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A Comparitative Study on Black Cotton Soil Stabilization Using Xanthan Gum and Coconut Fiber

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Abstract - *Black cotton soil is an expansive soil known for its significant swelling and shrinkage properties, posing challenges for lightly loaded structures due to its weak engineering properties. The study examines the stabilization of black cotton soil using eco-friendly additives Xanthan Gum (XG) and Coconut Fiber (CF) to enhance its geotechnical performance. The experimental program included Atterberg's limits, Standard Proctor test, California Bearing Ratio (CBR) test, and Unconfined Compression Strength (UCS) test conducted on soil samples treated with varying percentages (0.25%, 0.5%, 0.75%, and 1%) of Xanthan Gum and Coconut Fiber. Results indicated that the liquid limit and plasticity index decreased while the compaction and strength properties improved significantly. The optimum combination of 0.75% XG and 0.5% CF achieved the highest UCS of 79 kN/m² and improved cohesion to 39.5 kN/m². The CBR value at 5 mm penetration increased to 2.23%, demonstrating enhanced load-bearing capacity. Maximum dry density reduced with increasing XG and CF content due to lighter material incorporation, while the optimum moisture content improved, favouring better soil workability. The research validates the potential of XG and CF as sustainable soil stabilizers, offering a cost-effective solution for improving the engineering properties of expansive soils, ensuring stability in structural foundations.*

***Key Words*: Black Cotton Soil, Soil Stabilization, Xanthan Gum (XG), Coconut Fiber (CF), Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR).**

1.INTRODUCTION

Soil is a vital substance used for construction purposes so it is very important to acknowledge the properties and feasibilities of soil before using in any kind of construction process. Many areas in India consist of soils with high clay or silt contents, low strengths and poor bearing capacities. The stabilization of soil is an effective method for improving soil properties and pavement performance. There are many stabilization methods which includes physical, chemical, or polymer, among them using different stabilizing agents, may be effective to improve the soil properties rather than removing and replacing the materials. Availability or financial considerations may also taken as a determining factor on which a stabilizing agent is selected.

To address the concerns regarding high costs and significant environmental impacts like elevated carbon emissions, an eco-friendly combination of xanthan gum which is a natural biopolymer derived from microbial fermentation and coconut fiber which is a renewable and biodegradable material is used.

The main objective of soil stabilization is to improve the strength and stability of the soils and also to lower the construction cost. The stability and bearing capacity of soil depends on shear strength, which is directly proportional to the soil type and conditions. In some situations, the soils which do not have the desired engineering properties will produce satisfactory strength when the additives on soil blend each other. These materials will be more stable and fulfil the desired conditions.

2. OBJECTIVES

- To study the general characteristics of the soil.
- To study the characteristics of soil with varying percentages of Xanthan Gum and Coconut Fiber.
- To compare the test results of black cotton soil and the soil with varying percentages of Xanthan Gum and Coconut Fiber.

3. METHODOLOGY

It involves the collection of materials and standard laboratory tests in the black cotton soil.

3.1 Materials Used

3.1.1 Black Cotton Soil

This soil is also known as regur soil which is characterized by its dark color, high clay content and unique properties such as swelling when wet and shrinking when dry. The expansive and shrinkage behaviors can lead to significant challenges in construction, as they may cause foundation movement and cracking. To improve its performance of stabilization, sustainable materials like xanthan gum and coconut fiber are used.

The soil sample was collected from Perumatty, Palakkad, Kerala.

Fig -1: BC soil

3.1.2 Xanthan Gum

Xanthan gum is a polysaccharide commonly used as a thickening agent and a stabilizer in various industries produced by fermenting simple sugars with a bacterium called Xanthomonas campestris.

Fig -2: Xanthan Gum

Table -1: Chemical composition of Xanthan Gum

Sl. No	Composition	Percentage Range
1	Glucose	37–45%
2	Mannose	30–36%
3	Glucuronic Acid	15–20%
4	Acetyl Groups	4–7%
5	Pyruvic Acid	2–5%

3.1.3 Coconut Fiber

It is a natural material extracted from the outer husk of coconuts. It improves the mechanical properties of the soil by adding reinforcement, increasing its shear strength, and reducing erosion.

Fig -3: Coconut Fiber

Table -2: Chemical composition of Coconut Fiber

Sl. No	Composition	Percentage Range
1	Cellulose	32-43%
2	Hemicellulose	10-25%
3	Lignin	40-45%
4	Pectin	2-5%
5	Ash	2-5%

3.2 Sample Preparation

The soil is mixed at various combinations of XG and CF to improve the strength and bearing capacity. The various combinations of samples which includes in this paper are follows:

Table -3: Compositions of Sample

Sample Name	Particulars of the Sample
Sample 1	Soil + XG-0% + CF-0%
Sample 2	Soil + XG-0.25% + CF-0.25%
Sample 3	Soil + XG-0.5% + CF-0.5%
Sample 4	Soil + XG-0.75% + CF-0.75%
Sample 5	Soil + XG-1% + CF-1%
Sample 6	Soil + XG-0.25% + CF-0.5%
Sample 7	Soil + XG-0.5% + CF-0.25%
Sample 8	Soil + XG-0.5% + CF-0.75%
Sample 9	Soil + XG-0.75% + CF-0.5%
Sample 10	Soil + XG-0.75% + CF-1%
Sample 11	Soil + XG-1% + CF-0.75%

4. EXPERIMENTAL STUDY

The soil sample with varying compositions of 0, 0.25%, 0.5%, 0.75% and 1% of XG and CF are prepared and tests are performed. The experimental studies are done as mentioned in table-3 respectively.

4.1 Atterberg's Limit Test (IS: 2720-5-1985)

It is to determine the liquid limit, plastic limit, shrinkage limit and plasticity index of BC soil. The liquid limit (LL) indicates the moisture content at which soil changes from plastic to liquid state which is measured using Casagrande apparatus, The plastic limit (PL) is the moisture content at which the soil can be rolled into thin threads (3 mm diameter) without crumbling and the shrinkage limit (SL) is the moisture content where further drying does not reduce soil volume. The difference between the liquid limit and plastic limit is called plasticity index (PI) which measures the soil's plasticity.

Table -4: Values of Atterberg's Limit Test

Liquid Limit (%)	Plastic Limit (%)	Shrinkage Limit (%)	Plasticity Index (%)
30	17	16.8	13
34.25	23	17.4	11.25
45.8	36.43	18.4	9.37
54.34	46.44	17.1	7.9
43.78	37.18	16.8	6.6
39.64	28.37	17.7	11.27
42.1	31.52	18.1	10.58
49.23	41.38	17.1	7.85
57.35	52.14	16.2	5.21
51.67	44.2	17.1	7.47
47.39	41.27	18.2	6.12

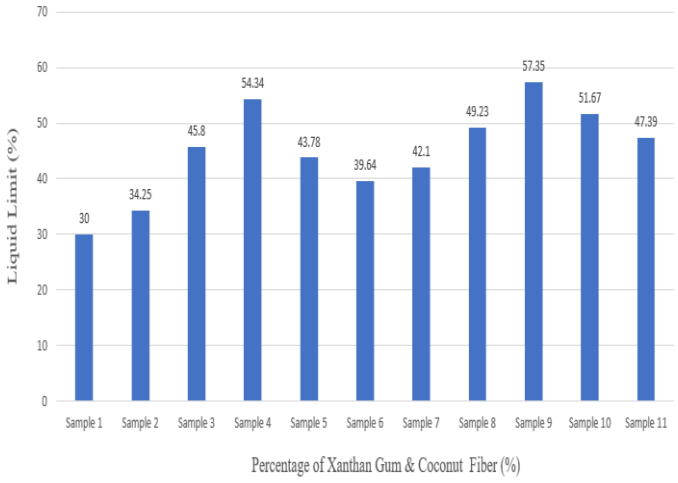

Fig -4: Liquid Limit

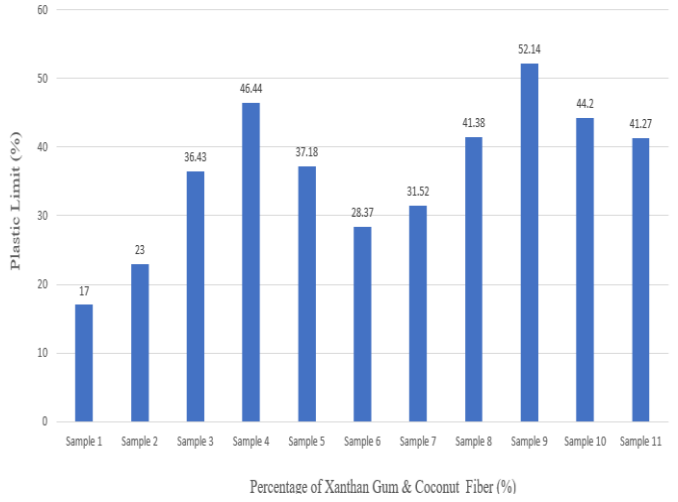

Fig -5: Plastic Limit

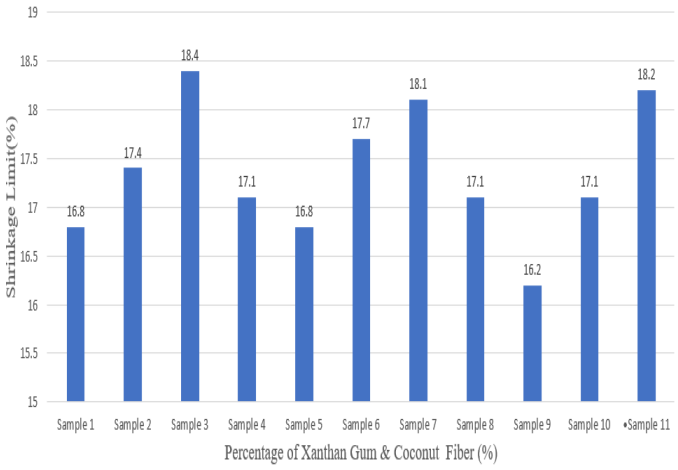

Fig -6: Shrinkage Limit

4.2 California Bearing Ratio Test (IS:2720-PART 16-1987)

This test is for assessing the strength and load-bearing capacity of subgrade soils, which form the for structures such as roads, pavements, and buildings. By determining the CBR value, we can evaluate whether the soil is suitable for construction or if it requires stabilization or replacement. The test results guide the design of proper foundation thicknesses, pavement layers, and other structural elements to ensure durability and stability.

Table -5: Values of CBR Test

CBR value @2.5mm penetration	CBR value @5mm penetration
0.52	0.81
0.96	1.43
1.44	2.11
1.35	2.05
1.13	1.68
0.99	1.48
1.38	2.03
1.4	2.10
1.49	2.23
1.32	1.90
1.28	1.94

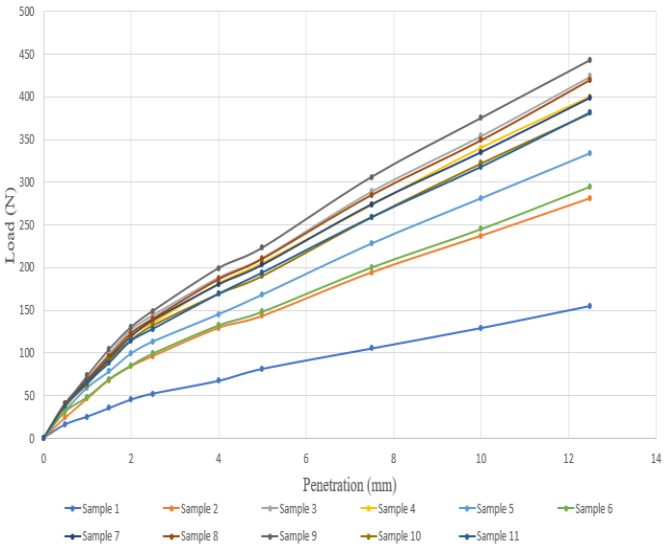

Fig -7: CBR Graph

4.3 Standard Proctor Test (IS: 2720-PART 7-1980)

This test is used to determine the optimal moisture content (OMC) and maximum dry density (MDD) of a soil sample and also helps to establish the relationship between soil moisture and compaction, which is critical for ensuring stability and strength.

Table -6: Values of Compaction Test

Maximum Dry Density (g/cc)	Optimum Moisture Content (%)
1.79	17
1.77	21.4
1.74	22.05
1.781	21
1.791	20.6
1.76	21.9
1.75	22
1.78	21.2
1.81	20.1
1.779	21.3
1.747	22.02

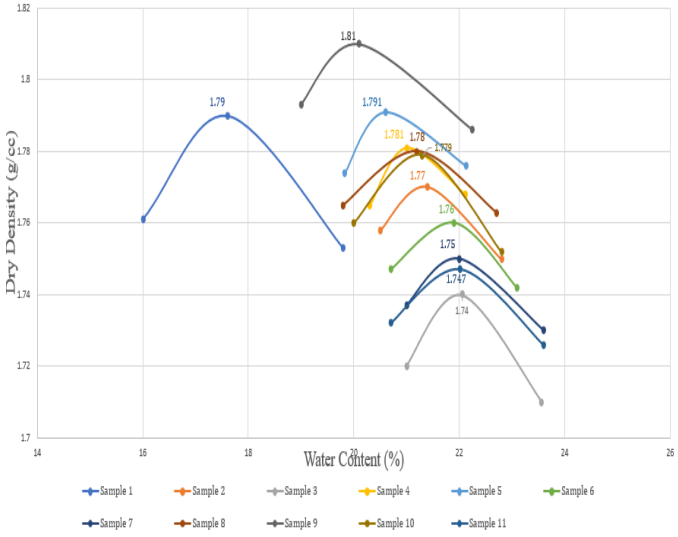

Fig -8: Compaction Graph

4.4 Unconfined Compression Test (IS: 2720- PART 10-1991)

This test is used for determining the compressive strength of cohesive soils without lateral confinement. The test continues until the sample fails, and the corresponding stress at failure is recorded as the unconfined compressive strength (UCS).

Table -7: Values of UCC Test

Unconfined Compressive Strength (kN/m^2)	Cohesion (kN/m^2)
48	24
52	26
70	35
75	37.5
68	34
59	29.5
65	32.5
72	36
79	39.5
72	36
69	34.5

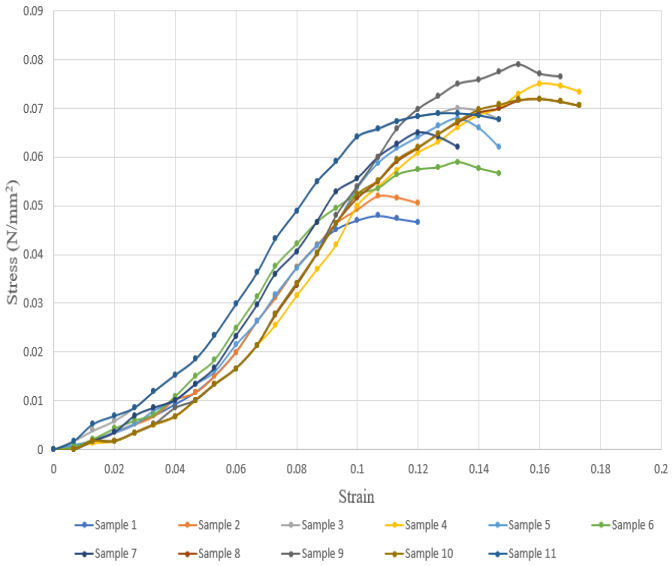

Fig -9: UCC Graph

5. CONCLUSIONS

The study concludes with several significant observations about the stabilization of black cotton soil using xanthan gum (XG) and coconut fiber (CF):

- The research confirms that the addition of 0.75% xanthan gum and 0.5% coconut fiber provides the most effective stabilization. This mix achieves the highest compressive strength and bearing capacity, marking it as the optimal percentage for soil enhancement.
- The improvement in liquid limit and plastic limit reduces soil swelling, which is crucial for maintaining its structure under varying moisture conditions. And decrease in the shrinkage limit prevents soil shrinkage, ensuring dimensional stability.
- The increase in UCC and CBR values highlights significant advancements in the soil's ability to bear loads, resist settlement, and achieve greater stability.
- The use of XG and CF as biopolymers showcases the potential of eco-friendly and sustainable soil stabilization methods. These additives not only enhance soil performance but also align with environmental conservation goals.
- This paper emphasizes the importance of incorporating natural materials to promote sustainable construction practices as It paves the way for eco-conscious engineering solutions that balance strength, stability, and environmental responsibility.

REFERENCES

[1] Arab, M.G., Mousa, R.A., Gabr, A.R., Azam, A.M., El-Badawy, S.M., Hassan, A.F, "Resilient behavior of sodium alginate-treated cohesive soils for pavement applications", Journal of Materials in Civil Engineering, vol.31,Nov2018,https://doi.org/10.1061/(ASCE)MT.1943-5533.0002565.

[2] B. Irem, J. Akbar, & A. Selim, "Strength properties of xanthan gum and guar gum treated kaolin at different water contents", Journal of Rock Mechanics and Geotechnical Engineering, vol 13,Ocb 2021,pp. 1160-1172, https://doi.org/10.1016/j.jrmge.2021.06.007.

[3] Jayaprakash Reddy, B.J.S. Vara," Long-term and durability properties of xanthan gum treated dispersive soils – An eco-friendly material, material today proceeding,vol44, https://doi.org/10.1016/j.matpr.2020.09.472.

[4] R. Joga, B.J. Varaprasad." Effect of xanthan gum biopolymer on dispersive properties of soils", World Journal of Engineering, vol 17Jul 2020, pp. 563-571, https://doi.org/10.1108/WJE-05-2020-0152