Effect of Sugarcane Molasses and Bamboo Fiber on Geotechnical Properties of Expansive Clay Soil

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Abstract: **Expansive clay soils are characterized by high plasticity, large swelling potential, and low strength, which often create serious problems for foundations and pavement structures. Stabilization using eco friendly materials has recently become an important alternative to conventional stabilizers such as lime and cement. This study examines the influence of sugarcane molasses and bamboo fiber on the engineering behavior of expansive clay soil. Different proportions of molasses (2%, 4%, 6%, and 8%) and bamboo fiber (0.5%, 1%, and 1.5%) were incorporated in to the soil based on dry weight. Laboratory investigations including, Standard Proctor compaction, Atterberg limits, Unconfined Compressive Strength (UCS), and California Bearing Ratio (CBR) tests were conducted. The experimental results revealed that the addition of molasses and bamboo fiber decreased the plasticity index, improved the maximum dry density, and enhanced the strength characteristics of the soil. The highest performance was achieved using a mixture containing 6% molasses and 1% bamboo fiber, which produced significant increases in UCS and CBR compared with untreated soil. The findings indicate that agricultural by-products such as molasses and bamboo fiber can serve as effective and sustainable materials for the improvement of expansive clay soils**

Keywords: Expansive soil, soil stabilization, sugarcane molasses, bamboo fiber, CBR, UCS

I. INTRODUCTION

Expansive clay soils are widely distributed in many parts of the world and are recognized for their substantial volume change behavior when exposed to moisture variations. These soils undergo expansion when exposed to water and shrink upon drying, which leads to structural damage in pavements, foundations, and retaining structures. In countries such as India, expansive soils occupy millions of hectares and present serious challenges for civil engineering projects.

Soil stabilization is considered one of the most effective methods to enhance the engineering properties of weak soils. Traditional stabilizers such as lime and cement are commonly used; however, these materials can be costly and may have environmental impacts due to high carbon emissions. Consequently, researchers are exploring the use of agricultural by-products and natural fibers as alternative stabilizing agents.

Sugarcane molasses, a by-product of the sugar industry, contains sugars and minerals that improve bonding between soil particles and promote a chemical reaction that improves soil strength. In the addition of molasses has been reported to increase the California Bearing Ratio (CBR), reduce plasticity index, and improve compressive strength of expansive soils. Similarly, bamboo fiber is a natural reinforcement material with highest tensile strength and flexibility. When mixed with soil, fibers act as reinforcement elements that restrict soil deformation and improve shear resistance. This research focuses on evaluating the combined effect of sugarcane molasses and bamboo fiber on the geotechnical behavior of expansive clay soil.

II. OBJECTIVES OF THE STUDY

The main objectives of this research are:

1. To evaluate the basic physical and engineering properties of expansive clay soil.
2. To analyze the effect of sugarcane molasses on soil stabilization.
3. To evaluate the reinforcing influence of bamboo fiber in clay soil.
4. To identify the optimum combination of molasses and bamboo fiber for improving soil performance.
5. To evaluate the differences in properties between untreated soil and stabilized soil mixtures

III. LITERATURE REVIEW

S. Ahmad et al. (2024) examined the improvement of expansive subgrade soil by incorporating sugarcane molasses together with cement. Their results indicated that molasses can enhance soil compaction characteristics and significantly increase the California Bearing Ratio (CBR), making the soil more suitable for pavement applications.

B. Taye (2015) investigated the strengthening of expansive clay using molasses combined with cement. The study reported that molasses helps reduce the plasticity index and improves bonding among soil particles, resulting in higher compressive strength.

A. Chakraborty, A. Borah, and D. Sharmah (2016) Investigated the application of agricultural waste materials like sugarcane straw ash for soil stabilization and heir findings demonstrated that such by-products can improve compaction behavior and strength parameters of expansive soils

J. Kaima et al. (2023) conducted an experimental investigation on the tensile behavior of bamboo fiber bundles. The research revealed that treated bamboo fibers possess considerable tensile strength, which makes them suitable as reinforcement materials in geotechnical applications.

E. Agate et al. (2024) evaluated expansive soil stabilized with bamboo charcoal and other additives for road subgrade construction. Their work showed noticeable improvements in shear strength and CBR values after stabilization.

Although several reports have investigated molasses and bamboo materials separately, few research has been conducted on the combined use of sugarcane molasses and bamboo fiber for stabilizing expansive clay soil

IV. Materials Used

A. Expansive Clay Soil

The soil utilized in this study was collected from a depth of approximately 1 m below ground level. The soil was air-dried, pulverized, and passed through a 4.75 mm sieve before testing.

TABLE I. Basic Properties of Natural Soil

Properties	Value
Liquid Limit	58%
Plastic Limit	29%
Plasticity Index	29
Specific Gravity	2.68
Maximum Dry Density	1.62 g/cc
Optimum Moisture Content	18%
UCS	145 kPa
CBR	2.8%

B. Sugarcane Molasses

Molasses is a viscous liquid obtained during sugar production. It contains sugars, calcium ions, and organic compounds that increase soil particle bonding and reduce plasticity. The adhesive nature of molasses helps fill voids and enhance soil strength.

C. Bamboo Fiber

Bamboo fibers were extracted from bamboo stems and cut into lengths of approximately 20–30 mm. Bamboo fiber offers superior tensile strength and flexibility, making it suitable for reinforcing soil.

TABLE II. Properties of Bamboo Fiber

Properties	Value
Density	1.2 g/cm³
Tensile Strength	400–800 MPa
Length Used	25 mm
Diameter	0.5–1 mm

V. Methodology

A. Preparation of Sample

The collected soil was first air-dried and crushed to break down lumps. It was then sieved through a **4.75 mm sieve** to obtain uniform particles for testing. Different percentages of sugarcane molasses and bamboo fibers were incorporated into the soil based on its dry weight. Molasses contents of **0%, 2%, 4%, 6%, and 8%** were used, while bamboo fiber contents were **0%, 0.5%, 1%, and 1.5%**.

The required amount of molasses was blended with water and then blended thoroughly with the soil. Bamboo fibers of approximately **25 mm length** were distributed uniformly throughout the soil mixture to avoid clustering. The prepared specimens were subsequently compacted and tested in the laboratory.

B. Laboratory Tests

The subsequent tests were performed in accordance with standard procedures:

1. Atterberg Limits Test
2. Standard Proctor Compaction Test
3. Unconfined Compressive Strength Test
4. California Bearing Ratio Test

VI. Results and Discussion

A. Effect on Atterberg Limits

TABLE III. Effect on Atterberg Limits

Molasses (%)	Fiber (%)	Liquid Limit	Plastic Limit	Plasticity Index
0	0	58	29	29
4	0.5	54	30	24
6	1	50	31	19
8	1.5	49	31	18

Observation

- Liquid limit decreased with increasing molasses content.
- Plasticity index reduced significantly.
- Fibers helped restrict soil deformation.

This reduction in plasticity indicates improved soil stability and reduced swelling potential.

B. Compaction Characteristics

TABLE IV. Compaction Characteristics

Mix	MDD (g/cc)	OMC (%)
Natural Soil	1.62	18
4% Molasses + 0.5% Fiber	1.66	17
6% Molasses + 1% Fiber	1.70	16
8% Molasses + 1.5% Fiber	1.69	16.5

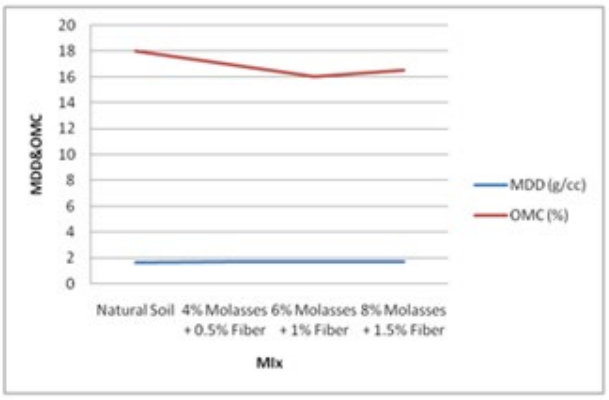

Fig. 1.

Observation

- Maximum Dry Density (MDD) showed an increase with stabilization.
- Optimum Moisture Content(OMC) slightly decreased.

Molasses improves particle bonding and reduces voids in soil.

C. Unconfined Compressive Strength

TABLE V. UNCONFINED COMPRESSIVE STRENGTH

Mix	UCS (kPa)
Natural Soil	145
4% Molasses + 0.5% Fiber	210
6% Molasses + 1% Fiber	265
8% Molasses + 1.5% Fiber	255

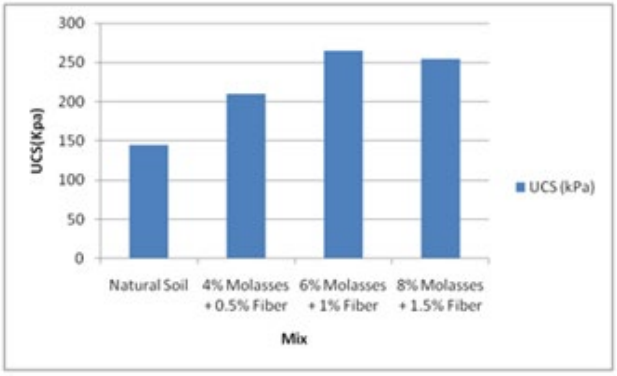

Fig. 2.

Observation

The UCS increased significantly after stabilization.

The optimum mix was **6% molasses + 1% bamboo fiber**.

D. California Bearing Ratio

TABLE VI. CALIFORNIA BEARING RATIO

Mix	CBR (%)
Natural Soil	2.8
4% Molasses + 0.5% Fiber	5.6
6% Molasses + 1% Fiber	8.9
8% Molasses + 1.5% Fiber	8.2

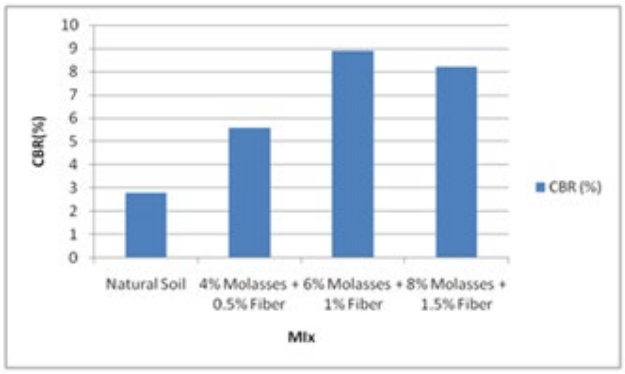

Fig. 3.

Observation

- CBR value increased by approximately three times compared with untreated soil.
- Higher fiber content improved resistance against penetration.

Improvement in CBR indicates that the stabilized soil can be effectively used as pavement sub grade material.

VII. MECHANISM OF STABILIZATION

A. Molasses Stabilization

Sugarcane molasses contains sugars, calcium ions, and Organic substances able to interact with clay minerals. When incorporated into the soil, these compounds promote chemical reactions such as cation exchange and improved particle bonding. As a result, clay particles are rendered more stable, which reduces swelling potential and enhances soil strength.

B. Fiber Reinforcement

Bamboo fibers function as reinforcing elements within the soil structure. These fibers bridge soil particles and provide resistance against deformation when external loads are applied. The presence of fibers helps control cracking, increases tensile resistance, and enhancing the overall shear resistance of the soil.

The **integrated effect of molasses and bamboo fiber** results in better inter-particle bonding and reinforcement, which ultimately increases the load-carrying capacity of the stabilized soil.

VIII. ADVANTAGES OF USING MOLASSES AND BAMBOO FIBER

1. Eco-friendly and biodegradable materials
2. Utilization of agricultural waste

3. Cost-effective compared with cement stabilization
4. Improvement in soil strength and durability
5. Reduced environmental impact

IX. CONCLUSIONS

Based on the experimental investigation carried out in this study, the following conclusions can be drawn:

1. The incorporation of sugarcane molasses reduces the plasticity index of expansive clay soil, indicating a decrease in swelling tendency.
2. Bamboo fibers act as reinforcing elements that increase the strength characteristics of the soil.
3. The stabilization process resulted in an increase in maximum dry density while slightly reducing the optimum moisture content.
4. An enhancement in the unconfined compressive strength of the soil was increased significantly after the addition of molasses and bamboo fibers.
5. The California Bearing Ratio values improved considerably, indicating better load-bearing capacity for pavement subgrade applications.
6. The most effective mixture observed study used a mixture containing 6% molasses and 1% bamboo fiber.
7. The results confirm that agricultural by-products such as molasses and bamboo fiber can be employed for environmentally friendly and cost-effective stabilizing materials for expansive soils.

REFERENCES

[1] S. Ahmad, T. Peng, H. Ayaz, and Y. Wu, “Improving geotechnical properties of expansive subgrade using sugarcane molasses and cement,” Applied Sciences, vol. 14, no. 20, 2024.

[2] B. Taye, “Stabilization of expansive clay soil with sugarcane molasses and cement,” M.S. thesis, Addis Ababa Univ., Ethiopia, 2015.

[3] A. Chakraborty, A. Borah, and D. Sharmah, “Stabilization of expansive soil using sugarcane straw ash,” ADBU Journal of Engineering Technology, vol. 5, no. 1, pp. 1–6, 2016.

[4] J. Kaima, I. Preechawuttipong, and R. Peyroux, “Experimental investigation of bamboo fiber bundles tensil estrength,” 2023.

[5] E. E. Agate, N. Timothy, and A. O. Nathaniel, “Performance of expansive soil stabilized incorporated with bamboo charcoal, quarry dust and lime for road subgrade,” 2024.