FOUNDATION NATION™
FSI NEWSLETTER FOR DESIGN PROFESSIONALS

Geotechnical Investigation Guidelines For Helical Pile Design

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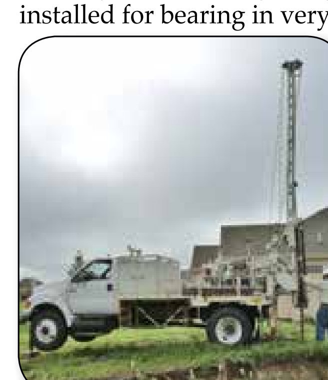
Design professionals rely on site-specific geotechnical investigations to provide soil strength parameters for use in foundation design. However, when these investigations do not properly identify a suitable bearing stratum, the project may be impacted with additional costs or delays until adequate information is obtained. At the very least, contractors left to bid on a project with insufficient soil information will do so conservatively. These bid proposals are then often filled with clauses outlining potential change order items; e.g., additional footage, revisions to the shaft configuration, revisions to the helix plate configuration, costs and responsibility due to failed load tests, etc. These extras often add up to many times the cost to simply complete deeper soil borings and obtain the necessary soil information.

Geotechnical Investigation Guidelines. Helical piles and anchors are best suited for medium dense to dense sands and stiff to very stiff clay soils, although they can be effectively designed and installed for bearing in very dense sands and hard clay. With proper design and installation techniques, helical piles may also be considered for bearing on or within soft or weathered bedrock. A competent bearing stratum should be identified by the geotechnical investigation. For compression piles, the geotechnical investigation should extend at least 5 to 10 feet below the anticipated termination depth of the pile. Soil strength parameters for that 5 to 10 feet should be equivalent to or greater than the strength parameters at the helix bearing depths.



Truck-mounted drill rig

The Standard Penetration Test (SPT) completed in accordance with ASTM D1586 is a common method of retrieving disturbed soil samples in the field while also providing correlations to soil strength parameters. The SPT is performed by driving a 2-inch O.D. split barrel sampler 18 inches with a 140 pound hammer falling a distance of 30 inches. The number of blows required to drive the sampler the final 12 inches is recorded as the standard penetration number, or N-value. Typically, N-values of 15-30 blows per foot for clay soils and 10-30 blows per foot for sand are preferred for providing end-bearing resistance for helical piles or anchors. N-values higher or lower than those ranges may also be considered.

The standard penetration test provides a reasonable indication of strength and density of granular soils with correlations available to relate SPT N-values to relative density, unit weight and internal friction angle. That said, laboratory direct shear tests or triaxial tests provide even more accurate estimates of soil strength which may be warranted for large projects. The additional cost of performing these tests could be offset by a more economical pier design that would not have been considered using SPT results alone.

Sampling per SPT

SPT N-values may be inconsistent for fine-grained, cohesive soils and may not accurately reflect the soil shear strength. Tests may also be conducted on intact cohesive soil samples with pocket penetrometers. These results can vary widely between technicians depending upon the accuracy of the instrument and how closely the test procedure is followed. Laboratory testing of cohesive samples collected using undisturbed sampling methods, such as Shelby tube sampling (ASTM D1587), provides more reliable results. The two more common methods for laboratory testing of undisturbed samples of cohesive soils are the unconfined compression test and the triaxial shear test. Undrained shear strengths ranging from 1500 psf to 4,000 psf are preferred for use of helical piles or anchors, although higher or lower values may also be considered.

For many projects, an appropriate level of geotechnical information has not been obtained prior to initiating a preliminary design for helical piles. New construction helical piles are often an afterthought following a shallow geotechnical investigation and discovery of weak, near-surface soils. Helical piles are then listed in the geotechnical report or

Continued on back . . .

Distribution Checklist

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Advancing helical test probe; torque recorded at one-foot intervals

on the project plans as a deep foundation alternative, but additional or deeper test borings are rarely completed.

Helical Test Probes. When geotechnical information is unavailable or insufficient for helical pile design, helical test probes may be performed to estimate soil strengths for design purposes. A typical helical test probe consists of a square bar or small diameter hollow round shaft helical pile with a single 10 or 12-inch helix plate on the lead section. For some soil profiles, a double-helix lead may be required to provide thrust to penetrate stiff or dense strata or advance through particularly soft zones. For these situations, a double 8/10 or 10/12 helix configuration generally works well. Installation torque should be monitored in one foot intervals from the ground surface to the termination depth. The torque readings must be taken with calibrated equipment such as a certified gear motor and calibrated pressure gages, or by using a calibrated torque transducer in line with the drive tooling. Helical test probes should be advanced to at least 10 feet below the anticipated termination depth of the production piles, or refusal. If the helical pile design is based solely on the results of helical test probes, a higher factor of safety should be considered. The number of helical test probes proposed for a given project depends upon project characteristics and the variability of subsurface conditions.

The information required when evaluating the results of helical test probes include the make and model of the gear motor, probe shaft geometry, probe plate configuration and torque monitoring calibration information. The helical test probe can be used to determine an "effective cohesion" profile with depth based on the helical plate area (Ah), an assumed torque correlation coefficient (Kt) and the test probe installation torque (T) using the ultimate capacity (Qu) equations for helical piles (see the latest edition of the FSI Technical Manual for additional information).

Since, $Qu = Kt*T$, and

$Qu = Ah*9*c$,

then effective cohesion (c_{eff}) can be back-calculated as;

$$c_{eff} = (Kt*T)/(Ah*9)$$

The effective cohesion values back-calculated from the helical probe can then be used to determine the pile configuration(s) required to achieve the pile capacities specified for the project. An example torque and effective cohesion versus depth plot for a 2.875-inch OD helical test probe with a 10/12 helix plate configuration is illustrated in Figure 1.

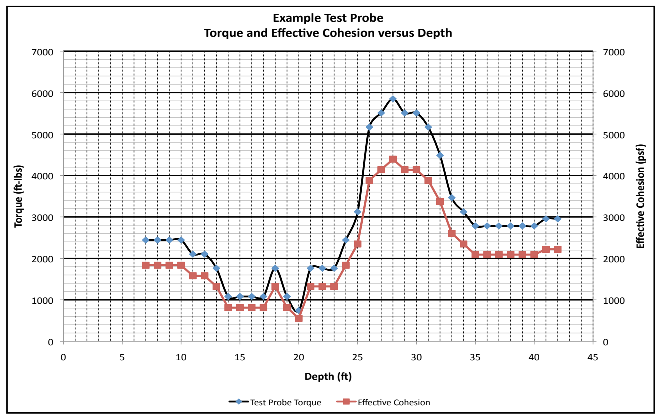

Figure 1: Example Helical Test Probe Results

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FOUNDATION NATION™
FSI NEWSLETTER FOR DESIGN PROFESSIONALS
Quarterly Newsletter • Issue 9
Fall 2011

CASE STUDIES

New Construction & Retrofit Helical Piles

Commercial

Project: Alta Vista Charter School ● **Location:** Lamar, CO
Foundation Supportworks™ Dealer/Installer: Complete Basement Systems

Challenge: In 2011, the school planned a "historic" renovation to approximately 6,240 square feet of the existing building as well as construction of a new addition of 18,000 square feet. The geotechnical exploration included six test borings completed to depths ranging from 10 to 25 feet. The borings encountered predominately clay soils with sand layers between about 13 and 20 feet. The clay soils in the upper 13 feet of the profile were described as soft to medium stiff with standard penetration test blow count values (N-values) of 2 to 5 blows per foot, the sands were described as loose to dense with N-values of 8 to 36 blows per foot and the deeper clays were described as very stiff to hard with N-values of 24 to 38 blows per foot. Groundwater was encountered at depths of 8 to 11 feet.

Solution: Helical piles were selected as the ideal deep foundation support option for this site given the subsurface conditions, groundwater levels, ease of installation and ability to efficiently size the piles for the design working loads ranging from 18.5 to 45 kips. Four different shaft sizes with five different helix plate configurations were utilized. Shaft sizes consisted of the HP288 (2.875" OD by 0.276" wall), HP349 (3.50" OD by 0.300" wall), HP350 (3.50" OD by 0.313" wall) and HP450 (4.50" OD by 0.337" wall). Helix plate configurations ranged from a triple-helix 10"-12"-14" to a five plate 10"-12"- 14"-14"-14". Five full scale load tests were completed for the project, one for each pile configuration. One hundred thirty-two (132) new construction helical piles were advanced to depths ranging from about 23 to 30 feet, bearing within the loose to dense sands and the very stiff to hard clay. Certified drive heads and a calibrated in-line torque transducer were used to accurately measure the applied torque. The piles were installed to near the torque ratings of the shafts in order to penetrate further into the bearing strata and ultimately minimize pile deflections under service loads. The torque-rated ultimate pile capacities were therefore more than twice the design working loads for a factor of safety greater than two. Four retrofit HP349 piles were also used to support a section of the existing building foundation.

Installing test and reaction piles


Installing HP450 helical pile

Model 349 Helical Piles

Commercial


Helical piles complete


Bridge set on new abutments

Project: Ben Bikin' Bridge ● **Location:** Sparta, WI
Foundation Supportworks™ Dealer/Installer: Foundation Supportworks of Wisconsin

Challenge: The bridge would be located at the intersection of Highway 16 and Water Street near a 32-foot tall fiberglass structure of Ben Bikin', a fictional character developed for marketing purposes. The original bridge design included two concrete abutments supported on driven steel "H" piles. Two H piles were planned per abutment with each pile driven to an ultimate capacity of 140 kips. The design working load per pile was on the order of 50 kips. With the project site located near a major intersection, city officials were concerned about large pile driving equipment blocking traffic and causing excessive disturbance to the site. Soil information for the project was also limited. Bedrock was estimated at a depth of approximately 35 feet below grade based upon pile driving logs from a highway bridge located 100 to 150 feet from the project site.

Solution: Installation of helical piles with a skid steer or mini-excavator would eliminate the concern of blocking traffic and also minimize disturbance to the site. Two helical piles were planned for each of the original H piles. The pile design considered buckling since it was also assumed that soft soils existed in the upper part of the profile. The foundation design included eight Model 349 (3.5-inch OD by 0.300-inch wall) round shaft helical piles with 10"-12"-14" triple-helix lead sections to support the design working load of 25 kips per pile. The piles would be installed to an ultimate capacity of at least 70 kips for a factor of safety (FOS) ≥ 2.8. Each helical pile was battered at five degrees from vertical away from the adjacent pile. Battering the piles provided proper spacing at the helix plate depths yet still allowed the tops of the piles to be within one foot of each other within the abutments. The helical piles were advanced to the bedrock and installed to torque values of at least 11,000 ft-lbs, correlating to ultimate capacities of at least 77 kips. The tops of the piles were cut off to the design elevation and new construction brackets were tack-welded in place. Three feet of pile length was left exposed above the bottoms of the excavations to allow the pile caps to be embedded mid-height within the concrete abutments. Foundation Supportworks of Wisconsin installed the eight piles in one day to an average depth of 32 feet below the bottoms of the excavations.

Model 350 Helical Piles

Commercial

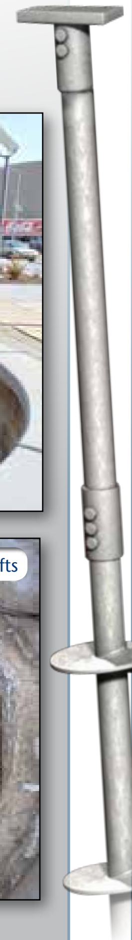
Project: Blue Cross Blue Shield Sculpture ● **Location:** Omaha, NE
Foundation Supportworks™ Dealer/Installer: Foundation Supportworks by Thrasher

Challenge: A 40-foot tall metal sculpture was planned near the main entrance of a building on the new Blue Cross Blue Shield business campus. Design of the sculpture was finalized during the last phases of the campus construction. Two test borings completed for the adjacent building encountered 48.5 to 53 feet of soft to medium stiff lean clay and fat clay over medium dense to very dense sand to depths of 95 feet and 111.6 feet. Layers of very stiff sandy lean clay (glacial till) were also sampled in one boring below a depth of 73.5 feet. With weak clay soils near the surface, differential settlement was a concern for a mat foundation. The structure would have to be supported on a deep foundation system to penetrate the weak clay soils and bear within the competent sands below. However, large pile installation equipment could not access the planned sculpture location without risk of damage to the existing pavements and sidewalks. Auger-cast piles, driven piles and drilled shafts would also be expensive options considering the mobilization costs and the limited number of piles required for the project.

Solution: Helical piles could support the combined structural loads of the sculpture and pile cap, while also being installed with smaller equipment. Determination of pile design loads considered anticipated pile movement, including elastic deformations, as well as potential bending or buckling of the pile shaft through the very soft clay layers. The foundation design included a 14-foot diameter, three-foot thick concrete pile cap and eight helical piles. The helical piles consisted of the HP350 (3.50" OD by 0.313" wall) hollow round shaft with 10"-12"- 14" triple-helix lead sections to support a design working compression load of 30 kips and a design working tension load of 10 kips (per pile). The piles were installed with a rubber-tired skid steer to depths of 57 to 60 feet below grade, or 53 to 56 feet below bottom of pile cap elevation. Ultimate pile capacities, determined by correlation to installation torque, exceeded the design working loads with factors of safety greater than two. The tops of the piles were cut to the design elevation to provide six inches of embedment within the pile cap. New construction brackets were welded to the tops of the piles. The eight piles were completed in one day.


Advancing lead section


Piles cut to design elevation; brackets welded to shafts



New Construction & Retrofit Helical Piles

Commercial


Helical pile installation in low overhead conditions

Retrofit pile systems used to re-level structure


BEFORE AFTER

Project: Bruce Howard Construction Company ● **Location:** Charles City, VA
Foundation Supportworks™ Dealer/Installer: JES Construction, Inc.

Challenge: In 2010, the Bruce Howard Construction Company began construction of a new 5,400 sq. ft. office and warehouse to serve as the company's new headquarters. The new building is a wood-framed, metal-sided structure supported by wood columns. Signs of settlement were observed soon after construction started, evident by racked windows, buckled siding and distress in the roof. Settlement up to four inches was measured. The general subsurface profile, determined from three test borings to depths of 40 feet, consisted of sandy and clayey fill soils to depths of 13.5 to 17.5 feet over native sand with isolated clay layers. A drainage swale was reportedly filled in to develop the property. The fill soils were variable in strength with standard penetration test blow count values (N-values) ranging from 4 to 16 blows per foot. The native sands were generally medium dense (N = 10 to 19 bl/ft) above 30 feet and medium dense to dense (N = 16 to 40 bl/ft) below 30 feet. The clay layers were described as stiff to very stiff in consistency.

Solution: The structural settlement was likely caused by consolidation of the loosely placed fill. One hundred fifty-two (152) helical piles with retrofit brackets were installed to re-support the existing building by extending through the fill to bear within the native medium dense to dense sands or stiff to very stiff clay. The retrofit pile system consisted of the Model 287 (2.875-inch OD by 0.203-inch wall) hollow round shaft with 8"-10"-12" triple-helix lead sections to support a design working load of 15 kips. The retrofit piles were installed to torque-correlated ultimate capacities of at least 30 kips to provide factors of safety (FOS) ≥ 2.0. Hydraulic cylinders were used to lift the foundations to near the original, pre-settlement elevations. Since the concrete floor had not yet been poured, a new structural slab was proposed. The structural slab was supported on new construction helical piles spaced at eight feet center to center in a grid pattern. The helical piles supporting the structural slab consisted of the Model 287 hollow round shaft with 10"-12" double-helix lead sections to support a design working load of 10 kips. The piles were installed to torque-correlated ultimate capacities of at least 20 kips to again provide FOS ≥ 2.0. The retrofit and new construction piles were installed to depths (below bracket bearing elevation) ranging from 22 to 40 feet.