*Summary of Final Report,* BC354-08
October 2003

# STATIC AND DYNAMIC FIELD TESTING OF DRILLED SHAFTS

## PROBLEM STATEMENT

The use of drilled shafts in foundations on waterway bridge crossings has seen a dramatic increase over the past twenty years. Constructed with diameters exceeding eight feet, drilled shafts are capable of resisting significant lateral loading (i.e., wind, ship impact, etc.) without submerged pile/shaft caps or large groups of piles. Generally, to validate shaft design and construction, either static bottom up (Osterberg) or top down dynamic (Statnamic) testing is performed. Currently, there are no suggested guidelines for the number of shaft field tests, nor is there available information comparing skin and tip resistance based on Osterberg and Statnamic tests.

## OBJECTIVES

The main objectives of this project were to (1) compare measured skin friction and end bearing from both Osterberg and Statnamic tests, and (2) develop a benefit vs. risk assessment for field testing (Osterberg & Statnamic) drilled shafts. Other goals of the research were to (1) validate current FDOT shaft design (skin friction) and quantify site spatial variability; and (2) evaluate/determine a shaft tip resistance model for Florida Limestone. To accomplish these objectives, the following work was carried out:

- Collect design (loads, etc.), geotechnical (insitu, laboratory, load test), and construction (pay items, as built, etc.) information on major bridge projects using drilled shaft foundations in past five to ten years in Florida;
- Reduce all the Osterberg and Statnamic Field Tests to obtain unit skin friction and end bearing at each site as well as the strengths (qu and qt) and stiffness (Modulus) data for the rock near each shaft;
- Develop Load Resistant Factor Design (LRFD) Resistance Factors and Allowable Stress Design (ASD) Safety Factors for different reliability (or risk) values from a comparison of measured to predicted skin and tip resistance;
- From both pay items and itemized cost records, for Osterberg and Statnamic records, develop a benefit cost vs. risk assessment of field-testing.

## FINDINGS AND CONCLUSIONS

The design, geotechnical, and construction information from eleven major FDOT bridge sites involving drilled shaft foundations and field load tests was collected and analyzed. Based on 27 Osterberg and 11 Statnamic field tests, researchers found that the measured Osterberg and

Statnamic shaft capacities did not differ by more than the site variability. In addition, the measured and predicted (FDOT) unit skin friction for the limestone compared favorably as represented by the proposed LRFD resistance factors, $\phi$, and ASD factors of safety. Also, the average unit skin friction variability over a site for a shaft was successfully characterized through the laboratory strength data. An end bearing analysis with associated LRFD resistance factors, $\phi$, was developed.

This study determined both the cost of performing load testing and the overall impact (in terms of time) that such testing has on construction. Using the construction information, researchers found that the typical cost of an Osterberg or a Statnamic test varied from $100,000 to $120,000 (in 2003 dollars), depending on shaft size, with a typical test requiring two days to complete.

Researchers determined that generating a cost (deep foundation) vs. reliability (or risk) plot for a site would assist design engineers in assessing quantities of field load testing and in comparing different foundation types (i.e., drilled shafts, driven piles, etc.). Based on the steepness of the plot, and on the cost of field load tests ($100,000 to $120,000), an estimate of field load testing may be assessed along with acceptable risk or reliability. Based on the end bearing analysis developed, the benefit/cost plot can be modified to include both skin friction and end bearing analyses.

## BENEFITS

*Plot of Foundation Cost Vs. Reliability* identifies significant differences in foundation costs if different ASD FS (Factor of Safety) or LRFD $\phi$ are used in design. This approach, therefore, may be used to estimate the number of field load tests during the design phase by comparing alternate foundation types (i.e. piles vs. shafts) during design. This process, with guidelines for load testing, should result in significant savings for drilled shaft installation.

This research project was conducted by Michael C. McVay, Ph.D., at the University of Florida. For more information, contact Sastry Putcha, Ph.D., P.E., Project Manager, at (850) 414 4148, sastry.putcha@dot.state.fl.us