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Effects of Palm Kernel Shells in Lateritic Soil for Asphalt Stabilization

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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 PI to increase to 19.1% and then subsequently reduced to 17.7 at 4% asphalt stabilization. The addition of 4% asphalt to 75% laterite and 25% PKS increased Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) to 1560 kg m^{-3} and 23.0% 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 36.87 kN m^{-2} while cured was 927.54 kN m^{-2} and a shear resistance of 28.48 kN m^{-2} was observed. The major finding revealed that the resulted stabilized soils mixes obtained were inadequate for subgrade, sub base and base courses in road construction.

Key words: Palm kernel, soil stabilization

INTRODUCTION

The necessity of borrowing materials (lateritic soil) for use in areas where the prevalent soil is not favourable 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. Palm kernel shell has been used as possible complement for lateritic soil because of its relative abundance and certain physical properties such as low density, high compaction characteristics and strong interlocking property. In addition, palm kernel shells are regarded as waste in this part of the world and are usually burnt. Finding effective use for it will therefore also help to reduce environmental pollution.

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 (Arthur *et al*., 1999).

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Table 1: Properties of palm kernel shell

Property	Quantity
Apparent specific gravity	1.14
Water absorption	21.3%
Loose bulk density	545 kg m^{-3}
Compacted bulk density	595 kg m^{-3}
Thermal conductivity	0.19 W m ~ °C-t
Aggregate crushing value	4.67%
Los angeles abrasion value	3.05%
Aggregate compressive strength	12.06 N mm^{-2}
Compressive strength	1.98 N mm^{-2}
Porosity	37%

Source: Akinyosoye, 1976

Stabilization techniques can be broken down into three categories (Hopkins *et al*., 1995) mechanical, physical and chemical. 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 (Hopkins *et al*., 1995). 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.

Stabilization fulfils a number of objectives that are necessary to achieve a lasting structure from locally available soil. Some of these are: better mechanical characteristics (leading to better wet and dry compressive strength), better cohesion between particles (reducing porosity, which reduces changes in volume due to moisture fluctuations) and improved resistance to wind and rain erosion. Suitable method of stabilization depends on the type of soil and a careful study of the local soil is necessary to suggest an effective method of stabilization. In the case of mechanical stabilization, the soil is compacted to a greater density and there will always be an improvement mechanically with virtually any type of soil. This is not true however with other forms of stabilization, where different soil mixtures can lead to better or worse properties using the same technique (Little, 1995).

Palm Kernel Shells which is a bye-product of the production of palm oil is 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 (Akinyosoye, 1976) (Table 1).

Asphalt has been used extensively over the years to successfully stabilize lateritic soils. Liquid asphalt products are most often derived from asphalt cement by blending petroleum distillates to form cutbacks or by emulsifying with water to form emulsified asphalts (Amu, 2000). Basically, asphalt is used as a wearing course for pavement, water proofing, insulation, protective coatings, surface treatments, adhesives, among others.

For the purpose of this study, blended palm kernel shells have been used to modify lateritic soil obtained along Ede road in Ile-Ife, Osun State, Nigeria. The objectives are, to investigate the effects of palm kernel shells on lateritic soil and to study the stabilization characteristics of asphalt on palm kernel blended lateritic soil. Palm kernel shells have been used because of their good interlocking characteristics, low specific gravity and high porosity.

MATERIALS AND METHODS

This study was conducted between January and October 2005 in the Transportation Laboratory of Civil Engineering Department, Obafemi Awolowo University, Ile-Ife, Nigeria. The materials used for the study are, lateritic soil sample, palm kernel shells, asphalt and water (distilled and potable water).

Five samples of lateritic soil named A-E were obtained from Ede road, Ile-Ife, Nigeria. The lateritic soil samples were obtained by digging to a depth of 0.1 m beneath the top soil. All the five samples of the lateritic soil were subjected to preliminary tests, while only sample C, being the poorest, was used for the engineering test. The palm kernel shells used in this study were purchased at Sabo market in Ile-Ife, Nigeria. They were washed, dried and subsequently crushed using a mechanical grinder. Cut-back asphalt was used which was obtained from the road section of the maintenance department of Obafemi Awolowo University, Ile-Ife, Nigeria. The asphalt was thinned with petrol to obtain the cut-back.

The samples were subjected to preliminary tests to determine their natural moisture contents, specific gravities and plasticity indices. The soil samples were subjected to preliminary classification tests to determine the natural moisture content, specific gravity, particle size analysis, Atterberg's limits and engineering tests, such as compaction, California bearing ratio, undrained triaxial shear strength and unconfined compression test.

RESULTS AND DISCUSSION

The soil was classified using the AASHTO soil classification system. A summary of the results obtained from preliminary tests (natural moisture content, specific gravity and Atterberg's limits tests) carried out on the five samples of lateritic soil is shown in Table 2. Sample C was determined to be the least suitable as a sub grade material and therefore found suitable for the study in order to fully discover the stabilization effect. This value falls within the range given by Braja (2000) for expansive clayey soils.

The summary of 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 3. The Liquid Limit (LL) and the Plastic Limit (PL) of the natural soil sample were 31.0 and 13.60%, respectively and its Plasticity Index (PI) was 17.40%, indicating a moderately plastic soil (Whitlow, 1995).

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 17.4-16.60% 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 PI (17.4%)

Table 2: Results of preliminary analysis of samples

	Sample				
Property	A	B	C	D	E
Natural moisture content (%)	10.62	8.03	10.87	6.05	9.29
Specific gravity	2.91	2.70	2.93	2.63	2.83
Liquid limit (%)	29.30	51.50	31.00	21.60	26.00
Plastic limit (%)	15.10	36.20	13.60	11.10	14.50
Plasticity index (%)	14.20	15.30	17.40	10.50	11.50

Table 3: Results of Atterberg's limits test

Composite mix (%)	Asphalt (%)	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
100% Laterite+0% Palm kernel shells	0	31.0	13.6	17.4
	2	39.5	19.6	19.9
	4	38.5	15.9	22.6
	6	37.2	20.6	16.6
	8	50.5	28.9	21.6
	10	41.9	20.0	21.9
75% Laterite+25% Palm kernel shells	0	51.0	31.9	19.1
	2	45.0	20.7	24.3
	4	39.8	22.1	17.7
	6	40.0	18.9	21.0
	8	40.0	16.0	23.9
	10	39.8	16.4	23.4
50% Laterite+50% Palm kernel shells	0	54.5	40.7	13.8
	2	49.0	37.4	11.6
	4	46.0	40.6	5.4
	6	46.1	34.6	11.5
	8	47.2	37.1	10.1
	10	46.0	34.5	11.5

Table 4: Compaction test results

Composite mix	Asphalt (%)	MDD (kg m^{-3})	OMC (%)
100% laterite+0% PKS	0	1570	16.0
	6	1630	15.0
75% laterite+25% PKS	0	1400	19.0
	4	1560	23.0
50% laterite+50% PKS	0	1117	28.0
	4	1118	25.5
25% laterite+75% PKS	0	990	36.0
0% laterite+100% PKS	0	727	35.9

with the optimum PI (17.7%) obtained using 75% laterite-25% PKS mix, it is shown that the PI of the soil sample is increased when 25% PKS is mixed with the soil, even at its optimum mix with asphalt, the PI obtained was greater than the natural soil's PI. It was not possible to carry out Atterberg's limits tests on samples containing more than 50% by weight of palm kernel shells because the soil flowed very easily and could not be rolled into a thread.

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 4. The natural lateritic soil sample had a maximum dry density of 1570 kg m^{-3} and optimum moisture content of 16%, the addition of 6% asphalt increased the MDD to 1630 kg m^{-3} while the OMC decreased to 15%. When 75% laterite and 25% PKS mix was compacted, the MDD obtained was 1400 kg m^{-3} and OMC 19%, with 4% of asphalt, the MDD and OMC increased to 1560 kg m^{-3} and 23.0%, 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 (Lambe and Whiteman, 1979).

Figure 1-4 present some graphs of the soaked and the unsoaked CBR tests, for the 0% mix unstabilized soil sample, the average unsoaked CBR value was 1.43% and when soaked for 72 h it

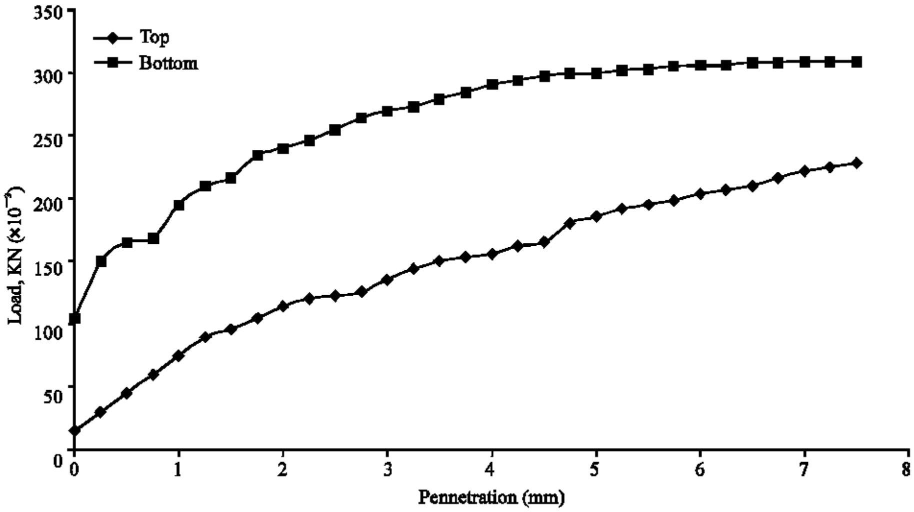

Fig. 1: Unsoaked CBR for 100% lateritic soil (unstabilized) sample

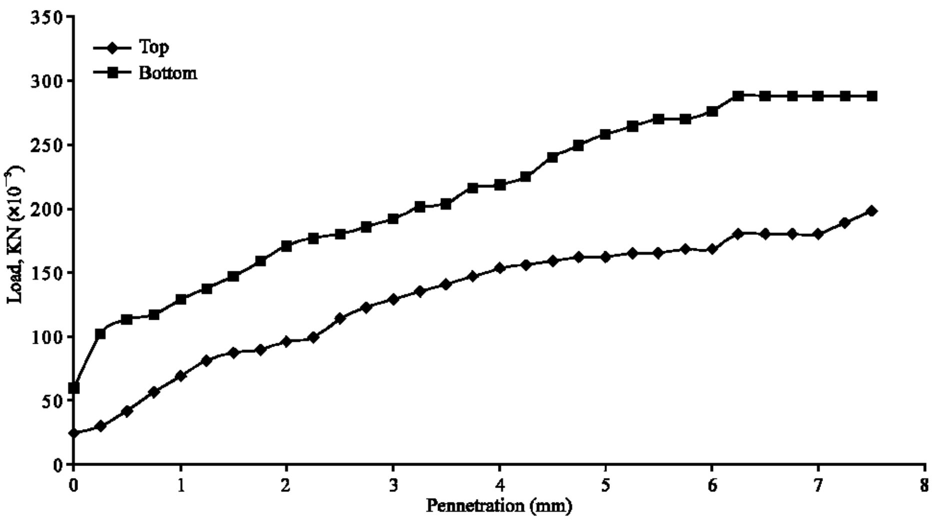

Fig. 2: Soaked CBR for 100% lateritic soil (unstabilized) sample

reduced to 1.11%. From the result, the lateritic soil sample has high clay content and high plasticity index, it is also poorly drained. Therefore, the natural lateritic soil sample used is not a good subgrade, 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. The minimum specified requirements of CBR subgrade, sub base and base courses are 10% CBR (soaked), 30% CBR (soaked) and 80% CBR (unsoaked), respectively (Anonymous, 1970). From the results, none of the soil mixtures, either stabilized or unstabilized met these minimum requirements; they are therefore not good as road construction materials.

Table 5 shows the summary of the result of the unconfined compression tests, the natural sample stabilized with the 6% asphalt gave an uncured strength of 34.12 and 213.67 kN m^{-2} when cured; this

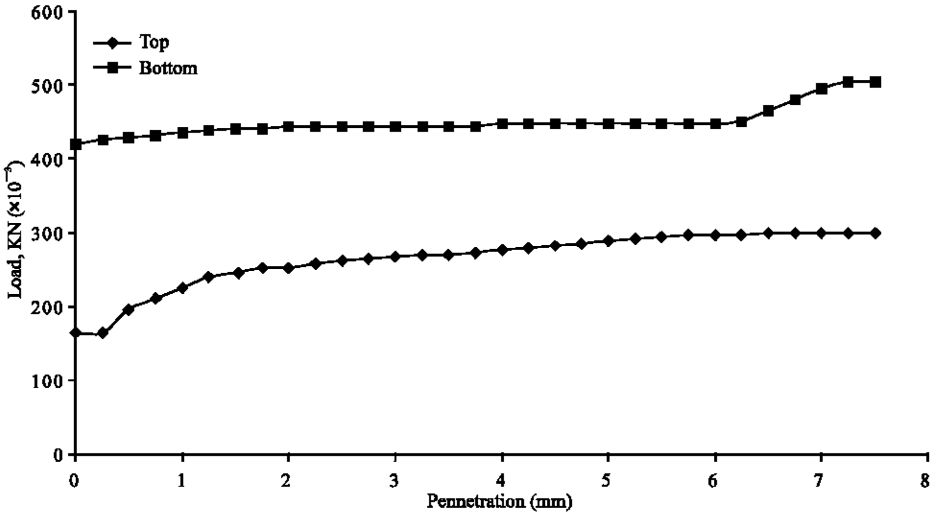

Fig. 3: Unsoaked CBR for 6% asphalt-stabilized lateritic soil sample

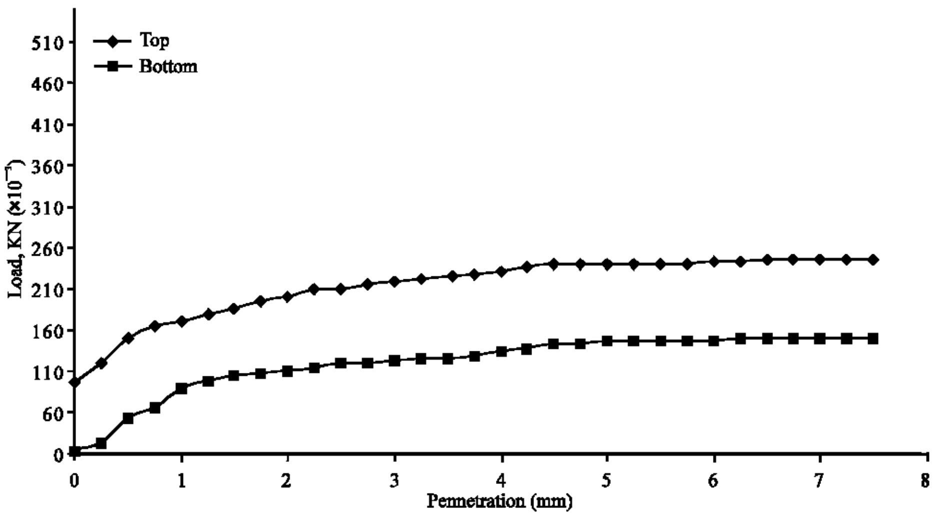

Fig. 4: Soaked CBR for 6% asphalt-stabilized lateritic soil sample

Table 5: Results of unconfined compression test

Composite mix	Asphalt (%)	Type of specimen	Applied axial load (N)	Compressive stress (kN m^{-2})	Cohesion (kN m^{-2})
100% Laterite+0% PKS	0	Uncured	45	39.46	19.73
		Cured	1175	1029.00	514.50
	6	Uncured	39	34.12	17.06
		Cured	1044	913.67	456.84
75% Laterite+25% PKS	4	Uncured	42	36.87	18.44
		Cured	1056	927.54	463.77

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 4% asphalt gave an uncured strength of 36.87 kN m^{-2} and cured strength of 927.54 kN m^{-2}. From the results, it could be seen that the compressive strength of the asphalt stabilized composite mix (75% lateritic and 25%

Table 6: Shear strengths of samples subjected to the same normal stresses

Composite mix	Asphalt (%)	Total normal stress (KN m^{-2})	Cohesion(C) (KN m^{-2})	Angle of internal friction (Φ^0)	Shear strength (KN m^{-2})
100% laterite + 0% PKS	0	200	20	8	48.11
	6	200	22	10	57.27
75% laterite + 25% PKS	4	200	18	3	28.48

PKS) was greater than that of the asphalt stabilized lateritic soil. Therefore, compressive strength is improved by adding palm kernel shells to lateritic soil.

When the three samples were subjected to a total normal stress of 200 kN m^{-2}, analysis showed that the maximum yield or shearing stress of the unstabilized lateritic soil sample was 48.11 kN m^{-2} while the 6% asphalt-stabilized lateritic soil showed stress of 57.27 kN m^{-2}. The composite mix had a shearing stress of 28.48 kN m^{-2} when stabilized with 4% asphalt as seen from Table 6. This shows 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.

CONCLUSIONS

From the results of this study, the following significant findings were obtained:

- Asphalt stabilization of palm kernel blended lateritic soil will reduce the plasticity index.
- The introduction of palm kernel shells in the natural soil will cause a reduction in maximum dry density, California bearing ratio and compressive strength of the composite mixtures.
- The resulting stabilized soils obtained for each of the composite mixes were found to be inadequate for subgrade, sub base and base courses.
- Palm kernel shell is therefore not a suitable complementary substitute for lateritic soil which can easily be upgraded by stabilization.

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REFERENCES

Akinyosoye, G., 1976. Construction Aggregates. 1st Edn., Spon Press, London, pp: 107-110.

Amu, O.O., 2000. Comparative study of stabilizing laterite with lime and asphalt. M. Eng. Thesis, Federal University of Technology, Akure, Nigeria.

Anonymous, 1970. General Specifications for Roads and Bridges. Federal Ministry of Works and Housing Lagos, Nigeria, 11: 22-28.

Arthur, W., S.K. Peter, A. Roy and C. Malcolm, 1999. Roadwork: Theory and Practice. 4th Edn., Butterworth Heinemann, Oxford.

Braja, M.D., 2000. Fundamentals of geotechnical engineering. Thompson Learning, USA., pp: 98-107.

Hopkins, T.C., T.L. Beckham and D.Q. Hunsucker, 1995. Modification of highway soil subgrades. Research Report KTC, pp: 94-11.

Lambe, T.W. and V.R. Whiteman, 1979. Soil Mechanics, SI Version. John Wiley and Sons, Inc., New York, pp: 67-75.

Little, D.N., 1995. Stabilization of Pavement Subgrades and Base Courses with Lime. 3rd Edn., Kendall Hunt Publishing Company, Dubuque, Iowa, pp: 34-56.

Whitlow, R., 1995. Basic Soil Mechanics. 3rd Edn., Addison Wesley Longman Limited, Edinburgh Gate, pp: 98-100.