Effect of natural fibers on the soil compaction characteristics

N F Bawadi¹, N S Ahmad¹, A F Mansor², S A Anuar¹ and M A Rahim¹

¹School of Environmental Engineering, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia
²Faculty of Engineering Technology (Civil), Universiti Malaysia Perlis, Level 1, Block S2 UniCITI Alam Campus, Sg Chucuh, Padang Besar, 02100 Perlis, Malaysia

Abstract. Clay soils are considered as a problematic soil in term of water absorption rate. The ideas of soil improvement method had been widely used to modify the physical and mechanical properties of clay soil. This study aims to identify the optimum percentage mixing of natural fibers in influencing the compaction characteristics. X – ray fluorescent test (X-RF) and Standard Proctor test has been performed to determine the chemical composition of natural fibers and compaction characteristics of soil samples. Natural fibers such as banana, kenaf, and coconut coir were used as a natural soil stabilizer with varying percentage mixing to increase the properities and stability of soil samples. Experimental data obtained from compaction test shows that the appropriate maximum dry density and optimum moisture content for each natural fiber are at 0.5% natural fibers mixing. In this study, the maximum dry density and optimum moisture content for untreated samples are 1650 kg/m³ and 7.8%, respectively. Meanwhile, for treated soil samples that mixed with banana, coconut and kenaf fibers are 1760 kg/m³, 1780 kg/m³, 1670 kg/m³ and 8.2%, 8%, 11%, respectively. Hence, 0.5% mixing with banana fibers indicated the best possible amount of dry density and moisture content among other natural fibers. Therefore, this study proved that natural fibers can act as a good natural soil stabilizer in increasing stability of clay soil.

1. Introduction
Nowadays, the ideas of mixing the natural fibers as a soil stabilizer to increase the properities of soil samples are become prominent in solving the geotechnical issues such as settlement problem and bearing capacity failures. Soil improvement interacts with the soil through friction and adhesion properties. The practicing engineers are employing this technique for stabilization of thin soil layers, repairing slopes failure, soil strengthen around the footings and earth retaining structures [1]. Natural fibers have affordable cost, strength, environmentally friendly characteristics and easily to be obtain in Malaysia. Due to tropical weather in Malaysia, coconut trees, kenaf and banana plants are widely grown. These natural fibers have biodegradable characteristics and will not create any environmental pollution in our country.

The strength of soil can be increase by inclusion of fiber content within or upon compacted inside deposited granular soil. These elements can be oriented randomly within a compacted soil mass by mixing them with soil prior to compaction [2]. In certain condition of construction, the soil compaction is compulsory to be done in increasing the density of soil. Improper performing the compaction process may cause the settlement of the soil and resulting unnecessary maintenance costs or structure failure. Several laboratory studies have been conducted to evaluate the effect of inclusion fibers with or without additives treated with soil mass. Based on the previous studies, the addition of fibers as a soil improvement in soil mass had caused significant enhancement in the strength of soil. Commonly, the high tensile strength and the extendibility of the added fibers effectively help in reducing the compressibility and brittleness of the soil which is roughly remarkable to soil
This study aimed to determine the maximum dry density and optimum moisture content for untreated (sample control) and treated natural fibers and also identify the optimum percentage natural fibers mixing in increasing the strength of clay soil.

2. Materials and methodology
Soil samples have been collected near to the detention pond area at the Pauh Putra campus of Universiti Malaysia Perlis (UniMAP). In order to collect 0.5m to 1m depth of soil samples, the hand auger equipment has been used and the samples were handled correctly and carefully to minimize the disturbances on the soil samples such as changes in moisture content of soil which will contribute to inadequately of laboratory results. Meanwhile, the natural fibers samples which consist of banana, coconut and kenaf as shown in Figure 1 were dry in the oven at 110°C until it completely dry and grind until it passed through 63µm of the sieve size.

2.1. Materials
The natural fibres have common constituents, but in varying amounts. In order to get a better understanding of what banana, coconut and kenaf fibers is capable of, each of its components are briefly examined using X-Ray Fluorescence (X-RF) analysis. The assessment of soil moisture content is one of the necessary evaluations that need to be considered in this research. All soil samples obtained from the sites were taken to the laboratory immediately for moisture content and particle size distribution test.

![Figure 1. Natural fibres samples after drying process.](image1)

The procedure in determine moisture content are simple and very convenient to be handle. A small amount of clay soil has been weighed and dried in the oven up to 24 hours. After the soil samples are dried, the samples are weighed to obtain the different between wet and dry sample. Although this test is simple to be handle, the soil need to be tested right after the soil were collected from the site to avoid any disturbance in term of moisture loss to attain superior and desired results.

2.2. Method of standard proctor compaction test
In this study, Standard Proctor Compaction test with 2.5kg weight hammer has been selected in obtaining the compaction characteristics of untreated and treated soils samples that mixed with the natural fibers which involving the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) by following the procedure in ASTM D698. Both compaction parameters are very important in identifying the optimum percentage mixing of natural fibers that modify the OMC and MDD of treated clay soils.
3. Results and discussion

3.1. Chemical compositions of natural fibers

The constituents of chemical compositions for banana, coconut and kenaf fibers as tabulated in Table 1. It is obviously shows that the natural fibers consist of calcium, aluminium and silica compositions have high variability in strength properties [4]. Due to the natural alignment of the chemical bonds within the structure of these natural fibers, it is expected that their linear chained polymers would possess significant strength and stiffness of soil sample [4].

Table 1. Comparison between chemical compositions of natural fibers.

| Chemical composition (%) | Natural fibers |
|--------------------------|---------------|
|                          | Banana | Coconut coir | Kenaf |
| Calcium                  | 67.7   | 16.7         | 38.4  |
| Potassium                | 21.9   | 40.9         | 32.9  |
| Iron                     | 4.53   | 7.58         | 6.26  |
| Silica                   | 2.0    | 4.90         | 5.1   |
| Aluminium                | 0.2    | 5.0          | -     |

As mentioned in Table 1, the banana fiber shows the highest calcium content among other fibers. The amount of 67.7% calcium content able to increase the strengthness of the soil based on chemical reactions between soil and fiber. According to Prajisha (2015), by mixing the calcium hydroxide as a stabilizer in a soil, pozzolanic reactions will occur and it’s lead to the modification of soil properties and directly improves the strength of the soil [5].

3.2. Compaction characteristics

In this study, the result obtained for average moisture content is 23.13%. The percentage of soil moisture content are used as an indicator in determining the percentage of water content that required to be mixed with soil sample for standard proctor compaction test. The effectiveness of the standard proctor test is usually measured by the water content of soil in indicating MDD and OMC [6].

In this study, standard proctor test was carried out to determine the MDD and OMC of soil samples. Ten samples are used in laboratory testing to evaluate the maximum dry density of soil sample. Out of ten samples, one sample are used in determined the maximum dry density for untreated soil sample while others nine samples are used for treated soil sample with different percentage mixing of natural fibers mixing. Hence, the different between untreated and treated soil sample can be compared and identified. Data analysis highlighted on the MDD and OMC for untreated and treated clay soil. Figure 2 and Figure 3 shows the data analysis for MDD and OMC between untreated and treated clay soil sample for this study.
Figure 2. Data analysis for maximum dry density.

Figure 2 shows the difference between untreated and treated soil sample for MDD. This study showed that when natural fibers are mixed with soil sample, the value for MDD are gradually increase compare to untreated soil and its followed by increasing the percentage of fibers mixed with soils, the value for MDD also increased. As the percentage of natural fibers mixing reached at 1.00% of natural fiber, the MDD started to decrease and lower than the untreated soil. It is because, the cell strands of natural fibers have less specific weight in comparison with the soil grains, and hence the unit weight will be decrease.

Figure 3. Data analysis for optimum moisture content.

Based on the Figure 3, the values for OMC are increased as the percentage of natural fiber increase. From the result, the OMC is increasing as the percentage of mixing and percentage of water content are increasing. Therefore, the higher natural fiber mixed, the higher the OMC which basically caused the reduction in MDD. Based on these results, it can be clarified that the uses of natural fiber
reinforcement in clay soils will influence the changes of physical properties of clay soil such as the moisture content. Otherwise, based on the results in this study, the use of natural fibers also acts as soil reinforcement to increase the strength of the soil. The uniformly mixing of soil mass with short discrete fibers, may influence the increasing of isotropic in the strength of the soil composite without developing continuous planes of weakness and decreased the stiffness of the soil. Other than that, natural fibers solutions do not require special design and the fibers are simply added and mixed randomly with soil, in much the same way as cement, lime, or other additives.

4. Conclusion
This study conducted with different percentage of natural fibers mixing. Based on the results obtained, when 1% natural fibers mixed with soil sample, the fibers absorbed large amount of water inside the soil grains and caused the reduction of MDD. In this case, high percentage of natural fibers mixing is not relevant to be used as the application of soil stabilizer in order to avoid any failure in future as the dry density drastically decreases after adding the natural fibers. Therefore, the optimum percentage mixing for natural fibers are 0.5% as resulted in this study.

Based on the findings obtained in this study, a few recommendations can be made in order to achieve more reasonable result in future. The 0.7% percentage mixing is suggested to be used in increasing the MDD of treated soil sample. Researcher also recommend by applying these natural fibers to mix with marine clay since marine clay possessed different characteristics which consists chloride (Cl) compositions.

Acknowledgment
The authors wish to extend appreciation to Research Management and Innovation Centre of Universiti Malaysia Perlis (UniMAP).

References
[1] Chaple P M and Dhatrak A I 2013 The International Journal of Engineering and Science 2 4 pp 54–64
[2] Shukla S K 2017 Fundamentals of Fiber-Reinforced Soil Engineering (Singapore: Springer)
[3] Anggraini V, Asadi A, Huat B B K and Nahazanan H 2015 Journal of the International Measurement Confederation 59 pp 372–381
[4] Jústiz-Smith N G, Virgo G J and Buchanan V E 2008 Material Characterization 59 9 pp 1273–1278
[5] Prajisha J P and ARA 2015 Open Access Article MDPI 5 pp 282-296
[6] Ng K S, Chew Y M, Osman M H and Mohamad G S K 2015 International Conference on Advances in Civil and Environmental Engineering 7 B1-B8