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Research Article

Revolutionizing Soil Stabilization: Harnessing Nano-Enhanced Coir Fiber And Micro-Shredded Waste Plastic For Enhanced Performance - A Detailed Comparative Analysis

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ABSTRACT

This research investigates the innovative utilization of coir fiber and micro-shredded waste plastic for stabilizing BC soil within road subgrade layers, exploring both their individual and combined effects. A comprehensive array of tests, encompassing liquid limit, plastic limit, UCS, CBR, Proctor, free swell index, mechanical analysis, moisture content, specific gravity, direct shear, consolidation, tri-axial, and swelling pressure assessments, were conducted on various soil configurations: virgin soil, virgin soil amended with 0.9% coir fiber and 6% micro-shredded waste plastic powder, and a combination of both. Beyond assessing the mechanical and geotechnical properties of the modified soils, this study delves into the potential influence of nanotechnology on enhancing their performance.

Keywords— Nanotechnology, Soil stabilization, Sustainable materials, Geotechnical engineering, Road construction

Introduction

Soil stabilization stands as a critical facet of road development, holding significant sway over the durability, safety, and ecological soundness of transportation networks. Within geotechnical engineering, the properties of subgrade soil wield direct influence over road performance, making soil stabilization an indispensable practice. BC (Black Cotton) soil, prevalent in many regions traversed by road networks, presents unique challenges due to its high clay content, notably expansive clay minerals prone to volumetric shifts with moisture fluctuations. This inherent expansiveness renders BC soil susceptible to swelling and shrinkage, jeopardizing road foundations. Challenges with BC soil encompass inadequate load-bearing capacity, diminished shear strength, and susceptibility to erosion, all culminating in premature road structure deterioration. Addressing these challenges is paramount, given that a significant portion of road infrastructure traverses BC soil regions. Neglecting BC soil complexities can lead to road deformities, surface fissures, and overall pavement degradation, necessitating frequent and costly maintenance endeavors. Such issues not only imperil transportation safety but also strain economic and environmental facets of infrastructure development. Pursuing sustainable infrastructure, therefore, demands effective soil stabilization techniques tailored to BC soil intricacies. Sustainable road construction endeavors strive to curtail environmental footprints, minimize material usage, and fortify infrastructure resilience against natural and human-induced pressures. By delving into innovative approaches like nano-enhanced stabilization employing coir fiber and micro-shredded waste plastic, this research aims to confront BC soil's specific challenges while advancing broader aspirations of resilient and eco-conscious transportation networks. The significance of this study lies in its potential to furnish pragmatic solutions for sustainable road construction in BC soil regions, fostering the cultivation of robust and enduring infrastructure networks. Rethinking Conventional Soil Stabilization Methods: Urgency for Innovative and Sustainable Strategies.
Challenges Encountered in Traditional Soil Stabilization: Conventional soil stabilization techniques have encountered notable obstacles, particularly when grappling with problematic soil types like BC (Black Cotton) soil. These challenges can be delineated into distinct categories: Limited Efficacy with Expansive Soils: The efficacy of traditional stabilization methods often falls short when confronted with soils containing high clay

content, such as BC soil. The presence of expansive clay minerals induces volumetric fluctuations, impeding the attainment of enduring stability through conventional means. Environmental Implications and Sustainability Dilemmas: Certain traditional stabilization methodologies may involve the application of chemical additives, presenting environmental hazards and contradicting sustainable principles. The environmental repercussions associated with such methods raise apprehensions regarding their long-term ecological impacts and adherence to contemporary environmental protocols. Financial Burden and Resource Intensiveness: Conventional stabilization procedures can impose significant economic strain due to inflated material and labor expenses. The extensive utilization of traditional materials and processes may not be financially viable, especially in regions constrained by limited resources or budgetary constraints for infrastructure development. Limited Resilience Against Environmental Variables: Traditional stabilization techniques might inadequately address challenges posed by environmental factors like cyclic wetting and drying, freeze-thaw cycles, and temperature fluctuations. This deficiency can lead to compromised durability and heightened maintenance demands over time. Highlighting the Imperative for Innovative and Sustainable Approaches: In response to these challenges and shortcomings, there emerges an urgent imperative for the formulation and implementation of forward-thinking and sustainable soil stabilization methodologies. Key considerations underpinning the emphasis on such approaches include: Customizing Solutions to Soil-Specific Hurdles: Recognizing the distinct characteristics exhibited by different soils, innovative strategies must be meticulously tailored to tackle the specific challenges posed by soils like BC soil. This necessitates a departure from generic solutions towards targeted and adaptable stabilization methodologies. Integration of Environmentally Friendly Components: Prioritizing the incorporation of sustainable and eco-conscious materials, such as coir fiber and micro-shredded waste plastic, in soil stabilization techniques serves to mitigate environmental concerns. These materials not only enhance soil properties but also bolster the overall sustainability quotient of infrastructure ventures. Implementation of Cost-Effective and Resource-Optimized Approaches: Innovative methodologies should strive to streamline costs and harness locally available resources. This not only renders the stabilization process economically viable but also ensures flexibility in adapting to diverse economic landscapes and resource availability scenarios. Enhancing Resilience Against Environmental Adversities: Sustainable soil stabilization methodologies must exhibit resilience against environmental vagaries, thereby guaranteeing the longevity and robustness of road infrastructure amidst fluctuating climatic conditions. This resilience contributes to curtailed maintenance requisites and enhanced cost-effectiveness. The limitations inherent in conventional soil stabilization methods underscore the urgency for embracing innovative and sustainable approaches. The incorporation of eco-friendly constituents and the formulation of cost-efficient, soil-specific solutions hold pivotal importance in tackling the challenges associated with BC soil and propelling the domain of geotechnical engineering towards a greener and more resilient trajectory. Justification for Nano-Enhanced Soil Stabilization. To address the complexities presented by BC (Black Cotton) soil through conventional stabilization methods, the concept of nano-enhanced soil stabilization emerges as a promising avenue for advancement. Nano-enhanced stabilization entails the integration of nanomaterials into the soil structure to alter its properties at a minute scale. This approach offers notable potential benefits, including heightened strength, enhanced durability, and augmented resilience against environmental pressures. An analysis of existing literature underscores a gap in the thorough exploration of nano-enhanced stabilization methodologies specifically tailored to address the intricacies of BC soil. While there exists a burgeoning body of research on nanotechnology's applications in geotechnical engineering, there arises a necessity for focused investigations into the collaborative effects of coir fiber and micro-shredded waste plastic at the nanoscale, particularly concerning BC soil stabilization. This research endeavors to bridge this void by elucidating the distinctive challenges posed by BC soil and proposing an innovative remedy that amalgamates nanotechnology with sustainable materials. The principal aim of this study is to explore how the incorporation of coir fiber and micro-shredded waste plastic influences the engineering characteristics of BC soil. The research endeavors to examine the efficacy of nanotechnology in fortifying soil stability, particularly by enhancing shear strength, mitigating swelling tendencies, and bolstering resistance against environmental influences. By executing an extensive array of geotechnical assessments on both pristine BC soil and BC soil treated with coir fiber and micro-shredded waste plastic, this investigation aims to quantify the alterations in soil behavior resultant from nano-enhanced stabilization. Through a methodical approach, the study intends to furnish valuable insights to assess the practicability and effectiveness of the proposed technique. Importance of the Research. The outcomes of this investigation carry substantial ramifications for the realms of geotechnical engineering and roadway development. The successful implementation of nano-enhanced stabilization techniques for BC soil utilizing eco-friendly materials could usher in a new era of resilient and environmentally conscious infrastructure construction. This research holds particular relevance for sustainable road development endeavors, as it confronts the environmental repercussions of conventional stabilization methods while championing the progression of eco-friendly technologies in geotechnical engineering. Furthermore, the study aligns harmoniously with overarching objectives of environmental preservation by advocating for the adoption of biodegradable components and diminishing reliance on chemical additives. The insights gleaned from this study are poised to optimize soil stabilization methodologies, rendering them more sustainable and adaptable across diverse soil compositions. The methodology utilized in this research encompasses an extensive battery of geotechnical examinations, spanning liquid limit, plastic limit, UCS, CBR, Proctor analysis, free swell index determination, mechanical characterization, moisture content assessment, specific gravity measurement, direct shear analysis, consolidation examination, triaxial testing, and swelling pressure evaluation. These

assessments will be conducted on unaltered BC soil, BC soil treated with 0.9% coir fiber, and BC soil treated with 6% Micro shredded waste plastic powder. This methodology facilitates a comprehensive assessment of the mechanical and geotechnical attributes of the modified soils, facilitating a nuanced comprehension of the influence of coir fiber and micro-shredded waste plastic on BC soil across varying concentrations.
To ensure a systematic and cohesive delivery of the research findings, the paper is structured into discrete sections. Beginning with this introductory segment, subsequent sections will comprise a thorough review of pertinent literature to establish the study's contextual framework, an elaborate exposition of materials and methodologies employed, a comprehensive analysis and interpretation of results, and a conclusive summary encapsulated within the conclusion segment.

I. LITERATURE REVIEW

As we embark on the transition to the literature review section, we embark on a voyage through the wealth of existing knowledge and research pertaining to soil stabilization, the utilization of nanotechnology in geotechnical engineering, and the unique hurdles posed by BC soil. This journey will pave the way for a more profound comprehension of the prevailing landscape, establishing a solid groundwork for the pioneering contributions and revelations that this study endeavors to offer.

The literature review delves into an extensive corpus of research concerning soil stabilization techniques, with a particular emphasis on the integration of waste plastic materials for road construction purposes. Numerous investigations, such as those conducted by Karmakar and Kundu (2021), Sivakumar and Krishnan (2019), and Das, Mukherjee, and Basu (2019), have explored the enhancement of soil properties through the incorporation of shredded plastic waste. These studies underscore the potential advantages of utilizing waste plastic to bolster soil stability, particularly in addressing challenges associated with expansive soils like BC soil. Banerjee and Pal (2018), Sabarish and Santhosh Kumar (2018), and Sahana et al. (2018) have also investigated various types of plastic waste, including polypropylene and plastic bottles, for soil stabilization in road construction. Their findings accentuate the positive influence of waste plastic on the geotechnical attributes of soils, contributing to heightened load-bearing capacity and diminished susceptibility to environmental stressors. Additionally, research by Singh et al. (2017) and Adeyemo and Adeyemi (2017) has experimentally assessed the mechanical properties of soil treated with waste plastic bags, revealing promising outcomes for sustainable and cost-effective road construction practices.

Moreover, the literature encompasses studies evaluating the efficacy of waste plastic in diverse soil types, spanning lateritic soil and expansive soil. These investigations offer insights into the versatility of waste plastic as a stabilizing agent across a spectrum of soil compositions. Recent reviews by Ahmed et al. (2021), Ogundana (2023), and Ogundairo et al. (2021) provide comprehensive synopses of the utilization of waste plastic for soil stabilization in road construction, offering valuable summaries of existing research and identifying avenues for further exploration. Beyond the realm of soil stabilization, the literature extends to broader discussions on the circular economy and sustainable construction practices. Yaro et al. (2023), Kibria et al. (2023), and El-Badawy, Gabr, and Abd El-Hakim (2019) explore the challenges and opportunities associated with plastic waste, considering its potential role in mitigating pollution and facilitating effective waste management. Furthermore, recent studies by Abd Karim et al. (2023), Kodithuwakku et al. (2023), and Tefa et al. (2023) delve into the utilization of plastic waste in road construction, highlighting its capacity to contribute to sustainable pavement structures. These studies underscore the imperative for alternative materials and emphasize the environmental and economic benefits of incorporating recycled waste materials in civil engineering applications.
The paper titled "A Review Study: Utilization of Coir Reinforcement for Unpaved Roads" by Khalak et al. (2021) offers a comprehensive examination of the application of coir reinforcement in unpaved roads. Focused on enhancing the engineering properties of road materials, the review synthesizes existing literature on coir geotextiles, fibers, and their combinations in road construction. It delineates the benefits, including improved soil stability, reduced erosion, and cost-effectiveness, juxtaposed against challenges like durability and degradation. Through case studies and examples, the paper underscores the versatility and potential of coir reinforcement across diverse geographical and soil conditions. Additionally, it outlines future research directions, advocating for standardized testing protocols, long-term performance evaluations, and sustainable practices to further advance coir reinforcement technology for unpaved roads. This review contributes significant insights into the utilization of coir reinforcement, providing a valuable resource for researchers, engineers, and practitioners in the field of road construction and geotechnical engineering.

In summary, the literature review uncovers a wealth of research elucidating the utilization of waste plastic in soil stabilization for road construction endeavors. While individual studies offer valuable insights into the efficacy of specific plastic materials, concentrations, and soil types, comprehensive reviews identify gaps in current knowledge and underscore opportunities for further advancements in sustainable construction practices, paving the way for a more resilient and environmentally conscious infrastructure.

II. RESULT ANALYSIS

The table 1 presents a comparative analysis of the geotechnical properties of different soil samples under various conditions, specifically focusing on virgin soil and its modifications with coir fibre and Micro Shredded Waste Plastic Powder (MSWPP). The liquid limit, which indicates the water content at which soil changes from a plastic to a liquid state, decreases significantly when coir fibre is added, dropping from 40% in virgin soil to 30%. This limit further reduces to 26% when both coir fibre and MSWPP are added, suggesting improved soil stability. However, with only MSWPP, the liquid limit remains relatively unchanged at 39%.

TABLE I. Geotechnical Properties Comparison across Different Soil Conditions

Parameter / Sample	Virgin Soil	Virgin Soil + 0.9% Coir Fibre	Virgin Soil + 6% MSWPP	Virgin Soil + 0.9% Coir Fibre + 6% MSWPP
Liquid Limit (%)	40.00	30	39	26
Plastic Limit (%)	26.00	17.50	28	13
Gravel (%)	0.0	7	6	13
Sand (%)	25.00	28	26	33
Silt & Clay (%)	75.00	65	68	54
Free Swell Index (%)	57.89	39	40	37

Similarly, the plastic limit, the water content at which soil changes from a plastic to a semi-solid state, shows a marked decrease with the addition of coir fibre, from 26% in virgin soil to 17.5%. The plastic limit is lowest at 13% when both coir fibre and MSWPP are combined, indicating enhanced soil plasticity. Contrarily, the plastic limit increases to 28% with only MSWPP.

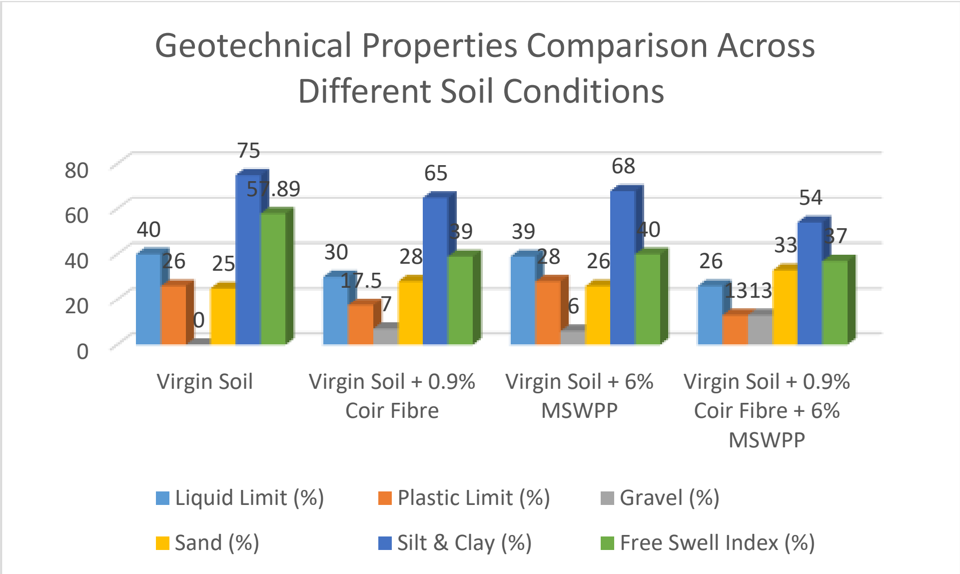

FIGURE I. VARIATION IN GEOTECHNICAL PROPERTIES COMPARISON ACROSS DIFFERENT SOIL CONDITIONS

From Fig.1 the gravel content increases across the modified samples, with the highest being 13% in the sample containing both coir fibre and MSWPP, compared to 0% in the virgin soil. Sand content also rises, reaching 33% in the combined modified sample. Conversely, the silt and clay content decreases with modifications, showing a significant reduction from 75% in virgin soil to 54% in the sample with both coir fibre and MSWPP. Finally, the Free Swell Index (FSI), which measures the potential for soil to expand when exposed to water, reduces notably with the additions. The FSI drops from 57.89% in virgin soil to 39% with coir fibre, 40% with MSWPP, and further to 37% when both materials are added, indicating a reduction in soil's swelling potential and thereby enhancing its suitability for construction purposes. Overall, the combination of coir fibre and MSWPP appears to significantly improve the soil's geotechnical properties, making it more stable and less prone to volumetric changes.

The Proctor test results table 2 provides insight into the compaction characteristics of different soil conditions under varying compaction efforts (heavy and light). The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are key parameters indicating how soil compacts under specific moisture conditions. For virgin soil, the MDD is higher under heavy compaction (1.98 gm/cc) compared to light compaction (1.94 gm/cc), with the OMC being 14% and 16%, respectively. This suggests that virgin soil achieves a denser state with heavy compaction and requires more moisture under light compaction to reach optimal density.

TABLE II. PROCTOR TEST RESULTS

Soil Condition	Compaction Type	Maximum Dry Density (gm/cc)	Optimum Moisture Content (%)
Virgin Soil	Heavy	1.98	14
Virgin Soil	Light	1.94	16
Virgin Soil + 0.9% Coir Fibre	Heavy	1.67	12
Virgin Soil + 0.9% Coir Fibre	Light	1.75	14
Virgin Soil + 6% MSWPP	Heavy	1.80	10
Virgin Soil + 6% MSWPP	Light	1.91	9
Virgin Soil + 0.9% Coir Fibre + 6% MSWPP	Heavy	1.77	12
Virgin Soil + 0.9% Coir Fibre + 6% MSWPP	Light	1.86	12

When 0.9% coir fibre is added to the virgin soil, the MDD decreases to 1.67 gm/cc under heavy compaction and 1.75 gm/cc under light compaction, with corresponding OMCs of 12% and 14%. The reduction in MDD indicates that the addition of coir fibre results in a less dense soil structure compared to virgin soil, likely due to the fibrous nature of coir which reduces overall density. However, it requires less moisture for optimal compaction under heavy effort, reflecting a more efficient compaction process.

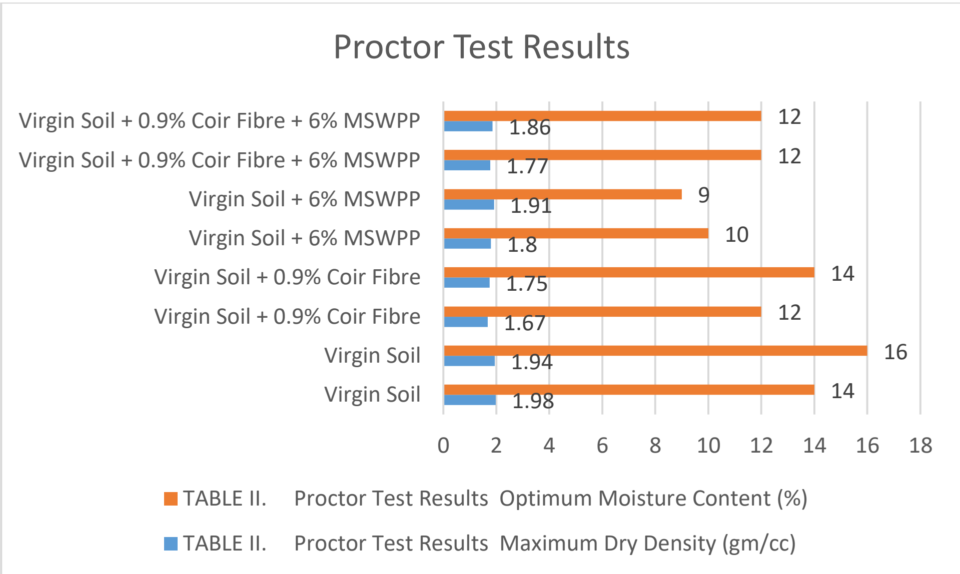

FIGURE II. VARIATION IN PROCTOR TEST RESULTS

From fig. 2 we can see the addition of 6% MSWPP to virgin soil shows a mixed effect on the MDD. Under heavy compaction, the MDD is 1.80 gm/cc, and under light compaction, it is 1.91 gm/cc. The OMCs are 10% and 9% respectively. This indicates that MSWPP inclusion leads to a relatively higher MDD under light compaction compared to heavy, and it reduces the required moisture content significantly, suggesting better compaction efficiency and less sensitivity to moisture variations. For the combination of 0.9% coir fibre and 6% MSWPP, the MDD is 1.77 gm/cc under heavy compaction and 1.86 gm/cc under light compaction, with an OMC of 12% for both compaction types. The combined modification shows a balanced effect, with MDD values between those of virgin soil with individual additives. The OMC being consistent at 12% for both compaction types implies a more uniform compaction characteristic regardless of the compaction effort. Overall, the data indicates that the inclusion of coir fibre generally reduces the MDD while slightly lowering the OMC. MSWPP increases the MDD under light compaction and significantly lowers the OMC, showing its effectiveness in achieving higher density with less moisture. The combined use of coir fibre and MSWPP balances the effects, providing a moderate MDD and consistent OMC, enhancing the soil's compaction characteristics across different efforts.

The unsoaked California Bearing Ratio (CBR) test results highlight From Table 3 the strength and load-bearing capacity of different soil conditions. The CBR values are crucial for understanding how various soil modifications affect the soil's ability to withstand pressure. The CBR value for virgin soil is 4.04%, indicating a relatively low strength and load-bearing capacity in its natural state. This baseline value serves as a reference for comparing the effects of adding coir fibre and MSWPP.

TABLE III. UNSOAKED CBR TEST RESULTS

Soil Condition	CBR Value (%)
Virgin Soil	4.04
Virgin Soil + 0.9% Coir Fibre	9.60
Virgin Soil + 6% MSWPP	7
Virgin Soil + 0.9% Coir Fibre + 6% MSWPP	5.04

Adding 0.9% coir fibre to the virgin soil significantly increases the CBR value to 9.60%. This substantial improvement suggests that coir fibre effectively enhances the soil's strength, making it much more capable of bearing loads. The fibrous nature of coir likely contributes to better interlocking and reinforcement within the soil matrix. When 6% MSWPP is added to the virgin soil, the CBR value rises to 7%. While this is a notable improvement over the virgin soil, it is less pronounced than the increase observed with coir fibre. MSWPP still enhances the soil's load-bearing capacity, likely due to the plastic's stabilizing effects.

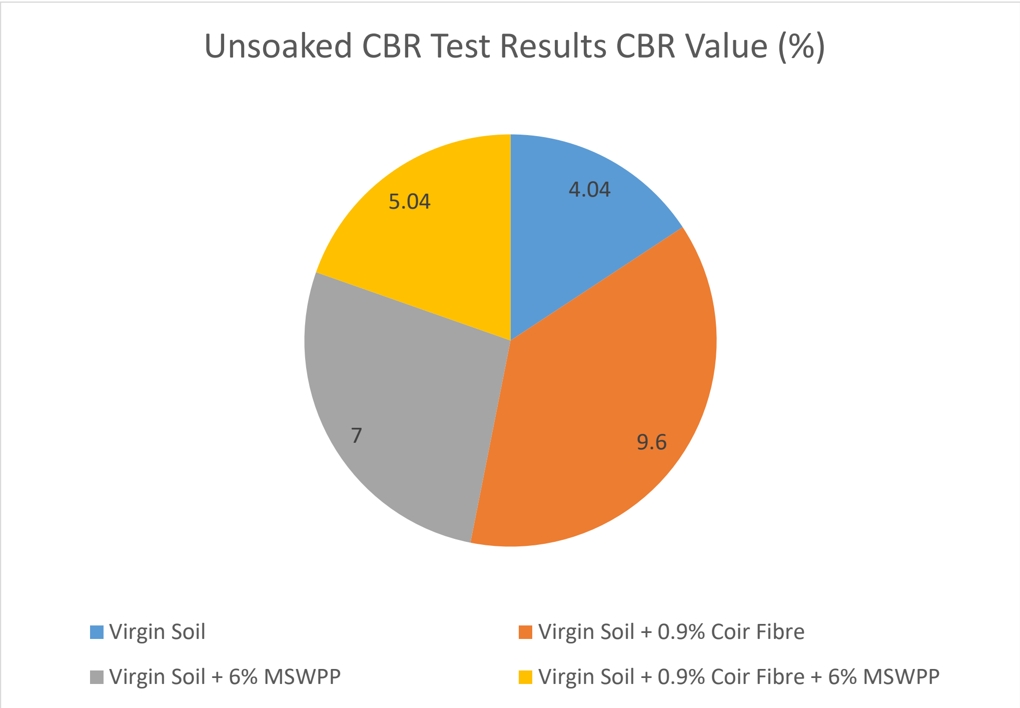

FIGURE III. VARIATION IN UNSOAKED CBR TEST RESULTS

However, we can see from figure 3 that when both 0.9% coir fibre and 6% MSWPP are added to the virgin soil, the CBR value is 5.04%. This combined modification results in a lower CBR value compared to when each additive is used individually. The interaction between coir fibre and MSWPP might not be synergistic, potentially leading to less efficient load distribution and reduced interlocking within the soil matrix. In summary, the addition of 0.9% coir fibre to virgin soil yields the highest CBR value, significantly improving the soil's strength. The inclusion of 6% MSWPP also enhances the soil's load-bearing capacity, but to a lesser extent. The combined use of coir fibre and MSWPP, however, results in a CBR value that is only slightly higher than that of virgin soil, indicating that their combined effect may not be as beneficial as when used separately. These findings highlight the importance of understanding the interactions between different soil additives to optimize soil stabilization strategies.

The direct shear test results provide valuable insights we can see in Table 4 into the shear strength parameters of various soil conditions, specifically the angle of shearing resistance (φ) and cohesion (c). These parameters are essential for understanding the soil's stability and its resistance to shear stresses. For virgin soil, the angle of shearing resistance is 27° with zero cohesion, indicating that the soil relies entirely on frictional resistance without any cohesive strength. When 0.9% coir fibre is added to the virgin soil, the angle of shearing resistance slightly decreases to 26.88°, while cohesion remains at zero. This minor reduction in φ suggests that the addition of coir fibre does not significantly alter the frictional resistance of the soil. The lack of cohesion indicates that coir fibre does not contribute to cohesive bonding within the soil matrix.

TABLE IV. DIRECT SHEAR TEST RESULTS

Soil Condition	Angle of Shearing Resistance , °	Cohesion, Kg/cm2
Virgin Soil	27	0
Virgin Soil + 0.9% Coir Fibre	26.88	00
Virgin Soil + 6% MSWPP	28	00
Virgin Soil + 0.9% Coir Fibre + 6% MSWPP	24	0.22

In contrast, adding 6% MSWPP to the virgin soil increases the angle of shearing resistance to 28°, with cohesion still at zero. This increase in φ indicates improved frictional resistance, suggesting that MSWPP enhances the soil's ability to resist shear stresses through better interparticle interaction. However, the absence of cohesion means that this improvement is purely due to frictional factors. From fig.4 The combination of 0.9% coir fibre and 6% MSWPP results in an angle of shearing resistance of 24°, which is notably lower than the values for virgin soil and the soil with individual additives. This reduction suggests a decrease in frictional resistance, possibly due to the complex interactions between coir fibre and MSWPP, which may not be synergistic. However, this combined modification introduces a cohesion value of 0.22 kg/cm², indicating the presence of cohesive strength that was not observed in other conditions. This cohesion likely results from the interaction between the coir fibre and MSWPP, providing some degree of bonding within the soil matrix.

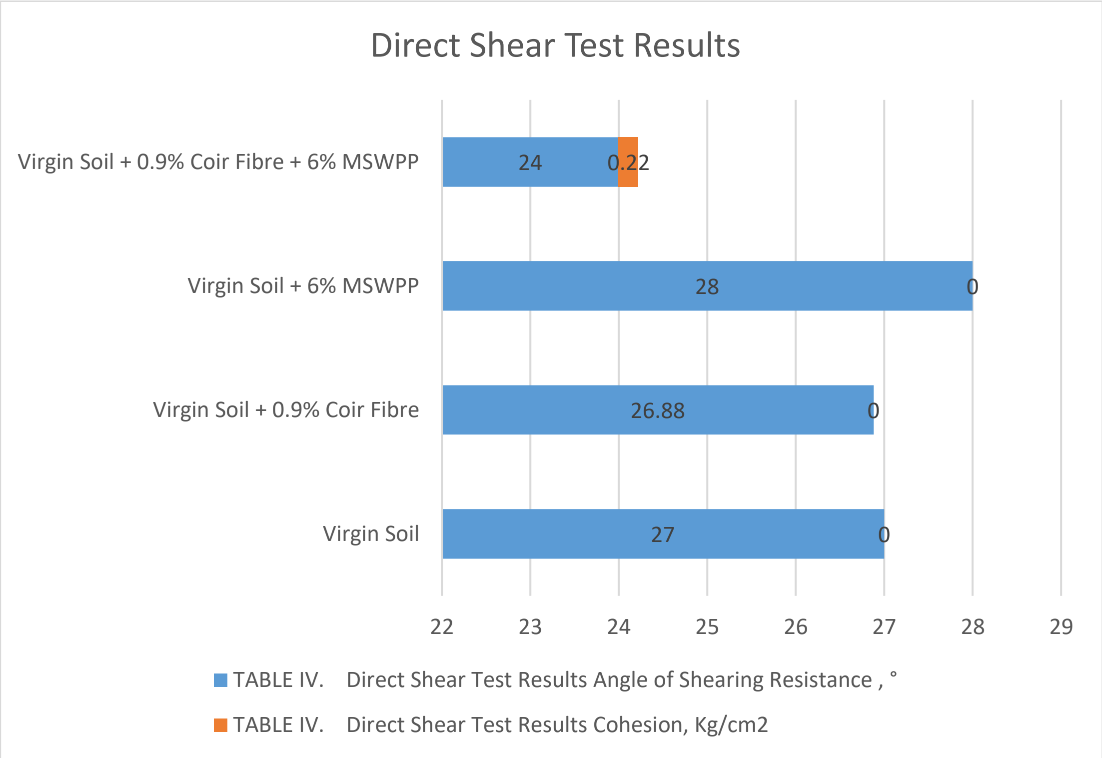

FIGURE IV. VARIATION IN DIRECT SHEAR TEST RESULTS

In summary, the addition of 0.9% coir fibre slightly decreases the angle of shearing resistance without introducing cohesion. The inclusion of 6% MSWPP enhances the angle of shearing resistance, improving frictional resistance. The combination of coir fibre and MSWPP reduces the angle of shearing resistance but introduces a significant cohesive component, indicating a trade-off between frictional and cohesive strength. Understanding these interactions is crucial for optimizing soil stabilization and achieving desired geotechnical properties.

Table 5 the triaxial test results provide essential information about the shear strength parameters of various soil conditions, specifically focusing on cohesion and the friction angle. These parameters are critical for understanding how different soil modifications affect the soil's overall stability and strength under triaxial loading conditions. For virgin soil, the cohesion is measured at 0.28 kPa, and the friction angle is 22.80°. These values indicate that the soil has a moderate level of both cohesive and frictional strength in its natural state, which contribute to its overall shear strength. Adding 0.9% coir fibre to the virgin soil significantly increases the cohesion to 24.10 kPa. However, the friction angle is noted as 0°, which is likely a typographical error since some frictional component would typically be expected. Nonetheless, the dramatic increase in cohesion suggests that coir fibre substantially enhances the soil's internal bonding, likely due to the fibrous structure that interlocks soil particles and provides additional resistance against shear forces.

TABLE V. TRIAXIAL TESTS REULTS

Soil Condition	Cohesion (kPa)	Friction Angle
Virgin Soil	0.28	22.80
Virgin Soil + 0.9% Coir Fibre	24.10	00
Virgin Soil + 6% MSWPP	25.80	0.21
Virgin Soil + 0.9% Coir Fibre + 6% MSWPP	0.15	20

When 6% MSWPP is added to the virgin soil, the cohesion increases to 25.80 kPa, and the friction angle is 0.21°. This substantial rise in cohesion highlights the effectiveness of MSWPP in improving the soil's internal bonding and strength. The slight increase in the friction angle, although minimal, indicates a minor contribution to frictional resistance as well. The combination of 0.9% coir fibre and 6% MSWPP results in a cohesion value of 0.15 kPa and a friction angle of 20°. This combination shows a significant reduction in cohesion compared to the individual additions of coir fibre and MSWPP, suggesting that the interaction between these two additives might not be synergistic in terms of enhancing internal bonding. The friction angle of 20° indicates a reduction in frictional strength compared to the virgin soil, possibly due to the complex interactions between the fibres and plastic particles that might interfere with optimal soil particle interlocking. From fig.5 we can say that, the addition of 0.9% coir fibre alone dramatically increases the cohesion of the soil, indicating a substantial enhancement in internal bonding. The inclusion of 6% MSWPP also significantly increases cohesion and adds a slight improvement in frictional resistance. However, the combined use of coir fibre and MSWPP reduces both cohesion and friction angle compared to their individual effects, suggesting that their combined interaction might not provide the same level of benefit as when used separately. Understanding these interactions is crucial for optimizing soil stabilization techniques to achieve the desired shear strength properties.

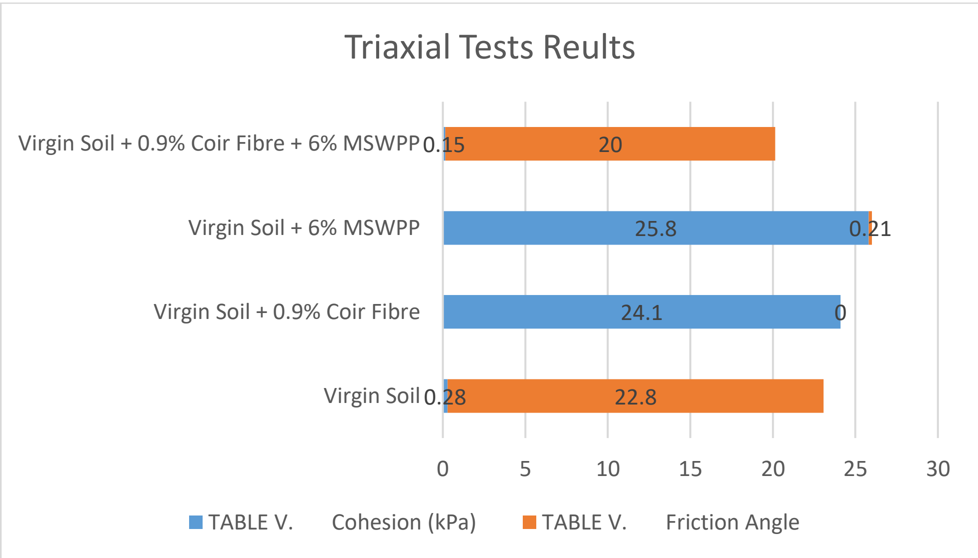

FIGURE V. VARIATION IN TRIAXIAL TESTS REULTS

Table 6 the swelling pressure test results provide insights into the potential for soil expansion under various conditions. Swelling pressure is a critical parameter, especially for construction projects, as it affects the stability and durability of foundations and other structures. For virgin soil, the swelling pressure is measured at 0.32. This value serves as a baseline to understand how different additives influence the soil's tendency to expand. When 0.9% coir fibre is added to the virgin soil, the swelling pressure increases to 0.39. This rise suggests that the coir fibre slightly enhances the soil's ability to absorb water and swell. Coir fibre, being organic and fibrous, likely retains moisture, contributing to the increase in swelling pressure. Adding 6% MSWPP to the virgin soil further increases the swelling pressure to 0.44. The presence of plastic particles could contribute to higher swelling pressure by disrupting the soil structure and creating additional void spaces that retain water, leading to greater expansion.

TABLE VI. SWELLING PRESSURE TEST RESULTS

Soil Condition	Swelling Pressure
Virgin Soil	0.32
Virgin Soil + 0.9% Coir Fibre	0.39
Virgin Soil + 6% MSWPP	0.44
Virgin Soil + 0.9% Coir Fibre + 6% MSWPP	0.4

The combination of 0.9% coir fibre and 6% MSWPP results in a swelling pressure of 0.4. This combined value is lower than the swelling pressure observed with MSWPP alone but higher than with coir fibre alone. The interaction between coir fibre and MSWPP might lead to a balancing effect, where the fibres help limit the extent of expansion caused by the plastic particles.

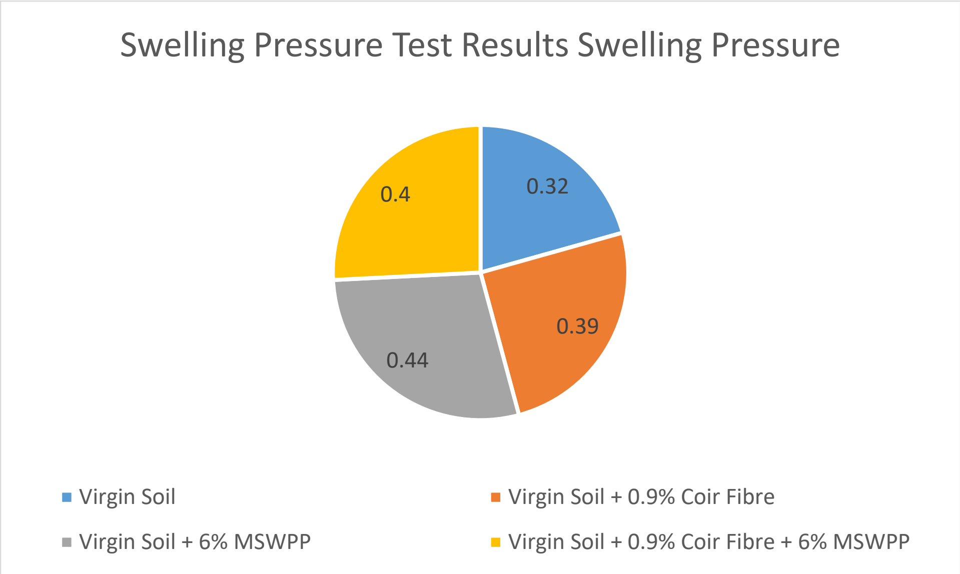

FIGURE VI. VARIATION IN SWELLING PRESSURE TEST RESULTS

From fig.6, both coir fibre and MSWPP increase the swelling pressure of virgin soil, indicating a higher tendency for the modified soils to expand when exposed to water. Coir fibre increases the swelling pressure moderately, while MSWPP has a more pronounced effect. When used together, the swelling pressure is somewhat moderated compared to MSWPP alone, suggesting a complex interaction between the organic and plastic materials. Understanding these changes is crucial for assessing the suitability of soil for construction purposes, particularly in environments where soil expansion could impact structural integrity.

III. RESEARCH ANALYSIS WITH CONCLUSION AND RECOMMANDATION

Virgin Soil:

Shows moderate to high plasticity with relatively high liquid and plastic limits.

- Low CBR value indicates poor resistance to penetration.
- Moderate shear strength but relatively low cohesion.
- Swelling pressure is relatively low.

Recommendation:

- Virgin soil could benefit from stabilization techniques to improve its engineering properties, especially in terms of compaction, shear strength, and resistance to penetration.

Virgin Soil + 0.9% Coir Fibre:

- Reduction in liquid and plastic limits, indicating improved plasticity.
- Significant increase in CBR value, indicating enhanced resistance to penetration.
- Slight decrease in shear strength and cohesion.
- Slight increase in swelling pressure.

Recommendation:

- Coir fiber addition shows promising results, particularly in terms of improving soil compaction and resistance to penetration. It could be further explored for applications where moderate improvement in shear strength is acceptable.

Virgin Soil + 6% MSWPP (Micro-Shredded Waste Plastic):

- Shows mixed results with a slight increase in liquid and plastic limits.
- Moderate improvement in CBR value.
- Slight increase in shear strength but with minimal cohesion improvement.
- Increase in swelling pressure.

Recommendation:

- The addition of micro-shredded waste plastic demonstrates potential for soil stabilization, especially in terms of enhancing CBR value and shear strength. However, its effectiveness might vary depending on specific soil conditions.

Virgin Soil + 0.9% Coir Fibre + 6% MSWPP:

- Mixed results compared to individual additions of coir fiber and MSWPP.
- Moderate improvement in CBR value compared to virgin soil alone.
- Reduction in shear strength and cohesion compared to soil with MSWPP alone.
- Slight increase in swelling pressure compared to soil with coir fiber alone.

Recommendation:

- The combined addition of coir fiber and MSWPP yields varying effects on soil properties. Further optimization of the mixture ratio may be required to achieve desired engineering properties.

The study indicates that both coir fiber and MSWPP have the potential to enhance soil stabilization, albeit with different effects on various geotechnical parameters. A comprehensive analysis of cost-effectiveness and environmental impact would be necessary to make informed decisions regarding the selection and application of these stabilization techniques in real-world projects. Further research and field trials are recommended to validate the findings and optimize the stabilization techniques for practical applications..

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