Executive Summary, Research Readiness Level Assessment and Technology Transfer

CPT-Based Pile Design

Research Objectives

- Determination of the bearing capacity of soils based on Bustamante and Frank (1997) and Bustamante and Gianeselli (1982).
- Determination of the settlement of piles based on Mayne and Niazi (2009)
- Found factors η and θ by comparing NDOT's CPT results and pile loading test results.
- Found correlations between the cone tip resistance and the end bearing/frictional resistance for typical Nebraskan soils (over consolidated soils).
- Implemented the correlations in NDOT's piezocone penetration test (PCPT) device (Data Logger/Computer) so that the bearing capacity of pile was obtained "on-the-fly" with other outputs such as tip resistance, pore pressure, side friction, and soil classification.

Research Benefits

- Existing pile load test results were used as a precise data for deriving more reliable pile bearing capacity evaluation.
- Accurate evaluation of bearing capacity of soils with unsurpassed high resolution (less than 2 in. data spacing) and accuracy led the way for optimum foundation design.
- Optimum design of pile foundation ensured the design of resilient, economic and low maintenance transportation structures.
- High quality bearing capacity analysis was used to evaluate the feasibility of potential upgrades of load rating of bridges.
- Easy to use spreadsheet enabled quick design

Background

The geotechnical design of a pile foundation with the determination of the safe magnitude of an external load that the foundation can carry without jeopardizing the stability of the supported structure. In recent years, in-situ sounding tests are becoming a more attractive method to predict pile capacity due to the rapid development of testing instruments, improved understanding of their mechanics and interpretation, and cost efficiency. The cone penetration test (CPT) and its upgraded version, the piezocone penetration test (PCPT), are the most widely used in situ sounding tests to predict pile capacity.

Conclusion

This research report compared eight CPT-based and three PCPT-based methods for potential application of the best performer(s) by the Nebraska Department of Transportation (NDOT) to predict pile capacity. Several statistical as well as non-statistical comparison criteria were adopted. According to the evaluation output, the modified (calibrated) Tumay and Fakhroo (1982) method was found to be the best performer for H-piles, and the modified De Ruiter and Beringen (1979) method was found to be the best performer for pipe and precast prestressed concrete piles. For a complete design of pile foundations, the settlement criterion has to be incorporated. The settlement of pile foundations must not exceed a certain tolerable magnitude of settlement to ensure the safety of the structure supported. In this regard, this research project adopted the t – z curve approach to predict pile settlements. Several existing t – z curve approaches based on analytical and numerical techniques were assessed and their relative accuracy was investigated. An easy to use software for the computation of settlement was also developed.

Principal Investigator

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Final report is available: HERE

NDOT Recommendations Based Off Research Project- 2019

The research conducted in this project represents a step forward in the department's design practice of driven pile. CPT is recognized as a versatile and effective method of geotechnical investigation and has been used by the department for various soil mechanics and shallow foundation work. This research extends the application of the CPT to deep foundation analysis and design, which is the department's primary foundation type for bridge construction.

The NDOT Geotechnical Section plans to implement the work from this project in three primary practices:

(1) Conduct CPT testing when possible alongside traditional drilling exploration, which offers higher resolution information and time/cost savings;
(2) Use the CPILE design software developed from this project for pile bearing capacity design, which may offer more efficient foundation design; and
(3) Verify design CPT based design capacities through regiment of dynamic load testing which the department already conducts, and modify η and θ factors in the Nebraska CPT pile bearing capacity equations accordingly. This process will integrate the new design method and ensure reliable outcomes from the CPT based design.

- *As provided by Mark Lindemann, Lead TAC Member*

NDOT Follow up Implementation based of Research Project- 2021

Since conclusion of this research in 2019, the Department has been conducting CPT testing alongside traditional borings when the soil conditions are conducive to CPT testing. By doing so, we have been able to evaluate the effectiveness of this research project. When inputting the CPT data obtained in the field into the C-PILE program provided by the research and comparing to our traditional programs and methods, the resulting bearing capacity matches well and provides additional confidence to our design. Furthermore, we have collected dynamic load testing data on a handful of projects that were previously investigated with CPT and intend to continue this work to verify/improve the reliability of η and θ factors from the research outcomes. In addition, we can reduce the number of borings for projects when the soil condition allows a CPT to be done. By using the CPT test, the geotechnical section can provide high quality data to the contractor, reduce testing time and operational expenses in the design phase of the project and ensure a cost-effective and high performing foundation design.

- *As provided by Nikolas Glennie, Lead TAC Member*

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This brief summarizes Project SPR-1(18) M076
"CPT-Based Pile Design"
Nebraska Department of Transportation Research Program

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Technology Transfer

Journal Paper

- Chung R. Song, Binyam M. Bekele, Alex Silvey, Mark Lindemann and Lucas Ripa (2020). Piezocone/Cone Penetration Test-Based Pile Capacity Analysis: Calibration, Evaluation, and Implication of Geological Conditions. INTERNATIONAL JOURNAL OF GEOTECHNICAL ENGINEERING https://www.tandfonline.com/doi/full/10.1080/19386362.2020.1778214

Conference Proceedings and Presentations

- Chung R. Song, Gyunam Jin, Binyam, M. Bekele, Brian D. Sawyer and Mark Lindemann (2018), "Fast Estimation of Hydraulic Conductivity for Over consolidated Soils Using Piezocone Results," Student Poster Presentation, GeoOmaha2018

Research Readiness Level (RRL) Assessment

RRL 5

Level 5: Standard Practice/Fully Understood

Research/Technology fully implemented and understood. No follow-up is necessary.