



## Experimental Study on the Geotechnical Properties of Soils Treated with Banana Leaf Ash

T. S. Daramola, E. O. Olaniregun, G. O. Adunoye

Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria  
 Email: [kayadunoye@yahoo.com](mailto:kayadunoye@yahoo.com); Telephone: +2348033579586

**Abstract:** There is an increasing need to improve the engineering properties of soils using locally available and economical materials. This work therefore studied the effect of banana leaf ash (BLA) on the geotechnical properties of selected lateritic soils. To achieve the aim of this study, lateritic soil samples were collected from identified locations in Ile-Ife, Osun State, Nigeria. In their natural states, the soil samples were subjected to the following laboratory tests, using standard procedures: natural moisture content, specific gravity, grain size analysis, Atterberg limits, compaction and California bearing ratio (CBR). The BLA was added to the soil samples in 2 %, 4 % and 6 % proportions by weight of soil; and the geotechnical properties were also determined for the soils with BLA. Results showed that addition of BLA improved the properties of the soils, that is, with the addition of BLA, reduction was generally noticed in the values of plasticity index for both soils. The optimum values of CBR were 39 % (sample A) and 30 % (sample B), which were obtained at 4 % BLA for the two samples. The study concluded that BLA can cause significant improvement in the strength of lateritic soils.

[Daramola, T. S., Olaniregun, E. O., Adunoye, G. O. **Experimental Study on the Geotechnical Properties of Soils Treated with Banana Leaf Ash**. *N Y Sci J* 2021;14(1):32-37]. ISSN 1554-0200 (print); ISSN 2375-723X (online). <http://www.sciencepub.net/newyork>. 6. doi: [10.7537/marsnys140121.06](https://doi.org/10.7537/marsnys140121.06).

**Keywords:** Ash, banana leaf, geotechnical properties, soil strength, strength improvement

### 1. Introduction

Soil stabilization is the alteration of soils to enhance their physical properties. It can increase the shear strength of a soil and/or control the shrink-swell properties of the soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. In other words, soil stabilization is a general term for any physical, chemical, biological or combined method of changing a natural soil to meet an engineering purpose. In civil engineering construction, 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). The laterite and lateritic soils can be effectively stabilized to improve their properties for particular uses. Literature has shown that some soil stabilizing agents that have been used successfully include: cement, asphalt/bitumen and lime. Mechanical stabilization is also often utilized.

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 and at a very low cost (Bello *et al.*, 2015). Therefore alternatives (stabilizing materials) are used in geotechnical engineering for soil stabilization, that is, they may be

used to influence the geotechnical properties of soil. One of such alternatives is banana leaf ash.

Banana leaf ash (BLA) is an agricultural waste. BLA, though may be a weak pozzolan, contains pozzolanic compounds that readily react with lateritic soil in a bid to improve the engineering performance of the soil (Sakthivel *et al.*, 2019). The chemical composition of typical BLA is shown in Table 1.

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

Compound	Composition in BLA (%)
Silicon dioxide (SiO <sub>2</sub> )	48.7
Iron oxide (Fe <sub>2</sub> O <sub>3</sub> )	1.4
Aluminum oxide (Al <sub>2</sub> O <sub>3</sub> )	2.6
Sodium oxide (Na <sub>2</sub> O)	0.21
Calcium oxide (CaO)	21.5
Magnesium oxide (MgO)	4.84
Sulphur trioxide (SO <sub>3</sub> )	0.71
Potassium oxide (K <sub>2</sub> O)	2.16
Loss on Ignition (LOI)	5.06 - 16.90

Nnochiri and Aderinlewo (2016) investigated the geotechnical properties of lateritic soil stabilized with BLA. After determining the natural properties of the soil, they added the BLA to the soil at varying proportions of 2 %, 4 %, 6 %, 8 % and 10 % by

weight of soil. They observed that the BLA enhanced the strength of the lateritic soil; and therefore concluded that the BLA satisfactorily acts as a cheap stabilizing agent for subgrade purposes.

Olutaiwo and Olusola (2017) studied the effect of BLA on cement-modified lateritic soil. After determining the geotechnical properties of soil stabilized with BLA and also stabilized with BLA and cement combined, they observed that there was improvement in soil properties with increase in BLA proportion. They also observed that the maximum values of maximum dry density (MDD), California bearing ratio (CBR) and unconfined compressive strength (UCS) were obtained at optimum 2 % proportion of BLA. However, in comparison with cement, they concluded that BLA was a weak pozzolan.

Krishnan *et al.* (2019) studied the stabilization of black cotton soil using banana tree ash. They observed that the (CBR) value increased with increasing percentage of banana tree ash up to an optimum percentage i.e. 20%; and that the basic and strength tests conducted showed significant improvement in the properties of the soil after the addition of banana tree ash.

Gobinath *et al.* (2019) studied the effects of reinforcing a sodium silicate stabilized soil with banana fibre. They observed that the strength of the soil increased with increase in banana fibre, with the highest strength obtained at optimum 0.5 % of banana fibre. They concluded that banana fibre-reinforcement of the sodium silicate stabilized sandy soils made the soil become suitable for road pavement application as sub-base material.

Several highway 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 the soil better engineering properties in both strength and water-proofing has been of paramount importance to the transportation engineers (Amu *et al.*, 2011).

The deplorable state of Nigeria's economy has brought about inflation. Therefore the use of stabilizing agents like cement (lime), fly ash and so on has become more expensive, thus making it necessary to find a good and affordable replacement for the stabilizing agents. Therefore, the use of BLA provides a cheaper means of stabilizing soil, thus improving the strength of the soil, while providing a productive means of ridding the environment of agricultural waste (Amu and Adetuberu, 2010).

The aim of this work was to study the effects of BLA on the strength characteristics of selected lateritic soils. The specific objectives were to: (i) characterize the selected soil samples; (ii) determine the strength properties of the soil samples in their natural state; and (iii) evaluate the strength properties of soil samples after addition of BLA.

## 2. Materials and Methods

### 2.1 Materials and equipment

The main materials used for this study were lateritic soils and banana leaves. The equipment used for laboratory analyses are contained in Table 2.

Table 2: List of equipment

Apparatus	Purpose
Sampling/measuring cans	For oven-drying of soil
Set of BS sieve	Seive analysis
Mechanical sieve shaker	Shaking of sieves
Digital Weighing scale	Measurement of soil mas
Mechanical weighing balance	Weight measurement
Drying oven	Drying of soil samples
California bearing ratio (CBR) machine	Determination of soil CBR
Atterberg limit apparatus	Determination of Atterberg limits
Pycnometer	Determination of density of soil
Standard proctor compaction apparatus	Compaction of soil

### 2.2 Soil sampling and preparation

Lateritic soil samples were collected from two different active borrow pits, one at Ede road Ile-Ife (Longitude 7°29'43"N, Latitude 4°31'45"E) and the other at Ipetumodu off Ife-Ibadan express way, Ile-Ife

(Longitude 7°29'53"N, Latitude 4°26'57"E); both locations are in Osun state, Nigeria. One sample was collected from each location. About 25 kg of soil was collected from each location with the aid of hand auger using disturbed sampling method. The samples

were collected inside polythene bags, sealed and immediately transported to the Geotechnical Engineering Laboratory of the Department of Civil Engineering, Obafemi Awolowo University (OAU), Ile-Ife, Nigeria. At the Laboratory, samples were immediately taken for the determination of natural moisture content, while the rest soil was air-dried for subsequent laboratory analysis.

### 2.3 Preparation of banana leaf ash (BLA)

Banana leaves were obtained from Opa, Ile-Ife, Osun state, Nigeria. They were cleansed and sun-dried for 3 days. To produce BLA, the dried leaves were subsequently taken to the Material Laboratory of the Department of Material Science and Engineering, OAU, Ile-Ife, where it was subjected to burning in the furnace at a temperature of 550°C. After burning, the obtained BLA was sieved through British Standard (BS) sieve No. 40; the content passing was stored in an air tight polythene material (to avoid any form of hydration), for use in the study.

### 2.4 Preliminary and geotechnical tests on soil samples in their natural state

The following preliminary and geotechnical tests were carried out on soil samples in their natural states: natural moisture content determination, grain size analysis, specific gravity determination, Atterberg limits (liquid limit, plastic limit and plasticity index) determination, compaction, CBR. All the tests were conducted in accordance with standard procedures as detailed in BS 1377 (1990). Plastic limit was obtained from the arithmetic difference between liquid limit and plastic limit; and the method used for compaction was standard proctor.

### 2.5 Evaluation of the effects of BLA on soil samples

The BLA component used for this study was the content that passed BS sieve No. 40. The BLA was added to the soil samples in 2 %, 4 % and 6 %

proportions. For each of the combinations, the following tests were conducted on the soils, using standard procedures in accordance with BS 1377 (1990): Atterberg limits, compaction and CBR. The results were compared with that of natural samples and the effect of BLA on the soil samples were evaluated.

## 3. Results and Discussion

### 3.1 Properties of soil samples in their natural state

The results of the various tests conducted on the soil samples in their natural state are presented in Table 3.

The moisture content of soil is greatly affected by its void ratio. The higher the void ratio of a soil, the higher its moisture content; and, from the values of moisture content (Table 1), sample A could be said to have a lower void ratio than sample B; hence a higher strength.

The Specific gravity of the solids making up a given soil sample is useful in checking for the phase relationship between matters (Gidigas, 1971). It is generally accepted that the specific gravity of lateritic soil is very high, ranging between 2.65 and 2.85. The values of the specific gravity for the two soils therefore fall within the expected range for lateritic soils.

According to Das (2006), a soil is said to be clayey soil if it has a plasticity index greater than or equal to 11 %. Therefore, since the two soil samples have PI values of 17.2 % and 38 % respectively (Table 1), which are greater than 11 %, it could be said that the two soil samples have relatively high clay content. The results of Atterberg limit test and sieve analyses showed that the soil samples could be classified as A-2-7, according to AASHTO classification.

Table 3: Properties of soil samples in their natural states

Properties	Sample A	Sample B
Natural moisture content (%)	14.19	28.26
Specific Gravity	2.74	2.76
Liquid Limit (%)	43.8	64
Plastic Limit (%)	26.6	26
Plasticity Index (%)	17.2	38
Percentage passing sieve No. 200 (fines)	0.359	1.609
Percentage passing sieve No. 40	37.891	50
AASHTO Classification	A-2-7	A-2-7
OMC (%)	28.2	23.6
MDD (Kg/m <sup>3</sup> )	1624	1476
CBR (%)	12	12

The values of the compaction characteristics - MDD and optimum moisture content (OMC) – (Table 1) indicate that, if the soil samples are subjected to the same compaction method on the field, sample A would have the higher dry density. Also, the two samples have the same value (12 %) of CBR (Table 1). The values of the CBR indicate that the soil samples are only suitable for sub-grade fill in road construction (FMWH, 1997).

**3.2 Effects of BLA on soil properties**

Figure 1 is a graphical representation of the relationship between liquid limit and BLA. As presented in the Figure, for both samples A and B, liquid limit generally decreased with increase in BLA content. For sample A, there was an increase in liquid limit at 4 % BLA, but the highest value of liquid limit was still recorded at 0 % (natural state).

With respect to plastic limit (see Figure 2), for sample A, plastic limit increased with increase in BLA content, with the highest value obtained at the highest BLA content (6 %). For sample B, optimum BLA, corresponding to highest plastic limit, is 4 %.

Figure 3 shows that plasticity index generally reduced with increase in BLA. The maximum values of plasticity index was obtained at natural state. In other words, the addition of BLA did not increase the value of plasticity index.

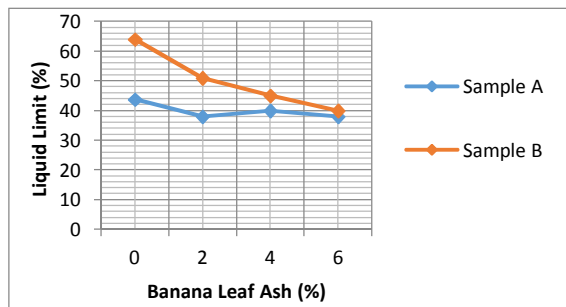


Figure 1: Variation of Liquid Limit with BLA

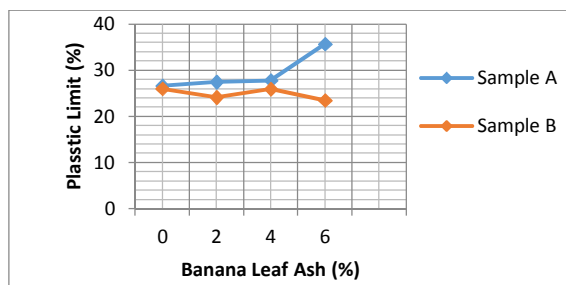


Figure 2: Variation of plastic limit with BLA

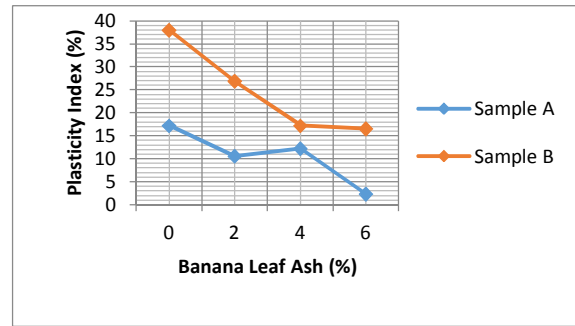


Figure 3: Variation of plasticity index with BLA

As seen in Figure 4, for sample A, the OMC decreased with increase in BLA until 4 % BLA when it increased again to 6 %. However, the highest OMC was still recorded at 0 % BLA (natural state) of soil. For sample B, optimum value of BLA (corresponding to highest OMC) was obtained at 2 % BLA. Figure 5 also shows that the optimum BLA, which gave the highest value of MDD is 2 %.

From Figure 6, it is seen that maximum values of CBR for the two soils were obtained at 4 %. That is, the optimum BLA content for CBR is 4 %.

The increment in the CBR values after the addition of 2 % BLA (Figure 6) could be attributed to the gradual formation of cementitious compound (Calcium Silicate (CaSiO<sub>3</sub>)) between the BLA and Calcium Hydroxide (Ca (OH)<sub>2</sub>) present in the soil. Lateritic soils are known to contain a very high percentage of Ca (OH)<sub>2</sub> and when this combines with about 50 % SiO<sub>2</sub> content present in BLA (see Table 1), CaSiO<sub>3</sub> is produced (Equation 1). According to Mohanalakshmi *et al* (2016), CaSiO<sub>3</sub> has its chemical properties very similar to that of cement; and because of this similarity, CaSiO<sub>3</sub> can be used as a stabilizing agent. It is primarily used in ceramics and tile factories.

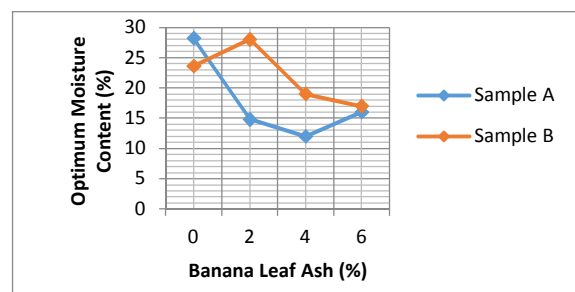
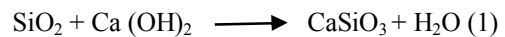


Figure 4: Variation of optimum moisture content with BLA

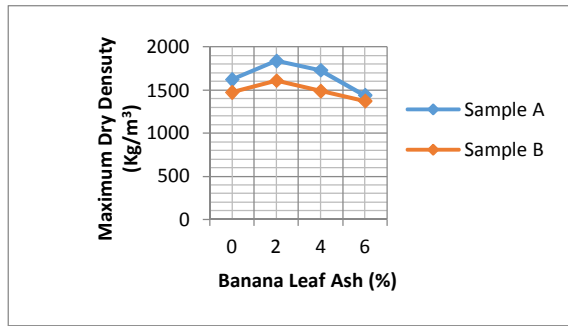


Figure 5: Variation of maximum dry density with BLA

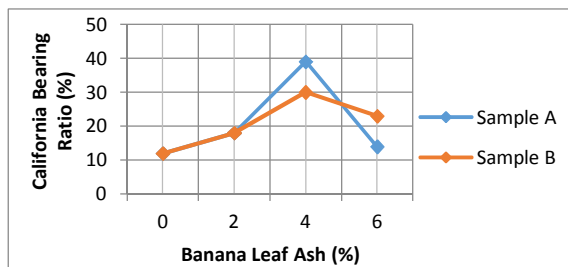


Figure 6: Variation of California bearing ratio (CBR) with BLA

#### 4. Conclusion

A study has been carried out on the effects of BLA on selected soils. The soil samples were found to be expansive in their natural states, with relatively high plasticity. The addition of BLA improved the quality of the soils by: reducing their plasticity index; and causing a reduction in the OMC, with a corresponding increase in MDD. This implies that 2 % optimum value of BLA could be used to improve soils belonging to the A-2-7 group of the AASHTO classification. It was also found that the CBR values of the soils could be maximized at 4 % optimum content of BLA. It could be concluded that BLA can be used to significantly improve the strength of lateritic soils.

#### Acknowledgements:

Authors are grateful to Mr. T. Y. Olasupo of the Geotechnical Engineering Laboratory, Department of Civil Engineering, Obafemi Awolowo University (OAU), Ile-Ife for his assistance during the laboratory work. Thanks to all technical staff at the Material Laboratory of the Department of Materials Science and Engineering, OAU for their assistance during the preparation of banana leaf ash for this study'.

#### Corresponding Author:

Dr. G. O. Adunoye  
Department of Civil Engineering  
Obafemi Awolowo University  
Ile-Ife, Nigeria  
Telephone: +2348033579586  
E-mail: [kayadunoye@yahoo.com](mailto:kayadunoye@yahoo.com)

#### References

1. Amu OO, Adetuberu, AA. Characteristics of bamboo leaf ash stabilization on lateritic soil in highway construction. *International Journal of Engineering and Technology* 2010; 2(4): 212-219.
2. Amu OO, Ogunniyi SA, Oladeji OO. Geotechnical properties of lateritic soil stabilized with sugarcane straw ash, *American Journal of Scientific and Industrial Research* 2011; 2(2): 323-331.
3. Bello AA, Ige JA, Hammed A. Stabilization of lateritic soil with cassava peels ash, *British Journal of Applied Science and Technology* 2015; 7(6): 642-650.
4. British Standard 1377. *British Standard Methods of Tests for Soil for Engineering Purposes, Part 2*. British Standard Institute, London 1990.
5. Das BM. *Principles of Geotechnical Engineering*, 7th ed. Cengage Learning, USA 2006.
6. Das BM. *Principles of Geotechnical Engineering*, 8th ed. Cengage Learning, USA 2010.
7. Federal Ministry of Works and Housing. *General Specifications for Roads and Bridges 1997; Volume II*, pp 145-284.
8. Gidigasu MD. The importance of soil genesis in the engineering classification of Ghana soils. *Engineering Geology* 1971; 5: 117-161.
9. Gobinath R, Akinwumi II, Afolayan OD, Karthikeyan S, Manojkumar M, Gowtham S, Manikandan A. Fibre-reinforcement of a soil stabilized with sodium silicate. *Silicon* 2019; 12: 357-363.
10. Krishnan 1KVB, Jananee BR, Dinesh U, Sanjai KS. Stabilization of black cotton soil using banana tree ash. *International Journal of Research in Engineering and Management* 2019; 1(1): 277-285.
11. Mustapha MA. Effect of Bagasse ash on cement stabilized laterites, Seminar paper presented at the Department of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria 2005.
12. Nnochiri ES, Aderinlewo OO. Geotechnical properties of lateritic soil stabilized with banana

- leaves ash, FUOYE Journal of Engineering and Technology 2016; 1(1): 116-119.
13. Olutaiwo AO, Lawal AO. Effect of banana leaf ash on cement-modified lateritic soil, International Journal of Engineering and Technical Research 2017; 7(6): 25-28.
  14. Osinubi KJ. Evaluation of admixture stabilization of Nigeria black cotton soil. Nigerian Society of Engineers Technical Transaction 1999; 34(3): 88-96.
  15. Sakthivel S, Parameswari R, Gomathi M. Experimental investigation on concrete with banana fiber and partial replacement of cement by banana leaf ash. International Research Journal of Engineering and Technology 2019; 6(3): 3914-3919.

1/14/2021