Final Report

Design and Installation of Torque Anchors for Tiebacks and Foundations

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NOMENCLATURE

Symbol	Description	Page
Q_u	Calculated Ultimate Capacity	17
Q_h	Individual Helix Capacity	17
q_h	Soil Bearing Capacity	17
A_h	Helix Plate Area	17
c	Soil Cohesive Strength	17
ϕ	Soil Friction Angle	17
γ	Soil Unit Weight	17
N_c	Bearing Capacity Factor for Cohesion	18
N_γ	Bearing Capacity Factor for Friction	18
N_q	Bearing Capacity Factor for Surcharge	18
d_h	Helix Diameter	18
H	Embedment Depth	18
Q_f	Friction Capacity of the Soil Cylinder	18
D_a	Average Helix Diameter	19
H_1	Embedment Depth of Top Helix	19
H_n	Embedment Depth of Bottom Helix	19
K_u	Uplift Coefficient for Helical Anchors	19
T	Average Torque Value (ft-lb)	20
K_t	Torque Factor (ft^{-1})	20

OVERVIEW OF HELICAL ANCHORS

1.1 INTRODUCTION

Helical anchors are geotechnical tools composed of a steel shaft with helical plates welded near the end. Their applications include both light and heavy foundation systems for new construction, tie downs for structures subject to uplift, piers to underpin and level structures subject to settlement, and tiebacks and soil nails for the retention of slopes and structures. They are typically installed into the ground by truck or trailer mounted augering equipment.

Earth Contact Products offers a standard line of Helical Torque Anchor™ configurations, and also fills custom orders. All of ECP's anchors are constructed with structural steel and are manufactured with a carefully maintained helix pitch. Helix plates are secured to the anchor shaft with a double weld, in order to assure the durability of the anchor. A full listing of Earth Contact Products Helical Torque Anchors and Accessories can be found in *Foundation Repair Products and Helical Torque Anchors*.

1.2 HISTORY OF HELICAL ANCHORS

Helical anchors have evolved from early foundations known as screw piles or screw mandrills. The earliest reported screw piles were constructed of a timber fitted with an iron screw propeller. These primitive screw piles were twisted into the ground by hand and promptly withdrawn. They remaining hole was filled with a crude concrete and served as a foundation.

The earliest known application of power-installed helical anchor foundations is credited to Alexander Mitchell, a blind English brickmaker, in 1833. Mitchell applied his 'screw pile' design to the foundation systems for a series of lighthouses in the English tidal basin. Although Mitchell's design was successful, power-installed helical anchors did not see widespread use until the twentieth century. The first commercially feasible helical anchor was developed for the electrical power industry in response to the need for rapidly installed guywire anchors and transmission line tower foundations.

The technology developed during World War II, and the subsequent development of reliable hydraulic torque drive devices and truck mounted auger rigs further revolutionized the industry. In the past twenty-five to thirty years, helical anchors have begun to see expanded use in a variety of geotechnical engineering applications. When properly designed and installed for a given application, helical anchors have been proven to sustain uplift, compressive, and lateral pullout loads, as well as some horizontal lateral loads.

1.3 COMPONENTS

Helical anchors are constructed of two main structural elements: the anchor shaft and the helix plates. Figure 1.1 shows a typical helical anchor section with a solid square anchor shaft and two helix plates.

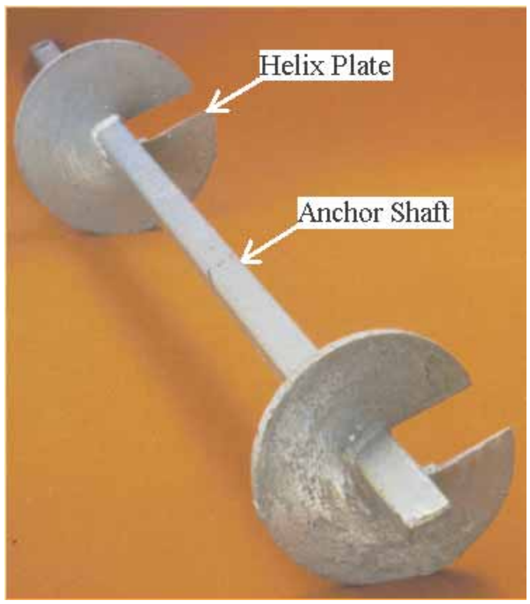


Figure 1.1. Helical Anchor Components

The anchor shaft is composed of structural steel and may be circular or square, hollow or solid. Typical dimensions of the anchor shaft are in the range of 1½ to 3½ inches (4 to 9 centimeters) diameter or width. The helix plates are also constructed of structural steel and are formed with a carefully maintained pitch, such that the anchor disturbs the surrounding soil as little as possible during installation. The typical thickness of the helices is in the range of 3/8 to 1/2 inches (1 to 2 centimeters), while typical diameters range from 6 to 14 inches (15 to 36 centimeters). While these dimensions are the most common, helical anchors have been specially manufactured for high compression loading situations with shaft diameters as large as 12 inches (0.3 meters) and helix diameters as large as 48 inches (1.2 meters).

Helical anchors are constructed in two sections: lead sections and extension sections. Lead sections are composed of the steel anchor shaft with the helix plates welded to it. Helix plates are typically spaced three helix diameters from one another along the lead section shaft. Lead sections can have a variety of lengths, generally ranging from 10 inches to 10 feet (0.25 to 3 meters). Because of the required three helix diameters spacing, the greatest number of helices that is typically attached to one lead section is three. If the anchor design requires more than three helices, lead sections can be connected together until the requirements are met. Because helical anchors are screwed into the ground using torque motors, the maximum number of helices on any one anchor eventually becomes limited by the installation torque. For practical purposes, the number of helices on any one anchor should be limited to four or five, with the absolute maximum being eight. A typical two-helix lead section is shown in Figure 1.2.

Figure 1.2. Lead Section

Extension sections are lengths of steel anchor shaft used to increase the total length of the helical anchor. Typical lengths of extension sections range from 3 to 10 feet (0.9 to 3 meters). Similar to the total number of helices on an anchor, the total anchor length will also eventually become torque limited. Sections are connected using an overlapping end and a steel pin, as shown in the typical extension section in Figure 1.3 (ECP 2002).

Figure 1.3. Extension Section

1.4 APPLICATIONS

Helical anchors have been proven successful in a large variety of applications, involving a number of different loading situations. Helical anchors were originally designed to sustain the substantial uplift loads from the wind and overturning moments on transmission line towers. Today, there are a number of situations in which helical anchors are loaded primarily in uplift. They remain the most common foundation system for transmission line towers. They are also used as anchors for major pipeline systems, both on land and in major bodies of water. Helical anchors are commonly used to secure tie downs for mobile homes, temporary structures, and other light structures subject to wind loads. In areas with highly swelling soils, helical anchors are frequently used for both new and retrofit construction to overcome the difficulties associated with volumetric change. In addition, the use of helical anchors is no longer limited to light loading situations. The ultimate tensile capacity of helical anchors can be in excess of two hundred thousand pounds.

Helical anchors are being used for an increasing number of compressive loading situations as well. They are commonly used as foundation systems for light construction, such as residential homes and small businesses. They are also used as piers to shore, underpin, and level structures which have experienced settlement or undermining due to loose soils, compressible fill, erosion, excavation, or other means. Helical anchors have been specially designed with larger shaft sizes for heavy loading applications, used for column loads in excess of one hundred thousand pounds. Helical anchors are also being used as tiebacks and soil nails. They are being applied as tiebacks in lieu of traditional grouted anchors with increasing frequency. Helical anchors installed as tiebacks are typically screwed into the soil slope at an angle zero to twenty-five degrees from the horizontal. The upper-most helix must be placed a minimum of three helices beyond the active zone and the anchors should be pre-tensioned in a manner similar to traditional tiebacks. When applied as soil nails, helical anchors are installed close together and act to internally reinforce the soil mass. They are not tensioned after installation and act as passive elements.

1.5 ADVANTAGES

Helical anchors offer many advantages for both new construction and remediation or retrofit of existing construction. Reliability is the most obvious advantage. When properly installed, helical anchors are proven to meet and even exceed their design capacities. Helical anchors can be installed with standard truck or trailer mounted augering equipment and installation can be accomplished quickly with minimal site disturbance. Unlike many other deep foundation types, helical anchors can be installed in areas with limited access and can be loaded immediately. Another proven advantage of helical anchors is that installation torque can be directly correlated to in-place anchor capacity, eliminating many of the uncertainties involved with other deep foundation systems. Finally, helical anchors can be applied in a wide variety of soil conditions and have been proven cost-competitive.

1.6 DISADVANTAGES

Like all foundation alternatives, there are some conditions where helical anchors should not be used. Helical anchors should not be installed in subsurface conditions where the encountered material may damage the helices or the shaft, or where installation depths are restricted. This would include soils containing cobbles, large amounts of gravel, boulders, and construction rubble. In extremely soft soils, typically those with standard penetration test (SPT) N-values less than five, buckling of anchors in compression must be considered during design. Also, standard helical anchors are not effective in supporting structures with large lateral loads and/or overturning moments.

1.7 GENERAL DESIGN APPROACH

All helical anchor design should begin with a thorough site investigation. The engineer should have a good understanding of soil properties, the influence of groundwater, anticipated loads, and allowable settlement before beginning design. Soil properties should be estimated for the critical loading condition based upon the results of the site investigation and the application of engineering judgment. Helical anchor configurations should be selected and appropriate helical anchor design equations should be used to determine the ultimate capacity of the given configuration. The calculated ultimate capacity should be divided by a factor of safety to obtain the allowable anchor capacity. The factor of safety should be selected based upon the importance of the structure, thoroughness of the site investigation, and reliability and variability of the design loads and soil properties.

Different helical anchor configurations should be examined to determine the safest and most cost effective design. Helical anchors should be installed by knowledgeable installation professionals. Proper installation procedures are critical for satisfactory performance of helical foundations. Care must be taken to insure against applying excessive down pressure (crowd), and excessive torque. Proper crowd and torque should result in the helical anchor essentially pulling itself into the ground. The installer and engineer should communicate about field conditions that may differ from those anticipated so the helical anchor design can be adjusted if needed. Torque should be monitored during installation and used as an indicator of anchor capacity. Finally, selected helical anchors should be load tested to validate design assumptions.

2.0 SITE CHARACTERIZATION

2.1 PURPOSE

A thorough understanding of the character of the subsurface site stratigraphy must be obtained before the appropriate foundation system can be determined. The site characterization process is absolutely critical to the effective and appropriate use of any foundation, including helical anchors. Failure to properly define subsurface conditions and soil properties prior to design and installation can potentially result in inadequate designs, failure of the selected geotechnical system, and the corresponding legal liability.

The site characterization program provides the engineer with necessary information about the site layout and subsurface conditions. A comprehensive geotechnical site investigation enables the design engineer to first decide if helical anchors are appropriate for the site, and second, properly design the size and capacity of the helical anchor system. Guidelines for site characterization can be found in "Standard Guide to Site Characterization for Engineering Design and Construction Purposes", ASTM D 420-98.

2.2 GOALS

Prior to planning and commencing a site investigation, the engineer should focus on the specific information he or she needs, and should outline the specific goals of the site investigation program. Typical goals of site investigation programs include determining general subsurface stratigraphy, locating the groundwater level, determining soil types and properties, examining surface features such as outcrops, drainage, and vegetation, evaluating site access, and, ultimately, evaluating the applicability of different foundation systems for the project. For helical anchors, there are three main soil properties that must be obtained during a site investigation: cohesive strength (c), friction angle (ϕ), and unit weight (γ).

2.3 PROCEDURE

A properly orchestrated site investigation is the key to a successful construction project. The site investigation process incorporates six main steps: budget, literature search, field reconnaissance, exploratory drilling and sampling, laboratory testing, and data compilation and analysis.

2.3.1 Budget. Funds should be allocated for site investigation in the preliminary design phases of a project. It should be emphasized that geotechnical investigation is an investment in the quality of a project, and should never be viewed as an extraneous cost. A very general rule of thumb for the cost of a geotechnical investigation is between three and five percent of the total project budget. The magnitude of the site investigation budget is dependent upon a number of factors, particularly the magnitude and importance of the proposed construction and the homogeneity of the area geology.

2.3.2 Literature Search. The literature search is one of the first steps in the site investigation process and consists mainly of compiling existing information about the proposed structure and the site itself. Documents to look for include the design plans for the proposed construction, previous soils reports and boring logs from the construction site or nearby sites, and maps locating underground utilities, among many others.

2.3.3 Field Reconnaissance. Field reconnaissance is necessary to evaluate any potential problems on the site that may not be evident from the results of the literature search. Things to look at during a field reconnaissance include evidence of previous development or grading, old landslides or other stability problems, site drainage, the performance and condition of nearby structures, and site access. The engineer can also look at surface soils and any exposed geological strata during the reconnaissance.

2.3.4 Data Compilation and Analysis. The final step in the geotechnical investigation process is the compilation and analysis of the collected data. This compilation is most likely in the form of a geotechnical site investigation report, complete with final boring logs and test results. With the complete results of the geotechnical site investigation, the design engineer can proceed to evaluate the applicability of different solutions to the project. If helical anchors are selected, they can now be designed with a higher degree of confidence in soil conditions and, thus, a higher degree of confidence in their capacity. By properly applying the results of the geotechnical investigations, helical anchors will continue to have the success they have enjoyed in the past, and will likely continue to see expanded use in the geotechnical industry.

2.4 UNCERTAINTY IN SOIL PROPERTIES

Even with the optimal site characterization program, it is impossible to correctly identify all of the subsurface features and soil properties on a site. Engineering decisions must be made as to how representative subsurface data is and what parameters should be selected for design.

Factors of safety should be applied based upon the variability of the site and the engineer's level of confidence in the design parameters. If a reliability-based design approach is employed, adjustments should also be taken based upon the data available.

2.5 IMPACT OF HELICAL ANCHOR INSTALLATION ON SOIL PROPERTIES

The installation process for helical anchors typically has minimal impact on in situ soil properties. They are considered a low displacement foundation member because of their geometry and the manner in which they are installed. The center shaft is considered a slender member and causes a relatively small disturbance of the surrounding soil. When properly installed, it can be assumed that all of the helices follow the same path as the lead helix as they are screwed into the ground; that is, the lead helix cuts a path through the soil and each of the following helices is advanced through the same path, leaving the majority of the soil relatively undisturbed.

While helical anchors typically have a minimal effect on in situ soil properties, there are soil-anchor interaction mechanisms worth noting. Shaft friction is a complex phenomenon that often contributes to the capacity of deep foundations. When helical anchors are installed in clay, the disturbance of the soil causes a change in the shear strength of the soil and simultaneously induces lateral stresses. With time, these lateral stresses cause a change in water content and subsequent change in shear strength in the soil along the shaft. Although it is likely that shaft friction contributes to the capacity of helical anchors, the term is generally ignored in helical anchor design because of the uncertainties involved. This assumption is considered conservative.

The installation process may also cause some unit weight change in the surrounding soil. The effect of this change is minimal in cohesive soils, and is probably most notable in loose to medium dense sands where the void ratio is most readily reduced. Still, the densification effect is small and the potential strength increase should be neglected during helical anchor design. Helical anchor design should be based on site investigation data and engineering judgment. Ignoring the effects of potential densification during installation is considered conservative.

3.0 HELICAL ANCHOR DESIGN THEORY

This section will discuss the two primary design methods, individual plate bearing and cylindrical shear friction, as well as the most well known empirical correlation, installation torque.

3.1 INDIVIDUAL PLATE BEARING.

The individual plate bearing capacity method is based on the assumption that each helix plate acts independently on the soil. The ultimate capacity of the anchor is then the summation of the individual helix capacities. Figure 3.1 illustrates the individual plate bearing capacity method in uplift loading.

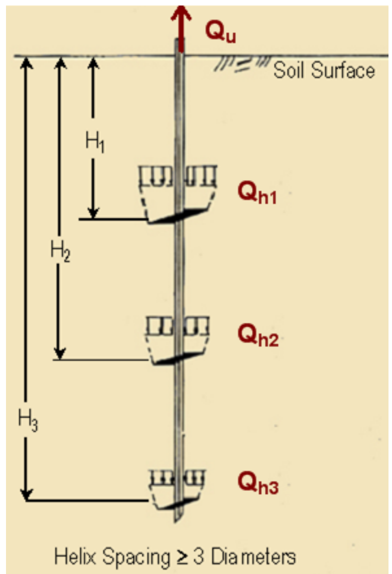


Figure 3.1. Individual Plate Bearing Capacity Theory

The individual plate bearing capacity method is the adaptation of traditional bearing capacity theory, as developed by Terzaghi, Meyerhof, Hansen, and Vesic. Equations 1 and 2 show the general format of the individual plate bearing capacity method as it is applied to helical anchors. Q_u is the ultimate capacity of the anchor and Q_{hi} is the capacity of an individual helix The bearing capacity of the soil, q_{hi}, as defined by traditional theory, is composed of three terms as shown in Equation 3.

$$Q_u = \sum_{i=1}^{N} Q_{hi} \tag{1}$$

$$Q_{hi} = q_{hi} \cdot A_{hi} \tag{2}$$

$$q_{hi} = c_i N_c + \tfrac{1}{2} d_{hi} \gamma_i N_\gamma + \gamma_i H_i N_q \tag{3}$$

The first, second, and third terms in Equation 3 are the contributions of cohesion, friction, and overburden to capacity, where c_i is soil cohesive strength, d_{hi} is helix diameter, γ_i is soil unit weight, and H_i is helix embedment depth. Likewise, N_c, N_y, and N_q are the bearing capacity factors for cohesion, friction, and surcharge, respectively, and are typically a reduced version of Meyerhof's traditional bearing capacity factors.

Since the individual plate bearing capacity method for helical anchors is an adaptation of traditional bearing capacity theory, there are adjustments that have been made between the respective equations. First, when the individual plate bearing capacity method is applied to helical anchors, the helix plates must be spaced at least three helix diameters apart. Second, the N_γ term of the bearing capacity equation is typically ignored in helical anchor design. It is a common observation in geotechnical engineering that when the foundation width, or helix diameter in this case, is small, that the N_γ term contributes only a small percentage to capacity. Since helix diameters are generally in the range of eight to fourteen inches in diameter, ignoring this term is considered reasonable and conservative.

Third, the bearing capacity factors used in helical anchor design are typically a reduced version of the traditional factors proposed by Meyerhof. Meyerhof's bearing capacity factors are based upon the assumption that the bearing soil is relatively undisturbed. Mitsch and Clemence showed good agreement with Meyerhof's bearing capacity factors for the top helix plate in uplift loading, but also showed that soil between multiple helices is churned up during installation. They noted that the coefficients of lateral earth pressure for uplift are thirty to forty percent lower than the coefficients proposed by Meyerhof and Adams. Mitsch and Clemence attributed this reduction to the shearing disturbance that is caused during anchor installation. As a result, when the individual plate bearing capacity method is applied to a multi-helix anchor, the bearing capacity factors should be reduced in order to account for the reduction in lateral earth pressure.

1.1 3.2 CYLINDRICAL SHEAR FRICTION

The cylindrical shear friction capacity method is based on the assumption that helical anchor behavior is intermediate between that of grouted and spread anchors. Helical anchor capacity comes from the frictional strength between the soil cylinder encapsulated by the helices and the surrounding soil cylinder, and from the bearing capacity of either the uppermost helix plate or the bottom helix plate, for uplift and compression loading, respectively. Figure 2.6 illustrates the cylindrical shear friction capacity method as it is applied in uplift loading. Q_h is the strength of the top helix plate and Q_f is the frictional strength of the soil cylinder.

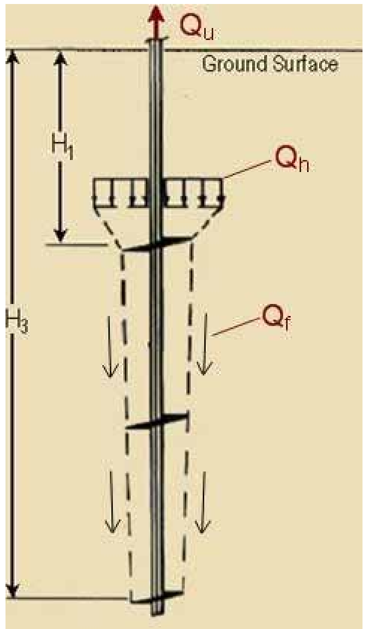


Figure 3.2. Cylindrical Shear Friction Capacity Method

The general format of the cylindrical shear friction capacity method is given in Equation 4, where Q_h is the bearing capacity of the top helix plate if loading is in uplift or the bottom helix plate if loading is in compression, and Q_f is the frictional strength between the encapsulated soil cylinder and the surrounding soil mass. Q_h is defined in accordance with Equation 2 of the individual plate bearing capacity method. Q_f was defined for cohesionless soils by Mitsch and Clemence as shown in Equation 5. For cohesive soils, Q_f was defined by Mooney, Adamczak, and Clemence as shown in Equation 6. H_1 is defined as the depth of the uppermost helix, H_3 is the depth to the bottom helix, D_a is the average helix diameter, and K_u is the uplift coefficient for helical anchors. K_u is defined by Mitsch and Clemence as shown in Figure 2.7 (Mitsch and Clemence 1985).

$$Q_u = Q_h + Q_f \tag{4}$$

$$Q_f = \frac{\pi}{2} D_a \gamma \cdot \left(H_n^2 - H_1^2\right) \cdot K_u \tan(\varphi) \tag{5}$$

$$Q_f = \pi D_a c \cdot \left(H_n - H_1\right) \tag{6}$$

K_u as defined by Mitsch and Clemence (1985)	
Friction Angle (ϕ)	Uplift Coefficient, K_u
25	0.70
30	0.90
35	1.50
40	2.35
45	3.20

Table 3.1. Recommended Uplift Coefficients (K_u) for Cylindrical Shear Friction Capacity

3.3 INSTALLATION TORQUE.

The concept that installation torque can be used as an empirical indicator of helical anchor capacity has been endorsed by helical anchor manufacturers for a number of years. The required torque is monitored during installation until the anchor reaches its design depth or until the anchor can no longer be advanced. The torque readings are then averaged over the distance of the final three helix diameters or the last three feet of installation. This averaged torque value, T, usually in the units of ft-lb, is then multiplied by the torque factor, K_t, usually in the units of ft^{-1}, to obtain the ultimate capacity, Q_u. Most manufacturers recommend a torque factor, K_t, between 8 and 17 ft^{-1}, with the most common value being 10. However, the most effective way to apply the empirical relationship of installation torque is with the use of field load testing to back calculate the value of K_t. On a relatively homogenous site, a properly conducted load test that is used to compute the torque factor value can be of great benefit in evaluating as-installed anchor capacity. Equation 7 shows the relationship between installation torque and ultimate anchor capacity.

$$Q_u = k_t \cdot T \tag{7}$$

4.0 EARTH CONTACT PRODUCTS DESIGN EQUATIONS

Earth Contact Products recommends the individual plate bearing capacity method for helical torque anchors in all soil types. The cylindrical shear friction capacity method may be used as an alternate in cohesive soils. The following equations can be applied to helical anchor design regardless of anchor orientation (vertical or horizontal) and direction of loading (tension or compression).

1.2 4.1 DESIGN EQUATIONS

The individual plate bearing capacity method, as shown in Equations 8 and 9, can be used to calculate ultimate helical anchor capacity in all soil types. Earth Contact Products' recommended bearing capacity factors are shown in Table 4.1.

$$Q_u = \sum_{i=1}^{N} Q_{h_i} \tag{8}$$

$$Q_{h_i} = A_{h_i} \cdot \left(cN_c + qN_q\right) \tag{9}$$

The cylindrical shear friction capacity method, as shown in Equation 11, can be used to calculate ultimate helical anchor capacity in purely cohesive soils.

$$Q_u = A_h \cdot \left(9c + q\right) + \pi D_a c \cdot \left(H_n - H_1\right) \tag{10}$$

Allowable helical anchor capacity, Q_a, is obtained by dividing the ultimate calculated capacity, Q_u, by a factor of safety, FS. Factors of safety should be determined based upon the extent of the subsurface investigation, the designer's confidence in the assumed soil parameters, and the importance of the structure. Earth Contact Products recommends a minimum factor of safety of 2 in cohesive soils and a minimum factor of safety of 4 in cohesionless soils. If settlement is not a concern, a smaller factor of safety may be considered in cohesionless soils.

$$Q_a = Q_u / FS \tag{11}$$

Table 4.1. Earth Contact Products' Recommended Bearing Capacity Factors

ϕ	N_q	N_c
0	1	9
5	1	9
10	2	9
15	3	10
20	5	15
25	9	22
26	10	24
28	13	28
30	17	34
32	22	41
34	28	50
36	37	63
38	49	79
40	66	101
45	149	203
50	391	468

Earth Contact Products recommends the installation torque method as a means of quality control during installation. The method, as shown in Equation 12, provides an indicator of helical anchor capacity and can be of great value in the field, particularly if site conditions differ from conditions anticipated during design. Installation torque should be monitored during helical anchor installation and torque values should be recorded every foot. The last three torque values should be averaged to obtain the torque value, T (ft-lb). The torque value, T, is multiplied by the torque factor, K_t, to obtain an estimated value of ultimate helical anchor capacity, Q_u. If possible, a load test taken to failure should be conducted to back calculate a site specific torque factor, Kt. On sites with relatively homogenous soil conditions, back calculation of Kt has been shown to be an excellent indicator of helical anchor capacity. If it is not possible to conduct a load test, a torque factor of 10 ft^{-1} is recommended to obtain a reasonable estimate of anchor capacity.

$$Q_u = k_t \cdot T \qquad (12)$$

Definition of Terms:

Q_a	=	Allowable Helical Anchor Capacity
Q_u	=	Ultimate Helical Anchor Capacity
FS	=	Factor of Safety (2.5 for Uplift and Compression, 3 for Lateral Loading)
Q_{hi}	=	Individual Helix Plate Capacity
A_{hi}	=	Individual Helix Plate Area
c	=	Soil Cohesive Strength
q	=	Overburden Stress (Embedment Depth, H, times Soil Unit Weight, γ)
ϕ	=	Soil Friction Angle
N_c	=	Bearing Capacity Factor for Cohesion (Table 4.1)
N_q	=	Bearing Capacity Factor for Friction (Table 4.1)
D_a	=	Average Helix Diameter
H_n	=	Embedment Depth of Bottom Helix
H_1	=	Embedment Depth of Top Helix
K_t	=	Torque Factor (ft^{-1}) – Recommended Value = 10 ft^{-1}, or as Determined by

Field Testing

T = Torque Value (ft-lb) – Average Value of Last 3 Installation Torque Readings

4.2 INSTALLATION DEPTHS

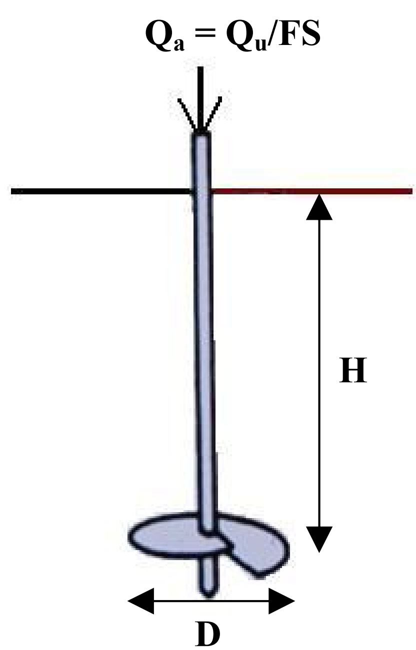
Helical torque anchors used in uplift or compression should be installed to a minimum depth of embedment of 3 top helix diameters or the frost line below the ground surface whichever is deeper. In the way, full capacity of the top plate can be utilized and problems with frost heave and freeze-thaw softening of the soils will be minimized.

The upper-most helix for helical torque anchors used in tiebacks must be placed a minimum of 3 diameters beyond the active zone. The anchors should be pre-tensioned in a manner similar to traditional tiebacks.

4.3 HELICAL EXAMPLE CALCULATIONS

The following examples are provided as a reference for using the design equations. Examples are included for the case of a single helix anchor in sand with no groundwater, a single helix anchor in sand with groundwater at the surface, a double helix anchor in sand with no groundwater, a single helix anchor in clay with no groundwater, a double helix anchor in clay with no groundwater, and a double helix anchor in clay with groundwater at the surface.

4.3.1 Single Helix Anchor in Sand with No Groundwater



Soil Parameters: γ=105 pcf, c=0 psf, ϕ=30°

Helical Anchor Properties: H=10 ft., D=1 ft.

Individual Plate Bearing Capacity Method:

$$A_{h_i} = \frac{\pi}{4}\cdot\left(1^2\right) = .785\ \text{ft}^2$$

From Table 4.1., N_c=34 and N_q=17.

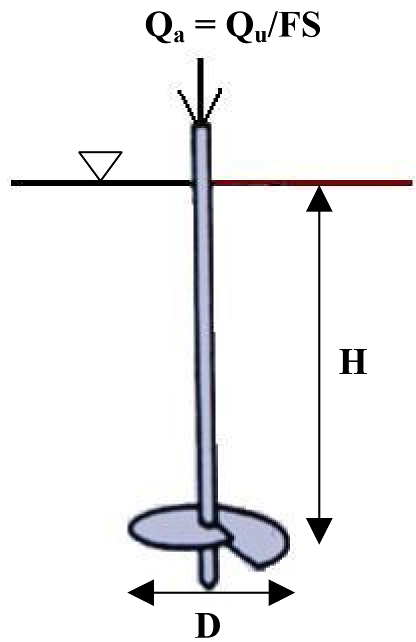
$$q = \gamma H = \left(105\ \text{pcf}\right)\cdot\left(10\ \text{ft}\right) = 1050\ \text{psf}$$

$$Q_{h_i} = 0.785\ \text{ft}^2\cdot\left(0\ \text{psf}\cdot 34 + 1050\ \text{psf}\cdot 17\right) = 14000\ \text{lb}$$

$$Q_u = \sum_{i=1}^{N} Q_{hi} = 14000\ \text{lb}$$

$$Q_a = Q_u/FS = 14000\ \text{lb}/3 = 4700\ \text{lb}$$

4.3.2 Single Helix Anchor in Sand with Groundwater at the Surface



Soil Parameters: γ=105 pcf, c=0 psf, ϕ=30°

Helical Anchor Properties: H=10 ft., D=1 ft.

Individual Plate Bearing Capacity Method:

$$A_{h_i} = \frac{\pi}{4}\cdot\left(1^2\right) = .785\ \text{ft}^2$$

From Table 4.1., N_c=34 and N_q=17.

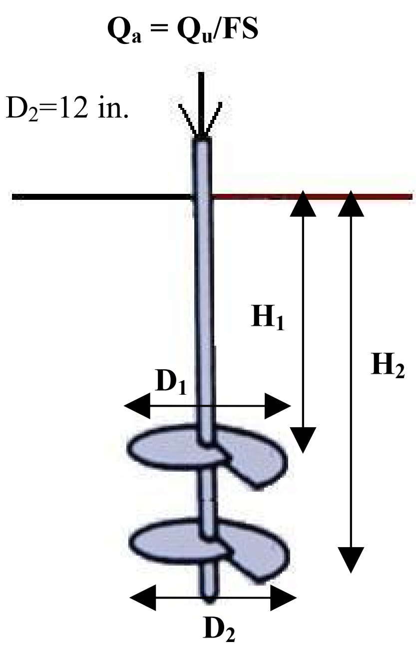
$$q = \gamma H = \left(105\text{-}62.4\ \text{pcf}\right)\cdot\left(10\ \text{ft}\right) = 426\ \text{psf}$$

$$Q_{h_i} = 0.785\ \text{ft}^2\cdot\left(0\ \text{psf}\cdot 34 + 426\ \text{psf}\cdot 17\right) = 5700\ \text{lb}$$

$$Q_u = \sum_{i=1}^{N} Q_{hi} = 5700\ \text{lb}$$

$$Q_a = Q_u/FS = 5700\ \text{lb}/2.5 = 1900\ \text{lb}$$

4.3.3 Double Helix Anchor in Sand with No Groundwater



Soil Parameters: γ=105 pcf, c=0 psf, ϕ=30°

Helical Anchor Properties: H_1=10 ft., D_1=14 in., H_2=13 ft., D_2=12 in.

Individual Plate Bearing Capacity Method:

$$A_{h1} = \frac{\pi}{4}\cdot\left(1.16^2\right) = 1.07\ \text{ft}^2$$

$$A_{h2} = \frac{\pi}{4}\cdot\left(1^2\right) = .785\ \text{ft}^2$$

From Table 4.1., N_c=34 and N_q=17.

$$q_1 = \gamma H_1 = \left(105\ \text{pcf}\right)\cdot\left(10\ \text{ft}\right) = 1050\ \text{psf}$$

$$q_2 = \gamma H_2 = \left(105\ \text{pcf}\right)\cdot\left(13\ \text{ft}\right) = 1365\ \text{psf}$$

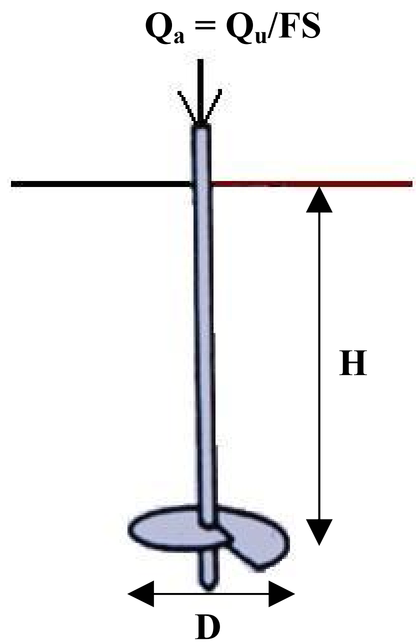
$$Q_{h1} = 1.07\ \text{ft}^2\cdot\left(0\ \text{psf}\cdot 34 + 1050\ \text{psf}\cdot 17\right) = 19100\ \text{lb}$$

$$Q_{h2} = 0.785\ \text{ft}^2\cdot\left(0\ \text{psf}\cdot 34 + 1365\ \text{psf}\cdot 17\right) = 23200\ \text{lb}$$

$$Q_u = \sum_{i=1}^{N} Q_{hi} = 19100 + 23200 = 42300 \text{ lb}$$

$$Q_a = Q_u / FS = 43200 \text{ lb} / 3 = 14400 \text{ lb}$$

4.3.4 Single Helix Anchor in Clay with No Groundwater



Soil Parameters: γ=100 pcf, c=1800 psf, ϕ=0°

Helical Anchor Properties: H=10 ft., D=1 ft.

Individual Plate Bearing Capacity Method:

$$A_{h_i} = \frac{\pi}{4} \cdot \left(1^2\right) = .785 \text{ ft}^2$$

From Table 4.1., N_c=9 and N_q=1.

$$q = \gamma H = (100 \text{ pcf}) \cdot (10 \text{ ft}) = 1000 \text{ psf}$$

$$Q_{h_i} = 0.785 \text{ ft}^2 \cdot (1800 \text{ psf} \cdot 9 + 1000 \text{ psf} \cdot 1) = 13500 \text{ lb}$$

$$Q_u = \sum_{i=1}^{N} Q_{hi} = 13500 \text{ lb}$$

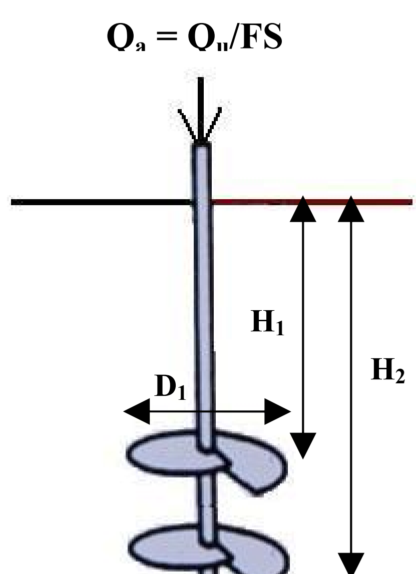
$$Q_a = Q_u / FS = 13500 \text{ lb} / 3 = 4500 \text{ lb}$$

4.3.5 Double Helix Anchor in Clay with No Groundwater

Soil Parameters: γ=100 pcf, c=1800 psf, ϕ=0°

Helical Anchor Properties: H_1=10 ft., D_1=14 in., H_2=13 ft., D_2=12 in.

Individual Plate Bearing Capacity Method:



$$A_{h1} = \frac{\pi}{4} \cdot \left(1.16^2\right) = 1.07 \text{ ft}^2$$

$$A_{h2} = \frac{\pi}{4} \cdot \left(1^2\right) = .785 \text{ ft}^2$$

From Table 4.1., N_c=9 and N_q=1.

$$q_1 = \gamma H_1 = (100 \text{ pcf}) \cdot (10 \text{ ft}) = 1000 \text{ psf}$$

$$q_2 = \gamma H_2 = (100\ \text{pcf}) \cdot (13\ \text{ft}) = 1300\ \text{psf}$$

$$Q_{h1} = 1.07\ \text{ft}^2 \cdot (1800\ \text{psf} \cdot 9 + 1000\ \text{psf} \cdot 1) = 18400\ \text{lb}$$

$$Q_{h2} = 0.785\ \text{ft}^2 \cdot (1800\ \text{psf} \cdot 9 + 1300\ \text{psf} \cdot 1) = 13700\ \text{lb}$$

$$Q_u = \sum_{i=1}^{N} Q_{hi} = 18400 + 13700 = 32100\ \text{lb}$$

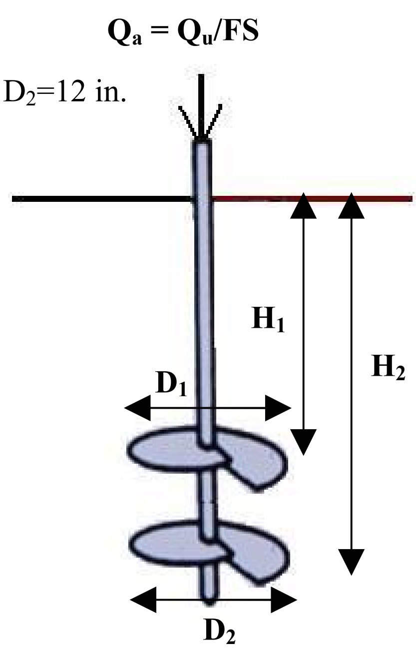
$$Q_a = Q_u / FS = 32100\ \text{lb} / 2 = 16100\ \text{lb}$$

4.3.6 Double Helix Anchor in Clay with Groundwater at the Surface

Soil Parameters: γ=100 pcf, c=1800 psf, ϕ=0°

Helical Anchor Properties: H_1=10 ft., D_1=14 in., H_2=13 ft., D_2=12 in.

Individual Plate Bearing Capacity Method:



$$A_{h1} = \frac{\pi}{4} \cdot (1.16^2) = 1.07\ \text{ft}^2$$

$$A_{h2} = \frac{\pi}{4} \cdot (1^2) = .785\ \text{ft}^2$$

From Table 4.1., N_c=9 and N_q=1.

$$q_1 = \gamma H_1 = (100\text{-}62.4\ \text{pcf}) \cdot (10\ \text{ft}) = 380\ \text{psf}$$

$$q_2 = \gamma H_2 = (100\text{-}62.4\ \text{pcf}) \cdot (13\ \text{ft}) = 490\ \text{psf}$$

$$Q_{h1} = 1.07\ \text{ft}^2 \cdot (1800\ \text{psf} \cdot 9 + 380\ \text{psf} \cdot 1) = 17700\ \text{lb}$$

$$Q_{h2} = 0.785\ \text{ft}^2 \cdot (1800\ \text{psf} \cdot 9 + 490\ \text{psf} \cdot 1) = 13100\ \text{lb}$$

$$Q_u = \sum_{i=1}^{N} Q_{hi} = 17700 + 13100 = 30800 \text{ lb}$$

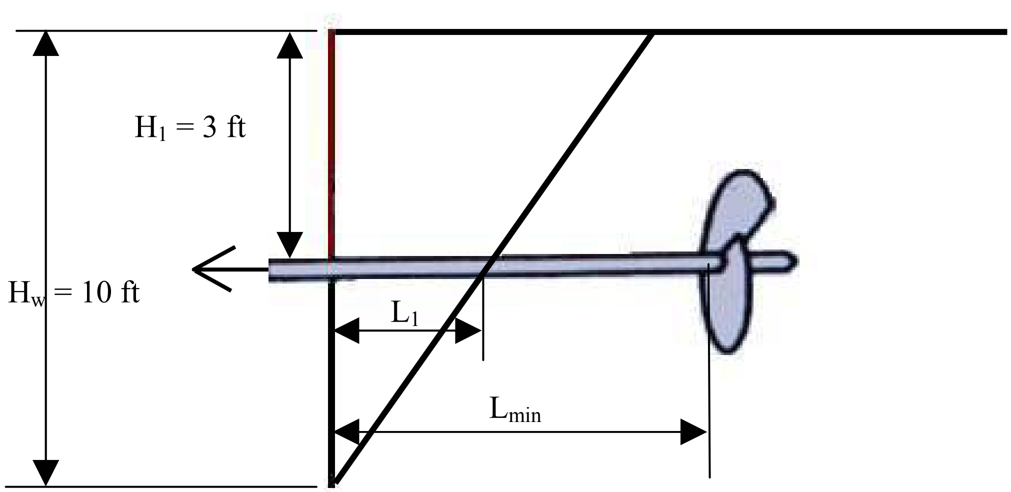
$$Q_a = Q_u / FS = 43200 \text{ lb} / 3 = 14400 \text{ lb}$$

4.3.7 Horizontal Pullout – Single Helix Anchor in Sand with No Groundwater

Soil Parameters: γ=105 pcf, c=0 psf, ϕ=30°

Helical Anchor Properties: H_w=10 ft., D_1=1 ft., H_1=3 ft

Individual Plate Bearing Capacity Method:



$A_{hi} = \frac{\pi}{4} \cdot \left(1^2\right) = \ .785 \text{ ft}^2$

$L_1 = (H_{wall} - H_1) \cdot \tan(90\text{-}\Theta) = 4.04 \text{ ft}^2$

$L_{min} = L_1 + 3D_1 = 7.04 \text{ ft} \ \approx 7 \text{ ft}$

From Table 4.1., $N_c = 34$ and $N_q = 17$

$q = \gamma \cdot L_{min} = 105 \cdot 7 = 735$ psf

$Q_u = A_1 \cdot (q_0 \cdot N_q) = .785 \cdot (735 \cdot 17) = 9800$ lb

FS = 4

$Q_a = Q_u/FS = 9800 \text{ lb}/4 = 2450$ lb

4.3.8 Horizontal Pullout-Single Helix Anchor in Clay with Groundwater at the Surface

Same anchor configuration as 4.3.7.

Soil Parameters: γ=100 pcf, c=1800 psf, ϕ=0º

Helical Anchor Properties: H_1 = 10 ft., D_1 = 14 in.

Individual Plate Bearing Capacity Method:

$Q_{h_i} = A_{h_i} * (cN_c + qN_q)$

$A_{h_1} = \frac{\pi}{4} * (1.16^2) = 1.07 \text{ ft}^2$

From Table 4.1., N_c = 9 and N_q = 1.

$L_1 = (H_{wall} - H_1)*\tan(90-\Theta) = 4.04\ ft^2$

$L_{min} = L_1 + 3D_1 = 7.04$ ft say 7 ft

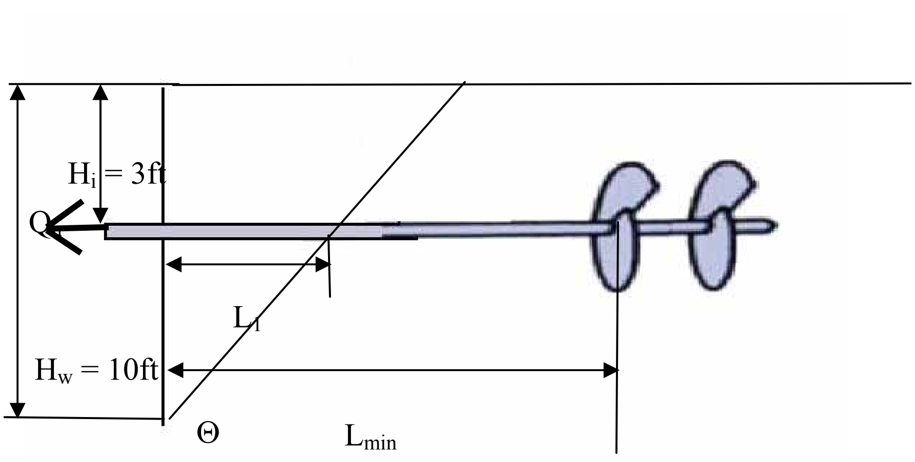
$q = \gamma L_{min} = 105*7 = 735$ psf

$Q_u = 1.07*(1800*9+735*1) = 18100$ lb

FS = 2

$$Q_a = \frac{Q_u}{FS} = \frac{18100\ lb}{2} = 9050\ lb$$

4.3.9 Horizontal Double Helix Anchor in Sand with No Groundwater



Soil Parameters: γ=105 pcf, c=0 psf, ϕ=30º

Helical Anchor Properties: D_1 = 14 in. D_2 = 12 in.

Individual Plate Bearing Capacity Method:

$$A_{h_1} = \frac{\pi}{4}*(1.16^2)=1.07 \text{ ft}^2$$

$$A_{h_2} = \frac{\pi}{4}*(1^2)=.785 \text{ ft}^2$$

From Table 4.1., $N_c = 34$ and $N_q=17$

$L_1 = \left(H_{wall}\text{-}H_1\right)\tan(90\text{-}\Theta) = 2.24$ ft

$L_{min} = L_1 + 3D_1 = 5.7$ ft

$q_1 = \gamma L_{min} = 105 * 5.7 = 600$ psf

$Q_1 = A_1(cN_c + q_1N_q) = 10800$ lb

$q_2 = \gamma(L_{min}+D2) = 105 * (5.7+8.5) = 892.5$ psf

$Q_2 = A_2(cN_c + q_2N_q) = 11900$ lb

$Q_u = Q_1 + Q_2 = 10800 + 11900 =22700$ lb

FS = 4

$Q_a = Q_u/FS = 22700$ lb/4 = 5675 lb

4.3.10 Horizontal Double Helix Anchor in Clay with Groundwater at the Surface

Soil Parameters: γ=100 pcf, c=1800 psf, ϕ=0º

Helical Anchor Properties: D_1 = 14 in. D_2 = 12 in.

Individual Plate Bearing Capacity Method:

$$A_{h_1} = \frac{\pi}{4}*(1.16^2)=1.07 \text{ ft}^2$$

$$A_{h_2} = \frac{\pi}{4}*(1^2)=.785 \text{ ft}^2$$

From Table 4.1., $N_c = 9$ and $N_q=1$

$L_1 = \left(H_{wall}\text{-}H_1\right)\tan(90\text{-}\Theta) = 2.24$ ft

$L_{min} = L_1 + 3D_1 = 5.7$ ft

$q_1 = \gamma L_{min} = 105 * 5.7 = 600$ psf

$Q_1 = A_1(cN_c + q_1N_q) = 1.07(1800*9+600*1) = 17900$ lb

$q_2 = \gamma(L_{min}+D2) = 105 * (5.7+8.5) = 892.5$ psf

$Q_2 = A_2(cN_c + q_2N_q) = 1(1800*9+892.5*1) = 17100$ lb

$Q_u = Q_1 + Q_2 = 17900 + 17100 = 35000$ lb

FS = 2

$Q_a = Q_u/FS = 35000$ lb/2 = 17500 lb

5.0 LOAD TESTING

5.1 PURPOSE OF LOAD TESTING

Load testing is a valuable tool in helical anchor design and installation. Different types of load tests can serve several different purposes depending on the type of application. Primarily, load tests provide a means of design validation and quality control and assurance. Load tests can be used to confirm that installation methods are performing satisfactorily or to induce settlement before the structure goes into service.

5.2 TYPES OF LOAD TESTS

Several different types of load tests are described in the following sections, including proof tests, performance tests, creep tests, and tests to failure. Regardless of the type of test, the load is typically applied using a hollow-center hydraulic jack that bears against the pile cap or wall. Dial gauges are mounted in the axial direction (along shaft axis) to measure anchor movement.

5.2.1 Proof Test. Proof tests assure the designer that the anchor will be able to Carry the design load. Successively larger loads are applied during a proof test, so that a load-deformation curve can be plotted. In most cases, a small initial load is applied, and is then increased to 25, 50, 75, 100, and 120 percent of the design load. The dial gauge is read at each increment. Figure 5.1 shows an example of a typical curve that might be obtained from a proof test (ASCE 1997). For helical anchors installed as tiebacks, proof load tests should be performed on each anchor to induce the pretension load.

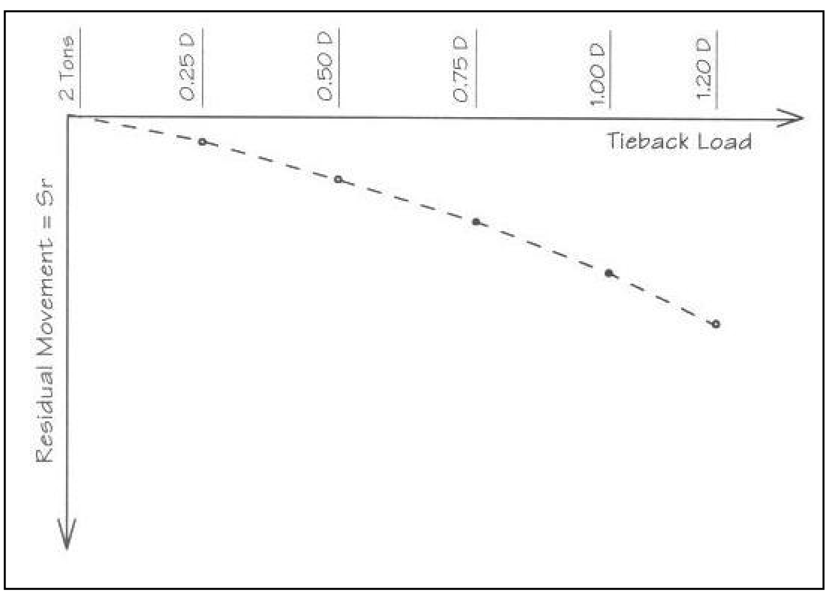
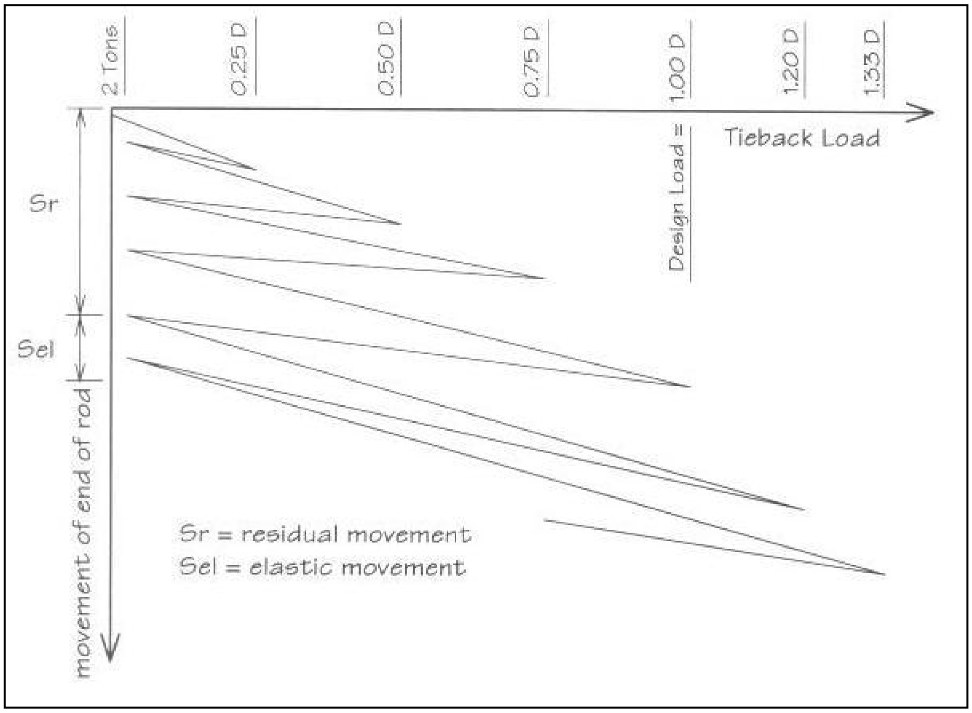


Figure 5.1. Typical Proof Test Results

5.2.2 Performance Test. The performance test is an expanded version of the proof test. It involves additional load increments and multiple load cycles. The performance tests provide information about anchor behavior during its lifetime, as it is loaded and unloaded with time. An example of the load cycles that might be involved in a performance test is shown in Figure 5.2. Design load is indicated by the letters 'D.L.' An example of a typical performance test curve is shown in Figure 5.3 (ASCE 1997).

Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
0 tons	2 tons	2 tons	2 tons	2 tons	2 tons
2 tons	.25 D.L.	.25 D.L.	.25 D.L.	.25 D.L.	.25 D.L.
.25 D.L.	.50 D.L.	.50 D.L.	.50 D.L.	.50 D.L.	.50 D.L.
	.25 D.L.	.75 D.L.	.75 D.L.	.75 D.L.	.75 D.L.
		.50 D.L.	1.0 D.L.	1.0 D.L.	1.0 D.L.
		.25 D.L.	.75 D.L.	1.2 D.L.	1.2 D.L.
			.50 D.L.	1.0 D.L.	1.33 D.L.
			.25 D.L.	.75 D.L.	1.2 D.L.
				.50 D.L.	1.0 D.L.
				.25 D.L.	

Figure 5.2. Typical Performance Test Load Cycles



igure 5.3. Typical Performance Test Results

5.2.3 Creep Test. The creep test is performed specifically to study time-dependent movement of the helical foundation under constant load. A constant load is applied to the anchor and readings are taken at specific times (i.e. 1, 2, 3, 4, 5, 7, 10, 15, 20, 25, 30, 45, 60, and 100 minutes). The time-deformation curve is plotted in semi-log scale. For an anchor to be acceptable, creep must decrease with time and cannot exceed the total limits.

5.2.4 Ultimate Load Test. The ultimate load test loads the anchor to failure. Failure is usually defined as complete soil breakout or some pre-described amount of deformation, usually 5 or 10 percent of the helix diameter. Procedures such as Davidson's method for determining failure load can be used as well. Ultimate load tests can be of particular use on large jobs where it is desirable to verify ultimate load predictions or to back calculate the torque factor, K_t.

6.0 EXAMPLE SPECIFICATIONS

6.1 INSTALLING CONTRACTOR

Torque Anchor™ Foundation Systems shall be installed by authorized Earth Contract Products Installers. These Installers shall have satisfied the certification requirements relating to the technical aspects of the product and the ascribed installation techniques.

6.2 CODES

All work as described herein shall be performed in accordance with all applicable safety codes in effect at the time of installation.

6.3 TORQUE ANCHOR LOCATION

It is the Responsibility of the installer to determine the location of, and avoid contacting, any and all underground utilities (gas, electricity, water, telephone, TV, etc.). Torque Anchors must be installed at the locations inclinations and depths given on the construction documents. Deviations from eh construction documents must be approved by the Engineer or the Engineer's Representative.

6.4 CONSTRUCTION DOCUMENTS

The construction documents shall include, but is not limited to the following:

1. Total number of torque anchors required
2. Locations of the individual torque anchors
3. Size and number of helices per torque anchor
4. Minimum installed depth of the anchor
5. Minimum final installation torque of the torque anchors
6. If load testing is required, plan per paragraph ???.

6.5 TORQUE ANCHOR SELECTION

The lead sections with helices and extension sections shall be manufactured by the Earth Contact Products Company and as shown on attached Drawings. All units shall conform to the material specifications as referenced on these drawings. The number and sizes of helices, and the shaft size of torque anchor shall be as shown on the construction documents.

6.6 FIELD TESTING

The installer shall have the option of performing a load test of other method approved by the engineer. The data acquired along with other information available about the site shall be used in determining the proper torque anchor.

6.7 INSTALLATION EQUIPMENT

6.7.1 Installing Units Installation units shall consist of rotary type torque motors with forward and reverse capabilities. These units shall be either eclectically or hydraulically powered. Tests units shall be capable of developing the minimum torque as required by the Construction documents. These units shall be capable of positioning the torque anchor at the proper installation angle. This angle varies between 0 (vertical) to 10 degrees depending upon application and type of foundation termination specified. These units shall be in good working condition and capable of being operated in a safe manner.

6.7.2 Installation Tooling Adapters approved by the Engineer of Record shall be employed to connect the installation units to safely the torque anchors and extensions. Theses adapters shall have torque capacity ratings at least equal to the minimum ultimate torque rating of the torque anchors as specified for the project. These adapters shall be securely connected to the torque during installation to prevent accidental separation.

6.7.3 Torque Monitoring Devices The torque being applied by the installing units shall be monitored throughout the installation process. Torque monitoring devices shall be either a part of the installing unit or an independent device in-line with eh installing unit. Calibration data for either unit shall be available for review by the owner or owner's representative. (In-line gauges, shear pin, in-line transducers)?

6.8 POSITIONING AND INSTALLING

The torque anchor shall be positioned as shown on the Construction documents. Proper angular alignment shall be established at the start of installation. The torque shall be installed in a smooth, continuous manner. The rate of torque anchor rotation shall be in the range of 5 to 20 revolutions per minute. Sufficient down pressure shall be applied to advance the torque anchor. Plain extension material may be required to position the torque anchor at the depth required by the Construction documents. Extensions shall be coupled to the torque anchor using the bolts provided with the extension. These bolts shall be installed and tightened to approximately 40 ft. lb. of torque.

6.8.1 Installation Torque Installation torque shall be monitored throughout the installation process. If underground obstruction are encountered during installation, the Installer shale have the option of removing the obstruction if possible or relocating the torque anchor to a position approved by the engineer or the engineer's representative. This latter option may require the relocation of adjacent torque anchors.

6.8.2 Termination of Installation The maximum installation torque shall at no time exceed the torque rating of the torque anchor shaft as specified for the project. Torque anchors shall by installed to the minimum torque value as shown on the Construction documents. If the minimum torque requirement has not been satisfied at the minimum depth level, the installer shall have the following option:

a. Install the torque anchor deeper using additional plain extension material until the specified torque level is obtained, or
b. Remove the existing torque anchor and install a torque anchor with larger and/or more helices. This revised torque anchor shall be installed at least three (3) feet beyond the termination depth of the original torque anchor.
c. Add additional torque anchors.

6.9 DEPTH OF INSTALLATION

The minimum depth of installation shall be as shown on the Construction documents. If the installer cannot achieve the depth shown of the Engineer's Construction documents, the engineer shall be contacted before proceeding further. If the maximum torque rating of the installing unit has been reached by that of the torque anchor has not prior to satisfying the minimum depth requirement, the Installer shall have the option of utilizing a higher torque installing unit to drive the torque anchor deeper.

If the minimum torque rating of the torque anchor and/or installing unit has been reached prior to satisfying the minimum depth level, the Installer shall have the following options:

a. Terminate the installation at the depth obtained, or
b. Remove the existing torque anchor and install a torque anchor with smaller and/or fewer helices. This revised torque anchor shall be installed at least three (3) feet beyond the termination depth of the original torque anchor.

7.0 INSTALLATION RECORDS

Written installation records shall be maintained for each torque anchor. These records shall include, but are not limited to the following:

1.0 Project name and/or location

2.0 Name of authorized Earth Contacts Products Installer

3.0 Name of Installer's foreman or representative who witnessed the installation

4.0 Date and Time of Installation

5.0 Location and reference number of torque anchor

6.0 Descriptions of lead sections and extensions installed

6.1 Overall depth of installation as referenced from bottom of grade beam or footing

7.0 Torque readings for the last three (3) feet of installation if practical. In lieu of this requirement, the termination torque shall be recorded as a minimum

8.0 Any other applicable information relating to the installation

8.0 TORQUE ANCHOR LOAD TESTING

The actual load capacity of a Torque Anchor-soil system can best be determined by testing. Testing measures the deformation of the Torque Anchor as loads are applied. The data from the test can be used by design engineers to prove or modified designs, quality assurance and acceptance or rejection. Testing shall be required only if specified on the Construction documents or if deemed necessary by the Engineer of Record due to unusual subsurface conditions. Testing, if required, shall be performed in accordance with the test plan contained in the Construction documents or, if required by the Engineer of record due to unusual subsurface conditions, in accordance with the test plan set forth by the Engineer of Record prior to the beginning of the test.

8.1 TEST PLAN

The test plan shall include, but not be limited to, the following:

1. The number and location of tests, based on site and subsurface conditions
2. The maximum load to be applied during the test
3. The acceptance criteria including load versus displacement.

8.2 APPARATUS FOR APPLYING LOADS

The test equipment shall be capable of applying a compression or tension load equal to the maximum test load specified in the test plan. If the test requires additional torque anchors for reaction, these torque anchors shall be installed to the same torque requirements as the test torque anchor.

8.3 APPARATUS FOR MEASURING MOVEMENTS

A suitable system for measuring movements of the Torque Anchor as it is loading is required. Reference beams and a wire support must be firmly embedded in the ground at a clear distance of not less than 8 ft from the test anchor. Reference beams shall be of sufficient stiffness to support instrumentation.

8.3.1 Torque Anchor Tip Movements The apparatus for measuring the axial movement of the anchor tip shall consist of a primary and secondary system.

8.3.2 Dial Gauges Dial gauges must have at least a 3-in. travel.

8.3.3 Wire, Mirror, and Scale The system is described in ASTM D3689, Standard Test Method for Individual Piles Under Static Axial Tensile Load.

8.3.4 Surveyor's Level or Laser Beam The system is described in ASTM D3689, Standard Test Method for Individual Piles Under Static Axial Tensile Load.

8.3.5 Other Types of Measuring Apparatus Any other type of measuring device such as electric or optical gages of proven reliability and that yield an accuracy of 0.001 in. may be used.

8.4 LOADING PROCEDURES

The torque anchor shall be tested to the greater of the design load or its ultimate capacity, defined as the maximum load the torque anchor can resist at continuous creep conditions.

8.4.1 General Apply tensile test loads with a hydraulic jack in line with the central longitudinal axis of the anchor.

8.4.2 Standard Loading Procedure The standard loading procedure shall be as described in ASTM D3689, Standard Test Method for Individual Piles Under Static Axial Tensile Load, paragraph 7.2.

8.4.3 Optional Loading Procedures Optional loading procedures such as loading in excess of 200% of anchor design uplift capacity, constant time interval loading, constant rate of uplift and the quick load test method are available and are described in This system is described in ASTM d3689, Standard Test Method for Individual Piles Under Static Axial Tensile Load, paragraphs 7.6.

8.5 PROCEDURE FOR MEASUREING ANCHOR MOVEMENTS

Procedures for measuring anchor movements are presented in This system is described in ASTM d3689, Standard Test Method for Individual Piles Under Static Axial Tensile Load, paragraph 8.

8.6 TEST RECORDS

Test records shall include the following when applicable:

8.6.1 General

8.6.1.1 Project Identification

8.6.1.2 Project location

8.6.1.3 Test Site location

8.6.1.4 Owner

8.6.1.5 Structural Engineer

8.6.1.6 Geotechnical Engineer

8.6.1.7 Anchor Contractor

8.6.1.8 Test boring contractor

8.6.1.9 Designation and location of nearest test boring with reference to test anchor.

8.6.1.10 Log of nearest test boring

8.6.1.11 Horizontal control datum, and

8.6.1.12 Vertical Control datum.

8.6.2 Anchor Installation Equipment

8.6.2.1 Make, Model, Type and Size of Torque motor

8.6.2.2 Rated Energy of Torque motor

8.6.3 Test and Reaction Anchors

8.6.3.1 Identification and location of test and reaction anchors

8.6.3.2 Design load of anchor

8.6.3.3 Length of test anchor

8.6.3.4 Number and sizes of helices

8.6.3.5 Embedded length of Torque Anchor

8.6.4 Anchor Installation

8.6.4.1 Date Installed

8.6.4.2 Installation torque logs

8.6.4.3 final torque readings

8.6.5 Anchor Testing

8.6.5.1 Date Tested

8.6.5.2 Type Tested

8.6.5.3 Sketch showing layout and spacing of anchors in group.

8.6.5.4 Brief description of load apparatus

8.6.5.5 Description of instrumentation used to measure anchor movements including location of gages or other reference points.

8.6.5.6 Tabulation of all time, load and movement readings.

8.6.5.7 Groundwater Level

8.6.5.8 Notation of any unusual occurrences during testing

8.6.5.9 Temperature and weather conditions during test.

9.0 MATERIAL SPECIFICATIONS

9.1 Earth Contact Products Torque Anchor foundation Systems Components

ECP Helix Diameters

Helical Torque Anchors 1-1/2" Solid Square Shaft		
Torque Anchor Lead Units		
Part Number	Description	Weight Per Piece
TAH-150-10"	1-1/2" Solid Square x 10" Length	6 lbs
TAH-150-36"	1-1/2" Solid Square x 36" Length	23 lbs
TAH-150-48"	1-1/2" Solid Square x 48" Length	31 lbs
TAH-150-60"	1-1/2" Solid Square x 60" Length	38 lbs
TAH-150-72"	1-1/2" Solid Square x 72" Length	46 lbs
TAH-150-120"	1-1/2" Solid Square x 120" Length	77 lbs
Torque Anchor Flights		
TAF-Flight Sizes (50k Material)	Description	Weight Per Piece
6" x 3/8" Thk	6" Dia. x 3/8" Thk	3 lbs
8" x 3/8" Thk	8" Dia. x 3/8" Thk	5 lbs
10" x 3/8" Thk	10" Dia. x 3/8" Thk	7 lbs
12" x 3/8" Thk	12" Dia. x 3/8" Thk	11 lbs
14" x 3/8" Thk	14" Dia. x 3/8" Thk	15 lbs
HTAF-Flight Sizes (50k Material)	Description	Weight Per Piece
10" x 1/2" Thk	10" Dia. x 1/2" Thk	10 lbs
12" x 1/2" Thk	12" Dia. x 1/2" Thk	14 lbs
14" x 1/2" Thk	14" Dia. x 1/2" Thk	19 lbs
Torque Anchor Extensions		
Part Number	Description	Weight Per Piece
TAE-150-36"	1-1/2" Solid Square 36" Extension	28 lbs
TAE-150-60"	1-1/2" Solid Square 60" Extension	43 lbs
TAE-150-84"	1-1/2" Solid Square 84" Extension	54 lbs
TAE-150-120"	1-1/2" Solid Square 120" Extension	77 lbs

Table 9.1 Helical Torque Anchors 1-1/2" Solid Square Shafts

Helical Torque Anchors 1-3/4" Solid Square Shaft		
Torque Anchor Lead Units		
Part Number	Description	Weight Per Piece
TAH-175-36"	1-3/4" Solid Square x 36" Length	31 lbs
TAH-175-48"	1-3/4" Solid Square x 48" Length	42 lbs
TAH-175-60"	1-3/4" Solid Square x 60" Length	52 lbs
TAH-175-72"	1-3/4" Solid Square x 72" Length	62 lbs
TAH-175-120"	1-3/4" Solid Square x 120" Length	104 lbs

Torque Anchor Flights		
TAF-Flight Sizes (50k Material)	Description	Weight Per Piece
8" x 3/8" Thk	8" Dia. x 3/8" Thk	5 lbs
10" x 3/8" Thk	10" Dia. x 3/8" Thk	7 lbs
12" x 3/8" Thk	12" Dia. x 3/8" Thk	11 lbs
14" x 3/8" Thk	14" Dia. x 3/8" Thk	15 lbs
HTAF-Flight Sizes (50k Material)	Description	Weight Per Piece
10" x 1/2" Thk	10" Dia. x 1/2" Thk	10 lbs
12" x 1/2" Thk	12" Dia. x 1/2" Thk	14 lbs
14" x 1/2" Thk	14" Dia. x 1/2" Thk	19 lbs
Torque Anchor Extensions		
Part Number	Description	Weight Per Piece
TAE-175-36"	1-3/4" Solid Square 36" Extension	31 lbs
TAE-175-60"	1-3/4" Solid Square 60" Extension	52 lbs
TAE-175-84"	1-3/4" Solid Square 84" Extension	73 lbs
TAE-175-120"	1-3/4" Solid Square 120" Extension	104 lbs

Table 9.2 Helical Torque Anchors 1-3/4" Solid Square Shaft

Helical Torque Anchors 2-7/8" O. D. Round Shaft		
Torque Anchor Lead Units		
Part Number	Description	Weight Per Piece
TAH-288-48"	2-7/8" O. D. Round x 48" Length	29 lbs
TAH-288-60"	2-7/8" O. D. Round x 60" Length	37 lbs
TAH-288-72"	2-7/8" O. D. Round x 72" Length	44 lbs
Torque Anchor Flights		
TAF-Flight Sizes (50k Material)	Description	Weight Per Piece
10" x 3/8" Thk	10" Dia. x 3/8" Thk	7 lbs
12" x 3/8" Thk	12" Dia. x 3/8" Thk	11 lbs
14" x 3/8" Thk	14" Dia. x 3/8" Thk	15 lbs
HTAF-Flight Sizes (50k Material)	Description	Weight Per Piece
10" x 1/2" Thk	10" Dia. x 1/2" Thk	10 lbs
12" x 1/2" Thk	12" Dia. x 1/2" Thk	14 lbs
14" x 1/2" Thk	14" Dia. x 1/2" Thk	19 lbs
Torque Anchor Extensions		
Part Number	Description	Weight Per Piece
TAE-288-36"	2-7/8" O. D. Round x 36" Length	22 lbs
TAE-288-60"	2-7/8" O. D. Round x 60" Length	37 lbs
TAE-288-84"	2-7/8" O. D. Round x 84" Length	51 lbs
TAE-288-120"	2-7/8" O. D. Round x 120" Length	73 lbs

Table 9.3 Helical Torque Anchors 2-7/8" O. D. Round Shafts

Helical Torque Anchors 3-1/2" O. D. Round Shaft		
Torque Anchor Lead Units		
Part Number	Description	Weight Per Piece
TAH-350-48"	3-1/2" O. D. Round x 48" Length	39 lbs
TAH-350-60"	3-1/2" O. D. Round x 60" Length	45 lbs
TAH-350-72"	3-1/2" O. D. Round x 72" Length	54 lbs
Torque Anchor Flights		
TAF-Flight Sizes (50k Material)	Description	Weight Per Piece
10" x 3/8" Thk	10" Dia. x 3/8" Thk	7 lbs
12" x 3/8" Thk	12" Dia. x 3/8" Thk	11 lbs
14" x 3/8" Thk	14" Dia. x 3/8" Thk	15 lbs
HTAF-Flight Sizes (50k Material)	Description	Weight Per Piece
10" x 1/2" Thk	10" Dia. x 1/2" Thk	10 lbs
12" x 1/2" Thk	12" Dia. x 1/2" Thk	14 lbs
14" x 1/2" Thk	14" Dia. x 1/2" Thk	19 lbs
Torque Anchor Extensions		
Part Number	Description	Weight Per Piece
TAE-350-36"	3-1/2" O. D. Round x 36" Length	26 lbs
TAE-350-60"	3-1/2" O. D. Round x 60" Length	45 lbs
TAE-350-84"	3-1/2" O. D. Round x 84" Length	63 lbs
TAE-350-120"	3-1/2" O. D. Round x 120" Length	90 lbs

Table 9.4 Helical Torque Anchors 3-1/2" O. D. Round Shafts

Common Cohesive Strength Values		
Very soft cohesive soil	0 - 250	psf
Soft cohesive soil	250 - 500	psf
Medium stiff cohesive soil	500 - 1000	psf
Stiff cohesive soil	1000 - 2000	psf
Very stiff cohesive soil	2000 - 4000	psf
* NAVFAC 7.02 Foundation & Earth Structures 1986		

Table 9.5a Common Cohesive Strength Values

Common Cohesive Strength Values				
Very Soft	0 - 0.5	ksf	0 - 25	kPa
Soft	0.5 - 1	ksf	25 - 50	kPa
Firm	1 - 2	ksf	50 - 100	kPa
Stiff	2 - 3	ksf	100 - 150	kPa
Very Stiff	3 - 4	ksf	150 - 200	kPa
Hard	>4	ksf	>200	kPa
Kulhway & Mayne " Manual on Estimation Soil Properties for Foundation Design, 1990				

Table 9.5b Common Cohesive Strength Values