Influence of Banana Fiber on Shear Strength of Clay Soil

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Abstract. Recently, the agricultural waste have been enticed increasing attention in geotechnical engineering as a natural soil reinforcement in improving strength and stability of soils. Agricultural waste fiber was chosen as it is cheap, locally available, bio-degradable and eco-friendly. In this study, the implementation of banana fibers has been used as a natural soil reinforcement in influencing the strength of clay soil. In order to investigate the influence of banana fiber in strengthen the clay soil, three different percentage mixing of banana fiber in clay soil has been tested using Unconsolidated Undrained Triaxial and California Ratio Bearing (CBR) tests. The results of X-Ray Fluorescence (X-RF) indicated that average 45% of chemical compositions inside the banana fibers are calcium hydroxide which resulting the pozzolanic reactions and lead to the modification of soil properties and improve the strength of soil. This research is important in order to find the suitability of banana fiber as admixture in soil stabilization. Banana fiber as admixture in soil stabilization will contribute to conservation of the environment. The results from the tests conducted have shown that the soil treated with 1% fibre content improved tremendously in term of shear strength compared to untreated sample. However, based on the regression analysis, 0.5% mixing of banana content indicate the optimum percentage mixing of banana fiber in clay soil.

1. Introduction

The construction in the area of on clay soil commonly encountered to stability problems. It is due to the nature of clay soil in which it has low bearing capacity, low durability and is very compressible [1]. Theoretically, the application of soil reinforcement may influence the increasing of soil strength. Nowadays, the usage of agricultural waste or natural fibers as a soil fiber-reinforcement are widely used because the easiness to adapt and acquire, natural friendly and economically compared to synthetic fiber materials.

There are abundant of calcium and pottasium present in banana fibre and previous research [2, 3] stated that both these chemical composition are able to improve the soil strength. A research performed in asoft soil reinforced with untreated and rubber coated banana fiber and resulted that the rubber coated banana fibers able to improve unconfined compressive strength of the soil [4]. Therefore, this research has been investigate the mechanisms influencing strength of treated soil using natural waste originate from banana fiber. In the other sides, the aim of this research is to investigate the chemical composition of banana fibers and identify the optimum percentage mixing of banana fiber that contributes in stabilizing clay soil.
2. Materials and Laboratory Testing

2.1 Materials
This research consists of three major stages which involving the stage of samples collection for soil and banana fiber, laboratory testing and data analysis. There are 12 clay soil samples were collected at construction site area Kangar, Perlis as shown in figure 1. These samples were collected based on the surrounding and the purpose of land use. Disturbed sample was used in this study and those samples were collected by using hand auger at the depth of 1m from the surface. There are 12 points at site where soil sample were collected and the distance between these points are about two meters apart. All samples are kept in a air-tight container to preserve the originality condition of clay soils, directly minimize the losses of moisture content. At the early step, all samples are being air-dried before mixing with banana fibers in order to study the influence of fibers in soil.

The banana tree is obtained from a village located in Mata Ayer, Perlis. The stem of banana tree undergone decertification process using knife and is kept for drying in the oven at 110\(^\circ\)C for almost 2 weeks to ensure the banana fibers extracted are completely dried before mixed in clay soils and proceed for testing. The dried decortified banana fibers are cut into various and shorter lengths and proceed to grinding process until the fiber passed through 63μm of the sieve size.

2.2 Laboratory Testing
In this research, it is compulsory to conduct X-Ray Fluorescense (X-RF) in order to identify the chemical compositions inside the banana fibers. In performing the test, the fiber has been grinded into a powder form. The identification of chemical compositions inside the banana fiber is needed to prove the reaction between the chemicals contained in the fiber as well as the soil which helps to improve the strength properties of clay soil.

The physical tests of soil consist of moisture content and the Atterberg’s Limits testing. In accordance with BS1377; Part 2; 1990, the soil representatives are weighed before put in the oven to dry for at least 12 hours. The soil representatives are assumed to be without moisture content after oven-dried then re-weighed. The Plastic Limit (PL) and Liquid Limit (LL) of original soil sample are determined using Casagrande method according to BS1377; Part 2; 1990. These tests will enable the classification of soil type using Plasticity Index Chart in BS1377. This is necessary as clay type of soil is to be used in this research.
The strength of soil is determined through the California Bearing Ratio (CBR) test and Unconsolidated Undrained (UU) Triaxial test. CBR test is conducted based on BS1377; Part 4; 1990. The test is conducted on soil with 0%, 0.3%, 0.5% and 1% banana fiber respectively of the weight of 4.5kg soil. The mixture of fiber and clay soil are mixed thoroughly before the start of test. Meanwhile, for UU Triaxial test is conducted in accordance with the BS1377; Part 7; 1990. The test is conducted for the 0%, 0.3%, 0.5% and 1% fiber content soil sample repeated under increased cell pressure of 70kPa, 150kPa and 210kPa each.

3. Results and Discussion

3.1 Chemical Compositions

X-ray Fluorescense (XRF) test is an analysis to determine the elemental composition in a material. Based on the result obtained in figure 2, it shows that the chemical composition of calcium and potassium are the most abundant chemical composition can be found in banana fiber. Each chemical compositions contributes to 44% of calcium and 33% to potassium in average. It is followed by presenced of 10%, 9% and 4% in average for chlorine, iron and sulphur, respectively.

![Figure 2. Result of X-RF test for banana fibers](image)

The presence of calcium may affects internal friction of soil linearly with the bulk density of soil which improve the shear strength of soil [2, 5, 7]. The existence of calcium also help in stabilizing the soil structure by absorbing the sodium from the soil and avoid the damaging of soil structure. In addition, the previous study by a few researchers also stated that when the potassium chloride apply or mix to soil, its may cause an increasing of shear strength and Atterberg limits [3, 6]. These are the reasons supporting the use banana fiber to reinforce soil.

3.2 Physical Properties

The total of twelve clay soil samples are used to determine the physical properties of control samples and the results as tabulated in table 1. The specific gravity value for the clay soil was 2.62, which is in the range of 2.44 to 2.92 [8, 9]. The average moisture content for control sample obtained is 29.97% and it can be considered as high moisture condition which caused by the frequent rain at the time when the soil sample is collected. High moisture content affect the shear strength of soil where the shear strength decreases as the moisture content increases [10].

The liquid limit and plastic limit are the limitation of moisture content conditions where soil turn into plastic state and liquid state. Based on the test conducted, the result obtained are 67% and 30%
for liquid limit and plastic limit, respectively. The results obtained for consistency limit reflect to previous study which plastic limit of clay would probably from 25% to 55%, the liquid limit from 50% to 115% and plastic index from 25% to 60% with the variations depending upon particle size [11]. Meanwhile, based on the plotted result from plasticity index chart the clay samples has been classified as high plasticity which is suitable to be used for this research. The plasticity index also gives a good indication of compressibility where the greater plasticity index, the greater level of soil compressibility which plasticity index greater than 35% considered as high plasticity [12].

| Table 1. Physical Properties of Clay Soil used in this study |
|--------------------------------------------------------------|
| Soil Properties                                            | Values |
| Moisture Content (%)                                       | 29.97  |
| Specific Gravity                                           | 2.62   |
| Grain Size Analysis (%)                                    |        |
| Sand                                                        | 10     |
| Silt                                                        | 25     |
| Clay                                                        | 65     |
| USCS CH (clay with high plasticity)                        |        |
| Consistency Limit (%)                                      |        |
| Liquid Limit                                               | 67     |
| Plastic Limit                                              | 30     |
| Plasticity Index                                           | 37     |
| Compaction Analysis                                        |        |
| MDD (Mg/m3)                                                | 1.58   |
| OMC (%)                                                     | 23.5   |

3.3 Strength Properties

Based on the CBR test performed, the clay soil samples that treated with 0.5% fiber content show the highest rate of force increasing at 2.5mm penetration as shown in figure 3. However, the samples treated with 1% fiber content produced highest force required for penetration at 5mm at the end stage of test.

![Figure 3: Correlation between CBR value and percentage mixing of banana fiber content](image)

The maximum force generated for penetration of untreated samples range between 0.18kN to 0.64kN, while it is much higher for the treated sample where the maximum force is generated for sample 2 treated with 1% fiber content of 2.09kN at 5mm penetration. It can be concluded that the soil
treated with 1% fiber content produced highest force for penetration at 5mm therefore showing the highest bearing capacity.

As shown in figure 3, the CBR values of untreated soil samples (control samples) are very low and poor as stated in JKR Standard which CBR value between 3% and below considered as poor strength. The application of banana fibers as a soil reinforcement, shows the increment of strength value based on the result of CBR in range 4% to 9% which reflect to JKR standard that states 3% to 5% is normal strength and 5% to 15% is in a good strength. The regression analysis equation as shows in figure 3 and tabulated in table 2 may assist in determination of optimum percentage mixing of banana fiber content in clay soil. As shown in figure 3, the results of both regression analysis shows that the optimum percentage mixing of banana fiber is at 0.5% mixing.

### Table 2. Correlation Equation in determining optimum banana fiber content

| Penetration | Correlation Equation | R²  |
|-------------|----------------------|----|
| At 2.5 mm   | CBR = -1.01BF² + 6.56BF - 3.89 | 0.97 |
| At 5.0 mm   | CBR = -1.583BF² + 11.67BF - 6.01 | 0.99 |

**Figure 4.** Shear strength under different cell pressure for several percentage mixing of banana fiber

The triaxial test enabled the performance of soil while under different cell pressure to be determined. figure 4 illustrated the improvement in shear strength after soil is treated with several percentage of banana fiber content. Findings from the research performance, 1% mixing of banana fiber produced the highest shear strength under different cell pressure. This finding is in line with the results obtained from the previous study which stated that an increasing in soil compressive strength when application of rubber coated banana fibers [4].

### 4. Conclusion

This study was focused on determining the properties for waste-soil mixtures and investigating the influence of banana fiber into clay soils for the purpose of natural soil reinforcement. These objectives were determined by conducting various laboratory tests on soil specimens with three percentage mixing of banana fibers which is 0.3%, 0.5% and 1% and follow by control sample to investigate the untreated and treated properties of clay soils. The results obtained indicate an increment in of CBR value and shear strength of clay soils after application of banana fibers with 0.5% optimum percentage mixing. A good correlation has been found between CBR value and percentage mixing of banana fiber.
content and thus additive of banana fiber in clay soil could be used as alternative natural reinforcement material in increasing soil strength.

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