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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This research aims to investigate the impact of soil inherent variability on commonly encountered geo-structures, such as slopes and underground tunnels. Real Cone Penetration Test (CPT) data from engineering projects related to underground tunneling are utilized to evaluate the various sources of uncertainty prevalent in geotechnical engineering. Additionally, conditional simulation techniques are applied to analyze slope stability and simulate underground tunneling, to reduce uncertainties in the predictions of response behavior. The title of this research is 'Evaluating the Impact of Geotechnical Uncertainty on Slope Stability and Tunneling-Induced Settlement', spanning five chapters. Summaries for each chapter are provided below:

Chapter 1: Introduction. This chapter serves as an introduction to the concept of geotechnical uncertainty and the use of conditional and unconditional random fields. It outlines the objectives and scope of this dissertation, which aims to address the challenges posed by geotechnical uncertainty in various geotechnical engineering applications.

Chapter 2: Effect of spatial variability on stability and failure mechanisms of 3D slope. This chapter evaluates the factor of safety, sliding volume, and failure mechanism of 3D spatially varied slope by 3D random field and a 3D Limit Equilibrium Method (LEM) in together with a hypothetical 3D slope model. As most studies focusing on the factor of safety with a 2D plain-strain assumption, the chapter aims to establish detailed relationships between factors of safety, sliding volume, and failure mechanisms while considering 3D soil spatial variability. It is highlighted that the variations in the stability number and sliding volume are found to increase with increasing randomness of soil properties, which triggers more kinds of failure mechanism. In addition, the stochastic response surface method with spatial averaging assumption is conducted for reducing the computational load, and result shows that the proposed method is sufficient for estimating the factor of safety for a 3D spatially variable model slope.

Chapter 3: Uncertainty assessment in 3D slope stability and failure mechanisms. This chapter assesses the uncertainty in the stability number (factor of safety) and sliding volume of 3D slope considering the spatial variability of soil properties, by adopting a 3D conditional random field. Similar to Chapter 2, a hypothetical 3D slope model and the Random Field Limit Equilibrium Method methodology are utilized. In addition, Chapter 3 introduces a 3D conditional random field approach based on the Kriging algorithm, which incorporates a limited number of cone penetration test (CPT) data into the 3D slope model. The CPT data is assumed to have shear strength parameters such as cohesion and friction angle. The evaluation adopts a single-row CPT sampling pattern, and the optimal sampling location for a 30° slope is determined to be near the slope shoulder. This optimal location leads to a 30% reduction in variance for the stability number and a 20% reduction in variance for the sliding volume. Four failure mechanisms identified in the unconditional simulation are selected as target failures for the proposed conditional simulation procedure. The sampling location in the study domain is adjusted to investigate the sampling efficiency for each failure mechanism. Optimal sampling locations are found to be near the slope toe for base failures and close to the slope shoulder for face failures. To quantify the uncertainty in the estimation of the failure mechanisms, the occurrence of a failure mechanism that differs from the targeted failure is considered. The minimum uncertainty in the failure mechanism (0.49) is obtained when conditioning the data at the optimal sampling location near the slope shoulder for the target face failure (M_{f2}).

Chapter 4: Practical study: Assessing the influence of geotechnical uncertainty on underground tunneling. This chapter assesses the different sources of geotechnical uncertainty through real sit

investigations from a practical underground tunneling project, and investigates their influence on underground tunneling. Four cone penetration test (CPT) data are used to determine the inherent variability, random test error, statistical uncertainty, and transformation uncertainty. To account for systematic errors in the measurement uncertainty, three design scenarios are assumed: Optimistic, Neutral, and Pessimistic. A 3D numerical model is developed to simulate the shield excavation of a new metro line passing underneath an existing metro line. The predictions of existing tunnel settlements and the location of the maximum settlement are evaluated. It is observed that the predicted settlements in the existing tunnel for all three scenarios follow a log-normal distribution with a 99% significance level. The estimated log-normal cumulative density function (CDF) for existing tunnel settlement is then used for probabilistic analysis, with the real monitored settlement data represented using percentiles within the estimated CDF. It is noted that settlement prediction accuracy is more challenging near the junction compared to locations further away. Minimizing measurement errors (switching from the Pessimistic to the Optimistic scenario) leads to a 36% improvement in predicting the maximum settlement and a 34% improvement in predicting the maximum settlement location. Conditional simulation is conducted using the available CPT data, and the predicted tunnel settlements also follow a log-normal distribution at a 99% significance level. The estimated CDF for predicted settlement in the conditional simulation exhibits larger percentiles for the monitored settlement, indicating improved accuracy in settlement prediction. Two types of errors, positive and negative errors, are considered, representing predicted settlements exceeding and falling below the monitored values, respectively. Positive errors are found to be more significant in the simulation, leading to overestimated settlements and a conservative design. Conditional simulation results in a 60%, 58%, and 48% reduction in settlement overestimations for the Pessimistic, Neutral, and Optimistic design scenarios, respectively. Finally, the contribution of each source of uncertainty to the maximum settlement in the existing tunnel is evaluated, revealing that the magnitude of each uncertainty input largely determines its contribution.

Chapter 5: Conclusions and recommendations. This chapter summarizes the dissertation, and significant findings, and gives future recommendations.