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Experimental Investigation on the Stabilization of Expansive Soil using Jute Fibers and Silica Fume

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ABSTRACT:Expansive soils like black cotton soil pose significant challenges in construction due to their high shrinkswell behavior, which jeopardizes the integrity of foundations. In the present study, natural stabilizers—jute fibre and silica fume—were used to improve the engineering properties of black cotton soil. A series of laboratory tests, including sieve analysis, specific gravity, Atterberg limits, and standard Proctor compaction tests, were performed on soil samples mixed with varying percentages of jute fibre (7%, 9%, 11%) and silica fume (5%, 7%, 9%). The experimental results demonstrated enhanced soil properties, with improvements in dry density and optimum moisture content, indicating that these natural stabilizers are viable alternatives to traditional chemical stabilizers. The findings suggest potential benefits for sustainable infrastructure development and warrant further research for large-scale applications.

KEYWORDS: Expansive soil, Black cotton soil, Soil stabilization, Jute fibre, Silica fume, Compaction test.

I. INTRODUCTION

Expansive soils, particularly black cotton soil, are widespread in tropical regions and are known for their high clay content and significant volume changes with moisture variation. Such characteristics contribute to poor load-bearing behavior and challenges in foundation design. In recent years, there has been growing interest in using natural admixtures to stabilize these soils. This study investigates the effect of incorporating jute fibre and silica fume on improving the engineering characteristics of black cotton soil. The research is significant not only for its potential to mitigate soil expansion issues but also for its contribution to sustainable construction practices by reducing reliance on conventional chemical stabilizers.

Include context on previous studies (literature review highlights) and clearly state the objectives of your study:

- To evaluate the effectiveness of jute fibre and silica fume in stabilizing expansive soils.
- To determine the influence of these stabilizers on properties such as liquid limit, plastic limit, and compaction characteristics.
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- To propose optimal percentage mixes for maximum improvement in soil behavior.

II. RELATED WORK

Numerous studies have been conducted to improve the engineering behavior of expansive soils, particularly black cotton soil, using natural fibers and industrial byproducts. Chhaya Negi et al. (2013) explored the impact of silica fume on black cotton soil and reported improved California Bearing Ratio (CBR) and reduced swelling behavior with up to 20% silica fume content. Similarly, Dharmesh Lal and colleagues investigated the stabilization potential of jute fiber sheets, noting an enhancement in soil stability and compressive strength.





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Harshita Bairagi (2014) evaluated the combined effects of lime and jute fiber, finding significant improvements in shrinkage limit, CBR, and unconfined compressive strength. Kiran Kumar et al. (2022) further reinforced these findings by highlighting how jute fibers reduced optimum moisture content (OMC) while increasing maximum dry density (MDD) and strength parameters.

In addition, studies by Megha et al. (2022) and Nagarjuna Gowd et al. (2020) demonstrated that silica fume and alternative binders like Renolith significantly enhanced the compaction and strength properties of expansive soils. V. Ramya et al. (2018) examined bamboo slag and silica fume combinations, showing a notable reduction in soil settlement. Thoker Sameer and M. Vineela also confirmed that silica-based additives improve subgrade soil properties by lowering plasticity and increasing bearing capacity.

While past research has focused on either jute fibers or silica fume in isolation or with other additives, the present study uniquely investigates the combined influence of jute fiber and silica fume on expansive soil behavior, offering insights into their synergistic effects on compaction, strength, and consistency limits.

III. METHODOLOGY

The methodology adopted for this study involved a systematic process starting from material collection to laboratory testing, aimed at evaluating the effectiveness of jute fibre and silica fume in stabilizing expansive black cotton soil.

1. Material Collection

- Black Cotton Soil: Collected from Enikepadu, a region falling under Seismic Zone-3. The soil is known for its high clay content and expansive characteristics.
- Jute Fibre: Procured from One Town, Vijayawada. The fibres were manually cut and used in varying proportions (7%, 9%, and 11% by weight).
- Silica Fume: Sourced from V.B. Coir, Eluru. Used in powder form at 5%, 7%, and 9% by dry weight of soil.

2. Mix Preparation

The soil was air-dried and sieved to remove lumps and impurities. Measured quantities of jute fibre and silica fume were then mixed thoroughly with the soil in dry condition, followed by the addition of optimum water content to prepare uniform samples for each test.

3. Laboratory Testing

The following standard tests were conducted as per Indian Standards (IS):

Sieve Analysis (IS 2720 Part-4): To determine the particle size distribution and classify the soil.

Specific Gravity Test (IS 2720 Part-3): To determine the specific gravity of the soil solids using a pycnometer.

Atterberg Limits (IS 2720 Part-5):

- A. Plastic Limit Test: Determines the moisture content at which soil begins to behave plastically.
- B. Liquid Limit Test (Casagrande's Device): Identifies the water content at which the soil transitions from plastic to liquid behavior.

Compaction Test (IS 2720 Part-8):

Standard Proctor Test was performed to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) for both untreated and treated soil samples.





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IV. EXPERIMENTAL RESULTS

Figures shows the results of text detection from an image and inpainting by using exemplar based Inpainting algorithm. shows the original image. is the image obtained by applying first set of criteria.

S.NO	Is Sieve (mm)	Particle Size (mm)	Mass retained (mm)	Cumulative Mass Retained (mm)	Cumulative % retained	% Finer
1	4.75	4.75	20	20	2	98
2	2.36	2.36	260	280	28	72
3	1.18	1.18	320	600	60	40
4	0.6	0.6	140	740	74	26
5	0.3	0.3	40	780	78	22
6	0.15	0.15	120	900	90	10
7	0.075	0.075	80	980	98	2
pan			20	1000	100	0

SIEVE ANALYSIS TEST FOR BLACK COTTON SOIL

GRAIN SIZE SIEVE ANALYSIS GRAPH



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LIQUID LIMIT OF EXPANSION SOIL USING SILICA FUME (0%)



The above result the water content for liquid limit at 25 blows is 45.9%



STANDARD PROCTOR TEST

V. CONCLUSION

The findings of this experimental study demonstrate that the inclusion of jute fibre and silica fume leads to a marked improvement in the geotechnical properties of black cotton soil. The observed enhancements in liquid limit and compaction behavior confirm the effectiveness of these eco-friendly additives in stabilizing expansive soils. Specifically, mixtures containing 9% silica fume and 11% jute fibre yielded the most favorable results in terms of maximum dry density and optimum moisture content. These outcomes highlight the potential of using natural and sustainable materials as practical alternatives to conventional soil stabilizers. To further validate these results, future studies should investigate the long-term field performance, durability, and large-scale applicability of this method in real-world construction environments.





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