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Influence of admixture of Bamboo leaf ash and lime on the Compaction characteristics of lateritic soil

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Abstract

This study investigated the impact of compactive efforts 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. Compaction tests (using British Standard Light (BSL), British Standard Heavy (BSH) and West Africa Standard (WAS) compactive efforts) were performed on the sample in both natural and stabilized states by incorporating 2, 4, 6 and 8% Bamboo Leaf Ash mixed together with 1, 2, and 3% lime by weight of soil sample. Maximum dry density (MDD) increased to 1766 kg/m^3 at 3% lime and 6% BLA, 1818 kg/m^3 at 3% lime and 8% BLA and 1866 kg/m^3 at 3% lime and 2% BLA while the optimum moisture content decreased to 12.70% at 3% and lime 8% BLA, 11.40% at 2% lime 6% BLA and 11.12% at 3% lime and 2% BLA for BSL, WAS and BSH, respectively. 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, Compactive efforts, Lateritic soil, Lime, Stabilization.

Introduction

Laterite is a soil and rock type rich in iron and aluminium and occur largely in sultry and temperate areas with hot and moist climate conditions. Lateritic soil consists of high plastic clay which can cause pavements, highways, building foundations, hydraulic structures or any civil engineering work to weaken and damage (Fitsum, 2018). Lateritic soil typically has low bearing ability and low strength due to the high content of clay in its original 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, thus the need for stabilization (Bello et al., 2015). In improving or stabilizing weak soils (instead of providing alternative soils that may prove financially unwise) in order to fulfil the demands of geotechnical engineering, more attention needs to be paid to the use of potentially cost-effective materials locally accessible from industrial and agricultural waste to improve the properties of deficient soils. The possibility of blending natural lateritic soil with certain chemical additives improves its engineering properties, both in terms of impermeable and strength, and further 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 to the health risks that they pose (Asha *et al*., 2014).

Laterites are weathering products produced on a variety of rocks that contain a high amount of iron content that may be igneous, sedimentary or metamorphic in origin. It has been observed that high seasonal precipitation, high temperature, extreme leaching, heavy oxidizing climate, subdued topography, long weathering period and chemically unstable parent rock may be the optimum conditions relevant in the formation of laterites. He also noted that the adequate supply of iron sesquioxide that may come from the underlying parent material or from an adjacent region of higher topography is important in the formation process. High water content and high temperatures induce extreme chemical weathering that generates residual soils that are well formed (De Vallejo and Ferrer, 2012).

Bamboo is also one of the earliest construction materials used by human beings. It has been widely used for household products and has been applied to engineering settings due to advances in manufacturing technology and increased market demand. In addition, several positive features of modern building materials found in it have increased the interest of engineers and architects in using bamboo as an engineering material (Hailu, 2011). 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 600 ^{0}C 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 and was sieved through sieve No 200.

Methods

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, British Standard Light (BSL), West Africa Standard (WAS), and British Standard Heavy (BSH) were adopted for this research.

The BSL compactive effort is the conventional energy level which involves using a cylindrical metal mould (Proctor mould) of about 1000cm^3 and a rammer of 2.5kg. The soil was compacted inside the mould by separating it to 3 layers and 27 blows was applied to each layer using 2.5kg rammer falling from a height of 300mm.

BSH compactive effort is the conventional energy level which involves using a cylindrical metal mould (Proctor mould) of about 1000cm^3 and a rammer of 4.5kg. The soil was compacted inside the mould by separating it to 5 layers and 27 blows was applied to each layer using 4.5kg rammer falling from a height of 450mm.

WAS compactive effort is the conventional energy level which involves using a cylindrical metal mould of about 1000cm^3 and a rammer of 4.5kg. The soil was compacted inside the mould by separating it to 5 layers and 10 blows was 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 were used for each 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

Index Properties Test

Table 1 shows the properties of the soil while Figure 1 shows the particle distribution curve.

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.

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).

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 responsiveness to water and filled the entire gap present in the natural soil which is a sign of soil improvement.

Table 1: Properties of the natural 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)	1412(BSL), 1477(WAS), 1529(BSH)
Optimum moisture content (%)	19.40(BSL), 16.80(WAS) 14.77(BSH)
AASHTO classification	A–7–5 (6)
USCS classification	MH
Colour	Reddish brown

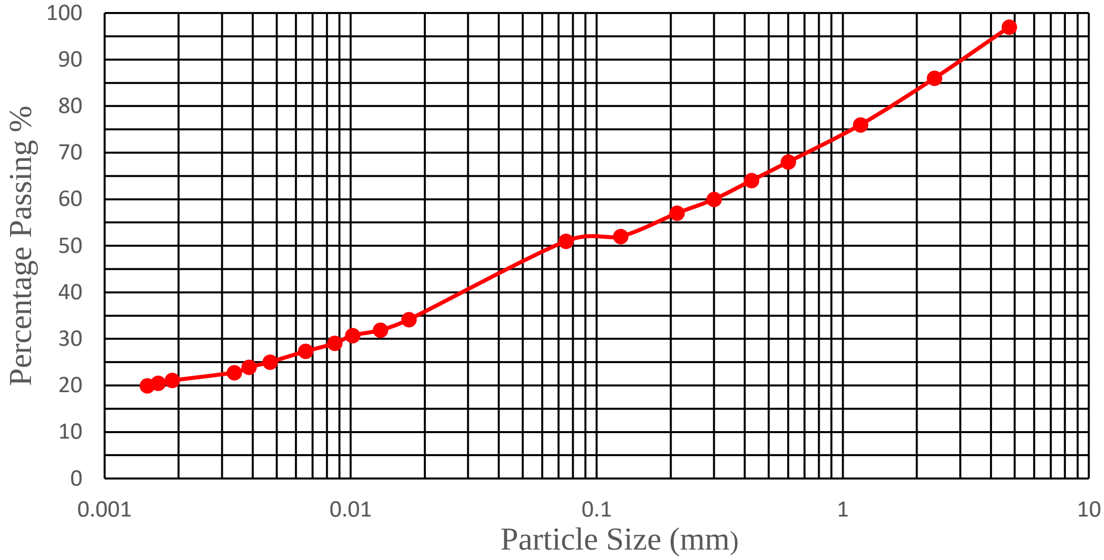

Figure 1: Particle size distribution curve for the Soil Sample.

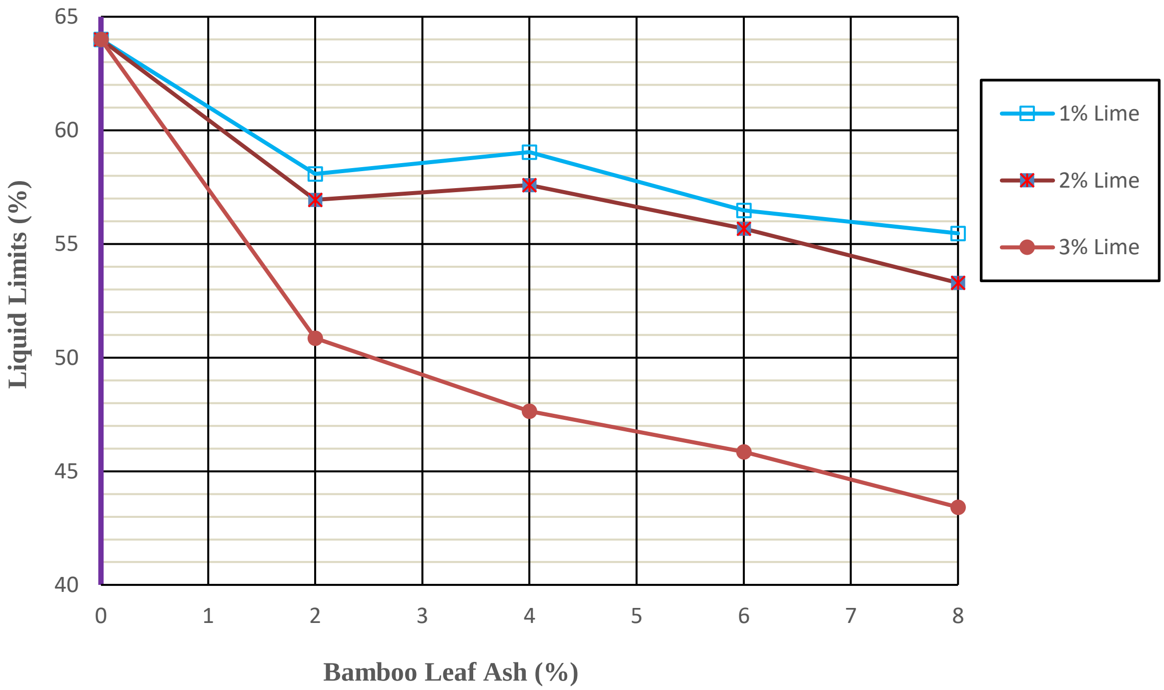

Figure 2: Variation of liquid limit with lime-BLA content

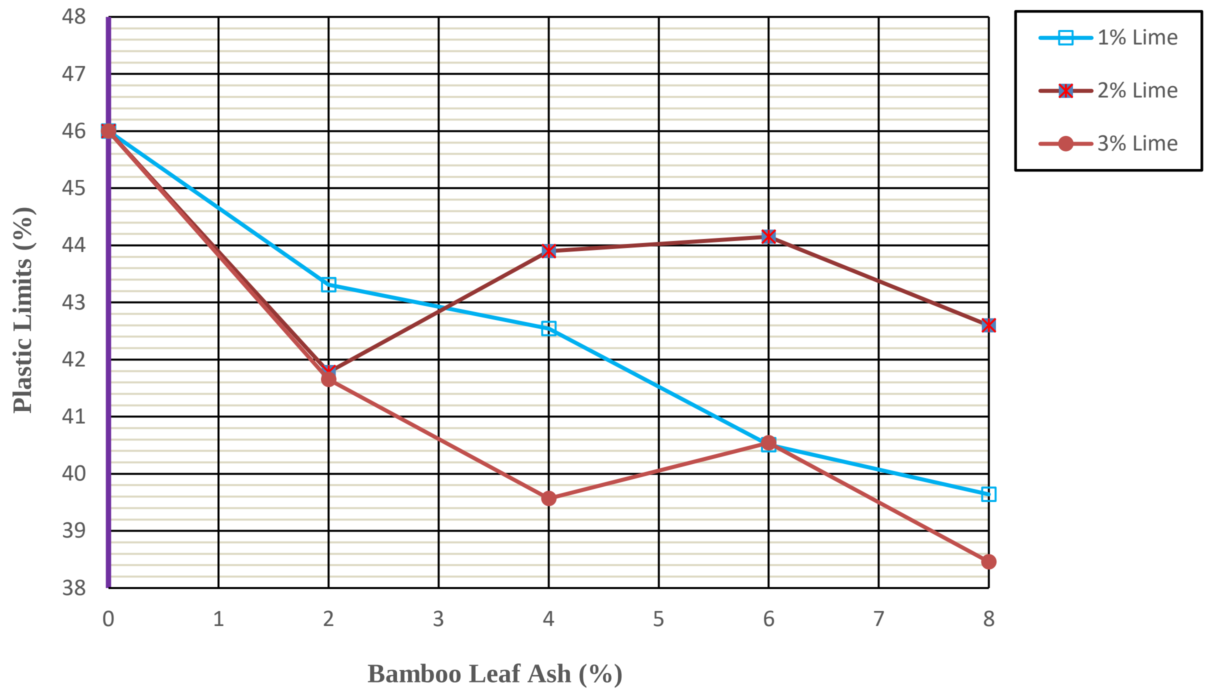

Figure 3: Variation of Plastic limit with lime-BLA content

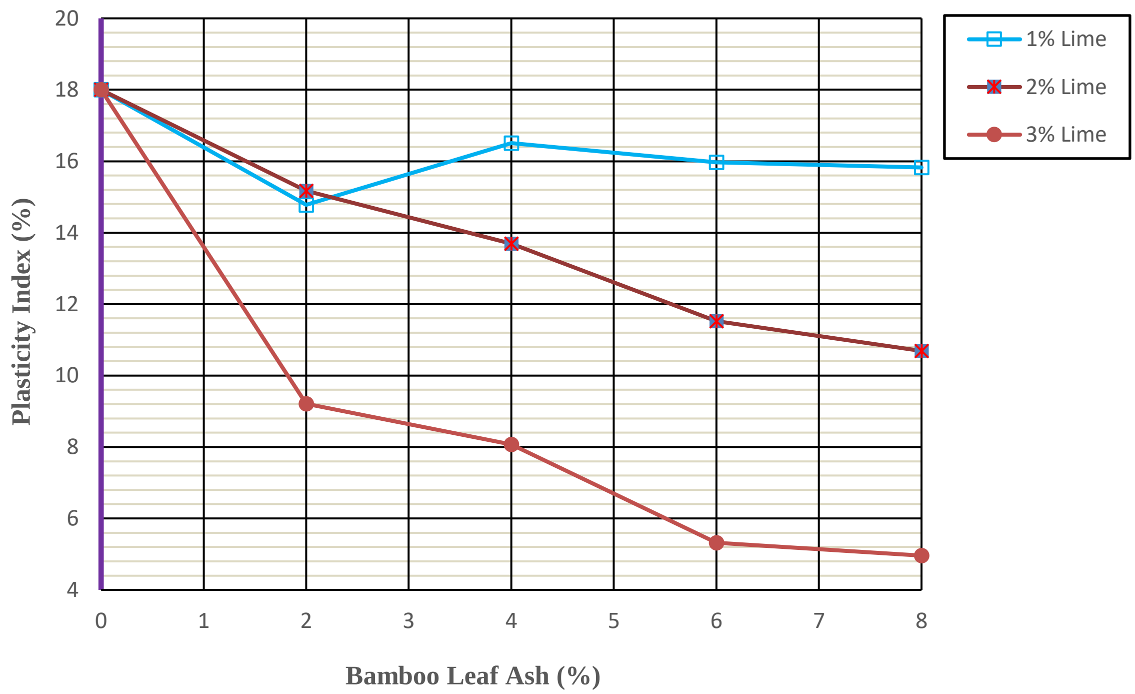

Figure 4: Variation of Plasticity index with lime-BLA content.

Compaction

The compaction was carried out using British standard light (BSL), West African standard compaction (WAS) and British standard heavy (BSH) compactive effort. In general, the maximum dry density (MDD) improved for each compactive energy with an increase in lime-BLA content. For British Standard Light effort, the MDD increased from a value of 1412 kg/m^3 at 0 percent to a peak value of 1766 kg/m^3 at 3 percent lime-6 percent BLA. Using West African Standard Compactive effort, the same trend was observed as that of BSL with an increase in MDD from 1477 kg/m3 at natural state of the soil to 1818 kg/m3 at 3% lime-8% BLA. With British standard heavy Compactive effort, the MDD increased from a value of 1529kg/m^3 at 0% to peak value of 1866 kg/m^3 at 3% lime-2% BLA but with momentous decrease to 1850, 1800 and 1822 kg/m^3 at 3% lime-4% BLA, 3% lime-6% BLA and 3% lime-8% in that order This also match to the work of (Adeyemo *et al*, 2019). Figure 5-7 shows the variation of maximum dry density with the percentage of lime and BLA for the three compactive energy. The decrease in the MDD value may be credited to the regular and increasing replacement of the soil with low specific gravity ash particles as the application of the BLA kept increasing in the mix, whereas 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.

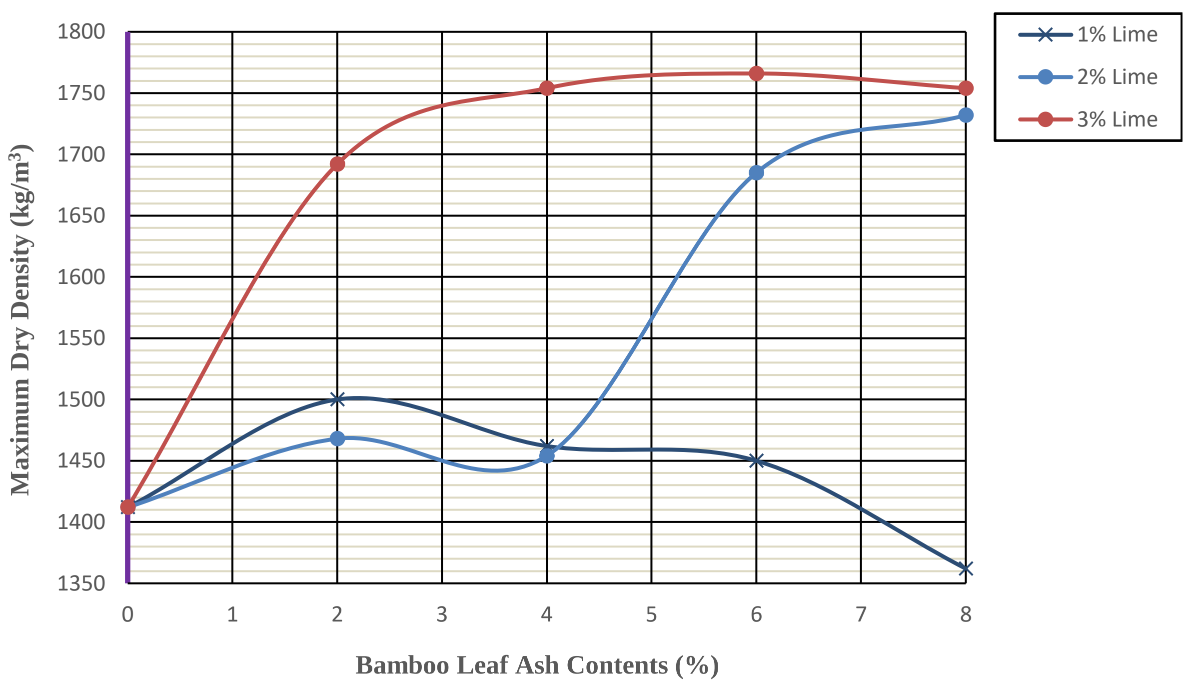

Figure 5: Variation of MDD with lime-BLA content for BSL Compactive effort

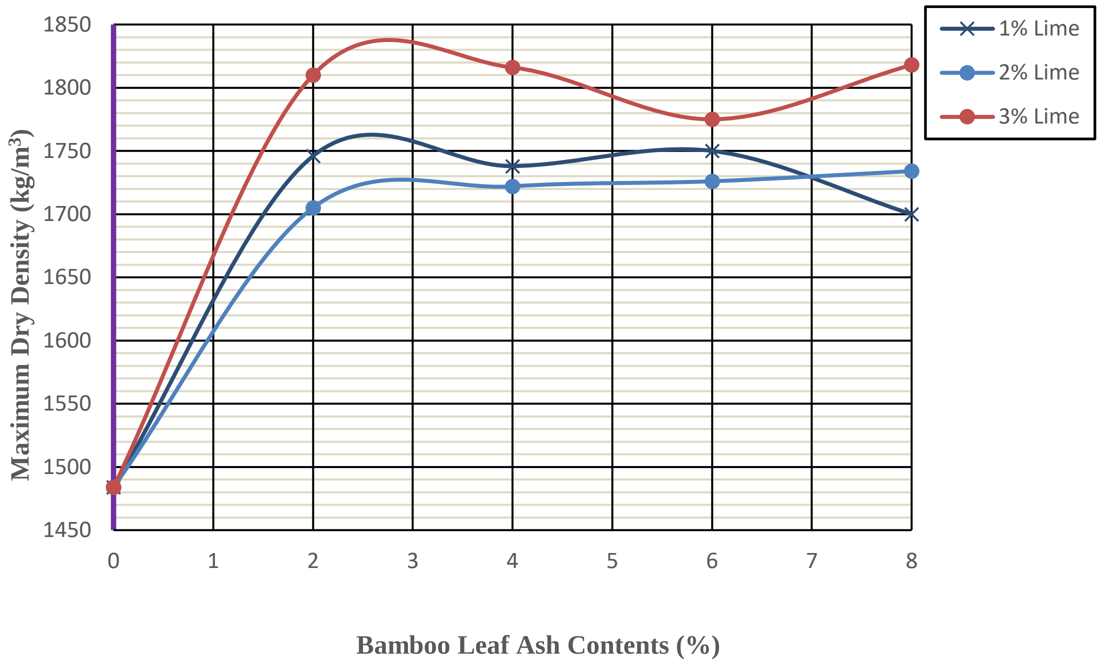

Figure 6: Variation of MDD with lime-BLA content for WAS Compactive effort

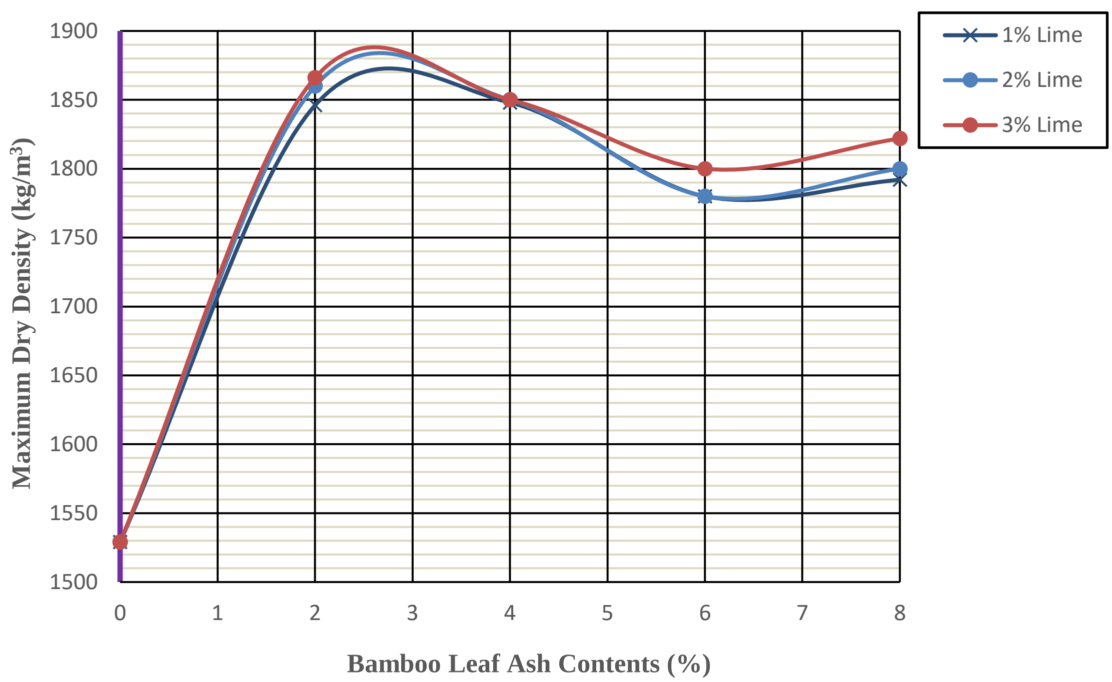

Figure 7: Variation of MDD with lime-BLA content for BSH Compactive effort

With the rise in lime-BLA content and the rise in compactive energies from BSL Compactive effort to WAS Compactive effort then to BSH effort, the OMC of the soil sample decreased significantly. For BSL effort, the optimum moisture content decreases from 19 percent at 0 percent to 13 percent at 3 percent lime-8 percent BLA. The OMC decreased from 17% at 0% to 11% at 2% lime 6% BLA, after which it began to steadily increase to a peak value of 16% at 3% lime 8% BLA for WAS. The OMC reduced from 15% at natural state to 11% at 2% lime 6% BLA mix for BSH Compactive effort. Figures 8-10 shows variation of optimum moisture content with the percentage of lime and BLA for the three compactive energies.

The decrease in OMC could be attributed to the fact that the addition of lime-BLA content to the soil reduces the draw to 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).

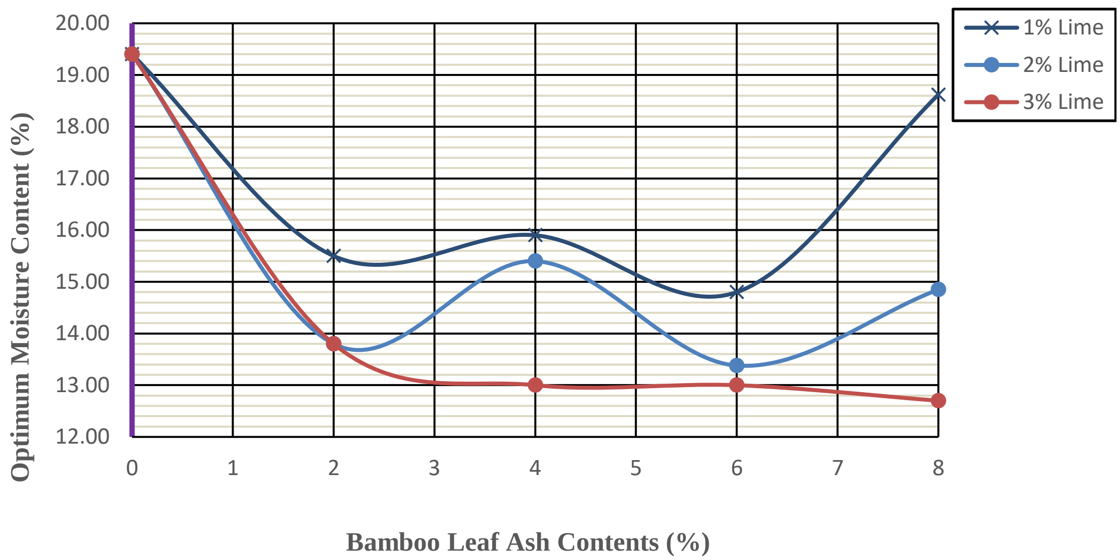

Figure 8: Variation of OMC with lime-BLA content for BSL Compactive effort

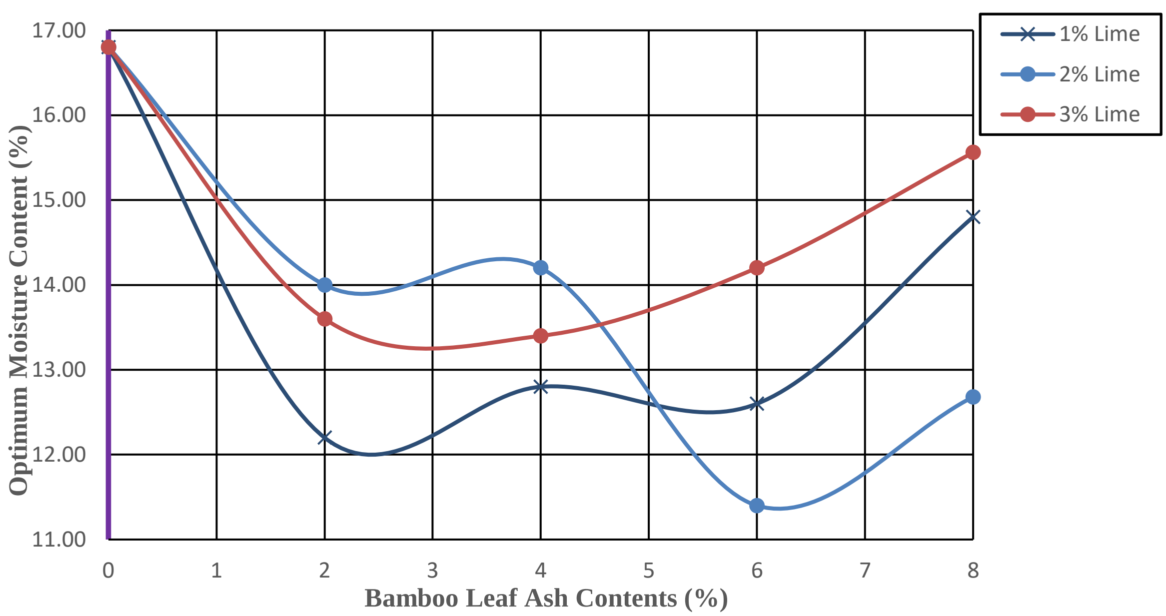

Figure 9: Variation of OMC with lime-BLA content for WAS Compactive effort

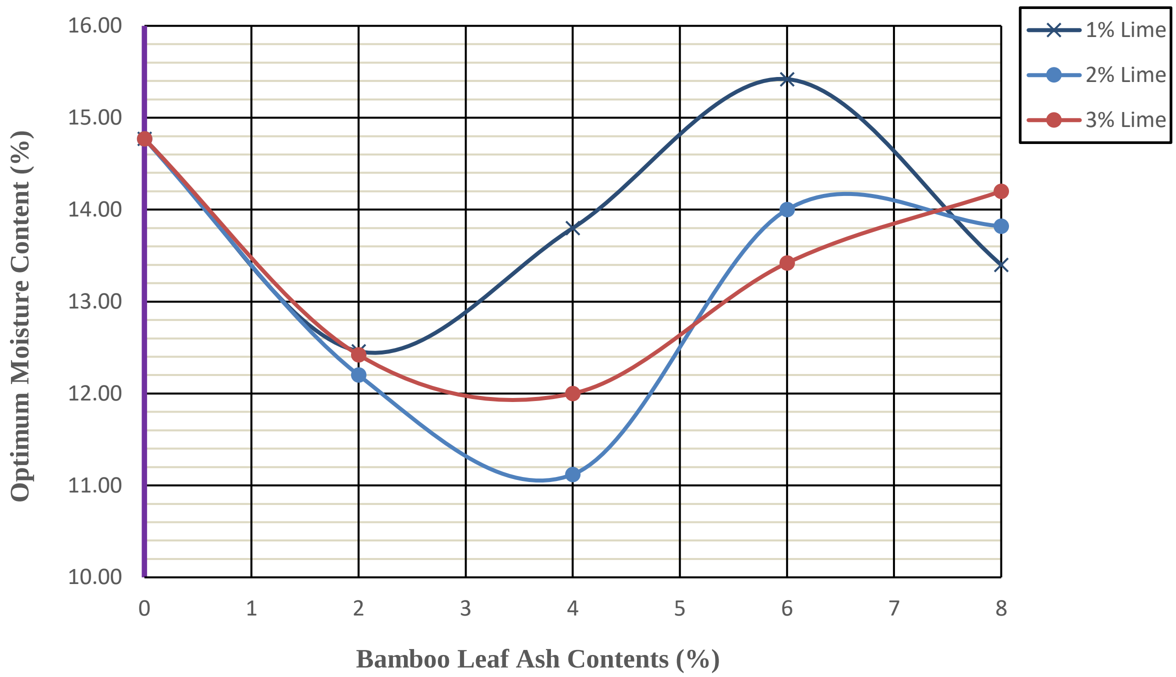

Figure 10: Variation of OMC with lime-BLA content for BSH Compactive effort

Conclusion

From the study, the following conclusions were drawn:

i. 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.
ii. 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.
iii. The Maximum dry density values increased considerably for all the three compactive efforts while the Optimum moisture contents values also reduced.

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