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Effect of Banana Leaf Ash on Cement - Modified Lateritic Soil

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***Abstract*— Preliminary investigation on laterite soil sample collected from old Julius Berger borrow pit in Ejio area of Arigbajo in Ifo Local Government Area, Ogun State (6.849˚N, 3.211˚E), classified the soil as A-2-7(4) [AASHTO classification]. The soil was mixed with Banana Leaf Ash (BLA) in varying percentages of 0%, 2%, 4%, 6%, 8%, 10%, and 12% and the effect of BLA on the soil sample was determined for Liquid Limit, Plastic Limit, Compaction (MDD % OMC), CBR and Unconfined Compression Test. These tests were repeated for the soil sample + BLA + cement. The results of the treated soil 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), California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) increased up to 2% BLA before starting to decrease steadily. This implies that the Banana Leaf Ash (BLA) is a weak pozzolan.**

***Index Terms*— Laterite; Banana Leaf Ash (BLA); Stabilization; California Bearing Ratio (CBR); Unconfined Compressive Strength (UCS)**

I. INTRODUCTION

Most common materials used for construction are lateritic soils because they occur naturally with intense weathering (in the tropics). They are found in the tropical environment, where there is an intense chemical weathering and leaching of soluble minerals. Laterites are reddish brown well graded and sometimes extend to depth of several tens of metres. Laterite is soil layer that is rich in iron oxide and derived from a wide variety of rocks weathering under strongly oxidizing and leaching conditions. It forms in tropical and subtropical regions where the climate is humid. Lateritic soils may contain clay minerals; but they tend to be silica-poor, for silica is leached out by waters passing through the soil. Typical laterite is porous and claylike. It contains the iron oxide minerals goethite, $HFeO_2$; lepidocrocite, FeO(OH); and hematite, Fe_2O_3. It also contains titanium oxides and hydrated oxides of aluminum, the most common and abundant of which is gibbsite, $Al_2O_3 \cdot 3H_2O$. The aluminum-rich representative of laterite is bauxite [Matawal & Tomarin, 1996].

Several highways pavement in Nigeria roads are failing 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 reagent to give it better engineering properties in both strength and waterproofing has been of paramount importance to the transportation engineers [Amu, et.al. 2011]. In a bid to improve the engineering properties of soil to make it suitable for road construction, several researches on soils stabilization have been carried out. Banana leaf is a major by product before and after harvest of banana.

Nigeria is one of the largest banana and Plantain growing countries in Africa. Nigeria produces 6.32 million tonnes of banana annually [NHRIFAO, 2011]. It is also the largest plantain producing country in West Africa, making the crop one of the important staples in the country. The main Banana and Plantain growing regions in Nigeria are found in the South and Central regions of Nigeria. The largest quantities are produced in Edo, Ondo, Delta, and Ogun States. Other producing states are Rivers, Cross River, Oyo, Akwa Ibom, Ebonyi, Ekiti, Imo, Plateau, Osun, Bayelsa, Kogi, Abia, Anambra and Enugu. Plantain cultivation is not limited to big plantations but is often grown in small orchards which sometimes go unnoticed.

II. LOCATION OF STUDY AREA

The disturbed soil samples used for this study were collected at the old Julius Berger borrow pit in Ejio area of Arigbajo in Ifo Local Government Area, Ogun State (6.849˚N, 3.211˚E), along the Lagos – Abeokuta Expressway. The top soil was taken at a depth of about 3m, sealed in plastic bags and put in sack to avoid loss of moisture during transportation.

III. MATERIALS AND METHODS

Banana leaf ash

The Banana Leaf Ash (BLA) used for this study was obtained locally from the burning of dry banana leaves sourced from different banana plantation farms around Ifo town in Ogun State. The leaves were completely burnt under atmospheric condition, sealed up in plastic bags and transported to the laboratory. The ash was then passed through British Standard 75-micron sieve and kept to be mixed with the ‘soil-cement’ in the appropriate percentages.

Laterite soil

Lateritic soils as a group, rather than well-defined materials, are most commonly found in leached soils of humid tropics. Laterite is a surface formation in hot and wet tropical areas which is enriched in iron and aluminum and develops by intensive and long lasting weathering of the underlying parent rock [Gidigasu, 1976]. In order to fully appreciate the usefulness of lateritic soil, its problems (in both field and laboratory) would have to be identified and useful solutions applied.

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IV. Methods of Testing

Soil Tests

The laboratory tests carried out in pursuit of the objectives of this study were particle size distribution, Atterberg Limits, Compaction Characteristics, CBR and the Unconfined Compression Strength. Two controls were established for this study: the soil sample without any binder, and the soil sample with 5% Ordinary Portland Cement – an established soil stabilizing agent. These provided a framework within which to observe and compare the relative behaviour soil-BLA and soil-BLA-cement samples subjected to the same tests under similar conditions. All tests were carried out in accordance with the standard procedures of BS 1377: 2000 [BS 1377, 1990].

V. Results and Discussion

Classification of Sample Soil

The geotechnical index properties of the laterite before addition of stabilizers are shown in Table 1. The particle size distribution of the natural soil is shown in Figure1.

Table 1. Properties of the Natural Soil before Stabilization

Summary of Preliminary Tests on Soil Sample	
NATURAL MOISTURE CONTENT (%)	14.80
SPECIFIC GRAVITY	2.45
LIQUID LIMIT (%)	45
PLASTIC LIMIT (%)	15
PLASTICITY INDEX (%)	30
MAXIMUM DRY DENSITY (g/cm^3)	1.415
OPTIMUM MOISTURE CONTENT (%)	17.0
UNSOAKED CBR (%)	23
SOAKED CBR (%)	18
UNCONFINED COMPRESSIVE STRENGTH (MN/m^2)	141
AASHTO CLASSIFICATION	A-2-7(4)
COLOUR	REDDISH-BROWN

The overall geotechnical properties of the soil classified as A-2-7(4) in the AASHTO classification system, shows that it falls below the standards recommended for most geotechnical construction works and would therefore require stabilization [AASHTO, 1986].

Chemical analysis of Banana Leaf Ash

Chemical analysis of Banana Leaf Ash passing the 75-micron sieve was carried out at the analytical laboratory of Lafarge-WAPCO Cement Factory in Ewekoro, Ogun State Nigeria by the X-Ray Flourescence (XRF) technique using the Thermo Fisher Model ARL 9900. The result is presented in Table 2.

The oxide composition of the BLA is shown in Table 2. The combined percent composition of silica, Al_2O_3 and Fe_20_3 is less than 70. This shows that it is a weak pozzolana [Osula, 1991].

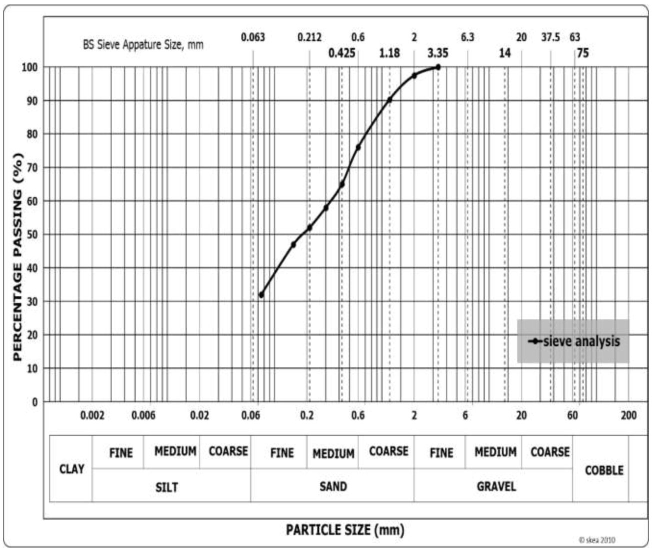

Figure 1: Particle Size Distribution for the Natural soil

Table 2. Oxide composition of BLA

S/N	Compound	Composition (%)
1	SiO_2	47.24
2	Fe_2O_3	0.85
3	Al_2O_2	2.71
4	CaO	21.50
5	MgO	4.84
6	SO_3	0.71
7	K_2O	2.16
8	Na_2O	0.00
9	LOI	16.90

Effect of Treatment of Soil Sample with BLA (2% - 12%) and 5% Cement

Compaction Test

The summary of compaction test results is shown in Figures 2 and 3.

The optimum moisture content of the soil sample was 17.0% with a Maximum Dry Density (MDD) of 1.415 g/cm^3.

In the soil sample + BLA, the addition of BLA at 2% - 12% resulted in increase of the OMC of the soil and a corresponding decrease in the MDD.

For Soil + BLA + 5% Cement, the increase in OMC was due to the addition BLA + Cement, which decreased the quantity of free silt and clay fraction and coarser material with larger surface areas were formed (these processes need water to take place). This implies that, apart from the water needed by the soil, more water was needed in order to compact the soil – BLA mixtures.

The initial decrease in the MDD can be attributed to the replacement of soil by the BLA-cement which has relatively lower specific gravity compared to the soil. It may also be attributed to coating of the soil by the BLA which result to large particles with larger voids and hence less density [Ola (1977) and Osula (1991)].

The increase in MDD with cement content is attributed to the relative higher specific gravity of cement (3.15) to that of the soil (2.45) [Osinubi, 1997].
The increase in OMC with cement content was as a result of water needed for the hydration of cement [Osinubi, 1999].

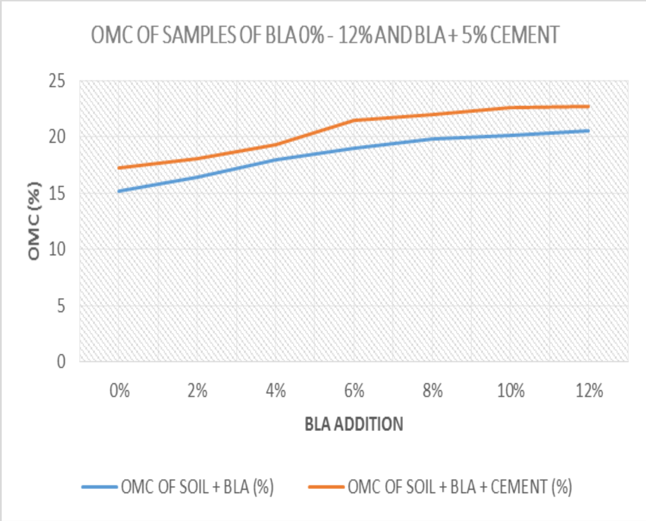

Figure 2: Results of OMC for Soil + BLA and Soil + BLA + 5%Cement

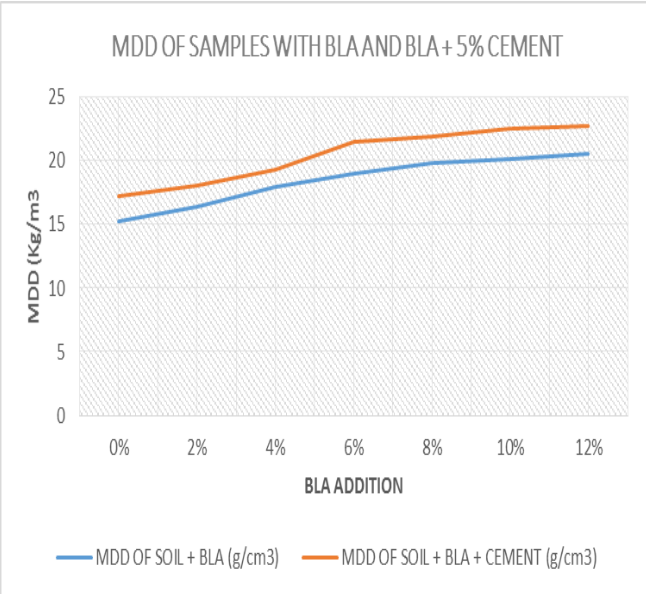

Figure 3: Results of MDD for Soil + BLA and Soil + BLA + 5%Cement

California Bearing Ratio

The CBR results with increase in BLA from 0 to 12% only and then with 5% OPC, are shown in Figures 4 and 5.
Addition of cement and BLA to the soil showed marked improvement in the CBR compared to the CBR value of 23% (unsoaked) and 18% (soaked) recorded for the natural soil. The soaked CBR values of the BLA cement modified soil increased from 18% for the natural soil to 145% for 2% BLA before it started to decline to 106% for 12% BLA. This is probably due to the increase in BLA content in the sample; during curing. Rather than increasing in strength, it absorbed and retained water, which led to decrease in strength.
The unsoaked CBR values of the BLA cement-stabilized soil increased from 23% for the natural soil to 85% for 2% BLA before it started to decline steadily to 14% for 12% BLA. The improvement up to 2% BLA + 5% cement resulted from the secondary cementitious materials as a result from the reaction between the lime liberated from the hydration reaction of cement and the pozzolanic BLA [Mustapha, 2005].
The minimum requirements by FMW&H for CBR sub-grade, sub-base and base course are 10%, 30% and 80% (untreated soil) [NGS, 1997] indicating the BLA-stabilized lateritic soil will be most suitable mostly for sub-grade and filling.

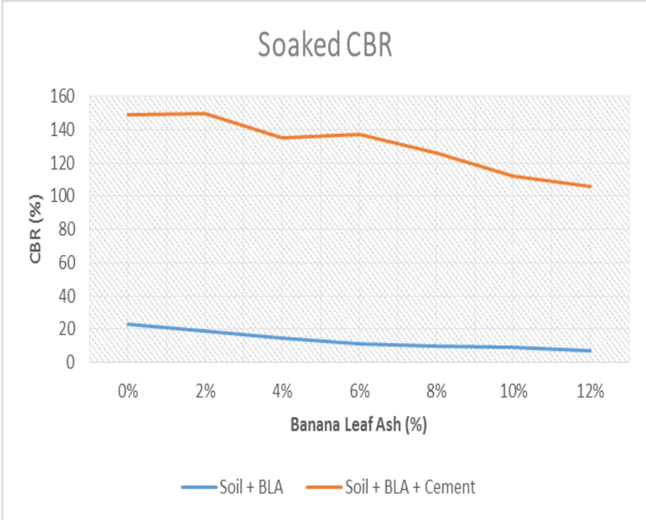

Figure 4: Results of Soaked CBR

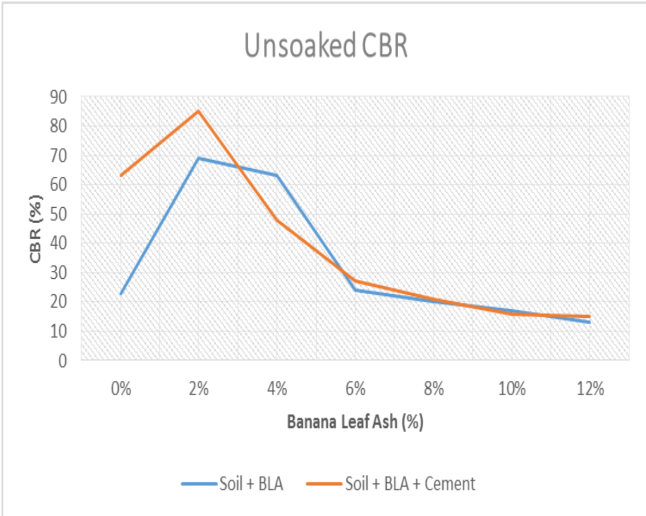

Figure 5: Results of Unsoaked CBR

Unconfined Compressive Strength

Unconfined compressive strength (UCS) has been the most common and adaptable method of evaluating the strength of stabilized soil. It is the main test recommended for the determination of the required amount of additive to be used in stabilization of soil [Singh, 1991]. Variation of UCS with increase in BLA from 0% to 12% with 5% cement contents for 7 days curing period were studied and the results are shown in Figure 6. There was some improvement in the UCS (with addition of 5% cement and 2% BLA) compared to the UCS value of 141KN/m^2 for the natural soil but thereafter, the values started decreasing steadily with increase in the BLA content.
Further addition of BLA above 2% seems to inhibit the hydration process of cement which may be responsible for the decrease in the value of UCS above 2% BLA.

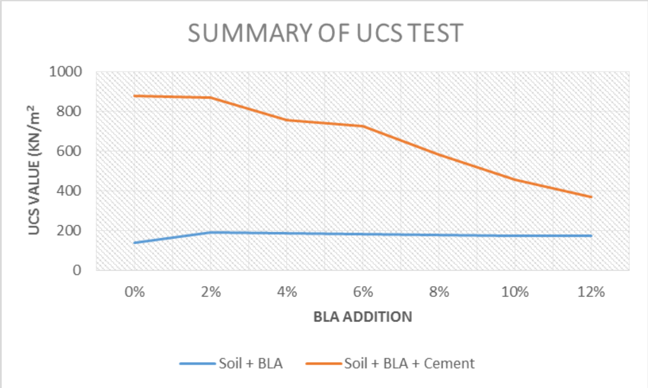

Figure 6: UCS Results of Soil Sample (with BLA and 5% Cement) at 7 days Curing

VI. CONCLUSIONS

From the results of the investigation carried out within the scope of the study, the following conclusions can be drawn:

i. The laterite was identified to be an A-2-7(4) soil based on AASHTO (1986) classification system.

ii. There was improvement in the CBR with 5% cement addition compared with the CBR of the natural soil. There was slight increase in CBR with addition of BLA to 2% maximum compared with the CBR of 5% cement.

iii. There was increase in UCS with 5% cement addition compared with the UCS of the natural soil. There was slight increase in UCS over that of the natural soil though the value increased up to 2% BLA before it started to decrease.

iv. BLA may not be used as an alternative replacement or as a partial replacement of cement.

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