PUTTING RESEARCH TO WORK **BRIEF**

Exploring the Cone Penetration Test: Faster and Cheaper?

Before building bridges, retaining walls and other structures requiring deep foundations, engineers must conduct a sub-surface investigation to determine if the soil has adequate strength to support these structures. Soil boring with a drill rig and Shelby tube is a common method for determining the variation of soil properties at different depths, with collected soil being characterized by standard laboratory methods. In cases where such sampling is problematic due to access or space limitations, DOTs often use the Standard Penetration Test, or SPT, in which the number of hammer blows required to drive a tube into the ground is taken as a measure of soil density. The SPT also collects soil boring samples for further laboratory testing if necessary.

While both conventional soil borings and the SPT are simple and inexpensive tests to perform on site, they only provide an approximation of soil strength and other properties. A more accurate field method is the cone penetration test, or CPT, in which a cylindrical probe with a cone-shaped tip—called a cone penetrometer—is pushed deep into the ground at a rate of 1 to 2 centimeters a second. Sensors in the cone continuously measure three parameters—cone tip resistance, sleeve friction and penetration pore pressure at the cone shoulder—displaying the values in real time on a field computer.

What's the Problem?

Despite its usefulness, few state DOTs consistently use the CPT on their projects, typically because it requires expertise to use the equipment and interpret the results, and because the probe can have difficulty penetrating hard and gravelly soils. One exception is Minnesota DOT, which makes frequent use of the CPT, in soils similar to those found in Wisconsin, suggesting that the test may also be a viable option for WisDOT.

Research Objectives

This project was undertaken to identify the advantages and limitations of the CPT device, its applicability to Wisconsin's geology and the correlation of its output to current WisDOT practice. The device would be used at various locations around the state, with results compared to data obtained both from current drilling methods and from previous CPT projects.

Methodology

Researchers began by conducting a literature search on the interpretation of CPT results, and compiling and analyzing a database of CPT measurements from past projects in Wisconsin and other states.

Researchers then performed 61 cone penetration tests at 14 sites in Wisconsin in order to evaluate a range of soil types typically encountered in foundations engineering projects in the state. Site selection was also determined by accessibility to CPT equipment and proximity to sites with existing boring data. For each test, the cone penetrometer was advanced into the ground until it reached the point where continuing to advance it was no longer possible and might lead to equipment damage. At four locations, researchers also used the SPT to take boring samples.

Researchers organized the resulting data, along with data from previous SPT and CPT projects, within a Geographic Information System that allowed the overlaying of aerial photographs, topographic maps, surface geologic maps and test locations. They then analyzed the results, comparing CPT data to SPT data and evaluated the cost-effectiveness of the CPT.

Results

Field results reinforced existing data to suggest that the CPT can be used successfully in Wisconsin soils, with tests in this study frequently achieving penetration depths of greater than 75 feet. The CPT

Investigator

"This study showed that the cone penetration test can be used to collect a higher volume of data more reliably and quickly than current methods, and may also lead to cost savings."

—James Schneider
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Researchers used this 24-ton CPT truck from the University of Wisconsin–Madison to perform cone penetration testing at sites around the state. The modified truck transports the test equipment and powers the hydraulic system that jacks up the truck and pushes the cone into the ground.

produces more reliable data more quickly than the current use of the SPT for drilling, sampling and lab testing. It also produces a high volume of data, enhancing the ability to assess uncertainties and variability in soil conditions at a given site.

The CPT may fail to penetrate the ground adequately if gravel or cobbles are present. However, these disadvantages have been overcome by MnDOT and local CPT contractors working on the Marquette and Mitchell interchanges in Wisconsin, where the penetrometer reached a maximum depth of 92 feet. MnDOT's experience also suggests that successful use of the CPT by WisDOT will require further review and refinement of methods.

Benefits and Implementation

WisDOT plans to use the CPT on transportation projects in Wisconsin as a complement to SPT drilling, which will help reduce the total amount of time required for soil testing. Researchers recommend that the cone penetration tests be conducted a week or two before drilling so that the scope of drilling can be expanded if the CPT is not successful. High-quality boring samples should then be taken adjacent to cone penetration test sites, with targeted sampling of critical and representative layers rather than sampling at standard intervals.

Further Research

Researchers recommend modifications of SPT sampling and laboratory testing procedures for WisDOT projects to improve consistency between laboratory and field results. This consistency is critical to achieving cost savings using the CPT. WisDOT also plans to continue to track CPT use in other states, and will participate in the FHWA CPT Users Group.

This brief summarizes Project 0092-10-10, "Cone Penetrometer Comparison Testing," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research Program, 4802 Sheboygan Ave., Madison, WI 53707.

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"This technology is useful for determining variations in soil properties at different depths, which is critical for understanding the soil's ability to support structures."

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