Covenant Journal of Engineering Technology (CJET) Vol.4 No.1, June 2020
ISSN: p. 2682-5317 e. 2682-5325 DOI: xxxxxxxxxxxxxxxxxxx

An Open Access Journal Available Online

Effects of Compactive Effort on Laterite - Oil Palm Empty Fruit Bunch Ash Mixture

Oke Joy A[1]. & Osinubi Kolawole J[2].

[1]Department of Civil & Environmental Engineering, University of Lagos, Akoka, Lagos
[2]Department of Civil Engineering, Ahmadu Bello University, Zaria Kaduna State,
idaraobong2013@gmail.com

Received: 20.03.2020 Accepted: 02.06.2020
Date of Publication: June, 2020

Abstract: The effect of three compactive efforts, i.e., British Standard light; BSL (or standard Proctor), West African Standard; WAS (or 'Intermediate') and British Standard heavy; BSH (or Modified Proctor) on laterite treated with up to 14 % oil palm empty fruit bunch ash (OPEFBA) by dry weight of the soil was investigated. Index and compaction (Optimum moisture content, OMC and Maximum dry density, MDD) tests were carried out. The Atterberg limits (Liquid Limit, Plastic Limit and Plasticity Index) generally decreased with increasing OPEFBA content. The OMC values increased from 18.5, 17.1 and 16.1% to 23.3, 20.1 and 21.4 %, respectively, while MDD values generally decreased from 1.60, 1.60 and 1.75 Mgm-3 to 1.51, 1.49 and 1.58 Mgm-3 respectively for BSL, WAS and BSH compactive effort, respectively. Based on the results obtained, laterite treated with 8 % OPEFBA and compacted with at least BSL energy is recommended for use in the construction of the sub-base layer of low-volume roads. The benefits of using OPEFBA as a sustainable indigenous construction material include reductions in the adverse environmental impact of oil palm empty fruit bunch waste as a result of its application in road construction.

Keywords: California bearing ratio, Compactive effort, Laterite, Oil palm empty fruit bunch ash,
Unconfined compressive strength, Stabilization

1. Introduction

It is essential to know the properties of soil when any form of construction is to be carried out. The type of soil to be used for a construction purpose determines the engineering properties to be tested. These tests are carried out as a guide on the soil improvement method to be adopted. Therefore, soil improvement enhances the engineering properties required for specific construction work.

Different types of soils exist for various construction purposes. These soils range from sandy soils to soils that are predominantly clay or silts. For road construction in the tropical regions of the world, residual laterite soils are most commonly used because of its abundance and its economic attraction. Laterites are found in a tropical environment where there is intense chemical weathering and leaching of soluble minerals. Laterites occur in different forms in Nigeria and throughout tropical Africa. Among the residual soils occurring in West Africa, many engineers assume laterites to be the best material for the construction of medium trafficked roads [1].

Laterites that are not suitable for road bases require the improvement of their engineering properties using the stabilization method, which is a permanent physical and chemical alteration of soil and aggregates to enhance their engineering properties for proper support to pavements and foundations [2-4]. Improvements in the engineering properties of soils by stabilization can increase soil strength (shearing resistance), stiffness (resistance to deformation) and durability (wear resistance), thereby causing reductions in swelling potential or dispersivity (tendency to deflocculate) in wet clay soils while improving some desirable characteristics, such as dust proofing and waterproofing on unsealed roads [5-7].

Lime, cement, lime-pozzolan, asphalt and granular additives have been used as various methods of stabilizing laterites [8]. However, stabilization of laterites with cement or lime admixtures which are known as conventional stabilizers, was active but costly [9-13]. This is one of the reasons developing and undeveloped nations are lagging in acquiring accessible roads to meet the needs of the people. As a result of this, the use of lime and locally available industrial or agricultural wastes (i.e., sugarcane bagasse, sugarcane straw ash, palm kernel shell ash and cassava peel ash) as alternatives to cement and lime for soil stabilization have been studied [13-18].

Research is on-going in the area of use of agricultural or industrial waste as cheaper means of soil stabilization, and in this study, using oil palm empty fruit bunch ash as a stabilizer to laterite soil contributes to the on-going effort. Oil palm crop is an industrial plant found in abundance in the southern and western parts of Nigeria which is grown mainly for its oil production. Its by-products as well as the waste generated from the palm oil products such as the Oil Palm Empty Fruit Bunch (OPEFB) has so many economic uses some of which have been incorporated in the road construction industry [17]. The study was aimed at the evaluation of the effect of compactive effort on laterite stabilized with oil palm empty fruit bunch ash as a sustainable road construction material.

1.2. Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) is the appropriate procedure for testing the equality of several means. It is a statistical tool used to compare differences of means between more than 2 groups. It can also be referred to as a procedure whereby the total variation in the dependent variable is subdivided into essential components that are observed and treated systematically. It does this by looking at differences in the data and identifying where such variations are found. This difference is referred to as an analysis of variance hence its name. Specifically, ANOVA compares the amount of difference between groups with the amount of variation within groups. It can be used for both observational and experimental studies.

Mathematically, ANOVA can be represented with:

$$x_{ij} = \mu_i + \epsilon_j \quad (1)$$

Where:

x = individual data points

i,j = group and individual observation

= unexplained variation and parameters of the model

= population means of each group

= group mean plus error in each data point

In this study, the value of alpha (α) was taken as 0.05, and ANOVA was used to test the means of the data by comparing the F-ratios and the p-values.

2. Materials and Methods

2.1. Materials

Soil: The laterite sample used in this study was collected from a borrow pit located along Itokin Road, Ikorodu North Local Government Area in Lagos state at a depth of about 1.5 – 2.5 m to avoid the organic topsoil using the method of disturbed sampling.

Oil Palm Empty Fruit Bunch Ash (OPEFBA): The oil palm empty fruit bunch (OPEFB) used in this study was collected as waste from a local milling factory in Atan, Ijebu North East Local Government Area in Ogun State. The OPEFB was sun-dried to get it as close as possible to a dehydrated state for ease of open-air burning. The burning was carried out at a temperature above 648oC. According to the Alaska Department of Environmental Conservation, the operational phase of a burn cycle occurs at temperatures above 1200°F (648.88oC) and so at this phase, all waste should be consumed entirely to ash. After the empty fruit bunch ash (OPEFBA) cooled, it was passed through a 0.075 mm aperture sieve size and stored in air-tight containers to avoid pre-hydration.

2.2. Methods

2.2.1. Index properties: Index properties (Atterberg limits, sieve analysis, specific gravity) tests were carried out by the procedures outlined on the natural laterite [19].

2.2.2. Compaction: The experiment was carried out to obtain the relationship between dry density and moisture content of the soil compacted with BSL, WAS and BSH energies. The tests were carried out on both the natural laterite and OPEFBA treated soil at a stepped concentration of 0, 2, 4, 6, 8, 10, 12 and 14 % by dry weight according to codes [19-21]. The standard Proctor mould having a volume of 1000 cm3 was used. For the BSL compaction, the sample was compacted using a 2.5 kg rammer falling from a height of 300 mm in 3 layers, each layer receiving 27 blows. For the WAS compaction, the sample was compacted in 5 layers of approximately equal mass with each layer receiving 10 blows using a 4.5 kg rammer falling through a height of 450 mm, and for the BSH compaction, the sample was compacted in 5 layers of approximately equal mass with each layer receiving 27 blows of 4.5 kg rammer falling through a height of 450 mm.

2.2.3. Strength: Strength tests (i.e., California bearing ratio and unconfined compression) were carried out on the natural and OPEFBA treated soils. The specimens were prepared at their respective optimum moisture contents (OMCs). For the CBR test, the specimens were compacted and placed in sealed polythene bags for seven days and then tested on the eighth day for un-soaked specimens, and for the soaked samples, the specimen was also placed in sealed polythene bags for six days, thereafter soaked for 24 hours and then tested on the eighth day. For the test to determine unconfined compressive strength (UCS), the specimens were cured for 7, 14, and 28 days, respectively. The strength tests were carried out in accordance with codes using the three compactive efforts [19-21].

2.2.4. Analysis of Variance (ANOVA): ANOVA was used to compare the means between two or more groups of experimental results obtained. A significant P-value; alpha (was taken as $p < 0.05$) which suggests that at least one group mean is significantly different from the others. Two types of the hypothesis that exist in ANOVA were considered; the Null Hypothesis (H0), which means that all population means are equal, and the Alternative Hypothesis (H1), which means that at least one population mean is different from the rest. Where the p-value is less than specified alpha and F is greater than Fcrit, the null hypothesis is rejected and vice versa.

3. Discussion of Results

3.1. Oxide compositions of oil palm empty fruit bunch ash and natural laterite

Chemical analyses were carried out on the ash and the laterite soil used in the study. The oxide compositions of the oil palm empty fruit bunch ash (OPEFBA) obtained are shown in Table 1. The combined composition of SiO2, Al2O3, and Fe2O3, in the OPEFBA used for this study, did not satisfy the requirement for pozzolanas [22], which stipulates a minimum combined proportion of 70 %. However, the ash has relatively high CaO contents of 52.15 %, which was responsible for the hardening observed in results obtained. Also, the chemical composition of the natural laterite summarized in Table 2 showed that the silica-sesquioxides ratio i.e. SiO2/(Fe2O3+Al2O3) is 1.22. This value implies that the soil used in the study is true laterite [23].

Table 1: Oxide composition of oil palm empty fruit bunch ash

Oxide	SiO_2	Al_2O_3	Fe_2O_3	K_2O	**CaO**	**MgO**	Na_2O	SO_3	**LOI**
Conc.%	0.05	0.003	0.007	1.24	52.15	11.10	2.72	ND	0.001

ND: Not Detected
LOI: Loss on Ignition
SG: 2.31

Table 2: Oxide composition of the natural laterite used in the study

Oxide	SiO_2	Al_2O_3	Fe_2O_3	K_2O	**CaO**	**MgO**	Na_2O	SO_3	**LOI**	$SiO_2/(Fe_2O_3+Al_2O_3)$
Conc.%	44.94	36.88	0.03	0.02	1.43	0.15	0.05	0.0	0.008	1.22

3.2. Index properties of natural Laterite

The natural laterite soil, which was classified as A-7-6 (15) and CL using the AASHTO and Unified Soil Classification System (USCS) respectively, has the gradation curve shown in Figure 1. The index properties of the natural laterite are summarized in Table 3.

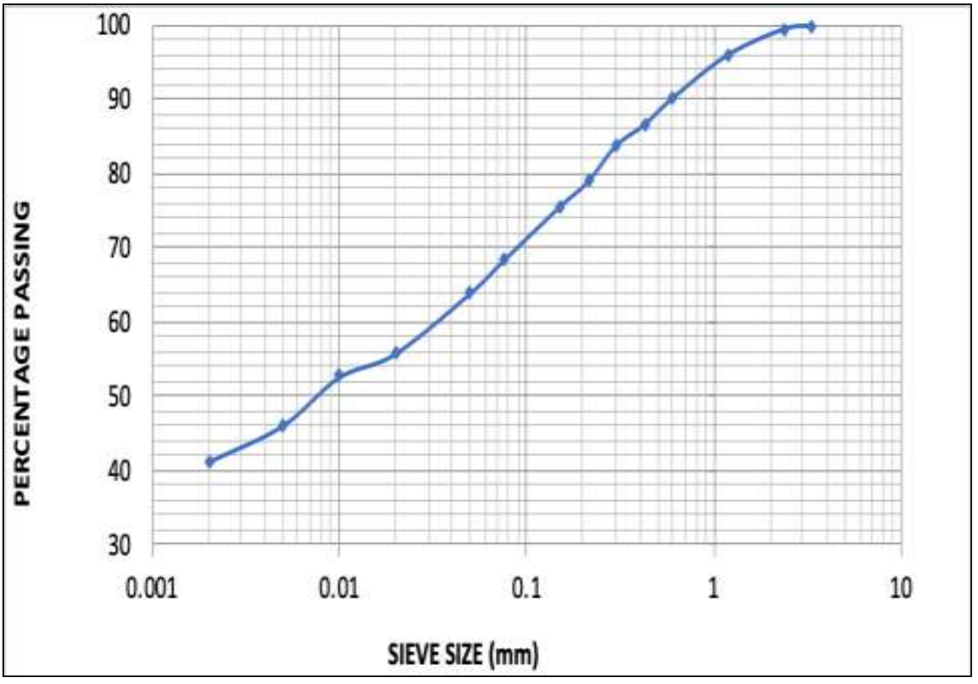

Figure 1. Particle size distribution (gradation curve) of the natural laterite.

Table 3: Index Properties of the Natural Laterite.

Property	Quantity
Natural Moisture Content, %	23.4
Percentage Passing No. 200 sieve (75 µm aperture)	68.2
Liquid Limit, %	47.0
Plastic Limit, %	24.0
Plasticity Index, %	23.0
Linear Shrinkage, %	9.4
Specific Gravity	2.62
Group Index	15
AASHTO Classification	A-7-6
USCS	CL
Maximum Dry Density, Mgm^{-3}	
British Standard light	1.6
West African Standard	1.6
British Standard heavy	1.8
Optimum Moisture Content, %	
British Standard light	18.5
West African Standard	17.1
British Standard heavy	16.1
Unconfined Compressive Strength (28 days curing), kNm^{-2}	210.0
British Standard light	285.0
West African Standard	425.0
British Standard heavy	
California Bearing Ratio (24 hours soaking), %	11.0
British Standard light	13.0
West African Standard	16.0
British Standard heavy	
California Bearing Ratio (un-soaked), %	15.0
British Standard light	17.0
West African Standard	22.0
British Standard heavy	Reddish-brown Colour

It was observed that the liquid limit (LL), plastic limit (PL), plasticity index (PI) and Linear Shrinkage (LS) values decreased with higher OPEFBA content from 47.0, 24.0, 23.0 and 9.4 % for the natural soil to 26.0, 19.0, 7.0 and 4.0 %, respectively, at 14 % OPEFBA treatment.

A decrease in LL resulted from the effect of the Ca^{2+} in the OPEFBA on the high affinity for Si/Al of the clay and silt fractions of the soil as well as the agglomeration and flocculation of the clay particles which resulted in the of exchange ions at the surface of the clay particles [24, 25]. The decrease in the PL might be due to the cation exchange reaction that liberated absorbed water molecules at the outer layers of the soil, which led to the flocculation and aggregation of the soil [11, 24-26]. The reduction in the

PI could be attributed to the depressed double layer thickness due to cation exchange by potassium, calcium and ferric ions and also gave an indication of a more stable soil with marked increased workability [7, 25].

The reduction in LS can be attributed to the input of the OPEFBA with a relatively high calcium content (see Table 1), which reduced the fine-grained soils with the formation of coarser fractions. This is a sign of improvement in the soil properties.

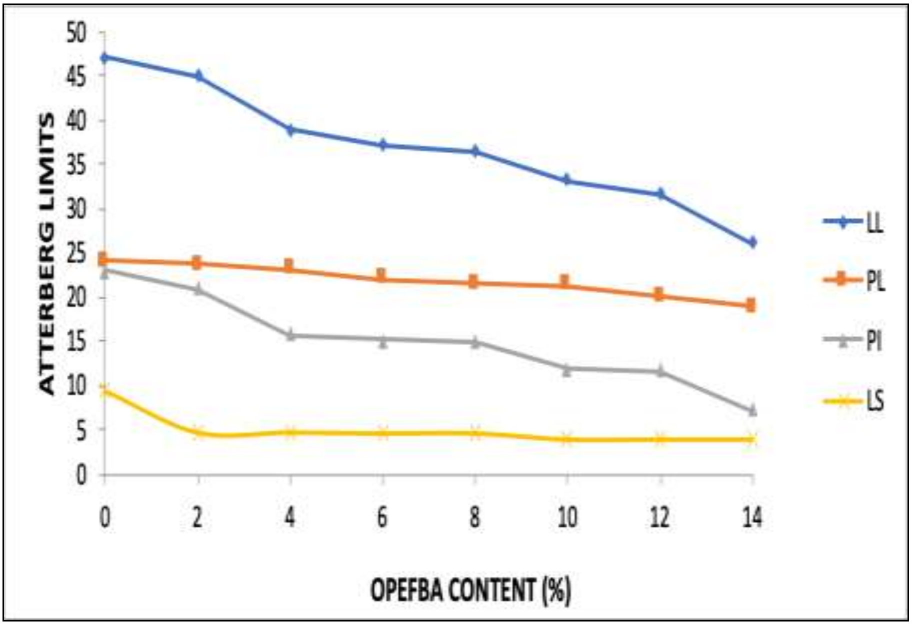

Figure 2. Variation of Atterberg limits of laterite with oil palm empty fruit bunch ash (OPEFBA) content

Table 4: Single Factor Analysis of Variance for Index Tests of Laterite Soil –OPEFBA Mixtures

Property	Source of Variation	Degree of Freedom	F_{cal}	P-value (Pv)	F_{crit}	Remark
LL	OPEFBA	15	96.79	1.14E-07	4.60	Pv < α, implies effect is statistically significant
PL	OPEFBA	15	65.70	1.18E-06	4.60	Pv < α, implies effect is statistically significant
PI	OPEFBA	15	9.18	9.00E-03	4.60	Pv < α, implies effect is statistically significant
LS	OPEFBA	15	1.21	2.89E-01	4.60	Pv > α implies effect is not statistically significant

The single factor ANOVA test on the LL, PL, PI, and LS is shown on Table 4. Since the values of F for LL, PL and PI are greater than their corresponding F_{crit}, it implies that the null hypothesis should be rejected and the alternative hypothesis should be accepted. In addition, since their respective p-values are less than the specified alpha of 0.05, it shows that the effect of the OPEFBA is statistically significant in the results of the tested parameters; LL, PL and PI. It implies that there is a significant statistical difference between the means of each of the properties tested. On the other hand, the F value for LS is less than F_{crit}. Also, the p-value is greater than the specified alpha of 0.05 and so for this case, the effect of OPEFBA is not statistically significant in the tested parameter hence, the alternative hypothesis should be rejected.

3.3. Compaction characteristics

3.3.1. Optimum moisture content: The variation of optimum moisture content (OMC) of laterite with OPEFBA contents for the BSL, WAS and BSH compactive effort is shown in Figure 3. It was observed that there was a general increase in OMC with the increased OPEFBA content for all the specimens compacted. The values increased form 18.5, 17.1, and 16.1 % for the natural soil to 23.3, 20.1 and 21.4% at 14 % OPEFBA content using the BSL, WAS and BSH compactive efforts respectively. The observed increase in the OMC with increased OPEFBA content is in line with the findings [24-29]. These trends are also in agreement with the established trend for stabilization of laterite with cement and lime [9], South Chicago clay with lime-kiln dust [30], laterite with rice husk ash [31] and laterite with bamboo leaf ash [7]. The increase in OMC value was due to the addition of OPEFBA, which decreased the number of free silts and clay fractions and so coarser materials with larger surface areas were formed, which implies that more water was needed in order to compact the soil-OPEFBA mixtures. There was an increasing desire for water commensurate with the higher amount of the additives because more water was required for the disassociation of admixtures with Ca^{2+} and OH^- ions to supply more Ca^{2+} for the cation exchange reaction [6, 24-26, 29].

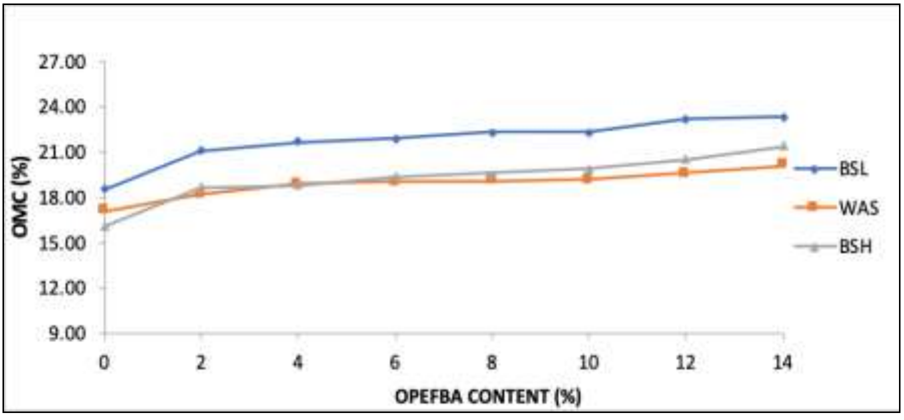

Figure 3. Variation of optimum moisture content (OMC) of laterite with oil palm empty fruit bunch ash (OPEFBA) content.

3.3.2. Maximum dry density: The variation of maximum dry density (MDD) of laterite – OPEFBA content is shown in Figure 4. Generally, the MDD values increased with higher compactive efforts and decreased with increasing OPEFBA content. It was noticed that for the WAS and BSH compactive effort, the MDD initially increased from 1.60 and 1.75 Mgm^{-3} for the untreated soil to 1.62 and 1.75 Mgm^{-3} at 2 % OPEFBA content and thereafter decreased with increase in OPEFBA content to 1.49 and 1.58 Mgm^{-3} at 14 % OPEFBA content respectively. The initial increase is a general indication of soil improvement [16, 25]. It may be due to cation exchange reactions and may also be due to the OPEFBA occupying the voids within the soil matrix and in addition, causes the flocculation and agglomeration of the clay particle due to the exchange of ions [24, 32].

Results for the BSL compaction shows a decrease from 1.60 Mgm^{-3} for the natural untreated laterite soil to 1.51 Mgm^{-3} at 14 % OPEFBA content. The results are in line with the established trend for stabilization of laterite with cement and lime, respectively [9], laterite with rice husk ash [31], laterite with bamboo leaf ash [7] and South Chicago clay with lime-kiln dust [30]. This has been explained for lime and fine-grained soils in terms of the flocculation and agglomeration of the soil which form larger particles with subsequent increase in air voids giving rise to reduced dry densities [9]. This explanation is considered to hold true for OPEFBA given that K_2O and CaO contents of the ash which adds up to 53.39% could combine with any naturally occurring CaO in the lateritic soil [33] to initiate cation exchange, flocculation and agglomeration of the soil, in a manner similar to the effect of lime stabilization [30]. The decrease in dry densities may also be due to the flocculated and agglomerated clay particles occupying larger spaces leading to a corresponding decrease in dry densities. This trend is in agreement with the findings reported by [24, 25, 29, 34]. Another explanation for this observation could be the replacement of the higher specific gravity of laterite (2.62) with OPEFBA of lower specific gravity (2.31) that resulted in a higher volume mix requiring the addition of more water thereby leading to more reduction in density since water has an even lower specific gravity. The decrease in MDD could also be due to the fact that for any soil/admixture, there is always a water content that produces maximum strength [26]. As expected, higher dry densities were achieved with greater efforts for all the OPEFBA used in the study.

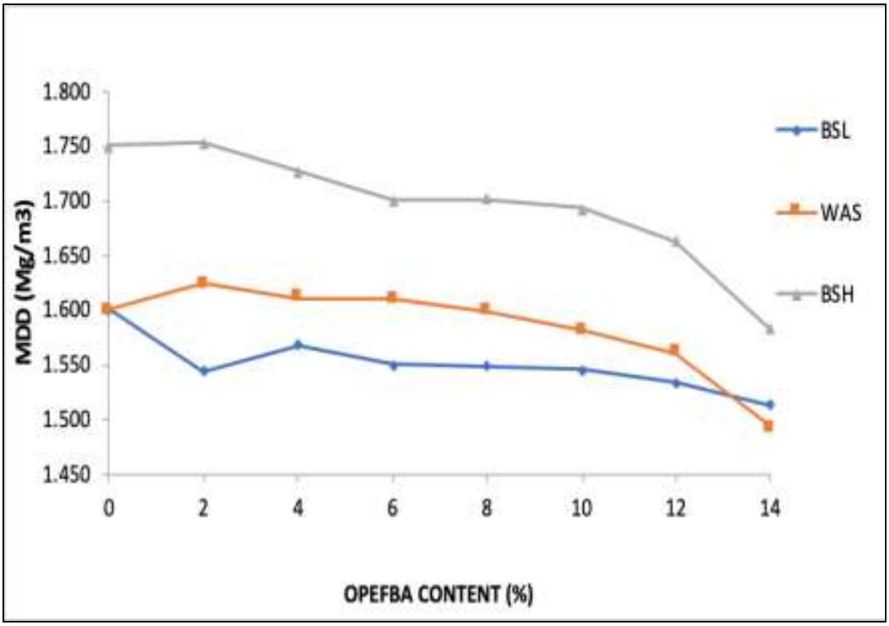

Figure 4. Variation of maximum dry density (MDD) of laterite with oil palm empty fruit bunch ash (OPEFBA) content.

Table 5: Two Factor Analysis of Variance for Compaction Characteristics of Laterite–OPEFBA Mixtures

Property	Sources of Variation	DF	F cal	P-value (Pv)	F crit	Remark
OMC	OPEFBA	7	32.02	1.44E-07	2.76	Pv < α, implies effect is statistically significant
	Compactive effort	2	120.03	1.54E-09	3.74	Pv < α, implies effect is statistically significant
MDD	OPEFBA	7	9.19	2.57E-04	2.76	Pv < α, implies effect is statistically significant
	Compactive effort	2	95.56	6.9E-09	3.74	Pv < α, implies effect is statistically significant

The ANOVA test on the OMC and MDD result (see Table 5) shows the effect of OPEFBA and compactive efforts (BSL, WAS and BSH) on the laterite – OPEFBA mixtures. From the assessment of the table, the F values for both sources of variation on the tested properties; OMC and MDD are greater than the F_{crit} values. The P-values in all cases is less than the specified alpha, hence the null hypothesis for the compaction characteristics should be rejected and the alternative hypothesis should be accepted. This implies that there is a significant statistical difference between the means of each of the properties (OMC and MDD) tested.

3.4. Strength Characteristics

3.4.1. California bearing ratio

Un-soaked: The variation of the un-soaked CBR values after nylon curing for 6 days for the natural and OPEFBA treated soil is shown in Figure 5. The un-soaked CBR values increased from 15.0, 17.0 and 22.0 % for the natural laterite to peak values of 70.0, 80.0 and 85.0 % at 8% OPEFBA content and then decreased to 40, 46 and 51% at maximum of 14 % EFBA content using the BSL, WAS and BSH compactive efforts respectively. This increase in the CBR could be as a result of the presence of adequate amounts of calcium required for the formation of calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH), which are the major compounds responsible for strength gain [13].

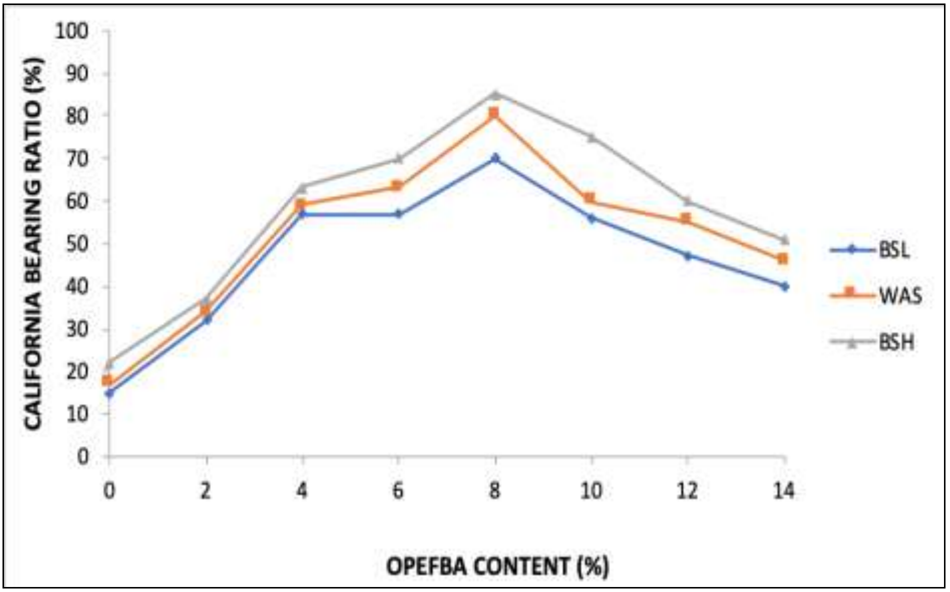

Figure 5. Variation of California bearing ratio (un-soaked condition) of laterite with oil palm empty fruit bunch ash (OPEFBA) content.

Soaked: The variation of CBR value (24 hours-soaked conditions) for natural and OPEFBA-treated laterite is shown in Figure 6. A peak value of 44.0, 50.0, and 53.0 % at 8 % OPEFBA content was obtained which decreased to 37.0, 39.0, and 40.0 % at 14% OPEFBA content using the BSL, WAS and BSH compactive efforts respectively. The lower values recorded in comparison to the un-soaked CBR values were due to the ingress of water into the specimen, which led to a reduction in strength. The results show that the CBR values did not decrease very significantly when soaked however, relating to the required specifications for sub-base course construction, it meets the 20-30% strength requirements [21].

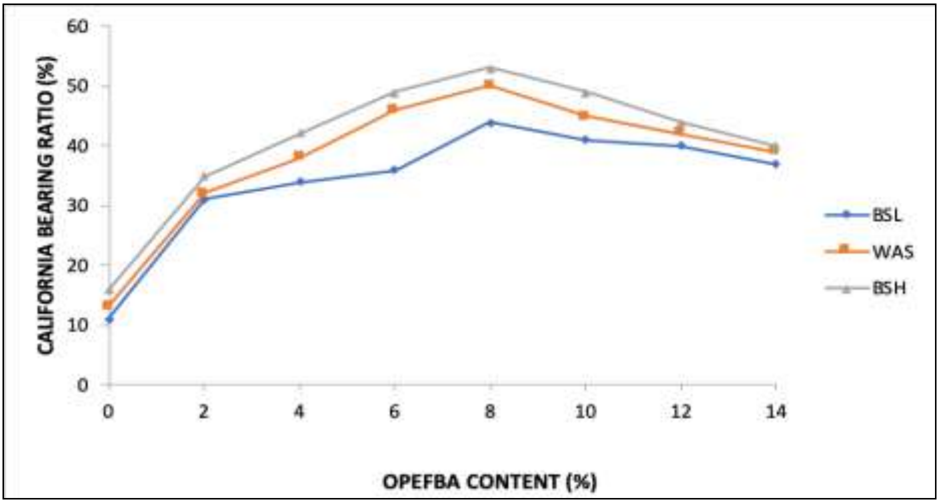

Figure 6. Variation of California bearing ratio (soaked conditions) of laterite with oil palm empty fruit bunch ash (OPEFBA) content.

Table 6: Two Factor Analysis of Variance for California Bearing Ratio of Laterite Soil – OPEFBA Mixtures

Property	**Sources of Variation**	**DF**	**F cal**	**P-value (Pv)**	**F crit**	**Remark**
UN-SOAKED CBR	OPEFBA	7	138.89	7.62E-12	2.76	Pv < α, implies effect is statistically significant
	Compactive effort	2	31.83	6.19E-06	3.74	Pv < α, implies effect is statistically significant
SOAKED CBR	OPEFBA	7	104.53	5.34E-11	2.76	Pv < α, implies effect is statistically significant
	Compactive effort	2	26.18	1.86E-05	3.74	Pv < α, implies effect is statistically significant

The ANOVA test on the effect of OPEFBA and compactive effort as sources of variation on the CBR tests (un-soaked and soaked) are presented in Table 6. From the assessment of the table, the F values are greater than the F_{crit} values. The P-values in all the cases are less than the specified alpha of 0.05 hence, the null hypothesis is rejected and the alternative hypothesis should be accepted. It implies that there is a significant statistical difference between the means of each of the un-soaked and soaked properties tested.

3.4.2. Unconfined compressive strength: The variation of unconfined compressive strength (UCS) of laterite soil with OPEFBA content cured for 7, 14, and 28 days using the BSL, WAS and BSH compactive efforts are shown in Figures 7, 8 and 9 for which a similar trend was observed. The untreated UCS values for 7 days curing period show a steady increase from 161.0, 213.0 and 355.0 kNm^{-2} to peak values of 253.0, 310.0 and 494.0 kNm^{-2} at 8 % OPEFBA content and then a steady decrease to 228.0, 244.0 and 254.0 kNm^{-2} at 14 % OPEFBA content. For the 14 days curing periods, a steady increase from a value of 194.0, 250.0 and 398.0 kNm^{-2} for the natural laterite to 462.0, 658.0 and 730.0 kNm^{-2} at 8 % OPEFBA content as well as a steady decrease in strength to 381.0, 438.0 and 443.0 kNm^{-2} was observed, and for the 28 days curing, a steady increase from a value of 210.0, 285.0 and 425.0 kNm^{-2} for the natural soil to 577.0, 725.0 and 840.0 kNm^{-2} at 8 % OPEFBA content and then a decrease to 408.0, 640.0 and 691.0 kNm^{-2} at 14 % OPEFBA content was also observed.

The increase in UCS values could be attributed to ion exchange at the surface of the clay particles. The Ca^{2+} in the additives reacted with the lower valence metallic ions in the clay microstructure, which resulted in agglomeration and flocculation of the clay particles [35]. The increase in the UCS values was primarily due to the formation of various compounds such as calcium silicates hydrates (CSH) and calcium aluminate hydrates (CAH) and micro fabric changes, which are responsible for strength development [13, 25, 36, 37].

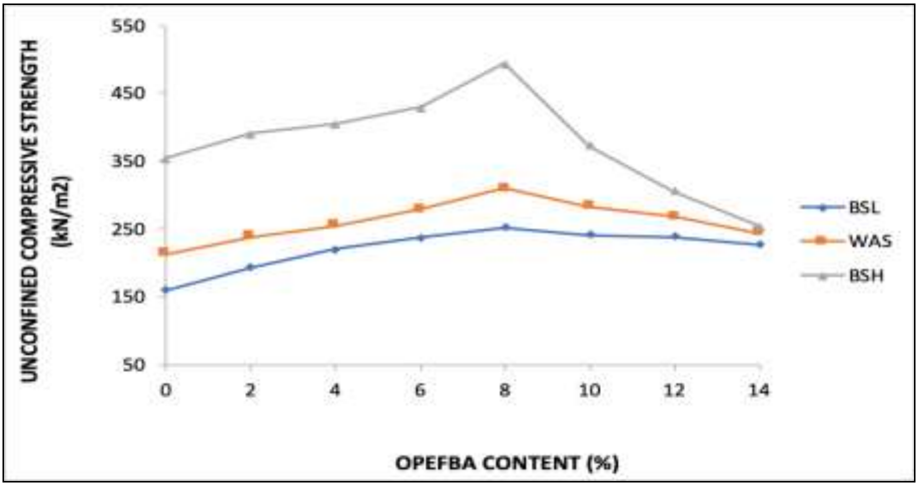

Figure 7. Variation of unconfined compressive strength (7 days curing period) of laterite with oil palm empty fruit bunch ash (OPEFBA) content

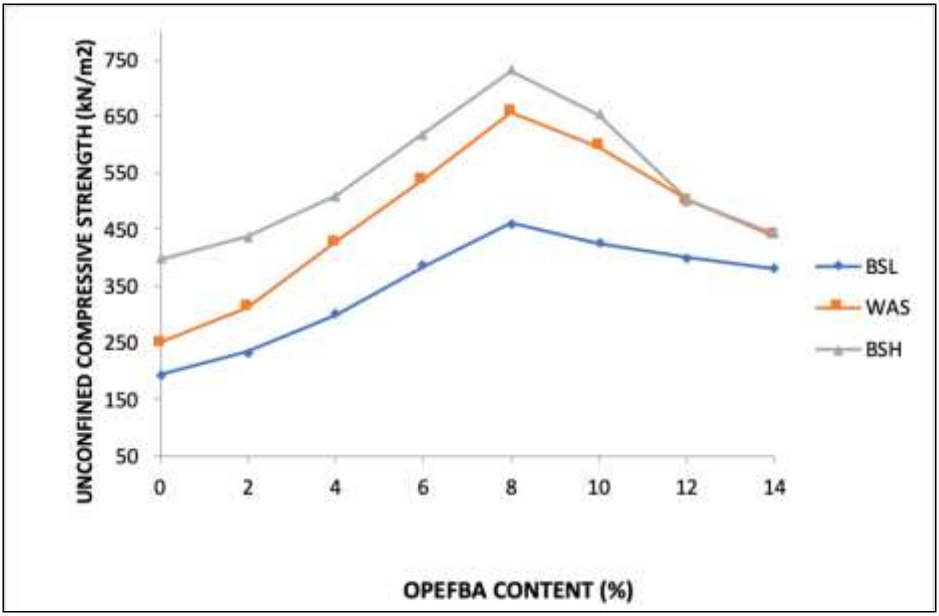

Figure 8. Variation of unconfined compressive strength (14 days curing period) of laterite with oil palm empty fruit bunch ash (OPEFBA) content.

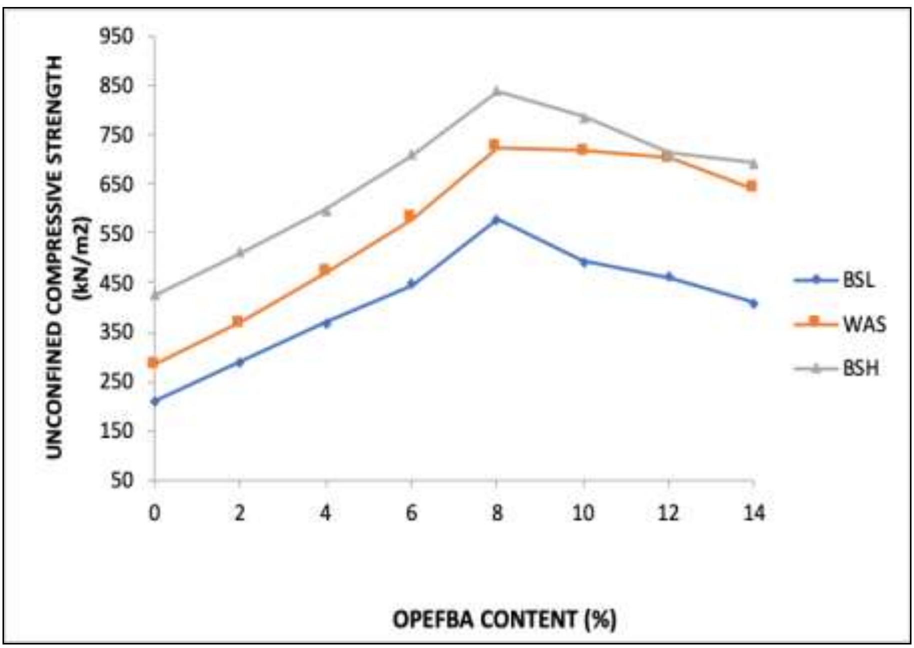

Figure 9. Variation of unconfined compressive strength (28 days curing period) of laterite with oil palm empty fruit bunch ash (OPEFBA) content.

Table 7: Two Factor Analysis of Variance for Unconfined Compressive Strength of Laterite Soil –OPEFBA Mixtures

Property	**Sources of Variation**	**DF**	**F cal**	**P-value (Pv)**	**F crit**	**Remark**
UCS-7 DAYS	OPEFBA	7	2.62	0.06	2.76	Pv > α, implies effect is not statistically significant
	Curing period	2	32.29	5.7E-06	3.74	Pv < α, implies effect is statistically significant
UCS-14 DAYS	OPEFBA	7	22.29	1.44E-06	2.76	Pv < α, implies effect is statistically significant
	Curing period	2	41.81	1.25E-06	3.74	Pv < α, implies effect is statistically significant
UCS-28 DAYS	OPEFBA	7	44.39	1.7E-08	2.76	Pv < α, implies effect is statistically significant
	Curing period	2	97.69	5.97E-09	3.74	Pv < α, implies effect is statistically significant

The analysis of variance (ANOVA) tests on the UCS results are shown in Table 7. From the assessment of the table, it can be deduced that the F values for the 7 days OPFEBA source of variation was less than F_{crit}, whereas, for the 14- and 28-days duration, the F values are higher than the F_{crit} values. Comparing the P-values to the specified alpha, the P-value for the 7 days OPFEBA source of variation is greater than the specified alpha whereas, the P-values in other cases are less than the specified alpha hence, the null hypothesis accepted for the 7-days OPEFBA variation but rejected for the other tests. This further implies that there is no significant statistical difference between the means of the OPEFBA property tested for 7-days. For the other parameters tested, results show that there is a significant statistical difference between their means.

4. Conclusion and Recommendation

A reddish-brown soil (laterite) collected from Ikorodu North Local Government Area in Lagos state was air-dried and treated with oil palm empty fruit bunch ash (OPEFBA) in stepped concentrations of 0, 2, 4, 6, 8, 10, 12 and 14% by dry weight of soil. Preliminary investigations carried out showed that this soil falls under the CL group in the Unified Soil Classification System, (USCS) or classified as A-7-6 (15) in the American Association of State Highway and Transportation Officials, (AASHTO) respectively The values of the preliminary tests indicate that the soil in its natural state cannot be used as a road construction material but when treated with 8% OPEFBA content by dry weight and compacted with a minimum BSL energy, the treated laterite is suitable for use as a sub-base construction material in low-volume roads or as a stabilizer for the rehabilitation to sub-base of ways. The ANOVA tests show that there are significant statistical differences between the means of each property tested as most of all the results showed a null hypothesis.

References

[1] Madu, R. M., (1975). Sand-laterite mixtures for road construction (A laboratory investigation), Civil Engineering Department, University of Nigeria Nsukka, Nigerian Journal of Technology, Vol. 1, 1, 28-37.

[2] Asphalt Recycling & Reclaiming Association (2001). United States Federal Highway Administration. Annapolis, MD: Asphalt Recycling & Reclaimation Association.

[3] Alayaki, F.M., (2012) Water absorption properties of laterite soil in road pavement: A case study Ife-Ilesha highway, South Western Nigeria. International Journal of Emerging Technology and Advanced Engineering Website: IJETAE Vol. 2, 11, 51-57.

[4] Amadi A.N., Akande W. G., Okunlola I. A., Jimoh M.O., Francis Deborah G. (2015). Assessment of the geotechnical properties of lateritic soils in Minna, North Central Nigeria for road design and construction. American Journal of Mining and Metallurgy, **3, 1,** 15-20. DOI: 10.12691/ajmm-3-1-3.

[5] McNally, G. H., (1998). Soil and rock construction materials, Routledge, London. 276-282, 330-341.

[6] Musa, A., (2008). Potential of rice husk ash for soil stabilization. AUJ.T. 11(4) Pp. 246-250.

[7] Amu, O.O. and Adetuberu, A.A. (2010). Characteristics of bamboo leaf ash stabilization on lateritic soil in highway construction. International Journal of Engineering and Technology. 2, 4, 212- 219.

[8] Kowalski, T. E. and Starry, D. W., (2007). Modern soil stabilization techniques. Paper prepared for presentation at the characterization and improvement of soil and material session of the 2007 Annual Conference of the Transportation Association of Canada, Saskatoon, Saskatchewan.

[9] Ola, S.A. (1983). Tropical soils in engineering practice.

Balkema Publishers, Rotterdam, Netherlands.

[10] Balogun, L. A., (1991). Effects of sand and salt additives on some geotechnical properties of lime stabilized with black cotton soil. The Nigerian Engineer. 26, 2, 15-24.

[11] Osinubi, K. J. (1995). Lime modification of black cotton soil. Spectrum Journal, 2, 1 and 2, 112-122.

[12] Alhassan, M. and Mustapha, M., (2007). Effect of rice husk ash on cement stabilized laterite: Department of Civil Engineering, Federal University of Technology, Minna, Niger State. Leonardo Electronic Journal of Practices and Technologies. ISSN 1583-1078, 47-58.

[13] Bello, A.A., Ige, J.A., Ayodele, H. (2015). Stabilization of lateritc soil with cassava peel ash. British Journal of Applied Science and Technology. BJAST.2015.180. ISSN: 2231-0843 7, 6, 642-650.

[14] Osula, D. O. A., (1991). Lime modification of problem laterite. Engineering Geol. 30, 14-19.

[15] Osinubi, K. J., and Mustapha, A. M., (2008). Effects of compactive efforts on cement-sugarcane bagasse ash-laterite mixture submitted to the Nigerian Society of Engineers Technical Transactions. 43, 2, 33-46.

[16] Amu, O.O., Ogunniyi, S.A. and Oladeji, O.O (2011). Geotechnical properties of lateritic soil stabilized with sugarcane straw ash. AMERICAN JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH © 2011, Science Huβ, http://www.scihub.org/AJSIR ISSN: 2153-649X doi:10.5251/ajsir.2011.2.2.323. 331.

[17] Olutoge, F. A., Quadiri, H. A., Olafusi, O. S., (2012). Investigation of the strength properties of palm kernel shell ash concrete. Engineering, Technology & Applied Science Research. 2, 6, 315-319.

[18] Edeh, J., Tyav, S., and Osinubi, K. (2014.) Cassava peel ash stabilized lateritc soil as highway pavement material. Pavement Materials, Structures, and Performance. https://doi.org/10.1061/978078 4413418.037, 375-382.

[19] BS 1377 (1990). Methods of testing soil for civil engineering purposes. British Standards Institute, London.

[20] BS 1924 (1990). Methods of tests for stabilized soils. British Standards Institute, London.

[21] Federal Ministry of Works and Housings (FMW&H), 1997. Roads and Bridges. In: Nigerian General Specification, Abuja, Nigeria, 13–25.

[22] American Society for Testing Materials (ASTM C618-78). Standard specification for fly ash and raw or calcined natural pozzolan for use as a mineral admixture in Portland cement concrete.

[23] Joachin, A.W.R., and Kandiah, S., (1941). The composition of some local laterites (cabooks), soil concretions and clays. Tropical Agriculturist, Ceylon, 96, 67-75.

[24] Osinubi, K. J**.,** Yohanna, P., and Eberemu, A. O., (2015). Cement modification of tropical black clay using iron ore tailings as admixture. Transportation Geotechnics, Elsevier 5, 35 – 49.

[25] Oke, J. A. and Osinubi, K. J. (2019). Oil palm empty fruit bunch ash as a sustainable stabilizer for laterite sub- base of highway pavements. IOP Conference Series: Materials Science and Engineering. 640, 1, 1-11.

[26] Osinubi, K. J. (1999). Evaluation of admixture stabilization of Nigerian black cotton soil. Nigerian Society of Engineers Technical Transactions. 34, 3, 88-96.

[27] Ola S. A. (1975). Stabilization of Nigerian lateritic soils with cement, bitumen, and lime, Proceedings of the 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering.

[28] Gidigasu, M. D., (1976). Laterite soil engineering: Pedogeneses and engineering principles. Development in geotechnical engineering, Amsterdam, Elsevier Scientific Publishing Company.

[29] Oke, J. A. and Olowoyo, M. K. (2019). Stabilization of laterite soil with eggshell powder and sodium silicate used as fill material in road construction. AZOJETE, 15, 3, 586-597.

[30] Daita, K.R., Drnevich, V.P., and Kim, D. (2005). Family of compaction curves for chemically modified soils. Publication FHWA/IN/JTRP-2005/07. Joint Transportation Research Program, INDOT and Purdue University, West Lafayette, Indiana, US.

[31] Alhassan, M., (2008). Potentials of rice husk ash for soil stabilization. A.U. Journal of Technology, 11, 4, 246 - 250. Available at www.journal.au.edu/au_techno. [November 26 2011].

[32] O'Flaherty, C. A., (1988). Highway Engineering. Vol. 2, Edward Arnold, London.

[33] Alao, D.A., (1983). Geology and Engineering Properties of Laterites from Ilorin, Nigeria. Engineering Geology, Journal. Elsevier Science Publishers, Amsterdam, the Netherlands. 19, 111 – 11.

[34] Lees, G., Addelkader, M. O., and Hamdani, S. K., (1982). Sodium chloride as additive in line-soil stabilization. Journal Institute of Highway Engineers. 29, 11, 8-16.

[35] Moses, G. K., and Saminu, A., (2012). Cement klin dust stabilization of compacted black cotton soil. IRJI Journal of Research in Engrg. 17, 826-834.

[36] Osinubi, K.J., Oyelakin, M. A., and Eberemu, A.O., (2011). Improvement of black cotton

soil with ordinary Portland cement - locust bean waste ash blend. 16, 619-627. Bund F.
[37] Negi, A. S., Faizan, M., Siddharth, D. P., Singh, R. (2013). Soil stabilization using lime. International Journal of Innovative Research in Science, Engineering and Technology. 2, 2, 448-453.