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Strength Characteristics Determination of Palm Kernel Shell Ash (PKSA) In Cement – Modified Lateritic Soil

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---*ABSTRACT*---

This write-up describes an experimental study on the effects of Palm Kernel Shell Ash (PKSA) on CBR and UCS parameters of cement-modified soil samples. PKSA was used to stabilize plain and also cement-modified soil samples at 2%,4%,6%,8%,10% and 12% by dry weight of the soil. The results showed significant increase in the strength parameters of the soil modified with PKSA and cement, by 51%, 391%, and 32% for MDD, CBR and UCS respectively. Regression Analysis was carried out to establish the relationship between the soaked CBR and PKSA at 3% cement addition. Comparative Cost Analysis was carried out in order to investigate the economic advantage of the experimental exercise.

Keywords *–California Bearing Ratio (CBR), Palm Kernel Shell, Soil Improvement, Strength Characteristics, Unconfined Compressive Strength (UCS).*

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I. INTRODUCTION

Since ancient times, transportation of human, equipment and materials has been one of the biggest challenges facing many countries. In recent times therefore, there is the need for these nations, especially those with high human population to construct highways and railway lines on land to cater for the needs of the people. These transportation facilities have to be improved on, to meet the challenges of ever increasing road and rail traffics in these countries.

In every country of the world, there are professional institutions whose primary responsibilities include providing transportation routes, and highways which are not only cost effective, but durable and safe, considering the limited resources available to many of these countries.

Most of the time, the existing natural soils are not strong enough to carry the design traffic load, therefore, the soil on which these transport facilities are built must therefore be improved on in order to ensure longevity, safety and convenience of the end user. It is therefore the responsibility of the design engineer to provide an improvement for these soils by stabilization.

It is a known fact that, some materials classified as Agriculture wastes, are commonly dumped openly causing environmental hazard. One of such materials is Palm Kernel Shells, a by-product of palm tree fruit commonly found in tropical countries. The Western, Mid-western parts of Nigeria including Lagos state which accounts for 30% of palm kernel shell wastes in the country, while Kwara, Sokoto, Plateau and Benue states account for 5% [1].

II. LITERATURE REVIEW

The possibility of complementing poor lateritic soils with Palm Kernel Shells (PKS) and subsequent stabilization of the resulting composite mix with asphalt has been investigated [2]. The study revealed that palm kernel shell alone was not a suitable stabilizing agent for lateritic soils but when lateritic soil (75%) was mixed with PKS (25%) and the mix stabilized with 5% asphalt, an improvement was recorded on the Unconfined Compressive Strength (UCS).

Adetoro and Adekanmi [3] analyzed the influence of Palm Kernel Shell Ash (PKSA) and Sawdust Ash (SDA) on the geotechnical properties of Ekiti state soil. The result concluded that the additives (PKSA and SDA) had positive influence on the geotechnical properties of the soil in the study area. The additives really improved the geotechnical properties, thus making the soil better materials for construction purpose.

Amu et.al. [4] studied the stabilization characteristics of lime on palm kernel blended soil and discovered that the un-soaked CBR of the natural sample reduced from 10.77 to 4.02 at 6% lime + 25% PKS + 75% laterite. They also found out that Liquid limit (LL), Optimum Moisture Content (OMC) and Shear Strength, all increased. The study therefore, concluded that PKS is not a good complement for lateritic soil in lime stabilization. However, Olutaiwo et. al. [5], on their research on "*Structural Evaluation of the effect of Pulverized Palm Kernel Shell (PPKS) on cement-modified lateritic soil"*; discovered that the properties of the lateritic soil improved when stabilized with cement and pulverized palm kernel shell, compared with when it was stabilized with PPKS alone.

Onyelowe and Maduabuchi [6], investigated the strength properties of A-2-7 soil, with a control measure of micro-sized palm kernel shell ash (MSPKSA) as additives. The findings showed that the strength characteristics of the soil improved with the addition of waste PKSA.

III. MATERIALS AND METHODOLOGY

Lateritic soil

The lateritic soil sample was taken from a borrow pit located at Agbara road, Atan, in Ogun state, South-West Nigeria (6^o 46' 00" N, 2^o 48' 00" E). The sample soil has engineering properties as presented in Table 1.

TABLE 1: Engineering Properties of the Lateritic Soil Sample

S/N	PROPERTIES	CHARACTERISTICS VALUE
1	Natural moisture contents (%)	10.17
2	Specific Gravity	2.5
3	Liquid Limit (%)	34.98
4	Plastic Limit (%)	22.2
5	Plastic Index (%)	12.78
6	AASHTO Classification	A– 6
7	Unified Classification System	CL
8	Soil Type	Sandy Clay
9	Colour	Reddish Brown
10	CBR (un-soaked), %	70.08
11	CBR (soaked), %	18.05
12	OMC (%)	16
13	MDD (g/cm^3	1.67

Ordinary Portland Cement (OPC)

Dangote 3X 42.5R Ordinary Portland Cement was used for this Research and was sourced locally.

Palm Kernel Shell Ash (PKSA)

The Palm Kernel Shell was collected from Odobor farm, Ekiti state, Southwest, Nigeria. The material was pulverized and burnt to ash at a control temperature of 700^0 C. The chemical composition of the PKSA is presented in Table 2.

TABLE 2: Chemical Composition of Ordinary Portland Cement (OPC) and Palm Kernel Shell Ash (PKSA)

Chemical Composition	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	TiO_2	P_2O_5	MnO
PKSA (%)	41.12	4.25	5.13	18.36	3.83	2.77	5.45	1.89	2.67	12.91	1.62
OPC (%)	21	3.3	5.3	65.6	1.1	2.7	-	-	-	-	1.0

The laboratory tests conducted are listed in Table 3.

TABLE 3: Laboratory Tests Conducted

Specimen	Tests Conducted
Untreated Soil Sample	• Atterberg Limits • Sieve Analysis • Specific Gravity • Compaction • CBR (un-soaked and soaked) • UCS (0, 7 and 14days cured)
Soil Sample + 3% OPC.	• Atterberg Limits • Compaction • CBR (un-soaked and soaked) • UCS (0, 7 and 14days cured)
Soil Sample + PKSA (2% - 12%)	• Compaction • CBR (un-soaked and soaked) • UCS (0, 7 and 14days cured)
Soil Sample +3% OPC + PKSA (2% - 12%)	• Compaction

	• CBR (un-soaked and soaked) • UCS (0, 7 and 14days cured)

The Laboratory Tests were conducted according to ASTM D4318 - Standard Test for Liquid Limit, Plastic Limit, and Plastic Index of Soils. ASTM D422 – Standard Test Method for Particle- Size Analysis of Soils. ASTM D854-00 - Standard Test for Specific Gravity of Soil solids by water pycnometer. Compaction, CBR and UCS were carried out as specified by BS Code of Practice Procedures 1377:1990 (Methods of Tests for Civil Engineering Purposes).

IV. RESULTS, ANALYSES AND DISCUSSIONS

Effect of PKSA on Atterberg Limits

The results, as seen in Fig. 1, shows a decrease in the liquid limit with up to 4% PKSA content, after which gradual increment was observed with percentage increment in PKSA. Similar trend was observed with OPC included in the soil matrix but with gradual decline after 8% PKSA content.

Fig 2 also shows corresponding decrease in plastic limit for both the soil-PKSA and soil-PKSA-cement samples.

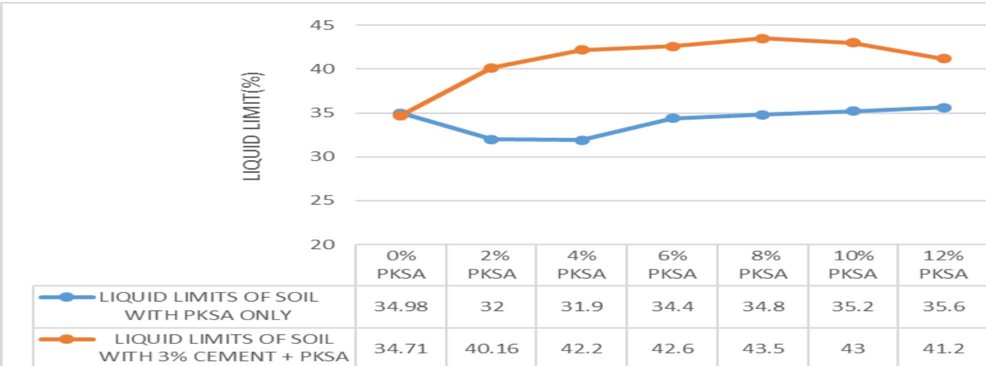


Fig. 1: liquid limits of the soil with 3% OPC and varying percentages of PKSA

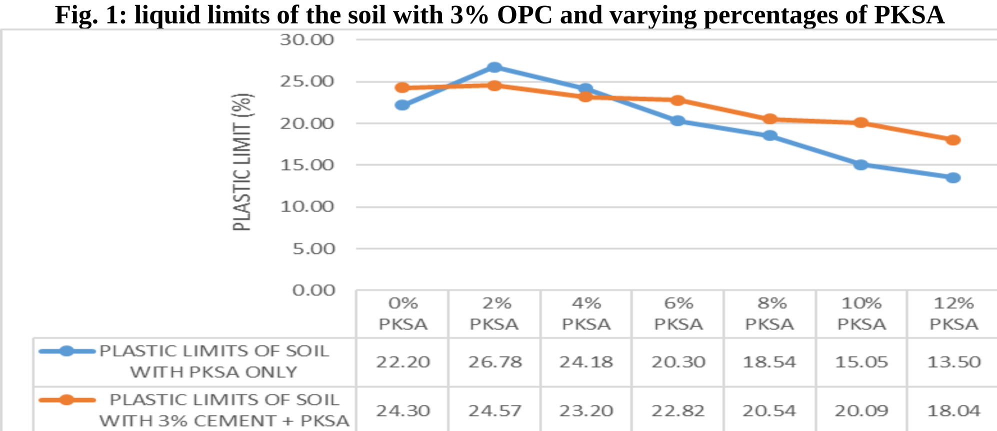


Fig. 2: plastic limits of the soil with 3% OPC and varying percentages of PKSA

Effect of PKSA on Compaction Characteristics of the Soil Samples

The compaction results as presented in Figs. 3 and 4 show increase in Optimum Moisture Content (OMC) with increment in PKSA for samples containing OPC and those not containing. This is because more water was required for hydration. Maximum Dry Density invariably decreased as OMC increased.

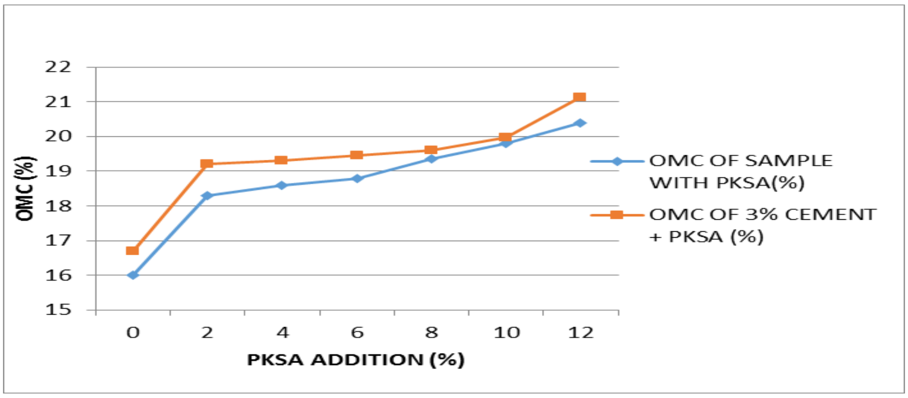


Fig. 3: OMC of soil samples with varying percentages of PKSA

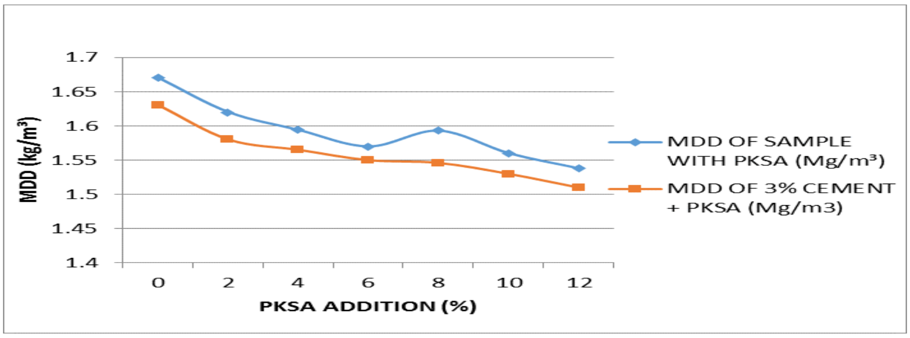
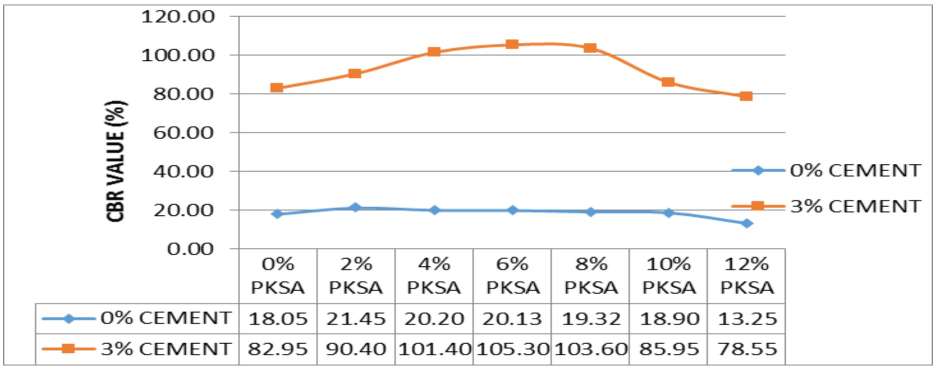


Fig. 4: MDD of soil samples with varying percentages of PKSA

Effect of PKSA on California Bearing Ratio (CBR) of the Soil Samples

The soaked CBR values for the samples are shown in Fig. 5. The results show very little improvement in soaked CBR (with PKSA only), with the optimum at 4% PKSA content but with the inclusion of 3% OPC, significant improvement was noticed, with optimum value obtained at 6% PKSA content.



	0% PKSA	2% PKSA	4% PKSA	6% PKSA	8% PKSA	10% PKSA	12% PKSA
0% CEMENT	18.05	21.45	20.20	20.13	19.32	18.90	13.25
3% CEMENT	82.95	90.40	101.40	105.30	103.60	85.95	78.55

Fig. 5: soaked CBR values of soil samples with varying percentages of PKSA and 3% OPC

Effect of Cement and PKSA on Unified Compression Strength of the Soil Samples

Figs. 6 and 7 shows that the Unconfined Compressive Strength (UCS) is generally higher when the specimen is cured; the longer the curing period, the higher the UCS attained. However, the optimum result was observed at 4% PKSA and 2% PKSA content for both samples with OPC and without, respectively.

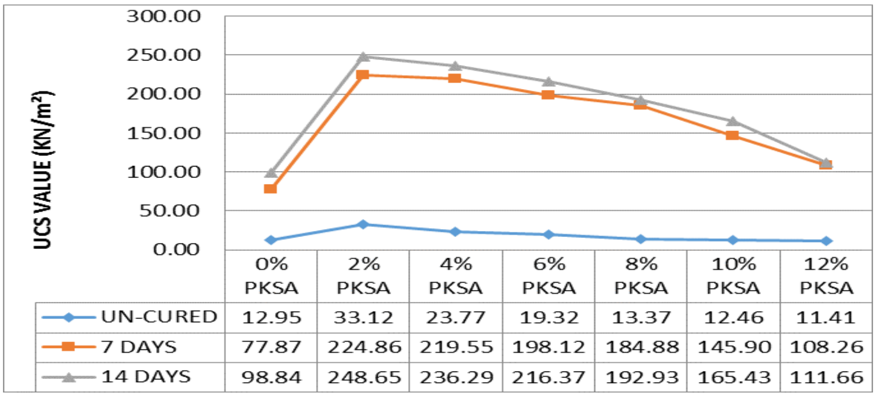


Fig. 6: UCS values of soil samples with varying percentages of PKSA

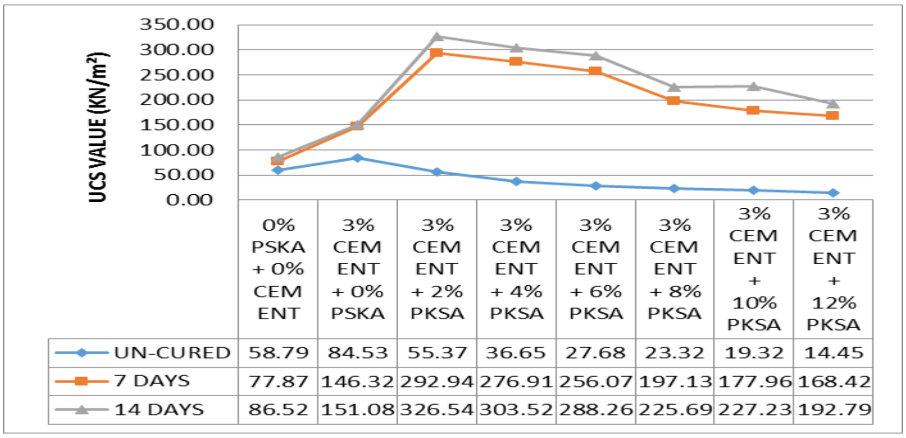


Fig. 7: UCS values of samples with 3% OPC and varying percentages of PKSA

Regression Analysis

Regression analysis was conducted using Microsoft Excel software package to establish a relationship between the soaked CBR value and PKSA contents at 3% OPC content. The data analyzed and results obtained are presented in Tables 4 and 5.

TABLE 4: Soaked CBR Values of Soil with Varying PKSA + 3% OPC

SOAKED CBR (%)	PKSA (%)
82.95	0
90.4	2
101.4	4
105.3	6
103.6	8
85.95	10
78.55	12

The estimated regression obtained is $\mathbf{Y = 94.725 - 0.355X_1}$; where: Y is the Soaked CBR Value and X_1 is the Percentage PKSA Content. This therefore suggests that for a percentage increase in PKSA, CBR decreases by 0.355 units.

Comparative Cost Analysis

Two stabilization options were considered for this analysis: Option A with soil stabilized with 5% OPC only and option B with soil stabilized with 6% PKSA and 3% OPC. The two options had soaked CBR over 100%, therefore minimum thickness of 150mm is assumed [7]. The summary of the analysis is shown in Table 5. Other assumed parameters are:

Length of Road = 1km = 1,000 m; Width of Road = 7.3 m; Cost of OPC/ton = N57,000; Cost of lateritic Soil Base material/ton = N1,200; and Cost of procuring PKSA = N7,890.00/ton

The cost of transportation, labour, equipment and other miscellaneous are not included in the analysis, as rates depend on the location of the subject road and the materials' source.

Design Option A (Soil + 5% Cement)

i. Lateritic Soil

Thickness = (1000 x 7.3 x 0.15) x 95% =1,040.25m^3. (Taking 1 ton = 0.40m^3 in Lateritic soil unit scale)
Therefore, 1,040.25m^3 of Lateritic Soil = 2,600.63 tons
Cost of Lateritic soil = 2600.63 x N1,200.0 = **N3,120,756.00**

ii. Ordinary Portland Cement (OPC)

Thickness = (1000 x 7.3 x 0.15) x 5% = 54.75m^3. (Taking 1 ton = 0.3247m^3 in cement unit scale)
Therefore, 54.75m^3 cement = 168.63 tons
Cost of Cement = 168.63 x N57,000.0 = **N9,611,910.00**
Therefore, total cost for base course material = **N12,732,666.00**

Design Option B (Soil + 3% Cement + 6% PKSA)

i. Lateritic Soil

Thickness = (1000 x 7.3 x 0.15) x 91% = 996.45m^3. (Taking 1 ton = 0.40m^3 in Lateritic soil unit scale)
Therefore 996.45m^3 of Lateritic Soil = 2,491.125 tons
Cost of Lateritic soil = 2,491.13 x N1,200.0 = **N2,989,356.00**

ii. Ordinary Portland Cement (OPC)

Thickness= (1000 x 7.3 x 0.15) x 3% = 32.85m^3. (Taking 1 ton = 0.3247m^3 in cement unit scale)
Therefore 32.85m^3 Cement = 101.17 tons
Cost of Cement = 101.18 x N57,000.0 = **N5,767,260.00**

iii. PKSA

Thickness = (1000 x 7.3 x 0.15) x 6% = 65.7m^3. (Taking 1 ton of PKSA = 0.4300m^3 in PKSA unit scale)
Therefore 65.7m^3 of PKSA = 152.78 tons
Cost of PKSA= 152.78 x N7,890 = **N1,205,434.20**
Therefore, Total cost for base course material **= N9,962,050.20**

TABLE 5: Summary of Comparative Costs of Base Course Materials

DESIGN OPTIONS	CBR (%)	COST OF BASE COURSE (N)
Soil + 5% Cement	106.35	**12,732,666.00**
Soil + 3% Cement + 6% PKSA	105.30	**9,962,050.20**
Difference		**2,770,615.80**
% Difference		**21.76%**

IV. CONCLUSIONS

The following conclusions are made based on the results obtained in this study:

- The addition of PKSA increases the OMC of the soil sample and decreased the MDD.
- PKSA alone is not a suitable stabilizing agent for lateritic soils but when mixed with 3% OPC, significant results can be obtained in terms of strength.
- Utilization of PKSA in stabilizing soil proved economically advantageous, as obtained from the comparative cost analysis. It is also environmentally beneficial as this provides a viable alternative to disposing palm kernel shell wastes.

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