

# **An Experimental Study on Stabilization of Black Cotton Soil by Lime and Sisal Fibre**

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**ABSTRACT:** The main objective of this study is to assess the possibility of using Lime and Sisal Fibre as stabilizing agents and to understand the effectiveness of these additives in controlling several properties of expansive soils like Black Cotton Soil under controlled laboratory conditions. To achieve this goal several experimental studies like Heavy Compaction Test, California Bearing Ratio Test, (CBR), Unconfined Compressive Strength (UCS) Test, Consolidation etc., were carried out with addition of different percentages of Sisal Fibre and Lime in Black Cotton Soil as trial and error process. In present study, the soil samples prepared with addition of Sisal Fibres by 0%, 0.25%, 0.5%, 0.75%, and 1% at 4% Lime as constant additive. The average length of Sisal Fibre is used in this study is approximately 10-15mm. At first, Optimum Moisture Content (OMC) was determined through modified proctor test. At obtained OMC, different tests like CBR, UCS and Consolidations tests were conducted. CBR test was carried in both unsoaked and soaked condition and maximum values was obtained where 0.75% Sisal Fibre was added. UCS test was carried at 0, 3, 7, 14 and 28 days curing periods, and maximum value obtained where 0.5% Sisal Fibre added at long curing days. Gradual increment in UCS was observed for lower curing periods. Based on Consolidation Test, observed that the addition of Sisal Fibre gives positive improvement in consolidation characteristics of Black Cotton Soil.

**KEYWORDS:** Black Cotton Soil, Lime, Sisal Fibre, OMC, MDD, CBR, UCS, Consolidation.

## **I. INTRODUCTION**

In today's world, due to 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 sky scrapers, from bridges to airports and from 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 site for construction 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 is 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 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.

Paper is organized as follows. Section II presents the literature survey on related work performed by several authors. Section III describes about the Materials and Methodology. In this, what are the materials taken for study, and methodology implemented on whole study are explained. Type of tests conducted and their procedure followed are mentioned in Section IV. Section V presents experimental results. Finally, Section VI presents conclusion.

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## II. RELATED WORK

The detailed literature survey related to this study was presented in this section Work done by some researchers, which was related to present study are analysed and some of those are mentioned in below paragraphs.

Amrutha Mathew and Dr. Raneesh.K.Y (2016), were studied the effect of Sisal Fibre, Bagasse Ash and Glass powder in improving the characteristics of Black Cotton Soil. Sisal Fibre used are around 0.2 mm diameter and 15 mm to 20 mm length and are randomly mixed with soil in varying percentages (0.3%, 0.6%, 0.9%, and 1.2%) by dry weight. Bagasse Ash mixed with soil at 3.5%, 7%, 10.5% and 14%. And Glass powder is mixed with soil in varying percentages at 7%, 14%, 21%, and 28%. Various tests were carried on the trial mixes with different percentages as mentioned before. The individual optimum percentages obtained are Sisal Fibre at 0.9%, Bagasse Ash at 7% and Glass Powder at 14%. And finally the concluded that, Sisal Fibre, Bagasse Ash and Glass Powder Waste can be used as the stabilizers for the improvement of strength properties of the soil.

Abhijith S and Aruna T (2015), were carried a study to evaluated the effect of Ground Granulated Blast Furnace Slag (GGBS) and Sisal Fibre on compaction and strength properties of Black Cotton Soil. GGBS and Sisal Fibre are mixed in Black Cotton Soil at different percentages by dry weight of soil and GGBS percentages varies from 10%, 20%, 30%, and 40%. Sisal Fibre percentages varies from 10.25%, 0.5%, 0.75%, 1.0%, 1.25%, and 1.5%. A series of tests were conducted to study the effect of GGBS and Sisal Fibres on strength characteristics of Black Cotton Soil and stated that the individual optimum percentages of GGBS is 20% and Sisal Fibre is 0.75%. From the study, the stated that the UCS is increased 4 times that of Black Cotton Soil and the curing period increased the UCS of specimens having GGBS and Sisal Fibre.

Sabreena Mohammad, Deeba Qadir and Sarmistha R. Paul (2017), were studied to evaluate the effect of Jute Fibre with the addition of Lime in Black Cotton Soil. Jute Fibre was added at 0, 0.25, 0.5, 0.75, and 1.0%. Jute Fibre was added at two different lengths and those are 20mm and 40mm. After completing the detailed experimental study, they were given following conclusions. As the amount of Jute Fibre & Lime increases there is apparent reduction in maximum dry density and increase in optimum moisture content. Addition of Jute Fibres to Lime stabilized expansive soil decreases its swelling behaviour and increases UCS. They also concluded that there is significant effects of length on the UCS value of soil. The strength value of soil increases with the increase in length of fibre.

From the above literatures, it is concluded that the natural fibres like Jute Fibre, coconut coir fibre, banana fibre, Sisal Fibre, etc. can be used to strengthen the expansive soils like Black Cotton Soil in random inclusion manner.

## III. MATERIALS AND METHODOLOGY

Different types of materials used in this study are Black Cotton Soil, Sisal Fibre, Lime and their details along with properties are explained in below sections.

### A. Black Cotton Soil

The Black Cotton Soil used in this study was collected at a depth of 1 to 1.5 m from Thummalapalli Village, Allavaram Mandal, East Godavari District of Andhra Pradesh, India. The collected soil was subjected to air dried for further experimentation. And the properties of Black Cotton Soil determined through several preliminary tests and those are presented in Table – 1.

Table – 1: Properties of Black Cotton Soil

Properties	Value
Color	Black
Specific Gravity	2.67
Liquid Limit (%)	52
Plastic Limit (%)	25.15
Plasticity Index (%)	26.85
Classification	CH
Optimum Moisture Content (%)	20

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Maximum Dry Density (g/cc)	1.5
Unsoaked CBR	2.9
Soaked CBR	2.1
Unconfined Compressive Strength (kg/cm <sup>2</sup> )	0.9
Differential Free Swell (%)	50
Coefficient of Compressibility (cm <sup>2</sup> /kg)	0.043
Compression Index (cm <sup>2</sup> /kg)	0.056
Coefficient of Volume Change (cm <sup>2</sup> /kg)	0.029

## B. Sisal Fibre

Sisal Fibre is the natural fibre 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 0.2mm and the average length of fibre used in this study is about 10 – 15mm. Sisal Fibre used was shown in Fig. 1.



Fig. 1. Sisal Fibre

## C. Lime

Locally available fine Lime Stone Powder was used in this study and it was collected from Supraja Enterprises, Vijayawada, Krishna district of Andhra Pradesh, India.

## D. Methodology

Black Cotton Soil was collected and it was subjected to air dried to carry further experiments on it. The total study was carried in 3 phases.

In phase 1, preliminary tests like Specific gravity, Liquid limit, Plastic limit, differential free swell were conducted on existed soil.

In phase 2, Lime was added to Black Cotton Soil at 0, 2%, 4% and 6%. Modified Compaction Test was conducted to these samples and OMC, MDD were obtained. Maximum values are obtained for the proportion having 4% Lime.

In phase 3, at 4% Lime, Sisal Fibre was added by 0%, 0.25%, 0.50%, 0.75%, and 1% in random inclusion manner. Total 6 samples were prepared and those are presented in Table – 2. Several tests like, Modified Compaction, CBR, UCS and Consolidation were carried on these samples to analyze the effect of these in changing the engineering properties of Black Cotton Soil.

Table – 2 presents the type of samples of Black Cotton Soil prepared at different percentages of Lime and Sisal Fibre. And the notation used to represent the sample type in some graphs evaluated through test results are also mentioned.

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Table – 2: Types of Samples Prepared & Tested

S.no	Sample Prepared	Notation
1	Black Cotton Soil (BC)	L0 – S0
2	BC + 4% Lime	L4 – S0
3	BC + 4% Lime + 0.25% Sisal Fibre	L4 – S0.25
4	BC + 4% Lime + 0.50% Sisal Fibre	L4 – S0.50
5	BC + 4% Lime + 0.75% Sisal Fibre	L4 – S0.75
6	BC + 4% Lime + 1.00% Sisal Fibre	L4 – S1.00

Soil samples according to these percentages are prepared and several tests were conducted on these samples and the testing methods carried were explained in following section.

## IV. LABORATORY TESTS CONDUCTED

In order to determine the effect of Lime and Sisal Fibre in Black Cotton Soil, different tests were conducted on the samples which were mentioned in Table – 1. And the testing procedure followed are explained in below sections.

### A. Index Properties

Liquid Limit, Plastic Limit, Specific Gravity, and Differential Free Swell (DFS) tests were carried on collected soil by following IS standard procedures. IS: 2720 - Part 5 (1985) was used to determine the Liquid and Plastic limits. By using these and plasticity chart, the type of soil was classified. Pycnometer method described in IS: 2720 – Part 3 (1980) was used to determine the Specific gravity. DFS was measured as per IS 2720 – Part 11 (1977).

### B. Compaction Characteristics

The Compaction Characteristics of soil samples with different percentages of Lime and Sisal Fibre were determined by using Modified (Heavy) Compaction method as per IS: 2720 – Part 8 (1983). By using this test, the relationship between the OMC and MDD for different samples was evaluated.

### C. California Bearing Ratio (CBR)

The standard procedure mentioned in IS: 2720 – Part 16 (1979) was followed to determine the CBR value. The CBR test was conducted on Black Cotton Soil with different percentages of Lime and Sisal Fibre in both Unsoaked and Soaked conditions. In order to calculate the soaked CBR, sample was immersed in water for 96hrs.

### D. Unconfined Compressive Strength (UCS)

UCS Test was carried on cylindrical soil samples with different percentages of Lime and Sisal Fibre. Split mould was used to prepare the sample, and test was conducted on samples as per IS: 2720 – Part 10 (1991). UCS was calculated on samples at 0, 3, 7, 14, 28 days curing periods.

### E. Consolidation Characteristics

Consolidation Characteristics of soil samples were determined as per IS: 2720 – Part 15 (1986). The pressure applied on consolidometer assembly are 0.1, 0.2, 0.4, 0.8, 1.6 kg/cm<sup>2</sup>. From this test, Coefficient of Compressibility ( $a_v$ ), Compression Index ( $c_c$ ) and Coefficient of Volume Change ( $m_v$ ) were calculated and their variation with different percentages of Lime and Sisal Fibre in Black Cotton Soil was analyzed.

The above mentioned tests were carried on different types of soil samples (as mentioned in Table – 2) and their test results were presented in below section.

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## V. RESULTS AND DISCUSSION

### A. Index Properties

The basic index properties of collected soil are, Liquid Limit is 52%, Plastic Limit is 25.15% and Plasticity Index is 26.85%. Based on these, the soil was classified as CH (Clay with High Plasticity). Specific gravity obtained is 2.67. And Differential Free Swell is 50%. From DFS, the soil was classified as High Expansive Soil.

### B. Compaction Characteristics

Modified Compaction test was conducted on soil samples and the MDD and OMC obtained for untreated soil are 20% and 1.50g/cc. OMC was increased and MDD was decreased with the addition of Sisal Fibre. The variation of OMC and MDD with different percentages of Lime and Sisal Fibre was shown in Fig.2.

Fig.2 presents compaction curve which was the graph between water content as abscissa and dry density as ordinate. The peak dry density obtained on curve is taken as MDD and corresponding water content is taken as OMC. The variation of all compaction curves for the samples mentioned in Table – 2 are presented in fig.2 itself.

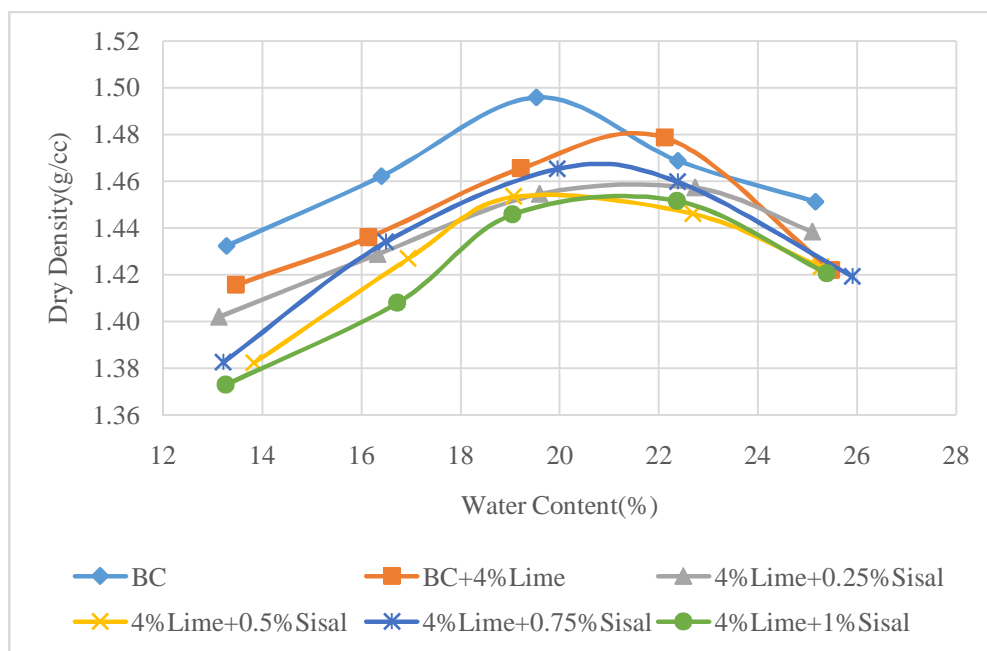


Fig. 2. Compaction Curves for samples with different percentages of Lime and Sisal Fibre

### C. California Bearing Ratio

The variation of Load with Penetration graphs for Black Cotton Soil along with different percentages of Lime and Sisal Fibre in both Unsoaked and Soaked condition were shown in Fig. 3 and Fig. 4 respectively.

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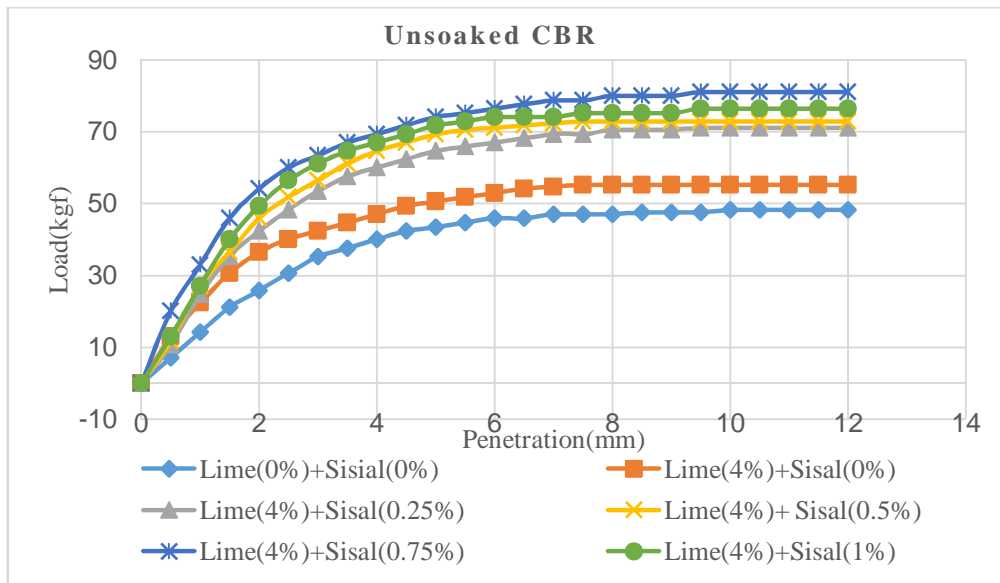


Fig. 3. Load Vs Penetration Graphs of Unsoaked CBR

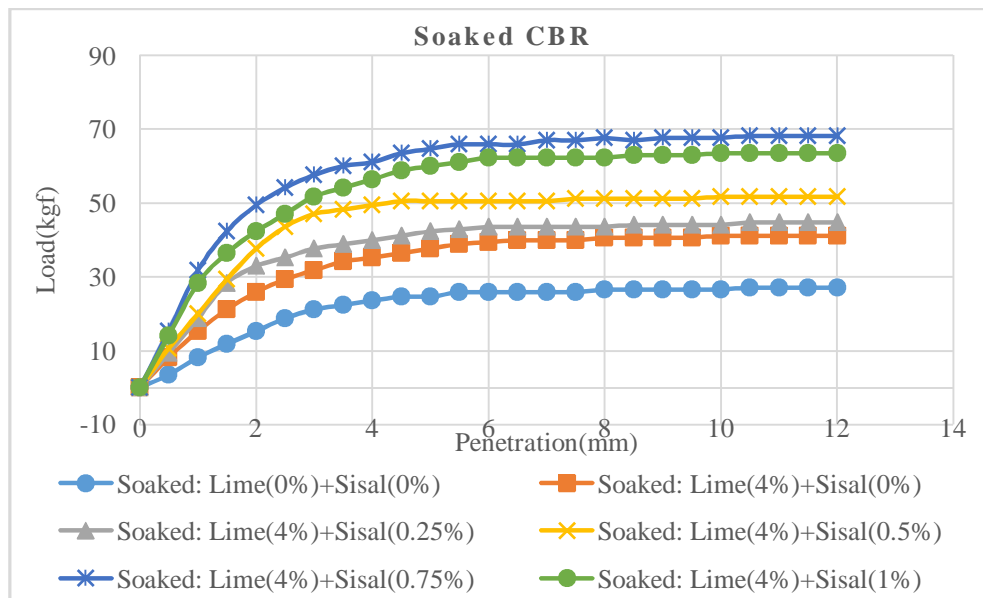


Fig. 4. Load Vs Penetration Graphs of Soaked CBR

And the Final CBR values obtained and their variation are shown in Fig. 5. For Untreated Soil, obtained CBR values are 2.2% and 1.4% in Unsoaked and Soaked condition respectively. With the addition of Sisal Fibre, CBR values are increased and the maximum value of CBR is obtained at Black Cotton Soil with 4% Lime and 0.75% Sisal Fibre and the values are 4.4% and 3.9% in Unsoaked and Soaked condition respectively. To understand the notations used in abscissa as Sample Type, refer Table – 2.



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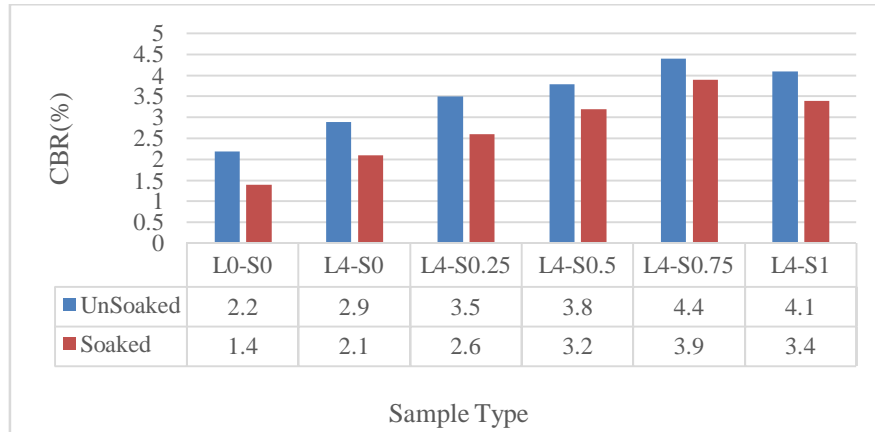


Fig. 5. Variation of Unsoaked and Soaked CBR at Different Percentages of Lime and Sisal Fibre

### D. Unconfined Compressive Strength

UCS at 0, 3, 7, 14, and 28 days curing periods was calculated. And the variation of UCS with Curing Days was shown in Chart – 5. The UCS values are increased when Lime and Sisal Fibre were added to Black Cotton Soil. For 0, 3, and 7 days curing period, UCS values was gradually increased with the addition of Sisal Fibre. At 14 days curing period, maximum values is obtained at 0.75% Sisal Fibre. At 28 days curing period, the UCS with 0.75% and 1% Sisal Fibre was decreased and maximum obtained for 0.5% Sisal Fibre. However, all these were increased values, when compared with UCS of untreated soil. To understand the notation used for curves in fig. 6, refer Table – 2.

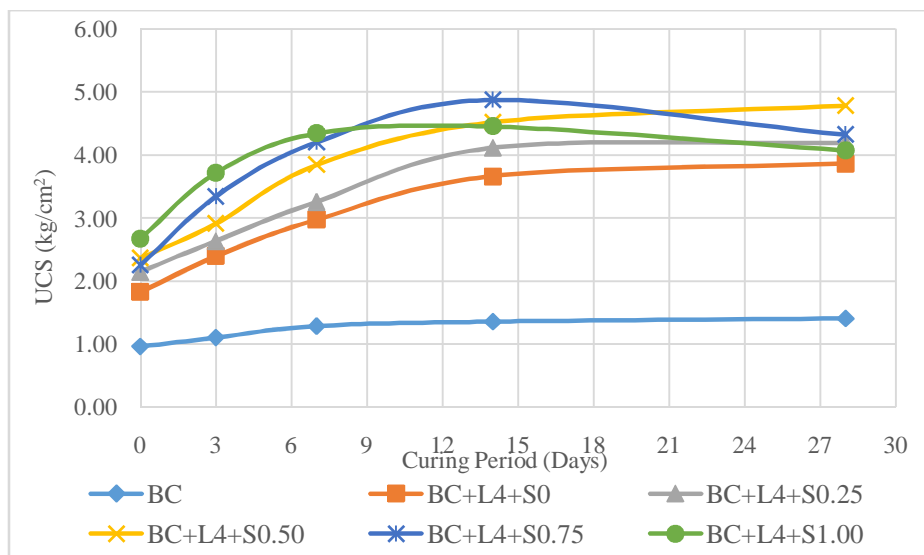


Fig. 6. Variation of UCS at Different Curing Periods for samples with different percentages of Lime and Sisal Fibre

### E. Consolidation Characteristics

Total 3 coefficients, Coefficient of Compressibility ( $a_v$ ), Compression Index ( $c_c$ ) and Coefficient of Volume Change ( $m_v$ ) are calculated from consolidation test and the values re resulted and their variation with different percentages of Lime and Sisal Fibre are shown in Fig. 7, Fig. 8 and Fig. 9. When comparted with Black Cotton

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Soil, all three coefficients were decreased i.e., Consolidation characteristics were improved when Lime and Sisal Fibre were added to Black Cotton Soil.

Fig.7 presents the graph between variation of Coefficient of Compressibility ( $a_v$ ) at different percentage of Lime and Sisal Fibre as ordinate and Sample Type as abscissa. To understand the notation of Sample Type represented in abscissa, refer Table – 2.

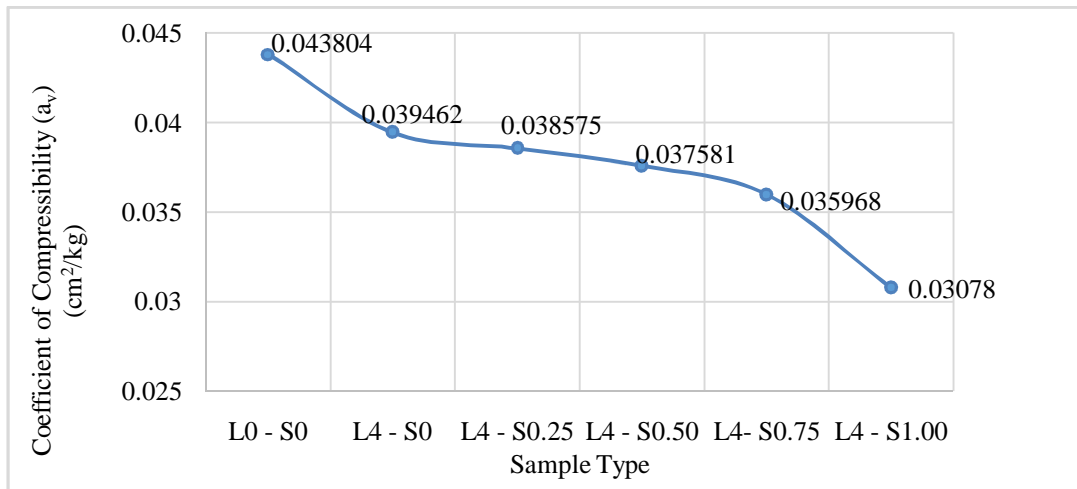


Fig. 7. Variation of Coefficient of Compressibility ( $a_v$ ) at different percentages of Lime and Sisal Fibre

Fig.8 presents the graph between variation of Compression Index ( $c_c$ ) at different percentage of Lime and Sisal Fibre as ordinate and Sample Type as abscissa. To understand the notation of Sample Type represented in abscissa, refer Table – 2.

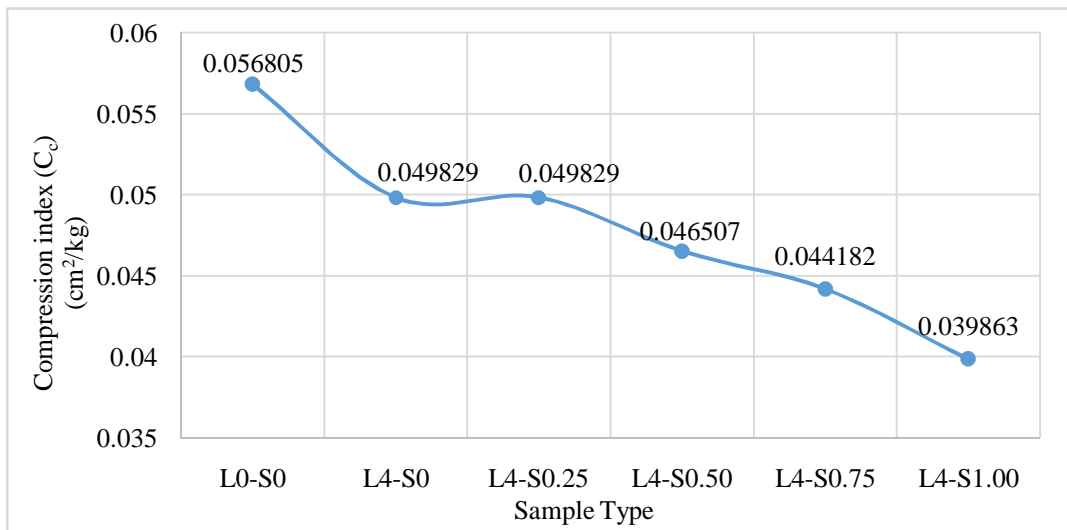


Fig. 8. Variation of Compression Index ( $c_c$ ) at different percentages of Lime and Sisal Fibre

Fig.9 presents the graph between variation of Coefficient of Volume Change ( $m_v$ ) at different percentage of Lime and Sisal Fibre as ordinate and Sample Type as abscissa. To understand the notation of Sample Type represented in abscissa, refer Table – 2.



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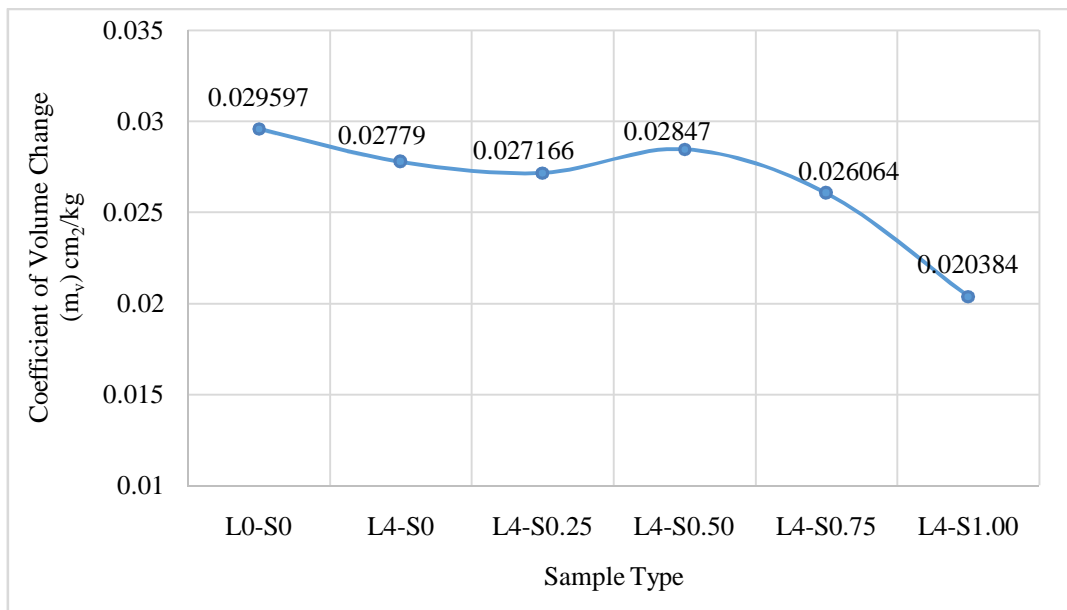


Fig. 9. Variation of Coefficient of Volume Change ( $m_v$ ) at different percentages of Lime and Sisal Fibre

## VI. CONCLUSION

From overall study, following conclusion were made based on laboratory test results.

- From the initial tests on collected soil, concluded that the taken soil is CH (Clay with High Plasticity) and High expansive soil.
- Observed that the OMC value is increased with the increase in addition of Sisal Fibre.
- CBR value is gradually increased up to 0.75% addition of Sisal Fibre. Unsoaked CBR value is increased from 2.2% to 4.4% and Soaked CBR is increased from 1.4% to 3.9%. After that for the addition of 1% of Sisal Fibre, CBR was decreased in both unsoaked and soaked conditions.
- At 0, 3, and 7 curing days, UCS value is gradually increased with the addition of Sisal Fibre. At 14 days, maximum value is obtained at 0.75% Sisal Fibre. And at 28 days Curing period, maximum UCS value is obtained at 0.50% Sisal Fibre and the UCS value is decreased for 0.75%, 1% Sisal Fibre when compared with earlier curing periods. But when compared with normal soil, UCS was increased for all samples.
- Coefficients obtained through consolidation were decreased for all samples. Coefficient of Compressibility ( $a_v$ ) was decreased from 0.043 to 0.030  $\text{cm}^2/\text{kg}$ . Compression Index ( $c_c$ ) was decreased from 0.056 to 0.039  $\text{cm}^2/\text{kg}$ . And Coefficient of Volume Change ( $m_v$ ) is decreased from 0.029 to 0.020  $\text{cm}^2/\text{kg}$ . Hence, Consolidation characteristics were positively improved with the addition of Sisal Fibre and Lime.
- Finally concluded that, the optimum percentage of as stabilizing additives of Black Cotton Soil is 4% Lime and 0.75% of Sisal Fibre.

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