FOUNDATION SUPPORTWORKS™

HELICAL FOUNDATION SYSTEMS

STABILITY. SECURITY. INTEGRITY.

Foundation Supportworks™ offers a complete line of helical products for use as new construction helical piles, retrofit piers, or anchors and tiebacks.

Helical Foundation System

PN #MBHFS

About FOUNDATION SUPPORTWORKS

Omaha, Nebraska

Seymour, Connecticut

Foundation Supportworks™ (FSI) is a leading manufacturer of helical pile systems, hydraulically-driven push pier systems, wall anchoring and wall bracing systems, and supplemental crawl space support systems. FSI was founded on the principles of integrity, quality and service and it is our mission to provide the industry with innovative solutions that are appropriately designed and tested, expertly installed and dependable to perform as promised.

Foundation Supportworks' commitment to its network of installing contractors and, ultimately, the end consumer, is apparent by employing a team of customer service and dealer support staff unparalleled in the industry. Our staff of full-time employees includes a professional corporate trainer, geotechnical and structural engineers, and entire graphics and website development departments.

FSI has major dealer support facilities in Omaha, Nebraska and Seymour, Connecticut,.

ENGINEERING

Foundation Supportworks™ has both geotechnical and structural engineers on staff for product design, quality assurance of products and support to our network of installing contractors. Our in-house engineers are available to assist with preliminary designs and provide technical support to engineers, architects, building departments and general contractors. Our engineers are experts in the industry and routinely present technical information at industry trade conferences, engineering and architectural meetings and conferences, as well as to contractors and home inspectors.

HELICAL PILES

Helical piles are a factory-manufactured steel foundation system consisting of a central shaft with one or more helix-shaped bearing plates and a bracket that allows attachment to a structure. The helix plates are commonly referred to as blades or flights and are welded to the lead section. Extension shafts, with or without additional helix plates, are used to extend the pile to competent load bearing soil and to achieve design depth and capacity. Brackets are used at the tops of the piles for attachment to structures, either for new construction or retrofit applications. Helical piles are advanced (screwed) into the ground with the application of torque.

The terms helical piles, screw piles, helical piers, helical anchors, helix piers, and helix anchors are often used interchangeably by specifiers. However, the term "pier" more often refers to a helical pile loaded in axial compression, while the term "anchor" more often refers to a helical pile loaded in axial tension. The term "pile" traditionally describes a deep foundation that can resist both tension and compression loads.

DID YOU KNOW?

The use of helical piles and anchors in construction dates back nearly 200 years. In the 1830's, the earliest versions of today's helical piles were used in England for moorings and for the foundations of lighthouse structures. Today, helical piles are used in both tension and compression load applications and are gaining worldwide acceptance throughout the construction industry and engineering community due to the versatility of both the product and the installation equipment. In 2007, the International Code Council Evaluation Service (ICC-ES) approved AC358, Acceptance Criteria for Helical Foundation Systems and Devices. Helical piles are also now included in sections of the 2009 International Building Code.

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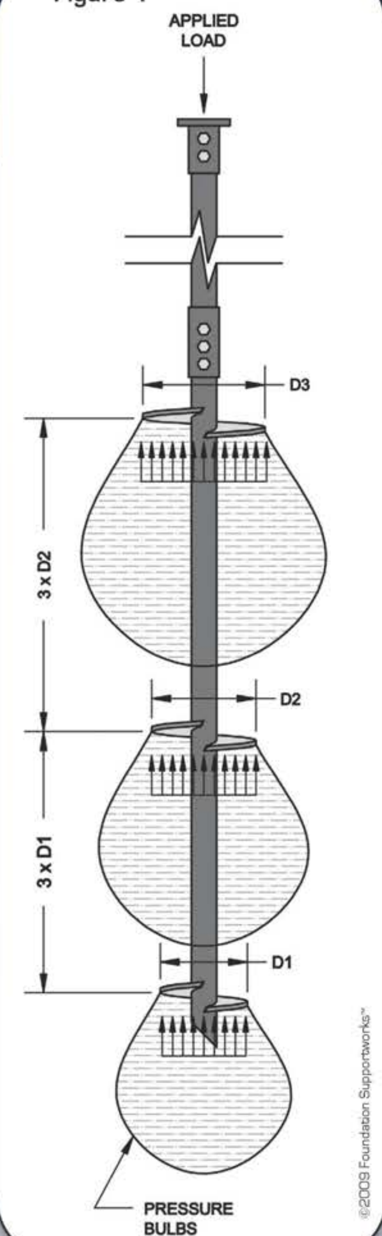
▶ DESIGN CONSIDERATIONS

Helical piles are designed such that most of the axial capacity of the pile is generated through bearing of the helix plates against the soil. The helix plates are typically spaced three diameters apart along the pile shaft to prevent one plate from contributing significant stress to the bearing soil of the adjacent plate. Significant stress influence is limited to a "bulb" of soil within about two helix diameters from the bearing surface in the axial direction and one helix diameter from the center of the pile shaft in the lateral direction. Each helix plate therefore acts independently in bearing along the pile shaft (See Figure 1).

Multiple piles shall have a center to center spacing at the helix depth of at least four (4) times the diameter of the largest helix plate (ICC-ES AC358). The tops of the piles may be closer at the ground surface but installed at a batter away from each other in order to meet the spacing criteria at the helix depth. For tension applications, the uppermost helix plate shall be installed to a depth at least twelve (12) diameters below the ground surface (ICC-ES AC358). The actual depth will vary depending upon soil conditions and capacity requirements, but should not be less than 12 diameters.

The uppermost helix plate shall be embedded in the ground to a depth of at least five (5) diameters to create a deep foundation bearing condition. The upper helix plate shall also be located below the depth of seasonal frost penetration and below the "active zone"; i.e., the depth of soil that undergoes seasonal volume changes with changes in moisture content.

Figure 1



▶ DETERMINATION OF CAPACITY

The ultimate capacity of a helical pile may be calculated using the traditional bearing capacity equation:

$$Q_u = \sum [A_h (cN_c + q'N_q)]$$

Where,
- Q_u = Ultimate Pile Capacity (lb)
- A_h = Area of Individual Helix Plate (ft^2)
- c = Soil Cohesion (lb/ft^2)
- N_c = Dimensionless Bearing Capacity Factor
- q' = Effective Vertical Overburden Pressure (lb/ft^2)
- N_q = Dimensionless Bearing Capacity Factor

Total stress parameters should be used for short-term and transient load applications and effective stress parameters should be used for long-term, permanent load applications. A factor of safety of 2 is typically used to determine the allowable soil bearing capacity if torque is monitored during the helical pile installation.

**Like other deep foundation alternatives, there are many factors to be considered in designing a helical pile foundation. Foundation Supportworks™ recommends that helical pile design be completed by an experienced geotechnical engineer or other qualified professional.*

Another well-documented and accepted method for estimating helical pile capacity is by correlation to installation torque. In simple terms, the torsional resistance generated during helical pile installation is a measure of soil shear strength and can be related to the bearing capacity of the pile.

$$Q_u = K_t \times T$$

Where,
- Q_u = Ultimate Pile Capacity (lb)
- K_t = Torque Correlation Factor (ft^{-1})
- T = Installation Torque (ft-lb)

The torque correlation factor is not a constant and varies with soil conditions and size of the pile shaft. Load testing using the proposed helical pile and helix blade configuration is the best way to determine project-specific K_t values. However, ICC-ES AC358 provides default K_t values for varying pile shaft diameters. These K_t values are generally considered conservative for most soil conditions.

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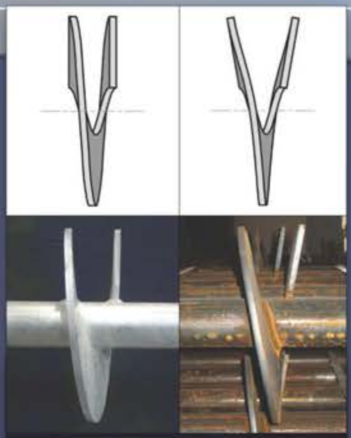
▶ HELIX PLATES

Figure 2



Correct Incorrect

The initial installation of a helical pile is performed by applying a downward force (crowd) and rotating the pile into the earth via the helix plates. Once the helix plates penetrate to a depth of about 2 to 3 feet, the piles generally require less crowd and installation is accomplished mostly by the downward force generated from the helix plates, similar to the effect of turning a screw into a block of wood. Therefore, the helix plate performs a vital role in providing the downward force or thrust needed to advance the pile to the bearing depth. The helix plate geometry further affects the rate of penetration, soil disturbance and torque to capacity correlation. The consequences of a poorly-formed helix are twofold; (1) the helix plate severely disturbs the soil with an augering effect which (2) directly results in more movement upon loading than a pile with well-formed helices. The differences between a well-formed helix and poorly-formed helix are visually obvious and are shown in Figure 2.

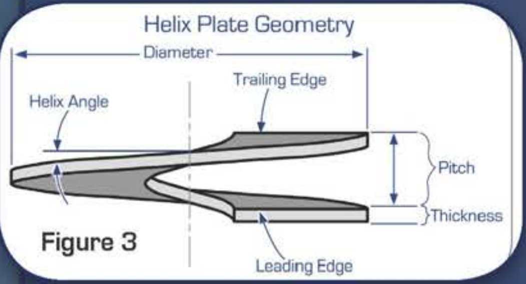


Figure 3

ICC-ES AC358 establishes design and testing criteria for helical piles evaluated in accordance with the International Building Code. AC358 further provides criteria for helix plates in order to be considered as a "conforming system". Foundation Supportworks helical piles feature plates manufactured with a helix shape conforming to the geometry criteria of ICC-ES AC358 (See Figure 3). Conversely, blades that are not a helix shape are often formed to a "duckbill" appearance. These plates create a great deal of soil disturbance, do not conform to the helix geometry requirements of ICC-ES AC358, and their torque to capacity relationships are not well documented.

▶ COUPLER DETAIL

Figure 4

FSI external welded coupler

The coupler detail for a helical foundation system is yet another extremely important feature when considering helical piles and when selecting or specifying a product manufacturer. Manufacturers may advertise that they carry the same or equivalent helical shaft. However, shaft and coupler details are not consistent between manufacturers and these differences may not be readily apparent by simply reviewing product capacity tables. Some manufacturers rate their products based upon the capacities of the gross section of the shaft, thereby ignoring any limitations caused by the coupled connections. For these "equivalent" products, there can be dramatic differences in material properties, tolerances, spacing of bolt holes, oversize of bolt holes, general fit-up, weld quality, etc.

Figure 5

FSI external detached coupler

Figure 6

Upset coupler with oversized closely-spaced bolt holes

Some of the more common coupler details for round shaft include external welded, external detached, internal detached, and forged and upset. External couplers utilize tube or pipe sections with an internal diameter slightly larger than the outside diameter of the central shaft material (See Figure 4 and Figure 5). These couplers can be sized to provide tight connections that reduce angular deformation and variances from straightness. Such displacements at the couplers introduce eccentricities to the system which can significantly reduce the allowable compressive capacity of the pile, especially considering the slenderness of the more widely used shaft material (typically 3.5-inch outside diameter and smaller). Internal detached couplers are made from solid round stock or tube or pipe material but with an outside diameter smaller than the inside diameter of the central shaft material. Internal coupler diameters may be significantly undersized to prevent interferences with internal weld beads of the central shaft or due to the variations that are typical in wall thicknesses and inside diameters of pipe sections. Larger gaps between the inside diameter of the shaft and the outside diameter of the coupler can result in a connection with more potential for angular displacements.

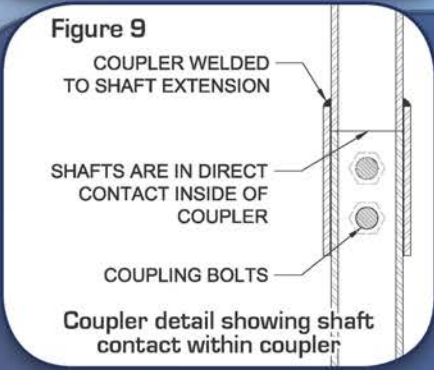
Figure 7

Coupler tolerances; (A) Competitor upset coupler, (B) FSI external welded coupler

Figure 8

Competitor upset coupler variance from straightness

Forged and upset couplers are formed by heating one end of the shaft, placing this end in a form and then enlarging the end with a hammer-like tool or press (See Figure 6). With this method of manufacturing, it is difficult to create tight connections to strict tolerances. It is not uncommon to have 1/8-inch or more difference between the outside diameter of the shaft and the inside diameter of the upset coupler of the round shaft (See Figure 7). Again, the greater the freedom allowed in the connection, the greater the potential variance from straightness and the higher the potential for bending or buckling of the pile under high compressive loads (See Figure 8). The risk of pile buckling further increases with unsupported lengths above the ground surface, or if the pile extends



Coupler detail showing shaft contact within coupler

through soil strata consisting of soft clays or very loose sand.

FSI round shaft helical piles are manufactured with external welded or detached couplers. These systems are manufactured to strict tolerances to allow the pile shafts to be in direct contact inside the coupling, similar to Figure 9. Why is this important? The load path for piles under compression is then directly through the shafts of the extensions and lead section without having to pass through welds and bolts at each connection. The annular space between the pile shaft and coupler is also kept as tight as practical to maintain pile rigidity while also providing connections that are easily joined in the field (See Figure 10 and Figure 11).


Figure 10

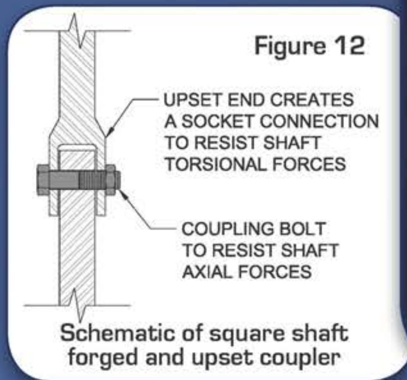
FSI external welded coupler


FSI external detached coupler

Figure 11

The most common coupler detail for solid square shaft utilizes a forged and upset end (See Figures 12 & 13). Cast detached couplers have also been used in lieu of the upsetting process. The upset end of square shaft is created in a similar manner as for the round shaft, except for forming a square socket connection. Figure 14 clearly shows a comparison of coupling rigidity between an FSI external welder coupler for round shaft and a typical upset coupler for square shaft. A similar draping effect is typical for round shaft helical piles with upset couplers.

FSI recommends that the design engineer request product drawings and review coupling details, tolerances and general fit-up prior to product selection.



Schematic of square shaft forged and upset coupler


Figure 13

Square shaft forged and upset coupler

▶ ROUND VS. SQUARE

Solid square shaft helical piles have been used successfully for decades in tension applications; i.e., as anchors, tiebacks and soil nails, and have proven to be a suitable and reliable support alternative for such projects. Not surprisingly, manufacturers then adapted the use of square shaft helical products to be installed vertically for the support of compression loads. Hollow round shaft piles have also been used in both tension and compression applications. In general, FSI believes that hollow round shafts are better suited for compression applications whereas solid square shaft may provide some advantages in tension applications. That said, project and site-specific soil conditions vary which may push the merits and advantages of one system over the other, and the design professional should select the product best suited for the project.

Hollow round shaft helical piles are particularly suited to compression loading applications and offer the following advantages over comparably sized square shaft piles.


Coupler Rigidity Comparison: FSI round shaft external welded coupler vs. typical upset coupler for square shaft

Figure 14

• Round shaft helical piles, excluding those with upset couplers, generally have more rigid coupling connections. Square shaft helical piles typically have a socket and pin coupling which increases variances from straightness, introduces eccentricity to the system, and increases buckling potential (See Figure 14). Square shaft piles may be considered for light concentric compression load applications and in soil profiles that offer sufficient lateral support for higher loads; e.g., Standard Penetration Test (SPT) blow count values ≥ 10 blows/foot (ASTM D1586).

• As stated in the Coupler Detail section, The FSI round shaft helical piles are designed so the pile shafts are in direct contact within the coupling connections. The load path for round shaft piles in compression is then directly through the shafts without having to pass through the welds or bolts at each coupling. Shaft to shaft contact is more difficult to achieve within forged, upset couplers. For square shaft piles, both compression and tension loads may then be transferred through the single coupling bolt in double shear.

• The area of steel for a round shaft is located outward from the centroid, thereby providing a greater structural section modulus and a higher moment of inertia. In layman's terms, a round shaft pile is more resistant to bending (See Figure 15). This is an important consideration for piles with unsupported lengths, piles penetrating loose or soft soils, or for piles that are eccentrically loaded such as in a retrofit application.

• Round shaft typically has a higher installation torque rating than a comparably-sized square shaft. For certain product comparisons, this results in higher pile capacities.


Figure 15

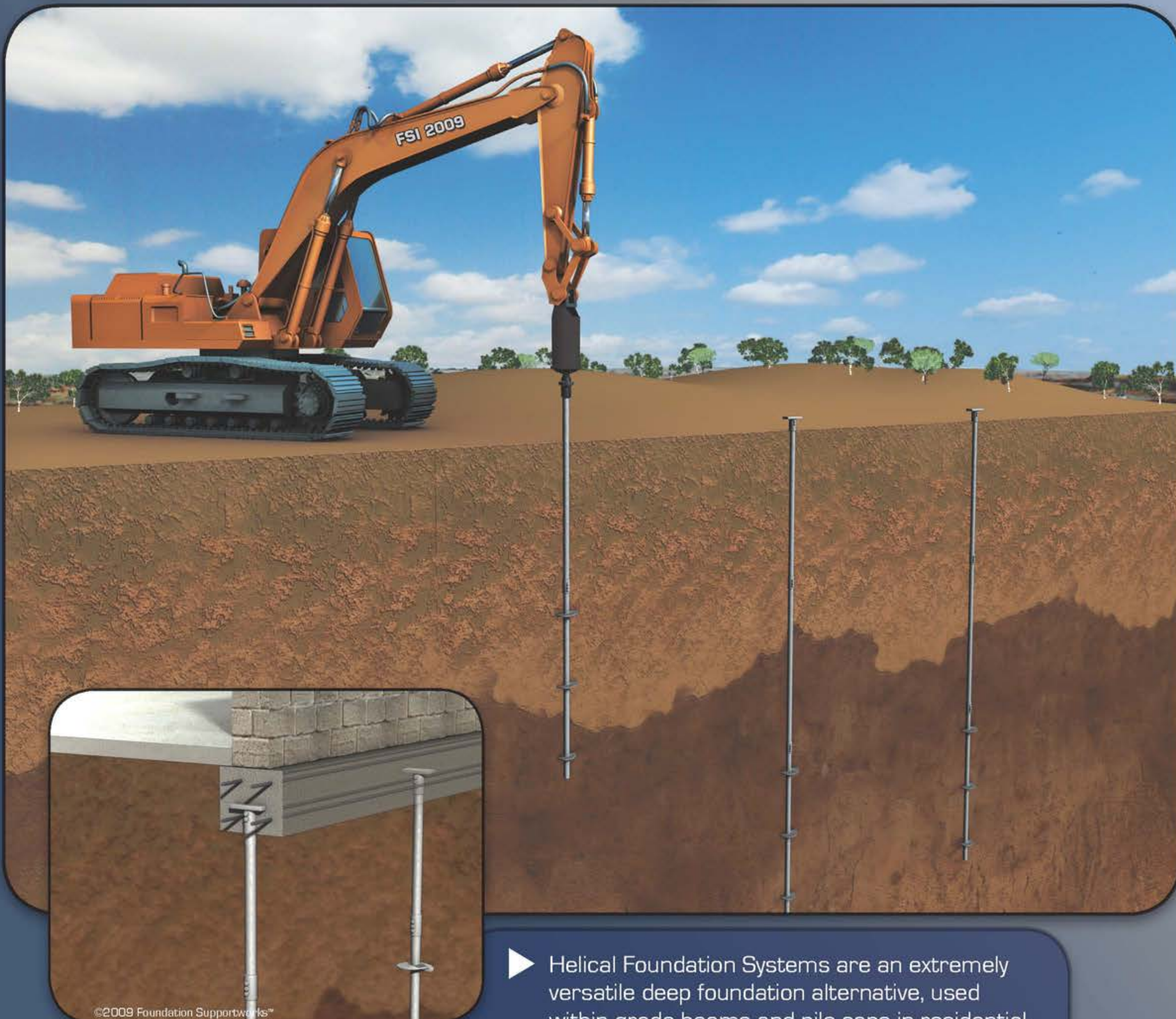
Section comparison between 2.875" diameter round shaft and 1.5" square shaft

• Round shaft offers a higher lateral resistance with more shaft area exposed to the surrounding soil. If necessary, hollow round shafts can also be grout-filled to further improve the pile stiffness.

Helical Foundation Systems

NEW CONSTRUCTION APPLICATIONS

FOUNDATION SUPPORTWORKS™

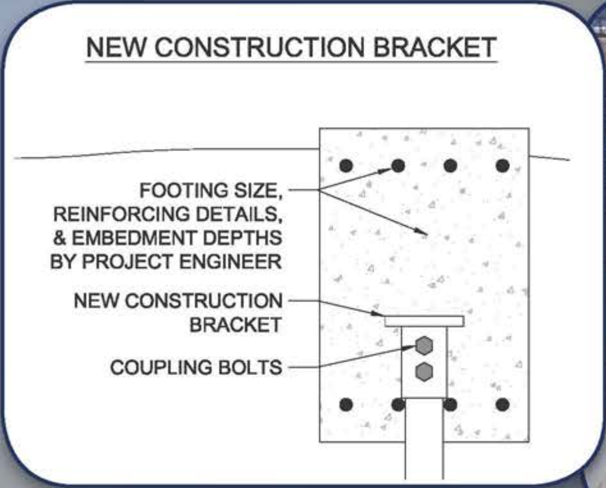


▶ Helical Foundation Systems are an extremely versatile deep foundation alternative, used within grade beams and pile caps in residential, commercial and industrial load applications.

Helical Foundation Systems

ADVANTAGES

- High capacity deep foundation alternative – Ultimate torque-rated capacities on the order of 130 kips may be achieved with helical shaft sizes up to 4.5 inches in diameter.
- All-weather installation – Helical piles can be installed through inclement weather and freezing temperatures.
- Installed in areas of limited or tight access – Helical piles can be installed with hand-held equipment, mini-excavators, skid steers, backhoes and larger track equipment. The equipment and drive heads can be sized according to the project design loads, as well as site access.
- Vibration-free installation – Rotary installation of helical piles does not produce ground vibrations, unlike traditional driven piles or rammed aggregate soil improvement options.
- Install quickly without generating spoils – Helical piles do not auger soils to the surface. Therefore, there are no hauling or disposal costs for spoils similar to auger-cast piles or drilled shafts. For contaminated sites, disposal and/or treatment of disturbed material can be extremely costly or make the project cost-prohibitive.
- Support of temporary structures – Helical piles can be removed from the ground by reversing the installation process.
- Foundation concrete can be poured immediately following installation - Installed steel piles do not require a curing period like drilled shafts or auger-cast piles.



Helical Pile Capacities Summary

			Default Torque Correlation Factor(6) K_t (ft^{-1})	Maximum Installation Torque (ft-lbs)	Maximum *Ultimate* Torque Correlated Soil Capacity(6,7) $Q_u = K_t \times T$ (kips)	Maximum Allowable Mechanical Shaft Capacities(3,5) Axial Compression (kips)	Maximum Allowable Mechanical Shaft Capacities(3,5) Axial Tension (kips)
Shaft	HA150	1 1/2" Square Bar	10	6,500	65.0(8)	26.5(1,8)	26.5(1)
Shaft	HA175	1 3/4" Square Bar	10	10,000	100.0(8)	65.7(8)	36.1(1)
Shaft	HP287	2 7/8" OD x 0.203" Wall	9	5,600	50.4	46.4(4)	23.6(2)
Shaft	HP288	2 7/8" OD x 0.276" Wall	9	7,900	71.1	65.4(4)	34.1(2)
Shaft	HP349	3 1/2" OD x 0.300" Wall	7	13,000	91.0	88.7(4)	50.8(2)
Shaft	HP350	3 1/2" OD x 0.313" Wall	7	16,000	112.0	107.8(4)	62.5(2)
Shaft	HP450	4 1/2" OD x 0.337" Wall	6	22,000	132.0	109.9(4)	54.7(2)

▶ NOTES:

(1) - Governed by AISC allowable capacity of single Ø3/4" (HA150) or Ø7/8" (HA175) Grade 8 bolt in double shear.

(2) - Governed by bearing at the bolt holes.

(3) - Capacities include a scheduled loss in steel thickness due to corrosion for black, uncoated steel. Scheduled thickness losses are for a period of 50 years and are in accordance with ICC-ES AC358.

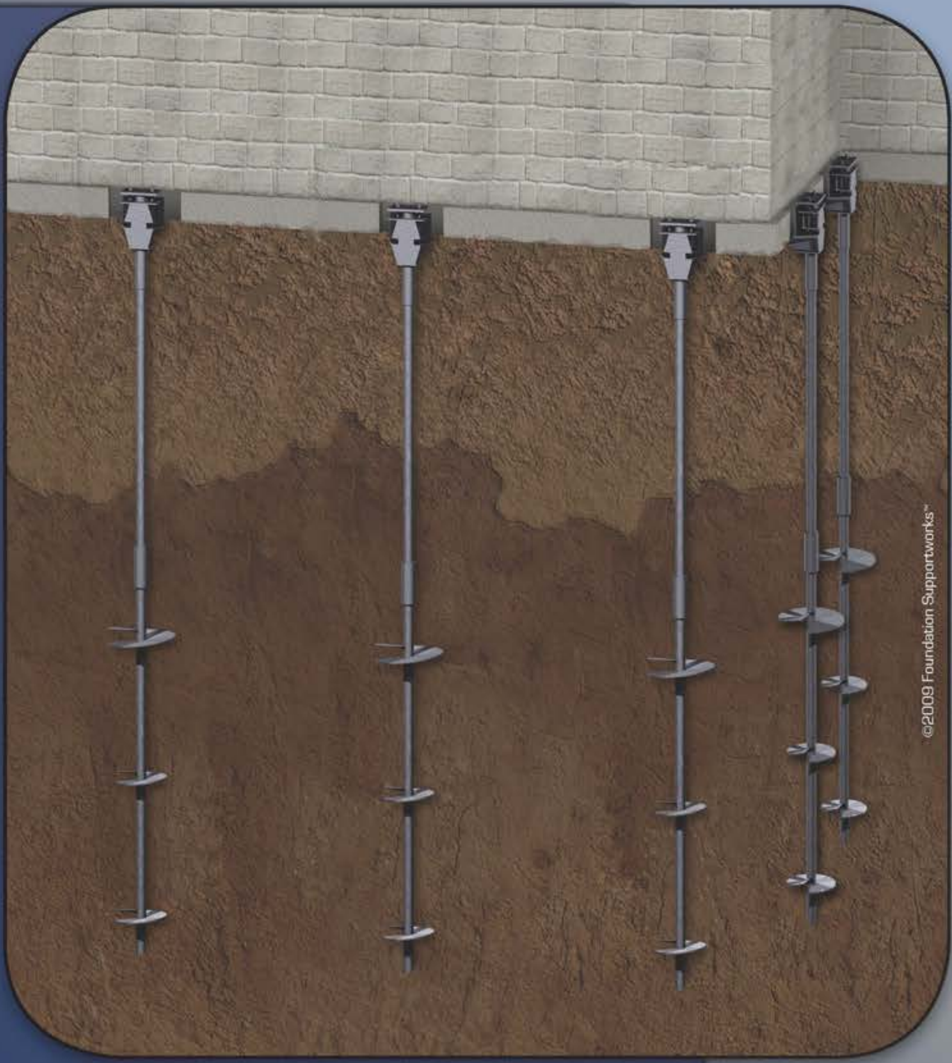
(4) - Allowable compression capacities are based on continuous lateral soil confinement in soils with SPT blow counts ≥ 4. Piles with exposed unbraced lengths or piles placed in weaker or fluid soils should be evaluated on a case by case basis by the project engineer.

(5) - Listed mechanical capacities are for the shaft only. System capacities should also not exceed the installed torque-correlated capacity or those listed in bracket capacity tables.

(6) - Listed default K_t factors are widely accepted industry standards. They are generally conservative and are consistent with those listed in ICC-ES AC358. Site-specific K_t factors can be determined for a given project with full-scale load testing.

(7) - Soil capacities listed are ultimate values at maximum installation torque. Allowable soil capacity values are obtained by dividing the ultimate values by the appropriate factor of safety (FOS). FOS is most commonly taken as 2.0, although a higher or lower FOS may be considered at the discretion of the helical pile designer or as dictated by local code requirements.

(8) - Square shaft piles may be considered for compression applications in soil profiles that offer sufficient continuous lateral support; e.g., in soils with SPT blow counts ≥ 10. Even in these higher strength soil conditions, buckling analyses should be considered, taking into account discontinuities and potential eccentricities created by the couplers.



Helical piles used in retrofit applications utilize side-load brackets that introduce eccentricity to the system. The pile shaft is not located directly under the footing or structural load. Therefore, retrofit piering systems are eccentrically loaded and must be designed to resist the bending forces generated by this loading condition (See Figure 16).

Most helical piles, especially in retrofit applications, have outer dimensions of 3.5 inches or less. These sections are therefore very sensitive to the bending moments introduced by this eccentricity, thereby reducing the capacity of the pier to carry axial load. The retrofit pier does not act as a pure column as in a new construction application, but rather as a beam-column that must resist both axial load and bending. The pier shaft has quantifiable axial and bending capacities, and independent of the other, may be significant. However, when both of these forces are applied concurrently to the same section, both the allowable compressive capacity and allowable bending capacity are reduced. In fact, according to AISC design methods, the allowable compressive capacity may be reduced by one-half or more for certain pile sections when applying a bending moment generated by an eccentricity of only two inches or less, which would be considered typical for many retrofit piering systems.

Foundation Supportworks™ addresses the issue of retrofit helical pier eccentricities either of two ways. The first is to increase the stiffness of the pier system and then allow more of the resulting bending forces to be transferred through the pier system itself. This is accomplished by incorporating an external sleeve to resist the bending forces. The external sleeve extends through and below the foundation bracket to essentially create a bracket that is 30 inches tall. Since the external sleeve and the pier shaft are confined by the earth, the bending moment dissipates quickly into the surrounding soils and generally within the first few feet. The depth at which the bending moment dissipates is a function of the soil strength and is greater in soft soils and less in stiff soils. With the external sleeve present to resist most of the bending forces, the capacity of the pier section is preserved to resist the axial compressive forces.

The second way to address retrofit helical pier eccentricities is to increase rigidity of the bracket connection to the foundation. With an adequately designed, rigid connection, much of the eccentricity is transferred back to the foundation and less to the pier section. This connection detail typically consists of several strategically-located, deeply embedded adhesive anchors.

Retrofit Bracket System Capacities

		Allowable Mechanical Capacities(1,2,3)			
		FS288B Bracket		FS288BL Bracket	
		30" Sleeve (kips)	48" Sleeve(4) (kips)	30" Sleeve (kips)	48" Sleeve(4) (kips)
Shaft	HP287	21.2	26.5	21.2	26.5
Shaft	HP288	28.8	36.2	28.8	36.2

		Allowable Mechanical Capacities(1,2,3)			
		HP350BS Bracket		HP350B Bracket	
		30" Sleeve (kips)	48" Sleeve(4) (kips)	with NO Anchors (kips)	with Adhesive Anchors(5) (kips)
Shaft	HP349	35.6	41.1	29.2	36.0
Shaft	HP350	44.5	51.5	36.5	45.0

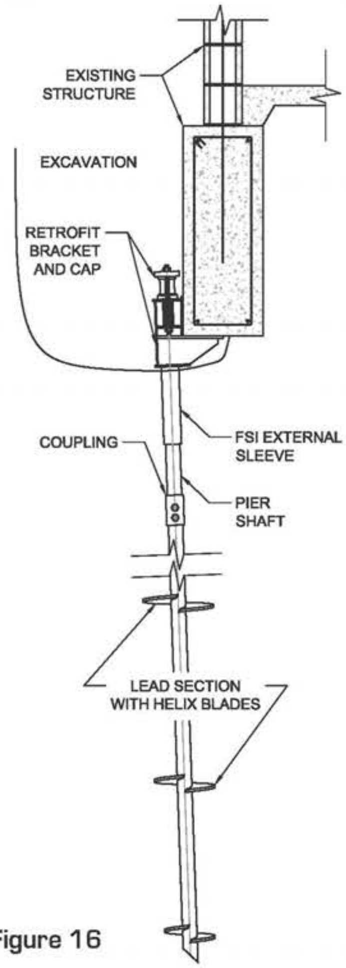
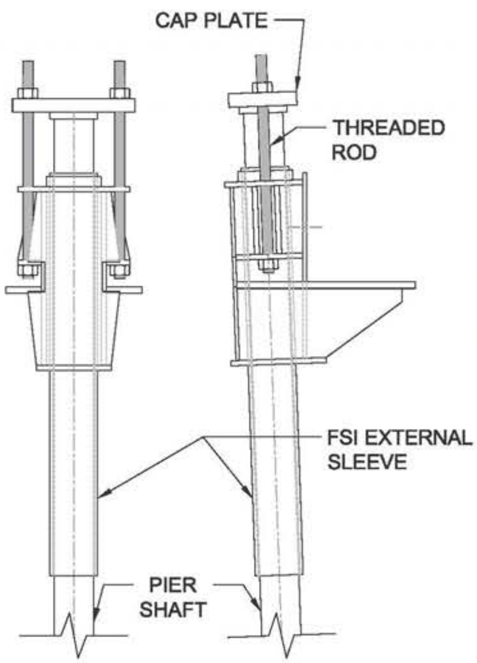


Figure 16

Retrofit Bracket (typ.)



NOTES:

(1) - Brackets shall be used for support of structures that are considered to be fixed from translation. Structures that are not fixed from translation shall be braced in some other manner prior to installing helical retrofit brackets systems.

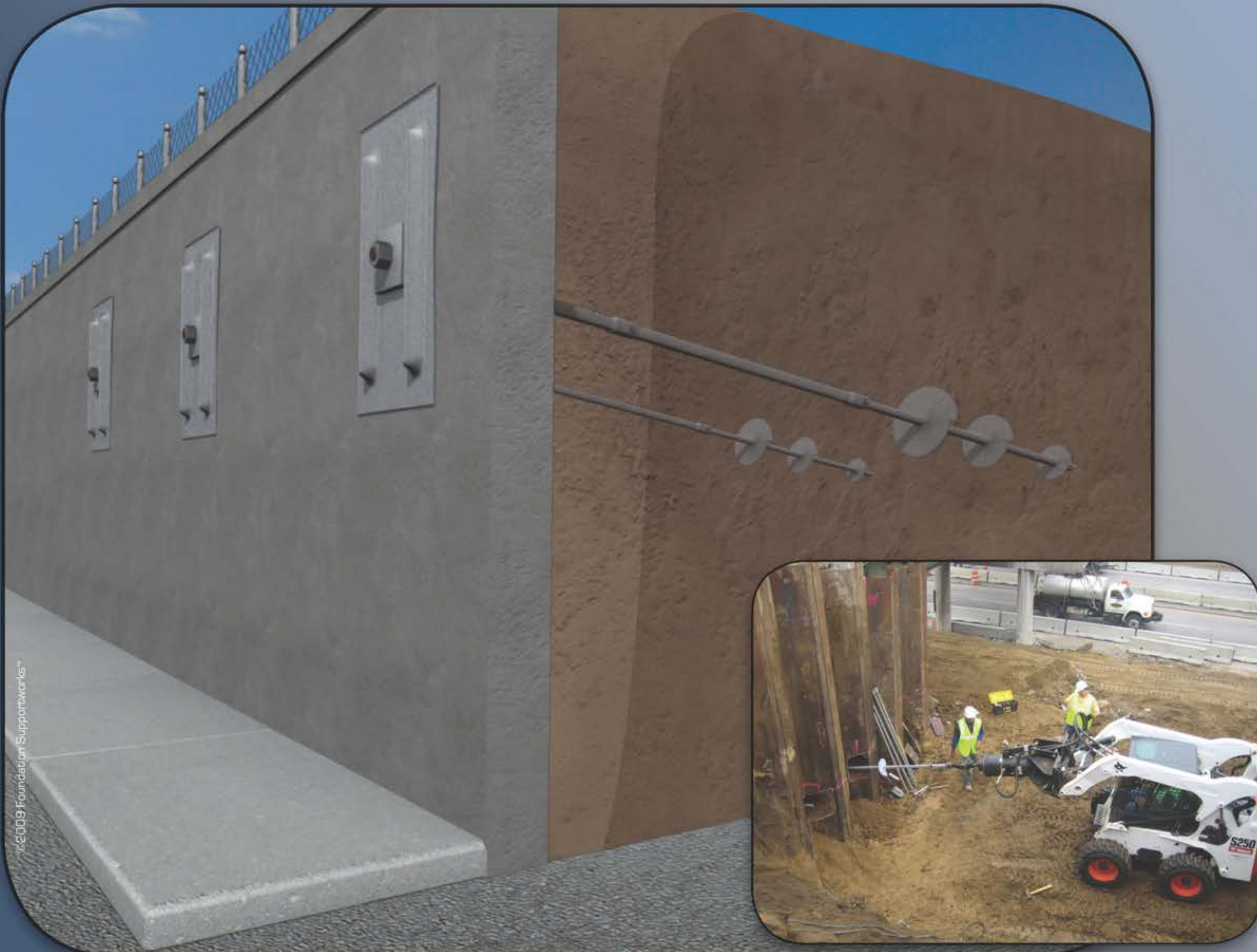
(2) - Listed allowable capacities are based on continuous lateral soil confinement in soils with SPT blow counts ≥ 4. Piles with exposed unbraced lengths or piles placed in weaker or fluid soils should be evaluated on a case by case basis by the project engineer.

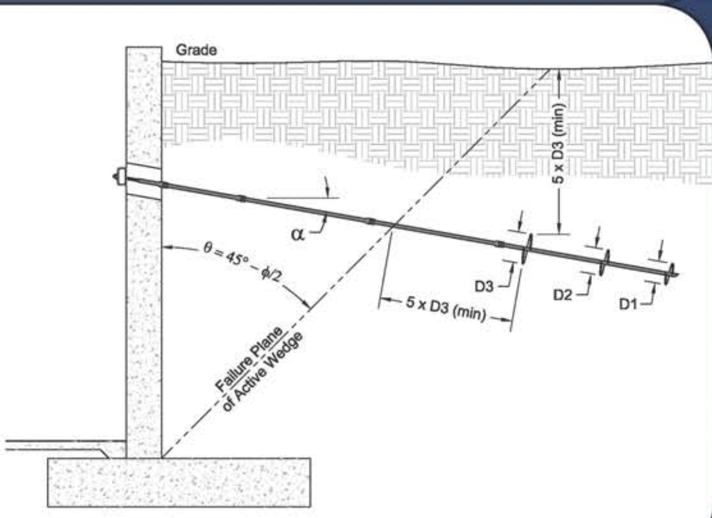
(3) - Listed allowable capacities are for the specific shaft/bracket combination shown. System capacities should also not exceed the torque-correlated soil capacity achieved during installation.

(4) - The use of a 48" sleeve in most cases is impractical due to the potential for coupler interference. A 48" sleeve should only be used with pier extensions of sufficient length and when the coupler location can be well controlled.

(5) - Capacities shown with adhesive anchors utilize six Ø5/8" B7 threaded rods with Simpson AT adhesive installed to a minimum embedment of 7.5" into concrete with a minimum compressive strength f'c = 2,500 psi.

HELICAL ANCHORS AND TIEBACKS





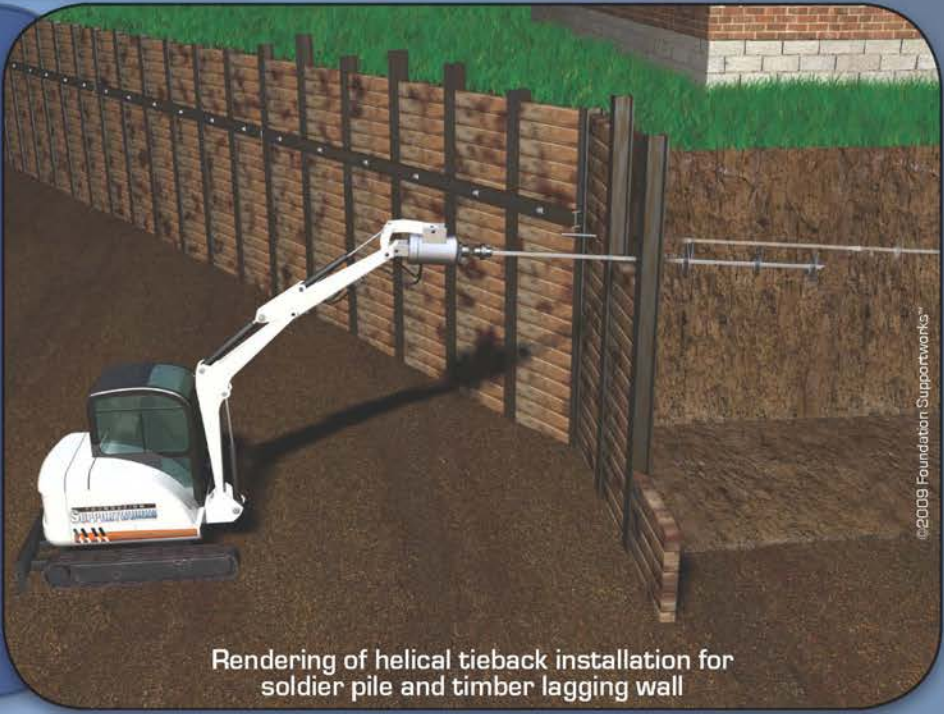
Wall stabilization, earth retaining, or embankment stabilization projects often utilize helical tiebacks or helical soil nails as system components. Helical tiebacks and helical soil nails may consist of either hollow round shaft or solid square shaft, although square is more common due to its socket-and-pin style coupling (quick connection) and the ability to penetrate further into the soil with a similar amount of installation torque than a comparably-sized round shaft. The end of the shaft is typically fitted with an adaptor to transition the shaft to threaded rod. Plate brackets can be cast into the concrete of a poured concrete wall or mounted to the face of an existing concrete wall, sheet pile wall, or soldier beam and lagging wall. Walers may also be considered to more uniformly spread the tieback or soil nail load to the wall.

HELICAL ANCHORS AND TIEBACKS

FOUNDATION SUPPORTWORKS™

Helical anchors/tiebacks are commonly used in tension applications to provide either temporary or permanent lateral or tie-down support for applications including:

- Earth retention systems such as concrete retaining walls, soldier pile and timber lagging and sheet piling
- Seismic restraint for foundation uplift and lateral support systems
- Guy anchor support for power line and communication towers
- Sea walls and marine bulkhead support



Rendering of helical tieback installation for soldier pile and timber lagging wall

INSTALLATION METHODS

Helical foundation systems are an extremely versatile deep foundation alternative that can be installed with hand-held equipment, mini-excavators, skid steers, backhoes, or tracked excavators, so the equipment can be sized to fit the project.

Mini-excavator


Excavator


Hand-held equipment


Backhoe

Skid steer

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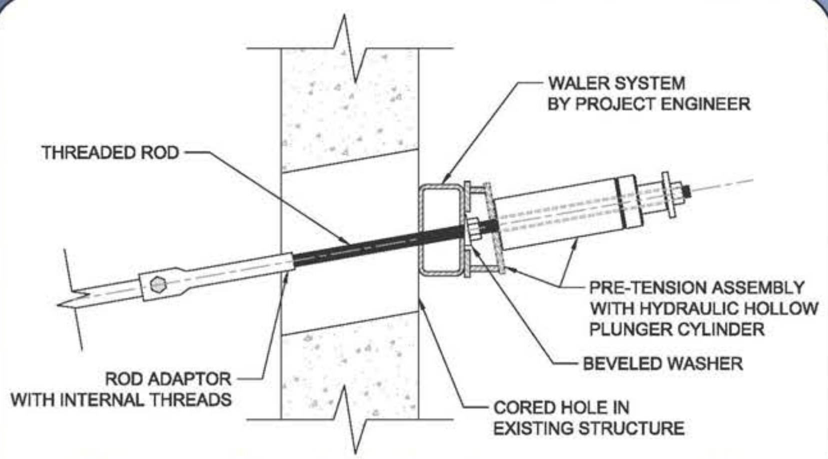
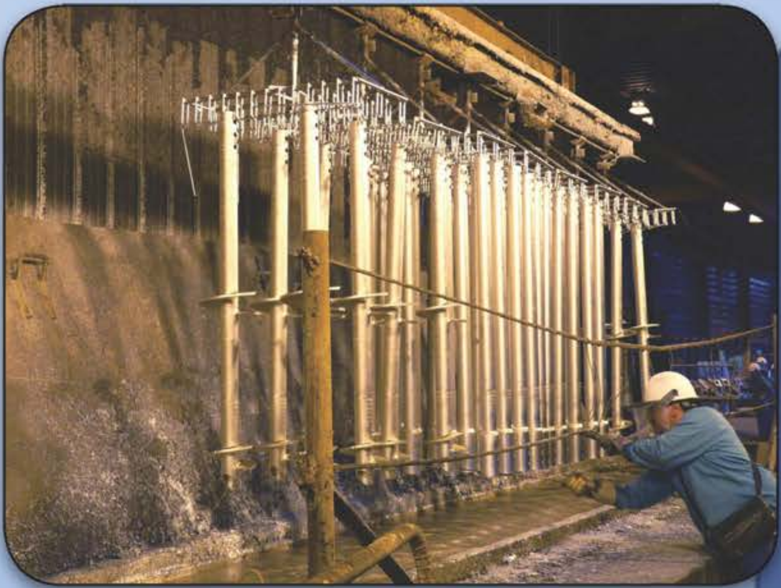
▶ PRE-TENSIONING

Foundation Supportworks™ recommends that all helical anchors and tiebacks (excluding soil nails) be pre-tensioned following installation. Pre-tensioning to the design working load minimizes deflection of the anchors and structure as the anchors are put into service and the soil strength around the helix plates is mobilized. Anchors can be "pull tested" or load tested to typically two (2) times the design working load or more to identify the ultimate system capacity, better assess soil conditions and soil/anchor interaction, and validate design assumptions and parameters.



Schematic of helical tieback and pre-tension assembly


Pre-tensioning helical tiebacks



▶ CORROSION DISCUSSION

Corrosion is a very common point of discussion for many specifiers who are considering the use of helical foundation systems. It is certainly a fair question, and although corrosion is a very real and complex topic that needs to be addressed by anyone who designs steel products for use underground or out in the elements, it is actually very rare that losses due to corrosion will govern the design of a helical foundation system. The reason for this has to do with the way helical foundation systems are installed. There is typically much more steel required to resist the torsion forces during installation than is required to resist the axial forces that the pier will resist while in service. ICC-ES AC-358 addresses the issue of corrosion and quantifies the amount of corrosion loss that needs to be considered for any helical product seeking evaluation, and Foundation Supportworks designs their products with these criteria in mind. More specific and detailed information about corrosion is available in the FSI Technical Manual.

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