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Editorial

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In the design of geotechnical infrastructure, engineers have to deal with naturally occurring soils and rocks which are subjected to spatial variability as well as other uncertainties such as errors in measurement and in modeling methods. Reliability assessment which provides a systematic approach for quantifying the risk of failure has been shown to be a promising tool for solving these challenging geotechnical engineering problems. The method provides a more consistent measure of the level of safety or "structural reliability" through the evaluation of a reliability index and the associated "failure" probability, and is a method that satisfies the need to clearly convey safety issues to the public and regulatory authorities. Various methods for calculating the reliability of geotechnical infrastructures with regard to the assessment of the ultimate and serviceability limit states have been proposed by many researchers and these approaches include: the direct Monte Carlo Simulation, Bayesian and other sampling techniques, the first-order reliability method and the second-order reliability method, the random field method, the response surface method and other surrogate models with the related probabilistic procedures.

In this special issue of *Geoscience Frontiers*, we assemble eleven invited papers which provide insights on the latest developments and challenges in applying probabilistic and reliability methods to geotechnical infrastructure design.

Both soils and rocks inherently exhibit spatial variability due to complex geological processes during their formation. The scale of fluctuation SOF is an important parameter for soils and rocks, because it characterizes the spatial correlation structure of a soil or rock property. Various researchers in the literature have shown that the SOF has significant impact on the reliability of a geotechnical system. The first two papers in this issue examined the SOF in soils and rocks, respectively. The study by Ching et al. (2018) demonstrates the possibility of identifying the horizontal scale of fluctuation with limited cone penetration test soundings using a Bayesian approach. Liu and Qi (2018) study the autocorrelation structures and scales of fluctuation of the uniaxial compressive strength and elastic modulus of intact sedimentary and igneous rocks using a Bayesian model class selection approach and a Bayesian updating method, respectively.

Lü et al. (2018) illustrate the influence of the spatial variability in rock mass properties on tunnel convergence. The finite difference method with interpolated autocorrelation was used to model the spatial variability of rock mass properties. An iterative procedure using the first-order reliability method and response surface method was then employed to compute the reliability index. The analyses indicated that the probability of failure could be noticeably overestimated in the case where the spatial variability is neglected. Ji et al. (2018) propose a simplified first-order reliability method algorithm for correlated non-normals to perform reliability analysis. A practical case study example indicated that ignoring the 2D spatial variability could result in a conservative estimation of the probability of failure.

The next paper by Aladejare and Yu Wang (2018), a Bayesian approach attempts to characterize the correlation between the cohesion (c) and friction angle (ϕ), and an expanded reliability-based design approach is developed to assess the influence of correlation between c and ϕ on the reliability of a rock slope. Two rock slope cases were used as illustrative examples to demonstrate the impact of correlation on the failure probability of the rock slopes.

Random fields were incorporated into the finite element method to assess the stability of slopes in the next two papers. Liu et al. (2018a) use the 3D non-Gaussian random fields to capture the randomness in soil strength, and then incorporated the random fields into finite element methods to evaluate the slope stability. Since 3D random field finite element analysis is time-consuming, a simple method of selecting the most critical cross-section for 2D analysis was proposed. Based on this approach, the study shows that the 2D plane strain analysis gives a slightly more conservative result compared to the corresponding full 3D analysis. Liu et al. (2018b) examine the random nature of the geometric interfaces between soil and rock by simulating the rock-soil slope as a two-phase random medium in order to study the influence of the inclination of the soil layer on the stability of the slope.

Determining the soil-water characteristic curve (SWCC) at a site is an essential step for implementing unsaturated soil mechanics in geotechnical engineering practice. As direct laboratory and in-situ measurements of unsaturated soils are very costly and time-consuming. Wang et al. (2018) propose a Bayesian approach for estimating the SWCC based a limited number of test data. The proposed approach provides a rational tool to deal with such uncertainty in determining SWCC in a quantifiable manner.

With the advent of new sensing and wireless communication technologies, low-cost sensors are being massively employed in many engineering applications. The primary objective of the contribution by Li et al. (2018) is to demonstrate an efficient Bayesian network method to evaluate the slope safety using large quantity field monitoring information. A Bayesian network involving spatially correlated geotechnical parameters and many of observational points was developed and subsequently simplification

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techniques were applied to improve the computational efficiency. A slope example with multiple sources of monitoring information at multiple points was presented to illustrate the proposed model and optimization of the monitoring layout.

Concerning the structural integrity and reliability of offshore geotechnical infrastructures, fatigue assessment was conducted by Zhang et al. (2018) for offshore pipeline with 3-D interacting coplanar cracks under cyclic tensile loadings. The validation on their numerical results was made through some experimental results. A systematic study was then performed to investigate the fatigue crack initiation and fatigue crack growth of offshore pipelines. In the closing paper of this special issue, Xiao et al. (2018) propose a nonlinear regression model for predicting the peak-failure strength on the spatially varying rockfill materials. The predictions by this model were in good agreement with the test data on the peak-failure stress ratio or the peak-failure friction angle under different general stress paths.

We are privileged to be invited by Prof. Xuanxue Mo Editor-in-Chief, and Prof. M. Santosh Editorial Advisor of *Geoscience Frontiers* to edit this special issue. We are grateful to the authors for their generous contributions and patience during the review process. Our heartfelt thanks also go to the dedicated reviewers for their useful comments. We would also like to acknowledge the immense support from Dr. Lily Wang, Editorial Assistant of *Geoscience Frontiers* for her dedicated assistance during the review and processing of the manuscripts for this issue.

References

Aladejare, A., Wang, Y., 2018. Influence of rock property correlation on reliability analysis of rock slope stability: from property characterization to reliability analysis. Geoscience Frontiers 9 (6), 1639–1648.

Ching, J., Wu, T., Stuedlein, A., Bong, T., 2018. Estimating horizontal scale of fluctuation with limited CPT soundings. Geoscience Frontiers 9 (6), 1597–1608.

Ji, J., Zhang, C., Gao, Y., Kodikara, J., 2018. Effect of 2D spatial variability on slope reliability: a simplified FORM analysis. Geoscience Frontiers 9 (6), 1631–1638.

Li, X., Zhang, L., Zhang, S., 2018. Efficient Bayesian networks for slope safety evaluation with large quantity monitoring information. Geoscience Frontiers 9 (6), 1679–1687.

Liu, H., Qi, X., 2018. Random field characterization of uniaxial compressive strength and elastic modulus for intact rocks. Geoscience Frontiers 9 (6), 1609–1618.

Liu, Y., Xiao, H., Yao, Kai, Hu, J., Wei, H., 2018a. Rock-soil slope stability analysis by two-phase random media and finite elements. Geoscience Frontiers 9 (6), 1649–1655.

Liu, Y., Zhang, W., Zhang, L., Zhu, Z., Hu, J., Wei, H., 2018b. Probabilistic stability analyses of undrained slopes by 3D random fields and finite element methods. Geoscience Frontiers 9 (6), 1657–1664.

Lü, Q., Xiao, Z., Zheng, J., Shang, Y., 2018. Probabilistic assessment of tunnel convergence considering spatial variability in rock mass properties using interpolated autocorrelation and response surface method. Geoscience Frontiers 9 (6), 1619–1629.

Wang, L., Cao, Z., Li, D., Phoon, K.K., Au, S., 2018. Determination of site-specific soil-water characteristic curve from a limited number of test data – A Bayesian perspective. Geoscience Frontiers 9 (6), 1665–1677.

Xiao, Y., Meng, M., Chen, H., He, X., Ran, J., Shi, W., 2018. Nonlinear regression model for peak-failure strength of rockfill materials in general stress space. Geoscience Frontiers 9 (6), 1699–1709.

Zhang, Y., Zhong, M., Luo, J., 2018. Fatigue crack growth investigation on offshore pipelines with three-dimensional interacting cracks. Geoscience Frontiers 9 (6), 1689–1697.

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