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GEOTECHNICAL PROPERTIES OF LATERITIC SOIL STABILIZED WITH CEMENT AND PULVERIZED WOOD CHARCOAL

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Abstract. This study investigates the geotechnical properties of lateritic soil stabilized with pulverized wood charcoal (PWC) in comparison with the same soil stabilized with cement which is considered to be the best stabilizer. Classification of the soil according to AASHTO revealed that the soil is an A-6 soil. Chemical tests carried out on PWC and ordinary Portland cement (OPC) indicated that the major oxides present in the OPC sample were CaO and SiO_2 at 60.50% and 21.40% respectively and in the PWC were CaO and SiO_2 at 39.46% and 28.46% respectively. This distinctly high concentration of CaO is responsible for their high stabilizing property. Compaction, California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) tests carried out on the lateritic soil in its natural state and when PWC was added in varying proportions of 2, 4, 6, 8 and 10% by weight of soil indicated that the stabilizer enhanced the strength of the lateritic soil. The unsoaked CBR value of the soil attained the optimum value of 13.68% on addition of 6% PWC by weight of soil. The unconfined compressive strength improved from 148.65kN/m^2 in the natural state to 296.6kN/m^2 at 10% PWC addition. Based on the geotechnical properties obtained, charcoal has a high potential of being a veritable soil stabilizer and compares favourably with cement in compressive strength.

Keywords: *compaction, California Bearing Ratio, Unconfined compressive strength, optimum.*

Introduction

Laterites are products of tropical weathering with red, reddish brown and dark brown colour with or without nodules or concreting and generally (but not exclusively) found below hardened ferruginous crust or hard pan [1]. Lateritic soils are of great interest to researchers all over the world in regard to both their common and extensive occurrence and peculiar properties; they are widely used as fill materials for various construction works in most tropical countries. These soils are weathered under conditions of high temperatures and humidity with well-defined alternating wet and dry seasons resulting in poor engineering properties such as high plasticity, poor workability, low strength, high permeability, tendency to retain moisture and high natural moisture content. The effective use of these soils is therefore often hindered by difficulty in handling particularly under moist and wet conditions typical of tropical regions and can only be utilized after modification/stabilization. Lateritic soils that present such problems during construction processes are termed problematic laterites [2].

The modification/stabilization of engineering properties of soils is recognized by engineers as an important process of improving the performance of problematic soils and makes marginal soils perform better as civil engineering materials [3]. The application of chemicals such as ordinary Portland cement, lime and fly ash or a combination of these often results in the transformation of the soil properties which may involve the cementation of the particles [2]. Soil stabilization, which refers to the procedures employed with a view to altering one or more properties of a soil so as to improve its engineering performance, is one of the several soil improvement techniques available to the geotechnical engineer and its choice for any situation should be made only after a comparison with other techniques indicates it to be the best solution to the problem [4]. Stabilization is the process of blending and mixing materials with a soil to improve the properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation and improve the engineering properties of soil, thus making it more stable [5].

Soil stabilization is the alteration of soils to enhance their physical properties. Soil stabilization can also be defined as a soil improvement technique in which the resistance of the soil to the various types of deformations and forces is increased [6]. It can increase the shear strength of a soil, control its shrink-swell properties and improve its load bearing capacity. Soil stabilization can be utilized on roadways, parking areas, site development projects, airports and many other situations where sub-soils are not suitable for construction. It can also be used to treat a wide range of subgrade materials varying from expansive clays to granular soils as well as improve other physical properties of soils such as increasing their resistance to erosion, dust formation or frost heaving. The ability to blend the naturally occurring lateritic soil with some chemical additives to give it better engineering properties in both strength and water proofing is very essential [7].

Charcoal is a lightweight, black residue, consisting of carbon and any remaining ash, obtained by removing water and other volatile constituents from animal and vegetation substances. Charcoal is usually produced by slow pyrolysis - the heating of wood or other substances in the absence of oxygen [8]. Wood ash, similarly regarded as grounded charcoal, in general has a pozzolanic property which alters most properties of soil that makes it become suitable for construction [9].

In previous times, the most commonly used additive for soil modification or stabilization is Ordinary Portland Cement (OPC). However, the reasons for finding alternatives to cement are high cost of production, high energy demand and emission of CO_2 which is responsible for global warming [10]. The effect of the introduction of charcoal to the soil, much like Portland cement, is to cause flocculation and agglomeration of the clay particles due to ion exchange at the surface of the soil particles. The resultant effect of these reactions is to enhance workability and provide an immediate reduction in swell, shrinkage and plasticity [2].

Hence, this study shows that the use of charcoal as a stabilizer can improve the performance of lateritic soils at a cheaper and environmentally safer rate.

Materials and Methods

The major material used for this study is lateritic soil which was sourced from a point located in the Federal University of Technology, Akure (FUTA) north campus. The soil was sealed in plastic bags and kept in sacks to avoid loss of moisture. The pulverized wood charcoal (PWC) used was obtained from the famous King's Market located in Akure metropolis (Plate 1). Ordinary Portland Cement (OPC) was used as basis for comparison of results of strength with charcoal, and this was obtained from a retailer in Akure metropolis.

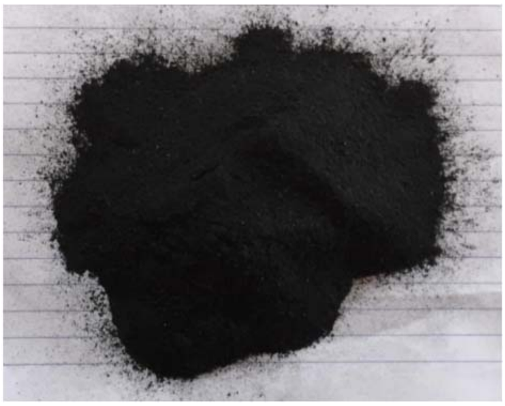

Plate 1. Sample of the Pulverized Wood Charcoal.

The lateritic soil samples were air-dried and then pulverized, under minimal pressure, to obtain particles passing sieve BS No. 4 (4.75mm opening). Wood charcoal lumps were also pulverized and sieved through BS sieve 212μm. An inorganic geochemical analysis was carried out on the PWC and OPC samples using an X-Ray Fluorescence Diffractometer. Preliminary tests such as natural moisture content, particle size distribution, Atterberg limits and specific gravity as well as engineering tests such as compaction test, California Bearing Ratio (CBR) and unconfined compressive strength tests were carried out on the lateritic soil samples in their natural state and on adding the stabilizers. In this investigation OPC and PWC were used to stabilize the lateritic soil samples in varying proportions of 2, 4, 6, 8 and 10% by weight of the soil. This study tries to implement that Lateritic Soil-PWC might have an equal advantage as the standard mix of Lateritic Soil-OPC.

Results and Discussion

Preliminary Tests

Table 1 presents the preliminary tests conducted on the lateritic soil sample to determine its natural properties. This revealed that the soil has a natural moisture content of 18.53% with a liquid limit of 34% and plastic limit of 21% Other index properties are as indicated. According to AASHTO classification, the lateritic soil is an A-6 soil, which makes it unsuitable as a subgrade material, hence, the need for stabilization.

Table 1

Geotechnical properties of the unstabilized lateritic soil

Properties	Quantities
Natural Moisture Content	18.53%
Percentage Passing BS No 200 Sieve	51.3%
Liquid Limit	34%

Continuation Table 1

Plastic Limit	21%
Plasticity Index	13
Linear Shrinkage	5%
Specific Gravity	2.68
AASHTO Classification	A-6
Maximum Dry Density	1785kg/m^3
Optimum Moisture Content	18.40%
California Bearing Ratio	17.32%
Unconfined Compressive Strength	148.70kN/m^2

Oxide Composition of the OPC and PWC

Results of X-Ray fluorescence diffractometer test on the OPC and PWC are shown in Table 2. The OPC sample as CaO and SiO_2 contents at 60.50% and 21.40% respectively while the PWC as CaO and SiO_2 contents at 39.46% and 28.46% respectively. This distinctively high concentration of CaO in both additives is responsible for their high stabilizing property.

Table 2

Oxide composition of OPC and PWC

Oxides	OPC (%)	PWC (%)
SiO_2	21.40	28.46
Al_2O_3	5.01	3.96
TiO_2	0.38	0.23
Fe_2O_3	4.30	1.95
MnO	0.21	0.62
MgO	1.35	4.32
CaO	60.50	39.46
Na_2O	0.35	0.12
K_2O	0.48	2.40
P_2O_5	1.55	1.29
SO_3	2.18	1.91
Fixed Carbon	-	15.28
Loss on Ignition	2.29	-

Compaction Test

Figure 1 shows that the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the soil sample in its natural form before stabilization were 1806 kg/m^3 and 19.52% respectively.

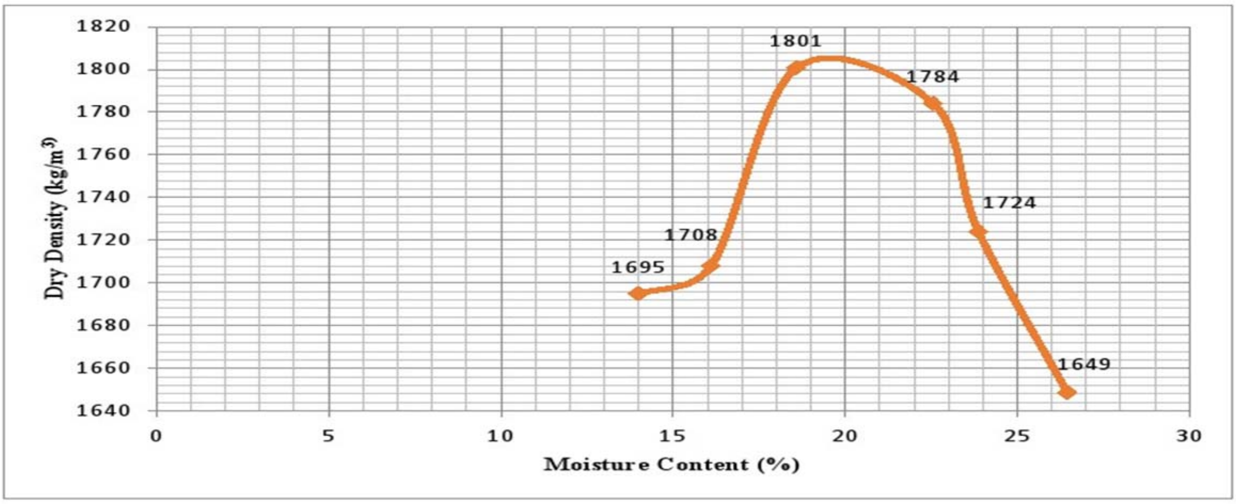

Figure 1. Compaction curve of the lateritic soil in its natural form.

With the addition of varying percentages of stabilizers (OPC and PWC) to the soil sample, variations in the values of OMC and MDD were observed as shown in Figures 2 and 3 respectively. As the percentage of OPC and PWC increased, MDD decreased and OMC increased.

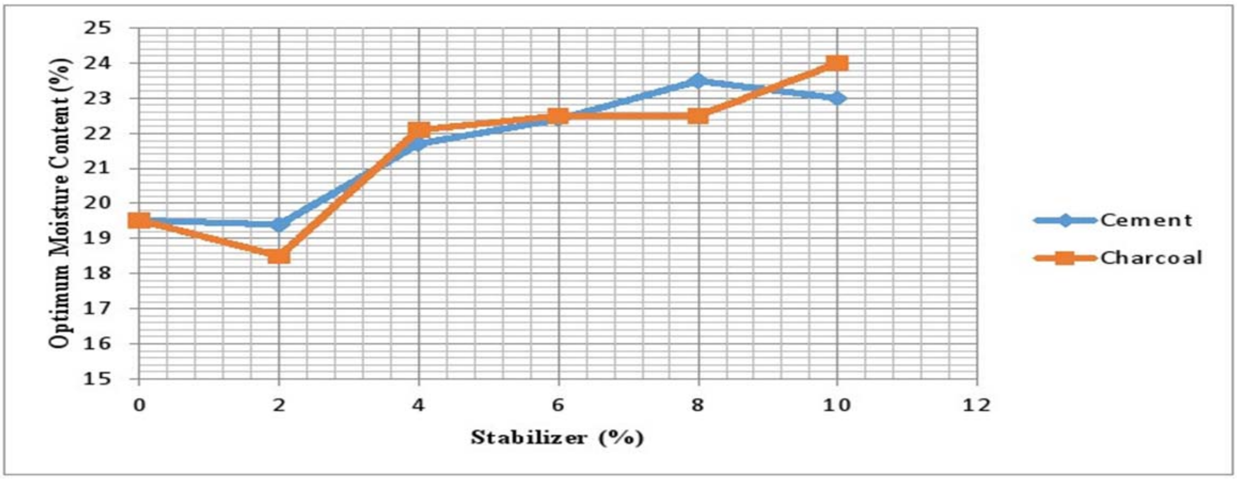

Figure 2. Variation of OMC with percentage of stabilizers.

For the OPC stabilizer, MDD decreased from 1730 kg/m^3 to 1673 kg/m^3 and OMC increased from 19.4% to 23.06% as its content varied from 2% to 10% while for PWC stabilizer, MDD decreased from 1650 kg/m^3 to 1494 kg/m^3 and OMC increased from 18.5% to 24% as its content varied from 2% to 10%.

The observed decrease in MDD values can be attributed to mixture of the sample with PWC which has low specific gravity of 1.10, as compared to lateritic soil and the pulverized nature of the PWC which could make it to act as filler in the soil voids. Increase in OMC values implies that more water is needed to compact the soil [11].

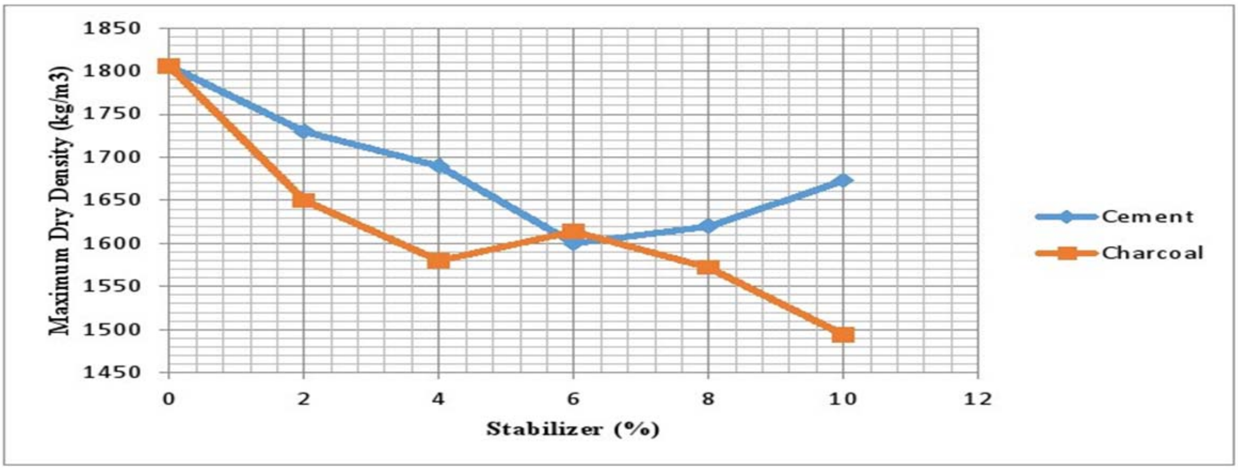

Figure 3. Variation of MDD with percentage of stabilizers.

California Bearing Ratio (CBR)

In the case of the OPC, the CBR increased progressively at 2% from 17.86% to 35.29% at 10% content. Increase in CBR with OPC can be attributed to the hydration of cement. As shown in Figure 4, for PWC, the CBR increased from 9.52% at 2% stabilizer to 13.68% at 6% content and then decreased to 9.47% at 8% content and 10.95% at 10% content.

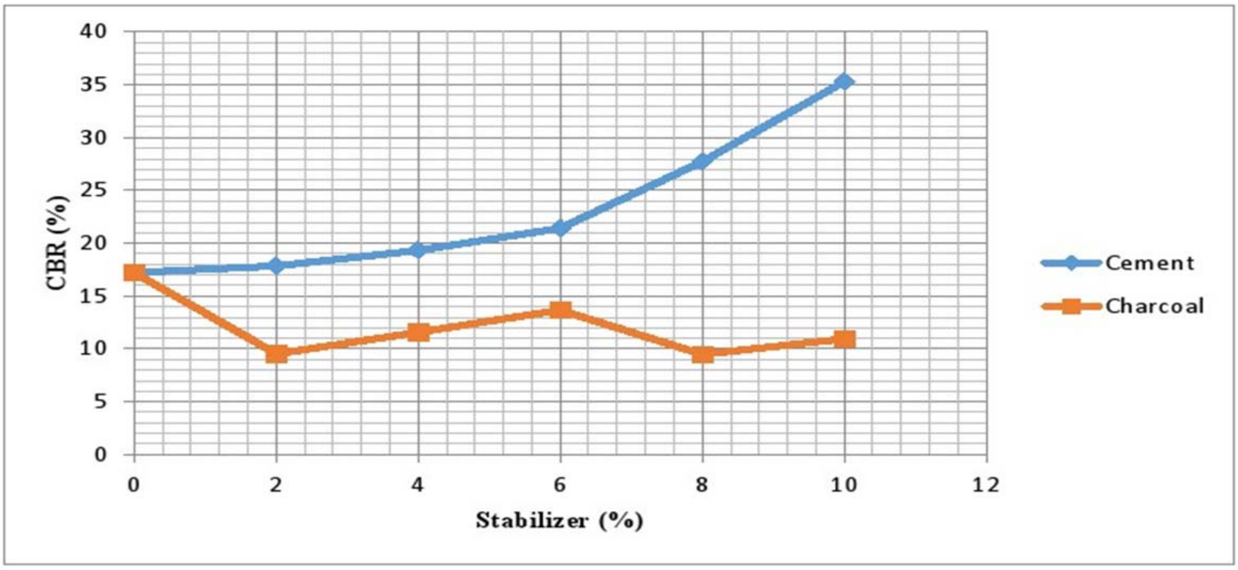

Figure 4. Variation of CBR with percentage of stabilizers.

The fluctuation in the CBR values may be due to the excess PWC which may not be used up in the reaction as the presence of naturally occurring Calcium Hydroxide in the soil may be small. The excess PWC filled the voids within the specimen and reduced the clay and silt content in soil and hence, reduced the bond/cohesion in the Soil-PWC mixture.

Unconfined Compression Strength Test (UCS)

The UCS test carried out showed a progressive increase at 2% value of 202.10kN/m^2 to 383.50kN/m^2 at 10% OPC content.

Figure 5 shows that there was an increase in the UCS values when the PWC was added from 135.10 kN/m^2 at 2% stabilizer to 296.60 kN/m^2 at 10% content. The increase in UCS value can be attributed to the fact that PWC contains a considerable amount of CaO which is capable to increase its resistance to shear failure.

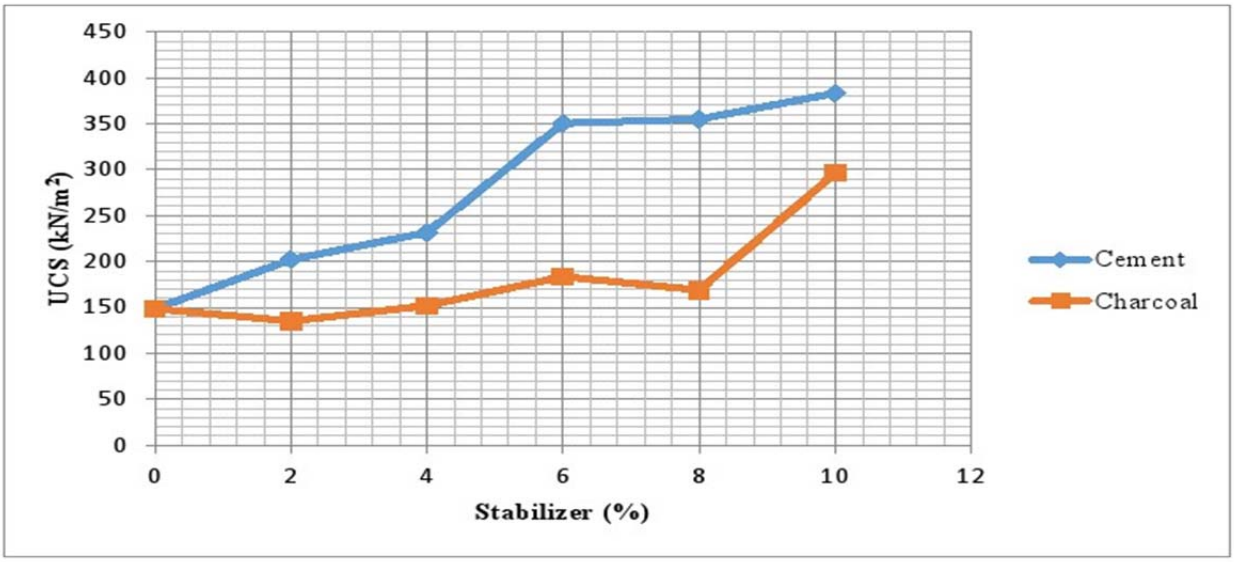

Figure 5. Variation of UCS with percentage of stabilizers.

Conclusion

The Atterberg limits test and the particle size distribution analysis carried out using the AASHTO classification system, revealed that the lateritic soil used is an A-6 soil (i.e. soil that cannot be used as subgrade material in road construction unless it is stabilized). The compaction test indicates that the maximum dry densities are obtainable for the lateritic soil treated with cement and charcoal at OMCs of 19.40% and 18.50% respectively. This is an indication of high strength in the soil as well as less susceptibility to changes in moisture content which may lead to swelling and shrinkage. Optimum CBR results can be achieved by adding 6% wood charcoal by weight of soil to the natural lateritic soil sample. The CBR tests also suggest that charcoal-treated-soils will only produce results comparable to cement-treated-soils under dry conditions. Hence, charcoal can be used as an alternative to cement under unsoaked conditions. The study has revealed that charcoal satisfactorily acts as a veritable stabilizing agent for subgrade purposes.

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