APPLICATION OF GEO-NATURAL FIBERS AND SUBGRADE CONSTRUCTION

MALLIKHARJUNA RAO MOTHIKA[1],Ms. K. M. JAYAKUMARI [2]

[1]M.Techstudent,[2]Assistant Professor, Dept.of Civil Engineering, SANKETIKA VIDYA PARISHAD ENGINEERING COLLEGE(Affiliated to Andhra University, Vishakhapatnam AP)P.M. PALEM, VISAKHAPATNAM -530041

Abstract : *The use of geo-natural fibres in subbase and subgrade construction is a new and environmentally friendly way to improve the mechanical qualities and durability of road and pavement infrastructure. The inclusion of various geo-natural fibres, such as jute, coconut, and sabai grass, into the subbase and subgrade layers of road building is investigated in this study. These natural fibres are environmentally friendly and locally available, making them an appealing alternative to typical building materials.*

The study looks at how these fibres affect the engineering properties of subbase and subgrade layers, such as tensile strength, load-bearing capacity, and resistance to soil erosion. The findings show that using geo-natural fibres improves soil stabilization, reduces settlement, and increases resilience to moisture-induced damage.

This study highlights the importance of sustainable construction techniques by encouraging the use of bio-based materials that lower the environmental imprint of infrastructure development. The findings have significance for low-cost, ecologically friendly road construction technologies, particularly in areas where natural fibres are abundant.

Keywords:*Geo-natural fibers, jute, coconut, sabai grass, subbase, subgrade construction, soil stabilization, sustainability, eco-friendly materials, road infrastructure, mechanical properties, load-bearing capacity*

I. INTRODUCTION

Infrastructure development is critical to promoting human civilization's social and economic advancement. As a result, there is an urgent need for rapid and broad developments in the transportation sector, resulting in massive road network expansion. In India, numerous government programs, such as the Pradhan Mantri Gram Sadak Yojana (PMGSY) and Bharat Nirman, help to encourage its spread.

The building of large road networks in India demands a large quantity of materials for sub-base courses, which include foundations, subgrades, and pavements. Subgrades and embankments have traditionally been built with locally obtained soil. However, in heavily populated places, acquiring large quantities of soil might be difficult logistically. Furthermore, it is critical to understand that in some areas, the quality of the available soil may be poor, necessitating the use of appropriate stabilizing technologies to obtain the required strength for subgrade and embankment building.Furthermore, as the need for transportation continues to rise, so do traffic loads and speeds. As a result, many old roads have deteriorated and no longer have the structural strength to withstand significant traffic loads. To meet these needs, sub-base and subgrade upgrades are required. There is a high demand for aggregates in India, and the soil around construction sites may be limited in supply or exhibit inadequate strength and compaction qualities even after comprehensive compaction efforts. As a result, these soils require reinforcement to prevent compaction issues and enhance strength.

Objective:

1.The primary goal of this empirical inquiry is to investigate the enhancement of compaction and strength properties in composite materials composed of natural fibers and soil.

2.The purpose of this research is to find the best soil dry-weight ratio and fiber lengths for optimizing the performance of these composite materials.

3.In the case of cohesive soils, the primary focus is on evaluating fiber incorporation in subgrade construction.

4.In cohesionless soil scenarios, the goal is to assess the viability of using fiber-reinforced soil in subbase applications.

5.The findings of this research project are expected to provide useful insights into the most effective combinations of fiber content and fiber length, consequently improving the properties of fiber-soil composites.

6. Based on the individual soil type under consideration, these findings will provide recommendations for the selection of optimal conditions in subgrade construction and subbase treatments.

7. In addition, by potentially reducing the demand for conventional reinforcement materials, our research

helps the development of sustainable construction methods.

Gray and Ohashi conducted a complete set of direct shear experiments on dry sand samples supplemented with three separate types of reinforcing fibers in 1983: synthetic polypropylene fibers, natural reed fibers, and metallic copper wire fibers. The primary goal of this study was to determine the effect of several elements on the shear strength of sand, namely the orientation of the fibers, their content, the fiber area ratio, and their inherent stiffness. The sand samples were rigorously produced in two different relative concentrations, 20% and 100%.

Al-Refeai (1991) conducted research with the primary goal of improving the strength properties of two separate types of sands. To fortify these sand materials, the researchers used reinforcing techniques utilizing polypropylene mesh, polypropylene pulp, and glass fibres. The examination included a lengthy series of triaxial tests to evaluate the strength qualities of these composite sand specimens.

In a second investigation, Ranjan et al. (1996) performed a series of triaxial compression tests on soil specimens fortified with discrete and randomly dispersed synthetic and natural fibres. This extensive testing program included a wide range of soil types, including sand, medium sand, fine sand, silty sand, and silt, each with a unique set of inherent qualities.

II. MATERIALS USED

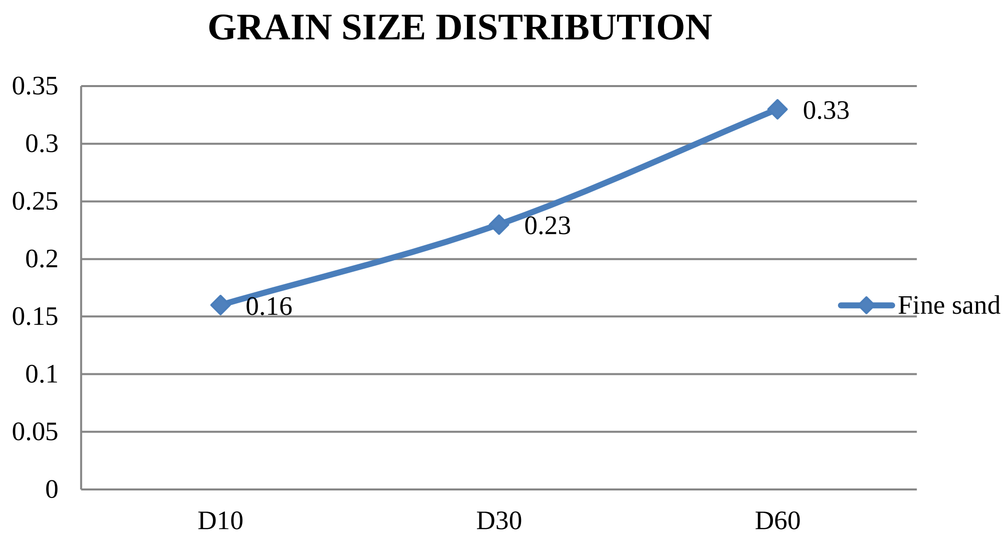
2.1 COHESIONLESS SOIL (SAND):

Fine sand was chosen as the preferred material for this experimental inquiry. This choice was primarily inspired by the prevalence of different sand kinds in various places across the country, making them practical choices for real-world deployments.

Physical properties of the sand used: Several tests were performed to determine the physical properties of the three cohesionless soil types.

Particle Size Distribution Analysis:

The particle size distribution analysis followed the techniques given in I.S. Code 2720, Part-IV, 1985. Figure 2.11 depicts visual representations of grain size distribution curves for three distinct sand kinds, including fine sand. Table 2.11 contains detailed information on the particle size distribution properties of



various sands.

Fig. 2.11 Grain size distribution curve for different types of sand

Sand type	Description	D_{10}	D_{30}	D_{60}	C_u	C_c	Remarks
I	Fine sand with brown colour	0.16	0.23	0.33	2.06	1.00	Poorly graded soil

Table 2.11: Characteristics of grain size distribution for the three types of sand

The physical properties of fine sand used is summarized in Table 2.12.

Properties	Fine Sand
Colour	Brown
Classification (IS)	SP
Specific Gravity (G)	2.63
D10, D30, D60 (mm)	0.16, 0.23, 0.33
Coefficient of Uniformity, Cu	2.06
Maximum dry density (gm/cc)	1.62

Optimum moisture content (%)	15.3
Angle of internal friction (φ)	38.8°
Unsoaked CBR (%)	8.4
Soaked CBR (%)	7.1

Table 2.12: Summary of Physical Properties of Sands

2.2 COHESIVE SOIL (CLAY):

On these clay soils, California Bearing Ratio (CBR) experiments were performed with specimens kept at their respective optimum moisture content (OMC). These investigations were carried out in both non-soaked and drenched settings, by the protocols indicated in I.S. 2720, Part-XVI, 1987. The unsoaked CBR value for fine sand was found to be 8.4, whereas the soaked CBR value for fine sand was found to be 7.1.

Particle Size Distribution Analysis:

The particle size distribution in cohesive soil was examined following the requirements stated in I.S. Code 2720, Part-IV, 1985, for determining the composition of various fractions within the cohesive soil matrix. Figure 2.21 depicts a graphical representation of the grain size distribution curve for cohesive soil. The effective diameters of the soil particles were determined to be 0.01mm, 0.022mm, and 0.032mm, respectively. The coefficient of uniformity was found to be 3.2, with a coefficient of curvature of 1.51.

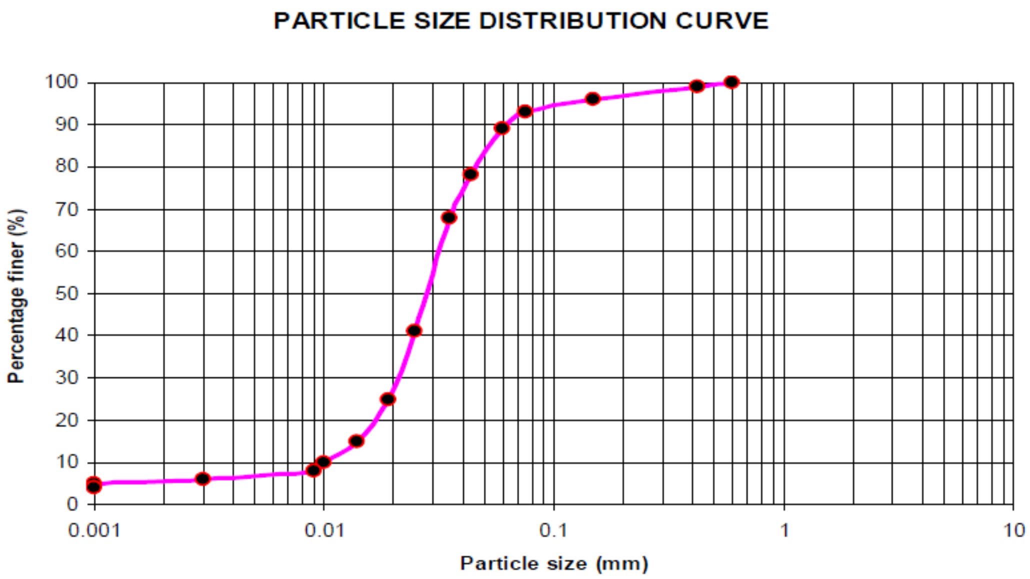


Fig. 2.21 Grain size distribution curve for cohesive soil

The physical properties of clay sand used is summarized in Table 2.22.

Properties of Clay	
Colour	Brown
I.S. Classification	CI
Specific Gravity	2.63
Coefficient of Uniformity, C_u	2.09
Liquid Limit (%)	41
Plastic Limit (%)	23
Plastic Index (%)	18
Maximum dry density (gm/cc)	1.58
Optimum moisture content (%)	19.2
Soaked CBR (%)	2.1
U.C.S. (kg/cm^2)	1.88

Table 2.22: Summary of Physical Properties of Clay

2.3 NATURAL FIBERS:

Natural fibres, namely jute and coconut fibre, were obtained from local markets for use in our study. Table 2.31 provides an overview of the physical properties of these fibres.

Tests	Jute Spoil	Coir
Density (g/mm)	1.47	1.40
Diameter (mm)	0.03-0.014	0.1-0.45

Table 2.31: Summary of Physical Properties of Fibers

Jute and coir fibres were methodically processed into separate segments with lengths ranging from 5 mm to 10 mm and 20 mm before being used as reinforcing materials. To achieve a consistent and homogeneous blend, these fibre segments were systematically integrated into the clay matrix at varied proportions, specifically 1%, 1.5%, 2%, and 2.5%.

Jute Fiber:

Natural jute fibres were purchased from local marketplaces and precisely sectioned into lengths of 5 mm, 10 mm, and 20 mm before being used as fibre materials.

Coir Fiber:

Natural coconut fibres were prepared in a laboratory setting, beginning with the purchase of mature coconuts from the local market. These fibres were methodically removed from the coconut shells and then sun-dried for a lengthy period. Following the drying method, the coir fibres were cleaned and sectioned into segments of 5 mm, 10 mm, and 20 mm in length for use as fibre materials.

III. RESULTSANDDISCUSSIONS

The study offers compaction curves that depict the interaction between dry density (D.D.) and moisture content (M.C.) in the context of fine sand using randomly dispersed jute fibres and coir fibres of varied lengths (20 mm, 10 mm, and 5 mm). Figures 3.1 and 3.2 depict these compaction curves, which correspond to the integration of different proportions and lengths of randomly scattered jute and coir fibre.

a)Fine sand - Jute Fiber Combination:

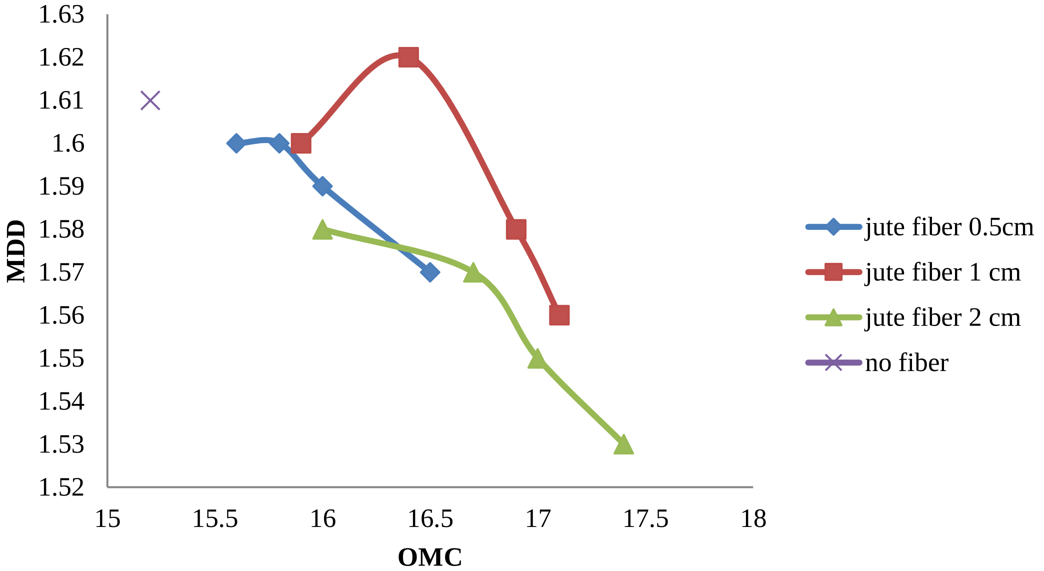


Fig 3.1: D.D. Vs M.C. curve for Fine sand mixed with Jute fibers of different lengths

(a) Fine sand – Coir fiber combination:

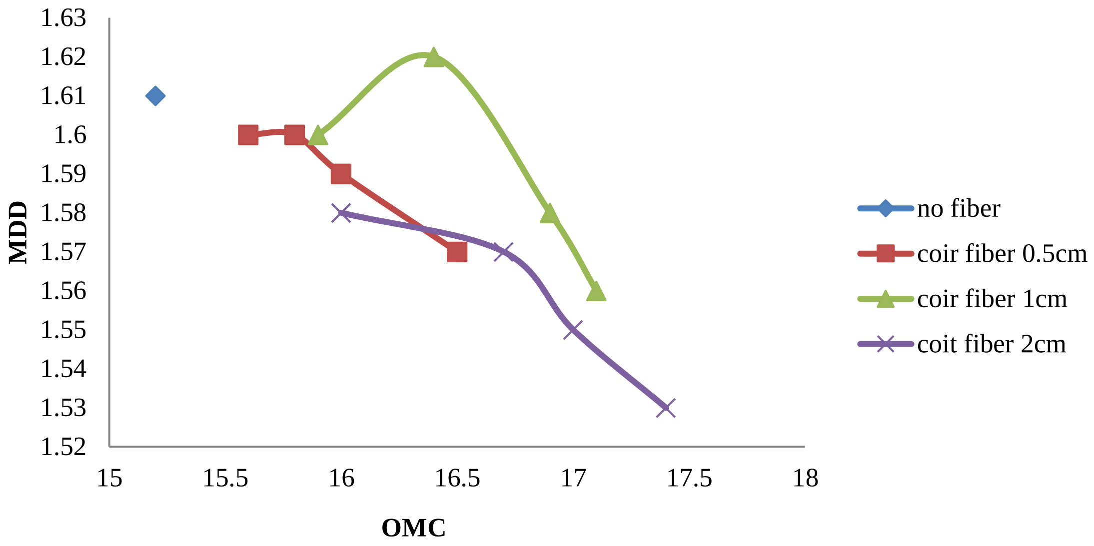


Fig 3.2: D.D. Vs M.C. curve for Fine sand mixed with Coir fibers of different lengths

Tables 3.3 and 3.4 detail the laboratory test results, which include unsoaked and soaked California Bearing Ratio (CBR) values. These findings apply to a wide range of combinations including various types of sand combined with jute and coir fibers.

Details of fiber and length	% of fiber	Fine Sand	
		Unsoaked CBR	Soaked CBR
No Fiber	0.0%	8.4	7.1
Jute Fibre 0.5cm	0.5%	10.5	9.7
	1.0%	11.6	10.4
	1.5%	12.2	11.2
	2.0%	10.8	9.6
Jute Fibre 1.0cm	0.5%	9.6	.7
	1.0%	10.3	9.1
	1.5%	10.7	9.7
	2.0%	9.7	8.5
Jute Fibre 2.0cm	0.5%	9.3	8
	1.0%	10.1	8.9
	1.5%	10.3	9.1
	2.0%	9.1	8.2

Table 3.3: Summary of Results of Unsoaked and Soaked CBR tests for jute fiber with fine sand

Details of fiber and length	% of fiber	Fine Sand	
		Unsoaked CBR	Soaked CBR
No Fiber	0.0%	8.4	7.1
Coir Fibre 0.5cm	0.5%	10.6	9.8
	1.0%	12.1	10.7
	1.5%	12.6	11.4
	2.0%	11.1	9.8
Coir Fibre 1.0cm	0.5%	10.1	8.9
	1.0%	11	9.6
	1.5%	11.6	10.2
	2.0%	10.6	9.1
Coir Fibre 2.0cm	0.5%	9.7	8.3
	1.0%	10.6	9.2
	1.5%	11.2	10
	2.0%	10.2	8.6

Table 3.4 Summary of the results of Unsoaked and Soaked CBR tests for Coir fiber with fine sand

Using data from routine Proctor tests, we plotted compaction curves, specifically dry density (D.D.) vs. water content (W.C.) curves. These curves enabled us to calculate the MDD and related OMC for soil mixed with randomly dispersed jute fibres of varying lengths (5 mm, 10 mm, and 20 mm) and coir fibre percentages. Figures 3.5 and 3.6 show the visual representation of the results.

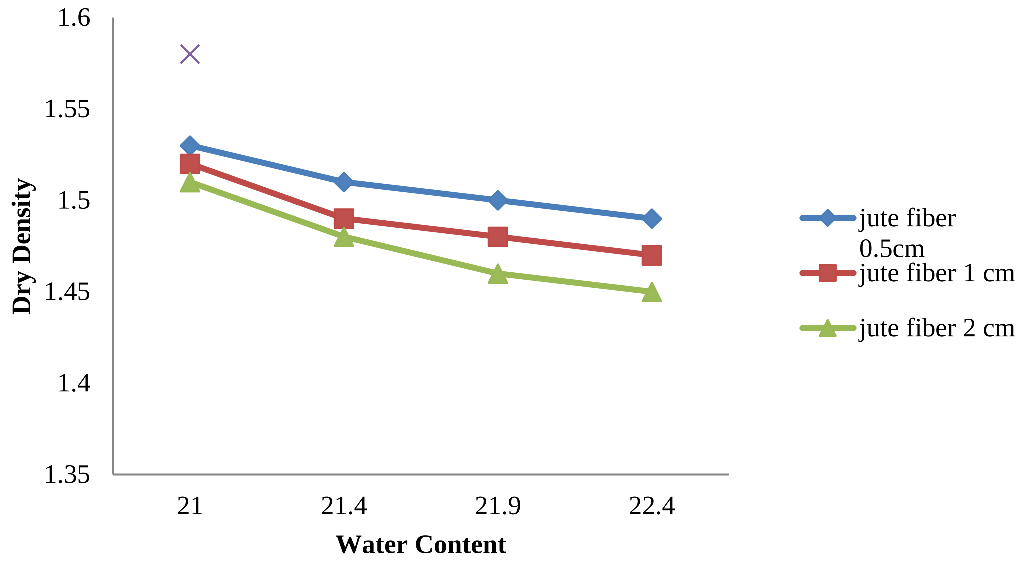


Figure 3.5: D.D. vs W.C. cuve for clay mixed with Jute fibers of different length

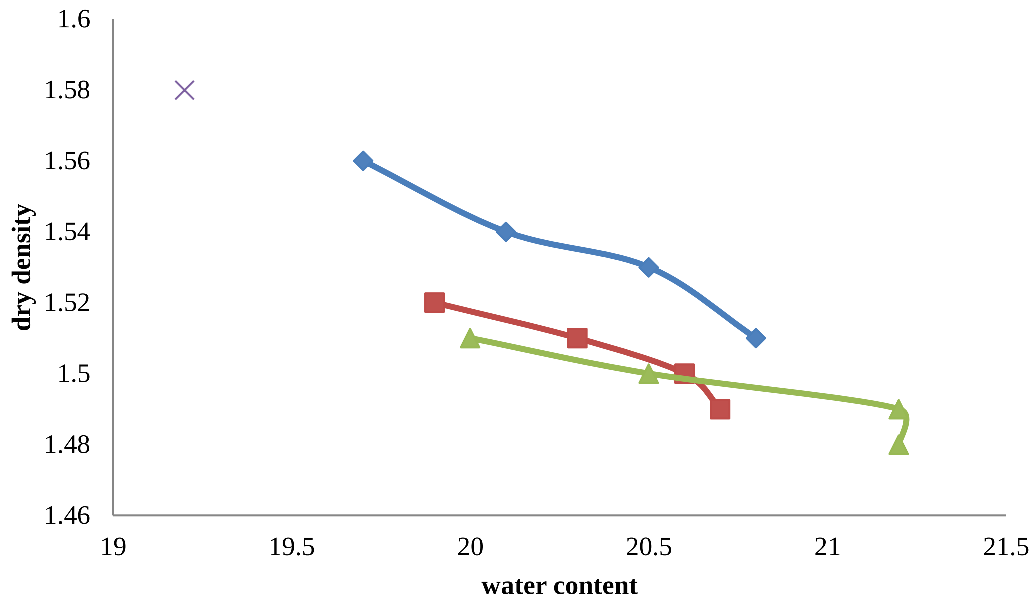


Figure 3.6: D.D. vs W.C. cuve for clay mixed with Coir fibers of different length

The unconsolidated and soaked California Bearing Ratio (CBR) values acquired from laboratory tests of a composite soil comprising jute and coir fibres are shown in Table 3.7.

Details of fiber and length	% of fiber	Jute Fiber		Coir Fiber	
		Unsoaked CBR	Soaked CBR	Unsoaked CBR	Soaked CBR
No Fiber	0.0%	3.8	2.1	3.8	2.1
Jute Fibre 0.5cm	0.5%	4.8	2.8	5	3
	1.0%	5.1	3.1	5.3	3.2
	1.5%	5.5	3.4	5.8	3.6
	2.0%	5	3.2	5.4	3.5
Jute Fibre 1.0cm	0.5%	4.8	2.9	5.2	3.1
	1.0%	5.2	3.2	5.5	3.4
	1.5%	5.7	3.5	6	3.8
	2.0%	5.4	3.3	5.6	3.6
Jute Fibre 2.0cm	0.5%	4.5	2.7	4.8	3
	1.0%	4.8	3.1	5.3	3.3
	1.5%	5.3	3.3	5.7	3.7
	2.0%	4.8	3.2	5.3	3.5

Table 3.7: Summary of Results of Unsoaked and Soaked CBR tests for clayey soil mixed with randomly distributed Jute Fibre, Coir Fibre

Details of fiber and length	% of fiber	UCS (kg/cm^2) value	
		Jute Fiber	Coir Fiber
Zero Fibre length	0.0%	1.88	1.88
Fibre length 0.5cm	1.0%	2.33	2.54
	1.5%	2.61	2.86
	2.0%	3.18	3.41
	2.5%	3.07	3.33
Fibre length 1.0cm	1.0%	2.41	2.66
	1.5%	2.74	2.99
	2.0%	3.34	3.72
	2.5%	3.18	3.52

Fibre length 2.0cm	1.0%	2.37	2.62
	1.5%	2.68	2.89
	2.0%	3.27	3.58
	2.5%	3.13	3.42

The unconfined compressive strength (UCS) values obtained from laboratory testing on clay soil amalgamated with jute fibre and coconut fibre are shown in Table 3.8 below.

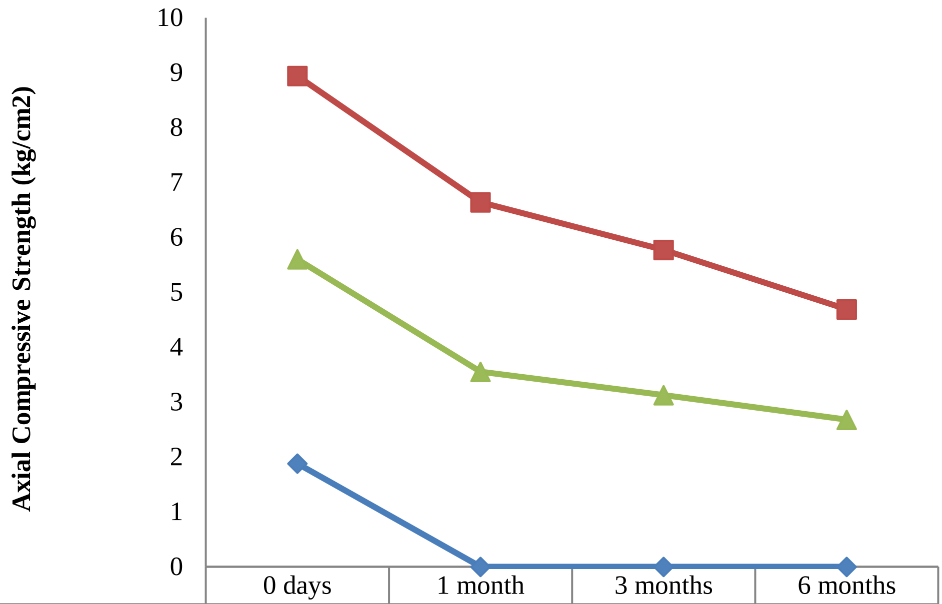
Table 3.8: Results of UCS tests for randomly mix Jute, Coir fiber with clayey soil

Table 3.9 summarizes the data about the unconfined compressive strength (UCS) values for clay soil infused with randomly dispersed jute fibre and coconut fibre, as measured throughout time.

Details of Fibre & length	**% of fiber**	**UCS value of clay in kg/cm^2 for time elapsed**			
		0 days	**1 month**	**3 months**	**6 months**
Clay without Fibre	0.0%	1.88	-	-	-
Clay with Jute Fibre (0.5 cm)	1.5%	3.34	3.09	2.64	2.01
Clay with Coir Fibre (0.5 cm)	1.5%	3.72	3.55	3.13	2.68

Table 3.9: results of UCS tests for clayey soil mixed with different fibers for various durations

The relationship between axial stress and strain is investigated using Unconfined Compressive Strength (UCS) experiments on clay mixed with randomly distributed natural jute and coir fibres. Figures 3.10 and 3.11 show the axial strain curves corresponding to the ideal fibre content and lengths.



	0 days	1 month	3 months	6 months
Clay with jute fiber 0.5 cm	3.34	3.09	2.64	2.01
Clay with coir fiber 0.5 c	3.72	3.55	3.13	2.68
clay without fiber	1.88	0	0	0

Figure 3.10: Axial stress vs resulting from UCS for Clay mixed with different types of fiber for time intervals of 4 days, 1 month, 3 months, 6 month

IV. Conclusion

Study on Fine Sand Mixed with Natural Fibers:

The compressive characteristics and California Bearing Ratio (CBR) values of fine sand augmented with two types of natural fibers: jute and coir fiber, are investigated in depth in this comprehensive experimental study. The study uses these fibres in various lengths and fractions, resulting in many major findings:

1. Impact on Maximum Dry Density (MDD): In fine sand, the MDD of sand-fibre composites decreases as fibre fraction and length rise.

2. Effect on Optimal Moisture Content (OMC): On the other hand, as the fibre % and length increase, the OMC of sand-fibre mix composites increases across all types of sands studied. Notably, the rate of increase in OMC is greatest for fibre lengths of 2cm and lowest for fibre lengths of 0.5cm.

3.Impact on CBR Values: CBR values, both unsoaked and soaked, increase with the addition of fibre % until they reach maximum values, at which point they begin to decline.

4. Effect of Fiber Length on CBR Values: CBR values, both unsoaked and soaked, indicate an upward trajectory with increasing fibre length until they reach their peak values, at which point they stabilize. This shows that longer fibre lengths have little effect on CBR values beyond the optimal length.

5. Optimal Fiber Content and Length: The optimal conditions for achieving maximum CBR values for fine sand mixed with randomly scattered jute or coconut fibres are a fibre content of 1.5% of the dry weight of sand and a fibre length of 0.5 cm.

These findings provide important insights into the possible use of natural fibres to improve soil engineering qualities, enabling decision-making in a variety of construction scenarios.

Study on Cohesive Soil Mixed with Natural Fibers:

The following conclusions emerge from systematic and thorough experimental research of the compaction and strength qualities of clay soil infused with various lengths and percentages of natural fibres, including jute and coir fibres:

1. Impact on CBR Values: Under both non-wet and drenched conditions, California Bearing Ratio (CBR) data show an initial increase as fibre content in the soil reaches a particular threshold. CBR values begin to fall after this point.
2. Effect of Fiber Length on CBR Values: As fibre length increases, both undrained and soaked CBR values of soil-fibre mix composites increase up to a maximum value. Further increases in fibre length after this peak have little effect on CBR values, demonstrating that fibre length beyond the ideal value has little effect on CBR values.
3. Optimal Fiber Content and Length: The ideal fibre concentration and length (found from soaked CBR testing) for clayey soil blended with randomly distributed jute or coconut fibres are 2% of soil dry weight and 1.0 cm, respectively, suggesting an inexpensive solution for subgrade construction in road applications.
4. Impact on Unconfined Compressive Strength (UCS) Values: As the percentage of fibre content in soil dry weight increases, so do the values of unconfined compressive strength (UCS), with a maximum limit of 2% of fibre content in soil dry weight. Further fibre additions result in lower UCS values after this point. The ideal fibre length for both types of fibres (jute and coir) has been determined to be 1 cm.
5. Comparison of UCS Increase:Notably, when jute fibre is mixed with clay soil, the increase in UCS values is greater than when coir fibre is mixed with clay soil.
6. Effect of Fiber Length on UCS Values:6. The UCS values of soil combined with randomly distributed fibres (jute and coir) increase with fibre length, stabilizing beyond the optimum length. Fibre lengths less than the ideal have no practical impact on UCS values.
7. Long-term UCS Value Changes: The unconfined compressive strength (UCS) values of clay-fiber composites gradually decrease over time. Notably, clay blended with coconut fibre shrinks at a lesser pace, particularly over 6 months.

These findings provide important insights into the utilization of natural fibres to improve the engineering qualities of clayey soils and provide guidelines for their use in building projects, notably subgrade construction for road applications.

References

1. Gray, D. H. and Ohashi, H. (1983), "Mechanics of fiber reinforcement in sand".Journal of Geotechnical and Geo-environmental Engineering, ASCE, vol. 109, no. 3,pp. 335-353.
2. Gray, D. H., and Al-Refeai, T. (1986). ‘‘Behavior of fabric versus fibre-reinforced sand.’’ J. Geotech. Engrg., ASCE, vol. 112(8),pp. 804–820.
3. Maher, M. H., and Gray, D. H. (1990). "Static response of sand reinforced with randomly distributed fibers". Journal of Geo-technical Engineering (ASCE), vol. 116, no. 11, pp. 1661-1677.
4. Al-Refeai, T.(1991) “Behavior of granular soils reinforced with discrete randomly oriented inclusions,” Geotextiles and Geomembranes, 10, pp319-333.
5. Ranjan, G., Vasan, R. M., and Charan, H. D. (1996). ‘‘Probabilistic analysis of randomly distributed fiber-reinforced soil.’’ J. Geotech. Eng.,122(6), pp.419–426.
6. Michalowski, R. L. and Zhao, A. (1996), "Failure of fiber-reinforced granular soils". Journal of Geotechnical and Geoenvironmental Engineering, ASCE, vol. 122, no. 3, pp. 226-234.
7. Consoli N.C., Prietto P.D.M. and Ulbrich L.A. (1998): Influence of Fiber and Cement Addition on Behavior of Sandy Soil, Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Vol.124, no.12, pp. 1211-1214.
8. Frost, J.D. and Han, J.(1999), “Behaviour of Interfaces between Fiber-Reinforced polymers and sands”, Journal of Geotechnical and Geo-environmental Engineering, ASCE, vol. 125, no. 8, pp. 633-640.
9. Santoni, et.al. (2001) “Engineering Properties of sand-fiber mixture for Road Construction” Journal of Geotechnical and Geoenvironmental Engineering, ASCE, vol. 127, no. 3, pp. 258-268.
10. Kaniraj, S. R. and Havanagi, V. G. (2001) "Behavior of cement-stabilization fiberreinforced fly ash-soil mixtures. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 127, no. 7, pp. 574-584.
11. Tingle, J. S., Santoni, R. S., and Webster, S. L. (2002). “Full scale field tests on discrete fibre reinforced sand.” Journal of Transportation. Engg. vol-128, no. 1, pp. 9–16.
12. Consoli, N. C., Casagrande, M. D. T., Prietto, P. D. M., and Thomé, A. (2003). “Plate load test on fiber-reinforced soil.” J. Geotech. Geoenviron. Eng., 129 (10), 951–955.
13. Rao GV, Dutta RK and Ujwala,D (2005). “Strength Characteristics of Sand Reinforced with Coir Fiber and Coir Geotextiles”, Electronic Journal of Geotechnical Engineering, 6 (2): pp.261-270.

14. Kumar, P and Singh, S.P.(2008) "Fiber-reinforced Flyash subbase in rural roads." Journal of Transportation Engineering (ASCE), vol 134 no 4 pp.-171-180.
15. Sreedhar. M.V.S, Sathish, T., Kumar, K.K. and Pravallika,P.K. (2009) "Investigations on effect of reinforcement in planar and fiber forms on CBR value of sand" Proc. Indian Geotechnical Conference, Guntur, India, Vol –1, pp. 194 – 197.
16. Chegenizadeh, A. and Nikraz, H.,(2011) " Study on strength of fiber-reinforced Clayey sand,", Proc.of the Internatioanl Conference on Science and Engineering, 2011, pp.356-359.
17. Tiwari,S.K. and Sharma,J.P. (2013), "Improvement of Local subgrade soil for road construction by the use of coconut coir fiber", Electronics Journal of Geotecnical Engineering, Vol-18, Bund T, 2013, pp.4303-4311.
18. Singh,R.R. and Mittal,S. (2014), "Improvement of Local subgrade soil for road construction by the use of coconut coir fiber", International Journal of Research in Engineering and Technology, Vol-3, no.5, May,2014, pp.707-711.
19. Santoni, R.L. and Webster, S.L. (2001) "Airfield and Roads construction using fiber stabilization of sands" Journal of Transportation Engineering, ASCE, Vol 127, no.2, pp.-96-104.
20. Rao, V.G. and Balan, K. (2000). "Coir Geotextiles—A Perspective", NBCC MDC Journal, Vol. 13, 11–15.