Postprint of Applied Research on Environmentally Friendly Polymer Stabilizer Technology for Soft Foundation Reinforcement

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Abstract

With the expansion of highway engineering construction scale, soft soil foundation treatment faces the dual challenges of high carbon emissions and insufficient performance from traditional curing agents. This study utilizes industrial solid wastes such as slag, fluorogypsum, and plant ash as base materials to develop a novel eco-friendly polymer curing agent. Through laboratory tests and engineering validation, the mechanical properties, deformation characteristics, and engineering application effects in soft foundation reinforcement are systematically investigated, aiming to provide technical support for low-carbon ground treatment. The research contents include: employing laboratory tests such as unconfined compression to design the mix proportion of slag-fluorogypsum-plant ash for reinforcing river silt, and investigating the influences of slag-to-fluorogypsum mass ratio, plant ash dosage ratio, cement content, and curing age on the unconfined compressive strength of solidified soil. The research indicates that a slag/fluorogypsum mass ratio of 2:1, plant ash dosage of 20%, and cement content of 20% constitute the optimal mix proportion, whose expansive cementitious products exhibit superior compactness compared to traditional cement-solidified soil, achieving a balance between economic efficiency and mechanical performance. Through static/dynamic triaxial tests, engineering practice is more accurately simulated to evaluate the mechanical properties and deformation characteristics of solidified soil under different stress conditions, investigating the influence laws of curing age, confining pressure conditions, and curing agent dosage on the deformation characteristics of solidified soil, and clarifying the influence laws of different factors on its stress-strain relationship, deformation modulus, dynamic stress-dynamic strain relationship, and dynamic elastic modulus under various conditions. Results demonstrate that increasing confining pressure, extending curing time, and augmenting curing agent dosage can significantly enhance shear strength, secant modulus, and dynamic elastic modulus, whereas high water content leads to their reduction. Through field test verification, the foundation cumulative settlement remains stable, the curing agent is relatively uniformly mixed with soft soil, and the eco-friendly polymer curing agent can significantly improve the bearing capacity of soft soil foundations, with characteristic values of bearing capacity exceeding 120.0 kPa after solidification, meeting design requirements. The research findings not only expand the application scenarios of industrial solid waste in geotechnical engineering but also provide an economical and efficient technical pathway for low-carbon transportation infrastructure construction, offering both significant ecological environmental benefits and engineering application value. Future work may further investigate adaptability to different soil types, durability, and multi-scenario curing processes to promote the standardization and large-scale application of eco-friendly polymer curing agents.

Full Text

Study on the Application of Environment-Friendly Polymer Curing Agent Stabilization Technology in Soft Foundation Reinforcement

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Abstract

As highway construction scales expand, soft soil foundation treatment faces dual challenges of high carbon emissions and insufficient performance from traditional curing agents. This study develops a novel environment-friendly polymer curing agent using industrial solid wastes such as slag, fluorogypsum, and plant ash as base materials. Through laboratory experiments and field validation, the mechanical properties, deformation characteristics, and engineering application effects of the curing agent in soft foundation reinforcement are systematically investigated, aiming to provide technical support for low-carbon ground treatment.

The research includes designing the mix ratio of slag-fluorogypsum-plant ash using laboratory tests such as unconfined compression tests to reinforce river channel silt, and investigating the effects of slag-to-fluorogypsum mass ratio, plant ash content, cement content, and curing age on the unconfined compressive strength of the stabilized soil. The results indicate that an optimal mix ratio consists of a slag/fluorogypsum mass ratio of 2:1, 20% plant ash content, and 20% cement content. The expansive cementitious products generated exhibit superior density compared to conventional cement-stabilized soil, achieving a balance between economic efficiency and mechanical performance.

Through static/dynamic triaxial tests, which more accurately simulate actual engineering conditions, the mechanical properties and deformation characteristics of the stabilized soil under various stress conditions are evaluated. The study examines the influence patterns of curing age, confining pressure conditions, and curing agent content on the deformation characteristics of stabilized soil, clarifying how different influencing factors affect its stress-strain relationship, deformation modulus, dynamic stress-dynamic strain relationship, and dynamic elastic modulus under various conditions. The results demonstrate that increasing confining pressure, extending curing time, and raising curing agent content can significantly enhance shear strength, secant modulus, and dynamic elastic modulus, while high water content leads to their reduction.

Field test validation confirms that cumulative foundation settlement remains stable, the curing agent mixes uniformly with soft soil, and the environment-friendly polymer curing agent can significantly improve the bearing capacity of soft soil foundations. The characteristic values of bearing capacity for the stabilized foundations all exceed 120.0 kPa, meeting design requirements.

The research findings not only expand the application scenarios of industrial solid wastes in geotechnical engineering but also provide an economically efficient technical pathway for low-carbon transportation infrastructure construction, delivering significant ecological environmental benefits alongside engineering application value. Future work may further investigate adaptability to different soil types, durability, and multi-scenario curing processes to promote the standardization and large-scale application of environment-friendly polymer curing agents.

Keywords: curing agent; soft foundation reinforcement; in-situ stabilization; laboratory test

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