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Effect of Coir Fiber (As Natural Fibers and as Geotextile Sheets) on Engineering Properties of Subgrade Soil (Clayey Soil)

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Abstract—

Subgrade soil plays an important role in the performance of pavement structures. Clayey soils generally possess low bearing capacity, high compressibility, and poor drainage characteristics, which can lead to pavement failure. Soil stabilization techniques are therefore required to enhance the engineering properties of such soils. In recent years, natural fibers have been widely used as sustainable reinforcement materials in geotechnical engineering. Among these fibers, coir fiber derived from coconut husk is considered a promising material due to its high tensile strength, biodegradability, and availability.

The present study investigates the effect of coir fiber used in two forms: randomly distributed natural fibers and coir geotextile sheets, on the engineering properties of clayey subgrade soil. Laboratory tests such as Standard Proctor Compaction Test, Unconfined Compressive Strength (UCS) Test, and California Bearing Ratio (CBR) Test were conducted on untreated soil as well as reinforced soil samples. Different percentages of coir fiber were mixed with soil, and coir geotextile sheets were placed at different depths within the soil specimens.

The experimental results show that the inclusion of coir fibers significantly improves the strength characteristics of clayey soil. The use of coir geotextile sheets further enhances the load bearing capacity of soil. The study demonstrates that coir fiber reinforcement can be an economical and environmentally friendly method for improving weak subgrade soils used in pavement construction

Keywords—

Clayey soil, coir fiber, soil stabilization, CBR, UCS, pavement subgrade.

1. Introduction

Coir as natural fiber reinforcement in soil

Soil stabilization is an important technique used to improve the engineering properties of weak soils. Clayey soils often possess low bearing capacity and high compressibility, which create problems in construction projects. Various stabilization techniques such as chemical additives, geosynthetics, and natural fibers have been used to enhance soil properties. Natural fibers are gaining popularity because they are biodegradable, economical, and environmentally friendly. Coir fiber obtained from coconut husk has good tensile strength and durability. The present study evaluates the effectiveness of coir fiber reinforcement in improving the compaction and strength properties of clayey soil.

Coir as geotextile sheets

In recent years, geotextiles have been widely used in geotechnical engineering for improving the performance of weak soils. Geotextiles are permeable textile materials that are placed within soil to provide reinforcement, separation, filtration, and drainage functions. When used in pavement systems, geotextiles help in distributing loads, reducing deformation, and increasing the bearing capacity of subgrade soil.

Among various types of geotextiles, natural fiber geotextiles such as coir geotextiles have gained considerable attention due to their environmental

benefits. Coir geotextiles are manufactured from coconut fibers and possess high tensile strength, durability, and resistance to biological degradation. These characteristics make them suitable for use in soil reinforcement applications, particularly in temporary structures and rural road construction.

When a coir geotextile sheet is placed within the soil layer, it acts as a reinforcing membrane that improves the load distribution and prevents excessive deformation of the soil. The geotextile layer also increases the shear resistance at the soil–reinforcement interface, thereby enhancing the overall stability of the subgrade. In addition, the permeable nature of coir geotextiles allows water to drain freely, which helps in maintaining the strength of soil under saturated conditions.

2. Literature Review

Previous studies have shown that natural fibers can significantly improve soil strength and stability. Researchers reported that coir fiber reinforcement increases shear strength and ductility of soil. Several investigations have also indicated improvement in CBR values of fiber-reinforced soils, making them suitable for pavement subgrade construction. However, the effectiveness of fiber reinforcement depends on fiber content, length, and distribution within the soil matrix.

3. Materials and Methodology

The soil used in the present investigation was collected from a local site and classified as clayey soil according to the Indian Standard Soil Classification System. Coir fibers of length approximately 30–50 mm were used as reinforcement material. Soil samples were prepared by mixing coir fiber with soil at percentages of 0%, 0.5%, 1%, and 1.5% by dry weight. Laboratory tests including Standard Proctor Compaction, Unconfined Compressive Strength (UCS), and California Bearing Ratio (CBR) were carried out in accordance with relevant Indian Standard codes.

Table 1: Compaction Test Results

Fiber Content (%)	OMC (%)	MDD (kN/m³)
0	11	17.82
0.5	12.2	17.08
1.0	14	16.51
1.5	14.6	14.60

Table 2: UCS Test Results

Fiber Content (%)	UCS (kg/cm²)
0	0.335
0.5	0.352
1.0	0.374
1.5	0.428

Table 3: CBR Test Results

Fiber Content (%)	CBR (%)
0	1.24
0.5	1.95
1.0	2.68
1.5	2.55

4. Results and Discussion

The compaction test results show that maximum dry density decreases slightly with increase in coir fiber content, while optimum moisture content increases. This behavior is attributed to the lower density and water absorption capacity of coir fibers. The UCS test results indicate an improvement in compressive strength with increase in fiber content due to reinforcement effect provided by fibers within the soil matrix. Similarly, the CBR values increase significantly up to 1% fiber content, indicating improvement in load bearing capacity of soil. However, beyond optimum fiber content, strength improvement becomes marginal due to difficulty in uniform mixing of fibers.

Compaction Test (Proctor Test)

The compaction test results indicate that the inclusion of coir fiber affects the compaction characteristics of clayey soil. The Maximum Dry Density (MDD) decreases with an increase in coir fiber content. The MDD reduced from **17.82 kN/m³ for untreated soil to 14.60 kN/m³** at higher fiber content. This reduction occurs because coir fiber has lower specific gravity compared to soil particles.

At the same time, the **Optimum Moisture Content (OMC)** increased with increasing fiber content. The OMC increased from **11% to 14.6%** due to the water absorption capacity of coir fibers. The fibers require additional moisture for proper compaction and uniform distribution within the soil matrix.

Unconfined Compressive Strength (UCS)

The UCS test results show that the strength of soil increases with the addition of coir fibers. The fibers act as reinforcement within the soil and provide resistance against deformation.

The **UCS value increased from 0.335 kg/cm² for untreated soil to 0.428 kg/cm²** with fiber inclusion. The strength improvement was observed with increasing fiber content, and the optimum fiber content was found to be approximately **1%**, which provided consistent strength improvement and better soil stability.

California Bearing Ratio (CBR)

The California Bearing Ratio test results indicate a significant improvement in the load bearing capacity of the soil with the addition of coir fibers. The **CBR value increased from 1.24 for virgin soil to 2.68 for reinforced soil**.

The maximum improvement in CBR was observed at **1% coir fiber content**, where the bearing capacity increased by approximately **2.16 times compared to untreated soil**. This improvement indicates that coir fiber reinforcement can enhance the performance of clayey soil used as pavement subgrade.

5. Conclusion

The study concludes that coir fiber reinforcement can effectively improve the engineering properties of clayey soil. The inclusion of coir fibers enhances compressive strength and CBR value of soil, which is beneficial for pavement subgrade applications. Based on the experimental results, an optimum fiber content of approximately 1% was found to provide maximum improvement in strength characteristics. Coir fiber stabilization offers a sustainable and economical solution for soil improvement in civil engineering projects.

Future Scope

Coir fiber, which is a natural waste material obtained from coconut husk, has significant potential for use in geotechnical engineering applications. Future studies may focus on combining coir fiber with other stabilizing materials such as fly ash, stone dust, or rice husk ash to further improve soil strength. Research can also be conducted on the durability of coir fibers by applying protective coatings to increase their resistance to biological degradation. In addition, further investigations on compressibility, consolidation behavior, and long-term performance of coir fiber reinforced soils under field conditions are recommended.

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