BAYESIAN INVERSE ANALYSIS IN
GEOTECHNICAL SITE CHARACTERIZATION

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Bayesian Inverse Analysis in Geotechnical Site Characterization
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Abstract

Determining the underground stratigraphy (i.e., number of soil layers and their thicknesses underground) and estimating soil properties are two important aspects in geotechnical site characterization. In general, the determination of underground conditions relies on several in-situ and/or laboratory tests (e.g., cone penetration test (CPT)). Interpretation of the results from these tests (e.g., cone tip resistance from CPT) is needed to determine the underground stratigraphy and estimate soil properties. It is well-recognized that site characterization data contains various uncertainties (e.g., inherent variability). Such uncertainties have not been explicitly considered in traditional geotechnical site characterization, which has been mainly deterministic. On the other hand, with the recent development of reliability-based design methods around the world, probabilistic interpretation of site characterization data are necessary to quantify these uncertainties in a rational and transparent manner.

To address this problem, a Bayesian inverse analysis framework is developed for proper characterization of uncertainties in the interpretation of site observation data. Various uncertainties arising in the data interpretation are considered explicitly in the Bayesian inverse analysis framework. The interpretation of site characterization data is treated as an inverse analysis problem, in which the data are used as the input of the inverse analysis for identifying the underground stratigraphy and estimating soil properties in each soil layer. The Bayesian inverse analysis framework is applied in the classification of soil type, liquefaction severity analysis and subdivision of soil strata in London Clay Formation (LCF).

Bayesian approaches are developed for identification of underground soil stratification and soil classification based on the Robertson chart using the Bayesian inverse analysis framework and CPT tests. The uncertainty in CPT-based soil classification using the Robertson chart is modeled explicitly in the Bayesian approaches. The proposed approaches
are illustrated and validated using a set of real-life CPT data obtained from a site at the National Geotechnical Experimentation Sites (NGES) of the Texas A&M University, USA and a series of simulated data, respectively. They are shown to properly identify the underground soil strata and classify the soil type of each layer.

Bayesian approaches are then developed for identifying the statistically homogeneous soil layers and characterizing the cyclic resistance ratio (CRR) in each layer using CPT tests, in which the inherent variability of the CRR is considered explicitly. The proposed approaches are illustrated and validated using a set of real-life CPT data collected from a site at the Dodd Farm, USA and a number of simulated data sets, respectively. It is shown that the proposed approaches provide proper identification of statistically homogeneous soil layers and characterization of the CRR. The estimated statistically homogeneous soil layers and soil properties (i.e., the CRR) from the Bayesian approaches are subsequently used to identify the liquefiable soil strata and quantify their liquefaction severity using Monte Carlo Simulations. In this way, various uncertainties in the interpretation of CPT data are incorporated into the liquefaction severity analysis properly. The proposed approaches are illustrated using a set of real CPT data collected from a site at the Dodd Farm, USA. It is shown that the proposed approach identifies the liquefiable soil strata and quantifies their liquefaction severity properly. In addition, a sensitivity study is performed to explore the effect of spatial variability on the soil liquefaction severity.

The Bayesian inverse analysis framework is also used for determining the layering structure in LCF based on water content data. The uncertainties in the scattersness of water content data are considered properly. The proposed approaches are illustrated and validated using a water content profile at St James’s Park, London and a number of simulated data sets, respectively. They are shown to correctly identify the soil strata in LCF. In addition, a sensitivity study is performed to explore the effect of data quantity on soil strata identification.
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