LTRC

Implementation Update

Research in Practice

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Evaluation of Bearing Capacity of Piles from Cone Penetration Test Data

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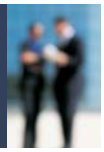
Inside:



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http://www.ltrc.lsu.edu/pdf/Pile-CPT-Final-Report.pdf

Introduction

Knowledge about the underlying soil is important in the design and construction of transportation infrastructures. The Louisiana Department of Transportation and Development (LA DOTD) annually spends millions of dollars on site investigation through subsurface exploration. The quality of subsurface exploration directly impacts the quality and efficiency of the design and construction of foundations for bridges and other structures. The precast prestressed concrete (PPC) pile is the primary foundation element used by LA DOTD to support its bridges.

Conventional site investigation based on soil borings and laboratory testing is expensive and time consuming, often requiring skilled, experienced technicians. Laboratory testing is performed on small, intact samples extracted from the borings. These samples are assumed to be undisturbed. However, sample disturbance is always possible during handling, transportation and/or test preparation. Hence, the laboratory-derived soil parameters may not truly represent the in-situ conditions. As an alternative to laboratory testing, in-situ tests such as cone or piezocone penetration tests (CPT/PCPT)

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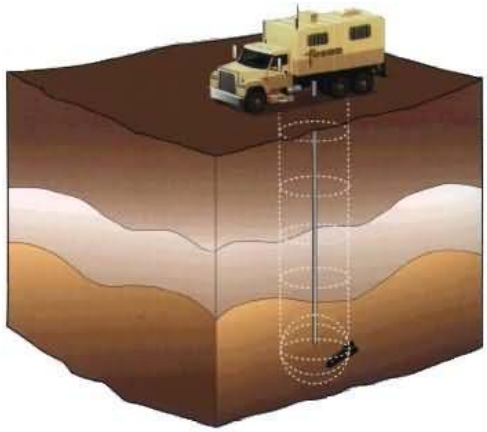


Fig. 1 Illustration of Cone Penetration Test System

can rapidly provide accurate and reliable results for assessment of the soil engineering properties. The CPT is a robust, simple, and economical test that can provide continuous soundings of subsurface soil with depth. The CPT test is conducted by advancing a cylindrical rod with a cone tip into the soil (Figure 1). During the test, the penetrometer measures the cone tip resistance and sleeve friction (and excess pore pressure when using the PCPT). These measurements can be used for detailed soil stratification and for determination of pile load capacities (Figure 2).

Louisiana started implementation of the CPT technology in the mid 1980's. Use of the technology was then limited to identifying elevations of dense sand layers for pile foundations. Soil borings were taken during the design phase to estimate pile lengths and CPT tests were conducted during bridge construction to better define pile tip elevations for plan lengths. Additional research was needed to better utilize the capabilities of the CPT technology.

Research Performed

The Louisiana Transportation Research Center (LTRC) has conducted research to investigate the load capacity of PPC piles driven into Louisiana soils. This project evaluated the performance of LA DOTD's conventional alpha-design method based on laboratory results and eight CPT methods in predicting the load capacity of PPC piles that derive its primary resistance from side friction. The CPT methods were Schmertmann, DeRuiter/Berningen, Bustamante/Gianeselli (LCPC/LCP), Tumay/Fakhroo, Aoki/De Alencar, Price/Wardle, Philipponnat, and the penpile method. The predicted capacity was compared to load capacity results obtained from pile load tests. The analysis was conducted on the results of LA DOTD test piles with corresponding soil borings and CPT soundings. A total of 35 friction piles were compared during the initial study with an additional 17 piles analyzed for verification of results.

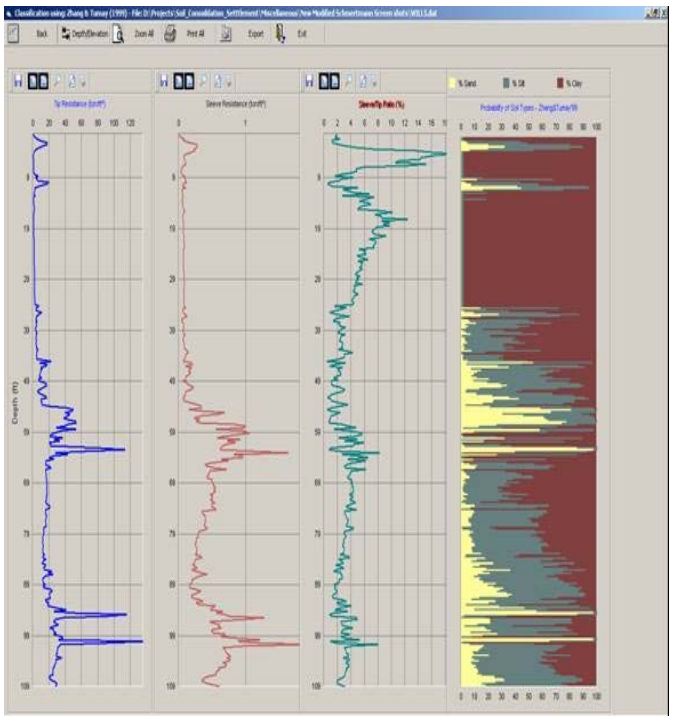
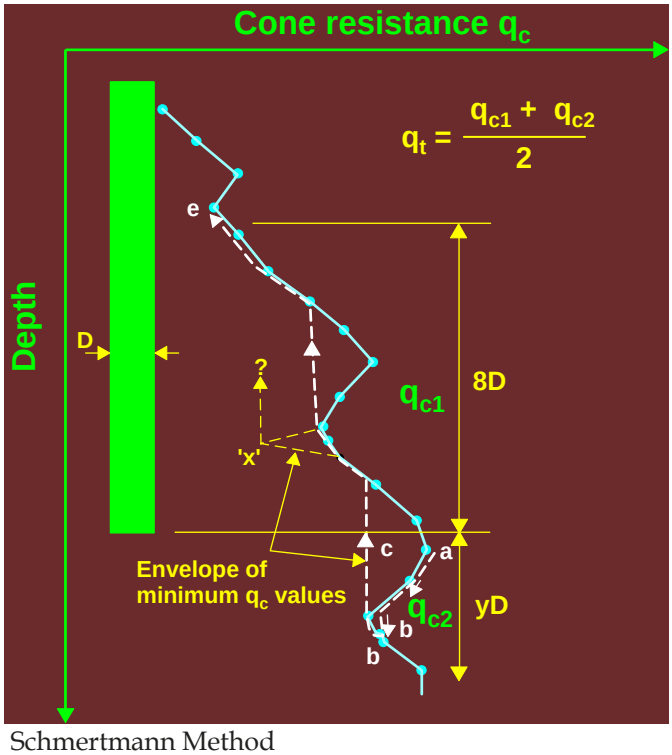
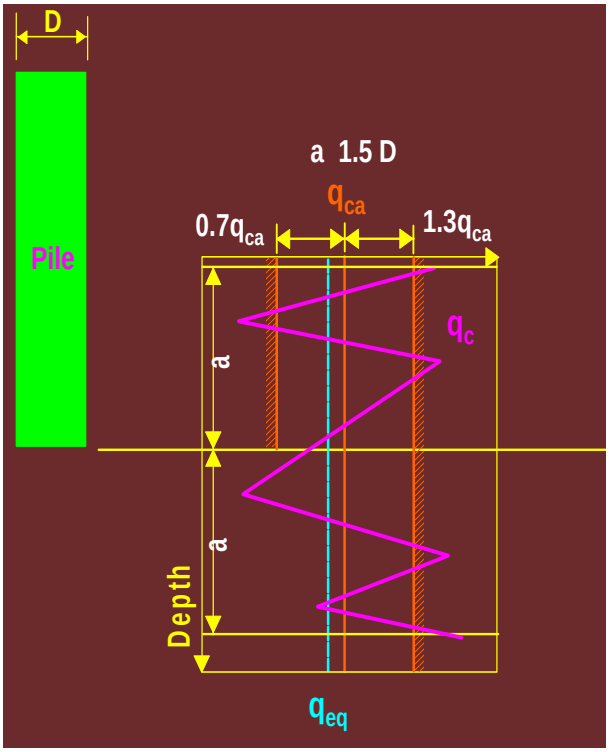


Fig. 2 Soil Classification with LSC-CPT



Schmertmann Method



LCPC CPT Method

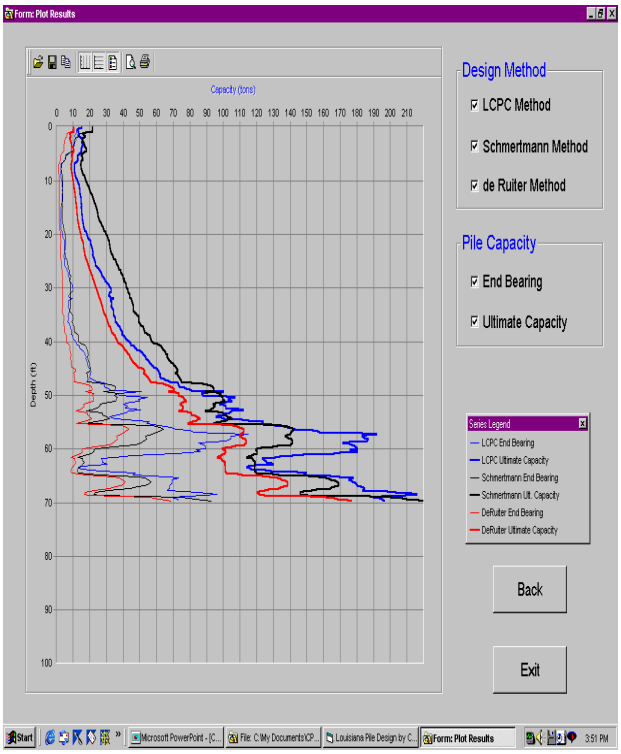


Fig. 3 Pile Prediction with LPD– CPT

Research Results

A statistical analysis and ranking criteria were used to compare the CPT methods and the conventional alpha design method. Based on the results, the de Ruiter/Beringen and LCPC methods showed the best capability in predicting the measured load carrying capacity of PPC piles driven into Louisiana soils. To facilitate the implementation of the CPT technology by LA DOTD for pile design and analysis, these methods, along with the Schmertmann method, were coded into a Visual Basic MS-Windows program (Louisiana Pile Design by CPT, LPD-CPT). The program provides the design engineers with pile ultimate capacity profile with depth (Figure 3). The LPD-CPT and other CPT programs are available for free download on the LTRC Web site at www.ltrc.lsu.edu.

Research Recommendations

CPT technology should be utilized in subsurface exploration for soil identification and classification, as well as site stratigraphy. Test results from traditional subsurface exploration methods should be compared to results interpreted from CPT methods. With time and experience, dependency on traditional subsurface exploration methods should be reduced, and the use of CPT technology should increase.

Cost-benefit analysis showed that implementation of CPT technology for prediction of pile capacity will result in cost reduction and time savings without compromising the safety and performance of pile-supported structures. Implementation of CPT technology in pile design will reduce the level of uncertainties associated with traditional design methods.

Implementation Feasibility

Contracts from recent geotechnical exploration and engineering projects were examined. When CPT technology is utilized in lieu of a conventional 200-ft depth soil boring, an average cost savings of $11,000 per boring is realized. Savings increase for over-water exploration. Use of CPT technology in lieu of an over-water soil boring saves more than $14,000.

A conventional land boring typically requires one workday for collection of the soil sample. In that same time period, four CPT soundings are possible. The most significant advantage of CPT technology is that results are immediately available, whereas the time required for laboratory testing of samples from soil borings averages three weeks.

Also the effect of adverse weather on soil boring operations is more costly than its effect on CPT soundings. Soil boring operations are typically discontinued during inclement weather. CPT operations are less susceptible to weather conditions.

Cost-benefit analysis showed that use of CPT methods for design/analysis of square PCC piles can reduce the cost of initial design as well as the cost of piling. CPT soundings can be used to identify location of dense sand layers for pile foundations, reducing the need for more costly soil borings while providing the information needed for accurate determination of required pile lengths.

Implementation Progress

Since the year 2000, CPT technology has been used with greater frequency for soil classification and pile design on LA DOTD bridge projects. Current LA DOTD geotechnical design guidelines require CPT soundings for each bridge project, subject to feasibility and economics. CPT soundings have been used in lieu of soil borings at more than 500 investigation points. Analysis of CPT data has allowed designers to reduce depth of planned borings, and occasionally, no borings are necessary at a site.

One example of CPT implementation is the site investigation for the LA 1 elevated bridge structure between Golden Meadow and Port Fourchon, which used 99 soil borings and 124 CPT soundings. Estimated savings due to the reduction in conventional borings exceed one million dollars (124 x $11,000 = $1,364,000).

CPT technology is also saving time and money on the reconstruction of the I-10 Twin Span Bridge over Lake Pontchartrain, which was damaged during Hurricane Katrina. This project used 30 soil borings and 80 CPT soundings.

The sand bearing strata varies tremendously within many bridge footings. Multiple CPT soundings are being taken at each footing to increase the accuracy of the pile lengths. Cost savings are estimated to be over one million dollars in pile lengths, pile cutoffs, and pile buildups.