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Panel discussion: Contribution to the discussion of ground property characterisation by means of in-situ tests

Débat de spécialistes: Contribution à la discussion sur la caractérisation des propriétés des sols par essais en place

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ABSTRACT: the technique of ***pattern recognition*** is advanced as a means of enhancing information from empirical in-situ tests and the effect of layering on cone resistance discussed.

RESUME: On propose la technique de ***pattern recognition*** pour l'amélioration des résultats des essais in-situ empiriques et on discute l'effet des couches sur la résistance pénétrométrique des sols.

1. INTRODUCTION

I wish to make remarks on two specific topics within the theme of this session. These are: 1) the better exploitation of results from in-situ tests, and 2) the effect of layering on penetration resistance.

2. IMPROVED EXPLOITATION OF TEST DATA

The recent increase in the power of office computers allows the possibility of quite elaborate manipulation of test data to be made in a fairly routine fashion. Two approaches may be taken. If the test corresponds to a solvable boundary value problem, for example the pressure meter test, then the test can be simulated for a given constitutive model, and parameter values found by trial and error. This approach has been elaborated by both the theme lecturer and the discussion leader. Where the test is difficult to simulate, for example the piezocone test (CPTU), advanced statistical procedures can be used to extract the maximum of information from the results. I would like to illustrate the latter approach with an example of the application of the *pattern recognition* technique to the estimation of liquefaction potential from CPTU data.

2.1 *Pattern recognition applied to the CPTU*

Pattern recognition is a statistical technique which enhances observed information. It can best be described by way of example: Consider the estimation of liquefaction potential using the CPTU test. First a model is constructed from case-history data which can then be applied to new cases. To form the model *training data* are gathered for sites that have been observed to have liquefied or not to have liquefied in past earthquakes. For each stratum, a vector of data is assembled comprising the three CPTU readings and other soil properties such as overburden stress, together with seismic data such as peak acceleration, magnitude and source distance. Each vector, or point in measurement space is labelled according to whether it represents a layer i) that liquefied or ii) one that did not liquefy because it was too fine-grained or iii) one that might have liquefied but in this instance did not (because it was too dense or was not shaken strongly enough). Thus our training data may be considered as points in measurement space, each belonging to one of these three groups.

The pattern recognition process seeks to enhance the distinction between the three groups. There are three steps. Firstly, from the training data, a set of orthonormal coordinates is found, and the transformation matrix formed. Cone resistance q_c and friction ratio R_f illustrate the usefulness of orthogonalisation. While these two measurements carry information about two independent properties (e.g. strength and grain size) they themselves are clearly correlated. The second step is to eliminate coordinates which help little in distinguishing between the 3 classes or groups of data. This gives us a new, simpler mutli-dimensional *feature space*. The third step in formulating the model is to plot each of the three classes of data in feature space and determine the probability distribution of each class.

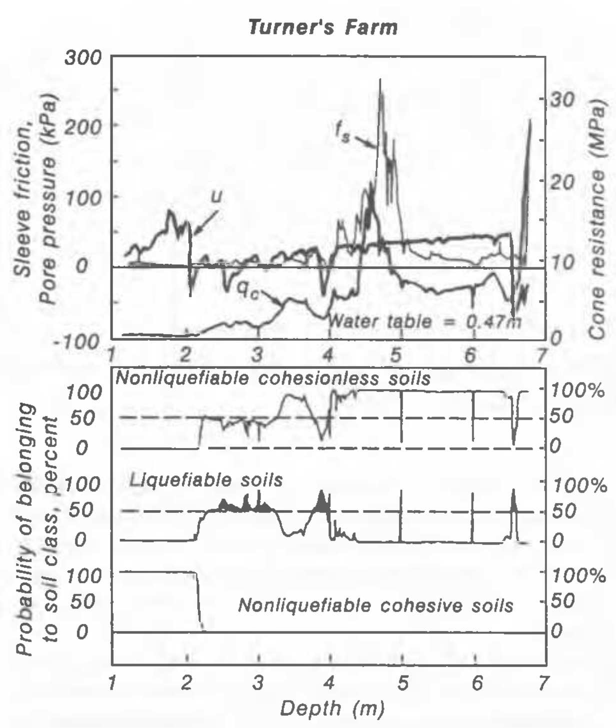

Figure 1. Example of evaluation of liquefaction potential using pattern recognition

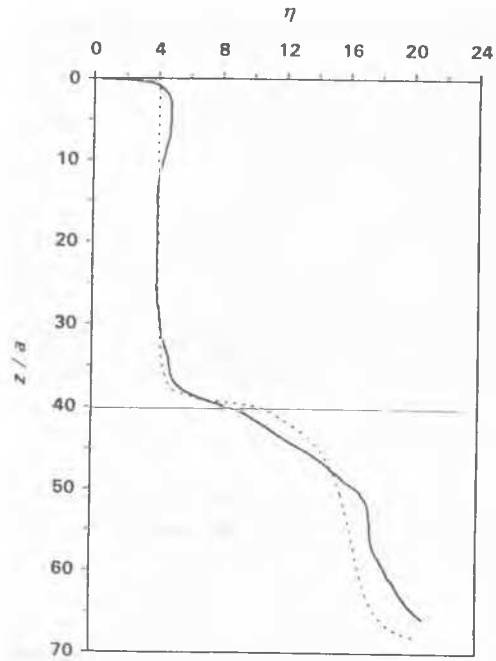

Figure 2. Dimensionless cone resistance η vs depth, from calibration chamber test; two soil layers

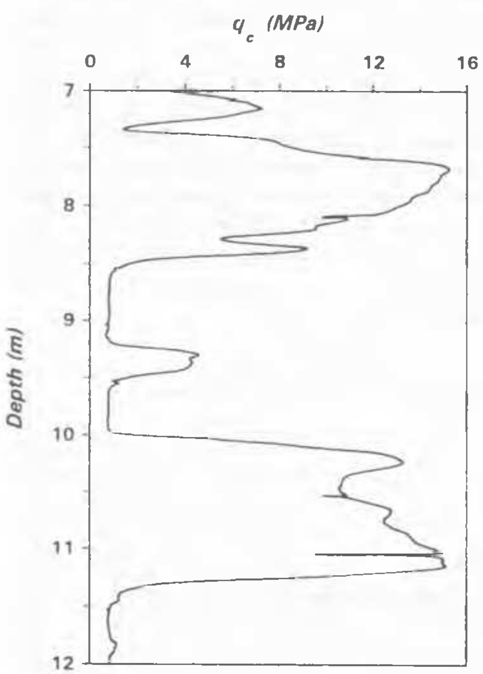

Figure 3. Cone resistance q_c in thin layer of sand (9.2 to 9.5m) affected by adjacent soft layers

The final model comprises a transformation matrix, transforming data in measurement space to feature space, and the three probability distributions. Thus, measurements for any new layer may be transformed into feature space and its probability of belonging to each of the three categories estimated.

Figure 1 shows the predictions for a site that liquefied in a 1991 earthquake in New Zealand, using a model formed from data recorded at site in the same region but which liquefied in an earlier 1968 earthquake. Note that the upper two metres comprises fine-grained soil that should not liquefy. The penetrometer then passes into cohesionless soil. From 2.2m to 3.2 m and again at about 4m the soil is loose enough to liquefy under the 1991 shaking. Around 3.5m and below 4m it is too dense to liquefy in this earthquake. Further details of the model and this example may be found in Dou and Berrill (1993).

3. EFFECT OF LAYERING ON CONE RESISTANCE

It is well known that as a penetrometer approaches a sharp boundary between two layers of different stiffness, the influence of the adjacent layer is felt well away from the boundary. In Figure 2 we see results from a cone penetration test in a calibration chamber with a layer of a loose sand overlying a dense layer. As the cone approaches the dense layer, q_c starts increasing several cone radii before the interface, and the effect of the soft layer is felt for a greater distance into the dense layer.

With thick layers, this is little problem. But with thin layers sandwiched between thicker ones, q_c may not reach its steady-state value, giving a completely erroneous picture of the state of the thin layer. Figure 3 shows an example of this effect with alternating layers of dense sand and clayey silt. In fact, the three layers of sand have similar densities. But in the thin layer, q_c does not develop beyond about one third of its true steady-state value.

This reduction in cone resistance can be predicted almost exactly by an elastic analysis (Vrengdenhil et al, 1995), implying that the zone of elastic response, outside the zone of plastic deformation, has an important influence on penetration resistance.

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