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Control of Embankment Settlement Field Verification on PCPT Prediction Methods

INTRODUCTION

Depending on loading and embankment height, the magnitude and progression of settlement can significantly impact the safety and serviceability of the infrastructures that are constructed on saturated fine-grained soils. Therefore, the construction of embankments, bridge abutments, and other structures on such soils requires a reasonable estimate of the magnitude and time-rate of consolidation of the natural soil deposits in order to conduct a rational and safe analysis and design of these structures.

Calculation of embankment settlement is usually made by using Terzaghi's consolidation theory based on laboratory tests. Laboratory tests, such as the oedometer consolidation test, are usually conducted on small intact samples recovered from embankment sites at selected depths. Inevitable sample disturbance makes consolidation parameters obtained from laboratory tests not truly representative of the actual in-situ conditions. Moreover, laboratory testing has great difficulty interpreting interbedded soils due to the limited number of samples. In contrast to laboratory tests, the piezocone penetration test (PCPT) can provide reliable results similar to laboratory tests in evaluating the actual strength and consolidation properties of the soil under in-situ stress and drainage conditions. PCPT has gained wide popularity and acceptance for subsurface investigation and soil characterization. PCPT is a robust, fast, and economical in-situ test that can provide continuous soundings of subsurface soil with depth.

A research project was conducted previously at the Louisiana Transportation Research Center (LTRC) to evaluate the current PCPT interpretation methods for their capability to accurately predict the consolidation parameters needed to calculate the magnitude and time-rate of consolidation settlement of cohesive soils as well as the overconsolidation ratio (OCR). The previous research recommended new interpretation methods for constrained modulus and the Teh and Houlsby method for horizontal coefficient of consolidation. In this study, more embankment sites were selected to verify the settlement prediction method based on PCPT and dissipation tests.

OBJECTIVE

The main objectives of this study were to (1) verify and calibrate the findings of previous research studies on estimating the magnitude and time-rate of consolidation settlement of soils from PCPT data, (2) compare the laboratory-calculated settlements under embankments with settlements predicted from in-situ PCPT data as well as measured field settlements, and (3) develop a computer program to estimate the consolidation settlement of embankments from PCPT data or other inputs.

SCOPE

The research focused on verification of the PCPT based prediction method of magnitude and time-rate of embankment settlement proposed in a previous research project. A comprehensive testing program including laboratory and field tests was conducted for each selected test site to estimate the consolidation properties needed for settlement calculation. Embankment settlements were monitored with instruments such as horizontal inclinometers and settlement plates. Predictions based on PCPT and dissipation test data were compared with predictions from laboratory tests and field measurements.

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METHODOLOGY

To verify the settlement prediction method by PCPT and dissipation test, two sites were selected: I-12 Juban Road Interchange site and Bayou Courtableau – LA 103 site. Laboratory tests, PCPT, and dissipation tests were conducted to determine the consolidation parameters of fine grained soils such as *M*, *OCR*, and c_v.

Laboratory tests included moisture content, Atterberg limits, density, oedometer tests, unconsolidated undrained (UU) tests, and k_o-consolidated undrained (CU) tests. 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 the laboratory tests.

The average PCPT measurements (q_c, u_1, and 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*) using the proposed PCPT interpretation methods by Abu-Farsakh (2004). The dissipation tests (with u_1) were used to predict the vertical coefficient of consolidation (c_v) at different penetration depths using the Teh and Houlsby method. The predicted consolidation parameters obtained from the interpretation methods were compared with the laboratory measured parameters obtained from one-dimensional oedometer tests. Settlement under embankment load was calculated using consolidation parameters obtained from both laboratory, PCPT, and dissipation tests. The predicted magnitude and time-rate of embankment settlement were compared with field measurements by a horizontal inclinometer and settlement plate as shown in Figures 1 and 2.

CONCLUSIONS

This study presented the verification of using the PCPT method for the prediction of magnitude and time-rate of settlement of embankments over fine-grained soils. Based on the data collected from I-12 Juban Road Interchange and Bayou Courtableau – LA 103, the following conclusions can be drawn:

- The PCPT method has comparable accuracy to the traditional laboratory method in prediction of the magnitude and time-rate of settlement.
- The interpretation of equations of $M = 3.15\, q_t$ and $M = 3.58(q_t - \sigma_{vo})$ had fairly good estimation of constrained modulus. These two correlation equations had a close or slightly better performance than the Sanglerat method.
- The Teh and Houlsby method gave close estimation of coefficient of consolidation considering the dispersive nature of the measurement of coefficient of consolidation.

RECOMMENDATIONS

Researchers recommended that LADOTD engineers gradually begin implementing the PCPT technology, particularly to estimate the consolidation settlement of fine-grained soils, in conjunction with the traditional laboratory calculation of settlements, continue the comparison between the consolidation settlements predicted from the PCPT data, the calculated settlements from laboratory consolidation parameters, and the field measured settlements until LADOTD engineers build enough confidence in the PCPT interpretation methods. With increasing confidence and experience, LADOTD engineers can move toward replacing the conventional subsurface exploration with piezocone penetration and dissipation tests for the estimation of consolidation settlement.

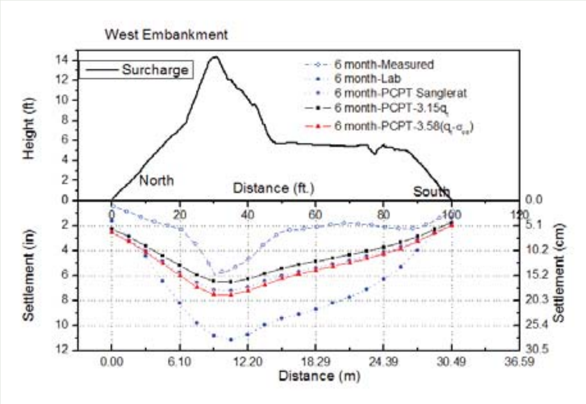

Figure 1
Comparison of predicted settlement profiles with field measurements for Bayou Courtableau Bridge - LA 103, west embankment

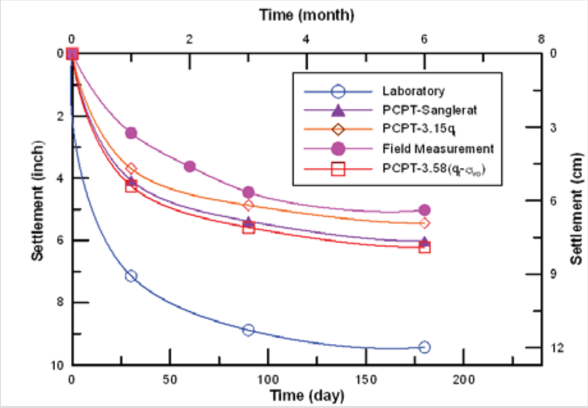

Figure 2
Comparison of predicted time-rate of with field measurements for Bayou Courtableau Bridge - LA 103, west embankment

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