*Summary of Final Report, BC354-42*
March 2003

# CALIBRATING RESISTANCE FACTORS FOR LOAD AND RESISTANCE FACTOR DESIGN FOR STATNAMIC LOAD TESTING

## PROBLEM STATEMENT

As a result of cost and lateral load considerations (i.e. ship impact, hurricanes, etc.), the use of larger and fewer foundation elements is becoming the norm on navigable waterways in Florida. Unfortunately, conventional top down static load testing to validate design/construction is generally limited to 1000-ton capacity (size of elements, cost, etc.). As an alternative, in the early 1980s, Berminghammer Foundation Equipment developed the Statnamic device with a 7500-ton capacity. Because of its large load capacity and quick and easy mobilization, the device has become a viable alternative to the conventional top down test. Initially accepted as a quasi-static test, it became evident that dynamic forces (inertia, damping) were present and had to be accounted for (Unloading Point Method). In addition, the LRFD resistance factors, $\phi$, needed to be established to use the test in design.

## OBJECTIVES

The objectives of this research included the following:

1. Collect a database of Statnamic and conventional load test results on driven piles and drilled shafts in different soil and rock conditions. The data was to be separated by geologic formation and foundation type.

2. Review and evaluate available methods for determining static load deformation response from Statnamic results. The latter was to include Unloading Point Method and Segmental Unloading Point Method.

3. Perform Numerical Simulations (LSDYNA) of the Statnamic Test to identify the influence of rate of loading, and magnitude of dynamic loading on the computed static resistance.

4. Develop LRFD resistance factors**,** $\phi$, for computed Statnamic capacities for different foundation types in different geologic formations (i.e. soil and rock).

## FINDINGS AND CONCLUSIONS

A database of thirty-seven drilled shafts and piles from around the world were recovered along with soil and rock information, which were added to FDOT database. Of the thirty-seven tests, twenty-nine were in predominately cohesionless soils and eight were in cohesive (clays) soils. For the twenty-nine (29) cases in cohesionless soils, seventeen (17) were for driven piles and twelve (12) were for drilled shafts. Due to the size of the database, it was decided to separate the LRFD resistance factor determination into the following groupings: (1) driven piles in rock and noncohesive soils; (2) drilled shafts in rock and noncohesive soils; and (3) driven piles or drilled shafts in sands-clays-rocks mixed layers. Based on the database and probabilistic approach, that is, FOSM (First Order Second Moment, FHWA), the recommended resistance factors for the Statnamic load test for deep foundations are as follows:

1. Resistance factor ($\phi$) for driven piles in rocks and noncohesive soils = 0.70
2. Resistance factor ($\phi$) for drilled shafts in rocks and noncohesive soils = 0.65
3. Resistance factor ($\phi$) for driven piles or drilled shaft in sands-clays-rocks mixed layers = 0.60

However, if drilled shafts or driven piles are embedded primarily in clays, the Statnamic load test is not recommended unless the conventional static load test is also performed for calibration purposes. It should be noted that these resistance factors were calibrated using the rate factors identified by Mullins (2002).

Numerical analysis of the Statnamic test applied to a drilled shaft founded in silty sand (no water) under varying load durations (80 to 240 milliseconds) revealed little if any difference in the predicted static capacity when back-computed from the Unloading Point Method. Varying the magnitude of dynamic load (1 to 25 MN) under the same duration of loading showed little if any difference in the back-computed static capacity up to and including 12.5 MN. However, in the case of 25 MN with high unit skin friction (i.e., rock: 7.5 tsf or 725 kPa), the UPM back-computed static resistance was higher. For the latter, either more inertia mass (i.e., not just the shaft, but adjacent soil-rock material) or damping was required in the UPM analysis.

## BENEFITS

The research has shown that Statnamic load testing is a viable and cost effective replacement for conventional top down load tests for piles and shafts. The effort developed LRFD resistance factors, $\phi$, for both piles and shafts founded in soil and rock for design. The data (37 cases) is available for further improvements in current shaft/pile design methods (i.e. SPT 97, etc.). It is recommended that the FDOT continue to collect data on Statnamic results to refine the LRFD assessment of resistance factors, especially for cohesive soils.

This research project was conducted by Michael C. McVay, Ph.D., at the Department of Civil and Coastal Engineering, University of Florida. For more information, contact Peter Lai, Project manager, at (850) 414 4306, or peter.lai@dot.state.fl.us