FOUNDATION NATION™
FSI NEWSLETTER FOR DESIGN PROFESSIONALS

PREDICTING HELICAL PILE CAPACITY

Jeff Kortan, P.E.• *Director of Engineering*

There are three common methods for predicting helical pile capacity; the **individual bearing method**, the **cylindrical shear method** and the **torque correlation method**. The first two methods are rooted in traditional geotechnical methodology, slightly modified with empirical data, and are generally used to calculate or estimate pile capacity during the design phase. The torque correlation method is fully empirical and generally used to confirm or verify capacity during pile installation.

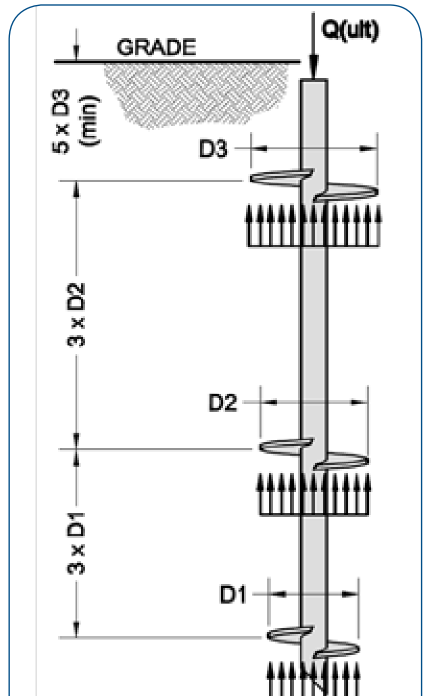

Figure 1
Individual Bearing Method

The **individual bearing method** states that the ultimate pile capacity is equal to the sum of the individual helix plate capacities. Figure 1 illustrates the load transfer mechanism for the individual bearing method in compression loading.

Helical pile capacity by the individual bearing method can be calculated from:

$$Q_u = \sum A_h (cN_c + q'N_q + 0.5\gamma DN_\gamma)$$

Where,

Q_u	=	Ultimate Pile Capacity (lb)
c	=	Cohesion at Helix Depth (lb/ft^2)
q'	=	Effective Vertical Overburden Stress at Helix Depth (lb/ft^2)
γ	=	Soil Unit Weight (lb/ft^3)
D	=	Diameter of Helix Plate (ft)
A_h	=	Area of the Helix Plate (ft^2)
N_c, N_q, N_γ	=	Dimensionless Bearing Capacity Factors

The last part of the equation is often ignored in the calculation of end-bearing capacity of deep foundations. The diameter or width of the pile is relatively small and therefore this portion of the equation contributes little to the overall pile capacity. With that portion of the equation conservatively ignored, the equation further simplifies to:

$$Q_u = \sum A_h (cN_c + q'N_q)$$

For purely cohesive soils with $\varnothing = 0$ and c = soil shear strength, $N_c \approx 9$ and $N_q = 1$. The equation can conservatively be rewritten as:

$$Q_u = \sum A_h (9c)$$

For purely granular (frictional) soils with c = 0, the equation can be rewritten as:

$$Q_u = \sum A_h (q'N_q)$$

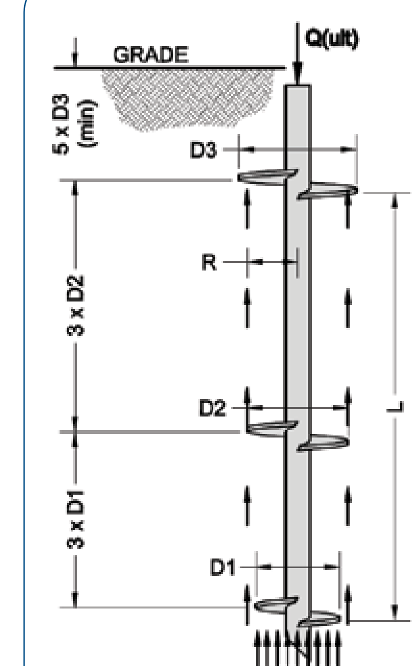

Figure 2
Cylindrical Shear Method

The **cylindrical shear method** assumes the development of a soil friction column (cylinder) between the upper and lower helix plates along with individual bearing of either the upper or lower helix, depending upon loading direction. Figure 2 illustrates the load transfer mechanism for the cylindrical shear method in compression loading.

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Distribution Checklist

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PREDICTING HELICAL PILE CAPACITY

Continued . . .

The helical pile capacity by the cylindrical shear method can be calculated as:

$$Q_u = 2\pi RL(c+K_o q'\tan\varnothing)+A_h(cN_c+q'N_q)$$

Where (in addition to the above definitions),

R	=	Average Helix Radius (ft)
L	=	Total Spacing Between All Helix Blades (ft)
K_o	=	Dimensionless At-Rest Earth Pressure Coefficient
$\varnothing$	=	Soil Friction Angle (degrees)

The individual bearing method and cylindrical shear method should provide similar results if reasonable, representative soil parameters are selected by the designer. That said, FSI promotes the use of the individual bearing method for determination of pile capacity due to its relative simplicity and since the original form from which this method is derived is widely accepted by the geotechnical engineering community.

The **torque correlation method** is a well-documented and accepted method for estimating 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:

$$Q_u = K_t \times T$$

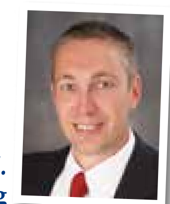
Where,

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

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 and 1.75-inch solid square shaft — K_t = 10 ft^{-1}
- 2.875-inch outside diameter round shaft — K_t = 9 ft^{-1}
- 3.0-inch outside diameter round shaft — K_t = 8 ft^{-1}
- 3.5-inch outside diameter round shaft — K_t = 7 ft^{-1}

Like other deep foundation alternatives, there are many factors to consider in designing a helical pile foundation. Foundation Supportworks™ recommends that helical pile design be completed by an experienced geotechnical engineer or other qualified design professional. Please consult the FSI Technical Manual for additional information.



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CASE STUDIES

New Construction Helical Piles

Commercial

Project: Pinckney Hill Plantation Home ● **Location:** Monticello, FL
Foundation Supportworks™ Dealer/Installer: Alpha Foundation Specialists, Inc

Challenge: A new 22,000 square foot slab-on-grade, single-family residence was planned within the Pinckney Hill Plantation development. The original geotechnical report for the project recommended that the structure be supported with shallow spread footings bearing within the anticipated five feet of new fill that would be placed across the site. Proposed earthwork and grading plans later changed to include only minor cuts and fills. A shallow foundation system was no longer a viable option due to the presence of existing fill and marginally expansive clay soils within the upper 15 feet of the profile. A second geotechnical exploration with six test borings was completed to develop recommendations for a deep foundation option.

The soils encountered at the site were highly variable between test boring locations. Belled drilled shafts, auger-cast piles and helical piles were considered to support the new home, but, ultimately, site access concerns, soft ground conditions and lower equipment mobilization costs made helical piles the more practical and economic solution.

Solution: Several helical test probes were completed across the site prior to selecting the production pile configuration. The test probe consisted of the Model 288 (2.875-inch OD by 0.276-inch wall) round shaft with a single 10-inch helix plate. The test probes were used to anticipate pile depths and determine a helix plate configuration by back-calculating soil strengths based upon the installation torque. With the results of the test probe, the Model 288 round shaft with an 8"-10" double-helix lead section was selected for the production piles. Two hundred eight (208) helical piles were advanced to a depth of 32 feet and installed to at least 4,500 ft-lbs of torque to correlate to ultimate pile capacities of at least 40 kips (FOS ≥ 2). Actual installation torques ranged from about 4,600 to 6,200 ft-lbs. New construction brackets were placed on the tops of the helical piles and cast into the structural grade beams. The installation of 208 helical piles took only seven days.


Advancing helical piles


New construction bracket to be cast into grade beam

Helical Tiebacks

Commercial


Tight access north side of wall; core-drilling 4" holes


Tiebacks installed

Project: Verizon Data Center ● **Location:** Omaha, NE
Foundation Supportworks™ Dealer/Installer: Foundation Supportworks by Thrasher

Challenge: An addition was planned for the existing Verizon Data Center building. The addition would be located within the paved area north, east and west of the existing loading docks. An existing concrete retaining wall creates the northern limits of the proposed building area and provides grade separation between the higher elevation paved surface to the south and cooling tanks, piping and equipment to the north, approximately 12 feet lower in elevation. The west approximate 40 feet of the retaining wall had an obvious bow of approximately six inches at mid-span. With the proposed addition planned above this section of the retaining wall, there was concern that any additional deflection or movement of the wall could affect the new structure planned as close as 18 feet from the wall.

Solution: Helical tiebacks were selected to stabilize the existing retaining wall prior to construction of the proposed addition. A mini-excavator was used to install the tiebacks and maneuver within the tight spaces on the north side of the wall. The proposed construction scope also included excavation of the backfill soils on the south side of the wall to upgrade the wall's drainage system with free-draining granular material. With this excavation made, tieback lead sections and extensions could be placed and coupled on the high side of wall, allowing smaller four-inch diameter core holes to be drilled through the wall to minimize cutting of reinforcing steel. Eight Model 150 (1.5-inch solid square shaft) helical tiebacks were installed with 12"-14"-14" helix plate configurations. The tiebacks were positioned six feet down from the top of the wall, spaced at four feet nine inches and installed at a downward angle of ten degrees. The tiebacks were advanced to the design length of 21 feet behind the wall and to installation torque values correlating to ultimate capacities of at least two times the design working load of 12 kips (FOS≥2). A tube steel waler system was installed to better distribute the tieback forces to the wall. The tiebacks were pre-tensioned following installation.

New Construction Helical Piles

Commercial

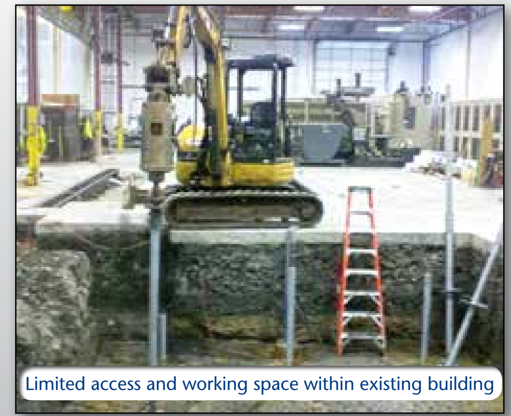
Project: A & G Machine - Equipment Foundations ● **Location:** Auburn, WA
Foundation Supportworks™ Dealer/Installer: TerraFirma Foundation Systems

Challenge: A & G Machine, an aircraft component manufacturer in Washington, planned to install two new pieces of heavy equipment in an existing 24,000 square foot building. Each piece of equipment would be supported on a mat foundation five feet thick and having approximate plan dimensions of 15 feet by 20 feet. The one test boring, completed from the top of floor slab elevation, sampled very soft to soft silt to a depth of about 20 feet over medium dense silty sand to the bottom of the boring at 34 feet. Groundwater was noted at a depth of 7.5 feet.

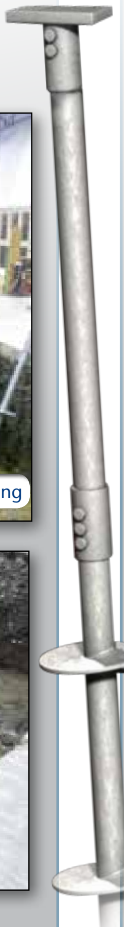
A mat foundation supported on grade would exert a bearing pressure of 1,400 pounds per square foot to the weak foundation soils, resulting in estimated settlements on the order of four to eight inches. The equipment and mat foundation would therefore have to be supported on piles to transfer the load to more competent soils. Equipment access, low overhead and limited working space conditions were considered in the evaluation of pile options.

Solution: Helical piles were ultimately selected to support the equipment foundations/pile caps. Helical piles could be installed with smaller equipment in the low overhead and limited access conditions, helical pile installation would not create spoils, low mobilization costs made helical piles a cost-effective solution compared to other deep foundation alternatives, and each phase of pile installation (12 piles per pile cap) could be completed in one day.

Each of the two pile cap designs included 12 Model 349 (3.5-inch OD by 0.300-inch wall) round shaft helical piles with 8"-10"-12" triple-helix lead sections. The piles were installed to torque values of at least 11,500 ft-lbs to provide torque-correlated ultimate pile capacities of at least 80 kips (FOS=2). Pile depths for the two phases of work ranged from 28 to 32 feet below bottom of pile cap elevation (33 to 37 feet below top of floor slab elevation).


Limited access and working space within existing building


Twelve helical piles installed for each pile cap



New Construction Helical Piles

Commercial


Load test arrangement


Helical piles advanced; congested working space

Project: Admission Center Addition ● **Location:** De Pere, WI
Foundation Supportworks™ Dealer/Installer: Foundation Supportworks of Wisconsin

Challenge: St. Norbert College planned a $1,175,000 addition and renovation to their existing admission center. The new addition consisted of a 60-foot diameter rotunda to be supported on deep pile foundations and grade beams. The geotechnical investigation included the advancement of three soil borings, with one boring located in the area of the rotunda addition. The soil profile observed at this location consisted of 5.2 feet of uncontrolled fill underlain by soft to medium stiff clay to approximately 20 feet. Very stiff to hard clay was then sampled from 20 to 27.5 feet over an apparent weaker clay layer with an SPT N-value of 4 blows per foot. Since the boring terminated at a depth of 30 feet, the thickness of this weaker layer was not determined.

A helical test probe was performed to further characterize the thickness of the very stiff to hard clay stratum and the soil conditions below the bottom of the boring. The helical test probe identified relatively soft soils from the bottom of the test boring to a depth of at least 42 feet. The deep foundation option would therefore bear within the very stiff to hard clay from 20 to 27 feet, or likely extend to depths exceeding 42 feet. Helical piles were selected as the ideal option since the helix plate size and spacing could be designed to bear in the very stiff to hard clay layer and support the design working load of 15 kips.

Solution: A full scale compression load test was performed to document the load to deflection characteristics prior to installation of production piles. The test pile consisted of a Model 287 (2.875-inch OD by 0.203-inch wall) helical pile with a 12"-14" double-helix lead section installed to a tip depth of 25 feet. The load test confirmed an ultimate capacity of 52 kips at a net deflection of 10 percent of the average helix diameter. Total deflection, including elastic compression, was 0.13 inch at the design working load. Based on the successful results of the load test, the project moved forward with the installation of 28 production piles, similar in configuration, depth and installation torque as the test pile. The load test and installation of the production piles were completed within one week.