USE OF COCONUT HUSK ASH AND CALCIUM CARBIDE RESIDUE AS LATERITE SOIL STABILISERS

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ABSTRACT

The ability to blend naturally occurring soil with some industrial and agricultural wastes to give better engineering properties in both strength and waterproofing is very essential. Thus, this research examines the importance of coconut husk ash (CHA) and calcium carbide residue (CCR) as laterite soil (LS) stabilisation. Various tests carried out were X-Ray Fluorescence (XRF) spectroscope analysis and particle size distribution of the LS while the stabilised LS with varying percentages of CHA and CCR at 2, 4, 6, 8 and 10% each using consistency limits, compaction and California Bearing Ratio (CBR) were also investigated. One-way analysis of variance (ANOVA) was used to analyse the stabilisation effects. The XRF spectroscope analysis revealed that silica-sesquioxide ratio of the soil is 0.88 indicating it as laterite while CHA and CCR are classified as class N pozzolan and cementitious material (CaO of 68.5%) respectively. The additives (CHA and CCR) at 4% improved the workability and decreased the infiltration capacity of the LS as it reduced the plasticity index from 24.6% to 6.2%. Also, at 4% CHA and CCR, the maximum dry density and optimum moisture content of the LS increased from $17.7\ kN/m^3$ *to* $20.5\ kN/m^3$ *and decreased from 11.8% to 9.1% respectively which enhanced the compactness of the LS. The blend of 10% CHA and CCR have the highest CBR value of 20.6% which significantly improves the strength of the LS. ANOVA showed that both additives had statistically significant (*$p < 0.05$*) effects on the CBR of the LS. The results indicated that the use of CHA and CCR can improve the engineering properties of laterite soil for use as subgrade road pavement.*

KEYWORDS: Analysis of variance, California bearing ratio, Pozzolan, Silica-sesquioxide ratio, X-Ray fluorescence.

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1. INTRODUCTION

Soil is the fundamental and most economical construction material as it bears load of pavements and structures transmitted through subgrades and foundations, respectively. The use of the existing soil at a construction site for engineering purposes may be hindered by poor engineering properties including low strength to withstand axle load, poor bearing capacity, and volumetric changes (Ogundare et al., 2024). Lateritic soil which is the most commonly type of soil used in hot and wet tropical regions of Southwestern part of Nigeria is readily available for road pavement because it is a soil type rich in iron and aluminium (Nnochiri and Ogundipe, 2017). However, soil varies in behaviour due to formation, rock components, drainage, and environmental factors (Arora, 2007) and researchers have shown that the suitability of a soil as a construction material is a function of its geotechnical properties (Ogundare et al., 2018; Venkatramaiah, 2012). Soils whose use is limited as a result of their engineering properties are referred to as deficient soils (Alhassan and Mustapha, 2015). Deficient soils are regarded as soils that do not meet some or all the criteria required for their satisfactory performance as geotechnical structures. These could either be for base courses for roads, embankments for a dam, subsoil base, clay liners for containment of leachate, and backfill for retaining walls (Alhassan and Mustapha, 2015). Such soils could be expansive, collapsible, dispersive, soft clay and saline soils which causes detrimental effects to buildings and road structures (Ogundare et al., 2024). Soil stabilisation is the alteration of one or more properties, by mechanical or chemical means, to create an improved material, possessing the desired engineering properties (Onyelowe and Okafor, 2012). Additionally, Ogundare et al. (2018) explained soil stabilisation as a process of treating a soil to maintain, alter or improve its performance as a construction material and very importantly to minimize the cost of earthworks.

The increasing population of the world, especially developing nations has led to increasing demand for roadways, railways, housing facilities, and other infrastructures. However, pavement failure is prevalent in Nigeria, a developing economy, with its consequent negative effects on the nation's socio-economy through fatal road accidents, loss of property, and lost travel time, amongst others (Ogundare et al ., 2024). The effort made by researchers, Ogundare et al., 2024; Nnochiri and Ogundipe, (2017); Adama et al., 2013; Osinubi and Alhassan (2008); Cokca (2001), to obtain cheaper additives that can be used to substitute the conventional soil-improving additives (cement and lime) led to the consideration of agricultural and industrial waste materials. Coconut tree is very abundant and renewable source of energy and when harvested, the husks are removed, thereby leaving the shell and the copra (Amu et al., 2011). These husks are considered waste materials and are usually dumped (Amu et al., 2011). Also, calcium carbide residue is a by-product of acetylene gas production and this gas is used around the world for welding, lighting, metal cutting, and ripening fruit (Saidu et al., 2020). Calcium carbide residue is obtained from a reaction between calcium carbide and water to form acetylene gas and calcium hydroxide in a slurry form, which mainly consists of calcium hydroxide ($\mathrm{CaOH_2}$) (Saidu et al., 2020). Hence, this research aims to evaluate stabilising lateritic soil incorporating coconut husk ash and calcium carbide residue.

2. MATERIALS AND METHODS

2.1 Materials

The soil sample used for this research was collected by the method of disturbed sampling at depth of 0.9 m to 1.5 m at latitude 7º 45' 42'' N and longitude of 4º 24' 34'' E along Iwo-Oshogbo road, Osun State, Nigeria. The soil sample was preserved in polythene bags and was air dried for 14 days before being used.

The coconut husk was obtained from local coconut dealers in Okeho, Oyo State. It was sun-dried to remove impurities and moisture. The ash was obtained through burning in an open metal drum (Amu et al., 2011) and was later transferred for further heating in an electric furnace. The material was placed in an alumina crucible and subjected to heat at a temperature of 700°C for 2 hours in an electrical furnace at a constant heating rate of 10 °C/min to obtain CHA. The ash obtained was sieved through British Standard (BS) sieve 425 μm (0.425mm) before usage.

The waste from calcium carbide was obtained from trash dumps generated by automobile workshops in Ede, Osun State. It was left to dry under natural air conditions, grind and sieved through a sieve with a 425 µm opening for use.

2.2 Methods

This research involved the following laboratory tests; X-Ray fluorescence spectroscope of lateritic soil, CHA, and CCR, particle size analysis, consistency limit, standard Proctor compaction, and California bearing ratio of the lateritic soil and the stabilised soil with 2, 4, 6, 8 and 10% each of CHA and CCR.

3. RESULTS AND DISCUSSION

3.1 X-Ray Fluorescence Test

The silica-sesquioxide (S-S) ratio of the soil sample as shown in Table 1 is less than 1.33 (0.88) which implies that the soil is laterite, while the coconut husk ash and calcium carbide residue are classified as class N pozzolan ($SiO_2 + Al_2O_3 + Fe_2O_3$ = 71.5%) according to ASTM C618 (2012) and cementitious material (CaO of 68.5%) respectively.

Table 1: Chemical Composition of LS, CHA and CCR

Oxide	Percentage Composition (%)		
	LS	**CHA**	**CCR**
SiO_2	27.43	45.04	6.50
Al_2O_3	31.23	14.06	2.53
Fe_2O_3	33.83	12.40	3.23
TiO_2	1.45	0.18	0.02
CaO	1.57	2.53	68.50
P_2O_5	0.08	0.01	0.25
K_2O	0.83	0.56	7.92
MnO	0.66	0.22	0.02
MgO	1.25	1.28	0.64
Na_2O	0.29	15.35	0.60
LOI	1.35	8.30	2.01
S-S Ratio	0.88		

3.2 Soil Classification

Based on the American Association of State Highway and Transportation Officials (AASHTO) classification and Unified Soil Classification System (USCS) ASTM D-2487 (2000), the soil sample is classified as A-7-6(16) and inorganic clay of low to medium plasticity (CL), respectively (Table 2) denoting the soil as weak subgrade material.

Table 2: Engineering Properties of the Laterite Soil

S/N	Engineering Properties	Value
1	Gradation test	
	Particle size (≤ 0.075mm) (%)	66.9
	AASHTO classification	A-7-6
	Group Index	16
	USCS classification	CL
2	Atterberg's limits	
	(a) Liquid Limit (LL) (%)	51.2
	(b) Plastic Limit (PL) (%)	26.6
	(c) Plasticity Index (PI) (%)	24.6
3	Compaction Characteristics	
	(a) Maximum dry density (kN/m^3)	17.7
	(b) Optimum moisture content (%)	11.8
4	California Bearing Ratio (Unsoaked) (%)	6.0

3.3 Consistency Limit

Data in Table 2 showed that the liquid limit of the lateritic soil (51.2%) does not meet the required specification (i.e ≤ 50%) for subgrade material as specified by Nigerian General Specification (1997). However, when added with varying content of additives (0 – 4% of CHA and CCR) as shown in Figure 1, the liquid limit and the plasticity index decreases from 51.2% and 24.6% to 39.5% and 6.2% respectively while at 6 – 10% of CHA and CCR, the liquid limit and the plasticity index increases from 44.0% and 19.0% to 50.1% and 18.2% respectively. This is in tandem with investigation by Popoola et al. (2019) as the additives enhanced the resilience and reduce the infiltration capacity of the laterite.

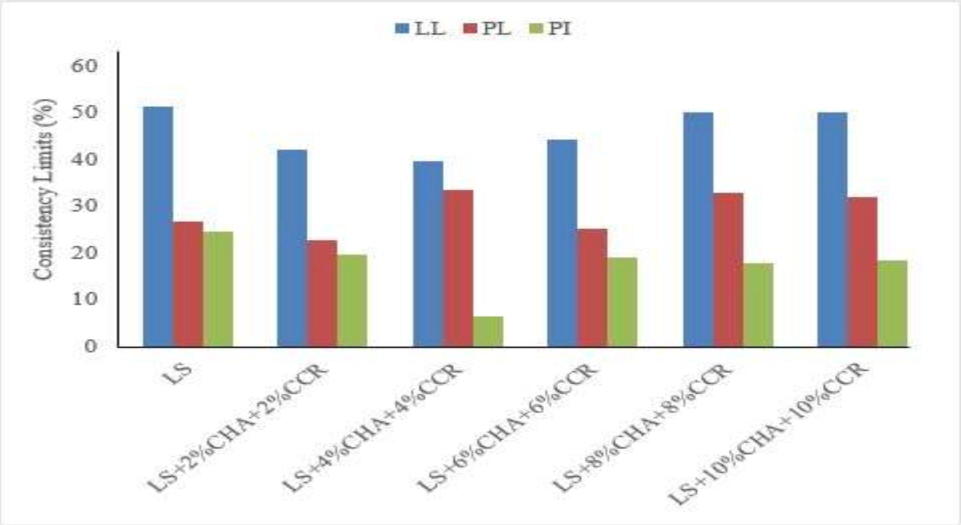

Figure 1: Consistency Limit Properties of LS Stabilised with CHA and CCR

3.4 Compaction Characteristics

As demonstrated in Figure 2, 0 – 4% of CHA and CCR increase the maximum dry density and decrease the optimum moisture content from 17.7 $\mathrm{kN/m^3}$ and 11.8% to 20.5 $\mathrm{kN/m^3}$ and 9.1% respectively while at 6 – 10% of the additives, the maximum dry density (MDD) decreases and optimum moisture content (OMC) increases from 19.6 $\mathrm{kN/m^3}$ and 15.0% to 18.8 $\mathrm{kN/m^3}$ and 16.0% respectively. The increase and decrease in the MDD and OMC could be as a result of the binding action of the pozzolan in coconut hask ash and calcium oxide in calcium carbide residue which increased the compactness of the laterite signifying enhancement of the soil properties. This also aligns with the investigation by Oluremi et al. (2012).

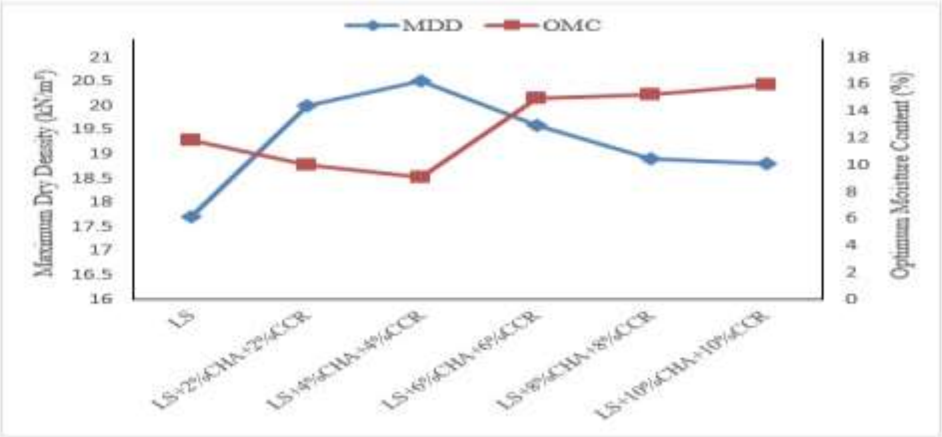

Figure 2: Compaction Properties of LS Stabilised with CHA and CCR

3.5 California Bearing Ratio (CBR)

Result from Figure 3 reveals that as the percentages of coconut husk ash and calcium carbide residue increases, the CBR (unsoaked) values increases with 10% of CHA and CCR yielding 20.6%. This is an indication that coconut husk ash and calcium carbide residue can be effectively used to improve the strength (CBR) of laterite. This also conforms with the findings reported by Ogundare et al. 2024; Popoola et al. (2019) and Oluremi et al. (2012).

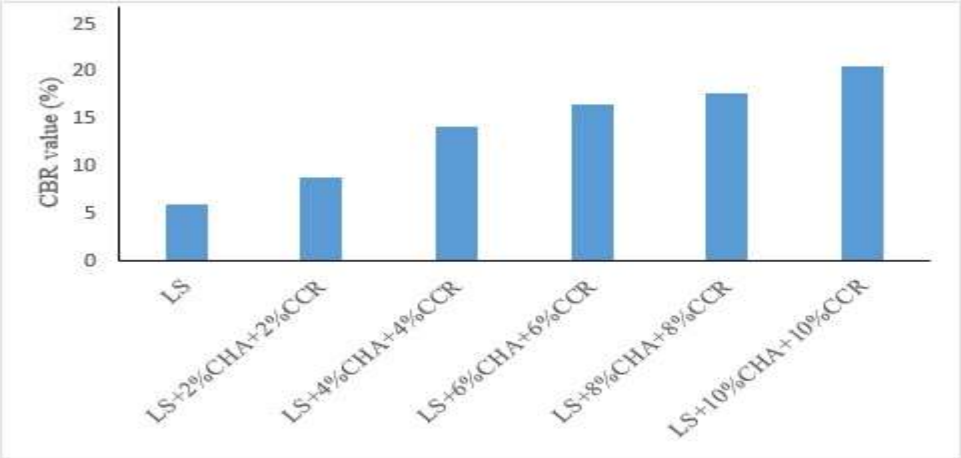

Figure 3: Unsoaked CBR values of LS stabilised with CHA and CCR

3.6 Statistical Analysis (Analysis of Variance)

One-way analysis of variance (ANOVA) was used to analyse the validity of the laboratory tests as shown in Table 3. This analysis was conducted to determine if there is a significant difference in the mean response variables among the percentages of the additives (CHA and CCR). For this research, the null hypothesis is percentages of CHA and CCR has no influence on the CBR of the laterite soil, while the alternate hypothesis is percentages of CHA and CCR influences the CBR of the laterite soil.

Table 3: One-way Analysis of Variance for CBR results of LS-CHA-CCR Mixtures

	Sum of Squares	df	Mean Square	F	P – Value
Between Groups	241.691	5	48.338	7.715	0.014
Within Groups	37.594	6	6.266		
Total	279.285	11			

Note: df = Degree of freedom; F = F Statistic

The result shows that the p – value (0.014) is less than 5% significance level suggesting that the difference are statistically significant. This denote that the percentages of additives (CHA and CCR) have significant effect on the CBR of the laterite soil.

4. CONCLUSION

The following conclusions were drawn from this research;

- The soil sample used for this research is laterite since the silica-sesquioxide ratio value is less than 1.33. However, the additives, coconut husk ash and calcium carbide residue are pozzolanic and cementitious materials, respectively.
- The soil sample is classified as A-7-6(16) and inorganic clay of low to medium plasticity according to AASHTO and USCS respectively.
- The consistency limits test result showed that the additives, coconut husk ash and calcium carbide residue enhanced the properties of the soil sample making it suitable as subgrade material.
- The increase and decrease in the MDD and OMC of the stabilised soil sample showed the compactness and improvement in the soil's sample characteristics.
- The CBR (unsoaked) test performed indicates that the additives, coconut husk ash and calcium carbide residue significantly boosts the strength and bearing capacity of the soil sample.
- The ANOVA test showed that the inclusion of coconut husk ash and calcium carbide residue significantly influence the stabilised laterite soil as the statistical analysis result comply with the laboratory CBR test.

REFERENCES

AASHTO (1986). Standard Specification for Transportation, Material and Methods of Sampling and Testing. 14th Edition, Amsterdam Association of State Highway and Transportation Official, Washington D.C.

ASTM C618-12 (2012). Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use in Concrete. ASTM International, West Conshohocken.

ASTM (2000). Standard Practice for Classification of Soils for Engineering Purpose. Unified Soil Classification System, ASTM Standards D 2487-00.

Adama, A. Y., Jimoh, Y. A. and Kolo, S. S. (2013). Effect of Locust Bean Pod Ash on Compaction Characteristics of Weak Sub Grade Soils. International Journal of Engineering Science Invention, 2(1), 25–30.

Alhassan, M. and Mustapha, A. M. (2015). Improvement of Deficient Soils in Nigeria using Bagasse Ash - A review. Proceeding of 17th International Conference on Civil and Building Engineering, 1040–1049.

Amu, O. O., Owokade, O. S. and Shitan, O. I. (2011). Potentials of Coconut Shell and Husk Ash on the Geotechnical Properties of Lateritic Soil for Road Works. International Journal of Engineering and Technology, 3(1), 87–94.

Arora, K. R. (2007). Soil Mechanics and Foundation Engineering (Geotechnical Engineering). Standard Publishers Distribution, Reprint Edition, 1, 5–9.

Cokca, E. (2001). Use of Class F Ashes for the Stabilization of an Expansive Soils. Journal of Geotechnical and Geoenvironmental Engineering, 127(7), 568–573. https://doi.org/10.1061/ (ASCE) 1090-0241(2001)127:7(568)

Nigeria General Specification, Bridges and Road Works (1997). Federal Ministry of Works and Housing: Abuja, Nigeria, 11, (Revised).

Nnochiri, E. S. & Ogundipe, O. M. (2017). Effects of Coconut Shell Ash on Lime Stabilized Lateritic Soil for Road Construction. Annals of Faculty Engineering Hunedoara - International Journal of Engineering, Fascicule 3, 55–59.

Ogundare, D. A., Adeleke, O. O. and Akinbuluma, A. T. (2024). Predictive Modelling and Functional Group of Clay Soil Treated with Steel Slag and Calcium Carbide Residue. Nigerian Journal of Technological Development, 21(3), 88–97. http://dx.doi.org/10.4314/njtd.v21i3.2715

Ogundare, D. A., Adeleke O. O. and Akinbuluma, A. T. (2024). Chemical and Mechanical Characterisation of Clay Soil Stabilised with Steel Slag and Calcium Carbide Waste. Civil and Sustainable Urban Engineering, 4(1), 55–64. https://doi.org/10.53623/csue.v4i1.427

Ogundare, D. A., Adebara, S. A., Familusi, A. O. and Adewumi, B. E. (2018). Stabilization of Subgrade using Geosynthetics (Case Study - Geotextile) under soaked condition. International Journal of Engineering, Tome XVI, Fascicule 4, 157–162.

Oluremi, J. R., Adedokun, S. I. and Osuolale, O. M. (2012). Stabilization of Lateritic Soil with Coconut Husk Ash. International Journal of Engineering Research and Technology, 1(8), 1–9.

Onyelowe, K. C. and Okafor, F. O. (2012). A Comparative Review of Soil Modification Methods. Asian Research Publishing Network, Journal of Earth Sciences, 1(2), 36–41.

Osinubi, K. J. and Alhassan, M. (2008). Use of Lime and Bagasse Ash in the Modification of Laterite. Nigerian Journal of Engineering, 14(1), 70–80.

Popoola, O. O., Adekanmi, J. S. and Olawale, B. O. (2019). Stabilization of Laterite Soil with Coconut Waste Ashes as a Partial Replacement for Lime. American Journal of Engineering Research, 8(2), 208–217. https://doi.org/10.24121/2347-4142.v8i2.145

Saidu, A. E., Alhassan, M. and Alhaji, M. M. (2020). Performance Evaluation of Full Depth Reclaimed Surface-Dressed Pavement Treated with Cement and Calcium Carbide Residue as Road Base. Proceeding of 18th International Conference and Annual General Meeting of Nigerian Institution of Civil Engineers, 157–171.

Venkatramaiah, C. (2012). Geotechnical Engineering, New Age International Publishers, New Delhi, 69–721.