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An Experimental Study on Stabilization of Loose Soil by using Sisal Fiber

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ABSTRACT

Soil Properties which creates a crucial impact on construction activities due to the rapid growth of urbanization and industrialization. Especially in expansive soils are creating worldwide problematic soil these having large volumetric change behavior when it undergoes a change in the moisture content. Among those, black cotton soil are one type of expansive soils and they show high swelling and shrinkage behavior owing to fluctuating water content. In India, black cotton soil covers as high as 20% of the total land area and majorly in central and south India. If it should be used as foundation material, Improvement of soil need to be done by adopting various techniques like soil stabilization, reinforcement etc. Usage of locally available admixtures is effective in terms of easy adaptability and economy.

The main objective of this study is to assess the possibility of using sisal fiber as a stabilizing agent and to understand the effectiveness of sisal fibers in controlling several properties of black cotton soil under controlled laboratory conditions. To achieve this goal several experimental studies like optimum moisture content, compressive strengths tests (UCS), CBR, etc., were carried out with the addition of different percentages of sisal in black cotton soil sample as trial and error process. In the present study, the soil samples prepared with the addition of sisal fibers by 0.25%, 0.5%, 0.75%, and 1% the average length of sisal fiber is going to use in this study is approximately 10-15mm. At first, Optimum Moisture Content (OMC) was determined through the proctor test. At those OMC, several tests like CBR, UCS were conducted. CBR test was carried in both Unsoaked and soaked condition and maximum values were obtained where 0.75% sisal fiber was added.

INTRODUCTION

In today's world due to the rapid growth of urbanization and modernization leads to scarcity of land for construction. Everywhere land is being utilized for various structures from an ordinary house to skyscrapers, from bridges to airports and from the village road to highways or expressway. Owing to this, construction of structures these days is being carried on land having weak or soft soil. The increasing value of land and due to limited availability of the site for constriction of structures and roads are done on the land having expansive clays. The stability of structure or road depends on soil properties on which it has built. The construction can be economical if the soils are good a shallow depth below the ground surface. In this case, shallow foundations such as raft foundations or footings can be used. However if the soil available on the top surface is weak and strong stratum is available at greater depth foundations such as pile foundations, deep foundation, caisson and well foundations can be used. Such foundations are not economical for small structures. In some cases, soil conditions are so poor even at greater depths. As the soils suitable for construction are limited, the weak soils need to be strengthened beforehand. This led to the development of various ground improvement techniques like soil stabilization, compaction and reinforcement.

Black Cotton Soil:

Rich proportion of montmorillonite is found in Black cotton soil from mineralogical Analysis. The high percentage of montmorillonite renders high degree of expansiveness. These property results cracks in soil without any warning. These cracks may sometimes Extent to the severe limit like ½" wide and 12" deep. So building to be founded on this soil May suffer severe damage with the change of atmospheric conditions. Black cotton soils Are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. This Black Cotton soils occurs mostly in the central and western parts and covers approximately 20% of the total area of India. Because of its high swelling and shrinkage characteristics, the Black cotton soils (BC soils) have been a challenge to the highway engineers. The Black Cotton soils are very hard when dry but lose its strength completely when in wet condition. It is observed that on drying, the black cotton soil develops cracks of varying depth. As a result of the wetting and drying process, vertical movement takes place in the soil mass. These movements lead to failure of pavement, in the form of settlement heavy depression, cracking and unevenness.

Differential free swell (DFS):

Free swell or differential free swell, also termed as a swell index, is the increase in the volume of the soil without any external constraint when subjected to submergence in water. For the determination of the differential free swell of soil, 20g of dry soil passing through a 425-micron sieve is taken. The soil is divided into two samples of 10g each. One sample of 10g is poured into a 100cc capacity graduated cylinder containing water, and the other sample of 10g is poured into a 100cc capacity graduated cylinder containing kerosene oil. Both the cylinders are kept undisturbed in a laboratory. After 24 hours, the settled volumes of both the samples are measured.

Differential Free Swell (DFS) is determined from the relation

$$DFS = \frac{V_d - V_k}{V_k} \times 100$$

Where,
- V_d = volume of soil specimen read from the graduated cylinder containing distilled water.
- V_k = volume of soil specimen read from the graduated cylinder containing kerosene.

Fig:1.0 Differential Free Swell Test

Compaction Test: (Modified Compaction)
Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content. A curve is drawn between the water content and the dry density to obtain the maximum dry density (MDD) and the optimum water content (OMC).

$$Dry\ Density = \frac{M/V}{1+w}$$

Where, M = Mass of the Compacted Soil, V=Volume of the Soil, w = Water Content

To determine the compaction characteristics of a soil specimen, there are two methods were present.

Light Compaction:
In this light compaction method, the standard cylindrical mould of capacity 1000cc with an internal diameter of 10cm and height 12.73 cm is used to determine the compaction characteristics of the soil sample. The weight of the hammer used in this is 2.6 kg with free drop 3.1cm. The soil is compacted in 3 layers and each layer is tamped to 25 times

Heavy Compaction:
The volume of the mould used in this compaction test is 2250cc with an internal diameter of 15cm and height of 12.73cm. Weight of the rammer used in this test is 4.89 kg with a free drop of 45cm. The soil is compacted in 5 layers and each layer is tamped to 25 times. In this study, Heavy Compaction (Modified Proctor) test was conducted at different percentages of water on all samples with different proportions of lime and sisal fiber. And the results from the compaction test are discussed in below sections

Fig.2.0: Types of molds and rammers used in Light and Heavy compaction tests

California Bearing Ratio Test:
The California Bearing Ratio Test is conducted for evaluating the Suitability of the Subgrade and the materials used in sub-base and base of flexible pavement.

The Plunger in the CBR test penetrates the specimen in the mould at the rate of 1.25mm per minute. The loads required for penetration of 2.5mm and 5.0mm are determined. The penetration load is expressed as a percentage of the standard loads at the respective penetration level of 2.5mm or 5.0mm

$$CBR\ Value = \frac{Penetration\ Load}{Standard\ Load}\ X\ 100$$

The CBR value is determined corresponding to both penetration levels. The greater of these values is used for the design of the pavement.

Test Procedure:
Take about 4.5 to 5.5kg of the soil which was passed through 20mm and retained in 45mm sieve. Insert the spacer discover the base and place coarse filter paper disc on the top of the displacer disc and fix the mould and collar on it. Mix the soil with water at OMC which was obtained in the compaction test. And compact the soil in 5 layers by giving 56 blows with heavy compaction rammer (4.89kg weight with 45cm drop) to each layer. Remove the extension collar and trim even the excess compacted soil carefully with a straight edge. Loosen the base plate and remove the spacer disc and invert the mold. Add annular masses to produce surcharge equal to 2.5 kg. A minimum of two annular masses should be placed.

Place the mold containing specimen in loading machine and apply the load on the plunger. Keep the rate of penetration as 1.25 mm/min. record the load corresponding to penetration 0.55,1.0,1.5,2.0,2.5,3.0,3.5, 4.0,5.0,7.5,10.0,and 12.5mm. However, record the maximum load and the corresponding penetration if it occurs at penetration of less than 12.5mm.

To calculate the Soaked CBR, Immerse the prepared sample with mould assembly in a tank full of water. Allow free access of water to the top and bottom of the specimen. Keep the mould in the tank undisturbed for 96hours. Take out the soaked specimen after 96hrs, allow it to drain off for 15min without disturbing the specimen. And then follow the procedure on load machine to calculate the soaked CBR.

BC: Black cotton Soil					
Observations & Calculations	Water Content				
	14%	17%	20%	23%	26%
Weight of the Mould + Soil (g)	8631	8810	9003	9025	9067
Weight of the Compacted Soil (g)	3651	3830	4023	4045	4087
Bulk Density (g/cc)	1.62	1.70	1.79	1.80	1.82
Water Content Determination					
Weight of the empty Cup (g)	22	29	35	26	30
Weight of the Cup + Wet Soil (g)	58	72	83	79	63
Weight of the Cup + Dry Soil (g)	49	58	64	60	44
Water Content (%)	13.28	16.41	19.53	22.39	25.16
Dry Density(g/cc)	1.43	1.46	1.50	1.47	1.45

Table2: Compaction Test Results of Black Cotton Soil:

Height of the Mould	12.73 cm
Diameter of the Mould	15.00 cm
Volume of the Mould	2250 cc
Weight of the Empty Mould	4980 gms

Consolidation Test:

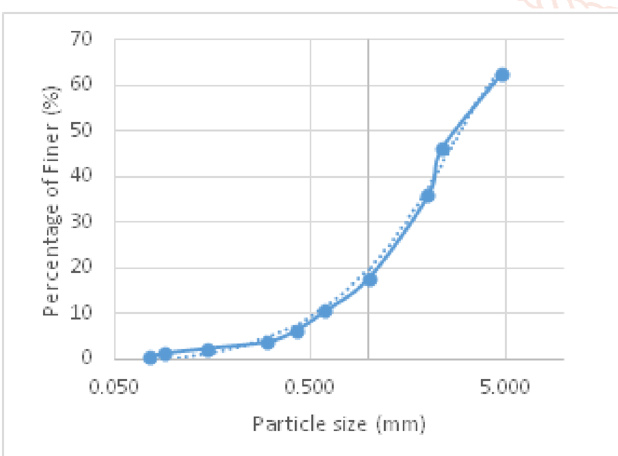
Consolidation of a saturated soil occurs due to the expulsion of water under a static, sustained load. The consolidation characteristics of soils are required to predict the magnitude and the rate of settlement. The following characteristics are obtained from the consolidation test.

$$Coefficeint\ of\ Compressibility, a_v = -\Delta e/\Delta\bar{\sigma}$$

$$Coefficient\ of\ Volume\ Change, m_v = \frac{-\Delta e}{1+e}\left(\frac{1}{\Delta\bar{\sigma}}\right)$$

$$Compression\ index, C_c = \frac{-\Delta e}{\log_{10}\frac{(\bar{\sigma}_0+\Delta\bar{\sigma})}{\bar{\sigma}_0}}$$

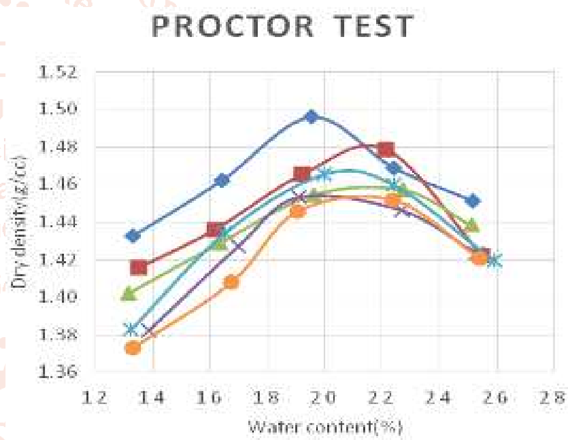
$$Coefficient\ of\ Consolidation, C_v = T_v\ d^2/t$$



Graph.1: Sieve Analysis Graph

Compaction Characteristics:

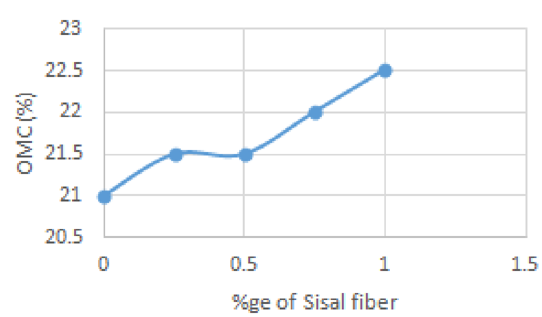
At first compaction characteristics of black cotton soil were determined to calculate the MDD and OMC the combinations with sisal fiber at 0.25%, 0.5%, 0.75%, 1% were made and the Compaction characteristics were determined. And the test results for all these combinations are as follows.



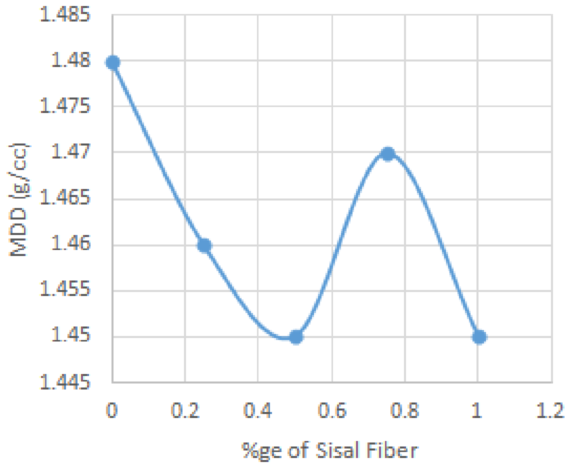
Graph 5.2: Compaction curves for soil samples with different percentages of Sisal fiber

Table3: OMC and MDD values of BC + Lime% + Sisal%

S. No	Sample	OMC (%)	MDD (g/cc)
1	Black Cotton Soil	20	1.5
2	BC + 0.25% Sisal	21.5	1.46
3	BC + 0.50% Sisal	21.5	1.45
4	BC + 0.75% Sisal	22	1.47
5	BC + 1.00% Sisal	22.5	1.45



Graph 5.7.3: Variation of OMC with different %ge of Sisal Fiber at 4% Lime



Graph 5.7.4: Variation of MDD with different %ge of Sisal Fiber at 4% Lime

CONCLUSIONS

In this study, the major properties studied are OMC, MDD, CBR, UCS, and Consolidation. Based on all investigations on all samples and when compared with normal soil, the following conclusions were made.

Optimum Moisture Content: (OMC)

Optimum moisture content (OMC) increased with the addition of sisal fiber.

For normal soil, OMC observed at 20% and it is increased to 21.5, 21.5, 22, and 22.5% with the addition of 0.25%, 0.5%, 0.75% and 1% sisal fiber respectively

Maximum Dry Density: (MDD)

Maximum dry density was decreased with the addition of sisal fiber

When Sisal fiber added, MDD value was decreased. But, at 0.75% sisal fiber addition was increased when compared to other sisal fiber additions.

California Bearing ratio: (CBR)

Both the Unsoaked and soaked condition of CBR were studied and Peak value was obtained at 0.75% sisal fiber addition in both conditions.

From 0 to 0.75% addition of sisal fiber, CBR value was gradually increased in both unsoaked and soaked condition.

But, CBR value was decreased after 0.75% of sisal fiber addition (i.e., at 1%)

Unconfined Compressive Strength: (UCS)

In UCS, Due to an increase in Sisal percentage the UCS value having increasing trend with respect to the parent soil.

In UCS, Due to an increase in Sisal percentage, the UCS value has been observed increasing trend up to 0.75% after that having a decreasing trend with Further increase of sisal content.

With overall observations of UCS, 0.5% and 0.75% addition was good, and more than that was not good.

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