PROBABILISTIC APPROACHES FOR GEOTECHNICAL SITE CHARACTERIZATION AND SLOPE STABILITY ANALYSIS

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岩土工程勘測以及邊坡穩定性分析的概率方法研究

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Abstract

In the last few decades, reliability-based design (RBD) approaches/codes and probabilistic analysis methods, such as probabilistic slope stability analysis with Monte Carlo Simulation (MCS), have been developed for geotechnical structures to deal rationally with various uncertainties (e.g., inherent spatial variability of soils and uncertainties arising during geotechnical site characterization) in geotechnical engineering. Applications of the RBD approaches/codes and probabilistic analysis methods in turn call for the needs of probabilistic site characterization, which describes probabilistically soil properties and underground stratigraphy based on both prior knowledge (i.e., site information available prior to the project) and project-specific test results. How to combine systematically prior knowledge and project-specific test results in a probabilistic manner, however, is a challenging task. This problem is further complicated by the inherent spatial variability of soils, uncertainties arising during site characterization and the fact that geotechnical site characterization generally only provides a limited number of project-specific test data. This study aims to address these challenges in probabilistic site characterization.

A Bayesian framework is first developed for geotechnical site characterization, which integrates systematically prior knowledge and project-specific test results to characterize probabilistically soil properties and underground stratigraphy. The Bayesian framework addresses explicitly the inherent spatial variability of soils and accounts rationally for uncertainties arising during site characterization. It is general and equally applicable for different types of prior knowledge and different amounts of project-specific test data. When the project-specific tests (e.g., standard penetration tests) only provide sparse data, the Bayesian framework is integrated with Markov Chain Monte Carlo Simulation (MCMCS) to develop an equivalent sample approach that generates a large number of equivalent samples

of the soil property concerned for its probabilistic characterization. The equivalent sample approach effectively tackles the difficulty in generating meaningful statistics from the usually limited number of soil property data obtained during site characterization. When a relatively large amount of project-specific test results (e.g., near-continuous measurements during a cone penetration test) are available, a Bayesian approach is developed that contains a Bayesian model class selection method to identify the most probable number of soil layers and a Bayesian system identification method to estimate the most probable layer boundaries and soil properties simultaneously. The equivalent sample approach and the Bayesian approach are illustrated using several sets of real observation data and simulated data. It is shown that they integrate prior knowledge and project-specific test data in a rational way and provide proper probabilistic characterization of soil properties and underground stratigraphy.

Inherent spatial variability of soils and uncertainties arising during geotechnical site characterization are then incorporated into probabilistic slope stability analysis using MCS. MCS is gaining popularity in probabilistic slope stability analysis due to its robustness and conceptual simplicity. However, it suffers from a lack of efficiency and resolution at small probability levels and does not offer insights into the relative contributions of uncertainties to failure probability. In this study, a MCS-based probabilistic slope stability analysis approach is developed using an advanced MCS method called "Subset Simulation". It is shown that the proposed probabilistic slope stability analysis approach significantly improves the efficiency and the resolution at relatively small probability levels. In addition, a probabilistic failure analysis approach is developed that makes use of failure samples generated in MCS to shed light on the relative contributions of various uncertainties to failure probability. The probabilistic failure analysis approach is illustrated through a case study. It is shown that effects of various uncertainties on slope failure probability are properly prioritized and quantified by the proposed approach.

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