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Investigating Biopolymer's Effect on Red Soil's Geotechnical Properties

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Abstract

This study investigates the effect of biopolymers, specifically Xanthan gum, on the geotechnical properties of red soils, a critical aspect of soil stabilization in civil engineering. Traditional stabilization methods often rely on chemical additives, which pose environmental concerns. Biopolymers, with their inherent biodegradability and low environmental impact, have emerged as a promising eco-friendly alternative. The study examines various biopolymers and their impact on the shear strength, compaction, and water retention of red soils, with a focus on optimizing biopolymer concentrations. Laboratory experiments, including Unconfined Compressive Strength (UCS), Proctor, and California Bearing Ratio (CBR) tests, were conducted to evaluate the mechanical behavior of soil with biopolymer additives. The results show a significant improvement in soil strength and stability, suggesting biopolymers as a sustainable solution for soil stabilization. This study contributes to the growing body of research on biopolymer-based soil stabilization, highlighting their potential benefits and real-world application in infrastructure projects.

Keywords–Soil Stabilization, Foundation, CBR Test, Proctor Test, UCS Test, Engineering properties, Soil Strength

1. Introduction

Soil stabilization plays a crucial role in civil engineering to enhance the strength and durability of soil for construction purposes. In this context, biopolymers, especially Xanthan gum, have emerged as a promising eco-friendly alternative to conventional chemical additives. This study explores the potential of Xanthan gum in stabilizing red soils, known for their poor geotechnical properties such as low strength and high compressibility. The objective is to enhance the mechanical and physical properties of red soils by incorporating biopolymers, thereby improving soil strength, reducing malleability, and increasing resistance to erosion. Through laboratory experiments, this research determines the optimal concentration of Xanthan gum required to achieve the desired level of soil stabilization. The findings contribute to the growing body of knowledge on biopolymer-based soil stabilization and offer sustainable solutions for infrastructure development.

2. Materials:

2.1 Soil Characteristics

Soil samples were collected from Andhra Pradesh, a region known for its extensive red soils, typically from a depth of 0-0.5 meters [1-2]. The red soil is characterized by its reddish color due to the high concentration of iron oxide. It has a sandy loam texture with a mixture of sand, silt, and clay particles. The soil's pH is slightly acidic to neutral, ranging from 6.5 to 7.5. Due to its poor geotechnical properties, the soil is prone to high compressibility and erosion, making it unsuitable for construction without stabilization [3].

Fig.1: Red Soil

2.2 Biopolymer

The biopolymer used in this study is Xanthan gum, a polysaccharide derived from renewable resources such as corn, sugarcane, or potato starch [4-5]. Xanthan gum is biodegradable, non-toxic, and environmentally friendly, making it an attractive alternative to traditional chemical soil stabilizers. The biopolymer was sourced from a commercial supplier and characterized by its molecular weight, degree of polymerization, and chemical composition. It was mixed with red soil samples in varying concentrations (0%, 10%, and 15%) to assess its impact on the soil's geotechnical properties.

3. Experimental Program

3.1 Sample Preparation

Soil and biopolymer mixtures were prepared by combining the red soil with Xanthan gum at concentrations of 0%, 10%, and 15%. The soil was thoroughly mixed with the biopolymer, and water was added in the proportion of 16.5% by weight of the soil to ensure proper compaction. The mixture was stirred continuously to achieve uniform distribution before being compacted into molds for testing. All measurements were carefully recorded using an electronic balance for accuracy and reproducibility of results.

3.2 UCS Test

The Unconfined Compressive Strength (UCS) test, conducted according to ASTM D2166/D2166M36 standards, was used to evaluate the compressive strength of the soil mixtures. The test involved applying an axial load to a soil sample at a strain rate of 1.5% per minute, with the maximum load used to calculate the soil's compressive strength. Additionally, Young's modulus (E) was determined from the slope of the linear portion of the stress-strain curve.

3.3 CBR Test

The California Bearing Ratio (CBR) test was performed to assess the soil's resistance to penetration under controlled conditions. The soil samples were compacted to the desired moisture content and placed in a standard CBR mold. The load required to penetrate the sample was measured and used to calculate the CBR value, which is an indicator of the soil's strength and suitability for use in road construction.

3.4 Proctor Test

The Proctor test was used to determine the optimal moisture content and maximum dry density of the soil mixtures. The soil was compacted in layers in a standard Proctor mold, and the wet and dry weights were recorded. This process was repeated for different moisture contents, and the data was used to generate a compaction curve for each mixture.

4. Results and Discussion

4.1 UCS

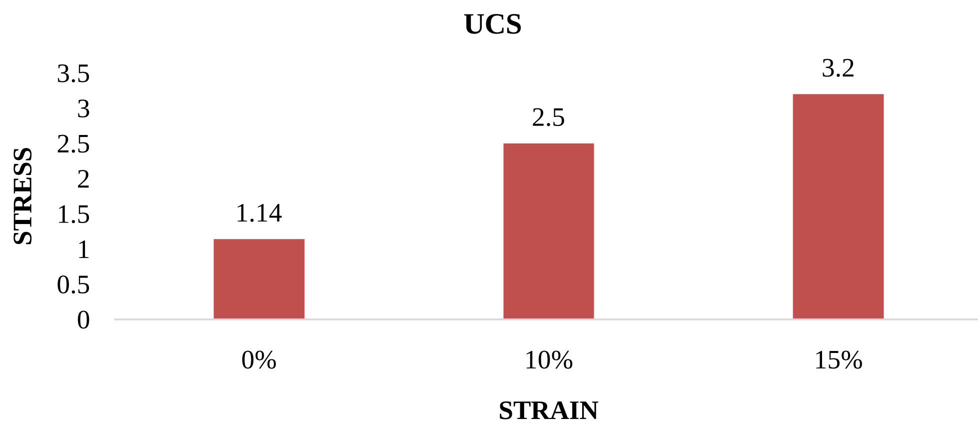

Fig.2: increase in shear strength and UCS values with increasing Xanthan gum concentration

The UCS results indicated a significant increase in soil strength with the addition of Xanthan gum. For the 15% concentration, the unconfined compressive strength increased by up to six times compared to untreated soil. This suggests that Xanthan gum enhances the soil's resistance to compression and improves its overall stability.

4.2 PROCTOR

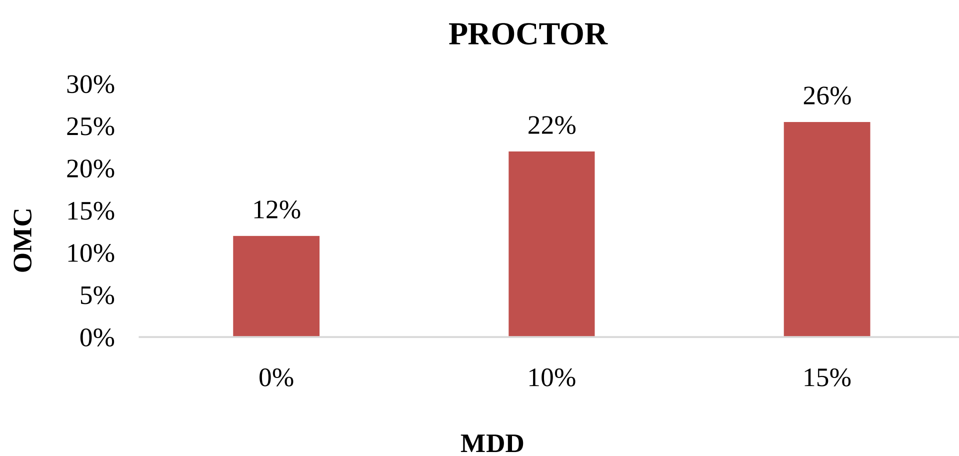

Fig. 3: Proctor test results

The Proctor test showed that the addition of Xanthan gum led to an increase in the maximum dry density (MDD) of the soil, with an optimal moisture content of 16.5% for all concentrations. This indicates that the biopolymer improves soil compaction, which is essential for enhancing soil strength and durability.

4.3 CBR

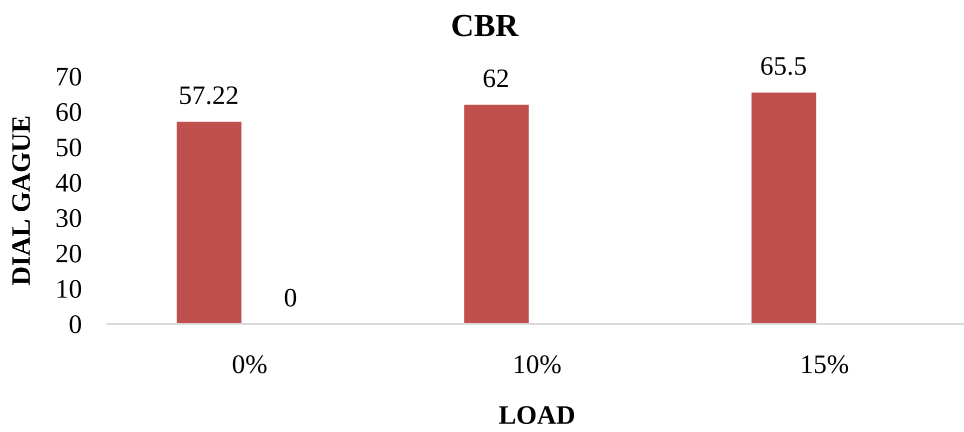

Fig.4: Improvement in CBR values with biopolymer addition

The CBR test results demonstrated that the addition of Xanthan gum significantly improved the soil's bearing capacity. The CBR value increased by up to 30% at the optimal concentration of 15%, indicating that the biopolymer enhances the soil's ability to support heavy loads, making it suitable for use in road construction and infrastructure development.

4.4 Without Bio-Polymer:

Compared to with bio polymer shows the more Xanthan gum improves soil strength and stiffness. Xanthan gum decreases soil hydraulic conductivity.Reduce soil loss and infiltration.In comparison to un stabilized soil, the chemical reaction creates a strong binding network in the soil structure, making the soil stronger, long-lasting, and of higher quality.

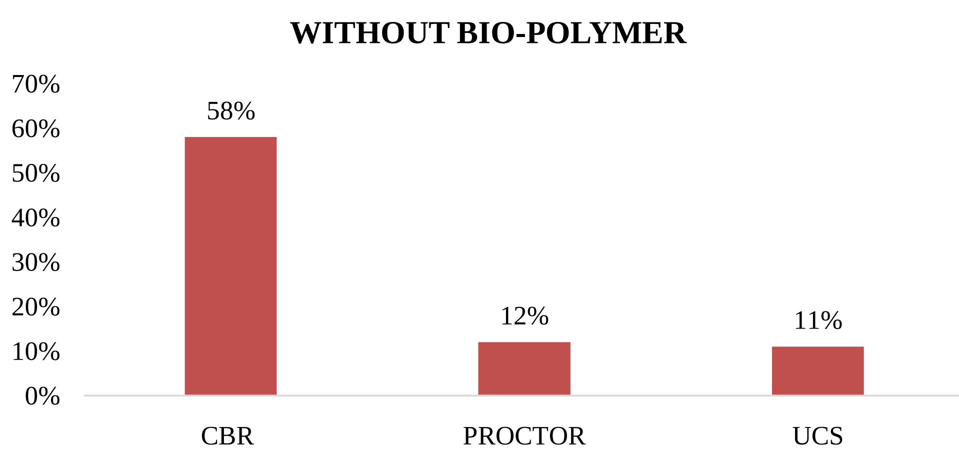

Fig.5: Performance comparison for soil without bio polymer

4.5 With Bio-Polymer:

An ideal solution for expansive sub grade stabilization, Xanthan gum at 15% concentration greatly increased the unconfined compressive strength, elastic modulus, and CBR values of the soil. Because of its higher adhesive strength and ability to cross link with soil particles, Xanthan gum dramatically increased soil strength up to a 10% dosage. This also improved unconfined compressive strength (UCS) and consolidation characteristics. The CBR value of fine sand soil contaminated with UCO is increased by Xanthan gum. In comparison to natural sand soil, optimal of 0.4% boosts CBR by 30%, helping to stabilize the soil for pavement projects.

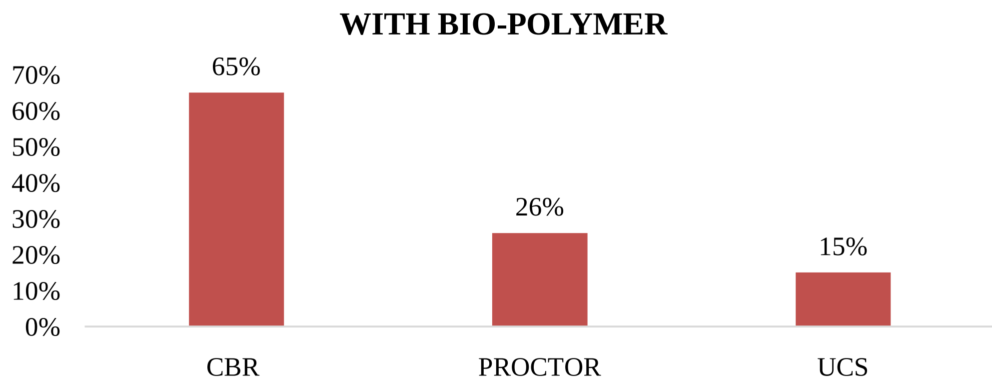

Fig.6: Performance comparison for soil with bio polymer

Figures 2–6 illustrate the results of the UCS, Proctor, and CBR tests for different concentrations of Xanthan gum. Figure 2 shows the increase in shear strength and UCS values with increasing Xanthan gum concentration. Figure 3 presents the Proctor test results, highlighting the impact of biopolymer concentration on maximum dry density and moisture content. Figure 4 demonstrates the improvement in CBR values with biopolymer addition. Figures 5 and 6 compare the soil's performance with and without Xanthan gum, showing significant improvements in strength and stability with biopolymer treatment.

5. Conclusion and Future Scope

Xanthan gum has shown great potential as an effective soil stabilizer for red soils, significantly improving their mechanical properties, including shear strength, compaction, and water retention. Its biodegradability and non-toxic nature make it an environmentally friendly alternative to traditional chemical stabilizers. However, challenges remain regarding the cost, scalability, and performance of biopolymers under varying field conditions. Future research should focus on optimizing biopolymer dosages for different soil types, exploring long-term performance, and addressing practical concerns such as cost-effectiveness and field application methods. By overcoming these challenges, biopolymers like Xanthan gum can provide sustainable and cost-effective solutions for soil stabilization in civil engineering projects.

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