Soils and Foundations 2016;56(4):712–718

HOSTED BY

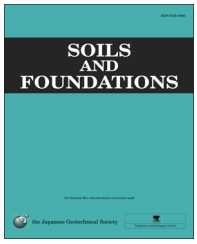
ELSEVIER

CrossMark

The Japanese Geotechnical Society

Soils and Foundations

www.sciencedirect.com
journal homepage: www.elsevier.com/locate/sandf



Technical Paper

Site characterization with multiple measurement profiles from different tests: A Bayesian approach

J.P. Wang

Department of Civil and Environmental Engineering, the Hong Kong University of Science and Technology, Kowloon, Hong Kong

Received 16 April 2014; received in revised form 5 April 2016; accepted 24 April 2016
Available online 11 August 2016

Abstract

Uncertainty studies and reliability assessments have become important topics/areas in geotechnical engineering, and different site-characterization approaches have been developed in an attempt to incorporate the sources of uncertainty into the analysis. Focusing on a target problem with multiple measurement profiles (with depth) from different testing procedures, this paper presents a site-characterization modeling to estimate the probability distribution of soil properties for a given site, considering the uncertainties from site-specific test-data scatter and from inherent soil variability in space (or in horizontal direction). More specifically, the modeling adopts the Bayesian approach to integrate the multiple sources of data, by using one as prior and the other as the so-called likelihood function. In addition to the algorithms, the approach was applied to a site with two sources of undrained shear strength from laboratory triaxial tests and in-situ plate bearing tests, and suggested a series of characteristic values for undrained shear strength for the site, corresponding to a given depth of interest, and to a given level of inherent soil variability in the horizontal direction.

Keywords: Site characterization; Different testing procedures; Bayesian approach

1. Introduction

Geotechnical variability and reliability analyses have become important topics/areas in geotechnical engineering. However, compared to man-made material, soil properties are of higher variability due to the complex process of soil formation. In addition to inherent soil variability, measurement error and transformation uncertainty (from an empirical model) are two other primary factors that make our best-estimated geotechnical data prone to high uncertainty (Phoon and Kulhawy, 1999a; 1999b). A more comprehensive review of geotechnical variability studies is given in one of the following sections.

In addition to characterizing the sources of uncertainty in geotechnical data (or soil properties), another group of geotechnical uncertainty studies is to perform site characterization in an attempt to incorporate those uncertainties into the analysis. For example, Cao and Wang (2014), Tan et al. (2003), and among others (Wang et al., 2010, 2014) have developd different approaches for site characterization in an attempt to consider different sources/types of uncertainty present in their target problem. A more detailed review on the studies is given in the following.

With multiple measurement profiles (with depth) as shown in Fig. 1, this paper introduces a site-characterization approach for such data present in a site. As opposed to other site-characterization studies, this method considers the data scatter of test results and inherent soil variability in space, with

E-mail address: jpwang@ust.hk
Peer review under responsibility of The Japanese Geotechnical Society.

http://dx.doi.org/10.1016/j.sandf.2016.07.011

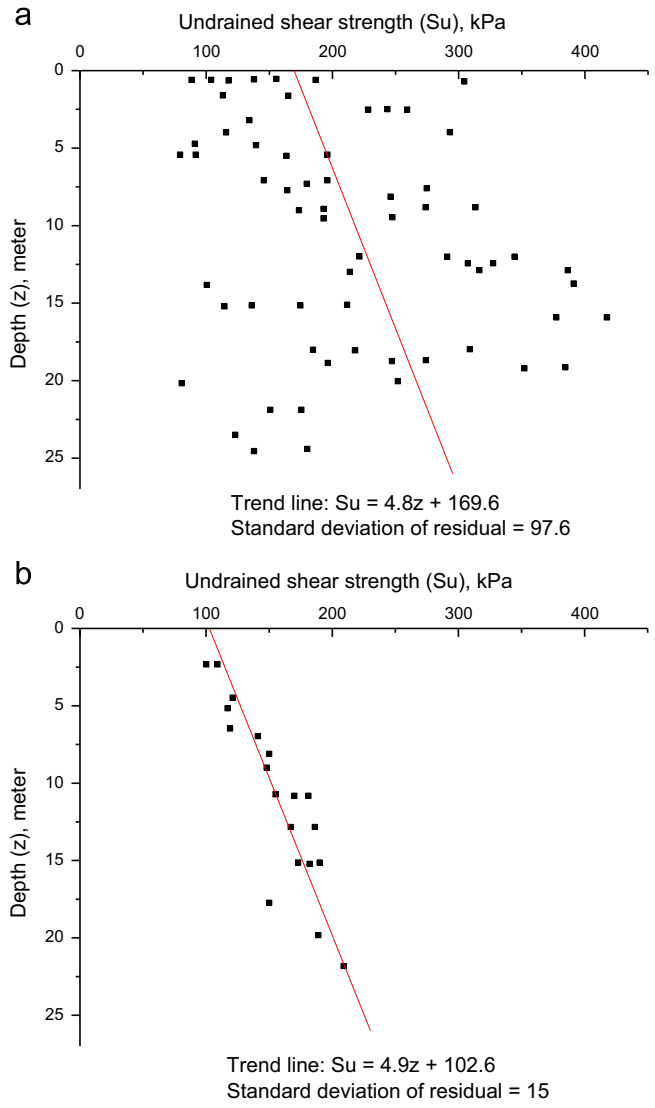


Fig. 1. Test results on undrained shear strength at the study site, (a) based on triaxial tests with 38-mm-diameter specimens, and (b) based on in-situ 865-mm-diameter plate bearing tests (after Clayton et al., 2013).

Bayesian updating to integrate such multiple sources of data from different test procedures. In addition to the algorithms, the model was applied to a site with two sources of undrained shear strength from different tests (Clayton et al., 2013), then suggests a series of characteristic values on undrained shear strength for the site, corresponding to a given depth of interest, and to a given level of inherent soil variability in the horizontal direction.

2. Overview of geotechnical variability study

Given the increasing number of works reported in the literature, it is clear that the geotechnical community has paid more attention to uncertainty studies and reliability analyses in the past decades (e.g., Ching et al., 2010; El-Ramly et al., 2003; Griffiths and Fenton, 2004; Lacasse and Nadim, 1996). Among them, one representative work given by Christian (2004) provides a comprehensive review and discussion on the topics, from the sources of geotechnical uncertainty, to reliability assessment algorithms (e.g., first-order second-moment), to Bayesian updating and inferences, and to the interpretations on probability of failure calculated from reliability analysis. Other representative and important works include those by Phoon and Kulhawy (1999a) that offered a best-estimate range regarding inherent soil variability and measurement errors for several soil engineering properties, which is useful (prior information) for geotechnical reliability assessments, especially when site-specific data are limited. In addition to those, several topics and applications are also covered by the scope of geotechnical variability and reliability assessment, such as probabilistic (or reliability-based) soil liquefaction assessment (e.g., Juang et al., 2002) and retaining-wall design (e.g., Low, 2005), in an attempt to incorporate the uncertainties present in the target problems into the geotechnical analyses and designs.

Different from "classical" statistical inferences based on "counting" samples, Bayesian inferences utilizing limited site-specific samples along with general prior information have been increasingly applied to geotechnical engineering. Christian (2004) used an example to help compare the difference between the "frequentist" approach and the Bayesian approach, demonstrating the nature and advantage of the Bayesian method that could obtain a more realistic inference with limited site-specific data, along with the "help" from prior "consensus" or information. Recently, more studies have employed the Bayesian approach for geotechnical engineering, in an attempt to integrate different sources/types of data to develop a Bayesian inference, which could be more realistic for the target problems (e.g., Zhang et al., 2009; Juang et al., 2013).

For example, Wang and Cao (2013) developed a Bayesian approach to estimate the statistics (e.g., mean and lower 5% quantile) of the soil's (i.e., clay) Young's modulus at a site with few site-specific data, based on the Bayesian posterior information developed a priori. Later, such a Bayesian approach was extended to characterize undrained shear strength (S_u) with site-specific test data on the soil's liquidity index (LI), along with several empirical models between LI and S_u (Cao and Wang, 2014). Similarly, different Bayesian site-characterization methods have been developed for different target problems, such as estimating the deformation moduli of rock masses (Feng and Jimenez, 2015), and estimating the probability distribution of the soil friction angle (Wang et al., 2010).

3. Site characterizations with multiple measurement profiles

In geotechnical engineering, it is common that multiple testing methods and procedures are available for measuring a given soil property. Fig. 1 provides an example from a site in the U.K., showing two measurement profiles with depth for the soil's undrained shear strength (at the same location), from triaxial tests with 38-mm-diameter specimens, and from in-situ 865-mm-diameter plate bearing tests (Clayton et al., 2013). From the test results, one observation is that the data from both tests indicate that the undrained shear strength of the soil tends increase with depth; another is that the data scatter from