Mechanical Properties and Microscopic Mechanisms of Biopolymer- and Geopolymer-Stabilized Soft Soil: Postprint

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Date: 2025-07-21T00:00:00+00:00

Abstract

Soft soil foundations, characterized by high compressibility and low bearing capacity, often necessitate treatment through chemical stabilization. This study investigates the stabilization effects and mechanisms of typical biopolymers and geopolymers on soft soils. Four stabilizers (A~D) were formulated using xanthan gum, recycled construction waste micro-powder + blast furnace slag powder + desulfurized gypsum powder + alkali activator, recycled construction waste micro-powder + cement + alkali activator, and pure cement as raw materials, respectively, to treat a lacustrine soft soil. Unconfined compressive strength (UCS) tests were conducted to examine the influences of curing age, stabilizer proportion and dosage, and number of wet-dry cycles on the mechanical properties of stabilized soil, with scanning electron microscopy employed to analyze the micro-mechanism. Results demonstrate that all four stabilizers significantly improve soft soil mechanical properties, albeit with distinct differences in effectiveness and mechanism. For stabilizer A, the strength of stabilized soil initially increased then decreased with increasing dosage, with an optimal xanthan gum content of 1.5% achieving a 28-day UCS of 376.3 kPa, which decreased by 24% after wet-dry cycling; the stabilization mechanism primarily depends on water consumption during xanthan gum hydration and the cementation and pore-filling effects of the resulting hydrogel on soil particles. For stabilizers B and C, strength exhibited a stable increasing trend with dosage, with optimal proportions and dosages of recycled micro-powder 10%: blast furnace slag powder 2.5%: desulfurized gypsum powder 2.5%: NaOH powder 0.75% and recycled micro-powder 8%: cement 4%: NaOH powder 0.72%, respectively, achieving 28-day UCS values of 1.75 MPa and 1.22 MPa, which remained above 1.20 MPa and 0.85 MPa after wet-dry cycling; both enhance soil structural compactness through encapsulation and cementation of soil particles by C-S-H gel hydration products and effective filling of inter-particle pores by ettringite, thereby substantially improving soft soil mechanical performance. Overall, stabilizers

B and C not only satisfy the strength requirements of the Technical Standard for Application of Soil Stabilizers, but also enable comprehensive utilization of solid waste resources, offering superior economic and environmental benefits compared to pure cement (stabilizer D).

Full Text

Preamble

Mechanical Properties and Microscopic Mechanism of Soft Soil Stabilized by Biopolymer and Geopolymer

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Abstract: Soft soil foundations, characterized by high compressibility and low bearing capacity, often require chemical stabilization treatment. This study investigates the stabilization effects and mechanisms of typical biopolymers and geopolymers on soft soils. Four stabilizers (A–D) were prepared using xanthan gum, construction waste recycled powder + blast furnace slag powder + desulfurized gypsum powder + alkali activator, construction waste recycled powder + cement + alkali activator, and pure cement, respectively, to treat a lacustrine soft soil. Unconfined compressive strength (UCS) tests were conducted to examine the effects of curing age, stabilizer ratio and dosage, and wet-dry cycles on the mechanical properties of the stabilized soil, while scanning electron microscopy was employed to analyze the microscopic mechanisms. The results demonstrate that all four stabilizers significantly improve the mechanical properties of soft soil, although their effectiveness and mechanisms differ. For stabilizer A, the strength of the stabilized soil initially increases then decreases with dosage, with an optimal xanthan gum content of 1.5%, achieving a 28-day UCS of 376.3 kPa that decreases by 24% after wet-dry cycles. The stabilization mechanism primarily relies on water consumption during xanthan gum hydration and the cementation and pore-filling effects of the resulting hydrogel on soil particles. For stabilizers B and C, the strength increases steadily with dosage, with optimal ratios and dosages of 10% recycled powder : 2.5% blast furnace slag powder : 2.5% desulfurized gypsum powder : 0.75% NaOH powder and 8% recycled powder : 4% cement : 0.72% NaOH powder, respectively. The corresponding 28-day UCS values reach 1.75 MPa and 1.22 MPa, remaining above 1.20 MPa and 0.85 MPa after wet-dry cycles. Both enhance soil structure density through the encapsulation and cementation of soil particles by hydration product C-S-H gel and effective pore filling by ettringite, thereby significantly improving soft soil mechanical performance. Overall, stabilizers B and C not only meet the strength requirements of the Technical Standard for Soil Stabilizer Application but also effectively utilize solid waste resources, offering better economic and environmental benefits compared with pure cement (stabilizer D).

Keywords: soft soil; xanthan gum; construction waste; industrial solid waste; unconfined compressive strength; microstructure

Note: Figure translations are in progress. See original paper for figures.