RESEARCH
PROJECT CAPSULE
April 2024
24-3GT
TECHNOLOGY TRANSFER PROGRAM

Statewide Calibration of CPT Direct Design Methods Using Static Load Test Data

JUST THE FACTS:

Start Date:
May 1, 2024

Duration:
36 months

End Date:
April 30, 2027

Funding:
TT-Fed/TT-Reg-5

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

POINTS OF INTEREST:

Problem Addressed / Objective of Research / Methodology Used / Implementation Potential

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PROBLEM

Deep foundations are typically considered when subsurface soil conditions are weak and unable to safely support superstructure loads. In these cases, pile foundations are used to carry superstructure loads and transfer them deep into the ground. Therefore, an accurate assessment of pile resistance is crucial for the safe and economical design of pile foundations and the performance of pile supported infrastructures.

Most of the soil deposits in southern Louisiana are soft in nature, and the high percentage of wetlands, marshes, swamps, bayous, rivers, and lakes makes it necessary to consider using deep foundations in the design of transportation infrastructure. Consequently, pile foundations are often used by the Louisiana Department of Transportation and Development (DOTD) to support highway bridges and other transportation infrastructures.

The CPT (or CPTu) test is one of the most useful in-situ tests for soil characterization. The CPT/CPTu is a simple, fast, robust, reliable, and economical test that can provide continuous soundings of subsurface soils. The CPT measures cone tip resistance (q_c), sleeve friction (f_s), and pore water pressure (U1 or U2) during intrusion. These measurements can be used effectively for soil identification and classification and for the evaluation of different soil properties. Due to the similarity between the cone and pile, the determination of pile resistance from CPT data was among the earliest applications of CPT.

With the growth of the pile load test (PLT) database to include CPTu data, all direct CPT/CPTu methods can be evaluated, existing methods can be modified with additional data, and new CPT/CPTu methods can be developed. It may be possible to organize the large pile-CPT/CPTu database by state region for the regional evaluation of different pile-CPT methods and their LRFD calibration. It is also possible to extend the CPT methods to include other pile types (e.g., H-piles, pipe piles, and timber piles).

OBJECTIVE

The primary objectives of this research project are to:

- Explore the possibility of organizing the PLTs and CPT/CPTu database by state region for the regional evaluation of pile-CPT/CPTu methods and calibration of the corresponding resistance factors (Φ).
- Organize the collected PLTs and CPT/CPTu database by pile type for the possible extension and evaluation of the direct pile-CPT/CPTu methods for each pile type and calibration of the corresponding resistance factors (Φ).
- Explore the potential application of the Bayesian algorithm to enhance the statistically limited or scattered data and update the statistical data (mean, m, and COV) for the better evaluation and calibration of the resistance factors (Φ).
- Re-evaluate and re-rank the different pile-CPT/CPTu design methods for estimating the ultimate capacity of different pile types and different regions using varying evaluation criteria.
- Explore the possibility of developing new pile design methods and modifying existing methods using machine learning (ML) algorithms to better evaluate the ultimate capacity of piles when utilizing CPT/CPTu data.

• Evaluate the available SCPT methods for generating the load-settlement curve of pile-load tests and measure the ultimate capacity of piles based on Davisson's interpretation criteria.
• Recalibrate the resistance factors for different direct pile-CPT/CPTu methods to use in the LRFD design of pile foundations.
• Update the LPD-CPT software to include the top-performed pile-CPT/CPTu/SCPT design methods in different state regions and for different pile types.
• Develop a methodology to perform the periodic and continuous recalibration of direct design methods and resistance factors.

METHODOLOGY

To achieve the objectives of this research, the team will complete the following tasks:

First, they will conduct a literature review of the direct CPT, CPTu, and seismic CPT (SCPT) pile design methods. Additionally, they will identify statewide project sites from the DOTD archives. These archives will include static, and possibly dynamic, load tests conducted on precast pre-stressed concrete (PPC) piles and other pile types (H-pile, pipe piles, timber piles, etc).

The research team will then collect all available CPT and CPTu tests and soil boring data from the identified project sites. Additionally, they will conduct SCPT tests near PLTs at the selected project sites. The data collected will be organized and evaluated based on pile type.

Next, the team will organize the collected pile-CPT/CPTu database for PPC piles by state region for the regional evaluation of these methods and the calibration of resistance factors for the LRFD design of piles. The team will use statistical and ML techniques to enhance the statistically limited or scattered data, enabling better analysis and calibration of the resistance factors for pile design methods.

The team will then use statistical analysis, multidimensional unfolding, reliability and efficiency analyses, and several other criteria to evaluate the ability of the varying CPT/CPTu pile design methods to estimate the ultimate capacity of different pile types and different regions. They will then evaluate the ability of the available SCPT methods to generate the load-settlement curve of pile-load tests and measure the ultimate capacity of piles based on Davisson's interpretation criteria.

Next, the team will develop new pile design methods and modify existing methods to better estimate the ultimate capacity of piles when utilizing the CPT/CPTu data for the entire state, for different regions, and for different pile types. They will then develop a machine-learning (ML) design method to evaluate the ultimate capacity of piles utilizing CPT/CPTu data and to generate the load-settlement curve of pile-load tests.

The team will next calibrate the resistance factors for the top-performing pile-CPT/CPTu/SCPT methods evaluated for different state regions and different pile types. They will implement these top-performing pile-CPT/CPTu/SCPT methods into the Louisiana Pile Design from cone penetration test (LPD-CPT) software.

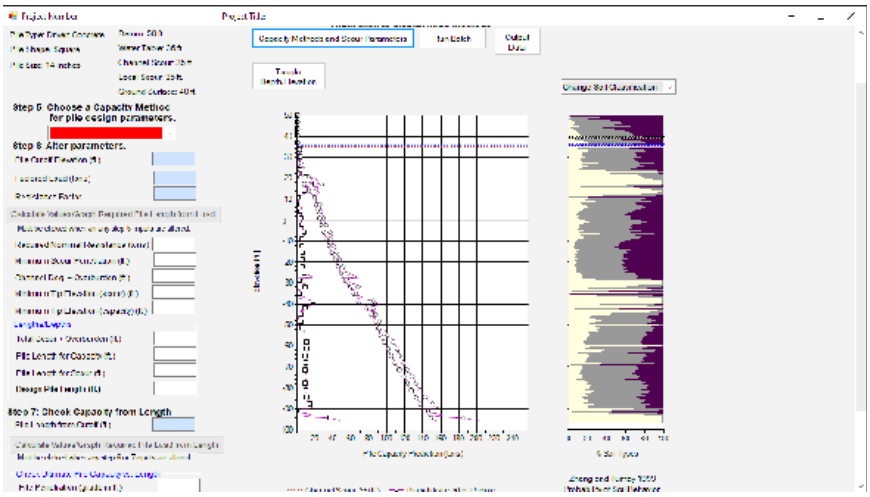

Figure 1. Louisiana pile design from Cone Penetration Test (LPD-CPT) software

Finally, the team will prepare a final report detailing their findings and recommendations.

IMPLEMENTATION POTENTIAL

The team anticipates that this research will identify the top-performed pile design methods utilizing CPT/CPTu/SCPT to accurately estimate the ultimate capacity of PPC driven in Louisiana soil. After comparing the measured and predicted ultimate pile capacities and evaluating the different pile design methods, the top-performed methods, along with any newly modified or developed methods (including ML methods), will be incorporated into the updated LPD-CPT software. The corresponding resistance factors (ΦR) for the top-performed methods will be calibrated. Incorporating these top-performed pile-CPT/CPTu/SCPT methods and developed ML methods will enable DOTD engineers to design pile foundations with greater precision and accuracy.