A Large-Scale Apparatus for Measuring Rheological Properties and Compressibility of Improved Soil: Postprint

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Abstract

Soil conditioning is one of the important methods to ensure tunnel face stability and excavation efficiency in Earth Pressure Balance (EPB) shield construction. Commonly used soil conditioning agents include water, foam, bentonite slurry, polymer and other materials. Currently, there is a lack of testing apparatus and experimental methods for evaluating the compressibility and shear strength of conditioned soil, as well as a lack of evaluation criteria and quantitative indicators for conditioned soil properties. This paper proposes a laboratory testing apparatus for measuring the rheological properties and compressibility of conditioned soil, which enables simultaneous compression testing and rotational shear testing, thereby solving the technical challenge that existing testing equipment cannot perform shear tests under multi-stage pressure conditions. This paper applies foam and bentonite slurry to conduct soil conditioning tests on cobble stratum soil, uses the proposed testing apparatus to measure the shear strength of conditioned soil at different rotational speeds, and obtains rheological curves and Bingham model equations for conditioned soil with different conditioning mix ratios. Based on the experimental results, regression analysis is performed on the consistency coefficient, yield strength, and slump using Design-Expert analysis software, and the functional relationship between conditioning agent parameters and conditioned soil property parameters is obtained, as well as the optimal mix ratios for foam-conditioned soil and bentonite-conditioned soil. It is proposed that the slump of conditioned soil should be in the range of 180mm-200mm, the yield shear strength should be less than 35kPa, and the consistency coefficient should be less than 10 kPa · s. The optimal soil conditioning mix ratios for cobble stratum obtained in this paper will provide construction guidance and theoretical support for EPB shield construction in cobble strata.

Full Text

Preamble

A Large-scale Instrument for Measuring the Rheology and Compressibility of Improved Soil

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Abstract

Soil conditioning is a critical method for ensuring face stability and excavation efficiency in Earth Pressure Balance (EPB) shield tunneling. Commonly used conditioning agents include water, foam, bentonite slurry, and polymers. However, there is currently a lack of testing instruments and experimental methods for evaluating the compressibility and shear strength of conditioned soil, as well as a deficiency in criteria and quantitative indicators for assessing its properties.

This paper presents a laboratory testing instrument designed to measure the rheology and compressibility of conditioned soil, enabling simultaneous compression and rotational shear testing to address the technical limitation of existing equipment that cannot perform shear tests under multi-stage loading conditions. Using this instrument, soil conditioning experiments were conducted on gravel stratum soil with foam and bentonite slurry, measuring shear strength at various rotational speeds to obtain rheological curves and Bingham model equations for different formulations. Based on these results, regression analysis of the consistency coefficient, yield strength, and slump was performed using Design-Expert software, establishing functional relationships between conditioning agent parameters and soil properties and determining optimal formulations for foam- and bentonite-conditioned soils. The study recommends conditioned soil should have a slump of 180–200 mm, yield shear strength less than 35 kPa, and consistency coefficient less than 10 kPa · s, providing valuable construction guidance and theoretical support for EPB shield tunneling in gravel strata.

Keywords

Earth Pressure Balance shield; soil conditioning; gravel stratum; foam; bentonite slurry

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