Influence of Natural Fibres in Strengthening of Black Cotton Soil

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Abstract. The expansive soil like black cotton soil spread over southern Indian terrain. As a fast-growing nation like India, the need for infrastructure activities quickly takes place. For better structural capacity the geotechnical features are important. The soil stabilization is a technique in the part of improving the soil engineering properties like California Bearing Ratio (CBR), shear strength and compaction factors. In the present study, the black cotton soil stabilized with fibres to improve the engineering properties of soil. The study carried with natural fibres like sisal, banana and jute fibres. The ratio of 0.2%, 0.4% and 0.6% added in the dry weight of soil fraction with the soil for the strength gaining. The addition fibres increase the strength in the reasonable value for CBR up to 21.55% in 0.4% of banana, 0.6% of sisal and 0.6% of jute fibre combination. Optimum Moisture Content (OMC) increased up to 20% for the same combination. The results provide the combined scattered fibre effect to increase the strength parameters of soil.

1. Introduction

The soil engineering properties are very important to improve the foundation detailing. The type of soil influences the project cost and as well as the life of substructure without compaction. The soil which holds the water with its structure itself like black cotton soil mineral montmorillonite exhibits the dewatering and cause swelling when temperature change or consolidation process took place in the soil. The soil can be stabilizing to withstand the load as a substructure. The fast-growing nation like India, focusing the development in infrastructure development, especially roadway and railways which need to be stabilized soil to provide better road network. The soil stabilization may change the properties of volume change due to water, shear strength, Atterberg’s limits and stability properties. The use of industrial wastes also considers for stabilization, not in high Sulphate area which leads to the high swelling condition [1]. The use of reinforcement in the form of fibres also changes the properties of soil by increasing its bearing ratio, which provides longer stability for the soil mass [2]. The properties of the clayey soil with fibres, and it has been improved by the addition of rice husk ask (RHA), bamboo fibre and banana fibre, when the optimum amount of RHA is added to the varying percentage of bamboo and banana fibre the optimum moisture content and maximum dry density is increasing [5]. The CBR value of the soil increases with the inclusion of jute fibres. When the jute
fibre content is increased, the CBR value of the soil is further increases and this increase is substantial up to fibre content 5% [3].

The clay soil CBR value increases by adding jute fibres with the significant effect of length and diameter of the fibre [4]. The CBR value of the soil were increased significantly when mixed with jute fibres from 0% to 5%. This paper shows the addition of jute fibres in black cotton soil decreases the swelling behaviour and increase the C.B.R value and unconfined compressive strength properties. From the literature study, the optimum fibre content may take as, 0.2% to 0.6% for sisal fibres, jute fibres and banana fibres for the present study.

The effect of natural fibre on clayey soil studied with different percentage of bamboo fibre and banana, fibre is added to the soil and the optimum percentage found out. The stabilization of clayey soil with bamboo fibre is carried out by blending the soil with different percentage of bamboo fibre (0.25% to 1.5%) and banana fibre (0.5% to 2%) and the optimum amount is found out. After the determination of basic properties of clayey soil, soil stabilized with bamboo fibre and banana fibre, the strength parameters like Maximum Dry Density and Unconfined Compressive Strength were determined by conducting compaction tests. It can be concluded that there was an increase in optimum moisture content with an increase in the percentage of bamboo fibre and banana fibre to the soil. The maximum dry density increases and optimum moisture content decreases with an increase in the percentage of fibre. Addition of various percentage of fibres shows the increased value for unconfined compression strength up to 1% for bamboo fibre and 0.75% for banana fibre. The CBR value increases as the amount of bamboo fibre increase up to 1% and banana fibre up to 0.5% then decreases on further addition. Thus, 1% of bamboo fibre and 0.75% of banana fibre was taken as the optimum percentage.

The improvement of soil subgrade reinforced with banana fibre and coir fibres. The aim of this study is the effectiveness of natural fibre (coir and banana fibre) on soil subgrade strengthening. CBR test was conducted on a soil sample before and after the addition of fibres. Fibers were added at 0.25%, 0.5%, 0.75%, 1% and 1.25%. Lengths of the fibre were taken as 20mm. The increase in CBR value leads to a decreasing thickness of pavements. It concluded that CBR value increases with an increase in fibre content at a different percentage. With an increase in fibre content CBR value also increases further and are substantial at 1% fibre content. Preparation of soil sample with more than 1% fibre content is difficult. It was also found that banana fibre has more CBR value with the same fibre content as that of coir fibre and thus banana fibre is more suitable than coir fibre.

2. Materials and Methodology

In this project, clay soil stabilization using fibres considered. The clay soil sample is taken from the site in Sitra, Coimbatore, at a depth of 1.5m. Fibres are collected from Kumarapalayam, Coimbatore.

2.1. Black cotton Soil

The soil excavated from the site taken for the basic soil property tests like specific gravity, OMC, Atterberg limits, dry density. The results were shown in Table 1.

| Properties            | Values   |
|-----------------------|----------|
| Specific Gravity      | 2.53     |
| Liquid limit          | 36%      |
| Plastic limit         | 25%      |
| Shrinkage limit       | 1.37%    |
| Optimum Moisture Content | 20%    |
| Dry density           | 1.67gm/cc|
Table 2. Physical and Engineering Properties of Coir, Jute

| Properties      | Coir  | Jute   |
|-----------------|-------|--------|
| Specific Gravity| 0.70  | 1.1    |
| Cut Length      | 20-50 mm | 20-50 mm |
| Diameter        | 0.2 – 0.25 mm | 2-3 mm   |
| Colour          | Brown            | Yellow with brownish |
| Aspect Ratio    | 100 - 250        | 10-25   |

Table 3. Engineering properties of Black cotton soil with fibre content

| Properties                      | Clay Soil (without fiber) |香蕉纤维（%） | 0.4%香蕉+sisal | 0.6%sisal纤维+0.4%香蕉纤维+Jute |
|--------------------------------|---------------------------|-------------|----------------|-------------------------------|
|                                | 0% | 0.2 | 0.4 | 0.6 | 0.2 | 0.4 | 0.6 | 0.2 | 0.4 | 0.6 |
| Liquid limit, %                | 36 | 40  | 45  | 45  | 40  | 45  | 50  | 10  | 50  | 50  |
| Plastic index, %               | 25 | 15  | 20.2| 20.2| 16  | 20.9| 25.9| 22  |21.5 |21.5 |
| Toughness                      | 2  | 0.02| 0.74| 0.85| 4   | 10  | 2.59| 2.2 | 3.22|1.09 |
| Optimum Moisture Content, %    | 20 | 20  | 20  | 20  | 20  | 20  | 20  | 20  |20   |20   |
| Max. dry Density, g/cc         | 1.67| 1.41| 1.54| 1.49| 1.49| 1.51| 1.52| 1.54|1.55 |1.54 |

3. Result and Discussion
3.1 Standard Proctor Test
Standard proctor test was carried out on the soils containing different fibres of different percentages addition such as 0.2%, 0.4% and 0.6%. This test is carried out to determine the maximum dry density (MDD) and optimum of moisture content (OMC).
3.2 Unconfined Compression Strength Test

The stress-strain curve of different percentage of fibres containing in the soil are 0.2%, 0.4% and 0.6% and fibre length which used in this study are 2 cm. By the addition of palm fibre in the soil, it will make the soil flexible [6]. It was also observed that the length of fibres affects the strength of soil because by testing the reinforced sample of decreased palm fibre length both maximum and residual strength decreased. The result of the inclusion of palm fibre shows that the strength decreases with increasing the percentage of fibres. Figure 2 shows the stress-strain with optimum of fibres.

According to the above results fibres which replaced the soil, grain controls the behaviour of soil specimen under load. The failure pattern which was observed was a bulging failure and no rupture failure was observed. Fibre length is important in strength because the increased length of fibre bear the load imposed to soil specimen who results into increase in bearing capacity of soil specimen. Addition of fibre combination into the soil makes the soil homogenous or uniform because the number of fibres per unit volume will increase. But when the percentage of fibre increases with constant fibre inclusion then it reduces the homogeneity of soil and results in irregularity in the failure surface [7].
This irregularity in failure surface gives strength to soil specimen because according to Coulomb theory soil fails at an angle of obliquity. Hence it is concluded that the inclusion of fibre is not that effective as compared to the length of the fibre. Sisal and jute fibres good in the tensile property, when added to soil specimen, shows an effect upon failure surface direction and shear zone [8]. This increase in tensile stress due to banana and jute fibre cause high compression in the soil which results in the soil to attain compressive stress in soil. Hence both the tensile stress and compressive stress starts acting in the soil specimen which leads to more ductility and strength in the soil specimen. From the above curve, it is found that by adding a combination of fibres in the soil strength of soil increased by 21% as compared to a combination of banana and sisal fibres and 12% from a virgin sample. All the fibre added specimens shows good performance in unconfined stress values compared to 0% fibre added soil specimen, which ensures the ductile property improved with fibre addition.

3.3 CBR test

Figure 3 shows the combination of fibres increases the bearing capacity of the soil and fails in an elastic manner, which provides safety against impact loads.

Table 4: Strength Properties of soil with various fiber addition

| Type of Soil Sample                          | UCC x10^{-3} N/mm² | CBR (%) (for 2.5mm penetration) | CBR (%) (for 5mm penetration) |
|---------------------------------------------|---------------------|--------------------------------|-------------------------------|
| Clay soil                                   | 8.1                 | 11.09                          | 12.62                         |
| Clay soil + 0.4% banana fiber               | 8.2                 | 11.69                          | 13.69                         |
| Clay soil + 0.4% banana fiber + 0.6% sisal fiber | 8.1               | 13.48                          | 14.39                         |
| Clay soil + 0.4% banana fiber + 0.6% sisal fiber + 0.6% jute fiber | 9.1            | 23.38                          | 21.58                         |

Figure 3: CBR for soil specimen with various % of various fibre addition
4. Conclusion

Experimental test conducted by standard proctor compaction test, unconfined compressive, California bearing ratio by adding a various percentage of banana fibre, sisal fibre and jute fibre. When comparing the various percentages of various fibres with nominal soil the following conclusion we obtained from the experimental investigation.

- The Optimum Moisture Content (20%) was found to be increased by using a variable percentage of fibres
- The California Bearing Ratio (21.55%) was found to be increased by using a variable percentage of fibre compare with normal black cotton soil
- The unconfined Compressive strength (0.12 N/mm²) will be increased at 0.6% sisal fibre and 0.6% jute fibre compared with normal black cotton soil parameters
- Atterberg's limits decrease considerably with the addition of 0.6% sisal fibre and 0.6% jute fibre
- In the light of above observation, the banana, sisal and jute fibres are used in combination with clay possessed certain properties which enables it to be used economically for improvement of black cotton soil.

References

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