View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by FUOYE Journal of Engineering and Technology (FUOYEJET - Federal University...



# Geotechnical Properties of Lateritic Soil Stabilized with Banana Leaves Ash

*Emeka Segun Nnochiri and Olufikayo .O. Aderinlewo

Department of Civil and Environmental Engineering, Federal University of Technology, Akure, Nigeria

**segunemeka@yahoo.com**

**Abstract**— This paper investigated the geotechnical properties of lateritic soil stabilized with banana leaves ash. The natural soil sample was gotten from the Federal University of Technology, Akure (FUTA), Nigeria, and were subjected to preliminary soil tests such as natural moisture content, specific gravity and atterberg limit at its natural state. Engineering tests such as compaction, california bearing ratio and unconfined compressive strength tests were also carried out on the lateritic soil at their natural states and at when the banana leaves ashes were added to the soil at varying proportions of 2, 4, 6, 8 and 10% by weight of soil. The result of the strength tests showed that the banana leaves ash enhanced the strength of the lateritic soil. The unsoaked CBR value of the soil at its natural state was 10.42 % and it got to optimum value of 28.10% by addition of 4% banana leaves ash by weight of soil. The unconfined compressive strength improved from 209.18 kN/m$^2$ at natural state to 233.77 kN/m$^2$ at 4% banana leaves ashes. It was therefore concluded that the banana leaves ash satisfactorily act as cheap stabilizing agents for subgrade purposes.

**Keywords**—banana leaves ash, geotechnical properties, lateritic soil, stabilization

## 1 INTRODUCTION

There are many definitions of laterites, of note to this study is as defined by (Ola, 1983), where laterites was defined as the products of the 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. According to Maignien (1966) and Gidigasu (1976), three major stages are involved in the process of laterization, they are as follows: the first stage, which is the decomposition. It is characterized by the physico-chemical breakdown of primary minerals and the release of constituent elements. The second stage involves leaching, under appropriate condition of combined silica and bases and the relative accumulation or enrichment from outside sources (absolute accumulation) of oxides and hydroxides of sesquioxides (mainly $Al_2O_3$ and $Fe_2O_3$, the most resistant component to leaching). The third stage is the hydration or dessication which involves partial or complete dehydration (some involving hardening) of the sesquioxide-rich materials and secondary minerals.

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 content of clay. When lateritic soil contains a large amount of clay materials its stability and strength and stability cannot be guaranteed under load in presence of moisture (Alhassan, 2008), lateritic soil consists of high plastic clay, the plasticity of the soil may result to cracks and damage on pavement, roadways, building foundations or any civil engineering construction projects. The improvement in strength and durability of lateritic soil in recent times has become imperative, this has geared researchers towards using stabilizing materials that can be sourced locally at a very low cost (Bello *et al.*, 2015). Where in most cases sourcing for alternative soil may prove economically unwise, to improve the soil by way of stabilizing available soil to meet the desired objective becomes a viable option (Mustapha, 2005; Osinubi, 1999).

*Corresponding Author

### 1.1 Stabilization

According to Oyediran and Kalejaye, (2011), Stabilization was defined as a means by which Soil properties are improved and made more suitable for construction purpose, which can be mechanical, chemical and sometimes biological. Ogunribido (2011) affirmed that local materials identified for use in stabilization can be classified as either agricultural or industrial wastes. 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.

### 1.2 Reasons for finding alternatives to cement

Aribisala (1989) deduced the following are the reasons for finding alternatives to cement: high cost of production, high energy demand and emission of $CO_2$ (responsible for global warming). In third world countries, the most common and readily that can partially replace cement without economic implications are bio-based materials and agro-based wastes, notable ones are Achawok ash, Bambara groundnut shell ash, bone powder ash, banana leaves ash, groundnut husk ash, rice husk ash and wood ash, bamboo leaves ash, some timber species and periwinkle shell ash. Banana leaves ash as used in this study has shown promises of pozzolanic materials in its chemical composition. Through research the locally sourced materials are fast gaining prominence because the over dependent on the utilization of industrially manufactured soil improving additives -cement, lime etc have kept the cost of construction of stabilized road financially high (Ogunribido, 2011). There are three purposes for soil stabilization, which includes; strength improvement, dust control and soil water proofing (Amu and Adetuberu, 2010).

### 1.3 Location of the study Area

According to Ademeso and Alabi, (2011) , the study area, Akure lies within longitudes $5^0$ 00'E and $5^0$ 17'E and latitudes $7^0$ 10' N and $7^0$20' N in the Southwestern part of Nigeria.

### 1.4 Aim of Study

This study examines the geotechnical properties of lateritic soil stabilized with ashes of banana leaves.

## 2 MATERIALS AND METHODS

Fresh banana leaves were collected from the abandoned farmland of the phase II of the Federal University, OyeEkiti. The fresh banana leaves were cut and dried in the sun to facilitate easy burning. The dried leaves were burnt to ashes and were thereafter collected in polythene bags, to ensure that the ash is prevented from moisture and contaminations from other materials and stored under room temperature until it was used. Furthermore, the ashes from the burnt leaves were sieved through BS Sieve 75 μm to get the very fine ash. The disturbed lateritic soil samples were collected within the campus of the Federal University of Technology, Akure (FUTA).

The lateritic soil was collected at depth representative of the soil stratum and not less than 1.2m below the natural ground level. It was later 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 air-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 samples were pulverised under minimal pressure. The ordinary portland cement was also used as basis for comparison of results of strength with the ashes of banana leaves. Each of the two additives was separately mixed with lateritic soil.

The preliminary tests such as the particle size distribution test, atterberg limit test and specific gravity tests as well as engineering tests such as; Compaction test, Unconfined Compressive Strength tests and California Bearing Ratio test were carried out on the unstabilized natural soil samples. Also, engineering tests such as Compaction (Maximum Dry Density and Optimum Moisture Content), Unconfined compressive strength tests and the California Bearing Ratio tests were carried out on the stabilized samples, using two separate additives, which were the ordinary portland cement on one hand and the banana leaves ash, on the other, both, at varying proportions of 2, 4, 6, 8 and 10% by weight of the soil.

## 3 RESULTS AND DISCUSSION

The results from the preliminary test such as natural moisture content, specific gravity, particle size analysis, atterberg limits and plasticity index before the addition of ashes of banana leaves are presented in Table 1.

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) | Silt-Clay (SC) |

The chemical composition of the ashes of the banana leaves is presented in Table 2, while the chemical composition of the ordinary portland cement is presented in Table 3. The engineering property tests are presented in Table 4.

Table 2.Chemical Composition of the ashes of the banana leaves

| Elemental Oxides | Weight % |
|---|---|
| CaO | 21.30 |
| MgO | 0.96 |
| K2O | 1.91 |
| SO2 | 1.32 |
| SiO2 | 48.70 |
| Na2O | 0.21 |
| Al2O3 | 2.60 |
| Fe2O3 | 3.40 |
| ZnO | 0.82 |

Table 3.Chemical Composition of Ordinary Portland Cement

| Elemental Oxides | Weight(%) |
|---|---|
| SiO2 | 20.05 |
| Al2O3 | 6.47 |
| Fe2O3 | 2.79 |
| CaO | 60.83 |
| MgO | 3.02 |
| K2O | 0.51 |
| Na2O | 0.48 |
| SO3 | 0.35 |
| TiO2 | 0.38 |
| LOI | 1.51 |

Table 4.Engineering Property tests for lateritic soil stabilized with banana leaves Ashes

| Banana leaves ash | OMC (%) | MDD (Kg/m³) | CBR (%) | Unconfirmed compressive strength (kN/m²) | Shear strength (kN/m²) |
|---|---|---|---|---|---|
| 0 | 10.7 | 1940 | 10.42 | 209.18 | 104.54 |
| 2 | 10.9 | 1935 | 11.42 | 220.18 | 111.22 |
| 4 | 11.8 | 1931 | 28.10 | 233.77 | 116.89 |
| 6 | 13.0 | 1928 | 12.78 | 201.90 | 100.95 |
| 8 | 13.8 | 1924 | 3.76 | 170.48 | 86.02 |
| 10 | 14.8 | 1906 | 6.26 | 191.56 | 95.78 |

Table 5. Engineering property for lateritic soil stabilized with ordinary portland cement

| Banana leaves ash | OMC (%) | MDD (Kg/m³) | CBR (%) | Unconfirmed compressive strength (kN/m²) | Shear strength (kN/m²) |
|---|---|---|---|---|---|
| 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 |

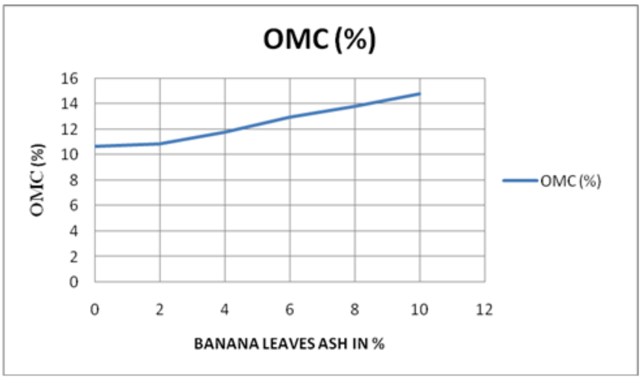


Fig. 1.Effects of the addition of BLA on the OMC of Samples

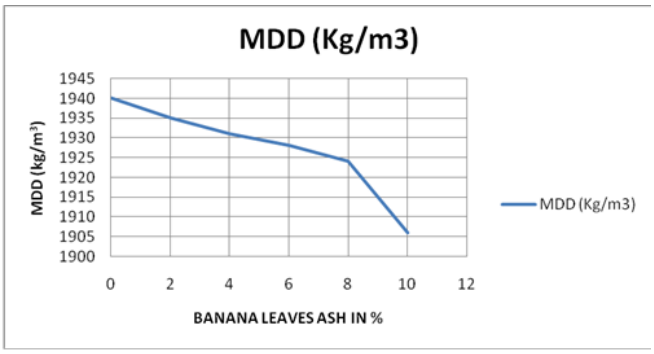


Fig. 2.Effects of the addition of BLA on the MDD of Samples

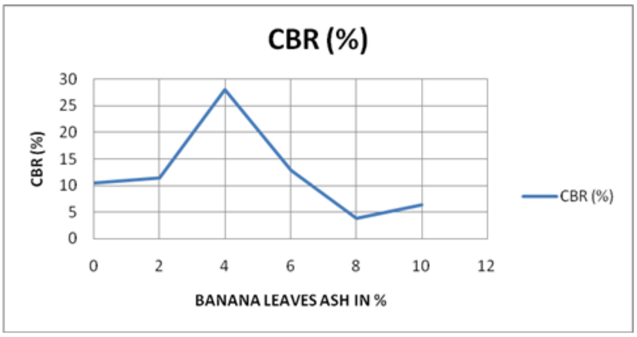


Fig. 3.Effects of the addition of BLA on the CBR of Samples

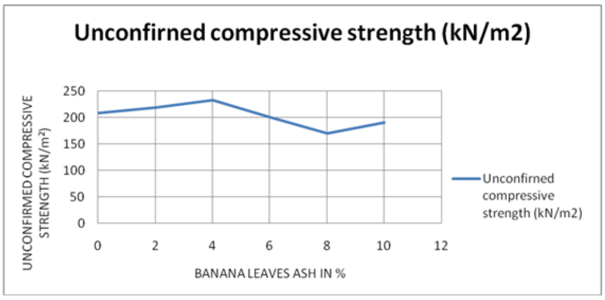


Fig. 4.Effects of the addition of BLA on the UCS of Samples

## 3.1 Compaction

The variation of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) with banana leaves ashes stabilizer at 2, 4, 6, 8 and 10% by weight of soil indicates that values of MDD decreased as values of OMC increased accordingly. The MDD reduced from 1940 to 1906 Kg/ m³, while the OMC increased from to 10.7% to 14.8 %. The observed decrease in MDD values can be attributed to mixture of the soil and banana leaves ash which has lower specific gravity compared to the soil.

The observed decrease in MDD may also be explained by considering the banana leaves ash as filler in the soil voids (Fatah *et al*., 2013). Increase in OMC values implies that more water is needed to compact the soil (Ogunribido, 2011). For the Ordinary Portland Cement; the increase in MDD from 1940 to 2070 Kg/m³ may be due to a decrease in the surface area of the clay fraction of the lateritic soil arising from the substitution of lateritic soil with cement (Joel and Joseph, 2015). According to Amu *et al*.,( 2011), increase in MDD values with increase in percentage of cement being added to lateritic soil indicates improvement in Soil properties. While increase in OMC values from 10. 7% to 15.6% implies that more water is needed to compact the soil (Joel and Joseph, 2015).

### 3.2 California Bearing Ratio

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 (Ogunribido, 2011). For the banana leaves ash, the CBR rose progressively at 0% value of 10.42% to 28.01% at 4% value. It reduced to 12.78% and 3.76% at 6% and 8% respectively. Decrease in the CBR values may be due to the excess banana leaves ash which was not mobilized in the reaction as the presence of naturally occurring Calcium hydroxide in the soil may be small. The excess banana leaves ash occupies space within the specimen and reduces the clay and silt content in soil and hence, reduces the bond/cohesion in the soil-banana leaves ash, (Adhikary and Jana, 2016).

According to Okafor and Okonkwo (2009), increase in values of CBR may be because of the gradual formation of cementitious compounds in the reaction between banana leaves ash and some amounts of Calcium hydroxide present in the soil. At 10%, it further rose to 6.26%. The optimum value is therefore at 4% of weight of soil. For the ordinary portland cement, the CBR rose from 10.42% at 0% to 87.32% at 6% value of weight of soil. It dropped to 78.91% and later rose to 80.41% at values of 8% and 10% respectively. According to (Joel and Joseph, 2015), increase in CBR with cement can be attributed to the hydration reaction of cement. The entire CBR values are unsoaked.

### 3.3 Consistency Limits

Consistency limits is an indicator of clay behaviour (Ogunribido, 2011). According to the Federal Ministry of Works and Housing (1997), it was specified that the maximum liquid limits of soil for subgrade should not exceed 40%, the liquid limits for the natural lateritic soil used in this study exceeded the stated 40% value. Hence, the need for stabilization.

## 4 CONCLUSION

This analysis of the geotechnical properties of lateritic soils using ashes of banana leaves as stabilizers while also using ordinary portland cement as the basis for comparison has been carried out in compliance with BSI (1990) and Head(1992). The study has revealed that banana leaves ash satisfactorily act as cheap stabilizing agents for subgrade purposes.

Optimum CBR results can be achieved by adding 4 % banana leaves ashes by weight of soil to the natural soil sample. Strength of lateritic soil stabilized with ashes of banana leaves increased. Cement still ranks higher above the banana leaves ash used in the study for improving the CBR of the lateritic soil.

## REFERENCES

Ademeso, O. A. and Alabi, K. (2011): "Geochemical Characteristics of the Charnockitic and Associated Granitic Rock, Akure Area, Southwestern Nigeria", *Nature and Science*, 9 (8).

Adhikary, S. and Jana, K. (2016): Potentials of Rice Husk Ash as a Soil Stabilizer. International Journal of Latest Research in Engineering and Technology, Vol. 2, Issue 2, February, 2016. Pp 40-48.

Alhassan, M. (2008): "Potential of Rice Husk Ash for Soil Stabilization," *AUJ.T.*, 2008; 71 (4): 246-250.

Amu, O. O. and Adetuberu, A. A. (2010): "Characteristics of Bamboo Leaf Ash Stabilization on Lateritic Soil in Highway Construction," *International Journal of Engineering and Technology*, Vol.2(4).

Amu, O. O., Ogunniyi, S. A. and Oladeji, O. O. (2011): "Geotechnical Properties of Lateritic Soil Stabilized with Sugarcane Straw Ash," *American Journal of Scientific and Industrial Research.*

Aribisala, O. A (1989): *"Sourcing of Local Raw materials and Investment Opportunity in Building/ Construction Industrial Sector,"* Published ATTCON Proceedings of the National Workshop, pp. 23-37.

Bello, A. A., Ige, J.A. and Hammed, A. (2015): "Stabilization of Lateritic Soil with Cassava Peels Ash," *British Journal of Applied Science and Technology* 7(6): 642-650.

British Standard Institution (1990): "Methods of Test for Soils for Civil Engineering Properties (1377)," *British Standard Institution*: London, UK.143

Federal Ministry of Works and Housing (1997): *General Specification for Roads and Bridges, Volume II, Federal Highway Department*, FMWH, Lagos, Nigeria.

Gidigasu, M.D.(1976): "Lateritic Soil Engineering: Pedogenesis and Engineering Principles; Developments in Geotechnical Engineering," *Elsevier scientific Publishing Company*, Armsterdam, pp. 554.

Head, K. H. (1992) : "Manual of Soil Laboratory Testing," *Soil Specification and Compaction Tests*, *2nd Edition*. Vol. 1; Pentech Press, London, UK.

Joel, M. and Joseph, E. E.(2015): "Comparative Analysis of Cement and Lime Modification of Ikpayongo Laterites for Effective and Economic Stabilization," *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)* 6 (1): 49: 56.

Maignien, R (1966): "Review of Research of Laterites," *Natural Resources Research IV*, United Nations Educational Scientific and Cultural Organisation, Paris, pp. 148

Mustapha, M. A. (2005): *"Effect of Bagasse Ash on Cement Stabilized Laterites,"* Seminar Paper presented at the department of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria.

Ogunribido, T.H.T. (2011): "Potentials of Sugar Straw Ash for Lateritic Soil Stabilization in Road Construction," *International Journal of Science Emerging Technologies*, Vol-3, No 5.

Okafor, O. F. and Okonkwo, U. N. (2009): Effects of Rice Husk Ash on some Geotechnical Properties of Lateritic Soil. *Leonardo Electronic Journal of Practices and Technologies.*

Ola, S.A. (1983): "Geotechnical Properties and Behaviour of some Nigerian Lateritic Soils". *Tropical Soils of Nigeria in Engineering Practice*. A.A. Balkema/Rotterdam.

Osinubi, K.J. (1999): *"Evaluation of Admixture Stabilization of* Nigeria *Black Cotton Soil*," Nigerian Society of Engineers Technical Transaction, 34(3), 88-96.

Oyediran, A.I and Kalejaye, M.(2011): "Effect of Increasing Cement Content on Strength and Compaction Parameters of some Lateritic Soil from Southwestern Nigeria," *EJGE* Vol. 16.