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Effect of West African Standard Compactive Effort on lateritic soil stabilized with Bamboo leaf ash admixed with lime

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Abstract: This study investigates the impact of West African Standard (WAS) Compactive effort on A-7-5 lateritic soil stabilized with Bamboo Leaf Ash (BLA) mixed with lime. Preliminary tests were conducted on the soil sample for identification and classification purposes. Samples were compacted in both the natural and stabilized states incorporating 2, 4, 6 and 8 percent Bamboo Leaf Ash mixed together with 1, 2, and 3% lime by weight of sample to the soil. The chemical composition test carried out on the BLA shows that the ash is a pozzolan and it belongs to class F. The Maximum dry density (MDD) increased from 1477 kg/m3 at 0% to 1818 kg/m3 at 3% lime 8% BLA, while the optimum moisture content decreased from 16.80% at 0% to 11.40 per cent at 2 per cent lime 6 per cent BLA. Based on these findings, the addition of lime-BLA enhanced the soil and has a promising prospect for stabilization of lateritic soil.

Keywords: Bamboo leaf ash, West African Standard Compactive effort, Lateritic soil, Lime, Stabilization

Introduction

Laterite is a type of soil that is rich in iron and aluminum and is found primarily in sultry and temperate climates with hot and humid weather. Lateritic soil is characterised by high plastic clay, which can weaken and damage pavements, highways, building foundations, hydraulic structures, and other civil engineering work (Fitsum, 2018). Lateritic soil normally has low bearing ability and low strength because of the high content of clay in its normal form. In the presence of water, when the lateritic soil comprises a significant number of clay products, the intensity and firmness of the soil cannot be accredited under load, necessitating the need for stabilization (Bello et al., 2015). To meet the demands of geotechnical engineering, more attention should be paid to the use of potentially cost-effective materials locally accessible from industrial and agricultural waste to improve the properties of deficient soils (rather than providing alternative soils that may prove financially unwise). Blending natural lateritic soil with certain chemical additives advances its engineering properties, both in terms of watertight and strength, and improves the safe disposal of industrial and agricultural waste products, which require urgent and cost-effective solutions due to the debilitating effect of these materials on the environment and the health risks they create (Asha et al., 2014).

Laterites are weathering products formed on a wide range of rocks with high iron concentration, which can be volcanic, sedimentary, or metamorphic in origin. High seasonal precipitation, high temperature, extreme leaching, heavy oxidizing climate, subdued topography, long weathering period, and chemically unstable parent rock have all been found to be optimum conditions for lateritization. It has been noticed that in the formation process, an appropriate supply of iron sesquioxide, which may come from the underlying parent material or from a nearby location of higher topography is essential. High water content and high temperatures induce extreme chemical weathering resulting in well-formed residual soils (De Vallejo and Ferrer, 2012).

Bamboo is an essential non-timber forest product which has numerous uses for people. One of the most foremost and outstanding uses of bamboo is its utilization by humans for construction. Bamboo has been used as a construction material from times past, especially by people who live in places where bamboo grew naturally and in large quantities. In ancient times bamboo was used to build houses because of its natural potency and flexibility. In the modern context and due to advancements in manufacturing technology and rising market demand, it has been widely employed for domestic products and applied to engineering settings (Rashmi et al, 2019).

Bamboo is one of the most ornamental and easy-to-grow gardens and potted plants. It is particularly suited to the Nigerian rainforest belt, where it is widely grown around banks of the river and other generally waterlogged areas. It has been identified that more than 1,200 species of bamboo are widely available and that seven of these varieties are present in Nigeria, 80 percent of which is the Bambusa Vulgaris species and is generally alluded to as Indian bamboo (Omotosho, 2003).

Bamboo leaf is a regularly used term for branches of a taxonomic group of large wood grasses. The complement of the bamboo leaf consists of two parts, the sheath and the blade. It has two unique types of leaves: the culm leaf and the foliage leaf. Culm leaves are coupled at the base of their sheaths directly to the Culm nodes at the sheath scar, while the foliage leaf blade is often connected to its sheath by a stem or a petiole, as evaluate to the Culm leaf blade, which is often without a petiole (Omotosho, 2003). Like wood, bamboo also has high strength properties to absorb shocks and impacts, a high strength to weight ratio and a high specific load bearing capacity. This makes it extremely suitable for building houses to withstand seismic and high wind force. The life span of bamboo can be greatly improved by providing adequate preservation handling. Bamboo, along with fast growing plantation and specie, is a very effective carbon sequesters and contributes to the decrease of the greenhouse effect (Yusoff et al, 2002). Bamboo generates a larger percentage of leaves that pollute the environment and one of the best ways to mitigate the risk they create is to look at how they can be used as a soil additive.

Lime is a chemical additive that is used in stabilizing soil. It's referred to as lime stabilization. Investigation has shown that lime combines well with moderate, generally coarse, fine-grained clay soils. In clay soil, the main benefit of lime stabilization is the improvement in soil plasticity: by reducing the soil moisture content, it becomes stronger. It also increases soil strength and longevity and limits the soil's tendency to swell (Bello, 2013). Lime in the form of quicklime (calcium oxide – CaO), hydrated lime (calcium hydroxide – Ca[OH]2) or lime slurry1 can be used for soil treatment. Quicklime is formed by the chemical transformation of calcium carbonate (CaCO3) into calcium oxide. Hydrated lime is formed when the quicklime reacts chemically with water. It is a hydrated lime that mixes with clay particles and eventually turns them into a solid cement matrix. (Lime treated soil construction manual).

Materials and Methods

Materials

Lateritic soil

The lateritic soil sample was collected (disturbed) from a borrowed pit along Fountain University Osogbo using a trial pitting process. This sample was collected in large bags while significant amounts were packed and sealed in polythene bags to avoid moisture absorption. Subsequently, the soil sample was air-dried, crushed and sieved through regular sieves for various types of tests, with the large sieve being BS No 4 sieve. (Aperture of 4.76 mm).

Bamboo leaf ash (BLA)

The bamboo leaves used for this study were collected from locations in Ede. The leaf was dried under laboratory condition to remove moisture content, Burned in outdoor environment to turned it to powdery form and partially to ash and afterwards heated in a furnace at 6000C for 2 hours to get the real ash content needed, after which it was cooled and then sieved through the sieve No 200 to get the ash. The ash was kept in an enclosed polythene bag to halt the moisture.

Lime

The lime utilized for this study was bought from a chemical shop in Ado-Ekiti and was sieved through sieve No 200.

Methods

Oxide Composition

The test was carried out to determine the chemical composition of both the soil, lime and the BLA. The chemical compositions of the samples were obtained using Thermo Scientific ARL QUANT'X EDXRF Spectrometer. X-ray Flourescence (XRF) analysis was done using the standard method with Montana soil SRM 2710 as a Thermo Fisher Scientific standard reference material.

Index Properties

Particle size distribution, natural moisture content, specific gravity and Atterberg limit tests were conducted on the soil sample in accordance with British Standards (BS 1377, 1990).

Compaction

This test is to determine the maximum dry density and the optimum moisture content at a given compactive effort. As specified by BS 1377: 1990, West African Standard (WAS) Compactive effort was adopted for this research.

The WAS compactive effort is the conventional energy level which involves using a cylindrical metal mould (Proctor mould) of about 1000cm3 and a rammer of 4.5kg. The soil was compacted inside the mould by separating it to 5 layers and 10 blows were applied to each layer using 4.5kg rammer falling from a height of 450mm. Air dried soil sample that passed through BS sieve with 4.76mm aperture mixed with 1% lime-2% BLA, 1% lime-4% BLA, 1% lime-6% BLA, 1% lime-8% BLA, 2% lime-2% BLA, 2% lime-4% BLA, 2% lime-6% BLA, 2% lime-8% BLA, 3% lime-2% BLA, 3% lime-4% BLA, 3% lime-6% BLA, 3% lime with 8% BLA by weight of dry soil was used for the Compactive effort.

The moisture content samples were taken from the top and bottom of the mould and the optimum moisture content was taken as the moisture content at which the maximum dry density is attained.

Results and Discussion

Oxide Composition

The elemental analysis carried out on lime, bamboo leaf ash (BLA) and the lateritic soil using X-Ray Flourescence revealed the oxide components as shown in Table 1. It was revealed that the lime contains a high amount of CaO (69.5%) which aids in the stabilization process and invariably makes lime an effective stabilizer. On the other hand, the BLA can be regarded as a pozzolan since it contains an appreciable content of SiO2 (75.35%) and this tends to improve the engineering properties of the lateritic soil used. The BLA qualifies as a pozzolan and it belong to class F since the percentage sum of its SiO2, Al2O3 and Fe2O3 components (84.44%) is greater than 70%.

Index Properties Test.

The natural moisture content of the soil sample is high and this indicates that the soil comprises wide open spaces. The specific gravity of the soil sample is 2.31 and falls in the range suggested in Bello (2013) for clay minerals as halloysite (2.0-2.55). This outcome indicates that the soil sample drops within the lateritic soil range with Halloysite being the major clay mineral in the soil. The specific gravity of the lime used is 2.35 and this falls within the range of hydrated lime (2.3-2.4) as specified by the National Lime Association. Bamboo leaf ash has specific gravity value of 2.05 which is in line with that used by Dhinakaran (2016) where the strength and durability of bamboo leaf ash was determined. The index properties of the soil are shown in table 2.

AASHTO classification system (1986) and the Unified Soil Classification System (USCS) were used to characterize the soil sample. The soil sample comes under the silt-clay material and A-7 category using the AASHTO classification system with more than 35 percent passing through sieve No 200. In addition, the soil sample falls under MH (sandy elastic silt) using USCS with more than 50% pass-through sieve No 200. Using the Liquid Limit (LL) and Plastic Index (PI), the soil sample was further categorized as A-7-5 (6). Figure 1 shows the particle distribution curve.

The results of the Atterberg limit test (Liquid Limit (LL), Plastic Limits (PL) and Plastic Index (PI)) before and after adding bamboo leaf ash and lime are shown in Figure 2-4. However according to Bello (2015) soils with a liquid limit of less than 35 percent are characterized as low plasticity, others with a liquid limit of between 35 per cent and 50 percent display medium plasticity, if it is between 50 percent and 70 per cent, have high plasticity, between 70 per cent and 90 percent, very high plasticity and if it is greater than 90%, it is exceptionally high plasticity.

The analysis indicated that the untreated soil falls within the group of high plasticity soil with a value of 64 per cent, but the incorporation of additives led to vary in the liquid limit range with a minimum value of 43.42 percent at 3 percent lime-8 percent BLA. The plasticity index (PI) declines with the percentage increase in the additive from 18 percent to a minimum of 5 percent at 3 percent lime-8 per cent BLA. This improvement can be credited to the reaction of lime and BLA to soil which reduced soil's sensitivity to water and filled the entire gap present in the natural soil which is a sign of soil improvement.

Table 1: Oxide Composition of the Laterite, Lime and Bamboo Leaf Ash used

Oxides	Concentration (%)		
	Laterite	Lime	Bamboo Leaf Ash
SiO_2	4.43	1.69	75.35
Al_2O_3	55.39	1.46	5.73
Fe_2O_3	4.43	0.04	3.36
CaO	0.15	69.5	3.06
P_2O_5	0.15	0.19	1.7
K_2O	2.18	0.03	5.23
MnO	0.05	0.0006	0.18
SO_3	0.21	1.38	1.17
TiO	0.74	0.005	0.29
CuO	0.008	0.00	0.006
ZnO	0.008	0.0004	0.083
Cr_2O_3	0.02	0.0003	0.005
NiO	0.006	0.0006	0.002
Cl	0.09	0.00	0.75
PbO	0.015	0.00	0.005
MgO	3.96	1.58	3.31
L.O.I	8.5	18.7	-

Table 2: Properties of the lateritic soil

Properties	Quantity
Natural moisture content (%)	17.06
Specific gravity	2.31
Liquid limit (%)	63
Plastic limit (%)	46
Plasticity index (%)	18
% Passing BS No. 4 sieve	97
% Passing BS No. 200 sieve	51
Maximum dry density (kg/m^3)	1477
Optimum moisture content (%)	16.80
AASHTO classification	A–7–5 (6)
USCS classification	MH
Colour	Reddish brown

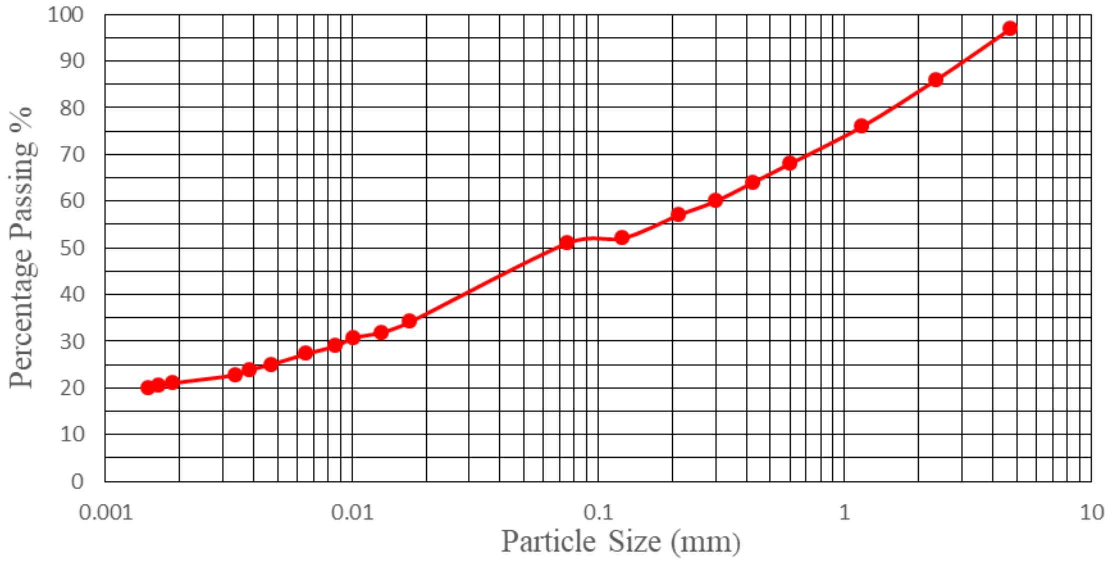

Figure 1: Particle size distribution curve for the Soil Sample.

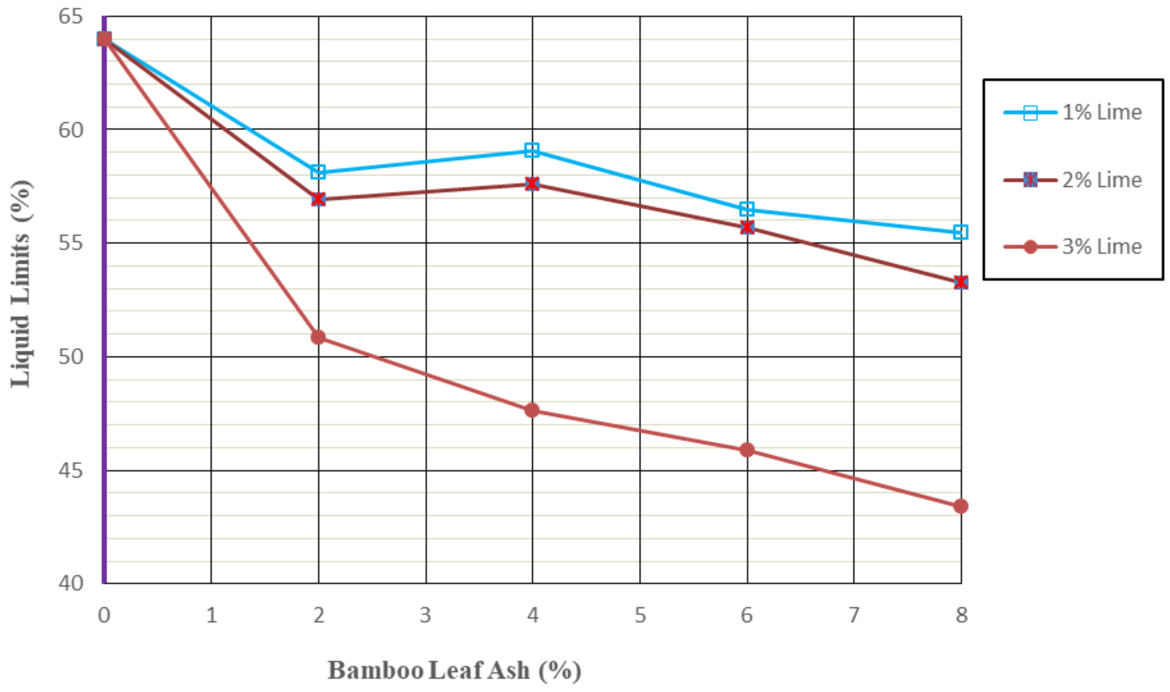

Figure 2: Variation of liquid limit with lime-BLA content

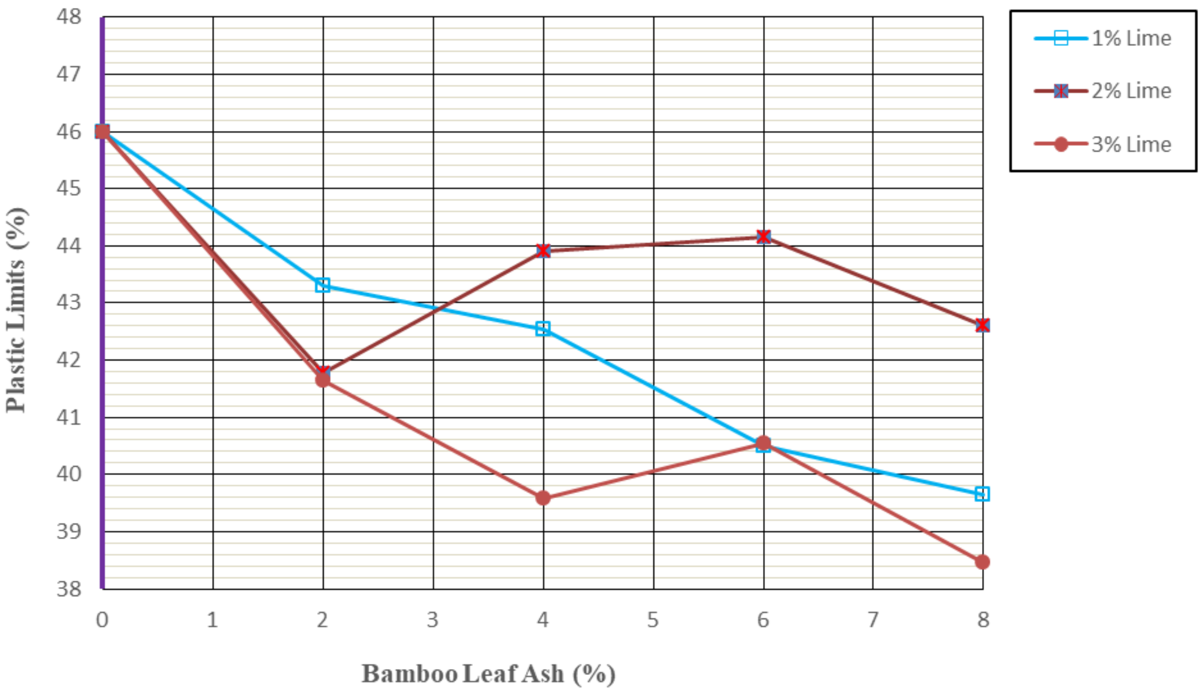

Figure 3: Variation of Plastic limit with lime-BLA content

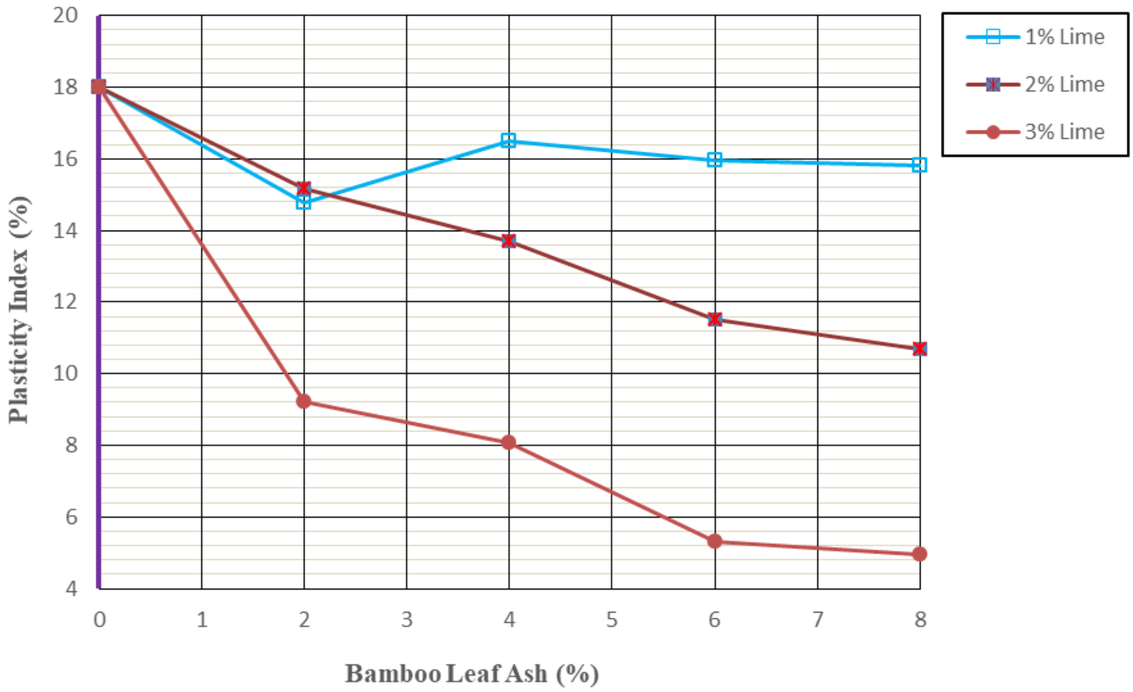

Figure 4: Variation of Plasticity index with lime-BLA content.

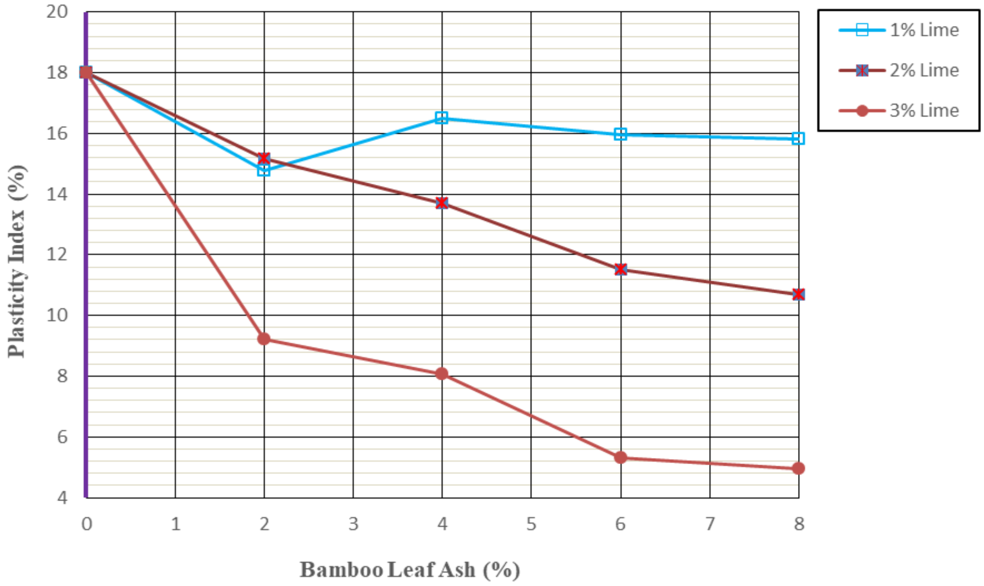

Figure 4: Variation of Plasticity index with lime-BLA content.

Compaction

The compaction test was carried out using West African Standard (WAS) Compactive effort. The test was done to obtain the relationships between the dry density and the moisture content of the soil. The maximum dry density (MDD) improved with an increase in lime-BLA content. MDD increased from a value of 1477 kg/m3 at 0% to a peak value of 1818 kg/m3 at 3% lime-6% BLA. This also matches to the work of (Adeyemo et al, 2019). Figure 5 shows the variation of maximum dry density with the percentage of lime and BLA for the compactive energy. The increase in MDD can be as a consequence of joint action of BLA and lime, lime released calcium oxide while BLA produced more silica that result to the flocculation and agglomeration of clay particles as a result of ion exchange.

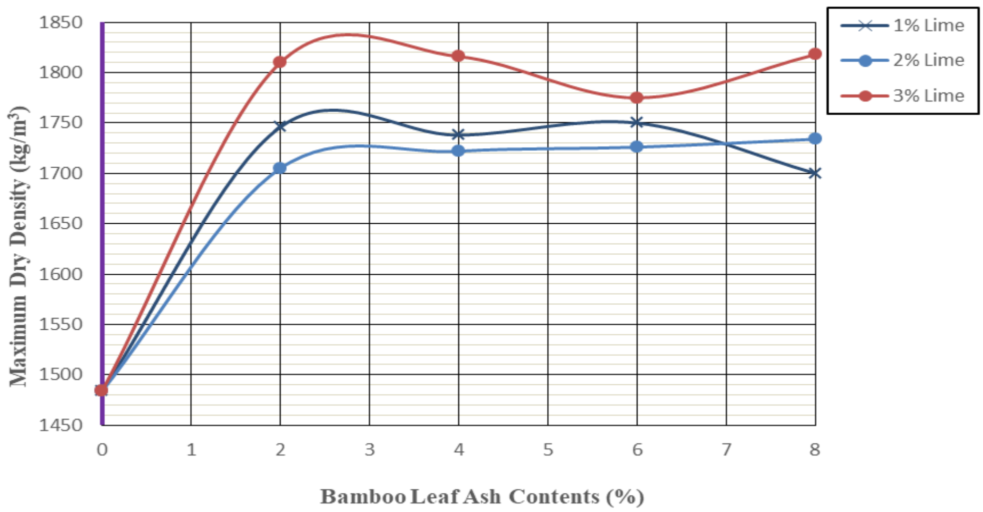

Figure 5: Variation of MDD with lime-BLA content for WAS Compactive effort

With the rise in lime-BLA content, the OMC of the soil sample decreased significantly. For WAS effort, the optimum moisture content decreases from 16.80% at 0% to 11.40% at 2% lime 6% BLA. Figures 6 shows variation of optimum moisture content with the percentage of lime and BLA used. The decrease in OMC could be attributed to the fact that the addition of lime-BLA content to the soil reduces the water content. The decrease in OMC with an increase in lime-BLA content might also be as a result of the joint action of BLA and lime that led to the flocculation of clay particles. This reduction in the OMC values of the soil will help in its workability because the lesser the optimum moisture content, the better its workability (Liu et al, 2003).

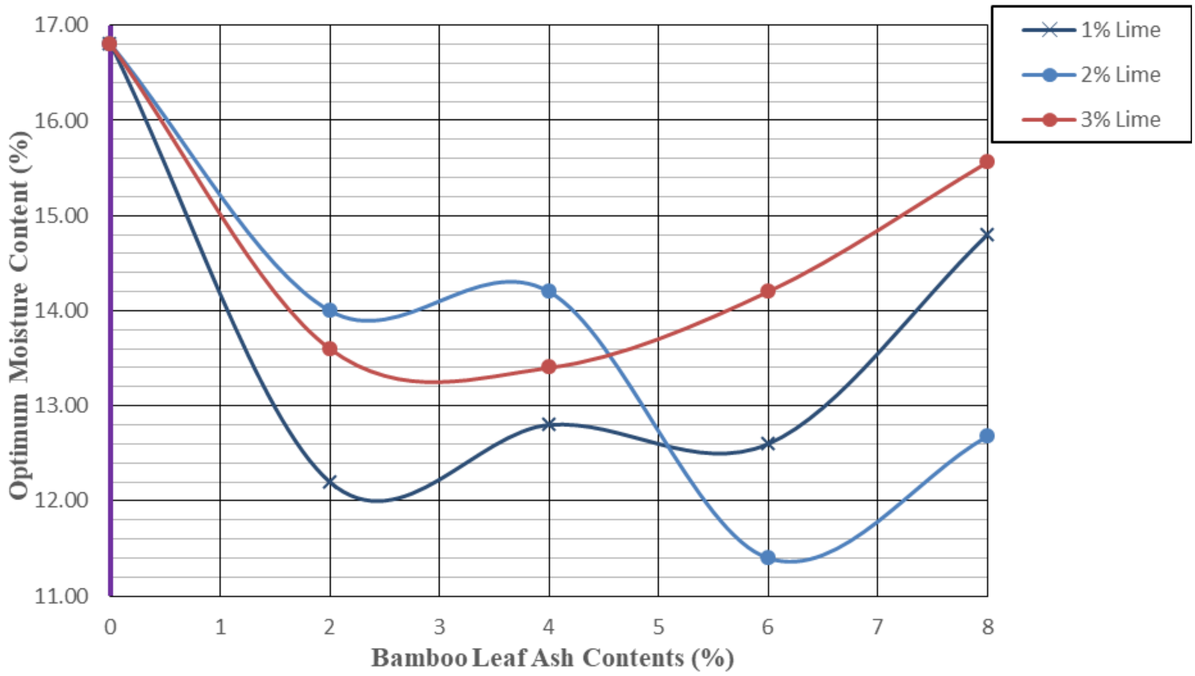

Figure 6: Variation of OMC with lime-BLA content for WAS Compactive effort

From the study, the following conclusions were drawn:

(1) Under general classification, the soil falls within silt-clay materials and can be classified as an A-7-5(6) and MH soil by AASHTO and the Unified Soil Classification structure respectively.

(2) The BLA is a pozzolan and it belongs to class F pozzolana

(3) Lime and BLA improved the qualities of the soil samples by reducing its plastic index (PI) appreciably, and this decline in PI is a sign that the soil enhanced.

(3) The Maximum dry density values increased considerably for all the trials while the Optimum moisture contents values also reduced.

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