Failures of Helical Piles and Helical Anchors and Associated Lessons Learned

Author: Howard Perko, Ph.D., PE, Director of Engineering, Magnum Piering, Inc., Cincinnati, OH, USA

Given the title of this article, there are probably a lot of deep foundation contractors that are ready to jump on a band wagon and say "see helical piles don't work". That is not the subject of this article. With the variety of subsurface profiles, diverse geologic conditions, and a myriad of structures to be supported, the geotechnical engineer and deep foundation contractor need as many resources in their tool belt as possible. Helical piles and helical anchors represent one of those tools which, when used correctly, perform effectively. Like all piles and ground reinforcing elements, helical piles and helical anchors used incorrectly can have less than favorable results.

In this article, a variety of projects are presented that experienced problems including one that resulted in a temporary moratorium on helical piles in New York City, a helical anchor wall at a stadium that "unzipped", a sea wall with poor load test results, excessive settlement of grouted helical piles, and a residential underpinning project where a worker was unfortunately killed. An attempt will be made to explain some possible reasons why these failures occurred and to offer solutions. Through a study of these case histories, the reader should gain important instruction for how to avoid these failures in the future.

New York City Project

In early 2008, helical piles failed during excavation along a building in New York City. The "rubble" footing rotated, the piles buckled, and the building settled severely. A supplemental waler and raker bracing system was installed with deadmen piles to arrest building movement.

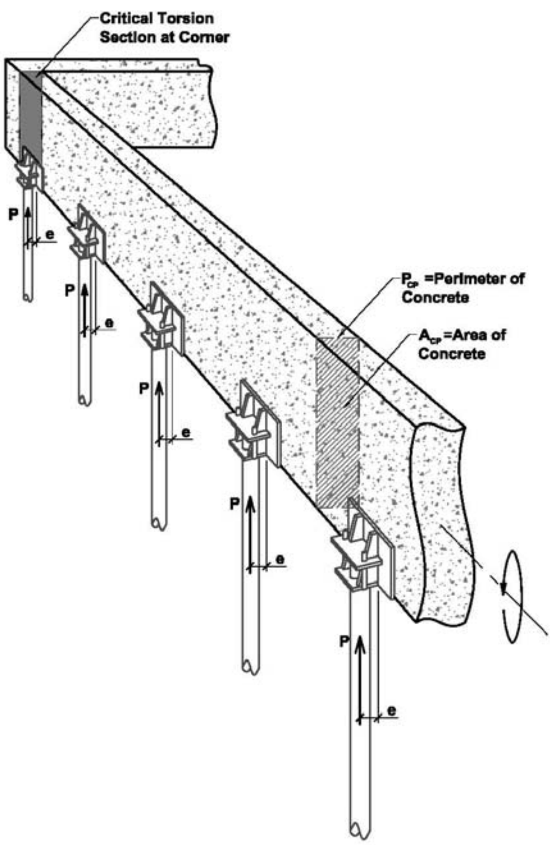
Shortly after the helical pile failure described above, the NYC Department of Buildings, Office of Technical Certification and Research (OTCR) issued a technical bulletin to all borough commissioners. The memo instituted an immediate moratorium on the use of helical piles in New York City. The bulletin cited these reasons for the moratorium: lack of national standards, seismic and corrosion concerns, and a rejection of a proposed helical pile code by the IBC structural committee.

Failure of Unbraced Helical Piles in New York City (Courtesy of NYC Department of Buildings, Office of Technical Certification and Research)

Since the issuance of the bulletin, the OTCR has been working diligently with Muesser Rutledge to develop provisions to include helical piles in the NYC building code. Many of the original reasons for the moratorium have been resolved. In October, 2008, Helical piles were accepted by the IBC structural committee and now appear in Chapter 18 of the 2009 International Building Code. It has been shown that the same engineering and design approaches used to address seismic application and corrosion of other deep foundations can be applied to helical piles. The OTCR has released a draft bulletin that addresses the use of helical piles in NYC to the DFI Helical Foundations and Tie-Backs Committee for review and comment on two separate occasions. It is anticipated that the OTCR will release a final bulletin to the public sometime this year.

The failure of helical piles in New York City can be explained by the lack of lateral bracing. Section 1808.2.9 of the 2008 New York City Building Code and the same section of the 2006 International Building Code state that all piles shall be laterally braced. The section goes on to state that bracing can be achieved by alternating the location of piles on either side of walls, using a minimum of three piles under isolated columns, and other means.

Lateral Bracing of Tilt-Up Walls using Anchor Ties into Building Slab (Courtesy of Dwyer Companies, Inc., Cincinnati, OH)



An Example Diagram Showing Internal Rotational Bracing (Perko, 2009)

The tops of helical piles can be braced by staggering locations along walls, installing ties to hold the wall/footing from rotating and moving laterally, or by direct bracing. Sometimes a foundation wall has sufficient internal strength to prevent lateral or rotational movement (Perko, 2009).

Stadium Project

I was recently given photographs of a failed stadium project and asked to estimate the cause of failure. Three rows of helical anchors were used in a top-down excavation for a below-ground stadium renovation. The failure of the approximately 15 feet deep shoring walls reportedly occurred as a progressive “un-zipping” of the wall.

With the limited data available, it is difficult to state for certain the cause of failure. However, some common causes of soil nail wall problems are described here. Soil nails and tie-backs are often confused as synonyms. In fact, they are very different. Soil nails serve to reinforce the soil mass. Soil nails are relatively short, close together, and the required facing is very thin. Tie-backs generally work by anchoring behind the active zone of soil and support the earth by holding back the facing. Soil anchors are typically long, far apart, fairly high-capacity, and the facing is heavily reinforced often with a waler. Tie-backs are usually post-tensioned, whereas soil nails typically are not.

In order for a helical anchor to function as a soil-nail, it must continuously bond with and reinforce the soil. The way this is accomplished is through an array of small diameter helical bearing plates mounted along the entire length of the shaft (e.g. 20 cm [8 in] diameter helices every 61 cm [2 ft]). Helical soil nails are generally spaced very close together (e.g. 120 cm to 180 cm [4 to 6 ft] on-center) and are required to resist fairly low tension forces. As a result of the low tension requirement, people errantly “value engineer” the project for fewer helical bearing plates thereby failing to reinforce the soil properly.

Another common failure mode of both soil nail and tie-back walls is bearing capacity failure. The weight of the facing and most importantly the downward component of thrust of all the anchors bear down on the bottom of the facing. Bearing capacity is most critical when soil nails or tie-backs are angled downward steeply. The helical anchors on the stadium project appear to be angled between 30 and 45 degrees from horizontal. This means that between 50 and 70% of the anchor force is oriented downward. The net result is a large force dragging the facing downward. Bearing capacity failure can be resisted by installing piles at the base of the wall or simply by forming a footing with the Shotcrete. Another way to reduce downward force is to install anchors horizontally.

Failure of Stadium Shoring Walls

Sea Wall Project

Our company was recently involved in the emergency repair of an old reticulated timber pile marine wall along Lake Superior. The repair consisted of installation of a new sheet pile wall with a single row of helical tie-backs. The 11 cm [4.5 inch] diameter shaft helical tie-backs were designed for a working load of 267 kN [60 kips]. The anchors reached torque just a few feet short of an anticipated dense layer, but were deemed admissible because of uncertainties within the ground. When it came time to proof test the tie-backs, the tests failed at about half of the anticipated capacity.

A supplemental set of 8 cm [3 in] diameter shaft helical tie-backs had to be installed. The second set of anchors was designed using exactly the same methods as the first set except they were designed for half the capacity with half the helical bearing plates. They were installed to roughly half the torque using a different torque motor. All of the supplemental anchors passed their proof test. What happened?

Emergency Sea Wall Repair

The inadequate proof tests on the first set of tie-backs for the sea wall were later explained by a lack of calibration. The first torque motor used on this project was supposed to generate 27 kN-m [20,000 ft-lbs] of torque. Subsequent calibration testing showed the first motor could only produce roughly 50% of the supposed maximum torque which correlated nearly exactly to the proof tests.

Grouted Pile Project

Some years ago, I was asked to review the failure of grouted helical piles. This project consisted of a number of high-end homes in northern Ohio. The subsurface conditions consist of fill placed on very soft, saturated, clay soils to raise site grades. The homes were constructed on square-shaft helical piles with grouted shafts using a proprietary method. Shortly after the homes were completed, they suffered severe settlement.

The settlement can be explained as a result of down-drag and insufficient pile length. Fill placed over soft clay typically results in long-term consolidation. The fill would produce negative skin friction on the grouted pile shaft. Pile length and pile capacity was insufficient to resist these additional down-drag loads.

Underpinning Accident

An addition was being constructed on the back of a home. The back wall experienced settlement because it was undermined by the new construction. It was desired to underpin, stabilize, and perhaps lift the back wall to its original elevation.

The existing home consisted of cast-in-place concrete basement walls supporting a wood frame structure with two courses of brick veneer. Penetrations had been made through the back basement wall for access to the new addition. The wall was free at both sides and held at the top only by brick ties. During installation of the first pile, the wall became unstable and tipped over. The weight of the nearly 6 ton section of basement wall instantly killed a worker.

Tragic Basement Wall Collapse due to Undermining

The cause of this accident was undermining the foundation wall. Foundation repair contractors and engineers need to be very cautious and take time to assess the stability of their surroundings. Let’s hope this tragedy is never repeated.