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Comparison on the Behaviour of Bamboo and Polypropylene Fibre in Soil Stabilization

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Abstract:** In the practice of geotechnical engineering, soil improvement is regarded as one of the most significant solutions, particularly in the case of weak soil conditions. Expansive soil exposed to climatic changes and moisture content, experiences a significant volume shift. Building foundations, paving structures, irrigation systems, and other geotechnical engineering projects are just a few examples. To prevent swelling and shrinkage characteristics, stabilizing the expansive soil is crucial. For considerations of sustainability and economy, stabilizing material selection is crucial. In this project, the soil stabilization is accomplished using reasonably priced and easily accessible materials like bamboo fiber and polypropylene fibre. Soil is replaced by NaOH treated bamboo fibre from 0.2 to 1% at the interval of 0.2% and the same is repeated by replacing the soil with 1% to 3% at the interval of 0.5%. It was observed that, there is marginal increase in dry density of the treated soil samples and reduction compressibility. The maximum Unconfined Compressive Strength (UCS) was obtained for optimum 0.4% of bamboo fibre and 1.5% of polypropylene fibre with replacement of soil. The performance of bamboo fibre was compared with that of polypropylene fibre. The bamboo fibre showed better results than polypropylene fibre.
***Keywords:** Soil Stabilization, bamboo fibre, polypropylene fibre*

I. INTRODUCTION

In Geotechnical Practice, improving the ground is regarded as one of the most crucial solutions, particularly in cases of weak ground. To enhance the engineering properties of various soils, soil reinforcement materials like geotextile geogrids and fibers are most frequently used nowadays. The Strength, bearing capacity, ductility and volume changes of the soil matrix are all significantly improved by fibre reinforcement. The use of natural and synthetic fibres for soil stabilization has become a significant trend in construction engineering, and research into their effectiveness is expanding quickly. In recent days, it has been investigated that addition of fibres will improve the ductility behaviour of the soil there by reducing the development of crack during shrinkage. One of India's most significant soil deposits is black cotton soil. Heavy water absorption causes black cotton bottoms to swell, soften, and lose their strength. Numerous soil improvement and geotechnical engineering projects use fibre reinforced stabilized soils. For economic development, the use of locally available materials should be encouraged in order to preserve natural resources for future generations. Rice straw, wheat straw, bamboo, wood and reeds were some of the natural materials used in ancient times to improve the strength properties of soil. Bamboo is considered a potential natural reinforcement material for improving and stabilizing soil. With the advent of synthetic fibres and its rapid development, various types of synthetic fabrics have been used as the main reinforcing agents for soil improvement purposes. Common locally available synthetic fibres such as glass, carbon, polyester, nylon, polyacrylonitrile, polyethylene, and polypropylene. Polypropylene fibres are produced by the worldwide, but instead of being used for construction purposes, they are largely discarded as waste in huge quantities, leaving a huge environmental footprint. Therefore, such wastes should be used effectively for the purpose of soil stabilization and can also reduce environmental pollution. Recent years have seen a number of studies on the use of polypropylene (PP) fibres to enhance the technical characteristics of troublesome clay soils. Due to their low cost, hydrophobicity, and chemical inertness, Polypropylene (PP) fibres are the most commonly used synthetic material in the world. The maximum dosage of bamboo fibres and polypropylene (PP) has been noted in the literature for the purpose of examining their impact on the technical characteristics of expansive soils.

To enhance various technical properties of expansive soil, such as consistency limits, compaction properties, compressibility, and resistance to cut, the ideal dosage of bamboo fibre ranges from 0.2 percent to 1 percent and that of PP fibre from 1 percent to 3 percent. Fibre reinforced soils are acknowledged as a good soil improvement technique with great application potential in various geotechnical engineering fields due to its benefits and promising properties. Through our project, we were able to compare how bamboo and polypropylene fibre performed as a soil amendment.

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II. MATERIALS USED

1) *Soil:* The soil sample used for this project work was collected from Industrial biotech block backside at our campus. The soil was dark grey in color. A disturbed sample is collected from a test pit at a depth below 1.2 m below the natural ground level in order to avoid the inclusion of organic matter. The obtained soil was air dried, pulverized manually and soil passing through 4.75 mm IS sieve.

TABLE 1. Properties of Subgrade Soil

S.NO	TEST CONDUCTED	PROPERTIES	RESULTS
1	Determination of moisture content	Moisture content(%)	17
2	Determination of Specific Gravity	Specific Gravity	2.75
3	Grain Size Distribution	%Gravel(>4.75 mm)	0
		%sand(4.75-0.075 mm)	34.45
		%silt and clay(<0.075 mm)	65.55
4	Atterberg's Limit	Liquid Limit(W_L)%	39.7
		Plastic Limit(W_P)%	26.07
		Plasticity Index (I_P)%	13.63
		Shrinkage limit (W_S) %	22
5	Standard Proctor Compaction Test	Optimum Moisture Content(%)	16
		Maximum Dry Density(g/cc)	1.64
6	Determination of compressive Strength	Unconfined Compressive Strength(kN/m²)	14.55
		Cohesive Strength(kN/m²)	7.28
7	IS Classification		Medium compressible clay (CI)

FIG 1. Black Cotton Soil

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2) *Bamboo fibre (BF):* The bamboo fibre is made from the starchy pulp of bamboo plants. Bamboo fibre is naturally anti-bacterial, UV protective, green and biodegradable, breathable and cool, strong, flexible, soft. Bamboo fibres are remarkably strong in tension but have low modulus of elasticity. The main advantage of these materials is that they are locally available and cost effective. Its low cost makes it attractive for geotechnical applications. Cellulose and lignin are the major constituents and higher lignin content makes the fibre stiffer and tougher.

FIG 2. Bamboo Fibre

TABLE 2. Properties of Bamboo Fibre

S.NO	PROPERTY	VALUES
1	Cellulose (%)	60.8
2	Lignin (%)	32.2
3	Others (%)	7
4	Tensile strength (Mpa)	615 to 862
5	Young's Modulus (Gpa)	35.45
6	Hemicellulose (%)	(20-25)
7	Type	Pulp
8	Colour	White

3) *Polypropylene fibre (PPF):* Using polypropylene fibre from discarded plastic also contributes to waste reduction and helps to avoid environmental risks. The process of increasing a soil's stability or bearing capacity is known as "soil stabilization," and it involves proportioning, controlled compaction, and the addition of the right admixture or stabilizers.

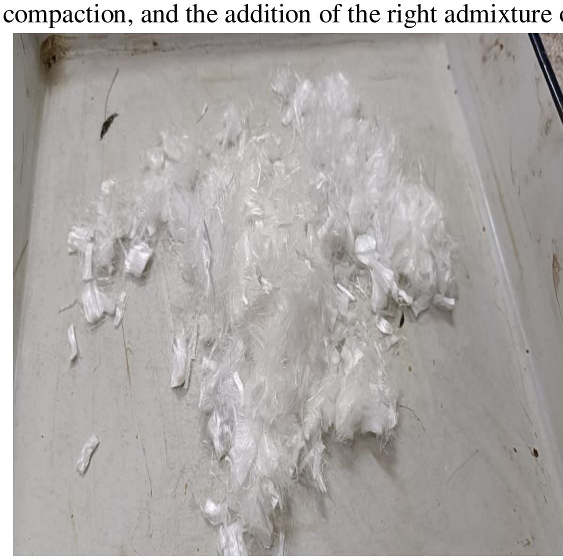

FIG 3. Polypropylene Fibre

TABLE 3. Properties of Polypropylene Fibre

S.NO	PROPERTY	VALUES
1	Appearance	White fibers
2	Specific gravity	0.91
3	Melting point	165^{o}C
4	Tensile strength (Mpa)	500 to 700
5	Length (mm)	12
6	Diameter (microns)	18
7	Aspect ratio (l/d)	670
8	Absorbancy (%)	<0.1

III. EXPERIMENTAL PROGRAM

A. *Treatment of Bamboo Fibre*

When incorporated into the soil mass, natural fibres gradually lose strength and other qualities. Natural fibres biodegradability issue can be solved with the right treatment techniques, such as alkali and other chemical treatments. In this investigation, alkali treatment is used. Fibers are cut to the desired length and immersed in 4% NaOH solution for 48 hours. Finally, fibers are oven dried until it gets dry.

B. *Standard Proctor Compaction Test*

The optimum moisture content and maximum dry density was obtained by conducting Standard Proctor Compaction Test as per IS: 2720 (Part 7)- 1980. The relation between moisture content and dry density obtained from compaction test. Proctor compaction test measures the maximum unit load that a particular type of soil can be compacted to use a controlled compact force at an optimal water content. It is the most common laboratory soil test and is the basis for all engineered compact soil placements for embankments, pavements and structural mills. The results of the Proctor test are compared to the measured densities of the compacted filled space to determine the degree of soil density. The Optimum Moisture Content and Maximum Dry Density for each sample is found with varying percentages of chemically treated bamboo fiber 0.2%, 0.4%, 0.6%, 0.8%, 1% and polypropylene fiber 1%, 1.5%, 2%, 2.5%, 3%.

C. *Unconfined Compression Test*

The Unconfined Compression test was conducted as per IS 2720 (Part 10):1991.

IV. RESULTS AND DISCUSSIONS

1) *SPC Test:* The effect of soil sample with NaOH treated bamboo fiber and polypropylene fibre in different proportions is calculated to found OMC and MDD.

TABLE 4. Standard Proctor Compaction Test for bamboo fibre with soil

S.NO	SOIL + PERCENTAGE OF BAMBOO FIBRE ADDED	OPTIMUM MOISTURE CONTENT (%)	MAXIMUM DRY DENSITY (g/cc)
1	Untreated soil	16	1.64
2	Soil + 0.2% bamboo fibre	16	1.73
3	Soil + 0.4% bamboo fibre	16	1.78
4	Soil + 0.6% bamboo fibre	16	1.75
5	Soil + 0.8% bamboo fibre	16	1.74
6	Soil + 1% bamboo fibre	16	1.71

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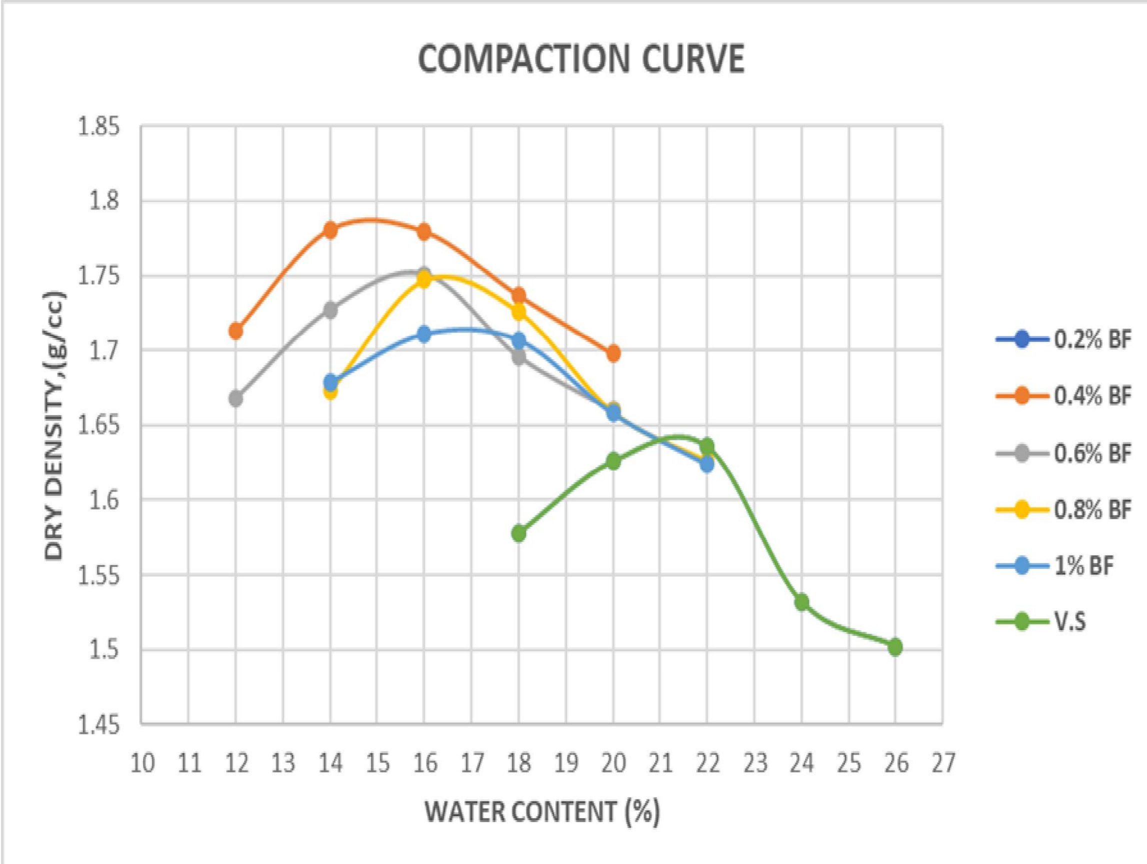

FIG 4. Compaction curve for soil with varying percentages of Bamboo fibres

The table 4 explains the individual effect of bamboo fibre. For this case, the OMC reaches maximum at 0.4% bamboo fibre and also the MDD reaches maximum because void ratio decreases and increasing depth of the soil by adding bamboo fibre to the soil. The Fig. 4 explains the effect of compaction on various percentages of bamboo fibre treated with soil.

TABLE 5. Standard Proctor Compaction Test for Polypropylene fibre with soil

S.NO	SOIL + PERCENTAGE OF POLYPROPYLENE FIBRE ADDED	OPTIMUM MOISTURE CONTENT (%)	MAXIMUM DRY DENSITY (g/cc)
1	Untreated soil	16	1.64
2	Soil + 1% polypropylene fibre	18	1.71
3	Soil + 1.5% polypropylene fibre	16	1.72
4	Soil + 2% polypropylene fibre	16	1.67
5	Soil + 2.5% polypropylene fibre	18	1.65
6	Soil + 3% polypropylene fibre	18	1.69

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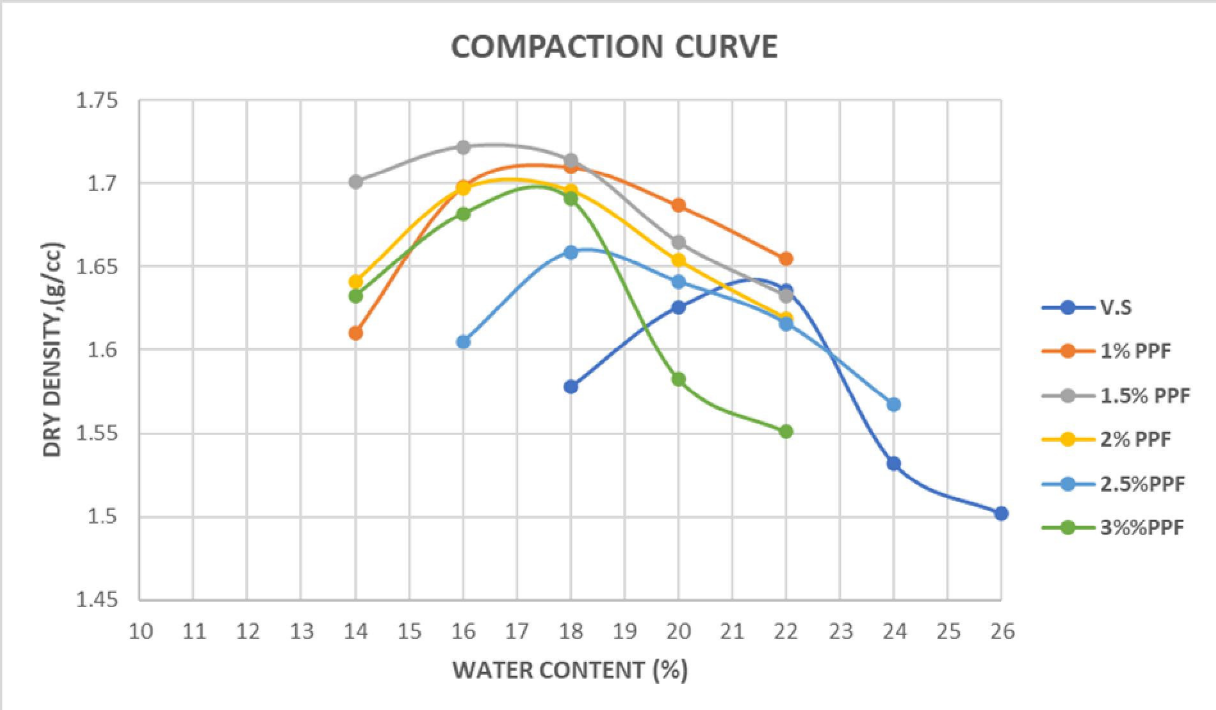

FIG 5. Compaction curve for soil with varying percentages of polypropylene fibres

The table 5 explains the individual effect of polypropylene fibre. At first, the soil was treated with polypropylene fibres at various percentages. For this case, the OMC reaches maximum at 1.5% polypropylene fibre and also the MDD reaches maximum by adding polypropylene fibre to the soil. The Fig. 5 explains the effect of compaction on various percentages of polypropylene fibre treated with soil.

2) *UCS Test:* The effect of soil sample with NaOH treated bamboo fiber and polypropylene fiber in different proportions is calculated to found UCS.

TABLE 6. Unconfined Compression Test for NaOH treated bamboo fibre with soil

S.NO	SOIL + PERCENTAGE OF BAMBOO FIBER ADDED	UNCONFINED COMPRESSIVE STRENGTH,UCS (kN/m^2)
1	Untreated soil	14.55
2	Soil + 0.2% bamboo fibre	18.76
3	Soil + 0.4% bamboo fibre	29.1
4	Soil + 0.6% bamboo fibre	20.73
5	Soil + 0.8% bamboo fibre	15.29
6	Soil + 1% bamboo fibre	13.11

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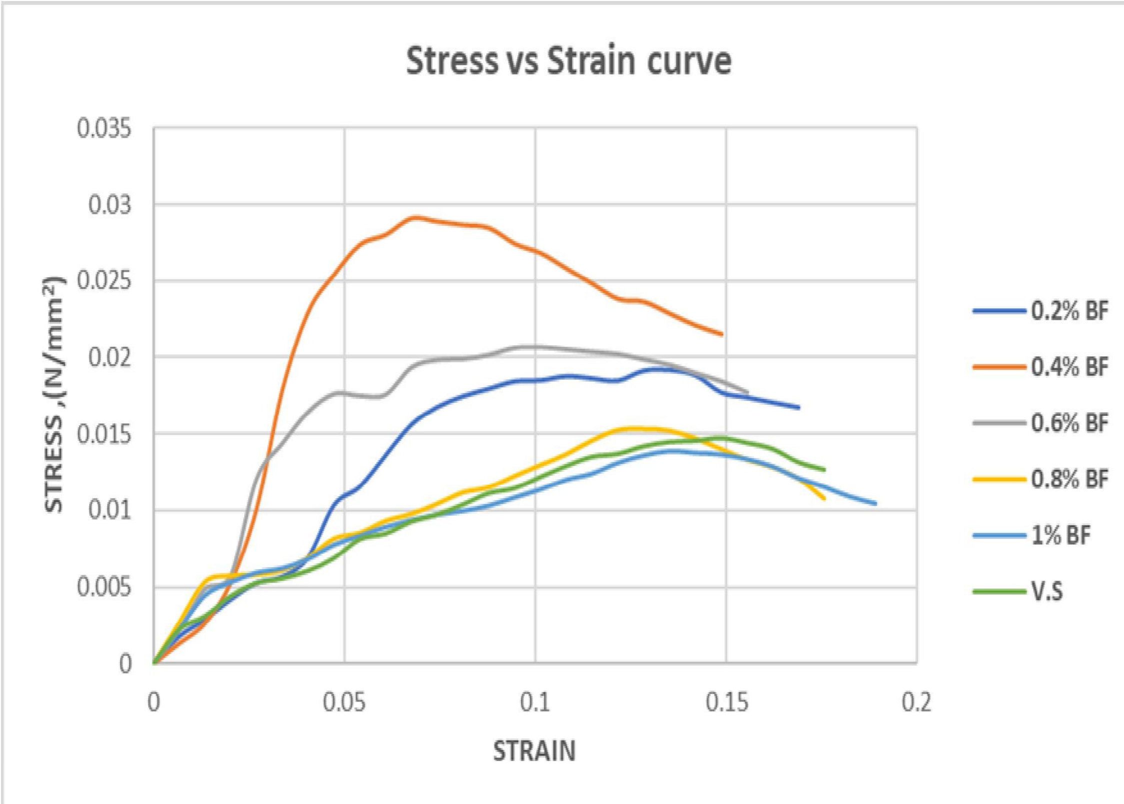

FIG 6. Stress vs Strain curve for soil with varying percentages of Bamboo fibres

The table 6 explains about the unconfined compression test when soil with NaOH treated with bamboo fibre is added in different percentages. The unconfined compressive strength value of soil treated with bamboo fibre was found to be 29.1 kN/m^2 at 0.4% which increases the strength of the soil in addition of fibre to the soil.

TABLE 7. Unconfined Compression Test for NaOH treated Polypropylene fibre with soil

S.NO	SOIL + PERCENTAGE OF POLYPROPYLENE FIBRE ADDED	UNCONFINED COMPRESSIVE STRENGTH,UCS (kN/m^2)
1	Untreated soil	14.55
2	Soil + 1% polypropylene fibre	10.24
3	Soil + 1.5% polypropylene fibre	15.09
4	Soil + 2% polypropylene fibre	6.75
5	Soil + 2.5% polypropylene fibre	10.53
6	Soil + 3% polypropylene fibre	11.12

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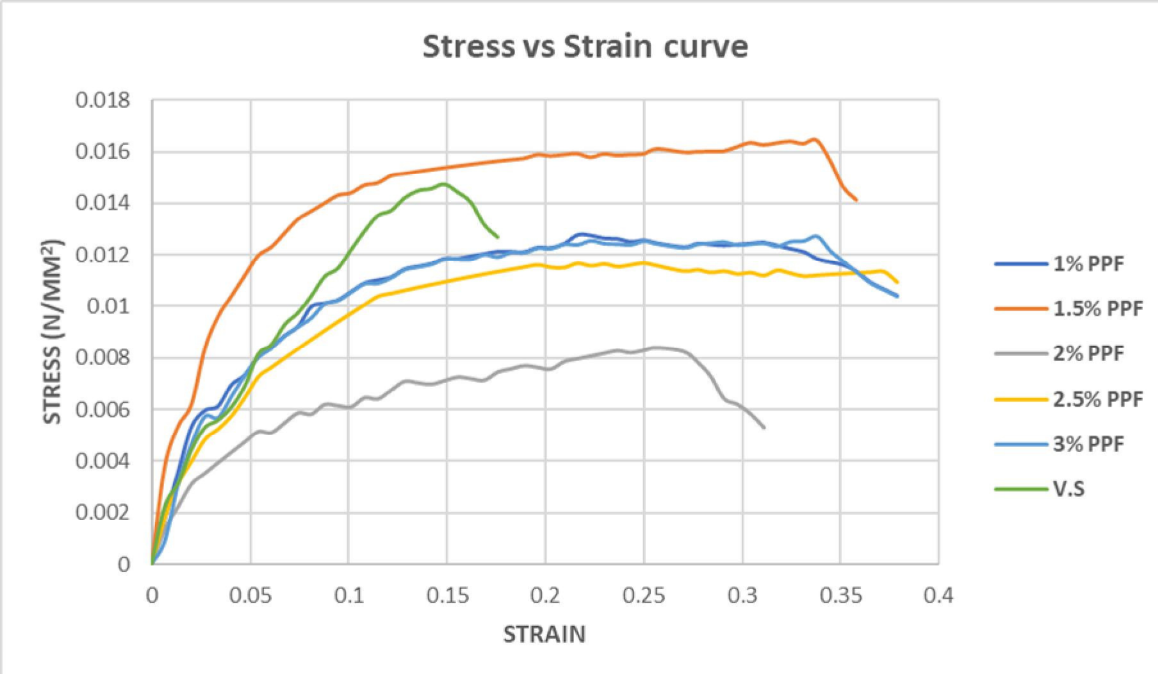

FIG 7. Stress vs Strain curve for soil with varying percentages of Polypropylene fibres

The table 7 explains about the unconfined compression test when soil is treated with polypropylene fibre is added in different percentages. The unconfined compressive strength value of soil treated with polypropylene fibre was found to be 15.09 kN/m.

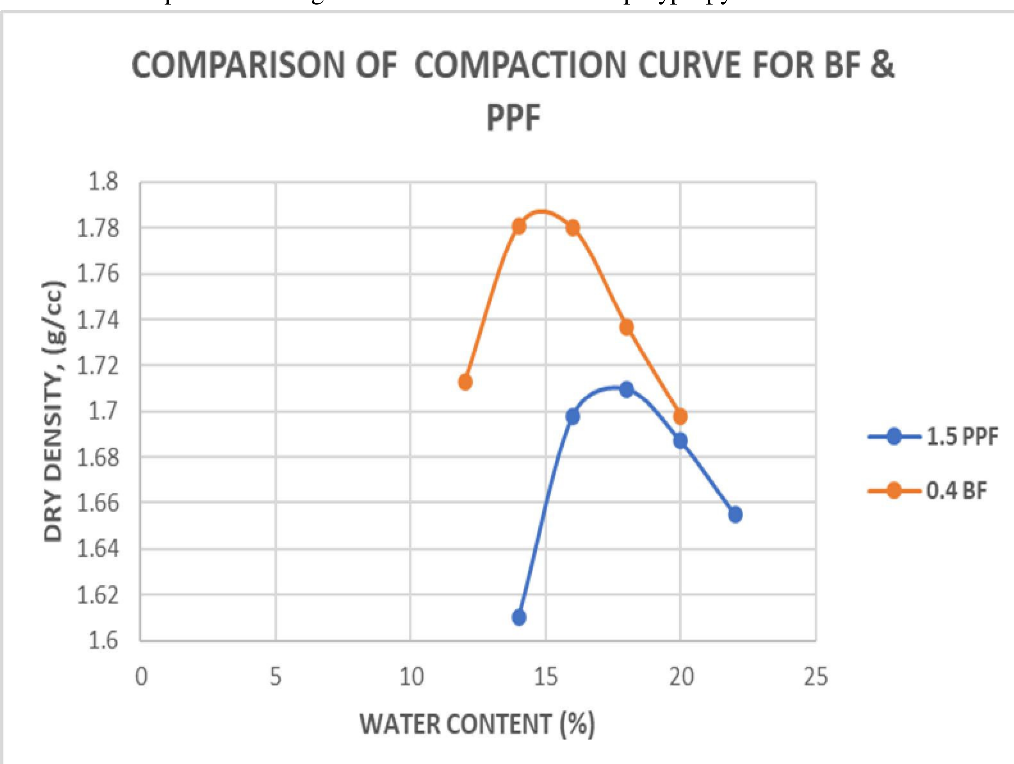

FIG 8. Comparison of compaction curve for Bamboo fibre and Polypropylene fibre

Fig 8 explains the comparision of compaction curve for bamboo fibre and polypropylene fibre in the addition of optimum percentage of fibres.

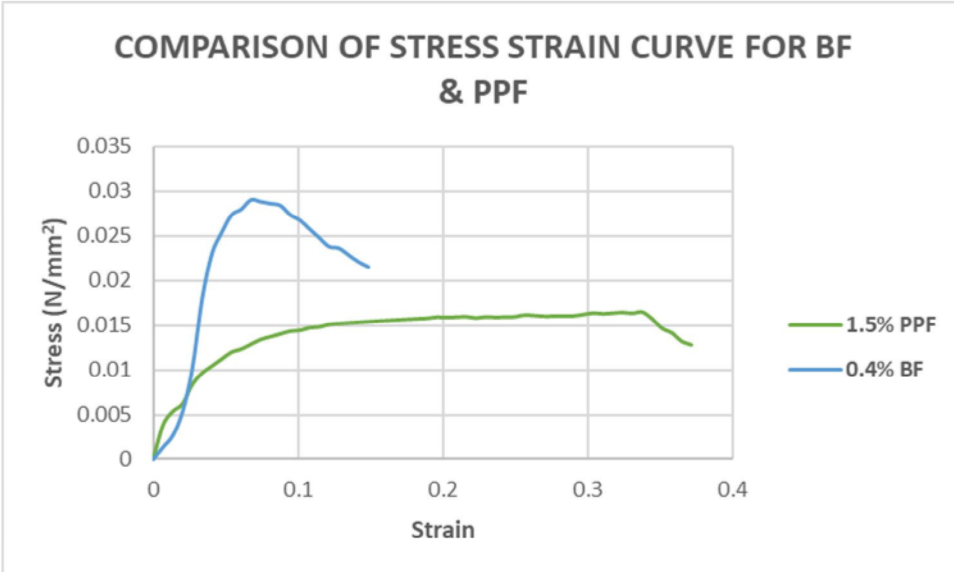

FIG 9. Comparison of Stress Strain curve for Bamboo fibre and Polypropylene fibre

Fig 9 explains the comparision of compaction curve for bamboo fibre and polypropylene fibre in the addition of optimum percentage of fibres. From the comparision of fibres bamboo fibre shows higher strength than polypropylene fibre. This is due to the alkali treatment of natural fibres which enhances the ductility of fibres and reduces the progressive loss of strength.

V. CONCLUSION

In this paper, two different types of fibres used to improve the strength characteristics of the soil. The following conclusions has been shown below.

1) The UCS results demonstrated that the strength of bamboo fibre (BF) is higher than that of polypropylene fibre (PPF)used in reinforcing the soil.
2) This shows the result of the natural fibers being alkali-treated, which increases their ductility and slows down the loss of strength and other properties when they are incorporated into the soil mass.
3) It was observed that, there is marginal increase in dry density of the treated soil samples and reduction compressibility.
4) The maximum Unconfined Compressive Strength (UCS) was obtained for optimum 0.4% of bamboo fibre and 1.5% of polypropylene fibre with replacement of soil.
5) The performance of bamboo fibre was compared with that of polypropylene fibre. The bamboo fibre showed better results than polypropylene fibre.

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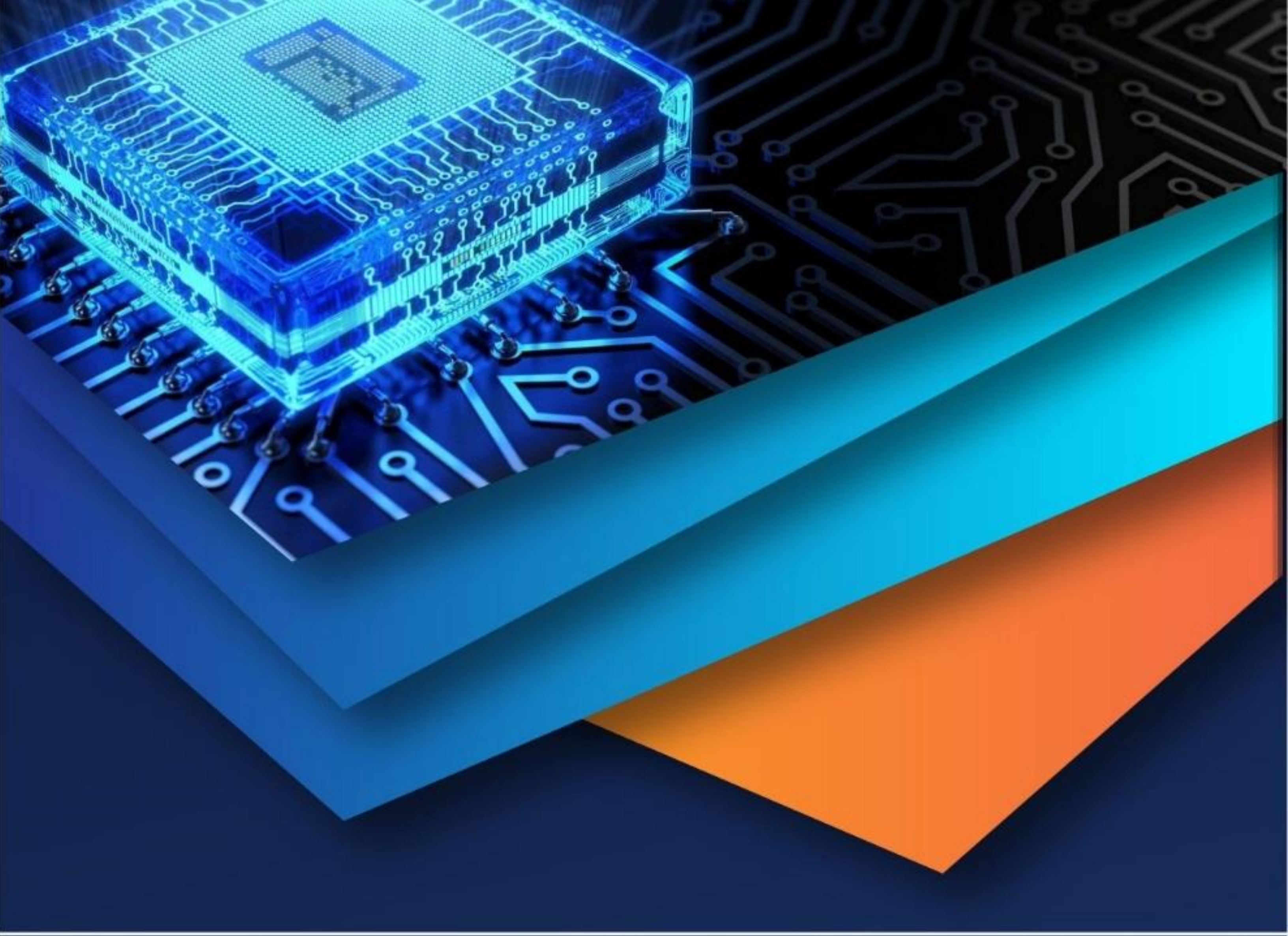

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