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Louisiana Transportation Research Center

Technical Summary
Report 386

July 2004

Evaluation of Consolidation Characteristics of Cohesive Soils From Piezocone Penetration Tests

Introduction

Saturated fine-grained soils can undergo large settlements over a long period of time. Therefore, the estimation of both the total settlement and the rate of change of cohesive soils under field loading is essential for geotechnical engineering design and analysis. The total settlement can be determined from deformation moduli such as the tangent constrained modulus, M, while the time rate of settlement is predicted using the vertical coefficient of consolidation, c_v.

The strength and consolidation characteristics of cohesive soils can be estimated from either laboratory or in-situ testing. The laboratory tests such as the oedometer consolidation test are usually conducted on small, presumably undisturbed intact samples. However, almost all recovered samples have a certain degree of disturbance, which makes the laboratory-derived parameters not entirely representative of in-situ conditions. The piezocone penetration testing (PCPT) has gained wide popularity for subsurface investigation, soil characterization and the evaluation of different soil parameters. The PCPT is robust, simple, fast and economical test that provides continuous soundings of subsurface soil. The PCPT is capable of distinguishing between different drainage conditions during penetration. Different interpretation methods have been proposed to determine the consolidation parameters of cohesive soils using the piezocone penetration and dissipation test data.

Objectives

The main objective of this study was to evaluate the current interpretation methods for their capability to reasonably predict the Consolidation parameters needed to estimate the magnitude and time rate of consolidation settlement in fine-grained soils using the piezocone penetration and dissipation tests.

Scope

This research project focused on predicting the magnitude and time rate of consolidation settlement for cohesive soils through the evaluation of strength and deformation parameters using the PCPT test data. The PCPT tests were conducted using the 60E Fugro piezocones of cross-sectional areas of 10 and 15 cm^2 with pore pressure measurements at the cone tip (u_1) and the base (u_2). All the dissipation tests were conducted using the u_1 measurement.

Research Approach

Several sites were selected in Louisiana to conduct in-situ field and laboratory tests. Seven of these sites were used to evaluate the different PCPT interpretation methods in order to possibly develop new correlations, and estimate the consolidation parameters of fine-grained soils (M, OCR, c_v). The other three embankments sites were used for verification by comparing the predicted settlements with the field measured settlements.

Principal Investigator: Murad Abu-Farsakh, Ph.D., P.E.
LTRC

LTRC Contact: Mark Morvant, P.E.
Phone 225-767-9124

Louisiana Transportation Research Center

Sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University

4101 Gourrier Avenue
Baton Rouge, LA 70808-4443
www.ltrc.lsu.edu

In each site, in-situ PCPT tests were performed, and soundings of cone tip resistance (q_c) sleeve friction (f_s) and pore pressures (u_1 and u_2) were recorded. Dissipation tests were also conducted at different penetration depths. High quality shelby tube samples were collected close to the PCPT tests and used to carry out a comprehensive laboratory testing program, including the unconfined compression test, triaxial test, and one-dimensional oedometer consolidation test. The tangent constrained modulus (M), overconsolidation ratio (OCR), and the vertical coefficient of consolidation (c_v), predicted using the different interpretation methods, were compared with the reference values determined from the laboratory consolidation tests.

The average PCPT measurements (q_c, u_1, u_2) that correspond to the same depths of the extracted shelby tube samples were calculated and used to predict the consolidation parameters (M, OCR) in the different PCPT interpretation methods. The dissipation tests using the pore pressure at the cone tip (u_1) were used to predict the c_v values at different penetration depths.

The results of this study were based on the comparison done between the predicted consolidation parameters obtained from the different PCPT interpretation methods and the laboratory measured parameters obtained from oedometer consolidation tests. However, the verification of the research findings was based on comparing the predicted consolidation settlement and field settlements measured using settlement plates.

Conclusions

Based on the results of this research study, the following conclusions can be drawn:

- The results of comparison and arithmetic analysis showed that the Sanglerat (1972) method can predict the constrained modulus (M) better than the other methods. The Kulhawy and Mayne (1990) and Senneset et al. (1988) methods overpredict the M by a factor of 1.5 to 2.0 times, while the Jones and Rust (1995) method underpredicts M by a factor of 0.8 times. Two linear correlations were also developed between M and both the corrected cone tip resistance (q_t) and the net cone tip resistance ($q_t - \sigma_{vo}$). These correlations showed better prediction of M than the other methods.

- The results of this study showed that all the investigated PCPT methods overestimated the OCR by a factor ranging from 2.0 to 4.27 times. Linear correlations were developed between OCR and both $(q_t - u_1) / \sigma'_{vo}$ and $(q_t - \sigma_{vo}) / \sigma'_{vo}$ ratios. The comparison between the measured and predicted OCR indicated that the two proposed normalized relationships gave a better prediction of the measured OCR than the other methods.

- The comparison plots between the measured and the predicted Log c_v values show wide scatters. This scatter, however, is consistent with other comparisons reported in the literature and can be considered acceptable compared to the variation of c_v values obtained from laboratory tests. The results of comparison and arithmetic analysis indicated that the Teh and Houlsby (1991) and Teh (1987) methods can predict c_v better than the other methods.

- The findings of this study were verified by comparing the predicted settlements using the proposed PCPT correlation, Sanglerat (1972) PCPT method, laboratory calculated settlement, and the actual field settlements measured in three selected sites. The results of this verification showed that the proposed PCPT method can predict the settlement better than Sanglerat (1972) PCPT method and the laboratory calculated settlements.

Recommendations

Based on research results, it is recommended that PCPT technology be implemented to estimate the consolidation settlement of fine-grained soils. Comparison of consolidation settlement predictions (both from PCPT data and from traditional laboratory analyses) with field-measured settlements should continue. With increased confidence and experience, engineers may eventually replace conventional subsurface exploration with PCPT methods for estimation of consolidation settlement.