

# Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures

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**Abstract:** The discharge of agricultural, industrial and domestic wastes is at increasing rate on daily basis in the developing countries. These wastes are generated in enormous quantity and improper waste management systems and lack of proper monitoring system leads to these wastes constituting nuisance to the environment. Converting these wastes to useful and economical additives for construction work is the aim of this study. This study analyses the results of the comparison between the strength characteristics of pozzolan stabilized lateritic soil using coconut shell husk ash (CSHA) and palm kernel shell husk ash (PKSHA) as admixtures. OMC, MDD, Particle Size Distribution, California Bearing Ratio, Triaxial Test, Unconfined Compressive Strength and Atterberg limit were investigated. The soil is a clayey soil classified as A-7-6(20) according to AASHTO and CH inorganic sandy fat clay according to Unified Classification System. CBR value of the unsoaked was greater than the soaked and it increased at different percentages of CSHA and PKSHA, at control CBR value for soaked and unsoaked at 2.5 and 5.5 penetrations were 4.0/6.0 and 3.0/6.0 KN respectively. At 10% CSHA, the CBR value improved to 13.0 KN and 9.0KN for unsoaked and soaked at 2.5mm at 5.0mm, while 10% PKSHA improved to 14.0 KN and 10 KN unsoaked and soaked at 2.5mm and 5.0mm respectively. Addition of CSHA and PKSHA increased optimum moisture content and decreased maximum dry density. UCS increased with respect to the curing days and different percentages of CSHA and PKSHA. At control, UCS was 6.43, 8.65 and 14.80 KN/m<sup>2</sup> for 0, 7 and 14days curing. It improved to 10.79, 31.82, 40.00 KN/m<sup>2</sup> at 10% CSHA and 11.38, 33.43 and 41.64 KN/m<sup>2</sup> at 10%PKSHA for 0, 7 and 14days curing respectively. PI and LL reduced and PL increased as percentages of CSHA and PKSHA increased. Coconut shell husk ash and palm kernel shell husk ash are good additives for soil stabilization as they increased and improved the strength characteristics of the soil.

**Keywords:** Pozzolan, strength characteristics, stabilized lateritic soil, coconut shell husk ash, palm kernel shell husk ash.

## INTRODUCTION

Soil stabilization refers to the procedure in which a special soil, a cementing material, or other chemical or non chemical materials are added to a natural soil or a technique used on a natural soil to improve its geotechnical properties, (Abood et al, 2007; Salahudeen and Ochebo, 2015). Soil stabilization techniques for road construction are used in most part of the world although circumstance and reasons for resorting to stabilization vary considerably. Nearly every road construction project will utilize stabilization techniques. When used, these stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion and serve as cementing and water proofing agents, (Janathan, 2004). Soil stabilization has widely been recommended for developing countries for various elements of their pavements. The reasons usually are that the use of local conditions is of paramount importance while developing any soil stabilization technique. This is because a

## **Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures**

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country's climatic conditions can affect the behaviour of stabilized soil materials as well as construction procedures. Soil stabilization can improve the shear strength of the soil and control shrinkage swell properties of the soil thus improving the load bearing capacity of foundation soils (Brenema, 2010). Laterite is a Reddish residual soil from rocks. Soils are mostly used for construction of road bases in Nigeria. Laterite is high in iron oxide and aluminium hydroxide content, but low in silica content (Kowalski et al, 2007). Lateritic soils are residual soils and are mainly found in the tropical and sub-tropical regions. These are soils formed by the leaching of lighter minerals like silica. Consequently, it is the enrichment of the heavier minerals like iron and aluminium oxides (sesquioxides). It was stated that the degree of laterization is estimated by silica-sesquioxide ratio (Makasa, 2004). Researches all over the world today are focusing on ways of utilizing, either industrial or agricultural wastes as a source of raw materials for the industry. These wastes utilization would not only be economical, but may also result to foreign exchange earnings and environmental pollution control (Bienia *et al*, 2006). In this research study, coconut shell husk and palm kernel shell husk wastes were considered as admixture. The disparity between countries with excellent roads and highway networks and those with poor ones can be expected to increase. This gap will be due to primary differences in the funding base resulting from socioeconomic and geopolitical conditions. At the same time, regions throughout the world share a common need to maintain and rebuild aging transportation system infrastructure. Yet if past policies prevail, money will be used primarily to build new facilities, with a smaller share of funds being allocated to maintaining and rebuilding existing facilities (Amoanyi, 2012; Breneman, 2009). The world already has many miles of unpaved and marginally paved roads. In many areas worldwide, new roads will be unpaved as well. In places where roads are paved, they will be replaced or repaired from the ground up. Because of aging, broken-down pavements may require recycling and rebuilding but more likely they are the result of poor support conditions combined with higher traffic loads. New roads, both paved and unpaved will probably be placed in locations where there were no roads before because of less ideal subgrade conditions. In all of these situations, less-than-desirable materials are likely to be used. Use of these materials will in turn require the application of stabilization techniques presently available, as well as those likely to evolve in the next century (Aigbodio *et al*, 2010). Hence in the new millennium, we will face the challenge of developing better chemical stabilizers and mechanical stabilization techniques; new, quicker, and better testing methods; and better and environmentally safe methods for using waste materials for highway construction. Research is needed in a number of areas to develop the materials and methods required to meet this challenge. The primary aim of this study is the comparison of the strength characteristics of pozzolan stabilized lateritic soil with coconut shell husk ash and palm kernel shell husk ash. Specifically, the objectives of the study were; (i) to determine the effect of palm kernel shell husk ash on pozzolan stabilized lateritic soil, (ii) to determine the effect of coconut shell husk ash on pozzolan stabilized lateritic soil and (iii) to compare the effects of coconut shell husk ash and palm kernel shell husk ash on the geotechnical properties of pozzolan stabilized Oboro lateritic soil.

## **MATERIALS AND METHODS**

### **Materials**

#### ***Lateritic Soil Sample***

The lateritic soil sample used for this research work was collected from a borrow pit located at Umuigu of Oboro in Ikwuano Local Government Area of Abia State. They were all collected at depths representative of the soil stratum and not less than the 1.2m below the natural ground level. These were kept safe and dry in bags and were later air dried in pans for two weeks to allow partial elimination of natural moisture which may affect analysis.

#### ***Pozzolan Soil***

The pozzolan soil sample used for this research work was collected from ohyia near mechanical village Enugu Port-Harcourt expressway, in Umuahia South Local Government Area of Abia State. The sample was collected

## **Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures**

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in a bag and it was air dried for two weeks to eliminate the moisture in it. It was then crushed to powder form using core cutter with bulk density mould.

### ***Palm Kernel Shell Husk***

The palm kernel shell husk was obtained from oil palm mill in Edem Inyang village in Ukanafun Local Government Area of Akwa Ibom State. The palm kernel shell husks were burnt in a no soil surface and it was sieved properly to obtain a finer particle passing sieve no. 200.

### ***Coconut Shell Husk***

The coconut shell husk used for this research was collected at Edem Ekpat Village in Etinan Local Government Area of Akwa Ibom State, Amaoba and Umudike villages in Ikwuano Local Government Area of Abia State. The coconut shell husk were burnt in a no soil surface, it was properly sieved to obtain a finer particle passing sieve no. 200.

## **Methods**

### ***Sieve Analysis***

Particle size distribution tests were performed on the pozzolan stabilized lateritic soil sample using standard sieves in line with British Standard methods (BS 1377-1990: Part 2)

### ***Atterberg Limits Tests***

Using the pozzolan stabilized lateritic soil sample retained on the 4.25mm sieve the Atterberg limits tests, comprising liquid limit (LL) and plastic limit (PL), were determined and the plasticity index (PI) was calculated in accordance with BS1377-1990: Part 2. The tests were carried out on the pozzolan stabilized soil and then on the soils with different proportions of coconut shell husk ash and palm kernel shell husk ash additive of 2.0%, 4.0%, 6.0%, 8.0% and 10.0% by mass of soil sample.

### ***Compaction Tests***

Proctor standard compaction tests to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the pozzolan stabilized lateritic soil were in accordance with (BS1377-1990: Part 4). The tests were carried out on the pozzolan stabilized soil and then on the soils with different proportions of coconut shell husk ash and palm kernel shell husk ash additive of 2.0%, 4.0%, 6.0%, 8.0% and 10.0% by mass of soil sample.

### ***California Bearing Ratio Test***

The California Bearing Ratio tests were conducted on pozzolan stabilized soil samples which have been compacted with 2.5kg rammer. The tests forces on a plunger at penetration of 2.5mm and 5.0 mm were determined and the California Bearing Ratio (CBR) was calculated as specified (BS1377-1990: Part 4). The tests were carried out on the pozzolan stabilized soil and then on the soils with different proportions of coconut shell husk ash and palm kernel shell husk ash additive of 2.0%, 4.0%, 6.0%, 8.0% and 10.0% by mass of soil sample.

### ***Specific Gravity Test***

Specific gravity tests were performed on the pozzolan stabilized lateritic soil sample using pycnometer in line with British Standard methods (BS 1377-1990: Part 2).

### ***Unconfined Compressive Strength Test and Triaxial Test***

The measurement of the effective shear strength parameters for cylindrical specimens of saturated soil which have been subjected to isotropic consolidation and then sheared in compression, under a constant confining

## Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures

pressure, by increasing the axial strain was studied. The test was performed unconsolidated under undrained conditions, with the possibility of measuring pore pressure and volume change. The test was carried out in accordance with (BS1377-1990: Part 8).

### RESULTS AND DISCUSSION

#### Laboratory Study Results and Data

The chemical composition of coconut shell husk ash and palm kernel shell husk ash according to (Johnson et al, 2012) and (Otunyo et al, 2010) are shown on Tables 1 and 2 respectively.

**Table1.** Chemical composition of coconut husk ash. (Johnson et al, 2012)

Compound	P2O5	SiO2	SO3	K2O	CaO	TiO2	V2O5	Cr2O3
% Composition	2.60	17.9	1.40	62.43	8.76	0.73	0.007	0.11
Compound	MnO	Fe2O3	NiO	CuO	BaO	ZnO	MnO3	Re2O7
% Composition	0.11	4.65	0.087	0.089	0.48	0.12	0.30	0.10

**Table2.** Chemical decomposition of palm kernel husk ash. (Otunyo et al, 2010)

Compound	Composition %
Carbonate	0.88
Silica	97.03
Ferric oxide	0.0296
Salinity	0.027
Aluminum oxide	0.032
Sulphur trioxide	0.52
Silt content	0.078
Organic matters	1.31
Magnesium	0.37

The following results were obtained from the chemical decomposition of pozzolan, CSHA and PKSHA.

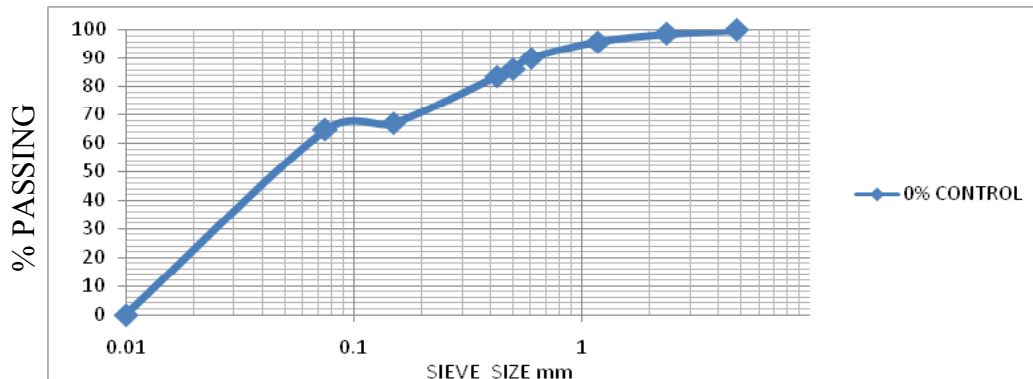
**Table3.** Chemical analysis of Pozzolan, CSHA and PKSHA

COMPOUNDS	PERCENTAGE %		
	Pozzolan	Coconut Shell Husk Ash	Palm Kernel Shell Husk Ash
SiO <sub>2</sub>	43.36	30.20	34.72
Al <sub>2</sub> O <sub>3</sub>	38.58	3.52	3.48
Fe <sub>2</sub> O <sub>3</sub>	0.35	3.61	1.82
P <sub>2</sub> O <sub>5</sub>	0.37	2.47	2.56
CaO	0.04	4.99	20.34
TiO <sub>2</sub>	1.67	1.03	12.36
MgO	0.04	21.36	1.48

**Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures**

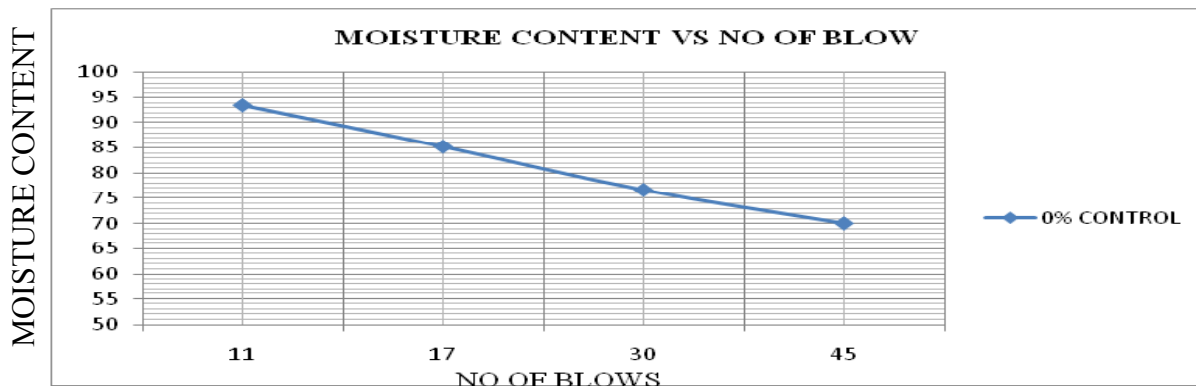
Na <sub>2</sub> O	0.05	1.97	1.99
K <sub>2</sub> O	0.00	0.98	2.01
MnO	0.00	0.96	0.08
Ignition loss 110-550°C	13.6	19.67	12.55
<b>Total</b>	<b>98.06</b>	<b>92.27</b>	<b>93.39</b>

The grading curve of classification for the oboro lateritic soil under study was carried out and shown in Figure 1.



**Fig1. Particle size distribution graph at 0% control**

The results of the Atterberg limit examination of the natural oboro lateritic soil and the studied effect of varied proportions of the CSHA and PKSHA are shown in Figure 2 and Table 4 and Figure 3.



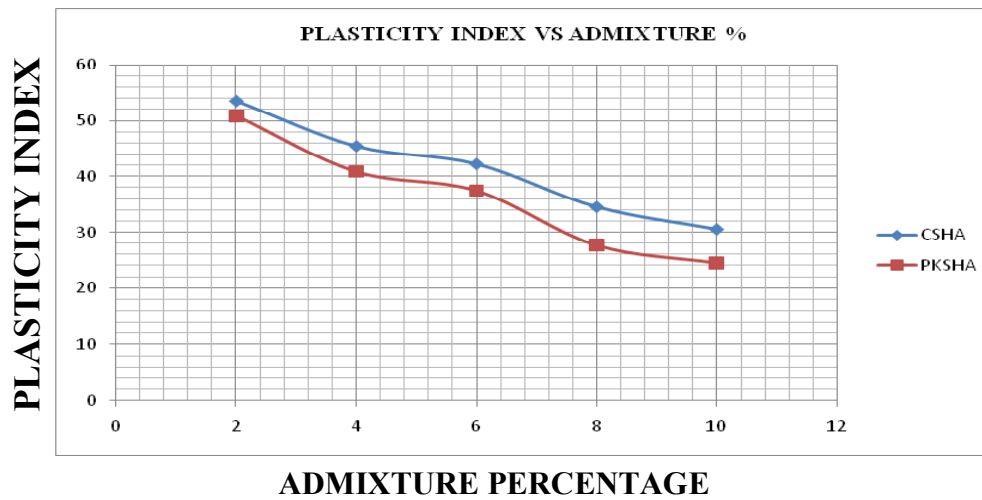
**Fig2. Atterberg limit graph at 0% (control)**

**Table4. Summary of test of the effect of CSHA and PKSHA on the Atterberg Limit of studied sample**

Quantity	LL	PL	PI	Moisture Content		
				93.3	76.6	70.0
0%	26.1	80.5	54.4	93.3	76.6	70.0
2% CSHA	27.4	81.0	53.6	92.9	90.8	86.2
2% PKSHA	26.2	77.0	50.8	82.1	78.8	77.0
4% CSHA	28.5	74.0	45.5	88.6	82.1	73.9
4% PKSHA	28.2	69.0	40.8	79.4	73.2	72.1

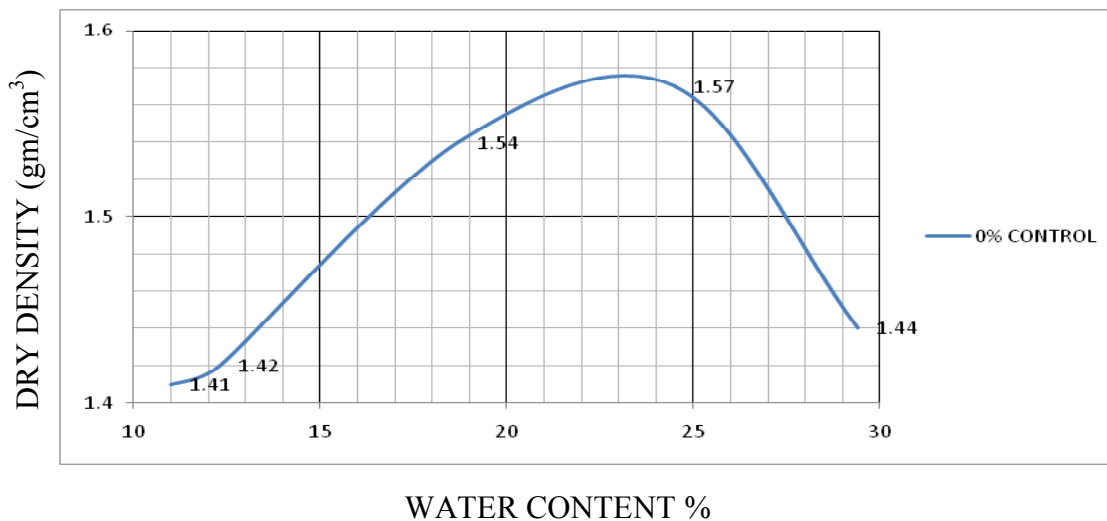
**Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures**

<b>6% CSHA</b>	29.7	72.0	42.3	82.9	75.0	65.0	61.1
<b>6% PKSHA</b>	29.6	67.0	37.4	76.3	69.1	63.9	58.5
<b>8% CSHA</b>	35.4	70.0	34.6	83.5	75.6	65.2	59.8
<b>8% PKSHA</b>	30.4	58.0	27.6	70.3	63.1	54.1	50.7
<b>10% CSHA</b>	38.4	69.0	30.6	85.1	75.0	66.3	59.6
<b>10% PKSHA</b>	32.1	56.5	24.4	62.9	57.9	55.3	53.4



**Fig3.** A graph of plasticity index against % of CSHA and PKSHA

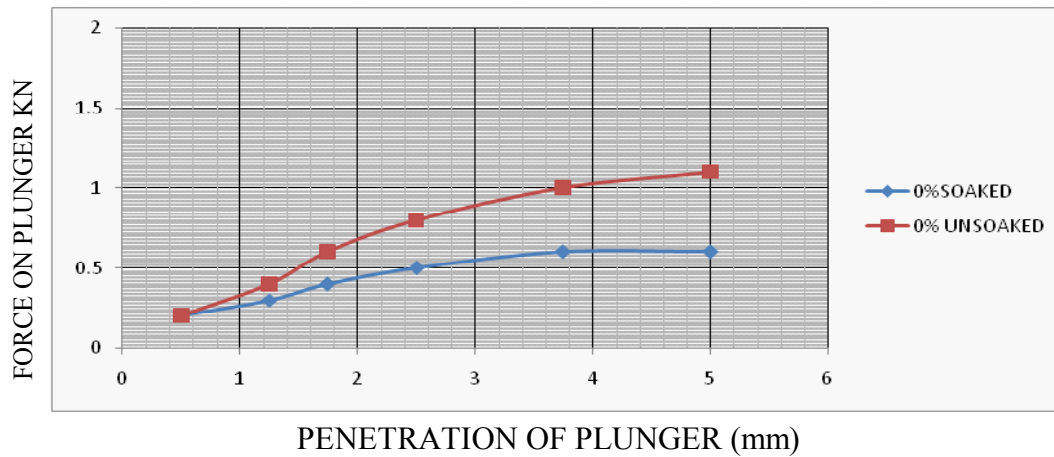
Figure 4 shows the compaction test result carried on the natural soil under study



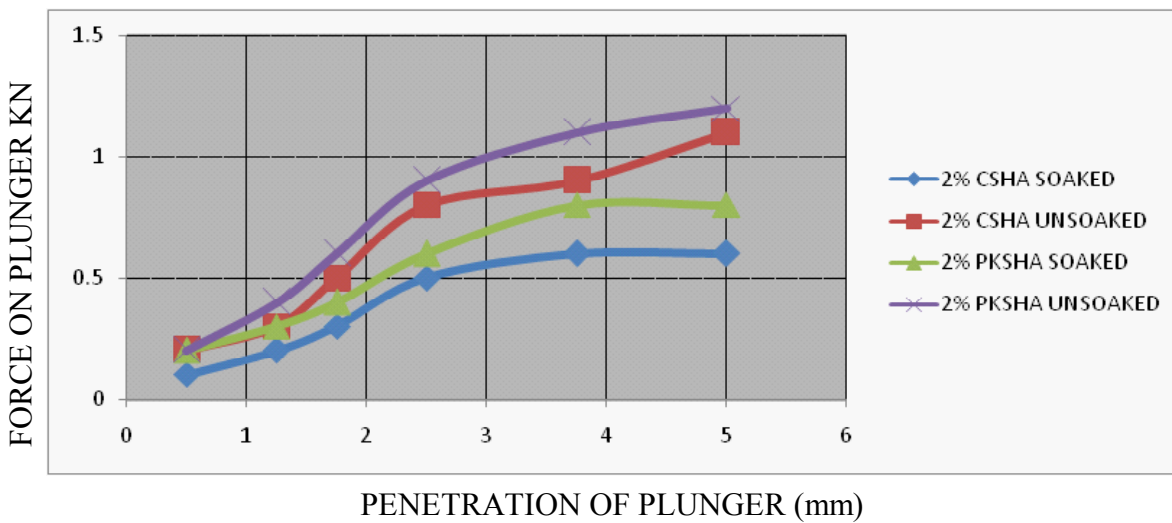
**Fig4.** A graph of dry density against water content at 0 % (control)

Figures 5, 6, 7, 8, 9 and 10 show the effect of the admixtures on the California bearing ratio of the studied sample under soaked and unsoaked conditions.

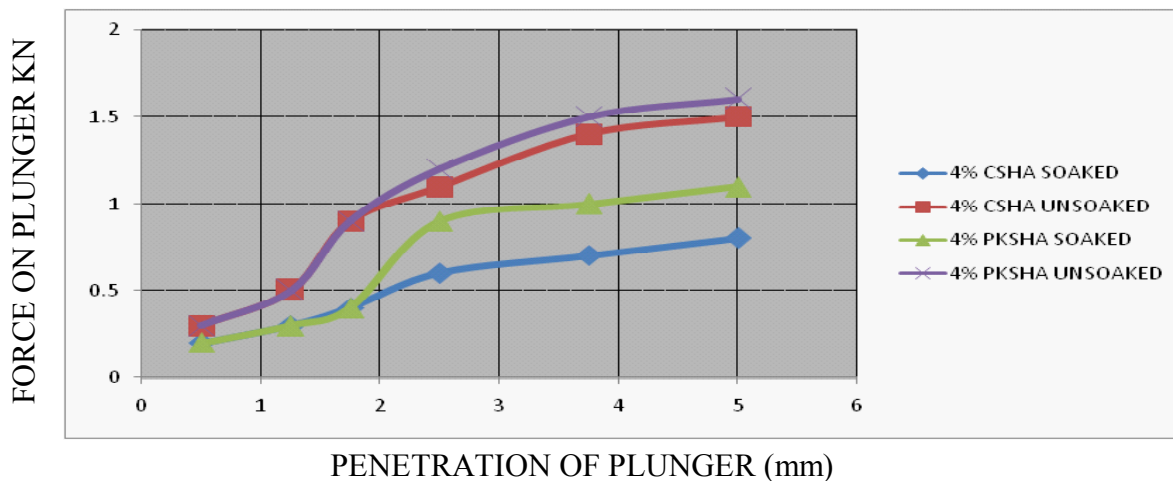
**Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures**



**Fig5.** Graphical representation of CBR curve at 0% soaked and unsoaked



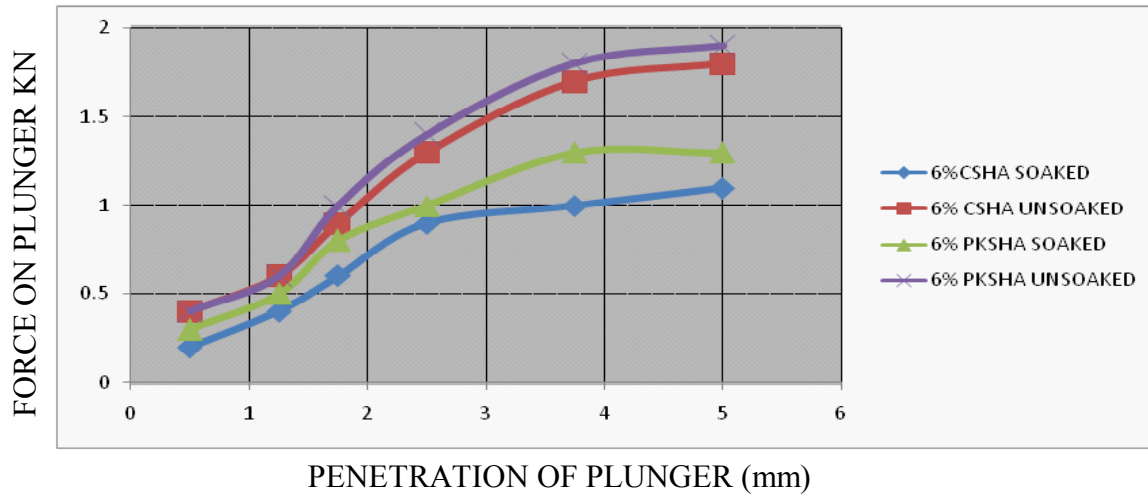
**Fig6.** Graphical representation of CBR curve of soaked and unsoaked for 2% CSHA and 2% PKSHA



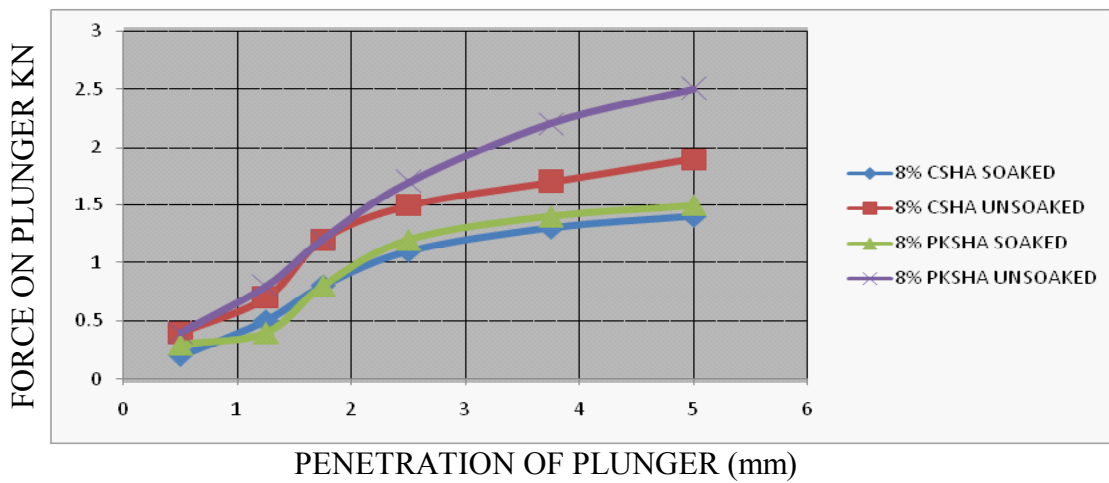
**Fig7.** Graphical representation of CBR curve of soaked and unsoaked for 4% CSHA and 4% PKSHA



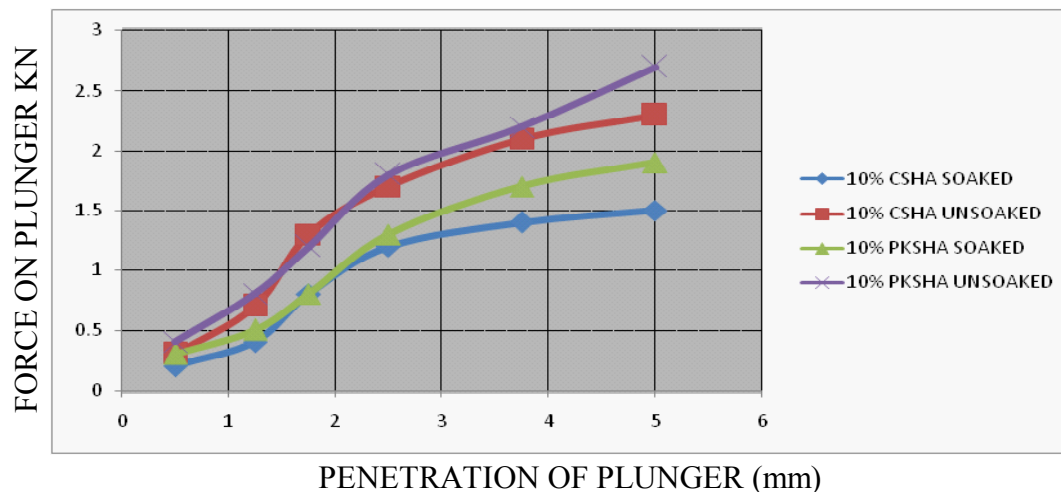
**Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures**



**Fig8.** Graphical representation of CBR curve of soaked and unsoaked for 6% CSHA and 6% PKSHA



**Fig9.** Graphical representation of CBR curve of soaked and unsoaked for 8% CSHA and 8% PKSHA



**Fig10.** Graphical representation of CBR curve of soaked and unsoaked for 10% CSHA and 10% PKSHA



## Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures

Figure 11 shows the effect of the varied proportions of admixtures on the unconfined compressive strength of the studied sample for 0, 7 and 14 days of curing.

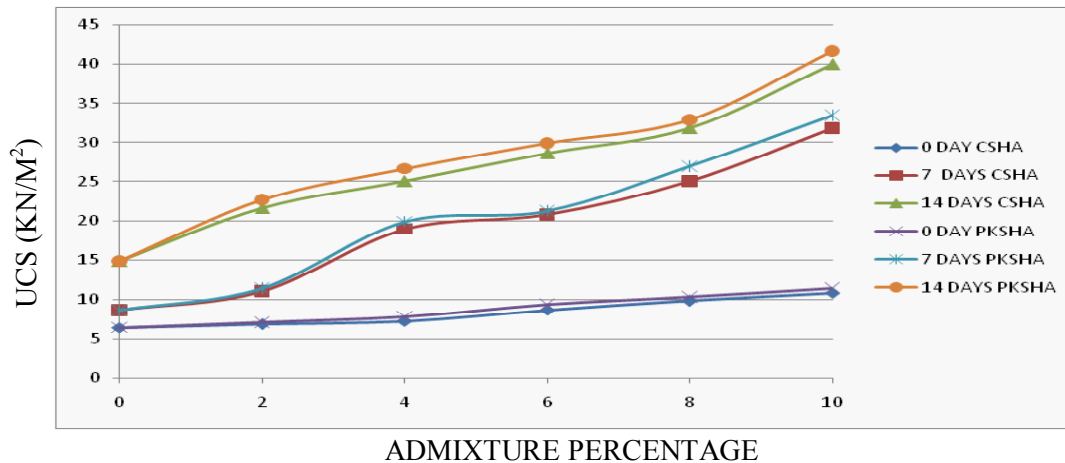


Fig11. graphical representation of UCS curves

## DISCUSSION OF RESULTS

### Effect of CSHA and PKSHA on Atterberg Limits of Pozzolan Stabilized Lateritic Soil

As pointed out by (Gogo, 1993), plasticity characteristics give an indication of the approximate water content which is likely to give the optimum workability during mixing and therefore plays an important role in stabilization. From Table 4 and Figure 3, the pozzolan stabilized soil at 0% (control), it is observed that the soil possesses plastic limit of 26.1, liquid limit of 80.5 and plasticity index of 54.4. At 2% CSHA and 2% PKSHA, the following were obtained, PL of 27.4, LL of 79, PI of 53.6, and LL of 77, PL of 26.2 and PI of 50.8 respectively. At 4% CSHA and 4% PKSHA, the following were obtained PL of 28.5, LL of 74.0, and PI of 45.5 and PL of 28.2, LL of 69 and PI of 40.8 respectively. At 6%, PL of 29.7, LL of 72 and PI of 42.3 for CSHA and PL of 29.6, LL of 67 and PI of 37.4 for PKSHA respectively. At 8% CSHA and PKSHA, PL of 35.4, LL of 70, and PI of 34.6 and PL of 30.4, LL of 58 and PI of 27.6 were obtained respectively, while PL of 38.4, LL of 69, PI of 30.6 and PL of 32.1, LL of 56.5 and PI of 24.4 were obtained for 10% CSHA and 10% PKSHA respectively. Generally, from Table 4 comparing the effect of CSHA and PKSHA on the Atterberg limit of pozzolan stabilized lateritic soil it was observed that the moisture content, plasticity index and liquid limit of pozzolan stabilized lateritic soil reduced by the addition of different percentages of coconut shell husk ash (CSHA) and palm kernel shell husk ash (PKSHA) but that of PKSHA reduced drastically than that of CSHA. At 10% PKSHA, liquid limit and plasticity index were 56.5 and 24.4 while 69 and 30.6 were obtained for 10% CSHA. The plastic limit increased in the addition of different percentages of CSHA and PKSHA, but CSHA increased more than PKSHA, therefore indicating that CSHA is abrasive plastic than PKSHA which reduces moisture content than CSHA.

### Effect of CSHA and PKSHA on California Bearing Ratio of Pozzolan Stabilized Lateritic Soil

From Figure 5, CBR value of 6.0 and 5.5 is obtained at 2.5 and 5.0 penetration for 0% unsoaked while 4.0 and 3.0 were obtained at 2.5 and 5.0 for 0% soaked. From Figure 5 to Figure 10 shows the different CBR value at 2.5 and 5.0 for 2% CSHA, 2% PKSHA, 4% CSHA, 4% PKSHA, 6% CSHA, 6% PKSHA, 8% CSHA, 8% PKSHA, 10% CSHA and 10% PKSHA soaked and unsoaked, which shows the graphical representation of CBR curve comparing the different percentages of CSHA and PKSHA. The notable effect of CSHA and PKSHA on pozzolan stabilized soil is that there was no effect on the soil at 2% CSHA as it maintained the same CBR value for 0% soaked and unsoaked. CBR value of the unsoaked was greater than the soaked and it increases at different percentage of

## **Comparison between the Strength Characteristics of Pozzolan Stabilized Lateritic Soil of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash Admixtures**

CSHA and PKSHA for soaked and unsoaked with exception of 2%CSHA. The CBR value of PKSHA at different percentages is greater than that of CSHA.

### **Effect of CSHA and PKSHA on Unconfined Compressive Strength of Pozzolan Stabilized Lateritic Soil**

Figure 11 shows the unconfined compressive strength of pozzolan stabilized soil for 0% and at different percentages of CSHA and PKSHA at 0day, 7days and 14days curing time which shows the graphical representative behaviour of UCS curves where UCS was plotted against percentage of CSHA and PKSHA. From the result obtained, it was noted that UCS increased with respect to the curing days. UCS also increased at different percentages of CSHA and PKSHA. The UCS of PKSHA increased more than that of CSHA when compared.

### **CONCLUSIONS**

From the observations on critical examinations and analyses and comparing of the results obtained during the investigation of the strength characteristics of pozzolan stabilized lateritic soil using coconut shell husk ash(CSHA) and palm kernel shell husk ash (PKSHA) as admixtures, the following conclusions have been drawn;

- From comparing the effect of CSHA and PKSHA on the Atterberg limit of pozzolan stabilized lateritic soil it was observed that the moisture content, plasticity index and liquid limit of pozzolan stabilized lateritic soil reduced by the addition of different percentages of coconut shell husk ash (CSHA) and palm kernel shell husk ash (PKSHA) but that of PKSHA reduced more in effect than that of CSHA. The plastic limit increased on the addition of different percentages of CSHA and PKSHA, but CSHA increased more than PKSHA, indicating that CSHA is abrasive plastic than PKSHA and PKSHA reduces moisture than CSHA.
- Addition of CSHA and PKSHA increased optimum moisture content and decreased maximum dry density. The increment in the OMC was almost at the same rate for both CSHA and PKSHA while the decrease in the MDD varies with different percentages of CSHA and PKSHA when compared to 0%.
- CBR value of the unsoaked was greater than the soaked and it increased at different percentages of CSHA and PKSHA for soaked and unsoaked with exception of 2%CSHA which maintained the same value with that of 0%. The CBR value of PKSHA at different percentages was observed to be greater than that of CSHA.
- That CSHA and PKSHA had no effect on the specific gravity of pozzolan stabilized soil. Specific gravity of CSHA was slightly greater than that of PKSHA.
- UCS increased with respect to the curing days. UCS also increased at different percentages of CSHA and PKSHA. The UCS of PKSHA increased more than that of CSHA.

Finally, CSHA and PKSHA have proven to be good admixtures in the stabilization of weak engineering soil though PKSHA has shown to be better by positively affecting the strength properties of oboro lateritic soil.

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