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Stabilisation of Lateritic Soil for Road Construction Using Banana Leaf Ash

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ABSTRACT: *In view of the need to stabilise poor lateritic soil for road construction, this study investigated the effects of banana leaf ash (content retained on British Standard sieve No. 40) on the strength characteristics of selected lateritic soils. This is with a view to ascertaining the possibility of using the referenced banana leaf ash (BLA) content to stabilise the soils, for road construction purpose. To achieve the aim of this study, two soil samples were collected from two identified borrow pits (one sample from each borrow pit – referred to as Sample A and Sample B respectively) in Ile-Ife, southwestern Nigeria. Using standard procedure, preliminary and geotechnical tests were conducted on the soil samples in their natural states. BLA was then prepared and introduced to the soils at varying proportions of 2 %, 4 % and 6 % by weight of dry soil. The Atterberg limits and California bearing ratio (CBR) were subsequently determined for the treated soils. For the natural soils, results showed that: the plasticity index values for Sample A and Sample B were 22.91 % and 26.60 % respectively; the specific gravity values were 2.71 and 2.75 respectively; the optimum moisture content (OMC) and maximum dry density (MDD) for Sample A were 26.50 % and 1.325 Mg/m^3 respectively, while for Sample B the values were 19.80 % and 1.643 Mg/m^3 respectively; and the CBR values were 6.85 % and 11.36 %, respectively. With the addition of BLA: plasticity index generally reduced with the lowest values (4.89 % and 6.24 % for sample A and Sample B respectively) at 6 % BLA content; the CBR steadily increased until optimum values (10.23 % and 22.73 % for Sample A and Sample B respectively) were obtained at 4 % BLA content. The study concluded that: BLA could be used to improve the properties of lateritic soils for road construction purpose; and the particle size of BLA used does not diminish the quality of BLA as a soil-stabilising agent.*

KEYWORDS: Banana leaf ash, road construction, soil properties, stabilisation of soil, strength characteristics

INTRODUCTION

Several highways pavement in roads are failing partly due to lack of use of soil with adequate engineering strength. So the need for improvement of the engineering properties of soil has been a paramount concern to the highway engineers. The ability to blend the naturally abundant lateritic soil with some chemical reagents to give the soil better engineering properties in both strength and water-proofing has been of paramount importance to the transportation engineers (Amu *et al*., 2011).

Because of the need to improve the strength and durability of engineering soil, several works have been done on soil stabilisation. Researchers are using stabilising materials that can be sourced locally at a very low cost (Bello *et al*., 2015). Nnochiri and Aderinlewo (2016) investigated the geotechnical properties of lateritic soil stabilised with banana leaf ash (BLA). They stabised the tested soil with BLA at varying proportions of 2 %, 4 %, 6 %, 8 % and 10 % by weight of dry soil. They observed that the BLA enhanced the strength of the lateritic soil, with the optimum values of unsoaked California bearing ratio (CBR) and unconfined compressive strength (UCS) obtained at 4 % BLA content. They therefore concluded that BLA satisfactorily acted as cheap stabilising agent for subgrade purposes.
Olutaiwo and Lawal (2017) studied the effect of BL A on cement-modified lateritic soil. The tested soil was mixed with BLA in varying percentages of 2 %, 4 %, 6 %, 8 %, 10 %, and 12 %. Liquid limit, plastic limit, compaction, CBR and UCS tests were conducted on the stabilised soil sample. These tests were then repeated after the addition of 5 % cement to the varying proportions of BLA as earlier stated. Results showed increase in the plastic limit, liquid limit, plasticity index and optimum moisture content (OMC) as the BLA content increased. The values of maximum dry density (MDD), CBR and UCS increased up to 2 % BLA before decreasing steadily. They concluded that BLA is a weak pozzolan compared to cement.

In addition to existing studies on stabilisation of soils with BLA, researchers (Krishnan *et al*., 2019; Gobinath *et al.*, 2019) have also studied the stabilisation or reinforcement of soils with banana fibre ash and banana tree. They observed that both banana fibre ash and banana tree in soils contributed to improvement of engineering properties of such soils. Researchers have observed that BLA contains pozzolanic compounds (Table 1) that readily react with lateritic soil in a bid to improve the engineering performance of the soil.

Table 1: Composition of banana leaf ash Source: (Sakthivel *et al*., 2019)

Compound	Composition in BLA (%)
Silicon dioxide (SiO_2)	
Iron oxide (Fe_2O_3)	1.4
Aluminum oxide (Al_2O_3)	2.6
Sodium oxide (Na_2O)	0.21
Calcium oxide (CaO)	21.5
Magnesium oxide (MgO)	4.84
Sulphur trioxide (SO_3)	0.71
Potassium oxide (K_2O)	2.16
Loss on Ignition (LOI)	5.06 - 16.90

Daramola *et al.* (2021) investigated the geotechnical properties of soils treated with BLA. They studied the specific effects of BLA content passing British Standard (BS) sieve number 40 on the geotechnical properties of selected soils. After determining the geotechnical properties of the soils in their natural states, BLA was added to the soil samples in 2 %, 4 % and 6 % proportions by weight of dry soil. The geotechnical properties were then determined for the soils treated with BLA. They observed that addition of BLA improved the properties of the soils, with optimum properties obtained at 4 % BLA content. They concluded that BLA can cause significant improvement in the strength of lateritic soils.

Existing available study largely focused on the effects of the whole particle (size) content of BLA on geotechnical properties of soils for different engineering purposes. Daramola *et al* (2021) focused on the effects of BLA content passing BS sieve number 40. This study therefore investigated the specific effects of BLA content retained on BS sieve number 40 on properties of selected lateritic soils for road construction purpose.

MATERIALS AND METHODS

The materials, equipment and methods adopted in this study are discussed as followed.

Materials and Equipment

The materials used for this study were lateritic soil samples and banana leaves. The following equipment and tools were used: containers, set of BS sieves, sieve shaker, specific gravity bottle, Casagrande apparatus, plastic limit apparatus, drying oven, compaction apparatus and CBR apparatus.

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Methods

Soil sampling and preparation

Lateritic soil samples were collected from two identified borrow pits in Ile-Ife, Osun State, Southwest Nigeria. The first borrow pii is at Osu, near Ife-Ilesa Expressway and the GPS (Geographic Positioning System) description of the sampling point here (Sample A) is 7.34’29”E and 4.37’42”N. The second sampling point (Sample B) is at a borrow pit around Oduduwa University (OUI) near Ipetumodu, with GPS description 7.30’53”E and 4.27’57”N. Disturbed sampling method was adopted and samples were collected at the surface. About 25 kg of each sample was collected in cellophane bags, properly sealed, labelled and taken to the Geotechnical Engineering Laboratory of Obafemi Awolowo University (OAU), Ile-Ife for analysis. At the Laboratory representative samples were taken for natural moisture content determine, while the rest samples were air-dried for further analysis.

Preparation of banana leaf ash (BLA)

Banana leaves were sourced locally from identified banana plantation/farm. They were washed clean of all dirt, sun-dried and then taken to the Material Laboratory of the Department of Materials Science and Engineering, OAU, Ile-Ife and burnt inside the furnace at a temperature between 600^{o}C and 700^{o}C to produced banana leaf asb (BLA). The obtained BLA was sieved through BS sieve No. 40. The content retained was kept and properly sealed for use in the Geotechnical Laboratory.

Geotechnical evaluation of soil samples in their natural state

Using standard procedure as outlined in BS 1377 (1990), the following geotechnical tests were conducted on the soil samples in their natural state: natural moisture content determination, specific gravity, particle size analysis, Atterberg limits, compaction and California bearing ratio (CBR).

Determination of characteristics of soils treated with BLA

BLA was added to the soil samples in varying proportions (that is, 2 %, 4 % and 6 % by weight of dry soil). Atterberg limits and CBR tests were conducted on the treated soil samples.

RESULTS AND DISCUSSION

The results obtained from the analysis are presented and discussed below.

Geotechnical properties of soils in their natural state

Table 2 presents the results of geotechnical tests conducted on the soil samples in their natural state. According to Jackson and Dhir (1996), the void ratio of the lateritic soil samples is the predominant factor that affects the moisture content of the samples. The higher the void ratio of a soil, the higher its moisture content. Therefore, it is generally accepted that the lower the moisture content the better the soil. Sample A has a higher moisture content, hence, a higher void ratio.

Table 2: Results of geotechnical tests on soil samples in their natural state

Property	Sample A	Sample B
Natural moisture content (%)	26.70	14.83
Specific Gravity	2.71	2.75
Liquid Limit (%)	65.02	63.98
Plastic Limit (%)	42.10	37.38
Plasticity Index (%)	22.91	26.60
Percentage passing sieve No. 200 (fines)	46.63	50.18
Percentage passing sieve No. 40	80.31	62.87
AASHTO Classification	A-2-7	A-2-7
Optimum moisture content (%)	26.50	19.80
Maximum dry density (Mg/m^3)	1.325	1.643
California bearing ratio (%)	6.85	11.36

According to Lamber and Whiteman (1969), the specific gravity of most lateritic soil falls within the range of 2.65-2.85. Thus, the values of specific gravity obtained (see Table 2) indicate that the degree of laterisation is high in the tested soil samples. Das (2006) states that, a soil is said to be clayey soil if fine fractions (fractions passing through sieve No 40) have a plasticity index greater than or equal to 11. The results of the Atterberg limits tests (Table 2) therefore showed that the tested soil samples have relatively high clay content (plasticity index: 11< 22.91, 11< 26.60). The two soil samples were also found to belong to A-2-7 group, according to American Association of State Highway and Transport Officials (AASHTO) classification.

The values of the compaction characteristics (MDD and OMC) in Table 2 clearly indicate that, if the soil samples are subjected to the same compaction method on the field, Sample B would have the higher dry density.The CBR values (Table 2) show that Sample A could only be used as a subgrade material, while Sample B could be considered as a fair sub base material in road construction.

Effects of BLA on the properties of soil

Figures 1, 2 and 3 respectively show the variations of values of liquid limit, plastic limit and plasticity index of the soil samples with varying proportions of BLA. On the addition of 2 % BLA, the liquid limit (Figure 1) decreased from 65.02 % to 55.65 % for sample A, and from 63.98 % to 51.63 % for sample B. For sample A, there was an increase in liquid limit at 4 % BLA, but the highest value of liquid limit was still recorded at its natural state. It could be generally said that addition of BLA to the soil samples did not lead to increase in the values of liquid limit.

As shown in Figure 2, the plastic limit slightly decreased from 42.11 % to 40.14 % for sample A, and from 37.38 % to 32.60 % for sample B on the addition of 2 % BLA. Overall, for Sample A, the highest value of plastic limit was obtained at 4 % BLA content; while for Samp;e B, the highest values of plastic limit was obtained at 6 % BLA content. Figure 3 shows that addition of BLA generally led to reduction in the values of plasticity index. This indicates an improvement in the soil samples, since lower plasticity implies better soil (Das, 2006). For Sample A, the lowest value of plasticity index was obtained at 6 % BLA content; while for sample B, the lowest value of plasticity index was obtained at 4 % BLA content.

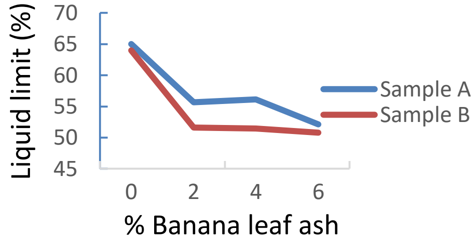

Figure 1: Variation of liquid limit with BLA

Figure 4 presents the variation of CBR values with varying proportions of BLA content. For Sample A, CBR values increased with the increase in BLA content until it got to the maximum at 4 % BLA content, after which it dropped. For Sample B, there was increase in CBR up to 4 % BLA, after which it dropped. It could therefore be said that, 4 % BLA content had maximum/optimum effect on the soil samples. This observation is also in agreement with some previous studies (Nnochiri and Aderinlewo, 2016; Daramola *et al.*, 2021).

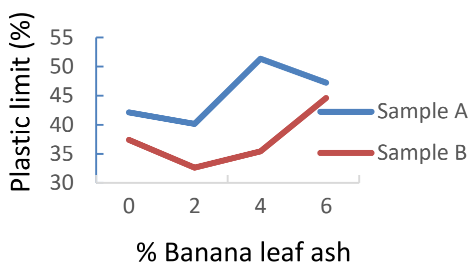

Figure 2: Variation of plastic limit with BLA

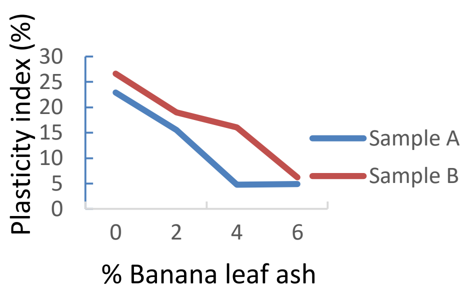

Figure 3: Variation of plasticity index with BLA

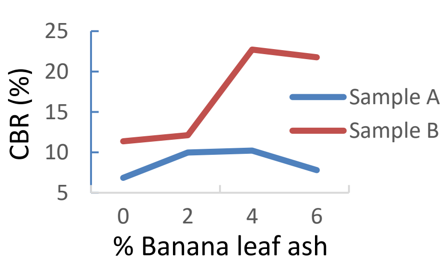

Figure 4: Variation of CBR with BLA

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CONCLUSION

The effects of banana leaf ash (content retained on BS sieve No. 40) on lateritic soils have been investigated, for the purpose of road construction. The tested soil samples were found to be poor to fair subgrade materials. The addition of BLA generally led to: reduction in the liquid limit of the soil samples; increase in the plastic limit; decrease in the plasticity index; and increase in the CBR. In other words, addition of BLA to the soil samples led to improvement in the properties of the soils, with optimum properties obtained at 4 % BLA content. Therefore, BLA could be used to stabilse the soils for the purpose of road construction. Comparing the outcome of this study with similar previous study, it is evident that the size of BLA particles used for soil stabilisation does not affect the performance of BLA as a soil soil-stabilising agent.

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