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Effect of Coconut Shell Husk Ash and Palm Kernel Shell Husk Ash on the Grading and Consistency Behaviour of Pozzolan Stabilized Oboro Lateritic Soil

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Abstract
The effect of Coconut shell husk ash and palm kernel shell husk ash on the grading and consistency of oboro lateritic soil stabilized with pozzolan has been studied in this research. Results of the grading analysis have shown that the natural soil was classified as A-7-6 soil according to the AASHTO classification system and CH-inorganic sandy fat clay according to USCS. The consistency result of the natural soil showed that the soil is highly plastic with a plasticity index of 54.4% > 17. The admixtures were used in the proportions of 2%, 4%, 6%, 8% and 10% and their proportional effect on the grading behaviour of the pozzolan stabilized soil showed that the uniformity and curvature of the soil improved with increased admixtures. CSHA recorded a better improvement with the uniformity of the soil while PKSHA recorded better improvement with the curvature of the soil. The consistency limits results showed that the plasticity of the stabilized soil decreased with increase in percentage of admixtures making the mixture less plastic. Finally it has been established that CSHA and PKSHA are good admixtures in the stabilization of weak and highly plastic engineering soil and are recommended for use.
Keywords: Coconut shell husk ash, palm kernel shell husk ash, grading and consistency behaviour, oboro lateritic soil, stabilized.

INTRODUCTION

Soil stabilization is the procedure in which soil, cementing material, or other admixtures 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 Ochepo, 2015). It is necessary that the behaviour of engineering soil is monitored to enable proper classification and characterization. The primary properties used in this purpose are grading and consistency.

Engineering Soil Grading

The process of grading engineering soils take two major procedures which depends primarily on the particle size retained or passing No.200 (75µm) sieve. If tye particle size is such that it is retained in the above sieve size, it is graded using sieve analysis otherwise a sedimentation analysis is adopted in which case either hydrometer or pipette or buoyancy analysis or even a combined procedure is used (Bardet, 1997). Sieve analysis determines the grain size distribution curve of soil samples by passing them through a stack of sieves of decreasing mesh opening sizes and measuring the weight retained on each sieve. Sieve can be performed in either wet or dry conditions. Grain size analysis is a basic laboratory test required to identify soils in engineering soil classification system shown in Figure 1 and Table 1 and their engineering properties assessed (Bardet, 1997).

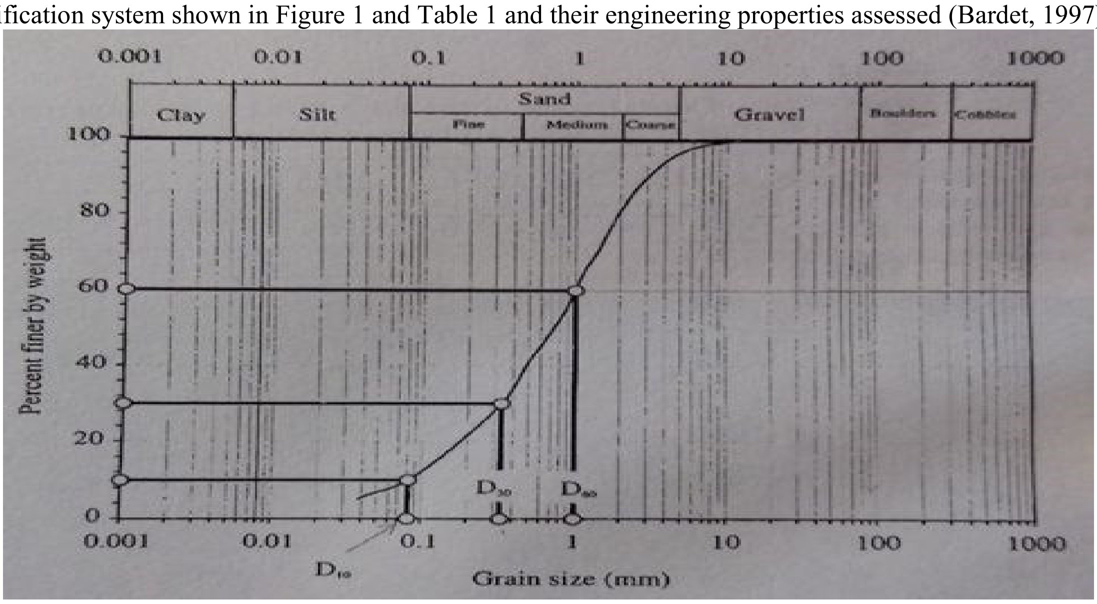
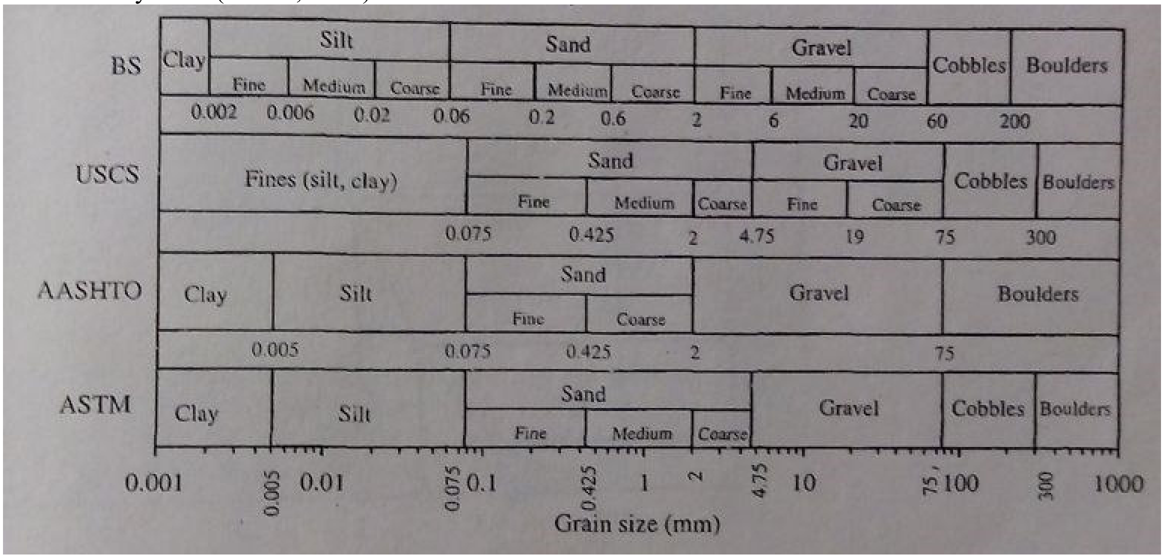


Figure 1: Grain size distribution chart (Bardet, 1997; Ranjan and Rao, 2011)

Table 1: Classification of particle size in the BS1377, USCS, AASHTO and ASTM engineering soil classification systems (Bardet, 1997).



The grain size distribution curve shown in Figure 1 enables engineering soils to be classified into uniforms soils characterized by the uniformity coefficient Cu, well-graded soils characterized by the coefficient of curvature Cc and poorly graded soils which apply to soils including uniform soils which do not comply with the description of well graded soils (Smith and Smith, 1998; Bardet, 1997). In geotechnical engineering, particle size analysis are useful for various practical applications, ranging from the selection of fill and aggregate materials, to road construction, drainage, fillers and grouting one of which can be x-rayed in this research study.

Consistency of Engineering Soil

Consistency is a term used to describe the degree of firmness of a soil in a qualitative manner by using descriptions such as soft medium, firm, stiff or hard or non plastic, low plastic, medium plastic or highly plastic. It indicates the relative ease with which a soil can be deformed and in practice, this is only associated with fine grained soils (Ranjan and Rao, 2011). Consistency examination of engineering soils makes available the following properties of the studied soil; liquid limit, plastic limit, plasticity index, liquidity index, relative consistency, shrinkage limit, toughness index etc. The engineering behaviour of fine-grained soils depends on factors other than the particle size distribution. It is influenced primarily by their mineral and structural composition and the amount of water they contain referred to as moisture content (Bardet, 1997). The liquid and plastic limits tests characterize the effect of water on fine-grained soils and help in their classification and to assess their mineral composition and engineering properties.

Soil Stabilization using Admixtures

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 soil engineer to be applied in soil modification. 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 admixtures. The disparity between countries with excellent roads and highway networks and those with poor ones can be expected to increase. 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; Sadeeq et al, 2015). 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). The primary aim of this study is the comparison of the grading and consistency 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 grading and consistency of pozzolan stabilized lateritic soil, (ii) to determine the effect of coconut shell husk ash on grading and consistency of pozzolan stabilized lateritic soil and (iii) to compare the effects of coconut shell husk ash and palm kernel shell husk ash on the grading and consistency properties of pozzolan stabilized Oboro lateritic soil.

MATERIALS AND METHODS

Materials

1. 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 at a depth of 2m below the natural ground level. These were kept safe and dry in bags and were later air dried in pans to allow partial elimination of natural moisture which may affect analysis.
2. 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 in a bag and it was air dried to eliminate the moisture in it. It was then crushed to powder form using core cutter with bulk density mould.
3. 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 sieve properly to obtain a finer particle and 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.

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). 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%.

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), liquidity index (LI) and shrinkage limit (SL) were calculated in accordance with (BS1377–1990: Part 2; ASTM D 1632; ASTM D 1633; ASTM D 5102-09; ASTM D-2166-06). 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%.

Compaction Tests

Proctor standard compaction tests to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the lateritic soil were carried out in accordance with (BS1377–1990: Part 4; ASTM D 1632; ASTM D 1633; ASTM D 5102-09; ASTM D-2166-06).

Specific Gravity Test

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

RESULTS AND DISCUSSION

Laboratory Study Results and Data Discussions

Fundamental laboratory examinations conducted on the oboro lateritic soil show that the soil was classified an A-7-6 according to AASHTO classification system and CH according to USCS shown in Table 1. The reddish brown lateritic oboro soil is also classified as a highly plastic soil with a plasticity index of 54.4% with kaolinite as the dominant clay mineral. Other consistency and strength properties are shown in Table 2.

Table 2: Properties of the Natural Oboro Soil Sample

Properties	**Quantity**
Percentage passing BS sieve no. 200	35.64
Liquid Limit (LL) (%)	80.5
Plastic Limit (PL) (%)	26.1
Plasticity Index (PI) (%)	54.4
Relative Consistency (RC) (%)	1.22
Liquidity Index (LI) (%)	-0.22
Shrinkage Limit (SL) (%)	9.77
AASHTO Classification	A-7-6
USCS	CH
Group Index	20
Specific Gravity	2.30
Natural Moisture Content (%)	14
Colour	Reddish brown
Optimum Moisture Content (OMC) (%)	24
Maximum Dry Density (MDD) (gm/cm^3)	1.57
Dominant Clay Mineral	Kaolinite
UCS KN/m^2 (0 days curing)	6.43
UCS KN/m^2 (7 days curing)	8.65
UCS KN/m^2 (14 days curing)	14.80
CBR at 2.5mm Unsoaked (%)	6.0
CBR at 5.0mm Unsoaked (%)	6.0
CBR at 2.5mm 24hrs Soaked (%)	4.0
CBR at 5.0mm 24hrs Soaked (%)	3.0
Void Ratio	0.5
Frictional Angle (deg)	36.3
Maximum Deviator Stress KN/m2	51.9

The results of the chemical composition of pozzolan, coconut shell husk ash and palm kernel shell husk ash carried out are shown in Table 3. The difference in the oxides of calcium, titanium and magnesium are high between CSHA and PKSHA.

Table 3: *Chemical analysis of Pozzolan, CSHA and PKSHA*

Compounds	**PERCENTAGE %**		
	Pozzolan	**CSHA**	**PKSHA**
SiO_2	43.36	30.20	34.72
Al_2O_3	38.58	3.52	3.48
Fe_2O_3	0.35	3.61	1.82
P_2O_5	0.37	2.47	2.56
CaO	0.04	4.99	20.34
TiO_2	1.67	1.03	12.36
MgO	0.04	21.36	1.48
Na_2O	0.05	1.97	1.99
K_2O	0.00	0.98	2.01
MnO	0.00	0.96	0.08
Ignition loss110-550^oC	13.6	19.67	12.55
Total	98.06	92.27	93.39

The grading curve of classification for the oboro lateritic soil under study was carried out and shown in Figure 1. This shows the particle distribution of the studied soil sample which has a Cu of 4.0 > 1 i.e. a non uniform soil and Cc of 0.75; inorganic sandy fat clay.

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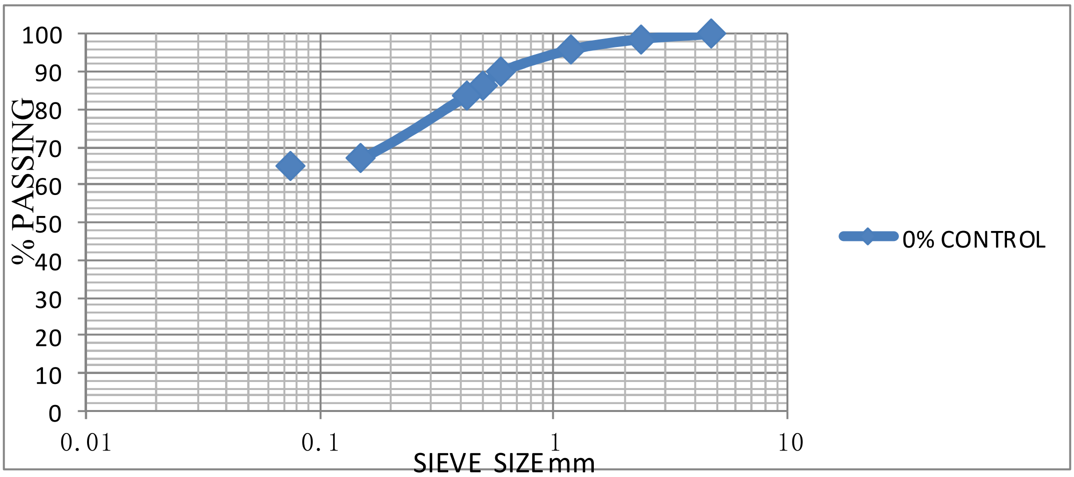

Figure 2: Particle size distribution graph at 0% control

Figures 3, 4, 5, 6 and 7 and Table 4 have shown the effect of the admixtures on the grading curve of the pozzolan oboro stabilized lateritic soil.

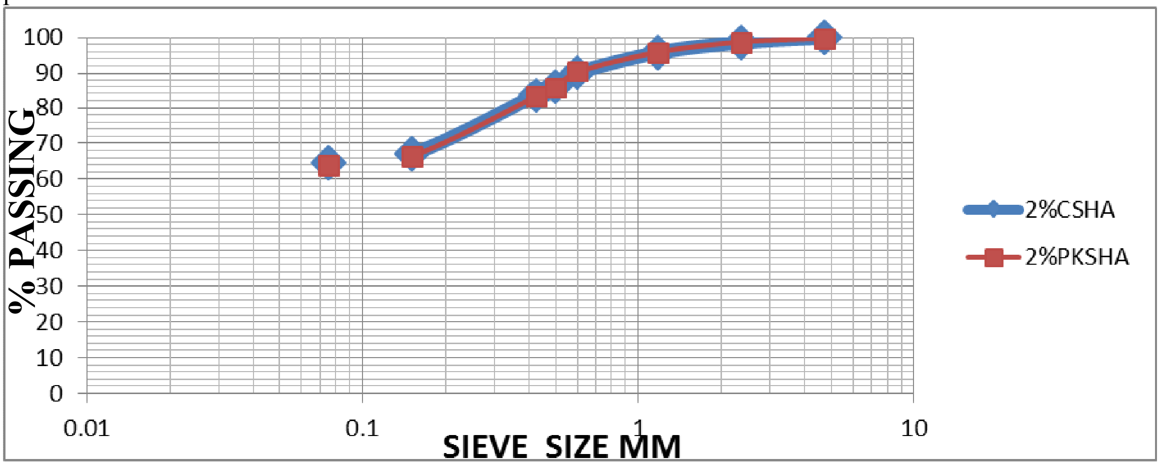

Figure 3: *Particle size distribution graph at 2% CSHA and 2% PKSHA*

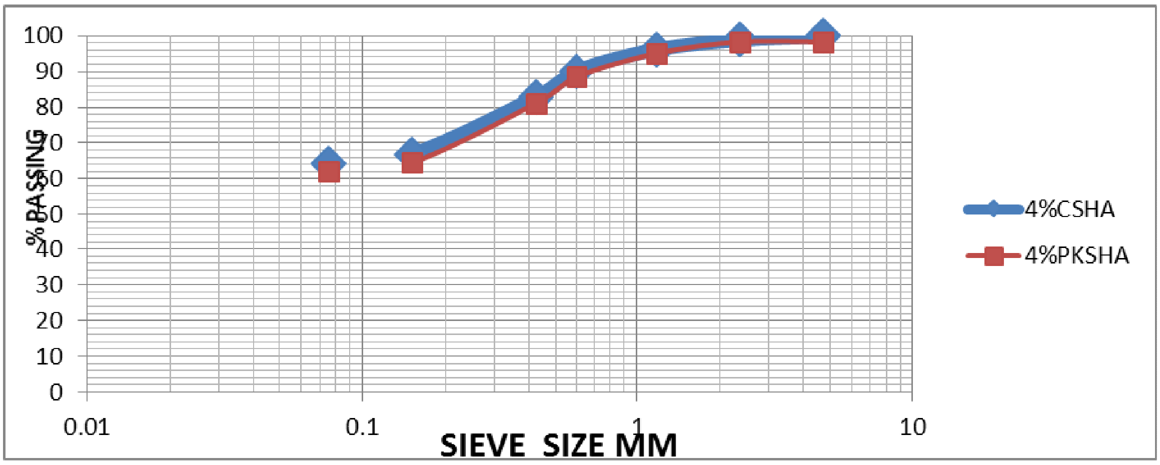

Figure 4: *Particle size distribution graph at 4% CSHA and 4% PKSHA*

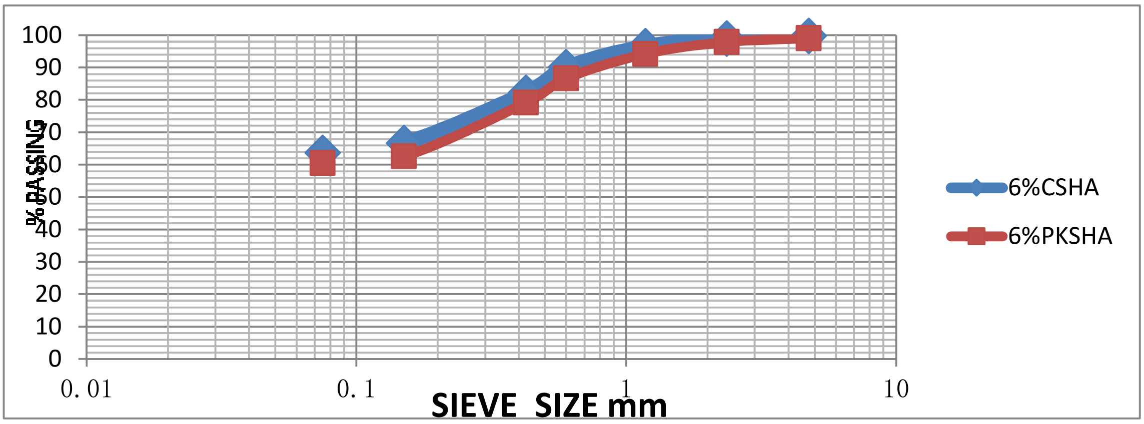

Figure 5: *Particle size distribution graph at 6% CSHA and 6% PKSHA*

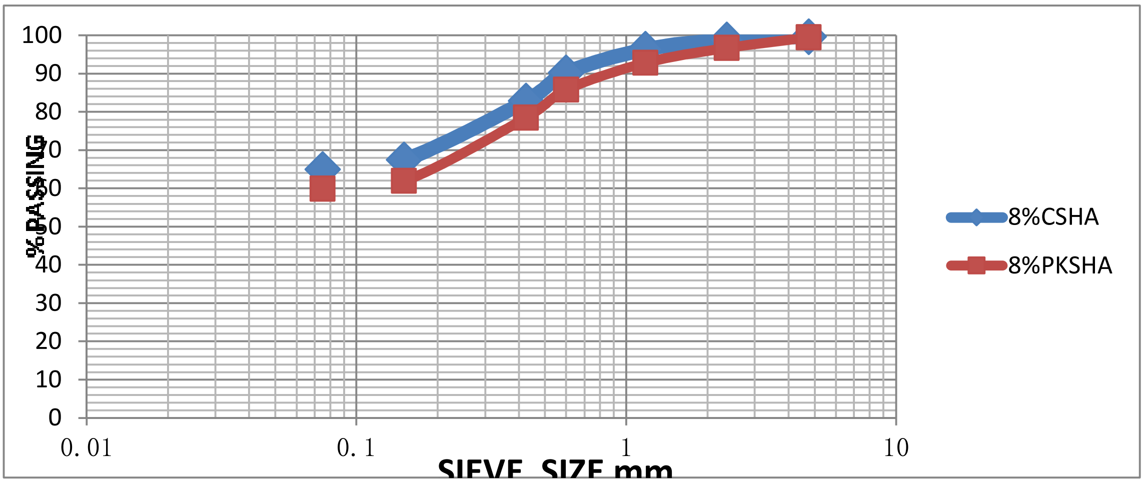

Figure 6: *Particle size distribution graph at 8% CSHA and 8% PKSHA*

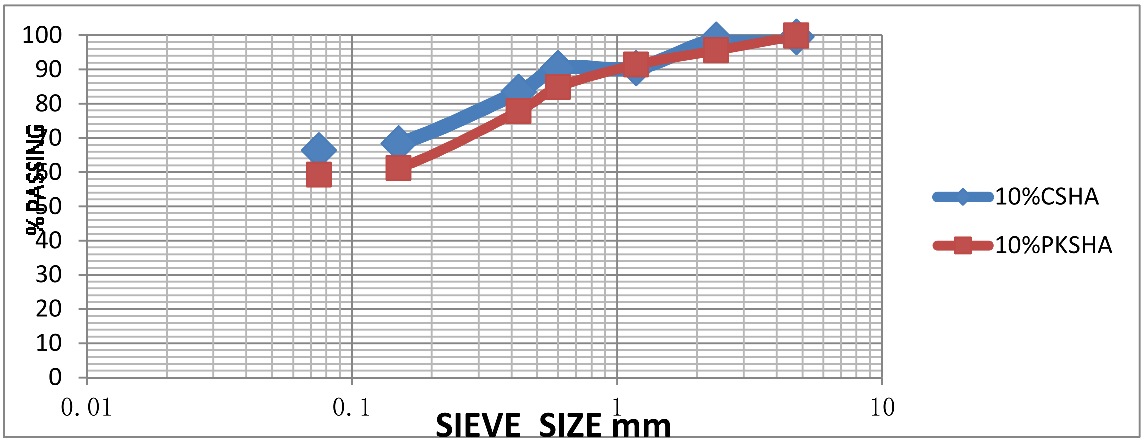

Figure **7**: *Particle size distribution graph at 10% CSHA and 10% PKSHA*

Table 4 has shown that the coefficient of uniformity (Cu) and coefficient of curvature (Cc) of the pozzolan stabilized oboro lateritic soil increased at the same rate for both CSHA and PKSHA admixture at 2% and 4% respectively. While PKSHA maintained a linear increase in Cu, CSHA maintained a linear increase in Cc. This implies that PKSHA maintained a more uniform stabilized mixture while CSHA maintained a graded stabilized mixture.

Table 4: Effect of Admixtures on the grading properties of pozzolan stabilized oboro lateritic soil

Admixture Proportions (%)		D_{10}	D_{30}	D_{60}	Cu	Cc
0	CSHA	0.015	0.026	0.06	4.0	0.75
	PKSHA	0.015	0.026	0.06	4.0	0.75
2	CSHA	0.014	0.025	0.065	4.64	0.67
	PKSHA	0.014	0.025	0.065	4.64	0.67
4	CSHA	0.013	0.025	0.065	5.0	0.74
	PKSHA	0.013	0.025	0.067	5.2	0.72
6	CSHA	0.013	0.025	0.065	5.0	0.74
	PKSHA	0.014	0.027	0.070	5.0	0.74
8	CSHA	0.013	0.025	0.064	4.9	0.75
	PKSHA	0.014	0.027	0.075	5.36	0.60
10	CSHA	0.012	0.025	0.060	5.0	0.87
	PKSHA	0.014	0.027	0.075	5.36	0.69

Figure 8 shows the compaction test result carried on the natural soil under study which has shown an OMC of 24% recorded at an MDD of 1.57gm/cm^3.

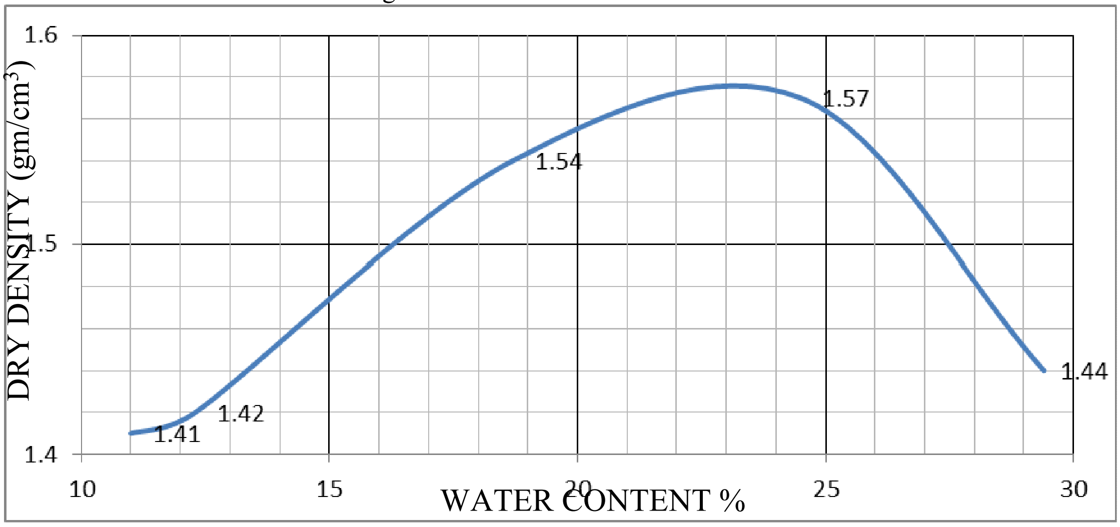

Figure 8: *A graph of dry density against water content at 0 % (control)*

The results of the consistency examination of the natural oboro lateritic soil and the studied effect of varied proportions of the CSHA and PKSHA at 2%, 4%, 6%, 8% and 10% are shown in Figures 9 and 10.

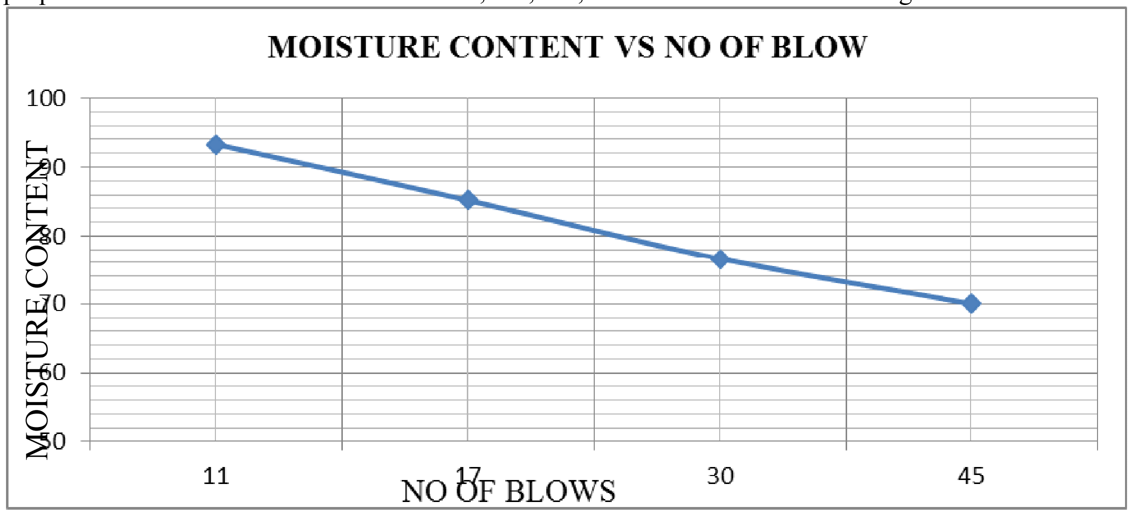

Figure 9: *Atterberg limit graph at 0% (control)*

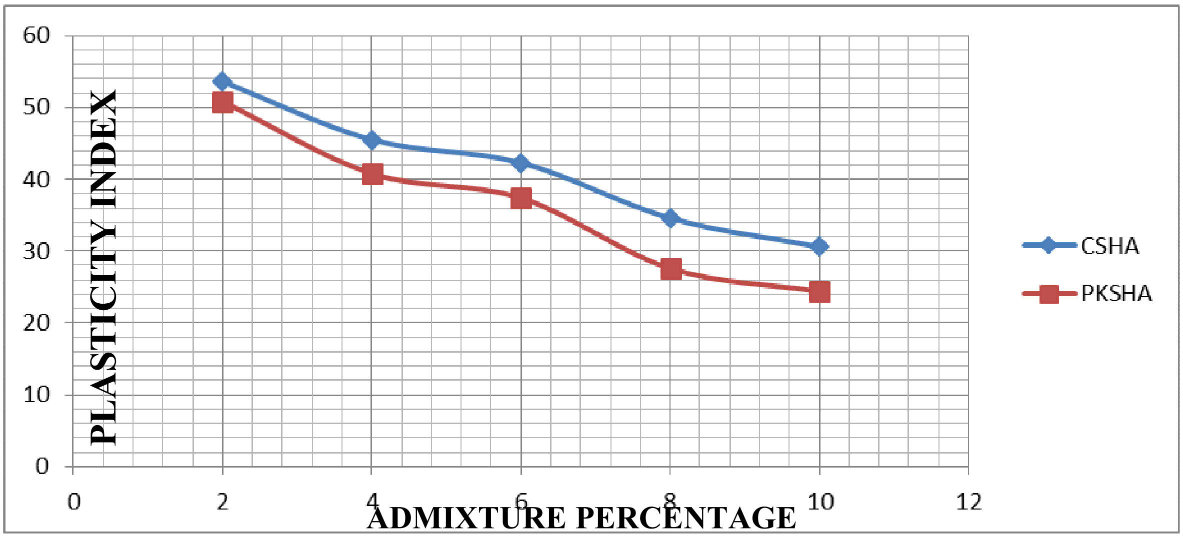

Figure 10: *A graph of plasticity index against % of CSHA and PKSHA*

As pointed out earlier, 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 Figure 9, 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 > 17 (highly plastic). 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 Figure 10 and comparing the effect of CSHA and PKSHA on the consistency 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. 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.

CONCLUSIONS

From the foregoing, it can be concluded as follows;

- The studied admixtures having improved the uniformity and curvature of the studied stabilized soil have proven to be good admixtures for the improvement of the grading properties of weak engineering soils.
- The effect of CSHA and PKSHA on the consistency limit of pozzolan stabilized lateritic soil has shown 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 and gives hope to the use of both admixtures in soil stabilization in that they reduced the plasticity of the studied soil.
- 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 grading and consistency of the stabilized soil.

RECOMMENDATION

With the trend of improvement recorded on the grading and consistency limits behaviour of pozzolan stabilized oboro lateritic soil, it is highly recommended to extend the use of higher proportions of the ashes. This will help establish how much of the admixture could be used to improve the soil grading and consistency properties for engineering works.

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