Piling Industry Canada

PIC magazine 2010

Cover photo courtesy of ICE

PUBLICATIONS MAIL AGREEMENT #40934510

Helical Pile Load Tests Made Simple

FIRST OSTERBERG CELL LOAD TEST PERFORMED ON A HELICAL PILE

BY DENTON A. KORT, P.E., OF LOADTEST, INC.,
TOM BRADKA, M.ENG., P.ENG.,
AND ALVIN PYKE P.ENG. OF HELICAL PIER SYSTEMS

As industry experts know, full-scale static load testing is a key element in confirming design parameters, minimizing risk and optimizing deep foundations. And Osterberg cell (O-cell®) bi-directional load testing has become the premier method for carrying out those tests. This risk-mitigation methodology has now been extended into a new arena. Late in 2009, Helical Pier Systems Ltd. (HPS) and LOADTEST Inc. (LTI) performed the world's first O-cell load test on a helical pile. This application of O-cell technology to helical piles reduces uncertainty and improves confidence in these foundations for a fraction of the cost and time required by conventional testing methods.

HELICAL PILES DEFINED

Helical piles, also known as screw piles, consist of one or more circular helical plates welded to either a steel cylindrical pipe or square steel shaft (Figures 1 and 2). The piles are advanced into the ground using a hydraulic torque motor, often mounted to a loader or other type of mobile construction machinery. Helical piles can be installed quickly and with minimal impact to the environment in any climate. The operation results in low installation noise, no vibrations, and no cuttings to excavate or remove. In addition to being simple to install, helical piles can be removed just as easily.

Standard round shaft diameters range from 73 millimetres to 405 millimetres in diameter with helix diameter sizes up to 1,015 millimetres. Single or multiple helix piles can be custom designed to any length within the safe and practical limits of the material. The simple design and installation makes helical piles versatile and economical for many different types of structures, both permanent as well as temporary. Due to the minimal invasiveness of the installation procedure, helical piles are also uniquely suited for underpinning and other remedial foundation support.

As with all deep foundation types, the helical pile design process addresses various sources of uncertainty. These uncertainties include estimation of loads, variability of ground conditions, geotechnical material properties, and prediction of the behavior of the superstructure, substructure and the soil that supports it. Closed form design philosophies based on limit state design or allowable (working) stress design incorporate safety factors that are intended to account for uncertainties and minimize risk. However, an acceptable safety factor applied to estimated resistances hardly ensures a safe design. Full-scale load testing is the only accurate method of verifying design assumptions, determining ultimate load carrying capacity and predicting the load-settlement behavior of a pile, thus enabling a true assessment of "safety". Even when incorporating static load tests, some design assumptions particular to helical piles, namely the resistances developed from the shaft versus that from the helix, are not addressed by traditional testing methods.


Figure 1


Figure 2

STATIC LOAD TESTS, THEN AND NOW

Historically, static load tests are performed on helical piles using traditional means. Conventional static pile load tests utilize a fixed reaction system and a jack to apply load to the pile head. The reaction system usually consists of a load beam connected to reaction piles or dead weights, where space and safety permit

(Figure 3). Displacements and/or strains are then recorded as load is increased. Typically, the test yields a load versus head displacement relationship and little else. These conventional static tests were the norm for nearly all deep foundations until the early 1990s when a new method of static load testing was introduced.


Figure 3

The Osterberg cell (O-Cell) bi-directional testing method enabled relatively low-cost, high-capacity static load testing of bored piles that were otherwise prohibitively expensive or technically impractical. The genius behind the innovation is a specially designed hydraulic jack (O-cell assembly) cast directly into the pile at a predetermined location (Figure 4). After curing or set-up, the O-cell is hydraulically pressurized from the surface, simultaneously loading the pile section above the O-cell and the pile section below it. By loading the pile internally, the pile component above the O-cell acts as reaction for loading the pile component below the O-cell, and vice-versa. As the load is applied during testing, electronic sensors measure the displacement of both pile sections. In this way, the O-cell simultaneously tests the end bearing and skin friction and quantifies their resistances individually, thereby maximizing the information obtained.

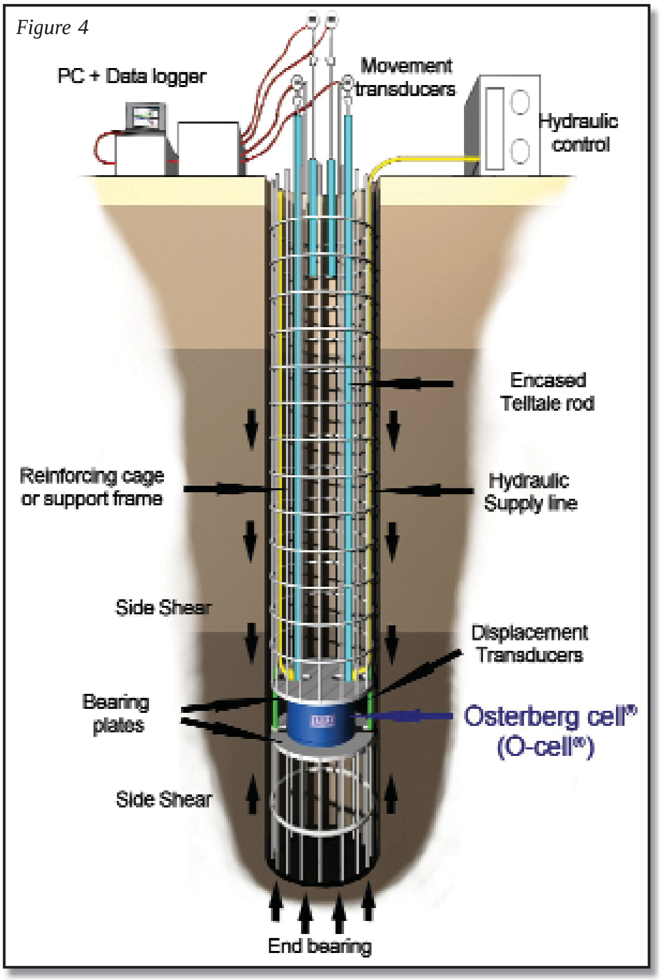

Figure 4

By eliminating the need for an external reaction in static pile load tests, the O-cell method improves safety and saves time and money because of the reduced effort required to prepare for testing. While the O-cell test has become the premier method for static load testing of bored piles and auger cast in place (ACIP) piles, until recently, it had never been used to test a helical pile.

O-CELL TESTING ON HELICAL PILES

The idea to use an O-cell to test a helical pile originally came to HPS Chief Engineer, Tom Bradka, while attending a seminar by Dr. Bengt H. Fellenius, a distinguished foundation engineer in the piling industry. Dr. Fellenius discussed the concept of O-cell bi-directional testing on bored concrete and driven steel piles, expounding on the advantages of testing piles in this manner. Tom soon began working on a concept to apply the same method to helical piles.

After the concept was presented to LTI, engineers from both companies jointly developed a method to incorporate the O-cell into a helical pile. Using a specially designed torque-transfer mechanism, the O-cell is installed in a space near the base of a two-piece helical pile (Figure 5). This patent-pending mechanism allows the pile to transfer torque across the plane of the O-cell while also allowing the pile to separate under load. The pile is then advanced into the ground using the traditional helical pile installation method. Once installed, all of the hydraulic and electronic connections are made and the test is carried out in general accordance with ASTM D1143, applying incrementally greater loads on the pile over specified time intervals.

The test site was located in Fort Saskatchewan; the centre of the industrial heartland of Alberta, Canada. This location was selected in part because a conventional static pile load test was completed on that site at an earlier date. Two piles were prepared for the test site; both fabricated at 219-millimetre in shaft diameter, with a single 457-millimetres diameter helix embedded fours metres below the ground surface to duplicate the dimensions used in the comparison test. One of the piles contained two additional helices above the O-cell location to pro-


Figure 5


Figure 6

vide additional upward resistance to loading, allowing the pile tip to be loaded to a higher displacement. A photo of the O-cell test in progress is included as Figure 6. The results from both O-cell test piles were then compared to the conventional load test results obtained from the earlier test program.

THE FINAL ANALYSIS

The advantages of this innovative application were clear from the beginning. Where traditional top-down pile load tests would normally take days to set up and complete, the O-cell load test was completed in only four hours by a team of engineers assembled by HPS and LTI. After the test was complete, the helical pile was extracted by reconnecting the drive head and reversing the torque motor. The O-cell and ancillary equipment were then removed for re-use on a subsequent test pile. Figures 7 and 8 show the helical pile after extraction.

This re-use was innovative in and of itself because when bored piles or ACIP piles are tested by this method, the O-cell cannot be retrieved and is considered to be sacrificial. In this case, two similarly equipped helical piles were installed, tested and removed all in a single day.

The O-cell test method allowed the LTI and HPS team of engineers to directly measure the resistances developed by the shaft friction (90 kN) and the helix and tip bearing (160 kN) independently. This information is critical in refining design parameters and confirming assumptions about how the load resistance is distributed in the helical pile. The data was also combined to produce an equivalent top-loaded curve to predict the head displacements that would occur in a conventionally loaded pile. The curve is presented in Figure 9.

IMPLICATIONS

Helical piles are quickly proving to be one of the most cost effective and versatile foundation systems available. The


Figure 7


Figure 8

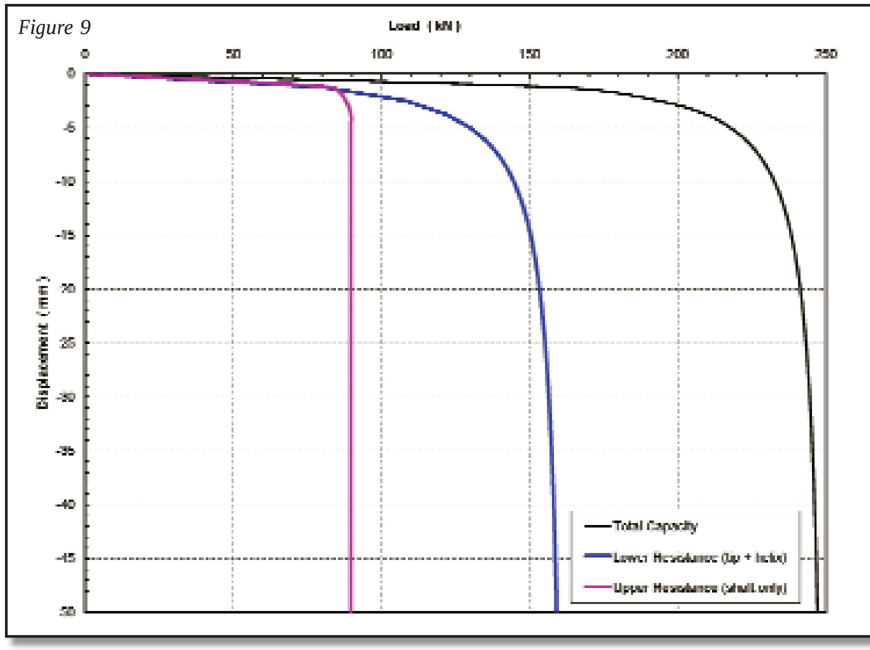

Figure 9

savings resulting from using helical piles in lieu of concrete or driven piles in some cases could be significant. Having an inexpensive and quick means of verifying capacity only adds to their allure.

Alvin Pyke, P.Eng. Chief Executive Officer for HPS, states that this test method will reduce the cost of load testing by as much as 80 per cent. By eliminating uncertainty through load testing and optimizing the foundation design, potentially significant cost savings can be passed on to the client. HPS has already decided to include O-cell testing as standard on all future helical pile projects. By adopting this approach HPS hopes to lead the industry toward performance-based design as a standard, allowing helical piles to make significant inroads as a preferred foundation alternative. ■