TECHNICAL SUMMARY
Evaluation of Bearing Capacity of Piles from Cone Penetration Test Data

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INTRODUCTION

Among the different in situ tests, cone penetration test (CPT) is considered the most frequently used method for characterization of geomedia. The CPT is a simple, quick, and economical test that provides reliable in situ continuous soundings of subsurface soil. The CPT can be used to classify soil strata and to estimate strength and deformation characteristics of soils. Due to the soft nature of soil deposits in Louisiana, the CPT is considered a perfect tool for characterization of Louisiana soils.

In deep foundation analysis and design, implementation of the CPT by DOTD has been limited to identification of dense sand layers required to support the tip of the end-bearing driven piles. Moreover, DOTD uses the CPT to provide a supplemental subsurface information between soil borings. Unfortunately, these are very limited applications compared to the wide range of CPT applications. The CPT technology is fast, reliable, and cost effective especially when compared to the traditional site characterization method (borings and laboratory/field tests). The DOTD materials section can perform an average of six to eight CPT tests per day. The estimated average cost is $14 per foot. Compared to $50 per foot, the CPT is faster and more economical than traditional boring methods. Implementation of the CPT can drastically decrease the number of soil borings and reduce the cost and time required for subsurface characterization.

OBJECTIVES

The goal of this research was to identify the most appropriate methods for estimating the ultimate axial load carrying capacity of driven piles from the cone penetration test data.

SCOPE

This research effort was focused on the applicability of eight CPT methods to predict the ultimate axial compression load carrying capacity of piles from CPT data. These methods are Schmertmann, de Ruiter and Beringen, Bustamante and Gianeselli (LCPC/LCP), Tumay and Fakhroo, Aoki and De Alencar, Price and Wardle, Philipponnat, and the penpile method. The predicted capacity was compared to the reference pile load capacity obtained from the pile load test using Butler-Hoy method.

The CPT methods were used to investigate the load carrying capacity of square precast prestressed concrete (PPC) piles of different sizes driven into Louisiana soils. Other pile types such as timber piles and steel pipes were not covered in the current analyses. Moreover, the analyses were conducted only on piles that were loaded to failure during the load test.

RESEARCH APPROACH

This study presents an evaluation of the performance of eight cone penetration test methods in predicting the ultimate load carrying capacity of square precast prestressed concrete (PPC) piles driven into Louisiana soils. A search in the DOTD files was conducted to identify pile load test reports with cone penetration soundings adjacent to test piles. Sixty piles were identified, collected, and analyzed. The measured ultimate load carrying capacity for each pile was interpreted from the pile load test using Butler-Hoy method, which is the primary method used by DOTD. The following methods were used to predict the load carrying capacity of the collected piles using the CPT data: Schmertmann, Bustamante and Gianeselli (LCPC/LCP), de Ruiter and Beringen, Tumay and Fakhroo, Price and Wardle, Philipponnat, Aoki and De Alencar, and the penpile method. The ultimate load carrying capacity for each pile was also predicted using the static á-method, which is used by DOTD for pile design and analysis.

Prediction of pile capacity was performed on sixty piles, however, the statistical analyses and evaluation of the prediction methods were conducted based on the results of thirty five friction piles plunged (failed) during the pile load tests. End-bearing piles and piles that did not fail during the load tests were excluded from the statistical analyses.

An evaluation scheme was executed to evaluate the CPT methods based on their ability to predict the measured ultimate pile capacity. Four different criteria were selected to evaluate the ratio of the predicted to measured pile capacities. These criteria are: the best-fit line, the arithmetic mean and standard deviation, the cumulative probability, and the Log Normal distribution. Each criterion was used to rank the prediction methods based on its performance. The final rank of each method was obtained by averaging the ranks of the method from the four criteria. Based on this evaluation, the de Ruiter and Beringen and Bustamante and Gianeselli (LCPC/LCP) methods showed the best performance in predicting the load carrying capacity of square precast prestressed concrete (PPC) piles driven into Louisiana soils. The worst prediction method was the penpile, which is very conservative (underpredicted pile capacities).

CONCLUSIONS

Based on the results of this study, de Ruiter and Beringen and Bustamante and Gianeselli (LCPC/LCP) methods showed the best capability in predicting the measured load carrying capacity of square PPC piles driven into Louisiana soils. These two CPT methods showed a better performance than the currently used á-method. Cost/benefit analysis showed that using the CPT methods for design/analysis of square PPC piles would cut the cost of initial design as well as the cost of piling.

The CPT methods that showed the best performance were implemented into a Visual Basic computer program to facilitate their use by DOTD design engineers. These methods are de Ruiter and Beringen, and LCPC/LCP. Schmertmann method was also implemented in the program since it is one of widely used CPT methods.