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IMPLEMENTATION SUMMARY

Technical Liaison:
Derrick Dasenbrock, MnDOT
Derrick.Dasenbrock@state.mn.us

Project Coordinator:
Kirsten Seeber, MnDOT
Kirsten.Seeber@state.mn.us

Principal Investigator:
David Saftner,
University of Minnesota Duluth

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$100,000

Cone penetration testing can be conducted safely from inside a truck container alongside a highway.

Putting Research into Practice: Guide for Using CPT in Geotechnical Design

A new geotechnical design guide uses cone penetration testing to characterize soils and foundation needs. A supplement to the agency's geotechnical design manual, this resource will provide improved methods for using CPT data in geotechnical design.

What Was the Need?

Designs for new bridges and structures require geotechnical investigation of a site's soil conditions to evaluate the strength, settlement and drainage of a proposed foundation. Common design procedures rely on boring samples from the site and on standard penetration tests (SPT), which entail driving a weighted steel rod into the soil and recording the number of blows it takes to drive the rod a specified distance. Using lab analysis of samples and on-site tests, engineers determine foundation properties for the new design.

The cone penetration test (CPT) has become an attractive alternative to the SPT. CPT employs a probe with a cone-shaped tip outfitted internally with various sensors. Equipment in a CPT truck pushes the probe into the soil at the site; engineers attach rod sections behind the probe to continue pushing it in the soil to the desired investigation depth, which is usually 30 to 150 feet for transportation projects. Standard sensors allow the CPT to directly measure tip stress, pore water pressure and soil resistance; other parameters can be measured with additional sensors.

The CPT safely and efficiently produces accurate data and repeatable results, yet relatively few engineers in the United States know how to employ these tests and use the data for geotechnical design inputs. Users can search geotechnical engineering resources to learn how CPT results can be applied, but no standard procedure or manual is widely available for transportation projects.

What Was Our Goal?

Investigators sought to develop a new CPT design guide based on the most current CPT in situ testing research and development. The guide is intended for use in evaluating the performance of proposed bridges and structures, embankments and roadway features.

What Did We Implement?

The research team produced the 2018 CPT Design Guide for State Geotechnical Engineers, with step-by-step instructions for using the CPT to evaluate soil properties at sites and to design shallow footings and deep foundations. The document provides an overview of the CPT, its use in analyzing and characterizing soils, background on computing engineering parameters derived from CPT measurements, and detailed procedures for using those parameters to design and analyze shallow and deep foundations. Also included are derivation background, case studies and examples to help guide the user through the design process.

How Did We Do It?

Investigators began by reviewing guidelines for geotechnical engineering design based on CPT methods. The research team identified the key soil properties measurable by the CPT that are required for designing shallow and deep foundations. Then team members evaluated numerous CPT-based methods used for shallow foundations and over 40 used

continued

"One of the biggest impediments to deploying cone penetration testing more widely has been the lack of a practical document that integrates the latest findings and best approaches, and puts that information to use."

—Derrick Dasenbrock,
Geomechanics/LRFD Engineer, MnDOT Office of Materials and Road Research

"Engineers can start using this design guide immediately in Minnesota—and elsewhere. The format is adaptable; California could add another module about earthquakes, for instance."

—David Saftner,
Associate Professor, University of Minnesota Duluth Department of Civil Engineering

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Minnesota Department
of Transportation
Research Services & Library
MS 330, First Floor
395 John Ireland Blvd.
St. Paul, MN 55155-1899
651-366-3780
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One operator can investigate soil and foundation conditions with a sophisticated CPT vehicle, even at a highway washout.

for deep foundations. Using the results of this evaluation, investigators identified methods with sufficiently robust and reliable performance that could be easily implemented by design engineers.

The team used CPT data from MnDOT geotechnical site investigations and developed short design case studies applying the recommended CPT design methods. After reviewing the CPT procedures with the Technical Advisory Panel, investigators organized design modules for soil characterization, shallow foundations and deep foundations, and documented the process in the design guide.

What Was the Impact?

The new guide is based on the current best practices for the CPT and was developed to establish MnDOT's geotechnical design process while accommodating ongoing research. The guide presents recommended design methods and offers step-by-step instruction on how to calculate engineering parameters from CPT measurements and apply those design inputs to efficiently design foundation systems. Examples of problems and solutions are provided in the context of Minnesota cases, although the techniques are broadly applicable.

The guide begins with a focus on characterizing soil properties from CPT measurements, providing an example for both sand and clay soils. The shallow foundation design module describes how to determine strength and soil settlement characteristics from CPT sensor readings using a method based on 166 full-scale field load tests. The deep foundation design module explains how to use the CPT to determine the required axial compression capacity of piling from a method based on 330 pile load tests.

What's Next?

The guide is a much-needed resource for geotechnical engineers both within MnDOT and outside of the agency. The improved methods for using CPT data will encourage more frequent and widespread use of the method, improving the quality and reducing the time and cost of site investigations.

Available on MnDOT's Geotechnical Engineering website as a supplement to the 2019 revision to the Geotechnical Engineering Manual, the guide will also be shared with a Federal Highway Administration CPT users group. Future considerations for the guide include a module on characterizing peat in organic soils and on seismic soil analysis.

This Implementation Summary pertains to Report 2018-32, "Cone Penetration Test Design Guide for State Geotechnical Engineers," published November 2018. The full report can be accessed at http://mndot.gov/research/reports/2018/201832.pdf.