JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ENHANCING SUBGRADE SOIL PERFORMANCE WITH SUSTAINABLE JUTE FIBRE

[1] S. M. Subash, [2] G.Janardhan Reddy, [3] D. Madhu, [3] N. Gopi, [3] N. Praveen, [3] P. Shivani

[1]Department of Civil Engineering,
[1]Guru Nanak Institute of Technology, Hyderabad, India.

Abstract : This study investigates the efficacy of jute fiber in soil stabilization through comprehensive experimental investigations. Soil samples collected from Guru Nanak Institutions site are characterized for mechanical and physical characteristics, and then cutting the jute strands into lengths of 30 mm.As per ASTM guidelines, testing for specific gravity, standard compaction, and California Bearing Ratio (CBR) are performed on untreated soil samples. To evaluate the effect of fiber stabilization on soil strength parameters, soil samples are mixed with varying percentages of jute fiber, and CBR tests are conducted again. Results show promising enhancements in soil stability with increasing percentages of jute fiber reinforcement. The understanding of jute fiber's potential as a long-term fix for soil stabilization in civil engineering applications is enhanced by this research.

Index Terms **- Soil Stabilization, Jute Fibre, Subgrade Soil, Sustainable Construction, and Engineering Performance**

1. INTRODUCTION

The improvement of subgrade soil is a crucial aspect in the realms of highway and geotechnical engineering. Subgrade soil serves as the foundation upon which transportation infrastructure and various civil engineering projects rely, thus necessitating its enhancement to meet engineering standards and ensure long-term stability. In this context, soil stabilization emerges as a fundamental technique aimed at modifying soil properties to bolster its engineering performance. One promising avenue for soil stabilization lies in the utilization of natural materials such as jute fibres. Jute fibres offer a sustainable and cost-effective solution due to their biodegradability and widespread availability. This study delves into the potential of utilizing jute fibres, cut into 30mm lengths, as soil stabilizers to enhance the performance of subgrade soil. The goal of this research is to clarify the role that stabilizing soil with jute fiber can play in enhancing its strength properties through an array of laboratory tests and analyses. This will open up the possibility to more environmentally friendly and sustainable methods in the field of civil engineering.

1.1 Importance of Subgrade Soil Improvement

Improving subgrade soil holds paramount importance in civil engineering and infrastructure development for several reasons. Firstly, the subgrade serves as the foundation upon which roads, highways, railways, and other transportation infrastructure are built. Its stability directly impacts the structural integrity and longevity of the entire construction. A weak or poorly stabilized subgrade can lead to uneven settling, rutting, and pavement failure, compromising safety and increasing maintenance costs.Furthermore, subgrade soil improvement is essential for mitigating the effects of environmental factors such as moisture, frost, and temperature variations. Enhanced soil stability helps to resist the detrimental effects of water infiltration and frost heave, which can cause significant damage to pavements and structures. Subgrade soil enhancement increases the soil's ability to support loads and resist deformation, which enhances the overall resilience and functionality of transportation networks.In addition to structural considerations, subgrade soil improvement plays a crucial role in optimizing construction efficiency and cost-effectiveness. Well-stabilized subgrade reduces the need for excessive excavation, grading, and aggregate materials, leading to streamlined construction processes and reduced construction time. Moreover, by providing a stable base for pavement layers, properly treated subgrade soil minimizes the likelihood of future maintenance and rehabilitation, resulting in long-term cost savings for infrastructure owners and operators. Overall, the importance of subgrade soil improvement lies in its integral role in ensuring the safety, longevity, and cost-effectiveness of transportation infrastructure. By enhancing soil stability and resilience, engineers can create robust foundations that withstand the rigors of traffic and environmental conditions, ultimately supporting sustainable and resilient infrastructure systems.

1.2 Scope

The purpose of this study is to investigate in detail whether using natural jute fibers as soil stabilizers can improve the performance of subgrade soil. The focus lies on evaluating the impact of jute fibre incorporation, specifically when cut into 30mm lengths, on various engineering properties of the soil. Laboratory tests including the California Bearing Ratio (CBR) test, standard compaction tests, and specific gravity tests will be conducted to assess the effects of jute fibre stabilization on soil strength, compaction characteristics, and density. Different percentages of jute fibre content (0.5%, 1%, and 1.5%) will be examined to determine optimal stabilization conditions. The study aims to provide insights into the feasibility and effectiveness of jute fibre as a sustainable soil stabilization solution, thereby offering valuable guidance for future engineering applications.

1.3 Significance of Sustainable Solutions

It is impossible to overestimate the importance of eco-friendly solutions in civil engineering, especially in light of the growing environmental concerns and the need for sustainable development. Sustainable soil stabilization techniques, such as the utilization of natural jute fibres, present a promising avenue for reducing the environmental footprint of construction activities. Unlike conventional stabilizers that may involve synthetic chemicals or non-biodegradable materials, jute fibres offer inherent biodegradability and are sourced from renewable natural resources. By opting for sustainable solutions like jute fibre stabilization, engineers and construction professionals can mitigate adverse environmental impacts, reduce reliance on finite resources, and contribute to the preservation of ecological balance. Furthermore, the adoption of sustainable practices aligns with evolving regulatory frameworks and societal expectations for environmentally responsible construction methodologies. This study underscores the significance of embracing sustainable solutions in soil stabilization, not only for meeting engineering requirements but also for promoting environmentally conscious practices that uphold the principles of sustainable development.

2. Literature Review

In the literature review, we explore various aspects related to soil stabilization techniques and the specific application of jute fibres as a soil stabilizer. Firstly, we provide an overview of different soil stabilization techniques, highlighting their principles and methodologies. This includes methods such as chemical stabilization, mechanical stabilization, and the use of natural fibres. Next, we delve into previous studies focusing on jute fibre stabilization, examining research findings, methodologies, and outcomes. These studies serve as valuable references to understand the effectiveness and limitations of jute fibre as a soil stabilizer in different contexts and soil conditions. Finally, we discuss the advantages associated with using jute fibre as a soil stabilizer. These advantages include its biodegradability, cost-effectiveness, and availability as a renewable resource. Additionally, jute fibres offer good tensile strength and are capable of improving soil stability while minimizing environmental impact. Overall, the literature review provides a comprehensive understanding of soil stabilization techniques and underscores the potential of jute fibre as a sustainable solution for soil stabilization in civil engineering applications.

2.1 A Critical Review on Previous Studies

Geotextiles play a crucial role in soil reinforcement, drainage improvement, erosion control, and embankment construction. While jute geotextiles offer eco-friendly soil enhancement, their susceptibility to degradation in soil environments poses challenges. Antimicrobial-treated jute geotextiles serve as alternatives to synthetic geosynthetics but are costly and may leach harmful chemicals. This study proposes a cost-effective treatment using fly ash to enhance jute geotextile properties, showcasing a 27% increase in load-bearing capacity and improved tensile strength, demonstrating promising practical applications.

Geo-reinforcement is crucial for enhancing soil strength in geo-structures. Polymer-based geosynthetics have been common, yet the need for sustainable options drives interest in lignocellulosic fibres. These fibres show promise for low-volume rural roads where traditional methods are costly. However, their utilization faces challenges like durability and compatibility. Extensive review spanning three decades elucidates their properties, treatment techniques, and mechanical performance. Laboratory and field investigations demonstrate the efficacy of coir and jute fibres, offering insights for future research.

The effect of jute fiber, lime, and slag-lime additions on micaceous clays' unconfined compressive strength (UCS) was examined in this study. The use of fibers, either separately or in conjunction with lime or slag-lime, was found to increase stiffness and UCS. As the fiber concentration increased, the UCS increased and peaked at 1%. Lime or slag-lime also enhanced UCS, with slag-lime producing better results. The most efficient way to achieve ASTM strength standards was by combining fibers with slag-lime. For economical reinforcing, a dosage of 1% fiber and 3% slag-lime was ideal.

The impact of adding jute fiber on expansive soil strength is examined in this study. According to laboratory results, as the proportion of fiber increases (0.30%, 0.60%, 0.90%), there are slight increases in the optimum moisture content (OMC) and modest decreases in the maximum dry density (MDD). CBR values rise from 3.61% to 8.17% with 0.6% fibre, then decline. Similarly, UCS values increase from 122.78 kPa to 138.50 kPa with 0.6% fibre before declining. Longer treatment durations enhance unconfined compressive strength, notably after 14 days.

The study focuses on employing waste renewable wool-banana (WB) fiber composites for agro-biogenic stabilization of expansive subgrade soils. The study intends to improve the California bearing ratio, peak strength, resilient modulus, and elastoplastic strain of expanding clays by adjusting the fiber dose. Results show a significant decrease in swell potential and substantial improvements in mechanical properties. The optimal fibre blend exhibits high ductility and cost-effectiveness, offering a sustainable solution for subgrade stabilization in civil engineering.

3. Methodology

The investigation of the effectiveness of jute fiber in soil stabilization entails a number of critical elements in the technique. First, soil samples are gathered and examined for mechanical and physical characteristics. Jute fibers are then prepared by cutting them into lengths of about 30 mm. Using ASTM D854, the specific gravity of soil and jute fiber is ascertained. In accordance with ASTM D698, standard compaction tests are carried out on soil samples to determine the ideal moisture content and maximum dry density. Following ASTM D1883, testing for the California Bearing Ratio (CBR) are then performed on untreated soil samples. Ultimately, to evaluate the effect of fiber stabilization on soil strength properties, different proportions of jute fiber are added to soil samples, and CBR tests are conducted again.

4. Experimental Investigations

4.1 Soil

- Soil sample collected locally from Guru Nanak Institutions site.
- In the laboratory, different index properties and compaction properties were identified.
- A standard compaction test was carried out to identify the ideal moisture content and maximum dry density.

4.2 Jute Fibre

- Jute fibre procured from local market, diameter of 2mm.
- Fibres cut into 30mm lengths for research purposes.
- Advantages of jute fibres include abundant availability, superior drapability, high moisture absorption, and high initial strength.

4.3 Physical Test

4.3.1 Specific Gravity Test

- The Pycnometer method is used in Geo-Technology laboratory.

- Specific gravity (GS) determined to understand soil characteristics.

4.4 Mechanical Test

4.4.1 Standard Compaction Test

- 5kg air-dried soil mixed with water, placed in mould in three layers.
- Each layer compacted with 56 blows from 7.5 kg hammer.
- Procedure conducted to determine soil compaction characteristics.

4.4.2 CBR Test for Normal Soil Sample

- 5kg soil sample with water content percentage.
- 56 blows applied using tampering rod in three parts.
- CBR test conducted to ascertain soil strength under standard conditions.
- CBR Test for Soil Sample by Using Jute Fibre:
- Similar procedure as for normal soil sample.
- Various proportions of jute fiber combined with a sample of soil.
- Jute fibre cut into 2mm diameter, 30mm lengths.
- Strength of soil with jute fibre evaluated through CBR test.

5. Results and discussion

This section presents the outcomes of the experimental investigations conducted to evaluate the effectiveness of jute fibre stabilization on soil properties. The results obtained from various tests, including specific gravity, standard compaction, and California Bearing Ratio (CBR) tests, are analyzed, and discussed in detail. Additionally, the discussion delves into the implications of these findings, considering the potential of jute fibre as a sustainable solution for soil stabilization in civil engineering applications. Furthermore, comparisons with standard soil stabilization techniques and previous studies are drawn to provide a comprehensive understanding of the observed results. This section offers insights into the performance and viability of jute fibre as a soil stabilizer, contributing to the body of knowledge in geotechnical engineering.

5.1 Specific Gravity of Soils

The specific gravity of soils, a fundamental parameter in geotechnical engineering, is determined through precise calculations. The specific gravity of the soil is obtained as 2.34. We can compute the specific gravity to ascertain important soil characteristics. This calculation enables us to understand the density of soil particles relative to water, providing valuable insights into soil behavior and compaction properties. The specific gravity values obtained contribute to the comprehensive analysis of soil properties, aiding in the development of effective engineering solutions and construction methodologies.

5.2 Standard Compaction Test

In the standard compaction test of red soil, conducted with a starting weight of 5kg and using a 7.5kg hammer, the soil's behavior under varying water contents was examined. The test involved adding different percentages of water to the soil sample and compacting it in a mold. The weights of the wet soil samples (w2-w1), wet density, and dry density of the soil were recorded for each water content percentage. For instance, at 6% water content, the weight of the wet soil was 3340gm, resulting in a wet density of 3.34 g/cm³ and a corresponding dry density of 3.306 g/cm³. A 1000cm³ volume was produced by the compaction process, which was carried out in a mold measuring 10 cm in diameter and 12.7 cm in height. Three layers of soil were crushed with a total of 56 blows from the 7.5 kg hammer. Important information about the compaction properties and density fluctuations of the red soil under various moisture levels is provided by these computations and observations.

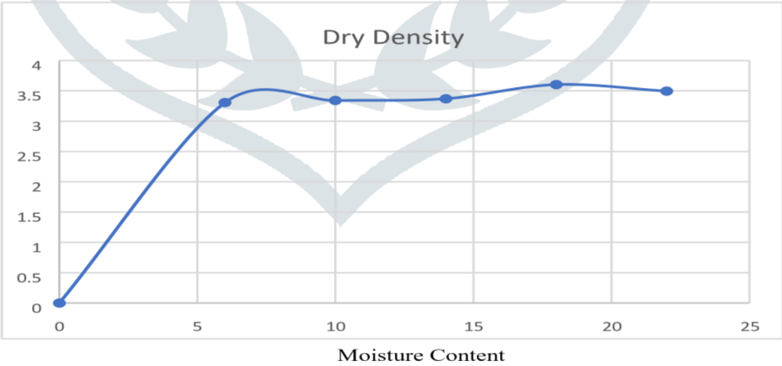

Fig.1: Maximum dry density curve for a given soil.

5.3 Compaction Test Data of Reinforced Soil with 0.5% of Jute Fibre

From the compaction test data of soil reinforced with 0.5% of jute fibre, several key observations can be drawn. Firstly, the test involved adding varying percentages of water to the soil samples, ranging from 6% to 22%. The weight of the mould plus the weight of the wet soil (w2) was recorded, and the difference between w2 and the weight of the mould (w1) provided the weight of the wet soil (w2-w1). This weight made it possible to calculate the soil's wet density (γ_{wet}), together with the mold's volume. Furthermore, the wet density and the percentage of water provided were used to calculate the dry density of the soil (γ_{dry}). Results indicated that as the percentage of water increased, the wet density of the soil decreased, with corresponding fluctuations in dry density. The compaction test, consisting of three layers and 56 blows per layer, provided valuable insights into the compaction characteristics of the reinforced soil, crucial for assessing its suitability for engineering applications.

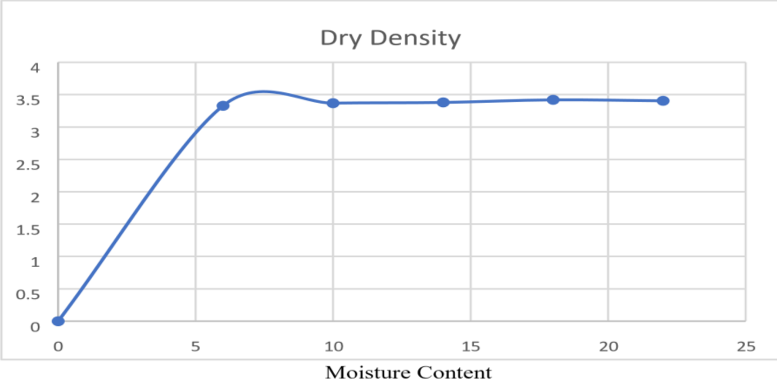

Fig. 2: Dry density of soil with 0.5 % of Jute fibre

5.4 Compaction Test Data of Reinforced Soil with 1% of Jute Fibre

- From the compaction test data of soil reinforced with 1% of jute fiber, conducted using a standard compaction method, several key observations can be drawn:
- The weight of the red soil used for the test was 5 kg, while the weight of the hammer utilized for compaction was 7.5 kg.
- With a jute fiber content of 1% (equivalent to 50 grams), the compaction process involved three layers and a total of 56 blows.
- The compaction test results illustrate the relationship between the percentage of water added and the corresponding weights of the wet soil in the mould (w_2-w_1).
- Wet density of the soil, calculated using the formula (w_2-w_1)/volume of mould, ranged from 3.3 g/cm^3 to 3.38 g/cm^3 for water contents varying from 6% to 22%.
- Dry density of the soil was determined using the formula $\gamma_{dry} = \gamma_{wet}/(1+w)$, yielding values ranging from 3.26 g/cm^3 to 3.34 g/cm^3 for the respective water contents.
- The calculations were based on the dimensions of the mould (10 cm diameter, 12.7 cm height) and the volume of the mould (1000 cm^3).

In general, the data obtained from the compaction test offer significant understanding of the compaction properties and density fluctuations of the 1% jute fiber-reinforced soil, which is crucial for determining the soil's appropriateness for engineering uses.

5.5 Compaction Test Data of Soil with 1.5% Jute Fiber

In this compaction test, red soil reinforced with 1.5% jute fiber content was analyzed to assess its density characteristics. The test involved adding varying percentages of water to the soil, followed by compaction using a 7.5kg hammer delivering 56 blows per layer across three layers. The wet density of the soil was calculated using the formula $\Upsilon_{wet} = (w_2 - w_1)$ / volume, resulting in values ranging from 3.08 g/cm³ to 3.16 g/cm³ for water contents ranging from 6% to 18%. Subsequently, the dry density of the soil was determined using the formula $\Upsilon_{dry}=\Upsilon_{wet}/(1+w)$, yielding values from 3.04 g/cm³ to 3.12 g/cm³. These density measurements provide crucial insights into the compaction characteristics of the reinforced soil, informing engineering decisions for construction applications.

5.6 California Bearing Ratio (CBR) Test Results

- Unreinforced Soil Sample Details: The CBR test was conducted on a red soil sample weighing 5kg with a water content of 6%, amounting to 300ml.
- CBR Test Data: The test results were recorded in Table 5.7, presenting the penetration depths in millimeters along with corresponding dial gauge readings and standard loads (Ps). The CBR values were calculated as percentages of the applied load (P or PC) to the standard load (Ps).
- Observation and Calculation: The observed load or corrected load for different penetration depths was determined based on the dial gauge readings and standard load conversion. For instance, at a penetration of 2.5mm, the observed load was computed as 147.5kg, while at 5mm, it was 196.25kg.
- Calculation of CBR: The California Bearing Ratio (CBR) values were calculated using the formula: CBR = (P/Ps) x 100, where P is the observed load and Ps is the standard load. For the 2.5mm penetration depth, the CBR was calculated as 10.7%, and for the 5mm penetration, it was determined as 9.5%.
- These CBR values provide essential insights into the soil's load-bearing capacity and compaction characteristics, crucial for engineering design and construction considerations.

5.7 CBR Test Data of Reinforced Soil with 0.5% of Jute Fibre

- The CBR test was conducted on reinforced soil samples containing 0.5% of jute fiber reinforcement.
- The soil sample consisted of 5kg of red soil with a water content of 6% (300ml) and jute fiber content of 0.5% (25 grams).
- Penetration values ranging from 0.5mm to 5mm were recorded during the test.
- Corresponding dial gauge readings and standard loads (Ps) were noted for each penetration value.
- Observed loads (Or) were calculated by converting dial gauge readings to corrected loads using the conversion factor.
- California Bearing Ratio (CBR) was determined for each penetration value by dividing the corrected load (Or) by the standard load (Ps) and multiplying by 100 to obtain the percentage.
- CBR values were calculated for penetration values of 2.5mm and 5mm, resulting in percentages of 10.89% and 10.6% respectively.
- These CBR values indicate the load-bearing capacity of the reinforced soil, demonstrating the effectiveness of jute fiber reinforcement in enhancing soil strength and stability.

5.8 CBR Test Results for Soil Reinforced with 1.5% Jute Fiber:

- Soil sample consisted of 5kg red soil with a water content of 6% (300ml) and jute fiber content of 1.5% (75 grams).
- CBR test conducted with penetrations ranging from 0.5mm to 5mm, corresponding to dial gauge readings.
- Observed load corrected to account for soil weight resulted in loads of 143.75kg for 2.5mm penetration and 210kg for 5mm penetration.

- CBR calculated as a percentage of standard load, yielding values of 10.47% for 2.5mm penetration and 10.21% for 5mm penetration.
- Results plotted on CBR curve (Figure 5.9), illustrating the soil's bearing capacity with 1.5% jute fiber reinforcement.

5.9 CBR Test Data for Soil Reinforced with Different Percentages of Jute Fiber:

- CBR tests conducted on soil samples reinforced with jute fiber lengths of 30mm and varying percentages (0.5%, 1%, and 1.5%).
- Penetrations ranging from 0mm to 5mm recorded for each fiber percentage, with corresponding dial gauge readings.
- Results tabulated to compare CBR values at different penetrations for each fiber percentage.
- Data indicates variations in CBR values with increasing jute fiber content, providing insights into the soil's strength characteristics under different reinforcement scenarios.

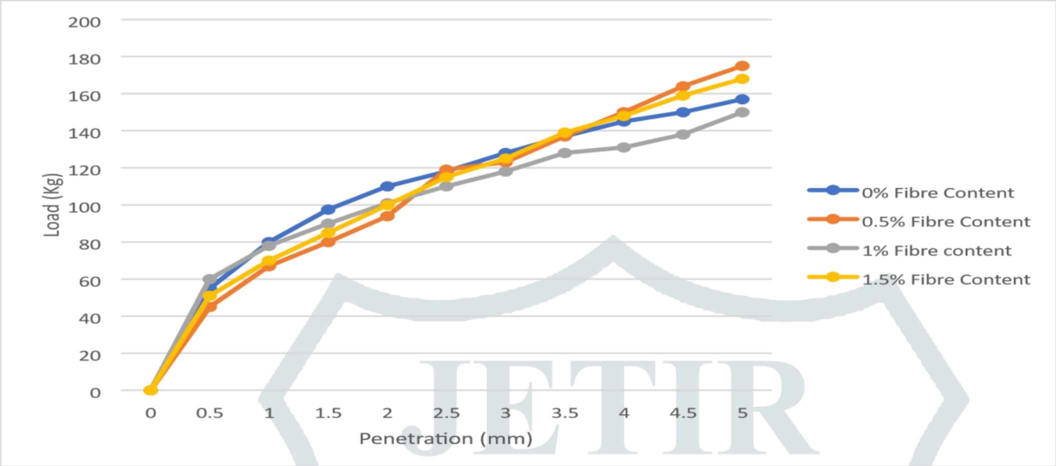

Fig. 3: CBR Curves Comparing Soil with Various Jute Fiber Percentages

Conclusions

This study's experimental investigations offer important new information about how well jute fiber stabilizes soil. The findings show that jute fiber improves soil strength and stability, particularly when added in larger percentages. The CBR tests reveal notable improvements in soil bearing capacity with increasing jute fiber reinforcement. These findings underscore the potential of jute fiber as a sustainable and cost-effective solution for soil stabilization in civil engineering applications. The study also emphasizes the significance of taking into account natural fiber reinforcement as a sustainable substitute for conventional soil stabilization techniques, advancing green infrastructure and sustainable building technologies.

Reference

[1] Chakravarthy, G.S., Guha Ray, A. and Kar, A., 2021. Effect of soil burial exposure on durability of alkali-activated binder-treated jute geotextile. Innovative Infrastructure Solutions, 6(2), p.62.

[2] Choudhury, P.K. and Das, K., 2022, August. Efficacy of jute geotextiles in mitigating soil-related problems along with a few case studies. In Transforming Coastal Zone for Sustainable Food and Income Security: Proceedings of the International Symposium of ISCAR on Coastal Agriculture, March 16–19, 2021 (pp. 755-766). Cham: Springer International Publishing.

[3] Ghosh, M., Saha, R. and Das, M., 2021. Application of Jute–Polypropylene Blended Geotextile in Black Cotton Soil Subgrade for Low Volume Road Construction. International Journal of Geosynthetics and Ground Engineering, 7, pp.1-18.

[4] Gowthaman, S., Nakashima, K. and Kawasaki, S., 2018. A state-of-the-art review on soil reinforcement technology using natural plant fiber materials: Past findings, present trends and future directions. Materials, 11(4), p.553.

[5] Gupta, S., GuhaRay, A., Kar, A. and Komaravolu, V.P., 2018. Performance of alkali-activated binder-treated jute geotextile as reinforcement for subgrade stabilization. International Journal of Geotechnical Engineering.

[6] Hejazi, S.M., Sheikhzadeh, M., Abtahi, S.M. and Zadhoush, A., 2012. A simple review of soil reinforcement by using natural and synthetic fibers. Construction and building materials, 30, pp.100-116.

[7] Komaravolu, V.P., GuhaRay, A. and Tulluri, S.K., 2021. Subgrade stabilization using alkali activated binder treated jute geotextile. In Problematic Soils and Geoenvironmental Concerns: Proceedings of IGC 2018 (pp. 343-354). Springer Singapore.

[8] Kumar, N., Kandasami, R.K. and Singh, S., 2022. Effective utilization of natural fibres (coir and jute) for sustainable low-volume rural road construction–A critical review. Construction and Building Materials, 347, p.128606.

[9] Kumar, S., Sahu, A.K. and Naval, S., 2021. Study on the swelling behavior of clayey soil blended with geocell and jute fibre. Civil Engineering Journal, 7(08), pp.1327-1340.

[10] Medina-Martinez, C.J., Sandoval-Herazo, L.C., Zamora-Castro, S.A., Vivar-Ocampo, R. and Reyes-Gonzalez, D., 2022. Natural fibers: an alternative for the reinforcement of expansive soils. Sustainability, 14(15), p.9275.

[11] Qamar, W., Khan, A.H., Rehman, Z.U. and Masoud, Z., 2022. Sustainable application of wool-banana bio-composite waste material in geotechnical engineering for enhancement of elastoplastic strain and resilience of subgrade expansive clays. Sustainability, 14(20), p.13215.

[12] Raman, D., 2021. Strength Improvement of Expansive Soil Treated with Jute Fiber Reinforcement (Doctoral Dissertation, National Institute of Technology Kurukshetra-136119).

[13] Sayida, M.K., Evangeline, S., Vijayan, A. and Girish, M.S., 2022. Durability study of coir geotextile embedded in different types of subgrade soil. Journal of Natural Fibers, 19(6), pp.2288-2298.

[14] Shirazi, M.G., Rashid, A.S.B.A., Nazir, R.B., Rashid, A.H.B.A., Moayedi, H., Horpibulsuk, S. and Samingthong, W., 2020. Sustainable soil bearing capacity improvement using natural limited life geotextile reinforcement—A review. Minerals, 10(5), p.479.

[15] Shukla, M., Shah, J. and Dave, T., 2018. Use of fibre reinforcement in soil for sustainable solution of infrastructure. In Innovative Research in Transportation Infrastructure: Proceedings of ICIIF 2018 (pp. 121-131). Singapore: Springer Singapore.

[16] Srishti, Sinhamahapatra, A. and Kumar, A., 2023. Assessing the non-wettability and sustainability of cellulosic jute for roadway applications. Cellulose, 30(12), pp.7839-7852.

[17] Syed, M., GuhaRay, A. and Goel, D., 2022. Strength characterisation of fiber reinforced expansive subgrade soil stabilized with alkali activated binder. Road Materials and Pavement Design, 23(5), pp.1037-1060.

[18] Thakur, R.N., Gupta, S.K., Sinha, A., Chawla, S. and Vadavadagi, S.S., 2021. A durability study of jute geotextile treated with bitumen emulsion. Journal of Natural Fibers, 18(3), pp.400-418.

[19] Zhang, J., Deng, A. and Jaksa, M., 2021. Enhancing mechanical behavior of micaceous soil with jute fibers and lime additives. Journal of Rock Mechanics and Geotechnical Engineering, 13(5), pp.1093-1100.