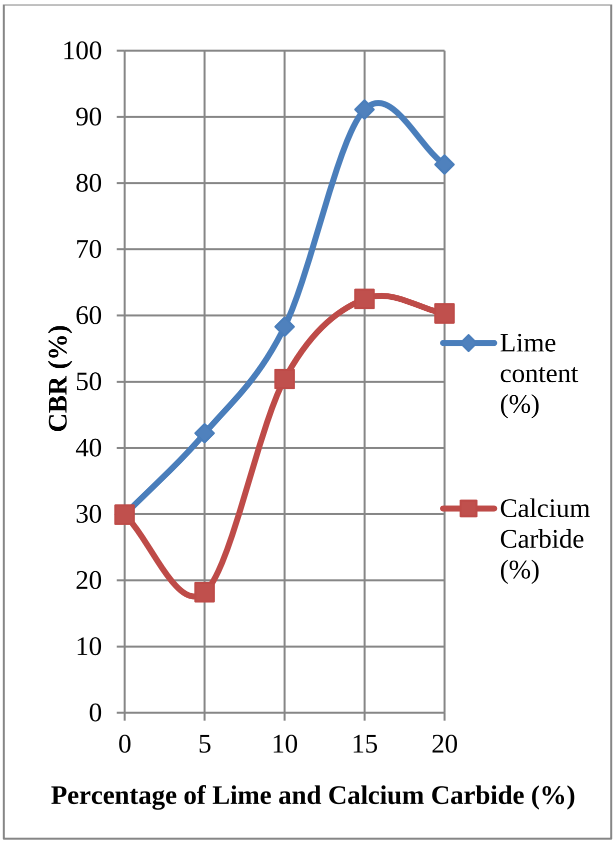

Figure 9: CBR of soil stabilized with Lime and Calcium Carbide residue

California Bearing Ratio

Results of CBR test of the soil sample increases from 29.9% to 62.5% at 15% of Calcium Carbide additive while the maximum value for CBR attained is 91.1% at 15% lime addition. The high percentage with Calcium Carbide causes increase in strength binding action of the additive.

4 CONCLUSION

The following conclusions were drawn from the study:
The Atterberg limit test shows that the addition of lime and Calcium Carbide reduces the plasticity index of the sample.

The maximum dry density of the Calcium Carbide stabilized soil reduced at 5% and then later increases at 10% and 15% but reduced at 20% however, maximum dry density of the lime content reduces as the percentage of lime addition increases, but maximum at 10%.

The Maximum dry density (MDD) shows an increase with higher compaction effort. It shows that as the percentage of Calcium Carbide increases, there is an increase in strength California Bearing Ratio curve with increase in optimum value at 15%. Therefore, Lime also shows an increase in the CBR curve and has the maximum strength at 15%.

The combination of hydrated lime and calcium carbide residue increased the CBR from 30% to 136%, and UCS from 475 kN/m^2 to 2803 kN/m^2 after 7 days curing. The optimum strength of stabilized soil was obtained at 15% hydrated lime and 10% calcium carbide residue addition respectively.

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REFERENCES

ASTM Standards on Soil Stabilization with Admistures. (2nd ed.). (2014, 03 23).
Bell, F.G. (1996). Lime Stabilization of clay minerals and soils. *J. Eng Geol, 42*, 223-237.
Bourman, R.P. (1993). Perennial problems in the study of laterite: A review. *Australian Journal of Earth Sciences*, 40 (4): 387–401.
B.S 1377, (1990). British Standard Institution Method of testing soil for civil Engineering purpose.. 84-108.
Charman, J.H. (1988). Laterite in road pavements. 8-17, 28-41.
Chou, L. (1987). Lime stabilization: reaction, properties, design and construction. State of Art Report and Transportation Research Board, Washing, DC.
Gidigasu, M.D. (1976). Laterite, soil engineering, development in geotechnical engineering. *9*, 420-477.
https://en.wikipedia.org/wiki/Laterite
Kogbe, C.A. (1975). Geology of Bigeria. The Elizabethan Publishing Co., Lagos, 332-338.
Lambe, T.W. (1965). Soil Testing for Engineers. John Wiley andSons Inc., London, 15-43.
Norton, H.J. (2000). Understanding Pottery Techniques. New York Studio Vista Publiisher, 102-115.
Oates, J.A. (1998). Lime and Limestone - Chemistry and Technology, production and Uses.
Osadebe, N. and Nwakonobi T.U. (2007). Structural Characteristics of laterized concrete at optimum mix proportion,. *Nigerian Journal of Technology, 26(1)*
Sergio, M. (2008). Available technologies for local buiding materials. 2.
Rajput, R.K. (2002). Engineering Materials (Including Construction materials). 71-142.
whitting, D.B. (2000). Pressure Acid Leaching of Nickel Laterites: A Review. Mineral processing and Extractive Metallurgy Review. *21(6)*, 527-599.
Witt, K.J. (1983). Permeability-anisotropy due to particle shape. *Journal of Geotechnical Engineering, 9*, 109.