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Ph.D. DISSERTATION DEFENSE

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Title:	Stochastic Design of Geotechnical Systems

Chairperson: Prof. George Korfiatis

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ABSTRACT

Geotechnical engineering confronts significant challenges arising from the limitations of deterministic methods, which often fail to fully accommodate the inherent variability of soil strength parameters. To address this gap, this dissertation proposes an advanced probabilistic framework for designing geotechnical systems. Traditional geotechnical designs rely on deterministic estimations based on specific field conditions, which inadequately capture the complexities and spatial variability of natural soils. The proposed framework integrates random field theory and the Single Random Variable (SRV) approach to quantify and incorporate the distribution of soil strength variability. By combining the Finite Element Method (FEM) with advanced computational techniques such as Multi-Layer Perceptron Artificial Neural Networks (MLP-ANN), the Non-dominated Sorting Genetic Algorithm II (NSGA-II) optimization algorithm, and decision-making methodologies including Ordered Weighted Averaging (OWA) and ELECTRE, this research introduces a robust and adaptable approach to probabilistic geotechnical design. To validate this framework, a case study focused on a nailed wall system adhering to the France standard was conducted, with soil strength parameters such as cohesion (c) and friction angle (φ) identified as uncertain variables. Stability assessment via Random Limit Equilibrium Method (RLEM) and Latin Hypercube Sampling (LHS) iterations indicated stability for a correlation length equal to the wall height (7.2 m). Subsequently, the Random Finite Element Method (RFEM) evaluated the wall's behavior under varying random fields, influencing critical parameters such as maximum displacement (H_{max}), maximum moment (M_{max}), and maximum shear force (V_{max}). Cumulative Distribution Functions (CDFs) were generated for these parameters, and through Simple Weighted Averaging (SWA) and OWA, different combinations of H_{max}, M_{max}, and V_{max} were analyzed to identify critical random field realizations and assess risk levels, represented by a newly introduced metric, the Decision Index (DI). Additional analysis of isotropic and anisotropic correlation lengths under varying Coefficients of Variation (COVs) highlights the importance of spatial variability in achieving reliable nailed wall designs. This dissertation further outlines a comprehensive framework for stochastic optimization and decision-making within geotechnical systems by integrating the NSGA-II with the ELECTRE decision-making algorithm. Utilizing the SRV approach and LHS techniques, this adaptable framework was demonstrated through the nailed wall case study, where parameters such as nail length (L), diameter (D), and horizontal spacing (S_h) were optimized to maximize the Factor of Safety (FS) while minimizing H_{max}, M_{max}, and V_{max}. MLP-ANN facilitated optimization, and applying Conditional Value at Risk (CVaR) at a 95% confidence level provided risk metrics for extreme events. The ELECTRE method then ranked Pareto-optimal solutions, offering a rigorous approach to prioritize objectives based on importance. This framework substantially enhances the reliability and safety of geotechnical systems under uncertainty, extending applicability across diverse geotechnical contexts.