

Original Research Article

Stabilization of Lateritic soil with Cassava Peels Ash

ABSTRACT

This research is aimed at assessing the impact of Cassava Peels Ash (CPA) on the stabilization of lateritic soil deposit found within Osogbo Local Government Area in Osun State, Nigeria. This project was carried out to study the characteristics of Cassava Peels Ash (CPA) stabilization on lateritic soil. Preliminary tests were performed on three samples, L1, L2, and L3 for identification and classification purposes followed by the consistency limit tests. Geotechnical property tests (compaction, California bearing ratio (CBR), and Unconfined Compression Test) were also performed on the samples, both at the stabilized and unstabilized states by adding 2, 4, 6, 8 and 10% Cassava Peels Ash (CPA) by weight of sample to the soils. The results showed that the addition of CPA improved the strengths of the samples. Optimum moisture contents (OMC) reduced to 14.58, 18.40 and 16.00% at 6, 4 and 6% CPA additions in samples L1, L2 and L3 respectively while **maximum dry density (MDD)** increased to 1470, 1410 and 1440 kg/m³ at 10, 4 and 2% CPA additions in samples L1, L2, and L3. The unsoaked CBR values of samples increased from 7.89 to 19.40% at 8% CPA stabilization for sample L1, for sample L2, it increases from 5.80 to 27.02% at 10% CPA stabilization and for sample L3 at the natural state, it increases from 14.50 to 18.20% at 4%. The shear strengths of samples L1, L2 and L3 also increased from 123.70 to 590.58kN/m² at 2% CPA stabilization, 293.48 to 297.67kN/m² at 10% CPA stabilization and 153.99 to 554.02kN/m² respectively. It was therefore concluded that Cassava Peels Ash has a good potential for stabilizing lateritic soil.

Keywords: *Flexible pavement; Compaction; California bearing ratio and Unconfined compressive Strength.*

1. INTRODUCTION

Technically, soil improvement could either be by modification or stabilization, or both. Soil modification is the addition of a modifier (cement, lime, etc.) to a soil to change its index properties, while soil stabilization is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification [1].

Lateritic soils are generally used for road construction in Nigeria. Lateritic soil in its natural state generally have low bearing capacity and low strength due to high content of clay. When lateritic soil contains a large amount of clay materials its strength and stability cannot be guaranteed under load especially in the presence of moisture [1]. Laterite develops beneath the surface in soil zones, unconsolidated sediments, or decomposed rocks where interrelations of ground water, soil/water table, and topography are favorable. Laterite is a residual of rock decay that is red, reddish in color and has a high content of oxides of iron and hydroxides of aluminum and low proportion of silica.

When lateritic soil consist of high plastic clay, the plasticity of the soil may cause cracks and damage on pavement, road ways, building foundations or any other civil engineering construction projects. The improvement in the strength and durability of lateritic soil in the recent time become imperative, this has geared up researchers toward using stabilizing materials that can be source locally at a very low cost. These local materials can be classified as either agricultural or industrial wastes [2]. The ability to blend the naturally occurring lateritic soil with some chemical additives to give it better engineering properties in both strength and water proofing is very essential [3,4,5,6].

Over the years, cement and lime have been the two main materials used for stabilizing soils. These materials have rapidly increased in price due to the sharp increase in the cost of energy and high demand for them. Thus has hitherto prevented third world countries like Nigeria in providing good road for its citizen particularly rural dwellers that are mostly agriculturally dependent. It has been shown by [4,7,8] that Portland cement, by the nature of its chemistry, produces large quantities of CO₂ for every ton of its final product which contributes to the melting of the ozone layer covering the earth surface. Therefore, replacing proportions of the Portland cement in soil stabilization with agricultural waste material like Cassava Peels Ash will reduce the overall environmental impact of the stabilization process.

Cassava Peels (CP) is a by-product of cassava processing, either for domestic consumption or industrial uses. Cassava peel constitutes between 20-35% of the weight of tuber, especially in the case of hand peeling. Based on 20% estimate, about 6.8 million tonnes of cassava peel is generated annually and 12million tonnes are expected to be produced in the year 2020 [5]. Indiscriminate disposal of cassava peels due to gross underutilization as well as lack of appropriate technology to recycle them is a major challenge, which results in environmental problem. Thus, there is need to search for alternative methods of making use of cassava peels. Therefore, the purpose of this study was to investigate the impact of Cassava Peels Ash on the stabilization of lateritic soils.

2. MATERIALS AND METHODS

2.1 Materials used

2.1.1 Soil

Collection of three lateritic samples labeled (L1, L2, L3) from the new Oba Adesoji Aderemi Ring road Osogbo, Osun State (behind Ilesha Garage, Ring road, Osogbo, Fountain University, Ring road Osogbo, and behind African Grammar school, Abeere end of the Ring road, Osogbo) disturbed sampling from a borrow pits at a depth of between 1.0m and 2.0m at. A study of the soil and geological maps of Nigeria after [9, 10], respectively, show that the study area lies within southwestern Nigeria basement complex which forms part of the African crystalline shield. The basement complex is composed predominantly of folded gneisses, migmatite, schist and quartzite of the Precambrian age. The soil samples were collected in large-to -medium-sized bags and thereafter transported to the Soil Mechanics Research Laboratory of the Department of Civil Engineering, Osun State University, Osogbo, Osun State. Each soil sample was spread and allowed to air-dry under laboratory conditions.

2.1.2 Cassava Peels ash

Cassava peels were collected from cassava peel site in Oke Baale, Osogbo. The ash was produced by first sun drying till the peel is well dried before burning. The ash was produced

by calcination at 700°C for 90minutes. The cassava peel ash was sieved using 75µm sieve size to get a fine ash. The chemical composition and physical characteristics are determined at Research Institute of Obafemi Awolowo University using X-ray diffractometry (XRD) and Differential thermal Analysis (DTA).

2.1.4 Water

Potable water was used for the preparation of the specimens at the various moisture contents.

2.2 Methods

2.2.1 Index Properties

The index properties of the natural and treated soil were determined in accordance with BS [11,12,13,14].

2.2.2 Chemical Composition

The chemical compositions of the soils were determined using X-ray fluorescence (XRF) and this was carried out at the Centre for Energy Research Technology (CERT), Obafemi Awolowo University Ile-Ife, Osun Nigeria. The analysis was determined using standard laboratory procedures outlined by [13,14,15] for analyzing the chemical constituents of soils including oxides expressed as percentage.

2.2.3 Sieve analysis

Hydrometer method was used to obtain values of the clay-size (percent < 0.002 mm) fraction of the soil constituents or particles. 250grammes of each soil samples was first measured and soaked using tap water for at least 2 days to ensure that the dry soil clods were softened. After soaking, the specimen was washed through BS No 200 (i.e., 0.075 mm) sieve. The material retained on the sieve after washing was collected into a small metal bowl, oven dried and sieved based on procedures outlined in [12,13,14]. Sieving was done in three replicates for each specimen. When the lateritic soil was treated with 2 - 12% bamboo leaf ash by dry weight of soil at optimum moisture content (OMC), less than 10% of the material passed through BS No. 200 sieve, and therefore did not meet the minimum requirement for sedimentation analysis to be carried out.

2.2.4 Specific gravity

Specific gravity tests were conducted based on procedures outlined in [11,12,13]. Tests were carried out in three replicates. The specific gravity for each of the specimen was calculated using the expression [13]:

$$G_s = \frac{\rho_L(m_3 - m_1)}{(m_4 - m_1) - (m_3 - m_2)} \dots\dots\dots (1)$$

where ρ_L = density of liquid used (ρ_L was assumed to be equal to 1.000 g/ml for this purpose since distilled water was used); m_1 = mass of density bottle (g); m_2 = mass of bottle + dry soil (g); m_3 = mass of bottle + soil + liquid (g); m_4 = mass of bottle + distilled water only (g). Average of three measurements was calculated and recorded in each case. Specific gravity tests were repeated whenever any value differed from the average value by more than 0.03.

2.2.5 Atterberg limits

Atterberg limits tests which are otherwise known as plasticity tests were conducted on air-dried soils that had previously been passed through sieve with 425 μm aperture (Head, 1992). Distilled water was used throughout the tests to determine the plasticity of the soils. The liquid limit was determined with the use of the Casagrande apparatus in agreement with Clause 4.5, Part 2 of [13]. The five-point system was employed in order to obtain the actual liquid limit values of the soils. The plastic limit of each soil was estimated on the basis of procedures outlined in Clause 5.3, Part 2 of [13]. Portions of paste with water contents close to the liquid limit were used for plastic limit determination. The plasticity index of each soil was obtained as the difference between the liquid limit and plastic limit. The percentage linear shrinkage of each soil specimen was determined according to procedures in Clause 6.5, Part 2 of [13]. Moisture content determinations for the liquid and plastic limits tests were carried out by oven-drying in conformity with Clause 3.2, Part 2 of [13].

2.2.6 Compaction of Soil

The standard Proctor (SP) compaction procedures were utilized during the tests. The SP compactions utilized 3 layers applying 27 blows each of a 2.5kg rammer falling from a height of 300mm using 1000cm³ mould.

2.2.7 California bearing ratio

The CBR were carried out in conformation with the recommendations of the Nigerian General Specifications for Roads and Bridges [15], which states that specimens be cured for 6 days unsoaked (that is, at a temperature of $25 \pm 2^\circ\text{C}$ and relative humidity of 100 %) and immersed in water for 1 day before testing.

2.2.8 Unconfined compressive test

Unconfined compression test was carried out on soil specimens previously mixed with tap water and compacted at moulding water contents in the range of 6.5 - 22.5% using British Standard Light energy. Compacted specimens were sealed in plastic bags and allowed to stand for at least 24 hours before trimming and testing. At least three specimens (38 mm

diameter by 76 mm high) per moulding water were used in the unconfined compression tests [16].

3. RESULTS AND DISCUSSION

3.1 Preliminary Test:

The results from the preliminary test such as natural moisture content, specific gravity, particle size analysis, atterberg limits and plasticity index before the addition of Cassava peels ash are presented in Table 1, particle size distribution for the samples are shown in Figure 1, atterberg limits tests after addition of Cassava peels ash of 2, 4, 6, 8 and 10% are presented in Table1 and engineering property tests such as compaction, California bearing ratio (CBR) and unconfined compressive strength test are presented in Table 2 and 3 respectively

Table 1: Summary of properties of soil samples

Properties	Sample		
	L1	L2	L3
Colour	Yellowish Brown	Yellowish Brown	Reddish Brown
Natural Moisture Content (%)	12.1	13.2	14.8
Percentage passing BS No 200 sieve	52	50	52
Liquid limit (%)	45	45	42
Plastic limit (%)	28	30	23
Plasticity Index (%)	17	15	19
Specific gravity	2.23	2.41	2.34
AASHTO Classification	A-7-6	A-7-5	A-7-6
Group Index	6	5	7
USCS Classification	CL	SC	CL
Optimum Moisture Content (%)	17.48	19.76	17.07
Maximum Dry Density (Mg/m ³)	1.4	1.38	1.43

Commented [E1]: Remove the vertical lines in all Tables. Refer to the attached published paper no. 2014_BJAST_12590. There are no vertical lines in the Tables

Formatted: Font color: Blue

Formatted: Font color: Blue

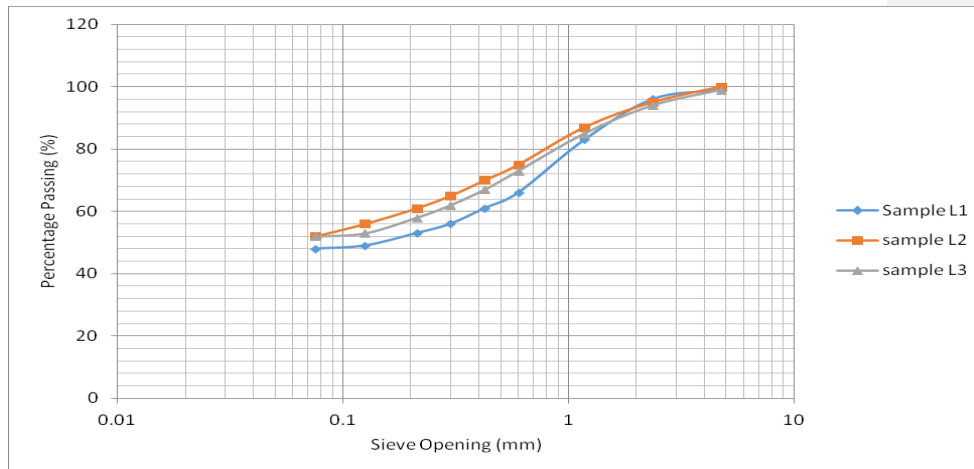


Fig. 1: Particle Size distribution of the natural soil.

The results shows that L3 has the highest natural moisture contents while L1 has the lowest (Table 1). The moisture content of soil depends largely on void ratio and specific gravity [6, 15,16,17,18]. Sample L3 has the largest void ratio compared to others. This also showed that the soil samples contained appreciable amount of moisture, which is a function of the climatic condition, such as temperature, amount, intensity and duration of rainfall.

The results of the specific gravity analysis sample L1, L2 and L3 are 2.23, 2.41 and 2.34 respectively. These values ranged within that given in [7] for clay minerals, as Halloysite (2.0 - 2.55). According [8,19,20] noted that the higher the specific gravity, the higher the degree of laterization. This indicates that soil L2, exhibits higher degree of laterization than samples L1 and L3. However, the specific gravity of Cassava peels ash is 2.05.

Commented [E2]: Information presented in the Table should not be repeated in the text. This information is already appearing in Table 1.

Formatted: Underline, Font color: Blue

Particle size distribution curve is shown in 1 below. The three samples were classified using the [9,20,21] soil classification system. All the samples fell within the silt-clay materials under the general classification as their percentages passing sieve No 200 were all more than 35%. They all fell within A-7 groups. Based on their Liquid Limit (LL) and Plastic Index (PI), samples L1, L2 and L3 were further classified as A-7-6(6), A-7-5(5) and A-7-6(6) respectively. This shows that all the samples fall below the standards recommended for most geotechnical construction works and would therefore require stabilization.

The results of the Atterberg's limits test (Liquid Limits (LL), Plastic Limits (PL) and Plastic Index (PI)) on the samples are shown in Table 1. The LL, PL and PI of the natural soil samples are 45%, 28% and 19% respectively for sample L1; 45%, 30% and 15% respectively for sample L2 and 42%, 23% and 19% respectively for sample L3. According to [10], liquid limit less than 35% indicates low plasticity, between 35% and 50% indicates intermediate plasticity, between 50% and 70% high plasticity and between 70% and 90% very high plasticity and greater than 90% extremely high plasticity. This shows that san

Formatted: Underline, Font color: Blue

Commented [E3]: Information presented in the Table should not be repeated in the text. This information is already appearing in Table 1.

L1, L2 and L3, have intermediate plasticity. The addition of Cassava peels ash in 2, 4, 6, 8 and 10% to the samples caused changes in the liquid limits and plastic limits of all the samples, which are shown in Table 1. The plasticity indices of samples L1, L2 and L3 decreased from 17.00% to 9.30%, 15.00% and 19.00% to 5.50% at 6% and 8% CPA addition respectively. These reductions in plasticity indices are indicators of soil improvement.

Table 2: Summary of Atterberg Limit for CPA

Samples	Lateritic soil + CPA (%)	Liquid Limit (%)	Plastic Limit (%)	<u>Plasticity Index (%)</u>
L1	0	45.00	28.00	17.00
	2	37.40	25.00	12.40
	4	42.30	25.00	17.30
	6	42.30	33.00	9.30
	8	43.60	27.70	15.90
	10	45.20	27.7	17.50
L2	0	45.00	30.00	15.00
	2	37.50	25.00	12.50
	4	38.70	30.40	8.30
	6	45.60	27.70	17.90
	8	41.00	35.60	5.40
	10	43.70	33.30	10.40
L3	0	42.00	23.00	19.00
	2	29.00	14.00	15.00
	4	39.70	27.70	12.00
	6	39.12	30.40	8.72
	8	38.80	33.30	5.50
	10	36.00	27.70	8.30

Engineering Tests: The summary of compaction, CBR and UCS are shown in Figure 2-3. The Optimum Moisture Contents (OMC) of samples L1, L2 and L3 are 17.48, 19.76 and 17.07% while the Maximum Dry Densities (MDD) are 1400, 1380 and 1430 kg/m³ respectively. The addition of increasing percentages of CPA in 2, 4, 6, 8 and 10% by weight of sample led mostly caused a corresponding reduction in OMC of the samples. The values of OMC at the natural states reduced to 14.58, 18.40 and 16.00% at 6%, 4% and 6% of CPA in samples L1, L2 and L3 respectively, while MDD values increased at the natural states to 1470, 1410 and 1440 kg/m³ at 10%, 4% and 2% in samples L1, L2 and L3 respectively. The lower the optimum moisture content, the better its workability and that increase in dry density is an indicator of improvement [11,20,21,22]. Thus, it has been shown that CPA stabilization has generally improved the soil samples and enhanced their workabilities.

Formatted: Underline, Font color: Blue

Commented [E4]: Information presented in the Table should not be repeated in the text. This information is already appearing in Table 2.

Commented [E5]: Remove the vertical lines in the Table. Refer to the attached published paper no. 2014_BJAST_12590. There are no vertical lines in the Tables

Formatted: Underline, Font color: Blue

Formatted: Underline, Font color: Blue

Formatted: Underline, Font color: Blue

Commented [E6]: Information presented in the Figure should not be repeated in the text. This information is already appearing in Figures 1 and 2.

Formatted: Underline, Font color: Blue

Commented [E7]: Information presented in the Figure should not be repeated in the text. This information is already appearing in Figures 1 and 2.

Table 3 shows the summary of the unsoaked CBR results on the soil samples. The results show that the CBR values of samples L1, L2 and L3 increased considerably with the addition of Cassava Peels Ash. The CBR value of sample L1 at the natural state increased from 7.89 to 19.40% at 8% CPA stabilization for sample L2, the CBR of the natural soil increased from 5.80 to 27.02% at 10% CPA stabilization and in sample L3 at the natural state increased from 14.50 to 18.20% at 4% CPA stabilization. The California Bearing Ratio (CBR) test is a relatively simple test that is commonly used to obtain an indication of strength of a subgrade soil, sub-base and the base course materials for use in road and airfield pavement design [12,22,23,24]. The results therefore showed that the strength of the samples in terms of their load bearing capacity greatly increased with CPA stabilization. These improvements in the CBR values of samples L1, L2 and L3 satisfy the minimum requirements that qualify them as road construction materials for subgrade and showed that the soil samples were effectively stabilized by CPA.

Table 3 shows the summary of the unconfined compression test results. It is a special type of unconsolidated-undrained test that is commonly used for clay specimens where the confining pressure (σ_3) is 0 and the major principal stress (σ_1) is the unconfined compression strength (q_u). The unconfined compression strength of samples L1, L2, and L3 increased considerably with the addition of Cassava Peels Ash. The sample strengths increased from 123.70 to 590.58kN/m² at 2% CPA stabilization, 293.48 to 297.67kN/m² at 10% CPA stabilization and 153.99 to 554.02kN/m² at 8% CPA stabilization in samples L1, L2 and L3 respectively. These results further confirmed the stabilizing potentials of CPA on lateritic soil if added at the optimum level.

Formatted: Underline, Font color: Blue

Commented [E8]: Information presented in the Table should not be repeated in the text. This information is already appearing in Table 3.

Formatted: Underline, Font color: Blue

Commented [E9]: Information presented in the Table should not be repeated in the text. This information is already appearing in Table 3.

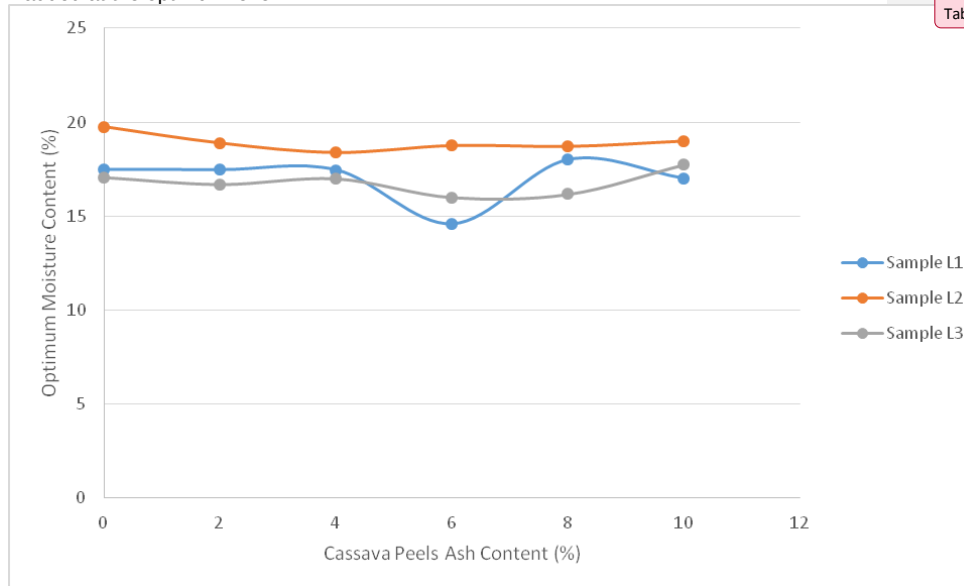


Fig. 2: CPA on the Optimum Moisture Content of the Samples

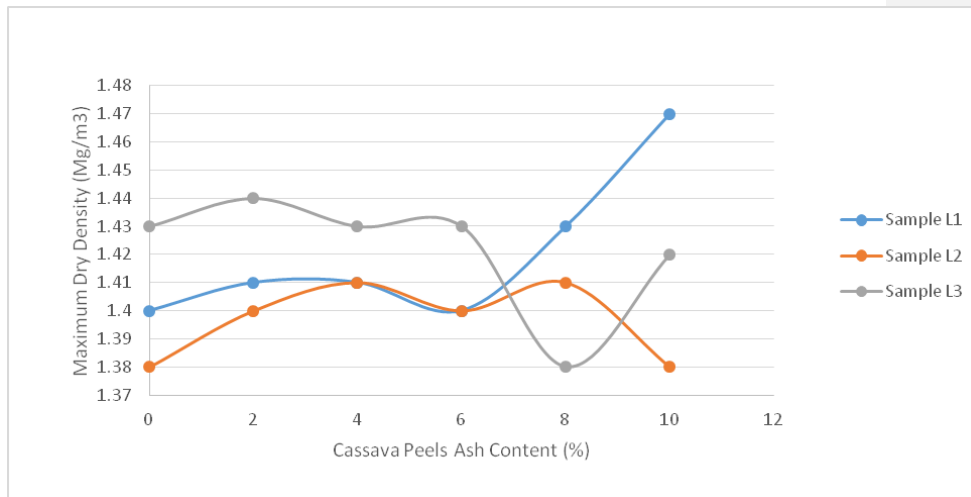


Fig. 3: CPA on the Maximum Dry Density of the Samples

Table 3: Summary of CBR and Unconfined Compressive Test

Sample	Percentage Stabilization (%)	California Bearing Ratio (Unsoaked) (%)	Unconfined Compressive Strength (kN/m²)
L1	0	7.89	123.70
	2	11.25	590.58
	4	12.63	511.53
	6	16.40	150.33
	8	19.40	490.82
	10	15.50	398.16
L2	0	5.80	293.48
	2	13.75	131.94
	4	16.46	187.55
	6	23.74	79.30
	8	25.45	110.19
	10	27.02	297.67
L3	0	14.50	153.99
	2	14.97	216.36

Formatted: Underline, Font color: Blue

Commented [E10]: Remove the vertical lines in the Table. Refer to the attached published paper no. 2014_BJAST_12590. There are no vertical lines in the Tables

Formatted: Underline, Font color: Blue

4	18.20	403.03
6	7.96	481.71
8	11.02	554.02
10	14.03	467.98

4. CONCLUSION

The soils samples were classified to be A-7-6, A-7-5 and A-7-6 [11] soil classification system. This fall within silt-clay materials under general classification. It was shown that Cassava Peels Ash (CPA) improved the qualities of the soil samples by significantly reducing their plastic indices. The plasticity indices of samples L1, L2 and L3 decreased from 17.00% to 9.30%, 15.00% to 5.40% and 19.00% to 5.50% at 6% and 8% CPA addition respectively. These reductions in plasticity indices are indicators of soil improvement.

The results showed that the addition of CPA improved the strengths of the samples. Optimum moisture contents reduced to 14.58, 18.40 and 16.00% at 6, 4 and 6% CPA additions in samples L1, L2 and L3 respectively while MDD increased to 1470, 1410 and 1440 kg/m³ at 10, 4 and 2% CPA additions in samples L1, L2, and L3. The unsoaked CBR values of samples increased to 19.40, 27.02 and 18.20% at 8, 10 and 4% CPA stabilization for sample L1, L2 and L3 respectively. The shear strengths of samples L1, L2 and L3 also increased from 123.70 to 590.58kN/m² at 2% CPA stabilization, 293.48 to 297.67kN/m² at 10% CPA stabilization and 153.99 to 554.02kN/m² respectively. The study therefore concluded that Cassava Peels Ash (CPA) has the potential to effectively stabilize lateritic soils for highway construction. Based on this study, it is therefore necessary to recommend Cassava Peels Ash as a stabilizing agent for improving soils with low California bearing ratio.

REFERENCES

- [1] Alhassan, M., (2008), Potential of Rice Husk Ash for soil Stabilization AUJ.T 71(4): 246 250.
- [2] Bello, A. A. and Osinubi, K. J. (2013). "Influence of compactive efforts on lateritic soil stabilized with bamboo leaf ash." The Twenty – Eighth International Conference on Solid Waste Technology and Management CD-ROM, 10 – 13 March, Philadelphia, PA, U.S.A. Session 7D: Ash Utilization and Treatment, pp. 1261 - 1276.
- [3] Amu, O.O, Bamisaye, O.F, and Komolafe, I.A., (2011). "The Suitability and Lime Stabilization requirement of Some Lateritic Soil Samples as Pavement". Int. Journal of Pure Applied Science and Technology. , 2(1): 29 – 46.
- [4] Bello, A. A. and Osinubi, K. J. (2013). "Influence of compactive efforts on lateritic soil stabilized with bamboo leaf ash." The Twenty – Eighth International Conference on Solid Waste Technology and Management CD-ROM, 10 – 13 March, Philadelphia, PA, U.S.A. Session 7D: Ash Utilization and Treatment, pp. 1261 - 1276.
- [5] Bello, A. A. and Olawale, G.O. (2013) 'Influence of compactive efforts on Lateritic soil with Rice Husk Ash and Cement.' Proceedings of the 11th National Civil Engineering Conference, Garden City 2013: Enhancing National Economic Growth Through Sustainable Civil Engineering Infrastructures, 6 – 8 November, Viontel hotel, Port Harcourt, River State, Nigeria, pp. 32 – 42.

Commented [E11]: Do not include these numerical values in the conclusion. The conclusion should be a summary of main ideas/results and its application/recommendation. Refer to the attached published paper no. 2014_BJAST_12590. There are no numerical values in the conclusion, even though they had too many numerical values in their results.

Formatted: Underline, Font color: Blue

Formatted: Underline, Font color: Blue

Commented [E12]: Do not include these numerical values in the conclusion.

- [6] Bello, A. A., Awogboro, O.S. and Oriaje, A. T. (2014) 'Influence of Compactive Efforts on Lateritic soil stabilized with Rice Hush Ash. *International Journal of Applied Engineering* 9(21) 9639-9653
- [7] Bello, A. A., Ige, J.A. and Ibitoye, G. I. (2014) 'Geotechnical properties of Lateritic soil stabilized with Cement-Bamboo Leaf Ash Admixtures. *International Journal of Applied Engineering Research*, 9(21) 9639-9653
- [8] Sear, L.K.A (2005). "Should you be using more PFA." *Proc. Int. Conf. Cement Combination for Durable Concrete* held at the University of Dundee, Scotland, UK. Lambe W.T. and Whitman V. R., (1979). *Soil Mechanics*, SI Version. New York: John Wiley and Sons, Inc.
- [9] Akintola, F. A. (1982). "Geology and Geomorphology" In: *Nigeria in Maps*. R.M Barbour, Editor, Hodder and Stoughton, London.
- [10] Areola, O. (1982). "Soils". In: *Nigeria in Maps*, R. M, Barbour, Editor Hodder and Stoughton, London U. K.
- [11] AASHTO. (1986). *Standard Specifications for Transportation Materials and Method of Sampling and Testing*. Amer. Assoc. State Highway and Transportation Officials, Washington, DC, USA.
- [12] BS 1377. (1990). *Methods of Testing Soil for Civil Engineering Purposes*. British Standards Institute, London.
- [13] BS 1924. (1990). *Methods of Test for Stabilized Soils*. British Standards Institute, London.
- [14] Head, K.H. (1992), *Manual of Soil Laboratory Testing*. Volume1: *Soil Classification and Compaction Tests*. Second Edition, Pentech Press, London.
- [15] Nigeria General Specification (1997). *Bridges and Road Works*. Federal Ministry of Works and Housing, Headquarters, Abuja, Nigeria. Vol. 11 (Revised)
- [16] Amu, O.O, Bamisaye, O.F, and Komolafe, I.A., (2011). "The Suitability and Lime Stabilization requirement of Some Lateritic Soil Samples as Pavement". *Int. Journal of Pure Applied Science and Technology*. , 2(1): 29 – 46.
- [17] Adesanya, O.A., Oluyemi, K.A., Josiah, S.J., Adesanya, R.A., Shittu, L.A.J., Ofusori, D.A., Bankole, M.A., and Babalola, G.B., (2008). "Ethanol Production by *Saccharomyces Cerevisiae* from cassia peel hydrolysate". *The Internet Journal of Microbiology* Vol. 5 No. 1. Pp. 25-35.
- [18] Lambe W.T. and Whitman V. R., (1979). *Soil Mechanics*, SI Version. New York: John Wiley and Sons, Inc.
- [19] Ola, S.A., (1978), "Stabilization of Nigeria Lateritic Soils with Cement, Bitumen and Lime", *Proc. 6th Reg. Conf. Africa on Soil Mechanics and Foundation Engineering*. Durban, South Africa.
- [20] Liu C. and Evett J. (2003), *Soils and Foundation*, 6th ed. USA: Prentice Hall.
- [21] De Graft-Johnson, J.W.S., (1969). *Engineering properties of lateritic soil proceedings of the special session in laterite soils.*, 4: 1050-1066.
- [22] Whitlow, R (1995). *Basic Soil Mechanics*. 3rd edition. Addison Wesley Longman Limited, Edinburgh Gate.
- [23] Lambe W.T. and Whitman V. R., (1979). *Soil Mechanics*, SI Version. New York: John Wiley and Sons, Inc.
- [24] Liu C. and Evett J. (2003), *Soils and Foundation*, 6th ed. USA: Prentice Hall.