MDD & OMC of Black Cotton Soil Reinforced with Randomly Distributed Banana Fibers

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Abstract. Expansive soil causes serious problems on civil engineering structures in arid and semi-arid climate regions of the world. Such soils, swell during rainy season and shrink in summer season. In India, expansive soil includes almost the entire Deccan plateau, and causes damage to buildings, roads, pipelines, and other structures every year. The black cotton soil had improved by various methods to enhance the engineering characteristics of soil. However, due to various issues such as leaching, release of mineral, these methods are not sustainable. Hence, an attempt had been made to improve black cotton soil characteristics by using the waste material such as banana fiber. In the present study, the experiments were conducted to understand the density & moisture content of soil by reinforcing the soil with randomly distributed banana fibers. The laboratory tests were conducted on locally available black cotton soil. The banana fiber were added to the soil in varying percentages of 0.0 %, 0.50 %, 1.00 %, 1.5 % and 2.00 % and in varying lengths of 1 cm, 2 cm and 3 cm randomly. The standard Proctor tests were conducted to study its effect of banana fiber on dry unit weight and OMC. It was observed that MDD is decreasing and OMC is increasing with increase in % of fibers and length of fiber.

1. Introduction

The civil engineering structures founded on the ground and transfer the load safely to it. The properties of soil below play major role in the stability of the structures. Expansive clays swell due to water absorption and shrink due to water evaporation. Hence, the structures founded on these grounds are severely damaged. The various techniques are used to avoid the problems caused by expansive soils. The improvement of soil is carried out with locally available waste material then it will possible to reduce the cost of structure. The best option is to reinforce the soil with some strong material. To improve the soil. The soil reinforcement is usually carried out with rod, strips, geo-membrane etc. Many researchers also attempted to make use of natural fibres such as jute, coir, and banana as reinforcing materials in soil. The natural fibre materials are available locally and are very cheap. Also they are biodegradable. Hence, use of natural fibres lead to green and sustainable ground improvement [1-9].

2. Literature Review

The reinforcement of soil using natural and artificial fibers is continually studied by various researchers. These studies are discussed below.
Babu and Vasudevan [1] studied the reinforcement of red soil using coir fibers and reported maximum increase of stress, toughness and stiffness of the soil when the fiber length was between 15 and 25 mm. Chaple and Dhatrak [2] investigated the properties of clayey soil reinforced with addition of coir fibers. The soil and coir fibers were mixed in proportions. The percentage of coir fibers varies from 0.0 %, 0.25 %, 0.50 %, 0.75 % and 1.00 %. It was observed that, OMC increased from 18.1 % to 20.76 % and MDD was decreases from 17.28 KN/m$^3$ to 16.62 KN/m$^3$. The increase in OMC may be due to water absorption by the fiber. Subramani and Udayakumar [7] reinforced clay soil with coconut fibers and reported maximum improvement in U.C.S. and C.B.R when 0.5% of coir mixed with the soil. Sunny and Joy [8] reinforced marine clay with banana fibers and reported that banana fiber content with 0.75% shows maximum improvement in the soil properties. The literature review shows improvement in various soil properties with the addition of natural fibres. Since, Jalgaon district is hub for production of banana and lot of banana trunk are available for making the fibres. Also, this area contains black cotton soil which causes many problems to structures. Hence, in order to solve the problem of banana waste and black cotton soil, an attempt has been made to understand the behaviour of banana fibres reinforced black cotton soil.

3. Methodology
The soil was collected from three different villages namely Nashirabad, Takarkheda and Dhamangaon of Jalgaon district from Maharashtra. All the sample were tested for plasticity characteristics and free swell index. The soil having high plasticity and high free swell index was selected for the study i.e. soil from Dhamangaon. The banana fibers were collected from Varangaon village from Jalgaon district of Maharashtra. The fibers were mixed in soil with proportions. The banana fibers vary from 0.0 %, 0.50 %, 1.00 %, 1.5 % and 2.00 %. The lengths of banana fibers were 1 cm, 2 cm and 3 cm. The standard Proctor tests were conducted with different % of banana fibers.

4. Materials and Methods

4.1. Black Cotton Soil
The soil was collected from various area within Jalgaon district of Maharashtra for testing. Various properties of soil are shown in Table 1. The soil from Dhamangaon village shows higher PI and DFS, hence selected for the study.

| Village    | LL (%) | PL (%) | Ip (%) | FSI (%) |
|------------|--------|--------|--------|---------|
| Nashirabad | 62.67  | 51.09  | 11.58  | 52.6    |
| Takarkheda | 64.67  | 52.26  | 9.41   | 63.40   |
| Dhamangaon | 85.33  | 62.72  | 22.61  | 69.53   |

4.2. Banana Fiber
The banana fiber is a natural fiber obtained from a banana plant. The fiber was obtained mainly from pseudostem, which acts as a strong fiber after proper drying. It is a better fiber with suitable stiffness and good mechanical properties. The fiber was obtained from Varangaon near Busawal in the district of Jalgaon of Maharashtra state, India. The banana fibers used for the present study in the percentage of soil varies as 0.0%, 0.50%, 1.00 %, 1.5 % and 2.00%. The length of banana fibers used was 1 cm, 2 cm and 3 cm.

4.3. Test Methods
The initial studies were directed to analyses geotechnical characteristics of black cotton soil i.e. liquid limit, free swell index and plastic limit. For determining maximum dry density and optimum moisture content of original and reinforced soil, standard Proctor test was also done.
5. Results and Discussion
The consequences of tests directed on Dhamangaon soil are presented in Table 2. As per IS soil classification, the soil was categorized as silt of high compressibility (MH). The MDD of sample at standard Proctor test was found to be 14.9 KN/m$^3$ and OMC as 29.6 %.

Table 2. Properties of black cotton soil

| Soil   | LL(%) | PL(%) | Ip(%) | FSI(%) | OMC(%) | MDD kN/m$^3$ |
|--------|-------|-------|-------|--------|--------|---------------|
| MH     | 85    | 62    | 23    | 70     | 29.6   | 14.9          |

5.1. Standard Proctor compaction test on soil with variation of banana fibers constituent
This was performed on reinforced soil with wavering percentage of banana fibers and length for obtaining maximum dry unit weight (MDD) and optimum moisture content (OMC) as shown in Figure 1. Similar curves were plotted for all the tests. Table 3, 4 and 5 illustrates OMC and MDD obtained from standard Proctor test for soil with wavering percentage of banana fibers for 1 cm, 2 cm, and 3 cm length of fiber.

Figure 1. Dry Unit Weight –Moisture Content Curve for 1 cm Length of Banana Fiber

Table 3. OMC and MDD for 1 cm length of Banana Fiber

| %Fiber added | 0   | 0.5 | 1.0 | 1.5 | 2.0 |
|--------------|-----|-----|-----|-----|-----|
| OMC(%)       | 29.6| 35.0| 35.4| 36.0| 36.4|
| MDD(KN/m$^3$)| 14.9| 14.7| 14.2| 13.9| 13.5|

Table 4. OMC and MDD for 2 cm length of Banana Fiber

| %Fiber added | 0   | 0.5 | 1.0 | 1.5 | 2.0 |
|--------------|-----|-----|-----|-----|-----|
| OMC(%)       | 29.6| 32.0| 34.0| 35.0| 36.6|
| MDD(KN/m$^3$)| 14.9| 14.4| 14.1| 13.7| 13.0|

Table 5. OMC and MDD for 3 cm length of Banana Fiber

| %Fiber added | 0   | 0.5 | 1.0 | 1.5 | 2.0 |
|--------------|-----|-----|-----|-----|-----|
| OMC(%)       | 29.6| 29.4| 32.6| 33  | 36.5|
| MDD(KN/m$^3$)| 14.9| 14.1| 13.8| 13.6| 12.74|

Figure 2 and 3 illustrates the variation of OMC and MDD attained from customary Proctor test for soil with wavering percentage of banana fibers for 1 cm, 2 cm, and 3 cm length of fiber. It shows that as the % content of fiber and length increases, the maximum dry density goes on decreasing. As the %
banana fiber content increases OMC increases and became same at 2% content while as the length increases, OMC decreases.

![Figure 2. Variation of MDD with % of Banana Fiber](image1)

![Figure 3. Variation of OMC with % of Banana Fiber](image2)

6. Conclusions
The black cotton soil was reinforced with banana fiber of varying length and %. The fibers were mixed in soil in randomly. The inclusion of fibers in soil has been studied for unit weight characteristics of reinforced soil. Addition of banana fibers influences the characteristics of black cotton soil. Some conclusion which can be drawn:

- Optimum moisture content of reinforced soil increased with percentage and length of banana fibers
- Maximum dry unit weight of reinforced soil reduces with percentage and length of banana fibers
- For fiber less than 2 cm length, 0.5% banana fiber shows maximum increase in OMC while for 3 cm length, 1 % banana fiber.
- The decrease in MDD is marginal at 0.5% or 1% banana fiber.

References
[1] Sivakumar Babu G and Vasudevan A 2008 Strength and stiffness response of coir fiber-reinforced tropical soil Journal of Materials in Civil Engineering 20 571-7
[2] Chaple P M and Dhatrak A 2013 Performance of coir fiber reinforced clayey soil The International Journal of Engineering Science 2 54-64
[3] Singh H 2013 Effects of coir fiber on CBR value of itnagar soil *International Journal of Current Engineering and Technology* 3 1283-6

[4] Bairagi H, Yadav R and Jain R 2014 Effect of jute fibres on engineering characteristics of black cotton soil *International Journal of Engineering Research & Technology (IJERT)* 3 1550-2

[5] Singh R and Mittal E S 2014 Improvement of local subgrade soil for road construction by the use of coconut coir fiber *International Journal of Research in Engineering & Technology* 3 707-11

[6] Kumar D, Nigam S, Nangia A and Tiwari S 2015 California bearing ratio variations in soil reinforced with natural fibres (a case study Bhopal Bypass Road) *International Journal on Emerging Technologies* 6 95

[7] Subramani T and Udayakumar D 2016 Experimental study on stabilization of clay soil using coir fibre *International Journal of Application or Innovation in Engineering Management Decision* 5 192-204

[8] Sunny T and Joy A 2016 Study on the effects of marine clay stabilized with banana fibre *International Journal of Scientific Engineering Research* 4 96-8