GLOBAL JOURNAL OF ENGINEERING, DESIGN & TECHNOLOGY
(Published By: Global Institute for Research & Education)
www.gifre.org

Physical Properties of Lime – Bamboo Leaf Ash Treated Samples of Lateritic Soils in Ado – Ekiti, Nigeria

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Abstract

This research was carried out to study the physical characteristics of Lime- Bamboo leaf ash stabilization on lateritic soil in highway construction. The physical characteristics of three selected samples in their natural untreated state and their responsiveness to treatment with lime-bamboo leaf ash stabilizing agent (i.e. additive) were determined in the laboratory. Percentages of the additive used on the lateritic samples varied from 0% to 10%. Results indicated increase in plastic and liquid limits of the samples while plasticity index, linear shrinkage and swell decreases with increase in the additive contents. Beneficial results were obtained especially from the treatment of the highly plastic and inorganic soil samples (i.e. soil samples A and B which in its untreated condition can often be detrimental for use as subgrade material in road construction due to differential expansion and shrinkage when undergoes change in moisture content) with the additive.

Keywords: Lateritic Soil, Physical properties, Shrinkage, Lime-bamboo leaf ash, Construction.

1. Introduction

As the conventional road construction materials become scarce or more expensive, there is the need to turn to alternatives. Difficulties in construction operations are often associated with clay soil. This may be due to the unsuitability of the clay soil for that particular purpose. When this occurs, it is possible that the properties of the soil may be improved by the addition of small amount (by weight) of lime-bamboo leaf ash. The use of these as an alternative materials result in two folds advantages - conservation of natural resources and disposal in the size of waste heaps. Most of these wastes have been used in many countries of the world. In Nigeria, these dignified wastes and by-products have not been known to have much economic value; rather they have constituted environmental hazards (Amu and Adetuberu, 2010; Das, 2000; Faluyi and Amu, 2004; Murthy, 1991).

Lateritic soil is a residual soil formed from the weathering of igneous rock under the conditions of high temperature and rainfall of the tropical region where the decomposition process results in a soil leached of silica (SiO_2) and Calcium trioxocarbonate IV ($CaCo_3$), but retaining high concentration of Iron and Aluminium Sesquioxides (Fe_2O_3; Al2O3). It is red, reddish brown or dark brown in colour . When Lime-bamboo leaf ash is added to the soil, a number of reactions take place. The short term reactions are hydration and flocculation (ion exchange) and long term reactions are cementations and carbonation. There are criteria for the lime mixture (Bell, 1993; Ingles and Metcalf, 1992).

Stabilization has been defined as any process by which a soil material is improved and made more stable (Whitlow, 1995). It is also described as the treatment of natural soil to improve its Engineering properties (Garber and Hoel, 2000). Soil Stabilization may be broadly defined as the alteration or preservation of one or more soil properties to improve the Engineering characteristics and performance of a soil. There are three purposes for soil stabilization, which includes strength improvement, dust control and soil waterproofing (Harris, 1994).

The stabilizing agent used in this study is mixture of lime-bamboo leaf ash. Bamboo leaf was burnt (to produce its ash) in an open atmosphere and then heated to 600^{o}C for two hours in a furnace. It was found with amorphous material containing amorphous silica. Chemical composition of the bamboo leaf ash and quicklime is shown in Table 1.

Table 1: Chemical Composition of Bamboo - leaf Ash and Quicklime (AfterAdemoroti, 1996)

SYSTEM	COMPOSITION (Wt %)										
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	SO_3	IR	IO
BLA	74.90	5.13	1.22	9.47	1.85	3.62	0.21	0.20	1.06		
QUICKLIME	30.41	5.03	4.10	51.56	3.65	0.90	0.23	-	2.53	0.15	1.44

The main objective of this study is to determine the physical properties of the lateritic soils treated with lime – bamboo leaf ash stabilizing agent. This will help in analyzing the effects of stabilizing the soils with lime - bamboo leaf ash. The past research works of Amu and Adetuberu (2010), Faluyi and Amu (2004) and others have shown possibilities of separate usages of the combined additives (i.e. Lime and bamboo leaf ash). The results of the study will provide reliable technical information on the physical properties of lateritic soils and a useful guideline for Highway Engineers in material selection for road construction especially in our tropical environment.

2. Materials and Methods

2.1 Materials and Preparation

The lateritic soil samples used for this study were obtained from different locations in Ado Ekiti, Nigeria. These samples were tagged with unique identifications - A, B and C. The samples are borrow pit materials used on

(i)Ado Ekiti – Ijan road rehabilitation project –Type A
(ii) Ado Ekiti- Iworoko road rehabilitation project - Type B
(iii) Ado Ekiti –Iyin road rehabilitation project - Type C

They were dug out from the ground, a depth not less than 150mm (natural ground formation with at least 300mm top soil removed). The soil samples were kept safe and dry in a jute bag in the soil laboratory at the Department of Civil Engineering, the Federal Polytechnic, Ado- Ekiti, Ekiti State, Nigeria. The soil samples were kept in clean plastic bags and properly sealed with adhesive tapes. Sample number with soil description, sampling depth and date of the sample were marked clearly on a paper and stapled to prevent loss of moisture. Portable water was obtained from the laboratory. Bamboo leaves were collected from the Federal Polytechnic, Ado - Ekiti and burnt in a furnace at the School of Science and Technology, the Federal Polytechnic, Ado Ekiti, within the range of 800^oC to 1000^oC. The ashes of the bamboo leaves obtained were kept in well-sealed polythene to prevent moisture absorption.

2.2 Methods

Identification and classification tests (Natural moisture content, Specific gravity, Particle size analysis and Atterberg limit tests) were performed on the three soil samples. Lime-Bamboo Leaf Ash (LBLA) in 2%, 4%, 6%, 8% and 10% proportion were mixed with the soil samples. The stabilizing potentials of LBLA on the soil samples were determined. The procedures for the various tests were carried out in accordance with BS 1377 (1990) standard methods. After the samples had been collected and treated, their properties were determined to ensure that when their response(s) to additives were studied, all relevant factors would be available for establishing a correlation between compositions of LBLA stabilization of the soils.

3. Results and Analyses

Results of the tests performed on the three samples were as recorded in Tables 2 - 4. Results of particle size analysis of the samples were shown in Table 2, results of Atterberg Limit tests and respective Group Index values for untreated soil samples were shown in Table 3, while results of Atterberg Limit tests values for treated soil samples were shown in Table 4. Graphs plotted for Atterberg Limits tests against LBLA contents were shown in Figures 1 - 4.

Table 2: Particle Size Analysis test Results for the Untreated Soil samples

MATERIAL	SAMPLE A	SAMPLE B	SAMPLE C
Clay	59.00%	47.00%	33.00%
Sand	41.00%	46.00%	58.80%
Gravel	0.50%	6.30%	8.40%

Table 3: Atterberg Limits tests Results for the Untreated Soil samples

SAMPLE	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	SPECIFIC GRAVITY	GROUP INDEX
A	38	21	17	2.58	8
B	43	30	13	2.37	4
C	37	22	15	2.45	1

From Tables 2 and 3, Soil sample A comprises of 41.5% coarse material and 59% fine with a Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI) and Group Index (GI) value of 38%, 21%, 17% and 8% respectively. The soil is classified as A-6 (Clayey soil) of fair to poor rating in terms of possible use as subgrade material according to American Association of State Highway and Transportation Officials Classification – AASHTO (1986). Soil sample B comprises of 52.3% coarse material and 47% fine with a LL, PL, PI and GI value of 43%, 30%, 13% and 4% respectively .The soil is classified as A-6 (clayey soil) of fair to poor rating as subgrade material according to AASHTO (1986) classification.

While Soil sample C comprises of 67.2% coarse material and 33% fine with a LL, PL, PI and GI value of 37%, 22%, 15% and 1% respectively. The soil is classified as A-2-6 (clayey gravel) of excellent to good rating as subgrade material according to AASHTO (1986) classification.

Generally, the physical inspection of the samples revealed that their colours vary from brownish red clay to brownish gravelly clay. Soil sample A is yellowish brown clay, soil sample B is brownish red clay while soil sample C is brownish red clay. The natural soil samples (i.e. untreated soil samples) have the following properties - LL ranges from 37% to 43%, PL ranges from 21 to 30, PI ranges from 13 to 17, specific gravity ranges from 2.37 to 2.58 and GI ranges from 1 to 8. The soils are A-2-6 and A-6 types based on AASHTO (1986) Classification system.

From the clay identification chart, using PL and PI as parameters, all the soil samples have kaolinite types of minerals, from plasticity chart for classification of cohesive soils all the soil types are inorganic silty clay and have medium compressibility system of rating as subgrade material. The soil sample C is rated between excellent and good while soil samples A and B are rated between fair and poor. This is an indication that soil samples A and B are not good for use as subgrade material except they are stabilized. The main benefits obtained when the lateritic soil is treated with additive like LBLA are improved workability, volume stability and increased strength.

Table 4: Summary of Tests Results for the Treated Soil samples

SAMPLE	ADDITIVE CONTENT (%)	ATTERBERG LIMIT TESTS			
		LL (%)	PL (%)	PI (%)	SL (%)
A	0	39.0	22.0	17.0	13.0
	2	54.0	40.0	13.0	12.0
	4	50.0	41.0	8.0	11.0
	6	49.0	43.0	6.0	10.8
	8	51.0	44.0	7.0	10.3
	10	56.0	47.0	10.0	9.2
B	0	41.0	27.0	13.0	9.4
	2	48.0	31.0	17.0	8.8
	4	46.0	32.0	14.0	8.7
	6	44.0	35.0	9.0	7.6
	8	47.0	33.0	12.0	7.5
	10	48.0	34.0	13.0	7.2
C	0	39.0	24.0	15.0	10.0
	2	47.0	36.0	10.0	9.4
	4	42.0	37.0	3.0	8.3
	6	40.0	36.0	2.0	7.6
	8	42.0	40.0	2.0	6.2
	10	43.0	41.0	2.0	5.6

From Table 4, effects of LBLA on Atterberg limits of clay soils can be observed and from this table, graphs were plotted for LL, PL, PI and Linear Shrinkage (LS) values against LBLA content (i.e. Additive content) values as shown in Figures 1 to 4.

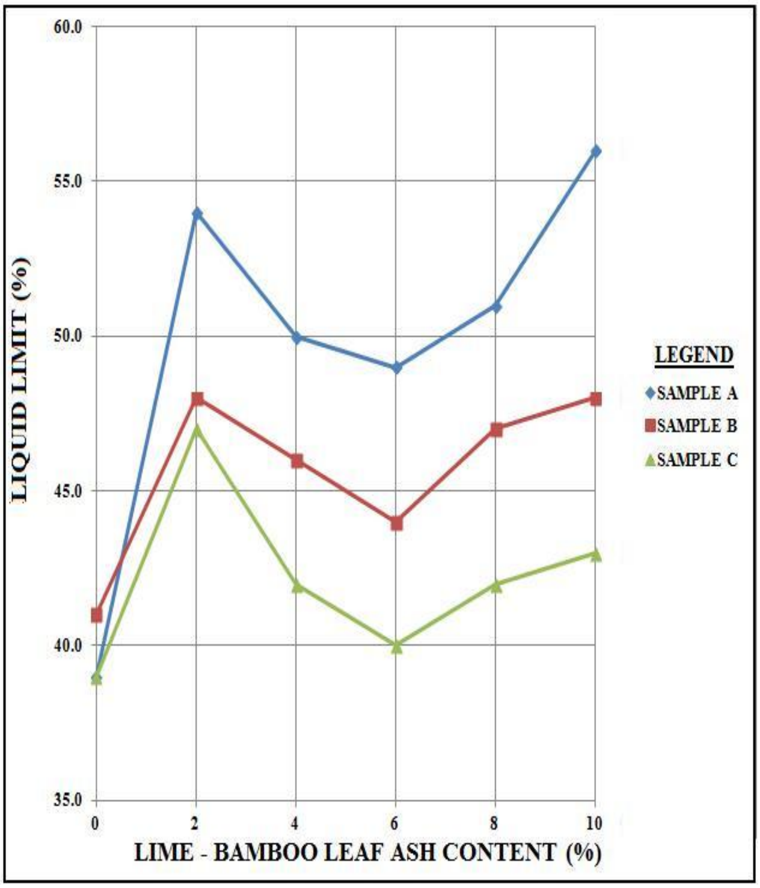

Figure 1: Graph of the Liquid Limits Test for the Treated Soil Samples

From Figure 1, it is observed that the LL values have sudden increment between 0% and 2% additive contents, drastic reduction between 2% and 6% additive contents and gradual increment between 6% and 10% additive contents for all the soil samples (i.e. A to C).

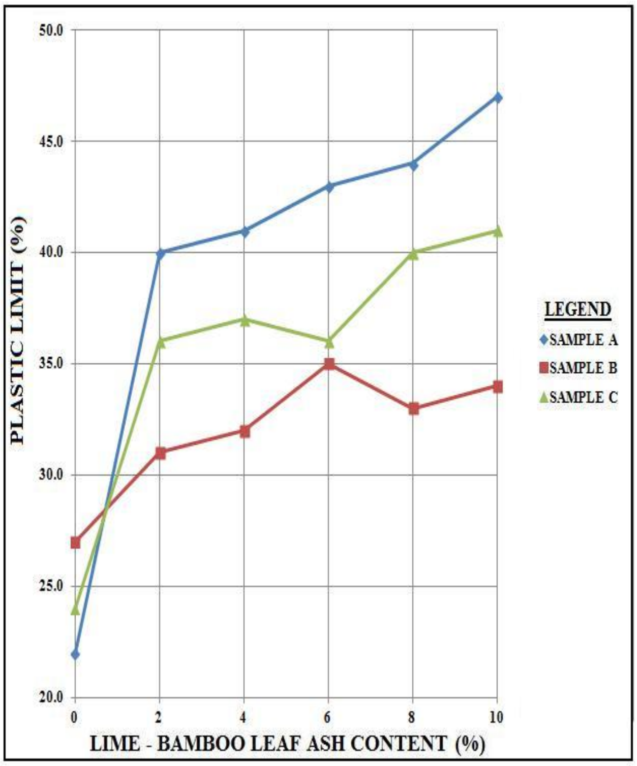

Figure 2: Graph of the Plastic Limits Test for the Treated Soil Samples

From Figure 2, it is observed generally that the PL values increase with increase in additive content. Moreover for the soil sample A, the PL values have sudden increment between 0% and 2% additive contents and gradual increment between 2% and 10% additive contents. For the soil sample B, the PL values have sudden increment between 0% and 2% additive contents, slight increment between 2% and 4% additive contents, slight reduction between 4% and 6% additive contents; and gradual increment between 6% and 10% additive contents. For soil sample C, the PL values have gradual increment from 0% to 10% except at 6% where there is sudden increment.

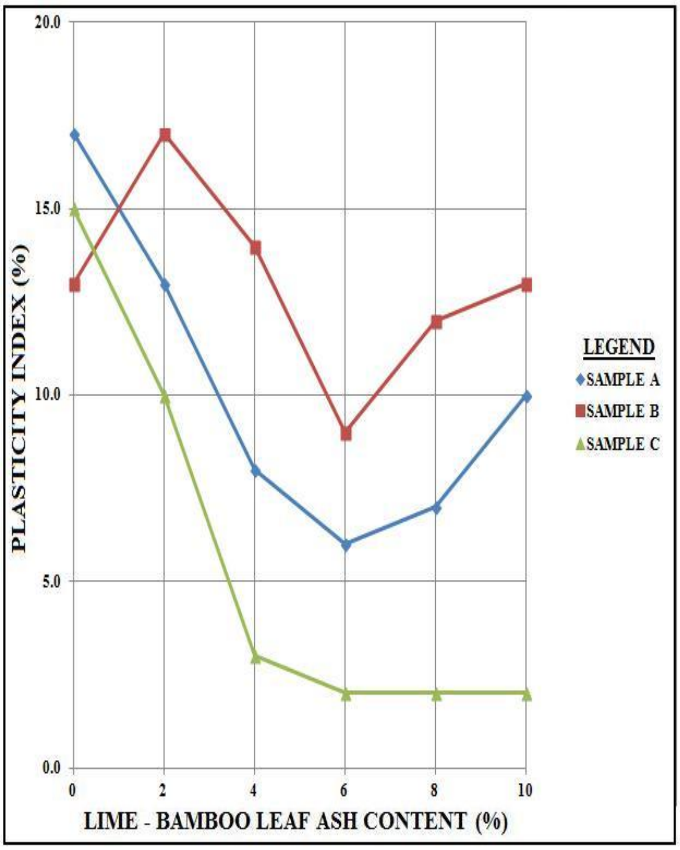

Figure 3: Graph of the Plastic Index Test for the Treated Soil Samples

From Figure 3, it is observed generally that the PI values decrease with increase in additive content. Nevertheless, for the soil sample A, the PI values have sudden reduction between 0% and 6% additive contents and gradual increment between 6% and 10% additive contents. For the soil sample B, the PI values have sudden increment between 0% and 2% additive contents, sudden reduction between 2% and 6% additive contents, and gradual increment between 6% and 10% additive contents. For soil sample C, the PI values have sudden reduction between 0% and 4% additive contents, gradual / slight reduction between 4% and 10%.

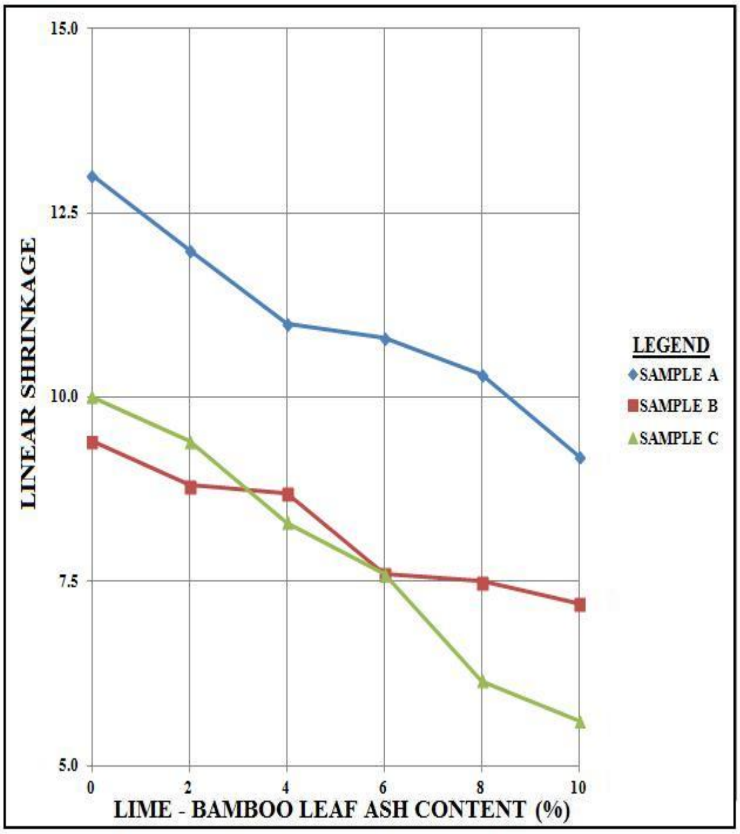

Figure 4: Graph of the Shrinkage Limits Test for the Treated Soil Samples

From Figure 4, it is observed generally that the LS values of all the soil samples decrease with increase in additive content, thus the shrinkage limit of the soils. From the above results and explanation, there is effect(s) of flocculation when the LBLA content reacted with the soil samples. The increase in PI values with increase in LBLA content between 6% and 10% portrayed presence of kaolinitic clay mineral. This was explained by Bell (1993), that "at times, LBLA treated of kaolinitic clay soil increase the PI".

4. Conclusion

The results of this investigation have shown that beneficial effects are obtained by the addition of small amount of LBLA to lateritic soils and specifically lead to the following conclusion

- The LL and PL of the mixture increases with increase in LBLA content while the PI of the mixture reduces consistently with increase in LBLA content from 0% to 6%, but increase slightly from 6% to 10%;
- The linear shrinkage and swell of the mixture decreased remarkably.
- Lime –bamboo treatment of lateritic soil improve their characteristics but at different rates. It is best suited for highly plastic clayey soils.

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