Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
C. R. Mecanique 333 (2005) 605–611
COMPTES RENDUS
MECANIQUE
http://france.elsevier.com/direct/CRAS2B/

Truth: non-additive measures for the determination of relative density of sands using CPT measurements

Chi Tran

Faculty of science and technology, WM University of Olsztyn, 10-724 Olsztyn, Poland

Received 27 April 2004; accepted 28 June 2005

Available online 26 August 2005

Presented by Évariste Sanchez-Palencia

Abstract

In this Note, a fuzzy-integral based approach is developed for aggregating some of the available correlations that are commonly used for determining relative density D_r, from cone penetration test (CPT) data, in which non-additive measures are used as fuzzy measures to relate the actual compressibility measured by the friction ratio of sands to the base correlations. The results of the case studied show that fuzzy measures and the fuzzy integral can be utilized for a new approach in geo-technical engineering. ***To cite this article: C. Tran, C. R. Mecanique 333 (2005).***

Résumé

Mesures a vérité non additive pour déterminer les densités relatives des sables utilisant les tests de pénétration du cone (tpc). Dans cette Note, on développe une approche utilisant les intégrales floues afin d'analyser les corrélations utilisées communément pour déterminer la densité relative D à partir de mesures obtenues dans les Tests de Pénétration Conique (TPC). Dans ces données, les mesures non-additives sont traitées comme mesures floues afin de rendre compte de la relation existant entre la compressibilité évaluée grâce au rapport entre le frottement des sables et les corrélations de base. Les résultats relevant du cas étudié montrent que les mesures floues et les intégrales floues peuvent être utilisées dans une approche nouvelle au génie géotechnique. ***Pour citer cet article : C. Tran, C. R. Mecanique 333 (2005).***

Keywords: Soils; Relative density; Truth measure; Measurable function; Fuzzy integral

Mots-clés : Sols ; Densité relative ; Mesures de verité ; Fonctions mesurables ; Intégrale floue

E-mail address: tran.chi@uwm.edu.pl (C. Tran).

1631-0721/$ – see front matter
doi:10.1016/j.crme.2005.07.020

1. Introduction

Relative density (D_r) is an important parameter in geomechanics. It indicates the state of density of a sandy soil and is used to estimate other engineering properties of soil. Several empirical correlations between D_r and CPT (cone penetration test) data are available in the literature. No single correlation, however, seems to be able to predict correctly D_r for all sands. For example, the correlation proposed by Villet et al. [1] is able to predict reliably D_r for sands of low compressibility. The correlation defined by Schmertmann [2] is more applicable to sands of high compressibility, while the correlation defined by Baldi et al. [3] was developed for sands of medium compressibility. In fact, the compressibility of sands is not a well-defined parameter. A comprehensive model involving all the three correlations is difficult to develop. It is often more practical to first perform a calculation based on each correlation and then combine the results into a single overall result using linearly weighted average operator. This method is based on the assumption that the effects of evaluation of individual compressibilities are independent of one another and consequently are additive. However, the partial compressibilities are not orthogonal, and significant coupling exists among them. The relationship among the partial scores associated with different compressibilities can be quite complex; their effects are interactive. Thus, a simple linear combination of the partial correlations is incapable of capturing the noise and synergy of the information contained in these correlations; a highly non-linear process is required in its place. For this purpose, we introduce an idea of non-additive measures/truth measures based on multi-valued logic. Then, an aggregation operator using fuzzy integral will be used to determine the relative density of sands from CPT data.

2. Classical approach for determining relative density

A general relationship, $D_r - q_c$, established by Kulhawy et al. [4] based on a database of 24 sands is represented as:

$$D_r^2 = \left(\frac{1}{Q_F}\right)\left[\frac{q_c/p_a}{(\sigma_v'/p_a)^{0.5}}\right] \tag{1}$$

where, p_a denotes atmospheric pressure; q_c the cone-tip resistance, σ_v' the effective overburden stress; Q_F is an empirical constant determined by least-square regression analyses for normally consolidated (NC) sands of low, medium and high compressibility, respectively. To characterize the sand compressibility, the friction ratio, r:

$$r = \frac{f_s}{q_c}\ [\%] \tag{2}$$

is usually used, where, f_s denotes the sleeve friction. To determine D_r, a weighted aggregation technique is developed in the paper presented by Juang et al. [5] and used to combine the three base correlations in the form:

$$D_r = D_r^L W^L + D_r^M W^M + D_r^H W^H \tag{3}$$

where D_r^k, $k = L, M, H$, are the relative densities, defined by (1), depending on the correlations defined for sands of low, medium and high compressibility, respectively, through an empirical constant Q_F; W^k, denotes weights which are determined based on a 'similarity' measure of three predefined levels of compressibility.

This technique is based on an implicit assumption that effects of the three compressibility levels (L, M, H) are viewed as additive $\{W^L + W^M + W^H = 1$ and $0 \leqslant W^J \leqslant 1\}$. This assumption is, however, not always reasonable as indicated by Viertl [6], Wang et al. [7], Chi [8] and others.

3. Truth – non-additive measures

First value of truth stated by true ($T = 1$) and then false ($\neg T = 0$) was introduced by Boole (1847). It is called two-valued $(T, \neg T)$ logic. In same way, we can state the terms: 'necessarily true', 'possibly true' $(\Box T, \Diamond T)$, in