Evaluation of Palm Kernel Shells for use as Stabilizing Agents of Lateritic Soils.

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Abstract-- **The possibility of complementing poor lateritic soils with Palm Kernel Shells (PKS) and subsequent stabilization of the resulting composite mix with asphalt was investigated. This is with a view to reducing construction cost by using local and readily available materials for road works. The scope was limited to the strength characteristics of the mix and did not consider other characteristics such as the resilient properties, fracture or fatigue. In the methodology, each of the composite mixes and the natural lateritic soil were subjected to percentages by weight of asphalt stabilization (2%, 4%, 6%, 8% and 10%), while PKS percentages of 25%, 50%, 75% and 100% by weight were used for the tests. Preliminary and strength tests were performed on the natural and composite mixes to determine their engineering properties under laboratory conditions. The results showed that the addition of 25% PKS to the natural soil caused the Plasticity Index (PI) to increase to 19.0% and then subsequently reduced to 18.0% at 4% asphalt - stabilization. The addition of 5% asphalt to 75% laterite and 25% PKS increased Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) to 1665 kgm^{-3} and 23.6% respectively, with a reduction in average CBR to 1.15% (unsoaked) and 0.55% (soaked). With the same composite mix, the uncured compressive strength was 31.56 KNm^{-2} while the cured was 931.62 KNm^{-2} and a shear resistance of 29.62 KNm^{-2} was recorded. Palm kernel shell alone was not able to stabilize the lateritic soils but when lateritic soil (75%) was mixed with PKS (25%) and the mix stabilized with 5% asphalt, there was improvement on the unconfined compressive strength.**

Index Term-- **Asphalt, cut back, laterite, perm kernel shell, stabilization**

INTRODUCTION

The necessity of borrowing materials (lateritic soil) for use in areas where the prevalent soil is of poor quality for construction has over the years caused a continuous increase in the cost of borrowing and transporting these materials. Sometimes there is need to stabilize the prevalent soil on site and here, the cost of stabilization is determined to a large extent from the optimal quantity of stabilizing agent (asphalt) required for effective stabilization. It is therefore necessary to seek a suitable complementary substitute for lateritic soil which can readily be available and easily upgraded by stabilization. This will reduce the quantity of borrowed lateritic soil and also the cost of stabilization and this study is an effort in that direction.

The main reason to improve soil is either to obtain a suitable physical grading for a poor soil or to improve some other physical characteristics such as the strength, stability or water resistance of the soil (1, 2 and 3). Stabilization techniques can be broken down into three categories mechanical, physical and chemical (6). Mechanical stabilization compacts the soil, changing its density, mechanical strength, compressibility, permeability and porosity. Physical stabilization changes the properties of the soil by acting on its texture, this can be done by controlling the mixture of different grain fractions, heat treatment, drying or freezing and electrical treatment. Chemical stabilization changes the properties of the soil by adding other materials or chemicals. This happens either by a physico-chemical reaction between the grains and the materials or added product, or by creating a matrix which binds or coats the grains of the soil being stabilized (6). Soil suitable for civil engineering construction should be well graded with a suitable content of fine and larger particles. For raw soils this is not often the case and soils have to be modified such that their grading is suitable for use.

Palm kernel shell which is the crash shell housing the palm kernel seed is derived from the oil palm tree (elaeis guineensis), an economically valuable tree, and native to western Africa and widespread throughout the tropics (9).
Palm kernel shell can be considered as a natural pellet and a high grade solid renewable fuel for burning as received both in co-firing with steam coal or burned at biomass power plants, usually blended with other grades of biomass, like wood chips. The palm kernel shell is also used as a source of fuel for the boilers. Unfortunately, the shell contains silicates that form a scale in the boilers if too much shell is fed to the furnace, thus limiting the amount of shell that can be utilized in the boilers. Residual shell is disposed of as gravel for plantation roads maintenance (4). Blacksmiths also buy the shells to use as fuel material in their casting and forging operations. Palm kernel shell is an industrial waste and it's available in large quantities especially in palm oil producing areas of southern Nigeria.

They are yet to be utilized to a great extent as a construction material. It is therefore hoped that, if found structurally adequate in modifying lateritic soil, it would offer some advantages, such as low density (which implies reduction in self weight of the lateritic soil), improved compaction characteristics, good thermal insulation and good sound absorption (Table I).

Blended palm kernel shells have been used to modify lateritic soil obtained along Iwofe road in Obio/Akpor local government area, Rivers State, Nigeria because of their good interlocking characteristics, low specific gravity and high porosity to establish whether they can make suitable stabilizing agents for improvement of soils for civil engineering construction.

Scope of research work

This study involved field sampling and laboratory analyses. The laboratory analyses included plasticity, compaction, California Bearing Ratio (CBR), unconfined compressive strength.

Description and Geology of study area

The study area is located in Iwofe road within Obio/Akpor local government area of Rivers State, Nigeria within the geographical coordinates of between 6 ^{o} 60' and 7^{o} 05'E and 4^{o}45' and 4 ^{o} 55'N.

Iwofe falls within the Niger Delta, which is a Tertiary sedimentary structure formed as a complex regressive offlap sequence of clastic sediments ranging in thickness from 9000-1200m (5). Starting as separate depocentres, the Niger Delta has coalesced to form a single united system since Miocene.

The Tertiary deltaic complex was therefore divided into three major facies units based on the dominant environmental influences (10). These main sedimentary environments are continental environment, the transitional environment and the marine environment. In an advancing delta, such as Niger Delta, sediments of the three environments mentioned above became stratigraphically imposed.

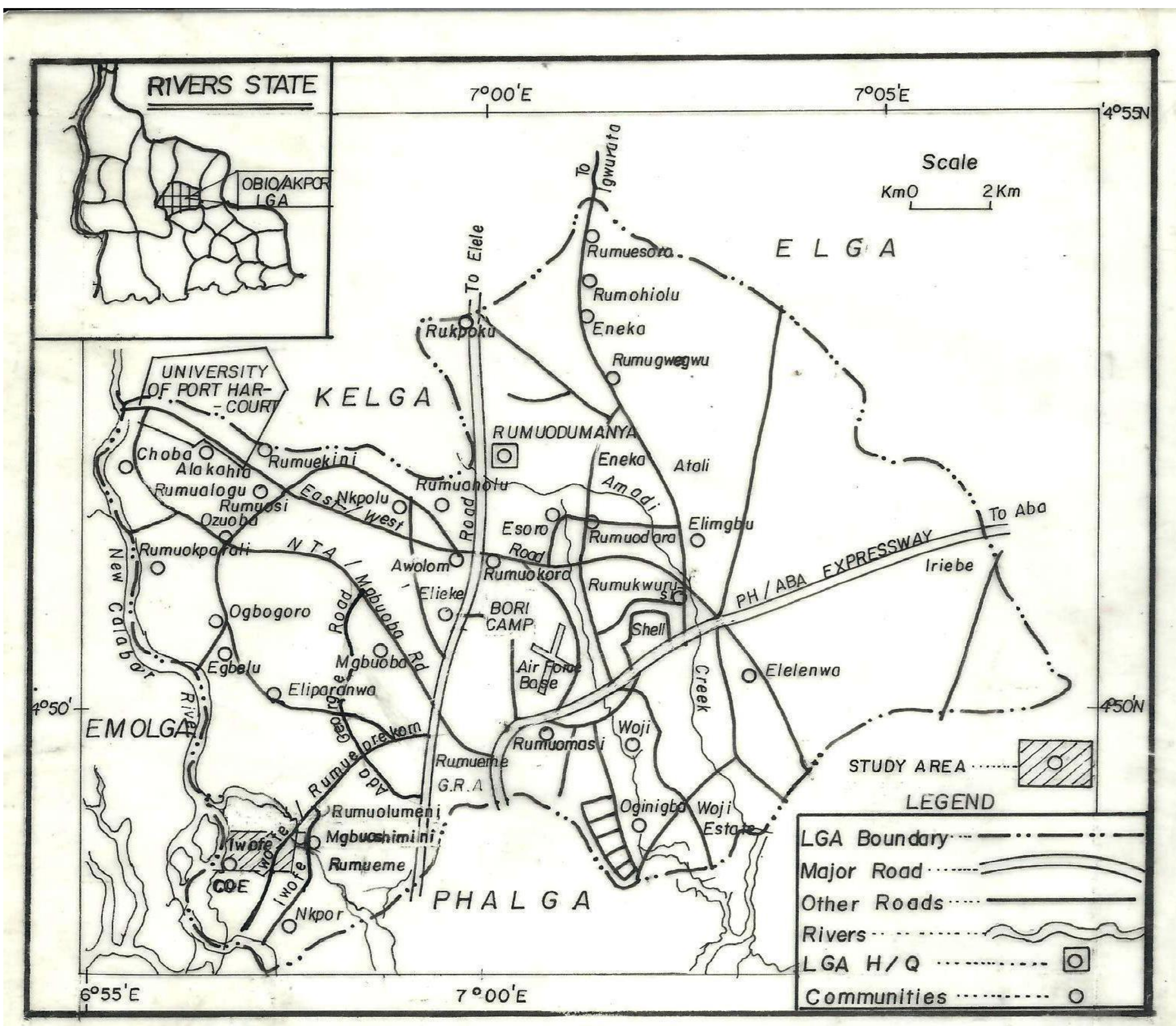

Fig. 1. Map of Obio/Akpor local government area showing study area.

The base of the stratigraphic sequence is represented by massive marine shales. The middle part of the sequence is represented by interbedded shallow marine fluvial sands, silt and clays which are typical of a paralic setting. The sequence is capped by a section of massive continental sands.

Due to the history or relative unbroken progradation throughout the Tertiary, these three depositional lithofacies are readily identified despite local facies variations, as three regional and diachronous formations ranging from Eocene to Recent age. The three formations are locally designated (from the bottom) as Akata Formation, Agbada Formation and Benin Formation respectively. Of these three formations, the Agbada Formation constitutes the main reservoir of hydrocarbons in the Niger Delta

Akata Formation

This is the basal major time transgressive unit in the Niger Delta Complex. This is the marine pro-delta megafacies, comprising mainly of shales with occasional turbidite sand and siltstone. The approximate range of thickness is from 0-6000m and the formation crops out subsea in the outer delta area but is not seen onshore. The formation consists of dark grey uniform shales, especially in the upper part. In some areas, it is sandy or silty in the upper part of the formation where it grades into the Agbada Formation.

Source rocks of the Niger Delta hydrocarbon have been a subject of some controversy. Some workers have proposed that shales of the paralic sequence (i.e. Agbada Formation) as the source rocks, while others argue that in most parts of the delta, the Agbada Formation is immature and suggested the source rocks to be the marine shales of Akata Formation that are more mature. Drilling activities have not penetrated the base of the Akata Formation probably because of its highly compacted and over-pressured nature.

Agbada Formation

The Agbada Formation underlies the Benin Formation and forms the second of the three strongly diachronous Niger Delta complex formations. As the principal reservoir of Niger Delta oil, the formation has been studied in some detail. The Agbada Formation consists mainly of sands, sandstones and siltstones. It consists of numerous offlap rhythms, the sandy parts of which constitute the main hydrocarbon reservoirs in delta oil fields. The shales constitute seals to reservoirs and as such are very important.

In the Agbada Formation, the sequence is divided into an upper unit consisting of sandstone-shale alternations with the former predominating over the latter and a lower unit in which the shales predominate and in places are thicker than the intercalated sandstones or sands. The sandstone percentage ranges from 75% near the upper limit of the formation to 50% and below in the lower part of the unit.

The sandstones or sands are very coarse to very fine grained. Slightly consolidated sands have a predominantly calcareous matrix but the majority is unconsolidated. They are often poorly sorted except where sand grades into shales. Lignite streaks are common but limonite coated grains and feldspars, which characterize the Benin Formation, are rare. Shell fragments and glauconite also occur.

The structural elevation of the base of the Akata Formation fluctuates widely throughout the delta because of synsedimentary diapirism largely within the Akata shale and the consequent growth fault development.

The paralic Agbada sequence consists of a series of offlap cycles which range in thickness from 50 to 330 ft. Most rhythms are less than 200 ft thick. Rhythms begin with marine sands laid down during marine transgression. They are followed by marine shales deposited as the offlap stage began. Laminated fluvio-marine sediments follow, having being laid down in the barrier foot environment. Barrier bar and/or fluviatile sediments succeed each other and the rhythm unit is often terminated by marine sediments laid down during the next marine transgression. These sediments frequently truncate the barrier sand deposit.

In addition to barrier bar sands, point bar sands, distributary channel sands and sandy beds can be distinguished in the rhythmic sequence. These were laid down as tidal channel fills river-mouth bars, natural levees and shallow marine sand bars. Sands may interfinger with lagoonal clayey deposits, tidal flat deposits, marshy oxbow lake deposits, tidal flat deposits and mangrove swamp deposits. In the upper parts of many of these offlap rhythms, dark lignitic intercalations occur. The Agbada Formation contains beds laid down in a variety of sub-environments which can be grouped together under one broad paralic environment. The zigzag facies line frequently shown on sections to show the stratigraphic boundary between the Benin Formation and the Agbada Formation must be thought of as demarcating a fairly broad zone rather than a sharp depositional contrast.

The Agbada Formation occurs almost delta wide beneath the Benin Formation. On the landward side of the Niger Delta complex, regional subsidence and warping have resulted in exposure and erosion of the older parts of the delta complex. The Ogwashi-Asaba Formation of Oligocene to Miocene age differentiated at outcrops probably pass in to the Agbada Formation in the subsurface. The two fold division of the Agbada Formation into a predominant upper sandy, sandy-shale alternating unit and a lower shaley unit, probably corresponds roughly to the Ogwashi-Asaba and Ameki divisions at outcrop. However, these two divisions are “up dip delta” units and cannot be differentiated delta-wide because the Agbada Formation becomes more marine inward. It is for this reason that only one subsurface formation name, i.e. Agbada is employed in most of the literature on the Niger Delta.

Benin Formation

The Benin Formation has been described as “Coastal Plain Sands” which outcrops in Benin, Onitsha and Owerri provinces and elsewhere in the delta area.

It consists mainly of sands and gravels with thickness ranging from 0 to 2100m. The sands and sandstones are coarse to fine and commonly granular in texture and can be partly unconsolidated. The sediments represent upper deltaic plain deposits. The sands may represent braided stream point bars and channel fills and/or crevasse splay deposits. The shales are few and thin and they may represent back swamp deposits.

Among the minor components, limonite coating, lignite streaks, haematite and feldspar are common. However, the formation lacks faunal content and this makes it uneasy to date although an Oligocene-Recent age is generally accepted. It is the main source of potable ground water in the Niger Delta area.

Methodology

Five samples of lateritic soil were obtained from Iwofe road, Obio/Akpor local government area, Rivers State and were subjected to natural moisture content, specific gravity and Atterberg's limits tests. The tests were carried out according methods specified by ASTM. Such engineering tests as compaction, California Bearing Ratio, undrained triaxial strength and unconfined compression were also carried out, Cut-back asphalt was used which was obtained from the road section of a maintenance work along Iwofe road, Rivers State. The asphalt was thinned with petrol to obtain the cut-back.

RESULTS AND DISCUSSIONS

The results are summarized in Table 1. the Atterberg's limits for the natural lateritic soil composite mix of 75% laterite and 25% PKS by weight, composite mix of 50% laterite and 50% PKS by weight before and after stabilization by asphalt at varied percentages ranging from zero to ten percent are shown in Table 2. The Liquid Limit (LL) and the Plastic Limit (PL) of the natural soil sample were 30.6% and 13.9% respectively and its Plasticity Index (PI) was 17.40%, indicating a moderately plastic soil (11).

The addition of asphalt in percentage(s) by weight to the natural (unstabilized) lateritic soil decreased the plasticity index of the lateritic soil sample from 17.4 to 16.2% at 6% addition of asphalt; this was the optimal mixture of asphalt with lateritic soil. The plasticity index increased with further addition of asphalt as a result of the additional water requirement of soil-asphalt mixture, which made the soil to swell, thus increasing its liquid limit. From the results, the introduction of 25% by weight of palm kernel shells into the natural soil caused an increase in the plasticity index of the soil before stabilization with asphalt. In addition to this, comparing the value of the natural plasticity index (17.4%) with the optimum plasticity index (18.0%) obtained using 75% laterite-25% PKS mix, it is shown that the plasticity index of the soil sample is increased when 25% PKS is mixed with the soil, even at its optimum mix with asphalt, the plasticity index obtained was greater than the natural soil's plasticity index.

Table I

Results of laboratory analysis of lateritic soil samples

Property	Sample				
	A	B	C	D	E
Natural moisture content (%)	10.22	7.70	10.01	6.53	9.17
Specific gravity	2.34	2.13	2.81	2.92	2.65
Liquid limit (%)	29.01	51.22	30.55	21.12	25.67
Plastic limit (%)	15.45	36.18	13.15	11.65	14.19
Plasticity index (%)	14.01	15.05	17.90	10.20	11.22

Table II

Results of Atterberg's limits test at varying proportions of PKS & Asphalt

Composite mix (%)	*Asphalt (%)*	*Liquid limit (%)*	*Plastic limit (%)*	*Plasticity index (%)*
100% Laterite + 0% Palm kernel shells	0	30.6	13.9	17.4
	2	39.2	19.8	19.3
	4	38.1	15.6	22.4
	6	37.6	20.1	16.2
	8	50.1	29.2	21.8
	10	42.1	19.5	21.4
75% Laterite + 25% Palm kernel shells	0	49.8	32.0	19.0
	2	45.5	20.9	24.1
	4	40.4	22.4	18.0
	6	39.8	19.1	20.8
	8	39.6	15.8	24.1
	10	40.1	16.1	23.6
50% Laterite + 50% Palm kernel shells	0	54.6	40.9	13.9
	2	48.9	37.5	11.8
	4	46.1	40.8	6.7
	6	46.3	34.8	11.1
	8	47.0	37.3	10.3
	10	46.2	34.7	11.2

Table III
Compaction test result

Composite mix	Asphalt (%)	MDD (kgm^{-3})	OMC (%)
100% Laterite + 0% PKS	0	1510	15.7
	5	1743	15.1
75% Laterite + 25% PKS	0	1443	19.2
	5	1665	23.6
50% Laterite + 75% PKS	0	1143	28.4
	5	1156	25.8
25% Laterite + 75% PKS	0	927	35.6
0% Laterite +100% PKS	0	740	36.1

The compaction tests were performed on all the mix ratios of laterite and palm kernel shells to determine their respective maximum dry densities (MDD) and optimum moisture contents (OMC). The summary of the compaction test are shown in table 3.3. The natural lateritic soil sample had a maximum dry density of 1510kgm^{-3} and optimum moisture content of 15.7%, the addition of 5% asphalt increased the MDD to

1743kgm^{-3} while the OMC decreased to 15.1%. When 75% laterite and 25% PKS mix was compacted, the MDD obtained was 1443kgm^{-3} and OMC 19.2%, with 5% of asphalt, the MDD and OMC increased to 1665kgm^{-3} and 23.6%, respectively. The reduction in the MDD and subsequent increase in the OMC of the natural soil when combined with PKS could be attributed to the low specific gravity value (1.12) of the palm kernel shells and also, its high water absorption capacity. However at optimum of asphalt, the MDD was increased, although not up to that of the natural soil, OMC also increased. The results showed that palm kernel shells increased the ability of the soil to absorb moisture but caused a reduction in the maximum dry density because of its low specific gravity value and high porosity. Generally, addition of asphalt to the different composite samples (lateritic + PKS) increased the MDD; however the presence of PKS which has high porosity and moisture absorption capacity increased the OMC considerably, this increase in OMC is unacceptable for road construction (7).

Figures 2 - 4 present some graphs of the soaked and the unsoaked California Baring Ratio (CBR) tests, for the 0% mix unstabilized soil sample, the average unsoaked CBR value was 1.43% and when soaked for 72 hours, it reduced to 1.11%.

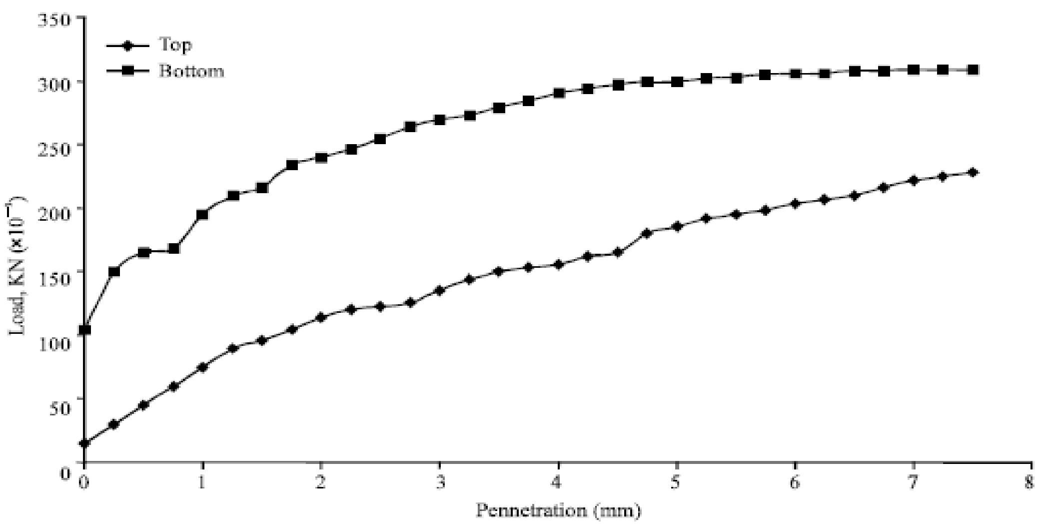

Fig. 2. Unsoaked CBR for 100% lateritic soil (unstabilized) sample

From the result, the lateritic soil sample has high plasticity index, it is also poorly drained. Therefore, the natural lateritic soil sample used is not a good sub-grade, sub base or base material. The addition of 6% asphalt increased the average unsoaked CBR value to 2.66 and 1.21% for the soaked sample, it acquired approximately 8% gain in strength, showing that asphalt stabilized lateritic soils gain strength with time.

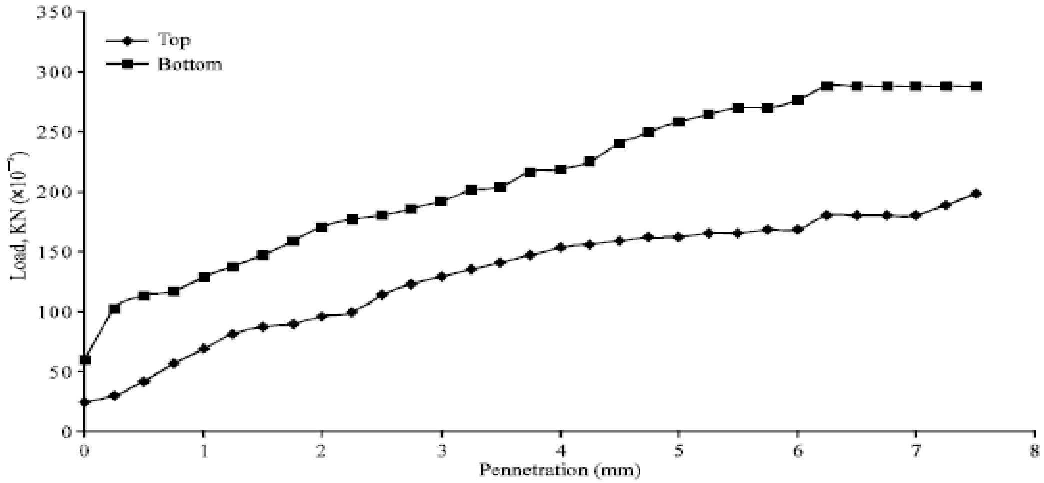

Fig. 3. Soaked CBR for 100% lateritic soil (unstabilized) sample

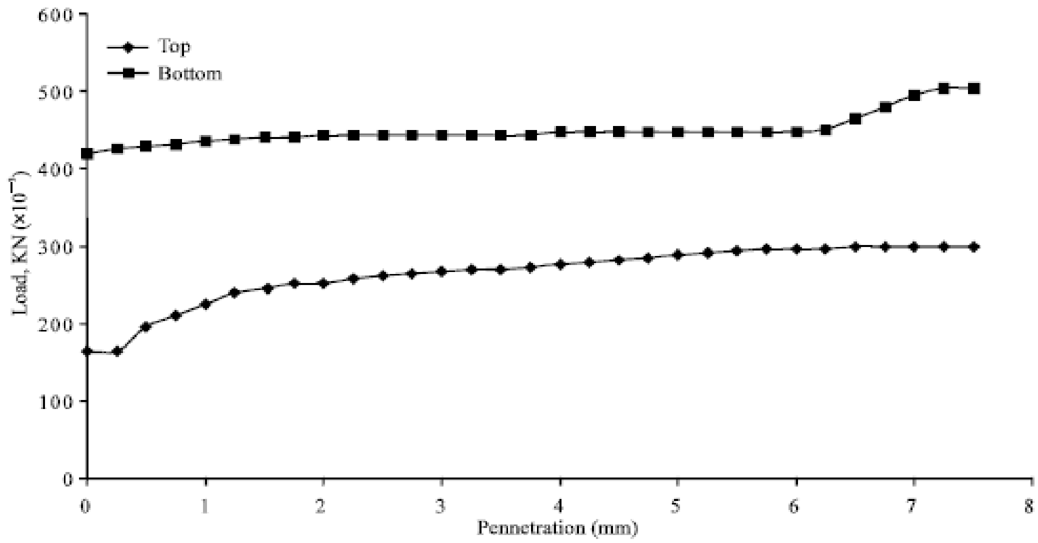

Fig. 4. Unsoaked CBR for 6% asphalt-stabilized lateritic soil sample

The results (Table IV) of the unconfined compressive strength tests, the natural sample stabilized with the 6% asphalt gave an uncured strength of 32.86 and 908.1kNm^{-2} when cured; this shows that strength is gained with curing time, as a result of the binding power of asphalt on lateritic soil.

However, the composite mix (75% lateritic and 25% PKS) stabilized with 5% asphalt gave an uncured strength of 35.56kNm^{-2} and cured strength of 931.62kNm^{-2}. From the results, it could be seen that the unconfined compressive strength of the asphalt stabilized composite mix (75% lateritic and 25% PKS) was greater than that of the asphalt stabilized lateritic soil.

Table IV
Results of unconfined compression test

Composite mix	Asphalt (%)	Type of specimen	Applied axial load (N)	Unconfined Compressive strength (KNm^{-2})	Cohesion (kNm^{-2})
100% Laterite + 0% PK	0	Uncured	44	37.98	18.80
		Cured	1168	1017.29	510.56
	5	Uncured	34	32.86	16.92
		Cured	1028	908.10	455.43
75% Laterite + 25% PK	5	Uncured	39	35.56	18.22
		Cured	1061	931.62	465.21

Therefore, unconfined compressive strength was improved by adding palm kernel shells to lateritic soil. When the three samples were subjected to a total normal stress of 200kNm^{-2}, analysis showed that the maximum yield or shearing stress of the unstabilized lateritic soil sample was 48.8kNm^{-2} while the 5% asphalt-stabilized lateritic soil showed stress of 57.11kNm^{-2}. The composite mix had a shearing stress of 29.62kNm^{-2} when stabilized with 5% asphalt as seen from table 4. This indicates that the shear strength of the lateritic soil was improved when stabilized with asphalt but significantly reduced when palm kernel shells were included in the soil. This reduction in shear strength can be attributed to the non-cohesive nature of palm kernel shells.

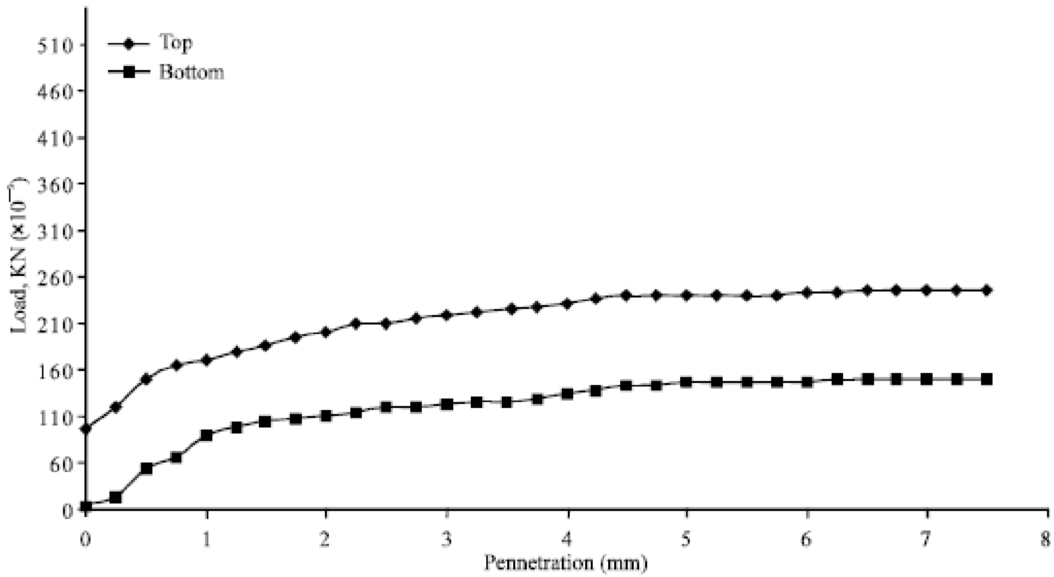

Fig. 5. soaked CBR for 6% asphalt-stabilized lateritic soil sample

CONCLUSIONS

We found out 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, suggesting that the strength properties of the soil mixtures can further be improved by stabilization. The results conform to the fact that stabilization of different soil mixtures can lead to better or worse properties using the same technique (8). We therefore believe that PKS can usefully be employed in the economic and effective stabilization of lateritic soils in the area for the construction of durable roads that will conform to standards.

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