

Stabilization of Black Cotton Soil with Blending of Coir Fiber

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Abstract

Stabilization of soil is a major challenge in civil engineering. About 20 % of land area in India is covered by black cotton soil. Structures built on black cotton soil may be damaged because of high swelling and shrinkage characteristics of this soil with variation of water content. Black cotton soil is an expansive soil which loses its strength in presence of water. On the other hand, it reflects behavior of shrinkage when loss of moisture is there. Because of its swelling and shrinkage properties, it is under category of expansive soil. The present paper is an attempt to develop an alternative method for stabilization of black cotton soil by using coconut fiber (coir) to control swelling properties of black cotton soil. Impact on its strength characteristics and dry density due to mixing of coir was also studied. The test results show that with blending of 2% coir fiber, the shrinkage limit is changed from 7.50% to 12.60%. Increase in compressive strength was observed from 1.09 to 1.32 kg per sq cm.

Keywords: Black cotton soil, coir fibers, swelling behavior, shrinkage, stabilization

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INTRODUCTION

Fast growth of infrastructure in India has led to increased construction activities. Construction of embankment for roads and highways passing through areas with black cotton soil needs special attention to provide stable foundation below embankment. Black cotton soil is clay of high plasticity. It has low bearing capacity and highly compressible nature. The expansive soil exerts upward swelling pressure in the structure. This pressure depends upon the degree of expansion [1–3]. Increase in pressure results in to uplift and cracking of structure. Common materials which can be used for stabilization of earth are Sand or Clay, Portland Cement, Lime, Bitumen, Pozzolanas (like fly ash, rice husk ash, volcanic ash), Natural fibers (grass, straw, sisal, sawdust), Sodium silicate(water-glass), Commercial soil stabilizers (for roads), Resins, Molasses, Gypsum etc. Coconut fiber is obtained from the fibrous husk (mesocarp) of the coconut (Cocos nucifera) from the coconut palm, which belongs to the palm family (Palmae). The use of coconut fiber as stabilizer can offers many advantages. Coconut fiber has high lignin content and thus low cellulose content, as a result of which it is resilient, strong and highly durable. The

remarkable lightness of the fibers is due to the cavities arising from the dried out sieve cells [4–10]. According to Majid (2011), there are many general advantages of coconut fibers e.g., they are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and not easily combustible [11]. The studies are important from view point of using this natural fiber for improvement in properties of black cotton soil which change with variation content in moisture content given in Table 1.

Table 1: Engineering Properties of Coir Fiber.

Property	Value
Length(mm)	15–280 mm
Density(g/cc)	1.15–1 A
Tenacity(gltx)	10.0
Breaking Elongation (%)	30%
Diameter(mm)	0.1–1.5
Rigidity Modulus(dynes/cmL)	1.8924
Swelling in Water(diameter) %	5.00
Moisture at 65%RH (%)	10.5
Specific Gravity	1.15
Young's Modulus(GN/sq-mm)	4.5

Table 2: Chemical Properties of Coir.

Content	Percentage
Lignin	45.84
Cellulose	43.44
Hemi Cellulose	0.25
Pectin and Related Compound	3.00
Ash	2.22

The present paper investigates the possibility of using coconut fiber for stabilization of black cotton soil to control swelling and shrinkage characteristics. Because of high lignin content of coir fiber, it has infield service life of 4 to 10 year and good tensile strength in wet condition too (Table 2). Coir fiber has property to retain much of its tensile strength when wet. The degradation of coir depends on the medium of embedment and the climatic conditions. It is found to retain 80% of its tensile strength even after six months. During shrinkage, fiber will impart more inter surface resistance in between fiber and soil with an added reinforcing effect, resulting in higher bearing capacity. On the other side, presence of fiber will control swelling characteristics of soil when soil mass is wet. Objective of our paper is to study comparative changes in properties of black cotton soil with an addition of 2% coconut fiber.

Following studies were carried out.

1. Change in swelling and shrinkage characteristics of black cotton soil with an addition of 2% coir (coconut fiber).
2. Change in compressive strength of black cotton soil due to addition of coir.
3. Change in OMC and MDD of black cotton soil due to addition of coir.

MATERIALS

Black cotton soil was collected from outer skirts of Gwalior city on Bhind Road. Samples were collected from layer below 2.00 m depth by excavating pits of 1.50 x 1.50 m size. The soil was sun dried for seven days then crushed into fine particle using the hand rammer. It was then allowed to pass through the 600 micron sieve. Coconut covers were collected from major temples of Gwalior city and used to get coir fiber of length varying from 50 to 180 mm. These fibers were cut randomly by scissor, in pieces of 50 to 70 mm lengths.

EXPERIMENTAL PROGRAMME

Samples of black cotton soil were prepared with and without coir fiber. The coconut fiber grated to smaller form was then mixed with the soil mix ratio by percentage weight of 100%: 2%, of soil and grated coconut fiber. Water was sprinkled on the stabilized soil while it is being mixed by hand until it form a firm lump when squeezed in the hand and just enough moisture appeared on the surface to give a shiny appearance. Following tests were conducted for assessment of properties of plane soil and soil blended with coir given in Table 3.

Table 3: List of Laboratory Test.

S. No.	Name of Laboratory Test Carried Out
1	Specific Gravity
2	Liquid Limit
3	Plastic Limit
4	Optimum Moisture Content
5	Maximum Dry Density
6	Unconfined Compressive Strength
7	Test for Swelling of soil

Above tests were carried out as per procedures described in various IS Codes. Specific gravity of soil was determined by density bottle method. Tests for Atterberg limits were carried out. Liquid limit plastic limit shrinkage limits were determined for samples of plane soil. Soil mixed with 2% coir fiber was tested for shrinkage limit. Water content of soil sample was determined by oven drying method. Unconfined compression test was conducted both on plane soil sample and sample blended with 2% coir fiber.

MOISTURE CONTENT DETERMINATION

Clean containers were weighed with their lid and wet stabilized soil was added to each and then weight was taken. The sample was then oven dried to a temperature of about 110 degree Celsius for 24 h and transferred into desiccators for another 6 h. The moisture content for each ratio of the stabilized soil was evaluated using the equation.

$$M = [M_w/M_d] \times 100$$

where;

M = moisture content%

M_w= mass of moisture (M1-Mc)

M_d = mass of dry soil ($M_2 - M_c$)
 M_c = mass of container
 M_1 = Mass of container + wet soil
 M_2 = mass of container + dry soil

COMPACTION TEST

Three kg of each sample were weighed and sieve through the 600 micron sieve. Water @ 3% of the dry soil was added and mixed thoroughly. Using a scoop, a trowel and a mixing bowl, water was added to mix and

turned over to form a homogeneous mixture. With a rammer falling freely through, the soil was compacted into three layers with 27 blows on each of the layer, making sure that the blows are evenly distributed. The collar of the mould was then removed and the soil trimmed off evenly with a straight edge. The cylinder was then cleaned and the weight of the mould with the soil in it is taken. Some quantity of the soil sample was then removed for moisture content determination.

Table 4: Comparative Results of Plane Soil and Soil Sample Blended with Coir Fiber.

S. No.	Laboratory Test	Value for Plane Soil Sample	Value for Soil Blended with Coir
1	Specific Gravity	2.63%	2.58
2	Liquid Limit	54.20%	-
3	Plastic Limit	29.10%	-
4	Shrinkage Limit	7.50%	12.60%
5	Optimum Moisture Content	20.10	27.20%
6	Maximum Dry Density	1.56 g/cc	1.51g/cc
7	Free Swelling Index	47%	32%
8	Unconfined Compressive Strength Test, at OMC.	1.09 Kg/cm ²	1.32 Kg/cm ²

RESULTS AND DISCUSSION

Moisture Content

The result of experiment conducted to evaluate the moisture content of the stabilized soil indicates that the moisture content of the soil sample was found to increases with addition of fiber which reflects moisture retention properties of the materials.

Compressive Strength

The increase in the compressive strength was observed due to the increased cohesive strength between the soil particles and the fibers. Hence, when compressive axial load is imposed on the sample, an internal tensile stress is reduced which tries to prevent the sample from splitting.

CONCLUSION

Tests conducted on black cotton soil blended with 2% coir fiber sample, lead to following conclusion. Appreciable increase in unconfined compressive strength was observed. It increased from 1.09 Kg/cm² to 1.32 Kg/cm².

1. Increase in optimum moisture content was observed from 20.10% to 27.20% due to blending of coir.

2. Blending of coir fiber results in to increase in shrinkage limit from 7.50% to 12.60%. It controls the swelling behavior of black cotton soil.

Above results indicate that the stabilization of black cotton soil can be done by blending of coir fiber with soil mass. Its swelling behavior is decreased and the unconfined compressive strength increases. Since, coir is a natural fiber and available in abundance this method can promote sustainable development.

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