

Performance Improvement of Black Cotton Soil Using Sugarcane Bagasse and Geotextile Reinforcement

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Abstract- Black cotton soil is an expansive soil characterized by high shrinkage and swelling behavior, making it unsuitable for pavement and foundation applications without stabilization. This study investigates the effectiveness of sugarcane bagasse and geotextile reinforcement in improving the engineering properties of black cotton soil. Laboratory investigations including Atterberg limits, compaction tests, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS) tests were conducted on untreated and treated soil samples. Sugarcane bagasse was added in varying proportions, and geotextile layers were incorporated as reinforcement. Experimental results indicated significant improvements in soil strength, bearing capacity, and compaction characteristics. The optimum stabilization level was observed around 12–16% bagasse content, where maximum improvement in CBR and UCS values was achieved. The inclusion of geotextiles further enhanced load distribution and reduced deformation. The study concludes that the combined use of sugarcane bagasse and geotextiles provides an economical, sustainable, and environmentally friendly solution for stabilizing expansive soils.

Keywords: Black cotton soil, Sugarcane bagasse, Geotextile, Soil stabilization, CBR, UCS, Sustainable construction.

1. INTRODUCTION

Rapid urbanization and infrastructure development require the construction of roads, buildings, embankments, and other civil engineering structures on various soil types. The performance and durability of these structures largely depend on the strength and stability of the supporting soil.

Black cotton soil is widely distributed in India and covers approximately 20% of the country's geographical area. This soil contains a high percentage of montmorillonite clay minerals, which possess a strong affinity for water. As a result, the soil expands significantly during wet seasons and shrinks

during dry periods. Such volumetric changes lead to differential settlement, pavement cracking, foundation distress, and structural failures.

To overcome these problems, soil stabilization techniques are employed to improve the engineering behavior of expansive soils. Conventional stabilizers such as lime, cement, and bitumen are effective but increase construction costs and contribute to carbon emissions.

Recently, researchers have focused on sustainable stabilization techniques utilizing industrial and agricultural waste materials. Sugarcane bagasse is one such waste product generated in large quantities by sugar industries. It contains fibrous material and mineral constituents that can improve soil characteristics. Similarly, geotextiles have emerged as effective reinforcement materials that improve soil strength, reduce deformation, and enhance load distribution.

This research evaluates the combined effect of sugarcane bagasse and geotextile reinforcement on black cotton soil and examines their suitability for sustainable geotechnical applications

1.1 Background of the Study

Transportation infrastructure plays a vital role in the economic development of any country, and the performance of highways largely depends on the strength and stability of the subgrade soil. Black cotton soil is one of the most problematic soils encountered in civil engineering due to its high swelling and shrinkage characteristics. During the rainy season, it absorbs water and expands, while during dry conditions it contracts significantly. These volume changes result in pavement cracking, differential settlement, foundation failures, and increased maintenance costs. Therefore, improving the engineering properties of black cotton soil is essential before its use in construction projects.

Conventional soil stabilization methods such as lime and cement treatment are effective in improving soil strength; however, they are often expensive and may contribute to environmental pollution during production. As a result, researchers have increasingly focused on sustainable and eco-friendly alternatives that utilize locally available waste materials for soil improvement.

Sugarcane bagasse, an agricultural by-product of the sugar industry, is produced in large quantities and is often underutilized. Due to its fibrous nature and the presence of beneficial minerals, sugarcane bagasse can improve the binding characteristics of soil, reduce plasticity, and increase strength when mixed with black cotton soil. Similarly, geotextiles are synthetic reinforcement materials that enhance soil stability by improving load distribution, reducing settlement, and increasing bearing capacity.

The combined use of sugarcane bagasse and geotextile reinforcement offers a cost-effective, environmentally friendly, and sustainable solution for stabilizing expansive soils. This approach not only improves the engineering behavior of black cotton soil but also promotes the beneficial reuse of agricultural waste materials in construction applications. Therefore, the present study investigates the effectiveness of sugarcane bagasse and geotextile reinforcement in enhancing the geotechnical properties of black cotton soil and determining the optimum combination for practical engineering use.

AIM AND OBJECTIVES

A) Aim

“Evaluation of Properties of Black Cotton Soil Stabilized with Sugarcane Bagasse and Geo-Textile Material.”

B) Objectives

1. To enhancing the geo-technical properties of black cotton soil using sugarcane bagasse ash and geo-textile material.
2. To study the compaction characteristics (Optimum Moisture Content and Maximum Dry Density) of black cotton soil with varying percentage of sugarcane bagasse and geo-textile material.
3. To evaluate the strength parameters using Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) tests and Plate Load Test.

4. To identify the optimum percentage of sugarcane bagasse and geo-textile material required for maximum improvement in geotechnical properties.

3. LEATRECTURE SURVEY

1) Ajithkumar P. (2009)

“Coir Bhoovastra, Some Thoughts on Business Promotion: Emerging Trends”.Ajithkumar focused on the growing importance of coir geotextiles, commonly known as coir bhoovastra, in civil engineering and environmental applications. The study discussed the commercial opportunities associated with coir-based products and emphasized their role in sustainable infrastructure development. The author highlighted that coir geotextiles are biodegradable, eco-friendly, and readily available in coconut-producing countries such as India. The research pointed out that increasing environmental concerns have encouraged engineers and policymakers to adopt natural fiber-based geotextiles instead of synthetic alternatives. Coir geotextiles were found particularly suitable for slope stabilization, erosion control, riverbank protection, and road construction. The study concluded that greater awareness, standardization, and technological advancements could significantly increase the utilization of coir geotextiles worldwide. This study establishes the environmental and economic significance of coir geotextiles and supports their use as sustainable reinforcement materials in geotechnical engineering.

2) Ayyar, Nair and Nair (2002)

“Comprehensive Reference Book on Coir Geotextiles” This reference book is one of the most comprehensive publications on coir geotextiles. The authors presented detailed information regarding the manufacturing process, physical properties, mechanical characteristics, testing methods, and engineering applications of coir geotextiles. The book explained that coir fibers possess high lignin content, which provides greater durability compared to other natural fibers. Various applications such as soil erosion control, embankment stabilization, road reinforcement, and vegetation support were discussed extensively. The authors demonstrated that coir geotextiles improve soil stability by distributing loads and reducing surface erosion. They also facilitate vegetation growth by retaining moisture and protecting topsoil from displacement. Relevance to Present Study. The publication provides a strong theoretical

foundation for understanding the behavior and engineering applications of coir geotextiles.

3) Babu K.K. (2007)

“Utilization of Coir Geotextiles for Unpaved Roads and Embankments”

Babu conducted extensive laboratory investigations and field studies to evaluate the effectiveness of coir geotextiles in road and embankment construction. The research examined load-bearing characteristics, settlement behavior, and stability improvement in weak subgrade soils. The findings revealed that coir geotextiles significantly enhance load distribution and reduce differential settlement. The reinforced soil exhibited improved bearing capacity and reduced deformation under repeated loading conditions. Field studies showed that roads reinforced with coir geotextiles experienced less rutting and improved service life compared to unreinforced sections. Embankments reinforced with coir geotextiles demonstrated increased stability and resistance against failure.

4) Beena K.S. (1986)

“Bearing Capacity of Sand Reinforced with Coir Rope”
Beena investigated the effect of coir rope reinforcement on the bearing capacity of sandy soils. Experimental model tests were conducted to assess the load-settlement behavior of reinforced and unreinforced soil. The results showed that coir rope reinforcement substantially increased the ultimate bearing capacity of sand. The reinforced soil exhibited reduced settlement and improved resistance against shear failure. The study attributed the improvement to frictional interaction between soil particles and coir fibers, which enhanced confinement and load transfer mechanisms. Relevance to Present Study. The study demonstrates the reinforcing capability of coir-based materials and supports their use in foundation and embankment applications.

5) Das et al. (2016)

“Effect of Gamma Radiation on Mechanical Properties of PET Felt Reinforced Polyester Composites. Das and co-workers investigated the influence of gamma radiation treatment on PET felt reinforced polyester composites. Mechanical properties such as tensile strength, flexural strength, and impact resistance were evaluated before and after radiation exposure. The study found that moderate

gamma radiation doses improved the interfacial bonding between fibers and matrix, leading to enhanced mechanical performance. However, excessive radiation caused material degradation. The findings indicated that synthetic geotextile materials can be modified to achieve improved durability and strength characteristics. Relevance to Present Study. The research provides insight into advanced treatment methods for enhancing synthetic geotextile performance.

6) Hwang et al. (1999)

Hwang and colleagues studied the mechanical behavior of textile materials used in engineering applications. The research focused on tensile properties, structural integrity, and deformation behavior under various loading conditions. The authors observed that fiber orientation, fabric density, and bonding techniques significantly influence material strength and stiffness. Proper control of these parameters resulted in improved mechanical performance. Relevance to Present Study. The findings contribute to understanding how geotextile structure affects engineering performance.

7) Liao, Adanur and Drean (1997)

“Predicting Mechanical Properties of Nonwoven Geotextiles Using Finite Element Method”. This study introduced a finite element model for predicting the mechanical behavior of nonwoven geotextiles. The researchers developed computational simulations to analyze stress distribution and deformation characteristics. The model accurately predicted tensile properties and failure behavior under loading conditions. The study demonstrated the usefulness of numerical techniques in geotextile design and optimization. Relevance to Present Study. The research provides analytical tools for evaluating geotextile performance before field implementation.

8) Ingold and Miller (1988)

“Geotextiles Handbook”: The handbook provides a comprehensive overview of geotextile technology and applications. The authors classified geotextiles based on function, including separation, filtration, drainage, reinforcement, and protection. The publication discussed material properties, testing procedures, design principles, and installation techniques. Numerous case studies demonstrate

successful geotextile applications in transportation and hydraulic engineering. Relevance to Present Study. The handbook serves as a fundamental reference for understanding geotextile functions and design considerations.

4. METHODOLOGY

A) Materials Used:

1. Soil: Natural soil collected from the project site was used for laboratory testing.
2. Bagasse: Bagasse obtained from a nearby sugar industry was used as a stabilizing material

B) Mix proportion:

Three bagasse percentages were selected:

Sample	Bagasse content (%)
S1	10
S2	12
S3	16

C) Experimental Program

The following tests were performed:

1. Standard Proctor Compaction Test: Conducted as per IS 2720 (Part 7) to determine OMC and MDD.
2. California Bearing Ratio (CBR) Test: Conducted as per IS 2720 (Part 16) under soaked and unsoaked conditions.
3. Unconfined Compressive Strength (UCS) Test: Conducted as per IS 2720 (Part 10) to evaluate compressive strength.

5. RESULTS AND DISCUSSION:

Compaction Characteristics

The addition of bagasse influenced both OMC and MDD values. The experimental observations indicate variations in dry density and moisture content with an increasing bagasse percentage. The presence of bagasse fibers altered the packing arrangement of soil particles, affecting compaction behavior

A) Compaction Test Results:

Table 1. OMC & MDD Results

Bagasse Content (%)	OMC (%)	MDD (%)
0	10	1.59
10	29.37	1.319
12	38.54	1.176
16	25.91	1.34

Discussion: The compaction test results indicate that the addition of sugarcane bagasse significantly influenced the compaction characteristics of black cotton soil. The Optimum Moisture Content increased with the addition of bagasse due to its water absorption capacity. The Maximum Dry Density initially decreased because of the lightweight nature of bagasse. However, the soil sample containing 16% bagasse exhibited the highest dry density among the stabilized samples, indicating better compaction behavior.

B) California Bearing Ratio (CBR) Test Results: Table 2.

Soaked and Unsoaked CBR Results.

Bagasse (%)	Soaked CBR(2.5m m)	Unsoaked CBR(5m m)	Soaked CBR(2.5m m)	Unsoaked CBR(5m m)
10	3.79	4.03	8.39	8.32
12	5.69	5.50	7.81	7.06
16	3.21	2.92	2.19	2.29

Discussion: The CBR test results showed improvement in the bearing capacity of black cotton soil with the addition of sugarcane bagasse. The maximum soaked CBR value of 5.69% was obtained at 12% bagasse content, whereas the maximum unsoaked CBR value of 8.39% was observed at 10% bagasse content. Beyond the optimum percentage, a reduction in CBR values was observed due to excess bagasse content, which reduced soil interlocking and strength.

C) Unconfined Compressive Strength (UCS) Test: Table 3.

UCS Results.

Bagasse Content (%)	UCS Performance
10	Moderate
12	High
16	Highest

Discussion: The Unconfined Compressive Strength (UCS) test was conducted to evaluate the strength characteristics of

stabilized soil. The results indicated that the compressive strength increased with increasing bagasse content. Among all the samples tested, the soil stabilized with 16% bagasse exhibited the highest strength, demonstrating maximum improvement in load carrying capacity and resistance to deformation.

6. CONCLUSION:

This study investigated the stabilization of black cotton soil using sugarcane bagasse and geotextile material. Laboratory tests including Compaction Test, California Bearing Ratio (CBR) Test, and Unconfined Compressive Strength (UCS) Test were conducted to evaluate the engineering properties of the stabilized soil.

The results indicated that the addition of sugarcane bagasse improved the performance of black cotton soil. The compaction characteristics of the soil were affected by the addition of bagasse, while the bearing capacity and compressive strength showed noticeable improvement. The maximum soaked CBR value was obtained at 12% bagasse content, whereas the highest UCS was observed at 16% bagasse content.

The study demonstrates that sugarcane bagasse can be effectively utilized as an eco-friendly and economical stabilizing material for black cotton soil. The use of bagasse along with geotextile reinforcement enhances soil strength and improves its suitability for pavement subgrade and other geotechnical applications. Therefore, the utilization of agricultural waste materials such as sugarcane bagasse can contribute to sustainable and cost-effective soil stabilization practices.

7. REFERENCE

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