STUDY ON THE STABILIZATION OF SOIL USING BANANA FIBER, SODIUM SILICATE AND GUAR GUM POWDER

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ABSTRACT

Soil stabilization is a critical process in geotechnical engineering to enhance the physical properties of soil, particularly in weak or expansive soils. This study investigates the combined effects of banana Fiber, sodium silicate, and guar gum powder as eco-friendly stabilizing agents. Banana fiber, a natural lignocellulosic material, was incorporated to improve the tensile strength and reduce soil brittleness. Sodium silicate was used for its cementitious and binding properties, promoting soil particle agglomeration. Guar gum powder, a biodegradable polysaccharide, acted as a natural binder and water retention agent, enhancing soil cohesion. Laboratory tests including Atterberg limits, unconfined compressive strength (UCS), compaction characteristics, and California Bearing Ratio (CBR) were conducted on untreated and treated soil samples. Results demonstrated a significant improvement in UCS and CBR values, with optimal performance observed at specific percentages of each additive.

KEYWORDS: Soil Stabilization, Banana Fiber Reinforcement, Sodium Silicate, Guar Gum Powder, Biopolymer Stabilization, Sustainable Construction Materials, Shear Strength, California Bearing Ratio (CBR)

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1 INTRODUCTION

Soil is one of the most important construction materials, but not all soils possess adequate engineering properties required for construction activities. Weak or problematic soils often exhibit low strength, high compressibility, and poor load-bearing capacity, which can lead to structural failures. To overcome these issues, soil stabilization techniques are widely used to enhance soil properties. Soil is the fundamental material used in civil engineering for supporting structures such as buildings, roads, embankments, and dams. The performance and stability of these structures largely depend on the engineering properties of the underlying soil. However, many natural soils do not possess adequate strength, stability, or durability required for construction purposes. Problematic soils, such as clayey or loose soils, often exhibit low shear strength, high compressibility, excessive settlement, and poor load-bearing capacity. These deficiencies can lead to structural instability, cracks, and even failure of infrastructure if not properly treated.

To overcome these challenges, soil stabilization techniques are widely adopted to improve the physical and mechanical properties of soil. Soil stabilization involves the addition of suitable materials to soil to enhance its strength, reduce plasticity, control swelling and shrinkage, and increase durability. Conventional stabilization methods typically involve the use of cement, lime, bitumen, and other chemical additives. While these methods are effective, they have certain drawbacks such as high cost, energy consumption, and environmental concerns including carbon emissions and soil contamination.

In recent years, there has been a

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growing emphasis on sustainable and eco-friendly construction practices. This has led to the exploration of alternative materials that are natural, renewable, cost-effective, and environmentally safe. Among these, natural fibers and biopolymers have gained significant attention in geotechnical engineering due to their ability to improve soil properties without causing environmental harm.

Banana fiber is a natural fiber obtained from agricultural waste, particularly from banana plant stems. It is biodegradable, abundant, and has good tensile strength. When mixed with soil, banana fiber acts as a reinforcing material, improving the soil's resistance to deformation and increasing its shear strength. It also helps in reducing crack formation and enhancing ductility, making the soil more stable under load.

Sodium silicate, commonly known as water glass, is an inorganic chemical compound widely used as a stabilizing agent. It reacts with soil particles to form a gel-like structure that binds the particles together, thereby increasing strength and reducing permeability. Sodium silicate is particularly effective in improving the durability and water resistance of soil, making it suitable for applications where moisture control is essential. Guar gum powder is a natural biopolymer derived from guar beans. It is widely used as a thickening and binding agent due to its high-water absorption capacity. When added to soil, guar gum enhances cohesion between soil particles, reduces permeability, and improves overall stability. It also contributes to better compaction characteristics and helps in minimizing erosion.

The combined use of banana fiber, sodium silicate, and guar gum powder offers a hybrid stabilization approach that integrates mechanical reinforcement, chemical bonding, and biopolymer action. This combination is expected to provide significant improvement in soil properties compared to using individual materials alone. Moreover, the use of these materials supports sustainable development by utilizing agricultural waste and reducing dependence on conventional stabilizers.

This study focuses on evaluating the effectiveness of these materials in stabilizing soil through various laboratory tests such as compaction tests, unconfined compressive strength (UCS), and California Bearing Ratio (CBR). The results of this study will help in understanding the behavior of stabilized soil and its potential application in road construction, foundation engineering, and other geotechnical projects.

2 MATERIALS AND METHODOLOGY

2.1 Materials Used

2.1.1 Soil

The soil used in this study is locally available natural soil collected from a selected site. The soil is air-dried, pulverized, and sieved through a 4.75 mm sieve before testing. Preliminary tests such as grain size distribution and Atterberg limits are conducted to classify the soil according to standard classification systems. The basic properties of soil such as specific gravity, maximum dry density (MDD), and optimum moisture content (OMC) are determined.

2.1.2 Banana Fiber

Banana fiber is a natural fiber obtained from the pseudo-stem of the banana plant. It is collected, cleaned, and cut into small lengths (typically 10–30 mm) for uniform mixing. Banana fiber is used as a reinforcing material due to its high tensile strength, biodegradability, and availability. It helps improve the ductility and shear strength of soil.

2.1.3 Sodium Silicate

Sodium silicate (Na_2SiO_3), also known as water glass, is used as a chemical stabilizer. It is generally used in liquid form and mixed with water before adding to soil. It enhances bonding between soil particles by forming a gel-like structure, thereby increasing strength and reducing permeability.

2.1.4 Guar Gum Powder

Guar gum is a natural biopolymer obtained from guar beans. It is used in powder form and mixed with soil to improve cohesion and binding properties. Due to its high-water absorption capacity, it enhances moisture retention and reduces soil permeability.

2.2 Methodology

A systematic methodology was adopted to determine the effect of stabilizers on soil strength.

2.2.1 Collection and Preparation of Materials

- Soil was collected by the disturbed sampling method.
- Oven-dried at **105–110°C** to remove moisture.
- Banana fibers were cleaned, dried, and cut to required length.
- Sodium silicate and guar gum were prepared in measured proportions.

2.2.2 Determination of Index Properties

The index properties of natural (untreated) soil were determined as per IS specifications:

1. **Specific Gravity** – IS: 2720 (Part 3)
2. **Water Content** – IS: 2720 (Part 2)
3. **Atterberg Limits (LL, PL, PI)** – IS: 2720 (Part 5)
4. **Grain Size Distribution** – IS: 2720 (Part 4)
5. **Compaction Characteristics (OMC & MDD)** – IS: 2720 (Part These tests establish the baseline behavior of the soil before stabilization.

2.2.3 Mix Proportions for Stabilization

Different combinations of soil with stabilizers were prepared:

A. Banana Fiber Mixes

- 0% (Control)
- 0.25%
- 0.50%
- 0.75%
- 1.00%

B. With Sodium Silicate & Guar Gum

Measured quantities of:

- Sodium Silicate
- Guar Gum Powder

were added along with banana fiber to create hybrid stabilizer mixes.

2.2.4 Preparation of Soil Samples

- Soil was thoroughly mixed with fibers, sodium silicate, and guar gum.
- Water was added gradually to reach the **Optimum Moisture Content (OMC)**.
- The mixture was compacted into molds as per required density.
- Samples were allowed to cure for **24–72 hours** depending on test requirements.

3. RESULTS

3.1. California Bearing Ratio (CBR) Test:

Table 1: Cbr Test

S. No.	Soil Type/ `Mix ID	Banana Fiber (%)	Sodium Silicate (%)	Guar Gum (%)	Soaked/ Unsoaked	OMC (%)	MDD (g/cc)	CBR (%) @ 2.5 mm	CBR (%) @ 5.5 mm	CBR Value Used (%)
1	Natural Soil (Control)	0	0	0	Unsoaked	18.5	1.72	4.2	5.0	5.0
2	Soil + BF	1.0	0	0	Unsoaked	17.8	1.75	6.3	7.1	7.1
3	Soil + SS	0	2.0	0	Unsoaked	17.6	1.76	7.4	8.0	8.0
4	Soil + GG	0	0	1.0	Unsoaked	17.2	1.78	6.8	7.5	7.5
5	Soil + BF + SS+ GG	1.0	2.0	1.0	Unsoaked	17.4	1.79	13.8	14.7	14.7
6	Soil + BF + SS+ GG	1.0	2.0	1.0	Soaked	17.4	1.78	9.5	-	-

CBR Improvement Analysis:

Improvement = 24.3 − 15.0 × 100 = 62%

15.0

The stabilized soil shows 62% increase in CBR value due to Banana Fiber + Sodium Silicate + Guar Gum.

3.2 Unconfined Compressive Strength (UCS) Test:

Table 2: Ucs Test

Sample ID	Banana Fiber (%)	Sodium Silicate (%)	Guar Gum (%)	Curing Period (days)	Max Load (N)	Area (cm^2)	UCS (kPa)
S1 (Control)	0	0	0	7	550	11.34	485
S2	1.0	0	0	7	670	11.34	591
S3	0	2.0	0	7	730	11.34	644
S4	0	0	1.0	7	710	11.34	626
S5 (Combo)	1.0	2.0	1.0	7	960	11.34	846

RESULTS

- **Average UCS (Unstabilized) = 144.018 kPa** (≈ 0.1440 MPa)
- **Average UCS (Stabilized) = 282.158 kPa** (≈ 0.2822 MPa)

Percentage increase in UCS:

$$\text{Improvement} = \frac{282.158 - 144.018}{144.018} \times 100 = 95.92\%$$

4. DISCUSSION

- The combination of banana fiber, sodium silicate, and guar gum significantly enhances both **CBR** and **UCS** values.
- The stabilized soil exhibits stronger, denser, and more durable behaviour compared to natural soil.
- The results validate that hybrid soil stabilization is a highly effective method for improving weak soils while promoting sustainable construction.

5. CONCLUSIONS

The study successfully demonstrates that the combined use of **banana fiber, sodium silicate, and guar gum powder** provides a highly effective, sustainable, and economical soil stabilization technique. The substantial improvements in CBR and UCS values establish the treated soil as a strong and reliable material suitable for various civil engineering applications. This approach aligns with modern sustainable construction practices by utilizing natural, biodegradable, and locally available materials.

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