

# Pier Tech<sup>®</sup>

SYSTEMS



FOUNDATION SOLUTIONS  
FOR THE 21ST CENTURY

DESIGN | ENGINEERING HANDBOOK



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# INTRODUCTION

**FORWARD**

The purpose of this manual is to briefly discuss Helical Pile design. It is our goal to make this manual as “user friendly” as possible, so we will continue to make changes, and updates. If there are sections that need further explanation, or there is additional information you would like included in a future version, please feel free to contact us.

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***Our Products***

www.piertech.com



Patented Tru-Lift Bracket & New Construction Tee Bracket



Foundation Underpinning Assembly



Square Shaft Anchors & Round Shaft Piers

***The PierTech Advantage***

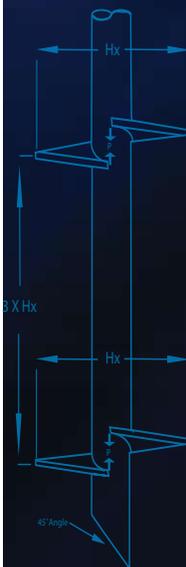
- Finest Quality - High Strength Steel
- Higher Torque Capacity
- Patented Cross-Bolt Connections
- Superior Lateral Strength And Stability
- All Manufacturing Processes Controlled By A Rigid Quality assurance program

***Additional Benefits***

- |                            |                  |
|----------------------------|------------------|
| ■ Cost Effective           | ■ Re-Usable      |
| ■ Quick Installation       | ■ Low-Noise      |
| ■ All Weather              | ■ Vibration Free |
| ■ No Curing Time           | ■ No Overburden  |
| ■ Can Be Battered          | ■ Site Verified  |
| ■ Proven Engineering       | ■ Loading        |
| ■ Environmentally Friendly |                  |



PierTech Tie-back Package



INTRODUCTION

## About Us

It is our mission at PierTech® Systems, to provide the construction industry with the highest quality, versatile, and most economical foundation solutions and products. We maintain a full compliment of technical and support personnel, with years of deep foundation and tieback experience.

PierTech® carefully selects and trains each distributor and dealer in our organization. We take pride in the fact that our network of people are highly experienced, and strive to serve the customer with integrity

Whether it's stabilizing a home, building a boardwalk, repairing a bridge abutment, or installing a tower, PierTech® has the materials and the expertise to complete your project.

With a product line that consists of galvanized round shaft Helical Piers, 2 7/8" - 12 3/4", and square shaft Helical Anchors, 1 1/4" - 2", no job is either too BIG or too SMALL.



2 7/8" O.D. x 12" Helicals Installed For A Boardwalk Project.



3 1/2" O.D. x 10", 12", 14" Helicals Installed Under A 250' Tall Communication Tower.



2 7/8" O.D. x 8" Helicals Installed For A New Home Construction Project.



High Capacity 8 5/8" O.D. x 20" Helical Installation.



## HISTORY OF HELICAL PILING/ANCHORING SYSTEMS

Originally Helical Piers or screw piles were used for the stabilization and support of lighthouses in tidal basins around England. Alexander Mitchell, an English brick maker, is credited with the design of the “screw pile” in 1833. The “screw pile” method worked extremely well, however, development of the helix-plate foundation did not take off immediately.

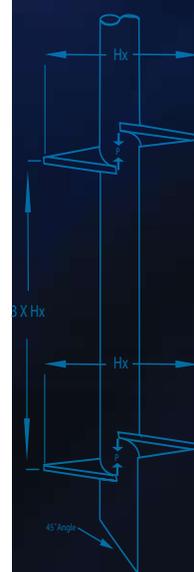
When the Helical Tension Anchor was produced, the use of the same or similar devices to resist compression loads was also developed.

Around the globe helical piers and anchors are used on a vast array of projects. Helical Applications include: pole bases and communication towers, utility and pipeline tie downs, tiebacks and wall anchors, deep foundation Piers for new construction, underpinning commercial and residential structures, boardwalks, bulkheads, sea walls, temporary and reusable wall anchors, slope stabilization, concrete slab lifting and stabilization, shoring, and concrete-less foundations. A helical pile can be used in nearly any situation and where driven or cast in place piles are currently used.

Job Categorization	Helical Piers	Push Piers	Drilled Piers	Driven Piles
Commercial jobs with heavy loads	X		X	X
Residential Projects & light Commercial	X	X	X	
Retaining Walls	X			
Beside Current Structures	X	X	X	
New Construction	X		X	X
Temporary Structures	X			
Corrosive Soils	X		X	
Deep Load Bearing Strata	X	X		
Constricted Working Area	X	X		
All Climate Installation	X	X		X
Limited Geotechnical Information	X			X
Low Working Space	X	X		
Remote Sites	X	X		

TABLE 1.1 HELICAL PIER FOUNDATION APPLICATIONS

Torque capacities of available installation equipment have increased over the past several years. PierTech supplies Hydraulic torque motors from 5,000 ft.-lb. to 150,000 ft.-lb. or more.



“Hand-held” equipment has expanded the available equipment in the lower range of torque, with a capacity up to 5,500 ft.-lb (7.5 kN-m). Though called “hand-held,” this equipment is hand-guided while a torque bar or other device is used to resist the torque being applied to the screw pile foundation.

Compared to other common foundations (footing, drilled pier, and driven pile), Helical Piers:
Proven Engineering
Site Verified Loading
Environmentally Friendly
Removable for Temporary Structures
Lighter and More Hassle-free than concrete
Resist Scouring for Bridge Uses
Can Determine Load Capacity From Installation Torque
Can Be Installed in Ground Water Without Pipe Casing
Installation in All Weather Conditions
Quick Installation
Can Be Battered for Greater Lateral Stability
Can Be Installed in Limited Access Areas
Vibration Free
Cost Effective
Can Be Grouted After Installation
Resist Corrosion Through Galvanization
No Return Visits Required
No Overburden
Can Be Affixed to Structures Immediately
Low Noise

TABLE 1.2 BENEFITS OF HELICAL PIERS

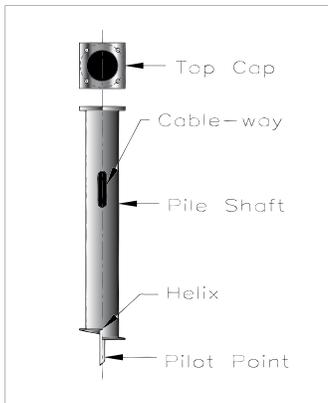
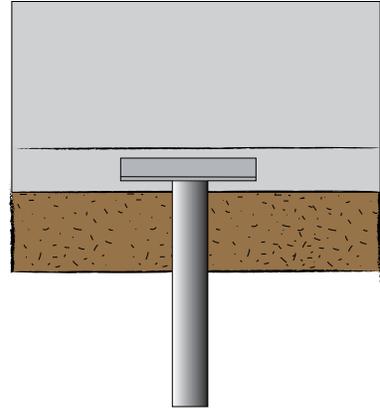


**USES OF HELICAL PIERS AND ANCHORS**

PierTech® supplies helical piers and anchors to industries including:

**New Construction**

Limited only by the accessibility of the installation equipment, helical piers can be installed in any climate. Helical piers are removable and reusable making them as permanent or temporary as the building or structure they support. Because there is no cement to cure, the building can be placed upon the piles immediately after installation. Helical piers allow the building to be placed upon sloped and uneven surfaces and leveling attachments ensure the building stays level.



**Street Light Bases**

PierTech® custom fabricates our light bases to ensure individual needs are met. Custom variables include: top cap thickness and size, hole size, cable-way size and position, pile shaft size and length, and helix diameter.

Advantages over other pilings include: speedy installation, installs in all weather conditions, easy clean up with no spoils to remove, pole can be place immediately, low noise and vibration, hot-dip galvanized for long life, removable and reusable.

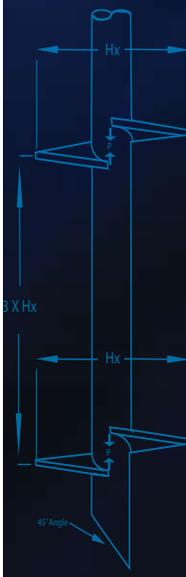
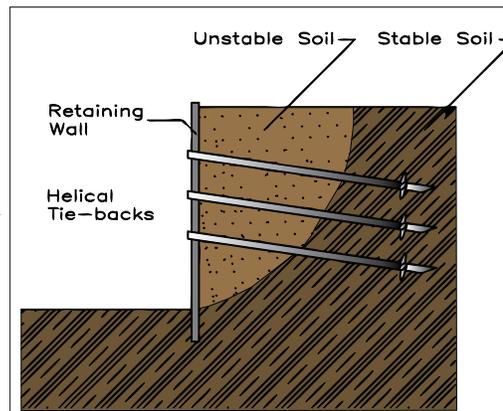
Applications include but are not limited to: residential/commercial lighting, parking lots, street and highway lighting, signage, bumper posts, flag poles, and column supports.

**Petroleum Industry**

PierTech® supplies helical piers and anchors that are ideal for a wide variety of oil and gas industry applications. With resistance to cyclical loading and vibration, helical piles are ideal under compressor stations and pump-jacks, oil and gas pipeline, pipe-racking, skid buildings, flare stacks, tanks, dehydrators, and separators.

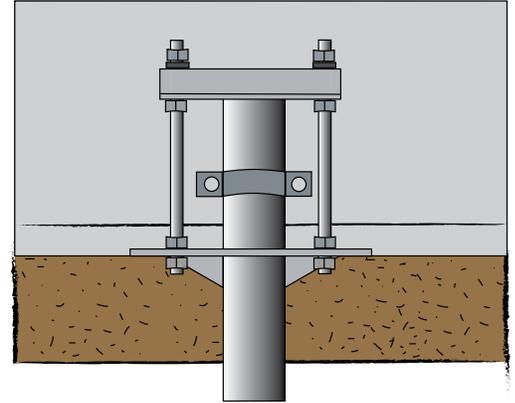
**Slope Stabilization**

PierTech® manufactures helical anchors for slope stabilization and restoration. Upon locating the fault line, anchors can be screwed virtually horizontally into stable soil. A retaining wall is then affixed to the anchors to maintain sloop integrity.



### Underpinning

Utilizing our patented Tru-Lift® bracket and helical piles, installers can restore and support failed foundations. After revealing the footings, Helical Piers are installed beneath the structure. Then using the Tru-Lift® bracket, the foundation is raised and stabilized. The foundation is then covered back up. This method is very cost-effective.



### General Foundations

The Helical Pier is extremely versatile and can be used in many load bearing situations.

- Static loads
- Alternating loads
- Vibration loads
- High moment of overturn loads
- Grade beams
- Floor slabs

PierTech® installers have projects ranging from less than twelve piles to major industrial projects of more than 500 piles. All piles are designed and pre-engineered to meet the needs of our customers.



# HELICAL PIER AND ANCHOR SYSTEMS

INTRODUCTION TO HELICAL PIER AND HELICAL ANCHOR SYSTEMS

For the purposes of this manual, Helical Anchors will be assumed to be in (tension) and Helical Piers in (compression). Helical Piers are comprised of a circular hollow steel pipe (shaft) and Helical Anchors are square solid steel shaft with one or more tapered, circular steel plates (helices) welded to them. The helices have a controlled (pitch), which allows the Pier/Anchor to be screwed into the ground with minimal soil disturbance. The shaft is used to transfer both torque during installation and axial loads to the helices, while providing lateral stability. The Helical Pier/Anchor is inserted into the soil and hydraulically rotated with constant downward pressure, advancing the Helical Pier/Anchor into the soil. Once installed, the Helical Pier/Anchor has soil bearing in both compression and tension, by transferring the structure's load to bearing stratum. The installation angle of the Helical Pier/Anchor can range from vertical to nearly horizontal.

Figure 1 shows a typical Helical Anchor configuration. Figure 2 shows a typical residential/light commercial Helical Pier configuration. Figure 3 shows typical high capacity commercial/industrial Helical Pier configuration with shaft diameters ranging from 3-1/2" to 12-3/4" O. D.

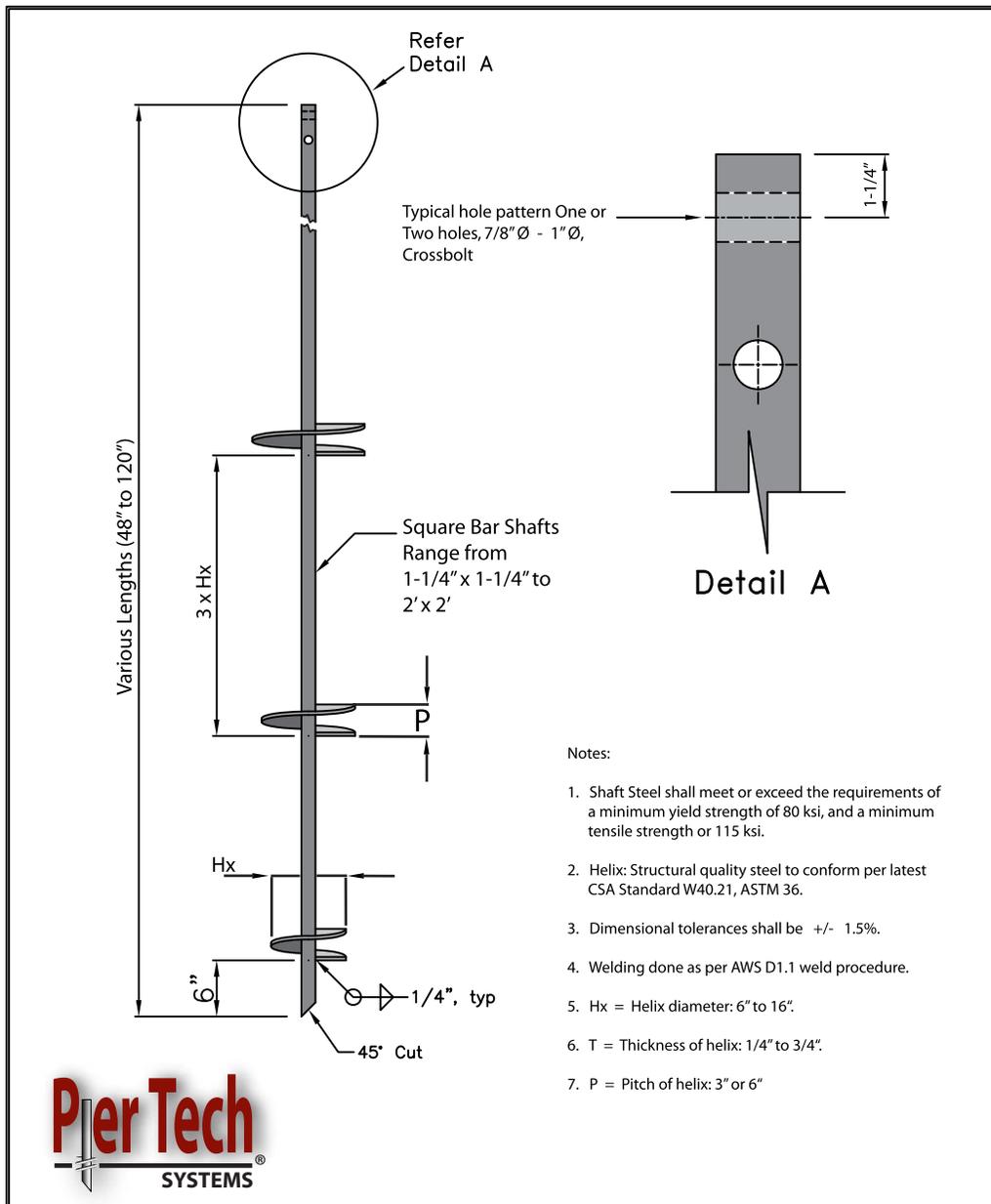


Figure 1: Multi-Helix Foundation Anchor

Nearly any pipe size can be utilized to manufacture Helical Piers. Although pipe in excess of 30" O. D. can be used, typical sizes are between 2-7/8" O. D. and 16" O.D. Helical Anchor shaft dimensions are 1 1/4" thru 2" typical. The maximum reach of the equipment used for installation generally determines the length of the Helical Piers/Anchors. Extensions can be utilized to increase the length of a Helical Pier/Anchor. Soil conditions, design loads, and the size of the shaft all determine the diameter of the helix. Helix diameters range from 6 inches to greater than 42 inches. Available depth of soil and torque determine the installation depth.

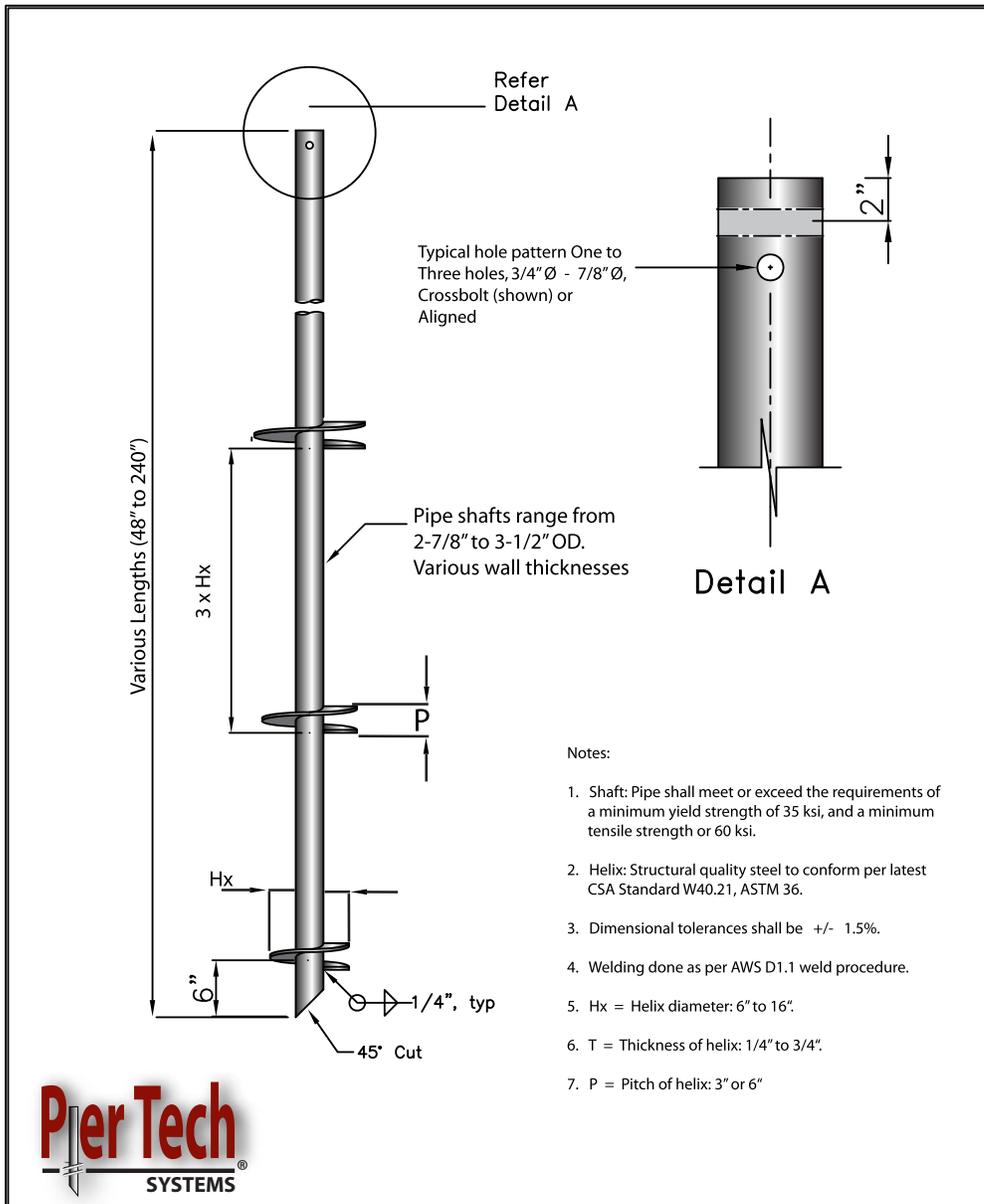
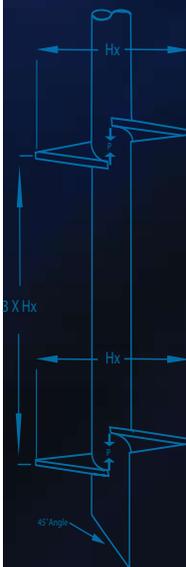


Figure 2: Typical Residential/Light Commercial Pier

PierTech® Helical Piers and Anchors generally have one or more helices. Spacing between any two helices is set in increments of the helix pitch and typically three times the diameter of the lower, smaller helix. Soil conditions and required load capacity will determine the helix size and number.



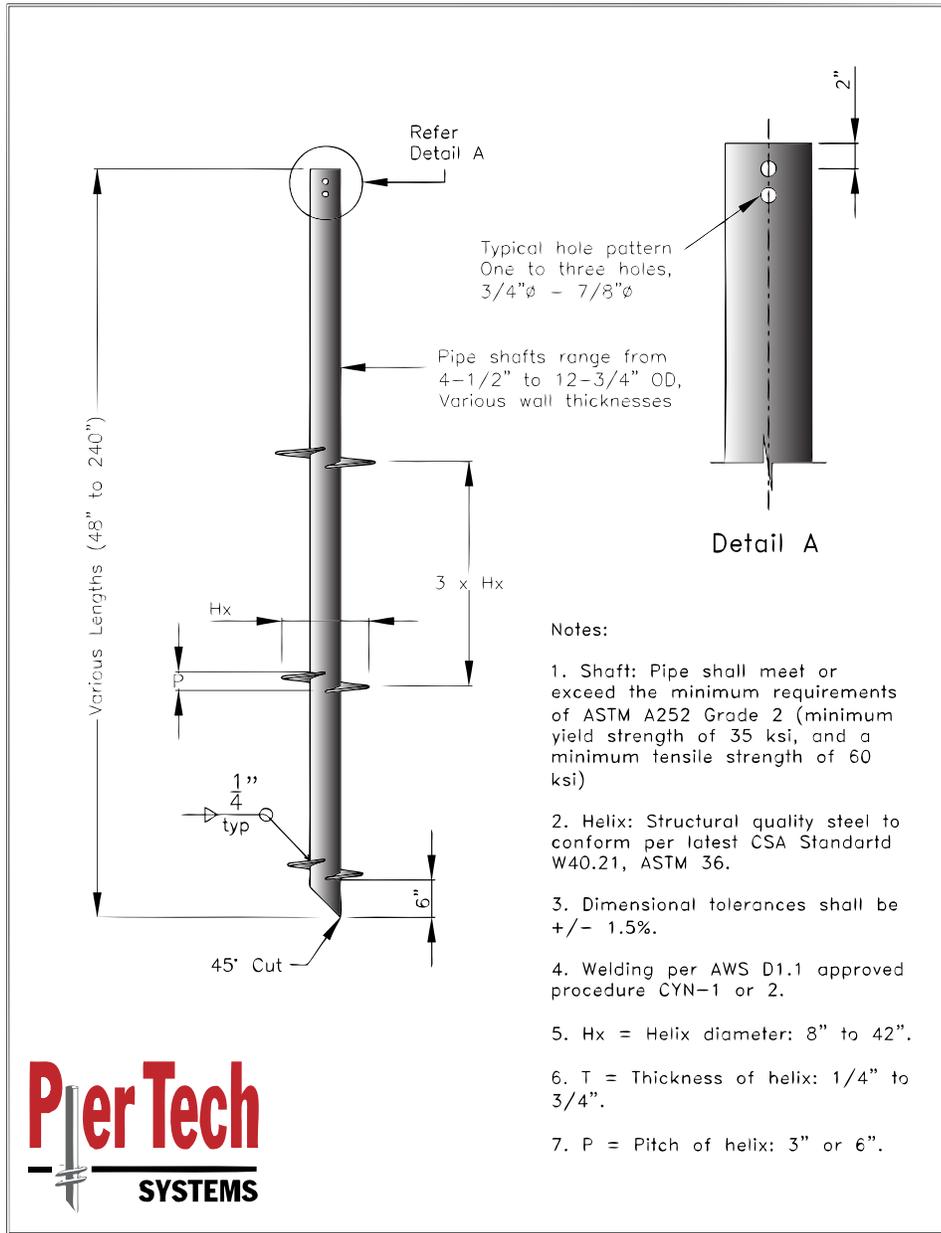


Figure 3: High Capacity Pier

**DESIGN REQUIREMENTS:**

“Bearing Capacity” = that load which can be sustained by a pile foundation without producing objectionable settlement or material movement – initial or progressive – resulting in damage to the structure or interfering with its use.

- As defined by The American Society of Civil Engineers -



Bearing Capacity depends on:	
1.	Soil Type and properties
2.	Groundwater and/or surface conditions
3.	Pile configuration (pipe size, helix size, number of helices, material thickness)
4.	Pile material used
5.	Dimension of pile (cross-section, length)
6.	Depth of installed pile
7.	Pile positioning (vertical, horizontal or battered)
8.	Distance between piles (interaction of piles, group effect)
9.	Installation torque
10.	Type of loading (alternating, step-loading, static and others)

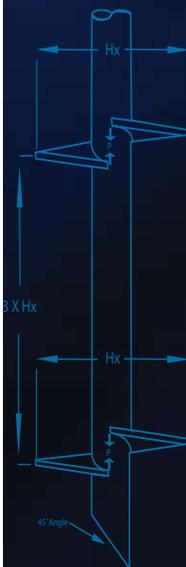
**INSTALLATION:**

For PierTech® Helical Piers/Anchors subjected to uplift (and/or frost jacking) the top helix will be driven a minimum of five (5) helix diameters or more than the maximum frost penetration depth of that area. The tip of each pile is cut to a 45° angle in order to make the installation a smoother process and to aid in targeting of the pile during installation.

Cut from steel plate, helices are and formed to the desired pitch which is typically 3.00” or 6.00”. Much like a screw goes into a block of wood, the Helix is formed so that it threads into the ground.

A variety of rotary hydraulic equipment is used to install piles including but not limited to: skid-steers, excavators, boom mounted utility trucks, nodwells and even portable handheld drive units.

Throughout the installation of each foundation anchor the torque will be continuously monitored and recorded. By measuring the hydraulic pressure that is used to screw in the anchor, continuous recording chart recorders are used. There is a direct relationship between installation torque and pile capacity in small shaft piles. Continuous monitoring and recording of torque throughout installation gives a profile of the core soil conditions.



**GEO**TECHNICAL

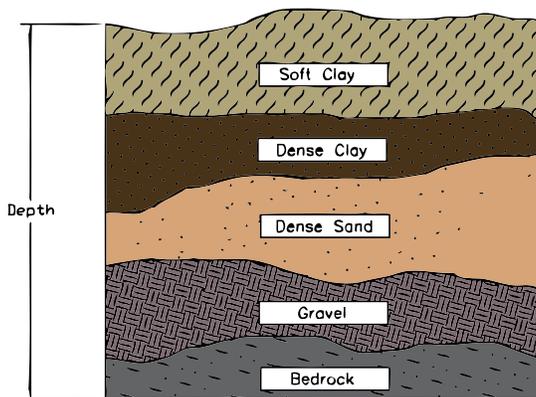
SOIL MECHANICS

The maximum capacity of a pile is the result of the strength of the surrounding soil because the loading force is transferred to the soil. There are typically two types of soils: cohesive and cohesionless. Cohesive soils are defined as soils whose internal angle of friction is approximately zero ( $\phi = 0$ ) while cohesionless soils are those whose internal angle of friction is greater than zero ( $\phi > 0$ ). Soils are also grouped according to strength. Table 3.1 below outlines common soil classification.

SOIL CLASS	DESCRIPTION OF SOIL
1	Rock
2	Dense Sand
3	Compact Clay and Mixed Gravel
4	Compact Sand
5	Loose, Sand, Gravel and Clay
6	Loamy Clay, Damp Clay
7	Loamy Silt, Wet Clay
8	Swamp, Peat

Table 3.1: Soil Classification

Soil naturally tends to develop in layers or strata, each with individual strengths and weaknesses. Figure 3.1 illustrates this stratification. As the pile is drilled into the ground, it will pass through different layers.

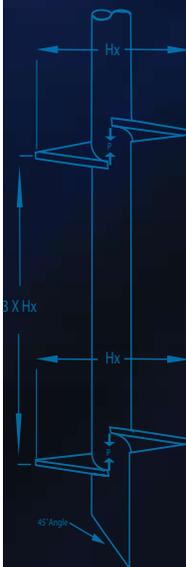


Because each layer has different characteristics, different torque values will be observed as the pile passes through each layer. During an ideal installation, the torque values will be constantly increasing, indicating the pile is being inserted into more dense soil. If a drop in torque is recorded, it is most likely that a soft layer (such as soft clay) was found. The pile must then continue to be inserted past the soft layer until a more dense soil (i.e. higher torque) is found.

Figure 3.1: Soil Strata

Cohesive and cohesionless soils have different reactions when exposed to stress. The particles of sand in cohesionless soils act independently of one another. This quality gives such soils many fluid-like characteristics. Cohesionless soils generally tend to compress when placed under stress. In contrast, cohesive soils have more rigid characteristics. Stiff clays tend to react more closely to rock, staying ridged and inflexible until failure. Soft clays have more pliable characteristics, bending and remolding under stress.

In tensile loading situations, the upward force pulls on the pile as a whole. In water saturated to fairly wet soils, a suction force forms, helping to offset the tension. The water in the soil exerts pore-water pressure on the surrounding soil. A low-pressure area is formed below the helix when an upward force is applied. This causes suction and pulls down on the helix. This occurrence is more visible in clays, where the soil is unable to fill the void. Figure 3.2 illustrates this.



Soils gain their load capacity from several variables

- The internal angle of friction,
- The adhesion factor,  $\alpha$
- The unit weight of the soil,  $\gamma$
- The un-drained shear strength of soil,  $C_u$
- The lateral earth pressure coefficient,  $K$

These variables are reliant on the type, moisture content and location of soils.

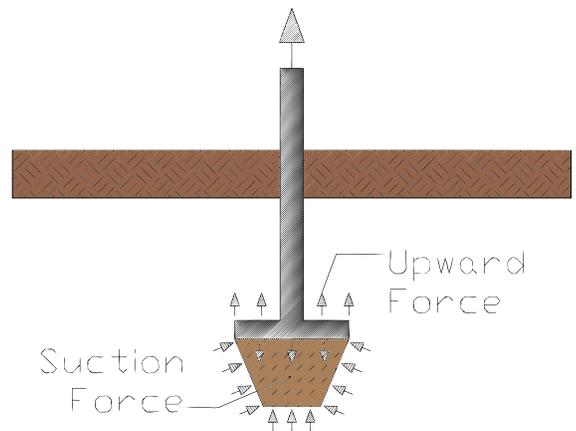


Figure 3.2: Suction Force under Tension

During installation, the adjacent soil is spread out by the spinning motion of the pile. This forms an area of compressed soil around the pile, as shown in Figure 3.3. This firmed soil increases the holding capacity of the pile. The pressure the soil applies can be divided into vertical and horizontal components. The proportion of these is referred to as the lateral earth pressure coefficient, which is used in the capacity formula.

$$K = \frac{h}{v} \quad \text{Eqn 3.1}$$

where:

- $h$  = horizontal soil stress
- $v$  = vertical soil stress

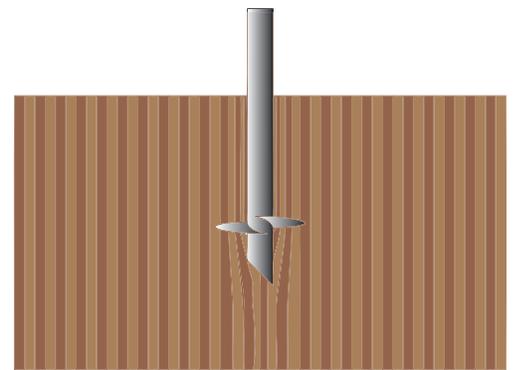


Figure 3.3: Soil Displacement

The force placed to the pile also aids in creating a friction force between the pile and the soil. The shaft adhesion factor measures this force of friction. This factor commonly varies with soil type, density and the soil's internal angle of friction. This friction helps to defy the applied force and helps determine the pile's capacity. The displaced soil pressure also helps reconsolidate soil that may have been disrupted during the installation process. Determining the adhesion factor may require soil testing and local soil understanding. Table 3.2 expressed soil skin friction in various types of soil.

The un-drained shear strength of soil is the maximum value of shear stress that may be produced before it yields or fails. This variable can only be found in cohesive soils and increases with the density of the soil. In other words, the higher the shear strength of the soil,  $C_u$ , the greater the bearing capacity it withholds.

	Soil Type	Skin Friction, psf (kPa)
Cohesive	Mud and Muck	50 - 100 (2.4 - 4.8)
	Soft Clay	200 - 600 (9.6 - 29)
	Medium Clay	500 - 1000 (24 - 48)
	Stiff Clay	700 - 1400 (34 - 67)
	Very Stiff Clay	1000 - 2000 (48 - 96)
Cohesionless	Silt	100 - 500 (4.8 - 24)
	Silt and Sand	500 - 1000 (24 - 48)
	Sand	500 - 1500 (24 - 72)
	Gravel and Sand	1500 - 3000 (72 - 144)
	Gravel	2000 - 4000 (96 - 192)

TABLE 3.2 SOIL SKIN FRICTION



This is illustrated in Table 3.3. In contrast to the shaft adhesion factor, the shear strength of soil is greater when density and depth increase.

All soil has a unique density and weight based on its water content, and its make up. To classify different type of soils the unit weight of the soil must be determined.

$$\gamma = W / V \quad \text{Eqn. 1.2}$$

Where

- W= weight of sample
- V= Volume of sample

Consistency	Undrained Shear Strength, $C_u$ kPa (psf)
Very Soft	< 12 (<250)
Soft	12 - 25 (250 - 520)
Firm	25 - 50 (520 - 1045)
Stiff	50 - 100 (1045 - 2090)
Very Stiff	100 - 200 (2090 - 4180)
Hard	>200 (>4180)

TABLE 3.3 UNDRAINED SHEAR STRENGTH

This is used to express the load the soil exerts on the pile. In times of tension, the surrounding soil helps to resist motion. This is particularly essential in situations of tensile loading. Soils with larger unit weights will increase the uplift capacity by applying more downward pressure.

To maintain soil integrity, soil disruption should be as limited as possible. In order to maintain soil strength the helix should be formed to a true helical shape, allowing the pile to cut into the soil. To ensure that the pile travels one pitch distance downward for every revolution, apply and maintain significant downward pressure. To verify that proper pressure is achieved an installation torque recorder can be used. This can also be used to determine the capacity of the pile.

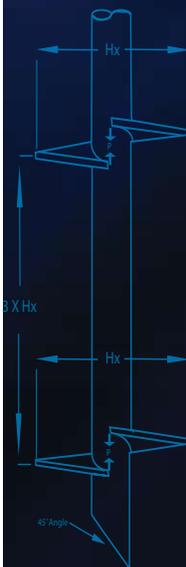
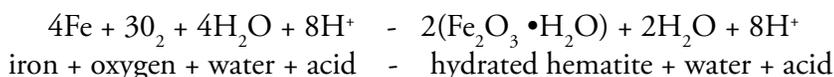
The information provided in this manual is for representational purposes and should not take the place of actual soil studies. A Geotechnical engineer should be consulted to discuss a more in-depth look at soil mechanics.

### CORROSION

*“Corrosion is the exothermic (energy producing) chemical transformation of a metal or metal alloy into an un-reactive covalent compound such as an oxide or silicate that is often similar or even identical to the mineral from which the metals were extracted.”* (Payer, J.H., et al., 1980).

A common term frequently used for the covalent compounds produced during the corrosion of iron and steel is “rust”. The makeup of rust relies on the density and type of other chemicals present during corrosion. Aqueous solutions that conduct electric charges through ions most commonly produce metallic corrosion. The electrochemical makeup of the aqueous solution most always controls the rate of corrosion and the makeup of the rust.

One example of the net chemical reaction for the corrosion of iron and steel in the presence acidic water with ample dissolved oxygen is provided below. Hydrated hematite is the brownish-red mineral most often referred to as rust. The density of hydrogen ions is characteristically represented by the pH (negative of the logarithm base 10 of the concentration of H+ ions).



Even though all hydrogen ions and some water are preserved on both sides of the net reaction above, these chemicals are significant facilitators of the corrosion reaction shown. Iron is made more chemically reactive by hydrogen ions removing electrons. Greater densities of hydrogen ions (lower pH) may cause greater corrosion rates. Water conducts the flow of ions and aids with the oxidation of iron. Corrosion rates are insignificant in the absence of water.

The electrochemical characteristics of soil usually govern the corrosion rate of helical piers and helical anchors. The characteristics of soil that control the corrosion rate are:

1. Acidity
2. Moisture content
3. Quantity of dissolved and free oxygen
4. Hydraulic conductivity
5. Presence of dissolved salts
6. The diffusion rate of oxygen

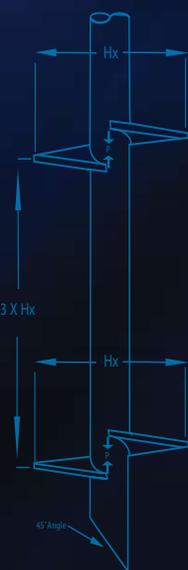
As a general rule, soils with high moisture content, ample supply of dissolved oxygen, considerable salt content, and high acidity are most corrosive. For more information on soil corrosion in the United States refer to the soil-testing programs conducted by the National Bureau of Standards between 1910 and 1955.

A function of moisture content, salt content, density, and soil type called resistivity is an easily measurable parameter that is often used to judge the corrosivity of soil. Table 3.4 shows a method of characterizing the corrosivity of soil based on resistivity (Modified from Miller, F.E., Foss, J.E., and Wolf, D.C., 1981). A study using steel and zinc loss in weight over time shown from Ramanoff (1989) was conducted to give a sample estimation of helical pier life as a function of soil resistivity. The results are shown in Fig. 3.4. Estimated helical pier life was considered to be the time when the entire zinc coating and 1/8-inch of steel helical blade thickness is lost to corrosion. The estimations are slanted in that a more practical mode of helical pier failure is the corrosion induced fracture of the shaft near the ground surface where there is increased oxidation and that the study only allowed for a 3 to 9.5 year benefit from the zinc galvanization. At the same time, the overall outcome of this slanted estimation is that the results are more conservative based on comparisons with other methods of estimation.

Table 3.4. Soil Corrosivity Classification

Corrosivity Class	Resistivity ( $\Omega$ cm)
Very Low	>10,000
Low	5,000 to 10,000
Moderate	2,000 to 5,000
High	1,000 to 2,000
Very High	<1,000

A measure of the permeability and diffusivity is not provided by Soil resistivity and therefore the residence time of water on buried surfaces is not provided. There is no simple method to measure soil parameters and determine soil corrosivity. However, low soil resistivity values point to areas of potentially high corrosivity that merit further investigation. (Jones, D.A, 1996)



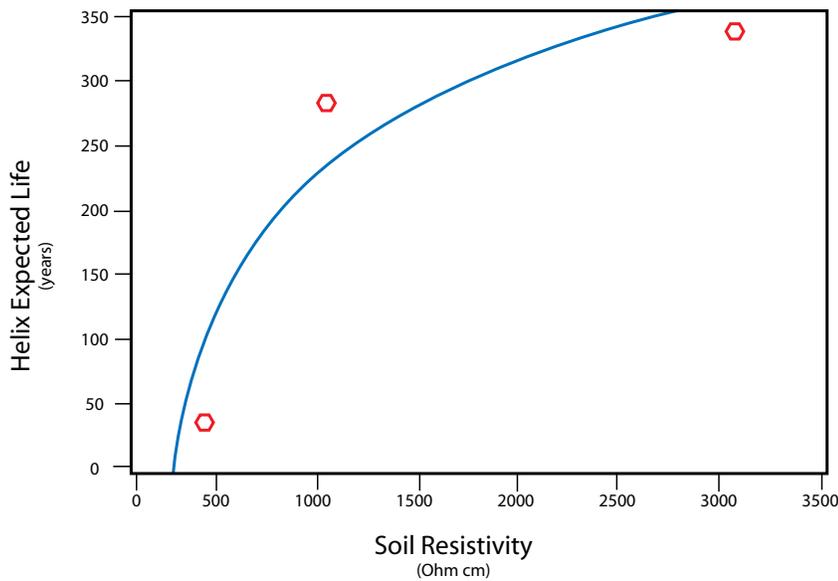


FIGURE 3.4 EXPECTED HELIX LIFE

Various types of steel, iron, and zinc corrode at essentially the same rate in nearly all soil types (Uhlig, H.H. and Revie, R.W., 1985). Due to this fact some engineers mistakenly believe that zinc coating of helical piers and helical anchors was unimportant. With more extensive knowledge of the function of zinc coating and corrosion proves that the zinc coating of helical piers and helical anchors is not only important but also necessary.

Table. 3.5 Estimation for Expected Helix Life

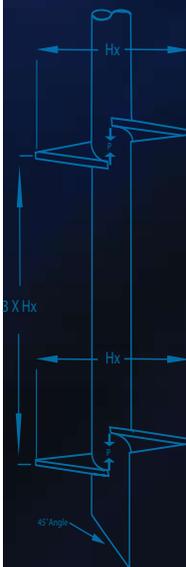
Various forms of corrosion include:	
1.	Uniform
2.	Galvanic
3.	Crevice
4.	Pitting
5.	Intergranular
6.	Cracking
7.	Erosion
8.	Dealloying
9.	Hydrogen damage

(Jones, D.A., 1996)

Uniform corrosion causes the largest amount of metal distortion. However crevice and pitting forms of corrosion are more sinister. Zinc coating shields iron and steel from these types of corrosion by passivity and galvanization.

Passivity:

This is produced by the development of a non-conductive, oxide surface film which lowers the rate of corrosion. This layer is formed by Zinc in the presence of dissolved carbon dioxide found in soil pore air and water. Applying a zinc coating will reduce uniform corrosion rates by a factor of 2 to 20, as established by the difference in total mass loss for buried galvanized and bare metal pipes (Uhlig, H.H. and Revie, R.W., 1985).



Galvanization:

This is a favorable result of galvanic corrosion. When two unlike metals or metal alloys are joined, the metal or metal alloy with an inferior corrosion probability will corrode and thus protect the other.

Zinc has a lesser corrosion probability than that of iron and steel and therefore acts as an anode for iron and steel that it is electrically joined to. During installation of helical piers and helical anchors, pits and scratches may penetrate the zinc coating. Galvanization protects the iron steel exposed in pits and scratches. It also protects against crevice and pitting corrosion. The zinc film will thwart corrosion of bare areas up to 1/8 inch wide (Industrial Galvanizers America, Inc., 1999).

Additional benefits of a zinc coating are:

1. It shields iron and steel surfaces both on the interior and exterior
2. The coating is harder than any paint
3. The coating is chemically bonded and normally never flakes or peels
4. The coating is immune to ultraviolet radiation damage

It is necessary for engineers to indicate hot-dip galvanization instead of continuously galvanized coatings. Hot-dip galvanized coatings are 80 to 100 microns in thickness, moderately flexible, and produce a zinc-iron alloy that is harder than steel. Continuously galvanized coatings are usually 12-25 microns thick, extremely flexible, and softer than steel. (Industrial Galvanizers America, Inc., 1999)

Electrically joining the helical pier to the ungalvanized structural steel in a building, bridge or other types of construction could alter the galvanic corrosion rate of the zinc coatings and can modify the electric potential of the helical pier with respect to the soil pore water aqueous solution. It is important for the pier to be electrically isolated from the rest of the structure.

When very high corrosive soils are encountered consult a corrosion engineer. It may be necessary to offer further corrosion protection for the purpose of extending the life of the structure. Cathodic protection is a possible option. However, the level of cathodic protection must be carefully controlled.

Cathodic protection:

It minimizes the corrosion rate by supplying an excess amount of electrons to a corroding metal surface. The excess electrons lower the rate of metallic ionization.



# DESIGN CRITERIA

**BEARING AND UPLIFT CAPACITY**

Pullout and bearing capacities of helical piers placed vertically are essentially the same provided a depth to blade diameter ratio is greater than 5. Three methods exist for determining bearing and pullout capacity: “cylindrical shear”, “individual bearing”, and “installation torque” (Ghaly and Clemence, 1998, A.B. Chance, 1993b). The installation torque method has been proven to have the most reliable results (Hoyt and Clemence, 1989). In ideal situations, the engineers should use all three methods and weigh them against the reliability of the input data.

In the “cylindrical shear” method, all of the soil between the blades is assumed to be mobilized. The ultimate capacity of a pier with multiple Helices is a combination of shear along the cylinder of soil between the blades and bearing capacity of the bottom helix (from Mitsch and Clemence, 1985, and Clemence, 1985).

$$Q_u = (2\pi RL)(c' + K_o \sigma'_v \tan \phi') + (\pi R_B^2)(1.3c'_c + \sigma'_v N_{qc}) \tag{Eqn. 4.1}$$

Where:

- R = the average helix radius
- R<sub>B</sub> = the bottom helix radius
- L = the total spacing between all helices
- $\sigma'_v$  = the effective vertical pressure at the helices
- c' = the soil cohesion
- $\phi'$  = the angle of internal friction of the soil
- K<sub>o</sub> = the coefficient of lateral earth pressure
- N<sub>c</sub> = bearing capacity factors
- N<sub>q</sub> = bearing capacity factors

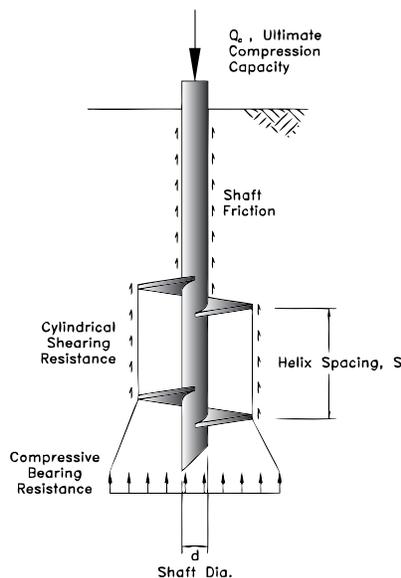


Figure 4.1 Compression Loading on a Multi-helix Pile

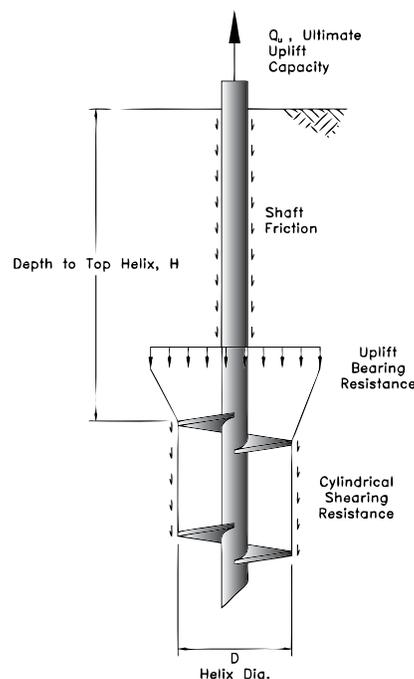


Figure 4.2 Tension Loading on a Multi-helix Pile

In the “individual bearing” method, each helical blade displacing the soil in a logarithmic spiral mode is the assumed failure mechanism. Therefore, the capacity of each helix is projected based on the well-known bearing capacity equation. Contributions of overload pressure and soil unit weight are ignored for uplift. This results in more conservative results for compressive loads. Ultimate capacity is the sum over N helices, given by (modified from A.B. Chance, 1995).

$$Q_u = \sum_1^N A_n (1.3c'N_c + \gamma'N_q) \tag{Eqn. 4.2}$$

Where:

N = the number of helices

n = an index from 1 to N

A<sub>n</sub> = helix area of helix n.

All other parameters have been defined previously.

It is suggested that the factors recommended for traditional bearing capacity analysis by DeBeer (1970) and Hansen (1970) be integrated. Given that the helical blades are spaced roughly 3 blade diameters apart, capacity results acquired using both “cylindrical shear” and “individual bearing” methods, Eqn. 4.1 and 4.2, should be more or less the same for most soil shear strengths.

It is common practice for soil engineers to provide values of net effective bearing capacity, q, and effective side shear resistance, s, for deep foundation design instead of the effective angle of friction, effective cohesion intercept, and at-rest lateral earth pressure coefficient. The “cylindrical shear” and “individual bearing” methods of helical pile capacity determination can be tailored to utilize these parameters as given by Eqn. 4.3 and 4.4.

$$Q_u = (2\pi RL)s + (\pi R_B^2)q \tag{Eqn. 4.3}$$

$$Q_u = \sum_1^N A_n q \tag{Eqn. 4.4}$$

It is important to note that s and q in Eqn. 1.3 and 1.4 are for ultimate bearing capacity determination. Soil engineers may provide permissible s and q values employing a factor of safety of 3. Based on the “installation torque” method, helix pier ultimate capacity is given by:

$$Q_u = K T \tag{Eqn. 4.5}$$

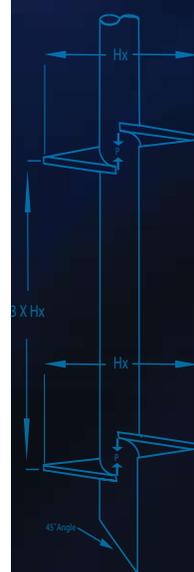
Where:

K = the capacity:torque ratio

T = the final installation torque

The K value is reliant on the geometry of the helix pier. For helical anchors with square shaft dimensions less than 2”, a value of 10ft -1 is suggested by Hoyt and Clemence (1989). It is recommended that K values should be used for other helical anchor geometries. PierTech Systems suggests that K values of 9ft -1 and 7ft -1 for 2-1/2” and 3” nominal diameter helical anchor shaft diameters.

A factor of safety of 3.0 is regularly used in bearing capacity calculations for footing and drilled caissons foundations. Although, in situations where the installation process includes an indirect measurement of soil strength at the foundation depth, lower factors of safety are acceptable. Pile driving is a commonly used example of this. The American Society of Civil Engineers Publication 20-96, “standard Guidelines for Design and Installation of Pile Foundations”, explains that a factor of safety of 1.5 is suitable for pile



foundation. Given that the installation torque of helical piers also supplies an indication of soil strength at the depth of the helices, a lower factor of safety is permitted for acceptable bearing and pullout capacity calculation. In general a factor of safety of 2 is used in helical pier design. The engineer should select a factor of safety that is steady with the trustworthiness of subsurface conditions, availability and accuracy of installation torque measurements, likelihood that live loads will be applied, and other typically considered factors.

### CAPACITY TO TORQUE RATIO

A main method for calculating helical pier capacity is based on relationships with installation torque (Hoyt and Clemence, 1989). The coefficient of proportionality,  $K$ , between capacity and torque varies for helical piers and anchors of different geometric configurations. Research suggests that  $K$  may depend on depth (Ghaly, Hanna, and, Hanna, 1991b). At the same time, there is research that indicates that  $K$  is independent of the helix radius and highly reliant on hub diameter (Hoyt and Clemence, 1989). Other research suggests that  $K$  is loosely correlated with the number of helical blades (Hargrave and Thorsten, 1992).

In addition to the empirical method involving installation torque, the capacity of a helical pier can be projected by two different methods of limit state analysis. The trouble with limit state analysis is that it involves familiarity of the soil shear strength and the capability to verify the likely mode of failure.

Torque measurements acquired during installation of helical piers are an indication of soil shear strength at the depth through which the helical blades are passing. Because of the intricate interaction of the blades with the soil, it is complicated to relate torque measurements directly with angle of internal friction and cohesion of the soil. To circumvent this trouble, Perko (2000) proposed a model in which the capacity of a helix pier is directly related to the installation torque by energy equivalence. This new method allows for downward pressure throughout installation, helical blade geometry, multiple helices, blade pitch per revolution, and hub radius consideration. Predictions based on this model measure up to data from preceding studies.

The energy model for calculating helical pier capacity/torque relations is based on the claim that penetration energy is proportional to the volume of soil displaced multiplied by the distance displaced. Helical pier installation characteristically involves drilling the pier into the ground and applying a downward force. The energy that is required to rotate an object is equal to the torque multiplied by the angle of rotation. Energy used by the downward force is merely the force multiplied by the distance over which the force acts. For one revolution, the volume of soil displaced by the helical pier is equivalent to the summation of the volumes of all the individual cutting blades plus the volume of soil displaced by the hub in moving downward the distance of the pitch as shown in figure 4.3. If the pitch is small, the volume of a helical plate is almost equal to the volume of a circular plate with the same radius. The distance necessary to displace the soil for helical blade insertion is roughly equal to half the thickness of the blades. For hub penetration, this distance is just about equal to the radius of the hub. Energy losses due to friction can be anticipated by converting soil shear stress into torque and multiplying by the angle of twist.

The acceptable movement of piers and anchors is typically limited to minimal displacements. The capacity for small displacements can be figured by an energy balance between the energy used during loading and the appropriate penetration energy of each of the supporting blades. Energy losses because of friction along the hub are considered to be insignificant. This is because only a portion of the shear strength is mobilized for small displacements. In addition, the capacity in uplift is about equal to the bearing capacity, since minute movements in either the upward or downward direction should rely only on the effective confining stress around the blades. The energy throughout loading can be determined by integrating the applied force



over a specific helical pier displacement. The volume of soil displaced by the helical pier is equal to the sum of the areas of the blades and the end area of the hub multiplied by the displacement distance. This presupposes that the end of the hub is closed or becomes blocked ruling out soil entry.

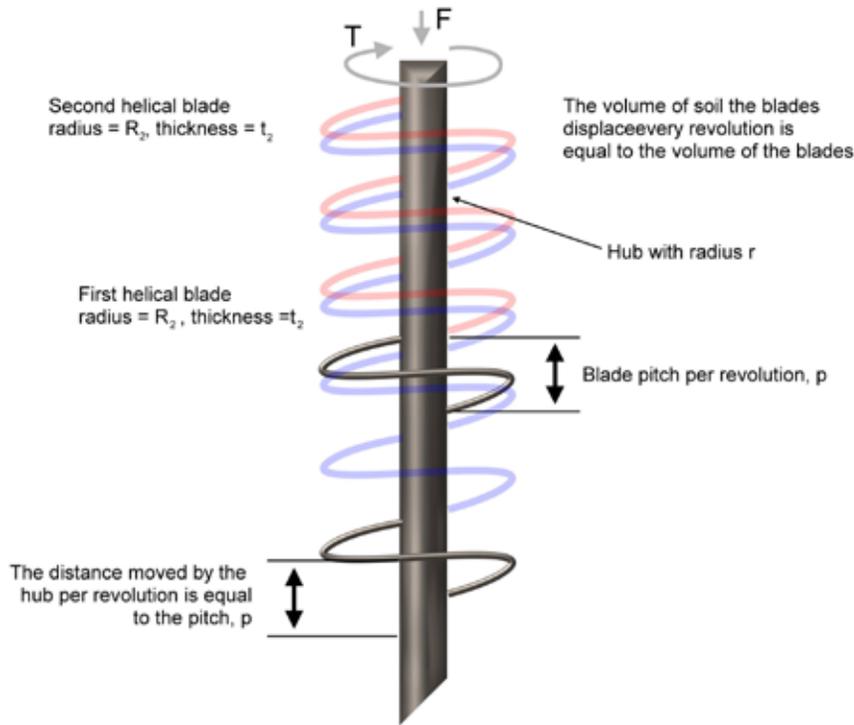


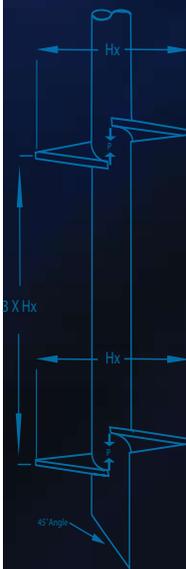
Figure 4.3 Helix Pier Installation Properties

The net product of these integrations and energy equivalencies is a relationship between installation torque and capacity given by:

$$Q = \frac{12d(2\pi T + Fp)[r^2 + \sum_m (R_m^2 - r^2)]}{3[2r^3p + \sum_n (R_n^2 - r^2)t_n^2] + 16\pi\alpha[3r^3\lambda + \sum_m (R_m^3 - r^3)t_m]} \quad \text{Eqn. 4.6}$$

- Where:
- d = helical pile displacement
  - T = torque
  - F = downward pressure during installation
  - p = helice blade pitch
  - r = helical pile shaft diameter
  - m = total number of helice blades
  - n = number of helice blades cutting independent paths
  - $R_m$  = radius of helice blade m
  - $R_n$  = radius of helice cutting blade n
  - $t_m$  = thickness of helice blade m
  - $t_n$  = thickness of helice blade n
  - $\alpha$  = ratio of side shear to penetration resistance
  - $\lambda$  = effective helical pile shaft length

It is recommended for helical pier displacement, d, to equal 1" (2.5cm) for helix pier design to be consistent with conventional foundation design thinking. The downward force exerted during helical pier instal-



lation is usually not more than 1 ton (9kN). This force multiplied by the pitch is insignificant compared to the installation torque multiplied by  $2\pi$  and can be ignored. The number of helical blades,  $m$ , is the number of blades cutting independent paths plus the number of blades following that path. It is recommended to have a ratio of side shear to penetration resistance,  $\alpha$ , of 0.5 for galvanized steel in most soils. An efficient helical pier shaft length,  $\lambda$ , equal to the pitch of the blades is recommended for square shaft helical anchors since the soil displaced away from the shaft within one revolution. An efficient helical pier shaft length,  $\lambda$ , equal to 2 to 3 times the blade pitch is suggested for round shaft helical piers based on comparisons with field measurements.

Capacity-Torque ratios researched by Hoyt and Clemence (1989) were compared with the energy model. The study by Hoyt and Clemence entailed 1-1/2", 1-3/4", and 2" O.D. square hubs and 3-12" and 8-5/8" O.D. round hubs. The amount of helices varied from 2 -14, and diameters varied between 6" and 20". Hoyt and Clemence discovered that the capacity/torque ratio depends primarily on the diameter of the hub. The quantities of helical blades and helical diameter generally have no influence on the ratio. They discovered a typical capacity/torque ratio (K) equal to 10ft -1 for square hub anchors that were tested, 7ft -1 for the 3-1/2" O.D. round-hub anchors, and 3ft -1 for the 8-5/8" O.D. round-hub anchors.

Configurations of the helical piers studied by Hoyt and Clemence are proprietary information. Therefore, a variety of helical pier configurations were assumed. The ratio of side shear to penetration stress,  $\alpha$ , was equal to 0.5 and the displacement at failure,  $d$ , was understood to equal 1". Results of this model match Hoyt and Clemence studies very well. A capacity/torque ratio (K) of approximately 37m -1 was obtained for three various square hub anchors with single and multiple 15.2cm O.D. helical blades. This ratio is not affected by downward force applied throughout installation and final installation torque.

The value of K goes down with rising values of R, which is opposite of the Hoyt and Clemence findings. Model prediction is based on 2 or more helical blades with identical radii and a helical pier displacement of 2.5cm. The research of Hoyt and Clemence are founded on helical piers with 2 or more blades, however it is unclear whether their blades had identical radii and what displacement was used to assign failure.

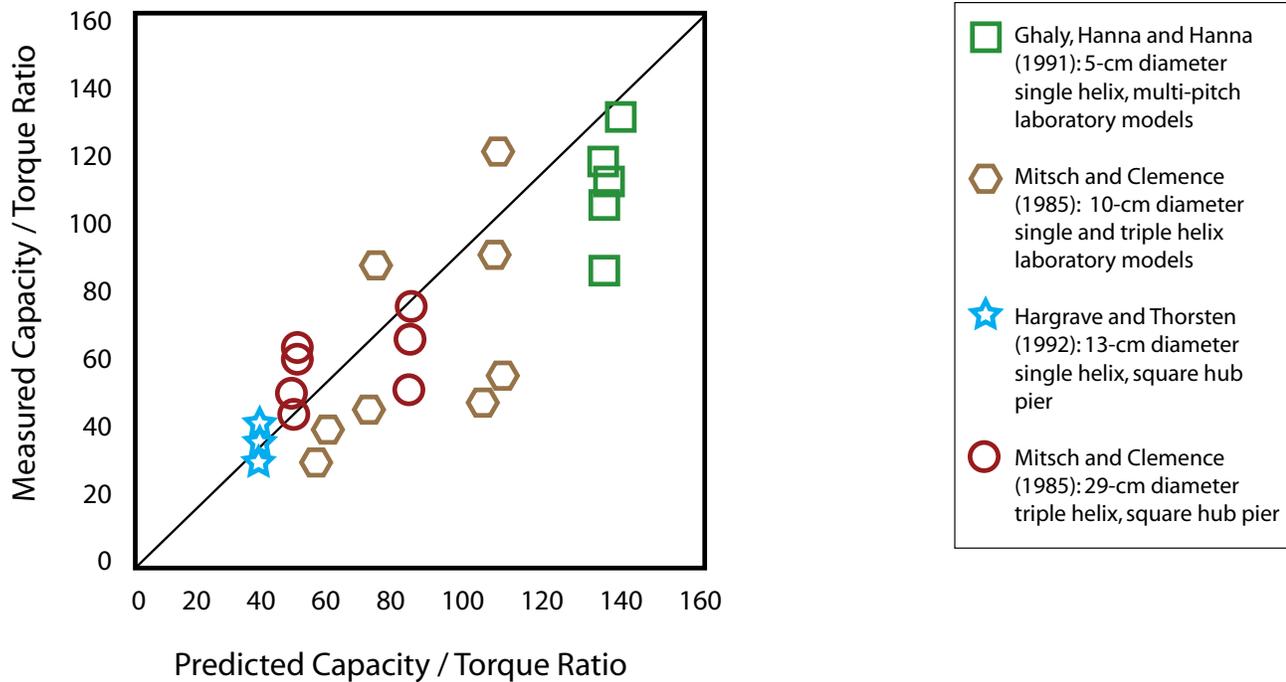
A decrease in the value of K is suggested with the increase of hub radius,  $r$ , which is steady with what Hoyt and Clemence found. The degree of the expected value of K for round-hub piers relies on the effective hub length,  $\lambda$ , which is assumed. Larger values of  $\lambda$  relate to smaller values of K. In order to equate the K value suggested by Hoyt and Clemence for 9cm O.D. round-hub anchors, a minimal value of  $\lambda$  was assumed. This shows that a majority of the soil breaks away from the hub throughout installation because of wobbling or that the soil shear strength minimizes to comparatively insignificant levels along the hub because of the large strains. A K value much lower than that of Hoyt and Clemence for the 22cm O.D. round-hub pier, even at minimal values of  $\lambda$ , is predicted. An explanation of this can be realized by recognizing that side friction along the hub was overlooked in the calculation of theoretical helical anchor capacity for minimal displacements. It seems that much of the bearing and pullout capacity of the 22cm O.D. round-hub pier is produced by friction along the hub. Peak stress along the hub for bearing and pullout capacity is roughly perpendicular to the peak shear stress and large strains that occur throughout torsional installation.

In order to confirm the model more extensively, it was weighed against other previously published field and laboratory data. Model predictions are compared with actual measured values in figure 4.4. The diagonal line in the figure signifies a 1:1 correlation between estimated and measured capacity/torque ratio, K. As illustrated in the legend to the right side of the figure, helix piers tested have a variety of sizes and styles. Measured values of K ranged from 9 to 37ft-1. Estimated values of K according to the model match this range and tendency.



The square symbols in the figure represent a laboratory investigation that was held by Ghaly, Hanna, and Hanna (1991). This study involved uplift capacity testing of a number of small helix anchors. Each anchor had a round hub with a single 5cm diameter helical blade. The pitch of each blade varied from 1 to 2cm per revolution. Installation torque ranged from 24 to 42 N-m. The model displays a weak dependence of K on pitch and matches the laboratory results. In addition, the investigation included unsymmetrical and parallel-blade, variable-pitch anchors. There is significantly more difficulty applying the model to these types of anchors. As a result, they were not analyzed.

Figure 4.4: model comparison with measured values

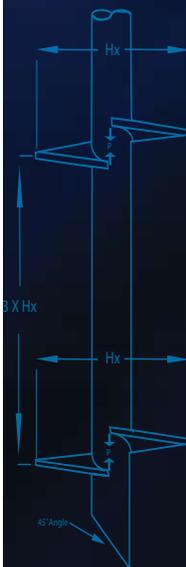


The circle symbols represent field tests performed by Mitsch and Clemence (1985) on square hub piers with triple 11.3” diameter helical blades. The hexagon symbols signify laboratory tests performed on 1/3 scale models. On some of the models uniform diameter triple helical blades were used and on others single blades were used. The model estimates almost the same value of K for single and multiple blade helix pier geometries. Many of the variations in K estimated by the model are the result of various values of measured helical pile displacement. For example, the circle symbols on the left side of figure 4.4 represent helical piles that reached peak capacity at a displacement of about 1”, while the circle symbols in the middle of the graph represent helix pier displacements of 2”.

The star symbols indicate field tests performed by Hargrave and Thorsten (1992) using square hub helical piles with single 10in diameter helical blades. Their field tests match the model matched with almost 1:1 correspondence.

**LATERAL RESISTANCE**

A model based on elastic theory for estimating the lateral load capacity of helical piles under static conditions in both cohesive and non-cohesive soils was proposed by Puri et al. (1984). The model estimations were shown to agree reasonably well and conservatively when compared to field load test results. Due to



the fairly small shaft diameters common to helical piles, many engineers have assumed that they provide little to no lateral load resistance for the structure supported. Instead, engineers design for development of passive resistance along the base and sides of the pier cap. This assumption may be reasonable when large structures are being supported, however it may be over kill and costly when small or lightly loaded structures are supported.

According to Puri et al. (1984) helix piers can develop substantial resistance to lateral loads, and this resistance is controlled by the interaction between the shaft and the soil. The effect of the soil between the helical blades was found to be insignificant provided the helical blades are installed to depths such that the pier behaves flexibly. Much like traditional pile or drilled pier foundations, Puri et al. proved that helical piles behave flexibly if the shaft length is greater than 4 to 5 T in sands and 4 to 5 R in clays. The relative stiffness factors, T and R are defined by Equations 4.7 and 4.8. The subgrade modulus is taken as 67 times the undrained soil shear strength.

Clays: 
$$R = \frac{EI}{K} \left( \frac{EI}{K} \right)^{0.25}$$
 Eqn. 4.7

Sands: 
$$T = \frac{EI}{n_h} \left( \frac{EI}{n_h} \right)^{0.2}$$
 Eqn. 4.8

where: E = Young's Modulus of the helix pier  
 I = Moment of inertia of the helix pier  
 n<sub>h</sub> = Modulus of subgrade reaction  
 K = Subgrade modulus

The lateral-load capacity can be p for flexibly behaving helix piers using procedures comparable to that developed for slender laterally loaded piles but altered to take into account the disturbance of soil during helical pile installation (Puri et al. 1984). The suggested model for lateral capacity is shown in Equations 4.9 and 4.10. The coefficients A<sub>y</sub> and B<sub>y</sub> can be obtained from Matlock and Reese (1962) for sands and from Davisson and Gill (1963) for clays. The coefficient C<sub>u</sub> was determined to be about 3.0 by correlation with the measured field behavior. The model compared well with full-scale field tests and with 1/4 scale model tests in clay and sand soils.

Clays: 
$$y = C_u \left[ A_y \left( \frac{PR^3}{EI} \right) + B_y \left( \frac{MR^2}{EI} \right) \right]$$
 Eqn. 4.9

Sands: 
$$y = C_u \left[ A_y \left( \frac{PT^3}{EI} \right) + B_y \left( \frac{MT^2}{EI} \right) \right]$$
 Eqn. 4.10

Where: P = Horizontal force at ground level  
 M = Moment acting at ground level

In applications with large or heavily loaded structures, it may be necessary to provide additional lateral



resistance beyond that provided by the shaft of vertical helix piers and passive earth pressures along grade beams and pier caps. This can be obtained by “battering” helix piers or by tie-back helical anchors.

**FOUNDATION DESIGN**

Figure 4.5 shows a sample foundation plan. The necessary ultimate capacities of the helical piers are shown in the foundation schedule. These loads are the total live and dead loads determined by typical structural engineering techniques multiplied by the factor of safety for bearing and pullout capacity (usually 2.0 for helical piers). Calculation errors in the field can be avoided by including the factor of safety for bearing and pullout capacity in the plans.

The contractor shall install the helical piers until the minimum torque is acquired signifying the necessary capacity has been reached. The number and size of helical blades necessary to attain the minimum torque depend on the soil stiffness. Characteristically, the contractor must depend upon his/her experience with local soil conditions to size the helical blades correctly so that the minimum torque is achieved within a useful depth.

There is considerable history in relating the ultimate bearing capacity of deep foundations with standard penetration resistance blow count measurements in present day geotechnical engineering practice. These relationships were used to create the helical pile sizing charts shown in Fig. 4.6. Standard helical piles have an ultimate capacity of 60 kips, therefore these charts should not be extrapolated. These charts are only for estimating helical pile sizes. They are not to be used for determination of the capacity of helical piles. Capacity determinations should be calculated either by using installation torque correlations or limit state methods (cylindrical shear and individual bearing) based on dependable geotechnical engineering data for the particular site. The most reliable method of predicting actual helical pile capacity is the installation torque. Therefore, torque correlations should always be integrated in the design of a helical pile foundation.

**Foundation Schedule**  
Use only Ingal/Precision Foundations, Inc. helical piers or equivalent with 2-1/2" diameter round-shaft.

Type	Capacity	Top Elevation
<b>a</b>	20 kips	101.0
<b>b</b>	25 kips	101.0
<b>c</b>	15 kips	99.8

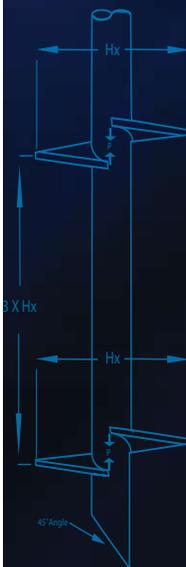
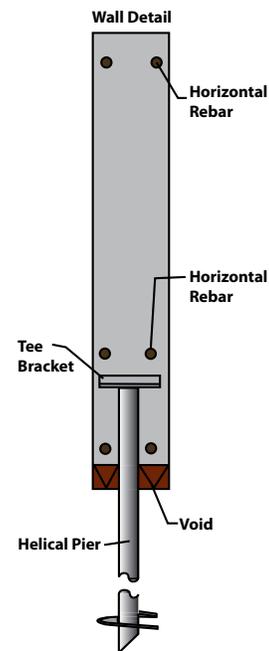
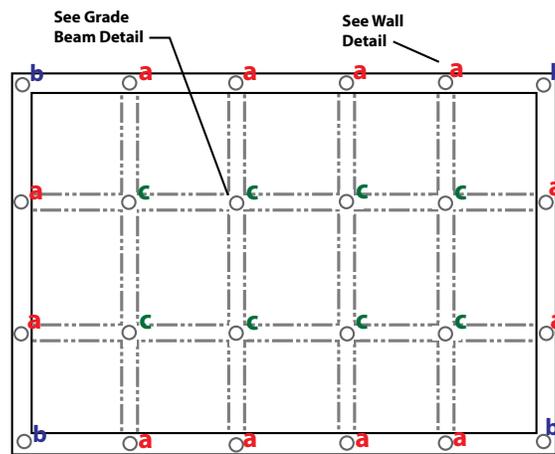
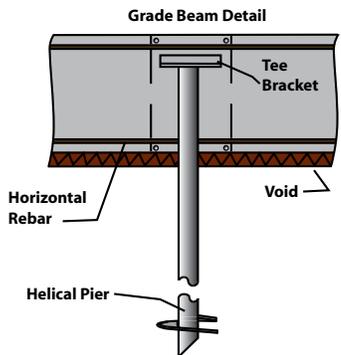


Figure 4.5 Foundation Plan  
The foundation engineer may suggest minimum helical blade dimensions based on the “cylindrical shear”

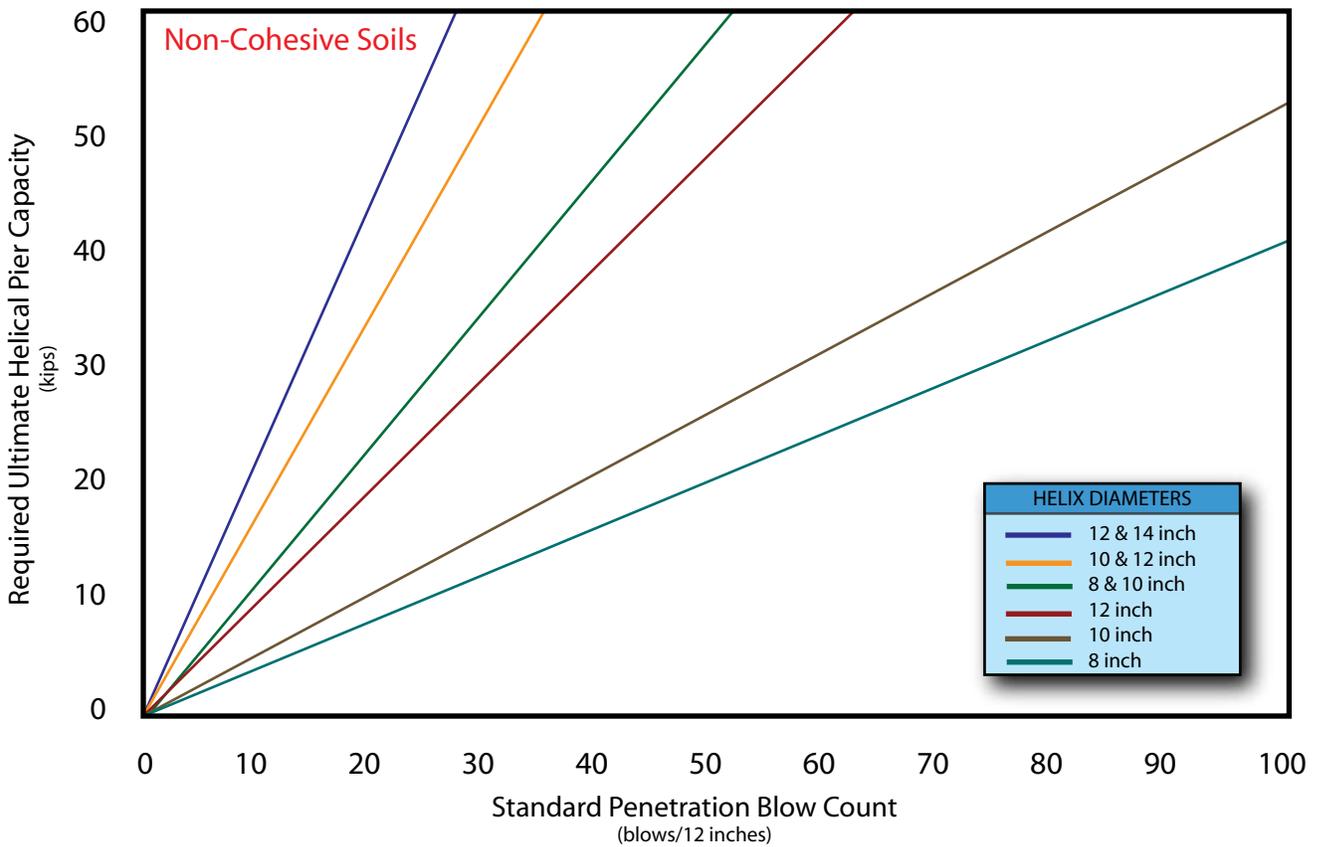
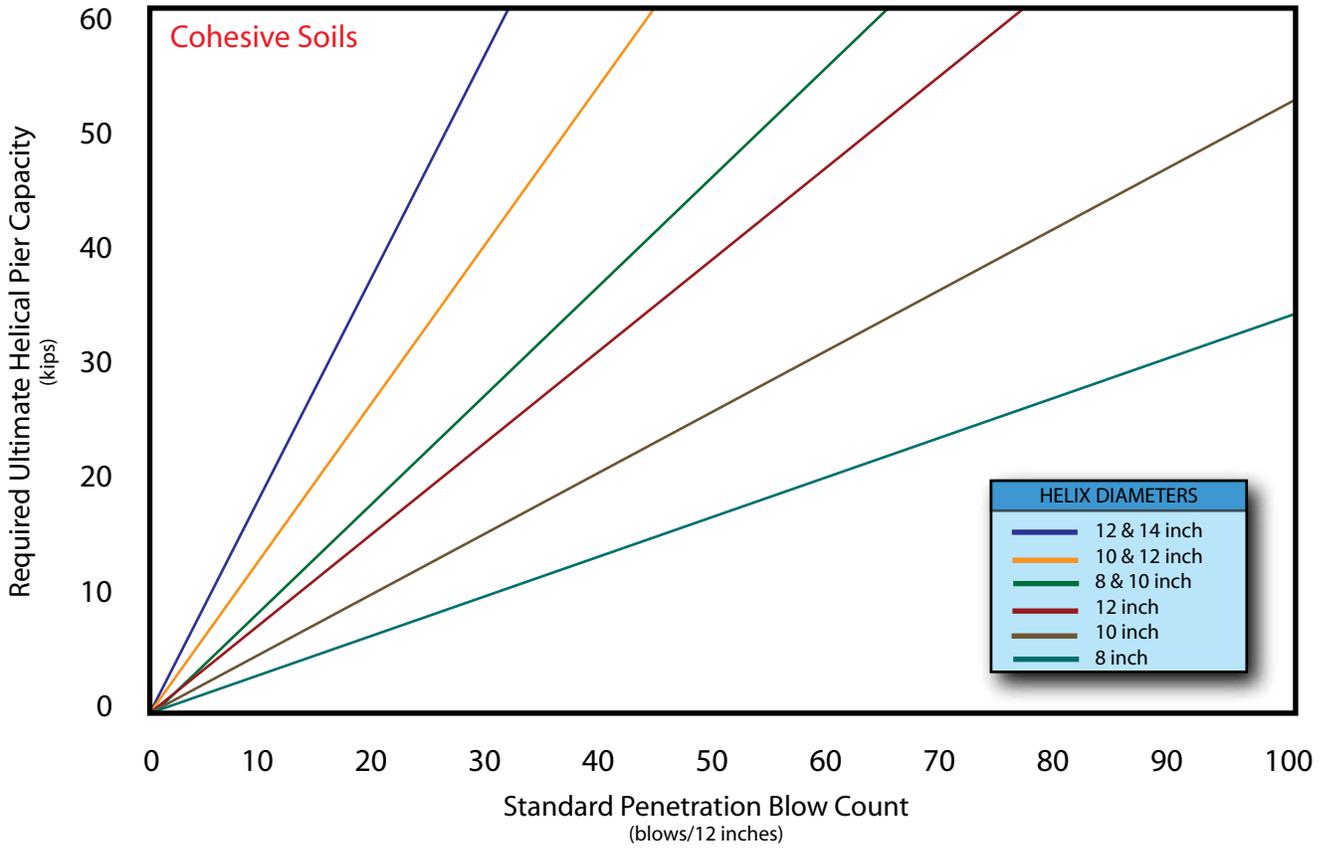


Figure 4.6: Helical Blade Sizing Guides

or “individual bearing” methods of helical pile capacity determination provided that the soil shear strength information is obtainable for the site. For example, consider the type “a” helical piles shown in Fig. 4.5. The necessary ultimate capacity together with a factor of safety of 2.0 is 20 kips. Assume the soil profile at the theoretical building site consists of 10 feet of wet, soft, non-engineered fill overlying moist, stiff, sandy clay to the depth explored. Also assume, the soil engineer suggests using an ultimate bearing capacity of 15,000 psf and an ultimate side shear strength of 5,000 psf for the portion of the deep foundation within the stiff sandy clays. Finally, assume a double blade helical pile. Then, according to Eq. 4.4 for the “individual bearing” method, one obtains

$$20,000 = 15,000(A_1 + A_2) \tag{Eqn. 4.11}$$

Where:

$A_1$  and  $A_2$  = the areas of the two blades

By trial and error, one may easily conclude that a helical pile with 10-inch and 12-inch diameter blades must yield the correct capacity. Assuming the blades are spaced 3 feet apart which is typical, this determination can be checked using the “cylindrical shear” method, Eq. 4.3.

$$20,000 =? (2\pi (5.5/12) 3) 500 + (\pi(5/12)^2) 5000 \tag{Eqn. 4.12}$$

$$20,000 < 21,129 \tag{Eqn. 4.13}$$

Eq. 4.13 indicates the capacity can be slightly higher than that predicted by Eq. 4.11, but for practical purposes the two calculations surrender the same end result.

It is sensible to advise a minimum length at least equal to 5 helical pile diameters in order for the capacity determination techniques to be valid since they presume a deep failure mode. The engineer may also find it essential to advise minimum helical pile lengths. Minimum helical pile penetrations are vital in the case of multiple helices in a soil profile consisting of a less firm material overlying a more competent bearing stratum. In this situation, the contractor ought to continue to install helical piles once the design installation torque is acquired until the helical pile has penetrated a minimum distance equal to the total spacing between helical blades to insure that all blades rest on the bearing stratum. Minimum helical pile lengths are also suggested in expansive soils. At the very least, helical piles should be drilled to bottom below the expected depth of wetting. Empty space shown below the outer walls and inner grade beams in Fig. 4.5 are also necessary in areas where expansive soils exist.

Note that helical piers can be used in all soil types given typical penetration blow counts are less than 50/6 (50 blows of a 140 lb. hammer falling 30 inches are required to drive a 1.5-inch diameter split spoon sampler 6 inches), in which helical pile refusal often occurs. If an underlying stratum exceeds blow counts of 50/6 and loads are compressive (i.e. no counterforts or other tensile loads), it is suitable to install the helical piles to refusal at the surface of the hard stratum. “Auguring” can happen at the top of the hard stratum so that necessary torque values can not be established. In this case, the “individual bearing” capacity method should be employed using the dimensions of the bottom blade and the shear strength of the hard stratum to establish the helical pile capacity resting on the hard stratum. PierTech Systems promotes a combination helical pier/anchor in situations where an underlying stratum exceeds blow counts of 50/6 and loads are tensile.

The PierTech® Tee Bracket is attached to the pile as shown in the details contained in Fig. 4.5.



The helical pile should be secluded from the rest of the reinforcing or structural steel in the building to avoid the creation of an electric potential which can influence corrosion rates. Horizontal reinforcing bars are suggested close to the ground surface and close to the top of the helical pile shaft to avoid lateral or bending motion of the helical pile within the foundation wall or grade beam.

Like the example shown in Fig. 4.5, the grade beams and foundation walls are covered adequately deep so that passive soil resistance is able to provide the necessary lateral load resistance for the structure. It has been proven, however, that helical piles can develop noteworthy lateral resistance. The structural engineer may decide to incorporate considerations for helical pile lateral resistance in the design. The engineer may use Equations 4.9 or 4.10 with an acceptable lateral displacement to conclude the minimum moment of inertia of the helical pile shaft. PierTech Systems 2.5-in and 3-in nominal diameter helical piles have area moments of inertia of 1.92 and 3.89 in<sup>4</sup>, respectively. Tubular helical pile shafts may be grouted for elevated moments of inertia. Rigid straight couplings should be used if helical pile shafts are relied upon for lateral load resistance.

### RETAINING WALL DESIGN

Two main methods of retaining wall design involving helical earth anchors exist:

1. Soil nailing
2. Tie-back

Soil nailing is the strengthening of earth behind the retaining wall so that the soil is vertically stable. Soil-nail walls classically have nominal facing thicknesses with the function of thwarting raveling of the slope face. Soil strengthening is made possible by grouting helical anchors continuously along the shaft or by using a continuous series of spaced-apart helical blades along the entire length of the shaft. Design loads equivalent to active earth pressures are proper for helical anchor tension. To design grouted helical anchor retaining walls, the Department of Transportation standards for soil-nail retaining walls may be used.

Post-tensioned helical anchors that are set in to depths further than the active zone of the soil are used in Tie-back retaining walls. Helical anchor capacity is calculated following the procedures offered in the chapter on Bearing and Pullout Capacity. Design loads identical to Peck's apparent earth pressure are suitable for tie-back anchor design. An example of this type of retaining wall design is provided below.

Helical earth anchors are spaced along the wall at the locations shown. The soil has a unit weight of 120 pcf, friction angle of 30°, and a cohesion of 0 psf. This friction angle corresponds to  $N_q$  equal to 14 and  $K_0$  equal to 0.5. The anchors were drilled to a final torque of 1,000 ft-lbs. The anchors are slanting 15 degrees from horizontal and are roughly 6 feet below the ground surface. Each anchor has dual 12-inch diameter blades spaced 3 feet apart. The anchors are drilled to a distance of 9 feet further than the theoretical active zone.

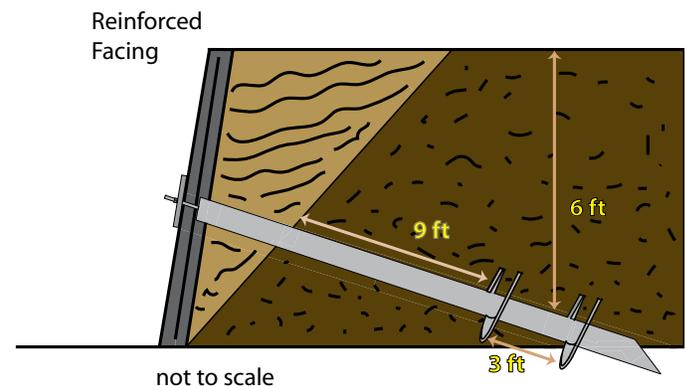


FIGURE 4.7: EXAMPLE RETAINING



Determination of the ultimate pullout capacity of one anchor is figured by the methods described in the section on Bearing and Pullout Capacity. According to the cylindrical shear method the pullout capacity is given

by:

$$Q_u = 2\pi(0.5)(3)[0+(0.5)(720)\tan(30^\circ)] \\ + \pi(0.5^2)[0+(720)(14)] \\ Q_u = 9,900 \text{ lbs}$$

Where:

The vertical stress was understood to be constant over the entire length of the anchor for simplicity.

According to the individual bearing method, the pullout capacity is:

$$Q_u = 2\pi(.5^2)[0+(720)(14)]$$

$$Q_u = 15,800 \text{ lbs}$$

Lastly, the pullout capacity by the installation torque method is:

$$Q_u = (10)(1,000)$$

$$Q_u = 10,000 \text{ lbs}$$

The cylindrical shear method was used to acquire the most conservative result in this example. Applying a factor of safety to this result, yields an acceptable pullout capacity for each anchor given by:

$$Q_a = 9,900/2 = 4,950 \text{ lbs}$$

The last step in helical anchor design is to confirm that the anchor is adequate to endure the estimated pullout capacity. Helical anchors are usually manufactured of high strength carbon steel having an ultimate tensile strength in the range of 35,000 to 70,000 psi. In this example, the helical anchor shaft ought to have a minimum cross-sectional area of 0.07 to 0.14 in<sup>2</sup>.

Also adding to the pullout capacity is the friction along the shaft of a helical anchor (Gahly and Clemence, 1998). Helical piers with large shaft diameters and that are installed deep may gain a substantial portion of their strength from the shaft to soil interface. Due to high strains resulting from turning during installation, residual shear strength parameters are fitting. Wobbling during installation needs to be taken into consideration because it causes the soil to separate from the anchor shaft. The adhesion and friction along the anchor shaft is expected to add only nominal additional strength for short helical anchors.

Anchor capacity is in a direction parallel with the anchor shaft. The angle of the anchor must be considered in the static free body force diagram. Although the active zone of earth pressure is shown by a wedge shape in Fig. 4.7, it is well known that Peck's apparent earth pressure diagrams should be used for tie-back earth retaining walls.

It is possible for the reinforced facing to be multi-layer or single layer reinforced shortcrete, precast panels,



or any other structurally appropriate system. It may be necessary to place helical piers vertically below the wall to provide a foundation if a heavier concrete or block wall is used.

Gahly and Clemence (1998) proved in theory that the pullout capacity of helical anchors installed in sand at an angle is superior to that of vertical anchors. This was explained by the formation of a larger zone of soil mobilization. In the case of retaining walls, however, it is projected that this effect is lost by the intrusion of the larger zone of mobilized soil with the active soil wedge. It is suggested that the effect of inclination angle and increased strength be ignored in order to be conservative.

Rao, and Prasad (1993), Rao, Prasad, and Shetty (1991), and Rao, Prasad, and Veeresh (1993) performed experiments on model earth anchors in a clay filled test cylinder. The blade spacing to diameter ratio was varied between 1 and 5 for the model anchors. Effects of blade spacing on cylindrical shear pullout were evaluated. Results suggested that at a blade spacing to diameter ratio of 1.5, the anchors displayed individual bearing failure as opposed to cylindrical shear.

The preceding experiments were performed on small laboratory model anchors. The maximum blade diameter was approximately 6 inches. Because cylindrical shear increases with  $R^2$  and plate bearing capacity with  $R^3$ , it is thought that the best blade spacing to blade diameter ratio increases for larger diameter helical anchors. Characteristically, helical anchors are manufactured with a blade spacing to blade diameter ratio of 3.

Tests were conducted by Ghaly and Hanna (1992), and Ghaly, Hanna, and Hanna (1991) on model helical anchors with varying geometries in a sand filled testing tank equipped with stress transducers. It was decided that the zone of soil stress-strain influence surrounding the blades of a helical anchor experiencing 90% of its designed pullout capacity is restricted by the ratio of depth to blade diameter and by the density of the surrounding sand. A transition between significant and minimal strain occurred at depth to blade diameter ratios of 7, 9, and 11 for loose, medium, and dense sand. It can be inferred from these results that helical anchors should be drilled to distances greatly beyond the projected active wedge of retained earth, so that these ratios are exceeded. In do this the zone of strain influence as a result of anchor pullout should not overlap the active wedge of retained earth.

It is thought that the transition between significant and minimal strain occurs at smaller depth to blade diameter ratios in cohesive soils as compared to that in sand. The transition between individual bearing limit state and cylindrical shear limit state at a depth to diameter ratio of 1.5 as is an example of this occurrence in clay. It is probable that helical anchors only need to be installed a distance beyond the active zone of a retaining wall equivalent to 1.5 to 3 times the helical blade diameter. Until more testing is available, a distance of 5 times the helical blade diameter is suggested in clay soils.

Standard design practice indicates that sufficient drainage should be provided for all earth retaining walls. Pore pressures will negatively affect soil shear strength and as a result anchor pullout may occur. Manufactured sand/gravel drains or drain board and weep holes should always be used. Drain materials must be compatible with the gradation of native soils.

Occasionally, retaining wall systems integrate the use of rigid, lightweight materials to lessen earth pressures. Styrofoam blocks can be utilized for this purpose. Helical anchors can easily penetrate Styrofoam making this type of system particularly attractive.



# JOB SITE INSPECTION AND TESTING

**FIELD INSPECTION**

A professional soils or structural engineering company should always inspect helical pier foundations.

The examiner should observe:

1. The method of installation
2. Method of torque measurement
3. Assembly of pier sections
4. Materials used
5. Any other relevant information

A sample inspection form is shown in Table 4. These records should be saved for each helical pier installation.

The installation torque readings with depth is essential for the inspector to monitor. There are various ways to measure torque including a hydraulic pressure gauge, an electric load cell, and a shear pin indicator.

The hydraulic pressure at the input to the power torque drive shows a sign of the torque being applied to the pier. Engine throttle settings, ambient air temperature, length and condition of hydraulic hose, engine speed and temperature, and hydraulic fluid type may cause hydraulic pressure correlations to fluctuate. Regardless of these possible fluctuations, monitoring hydraulic pressure is imperative because it provides a means for torque measurement throughout installation. PierTech manufactures devices that eliminate some of the above gauge fluctuation causes.

PierTech also manufacture digital load cell equipment. PierTech digital load cells provide continuous torque measurements. Electric load cells use resistive strain gages to calculate deflections in a structural steel load cell placed between the helical pier and the hydraulic power torque drive. PierTech digital load cells are incredibly accurate and can provide the engineer a detailed record of each pile installed.

The installer should maintain a continuous downward pressure on the helical pier to avoid “auguring” when taking torque readings. Auguring occurs when the vertical movement of the pier halts and the pier continues to spin in place. Torque readings at these times are worthless for correlations with pullout and bearing capacity. The helical pier should be installed the amount of the blade pitch for every revolution. The rotary drive should be revolved at a maximum of 20 revolutions per minute. Torque readings are most representative of the pullout and bearing capacity when the helical pier is in rotational motion. Torque readings may be slightly higher than this for an instant upon starting rotational motion.





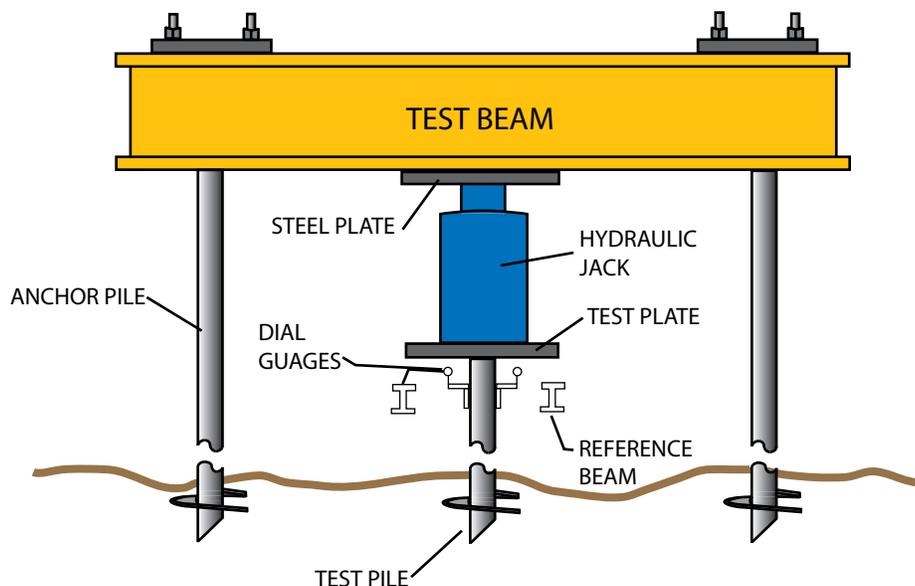
The concluding torque reading should be used for helical pier capacity calculation. Concluding torque measurements are taken at the final depth. If cobbles are present, torque values often display peaks. Peak torque readings are not reliable. An average torque reading can be used if it is difficult to distinguish between peaks. The project engineer should be alerted right away if conditions are other than shown on the drawings, and/or if minimum depth and/or torque cannot be achieved.

## FIELD TESTING

Field testing may be required to verify helical pier capacities on large or critical projects. Table 5 gives sample procedures for axial load field testing of helical piers. These procedures are significant to both tensile and compressive loading circumstances in the vertical direction. Conventional rock bolt test procedures utilizing a hydraulic jack and chair type equipment bearing on the bulkhead are suggested for testing the pullout capacity of tie-back anchors.

Table 5. Bearing and Pullout Capacity Sample Procedures

1. All helical piers should be screwed in to the preferred depth using a torque registering device to monitor installation torque throughout installation.
2. The necessary number of reaction helical piers should be screwed in. Monitor installation torque.
3. Create logs of installation torque versus depth for test piers and reaction piers and record qualitative observations on product performance during installations.
4. Raise channel test equipment over test pier. Configure for bearing capacity.
5. Drive large stakes into the ground at an adequate distance from the test equipment so it is not disturbed. By means of rigid cross members, mount dial gages over reaction piers.
6. Determine test pier displacement optically using a theodolite and target.
7. Nominally preload test pier to remove the majority of the flexure in the system.
8. Record load versus displacement for the test pier and reaction piers, until a maximum test pier displacement of 1-inch is reached.
9. Rerun test with channel equipment configured for pullout capacity.
10. Remove reaction piers.
11. Photograph and videotape installations, testing, and post test examinations.



# SPECIFICATIONS

## SAMPLE SPECIFICATIONS

This list of specifications is designed as a tool. It may be adjusted by the engineer to conform to the work involved for a particular project and the particular site conditions.

### SAMPLE SPECIFICATIONS FOR HELICAL PIER INSTALLATION

1. **SCOPE**  
The following specifications are to be used during the installation of helical piers on the drawn out plans upon approval from job engineer and General Contractor.
2. **SITE**  
Use equipment that will minimize the disruption of the environmental site and surroundings. Prior to installation, guarantee all underground services have been located, marked and identified
3. **UTILITIES**  
The General Contractor shall locate all of the subsurface structures and utilities. Any subsurface structures and utilities in nearby areas of the helical anchor/pier installations shall be clearly marked prior to helical anchor/pier installation work. No helical anchor/pier shall be installed within a horizontal distance from a utility or subsurface structure if that distance is equal to or less than half the depth of the utility itself
4. **SAFETY**  
Helical pier contractor and crew shall conduct construction operations in a manner as to assure maximum safety of all people and property in the immediate vicinity of helical pier installation work. Helical pier contractor shall provide and utilize hard hats, safety glasses, steel-toe boots and other safety clothing or equipment in accordance with General Contractor's safety plan and OSHA Standards.
5. **INSURANCE**  
The contractor shall obtain general liability insurance in accordance with the owner's contract and adequate workmen's compensation Insurance as prescribed by the workman's compensation act. The insurance should cover all of the contractor's personnel on site at anytime.
6. **CAPACITY**  
A Minimum Factor of Safety of 2 should be included in design loads and should be used to determine the required ultimate capacity of the helix piers. Helical anchor and pier capacity is dependent on the geometric configuration of the helical piles selected, the strength of the steel helices, subsurface conditions, and the torque applied during installation. Engineer's recommendations should be followed regarding the torque and bearing capacity. The ratio of required ultimate helical pier capacity to the total area of the helical blades shall not exceed the ultimate subsurface material bearing capacity provided by the soils engineer.
7. **MATERIALS**  
Helical anchors shall be square shaft and helical piers shall be round shaft both will have the required number of helical blades to provide the appropriate load carrying capacity. The strength of the helical plates, connections and hub shall be enough to support the design loads specified on the approved plans. Helical anchors and piers shall be protected from corrosion by hot dipped galvanizing.
8. **INSTALLATION**  
Installation is to be preformed by a trained and/or certified Pier Tech Systems contractor or dealer. Using hydraulic drive head, install helical piles to required depths, torques and position as shown in drawings and specifications Provide torque monitoring tool as a part of the installation equipment or as a separate in-line unit that will keep record of the torque and pressure. Torque shall be monitored throughout the entire installation process. Calibrated torque monitoring data will be made available upon request from the project engineer. Each Pile that is installed will have identification, complete torque, complete depth and a pile



description recorded in an installation summary. Torque head used should put out more torque than required minimum from engineer. Connect Manufacture’s approved adapters to the installation equipment. Install piles with a continuous motion, with an advancement rate of 5 to 20 rpm. This rate should match the pitch on the pile. Apply enough pressure downward to help the advancement of the pile into the ground. Following designed drawings align helical pile. Place anchor on pinned location and gain the necessary angular alignment. If soils is rocky, very hard or gravel move to offset marks for pile repositions. Make the connection with high grade bolts and nuts. If there is anything preventing the proper installment of the pier in the indicated position, remove the substance that is in the way or relocate the pile. If relocating the pile consult with the project engineer because this could effect the positioning of other piles. Minimum depth is typically considered 5 times the diameter of the uppermost helix or the maximum anticipated frost depth. Piles that reach max torque rating before reaching minimum indicated depth shall be subject to either termination at depth; only with the approval of project engineer. Or Replaces with smaller and /or fewer helix pile, installed beyond the termination point of original pile.

9. CONNECTIONS

Connect Manufacture’s approved adapters to the installation equipment. Connect the piers and extensions to the adapter using two pins.

10. MODIFICATIONS

If welding in the field is necessary, it should be in accordance with the “Code for Welding in Building Construction” of the American Welding Society. Cutting of manufactured helical anchor/pier blades is prohibited and shall not be performed without first consulting the Structural Engineer.

11. INSPECTION

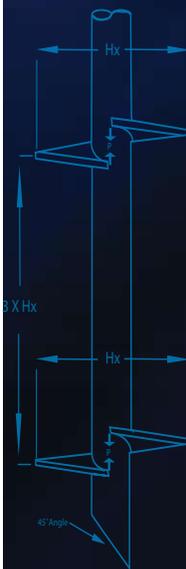
The representative of a structural engineering firm should observe the installation of helical anchors/piers to confirm the depth and installation torque. The representative should maintain a record of depth and torque readings. The Helical anchor/pier Contractor should provide the representative with recent calibration information for the instrument used to measure torque.

12. DRAINAGE

The contractor shall provide proper drainage in the site of all installed helical piers at all times during and after construction. Proper site drainage should include surface water runoff away from the structure and helix piers. If expansive soils are a concern, irrigation system shall not discharge within five (5) feet of an installed helix pier.

13. CLEANLINESS

When work is finished the Contractor will remove all equipment, tools, building materials, garbage, unused materials used for the job and restore all the landscaping to same quality as prior to the start of the job. While working the contractor and workers will keep the area as clean as possible



<b>Specification</b>	<b>A252 Piling Pipe</b>	
<b>Scope</b>	Covers average round shaft and square shaft piles and applies to piles that act as a permanent load bearing structure.	
<b>Types of Steel Allowed For Pipe Material</b>	Open-hearth, Basic Oxygen, Electric-furnace	
<b>Allowable Variables in Wall Thickness</b>	no more than 12.5%	
<b>Chemical Requirements</b>	<b>Seamless and Welded Pipe:</b> Open-hearth, Electric-furnace or Basic-oxygen	Phosphorus Max.% = 0.050
<b>Allowable Variations in Weights per Foot</b>	The weight of and length of pile shall not vary more than 15% over or 5% under the weight specified.	
<b>Allowable Variations in Outside Diameter</b>	No more than + or - 1% from the diameter specified.	
<b>Mechanical Tests Specified</b>	Tensile Test - Either longitudinal or transverse at option of manufacturer. Minimum yield determined by the drop of the beam, by the halt in the gage of the testing machine, or by the use of dividers.	
<b>Number of Tests Required</b>	One tensile property test per 200 lengths	
<b>Lengths</b>	May be ordered in single or double random lengths or in uniform lengths Single Random - 16'-25' md. Double Random - Over 25' Uniform - Plus or minus 1	
<b>Required Markings on Each Length</b>	Rolled, Die Stamped or Paint Stenciled Manufacturer's name, brand or trademark, heat number, method of pipe manufacture, size, weight, length, wall thickness and ASTM A@%@ and the Grade.	
<b>General Info</b>	Surface imperfections exceeding 25% of the nominal wall in depth are considered defects, Defects not exceeding 33.5% of the nominal wall in depth may be repaired by welding. Before welding, the defect shall be completely removed.	

Please note: the above was taken from ASTM Standard and API Specification 5L.

<b>Mechanical Properties</b>		<b>Grade 1</b>	<b>Grade 2</b>	<b>Grade 3</b>
Tensile Strength, min	Psi	50000	60000	66000
	Mpa	345	414	455
	kg/mm <sup>2</sup>	35.2	42.2	46.4
Yield Strength, min	Psi	30000	35000	45000
	Mpa	205	240	310
	kg.mm <sup>2</sup>	21.1	24.6	31.6
Elongation, min	%	30	25	24
Gauge Length	in	2 / (48t + 15)	2 / (40t + 12.50)	2 / (32t + 1.00)



## Grade J55 pipe

1. Pier Shaft: API 5CT Grade J55 pipe (API - American Petroleum Institute) Seamless Tubing

Chemical Specifications (%)

Grade	C	Mn	Ni max	Cu max	P max	S max
J55	0.35-0.45	0.990-1.30	.025	0.20	0.020	0.015
	Si	Cr	Mo	Al	V	Sn max
	0.15	max 0.25	-	min 0.015	-	0.03

Mechanical Specifications:

Yield Strength		Tensile Strength
min Psi (MPa)	max Psi (MPa)	Psi (MPa)
55000 (379)	80000 (552)	75000 (517)

Tolerances:

	Outside Diameter	Wall Thickness
API 5CT	+/- 1%	+20/-0%

2. Wall Thickness: 2-7/8" diameter (.217" w.t.) or 3-1/2" diameter (.254" w.t.)

3. Torques: The maximum torques are 8,000 FT.LBS. for 2-7/8" pipe and 11,000 FT.LBS. for 3-1/2" pipe.

4. Ultimate Capacity 2 7/8" piles - 80,000 lbs. (coupling bolt limitation)  
3 1/2" piles - 120,000 lbs.

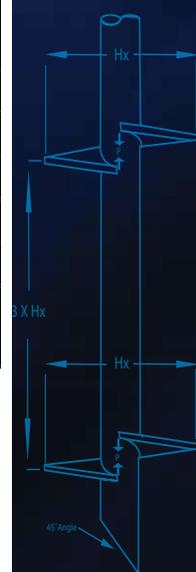
## Grade A36 Carbon Structural Steel

1. Pier Helicals: ASTM Grade A36/A36M

Product	Plates	Shapes	
Thickness, in.(mm)	To 3/4 (20), incl.	Over 3/4 to 1-1/2 (20 to 40), incl.	All
Carbon, max, %	0.25	0.25	0.26
Manganese, %	...	0.80 - 1.20	...
Phosphorus, max, %	0.04	0.04	0.04
Sulfur, max, %	0.05	0.05	0.05
Silicon, %	0.40 max	0.40 max	0.40 max
Copper, min, % when copper steel is specified	0.20	0.20	0.20

2. Mechanical Specifications: ASTM Grade A36/A36M

Plates, Shapes, and Bars:	
Tensile Strength, ksi (MPa)	58-80 (400-550)
Yield point, min, ksi (MPa)	36 (250)
Plates and Bars:	
Elongation in 8 in. (220 mm), min, %	20



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