2nd International Civil Engineering Conference (ICEC 2020)
Department of Civil Engineering
Federal University of Technology, Minna, Nigeria

Laboratory and Field Experimentation on the Use of Cement and Calcium Carbide Residue for Stabilization of Reddish Residual Soil

*** Kafinta, U.G[1], Alhaji, M. .M[2] and Alhassan, M[2].**
[1]Ministry of works and Infrastructure Development, Minna, Niger State
[2]Civil Engineering Department, Federal University of Technology, Minna, Nigeria
*Corresponding author email: kafintaumar@gmail.com

ABSTRACT
A fine lateritic soil collected at Lapai-Gwari along Talba farms, Niger State, Nigeria, was collected using the method of disturbed sampling. The soil was characterized and treated with cement and calcium carbide residue (CCR). The untreated lateritic soil and lateritic soil treated with 2, 4 and 6% cement which was admixed with 0, 2 and 4% CCR each. Compaction tests and California Bearing Ration (CBR) tests were carried out in the laboratory to evaluate the laboratory MDD and OMC as well as the laboratory CBR. The soil was divided in to category A (soil treated with cement and 2% CCR), category B (soil treated with 4% cement alone) and category C (soil treated with 4% cement and 2% CCR). These three categories of soil mixtures were constituted with their predetermined moisture contents and place on a road at three different sections (A, B and C). A light weight roller was used to compact the soil mixes at 30cm thick lifts. The roller was allowed enough passes until the laboratory predetermined MDD was achieved. In-situ dry densities were evaluated using sand replacement method while in-situ CBR was evaluated using dynamic cone penetration (DCP) tests after 1 day, 7 days, 14 days, 28 days, 60 days and 90 days. Result revealed that laboratory MDD and In-situ densities were observed to be in agreement. However, the laboratory CBR and field in-situ CBR showed wide differences. The in-situ CBR values were observed to increase with increase in curing days which confirms the action of the chemicals used in the stabilization.

Keywords: *calcium carbide residue, cement, laterite, stabilization.*

1.0 INTRODUCTION

The treatment of laterite to make them suitable for use as road building material is an age long practice, normally carried out with the aid of stabilizing agents. Stabilizing agents are additives used to initiate reactions that help improve the strength properties of soils. Common traditional stabilizing agents include cement, lime and bitumen (Ingles and Metcalf, (1992). Laterite is a common construction material available in almost all the countries of the humid tropics of the world. It is a soil group commonly found in the leached soils of the humid tropics and is formed under weathering systems that cause the process of laterization (Gidigasu et al, 1976). Laterite is one of the most common borrow material that is stabilized and used in the construction of different layers of flexible pavement (Ola 1983).

Lateritic soils are soils that are composed almost entirely of iron and aluminium oxides; they are usually reddish in colour and are the least soluble product of rock weathering in tropical climates (Thagesen, 1996). They are formed in regions of high temperature and abundant rainfall, where the soils are highly leached as common in the tropics (Okafo et al., 2009). Lateritic soils are very important in the construction industries as construction material and foundation support for engineering structures (Nwankwoala and Amadi, 2013). Almost all laterites are rusty-red coloration, because of high iron oxide content they develop 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 (tardy,1997).

Laterite is defined as the products of tropical weathering with red, reddish brown, and dark brown colour,with or without nudules or concreting and generally but not exclusively found below hardened ferruginous crust or hard pan, (Ola, 1983).

Laterite soils are formed in hot, wet tropical regions with an annual rainfall between 750mm to 3000mm, usually in area with a significant dry season on a variety of rocks with high iron content (Bell, 1993). Laterite is a group of highly weathered soils formed by the concentration of hydrated oxides of iron and aluminium (Thagesen, 1996). Laterite is found mainly but not exclusively, as a residual weathering production partially or totally decomposed basalts and other basic to intermediate igneous rocks (Ford 1989). Nigeria is among the countries blessed with vast deposit of laterite, which isresidual in nature and one of the cheapest materials for road construction (Umar and Elinwa 2005). However, not all deposits of laterite are suitable for use as base and sub-base materials in their natural state. Treatment with additives is normally required before such laterite can attain the desired properties (Umar and Elinwa 2005).

Soil stabilization is the method of improving soil properties by adding suitable stabilizers to it. It is very important to achieve the required strength for the soil especially in road construction project where an unsuitable base can lead to sudden failure of road (Garber, 2000). Soil stabilization is defined as the alteration of any property of a soil to improve its engineering performance. It can be done manually, mechanically or chemically depending on the type of material to be stabilized (Murthy, 2012). Soil stabilization can also be described as the treatment of natural soil to improve its engineering properties (Garber and Hoel, 2000). In general, soil stabilization is the process of creating or improving certain desired properties in a soil material so as to render it useful for a specific purpose.Lime and cement have been meaningfully used for soil stabilization and improvement (Rields and Brooks, 1999).Improvement in soil properties treated with cement has been attributed to the hydration reaction of cement, while changes in properties of soil associated with the use of lime can be attributed to the cation exchange, Pozzolanic and carbonation reactions of lime.(Rields and Brooks, 1999).

A number of researches have been made on utilization of locally-available waste materials to stabilize laterite for construction purposes such as bagasse ash, rice husk ash, locust bean pod ash, and sugarcane straw ash mixed to stabilize laterite (Osinubi et al, 1999).Researchers have shown that utilization of wastes has resulted in considerable savings in construction costs as well as improvement in the engineering properties of thesoil (Umar et al, 2005).Lateritic soils are in many cases classified as fair to poor clayey soil or exhibit unstable properties. This has led to the development of soil stabilization techniques which could alter the physical and engineering properties of the soil thereby improving such properties (Onyelowe and Okafor 2012). The use of calcium carbide residue waste in addition with cement and any other pozzolanic materials, have been studied by researchers (Horpibulsuk et al, 2013; Isah and Sharmila, 2015; Akinwumi et al, 2019; Joel and Edeh, 2014; Bandyopadhyay et al, 2016; Liu et al, 2018). All these studies were carried out at laboratory stage to evaluate the potential use of calcium carbide residue as stabilizing material. This study is intended to study the laboratory and field performance evaluation of calcium carbide residue (CCR) and cement forlaterite soil stabilization.

1.1 Test Location

The laboratory aspect of this study was carried out in Civil Engineering Department, Federal University of Technology, Minna, Nigeria. The In-situ field test was conducted on an access road between central workshop and Civil Engineering laboratory at Federal University of Technology, Minna, Nigeria, leading to Agricultural Engineering workshop. The first 200m of the road has earlier been constructed and paved with concrete while the next 100m of the road has also been paved with laterite stabilized with cement and reclaimed asphalt pavement. The remaining 400m section of the road has been left unpaved and is undergoing rapid erosion.

2.0 METHOD OF EXPERIMENTATION

2.1 Laboratory Tests

A substantial amount of lateritic silty soil was collected from a borrow pit at Lapai-Gwari using Tipper Lories. These soils were deposited close to the target road as shown in figure 1. Large amount of CCR was then collected from local welders, dried, pulverized and sieved through British Standard sieve 0.075mm before use.

Figure 1: Lateritic soil dump

Figure 2: Calcium carbide residue

Figure 3: Compaction test

Index properties tests were carried out on the untreated lateritic soil at Civil Engineering Laboratory, Federal University of Technology, Minna, Nigeria while microstructural tests were carried out on both the untreated lateritic soil and the CCR at Cape town, South Africa. Compaction tests were carried out on the untreated lateritic soil and lateritic soil mixed with varied composition of cement and calcium carbide residue (CCR).

Figure 4: California bearing ratio (CBR) test

The resultant compaction characteristics were used to mould California Bearing Ratio (CBR) specimen for CBR tests.

2.2 Field Tests

The field test was carried out on the remaining section of the road described above with 7.5m width and 15m length. The first 5.0m length was treated with 4% cement alone, the second 5.0m length was treated with 4% cement and 2% calcium carbide residue (CCR) while the third section was an untreated section. These sections were demarcated with wooden plank and the soil was manually mixed dry with the chemical after which predetermined amount of water was added.

(a)

(b)

Figure 5: Field Compassion

The constituted soil materials were then placed in appropriate positions in 30cm lift and compacted with a light roller. The roller was allowed enough number of passes until the predetermined MDD

Figure 6: Dry mix of soil, cement and CCR

Figure 7: Compaction with light roller

Compaction with light roller was achieved through the use of repeated in-situ density tests. Another 30cm thick soil was placed on top of the initially compacted surface and soaked with appropriate amount of water. The surface was then compacted to predetermined MDD with smooth surface finish.

In-situ density tests using sand replacement method and in-situ CBR tests using dynamic cone penetration (DCP) tests were conducted on the finished surfaces after 1, 7, 14, 28, 60 and 90 days of curing.

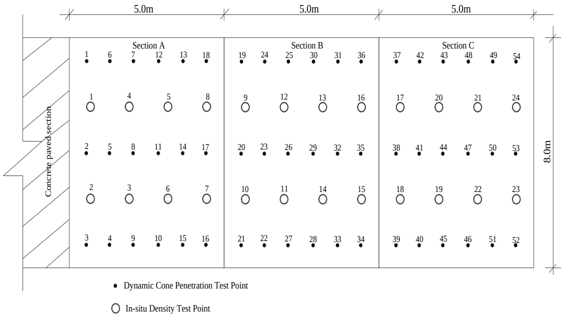

Figure 8: Field test points on sections (A, B &C)

Three dynamic cone penetration tests are carried out on each testing day while two in-situ density tests are carried out on each testing day. This is to obtain averages for each of the tests.

3.0 RESULTS AND DISCUSSION

3.1 Index Properties Test

The results of the index properties test of the untreated lateritic soil is shown in table 2. From the table,

Table 1 Summary Result of Index Properties of Natural Soil

Property	Quantity
Moisture Content (%)	17.94
Maximum Dry Density (g/cm3)	1.82
Percentage passing BS 0.075mm (%)	74.77
Liquid limit (%)	49.49
Plastic limit (%)	31.22
Plasticity Index (%)	18.27
California Bearing Ratio (CBR) % Unsoaked	34.77
Specific Gravity	2.43
AASHTO Classification	A-7-6
Colour	Reddish-brown
Unified soil classification system (USCS)	CL

The soil classified as clay of low plasticity according to unified soil classification system and A-7-6 according to AASHTO soil classification system. The soil cannot be used for any component of the road structure but can be stabilized to meet the desired strength and stability.

3.2 Laboratory and Field Densities

The result of the laboratory densities is shown on table 2. The MDD decreased with increase in additives from 1.822g/cm3 at 0% additive to 1.815g/cm3 at 4% cement additive and finally, to 1.756g/cm3 at 4% cement and 2% CCR. This is probable due to agglomeration of clay particles due to the reaction of cement and the lateritic clay. The increase in OMC observed was due to more water required by cement during the reaction.

Table 2: Summary of Laboratory MDD & OMC

ADDITIVES	MDD	OMC
0% additive	1.822	17.94
4% cement	1.815	19.47
4% cement + 2% CCR	1.756	18.36

Figure 9: In-situ density test using the method of sand replacement

The field densities were determined using the method of sand replacement as shown on figure 6. The results of the tests are shown on table 3. The trend showed increase in dry densities with increase in curing days and general reduction in moisture content with increase in curing days.

Table 3: Summary of field in-situ densities test

Section of the road	Day	MDD	OMC
A 4% Cement+ 2% CCR	1	1.596	8.56
	7	1.712	3.51
	14	1.781	5.77
	28	1.786	10.42
	60	1.645	13.30
	90	1.615	15.54
B 4% Cement	1	1.545	7.56
	7	1.719	4.57
	14	1.784	4.72
	28	1.788	9.72
	60	1.650	11.50
	90	1.550	14.45
C 0% Additive	1	1.516	4.96
	7	1.728	4.60
	14	1.737	4.52
	28	1.766	8.66
	60	1.590	11.89
	90	1.427	12.88

3.3 Laboratory and Field CBR Values

The laboratory CBR was carried out based on the method highlighted in BS 1377 (1992). The CBR results are shown on table 4. The values were averages obtained from the top and bottom of each CBR specimen.

Table 4: Summary of Laboratory CBR test

Composition	Average CBR
0% Additive	35.0
4% Cement	141.0
4% Cement + 2% CCR	188.0

Results showed that the unsoaked CBR values increased from 35% for the untreated soil to 188% for the soil treated with 4% cement and 2% CCR. This represents 4.4 times increase in CBR on addition of 4% cement and 2% CCR.

Figure 10: Dynamic Cone Penetration test on Finished Road Surface

The field CBR was determined using dynamic cone penetration test as in figure 7 where the number of blows for 10cm penetration were converted to CBR using the relationship giving as:

Log (CBR) = 2.46 – 1.2 Log (PI)
1

Where PI = Penetration index (mm/blow).
The result of the in-situ CBR are shown on table 5

From table 5, category A which is the untreated soil surface recorded lower in-situ CBR of between 12.9% after 1day curing to 24.2% after 60 days of curing. Category A is the soil treated with 4% cement and 2% CCR. The higher values of between 17.4% to 38.2% were recorded for soil within category A. The higher in-situ CBR compared to category B and C is due to the reaction of cement with the soil to bond the soil particles together

Table 5: Average number of blows on compacted surface with varied curing time.

Section of the road	Curing Time (days)					
	1 day days	7days	1 days	28days	60days	90
Section A	3	4	5	7	7	7
	4	4	5	7	8	10
	20	23	30	30	32	36
CBR Values	**17.4**	**20.5**	**27.9**	**30.6**	**33.1**	**38.2**
Section B	3	4	5	6	7	7
	3	4	5	5	7	9
	18	21	29	30	30	35
CBR Values	**15.3**	**18.8**	**27.0**	**28.6**	**30.6**	**36.5**
Section C	2	4	3	3	4	3
	3	3	4	4	7	5
	16	18	20	23	25	24
CBR Values	**12.9 21.4**	**15.7**	**17.4**	**19.9**		**24.2**

The occurrence of CCR in this medium tends to increase the CBR values above other categories. However, the laboratory CBR values were found to be far higher than the in-situ CBR values.

4.0 CONCLUSIONS

A fine lateritic soil used in this study classified as clay of low plasticity (CL) according to unified soil classification system and A-7-6 according to AASHTO soil classification test.

The laboratory compaction densities and field densities tend to agree to large extent.

The laboratory compaction densities and field densities tend to agree to large extent.

The laboratory CBR values and In-situ CBR values differ to a large extent. However, the In-situ CBR values of the untreated lateritic soil increased marginally when threated with 2% CCR.

5.0 REFERENCES

Akinwumi, I. I., Ajayi, O. O., Agarana, M. C., Ogbiye, A. S., Ojuri, O. O. and David, A. O. (2019), Investigation of Calcium Carbide Residue as a Stabilizer for Tropical Sand Used as Pavement Material, WIT Transactions on The Built Environment, 182, 285-294

Amadi, et al (2012) Strength consideration in the use of lateritic soil stabilized with as liners and covers in waste land-fills.

B.S 1377 (1990) Method of testing soil for civil engineering purposes, British standard institution. London. UK

Bandyopadhyay, T. S., Singh, A. K. and Singh, J. P. (2016), Stabilization of Soil Using GGBS and Calcium Carbide Residue, International Journal of Innovative Research in Science, Engineering and Technology, 5 (9), 17023-17030

Bell, F.G. (1993) Engineering Treatment of soil: soil stabilization. E and FN SPON: London, UK

Ford, O.S (1999). The economic mineral resources of the benue trough. In: C.A. Kogbe (ed). Geology of Nigeria. (pp 473-484). Jos, Nigeria. Rock view.

Garber, C.F and hoel, M.F, (2000). Fundamentals of geotechnical analysis. Geotechnical Engineering 15(g), 415-422

Gidigasu, M.D. (1976). Laterite soil engineering. Elsevier Scientific publishing company, Amsterdam Oxford New York.

Horpibulsuk, S., Phetchuay, C., Chinkulkijniwat, A. and Cholaphatsom, A. (2013), Strength Development in Silty Clay Stabilized with Calcium Carbide Residue and Fly ash, Soils and Foundations, 53 (4), 477-486

Ingles OG, Metcalf JB.(1992).Soil Stabilization Principles and Practice. Boston: *Butterworth Publishers*. Pp. 24.

Isah, B. W. and Sharmila, S. M. R. (2015), Soil Stabilization Using Calcium Carbide Residue and Cocoanut Shell Ash, Journal of Basic and Applied Engineering Research, 2 (12), 1039-1044

Joel, M. and Edeh, E. J. (2014), Stabilization of Ikpayongo Laterite with Cement and Calcium Carbide Waste, Global Journal of Pure and Applied Sciences, 20, 49-55

Liu, Y., Li, Y., Tang, Q., Ye, J. and Yang, Q. (2018), Strength Properties of Remoulded Sludge Stabilized with Calcium Carbide Residue, International Journal of Engineering Research and Technology, 7 (11), 214-217,

Murthy,V.N.S (2012). Soil mechanics and foundation series, new delhi. CBS publishers

Okafor, O.F and Okonkwo, N.U, (2009). Effect of Rice Husk Ash on some Geotechnical Properties of lateritic soil, Leonardo Electronic journal of practices and Technologies. 15, 67-74

Ola SA. (1983).Tropical Soils of Nigeria in Engineering Practices. Rotterdam: *Balkema Publishers*; Pp. 18.

Onyelowe, K.C, and Okafor F.O.A, (2012). Comparative Review of Soil Modification Methods. ARPN Journal of Earth Schiences, Vol. 1, No. 2, Pp 36-41.

Osinubi, K.j. (1999). Evaluation of Admixture stabilization of Nigerian Black cotton soil. Nigerian society of engineers, Technical Transaction.Vol.34.No.3, pp.88-96.

Reid, J.M and Brooks, A.H (1999) Investigation of lime stabilized contaminated soils, Engineering Geology, 53, 217-231.

Tardy, Y. (1997), Petrology of laterites and Tropical soils. London: Research Gate Publishers.

Thagesen, B (1996). Tropical Rocks and soils in highways and traffic engineering in developing countries. London:Ed chapman and hall publishers

Umar, S.Y and Elinwa A.U (2005). Effect of iron are tallings (10T) and lime on engineering properties of problem laterite Journal of raw materials research vol.2.Nol pp186-193

Umar, S.Y and Elinwa A.U (2005). Effect of iron are tallings (10T) and lime on engineering properties of problem laterite Journal of raw materials research vol.2.Nol pp186-193.