Geotechnical Properties of Flax Fiber Stabilized Soil

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Abstract: Engineers are often faced with the challenge of constructing with or on soils with poor strength that could pose challenges during the construction phase and service life of the facility. For better results, the geotechnical properties of the soil have to be improved. This study focused on the effect of flax fiber on the geotechnical properties of the soil. The soil samples were obtained from borrow pits within the University of Ibadan, Ibadan, Nigeria. The geotechnical properties CBR (California Bearing Ratio) and UCS (Unconfined Compressive Strength) of the natural soils among others were determined in accordance with BS 1377. Flax fibers of 0.3%, 0.6%, 0.9%, 1.2%, and 1.5% by weight were added to the subsoil. The mixtures geotechnical properties were measured. The results showed that the addition of flax fiber led to increase in the soil CBR from 3.1% to 15% and also its UCS witnessed tremendous increase. The soil maximum CBR and UCS were attained at optimum flax fiber content of 1.2%.

Key words: Soil stabilization, flax fiber, CBR, UCS.

1. Introduction

Earth has been used as a construction material for thousands of years, in its most primitive form dated back to the hunter-gatherer period where humans lived a migratory life and often constructed temporary, seasonal shelters from brush and wooden members which they then covered with mud [1]. Not much has changed today as man still relies on the soil heavily particularly for infrastructure and transport facilities as most facilities are built on the soil.

In most geotechnical engineering projects, it is not possible to obtain a construction site that will meet the design requirements without ground modification. The current practice is to modify the engineering properties of the native problematic soils to meet the design specifications [2]. Common flax was one of the first crops domesticated by man. Flax was thought to have originated in the Mediterranean region of Europe; the Swiss Lake Dwelling People of the Stone Age apparently produced flax, utilizing the fiber as well as the seed. Linen cloth made from flax was used to wrap the mummies in the early Egyptian tombs. In the United States, the early colonists grew small fields of flax for home use, and commercial production of fiber flax began in 1753. However, with the invention of the cotton gin in 1793, flax production began to decline [3].

Fiber from the New Zealand flax plant was used by Ref. [1] to reinforce soil-cement composites in an attempt to improve the strength and ductility of the composite material. Fiber lengths of 70 and 85 mm were investigated along with fiber content levels of 0.6% and 0.8% measured as a percentage of the dry mass of the soil in the composite. Significant improvement in the ductility of the soil-cement composite was realized with the addition of the flax fiber. An optimum fiber content of 0.6% and fiber length of 85 mm were achieved.

Ref. [4] used different fiber lengths (5-20 mm) of jute fibers in different percentages (0.2-1.0%) to reinforce soil. Bitumen was used for coating fibers to protect them from microbial attack and degradation. They concluded that jute fibers reduced the soil MDD (maximum dry density) and also its OMC (optimum moisture content). Maximum soil CBR (California Bearing Ratio) values were obtained with 10 mm long and 0.8% jute fibers, an increase of more than 2.5 times of the normal soil CBR value. Over the years, a lot of research has been carried out on fiber stabilized
soils. In Ref. [5] mixed polyester fibers of 12 mm in length with highly compressible clayey soil by varying fiber weight from 0% to 1% by weight. The results indicated that reinforcement of highly compressible clayey soil with randomly distributed fibers increased the soil ultimate bearing capacity and decreased its settlement capacity under ultimate load. Also the soil bearing capacity and the SBP (safe bearing pressure) increased with increasing in fiber content up to 0.50%.

Ref. [6] focused on the effects of flax fiber content, mix design and processing on the hardened soil properties (density, fiber orientation, surface quality, compressive and tensile strength). Effects of fiber addition on the mechanical performance of cast and extruded flax fiber reinforced composites were compared. It was noted that the addition of flax fiber had no significant effect on the compressive strength and for an aspect ratio that ranges between 133 and 300, it has been shown that 1% of fiber by volume of the dry soil results in significant enhancement in tensile behavior and above 2 % of fiber is detrimental. Soil reinforcement by fiber material is considered an effective ground modification method because of its cost effectiveness, easy adaptability and reproduction [7]. Fiber reinforced soil is a soil mass that contains randomly distributed fibers which provide an improvement in the mechanical behavior of the subsoil soil. Absence of weak plane is a foremost advantage of fiber reinforcement. Randomly distributed fibers provide interlocking and friction resistance to resist the movement of soil particles, which considerably increase soil load carrying capacity [8]. Even though many works on flax fibers applications are in literature, but with few on its impact on soil CBR and UCS. Consequently, the research focused on investigating the effect flax fiber on soil CBR and UCS.

2. Materials

Subsoil samples were excavated at depths of 1 m below the ground surface from two places in the University of Ibadan. They were air-dried, labelled and stockpiled for laboratory experiment. Soil sample A got from the Faculty of Technology and soil sample B obtained from the Abadina area. Each of the collected was divided into six portions. Flax fibers were procured from one of the major market in Ibadan Nigeria. The fiber length adopted was recommended by Ref. [9]. The procured flax fiber (Fig. 1) was cut into 85 mm strips. The flax fiber diameter was measured with caliper to be 0.31 mm.

Each portion of the soil was mixed with single dosage of flax fiber by weight. Altogether, six dosages of the fiber (0%, 0.3%, 0.6%, 0.9%, 1.2% and 1.6%) were applied to the six soil portions with the portion that received 0% flax fiber served as control soil. The laboratory tests carried out on all the soil portions were Atterberg limit tests, grain size analysis, compaction test, CBR and UCS tests. The tests were carried out in accordance with Ref. [7]. The Atterberg limit and grained size analysis were used for soil

Fig. 1  Flax fiber.
identification in line with the USCS (Unified Soil Classification System) and the America Association of State Highway and Transport Officials (AASHTO).

The compaction test was embarked upon to determine the soil MDD and the corresponding OMC. These values were used for the preparation of samples for CBR and UCS tests.

3. Results and Discussion

The two soils A and B were classified in accordance with the USCS and the AASHTO system. The parameters used were the soil’s particle size analysis result (Figs. 2 and 3), LL (liquid limit) and PL (plastic limit) values. The soil A LL and PL were 35% and 27.5% respectively. On the other hand, soil B LL and PL were 48% and 37.1%, respectively. Using the USCS classification system, soil A was SW (well graded sand), containing a little portion of gravel, with AASHTO classification A-2-4 (0). Soil B was SW, containing a little portion of gravel, with AASHTO classification A-2-7 (0).

The results of the compaction test were presented in Figs. 4 and 5. The MDD and OMC values decreased as the percentages of the fiber added to the soils increased. The development was attributed to increase in the water absorption rate of the fiber and increase in the voids caused by the fiber present.

The CBR results for the soils are shown in Figs. 6 and 7. The CBR values of the soils with flax fiber inclusion were noticed to have increased with increasing fiber content compared to the CBR value of the natural soil while soil B CBR attained peak value very close to 1.2% fiber addition. The findings were in agreement with Ref. [4] which recorded an increase in the CBR value of jute fiber reinforced soil. CBR is a measure of soil ability to resist penetration of the cone plunger. Where the bonds among particles and internal friction are strong enough, large magnitude of forces would be required to cause penetration for CBR measurement to take place. Usually, the plunger causes the soil particles to rearrange in the soil mass allowing penetration of the plunger. In the presence of flax fiber holds the soil particles together to increase both the bonds among particles and also their internal fiction.

Fig. 2 Grading curve for soil A.
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Fig. 3  Grading curve for soil B.

Fig. 4  OMC results for the two soils.
Fig. 5  MDD results for the two soils.

Fig. 6  The CBR values of soil A at different fiber contents.
Fig. 7  The CBR of soil B at different fiber contents.

Fig. 8  The UCS values of the soil B at different fiber contents.
The UCS results are shown in Figs. 8 and 9. The UCS value is a measure of the soil’s strength which is controlled by existing bonds among particles and internal particle friction. Soil A showed an improvement of 490%, while subsoil B showed an unconfined of 424%. The results were similar to those of Ref. [10] that reported an increase in the unconfined strength of the soil when stabilized with coir fiber.

4. Conclusion

The geotechnical properties of the two natural subsoils were determined, those of the soils with different flax fiber content were also determined. The results were analyzed and compared. The inclusion of flax fiber led to improvement in the soil CBR and UCS. Therefore, flax fiber is a potential fiber for soil reinforcement with 1.2% optimum.

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