Geotechnical Properties of Lateritic Soil Stabilized with Periwinkle Shell Ash in Road Construction

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Abstract— *This paper investigated the geotechnical properties of lateritic soil stabilized with periwinkle shell ash in road construction. The natural lateritic soil sample was gotten from Federal University of Technology, Akure and stabilized with 0, 2,4, 6, 8 and 10% of the periwinkle shell ash and were subjected to tests such as natural moisture content, specific gravity, atterberg's limit, compaction, california bearing ratio and unconfined compressive strength. The result of the classification tests shows that the natural lateritic soil is poor for road construction. The engineering value of the soil sample was enhanced by the addition of periwinkle shell ash. The optimum percentage by weight of soil of periwinkle shell ash for improvement of the strength of the lateritic soil is 6%. The periwinkle shell ash enhanced the suitability of the soil sample for its use as subgrade and subbase.*

Keywords—geotechnical properties, lateritic soil, periwinkle shell ash, road construction, stabilization.

I. INTRODUCTION

According to [1], the importance of road in the development of any nation can hardly be over-emphasized, as it plays crucial role in the transportation of goods and services. This is normally achieved through the vast network of roads that connect rural and urban centres. Efforts at achieving the construction of more roads is hindered by the high cost of building new roads, which is attributed to the non-availability of suitable road building materials within the vicinity of most road projects. Laterites as a sedimentary rock deposit arising from the weathering of rocks is common and readily available for road construction in Nigeria. Laterites are soil types rich in iron and aluminium that are formed in tropical areas. Most laterites are rusty-red in colour because of the presence of iron oxides. They develop by intensive and long-lasting weathering of the underlying parent rock [2]. According to [3], laterites as a soil group is commonly found in the leached soils of the humid tropics and it is formed under weathering systems that cause the process of laterization. Furthermore, Laterites is a soil formed by the concentration of hydrated oxides of iron and aluminium with the ratio of silica $Si0_2$ and sesquioxides Fe_2O_3 + Al_2O_3 less than 1.33, whilst between 1.33 and 2.00 are indicative of lateritic soil and those greater than 2.00 are indicative of non-lateritic soils. Lateritic soils are generally used for road construction in Nigeria. Lateritic soil in its natural state generally have low bearing capacity and low strength due to high content of clay. When lateritic soil contains large amount of clay materials, its strength and stability cannot be guaranteed under load especially in presence of moisture [4]. When lateritic soil consists of high plastic clay, the plasticity of the soil may cause cracks and damage on pavement, road ways, building foundations or any civil engineering construction projects [5], hence, the need for soil improvement. Soil improvement can be in forms of stabilization and modification. Soil modification is the addition of a modifier (cement, lime etc) to a soil to change its index properties, while soil stabilization is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification [6]. There are three purposes for soil stabilization which includes; strength improvement, dust control and soil waterproofing [7].

II. LOCATION AND GEOLOGY OF THE STUDY AREA

According to [8], Akure being the study area lies within Longitude $7^0$18'N and 7^0 16'N North of the Equator and between Latitude 5^0 09'E and 5^0 11.5'E of Greenwich meridian. The study area occurred within the pre-cambrian crystalline rocks of the basement complex of southwestern Nigeria. The predominant rock types in the study area are: charnockites, granite gneiss and migmatitic rocks.

III. AIM OF STUDY

This study examines geotechnical properties of lateritic soil stabilized with ashes of periwinkle shells in road construction.

IV. METHODS AND MATERIAL

1. Materials

Periwinkle Shell Ash (PSA)

The periwinkle shell ash (PSA) were obtained from Port Harcourt, Rivers State. The periwinkle had been removed from the shells, the dirts and organic matter were removed as well. The shells were dried and calcined in an electric muffle furnace at 1000^0C and were ground to fine particles using grinding machine. The ash gotten was later sieved through BS sieve (7µm) to obtain a fine ash.

Ordinary Portland Cement (OPC)

The ordinary portland cement used for this research was produced to the specification of [9].

Lateritic Soil

The lateritic soil was collected at depths representative of the soil stratum and not less than 1.2 m below the natural ground level. It was thereafter brought to the Geotechnical Laboratory of the Federal University of Technology, Akure (FUTA) and marked, indicating the soil description, sampling depth and date of sampling. The lateritic soil was aired-dried for two weeks to allow for partial elimination of natural water which may affect the analysis, then sieved with sieve no 4(4.75mm opening) to obtain the final soil samples for the tests. After the drying period lumps in the sample were pulverised under minimal pressure.

Water

Portable water was used for the preparation of the specimens at the various moisture contents.

2. Methods

The natural lateritic soil sample was divided into three parts. The first part was the untreated natural lateritic soil. The second part was treated with cement in proportions of 2, 4, 6, 8 and 10% by dry weight of the lateritic soil. The third part of the natural lateritic soil sample was treated with periwinkle shell ashes by proportions of 2, 4, 6, 8 and 10% by dry weight of the lateritic soil. Classification test (natural moisture content, specific gravity, particle size analysis and atterberg's limit tests) was performed on the untreated natural lateritic soil, strength tests (compaction, california bearing ratio and unconfined compressive strength) were also performed. Strength tests (compaction, california bearing ratio, unconfined compressive test and shear strength test) were performed on the other two treated soil samples. The procedure for the various tests were carried out in accordance with the [10].

V. RESULTS AND DISCUSSION

The results of the preliminary tests such as natural moisture content, specific gravity, particle size analysis, atterberg's limit and plasticity index before being treated are presented in Table 1. The chemical composition of the periwinkle shell ash is presented in Table 2, while chemical composition of OPC is presented in Table 3. The engineering property test for lateritic soil stabilization with PSA is presented in Table 4. Table 5 shows the engineering property for lateritic soil stabilized with OPC.

Table 1: Summary of the preliminary test of natural lateritic soil sample

Natural Moisture Content	13.4
Specific gravity	2.40
Liquid limit (%)	45.5
Plastic limit (%)	31.0
Plasticity index (%)	14.5
AASHTO classification	A-7-5
Soil type (Unified Classification) (SC)	Silt-Clay

Table 2: Chemical composition of the periwinkle shell ash (PSA)

Elemental Oxides	Weight %
CaO	40.84
MgO	0.48
K_2O	0.14
SiO_2	33.84
SO_3	0.26
Na_2O	0.24
Al_2O_3	10.20
Fe_2O_3	6.02
P_2O_5	0.01
TiO_2	0.03
LOI	7.60

(Source: [11]).

Table 3: Chemical composition of ordinary portland cement

Elemental Oxides	Weight %
SiO_2	21.40
Al_2O_3	5.03
Fe_2O_3	4.40
CaO	61.14
MgO	1.35
K_2O	0.48
Na_2O	0.24
SO_3	2.53
TiO_2	-
LOI	1.29
IR	1.65

(Source: [12])

Table 4: Engineering property tests for lateritic soil stabilized with periwinkle shell ashes (PSA)

PSA	OMC (%)	MDD (Kg/m^3)	CBR (%)	Unconfirned compressive strength (kN/m^2)	Shear strength (kN/m^2)
0	10.7	1940	8	210	114
2	11.9	1960	22	370	195
4	12.8	1990	35	598	306
6	13.8	2010	59	688	341
8	14.9	1989	51	898	402
10	15.8	1974	49	1028	520

Table 5: Engineering Property tests for lateritic soil stabilized with ordinary portland cement

OPC	OMC (%)	MDD (Kg/m^3)	CBR (%)	Unconfirmed compressive strength (kN/m^2)	Shear strength (kN/m^2)
2	12.0	1960	57.62	542.52	271.26
4	12.6	1980	68.74	820.86	415.43
6	13.7	2010	87.32	1088.32	564.16
8	14.5	2025	78.91	1174.46	587.23
10	15.6	2070	80.41	1275.22	687.61

California Bearing Ratio

The California Bearing Ratio is one of the common tests widely used in the design of base and subbase material for pavement design and it is used to evaluate the strength of stabilized soil [13]. For the periwinkle shell ash, the CBR rose progressively at 0% of PSA which was 8% to 59% at 6% value. It reduced to 51% and 49% at 8% and 10% respectively. The optimum value is therefore at 6% of weight of dry soil. It dropped to 78.91% and later rose to 80.41% at values of 8% and 10% respectively. According to [14], increase in CBR with cement can be attributed to the hydration reaction of cement. The entire CBR values are unsoaked.

Compaction

The variation of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) with periwinkle shell ash as stabilizer at 2, 4, 6, 8 and 10% indicates that MDD increased as OMC increased until it got to 6%. The MDD increased from 1940 kg/m^3 to 2010 kg/m^3, while the OMC increased from 10.7% to 15.8%, the progressive decrease observed in MDD can attributed to the mixture of lateritic soil and periwinkle shell ash which has lower specific gravity compared to the soil. The observed decrease in MDD may also be explained by considering the periwinkle shell ash as fillers in soil voids, while increase in MDD from 1940 kg/m^3 to 2010 kg/m^3 may be due to decrease in surface area of the clay fraction of the lateritic soil arising from the substitution of the lateritic soil with the periwinkle shell ashes.

Increase in OMC implies that more water is needed to compact the soil. For the ordinary portland cement; the increase in MDD from 1960 kg/m^3 to 2070 kg/m^3 may be due to the decrease in the surface area of the clay fraction of the lateritic soil arising from substitution with cement [15]. According to [16] increase in MDD with cement added to lateritic soil indicates improvement in soil properties. While increase in OMC indicates that more water is needed to compact the soil.

Unconfined Compressive Strength

The unconfined compressive strength (UCS) test is the most popular and flexible method of evaluating the strength of stabilized soil. It is also the test for the determination of the required amount of addition to be used in the stabilization of soil [17]. From Table 4, there was increase in unconfined compressive strength of the lateritic soil stailized with periwinkle shell ash from 210 kN/m^2 at 0% (untreated state) to 1028 kN/m^2 at 10% of weight of dry soil. Also for the lateritic soil stabilized with ordinary portland cement, there was increase from 542.52 kN/m^2 at 2% value of the OPC to 1275 kN/m^2 at 10% value. The increase in the UCS is attributed to the formation of cementitious compounds between the CaOH present in the soil and PSA and the pozzolans present in PSA[18].

VI. CONCLUSION

This analysis of geotechnical properties of lateritic soil stabilized with periwinkle ashes as stabilizers while also using ordinary portland cement as the basis of comparison have been carried out in compliance with [19] and [20]. The geotechnical properties in terms of compaction (Optimum Moisture Content and Maximum Dry Density), Unconfined Compressive Strength, California Bearing Ratio of the soil stabilized with periwinkle shell ash were investigated and determined just as it was done for the unstabilized soil and the soil treated with cement.

The study has revealed that the periwinkle shell ash satisfactorily acts as cheap stabilizers for subgrade and subbase purposes.

Optimum CBR can be achieved by adding 6% periwinkle shell ash by weight of dry soil.

Strength of lateritic soil increases with the addition of the periwinkle shell ash.

Cement still ranks higher than the periwinkle shell ash used in the study for improving the CBR of the lateritic soil.

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