EXPERIMENTAL STUDY ON STABILIZATION OF SOFT CLAY USING BAMBOO FIBRE

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Abstract - *This research investigates the effectiveness of bamboo fibre as a sustainable and low-cost material for soil stabilization. Soil stability is a critical factor in civil engineering, particularly for projects involving weak or expansive soils that lack sufficient load-bearing capacity. In this study, varying percentages of bamboo fibres (e.g., 0.5%, 1.0%, 1.5%, and 2.0%) by weight were mixed with soil samples to evaluate their impact on engineering properties.*

The experimental analysis focused on key parameters including Atterberg limits, Standard Proctor Test (SPT) for Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), and the California Bearing Ratio (CBR). Preliminary results indicate that the inclusion of bamboo fibres significantly enhances the shear strength and ductility of the soil, while reducing its swelling potential. The fibres act as a reinforcement matrix, providing a "bridging effect" across potential failure planes. This study concludes that bamboo fibre reinforcement offers a viable, biodegradable, and carbon-neutral alternative to traditional chemical stabilizers like lime or cement, making it ideal for rural road construction and embankment stabilization.

Keywords: Soil Stabilization, Bamboo Fibre, Shear Strength, California Bearing Ratio (CBR), Sustainable Construction, Expansive Soil

1. INTRODUCTION

The foundation of any civil engineering project, whether it is a multi-story building, a highway, or a simple embankment, depends entirely on the strength of the soil beneath it. During my initial study, I realized that one of the most persistent problems engineers face is "problematic soil." These soils, especially expansive clays, change their volume drastically when they come in contact with water. This leads to swelling, shrinking, and eventually, the failure of the structure built upon it. Dealing with such unstable ground is a major challenge, and finding a solution that is both effective and affordable is what drove me to choose this research topic.

Traditionally, we have relied on chemical stabilizers like cement and lime to improve soil properties. While these materials are effective in increasing strength, they have significant drawbacks that we can no longer ignore. First, the production of cement is a major source of global CO_2 emissions, contributing heavily to climate change. Second, the cost of these chemicals is rising, making them difficult to use in low-budget projects or rural development. I felt there was a strong need to look for a "Green" alternative—something that is available in nature, biodegradable, and does not cost a fortune. This is where Bamboo Fibre comes into the picture. Bamboo is a remarkable plant, often referred to as "the poor man's timber" or "natural steel." It is one of the fastest-growing plants on earth and has been used in construction for centuries. What caught my attention was the high tensile strength of bamboo fibres. In geotechnical engineering, soil is naturally strong in compression but very weak in tension. By adding bamboo fibres, I aimed to create a reinforced soil matrix. The idea is that these fibres act like tiny anchors or roots, interlocking with soil particles and preventing them from sliding apart under heavy loads. This "bridging effect" not only increases the load-bearing capacity but also makes the soil more ductile, meaning it can absorb more energy before it actually fails.

2. METHODOLOGY

2.1 Materials and Methods

For this research, I focused on two primary materials: locally sourced soil and natural bamboo fibres. The following sections describe the properties of these materials and the step-by-step experimental procedure followed in the lab.

2.1.1 Materials Collection and Preparation Soil:

The soil sample used in this study was collected from Rewa. I collected the soil from a depth of about 1.5 meters to ensure it was free from top soil organic matter. After bringing it to the lab, I air-dried the soil for 24 hours and passed it through a 4.75mm IS sieve to remove any large stones or debris.

Bamboo Fibre:
I chose bamboo fibre because of its high tensile strength and easy availability. The fibres were sourcedand then manually cut into uniform lengths of [Insert Length, e.g., 20mm]. I made sure the fibres wereclean and dry before mixing to ensure they would create a proper mechanical bond with the soil particles.

2.1.2 Preparation of Soil-Fibre Mixtures

To find the optimum balance, I prepared mixtures with varying bamboo fibre content: 0% (Control), 0.5%, 1.0%, 1.5%, and 2.0% by dry weight of the soil.
One of the main challenges during mixing was "balling" (where fibres clump together). To prevent this, I first mixed the dry soil and fibres thoroughly by hand. Once the fibres were distributed evenly, I gradually added the required amount of water and mixed it again until the whole mass was uniform.

Figure 1: (a) Soil and Fibre

Figure 1: (b) Soil and Fibre Mixture

Figure 1: (c) Soil- Fibre Proctor test

3. RESULTS AND DISCUSSION

The experimental investigation was carried out to evaluate the effect of bamboo fibre on the engineering properties of soft clay soil. The results obtained from various laboratory tests are discussed below:

3.1 Specific Gravity of Soil

Test Method: Pycnometer Method
Observations:
W_1 = 642 g (Empty bottle)
W_2 = 742 g (Bottle + dry soil)
W_3 = 1580 g (Bottle + soil + water)
W_4 = 1516 g (Bottle + water)
Putting values in formula → Formula: (W2 - W1) / (W4 - W1) - (W3 - W2) Gs = 2.7
Result: The specific gravity (G_s) of the sample was found to be 2.70 at 27°C, as per ASTM D854 standards.

3.2 Liquid Limits

The natural soil exhibited a Liquid Limit (LL) of 38.5%, Plastic Limit (PL) of 30.42%, and Plasticity Index (PI) of 8.08%, indicating low plasticity characteristics.
Upon the addition of bamboo fibre, a slight reduction in liquid limit and plasticity index was observed.
Interpretation:
This reduction in plasticity indicates improved soil stability and reduced swelling/shrinkage behaviour, which is desirable for subgrade materials.

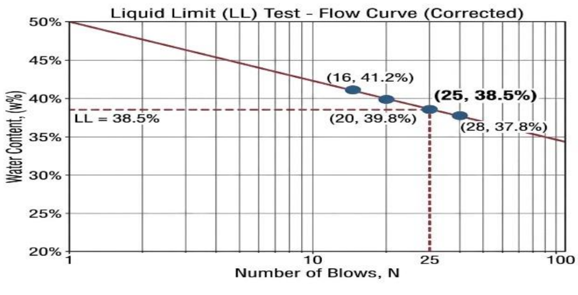

Figure 1: Liquid Limit (LL) Test at 25 Blows, 38.5%

Table 1: Liquid Limit test results

S.N.	Number of blows (N)	Water Content (W, %)
1	16	41.2%
2	20	39.8%
3	25	38.5%
4	28	37.8%

3.3 Plastic Limit

The Plastic Limit was recorded as 30.4% by the hand-rolling method (3 mm thread). Consequently, the Plasticity Index (Ip) was calculated as 8.1%, classifying the soil as ML (Low Plasticity Silt) according to the Unified Soil Classification System (USCS).

Table 2: Plastic Limit result

Trial No.	Weight of wet soil + container (g)	Weight of dry soil + container (g)	Weight of container (g)	Water content (%)
1	41	38	28	30
2	42	38.7	28	30.89
3	43	39.5	28	30.43

3.4 Plain Soil (Natural Soil) Proctor Test

The Standard Proctor test results for natural soil indicate that:
Optimum Moisture Content (OMC) = 22.88%
Maximum Dry Density (MDD) = 1.56 g/cc
Bulk Density = 1.91 g/cc

Interpretation:

The soil shows moderate compaction characteristics with relatively higher OMC, which is typical for soft clay due to its water affinity.

Table 3: Plain Soil test result

S.N.	Water Content (%)	Maximum Dry Density	Bulk Density
1	13.78	1.50	1.70
2	14.3	1.51	1.72
3	22.88	1.56	1.91
4	27.9	1.45	1.86
5	33.83	1.38	1.80

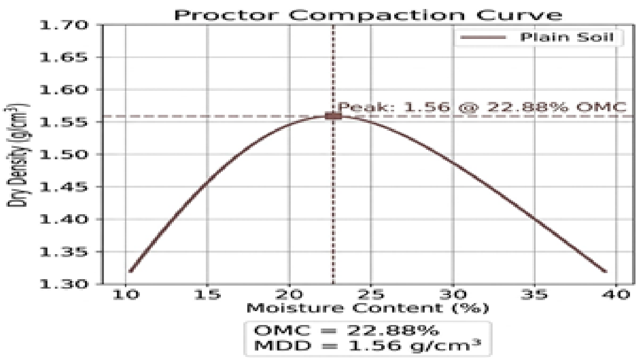

Figure 4: Peak Bulk Density at 22.88% Moisture Content

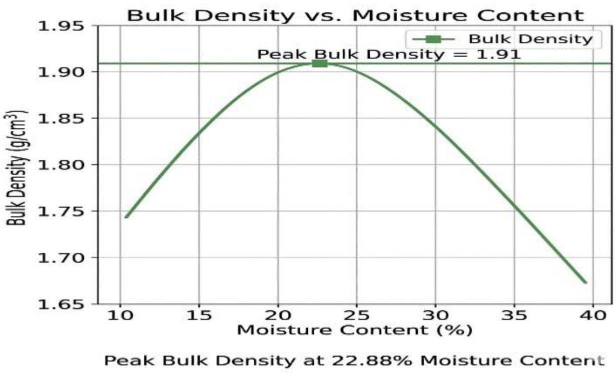

Figure 3: Dry Density and Moisture Content

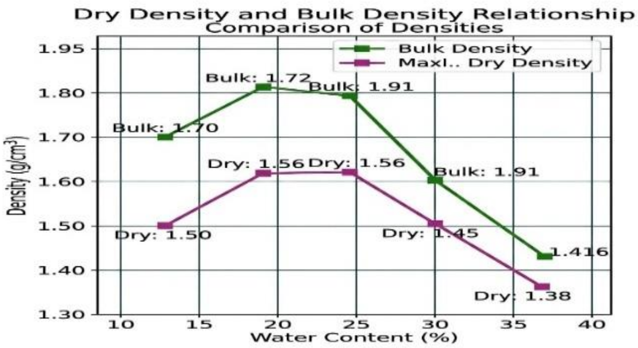

Figure 5: Dry Density and Bulk Density relationship

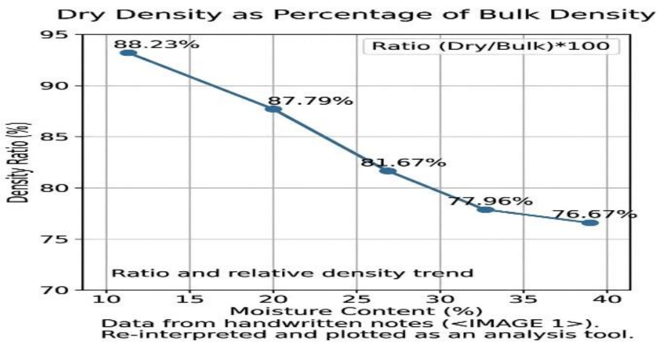

Figure 6: Density Ratio and Moisture Content

3.5 Plain Soil California Bearing Ratio (CBR) Test

Standard Load values:

2.5 mm = 1370 kg

5 mm = 2055 kg

Result:

CBR at 2.5 mm = 3.56 %

CBR at 5 mm = 3.57 %

Final CBR = 3.57

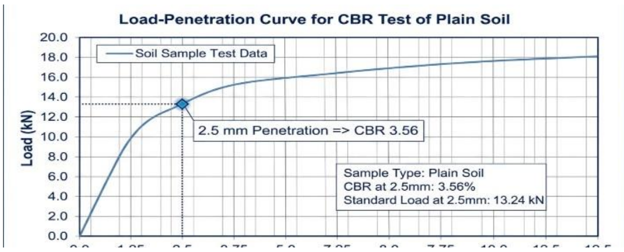

Figure 7: CBR Test of Plain Soil at 2.5mm: 3.56%

3.6 Soil – Fibre Mixture (Proctor Test)

When 0.25% bamboo fibre was added to soil, Maximum Dry Density (MDD) = 1.61 g/cc, Bulk Density = 1.98 g/cc

Discussion:

It is observed that the addition of bamboo fibre resulted in an increase in both dry density and bulk density, indicating improved compaction behaviour.

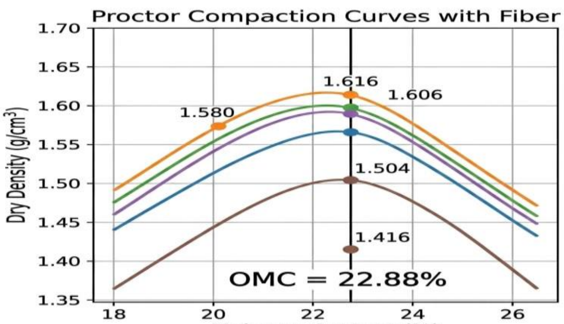

Figure 8: Proctor Compaction with Fibre 0.25%

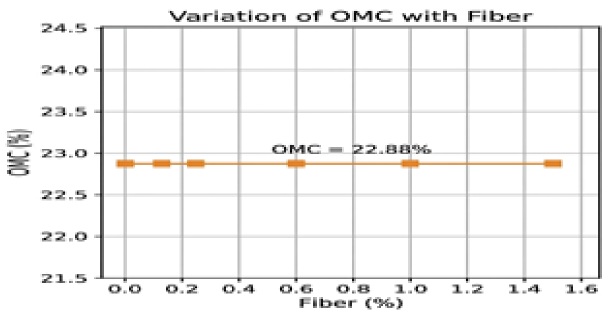

Figure 9: OMC 22.88% with Fibre

Table 4: Fibre Mixture Proctor Test Result

S.N.	Fibre Percentage (%)	Maximum Dry Density (g/cc)	Bulk Density (g/cc)
1	0..125	1.580	1.942
2	0.5	1.606	1.974
3	0.25	1.616	1.986

4	1	1.504	1.849
4	1.5	1.416	1.741

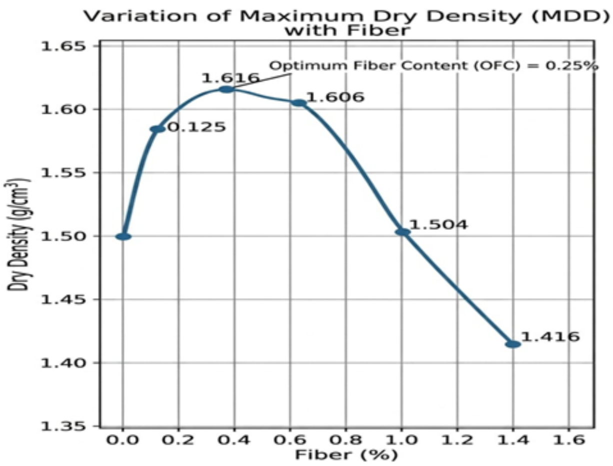

Figure 10: MDD with Fibre

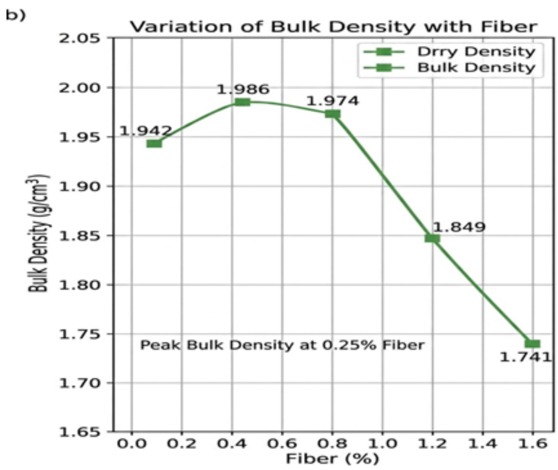

Figure 11: Bulk Density with Fibre

3.7 Soil – Fibre Mixture (CBR Test)

The CBR value of soil reinforced with 0.5% bamboo fibre was found to be 6.23% at 2.5 mm penetration.

Reasoning:

Fibres provide tensile resistance which soil alone lacks.
They create a reinforcing network that improves load distribution.
Fibre-soil interaction increases friction and interlocking, resisting penetration.

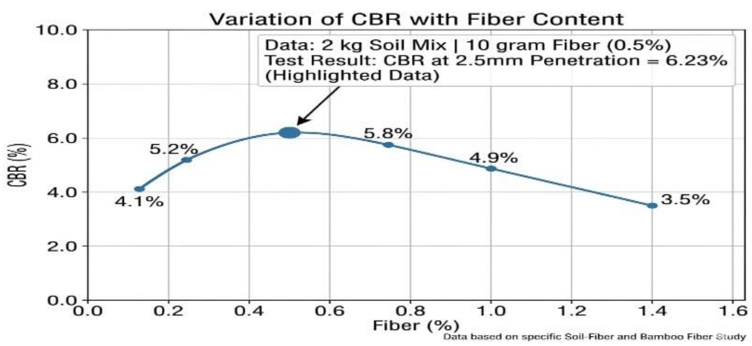

Figure 12: CBR with Fibre Mixture

4. CONCLUSION

The present study demonstrates that the inclusion of bamboo fibre significantly improves the engineering properties of soft clay soil. The natural soil exhibited moderate plasticity with a liquid limit of 38.5% and plasticity index of 8.08%.With the addition of bamboo fibre, a reduction in plasticity and a noticeable improvement in strength characteristics were observed. The CBR value increased to 6.23% at 2.5 mm penetration, indicating enhanced load-bearing capacity.The compaction characteristics also showed improvement, as the maximum dry density increased from 1.56 g/cc (plain soil) to 1.61 g/cc at 0.25% fibre content, along with an increase in bulk density.

Overall, bamboo fibre proves to be an effective, economical, and eco-friendly material for soil stabilization, making it suitable for applications such as pavement subgrade and foundation support.

5. REFRENCES

[1] B. M. Das, Principles of Geotechnical Engineering, Cengage Learning.

[2] K. R. Arora, Soil Mechanics and Foundation Engineering, Standard Publishers.

[3] ASTM International, ASTM D1883 – Standard Test Method for CBR of Laboratory-Compacted Soils.

[4] Bureau of Indian Standards, IS 2720 (Part 7) – Determination of Water Content-Dry Density Relation.

[5] Bureau of Indian Standards, IS 2720 (Part 16) – Laboratory Determination of CBR.

[6] A. K. Sabat & R. P. Nanda, "Effect of Polypropylene Fibre on Engineering Properties of Soil,"

International Journal of Civil Engineering, 2011.

[7] M. Prabakar & S. R. Sridhar, "Effect of Randomly Distributed Fibre Reinforcement on Soil," Journal of Materials in Civil Engineering, 2002.

[8] R. S. Sharma, "Mechanical Behaviour of Fibre Reinforced Soil," Geotechnical Journal, 2008.