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# A LABORATORY INVESTIGATION ON THE STRENGTH BEHAVIOUR OF EXPANSIVE SOIL TREATED WITH SISAL FIBRE AND LIME

[1]M. Harinadh Reddy, [2]Dr. K. Purnanandam

[1]*Post Graduate Student, Department of Civil Engineering,University College of Engineering, JNTUK Kakinada, A.P, India,*

[2]*Professor, Department of Civil Engineering, Rector of JNTUK, UCE- JNTUK Kakinada, Andhra Pradesh, India,*

***Abstract-- Expansive clay soils are considerably problematic soils in civil engineering constructions. Structures built on such type of soils show movements which are often detrimental and lead to structural damage. Damage from these soils is evidenced in many costly ways and is particularly obvious in buildings and pavements. Several methods are suggested as solutions to prevent damage to buildings in expansive soil areas. Especially expansive soils are worldwide problematic soil which is associated with the large volume change behavior when it undergoes a change in the water content. Expansive soils are found in some regions of India and many other countries. These soils pose major foundation problems, causing damage to the super structure if proper precautions have not been taken. Ground improvement technique such as soil stabilization and reinforcement are employed to improve the mechanical behavior of the soil and thereby enhancing the reliability of construction. The main objective of this study is to assess the possibility of using Sisal Fibre and Lime as stabilizing agents and to understand the effective performances of these admixture additives in controlling several properties of expansive soils under laboratory conditions. The present study deals with the strength behavior of the expansive soil that is collected from Amalapuram, East Godavari district, Andhra Pradesh, India, and the performance of sisal fibre as an admixture and lime as an additive for improving the strength characteristics and stabilizing the expansive soil.***

***Key Words—Expansive Soil, Sisal Fibre, Lime, OMC, MDD, CBR***

## I. INTRODUCTION

Expansive soils like Black Cotton soil prevail in most part of the earth. Expansive soils are those soils which are Swell considerably on absorption of water and they are shrink on removal of water. These soils experience a large moisture related volume changes during dry and wet season. Characteristics of the clayey soils are changed due to change in water content. These Expansive soils exhibits the larger amount of swelling and shrinkage characteristics to the presence of clay minerals such as montmorillonite, illite and Kaolinite etc. These soils pose several problems to the structures due to their volume changes. Among those, black cotton soil are one type of expansive soils and they shows high swell 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. They are predominant in the states of Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu. These soils have high swelling and shrinkage characteristics and extremely low CBR value and shear strength. In order to overcome these problems the soil must be stabilized. If it should be used as foundation material, Improvement of soil need to be done by adopting various techniques like soil stabilization, reinforcement etc. One method of controlling volume changes is to stabilize the soils with admixtures that prevent volume changes are adequately modify the volume change characteristics of soft clayey soil. Soil stabilization techniques are adopted to stabilize the expansive soils like cement, lime, fly ash etc… But these techniques became expensive so now a days adopting the special additives to stabilize the soil like Sisal Fibre. Sisal Fibre, upon mixing with soil, can be used an effective stabilizing agent for the improvement of problematic sols for use in subgrade. By mixing with lime develops pozzolanic reactions. Several researches have been made to improve the strength characteristics of the expansive soils.

**Fig.1 Presents the Sisal Fibre**

**Fig.2 Presents the Lime**

## II. OBJECTIVES OF THE STUDY

- The objectives of the present laboratory investigation are to determine the properties of the expansive soil and Sisal Fibre.
- To evaluate the performance of expansive soil when treated with Sisal Fibre as an admixture.
- To know the amount of Sisal Fibre and Lime required to stabilize the Black Cotton Soil.
- To analyze the variation of basic Engineering Properties like LL, PL, OMC, MDD and CBR with the addition of sisal fiber and lime at different percentage

## III. MATERIALS USED

*A. Expansive Soil (ES):* The soil used in this study is expansive soil was collected from Amalapuram East Godavari District Andhra Pradesh at a depth of 1.5m from ground level. The collected black cotton soil was subjected to air dried condition for further laboratory experimentation. The Index and Engineering properties of the expansive soil are determined as per IS code of practice. The properties of Black Cotton soil determined through several preliminary tests and those are listed in Table 1.

TABLE 1
PROPERTIES OF UNTREATED EXPANSIVE SOIL

| S.No | Property | | Expansive Soil |
|---|---|---|---|
| 1 | **Gravel (%)** | | *0.61* |
| 2 | **Sand (%)** | | *12.29* |
| 3 | **Fines (%)** | **silt** | *38.57* |
| | | **clay** | *48.53* |
| 4 | **Liquid limit (%)** | | *60* |
| 5 | **Plastic limit (%)** | | *29.29* |
| 6 | **Plastic index (%)** | | *30.71* |
| 7 | **Soil classification** | | *CH* |
| 8 | **Specific gravity** | | *2.673* |
| 9 | **DFS (%)** | | *110* |
| 10 | **OMC** | | *28.27* |
| 11 | **MDD (g/cc)** | | *1.473* |
| 12 | **Cohesion ($kg/cm^2$)** | | *0.58* |
| 13 | **CBR (%)** | | *2.2408* |

*B. Sisal Fibre (S.F):* Sisal Fibre is the natural fibre that is obtained from sisal plant. Sisal Fibre used in this study was collected from Sri Lakshmi Groups, Fibre production unit, Cherakupalli village, Guntur district of Andhra Pradesh, India. The average diameter of Sisal Fibre was 0.3mm and the average length of fibre used in this study is about 8mm. Physical and Chemical composition of sisal fibre are listed in Table 2 and 3 respectively.

TABLE 2
CHEMICAL COMPOSITION OF SISAL FIBRE

| S. No | Constituent Elements | Content (%) |
|---|---|---|
| 1 | **Cellulose** | *41.6-62.6* |
| 2 | **Hemi-Cellulose** | *9.2-14.6* |
| 3 | **Lignin** | *11.4-19.5* |

TABLE 3
PHYSICAL PROPERTIES OF SISAL FIBRE

| S. No | Constituent Elements | Content |
|---|---|---|
| 1 | **Density** | *1.28-1.42 g/cc* |
| 2 | **Tensile Modulus** | *4.6-16.8 GPa* |
| 3 | **Tensile strength** | *126-860 MPa* |
| 4 | **Elongation** | *1.54-3.85%* |
| 5 | **Fibre Diameter** | *145-440 µm* |

*C. Lime (L):* The lime stone powder used in this study was collected from Supraja Enterprises, 76/10/52, Bhavanipuram, V D Puram, Vijayawada, Andhra Pradesh 520012,India. Physical and chemical properties of lime are listed in Table 4.

TABLE 4
CHEMICAL AND PHYSICAL PROPERTIES OF LIME

| Property | value |
|---|---|
| **Silicon Oxide ($SiO_2$)** | *<2.5* |
| **Aluminium Oxide ($Al_2O_3$)** | *<1.5* |
| **Ferrous Oxide ($Fe_2O_3$)** | *<2* |
| **Calcium Oxide (CaO)** | *>83.3* |
| **Magnesium Oxide (MgO)** | *<0.5* |
| **Sodium Oxide ($Na_2O$)** | *0.4-0.5* |
| **Physical Appearance** | *Dry White Powder* |
| **Specific Gravity** | *2* |
| **Bulk Density** | *600-900 g/l* |

## IV. LABORATORY STUDIES

The laboratory studies were carried out on the samples of Expansive soil, Expansive soil and different percentages of Sisal Fibre, Expansive soil and different percentages of sisal fibre and lime.

*4.1 Liquid limit:*
Liquid limit test was conducted on Expansive soil, Expansive soil+1% Sisal Fibre and Expansive soil+1%S.F+4% Lime, using Casagrande's liquid limit apparatus as per the procedures in IS: 2720 part 4 (1970).

*4.2 Plastic limit:*

Plastic limit test was conducted on Expansive soil, Expansive soil+1% Sisal Fibre and ES+1%S.F+4% Lime., as per the specifications laid clown in IS: 2720 part ( 1970).

*4.3 Differential Free Swell:*

Differential Free Swell (DFS) is a parameter used for the identification of the expansiveness of the soil.

In this method two samples of oven dried soil sample passing through 425μ size sieve and weighing 20 gm each are used. One sample is poured slowly in 100cc capacity graduated cylinder filled with water and other sample is poured in another 100cc capacity graduated cylinder filled with kerosene (non-polar liquid). Both the cylinders are left for 24 hours and the respected volumes are noted to determine the free swell of a soil.

Differential Free Swell (%) = $\frac{vd-vk}{vk} * 100$

Where,

$V_d$ = volume of soil specimen read from the graduated cylinder filled with distilled water.

$V_k$ = volume of soil specimen read from the graduated cylinder filled with kerosene.

Because kerosene is a non-polar liquid, it does not cause any swell of the soil IS: 2720 (Part III- l980) gives degree of expansion of a soil depending upon its differential free swell as under.

TABLE 5
DIFFERENTIAL FREE SWELL

| S. No | Differential Free Swell | DFS |
|---|---|---|
| 1 | **Low** | *<20%* |
| 2 | **Moderate** | *20-35%* |
| 3 | **High** | *35-50%* |
| 4 | **Very High** | *>50%* |

*4.4 Proctor Modified compaction Test:*

Compaction characteristics of soil samples were conducted with different percentages of Lime and Sisal Fibre, were determined using Modified or Heavy Compaction method as per IS codes of practice IS: 2720 part-6 (1974).By using this test, get the relationship between the OMC and MDD for different samples was evaluated.

*4.5 Specific Gravity Test:*

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil. Specific gravity test was carried out by Pycnometer as per IS: 2720 Part 3 (1980).

*4.6 California Bearing Ratio Test:*

The standard procedure mentioned in IS: 2720 Part 8 (1979) was followed to determine the CBR value.The California bearing ratio test was conducted on the soil sample with varying four different percentages of Sisal Fibre. Sisal Fibre were added to soil in varying percentages (0.5,1,1.5,2%) respectively. CBR value increases up to 1 % addition of Sisal Fibre and then decreases. The maximum value of CBR for 1 % addition of Sisal Fibre was obtained as 3.809%. The CBR value showed an Increase from 2.2408% to 3.809% at 1% addition of Sisal Fibre. Further on addition of 2% lime to soil and 1% Sisal Fibre the CBR increased from 3.809% to 7.17% .

## V. RESULT AND DISCUSSIONS

The Index & Engineering properties of Expansive soil treated with Sisal Fibre with optimum expansive soil determined as per IS code of practice and presented in Table 6.

TABLE 6
PHYSICAL PROPERTIES OF STABILIZED EXPANSIVE SOIL WITH AN OPTIMUM OF 1% SISAL FIBRE

| S.No | Property | Untreated expansive soil |
|---|---|---|
| 1 | **Liquid limit (%)** | *60* |
| 2 | **Plastic limit (%)** | *29.29* |
| 3 | **Plastic index (%)** | *30.71* |
| 4 | **Soil classification** | *CH* |
| 5 | **Specific gravity** | *2.673* |
| 6 | **D.F.S (%)** | *110* |

| | | |
|---|---|---|
| 7 | **O.M.C** | *28.27* |
| 8 | **M.D.D (gm/cc)** | *1.473* |
| 9 | **Cohesion (kg/cm2)** | *0.58* |
| 10 | **Angle of shear resistance(ϕ)** | $17^0$ |
| 11 | **CBR (%)** | *2.2408* |

*5.1 Proctor Modified Compaction Results of Expansive Soil treated with Various Percentages of Sisal Fibre:*

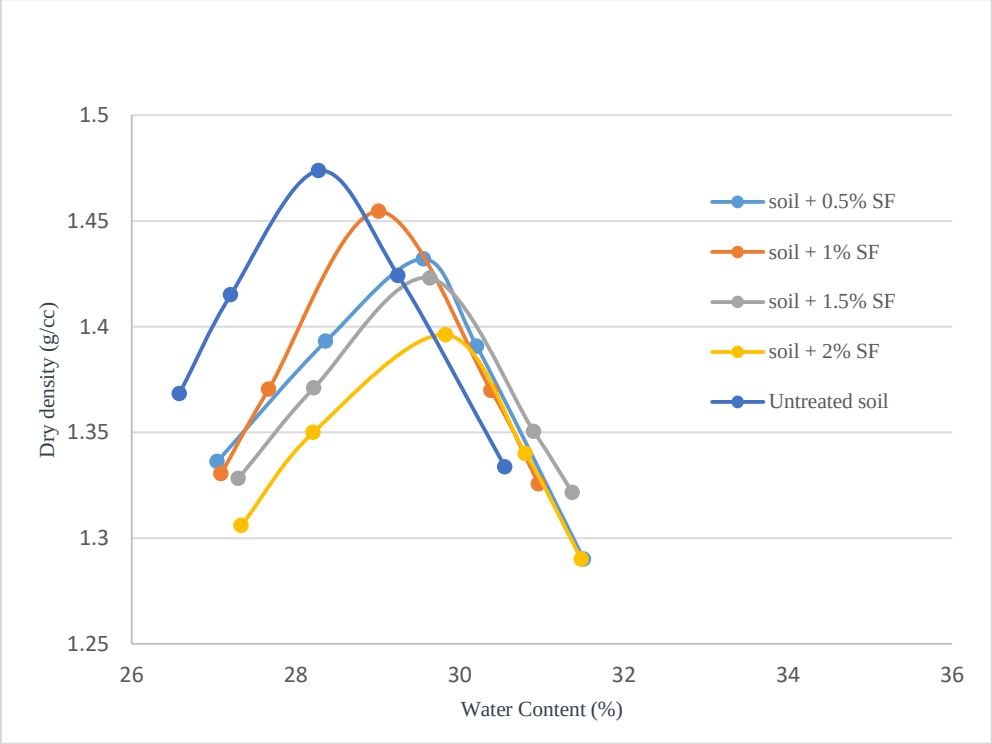


*Fig.3 OMC & MDD Values of Untreated Expansive Soil And with the addition of 0.5%, 1%, 1.5%, 2% Sisal Fibre*

TABLE 7
OMC AND MDD VALUES OF EXPANSIVE SOIL TREATED WITH DIFFERENT PERCENTAGES OF SISAL FIBRE

| **Mix proportion** | **MDD (gm/cc)** | **OMC (%)** |
|---|---|---|
| Soil | *28.27* | *1.473* |
| Soil+0.5% SF | *29.55* | *1.432* |
| **Soil+1% SF** | ***29.01*** | ***1.454*** |
| Soil+1.5% SF | *29.637* | *1.423* |
| Soil+2% SF | *29.827* | *1.3962* |

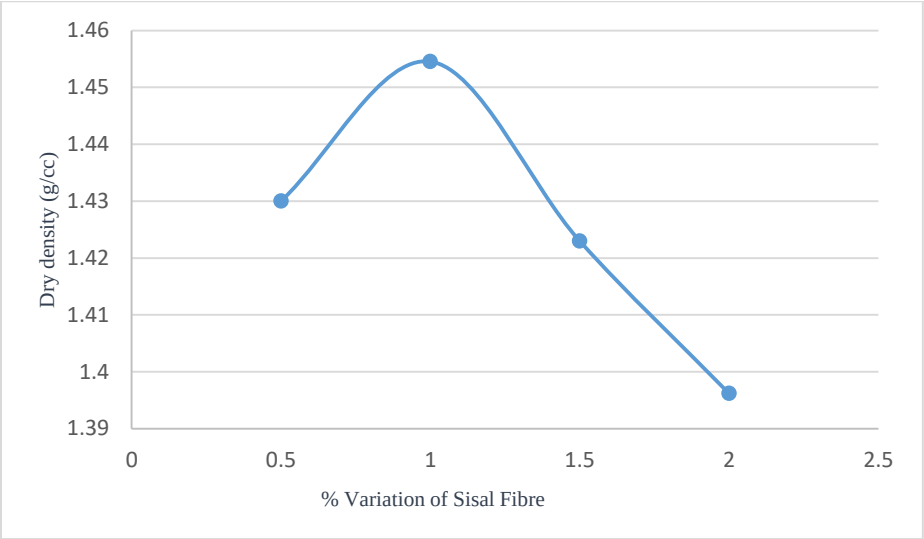


*Fig.4 MDD Values of Expansive Soil with % Variation of Sisal Fibre*

*5.2 CBR Test Results for Expansive Soil Treated With Various Percentages of Sisal Fibre:*

The soaked CBR values of various mixes of Expansive Soil and Sisal Fibre using OMC obtained from compaction are determined. The soaked CBR after immersing in water for four days, that is when full saturation is likely to occur, is also determined. Variation of CBR with % variation in Sisal Fibre is presented.

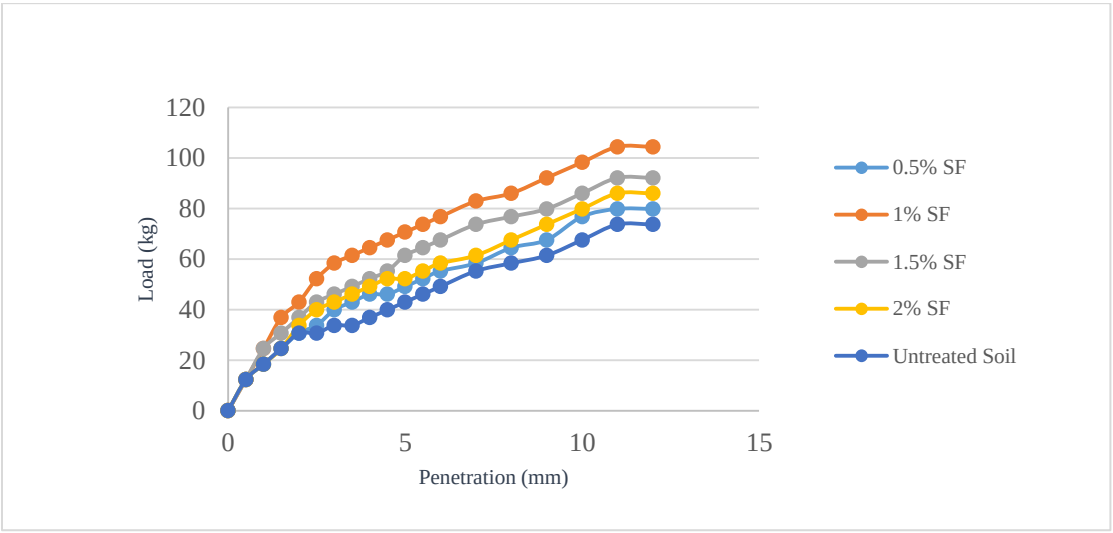


*Fig.5 CBR values of Expansive Soil Treated with Percentage Variation of Silsal Fibre*

TABLE 8
VARIATION OF SOAKED CBR VALUES AT DIFFERENT PERCENTAGES OF SISAL FIBRE

| **Mix Proportion** | **Soaked CBR (%)** |
|---|---|
| Soil | *2.2408* |
| Soil+0.5% SF | *2.464* |
| **Soil+1% SF** | ***3.809*** |
| Soil+1.5% SF | *3.137* |
| Soil+2% SF | *2.913* |

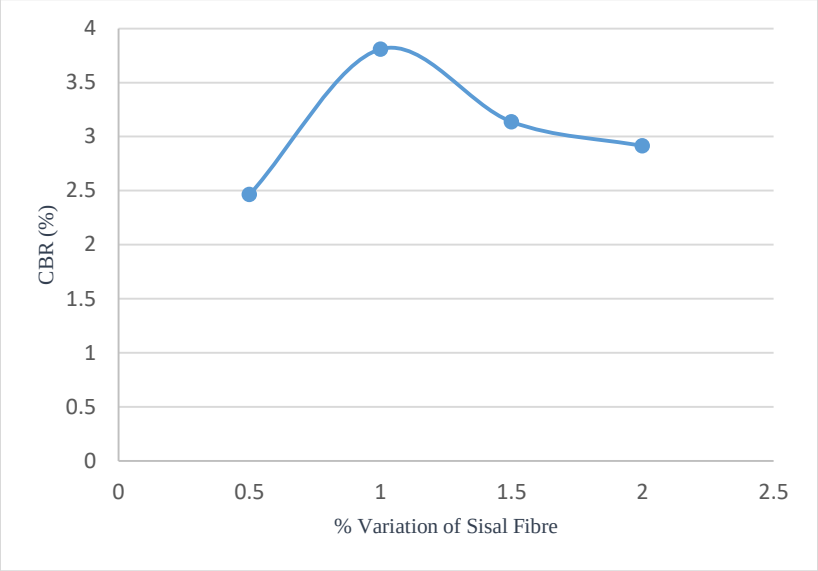


*Fig.6 Presents the CBR Values of Expansive Soil with % Variatio of Sisal Fibre*

*5.3 Proctor Modified Compaction Results of Expansive soil treated with Optimum 1% Sisal Fibre and different percentages of Lime :*

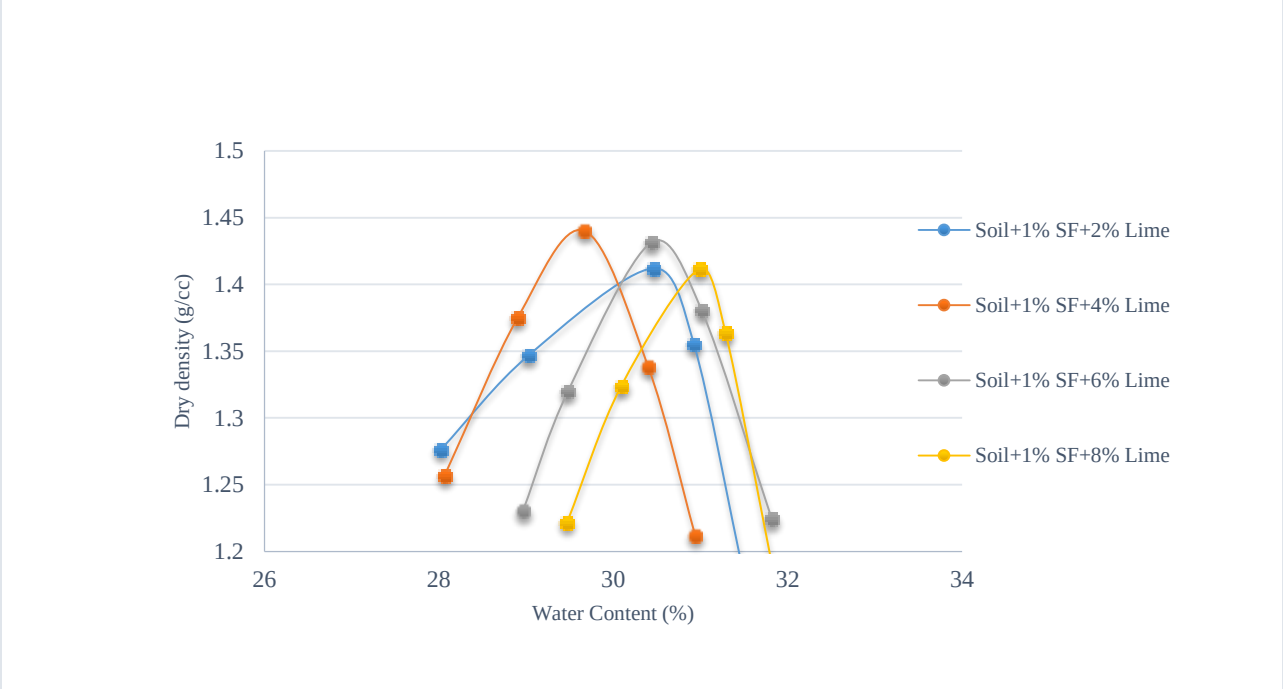


*Fig.7 OMC & MDD Values of Expasive Soil Treated with Optimum of 1% Sisal Fibre and with 2%, 4%, 6%, 8% of Lime*

TABLE 9
VARIATION OF MDD AND OMC OF EXPANSIVE SOIL TREATED WITH OPTIMUM 1% SISAL FIBRE AND DIFFERENT PERCENTAGES OF LIME

| **Mix Proportion** | **MDD (gm/cc)** | **OMC (%)** |
|---|---|---|
| Soil+1% SF+2% Lime | *30.462* | *1.411* |
| **Soil+1% SF+4% Lime** | ***29.669*** | ***1.440*** |
| Soil+1% SF+6% Lime | *30.444* | *1.431* |
| Soil+1% SF+8% Lime | *30.989* | *1.411* |

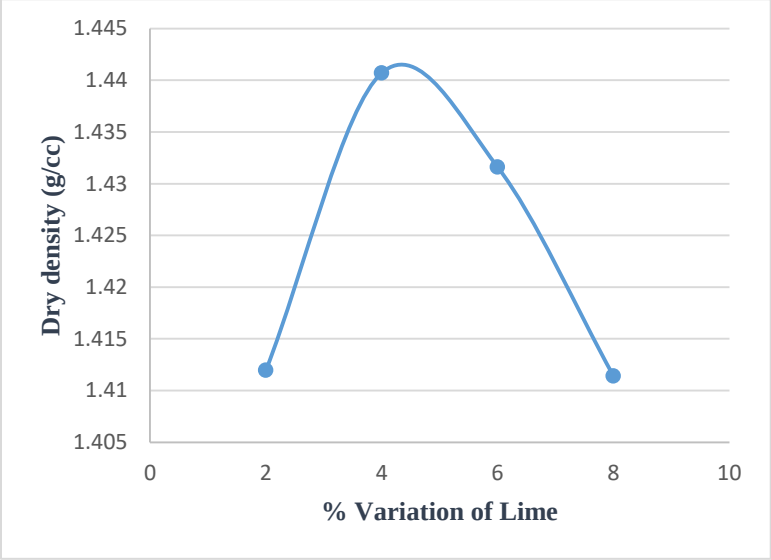


*Fig.8 MDD Values of Expansive Soil treated with optimum 1% S.F and % Variation of Lime*

*5.4 CBR Test Results for Optimum of Sisal Fibre Treated Expansive Soil with Various Percentages of Lime:*

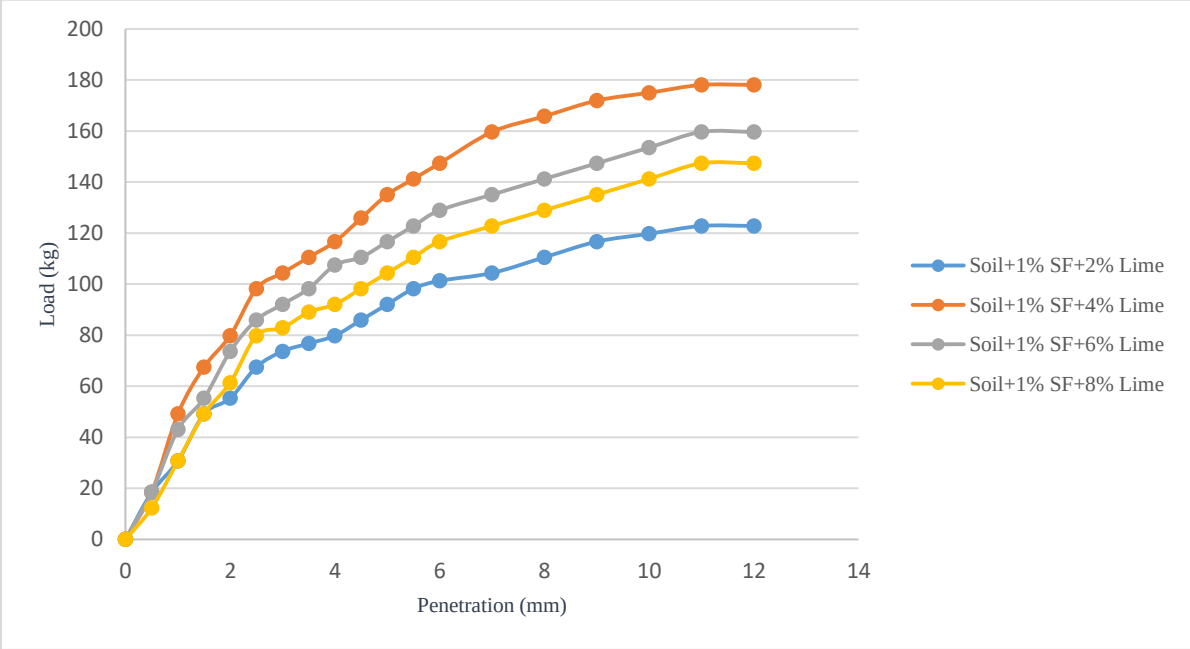


*Fig.9 Presents the CBR Values of Optimum Sisal fibre treated Expansive Soil with Percentage Variation of Lime*

TABLE 10
VARIATION OF SOAKED CBR VALUES OF OPTIMUM SISAL FIBRE TREATED EXPANSIVE SOIL WITH VARIOUS PERCENTAGES OF LIME

| **Mix Proportion** | **CBR (%)** |
|---|---|
| Soil+1% SF+2% Lime | *4.929* |
| **Soil+1% SF+4% Lime** | ***7.17*** |
| Soil+1% SF+6% Lime | *6.274* |
| Soil+1% SF+8% Lime | *5.826* |

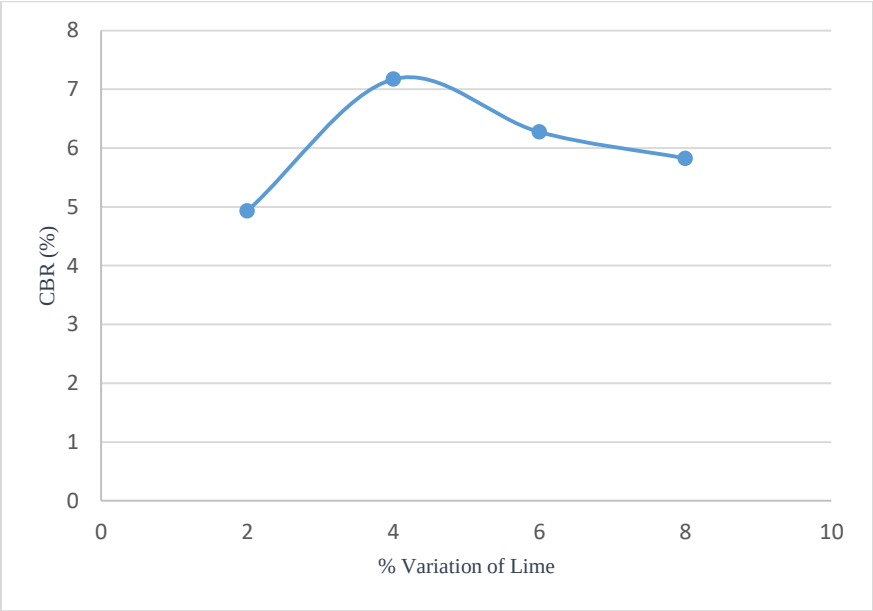


*Fig.10 Presents the CBR Values of Optimum sisal fibre treated Expansive Soil with various percentages of Lime*

TABLE 11
INDEX AND ENGINEERING PROPERTIES OF EXPANSIVE SOIL TREATED WITH OPTIMUM 1% SISAL FIBRE AND 4% LIME

| S.No | Property | Untreated expansive soil | Soil+1%S.F | Soil+1%S.F+4% lime |
|---|---|---|---|---|
| 1 | **Liquid limit (%)** | *60* | *47.26* | *22.84* |
| 2 | **Plastic limit (%)** | *29.29* | *24.77* | *17.68* |
| 3 | **Plastic index (%)** | *30.71* | *18.26* | *10.2* |
| 4 | **Soil classification** | *CH* | *CI* | *CL* |
| 5 | **Specific gravity** | *2.673* | *2.726* | *2.861* |
| 6 | **D.F.S (%)** | *110* | *60* | *40* |
| 7 | **O.M.C** | *28.27* | *29.01* | *26.669* |
| 8 | **M.D.D (gm/cc)** | *1.473* | *1.454* | *1.440* |
| 9 | **Cohesion (kg/cm2)** | *0.58* | *0.47* | *0.221* |
| 10 | **Angle of shear resistance(ϕ)** | $17^0$ | $23.7^0$ | $34.9^0$ |
| 11 | **CBR (%)** | *2.2408* | *3.809* | *7.17* |
| 12 | **Degree of Free Swell (%)** | *110* | *60* | *40* |

## VI. CONCLUSIONS

- It is observed that the liquid limit of Expansive Soil has been decreased by 21.23% on addition of 1% Sisal Fibre and it has been further decreased by 61.93% when 4% Lime added.
- It is noticed that the plastic limit of the Expansive Soil has been decreased by 15.43% on addition of 1% Sisal Fibre and it has been decreased by 39.63 % when 4% Lime is added.
- It is observed that the plasticity index of the Expansive Soil has been decreased by 40.54% into on addition of 1% Sisal Fibre and it has been further decreased by 66.78% when 4% Lime is added.
- It is noticed that the cohesion of Expansive Soil has been decreased by 14.545% on addition of 1% Sisal Fibre and it has been further decreased by 59.81% when4% Lime added.
- It is noticed that the angle internal friction of Expansive Soil has been improved by 39.41% on addition of 1% Sisal Fibre and it has been further improved by 105.29% when 4% Lime added.
- It is found that the O.M.C of the Expansive Soil has been increased by 2.617% on addition of 1% Sisal Fibre and it has been further increased by 4.948% when 4% Lime is added.
- It is found that the M.D.D of the Expansive Soil has been decreased by 1.289% on addition of 1% Sisal Fibre and it has been decreased by 2.24 % when 4% Lime is added.
- It is observed that the C.B.R value of the Expansive Soil has been increased by 69.98% on addition of 1% Sisal Fibre and it has been further improved by 219.97% when 4% Lime is added.
- It is observed that the DFS value of the Expansive Soil, has been decreased by 45.45% on addition of 1% Sisal Fibre and it has been further decreased by 63.63% when 4% Lime is added.

The soaked CBR of the soil on stabilizing is found to be 7.17%, but according to IRC 2001 the CBR value should be in between 5-6, to be used for Subgrade, and is satisfying. Thus the addition of 1% of Sisal Fibre and 4% of Lime improved the properties of the air dried Expansive Soil to the desirable extent, making it useful to be used in pavements.

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