Stabilization of Expansive Clay Using Calcium Lignosulfonate for Subgrade Application

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Abstract: The expansive clay soils like black cotton soil are very difficult in civil engineering because of high plasticity and swelling capacity as well as low bearing capacity. To enhance the engineering characteristics of these problematic soils, soil stabilization is normally embraced. An experimental study was conducted in the current research to determine the impact of calcium lignosulfonate on strength properties of clayey soil. The black cotton soil was sprayed with different percentages of calcium lignosulfonate in 1, 2, 3, 4 and 5 percent of weight of dry soil. The laboratory tests involved Atterberg limits, compaction properties, and California Bearing Ratio (CBR) tests to determine the enhancement of the soil properties. It was found that there was a visible decrease in plasticity and an increase in the compaction properties after the presence of the stabilizing agent was added. CBR values were found to rise sharply with the chemical content to reach an optimum dosage of 4, than the change was minimal. The greatest value of CBR occurred at 4% calcium lignosulfonate, which shows that the stabilized soil had a high load-bearing capacity. It can be concluded that calcium lignosulfonate may be a good eco-friendly stabilizing agent to enhance the strength properties of clayey soils turning them into appropriate pavement subgrade materials.

Keywords: Lignosulfonate; black cotton soil; California bearing ratio test

1. Introduction

Expansive soils especially black cotton soils are widely distributed in many parts of the world and cause great difficulties in the construction of civil engineering projects. These soils have high plasticity, large swelling and shrinkage behavior and low bearing capacity which causes structural instability and pavement failures. The poor engineering properties of such soils often require that they be stabilized before they can be used as foundation or subgrade materials.

Soil stabilization is a popular method to enhance the mechanical and durability qualities of challenging soils. Various stabilizing agents such as lime, cement, fly ash and chemical additives have been used for increasing strength and decreasing the plasticity of soil. In recent years, the use of environmentally friendly and sustainable stabilizing agents has attracted a lot of attention in geotechnical engineering.

Calcium lignosulfonate, which is a by-product of the paper and pulp industry, has become a promising chemical stabilizer for improving soils. It is well known for its binding properties and the ability to decrease soil plasticity and increase compaction and strength characteristics. The use of calcium lignosulfonate in soil stabilization is able to improve the values of the California Bearing Ratio (CBR), so that the soil can be used for pavement subgrade construction.

The current study is done to assess the influence of calcium lignosulfonate on engineering properties of clayey soil. Black cotton soil was treated by various percent of the chemical Stabilizer and some of the laboratory tests like Atterberg limits, compaction test, California Bearing Ratio (CBR) test were carried out in order to determine the improvement in soil properties. The main aim of this research is to find out the optimum percentage of calcium lignosulfonate needed to increase the strength characteristics of clayey soil and its suitability for civil engineering applications.

2. MATERIALS USED

Black cotton soil: soil used for the present investigation was the black cotton soil, collected from Krishna District of Andhra Pradesh in India. The postponed collected soil sample is of depth of around 1 - 1.5 m below the ground level to exclude the effect of organic matter and surface impurities. The soil was air-dried, pulverized and passed through 4.75 mm sieve followed by conducting laboratory tests.Black cotton soil is a vast clay soil having high plasticity, high swelling potential and low bearing capacity which is not suitable for construction without adequate stabilization. The behavior of this soil with respect to swelling and shrinkage is mainly due to the presence of montmorillonite (clay minerals).Laboratory tests were performed to determine the engineering properties of collected soil in accordance with the various standards such as IS 2720 (Methods of Test for Soils).

Table 1 Properties of Black cotton soil

PROPERTIES	VALUE
Free swell index	90%
Liquid limt	88.26%
Plactic limit	46.6%
Plasticity index	41.66%
Soil classification	CH
Omc	32.25%
Mdd	1.43

Calcium lignosulfonate: Calcium lignosulfonate is an organic polymer which is produced as a by-product of the paper and pulp industry during the sulfite pulping process. It serves as a binding agent. Due to its environmental friendliness and economy, calcium lignosulfonate is widely used in soil stabilization, dust control and road construction. When used together with clayey soils, calcium lignosulfonate bonds chemically with soil particles, thereby improving the compaction properties and strengthening soil properties such as California Bearing Ratio (CBR).

Table 2 Properties of Calcium lignosulfonate

PROPERTIES	VALUES
Appearance	Brown Powder / Liquid
Specific Gravity	1.25 – 1.30
pH Value	4 – 6
Solubility Completely	soluble in water
Lignosulfonate Content	55 – 65 %

3. METHODOLOGY

The methodology starts with sample collection and The collected soil is first air dried, pulverized and sieved through 4.75 mm sieve to remove the impurities and to get the uniform sample. After preparation the engineering properties of the natural soil is determined by testing of Atterberg limits test, Standard Proctor compaction test and Californian bearing ratio (CBR) test. Subsequently, the soil is treated with calcium lignosulfonate in varying concentration of 1%, 2%, 3%, 4% and 5% by weight of dry soil for preparing stabilized soil samples. The same laboratory tests, such as Atterberg limits, compaction and CBR tests, are then performed on these mixtures of treated soil. Finally, the test results of the natural and chemically treated soils are compared and analysed to assess the improvement developed in the soil strength and the effectiveness of calcium lignosulfonate for improving CBR characteristics of clayey soil.

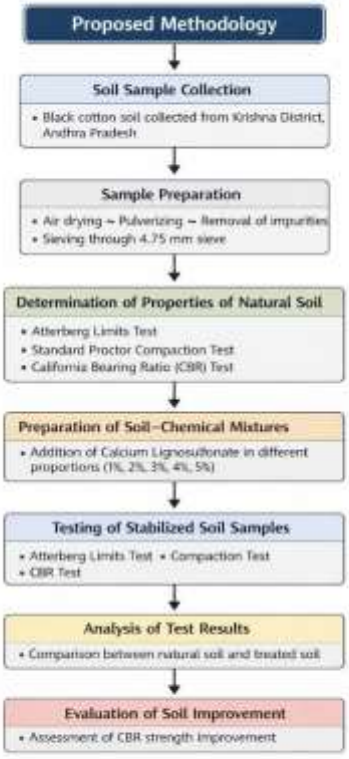
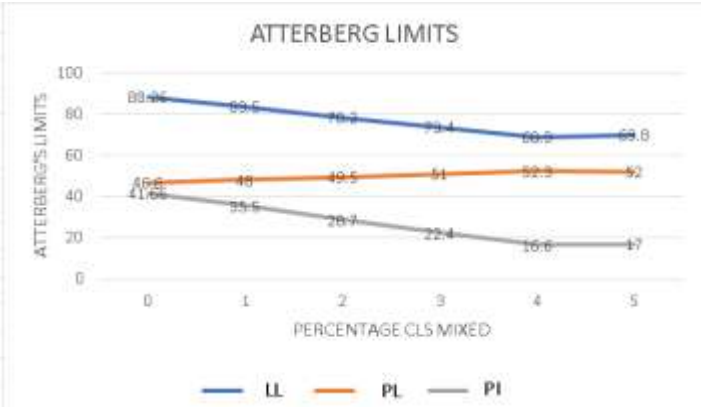


Figure: Flowchart showing the proposed experimental methodology for stabilization of black cotton soil using calcium lignosulfonate.

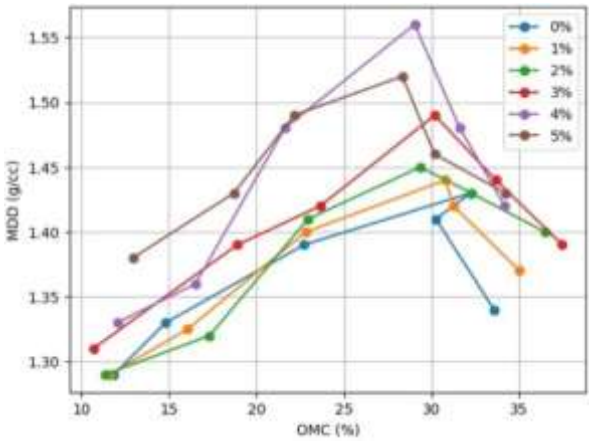
4. RESULTS AND DISCUSSIONS

4.1 Atterberg's limits: The effect of the chemical stabilization on soil consistency characteristics was analyzed by varying the Atterberg limits of black cotton soil with the addition of calcium lignosulfonate. The results indicate that the liquid limit of the soil decreased from 88.26% for natural soil to 68.90% for 4% calcium lignosulfonate content indicating that there is a decrease in the water holding capacity and plastic nature of the soil. The plastic limit displayed gradual increase from 46.60% to 52.30% with addition of the stabilizer which suggests better workability as well as better soil particle bonding. Consequently, the plasticity index decreased significantly from 41.66 to 16.60%, which showed a valueable reduction of the plastic characteristics of the clayey soil. This decrease in plasticity index shows that the addition of calcium lignosulfonate is effective in modifying the consistency characteristics of the black cotton soil and enhanced the engineering behavior of black cotton soil. The maximum improvement in Atterberg limits was obtained at 4% stabilizer content beyond which the change in properties was marginal.



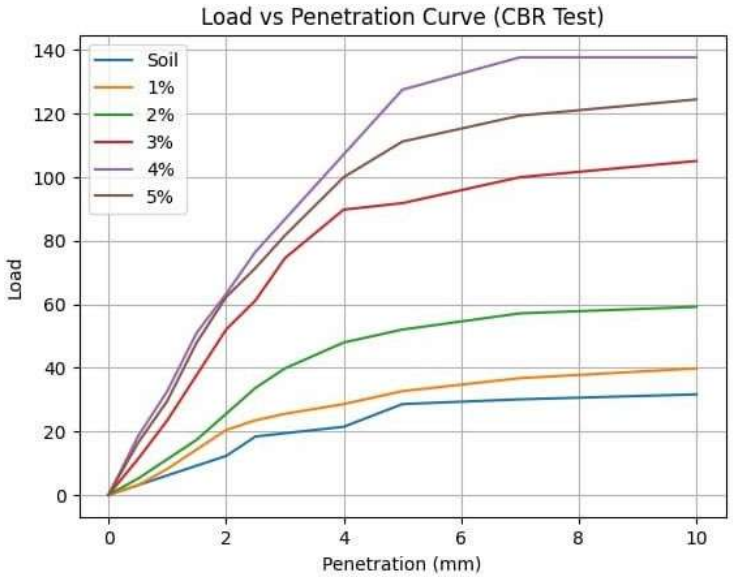
Graph 1: Atterberg limits

4.2 Standard proctor Compaction test: The different compaction characteristics of black cotton soil treated with varying percentages of calcium lignosulfonate was determined using the Standard Proctor compaction test. The results show the optimum moisture content for natural soil is reduced from 32.25% to 29.04% with 4% stabilizer content. This reduction implies an enhanced compaction efficiency by soil particles interaction and the stabilizing agent. The maximum dry density increased from 1.43g/cc to 1.56g/cc at 4% calcium lignosulfonate which shows improvement of soil particle arrangement and bonding within the soil matrix. However, at 5% stabilizer content, the maximum dry density slightly reduced to 1.52 g/cc which may be attributed to excess chemical content effect on the soil structure. These results indicate that an optimum effect of stabilization was attained with 4% calcium lignosulfonate.

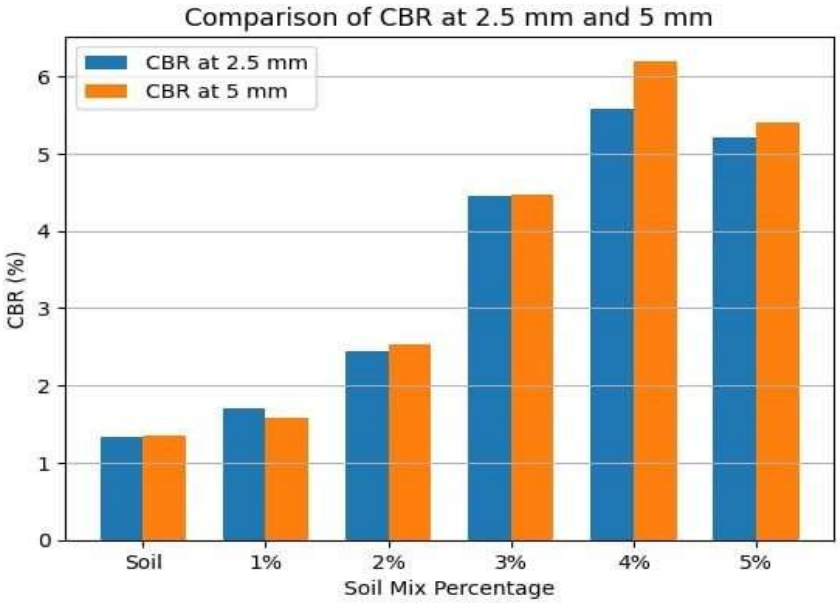


Graph 2: Compaction curve

4.3 California bearing ratio: The California Bearing Ratio (CBR) test was carried out for the strength characteristics of black cotton soil stabilized with calcium lignosulfonate. The untreated soil had very low CBR values (1.34% and 1.35% at 2.5 mm and 5 mm penetrations respectively) which is the indication of poor load bearing capacity. With addition of calcium lignosulfonate the CBR value was gradually increased due to some bonding among the particles and some modification in soil structure. The maximum CBR values of 5.58% and 6.20% at 2.5 mm and 5 mm penetrations respectively were obtained at 4% stabilizer content showing the optimum percentage of stabilization of soil. However further increase in stabilization content resulted in slight reduction in CBR values which may be attributed to the presence of excess chemical which interfere the arrangement of soil particle. The overall results shows that the effect of calcium lignosulfonate in increasing the load bearing capacity of black cotton soil is significant.



Graph 3: Load vs penetration



Graph4: Comparing CBR at 2.5 mm and 5mm for different percentages

5. CONCLUSION

In this study, Black cotton soil was stabilized with sodium lignosulfonate and its performance is evaluated using a series of laboratory experiments. The conclusions obtained from the results are summarized as follows.

- The present study was carried out to study the effect of calcium lignosulfonate on the engineering properties in the black cotton soil collected from Krishna district, Andhra Pradesh.
- The Atterberg limits test results showed that the addition of calcium lignosulfonate caused the reduction of the liquid limit and plasticity index of the soil; this implies the reduction of the plastic nature in the clayey soil.
- The results of compaction test showed an improvement in the soil compaction characteristics, in which maximum dry density was increased from 1.43 g/cc to 1.56 g/cc, while the optimum moisture content was decreased from 32.25% to 29.04% with the addition of the stabilizer.
- The results of CBR test showed that the strength of the soil was improved significantly. The CBR value showed an increase from 1.34% for untreated soil till 5.58% at 2.5 mm penetration and 6.20% at 5 mm penetration at 4% calcium lignosulfonate content.
- However, the further addition of stabilizer more than 4% spanned, the CBR values fell slightly indicating that excess of chemical doesn't aid further improvement in strength. Based on the experimental results, 4% calcium lignosulfonate was found to be optimum percent improvement of strength characteristics of black cotton soil making the stabilized soil more suitable for pavement subgrade applications.

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6. REFERENCES

1. Wu, D, She, W., Wei, L., Zuo, W., Hu, X., & Miao, C. (2020). Stabilization mechanism of calcium lignosulphonate used in expansion sensitive soil. Journal of Wuhan University of Technology - Materials Science Edition, 35(5), 847-855.
2. Moraes, L. R., Consoli, N. C., & Bastos, C. A. B. (2025). Stabilization of dispersive soil using calcium lignosulfonate: Strength, durability, and microstructure assessment. Geotechnical and Geological Engineering.
3. Zhang, H., Li, H., Zhang, H., Duan, D., Ding, Q., Ding, L., & Liu, Y. (2024). Experimental study on mechanical characteristics of stabilized soil with rice husk carbon and calcium lignosulfonate. Materials, 17(21), 5201.
4. Seco, A., Ramirez, F., Miqueleiz, L., & Garcia, B. (2021). Performance of calcium lignosulfonate as a stabiliser of highly expansive clay. Transportation Geotechnics, 27, 100469.
5. Kumar, A., Kumar, P., & Choudhary, A. K. (2026). Performance evaluation of stabilized clay using sodium lignosulphonate. Scientific Reports.
6. Rao, N. M., & Priyatham, B. P. R. V. S. (2021). Stabilization of subgrade soil using calcium lignosulfonate and granite dust - A review. EPRA International Journal of Research and Development, 6(9).