The Ohio Department of Transportation
Office of Research & Development
Executive Summary Report

Evaluation of Cone Penetration Testing (CPT) for Use with Transportation Projects

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Problem

The ODOT Office of Geotechnical Engineering (OGE) currently uses conventional drilling methods (e.g., hollow stem auger, solid stem auger) to perform subsurface investigations in soil. These techniques have been used for decades and have the advantage of a long track record of experience and success within the state. These methods are, however, time-consuming and expensive to perform, do not provide continuous data with depth, and are not well suited to some types of geologic and environmental conditions. Over the last 20 years, cone penetration testing (CPT) has been gaining acceptance in the U.S. and is now often used as an alternative or complementary procedure to conventional drilling in the performance of subsurface investigations. ODOT funded this project to investigate how CPT technology might be utilized to improve the quality and efficiency of ODOT's subsurface investigation program.

Motivation for the project was many fold. The adoption of CPT for ODOT's subsurface investigations is expected to save money through faster collection of data, collection of better and more consistent data, and collection of data that can be used directly in design work. An important upcoming need for ODOT is the mandate to move to Load and Resistance Factor Design (LRFD) methods. CPT data can be used more directly with these methods, which will result in improved designs and savings on construction costs. The routine availability of a CPT machine will complement existing conventional drilling equipment that ODOT currently uses for subsurface investigation. For some projects, CPT will be used to replace conventional drilling. For others, CPT will be used in addition to conventional drilling to provide more accurate and different types of information regarding soil layering and soil properties. For still others, CPT may not be used at all. It is envisioned that CPT will be used for major projects that require more detailed and extensive information about the subsurface. It will also be used to save money on a variety of projects.

Objectives

The objectives of the project were to: 1) evaluate the expected use of CPT in Ohio's geologic setting, 2) determine the requirements of a CPT machine for ODOT, 3) develop specifications for purchase of a CPT machine, 4) purchase the equipment, 5) conduct research testing on Ohio soils to evaluate suitability and usefulness of CPT, and 6) provide training to ODOT for routine use of the CPT machine in their subsurface investigation program.

The work was conducted in two phases. Phase I consisted of a feasibility study to evaluate ODOT needs for subsurface investigation and to determine how CPT could be used to improve and expand current investigation methods. Detailed specifications for purchase were also provided as part of Phase I. Phase II consisted of purchasing, research testing, and training for all CPT equipment, including quality assurance/quality control (QA/QC) procedures and methods for data transfer and analysis. Research testing was conducted to determine whether or not published CPT correlations for soil properties would be reliable for soil types commonly encountered in Ohio.

Description

The objectives of the project were achieved by completing the following tasks: 1) definition of CPT requirements, 2) initial vendor screening, 3) determination of vendor short list, 4) visit to manufacturing facilities, 5) compilation of CPT vendor matrix, 6) interviews with CPT equipment owners, 7) solicitation and evaluation of quotes for similar CPT equipment, 8) specification and ordering of equipment, 9) on site performance evaluation of equipment, 10) conducting CPT on a wide variety of Ohio soils, 11) side-by-side correlation of test data from CPT and conventional site investigation methods, and 12) conducting training sessions for ODOT personnel on CPT equipment and the routine use of CPT in their subsurface investigation program.

The CPT research program consisted of 106 soundings taken for 20 projects across the state. The combined (i.e., cumulative) depth of CPT work completed for all 20 projects was 1291 m. From these soundings, 383 CPT data points were extracted and compared with conventional test data. Not every soil property correlation has 383 data points because a similar quantity of laboratory or field data was not available for comparison in most cases.

Conclusions & Recommendations

Phase I

The following conclusions are reached as a result of a thorough investigation of vendors for possible purchase of CPT equipment for the ODOT subsurface investigation program:

- Based on experiences of several state DOTs and private consultants, CPT is expected to significantly expand the capabilities of current ODOT subsurface investigation methods. In addition, the speed at which CPT can be conducted relative to conventional drilling is expected to save significant time and money for ODOT transportation projects.
- Of the five manufacturers originally considered, equipment was specified for purchase from A. P. van den Berg of Heerenveen, the Netherlands. A. P. van den Berg makes excellent quality equipment and has industry-leading technology.
- A crawler-type CPT machine was specified with the capability for the following measurements: tip resistance, sleeve resistance, inclination, pore pressure, and shear wave velocity.

Phase II

The CPT machine is a very useful tool for ODOT subsurface exploration work and is expected to provide considerable cost savings over the long term. As with any new technology, time is needed to develop the skills necessary to efficiently perform CPT investigations and utilize the results to maximum advantage. It is expected that once ODOT engineers and geologists become familiar with its capabilities, CPT will become an important tool for ODOT going forward.

Certain steps are needed to maximize the usefulness of CPT for ODOT. In general, the research data show good correlations with site stratigraphy but not with soil properties. Possible reasons for this lack of success are:

- Complex stratigraphy, such as in parts of Ohio, produce high lateral and vertical

variability of soil deposits. Such lateral variation can invalidate correlations between side-by-side conventional boreholes and CPT soundings. Such vertical variation can alter CPT measurements due to the influence of soil layer boundaries.

- Many published correlations, which show less variability, were developed based on research with laboratory calibration chambers and hence reflect closely controlled soil conditions.
- Thin layers of material that appear in a CPT sounding profile may have been missed in a boring log.
- A larger data set is needed for many soil types and soil properties for the associated correlations to be statistically significant.
- Many variables that can affect conventional soil sampling and testing can introduce additional variability into the correlations.

Efforts to continue the CPT research program will augment the current database and help to bring clarity to these issues. CPT is best used in sands, silts and clays. Gravels present risk to the equipment and should be avoided if possible.

Research work needs to be continued to best identify uses of CPT data for Ohio transportation projects. In order to build the correlation database, conventional drilling and laboratory testing should be conducted near CPT soundings wherever possible. Additional testing and correlation work is needed for every soil type in Ohio. In particular, more laboratory test results are needed for unit weight, preconsolidation stress, permeability, coefficient of consolidation, effective stress shear strength parameters, and undrained shear strength. Offset boreholes for comparison and correlation should be located within 5-10 ft. of a CPT sounding.

A possible explanation for the lack of success reflected in the current soil property correlations is that they were prepared using the Ohio soil classification system as a basis, which was developed for pavement subgrade applications. It is recommended that ODOT consider using the Unified Soil Classification System (USCS) as a basis for future CPT correlation studies. This is consistent with many previous similar studies that have been based on the USCS.

Implementation Potential

The findings of this project represent a first step toward the routine use of CPT by ODOT for subsurface investigations. Based on the results of this study, ODOT will continue forward with further use of CPT for appropriate applications and will continue to develop the CPT database to improve the existing correlations for soil properties in Ohio.