[1.]Christopher Ajiboye FAPOHUNDA, [2.]Olugbenga O. AMU, [3.]O. J. OGUNBODE

EFFECT OF COCONUT LEAF ASH ON LIME STABILISED LATERITIC SOIL

[1.]Department of Civil Engineering, Federal University, Oye-Ekiti, NIGERIA
[2,3.]Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, NIGERIA

Abstract: This paper presents the results of the study conducted to evaluate the effect of coconut leaf ash (CLA) on lime stabilized lateritic soil. Three soil samples were collected at different points from the new Ife City Stadium, Ile-Ife, Nigeria. Preliminary tests such as natural moisture contents, particle size analysis, and specific gravity were performed on the collected soil samples at their natural states. The effects of adding Coconut Leaf Ash (CLA) at 2, 4, 6 and 8% at the optimum lime stabilization in the soil samples were examined with respect to Atterberg's limit characteristic, compaction, California Bearing Ratio (CBR) and Unconfined Compressive Strength test. The results showed that the plasticity index of sample A reduced at 6% and 8% CLA and in sample B at 2% and 8% CLA while sample C had the lowest plasticity index at 4% CLA, all at 6% optimum lime stabilization. The highest value of maximum dry density was obtained at 4% addition of CLA for all the soil samples. California bearing ratio (CBR) values decreased with increase percentage of CLA for sample A and increased significantly in sample B, while sample C has the highest CBR value at 8%. The compressive strength values of all the samples increased with CLA up to 6%. From these results, it can thus be concluded that CLA has the potential to improve the geotechnical properties of lime stabilized lateritic soils.
Keywords: Coconut leaf ash, Lateritic soil, Lime, Stabilization

1. INTRODUCTION

Lateritic soil is a type of soil, usually rusty red coloration that is abundant in the areas that lie in the hot and wet tropical regions of the world as shown in Figure 1.

These areas, as can be seen from Figure 1, include East, West and Central Africa, Indonesia, Thailand, Brazil and various island such as Hawaii and Cuba. According to Ugbe (2011), rusty red coloration that is characteristics of lateritic soils is a product of intensive weathering that occurs under tropical and subtropical climatic conditions resulting in the accumulation of the hydrated iron and aluminum oxides. Its abundance in Nigeria, for example, has promoted its use for constructional purposes, especially for road and pavement construction of all kinds.

Lateritic soil however varies in behavior due to formation, rock components, transportation, pressure, drainage, environment and other numerous factors (Arora, 2007). It has been established by many authors that most lateritic soils are poor in engineering properties (Ugbe 2011, Tan et al., 2016, Popoola et al., 2019). For example, because of high clay minerals content, lateritic soils have low bearing capacity, low strength and high plasticity in the presence of moisture (Nnoshiri and Emeka, 2017). The high plasticity especially causes cracks damage on pavement, road ways, building foundations or any civil engineering construction projects. Thus, subjection of lateritic soils to improvement methods has become necessary before use. One of the improvement methods usually adopted for lateritic soil is stabilization. Patel and Patel (2012) defined soil stabilization as a process of treating a soil to maintain, alter or improve the performance of the soil as a construction material. This usually involves the process of blending and mixing materials with a soil to improve certain properties of the soil (Ogundipe, 2013). Materials that have been used for stabilization includes cement, lime, bitumen, etc. Lime is however usually preferred to stabilize lateritic soils (Nagaraj et al., 2014 and Tan et a., 2016). Lime stabilization in particular involves two

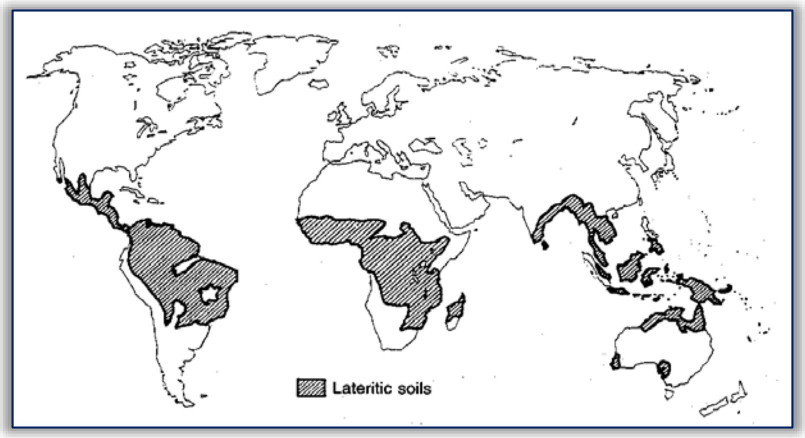

Figure 1: Distribution of Lateritic Soil (Source: Thagesen, 1996)

stages (Nnoshiri and Emeka, 2017). The first stage, which is known as immediate or short-term treatment, occurs with a few hours or days after lime is added.

Three main chemical reactions namely, cation exchange, flocculation-agglomeration and carbonation occur at this stage. The drying of wet soil and the increase of soil workability is attributed to the immediate treatment. The second stage requires several months and years to complete and is thus considered the long-term treatment. Pozzolanic reaction is the main reaction at this stage and results in the increase in soil strength and durability. According to Nnoshiri and Emeka (2017), lime may be an effective stabilizer in soils with clay content as low as 7 percent and in soils with plasticity indices below 10. In recent times, there have been concerns of potential pollution and threat to healthy environment caused by the presence of wastes (industrial and agricultural). Researchers are exploring the possibility of making these wastes fit for use for construction activities, and in particular, for soil stabilization, in conjunction with established stabilizers. The agricultural waste of coconut industry is the subject of this paper. Coconut has its scientific name as Cocos nucifera. According to Nnoshiri and Emeka (2017), this is a Spanish word from "coco", meaning 'monkey face' because the three indententations (eyes) on the hairy nut resembles the head and face of a monkey and "nucifera" means 'nut-bearing'. Coconut palm trees grow abundantly along the coastline of countries within 15° of the equators. When coconuts are harvested, coconut shells, coconut husks, coconut fibres/straw and coconut leaves, are some of the wastes that are generated.

Many researchers have worked on some of these as a potential stabilizer. For example, Nnoshiri and Emeka (2017) and Prasanna and Kumar (2017) investigated the potential of coconut shell ash as stabilizer of lime-stabilized lateritic soil. The results showed increase in CBR and UCS values and decrease in DD. They concluded that coconut Shell Ash (CSA) is an effective complement for lime stabilization in lateritic soil in the ranges of 0.4 – 0.8%. On the other hand, Popoola et al. (2019) worked on coconut shell ash (CSA) and coconut husk ash (CHA). They observed improvement in the geotechnical properties of the soil, at the dosages used for the investigation. Also, Vysakh and Bindu (2012) investigated on the combined coconut shell, leaf and husk ash (CSLHA) on geotechnical properties of soil. Their results show the addition of CSLHA improves the strength properties of soil, with the optimum dosage being 7% for pavement construction. There is however paucity of literature on the use of coconut leaf ash (CLA) as a stabilizing material. Thus, the aim of this work is to evaluate the geotechnical performance of CLA in lime-stabilized lateritic soil.

2. MATERIALS AND METHOD

— Materials

The materials used for this investigation are: laterite soil, hydrated lime, coconut leaves ash (CLA) and water. The soil samples were collected at three (3) different borrow pits at locations near new Ife City Stadium, Ile-Ife, Nigeria, and labelled respectively as sample A, B, and C. The samples were then stored in three (3) different sacks and kept away from water and sunlight in the laboratory for about two weeks for the samples to be properly air-dried. The hydrated lime, that is, calcium hydroxide $Ca\,(OH)_2$ that was used for the research was purchased from a chemical store in Ile-Ife city. Proper precautionary measures were taken during the course of this research to ensure that the lime was free from all contaminations and preserved from pre-reaction or from being moisturised before use. The amount to be used for each experiment was sieved to remove residual lumps which might have been formed during storage. Dried coconut leave was collected from Lagos Badagry beach, being a place where coconut trees are concentrated and procurement in large quantity is possible. The collected leaves were washed and later exposed to the atmosphere for sun drying, during which proper measures were taken to ensure they were free of contaminations that could alter the properties. After sun drying, the dried coconut leaves were subjected to open burning and the ash was collected for further drying in the oven at the temperature of $110^0C \pm 5$ for 24 hours in order to ensure that moisture is totally removed. Furthermore, the dried ash was sieved through a 63μm sieve in order to remove bigger sizes of ash particles and any possible impurities. Only the fine ashes passing through 63μm sieve was collected and used, in order to achieve a uniform powdery form of the samples for the research. Finally, the ash was stored in airtight container. The water used for this experiment was obtained from the tap water in the laboratory.

— Methods

In order to determine the index properties of the natural lateritic soil samples, preliminary investigations were carried out to obtain the followings: the moisture content, specific gravity, particle size distribution, Atterberg's limits, and the density. Later, engineering tests such as compaction, unconfined compression and California bearing ratio (CBR) were performed on the natural lateritic soil samples. The same engineering tests were repeated for the lime-stabilized soil samples at optimum level. Thereafter the lime stabilized soil samples were treated with coconut leaf ash (CLA) at 2, 4, 6, 8, and 10% by weight of the soil samples. Engineering properties were also performed on these lime-stabilized soils treated with various percentages of CLA. Atterberg limits tests were carried out in accordance with the British Standard Methods-BS 1377 (1990). For compaction test, the proctor standard compaction method was used which was carried out according to

BS 1377 (1990) for the purpose of determining the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils. For the CBR test, BS 1924 (1990) and the recommendation of the Nigerian General Specification, Federal Ministry of Works and Housing - FMWH (1997) were used. Also, for Unconfined Compressive Strength (UCS), the BS 1924 (1990) and the provisions of the Nigerian General Specification, Federal Ministry of Works and Housing - FMWH (1997) were adopted. For each of the mix, three specimens were prepared as stipulated by the Nigerian General Specification, Federal Ministry of Works and Housing (1997).

3. RESULTS AND DISCUSSION

— The properties of the Lateritic Soil

The results of the preliminary and engineering tests on the natural lateritic soil samples are presented in Table 1. The natural moisture contents of the collected soil samples A, B and C are 3.29, 6.46 and 9.66% respectively. The result shows that Sample A has the lowest natural moisture content while Sample C has the highest natural moisture content. The specific gravity result of samples A, B and C gave 2.381, 2.267 and 2.326 respectively as shown. The results of specific gravity for the three samples fall within the range of 2.0-2.55 which established that the samples contain halloysite minerals (Das, 2006); or close to bentonite minerals with specific gravity value of 2.34 as classified by Ventatramaiah (2006). The collected soil samples were classified using the method by American Association of State Highway and Transportation Officials (AASHTO, 1986) as A-7-6 soils which fall below the standard recommended for most geotechnical construction work (AASHTO 1986). Stabilization would therefore be required for these samples as established by Alhassan (2008). The liquid limit, plastic limit and plastic index values for sample A are 42.75, 24.09 and 18.66% respectively, Sample B has 46.80, 26.46 and 20.34% as liquid limit, plastic limit and plastic index values respectively while sample C has 54.90, 28.07 and 26.83% as respective values for liquid limit, plastic limit and plastic index. The results show that sample C exhibits the highest swelling characteristic and the most plastic material compared to samples A and B. According to Gidigasu (1973) which stated that liquid limit less than 35% indicates low plasticity, between 35% and 50% indicates intermediate or medium plasticity, between 50% and 70% high plasticity and between 70% and 90% very high plasticity. On this note, sample A and B have low plasticity while sample C belong to the intermediate class.

Table 1: Summary of the properties of natural soil samples

Properties	Sample A	Sample B	Sample C
Percentage passing BS No 200 sieve	50.60	56.60	74.80
Natural Moisture Content, %	3.29	6.46	9.66
Specific Gravity	2.381	2.267	2.326
AASHTO Classification	A-7-6	A-7-6	A-7-6
Liquid Limit, %	42.75	46.80	54.90
Plastic Limit, %	24.09	26.46	28.07
Plasticity index	18.66	20.34	26.83
Maximum Dry Density	1565	1546	1495
Optimum Moisture Content	22.20	24.00	27.80
California Bearing Ratio, %	1.20	2.00	7.30
Unconfined Compression Strength	46.04	52.27	89.99

— The Properties of Lime-stabilized Lateritic Soil

The geotechnical properties of soil samples stabilized with lime are presented in Tables 2 – 5. Table 2 shows that all the samples experienced reduction in plasticity index with the addition of lime at 6% optimum percentage. The lime helped to decrease the swelling potentials of the soil samples. It changed the structure of the soil by enlarging the particle sizes of the clay, coagulates them to silt and reducing the plastic index (Olanrewaju et al, 2011).

Table 2: Liquid Limit, Plastic Limit and Plasticity Index of Samples stabilized with Lime

Samples	% Lime Stabilisation	Liquid Limit (LL), (%)	Plastic Limit (PL), (%)	Plasticity Index (PI), (%)
A	0% 6%	42.75 45.30	24.09 31.80	18.66 13.50
B	0% 6%	48.74 50.60	26.46 31.38	22.28 19.22
C	0% 6%	54.90 54.00	28.07 38.54	26.83 15.46

Table 3: Compaction test results of samples stabilized with Lime

Sample	Unstabilized Soil (kg/m^3)	Lime Stabilized (kg/m^3)
A	1565	1576
B	1546	1608
C	1495	1524

Table 4: Unsoaked CBR values of samples stabilized with Lime

Sample	Unstabilized Soil (%)	Lime Stabilized (%)
A	1.2	5.3
B	2.0	9.6
C	7.3	8.3

Table 5: Unconfined compressive strength test results of samples stabilized with Lime

Sample	Compressive Strength (KN/m^2)	
	Unstabilized soil	Lime Stabilised
A	46.038	62.413
B	52.268	69.348
C	89.991	45.23

The results also showed increase in the dry density for all the samples in relation to samples without lime. The same trends were also observed in the results obtained for CBR and UCS values. Overall conclusion is that lime stabilization improves the geotechnical properties of all the soil samples.

— **The Properties of Lime-stabilized Lateritic Soil with CLA**

The results of the geotechnical investigations of lime-stabilized lateritic samples with different percentages of CLA are presented in Tables 6 – 9. Sample A had its lowest PI value at 8% CLA (12.87%) which is less than the value obtained (13.5%) when stabilized at optimum lime only, sample B had its lowest PI value at 8% CLA (16.57) which also less than the value obtained (19.22%) when stabilized with lime only and sample C has its lowest PI value at 2% CLA but more than the value obtained (15.46%) when stabilized with lime only. It can be concluded that samples A and B showed significant improvement with the addition of CLA on the lime stabilized samples while sample C did not.

Table 6: Atterberg's limits results for Lime-stabilized lateritic samples with CFA.

Samples	% CLA Stabilisation	Liquid Limit (LL), (%)	Plastic Limit (PL), (%)	Plasticity Index (PI), (%)
A	0%CLA	45.30	31.80	13.50
	2%CLA	44.20	26.07	18.13
	4%CLA	46.20	32.46	13.74
	6%CLA	47.70	34.65	13.05
	8%CLA	44.82	31.53	12.87
	10%CLA	47.90	28.70	19.20
B	0%CLA	50.60	31.38	19.22
	2%CLA	50.00	32.55	17.45
	4%CLA	55.40	34.94	20.46
	6%CLA	49.20	29.99	19.21
	8%CLA	48.30	31.73	16.57
C	0%CLA	54.00	38.54	15.46
	2%CLA	44.20	26.07	18.23
	4%CLA	54.40	40.15	18.25
	6%CLA	59.56	40.16	19.40
	8%CLA	60.00	37.97	22.03
	10%CLA	69.10	40.19	19.91

Table 7: Compaction Results for Lime-stabilized lateritic Samples with CLA

Samples	Percentage Stabilisation	Optimum Moisture Content (%)	Maximum Dry Density (Kg/m^3)
A	0 % CLA	26.0	1576
	4 % CLA	23.5	1584
	6 % CLA	24.5	1523
	8% CLA	26.8	1558
	10 % CLA	27.0	1500
B	0 % CLA	23.0	1608
	4 % CLA	23.6	1644
	6 % CLA	24.2	1558
	8% CLA	24.0	1558
C	0 % CLA	27.2	1524
	4 % CLA	28.2	1482
	6 % CLA	30.0	1483
	8% CLA	28.5	1482

The effects of CLA on the compaction characteristics of the soil samples are shown in Table 7. The addition of CLA into the lime-stabilized lateritic soil for sample A shows a decrease in OMC to 23.5% but a gradual increase occurred with more percentages of CLA. The same trend was observed in samples B and C, except that the highest OMC was noticed at 6% addition of CLA. The increased in OMC actually followed the trend recognized by Jha (2006) as due to the pozzolanic nature of CLA, requiring more water to react with and form molecules with the soil while the general decrease in the MDD can be attributed to the replacement of the soil by CLA which has lower specific gravity compared to that of the soil (Osinubi and Steven, 2006) as reflected in sample A, B and C. The CBR values resulting from this study are presented in Table 8.

Table 8: Unsoaked CBR Results for Lime-stabilized lateritic Samples with CFA

Samples	Percentage Stabilization	Unsoaked CBR Values (%)
A	0 % CLA	5.3
	4 % CLA	4.3
	6 % CLA	4.0
	8 % CLA	3.0
B	0 % CLA	9.6
	4 % CLA	8.2
	6 % CLA	8.8
	8 % CLA	10.1
C	0 % CLA	8.3
	4 % CLA	8.8
	6 % CLA	6.7
	8 % CLA	9.8

The unsoaked CBR values of sample A reduced to 4.3, 4.0 and 3.0% with the introduction of CLA in 4, 6 and 8% to the lime stabilized sample. The same trend initially presented in samples B and C except that at 8% addition of CLA, unsoaked CBRs of the two samples increased significantly. It thus follows that CLA can significantly increase the CBR values of some lime stabilized samples at around 8% addition of CLA.

Table 9: Compressive strength Results for Lime-stabilized lateritic Samples with CFA

Sample	Percentage Ash	Compressive Strength (KN/m^2)
A	0% CLA	62.41
	4% CLA	77.48
	6% CLA	63.67
	8% CLA	101.03
B	0% CLA	69.35
	4% CLA	59.15
	6% CLA	57.41
	8% CLA	70.11
C	0% CLA	45.23
	4% CLA	99.17
	6% CLA	106.97
	8% CLA	114.16

The results of unconfined compression strength (UCS) are presented in Table 9. The addition of 4, 6 and 8% percentages of CLA consistently increased the UCS of the lime stabilized sample C from the initial 45.23kN/m^2 to 114.16kN/m^2. Samples A and B also recorded improvements in their UCS at 8% additions of CLA. This is connected with the fact that the addition of CLA resulted in increased pozzolanic activities. These pozzolanic activities resulted in the formation C-S-H gel which has been known to be responsible for strength development in cement-based composites (Shetty, 2008, Neville, 2011).

4. CONCLUSIONS

From all these results above, it can thus be concluded that CLA has the potential to improve the geotechnical properties of lime stabilized lateritic soils.

References

[1] Alhassan, M. Potential of Rice Husk Ash for Soil Stabilization. AU Journal of Technology, 71(4), pp. 246-250, 2008.
[2] Arora, K. R.: Soil Mechanics and Foundation Engineering (Geotechnical Engineering). Standard Publishers Distribution. Reprint Edition, 1, pp. 5-9, 2010.
[3] AASHTO. Standard specifications for transportation materials and method of testing and sampling, American Association of State Highway and Transportation Officials, Washington D.C, USA, 1986.
[4] British Standards (BS) 1377.: Methods of Tests for Soils for Civil Engineering Properties. London: British Standards Institution, 1990.
[5] British Standards (BS) 1924.: Methods of Test for Stabilized Soils. British Standards Institutions, London, UK. 1990.
[6] Das, B. M.: Principles of Geotechnical Engineering' 5th edition, Singapore, Chris Carson Publisher, 2006.
[7] Federal Ministry of Works & Housing (FMWH).: General Specifications for Roads and Bridges. Volume II. Federal Highway Department, Lagos, Nigeria, 1997.

[8] Gidigasu, M. D.: Review of Identification and Evaluation of Problem Lateritic Soils in Highway Engineering, Transport Research Board, Washington, 1973.
[9] Jha, J. N. and Gill, K. S.: Effect of Rice Husk Ash on Lime Stabilization, Journal of the Institution of Engineers (India), 87, pp. 33-39, 2006.
[10] Nnoshiri, E. M. and Emeka, H. O.: Effects of coconut shell ash on lime-stabilized lateritic soil. MOJ Civil Eng., 2(4), pp. 140–143, 2017.
[11] Ogundipe, O. M.: An Investigation into the Use of Lime–Stabilized Clay as Sub grade Material, International Journal of Scientific and Technology Research, 2(10), pp. 35 – 42, 2013.
[12] Olarewaju A. J., Balogun, M. O. and Akinlolu, S. O. Suitability of Eggshell Stabilized Lateritic Soil as Subgrade Material for Road Construction, Electronic Journal of Geotechnical Engineering, 16, pp. 899-908, 2011.
[13] Patel, M. A, Patel, H. S.: A Review on Effects of Stabilizing Agents for Stabilization of Weak Soil. Civil and Environmental Research, 2(6), pp. 42 - 54, 2012.
[14] Popoola, O. O., Adekanmi, J. S. and Olawale, B. O.: Stabilization of Laterite Soil with Coconut Waste Ashes as a Partial Replacement for Lime, American Journal of Engineering Research, 8(2), pp. 208-217, 2019.
[15] Nagaraj, H. B., Sravan, M. V., Arun, T. J. and Jagadish, K. S.: Role of lime with cement in long-term strength of Compressed Stabilized Earth Blocks, International Journal of Sustainable Built Environment, 3, pp. 54–61, 2014.
[16] Neville, A. M.: Properties of Concrete, 5th Edition, London, Pearson Education, 2011.
[17] Prasanna, S. and Kumar, P.: Soil Reinforcement Using Coconut Shell Ash: A Case Study of Indian Soil, Journal of Civil Engineering and Construction, 6(2), pp. 73 – 78, 2017.
[18] Shetty, M. S.: Concrete Technology – Theory and Practice, Revised Edition, New Delhi S. Chand, 2008.
[19] Osinubi, K.J. and Stephen, T.A.: Effect of curing period on bagasse ash stabilized black cotton soil. Book of Proc. Bi-monthly Meetings/Workshop, Material Society of Nigeria., Zaria. 16, pp. 899-908, 2006.
[20] Tan, Y., Hu, M. and Li, D.: Effects of agglomerate size on California bearing ratio of lime treated lateritic soils. International Journal of Sustainable Built Environment, 5, pp. 168–175, 2016.
[21] Thagesen, B.: Tropical rocks and soils. In: Thagesen B. eds. Highway TrafficEngineering in Developing Countries, 1st Edition, London, E & F.N Spon, 1996.
[22] Ugbe, F. C.: Basic Engineering Global Geological Properties OF Lateritic Soils from Western Delta Research. Journal of Environmental and Earth Sciences, 3(5), pp. 571–577, 2011.
[23] Venkatramaiah C.: Geotechnical engineering. New Age International Publishers Ltd, 2006.
[24] Vysakh, P. and Bindu, J.: Stabilisation of lateritic soil using coconut shell, leaf and husk ash. 2012 International Conference on Green Technologies (ICGT). 2012

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665