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LRRB
LOCAL ROAD RESEARCH BOARD

TECHNICAL SUMMARY

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PROJECT COST:
$55,000

Bender elements are thin pieces of piezo-ceramic material that can be used to measure seismic wave velocities.

RESEARCH SERVICES SECTION

Can Cone Penetration Testing Measure the Resilient Modulus of Soils?

What Was the Need?

The Cone Penetration Test is becoming an increasingly popular exploration tool among geotechnical engineers. CPT is used to estimate the material properties, such as stiffness and strength, of subgrade soil. Engineers have traditionally used the Standard Penetration Test for estimating these properties, but CPT is faster, less labor-intensive and more accurate than traditional methods. CPT also produces a continuous digital data record, enabling analysis in real time.

Mn/DOT has used CPT for several years, but has had difficulty using it to distinguish soft clays, sensitive soils and organic rich soils. In addition, while previous studies have correlated CPT data to multiple soil properties, including friction angle, shear strength and soil type, there was little research correlating CPT measurements to resilient modulus—the laboratory measure of soil stiffness widely considered to be the best available predictor of pavement performance. Resilient modulus is included in the recent *AASHTO Mechanistic-Empirical Pavement Design Guide*. However, current modulus tests are considered too time-consuming and costly to conduct for every roadway design. Consequently, correlations from other tests are used to predict laboratory-resilient modulus values.

Mn/DOT would like to correlate on-site CPT testing with resilient modulus values without the need to test samples in the laboratory. This goal requires calibrating CPT by comparing its measurements to the known resilient modulus values of soil samples surrounding the site of CPT testing. Research was needed to assess the accuracy of CPT predictions of resilient modulus for various soil types. Highly organic soils, in particular, may necessitate significantly different engineering designs, and misidentifying such soils can lead to large design and construction cost overruns.

What Was Our Goal?

The objective of this project was to further the use of cone penetration testing for pavement applications by examining the feasibility of using CPT data to estimate resilient modulus and to identify highly organic soils.

What Did We Do?

This study consisted of two experiments. The first involved a statistical analysis to test the feasibility of correlating CPT measurements with resilient modulus and other test results from undistributed soil samples taken immediately adjacent to the CPT test locations.

In the second experiment, researchers attempted to develop a model to assist in identifying soils with problematic organic content. They used MatLAB statistical software to analyze and compare existing CPT soundings and the boring results. This analysis compared the feasibility of two model types:

- A model based on a discriminate analysis, in which the primary goal was to define a threshold dividing those soils of organic content greater than 10 percent from those with less than 10 percent.
- A model based upon a regression, in which the goal was to predict the actual organic content of any soil, and consequently whether or not the soil is above the problematic organic content threshold of 10 percent.

continued

"This study paves the way for future research into using CPT to measure resilient modulus and organic soil content. Expanding the primary data set in statistical models will help achieve this goal."

–Joseph F. Labuz,
Professor, University of Minnesota Department of Civil Engineering

"This report did not establish a link between resilient modulus and CPT test results. Many problems must still be overcome before CPT measurements can aid pavement design."

–Bruce A. Chadbourn,
Mn/DOT Assistant Pavement Design Engineer

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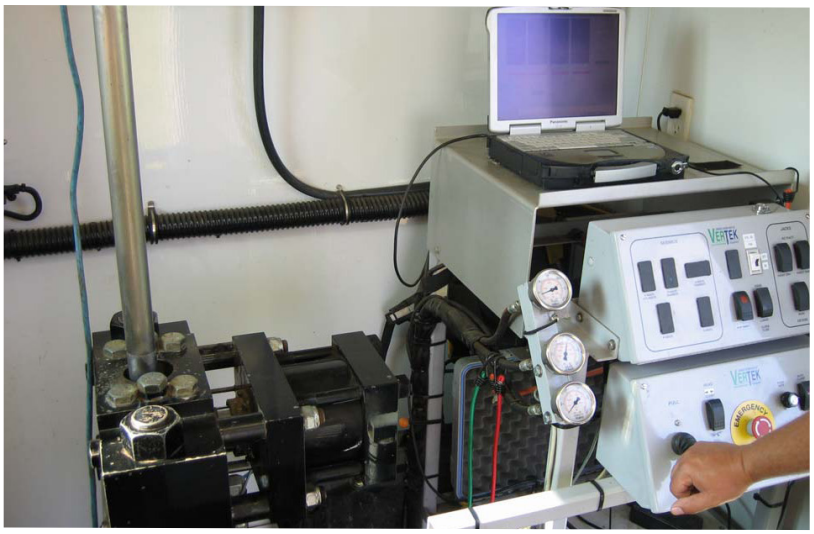

The CPT data acquisition system consisted of a personal computer program that records data in real time in one-second increments. CPT is monitored in real time to help avoid damaging the cone during advancement into hard layers.

What Did We Learn?

Results from the first experiment showed that the statistical analysis model used by researchers was not sufficient to allow the use of CPT to measure resilient modulus in the field. However, researchers found that a simple method for predicting resilient modulus through bender element seismic testing appears to be well-grounded in existing research and a promising form of laboratory testing.

In the second experiment, the model developed using a discriminate analysis was more accurate than the model developed using regression. However, the discriminate analysis model was not sufficient to allow CPT to be used in practice for identifying highly organic soils. This model generally underestimated organic content, identifying all soils as having organic contents of less than 10 percent, when in fact 43 percent of soils had an organic content of higher than 10 percent.

What's Next?

While further research is required for the use of CPT to measure resilient modulus in the field, this study provides groundwork for making better use of CPT in geotechnical and pavement engineering. Priorities for further research for statistically modeling the organic content of soils include expanding the size of the primary data set and using new parameters, including soil shear wave velocity and rate of pore water pressure dissipation.

This Technical Summary pertains to the LRRB-produced Report 2007-36, "Cone Penetration Testing in Pavement Design," published September 2007. The full report can be accessed at http://www.lrrb.org/PDF/200736.pdf.