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Assessment of sandy soil variability based on CPT data

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Abstract

This paper presents a statistical analysis to characterize soil variability based on the cone penetration tests (CPTs) data obtained from a site near to Jijel port located in northern of Algeria. Ten CPTs were performed to a depth between 10 m and 13 m in sandy soils within an area of 120x86 m^2. Only the vertical variability of the cone tip resistance (probability density function, coefficient of variation and scale of fluctuation) is considered and the data are analysed within a homogenous layer using the random field theory.

The results in terms of coefficient of variation and vertical scale of fluctuation are compared to the corresponding values available in the literature. The comparison showed different ranges of the vertical scale of fluctuation that may be due to the variation of the cone tip resistance in cohesionless soils. This variability will be integrated in a study of the potential liquefaction of the site.

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Keywords: variability; cone penetration test (CPT); random field; sand deposits.

1. Introduction

The Reliability based design of any project in geotechnical engineering requires information on soil variability that results from natural geological processes. This variability may be modelled as a random field characterized by a probability density function (PDF) with its statistics (mean and standard deviation), and the scale of fluctuation [1]. This statistical information of a soil property can be estimated reliably from an extensive in situ testing data.

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In general, cone penetration test (CPT) measurements are ideal for assessing soil variability because it provides near continuous test data efficiently and economically [2]. In addition, the measurements error associated to the test is very low and can be neglected.

This paper presents a statistical analysis to characterize soil variability based on ten cone penetration tests (CPTs) data obtained from a site near to Jijel port located in northern of Algeria. The CPT data consists of cone tip resistance, qc, sleeve friction and pore water pressure measurements. Only the vertical variability of the cone tip resistance is considered in this study, and the data are analyzed within a homogenous layer using the random field theory.

The final goal of this study is to incorporate soil variability in the assessment of the site liquefaction potential which is a large deformation problem.

2. Random field theory

Soil variability may be modelled using random field theory that considers a property of soil as a random variable characterized by a coefficient of variation (COV) and a scale of fluctuation (δ) representing the distance over which values of a soil property are correlated.

Spatial variability requires a data being homogenous and stationary. Soil homogeneity is important since the correlation structure of soil properties is dependent on soil type, while stationarity that considers data as independent of the location of the points is a statistical assumption. In random field theory, it is common to get stationary data by removing the low order of polynomial trend, usually no higher than a quadratic, obtained by ordinary least squares (OLS) regression [3, 4, 5].

Vanmarcke [1] suggested that scale of fluctuation could be determined by fitting a theoretical model to the sample autocorrelation function (ACF) which represents the variation of correlation coefficient of a propriety with a separation distance $\tau_j = j\,\Delta z$ between two points (Δz is the sampling interval).

After removing a trend from the data, the autocorrelation function (ACF) of residuals w (with zero mean), for different lags j = 0, 1….N-1 (where N is the total number of data), is evaluated as:

$$R(\tau_j) = \frac{\sum_{i=1}^{N-j} w_i\, w_{i+j}}{\sum_{i=1}^{N-j} w_i^2} \tag{1}$$

Various theoretical models have been proposed to fit the ACF [1, 3, 5]. In this study, it was found that cosine exponential model best fit the sample ACFs for nine CPTs data. The analytical expression of the cosine exponential model is given by:

$$R(\tau) = \exp\left(-b|\tau|\right).\cos(a\tau) \tag{2}$$

The parameters (a, b) of the model are calculated by the OLS method. The scale of fluctuation, δ_v, for this model, is then calculated using the following equation:

$$\delta_v = \frac{2.\,a^2}{a^2 + b^2} \tag{3}$$

3. Case study

The present study is based on cone penetration tests (CPTs) data obtained from a site near to Jijel port located in northern of Algeria. The site, receiving reinforced concrete silos for cereal storage, has been extensively investigated