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Evaluation of Laterite Soil Reinforced with a Mixture of Periwinkle and Palm Kernel Shells as Road Construction Materials in Niger Delta, Nigeria

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Abstract

Pollution is a very predominant problem in Nigeria. As a developing nation, we face challenges of constant economic recession which have an effect on so many facets of life including construction. In order to combat pollution and bad roads, waste can be used with other construction materials to construct better roads. This study evaluated laterite soil reinforced with a mixture of palm kernel and periwinkle shells as materials for road construction. The soil samples were obtained from a burrow pit at Iguosa Housing Estate, Benin City, Edo State Nigeria at 6°26'55''N 5°36'16''E. The geotechnical properties of natural soil were determined, which included specific gravity, mechanical sieve analysis, consistency limit, compaction, and California Bearing Ratio (CBR) tests. The strength properties of the soil reinforced with periwinkle shell (PS) and palm kernel shell (PKS) were carried out. These were done in proportions of 6%, 9%, 12% and 15% by volume. For the control sample, the average result of the specific gravity obtained was 2.47 which was below the standard of 2.50 to 3.0 for lateritic soils. The plasticity index was 19.49% which indicated that the soil is of medium plasticity. The sieve analysis indicated that the soil is classified as an A-2-6 soil. The Maximum Dry Density and the Optimum Moisture Content were 1.78 g/cm^3 and 10.3% respectively. The average value for the soaked CBR was 15.11%. When the soil was reinforced with equal proportion of PS and PKS, the OMC ranged from 11.30% to 11.70%, the MDD ranged from 1.73g/cm^3 to 1.75g/cm^3 and from the CBR tests, the value for the soaked CBR ranged from 1.26% to 23.21%. The optimum mix proportion was obtained to be 12% (6% for PS and 6% for PKS). This did not meet the requirement of 30% for subbase stated by the Federal Ministry of Works and Housing. Therefore, these soil reinforcement techniques with PS and PKS can only be used for Trunk D roads or as subgrade materials which require a minimum soaked CBR of 5%.

1. Introduction

Soil is any natural loose mineral particle that may or may not be organic, lying over the bedrock that is formed by the weathering of rocks. The soil type that is predominant in Edo State is laterite [1]. Lateritic soils located in Nigeria have been used extensively in the construction industry as subgrade and sub-base materials for road construction and are usually found in different drainage and sub-climate environments. Lateritic soils found everywhere shows unique physical, chemical and engineering properties. Therefore, a comprehensive evaluation must be carried out on any lateritic soil to determine if it meets the requirements of lateritic soils, before its utilization for any engineering purpose [2]. How then can we employ laterite soil as main materials in sub-bases and base courses? By Soil reinforcement or stabilization. Almost all road construction projects would require soil stabilization of some sort. It has even been recommended for developing countries. The release of waste into the environment from agriculture, industries and homes is increasing at an exponential rate all around the world. In developing countries, there are no functional waste management and monitoring systems and consequently, environmental pollution has become a threat to the sustainability of the human race. At the same time, the economic recession has greatly affected construction in Nigeria and other developing countries. The cost of cement, coarse aggregates and other conventional building materials have caused contractors to use substandard materials for road construction. The growing concern of resource depletion and global pollution has challenged many researchers and engineers to seek and to develop new materials relying on renewable resources. These include the use of by-products and waste materials in building construction [3]. Laterite soil is widely available in Edo State and is a potential material for road construction but it has some drawbacks. It consists of high plasticity that results in cracks and damage on building foundations, pavements and highway construction. For a material to be used as either a base course or sub-base course depends on its strength in transmitting the axle-load to the sub-soil and or sub-grade (the mechanical interlock) [4],[5]. So, there is a need to reinforce it with some aggregates. Palm kernel shells are abundant in palm oil-producing states in southern Nigeria. They are underutilized and are usually discarded or used on a small scale as fuel in furnaces and materials for filling potholes [6]. On the other hand, periwinkle shells are discarded after the edible parts are consumed by people in the coastal regions of Nigeria. These cause environmental pollution in that area [7]. The study was to investigate the suitability of laterite soil reinforced with a mixture of palm kernel and periwinkle shells as material for subgrade and subbase courses in road construction. If palm kernel shells and periwinkle shells are found suitable for construction, their large supply could be harnessed to reduce construction cost without undermining the strength/integrity of roads. This study has the potential for making sustainable roads from laterite reinforced with palm kernel shell and/or periwinkle shell which in turn would help to promote a cleaner environment. Periwinkle shells and palm kernel shells have been used by researchers in Nigeria for over 30 years as a conglomerate in concrete reinforcement, green concrete and asphaltic concrete [8],[9],[10],[11],[12]. However, in this study, palm kernel shells and periwinkle shells were used as a partial replacement for expensive coarse aggregates in sub-base and base course of flexible pavements in an area where laterite soil is abundant.

2.0 Methodology

2.1 Materials and Sample Preparation

The laterite soil was obtained from a burrow pit in the Iguosa Housing Estate Benin City Edo State Nigeria at 6°26’55’’N 5°36’16’’E. (Figure 1.0)

Commercially available periwinkle shells was air dried and broken into smaller bits (average of 6mm diameter) with pestle to reduce voids as shown in Figure 2.0 and the palm kernel shell (Figure 3.0)was obtained from a small palm oil producing corporation.

2.2 Laboratory Tests

The following tests were carried out on the laterite soil which is the control sample (CS) in accordance with the American Society for Testing and Materials (ASTM) standards and British Standards [13], [14].

1. Sieve analysis
2. Specific gravity test
3. Moisture Content test
4. Atterberg Limits test

When the soil was reinforced with a mixture of PKS and PS, these engineering tests were done:

1. Compaction test (Proctor test)
2. California Bearing Ratio (CBR) test

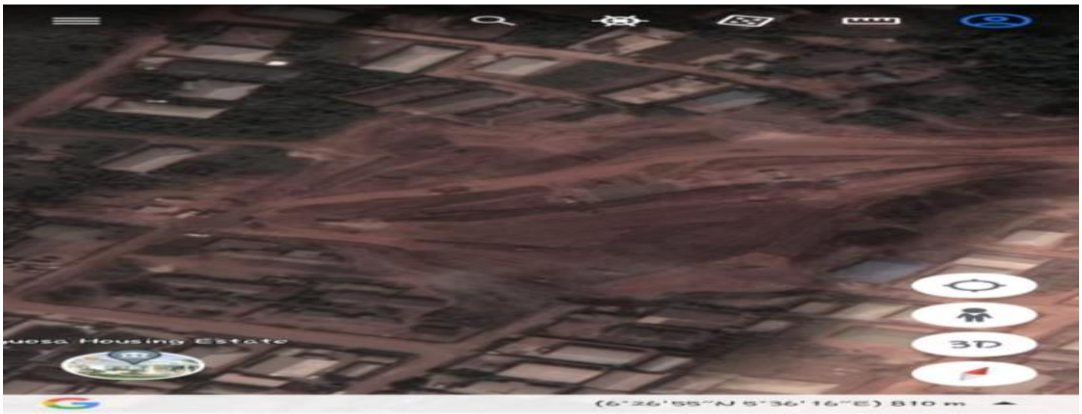

Figure 1.0: Location of the sample collection area (Google Earth)

Figure 2.0: Crushed Periwinkle Shell Sample

Figure 3.0: Crushed Palm Kernel Shell Sample

3.0 Result and Discussion

3.1 Control Sample

The summary of the mean results of the geotechnical engineering tests carried out on the control sample CS (soil only) are presented in Table 1.0.

Table 1.0: Summary of the geotechnical engineering test results (Control sample)

S/No	Laboratory Test		Result
1	Natural Moisture Content (%)		11.30
2	Specific Gravity		2.47
3	Atterberg Limit	Liquid limit (%)	39.12
		Plastic limit (%)	19.63
		Plasticity index (%)	19.49
4	Sieve analysis	Sieve size (mm)	Percentage passing (%)
		3.35	100
		2.36	96.5
		2.00	94.7
		1.18	86.1
		0.6	64.5
		0.425	54.9
		0.3	41.9

		0.212	30.2
		0.15	26.8
		0.075	23.1
5	Compaction	OMC (%)	10.3
		MDD (g/cm^3)	1.78
6	CBR	Top (%)	3.96
		Bottom (%)	15.11

From the sieve analysis, the percentage passing the 0.075mm sieve is 23.1%, the percentage passing the 0.425mm sieve is 54.9% and the percentage passing the 2.00mm sieve is 94.7%. From Atterberg limit test, liquid limit is 39.12%, the plastic limit is 19.63% and the plastic index is 19.49%. Since, the percentage passing 0.075mm sieve is less than 35% therefore it is a granular soil. The plasticity index is 19.49% and this shows the soil is of clayey type and has medium plasticity. Considering all other parameters, the soil is classified as an A-2-6 soil. Based on AASTHO specifications, soils in the A-2-6 class are good as subgrade materials [15].
The CBR for the bottom unsoaked was obtained to be 15.11% showing that it is suitable only to be used as subgrade material [16]. If it is to be used for subbase or base course, it would have to be stabilized or reinforced with other materials.

3. 2 Control Sample with PKS and PS

Presented in Table 2.0 are the summary of the results of the strength tests carried out on the control sample reinforced with a mixture of PKS and PS in equal proportions.

Table 2.0: Summary of the geotechnical test results (Sample with Periwinkle Shell and Palm Kernel Shell added in equal proportions)

S/No	Percentage Replacement (%)	Test		Result
1	6	Compaction	OMC (%)	11.70
			MDD (g/cm^3)	1.74
		CBR	Top (%)	7.43
			Bottom (%)	1.26
2	9	Compaction	OMC (%)	11.40
			MDD (g/cm^3)	1.75
		CBR	Top (%)	15.93
			Bottom (%)	4.77
3	12	Compaction	OMC (%)	11.30
			MDD (g/cm^3)	1.73
		CBR	Top (%)	23.21
			Bottom (%)	9.32
	15	Compaction	OMC (%)	11.30
			MDD (g/cm^3)	1.73
		CBR	Top (%)	8.51
			Bottom (%)	2.81

From Table 2.0, no sample had OMC less than the OMC of the control sample of 11.30% but the minimum MDD was obtained as 1.73 g/cm^3. The maximum CBR was obtained in the sample with 6% PS and 6% PKS (Mix) with a value of 23.21% at the top. According to the Federal Ministry of Works and Housing General Specification for Roads and Bridges, Volume II, this value is below the minimum requirement of subbase material. Hence, it cannot be used as subbase on Trunk A roads and can only be used for Trunk D roads or as subgrade materials which require a minimum soaked CBR of 5%.

4.0 Conclusion

From the critical examinations and analyses, it can be concluded that the appropriate mix ratio for the natural soil and the mixture of PS and PKS, is 6%. The use of soil reinforced with PKS and PS for subbase should be restricted to Trunk D roads or as subgrade materials which require a minimum soaked CBR of 5%. For Trunk A, B and C roads, the mixture would require a binder like cement before being considered as subbase and base course materials.

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