Compressibility characteristics of coconut fiber reinforced lateritic subgrade soil

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ABSTRACT: Weak lateritic subgrades are commonly encountered during rural road construction in Ghana. This makes it necessary to find economically efficient ways to improve the engineering properties of these marginal lateritic soils. The objective of this study was to evaluate the influence of coconut fiber on the compressibility characteristics of fiber reinforced marginal lateritic soil for low volume roads. The lateritic subgrade soil was reinforced with short randomly distributed coconut fibers as percentage (0-1% at an increment of 0.2%) of dry weight of soil with 30mm and 60mm fiber lengths. The composite mixes were subjected to the oedometer tests according to ASTM D2435-96 to investigate the compressibility characteristics of fiber-reinforced soil. The compression index, recompression index and coefficient of volume change were found to decrease with inclusion of fibers. On the other hand, the coefficient of consolidation increases with increase in fiber content irrespective of the fiber length with predicted linear equation as $C_v = 0.56 + 1.36FC$. From these consolidation parameters, the inclusion of fibers to the soil proved to be very effective.

1 INTRODUCTION

Low volume roads play a major role in the socio-economic development of rural communities. However, they carry low volumes of traffic and are normally designed and built to lower standards. In Ghana, lateritic soils are the most abundant naturally occurring materials used for the construction of roads. Most lateritic soils available for road construction usually have high fines content thus making them unsuitable for road pavement construction. Under such circumstances the road engineer may improve the problem soils through stabilization. Lime and cement have been reported to be good traditional stabilizers in improving poor lateritic soils (Lyon, 1971). In certain parts of the country, however, coconut plantations abound and these generate large quantities of coconut fiber as waste. A companion paper has reported on the effect of coconut fiber reinforcement on the strength of lateritic soil. This study reports on the effect of reinforcing with different percentages of coconut fiber ranging from 0.2% to 1% and of length of 30mm and 60mm on the compressibility characteristics of the lateritic soil. The presence of these randomly oriented coconut fibers in the pavement foundation layer may reduce the drainage path during consolidation process. Samples of lateritic soil were reinforced with various percentage of coconut fiber and subjected to one dimensional consolidation test in the oedometer test. The results are analysed and reported.

2 MATERIALS AND METHOD

The lateritic soil was obtained from KNUST campus at geographical coordinates 6.67209N and 1.56575W. Dry soil was mixed with known percentage of fiber at 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% having specified lengths of 30mm and 60mm respectively. The compaction tests were performed using Modified AASHTO standards (ASTM D 1557-91) after which each test specimen was prepared at the optimum moisture content. The consolidation properties of the fiber-reinforced soil were determined by conducting one dimensional consolidation test in accordance with ASTM D 2435-96. The conventional oedometer test apparatus with standard consolidation ring of 72mm diameter and 20mm height was used. Readings were taken before and after placement of each load where the load increment ratio was 1:1 and kept for 24 hours. The void ratio for each load increase was evaluated and the pressure void ratio variations were plotted to study the variations in compression index (C_c), recompression index (Cr), coefficient of volume change (M_v) and coefficient of consolidation (C_v) at pressure range of 200-400kPa.

3 RESULTS AND DISCUSSIONS

3 .1 *Lateritic Soil and Fibers*

The liquid limit and the plasticity index of the study soil were 51% and 27% respectively. The grading analysis gave 12% gravel, 42% sand, 23% silt and 23% clay. From these results, the material classifies as A-7-6 in the AASHTO classification system which puts it as a fair to poor material for subgrade of roads and also medium to high compressibility when compacted. The aspect ratios (l/d) of the fibers were 60 and 120 for the purpose of this study.

3.2 *Compressibility Characteristics*

Typical void ratio-pressure relationship curves for loading for soil mixed with 60mm fiber length are presented in Figure 1. As the fiber content increases there is an observed decrease in the initial void ratios. The void ratio at a pressure of 24.5kPa reduces from 1.341 for the unreinforced soil to 0.867 for 1% fiber content.

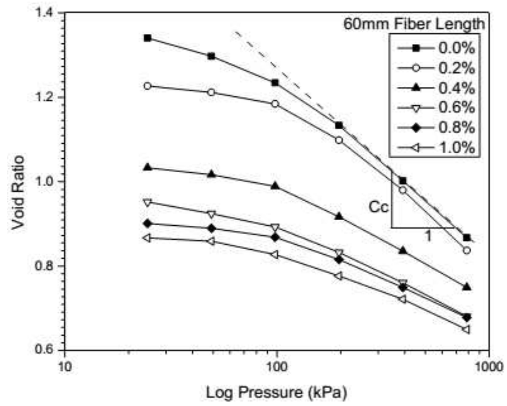

Figure 1. Void ratio - Pressure curve for coir fiber-reinforced soil

The compression index (C_c) obtained from the linear portions of the loading curve and the recompression index (C_r) obtained from the complete unloading portion are plotted against the fiber content in Figure 2. The C_c values show an initial relatively slow decrease with increasing fiber content, until a fiber content of about 0.2% beyond which the reduction becomes rapid until a fiber content of about 0.4%. After that the rate of reduction in C_c reduces until beyond a fiber content of about 0.6% there is insignificant change. It was also observed that this behavior was similar for both 30mm and 60mm length of fiber suggesting that the variation of C_c is independent of fiber length. At higher fiber content, because the overall volume occupied by the fiber in the soil matrix is relatively significant, it leads to more fiber-to-fiber interaction. Hence compression of the fiber in the mix is more dominant hence the reduction in compressibilility. Kar et. al, (2012) also reported a decrease in C_c values with increase in coir fiber inclusion in cohesive soil up to fiber content of 0.8% and increased thereafter. The C_r values exhibited similar behavior. The coefficient of volume change (M_v) also decreases with increase in fiber content (Figure 3) showing a trend similar to that exhibited by the compression index. The presence of more fiber increases the resistance of soil-fiber matrix to compression.

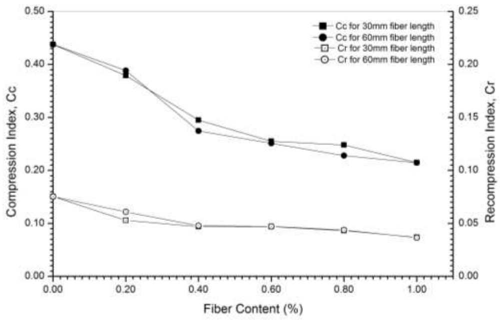

Figure 2. Variation of Compression and Recompression index with Fiber Content

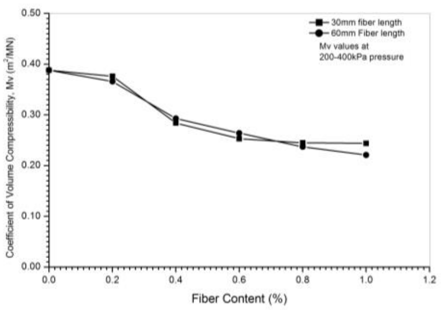

Figure 3. Variation of coefficient of volume change with Fiber Content

3.3 *Rate of Consolidation and Permeability*

The variation of the coefficient of consolidation (C_v) with increasing fiber content for the fiber-reinforced soil is shown in Figure 4. A linear relationship with high coefficient of regression values of 0.94 and 0.89 were obtained for the 30mm and 60mm fiber lengths respectively indicating very good linear fit. In fact a combined plot of all the results points for both 30mm and 60mm fiber length fiber lengths gave an equation of the C_v in terms of the fiber content FC as $C_v = 0.56 + 1.36FC$ with r^2 of 0.91.

The increase in C_v values irrespective of fiber length may be attributable to the fact that the drainage path becomes more accessible and continuous. The results of this study agrees with those by Kar et. al, (2012) who reported an increase in C_v values up to a fiber content of 1.0% which was the maximum fiber content investigated, and also with the results reported by Cyrus and Babu (2005) on Cochin marine clay reinforced with coir.

Most low volume roads have no water-proofing layer for surfacing. Therefore the reinforced layer needs to be made permeable to improve draining away of surface water. It was generally observed that the addition of fiber to the study soil slightly improves the permeability of the reinforced soil. The permeability of samples show a gradual increase as the fiber content increases which appears to be from the results of the increased *pipe network* in the sample formed by the fiber filaments. The permeability value of the unreinforced soil sample was evaluated to be 0.27×10^{-6}cm/s. The results from the reinforced samples all gave permeability values higher than the unreinforced soil samples but were all of the order 10^{-6}cm/s for all the fiber lengths and fiber content investigated. The length of the fiber used therefore appears not to have significant effect on the permeability.

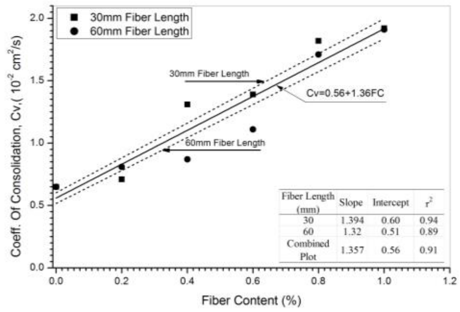

Figure 4. Variation of Coefficient of consolidation with Fiber Content

4 CONCLUSION

1. The compression index (C_c) of the coconut fiber-reinforced soil reduces from a value of about 0.44 as fiber content increases until at a fiber content of 0.6% and above the reduction become insignificant. The recompression index (C_r) showed similar trend.
2. The coefficient of volume change (M_v) decreases from a value of about 0.4m^2/MN with increase in fiber content and attains a stable value of about 0.22m^2/MN for fiber content exceeding about 0.6%
3. The coefficient of consolidation (C_v) increases with increase in fiber content according to a linear equation of the form $C_v = 0.56 + 1.36FC$.
4. Permeability of the reinforced soil was slightly improved when compared with the unreinforced samples. However, they were all of the order 10^{-6}cm/s.

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