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Potentials of Palm Kernel Shell Ash as Partial Replacement of Lime on the Geotechnical Properties of Lateritic Soil for Road Construction

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Abstract
The possibility of complementing poor lateritic soils with Palm Kernel Shell Ash (PKSA) and subsequent stabilization of the resulting composite mix with lime was investigated. The scope was limited to strength characteristics and cost analysis of the mix. Meanwhile, the PKSA was analyzed to be pozzolanic. Its oxides contents were similar to that of lime, though calcium content was much lower. The natural lateritic soil samples used were tested and found to be unsuitable for sub–base and base course of roads. Lateritic soil samples stabilized with Lime - PKSA of 2 to 8% satisfied the requirements for use as road sub – base. Stabilized lateritic soil containing 6-8% of the additives was suitable for base course in terms of CBR >30%. The PKSA is therefore recommended as partial replacement of lime in lateritic soil stabilization because of the strength and durability properties and reduced cost of stabilized soils.

Keywords: Palm kernel shell ash, Lime, Lateritic soil, Geotechnical properties, Stabilization, Road Construction

1. Introduction

In countries of the tropic, lateritic soils are encountered in various engineering projects which are good for gravel roads of the world including Nigeria [13]. There are instances where a lateritic soil may contain substantial amount of clay minerals such that its strength and durability cannot be guaranteed under load especially in the presence of moisture [2]. The alternate solution is to improve the available soil to meet the required properties [2, 6]. Cement, Lime, fly ash and bitumen have been used for stabilization. These materials have rapidly increased in price due to the sharp increase in the cost of energy [9]. Research has focused on the usage of ashes of agricultural waste materials to reduce costs and environmental hazard [14]. Addition of lime, palm kernel shell ash increased the soil strength in conformity with findings of previous research on stabilized lateritic soils in Nigeria using rice husk, coal fly ashes [11, 12]. Also, asphalt stabilization of palm kernel shell blended lateritic soils reduced the plasticity index and increased the Maximum Dry Density and Optimum Moisture Content [4]. Bamboo leaf as on lime stabilized lateritic soil increased the strength of lime stabilized lateritic soil for highway construction [5]. Table 1 shows the chemical analysis of lime.

Table 1: Chemical analysis of portland lime by absoprtion spectrophotometer

Element	Ca as CaO	Al as A_l2O_3	Si as SiO_2	Fe as Fe_2O_3	Ma as MgO	Na as NaO_2	K as K_2O
Concentration Ranges (%) of their Oxides	51.56	5.03	30.41	4.10	3.65	0.23	0.90

Source: [1]

Depending on the soil type 2% to 8% of lime by weight of dry soil is mixed with the soil to cause it to harden into a compact mass, which will not soften in the presence of water. The major hydration products are a series of Calcium Silicate Hydrate (CHS) and hydrated lime, $Ca(OH)_2$ [8]. Palm kernel shell used for this research is an agricultural waste that is generated in large quantity in Ekiti State. The aim of the research is to assess the properties of lateritic soil stabilized with ashes from the palm kernel shell ash as partial replacement of lime. The study area is located along Olujoda – Moferere Road (Ado – Ikere), Ado – Ekiti, the capital city of Ekiti State and Igbole – Ekiti in Ido – Osi Local Government Area of Ekiti State, Southwestern Nigeria. The towns are located between latitude 07^o 30^1 and 07^o 49^1 of the equator and Longitude 05^o 07^1 and 05^o 27^1 east of the Greenwich Meridian.

2. Materials and methods

The soil samples were collected at varying depths ranging from 0.4m – 1.7m at a major borrow pit, 1.6km away from Olujoda Hotel, along Ado – Ikere road, Ado Ekiti while the palm kernel shells were obtained from a local oil palm processing centre (Eku) at Igbole-Ekiti in Ido-Osi Local Government Area where they were abundantly available. The palm kernel shells used were collected dry at average inherent moisture constant of 0.1% and then oven – dried to 0% moisture at a temperature of 110^oC. The dried samples were in an open – top kiln to 610^o C at which the material spontaneously ignited with large supply of oxygen. Appreciable ashes began to appear in the furnace at a temperature of 1000^oC. Samples were made by blending both lime and palm kernel shell ash together in the ratio 2%, 4%, 6% and 8% by weight as recommended for lime soil stabilization [8]. Samples evaluated contained only lime as the stabilizing agent (as control) and lime and palm kernel shell ash mixed in ratio 3:1. The tests were implemented (consistency limits, grain size distribution, proctor compaction and California Bearing Ratio) using the appropriate standard equipment's. Soil samples were air–dried and thoroughly mixed to ensure a true representation of the samples (homogeneity). The homogenous samples were blended with lime and palm kernel shell ash (with defined proportion) and water was added to act as a medium for the reaction process. The procedures used in carrying out the above tests for this research were in accordance to [3, 7]. Chemical analyses of the lime and palm kernel shell ash additives were conducted to determine the oxide compositions. The lime and the palm kernel shell ash were dissolved in deionized water with addition of 2ml of 1M HCI, the mixture was then filtered and made up to 50ml in a standard flask. 0.3gm of the oven – dried sample was digested with a mixture of H_2SO_4 and HNO_3 by heating in hot plate for two hours. The digest was filtered and diluted with 8% – 10% HNO_3 and made up of 50ml in standard flask. Metals in all the digested samples were determined using Atomic Absorption spectrophotometer Brick Scientific Model 200A [1, 15]. The tests were performed at Civil Engineering soil laboratory of the Federal Polytechnic, Ado-Ekiti.

3. Results and discussion

3.1 Chemical Composition of Additives

Table 2 shows the oxide composition of lime and palm kernel shell ash additives. The iron, magnesium, sodium, potassium contents of the two additives was comparable with the Standard [1]. The calcium content of PKSA (6.49%) was low compared to lime (51.56%)

Table 2: Chemical composition of lime and palm kernel shell ash

Element	Ca as CaO	Al as A_l2O_3	Si as SiO_2	Fe as Fe_2O_3	Ma as MgO	Na as NaO_2	K as K_2O
Concentration Ranges (%) of their Oxides	51.56	5.03	30.41	4.10	3.65	0.23	0.90

3.2 Cost analysis

Table 3 shows data on costs of production of palm kernel shell ash relative to the price of lime. The palm kernel shell ash was cheaper than lime and would bring about cost reduction of 15% when mixed with lime in ratio 3:1.

Table 3: Cost of Palm kernel shell ashes (1 US $ = N420)

Cost of Collection (N/Kg)	1.50
Energy (fuel) cost of ash production (N/Kg)	20.0
Cost of polarization (N/Kg)	1.50
Total	23.00
Cost of lime at the local market is N/kg	85.00

3.3 Geotechnical properties of unstabilized lateritic soils

Table 4 showed the particle size distribution and other geotechnical characteristics of the unstabilized soil. In most systems of soil classification, the silt and clay grain sizes comprise the fraction passing 0.075mm sieve size while the sand fraction comprises grains passing the 2.36mm sieve size [14]. From table 4, the untreated samples showed gravel fraction of 61.5% and sand fractions of 38% with the silt and clay fractions less than 1%. The untreated laterite can be classified as A – 2 – 6 according to [3], but not a suitable material for base course and sub-base of roads because of the high plasticity index and low California Bearing Ratio [10].

3.4 Geotechnical Characteristics of stabilized lateritic soils

In Table 5, the liquid and plastic limits for soil samples containing mixture of lime and palm kernel shell ash additives were higher (42.0% to 44.5% and 23.00% to 38,5% respectively) than values for samples containing only palm kernel shell ash (36.9 to 43.3% and 25.0 to 34.6% respectively). The plasticity indices of samples stabilized with lime – palm kernel shell ash mixture were lower (12.5 to 6.0%), than values for samples containing only soil and palm kernel shell ash (11.9 to 8.7%). Stabilization using only lime increased the liquid and plastic limits (from 34.3 to 44.5% and 17.8 to 33.0% respectively), but reduced the plasticity index (from 16.5 to 11.5% as the percentage of the additives increased to 8%). Similar trends were observed for samples stabilized with mixture of lime and palm kernel ash and samples stabilized with palm kernel shell ash only. The liquid limits of all the samples at 2% to 8% additive were <45% as recommended for sub-base and base in seasonal wet tropical climates while samples treated with lime – palm kernel shell ash mixture >2% but not more than 8% or <2% palm kernel shell ash only met the requirement of plasticity indices <12%, as recommended for highway sub-base and base course material [10].

3.5 Compaction Characteristics

Table 6 shows the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of lateritic soil samples stabilized with palm kernel shell ash, lime – palm kernel shell ash and lime only. The stabilized samples with lime only showed an increase in the MDD from 1.89g/cc at 0% additive to 2.17g/cc at 8% additive. Stabilized with lime – palm kernel shell ash and only PKSA also increased the MDD from 1.89g/cc at 0% to 2.06g/cc and 2.04g/cc at 8% respectively. Stabilization with lime only, palm kernel shell ash only and lime-palm kernel shell ash mixtures increased the maximum dry density, indicating that palm kernel shell ash might be more suitable stabilizing agent. The OMC of samples treated with lime and PKSA were higher than that of unstabilized soil, while values for samples stabilized with lime-palm kernel shell ash were lower.

Table 4: Physical properties of the unstabilized soil sample

Description	Sieve size	Soil
		Red – brown sandy clay
	9.50mm	96.15
	6.70	87.00
	4.75	72.40
	2.36	37.6
	1.17	27.5
Grain size distribution	1.18	18.0
(percentage passing sieve	0.600	6.70
sizes)	0.425	6.00
	0.300	4.20
	0.212	1.30
	0.150	1.20
	0.075	0.40
Gravel content, %		61.50
Sand content, %		38.00
Fines content, %		<1.00
Specific Gravity		2.60
Liquid Limit, %		34.30
Plastic Limit, %		17.80
Plasticity Index		16.50
Optimum moisture content % (standard Proctor, %)		11.80
Maximum dry density (Standard Proctor) Kg/m^3.		1890.00
Group index		1.00
Unsoaked (CBR), %		21.00

Table 5: Consistency limits result for the treated samples

% Additive	Samples with lime only LL (%) PL (%) PI (%)	Samples with Lime & PKSA LL (%) PL (%) PI (%)	Samples with PKSA only LL (%) PL (%) PI (%)
2	42.0 27.0 15.0	35.0 23.0 12.0	36.9 25.0 11.9
4	43.0 29.0 14.0	39.0 31.0 8.0	38.7 27.4 11.3
6	44.5 32.0 12.5	42.0 35.0 7.0	39.3 28.2 11.2
8	44.5 33.0 11.5	44.5 38.5 6.0	43.3 34.6 8.7

Table 6: Compaction characteristics of stabilised laterite

% Additive	Lime only OMC (%) MDD(g/cc)	Lime + PKSA OMC (%) MDD(g/cc)	PKSA only OMC (%) MDD(g/cc)
0	11.8 1.89	11.8 1.89	18.8 1.89
2	13.9 1.99	8.0 1.96	14.0 1.92
4	12.5 2.04	7.0 2.00	14.0 1.94
6	11.1 2.08	12.0 2.02	13.0 1.98
8	13.0 2.17	11.0 2.06	12.0 2.04

Table 7, below shows that samples stabilized with only lime had the highest C.B. R values (49% –102%) followed by that stabilized with lime-palm kernel shell ash (29-93%) while samples containing PKSA only gave the lowest CBR (25 – 83%). Addition of lime and palm kernel shell ash increased raised the soil strength. This is in conformity with findings of previous research on stabilized lateritic soils in Nigeria using coal fly ashes and rice husk [14]. The CBR values of all the samples satisfied the requirements for road sub-base applications while only soils stabilized with 6 to 8% lime – PKSA mixtures met the requirements for base course application with C.B.R. values >80% [12].

3.6 Strength Characteristic

Table 7: C.B.R. Results for the Treated and Untreated Samples

% Additive	Soil + Lime only (%)	Soil + Lime + PHSA (%)	Soil + PKSA only (%)

0	21.0	21.0	21.0
2	49.0	29.0	25.0
4	71.0	74.0	73.0
6	86.30	84.0	80.0
8	102.0	93.0	83.0

Conclusion and recommandation

The possibility of complementing poor lateritic soils with palm kernel shell ash as partial replacement of lime for improved soil strength and reduction in cost of road construction have been investigated. The lateritic soils stabilized with palm kernel shell ash in quantities greater than 2% but less than 8% met the requirements for sub-base while lime - PKSA recommendation for base course. The use of the additive is advantageous because of low cost of the soil stabilized materials without undermining strength and durability and opportunity to convert waste to wealth.

Recommendation

The following are recommended based on the findings of this investigation:

1. Government and Civil Engineers (road designers) should encourage the use of the additives by specifying the materials for road construction in Nigeria
2. Field application of the stabilizing agent should be considered so that it will not be limited to standard laboratory experiment.
3. Further studies should be carried out to investigate the durability and service of road made with these additives as stabilizing agents

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