HelicalAnchors,Inc.

Engineering Design Manual

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Definition of Terms

Resistance - A force developed in opposition to a load applied to a structural system.

Capacity – The maximum resistance a system can mobilize; usually used in relation to the ability of a soil/structure system to support load. Also known as ultimate resistance.

Strength – The maximum resistance a structural member or assembly can mobilize without regard to the ability of soil to support load.

Design Load – The specified load for which a structural system is to be designed. It is related to, but may not be the same as, the maximum load the system is expected to experience during its lifetime.

Allowable Load – The maximum load that may be applied to a structural system while still maintaining an appropriate margin of safety to handle overloads, material and construction variations, environmental factors and other unspecified but reasonably foreseeable detrimental conditions.

Margin of Safety (Factor of Safety) – Margin of Safety is the difference between the actual performance capability of a system and its design requirement. Factor of Safety is the ratio of actual performance capability to design requirement.

Loads – Forces or other actions that result from the weight of building materials, occupants and their possessions, environmental effects, differential movement and restrained dimensional changes.

Ultimate – Describes the maximum load that can be supported by a structural member or soil/structure system under specific conditions, or the deflection that corresponds with that load.

Yield – Describes a load, strength or deflection, at which a structure departs from elastic behavior.

HelicalAnchors,Inc.

Helical Anchors Design Manual

Section 1

Introduction

The earliest recorded uses of helical anchors were by an Irish engineer, Alexander Mitchell, who used them to support a lighthouse. Screw piles were not popular because the force of many men was required to produce the necessary torque. Through the years screw piles were improved, and increased, especially when torque motors became available. Screw piles have become ideal for many applications and their popularity has risen to the point where any trained contractor can install them quickly and easily these days. Screw piles, also known as helical anchors, are convenient for easy access on construction sites that are inaccessible by larger equipment.

Helical Anchors Inc. with its 30+ years of experience in the earth boring industry brings new solutions to the soil stabilization and foundation industry. Helical Anchors Inc, a family owned and operated company applies its state of the art technology and expertise to change the way the foundation industry installs foundation piles/anchors. Our superior choice of raw materials, “new” design and fabrication techniques make our anchors the anchors of the future.

Advantages

Helical anchors have presented many solutions for different types of projects. This section will summarize the advantages of their use.

- They produce small or no vibration during installation, decreasing possible damage to the structures from soil movement.
- They can be installed in any weather conditions and may be loaded immediately after installation; there is no cure time as with concrete foundations.
- Easy installation; there is no need for excavation and they can be installed in limited access areas.
- They are quick to install and there is no need of big equipment in comparison with other types of deep foundation construction.
- They can be installed in soft surface and high water table conditions.
- Prediction of capacity is found after installation from torque to capacity relationship, useful to verify theoretical capacity.
- Installation produces no spoils to remove or remediate.

Unique Features

Helical Anchors, Inc. has developed new ways of fabrication with superior raw materials that make our products the best in the market.

- Seamless tube shafts with high tensile strength give our products higher torsion strength than our competitors. This allows installation into stronger soil strata for higher load capacity. Helical Anchors, Inc. products have the highest torque ratings in the industry.
- Our telescoping connections are precision CNC machined for a stronger connection.
- The connections are inertia welded allowing a streamlined one piece design.
- High-strength helical bearing plates combine with the high-torsion-strength shafts to allow higher compression loads than our competitors.
- Quality galvanizing (hot-dipped process) for enhanced underground corrosion resistance.

Description

A helical anchor is a steel shaft with one or more helical plates welded around it. Helical anchors are considered deep foundations and may be used to support any type of load. In simple words, it is a screw with a discontinuous thread and a uniform pitch.

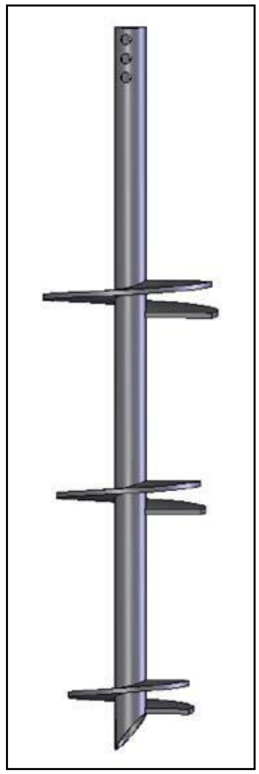


Figure 1: Lead Section

The central shaft is fabricated from seamless Grade 80 steel tubing, giving our products higher strength than our competition. Helical Anchors, Inc. offers a wide variety of shaft sizes for any kind of application. Shaft and helical bearing plate sizes available are shown in Appendix A. Shaft sections may be fabricated in various lengths ranging from 36” to 240” depending on job requirements. Couplings are inertia welded to the shaft ends to allow attachment of extensions for deeper penetration into the ground when needed.

Helical plates are fabricated with Grade 50 steel. They vary from 6” to 16” in diameter and have a thickness of 3/8” to 1” depending on job requirements. The number and sizes of helical plates may be varied to match soil conditions to the required anchor capacity. When multiple helix plates are provided on a single anchor they are positioned so that no plate is smaller than any preceding plate. The nominal pitch of each helix is three inches and to ensure that each of them develops full capacity, each succeeding plate is located above the preceding plate a distance equal to three times the diameter of the preceding plate.

The top of the helical anchor connects to the foundation or structure with different types of connectors depending on the application. These connectors allow the loads from the foundation to be transferred to the helical anchor and then to the soil at a deeper level.

Installation

A helical anchor is similar to a wood screw, one obvious difference being that the helical anchor has widely-spaced discontinuous threads. Helical anchors are screwed into the ground making sure they penetrate at a rate of about one pitch length (3 inches) per revolution. There are two ways helical anchors can be installed; one of them is using machine-mounted equipment and the other is hand-held. For an extensive detailed installation procedure, see the operations guide section of this manual.

Applications

The main purpose of a helical anchor is to transfer structural loads to soil. Nowadays, helical anchors are used for a variety of applications in tension, compression and lateral loads. Typical tension applications of helical anchors include guy anchors for poles and towers, tiebacks for temporary or permanent retaining walls and foundation tiedowns. They can also be used for underpinning to lift sinking foundations, deep foundation elements to support walkways and boardwalks, and tilt-up wall braces. Also, helical anchors have become a foundation of choice for lateral load applications including slope stabilization, poles, towers and fences.

Design Guide

Predicting Capacity

Capacity is defined herein as the maximum load a foundation /soil system can support. The bearing capacity of a helical anchor varies depending on many factors such as soil properties and conditions, anchor design characteristics, installation parameters, and load type (tension, compression, shear and/or overturning).

The equations used to predict capacity of helical anchors in tension and/or compression are based on the assumption that the anchors act as deep foundations. This requires that the bearing plates be embedded some minimum distance below the ground surface. However, after many years of study, researchers still haven't come to an agreement on just what the depth requirements are. Helical Anchors, Inc. recommends each helix be embedded at least three feet vertically and six times its own diameter measured along the shaft from the ground surface.

Though there are several theories for calculating the ultimate capacity of a helical anchor, Helical Anchors, Inc. products are designed to fit the assumptions of the two most common methods best. These are the individual bearing method, which assumes a bearing failure of the soil supporting each helix, and the torque correlation method which makes use of the empirically-derived relationship between installed capacity and the torsional resistance encountered during installation.

Individual Bearing Capacity

In the individual bearing method, capacity is determined by calculating the ultimate bearing resistance of the soil at each helix and multiplying it times the projected area of the helix. The total capacity of a multi-helix system is then the sum of the individual capacities.

The general equation used to calculate the bearing capacity of a single helix plate is the following:

Equation 1

$$Q_u = A_h(\mathrm{cNc} + \mathrm{q}'\mathrm{Nq} + 0.5\gamma' BN\gamma)$$

Where:
Q_u = Ultimate Capacity (lbs)
A_h = Projected Helical Plate Area (ft^2)
c = Soil Cohesion (lb/ft^2)
N_c = Bearing capacity factor for cohesion (dimensionless)
q' = Effective Overburden Pressure (lb/ft^2)
N_q =Bearing capacity factor for overburden (dimensionless)
γ' = Effective unit weight of the soil (lb/ft^3)
B = Footing width (ft)
N_γ = Bearing Capacity factor (dimensionless)

According to Bowles (1988) concerning Equation 1 (above); the base width term 0.5 γ'B N_γ can be neglected with little error where B < 3 to 4m. Since the width of a helical anchor will never exceed the limit mentioned above, the resulting equation for an individual helix then is the following:

Equation 2

$$Q_u = A_H\left(\mathrm{cN_c} + \mathrm{q'N_q}\right)$$

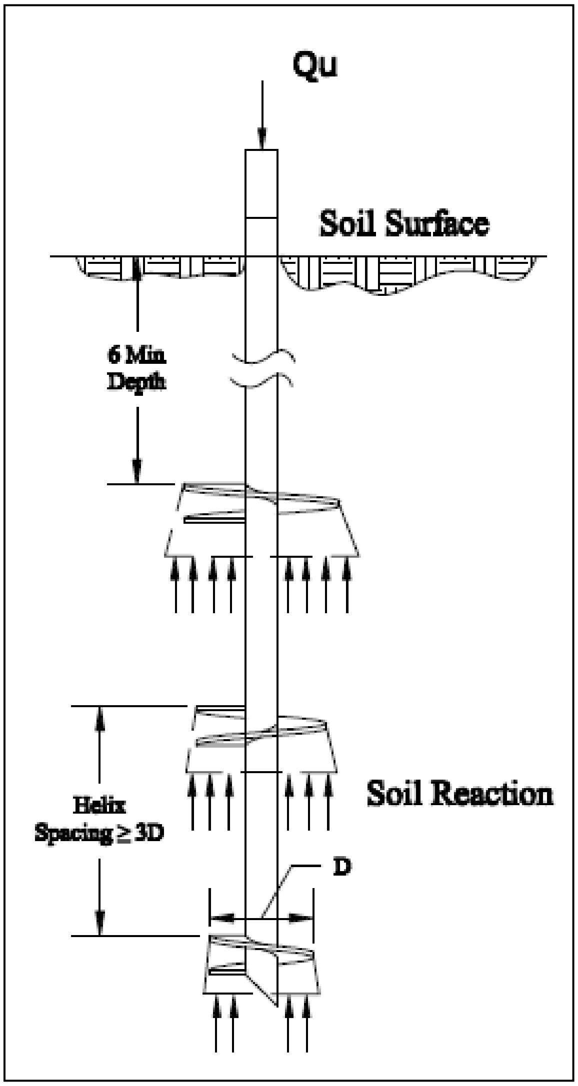


Figure 2: Bearing Capacity Resistance Diagram

When dealing with a multi-helix anchor, the same Equation 2 above is used with the difference that instead of being just one projected area, it will be all of the projected areas. Spacing between each helix for multi-helix anchors is of high importance since they need to be far enough apart so each helix plate can develop full capacity without overlapping. Helical Anchors Inc. has determined that helix plates must be spaced three times the diameter of the lower helix. (shown in Figure 2)

Friction along the shaft is commonly ignored when dealing with solid shafts because the small surface area per foot of length will create an insignificant resistance force to affect the total capacity. However, friction resistance might be taken into consideration for circular hollow shafts since they will have more surface area per foot of length developing greater resistance than solid shafts.

Commonly, soil is not homogeneous through the entire required depth of installation; a soil behavior analysis must be done in order to be able to calculate the theoretical ultimate capacity. The soil behavior varies quite a lot depending on the site conditions. Typically, soil can be simplified into non-cohesive and cohesive soil.

Non-Cohesive Soil

Cohesion is the term we use for shear strength that exists in the absence of compressive stress. In non-cohesive soils like sand and gravel, shear strength exists only in the presence of compressive stress. Due to the fact cohesion is zero (c =0) the ultimate capacity can be determined with the following equation where the first term of equation 2 is eliminated.

Equation 3

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

Effective overburden pressure, q', is the sum of the effective unit weights of the soil in overlying strata multiplied by the thicknesses of the strata.

Table 1: General Properties of Non-Cohesive Soil (ASCE 1996)

Soil Density Description	Relative Density "%"	SPT Blow Count "N"	Angle of Internal Friction Φ	Unit Weight (lb/ft^3) Moist "γ_m"	Unit Weight (lb/ft^3) Submerged "γ_{sub}"
Very Loose	0-15	0 – 4	< 28	< 100	< 60
Loose	16-35	5 – 10	28 – 30	95 - 125	55 – 65
Medium Dense	36-65	11 – 30	31 – 36	110 – 130	60 – 70
Dense	66-85	31 – 50	37 – 41	110 – 140	65 – 85
Very Dense	86-100	> 51	> 41	> 130	> 75

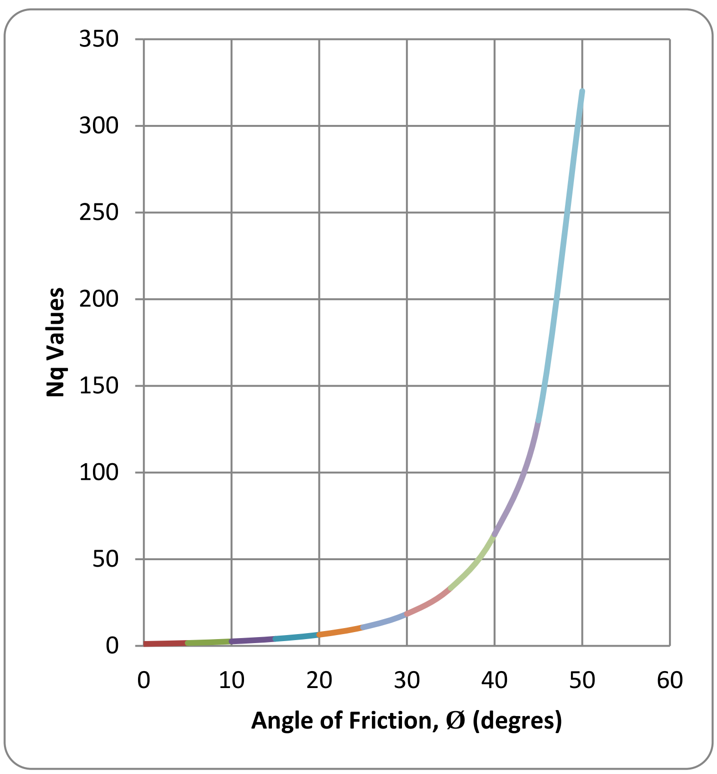


Figure 3: Bearing Capacity Factor, Nq

Note: When soil is below the ground water table, buoyancy forces reduce the contact forces between the soil particles reducing the overburden effect. The effective unit weight of soil below the ground water table is the saturated unit weight of the soil less the unit weight of water.

Bearing capacity factor Nq varies as a function of the soil's angle of internal friction which can be found in Table 1 above along with the soil density description. Helical Anchors Inc recommends the relationship given in Figure 3 for Nq values when using its helical anchors.

Cohesive Soil

Cohesive soil, such as clay, is composed of particles that adhere to each other even in the absence of compressive stress. When working with this type of soil under short-term loading the second term in equation 2 is eliminated because under such conditions the angle of internal friction, φ, of the soil is very small.

Table 2: General Properties of Cohesive Soil (after ASCE 1996)

Soil Consistency Description	SPT Blow Count "N"	Undrained Shear Strength "c" – lb/ft^2	Saturated Unit Weight (psf)
Very Soft	0 – 2	< 250	< 100 - 110
Soft	3 – 4	250 – 500	100 – 120
Firm	5 – 8	500 – 1,000	110 – 125
Stiff	9 – 16	1,000 – 2,000	115 – 130
Very Stiff	16 – 32	2,000 – 4,000	120 – 140
Hard	> 32	> 4,000	> 130

Helical Anchors, Inc. recommends a bearing capacity factor N_c of 9. The general equation is simplified to:

Equation 4

$$Q_u = \sum A_H (\mathrm{cN_c}) = \sum A_H (\mathrm{c} * 9)$$

Where: $\sum A_H$ = Sum of Projected helix area
c = cohesion value

Undrained Shear Strength, "c" or cohesion value is the maximum amount of shear stress that may be applied on the soil before the soil yields or fails. When dealing with cohesive soil as we can see in Table 2 above, the undrained shear strength increases proportionally with the consistency of the soil which makes the bearing capacity greater.

Projected helical plates areas

The projected area of an individual helix is the area of the helix plate less the cross sectional area of the shaft. As shown in Equation 4, the sum of the projected total areas is required to determine the capacity of a helical anchor. Table 3 below provides helical plate areas in square feet for the various shaft diameters.

Table 3: Projected Areas – ft^2

Shaft Diameter	Helical Plate Diameter				
	8" Dia.	**10" Dia.**	**12" Dia.**	**14" Dia.**	**16" Dia.**
2-3/8"	0.318	0.515	0.755	1.038	1.365
2-7/8"	0.304	0.500	0.740	1.024	1.351
3-1/2"	0.282	0.479	0.719	1.002	1.329
4-1/2"	0.239	0.435	0.675	0.959	1.286
5"	0.213	0.409	0.649	0.933	1.260
5-1/2"	----	0.380	0.620	0.904	1.231
6-5/8"	----	0.306	0.546	0.830	1.157
7"	----	----	0.518	0.802	1.129

Helical plates may be cut to a maximum of 90 degrees angle to improve penetration in rocky soils. Helical Anchors recommends an angle of approximate 60 degrees and no more than a maximum of 90 degrees angle due to welding limitations between plate and shaft. The projected areas will be reduced by approximate 20-25 % depending on the angle of cut. The reduction area of the helix must be taken into consideration when designing.

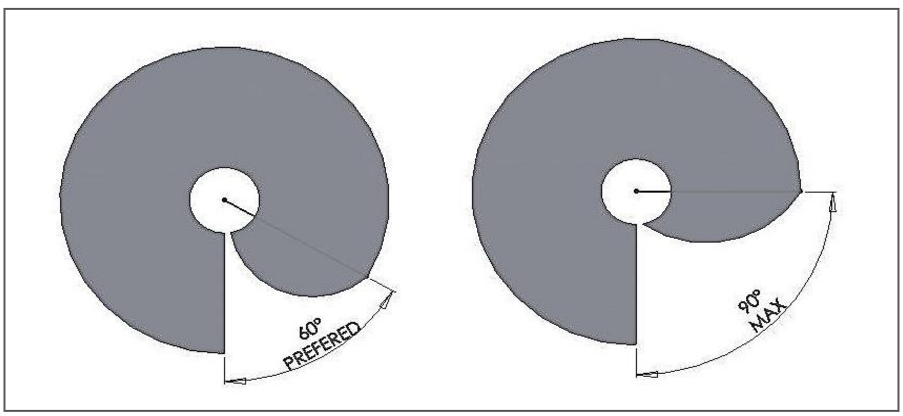


Figure 4: Alternative Helical Plates for Rocky Soils

One must also be aware of the ultimate capacities of each helix plate and plate/shaft weld when conducting a preliminary design. Most Helical Anchors helix plates have been tested at our facility and found to reach their ultimate strengths before any of the relevant serviceability limit states set forth in the International Codes Council Evaluation

Service's document AC 358 were reached. The ultimate strengths for the combinations of shaft diameter and plate size that have been tested are shown in Table A3 of Appendix A.

Torque vs. Capacity

The torque vs. anchor capacity method was developed many years ago when engineers noticed a relationship between torque applied during anchor installation and the installed anchor's load capacity. This method has been used for many years to verify the load capacity at installation. Using this method one multiples the effective torsional resistance encountered during installation of the helical anchor by an empirical factor Kt to determine the compression load limit or pullout resistance of the anchor. Torque vs. anchor capacity equation is shown below.

Equation 5

$$Q_u = K_t * T$$

Where: K_t = Empirical Torque Factor
T = Effective Torsional Resistance

Table 4: Torque Factor, K_t

Shaft Diameter	Empirical Factor, Kt
2-3/8"	9 - 10
2-7/8"	8 - 9
3-1/2"	7 - 8
4-1/2"	6 - 7
5"	6 - 7
5-1/2"	5 - 6
6-5/8"	4 - 5
7"	4 - 5

The empirical torque factor is related to friction during installation; therefore it is not a unique number. It ranges from 3 to 20 depending on shaft size and shape, soil properties, number of helix plates and their sizes. Unless the K_t factor value is provided from a load test, Helical Anchors Inc. recommends the empirical values given in Table 4. The empirical K_t values provided in Table 4 may vary depending on the soil conditions. Usually when dealing with loose or sensitive soil, the resulting values are lower than those shown in Table 4.

Note: Verify ultimate capacity by performing a field load test on any critical project.

Helical Anchors, Inc. utilizes an in-house torque machine to test representative samples of each anchor design for ultimate torsional strength. Table 5 below provides some of our product ratings obtained from these laboratory testing results. Table A1 in Appendix A provides a more extensive table of our product ratings and specifications.

Table 5: Helical Anchors, Inc. Shaft Ratings

Helical Anchors Product	Shaft Size (in)	Wall Thickness (in)	Ultimate Tension Strength (lbs)	Compression Index (lbs)	Ultimate Torsional Strength (ft-lb)
TS238190	2.375	0.190	125,000	100,000	6,500
TS238254	2.375	0.254	125,000	135,000	9,000
TS278217	2.875	0.217	180,000	140,000	13,000
TS278276	2.875	0.276	180,000	180,000	16,000
TS312254	3.500	0.254	250,000	210,000	18,000
TS312368	3.500	0.368	250,000	290,000	27,000
TS412250	4.500	0.250	275,000	260,000	30,000
TS412337	4.500	0.337	360,000	350,000	48,000

Note: The capacities listed in Table 5 for tension and compression are mechanical ratings.

Spacing, "X"

The equation shown below may be used to determine the spacing required from center to center of helical anchors used to support strip footings.

Equation 6

$$X = \frac{Q_u}{P * FS}$$

Where: Q_u = Ultimate Capacity of anchors
P = Distributed Load on footing
FS = Factor of Safety

Once the spacing is known, the number of helical anchors needed is found by dividing the total length of wall by the required spacing.

Ultimate Skin Resistance

There are three main methods for determining the ultimate skin resistance, known as the α, the β and the λ methods. All three methods utilize the same basic equation, the difference being in how the unit resistance (f_s) is calculated.

Equation 7

$$Qs = \Sigma Asfs$$

Where: Q_s = ultimate skin resistance (lb)
A_s = effective pile surface area over which f_s can be considered constant (ft^2)
f_s = unit skin resistance (psf)

The effective surface area, A_s, is just the circumference times the length in which f_s will be considered constant.

α Method

The α method uses a modification of the Mohr-Coulomb failure criterion to compute f_s as

Equation 8

$$f_s = \alpha c + qv' Ks Tan\delta$$

Where: α = cohesion factor
c = average cohesion for ΔL of interest
qv' = average effective vertical stress for ΔL of interest
Ks = average coefficient of lateral earth pressure for ΔL of interest
δ = average effective friction angle for ΔL of interest

λ Method

An alternative method for obtaining skin resistance was introduced by Vijayvergiya and Focht (1972).

Equation 9

$$f_s = \lambda(qv' + 2s_u)$$

Where: qv' = average effective vertical stress for ΔL of interest
s_u = undrained shear strength for ΔL of interest
λ = coefficient

β Method

A better correlation of load test and pile capacity using effective stress parameters was proposed by organizations which have reanalyzed existing data and supplemented with additional recent tests.

Equation 10

$$f_s = qv'KsTan\delta$$

$$f_s = \beta qv'$$

Where: qv' = average effective vertical stress for ΔL of interest
Ks = average coefficient of lateral earth pressure for ΔL of interest
δ = average effective friction angle for ΔL of interest
β = KsTanδ

Helical Tie Back Anchor Considerations

Tiebacks are designed to provide support against lateral forces created by soil. One of the most common applications for tiebacks is retaining walls, either temporary walls or permanent.

Note: Proper soil analysis must be done before installation. If conditions are unknown water pressure must be assumed to be present.

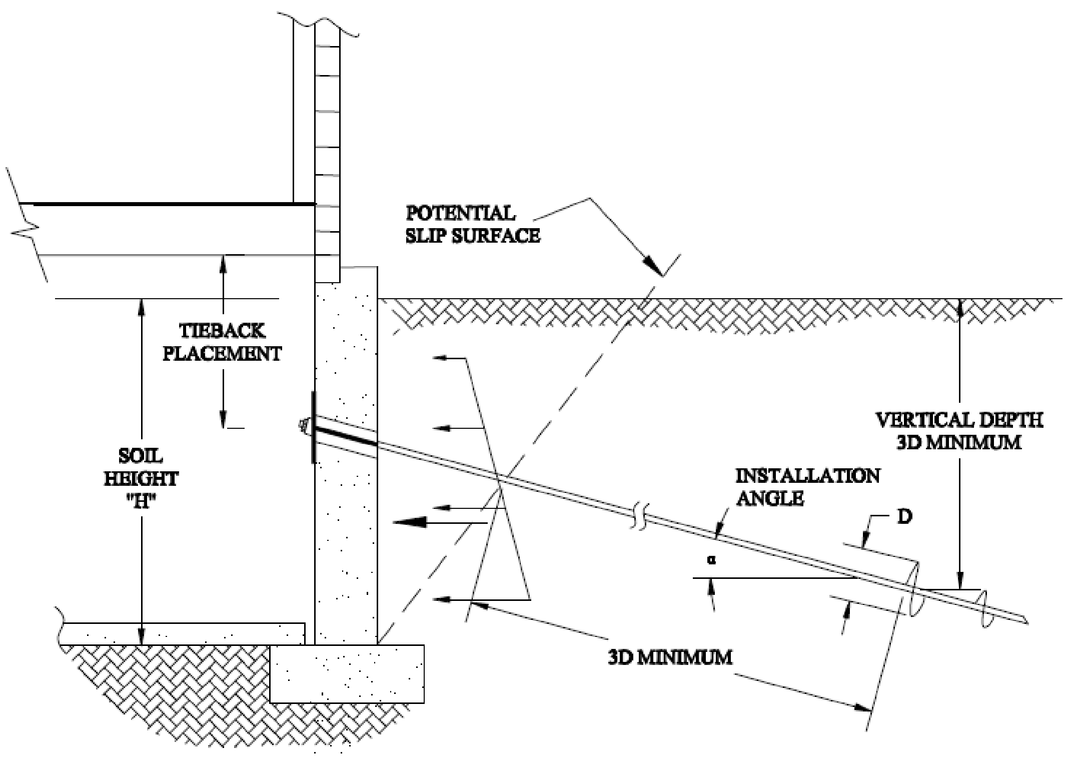


Figure 5: Tieback Application

The ultimate capacity is calculated by using the same general equation for bearing capacity shown above (Equation 2) taking into consideration the following requirements.

Tieback vertical placement depends on the soil height against the wall. Helical Anchors Inc. recommends tiebacks be installed close to any horizontal crack in the wall. In case more than one tier of tiebacks is needed, typically the location of the first tier is located at 20 to 50 percent of the distance from the surface to the bottom of the footing for walls up to 15 feet high.

Minimum vertical and axial embedment are required to avoid shallow failure mechanism. The minimum vertical embedment, as illustrated in Figure 4 varies depending on the diameter of the helix. Helical Anchors Inc. recommends a vertical embedment at least three times the largest helix diameter.

The axial embedment requirement will vary from project to project. Helical Anchors Inc. recommends a minimum axial embedment that places the last helix plate at least three times its own diameter beyond the potential slip surface as illustrated in Figure 4. The installation angle varies usually from 5° to 30° measured from the horizontal, but the typical value used in most cases is about 15°.

Design Example 1 – Cohesive Soil

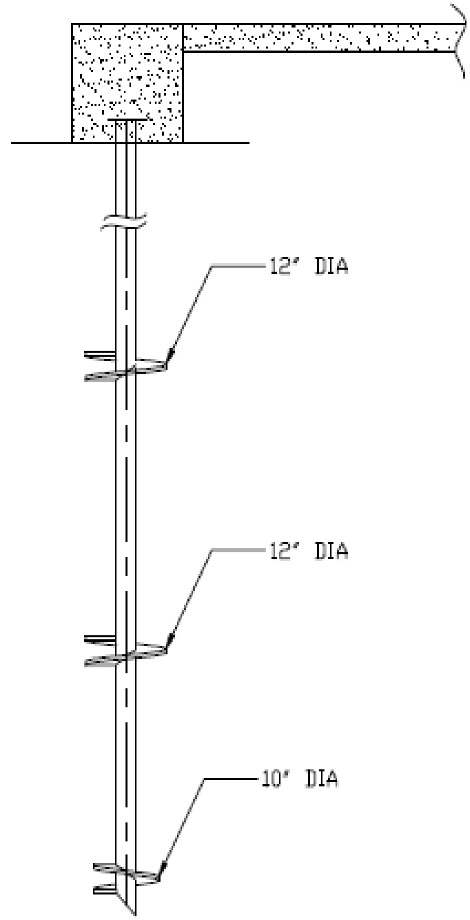


Figure 6: Sketch for example 1

Data

- New Building – Four Story Residence
- Concrete slab on grade
- Footing load - 5,500 lbs/ft
- 6 feet of poorly compacted fill, N = 5
  20 feet of stiff clay, N = 25-35,
  c = 4000 lb/ft^2

Design

1. Estimate the Ultimate Capacity required for the anchor.

Estimated pile spacing (x) = 6ft
A minimum factor of safety (FS) = 2.0

Estimating Required Capacity:

$$Q_u = X * P * FS$$
$$Q_u = 6ft * 5{,}500lb/ft * 2 = 66{,}000lb$$

2. Select the adequate equation for ultimate bearing capacity.

When the soil on site is classified as cohesive,
Equation 4 is use to determine the required projected area of helices.

$$\Sigma A_H = \frac{Q_U}{9c} = \frac{66{,}000lb}{9 * 4{,}000lb/ft^2} = 1.83ft^2$$

3. Select an appropriate helical anchor size to support the required load

From Table 5, a 2-3/8 (0.254 wall) tubular shaft is selected due to its compressive strength of 135,000 lbs.

Once the shaft has been determined, we need to select an appropriate combination of helices to meet the minimum required projected area. From Table 3 a combination of 10", 12"and 12" plate diameters on 2-3/8 is selected giving us a total helix projected area of 2.025 ft2 which is more than enough to support the required load.

$$\sum A_H = 0.515 + 0.755 + 0.755 = 2.025 \text{ ft2}$$

4. Required Effective Torsional Resistance

Using Equation 5 and Table 4 for Kt factor, the required effective torsional resistance is calculated to be:

$$T = \frac{Q_u}{K_t} = \frac{66{,}000lb}{10ft^{-1}} = 6{,}600ft - lb$$

5. Verify the selected helical anchor capacities exceed the requirements.

The ultimate capacity required was calculated to be 66,000 lbs with a required effective torsional resistance of 6,600 ft-lb. Reviewing Table 5, the 2-3/8 (.254 wall) helical has a torsional strength of 9,000 ft-lb with a mechanical compression rating of 135,000 lbs which will be more than adequate for this project. The area chosen for the helices was greater than the minimum required which could allow us to achieve even higher capacity. The following calculation shows the ultimate capacity the anchors can achieve based on the chosen area, if confirmed by a higher effective torsional resistance in the field.

$$Q_u = 9 * 4{,}000\frac{lb}{ft^2} * 2.025\ ft^2 = 72{,}900\ l\ ,$$

6. Minimum Tip Embedment

The length of the helical anchor is approximated by the minimum tip embedment. In this case, the minimum tip embedment will be approximately 16 feet, due to the poor soil at the surface and recalling that the helical plates are spaced three times the diameter of the lower plate.

The total helical anchor length will be determined when all installation requirements have been met. For this project it has been estimated at approximately 20 feet.

Design Example 2 – Non-cohesive Soil

Data

- New Building –Two story building
- Estimated weight 9,200 lb/ft
- Working Load 55,000 lbs
- 5 feet of sandy clay fill, stiff. γ_m = 110 pcf
- 25 feet of medium grained, well graded sand, medium dense γ_m = 125 pcf, N = 25, Ø = 34, Water table 15 ft

Design

1. Estimate the Ultimate Capacity required for the anchor.

A minimum factor of safety (FS) = 2.0

Estimating Required Capacity:

2. Select the adequate equation for ultimate bearing capacity.

When the soil on site is classified as non-cohesive, Equation 3 will be used to determine the required projected area of helices.

Choose a target depth, say h = 25 ft

N_q = 30 (from Figure 3 at Ø = 34)

3. Select an appropriate helical anchor size to support the required load

From Table 5, a 2-7/8 (0.276 wall) tubular shaft is selected due to its compressive strength of 180,000 lbs.

Once the shaft has been determined, an appropriate combination of helices is selected to meet minimum required projected area. From Table 3 a combination of 8”, 10”, and 12” plate diameters on a 2-7/8 is selected giving us a total helix projected area of 1.544 ft^2 which is more than enough to support the required load.

$$\sum A_H = 0.304 + 0.500 + 0.740 = 1.544\, ft^2$$

4. Required Effective Torsional Resistance

Using Equation 5 and Table 4 for Kt factor, the required effective torsional resistance is calculated to be:

$$T = \frac{Q_u}{K_t} = \frac{110{,}000 lb}{9 ft^{-1}} = 12{,}200 ft - lb$$

5. Verify the selected helical anchor capacities exceed the requirements.

The ultimate capacity required was calculated to be 110,000 lbs with an installation torque of 12,200 ft-lb. Reviewing Table 5, the 2-7/8 (.276 wall) helical selected has torsional strength of 16,000 ft-lb with a mechanical compression rating of 180,000 lbs which will be more than adequate for this project. The area chosen for the helices was greater than the minimum required which could allow us to achieve even higher capacity. The following calculation shows the ultimate capacity the anchors can achieve based on the chosen area, if confirmed by a higher effective torsional resistance in the field.

$$Q_u = 2{,}450 \frac{lb}{ft^2} * 30 * 1.544\, ft^2 = 113{,}484\, lb$$

6. Minimum Tip Embedment

The length of the helical anchor is approximated by the minimum tip embedment. In this case, the minimum tip embedment will be approximate 14 feet, due to the poor soil in the surface and recalling that the helical plates are spaced three times the diameter of the lower plate.

The total helical anchor length will be determined when all installation requirements have been met. For this project it has been estimated at approximately 28 feet.

HelicalAnchors,Inc.

Helical Anchors Operational Guide

Section 2

Warning! Before proceeding with installation, a careful examination of site conditions must be done, looking for possible existence and location of underground utilities. The stability of soil must be known as well as the integrity of the structure to carry the load between placements of piers.

Procedure

Note: When dealing with helical tiebacks, preparation must be done before installation. An area must be excavated to be able to reach the installation placement point. If anchors must be installed through a wall, a hole must be created to a size not smaller than the largest helix diameter.

The tip of the helical anchor lead section is located as shown on the drawings. The other end is connected to a hydraulic motor that must be attached to an appropriate machine for the job. These two operations may be done in reverse order at the operator's option. If a dangling-head digger motor is used, it usually is a little bit easier to attach the anchor to the digger first. The machine must be capable of providing sufficient downward pressure to advance the anchor uniformly at a rate of about 3 inches per revolution, and enough torque to reach the required effective torsional resistance termination criterion. The anchor should be driven into the soil in a smooth and continuous manner at a rate of rotation of 5 to 20 rpm. Once the lead section is installed, extensions may be attached if necessary to reach the minimum embedment length and effective torsional resistance termination criteria (both the minimum embedment length and the minimum effective torsional resistance criteria must be reached before the anchor can be terminated). Secure the extensions at the coupling with the bolts, pins or other devices provided with the anchor before continuing to drive the anchor. Again, the new section may be attached to either the digger motor or the already-installed anchor section first, at the operator's option.

If there is a maximum embedment length specified and the minimum effective torsional resistance is not met before the maximum embedment length is reached, some sort of remediation is required. On many projects, the specifications will include one or more pre-qualified remedies for this and other situations where the design termination criteria cannot be met. The contractor should at least be aware of any such pre-qualified remedies contained in the specifications, or if none are specified in the bidding documents he is encouraged to request them.

Length

As noted above, both the minimum embedment length and the minimum effective torsional resistance criteria must be satisfied before the installation can be terminated. It is permissible to continue the installation after both criteria have been met to bring the end of the last extension into compliance with the specified reveal, provided that the specified maximum embedment length, if any, is not exceeded and that the minimum effective torsional resistance criterion is still met when installation is terminated. Many contractors choose to simply stop the installation as soon as both termination criteria are met and cut the shaft off to meet the specified end reveal.

Connection to the Structure

Once anchor installation is complete, a proper adapter for the structure must be installed on the anchor. When dealing with uplift loading, the adapter must be securely attached to the helical anchor. The anchor installing contractor should make sure the connection to the structure is also secure, or if the connection is to be made after the contractor finishes his part of the job he should at least check to be sure that everything is in place so that a proper connection can be made at a later date.

Load Testing

Testing might be required by the owner/engineer in order to verify the capacity of the proposed or production helical anchors. The installing contractor is cautioned to be absolutely sure 1) the acceptance criteria for the test are documented in writing, 2) he/she understands the acceptance criteria and finds them reasonable, and 3) the responsibility for remediating any anchors that fail the test is documented in writing and understood by the contractor. Here again, specifying pre-qualified remedies for anchors that fail to meet the acceptance criteria can be very helpful in minimizing delays and cost over-runs due to non-conforming anchors.

Torsional Resistance

The torsional resistance experienced by the helical anchor during installation must be recorded in 1-foot intervals at least during the time that the effective torsional resistance is established (i.e., during the final length of embedment equal to three times the diameter of the largest helix). Helical Anchors, Inc. strongly recommends that the torsional resistance be recorded in no larger than 5-foot intervals throughout the installation. Torsional resistance can be monitored with a stand-alone torque sensor and readout mounted between the anchor drive tool and the drive head output shaft adapter. Another commonly used method is to monitor the pressure drop ("differential pressure") across a hydraulic motor used to install the anchor. Drive head manufacturers typically provide output torque vs. differential pressure calibration data for their products.

Copies of torsional resistance and field test reports should be given to the owner.

Clean up

The contractor should keep his portion of the construction site as clean and organized as possible. Particularly with occupied residential sites, the contractor should store excavation spoils on tarps and minimize collateral damage to the lawn, shrubs, trees and other landscaping items as much as possible. Restore any disturbed soil around the work area to the original dimensions or as specified by the engineer/owner. Dispose all construction waste in a safe and legal manner.

HelicalAnchors,Inc.

Push Piers
Design Manual

Section 3

Introduction

Pile systems have been improving through the years. Though many new methods and materials have been tested in history, modern construction has governed the repair and remediation techniques. The development of new technology has opened new opportunities for deep foundation systems. Though the most common application for push piers is structure restoration to its original position using an underpinning system, new applications and modifications are continually expanding and growing to meet the needs of the deep foundation industry.

Helical Anchors Inc. with its many years of experience in the drill pipe industry has developed a new product using superior raw material making our product stronger than any other competitor's. Helical Anchors' Push Pier does not depend on skin friction to provide support; a friction reduction collar on the lead section reduces the skin friction during installation. Each pier is field tested during installation making sure to exceed the minimum factor of safety proposed.

Push Pier Advantages

The advantages of push piers are very similar to those mentioned above for helical anchors.

- Each pier is load tested to verify capacity during installation.
- They produce small or no vibration decreasing possible damages to the structures from soil movement.
- They can be installed in any weather conditions and there is no need to wait for loading after installation; there is no cure time as with concrete foundations.
- Easy installation, no need for excavation and they can be installed in limited access areas.
- They are quick to install and there is no need of big equipment in comparison with other types of deep foundations construction.
- They can be installed in soft surface and high water table conditions.
- Installation produces no spoils to remove or remediate.

Description

Helical Anchors' Push Piers are tubular shafts made of seamless Grade 80 steel tubing. Each pier is pushed into the soil until it reaches a solid bearing stratum. The lead sections are fabricated in lengths of 41½” with couplings at the end so that extensions may be added for deeper penetration to support loads where the soil is denser or harder. Helical

Anchors Inc. offers a wide range of shaft sizes that accommodates any kind of application.

The push pier includes a friction reduction collar at the end of the lead section which reduces skin friction developed when the pier is driven into the soil. The pier does not depend at all on the skin friction for support. The installation process is in fact a field loading test, allowing the pier capacity to be monitored continually. The installer is thus able to ensure the required factor of safety is met or exceeded on every pier without costly additional testing.

Figure 7: Pier Lead

The push pier final section is attached to an adaptor that connects to the foundation or structure. These connectors allow the loads from the foundations to be transferred to the pier and then to the soil at a deeper level.

Installation

After proper examination of the site conditions and selection of the push pier size, a small excavation is made for access to the foundation bottom. The bracket attachment is secured to the footing along with the drive stand. Once, the push pier section is placed and plumb in the proper location, the hydraulic jacking system will push the pier into the soil. Extensions may be needed to reach an appropriate bearing stratum. The installation continues until the resistance to further embedment shows that the pier capacity is sufficient to provide the required factor of safety. For an extensive detail installation procedure, look at the operations guide section of this manual.

Figure 8: Pier Extension

Applications

Helical Anchors' Push Piers are commonly used to underpin foundations of existing structures. This may be to stabilize or remediate settled foundations or to prevent settlement of an existing structure when additional loading or adjacent excavation is anticipated.

Push piers transfer load from the surface foundation to a deeper competent soil stratum. The installation can be in interior or exterior locations and requires only minimal excavation and operating space. Push piers are connected to foundations through adapters that either extend under the footing or are connected to a vertical face of the footing or the supported structure. Push piers are not only used to stop settlement, but also to lift the entire structure.

Design Guide

Predicting Capacity

A theoretical solution for capacity is not fully developed at this point, but researchers are in the process of developing it. Helical Anchors Inc. uses the maximum installation force as an indication of ultimate capacity. It is of high importance to analyze the structural loads the pier will support so the installation force exceeds the total required load.

The structural loads are mainly dead load (D_L), live load (L_1L), snow load (S_1L), and wind load (W_1L). The required load, P, a helical anchor would support is the sum of all loads.

Equation 11

$$P = D_L + L_1L + S_1L + W_1L$$

The number of piers needed depends on the capacity of the pier and the total load to be supported. Table 6 below provides mechanical strength values to use in order to determine the maximum spacing possible to be able to support the total load required. The following equation is for maximum spacing:

Equation 12

$$X_{max} = \frac{R_{ult}}{FS * P}$$

Where:
X = maximum spacing between piers
R_{ult} = Design resisting load which can be found in Table 6
FS = Factor of safety (Helical Anchor Inc. recommends at least 2)
P = total required load

***Note.** The factor of safety will be determined by the project engineer; helical anchors Inc. will provided a pier that exceeds the required factor.

Table 6: Push Pier Product Ratings			
Helical Anchors Push Piers	**Shaft Size (in)**	**Wall Thickness (in)**	**Ultimate Mechanical Compressive Strength (lbs)**
PP278217	2.875 OD	0.217	140,000
PP278276	2.875 OD	0.276	180,000
PP312254	3.50 OD	0.254	205,000
PP412262	4.50 OD	0.262	275,000
PP412271	4.50 OD	0.271	285,000

Once the spacing is found, the number of piers depends on the length of footing or wall. Helical Anchors Inc. recommends the piers to be embedded in soils where N values range from 35 to 40 or higher for non-cohesive soils and from 40 to 50 for cohesive soils.

HelicalAnchors,Inc.

Push Pier Operational Guide

Section 4

Note: Before proceeding with the installation a careful examination of the site conditions must be done. Underground utilities must be located and the stability of soil must be known as well as the integrity of the structure to carry the load between placements of piers.

Foundation Exposure

An area is excavated adjacent to the foundation exposing the footing, stem wall, or bottom of the grade beam. The excavated area must be big enough to provide safe working conditions, typically about three feet wide and at least 15" beneath the proposed elevation of the pier bracket base. The footing surfaces where the bracket will be installed must be smoothed out using a chipping hammer until firm bearing surfaces are provided, free of dirt and loose concrete. When the footing extends outside the footprint of the supported wall or other structural element, it must be notched sufficiently to allow the bracket to mount within the "zone of influence" of the load. For concrete, this zone of influence is often taken as the zone encompassed by surfaces projected downward and outward at 45 degrees from the perimeter of the loaded area at the top of the footing to its bottom surface. If the footing supports a wall, Helical Anchors Inc recommends the footing be notched back all the way to the wall where possible. If any reinforcing steel is encountered, approval from the engineer is required before cutting them. Verify the smoothed surfaces are plumb or level as appropriate where the bracket will be positioned.

Bracket Installation
Under-footing 2-piece Pier Bracket

The pier bracket is connected temporarily to a drive stand or other suitable assembly that can support it during mounting to the concrete footing. The pier bracket is positioned underneath the foundation footing with its bearing plate under the bottom of the concrete footing. A hydraulic ram is then used to bring the bracket plate into bearing with the footing. A careful inspection should be made, making sure the face plates have continuous bearing across the entire piece. If the pier bracket does not fit properly pressure bearing grout must be applied to fill gaps. The pier bracket is then bolted to the footing with 1/2" diameter x 5-1/2" long anchor bolts to secure it in position. Vertical alignment should be verified to ensure the drive stand assembly frame is plumb prior to driving each pier section.

2-Piece Plate Pier Bracket

If the footing extends too far beyond the bracket mounting surface, it will have to be notched or cored through for the pier to pass through. Align the bracket centerline directly with the hole through the footing and carefully mark the locations of the anchor bolts on the mounting face of the structure. When a spread footing is not present a bolt template is used to locate and mark the anchor bolts where designed. Drill the mounting holes and insert the 3/4” diameter x 7-1/2” long anchor bolts where marked. These bolts go in the top four holes and should have a minimum embedment of 4-3/4”. The longer 3/4” diameter x 10” long bolts are placed in the four lower holes. The pier bracket is positioned and fastened with the washers and nuts provided with the anchor bolts. Carefully check for continuous bearing along the bracket plates and if necessary apply pressure grout where needed. Vertical alignment is inspected to ensure the pier bracket will be plumb.

Driving Pier Sections

Position the lead section into the drive stand with the friction reduction collar facing downward and drive it into the soil using the hydraulic drive cylinder assembly. Put together the next section at the top of the pier section and continue driving additional pier sections until the minimum required length and push pressure are reached. Record the resistance encountered during driving of each pier section. This is typically done just before shutting off the valve to add another pier section. The resistance encountered at the end of driving the final pier section is the ultimate plunging capacity of the pier.

Note: Ensure pier bracket is secured during installation of each pier section.

Cutting Final Pier Section

The final section installed may need to be cut to proper length. The length to be cut varies depending on the required lift. Cut the section so that after the lift is complete the top of the pier cap will be about 1/4" below the bottom of the lockoff pins. Cut the final section to length carefully ensuring a 90° angle with the pipe axis. If the pier settles during the lift the top of the pier cap will end up more than 1/4" below the bottom of the lockoff pins. Shims are used to fill the gap up to a maximum of 1" total accumulated shim height. Otherwise a new, longer final pier section must be cut so that the total shim height is held to 1" or less.

Transferring Loads to Piers

The pier cap is installed on top of the last pier section. The structural loads are transferred to each pier by using a 25-50 ton hydraulic ram between each pier cap and a lift head mounted to the bracket using the same holes that were used for the drive stand. Several rams are actuated simultaneously through the use of hydraulic manifold(s) to raise the structure to the desired elevation. The process should be carefully monitored to insure the structure is lifted properly and no footing cracks or movement in any direction occur. The flow to each ram is turned off when the desired elevation is reached at that location and the shut-off pressure is recorded. When all piers have been shut off at their proper elevations they are locked off mechanically using the lock-off pins and shims provided with the brackets. The hydraulic lifting jacks can then be de-pressurized and removed along with the lifting heads and their associated mounting pins. First reduce the overall system pressure to below the lowest individual pier shut-off pressure using the valve at the pump. Re-close the pump valve and begin de-pressurizing the individual piers, beginning with those that were shut off at the lowest pressure and proceeding in order of increasing shut-off pressure. Remove each jack after it is depressurized. Each time a pier valve is opened the pressure in the remaining system will increase. If the lowest-to-highest shut-off pressure sequence is followed, the system pressure should always be lower than the next shut-off pressure. If for any reason the lowest-to-highest shut-off pressure sequence is not followed, be sure to adjust system pressure with the pump valve as necessary to ensure the system pressure is lower than the shut-off pressure before opening any individual pier valve.

Note: Do not use any damaged or leaking hoses or hydraulic equipment. After completion of lift restoration, grout must be applied to the voids created between the foundation and underlying soil.

Clean Up

After all piers are mechanically locked off and the lifting heads and hydraulic lifting system are removed, backfill the excavations with the excavated soil. Place the soil in 6 to 8 inch thick layers and thoroughly tamp each layer to obtain maximum density before adding the next layer. Ensure the surface all along the foundation is sloped downward away from the structure for at least 10 feet measured perpendicular to the foundation. The drop must always be at least 2.4 inches vertical over the first ten feet horizontal and typically should be at least 6 inches over that distance. If this grading cannot be accomplished, or would cause drainage across property lines in excess of that which existed before the grading, an approved alternate method of diverting water away from the foundation must be provided. Dispose of all construction waste in a safe and legal manner.

HelicalAnchors,Inc.

Corrosion Overview

Section 5

Introduction

Corrosion of steel is defined as an electrochemical process in which a metal deteriorates due to its reaction with its surroundings. Given that helical anchors and push piers will be underground, corrosion must be considered in design of foundations and foundation repairs using them since it will affect the useful life of the structure. Corrosion will deteriorate the material and with time the material loss can result in significant reduction of areas causing structural capacity to decrease. Eventually if corrosion is not stopped, the capacity will be insufficient to support the applied load producing failure of the structure.

Underground steel corrosion will mostly depend on the conditions of the soil. The corrosion rate may vary from negligible effects to fast material loss. Many variables influence the corrosion rate, but the four most often considered in estimating rate are soil resistivity, pH, chloride content and sulfide/sulfate content.

Soil Resistivity

Soil resistivity has a great influence on corrosion rate. Resistivity itself depends quite a lot on moisture content. The higher the water content in soil, the lower the resistivity and the more potential of corrosion there is, but only until the saturation point is reached. After soil has reached the saturation point, more water has little effect on corrosion. Soils such as clay that tend to retain water have low resistivity which makes the soil highly corrosive. In general, high soil resistivity is unlikely to allow much corrosion, and low resistivity has more potential of corrosion. Table 7 provides common soil types and their corrosion potential. Measuring soil resistivity in the field consists of just sending a current though pins and measuring the voltage drop across the soil, then the soil resistivity is calculated with Ohm's Law.

Table 7: Soil Resistivity and Corrosion rate

<table>
<tr><th>Resistance Classification</th><th>Soil Resistivity</th><th>Soil Type</th><th>Resistivity Range(ohm/cm)</th><th>Corrosion Potential</th></tr>
<tr><td rowspan="2">Low</td><td rowspan="2">0 - 2000</td><td>clay</td><td>500 - 2000</td><td rowspan="2">Severe</td></tr>
<tr><td>silt</td><td>1000 - 2000</td></tr>
<tr><td rowspan="2">Medium</td><td rowspan="2">2000 - 10,000</td><td>Loams</td><td>3000 - 10,000</td><td rowspan="2">Moderate</td></tr>
<tr><td>Fine Silts & Organic</td><td>2000 - 10,000</td></tr>
<tr><td>High</td><td>10,000 - 30,000</td><td>Sand</td><td>10,000 - 30,000</td><td>Mild</td></tr>
<tr><td rowspan="2">Very High</td><td rowspan="2">above 30,000</td><td>Sand</td><td>30,000 - 100,000</td><td rowspan="2">Unlikely</td></tr>
<tr><td>Gravel</td><td>40,000 - 200,000</td></tr>
</table>

Soil pH

The term "pH" is a measurement of acidity or alkalinity with values ranging from 0 to 14. A pH value of 7 represents neutrality; lower values are termed acidic and higher values are alkaline. Soil pH has a relationship with Iron and Zinc which is used to determine the potential corrosion loss for metals. Figure 9 shows corrosion loss rate for both Iron and Zinc as a function of pH.

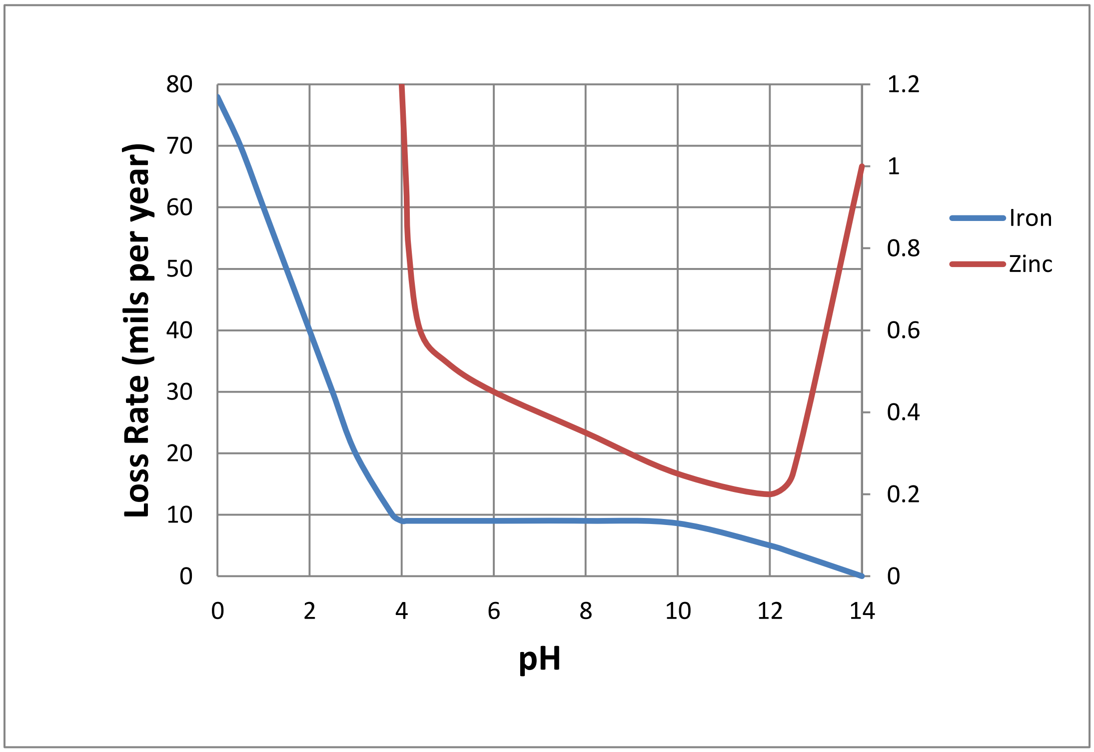


Figure 9: Effect of pH on Corrosion of Iron and Zinc

The figure shows the loss rate for Iron decreases rapidly when pH increases from 0 to 4, remains constant between values of 4 to 10, and then decreases slowly between pH of 10 and 14. Thus steel corrodes faster in acidic soils than alkaline ones.

Zinc Galvanization

It has been demonstrated that zinc used for galvanization is an effective protection to steel. Zinc coating not only provides a protective layer against the environment, but if the Zinc coating is scratched and steel surface is exposed, the zinc will protect the steel by corroding first. As illustrated in Figure 9, zinc loss is least in the range for pH between 5 and 12.5, but out of those boundaries corrosion loss rates increase dramatically.

Helical Anchors Inc. offers hot dip galvanizing on all its products, meeting all the procedure requirement of ASTM A123 Grade 100. The minimum coating according to ASTM A123 is 3.9mils or 2.3 oz/ft2 of zinc. Helical Anchors Inc. uses zinc thickness ranges from 4 to 6 mils.

HelicalAnchors,Inc.

Appendix A

Products Strength Rating

Helical Anchor Technical Data

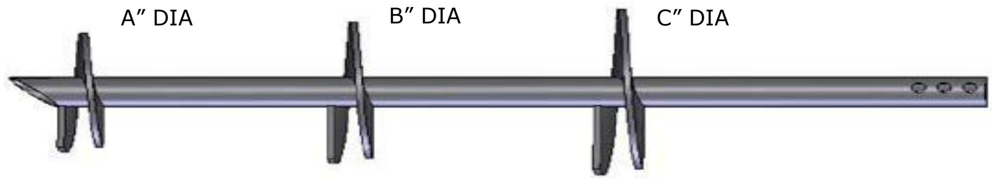
As mentioned before a helical anchor is considered as deep foundation that consists of a central shaft with bearing plates welded around it like a screw with discontinuous threads. Helical anchors may not be suitable in locations where surface material may damage the shaft or the helices such as soil containing cobbles, boulders, and large amount of gravel.

Product Specification

Each product has a unique part number which is specified with a prefix that defines the product category. After the prefix a number will follow representing the shaft size, wall thickness, and length of the shaft respectively. Once the shaft is defined, a number will follow for plate thickness and diameter of helix plate respectively if any.

Helical Anchors offers a wide variety of products including round corner square and tubular shaft. Most of them are shown in the following tables of this section. Helical Anchor is committed to testing and improving all our finished products to provide the best quality for the customer. Our unique facility is complemented with shaft torsion and helix flexure test machines that allow us to test all our products. Testing is still in process for some of our larger diameter shafts, otherwise results are shown in tables below.

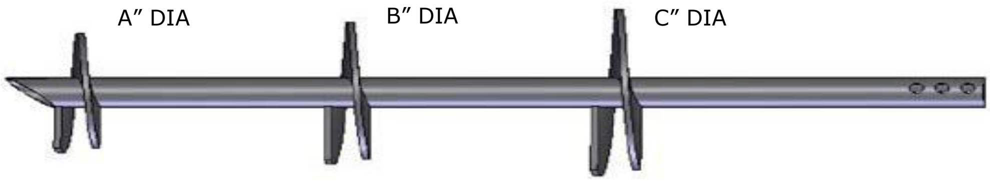
Helical Anchor, 2-3/8 (.254 wall) Tubular Leads



Product Description	Plate Diameter			Length	Weight	Part Number
	A	B	C			
2 3/8" X 5' (3/8" X 8")	8	---	---		35	TL23825460388
2 3/8" X 5' (3/8" X 10")	10	---	---		38	TL238254603810
2 3/8" X 5' (3/8" X 12")	12	---	---		42	TL238254603812
2 3/8" X 5' (3/8" X 14")	14	---	---	5'	46	TL238254603814
2 3/8" X 5' (3/8" X 8" & 10")	8	10	---		43	TL2382546038810
2 3/8" X 5' (3/8" X 10" & 12")	10	12	---		50	TL23825460381012
2 3/8" X 5' (3/8" X 12" & 14")	12	14	---		58	TL23825460381214
2 3/8" x 7' (3/8" X 8")	8	---	---		47	TL23825484388
2 3/8" x 7' (3/8" X 10")	10	---	---		50	TL238254843810
2 3/8" x 7' (3/8" X 12")	12	---	---		53	TL238254843812
2 3/8" x 7' (3/8" X 14")	14	---	---		58	TL238254843814
2 3/8" x 7' (3/8" X 8" & 10")	8	10	---	7'	55	TL2382548438810
2 3/8" x 7' (3/8" X 10" & 12")	10	12	---		61	TL23825484381012
2 3/8" x 7' (3/8" X 12" & 14")	12	14	---		69	TL23825484381214
2 3/8" x 7' (3/8" X 8", 10" & 12")	8	10	12		66	TL238254843881012
2 3/8" x 7' (3/8" X 10", 12" & 14")	10	12	14		77	TL2382548438101214
2 3/8" x 10' (3/8" X 8")	8	---	---		64	TL238254120388
2 3/8" x 10' (3/8" X 10")	10	---	---		67	TL2382541203810
2 3/8" x 10' (3/8" X 12")	12	---	---		71	TL2382541203812
2 3/8" x 10' (3/8" X 14")	14	---	---		75	TL2382541203814
2 3/8" x 10' (3/8" X 8" & 10")	8	10	---	10'	72	TL23825412038810
2 3/8" x 10' (3/8" X 10" & 12")	10	12	---		79	TL238254120381012
2 3/8" x 10' (3/8" X 12" & 14")	12	14	---		87	TL238254120381214
2 3/8" x 10' (3/8" X 8", 10" & 12")	8	10	12		83	TL2382541203881012
2 3/8" x 10' (3/8" X 10", 12" & 14")	10	12	14		94	TL23825412038101214

Note: Special order are available, allow extra time for processing
All products are Hot Dip Galvanized per ASTM A123
All products are available with 1/2” thick helix plate

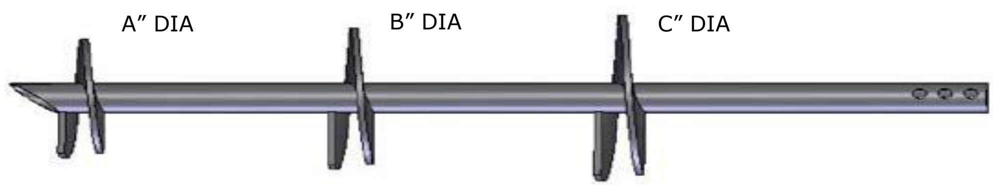
Helical Anchor, 2-7/8 (.276 wall) Tubular Leads



Product Description	Plate Diameter			Length	Weight	Part Number
	A	B	C			
2 7/8" X 5' (3/8" X 8")	8	---	---		45	TL27827660388
2 7/8" X 5' (3/8" X 10")	10	---	---		48	TL278276603810
2 7/8" X 5' (3/8" X 12")	12	---	---		51	TL278276603812
2 7/8" X 5' (3/8" X 14")	14	---	---	5'	56	TL278276603814
2 7/8" X 5' (3/8" X 8" & 10")	8	10	---		52	TL2782766038810
2 7/8" X 5' (3/8" X 10" & 12")	10	12	---		59	TL27827660381012
2 7/8" X 5' (3/8" X 12" & 14")	12	14	---		67	TL27827660381214
2 7/8" x 7' (3/8" X 8")	8	---	---		60	TL27827684388
2 7/8" x 7' (3/8" X 10")	10	---	---		63	TL278276843810
2 7/8" x 7' (3/8" X 12")	12	---	---		67	TL278276843812
2 7/8" x 7' (3/8" X 14")	14	---	---		71	TL278276843814
2 7/8" x 7' (3/8" X 8" & 10")	8	10	---	7'	67	TL2782768438810
2 7/8" x 7' (3/8" X 10" & 12")	10	12	---		74	TL27827684381012
2 7/8" x 7' (3/8" X 12" & 14")	12	14	---		82	TL27827684381214
2 7/8" x 7' (3/8" X 8", 10" & 12")	8	10	12		79	TL278276843881012
2 7/8" x 7' (3/8" X 10", 12" & 14")	10	12	14		90	TL2782768438101214
2 7/8" x 10' (3/8" X 8")	8	---	---		83	TL278276120388
2 7/8" x 10' (3/8" X 10")	10	---	---		86	TL2782761203810
2 7/8" x 10' (3/8" X 12")	12	---	---		90	TL2782761203812
2 7/8" x 10' (3/8" X 14")	14	---	---		94	TL2782761203814
2 7/8" x 10' (3/8" X 8" & 10")	8	10	---	10'	90	TL27827612038810
2 7/8" x 10' (3/8" X 10" & 12")	10	12	---		97	TL278276120381012
2 7/8" x 10' (3/8" X 12" & 14")	12	14	---		105	TL278276120381214
2 7/8" x 10' (3/8" X 8", 10" & 12")	8	10	12		102	TL278276120388101 2
2 7/8" x 10' (3/8" X 10", 12" & 14")	10	12	14		113	TL27827612038101214

Note: Special order are available, allow extra time for processing
All products are Hot Dip Galvanized per ASTM A123
All products are available with 1/2" thick helix plate

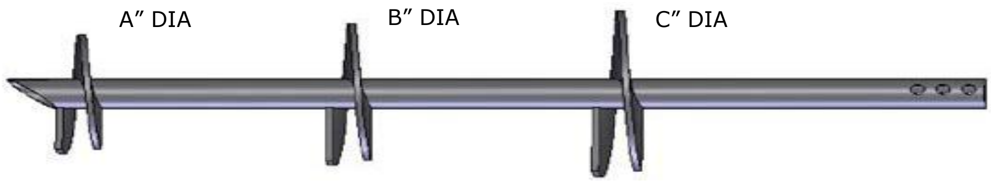
Helical Anchor, 3-1/2 (.254 wall) Tubular Leads



Product Description	Plate Diameter			Length	Weight	Part Number
	A	B	C			
3 1/2" X 5' (3/8" X 10")	10	---	---		50	TL312254603810
3 1/2" X 5' (3/8" X 12")	12	---	---		57	TL312254603812
3 1/2" X 5' (3/8" X 14")	14	---	---	5'	61	TL312254603814
3 1/2" X 5' (3/8" X 10" & 12")	10	12	---		64	TL31225460381012
3 1/2" X 5' (3/8" X 12" & 14")	12	14	---		72	TL31225460381214
3 1/2" x 7' (3/8" X 10")	10	---	---		71	TL312254843810
3 1/2" x 7' (3/8" X 12")	12	---	---		74	TL312254843812
3 1/2" x 7' (3/8" X 14")	14	---	---		79	TL312254843814
3 1/2" x 7' (3/8" X 10" & 12")	10	12	---	7'	81	TL31225484381012
3 1/2" x 7' (3/8" X 12" & 14")	12	14	---		90	TL31225484381214
3 1/2" x 7' (3/8" X 10", 12" & 14")	10	12	14		97	TL3122548438101214
3 1/2" x 10' (3/8" X 10")	10	---	---		97	TL3122541203810
3 1/2" x 10' (3/8" X 12")	12	---	---		101	TL3122541203812
3 1/2" x 10' (3/8" X 14")	14	---	---	10'	105	TL3122541203814
3 1/2" x 10' (3/8" X 10" & 12")	10	12	---		108	TL312254120381012
3 1/2" x 10' (3/8" X 12" & 14")	12	14	---		116	TL312254120381214
3 1/2" x 10' (3/8" X 10", 12" & 14")	10	12	14		123	TL31225412038101214

Note: Special order are available, allow extra time for processing
All products are Hot Dip Galvanized per ASTM A123
All products are available with 1/2" thick helix plate

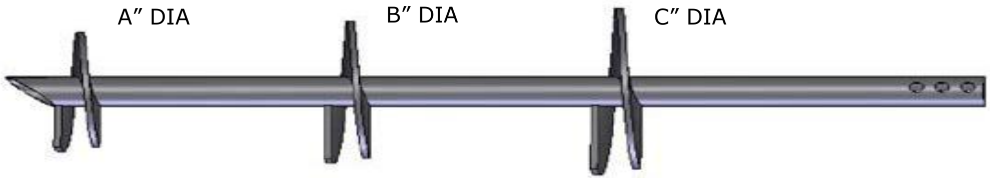
Helical Anchor, 3-1/2 (.368 wall) Tubular Leads



Product Description	Plate Diameter			Length	Weight	Part Number
	A	B	C			
3 1/2" X 5' (3/8" X 10")	10	---	---		70	TL312368603810
3 1/2" X 5' (3/8" X 12")	12	---	---		74	TL312368603812
3 1/2" X 5' (3/8" X 14")	14	---	---	5′	79	TL312368603814
3 1/2" X 5' (3/8" X 10" & 12")	10	12	---		81	TL31236860381012
3 1/2" X 5' (3/8" X 12" & 14")	12	14	---		89	TL31236860381214
3 1/2" x 7' (3/8" X 10")	10	---	---		95	TL312368843810
3 1/2" x 7' (3/8" X 12")	12	---	---		99	TL312368843812
3 1/2" x 7' (3/8" X 14")	14	---	---		103	TL312368843814
3 1/2" x 7' (3/8" X 10" & 12")	10	12	---	7′	106	TL31236884381012
3 1/2" x 7' (3/8" X 12" & 14")	12	14	---		114	TL31236884381214
3 1/2" x 7' (3/8" X 10", 12" & 14")	10	12	14		121	TL3123688438101214
3 1/2" x 10' (3/8" X 10")	10	---	---		132	TL3123681203810
3 1/2" x 10' (3/8" X 12")	12	---	---		136	TL3123681203812
3 1/2" x 10' (3/8" X 14")	14	---	---		140	TL3123681203814
3 1/2" x 10' (3/8" X 10" & 12")	10	12	---	10′	143	TL312368120381012
3 1/2" x 10' (3/8" X 12" & 14")	12	14	---		151	TL312368120381214
3 1/2" x 10' (3/8" X 10", 12" & 14")	10	12	14		158	TL31236812038101214

Note: Special order are available, allow extra time for processing
All products are Hot Dip Galvanized per ASTM A123
All products are available with 1/2” thick helix plate

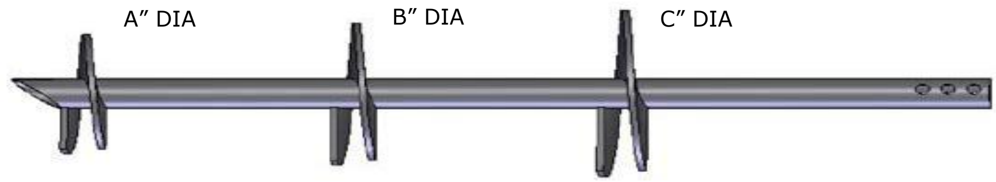
Helical Anchor, 4-1/2 (.250 wall) Tubular Leads



Product Description	Plate Diameter			Length	Weight	Part Number
	A	B	C			
4 1/2" X 5' (3/8" X 10")	10	---	---	5'	83	TL412250603810
4 1/2" X 5' (3/8" X 12")	12	---	---		87	TL412250603812
4 1/2" X 5' (3/8" X 14")	14	---	---		91	TL412250603814
4 1/2" X 5' (3/8" X 10" & 12")	10	12	---		93	TL41225060381012
4 1/2" X 5' (3/8" X 12" & 14")	12	14	---		101	TL41225060381214
4 1/2" x 7' (3/8" X 10")	10	---	---	7'	113	TL412250843810
4 1/2" x 7' (3/8" X 12")	12	---	---		117	TL412250843812
4 1/2" x 7' (3/8" X 14")	14	---	---		121	TL412250843814
4 1/2" x 7' (3/8" X 10" & 12")	10	12	---		123	TL41225084381012
4 1/2" x 7' (3/8" X 12" & 14")	12	14	---		131	TL41225084381214
4 1/2" x 7' (3/8" X 10", 12" & 14")	10	12	14		138	TL4122508438101214
4 1/2" x 10' (3/8" X 10")	10	---	---	10'	158	TL4122501203810
4 1/2" x 10' (3/8" X 12")	12	---	---		162	TL4122501203812
4 1/2" x 10' (3/8" X 14")	14	---	---		166	TL4122501203814
4 1/2" x 10' (3/8" X 10" & 12")	10	12	---		168	TL412250120381012
4 1/2" x 10' (3/8" X 12" & 14")	12	14	---		177	TL412250120381214
4 1/2" x 10' (3/8" X 10", 12" & 14")	10	12	14		183	TL41225012038101214

Note: Special order are available, allow extra time for processing
All products are Hot Dip Galvanized per ASTM A123
All products are also available with 1/2” thick helix plate

Helical Anchor, 4-1/2 (.337 wall) Tubular Leads



Product Description	Plate Diameter			Length	Weight	Part Number
	A	B	C			
4 1/2" X 5' (3/8" X 10")	10	---	---		65	TL412337603810
4 1/2" X 5' (3/8" X 12")	12	---	---		69	TL412337603812
4 1/2" X 5' (3/8" X 14")	14	---	---	5'	73	TL412337603814
4 1/2" X 5' (3/8" X 10" & 12")	10	12	---		75	TL41233760381012
4 1/2" X 5' (3/8" X 12" & 14")	12	14	---		83	TL41233760381214
4 1/2" x 7' (3/8" X 10")	10	---	---		88	TL412337843810
4 1/2" x 7' (3/8" X 12")	12	---	---		91	TL412337843812
4 1/2" x 7' (3/8" X 14")	14	---	---		96	TL412337843814
4 1/2" x 7' (3/8" X 10" & 12")	10	12	---	7'	98	TL41233784381012
4 1/2" x 7' (3/8" X 12" & 14")	12	14	---		106	TL41233784381214
4 1/2" x 7' (3/8" X 10", 12" & 14")	10	12	14		112	TL4123378438101214
4 1/2" x 10' (3/8" X 10")	10	---	---		122	TL4123371203810
4 1/2" x 10' (3/8" X 12")	12	---	---		126	TL4123371203812
4 1/2" x 10' (3/8" X 14")	14	---	---		130	TL4123371203814
4 1/2" x 10' (3/8" X 10" & 12")	10	12	---	10'	132	TL412337120381012
4 1/2" x 10' (3/8" X 12" & 14")	12	14	---		140	TL412337120381214
4 1/2" x 10' (3/8" X 10", 12" & 14")	10	12	14		147	TL41233712038101214

Note: Special order are available, allow extra time for processing
All products are Hot Dip Galvanized per ASTM A123
All products are also available with 1/2" thick helix plate

Helical Anchors Tubular Extensions

Product Description	Wall Size	Length	Weight	Part Number
2 3/8" X 5'	0.190	5’	27	TE23819060
2 3/8" X 7'		7’	36	TE23819084
2 3/8" X 10'		10’	50	TE238190120
2 3/8" X 5'	0.254	5’	33	TE23825460
2 3/8" X 7'		7’	45	TE23825484
2 3/8" X 10'		10’	62	TE238254120
2 7/8" X 5'	0.217	5’	40	TE27821760
2 7/8" X 7'		7’	53	TE27821784
2 7/8" X 10'		10’	71	TE278217120
2 7/8" X 5'	0.276	5’	47	TE27827660
2 7/8" X 7'		7’	62	TE27827684
2 7/8" X 10'		10’	85	TE278276120
3 1/2" X 5'	0.254	5’	61	TE31225460
3 1/2" X 7'		7’	79	TE31225484
3 1/2" X 10'		10’	105	TE312254120
3 1/2" X 5'	0.368	5’	76	TE31236860
3 1/2" X 7'		7’	101	TE31236884
3 1/2" X 10'		10’	138	TE312368120
4 1/2" X 5'	0.250	5’	79	TE41225060
4 1/2" X 7'		7’	101	TE41225084
4 1/2" X 10'		10’	135	TE412250120
4 1/2" X 5'	0.337	5’	111	TE41233760
4 1/2" X 7'		7’	141	TE41233784
4 1/2" X 10'		10’	186	TE412337120

Table A1: Helical Anchors Product Rating							
Helical Anchors Products	**Shaft Size (in)**	**Wall Thickness (in)**	**Ultimate Tension Strength (lbs)**	**Compression Load Limit (lbs)**	**Ultimate Torsional Strength (ft-lb)**	**Installation Torque Factor (k)**	**Capacity Based on Torsional Strength (lbs)**
TS238190	2.375 OD	0.190	125,000	100,000	6,500	9 - 10	65,000
TS238254	2.375 OD	0.254	125,000	135,000	9,000	9 - 10	90,000
TS278217	2.875 OD	0.217	180,000	140,000	13,000	8 - 9	117,000
TS278276	2.875 OD	0.276	180,000	180,000	16,000	8 - 9	144,000
TS312254	3.50 OD	0.254	250,000	210,000	18,000	6.5-8	144,000
TS312368	3.50 OD	0.368	250,000	290,000	27,000	6.5-8	216,000
TS412250	4.50 OD	0.250	275,000	260,000	30,000	5-6.5	195,000
TS412337	4.50 OD	0.337	360,000	350,000	48,000	5-6.5	312,000
TS500362	5.00 OD	0.362	413,000	413,000	74000*	4.5-6	413,000
TS512361	5.50 OD	0.361	510,000	466,000	90700*	4-5.5	466,000
TS700498	7.00 OD	0.498	999,000	814,000	180000*	3-4.5	814,000

Important Notes:

- HAI recommends only using 85% of the Ultimate Torsional Strength shown above in table A1 for 2-3/8 to 3-1/2 helical piles. All other diameter helical piles are recommended to be use to 95% of their Ultimate Torsional Strength
- When using helical piles for tieback or any battered application with more than 10 degrees from vertical, HAI recommends only using 80% of the Ultimate Torsional Strength which will only apply to 2-3/8 and 2-7/8 diameter helical piles.
- The ultimate torsional strength values shown above were determined by statistical analysis of laboratory testing results except for values with an asterisk next to them. Values with an asterisk next to them are calculated ratings.
- The capacities shown above in table A1 for ultimate tension strength and compression load limit are calculated ratings not determined by field tests.
- Our unique facility contains a torsion testing machine allowing us to test all our products. Helical Anchor Inc. is committed to testing and improving all of our finished products to provide the best quality for the customer. This table will be updated when testing is completed for those products with an asterisk.

Table A2: General Properties of Helical Anchors Shaft						
Helical Shaft Size	**Shaft Size (in)**	**Wall Thickness (in)**	**Area (in^2)**	**Radius of Gyration**	**Moment of Inertia (in^4)**	**Flexural Section Modulus**
TS238190	2.375	0.190	1.30	0.775	0.784	0.660
TS238254	2.375	0.254	1.69	0.755	0.965	0.813
TS278217	2.875	0.217	1.81	0.943	1.61	1.12
TS278276	2.875	0.276	2.25	0.924	1.92	1.34
TS312254	3.50	0.254	2.59	1.15	3.43	1.96
TS312368	3.50	0.368	3.62	1.11	4.50	2.57
TS412250	4.50	0.250	3.34	1.50	7.56	3.36
TS412337	4.50	0.337	4.41	1.48	9.61	4.27
TS500362	5.00	0.362	5.27	1.64	14.3	5.71
TS512361	5.50	0.361	5.83	1.82	19.3	7.03
TS700498	7.00	0.498	10.2	2.31	54.1	15.4

Table A3: Ultimate Capacities of Helical Anchors Helices						
Shaft Size (in)	**Thickness (in)**	**Helices Diameters (in)**				
		8	**10**	**12**	**14**	**16**
		Helical Anchor Helices Ultimate Capacities (lbs)				
2 3/8	3/8	97,000	78,000	66,000	52,000	---
2 7/8	3/8	112,000	84,000	82,000	65,000	40,000*
	1/2	151,000	97,000	100,000	80,000	60,000*
3 1/2	3/8	125,000*	91,000	83,000	68,000	46,000
	1/2	155,000*	108,000	113,000	104,000	82,000
4 1/2	1/2	---	120,000*	105,000	96,000	102,000

Important Note:
Ultimate Capacities of helices have been determined by statistical analysis of laboratory testing results. Helix plates are offered in 3/8" and ½" thickness for all our products.
*These are interim ratings since testing is still in process and table will be updated when testing is completed.

Appendix B

Evaluation Reports

Hoyt Engineering Associates

Blue Springs, MO

Helical Foundation & Push Pier Engineering
3105 South Fallbrook Court, Blue Springs, MO 64015
v (816) 220-9120 f (816) 220-9261 hoyteng@comcast.net

August 28, 2009

Evaluation of Tension, Compression, Flexure and Torsion Strengths of Helical Anchors, Inc. Helical Pier Shafts

At the request of Helical Anchors, Inc., I supervised physical testing and conducted structural analyses of their helical pier shaft assemblies to establish ultimate strength ratings in tension, compression, flexure and torsion. "Ultimate strength" is the maximum load that is reached in a strain-controlled test. Where ratings were established by testing, statistical analysis of the results was used to determine the 5% exclusion limit for the ultimate strength. Where ratings were established by calculation, the analyses were directed at predicting the 5% exclusion limit that could be expected to result from statistical analysis of laboratory test results from a statistically meaningful group of samples. The 5% exclusion limit is the strength that 95% of a total population of like products would be expected to meet or exceed. The resulting strength ratings should not be assumed to meet the requirements of the American Institute of Steel Construction's Allowable Strength Design (ASD), Load & Resistance Factor Design (LRFD), or 360-05 integrated design specifications, none of which apply to portions of structural elements that are embedded in the earth.

The results of the evaluations are given in the table below. These mechanical strength estimates form upper bounds to the ultimate loads that can be achieved in the field. Other limit states that may be the controlling factor in any specific project include pullout, plunging or overturning due to exceeding the soil's bearing capacity and shaft buckling under compressive loading, all of which must be evaluated in light of the soil profile in which the elements will be embedded. Serviceability limit states must also be considered in the determination of allowable loads for specific projects.

Shaft Designation	Calculated Minimum Ultimate Strength			
	Tension (lbs)	Compression (lbs)	Flexure (lb-in)	Torsion* (lb-ft)
2-3/8 x 0.190	125,000	100,000	70,000	7500
2-3/8 x 0.254	125,000	135,000	90,000	9000
2-3/8 x 0.280	125,000	140,000	90,000	8000
2-7/8 x 0.217	180,000	140,000	120,000	13,000
2-7/8 x 0.276	180,000	180,000	150,000	16,000
3-1/2 x 0.254	250,000	210,000	210,000	18,000
3-1/2 x 0.368	250,000	290,000	290,000	27,000
4-1/2 x 0.337	360,000	350,000	470,000	48,000

*Value determined by statistical analysis of laboratory testing results

I certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Robert M. Hoyt, PE, F.ASCE
President/Principal
Hoyt Engineering Associates

Robert M. Hoyt, PE

Robert M. Hoyt, PE

Date: 28 Aug 2009 License # 46668

Hoyt Engineering Associates

Blue Springs, MO

Helical Foundation & Push Pier Engineering
3105 South Fallbrook Court, Blue Springs, MO 64015
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October 16, 2009

Evaluation of Flexural Strengths of Helical Anchors, Inc. Helical Pier Helix Plates

At the request of Helical Anchors, Inc., I supervised physical testing of their helical pier shaft/helix plate assemblies and conducted data analyses to determine the average ultimate strengths thereof in flexural loading. "Ultimate strength" in this case was established as specified in the International Codes Council Evaluation Service's Acceptance Criteria AC358. That is, it was the maximum load that was reached in a strain-controlled laboratory test using a defined test fixture. The raw ultimate strength data was then normalized for the effects of corrosion over a 50-year lifetime as specified in AC358.

The normalized ultimate strength averages for the various combinations of plate OD, shaft OD and plate thickness are given in Table 1 below. These mechanical strengths, or appropriate sums thereof for multi-helix piers, form upper bounds to the ultimate load that can be achieved in the field. Other limit states that may be the controlling factor in any specific project include pullout, plunging or overturning due to exceeding the soil's bearing capacity and shaft buckling under compressive loading, all of which must be evaluated in light of the soil profile in which the elements will be embedded. Shaft coupling strength may be the controlling limit state for tension loading. Serviceability limit states must also be considered in the determination of allowable loads for specific projects.

Table 1: Mean Ultimate Strengths for Helix Plates and Helix Plate/Shaft Joints (lbs)

Helix Plate OD x Thickness (in)	Shaft OD			
	2-3/8 (in)	2-7/8 (in)	3-1/2 (in)	4-1/2 (in)
8 x 3/8	97,000	112,000	Not Tested	Not Tested
10 x 3/8	78,000	84,000	91,000	Not Tested
12 x 3/8	66,000	82,000	83,000	Not Tested
14 x 3/8	52,000	65,000	68,000	Not Tested
16 x 3/8	Not Tested	Not Tested	46,000	Not Tested
8 x 1/2	Not Tested	151,000	Not Tested	Not Tested
10 x 1/2	Not Tested	97,000	108,000	Not Tested
12 x 1/2	Not Tested	100,000	113,000	105,000
14 x 1/2	Not Tested	80,000	104,000	96,000
16 x 1/2	Not Tested	Not Tested	82,000	102,000

Robert M. Hoyt, PE, F.ASCE
President/Principal
Hoyt Engineering Associates

I certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Robert M. Hoyt, PE

Robert M. Hoyt, PE

Date: 16 Oct 2009 License # 46668

References

ASCE (1996), *Design of Sheet Pile Walls*, American Society of Civil Engineers, Reston, VA, 68 pp.

Bowles, J. E. (1988), *Foundation Analysis and Design*, 4th edition, McGraw-Hill Book Company, New York.

Das, B.M. (2004), *Fundamentals of Geotechnical Engineering*. 2th edition, Thomson-Engineering, Belmont, CA

Gere, James M. (2003) *Mechanics of Material*. 6th edition. Thomson-Engineering, Belmont, CA.

Vijayvergiya, V. N. and J. A. Focht, Jr. (1972). "A New Way to Predict Capacity of Piles in Clay", OTC Paper 1718, 4th Offshore Technology Conference, Houston, TX.