Geotechnical Investigation Guidelines for Helical Pile Designs

Don Deardorff, P.E. Senior Application Engineer

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 section, 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.

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 1,500 psf to 4,000 psf are preferred for use of helical piles or anchors, although higher or lower values may also be considered.

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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 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 with calibrated pressure gauges, 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 (A_h), an assumed torque correlation coefficient (K_t) and the test probe installation torque (T) using the ultimate capacity (Q_u) equations for helical piles.

Since,

$$Q_u = K_t * T, \text{ and}$$
$$Q_u = A_h * 9 * c,$$

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

$$c_{eff} = (K_t * T)/(A_h * 9)$$

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

Advancing helical test probe; torque recorded at one-foot intervals
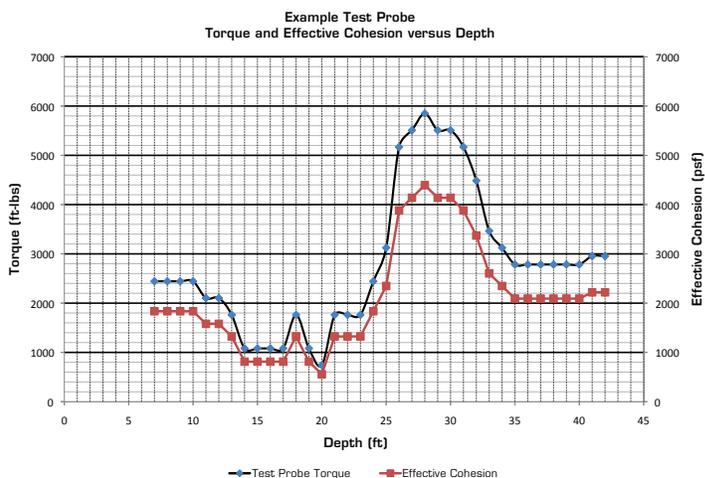
Don Deardorff, P.E. Senior Application Engineer

Don provides preliminary design assistance for installing contractors, engineers, architects and other design professionals. He specializes in large and challenging commercial and industrial applications involving helical piles, helical tiebacks, soil nail walls or hydraulically-driven push pier systems. Don has performed over 1,100 helical or push pier designs during his tenure as a helical design professional. With his industry knowledge and research experience, Don also assists with product development and verification testing, and the development of technical documents and presentations.