FOUNDATION NATION
FSI NEWSLETTER FOR DESIGN PROFESSIONALS

Monitoring Torque to Determine *Helical Pile Capacity*

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The torque correlation method is a well-documented and accepted method for estimating or verifying helical pile capacity. In simple terms, the torsional resistance generated during helical pile installation is a measure of soil shear strength and can be related to the bearing capacity of the pile with the following equation:

$$Q_u = K_t \times T$$

Where,

Q_u	=	Ultimate Pile Capacity (lb)
K_t	=	Empirical Torque Correlation Factor (ft^{-1})
T	=	Final Installation Torque (ft-lb)

The correlation of installation torque to helical pile capacity is generally accepted for the most commonly used shaft sizes with outside diameters up to about 4.5 inches, with some discussion about whether this method can be used for shaft sizes up to about 6 inches. For larger shaft sizes, the capacity of helical piles is generally determined by theoretical methods and then verified with full-scale load testing.

ICC-ES AC358 recognizes the following helical pile shaft sizes and default K_t factors for conforming systems, since the installation torque to capacity ratios have been established with documented research:

- 1.5 to 1.75-inch solid square shaft — $K_t = 10$ ft^{-1}
- 2.875-inch OD round shaft — $K_t = 9$ ft^{-1}
- 3.0-inch OD round shaft — $K_t = 8$ ft^{-1}
- 3.5-inch OD round shaft — $K_t = 7$ ft^{-1}

Monitoring torque is therefore a key process during the installation of helical piles. A number of devices are available to assist in determining torque and, ultimately, the calculation of pile capacity. These devices range from simple pressure gauges to more sophisticated electronic data acquisition systems. A few of those devices are presented below.

Dual hydraulic pressure gauges can be used to measure the "pressure drop" across a hydraulic torque motor. This method is based on the principle that the work output of the torque motor is directly related to the measurement of the pressure drop across the motor as force is applied. To measure the pressure drop, one gauge is placed in line with the feed from the hydraulic pump or machine to the drive head. A second gauge is placed in line with the return from the drive head back to the pump (Figure 1). The return line pressure is subtracted from the feed line pressure resulting in the determination of "differential" pressure. The installation torque can be calculated relative to the differential pressure by applying the gear motor multiplier (GMM) provided by the drive head manufacturer. Most drive head manufacturers provide correlation charts for quick conversion of differential pressure to torque.

Figure 1: Dual pressure gauges mounted to arm of excavator

Some operators choose to use a single gauge on the feed line side only, rather than to use a second gauge to measure back pressure. This can result in decreased accuracy and over-estimating of applied torque if back pressure is under-estimated or ignored all together.

Differential pressure gauge technology measures the feed and return line pressures to determine the pressure drop across the motor, but with ports for the lines within a single-gauge body. The differential pressure, as in the case of the TruTorque model (Figure 2), is related to torque by the GMM for a specific drive head and the dial face is manufactured to provide a reading of torque rather than pressure. A different differential pressure gauge is therefore needed for each drive head.

Electronic pressure indicators measure the feed and return line

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Distribution Checklist

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pressures with electronic pressure transducers. Low voltage power is supplied to the unit by either a portable battery pack or a direct connection to an appropriate low voltage source generated by the installation equipment. Instead of analog gauges, electronic indicators such as the PT Tracker by Marian Technologies (Figure 3) typically have a digital screen output to provide a direct reading of torque, which is generated by a pre-programmed relationship of the pressure drop across the motor and the GMM for the drive head being used. Some units have a selector switch that allows for torque readings with various motors. Some models also allow for data acquisition and/or blue tooth technology.

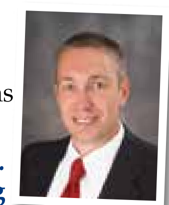
Figure 2: TruTorque Gauge

Figure 3: PT Tracker

Electronic torque transducers such as the Pro-Dig® Intelli-Tork system (Figure 4) are placed in line with the tool string. Torque is a true real time measurement and is generated continually during the installation of a helical pile or tieback. The Intelli-Tork system uses electronic strain gauge technology to measure the torque applied between the two flanges and then transmits the data via blue tooth wireless technology to a hand-held PDA. The PDA based system and software provide a remote visual indication of the torque during the installation. Software provided with the instrument has the ability to log the torque, depth and installation angle. Torque transducers can be recalibrated as needed to ensure accuracy. In turn, a properly calibrated torque transducer can be used to calibrate analog gauge systems relative to differential pressure.

Figure 4: Pro-Dig® Intelli-Tork

Installation torque should be monitored and documented at intervals specified by the engineer of record. At a minimum, torque readings should be obtained at the end of installation of each lead section and extension. In more critical applications, torque readings may be obtained for every foot of pile installation in order to develop a relative soil strength profile with depth. Torque should also be recorded every foot during the last three to five feet of installation for tension piles or tiebacks. The average installation torque over that length may then be used to determine the tension capacity. Please contact FSI if you have any questions about the above content or other topics regarding helical piles.



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CASE STUDIES

Model 288 Helical Piles

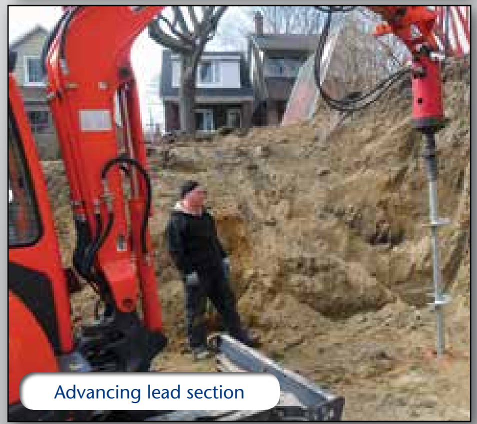
Residential

Project: Duplex Home Construction ● **Location:** Toronto, Ontario
Foundation Supportworks® Dealer/Installer: Foundation Supportworks® of Ontario

Challenge: A 2,600 square-foot duplex home was planned for construction on two residential lots sandwiched between properties with existing homes. The rears of the lots slope down to a heavily-wooded drainage valley. The proposed duplex was designed as attached two-story, wood-framed structures with basements. A geotechnical exploration at the site encountered approximately 10 to 16 feet of very loose to loose silty sand fill over generally medium dense to very dense sand and sandy silt (glacial till). Groundwater was observed at depths of 13 to 16 feet. The borings were completed at the pre-construction ground surface elevation before the basement excavation was made. The foundation design originally included 2.5-foot diameter drilled concrete caissons. However, anticipated limited working space within the basement excavation, environmental concerns (excessive removal of trees), and public disturbance from noise and vibration during installation, prompted the general contractor to seek an alternative deep foundation system. The relatively shallow groundwater conditions would also likely require the drilled shafts to be cased to prevent caving soils and to limit water infiltration.

Solution: Helical piles were selected as the ideal deep foundation solution for this project given the piles could be installed with smaller equipment in tight access and limited working space conditions. The product and installation equipment could also be mobilized to the site quickly. Thirty-seven (37) Model 288 (2.875-inch OD by 0.276-inch wall) round shaft helical piles with an 8"-10"-12" helix plate configuration were proposed for the design working load of 35 kips per pile. The piles were installed to torque values of at least 7,800 ft-lb for torque-correlated ultimate capacities of at least 70 kips (FOS ≥ 2). The piles were installed with a mini-excavator and a tracked skid steer to depths of seven to 16.5 feet below basement subgrade elevation. Adjustments were made to some of the pile locations after encountering tree roots or cobbles/boulders during installation. The piles were shifted several inches along the grade beams to new locations approved by the project engineer. The helical pile components were hot-dip galvanized for corrosion protection.


Soldier beam and wood lagging wall along property line


Advancing lead section

Model 150 Helical Tiebacks

Residential


Maneuvering for tieback installation


Tieback and waler installation complete

Project: Historic Home Tiebacks ● **Location:** Davenport, IA
Foundation Supportworks® Dealer/Installer: MidAmerica Basement Systems

Challenge: A historic home built in the early 1900's was experiencing both lateral and vertical movement as an adjacent 17-foot tall sheet pile retaining wall continued to lean down slope. The 75-foot long retaining wall is approximately eight feet from the home and roughly parallel to the rear foundation wall. The top of the retaining wall deflected seven inches over the past two years and had to be stabilized to prevent further movement of the home. Access to the back face of the sheet pile wall was limited due to existing trees and the steep slope, so a temporary earth embankment was constructed to provide a working surface for equipment and personnel. Soil borings completed between the retaining wall and the home identified clay fill with trace amounts of brick and stone to depths up to 10 feet. The fill was underlain by stiff to very stiff native lean clay (glacial till) to a depth of 24 feet.

Solution: The original design included three rows of tiebacks with a design working tension load of 21 kips each. A crane lowered a mini-excavator onto the temporary working surface and openings were torch-cut in the sheet pile wall at each anchor location. As the first tieback of the upper row was advanced, an obstruction was encountered at a length of approximately eight feet from the wall. The soils were excavated between the home and the retaining wall, exposing unexpected concrete underpinning beneath the existing foundation. This discovery prompted a redesign of the project, including eliminating a row of tiebacks, decreasing the tieback spacing, and coring holes through the existing concrete underpinning to allow for the installation of the tiebacks. The final tieback design included twenty-four Model 150 (1.5-inch round corner square bar) helical tiebacks with 12"-14" helix plate configurations. The tiebacks were generally positioned in rows six feet and 13 feet below the top of the sheet pile wall, spaced approximately five to six feet apart, and installed at a downward angle of 20 degrees. The tiebacks were advanced to lengths of 12 feet (bottom row) to 35 feet (top row) behind the wall and to installation torque values correlating to ultimate capacities of at least two times the design working load of 21 kips (FOS ≥ 2). The tiebacks were pre-tensioned to the design working load with a calibrated hollow-core hydraulic cylinder.

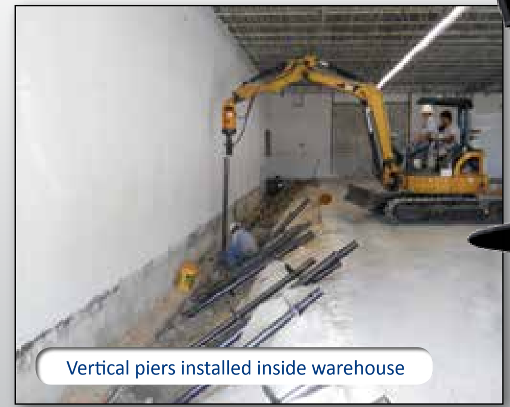
Model 350 Helical Piers

Commercial

Project: Former Oil Facility Warehouse Stabilization
Location: Pompano Beach, FL
Foundation Supportworks® Dealer/Installer: N Square, Inc.

Challenge: An environmental study discovered contaminated soils to depths of 20 feet and extending beneath one end of an existing warehouse. The 10,000 square-foot warehouse, constructed in 1968, is typical high bay warehouse construction with perimeter strip footings 30 inches wide by 12 inches thick, 18 feet high masonry block walls, and bar joists supporting a flat roof. In order to remove the contaminated soil, the entire length of one of the exterior walls would have to be supported with a deep foundation that extended below the proposed excavation depths. Test borings identified a general subsurface profile consisting of loose to medium dense fine sand from the surface to a depth of about 38 feet, over medium dense to dense sand from 38 feet to the completed depths of the borings at 50 feet. Groundwater was encountered at a depth of 16 feet.

Solution: Several deep foundation options were considered, but helical piers appeared to be the most feasible and economical. Helical piers can be installed within sand and below groundwater without the need for casing, they can be installed with smaller equipment inside the building, and the installation does not generate spoils that would have to be contained for proper treatment and/or disposal. The foundation support detail included 34 Model 350 (3.5-inch OD by 0.313-inch wall) retrofit helical piers with 10"-12"-14" triple-helix lead sections. The piers were designed and installed in order to support the design working load of 12 kips even after removal of the 20 feet of overburden soils. The piers were installed in a vertical orientation and to depths up to 45 feet. The piers were installed in 17 pairs across the inside and outside edges of the wall footing to allow steel beams to be placed on and welded to the retrofit brackets, spanning the footing width. Hydraulic cylinders were used to uniformly preload the piers prior to excavation. As the excavations were made, steel cross-bracing was field-welded to the piers to minimize unsupported lengths and prevent buckling. The pier installation, with welding of the cross-bracing, was coordinated with the excavation to remove the contaminated soil and completed within four days.


Vertical piers installed inside warehouse


Excavation of contaminated soil. Building stabilized with helical piers.

Models 288 and 350 Helical Piles

Commercial


Installing HP350 piles


Compression load test

Project: Kingsmill Marina ● **Location:** Williamsburg, VA
Foundation Supportworks® Dealer/Installer: JES Construction, Inc.

Challenge: The Kingsmill Resort planned to remove the existing one-story marina and restaurant building and replace it with a new two-story building. The project also included salvaging the existing deck that wrapped around the rear of the existing structure. A soil test boring completed on the property near the existing building encountered loose to medium dense silty sand to a depth of 22 feet, medium dense to dense silty sand to a depth of 32 feet, and loose to medium dense silty sand to the maximum depth explored of 50 feet. Groundwater was measured at a depth of 13 feet, but was understood to fluctuate with tidal surges and seasonal flows of the James River. Deep foundation support was proposed for the new building due to the relatively weak surface soils and the potential for erosion and scour along the shoreline.

Solution: Helical piles were ultimately selected over timber piles due to the smaller equipment required and the relative ease of pile installation in the limited working space adjacent to the existing deck. The proposed 29 helical piles would support a tension service load of 10 kips and compression service loads ranging from 13 to 55 kips. The Model 288 (2.875-inch OD by 0.276-inch wall) round shaft was selected to support compression service loads up to 34 kips and the Model 350 (3.5-inch OD by 0.313-inch wall) round shaft was selected to support compression service loads from 38 to 55 kips. Both pile configurations included 10"-12"-14" triple-helix lead sections. The Model 350 piles also included a 14" helix plate on the first extension. A calibrated electronic torque transducer was utilized to monitor pile installation torque directly, or to establish the differential pressure to torque correlation. Piles were installed to depths ranging from 21 to 31 feet and to torque-correlated ultimate capacities exceeding the service loads by a factor of safety of at least two. A compression load test (ASTM D1143) and a tension load test (ASTM D3689) were completed on sacrificial Model 288 piles installed to their respective torque requirements for the intended loads. Total pile head movement, including elastic shortening or lengthening, was measured at 0.39-inch for a compression load of 33 kips and 0.28-inch for a tension load of 10 kips. Both measurements were within the tolerable limits specified.