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Bamboo as Soil Reinforcement: A Laboratory Trial

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Abstract

A lateritic soil classified as A-6 under AASHTO soil classification system was reinforced with 0, 1, 2 and 3 bamboo specimens at laboratory trial level to evaluate its unconfined compressive strength (UCS) and modulus of rigidity. The soil specimens were molded in cylindrical form of 38mm diameter and 76mm height while the bamboo specimens were trimmed in to circular plates of 34mm diameter and 3mm thickness. The trial soil specimens are: soil specimen without bamboo specimen (0 bamboo), soil specimen with one bamboo specimen in the center (1 bamboo), soil specimen with one bamboo specimen on top and one at the bottom (2 bamboos) and soil specimen with one bamboo specimen on top, center and bottom (3 bamboos). Though, the dry density of the molded soil specimen decreased from 1.638Mg/m^3 at 0 bamboo to 1.470Mg/m^2 at 3 bamboos, the UCS increased from 226KN/m^2 at 0 bamboo to 621KN/m^2 at 3 bamboos. Also, for each of the 3 percentage strains (0.5, 1.0 and 1.5%) considered, the modulus of rigidity increased with bamboo specimens.

Keywords

Bamboo; Modulus of rigidity; Optimum moisture content; Friction.

Introduction

Since when [1], first developed the reinforcing technic to a stage where it can be economically applied to large soil structure, majority of the authors; [2], [3], [4], [5], and [6] concentrated on retaining structures. According to [7], reinforced earth can be defined as a construction material composed primarily of soil whose performance has been improved by the introduction of small quantities of other materials in the form of solid plates or fibers or fibrous membranes to resist tensile forces and interact with soil through friction and/or adhesion.

However, all the above mentioned materials employed as reinforcement in soils are presently expensive and would require a cheaper and abundant material with similar strength and durability to that of steel reinforcement. Bamboo, a perennial grass, belonging to the class monocotyledoneae, exists abundantly in tropical, subtropical and temperate zones of the world and have been mentioned by [8] as a potential material for reinforced earth. According to [9], more than 10 million tones of bamboo are produced annually with most coming from Asia. Studies have shown that bamboo posses high tensile and compressive strength and have been used as reinforcement in concrete especially when the specie is properly seasoned and have lasted more than 3 years [10], [11] and [12].

The aim of this work therefore is to carry out a laboratory trial on the use of cheap and abundant bamboo as a material for soil reinforcement.

Materials

Soil

The soil used in this study was a lateritic soil collected along Sarkin pawa-Kaduna road using the method of disturbed sampling. According to [13], the soil in this area belongs to Ferruginous tropical soil derived from acid igneous and metamorphic rocks. The soil was then air dried and pulverized appropriately.

Bamboo

The bamboo used for this study was collected from Pelemi, in Lapai Local

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Government, Niger State, Nigeria. This area lies between longitude 6°E and 7°E and latitude 9^0N and 10^0N. The area is drained by several rivers which are tributaries of River Niger. The rainfall in this area varies from 1000 to 1500mm per annum.

The bamboo specimens were cutted and trimmed into a circular plate of 34mm diameter and 3mm thickness. The smooth surface of the bamboo specimens was roughened to increase the friction between the specimen and the soil. The sketch of a bamboo specimen is shown in figure 1: below:

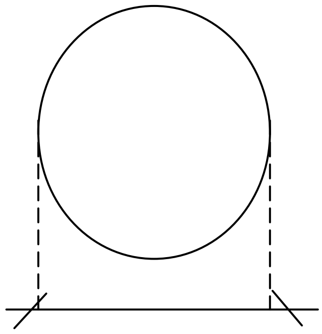

Figure 1. Bamboo specimen

Methodology

Tests including liquid limit, plastic limit, washed sieve, analysis, hydrometer analysis and specific gravity were performed on the air dried soil. Compaction test was also carried out on the soil to determine its optimum moisture content (OMC) and maximum dry density (MDD). All these tests were conducted according to procedures highlighted in [14] with modifications where necessary.

Unconfined compressive strength (UCS) specimens were molded in a triaxial compressive strength mould of diameter 38mm and height of 76mm. The specimens were prepared in four forms as shown in figure 2 below. These are soil specimen without bamboo specimen (0 bamboo), soil specimen with one bamboo specimen in the centre (1 bamboo), soil specimen with bamboo specimen on top and bottom (2 bamboos) and soil specimen with bamboo specimens on the top, centre and bottom (3 bamboos).

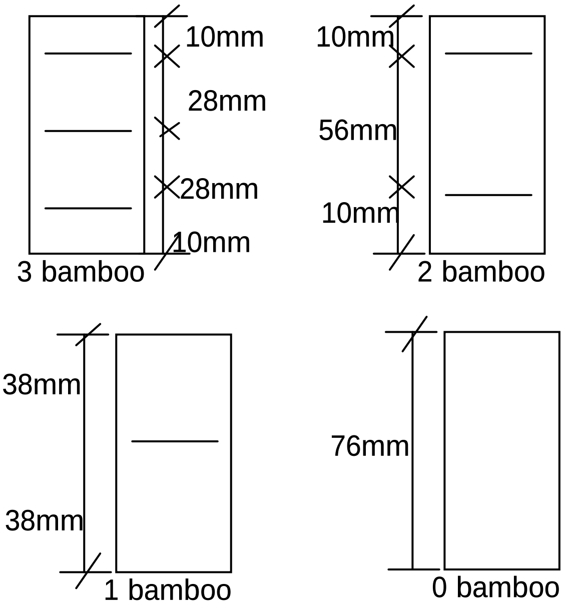

Figure 2. Soil specimens with 0, 1, 2 and 3 bamboo specimens

In all these tests, the bamboo specimen was placed horizontally in the layers. The same compaction effort was applied to all the four forms of soil-bamboo specimen system. During compaction, the bulk density and molding moisture contents were determined. The UCS test was then conducted on the four different soil-bamboo specimens and its failure stresses as well as the stress-strain relationship of each of the specimen systems determined.

Results and Discussion

The results of the index properties and grain size analysis are shown below in table 1 and figure 3 respectively.

Table 1. Index properties of the soil

Description	SG	LL(%)	PL(%)	PI(%)	MDD(KG/M^3)	OMC(%)	AASHTO
Values	2.58	30	25	5	1880	15.5	A-6

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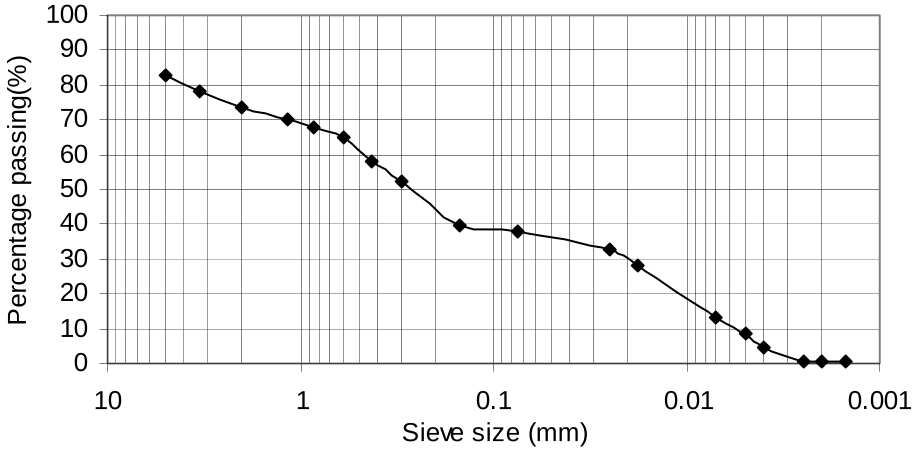

***Figure 3**. Particle size distribution for the sample*

The results of the grain size distribution and other index properties above showed that the soil classified under A-6 sub-group according to AASHTO soil classification system.

Dry Densities

The maximum dry density (MDD) and optimum moisture content (OMC) of the soil compacted at West African compaction energy level (WAS) is 1.88Mg/m^3 and 15.5% respectively. The variation of the molded dry densities for UCS specimens is shown in figure 4 below. The value of the molded dry densities decreased from 1.638Mg/m^3 at 0 bamboo specimens to 1.470Mg/m^3 at 3 bamboo specimens. This is probably due to low specific gravity bamboo that substitutes a high specific gravity soil sample.

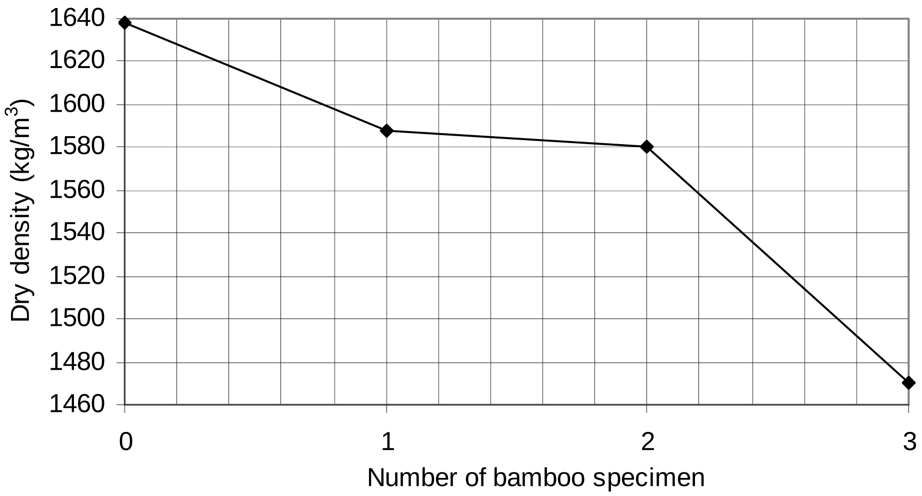

***Figure 4**. Change in dry density with number of bamboo specimen*

Unconfined compressive strength (UCS)

The UCS increased with increase in the number of bamboo specimens as shown in figure 5 below. The value increased from 226KN/m^2 at 0 bamboos to 621kN/m^2 at 3 bamboo specimens. This is probably due to the friction between the soil sample and the rough surface of the bamboo specimen.

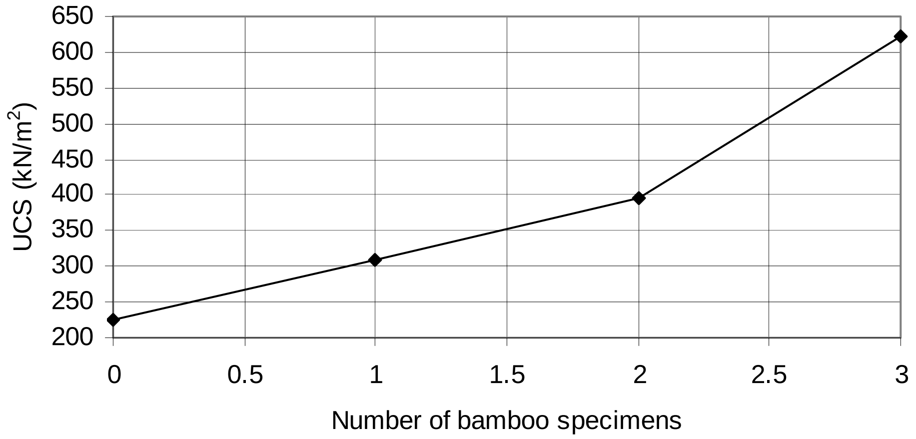

Figure 5*. Variation of UCS with the number of bamboo specimens*

Modulus of Rigidity

The stress - strain relationship for each of the molded specimens and variation of the modulus of rigidity at 0.5, 1.0 and 1.5% with the number of bamboo specimens are shown on figures 6 and 7 respectively, below. The trend of modulus of rigidity with percentage strain is erratic in nature. While modulus of rigidity of some soil-bamboo specimen decreases with increase in percentage strain, others increase in like order. At 0 bamboo specimen, the value decreased from 11,666KN/m^2 at 0.5% to 5000KN/m^2 at 1.5% while at 2 bamboo specimen, the value decreased from 23,448KN/m^2 at 0.5% to 8,928KN/m^2 at 1.5%. However, the trend for 1 and 3 bamboo specimens are different. At 1 bamboo specimen, the modulus of rigidity increased from 6,666kN/m^2 at 0.5% to 8,333KN/m^2 at 1.5% while the value increased from 15000KN/m^2 at 0.5% strain to 21428kN/m^2 at 1.5% for 3 bamboo specimens. Generally, the modulus of rigidity values increased with increase in the number of bamboo specimens.

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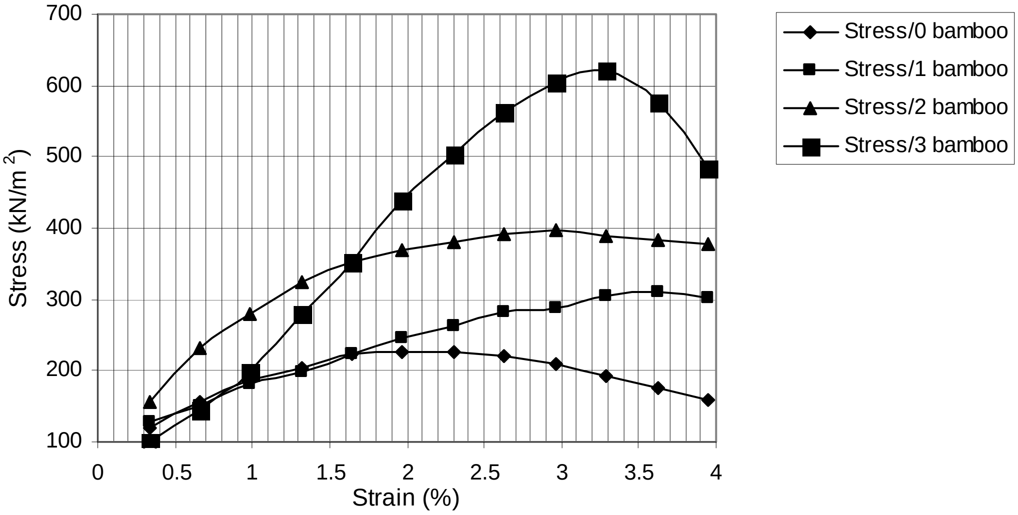

Figure 6. *Stress-strain relationship for specimens at 0, 1, 2, and 3 bamboo specimens*

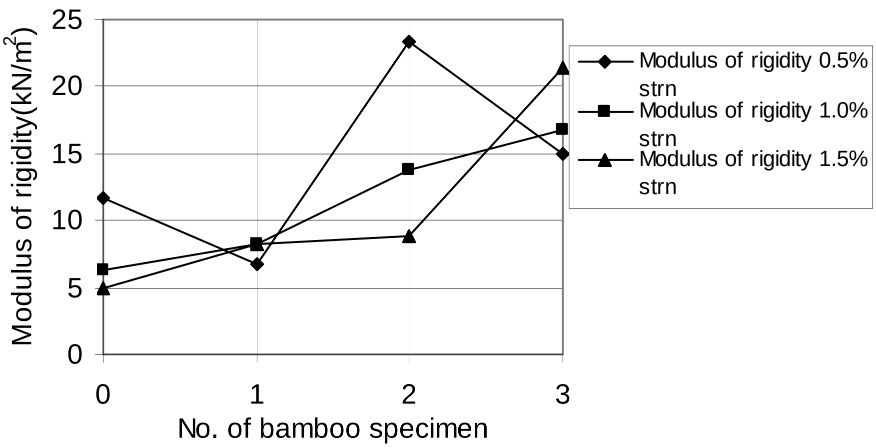

Figure 7. *Variation of modulus of rigidity with No. of Bamboo specimen*

This trend is in agreement with [7] and is due to friction between the soil and the rough surface of bamboo specimen.

Conclusions

In conclusion, it was observed that while the dry density of the molded specimens decreased with the number of bamboo specimens, the UCS and the modulus of rigidity increased with increase in the number of bamboo specimens. While the dry density of the molded specimens decreased from 1.638Mg/m^3 at 0 bamboos to 1.470Mg/m^3 at 3 bamboo specimens, the UCS increased from 226kN/m^2 at 3 bamboo specimens. Similarly, the modulus of rigidity also increased with increase in the number of bamboo specimens for each of the percentage strains considered. At 1.5%, the modulus of rigidity increased from 5000KN/m^2 at 0 bamboos to 21,428kN/m^2 at 3 bamboo specimens.

Recommended Area of Further Study

i. Employing statistical analysis to determine an empirical relationship between bamboo specimens, the spacing of the bamboo specimens and UCS values.
ii. The use of bituminous material on the smooth surface of bamboo specimen to mobilize shear strength.
iii. A prototype study of the potentials of bamboo as soil reinforcement.

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