Summary of Final Report, BC354-10
September 2003

DESIGN, CONSTRUCTION, AND EVALUATION OF A DUAL TIP PENETROMETER

PROBLEM STATEMENT

One of the more challenging types of soil for geotechnical engineers to deal with is cemented sands. While cementation can improve the static strength of sands, such strength gain is tenuous at best, since the energy imparted into a cemented soil mass (e.g., via pile driving, blasting or earthquake) can sever the interstitial bonds and result in a weakened soil mass. Indeed, the failure to correctly account for the presence of cemented sands can lead to unconservative foundation designs. Consequently, identifying cementation and degree of cementation is very important to designers who must weigh such effects in their design calculations. However, to date, the ability to determine whether subsurface soils contain cemented sands has proven elusive.

There are many insitu tests available to the foundation engineer; however, none can simultaneously identify sand cementation and quantify the degree of cementation. While the standard penetration test (SPT) can identify cementation via visual observation, the disturbed sample obtained from the SPT cannot be used for strength analyses. Likewise, standard cone penetrometer test (CPT) soundings may misinterpret highly cemented loose sand simply as very dense material.

OBJECTIVES

The goal of this research was to develop an insitu method for providing a reliable indicator of cemented sands, by exploring ways to adapt the electric cone penetrometer to more accurately read and manage the characteristics of cemented sand. Specific objectives included the following:

1. Design and build a modified cone penetrometer.
2. Verify that the designed device can operate in different soil types, especially cemented sands.
3. Test the device for the capability to simultaneously identify cemented sands and predict the tip capacity of a pile in cemented sand.

FINDINGS AND CONCLUSIONS

The Dual Tip Penetrometer (DTP) is the device that was designed to measure the broken-bond cemented sand bearing resistance. The DTP is similar to the standard electronic cone penetration test except for an additional bearing annulus located just above the friction sleeve. The annulus is a floating member that measures upward bearing resistance after the passage of the first tip. Since the annulus has the same 60° slope and bearing area (10 cm^2) as the first tip, the conjecture was that the first tip (T1) would break down the cementation bonds while the second tip (T2) would measure the residual or broken up bearing resistance. The difference in the two tip readings would indicate the degree of strength reduction.

In order to verify its operation, a calibration chamber was set up for testing the DTP in clean fine sand and artificially cemented sand. In addition to the calibration chamber tests, field tests were performed and compared with standard cone penetration tests conducted at the same locations. The Dual Tip Penetrometer and Cone Penetrometer were then used at the West Bay Bridge in West Bay, Florida, where driven pile data were available. The DTP results were employed in an attempt to predict pile capacities for the dynamically loaded test piles. These comparisons were compared with the capacities determined from Pile Driving Analysis data.

A preliminary chart, developed to identify cemented sands, is provided below. It is based on the DTP soil criteria for gravelly cemented sands:

$0.7 < T2/T1 < 2.1$
$0.2\% < FR < 1.5\%$
$5.0 < T1 < 35$ MPa

The degree of cementation appears to increase with increasing T1 bearing, and, more importantly, the wavelength of the sounding (the number of oscillations of a sounding profile for a given increment of depth) appears to be positively correlated to the presence of cemented sand. These observations are consistent among the numerous tests performed and bode well for the utilization of the DTP for foundation designs in cemented sands.

BENEFITS

The DTP is the first insitu device capable of investigating the cemented sand phenomena. As more data become available, FDOT will be able to use the results as input data to updated pile design software. Ultimately, insitu data acquired with this device should result in both cost savings as well as more efficient foundation designs by reducing the uncertainty associated with cemented sands.

This research was conducted by David Bloomquist, Ph.D., P.E., of the University of Florida. For more information, contact Peter Lai, at (850) 414-4306, peter.lai@dot.state.fl.us.