University at Buffalo
Department of Civil, Structural and Environmental Engineering
School of Engineering and Applied Sciences

ENGINEERING SEMINAR

Probabilistic Geotechnical Site Characterization through Stochastic Inverse Analysis of Geophysical Test Measurements

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Abstract

Conventional geotechnical site characterization approach of sampling at a few locations in a soil deposit to infer soil parameters for the entire site inherently suffers from uncertainty due to limited data. Even any statistical analyses like the Krigging or random field analysis with this limited information result in a bias in the estimated spatially variable soil parameters. Geophysical test measurements when analyzed with advanced algorithms like the partial differential equation (PDE) constrained full waveform inversion technique overcome the issue of limited data to a certain extent by integrating sparse measurements with PDE-driven model predictions. However, such approaches, due to their deterministic nature, fail to account for uncertain spatial variability of soil parameters and any measurement uncertainty associated with geophysical tests.

This research study develops a PDE-constrained stochastic inverse analysis methodology to probabilistically estimate site-specific soil modulus from a geophysical test measurement by accounting for the uncertain spatial variability of the soil deposit, and any measurement uncertainty. Hypothesizing the soil modulus to be a three-dimensional, heterogeneous, anisotropic random field, the methodology first formulates and solves a forward model that mimics a geophysical experiment using a stochastic collocation approach to characterize the effect of spatially variable, uncertain soil modulus on the model response variables, for example, accelerations at the sensor locations. The random field corresponding to soil modulus is characterized by a finite number of random variables by making use of a Gaussian mixture approach. The modeling of soil modulus by a Gaussian mixture approach mimics the soil formation process and parameters of the Gaussian mixture model can be related to correlation lengths. The stochastic collocation approach utilizes recently developed non-product quadrature method, conjugate unscented transformation, to accurately estimate statistical moments corresponding to the model response variables in a computationally efficient manner. The methodology then employs a minimum variance framework to fuse the information obtained from the model prediction and the sparse geophysical test measurements to update the statistical information pertaining to the soil modulus.

The methodology is illustrated using synthetic data from a fictitious geophysical experiment. Moreover, a probabilistic sensitivity analysis is carried out by varying the number and locations of sensors. It is observed that by judiciously selecting the sensor locations, following a set of information maps, obtained by exploiting the equations of the minimum variance scheme, more information may be extracted from any geophysical experiments, leading to less uncertain estimates of the soil parameter.

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