DETERMINATION OF AXIAL PILE CAPACITY OF LARGE DIAMETER STEEL AND PRESTRESSED CONCRETE CYLINDER PILES

PROBLEM STATEMENT

Large diameter cylinder piles offer an alternative to drilled foundations to support waterway bridge crossings in Florida. Specifically, because they are driven, cylinder piles are capable of mobilizing higher skin and tip resistance than comparably sized drilled shafts in Florida soils. Unfortunately, current design employs unit skin friction based on solid concrete piles and end bearing values based on small diameter steel pipe pile theory. Moreover, with little or no information on designing such piles and uncertain information on the soil-plug phenomenon that affects the pile tip resistance, current design employs large safety factors, which result in both longer piles and more piles than necessary.

OBJECTIVES

The purpose of this project was threefold: (1) develop and validate axial unit skin friction and end bearing resistance vs. SPT Blow Count, "N" for large diameter concrete and steel cylinder piles; (2) in the case of end bearing, identify whether ring area or total cross-sectional area is to be used; and (3) develop LRFD resistance factors and ASD factors of safety to be used in design. To accomplish the objectives, the following work was carried out:

- collect load testing information (i.e. static load tests), geotechnical information (insitu, laboratory, etc.) on large diameter cylinder piles which occurred over the past five to ten years in the United States (e.g., Florida, California, Virginia)
- reduce the load-test information to obtain unit skin friction and end bearing at each site, as well as a function of soil type and SPT "N" values
- determine whether large diameter cylinder piles should use ring area or total cross-sectional area for assessing static tip resistance
- develop LRFD Resistance Factors and ASD Safety Factors for different reliability (or risk) from a comparison of measured to predicted skin and tip resistance values

FINDINGS AND CONCLUSIONS

A total of 35 static load tests on cylinder piles with diameters ranging from 36" to 84" (most common 54") were collected from the Florida, California, Virginia, and Maryland DOTs and/or their consultants. Approximately 22 of piles were concrete and 13 were steel pipes. Each test case involved a conventional top down static load test, with load and deformation measured at the top. A few (9) were instrumented with strain gauges along their length. The piles were embedded in sand, silts, and clay soils. Twenty-one of the static load tests reached Davisson's failure capacity.

Using the database of piles, equations of unit skin friction and end bearing vs. SPT N values were developed for large diameter steel and prestressed concrete cylinder piles. For those piles that didn't have strain gauges to differentiate skin from tip resistance, DeBeer's method of plotting load vs. displacement on log-log plot was used to differentiate skin from tip resistance. A comparison of DeBeer's approach with the 9-instrumented cases was quite acceptable.

In determining end bearing, the use of the pile's cross-sectional pipe area or total cross-sectional area (i.e. $\pi(D_o^2 - D_i^2)/4$ vs. $\pi D_o^2/4$) was studied. Researchers found that under driving conditions, large open-ended piles tended to "cookie cut" and not "plug." The major cause was attributed to the inability of the unit skin friction on the inside of the pile to overcome the inertia force acting on the soil column within the pile. However, FEM studies on static or slow rates of loading (i.e., no inertia forces) suggested that under static loading the piles behaved like plugged piles—although somewhat differently than fully plugged piles.

Consequently, resistance factors, ϕ, and ASD Factors of Safety were developed for both "plugged" (ϕ= 0.61) and "unplugged" (ϕ= 0.76) scenarios. The lower resistance factors in the case of the plugged pile, i.e. LRFD resistance of 0.61vs. 0.76 for unplugged, is due to the higher end bearing computed in the plugged scenario.

BENEFITS

This study developed both unit skin friction and end-bearing resistance values for large diameter steel and concrete cylinder piles from insitu SPT values in various soil types. In addition, LRFD resistance factors, ϕ, and ASD factors of safety were established for the piles in Florida. The latter design curves, and LRFD resistance and ASD safety factors, will be incorporated into FB-Deep (SPT97) software for use by consultants. The design curves will result in more cost effective designs (i.e., cylinder piles vs. drilled shafts) and comparable foundation reliability with respect to the superstructure.

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