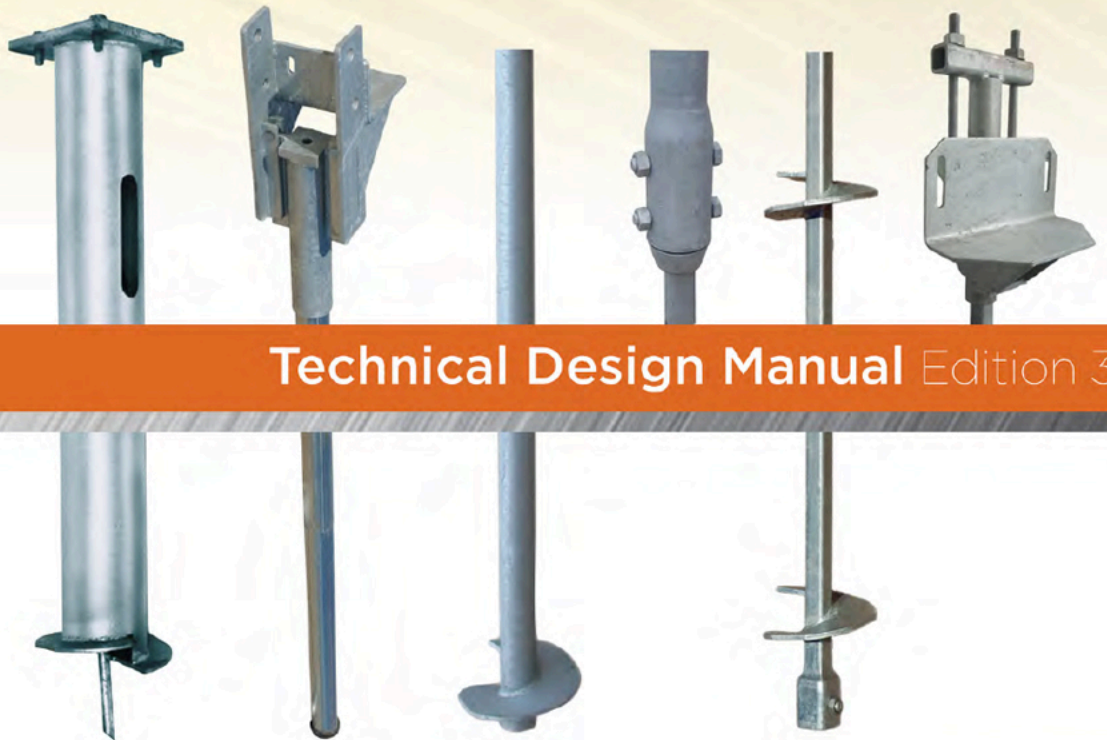


CHANCE™

LATLAS™



Technical Design Manual Edition 3





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INTRODUCTION



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SYMBOLS USED IN THIS SECTION

FS	Factor of Safety	1-4
ASTM.....	American Society for Testing and Materials	1-6
BOCA	Building Officials and Code Administrators International	1-6
ICBO.....	International Conference of Building Officials	1-6
SBCCI	Southern Building Code Congress International	1-6
ICC	International Code Council	1-6
PISA.....	Power Installed Screw Anchor	1-9
RR	Round Rod	1-9
SS.....	Square Shaft	1-9
HS.....	High Strength	1-10
PIF.....	Power Installed Foundation	1-10
SLF.....	Street Light Foundation	1-10
T/C.....	Tension/Compression	1-11
ICC-ES.....	ICC Evaluation Service, Inc.	1-13
kips.....	Kilopound	1-11

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

Hubbell Power Systems, Inc., shall not be responsible for, or liable to you and/or your customers for the adoption, revision, implementation, use or misuse of this information. Hubbell, Inc., takes great pride and has every confidence in its network of installing contractors and dealers.

Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

DEFINITION of ATLAS RESISTANCE® PIERS

The ATLAS RESISTANCE® Pier utilizes the weight of the structure as its reaction system to drive or push the pipe pier sections into the soil. Hubbell/CHANCE® has developed a lasting solution for many distressed foundation problems through its patented and tested ATLAS RESISTANCE® Pier System. The pier is an assembly of structural steel components that include a pier head assembly attached to the foundation or slab, which is then mounted on a steel pier that is installed to bedrock or firm bearing stratum. The unique friction reduction collar on the



lead section of the pier reduces skin friction on the pier pipe during installation. The pier capacity is primarily from end bearing on a hard/dense soil stratum. The ATLAS RESISTANCE® Pier has been successfully driven to depths of 200 feet to ensure proper and verified support.

Hubbell Power Systems, Inc. offers a broad range of applications for ATLAS RESISTANCE® Piers, including foundation underpinning and slab underpinning applications.

The ATLAS RESISTANCE® Pier is a manufactured, two-stage product designed specifically to produce structural support strength. First, the pier pipe is driven to a firm bearing stratum; then the lift equipment is typically combined with a manifold system to lift the structure (if required). This procedure provides measured support strength. Piers are spaced at adequate centers where each pier is driven to a suitable stratum and then tested to a force greater than required to lift the structure. This procedure effectively load tests each pier prior to lift and provides a measured Factor of Safety (FS) on each pier at lift.

Workspace is not normally a problem when using ATLAS RESISTANCE® Piers. They can be installed using portable equipment in an area that measures approximately three feet square. The pier may be installed from the interior or on the exterior of the footing.



HISTORY of PUSHED STEEL PILE SYSTEMS

The history of piling systems extends back to the ancient Greek, Roman and Chinese societies. Although numerous methods and materials have been utilized throughout the centuries, modern construction methods and practices have mandated the repair and remediation techniques of today's structures. The use of excavated foundations, footings, walls and beams, although providing adequate support in some soil conditions, have proven to be less desirable in a multitude of soil and site profiles. Fill areas, compressible soils, organics and expansive soils offer a greater challenge in the long term stability of foundations and are an underlying cause of billions of dollars of structural remedial repairs worldwide. The need for deep foundation underpinning systems increased dramatically in the 20th century with the building booms and growth in metropolitan areas.



In 1896, Jules Breuchaud, a contractor and civil engineer residing in New York, patented an “improved method of underpinning the walls of existing buildings” by a system of driving hollow, tubular column sections to bedrock or other firm strata using hydraulic jacks and a transverse beam system. Two sets of columns driven at opposite sides of the wall and beneath a transverse beam or beams utilized “the superincumbent weight of the building to resist the pressure of the hydraulic jacks, whereby the latter exerts a very powerful force in driving the column sections to bearing strata”. This method allowed for permanent or temporary support and raising or lowering of structures by patent definition.

In 1897, Richard S. Gillespie, another New York entrepreneur, patented a similar method of underpinning existing buildings by means of a reaction, or “pressure-resisting” column that provided the reaction force to drive “cylindrical columns” using a system of cantilevered beams, tie-rods and hydraulic rams restrained to the reaction column to allow for sinking pipe sections to bearing strata for support. This cantilevered approach allowed for placement of pipe supports beneath the middle of the building wall in lieu of the twin-column method developed by Breuchaud and also provided a method for driving deep foundation piles for new construction.

Another substantial advancement was developed and patented by Lazarus White, again of New York, in 1917. White addressed long-term stability issues encountered in previous similar methods by introducing the practice of pre-loading or as he termed it “the first or temporary load” encountered from the reaction during pushing the pipe against the structure load to a pre-determined capacity equal to 150% of the required load which is consistent with the installation methodology ATLAS RESISTANCE® Piers use today. Additionally, White also documented theories of the soil “pressure bulb” created at the pile tip which assumes compression of the soil

beyond the periphery of the pile for contributing to “a load in excess of that attributable to the resistance of the area of the end of the pile”.

One early documented adaptation incorporating the use of a steel, eccentrically loaded bracket with pushed piles as a load transfer method was revealed in a 1959 patent application by Guy Henry Revesz and Jack C. Steinsberger of Illinois. This patent, which was recognized in 1961, cited references to the early work of Breuchaud and Gillespie. The method of 150% pre-loading which was prevalent in the White Patent of 1917 is also a standard criterion in this 1961 patent methodology. Numerous similar patents for pushed or jacked piers surfaced in the 60’s and 70’s, further extending the work of these early pioneers.

APPLIED RESEARCH and DEVELOPMENT

The development of the ATLAS RESISTANCE® Pier system early in the 1980’s created new opportunities for building owners to reclaim the hard-earned equity of their structure’s previously de-valued state as a result of settlement. Since the ATLAS RESISTANCE® Pier is designed to actually restore the structural integrity and original elevation, building values and salability are usually recovered. Their two stage installation method provides

validation of load capacity along with a verifiable Factor of Safety for each pier installed.

Essentially, every single pier is load tested during the installation process. The friction reduction collar on the lead pier section reduces skin friction during installation which allows less driving force to be required to reach the bearing stratum. From the early three-piece ATLAS RESISTANCE® Pier System patent, numerous products and specialty equipment have been developed to serve the industry. The ATLAS RESISTANCE® 2- Piece, Plate Pier, Continuous Lift and Pre-Drilled systems represent the flexibility in design and application of the ATLAS RESISTANCE® product line. New applications and modifications of these systems are continually in a state of expansion and growth to meet the needs of the deep foundation industry and to maintain the “state of the art” status and reputation of the ATLAS RESISTANCE® Product line.

ATLAS RESISTANCE® Piers have earned the support of the engineering community through years of focus on engineering, preliminary design, continuing education through formal training and overall team effort philosophy of Hubbell Power Systems, Inc., its application engineers and its installing contractor force. The broad Hubbell Power Systems, Inc. product line is a direct result of the effort and interaction of innovative

engineers, installing contractors and owners to provide sound, economical solutions to structure settlement in a multitude of environments throughout the country.

TESTING and CODE COMPLIANCE

ATLAS RESISTANCE® Pier products have been subjected to full scale load tests under actual field conditions to determine their ultimate capacity. These tests were designed, conducted and certified under the direction by Dr. David C. Kraft, Ph.D., PE. The field load tests were carried out in close conformance to ASTM D1143-81, Piles under Static Axial Compressive Load. These field load tests were conducted in Independence, Missouri between June 3, and July 6, 1989.

ATLAS RESISTANCE® Models AP-2-3500.165 and AP-2-3500.165(M) comply with the structural provisions of the most recent editions of the Building Officials and Code Administrators International (BOCA) National Code, International Conference of Building Officials (ICBO) Uniform Code, Southern Building Code Congress International (SBCCI) Standard Code and the 2000 International Building and Residential Codes of the International Code Council (ICC) with the new 2002 Accumulative Supplement. A copy of this evaluation report, NER-579, is available online at www.abchance.com.

INTRODUCTION





APPLICATIONS

ATLAS RESISTANCE® Piers are used primarily for underpinning and the repair of residential and commercial buildings, retaining structures and slabs. They can be installed in either interior or exterior locations. They have been used to repair equipment and machinery foundations, warehouse buildings, tower foundations, etc. Special remedial repair brackets can be connected to either the bottom or side of an existing foundation. They can also be connected to the sides of circular or flat building columns. ATLAS RESISTANCE® Piers not only stop settlement, but can also be used to raise the structure, thus closing cracks and correcting other structural flaws resulting from settlement and/or ground movement. The design process should involve professional engineering input. Specific information involving the structure, soil characteristics and foundation conditions must be evaluated and incorporated into the final design.

ADVANTAGES of ATLAS RESISTANCE® PIERS

The advantages of ATLAS RESISTANCE® Piers are similar in nature to those cited later in this section for CHANCE® Helical Piles/Anchors. They are used when a deep foundation solution is required. They are installed with light weight, portable equipment that allows for installations in limited access areas and in low overhead conditions. Their installation is not weather dependent. They are ideal in contaminated soil areas, since no soil has to be removed for installation. Table 1-1 summarizes some of the advantages of ATLAS RESISTANCE® Piers.

INTRODUCTION

ATLAS RESISTANCE® PIER ADVANTAGES, TABLE 1-1

Summary of ATLAS RESISTANCE® Pier Advantages	
<ul style="list-style-type: none"> • No need for concrete to cure • Fast turnkey installation • Immediate loading • Equipment portability • Pre-engineered system • Easily field modified • On site load test on each pier • Two stage installation for load capacity checks 	<ul style="list-style-type: none"> • All weather installation • Solution for: <ul style="list-style-type: none"> - Restricted access sites - High water table - Weak surface soils • Environmentally friendly • No vibration • No spoils to remove



DEFINITION of HELICAL PILES/ANCHORS

The helical pile/anchor is basically a deep foundation system used to support or resist any load or application. Installed by mobile equipment ranging in size from lightweight units to heavier units depending on the load requirements, it can be loaded immediately. The helical pile/anchor's elegant simplicity is its greatest asset. Its mechanical design and manufacture balance the capacities of its three basic parts and maximize the efficient use of their material.

Essential Elements:

1. At least one bearing plate (helix)

Dies form each steel bearing plate into a true helix. The plates are formed in a true helical shape to minimize soil disturbance during installation (as opposed to the inclined plane of an auger which mixes soil as it excavates). Properly formed helical plates do not measurably disturb the soil. The helical bearing plates transfer the load to the soil bearing stratum deep below the ground surface. Hubbell Power Systems, Inc. defines "deep" as five helix diameters vertically below the surface where the helical plate can develop full capacity of the plate-to-soil interaction.

2. A central shaft

During installation, the central steel shaft transmits torque to the helical plate(s). The shaft transfers the axial load to the helical plate(s) and on to the soil bearing stratum. Theoretically, the shaft needs to be larger than the shaft material's allowable stress. Realistically, the shaft also needs to be strong enough to resist the torque required for installation and large enough in section for the soil to resist buckling, if used in a compression application.

3. A termination

The termination connects the structure to the top of the helical pile/anchor transferring the load down the shaft to the helical plate(s) to the bearing soil. To evenly distribute the structure load to the helical piles/anchors, the termination may be a manufactured bracket or an attachment produced on site as designed by the structural engineer. Such aspects dictate the termination's configuration as a function of its application and may range from a simple threaded bar to a complex weldment, as is appropriate to interface with the structure.

HISTORY and SCIENCE of CHANCE® HELICAL PILES/ANCHORS

In 1833, the helical pile was originally patented as a "screw pile" by English inventor Alexander Mitchell. Soon after, he installed screw piles to support lighthouses in tidal basins of England. The concept also was used for lighthouses off the coasts of Maryland, Delaware and Florida.

Innovations of the helical pile/anchor have been advanced by both its academic and commercial advocates. Considerable research has been performed by public and private organizations to further advance the design and analysis of helical piles and anchors. A partial list of publications related to helical pile research is included at the end

of this chapter. Much of the research was partially funded or assisted by Hubbell Power Systems, Inc. Contributions of financial, material and engineering support for research ventures related to helical piles is continued today by Hubbell Power Systems, Inc.

Today, readily available hydraulic equipment, either small or large, can install helical pile/anchors almost anywhere. Backhoes, skid-steer loaders and mini-excavators are easily fitted with hydraulically driven torque motors to install helical pile/anchors in construction sites inaccessible by the larger equipment required for other deep foundation methods. According to site conditions, installation equipment can include guided-head and articulated-head torque-head machinery, self-propelled, carrier-mounted, tracked, wheeled or floating.

The following summarizes a short list of Hubbell Power Systems, Inc. contributions to the helical pile/anchor industry. In 1940, the A.B. Chance Company sold the first commercially offered helical anchor tension application. It was installed by hand using a small tubular wrench. Other early developments include soil classifying measurement devices.

- **PISA® (Power Installed Screw Anchors)**

In the late 1950's, the A.B. Chance Company introduced the patented PISA® system. This coincided with the invention of truck-mounted hole-digging equipment following World War II. The PISA® system has become the worldwide method of choice for guying pole lines of electric and telephone utilities.

The PISA® system's all-steel components include one or two helix plates welded to a square hub, a rod threaded on both ends, a forged guy wire eye nut, and a special installing wrench. The square-tube anchor wrench attaches to the Kelly bar of a digger truck, fits over the rod, engages the helical hub and typically installs a PISA® anchor in 8 to 10 minutes. Rod and wrench extensions may be added to reach soil layers which develop enough resistance to achieve capacity. PISA® rods come in 5/8", 3/4" and 1" diameters.

Through A.B. Chance Company testing and close contact with utilities, the PISA® anchor family soon expanded to develop higher strengths capable of penetrating harder soils including glacial till. This quickly gave rise to the development of CHANCE® Helical Piles/Anchors with higher capacities and larger dimensions.



More recent developments include the SQUARE ONE® (1980) and the TOUGH ONE® (1989) patented guy anchor families with 10,000 and 15,000 ft-lb installing torque capacities. Unlike previous PISA® designs, these anchor designs are driven by a wrench that engages inside, rather than over, their welded socket hubs. Both use the PISA® extension rods with threaded couplings.

- **Round Rod (RR) Anchors**

In 1961, the A.B. Chance Company developed extendable Type RR multi-helix anchors, originally for use as tiedowns for underground pipelines in poor soil conditions on the Gulf of Mexico coast. These anchors are not driven by a wrench; instead, installing torque is applied directly to their 1-1/4" diameter shafts. Type RR anchors worked well in weak surficial soils, but their shaft (although extendable by plain shafts with bolted upset couplings) did not provide enough torque strength to penetrate very far into firm bearing soils.

- **Square Shaft (SS) Anchors**

Development of a high-torque, shaft-driven, multi-helix anchor began in 1963, culminating in the introduction of CHANCE® Type SS 1 1/2" Square Shaft multi-helix anchors in 1964-65. The SS anchor family since has expanded to include higher-strength 1-3/4", 2" and 2-1/4" square shafts. With the acquisition of Atlas Systems, Inc., in 2005, the Type SS product

line has been expanded to include 1-1/4" square shafts. Extension shafts with upset sockets for the 1-1/4", 1-1/2", 1-3/4", 2" and 2-1/4" square shafts also lengthen these anchors to penetrate most soils at significant depths for many civil construction applications including guying, foundations, tiebacks and more recently, soil nails (the CHANCE SOIL SCREW® Retention Wall System, 1997).

- **High Strength (HS) Anchors/Piles [now called Round Shaft (RS) Piles]**

Later in the 1960's, Type HS anchors developed first for high-torque guying requirements later were applied as foundation helical piles for utility substations and transmission towers. The HS anchor family has 3-1/2" pipe shafts which may be lengthened by extensions with swaged couplings. HS anchors now are used for a wide array of foundation applications. The Type HS Piles/Anchors are now referred to as Type RS Piles/anchors. Hubbell Power Systems, Inc. now offers 2-7/8" (RS2875.203, RS2875.276), 4-1/2" (RS4500.337), 6" (RS6625.280) and 8" (RS8625.250) pipe shafts in addition to the 3-1/2" (RS3500.300).

- **Power Installed Foundation (PIF) Anchors/Piles**

Also launched in the 1960's were non-extendable anchors termed Power Installed Foundations. PIF sizes and load capacities support requirements for foundations that support a broad range of equipment, platforms and field enclosures. Most versatile are the 5-ft to 10-ft-long PIFs with pipe shafts of 3-1/2", 4", 6-5/8", 8-5/8" and 10-3/4" diameters, each with a single helix of 10", 12", 14" or 16" diameter. Integral base plates permit direct bolt-up connections on either fixed or variable bolt-circle patterns.

Bumper post anchors are similar to the 3 1/2"-shaft PIF, but with fence-type caps instead of base plates, to serve as traffic barriers around booths, cabinets, doorways, etc. One with a 2-3/8" pipe shaft 69" long is called a Square Drive Foundation for its 2"-square drive head. The solid head is internally threaded for adding a straight stud or adjustable leveling pad after installation.

- **Street Light Foundation (SLF) Anchors/Piles**

In 1972, CHANCE® Street Light Foundations (SLF) were introduced. Anchors with pipe shaft diameters of 6-5/8", 8-5/8" and 10-3/4" in fixed lengths of 5, 8 and 10 feet. Complete with an internal cableway, these foundations with bolt-up base plates deliver the quick solution their name implies and now are used to support similar loads for a variety of applications.



- **Helical Pier Foundation Systems/Piles**

In 1985, CHANCE® patented products for repairing foundations of all residential and commercial buildings were introduced. Originally based on Type SS helical anchors, its special foundation repair brackets transfer structural loads to stable soil strata below weak surface conditions. Since then, the product also has been used to deepen foundations for new construction by installing the helical piles at intervals between footing forms prior to pouring reinforced concrete.

- **CHANCE HELICAL PULLDOWN® Micropiles**

Developed in 1997, for sites with especially weak surface soils, this patented innovative application of the helical pile integrates portland-cement-based grout to stiffen the shaft. By "pulling down" a special flowable grout as the foundation is screwed into the soil, the result is a pile with both a friction-bearing central shaft and end-bearing helical plates in competent substrata. Where needed for poor surface conditions, this performance combination converts sites previously deemed as "non-buildable" to usable sites suited for not only building construction but also telecom tower foundations in areas inaccessible by equipment utilized for other deep foundation

methods. It employs SS, RS and combinations of these two types of helical piles.

- **Large Diameter Pipe Piles (LDPP)**

To meet an industry need for helical piles with higher tension/compression capacities and larger bending resistance, the large diameter pipe pile research project was initiated in 2007. The research culminated in product offerings including extendable large diameter piles with a box coupling system capable of installation torques as high as 60,000 ft-lbs and compression capacities of 300 kips.

APPLIED RESEARCH and DEVELOPMENT

In addition to products developed for specific applications, significant contributions to the applied science of helical piles and anchors by Hubbell Power Systems, Inc. have been achieved. Among the various subjects which have expanded the body of knowledge are:

- **CHANCE® Civil Construction Soil Classification**

In 1945, A.B. Chance Company listed the first earth anchoring manual, which classified soils according to holding capacities as related to proper anchor selection. At sites where soil data was available, either by sample excavation or some rudimentary means of probing subsurface strata, this chart imparted a valuable basis for recommending the proper helical pile or anchor for a given load.

CHANCE® CIVIL CONSTRUCTION SOIL CLASSIFICATION , TABLE 1-2

Class	Common Soil-Type Description	Geological Soil Classification	Probe Values in/lbs (nm)	Typical Blow Count N per ASTM D1586
0	Sound hard rock, unweathered	Granite, Basalt, Massive Limestone	N.A	N.A
1	Very dense and/or cemented sands; coarse gravel and cobbles	Caliche, (Nitrate-bearing gravel/rock)	750-1600 (85-181)	60-100+
2	Dense fine sands; very hard silts and clays (may be preloaded)	Basal till; boulder clay, caliche; weathered laminated rock	600-750 (68-85)	45-60
3	Dense sands and gravel; hard silts and clays	Glacial till; weathered shales, schist, gniess and siltstone	500-600 (56-68)	35-50
4	Medium dense sand and gravel; very stiff to hard silts and clays	Glacial till; hardpan; marls	400-500 (45-56)	24-40
5	Medium dense coarse sands and sandy gravels; stiff to very stiff silts and clays	Saprolites, residual soils	300-400 (34-45)	14-25
6	Loose to medium dense fine to coarse sands to stiff clays and silts	Dense hydraulic fill; compacted fill; residual soils	200-300 (23-34)	7-14
**7	Loose fine sands; Alluvium; loess; medium-stiff and varied clays; fill	Flood plain soils; lake clays; adobe; gumbo, fill	100-200 (11-23)	4-8
**8	Peat, organic silts; inundated silts, fly ash very loose sands, very soft to soft clays	Flood plain soils; lake clays; adobe; gumbo, fill	less than 100 (0-11)	0-5

Class 1 soils are difficult to probe consistently and the ASTM blow count may be of questionable value.

* Probe values are based on using CHANCE® Soil Test Probe, catalog number C309-0032

** It is advisable to install anchors deep enough, by the use of extensions, to penetrate a Class 5 or 6, underlying the Class 7 or 8 Soils.



• **Torque-to-Capacity Relationships**

Installation torque-to-load capacity relationship is an empirical method that the A.B. Chance Company originally developed in the 1960's. The idea was that the installation energy (torque) required to install a helical pile/anchor can be correlated to its ultimate load capacity in soil. The analogy is similar to screwing a wood screw into a piece of wood. It takes more torsional energy to screw into dense wood, such as oak, than it does to screw into a soft wood, such as pine. Likewise, a wood screw in oak will require more effort to pull out than the same wood screw in pine. The same is true for helical piles/anchors in soil. Dense soil requires more torque (more energy) to install compared to a soft soil; and likewise dense soil will generate higher load capacity compared to a soft soil.

For the torque correlation method to work, torque must be measured. Hubbell Power Systems, Inc. Engineers have developed both mechanical and electronic indicators over the years, many of which are commercially available for torque measurement in the field. The most recent addition to the product line is the C3031578 Digital Torque Indicator, which features a continuous reading digital readout of installation torque up to 30,000 ft-lb. The Digital Torque Indicator is also available with a wireless remote display and a data logger. The data logger records torque and other installation data that is used as a permanent record.

• **Soil Mechanics Principles**

In the 1970s and early 1980s, changes in design philosophy led Hubbell Power Systems, Inc. Engineers to recognize that a deep buried plate (i.e., pile/anchor helix) transferred load to the soil in end-bearing. Theoretical capacity could then be calculated based on Terzaghi's general bearing capacity equation. The individual bearing method, discussed in detail in Section 5, calculates the unit bearing capacity of the soil and multiplies it by the projected area of the helix plate. The capacity of individual helix plate(s) is then summed to obtain the total ultimate capacity of a helical pile/anchor. Today, the individual bearing method is commonly used in theoretical capacity calculations and is recognized as one method to determine helical pile capacity in the International Building Code (IBC).



• **100+ Years of Field Test Data**

Hubbell Power Systems, Inc. Engineers continuously prove theory by conducting literally thousands of load tests in the field. It has been said that soil occurs in infinite variety of engineering properties can vary widely from place to place. This variability makes in-situ testing a vital part of sound geotechnical engineering judgment. Test results are available from Hubbell Power Systems, Inc. for typical capacity of helical piles/anchors in soil.

• **HeliCAP® Helical Capacity Design Software**

Hubbell Power Systems, Inc. Engineers developed HeliCAP® Helical Capacity Design Software to assist the designer to select the correct helical lead configuration and overall pile/anchor length. It also estimates the installation torque. This program



makes the selection of helical piles/anchors easier and quicker than hand calculations. To obtain a copy of the software, please contact your local Hubbell Power Systems, Inc. Distributor. Contact information for each distributor can be found at www.abchance.com.

- **SELECT-A BASE™ Lighting Base Program**

The SELECT-A BASE™ Lighting Base Program is an on-line program developed in 2009 by Hubbell Power Systems, Inc. Engineers for preliminary foundation selection for roadway, area, and site lighting poles and luminaires. The program incorporates a database of CHANCE® Lighting Bases designed using more than 100 years of research, development and testing of earth anchor systems. The program inputs include loading conditions (wind, moment, and/or lateral), pole/pole arm details and soil data. The software is free and easy to use on-line at www.abchance.com.

- **Inter-Helix Spacing**

Load transfer either above or below the helix plate results in a stress zone within a defined soil volume. For individual bearing to work properly, the helix plates must be spaced far enough apart to avoid overlapping their stress zones. The key is to space the helix plates just far enough apart to maximize the bearing capacity of a given soil. This works to reduce the overall length of the helical pile/anchor and increases the likelihood for all helix plates to be located in the same soil layer; which in turn leads to more predictable torque-to-capacity relationships and better load/deflection characteristics. Through years of research, the Hubbell Power Systems, Inc. Engineers determined that the optimal spacing for helix plates is three diameters. More specifically, the optimum space between any two helical plates on a helical pile/anchor is three times the diameter of the lower helix. Today, all CHANCE® Helical Piles/Anchors are manufactured using the industry standard of three diameter spacing.

- **Industry Standard: Helical Pile/Anchor Form Fits Function**

The helical pile/anchor is not a complex product, but it continues to serve ever-expanding roles in civil construction applications. However, you will probably not find helical piles/anchors mentioned in most foundation engineering textbooks; and as such familiarity with helical piles/anchors is still lacking among most civil and structural engineers with a foundation background. This trend is slowly changing. Since the first edition of this technical manual, helical piles are now listed as a deep foundation system in the 2009 and 2012 editions of the International Building Code. In addition, ICC-ES Acceptance Criteria AC358 for Helical Systems and Devices was published in 2007 and is now on its third revision. Hubbell Power Systems, Inc. was the first manufacturer of helical piles and anchors to obtain evaluation reports from all three model building code agencies – ICBO, BOCA, and SBCCI. Today Hubbell Power Systems, Inc. has evaluation reports for helical products both in the US and Canada. ESR-2794 is an ICC-ES evaluation report that demonstrates Code compliance with the IBC, and CCMC Report 13193-R is an NRC evaluation report that demonstrates Code compliance with the Canadian Building Code. Copies of ICC-ES ESR-2794 and CCMC 13193-R Evaluation Reports are available on www.abchance.com.

- **Instructor’s Curriculum for Foundation Engineering Courses**

In 2012, Hubbell Power Systems, Inc. contracted with Dr. Alan Lutenegger to develop an instructor’s curriculum on helical piles and anchors to be used for foundation engineering courses for undergraduates. The curriculum includes all the information needed for two lectures, design examples and homework. Also included is a Student Guide, which serves as the “textbook” for students.



APPLICATIONS

In its simplest form, the helical pile/anchor is a deep foundation element, i.e., it transfers a structure's dead and live loads to competent soil strata deep below grade. This is the same for any deep foundation element such as driven piles, drilled shafts, grouted tendons, auger-cast piles, belled piers, etc. Therefore, helical piles/anchors can be used as an alternative method to drilled shafts and driven piles. Practical constraints, primarily related to installation, currently limit the maximum design load per helical pile/anchor to 100 kips in tension and 200 kips in compression, which means helical piles/anchors can resist relatively light to medium loads on a per pile/anchor basis, and much heavier loading when used in pile groups. But as is the case with virtually all engineering problems, more than one solution exists. It is the responsibility of the engineer to evaluate all possible alternatives, and to select the most cost-effective solution.

Today, helical piles/anchors are commonly used for residential and light commercial and heavy commercial construction, machinery/equipment foundations, telecommunication and transmission towers, tie-downs for wind and/or seismic forces, and virtually any application where site access is limited or remote. They have become the deep foundation of choice for walkways and boardwalks in environmentally sensitive areas, such as wetlands and protected forestland. In expansive soil areas, helical piles can save money and time when compared to expensive over-excavation and fill options. Helical piles/anchors do have several advantages (see following section) that make them the foundation of choice for many applications including these general categories:

- Machinery/Equipment Foundations
- Limited Access Sites
- Wind and Seismic Loading
- Replacement for Drilled/Driven Piles

ADVANTAGES of CHANCE® HELICAL PILES/ANCHORS

Each project has unique factors that determine the most acceptable foundation system. The following summarizes situations where helical piles/anchors present sensible solutions.

- **Projects Requiring Deep Foundations due to Weak Surface Soil**

Helical piles/anchors are designed as end-bearing piles which transfer loads to competent, load-bearing strata. Helical piles/anchors eliminate high mobilization costs associated with driven piles, drilled shafts or auger-cast piles. They also don't require spoils to be removed and for flowable

CHANCE® HELICAL PILE/ANCHOR ADVANTAGES TABLE 1-3

Summary of CHANCE® Helical Pile/Anchor Advantages	
<ul style="list-style-type: none"> • No need for concrete to cure • Quick, easy turnkey installation • Immediate loading • Small installation equipment • Pre-engineered system • Easily field modified • Torque-to-capacity relationship for production control 	<ul style="list-style-type: none"> • Install in any weather • Solution for: <ul style="list-style-type: none"> - Restricted access sites - High water table - Weak surface soils • Environmentally friendly • No vibration • No spoils to remove

sands, soft clays and organic soils, no casings are required, unlike drilled shafts or caissons. When using the CHANCE HELICAL PULLDOWN® Micropiles, you have not only end-bearing capacity, but also the additional capacity from the friction developed along the grout/soil interface.

• Flooded and/or Poor Surface Conditions

When surface conditions make spread footings impossible and equipment mobilization difficult, helical piles/anchors are a good alternative since installation requires only a mini-excavator, a rubber-tired backhoe or small tracked machine.

• Limited Access

In confined areas with low overhead, helical piles/anchors can be installed with portable equipment. This is particularly useful for rehabilitation work.

• Expansive Soils

The depth of expansive soils from the surface varies, but a typical depth is approximately 10 feet. The bearing plates of a helical pile/anchor are usually placed well below this depth. This means that only the small-cross-section shaft of the helical pile/anchor is affected by the expansive soils. The swell force on the shaft is directly proportional to the surface area between the soil and the shaft, and the swell adhesion value. Since helical piles have much smaller shafts than driven piles or auger-cast piles, uplift forces on helical piles are much smaller. Research by R.L. Hargrave and R.E. Thorsten in the Dallas area (1993) demonstrated helical piles' effectiveness in expansive soils.

• Bad weather installation

Because helical piles/anchors can be installed in any weather, work does not need to be interrupted.

• Contaminated soils

Helical piles/anchors are ideal for contaminated soils because no spoils need to be removed.

• Temporary structures

Helical piles/anchors can easily be removed by reversing the installation process. This makes removal of temporary structures simple.

INTRODUCTION

- Remedial applications

Helical piles can supplement or replace existing foundations distressed from differential settlement, cracking, heaving, or general foundation failure. Patented products such as the CHANCE® Helical Pier Foundation System provide a complete solution. Hubbell Power Systems, Inc. uses patented products to attach the helical piles to existing foundations and either stabilize the structure against further settlement or lift it back to near original condition. This system is installed only by trained, authorized, and certified dealers/installing contractors.

Helical piles are ideal for remedial work since they can be installed by portable equipment in confined, interior spaces. Additionally, there is no need to worry about heavy equipment near existing foundations. And, unlike driven piles, helical piles are vibration-free. The building can continue to operate with little inconvenience to its occupants. Other deep foundation systems such as auger-cast piles disturb the soil, thereby undermining existing foundations.

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SOIL MECHANICS



REVIEW OF SOIL MECHANICS, SOIL BEHAVIOR, & GEOTECHNICAL SITE INVESTIGATIONS SECTION 2

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V	Volume	2-6
S	Degree of Saturation	2-6
e	Void Ratio	2-6
n	Porosity	2-6
γ_d	Dry Unit Weight (Dry Density)	2-6
γ_t	Wet (Total) Unit Weight (Wet Density)	2-6
γ_s	Saturated Unit Weight (Saturated Density)	2-6
γ'	Submerged Unit Weight (Submerged Density)	2-6
S_t	Soil Sensitivity	2-8
SL	Shrinkage Limit	2-7
PL	Plastic Limit	2-7
LL	Liquid Limit	2-7
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$L.I.$	Liquidity Index	2-7
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σ'	Effective Stress	2-11
σ	Total Stress	2-11
u	Pore Water Pressure	2-11
τ_f	Shear Strength	2-13
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SOIL MECHANICS

CFA	Continuous Flight Auger	2-15
HSA.....	Hollow Stem Auger	2-15
GWT	Ground Water Table	2-13
SPT	Standard Penetration Test	2-16
SS.....	Split Spoon	2-17
ST.....	Shelby Tube	2-16
CPT	Cone Penetration Test	2-18
CPTU.....	Piezocone Penetration Test	2-18
q _u	Unconfined Compressive Strength	2-22
UC.....	Unconfined Compression Test	2-22
N.....	Field Blowcount Value from Standard Penetration Test	2-17
DMT	Dilatometer Test	2-19
FVT	Field Vane Test	2-19
RQD	Rock Quality Designation	2-20
USCS.....	Unified Soil Classification System	2-6
VST	Vane Shear Test	2-19

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

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INTRODUCTION

The use of manufactured steel foundation products generally requires a prior geotechnical investigation of the subsurface condition of the foundation soils at the site of a proposed project. In addition to the geotechnical investigation, it is necessary to define the structural load requirements and required Factor of Safety (FS) for use in the overall design approach. CHANCE® Civil Construction manufactures or supplies two main lines of steel foundation products:

- ATLAS RESISTANCE® piers for underpinning and repair of residential and commercial buildings, retaining structures and slabs.
- CHANCE® Helical Piles for new construction and repair of residential and commercial buildings; CHANCE® Helical Tiebacks and a SOIL SCREW® Retention System used in excavation shoring systems, retaining walls and slope stabilization; and CHANCE® Helical Anchors are utilized for communication towers, transmission & distribution power lines, signs, light standards and commercial buildings subject to wind and earthquake load.

SOIL MECHANICS

Terzaghi stated in his book *Theoretical Soil Mechanics* (1943): “. . . the theories of soil mechanics provide us only with a working hypothesis, because our knowledge of the average physical properties of the subsoil and of the orientation of the boundaries between the individual strata is always incomplete and often utterly inadequate. Nevertheless, from a practical point of view, the working hypothesis furnished by soil mechanics is as useful as the theory of structures in other branches of civil engineering.”

Advance planning and careful observation by the engineer during the construction process can help fill the gaps between working hypothesis and fact. The intent of this section of the Design Manual is to provide a basic background or review of soil mechanics so the engineer can develop a useful “working hypothesis” for the design and use of CHANCE® Helical Piles and ATLAS RESISTANCE® Piers.

THE SOIL PROFILE

Rock or soil material, derived by geologic processes, are subject to physical and chemical changes brought about by the climate and other factors prevalent at the location of the rock or soil material. Vegetation, rainfall, freeze/thaw cycles, drought, erosion, leaching, and other natural processes result in gradual but profound changes in the character of the soil over the passage of time. These processes bring about the soil profile.

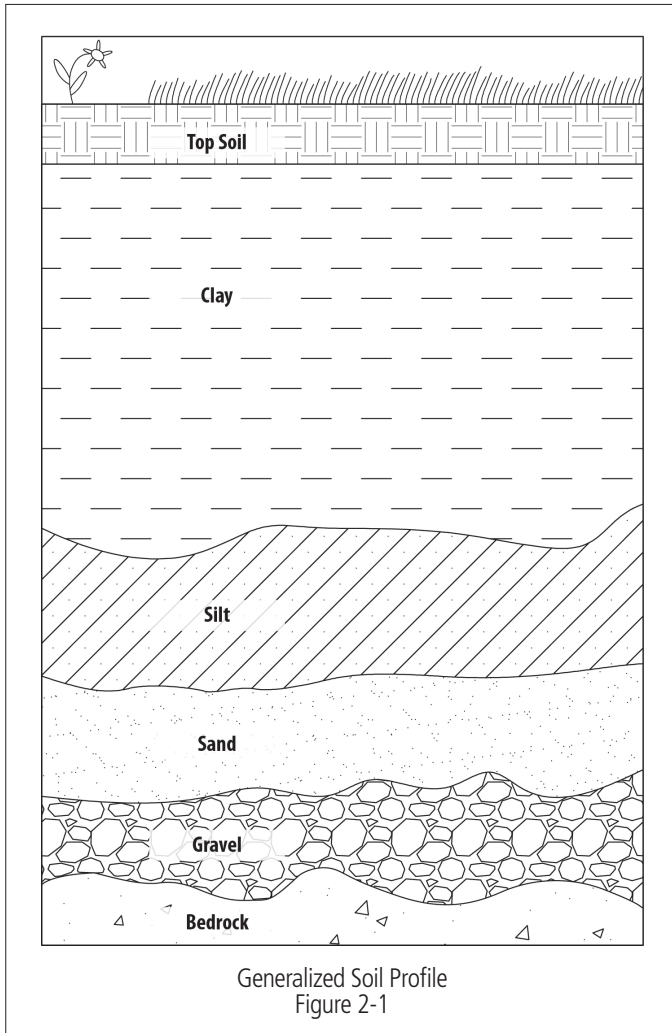
The soil profile is a natural succession of zones or strata below the ground surface. It may extend to various depths, and each stratum may have various thicknesses. The upper layer of the profile is typically rich in organic plant and animal residues mixed with a given mineral-based soil. Soil layers below the topsoil can usually be distinguished by a contrast in color and degree of weathering. The physical properties of each layer usually differ from each other. Topsoil is seldom used for construction. Figure 2-1 shows a typical generalized soil profile.

Deeper layers will have varying suitability depending on their properties and location. It is important to relate engineering properties to individual soil layers in order for the data to be meaningful. If data from several layers of varying strength are averaged, the result can be misleading and meaningless. Equally misleading is the practice of factoring a given soil’s engineering properties for design. This can lead to overly conservative foundation design.

DEFINITION of SOIL

Soil is defined as sediments or other accumulation of mineral particles produced by the physical or chemical disintegration of rock, plus the air, water, organic matter, and other substances that may be included. Soil is typically a non-homogeneous, porous, earthen material whose engineering behavior is influenced by changes in composition, moisture content, degree of saturation, density, and stress history.

SOIL MECHANICS



Generalized Soil Profile
Figure 2-1

The origin of soil can be broken down to two basic types: residual and transported. Residual soil is produced by the in-place weathering (decomposition) of rock by chemical or physical action. Residual soils may be very thick in areas of intense weathering such as the tropics, or they may be thin or absent in areas of rapid erosion such as steep slopes. Residual soils are usually clayey or silty, and their properties are related to climate and other factors prevalent at the location of the soil. Residual soils are usually preferred to support foundations, as they tend to have better and more predictable engineering properties.

Transported or deposited soils are derived by the movement of soil from one location to another location by natural means. The means are generally wind, water, ice, and gravity. The character of the resulting deposit often reflects the modes of transportation and deposition and the source material. Deposits by water include alluvial floodplains, coastal plains, and beaches. Deposits by wind include sand dunes and loess. Deposits by melting ice include glacial till and outwash. Each of these materials has behavioral characteristics dependent on geological origin, and the geological name, such as loess, conveys much useful information. Transported soils – particularly by wind or water – can be of poor quality in terms of engineering properties.

A soil mass is a porous material containing solid particles interspersed with pores or voids. These voids may be filled with air, water, or both. Figure 2-2 shows a conceptual block diagram of relative volumes of air, water, and soil solids in a given volume of soil. Pertinent volumes are indicated by symbols to the left while weights of these material volumes are indicated by symbols to the

right. Figure 2-2 also provides several terms used to define the relative amounts of soil, air, and water in a soil mass. Density is the mass of a unit volume of soil. It is more correctly termed the unit weight. Density may be expressed either as a wet density (including both soil and water) or as a dry density (soil only). Moisture content is the ratio of the weight of water to the weight of soil solids expressed as a percent. Porosity is the ratio of the volume of voids to the total volume of the soil mass regardless of the amount of air or water contained in the voids. Void ratio is the ratio of the volume of voids to the volume of solids.

The porosity and void ratio of a soil depend upon the degree of compaction or consolidation. For a particular soil in different conditions, the porosity and void ratio will vary and can be used to judge relative stability and load-carrying capacity – i.e., stability and load capacity increase as porosity and void ratio decrease. If water fills all the voids in a soil mass, the soil is said to be saturated, i.e., $S = 100\%$.

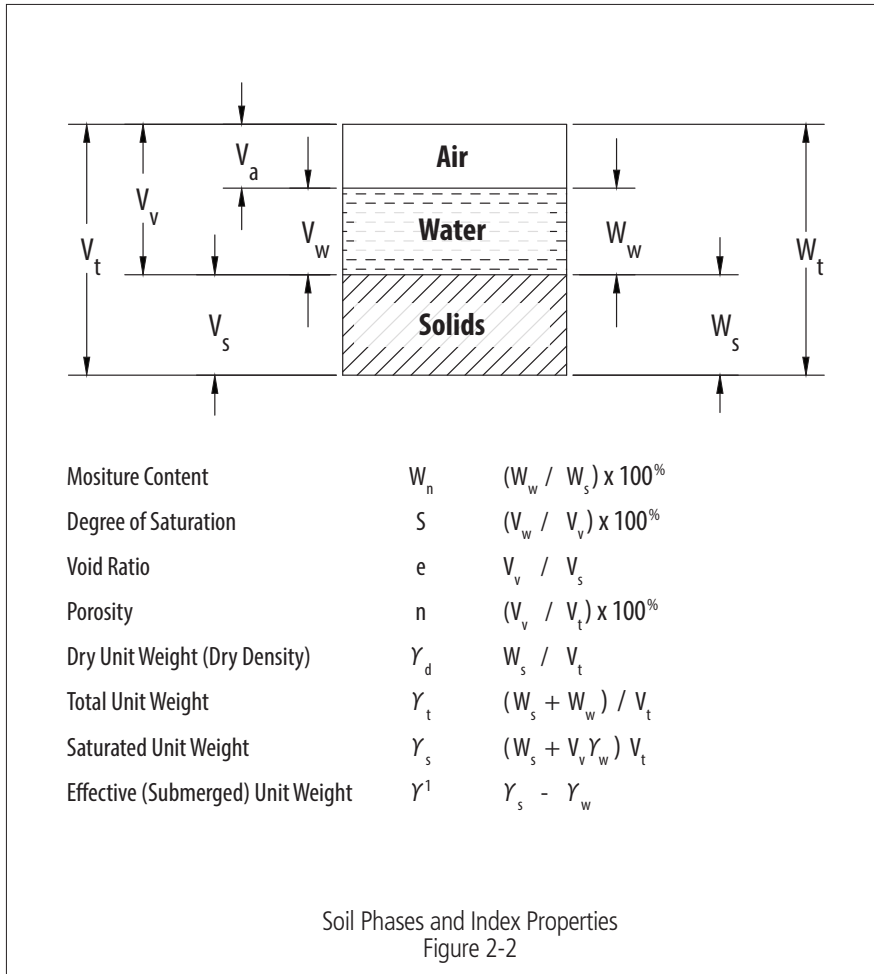
Permeability or hydraulic conductivity is the property of soil that allows it to transmit water. Its value depends largely on the size and number of the void spaces, which in turn depends on the size, shape, and state of packing of the soil grains. A clay soil can have the same void ratio and unit weight as a sand soil, but the clay will have a lower permeability because of the much smaller pores or flow channels in the soil structure. Water drains slowly from fine-grained soils like clays. As the pore water drains, clays creep, or consolidate slowly over time. Sands have high permeability, thus pore water will drain quickly. As a result, sands will creep, or consolidate quickly when loaded until the water drains. After drainage, the creep reduces significantly.

BASIC SOIL TYPES

As stated above, soil is typically a non-homogeneous material. The solid mineral particles in soils vary widely in size, shape, mineralogical composition, and surface-chemical characteristics. This solid portion of the soil mass is often referred to as the soil skeleton, and the pattern of arrangement of the individual particles is called the soil structure.

The sizes of soil particles and the distribution of sizes throughout the soil mass are important factors which influence soil properties and performance. There are two basic soil types that are defined by particle size. The first type is coarse-grained soils. Coarse-grained soils are defined as soil that have 50% or more particles retained by the #200 sieve (0.074 mm). The #200 sieve has 200 openings per inch.

Coarse-grained soils consist of cobbles, gravels, and sands. Coarse-grained soils are sometimes referred to as granular or cohesionless soils. The particles of cohesionless soils typically do not stick together



except in the presence of moisture, whose surface tension tends to hold particles together. This is commonly referred to as apparent cohesion.

The second type of soil is fine-grained soil. Fine-Grained soils consist of soils in which 50% or more of the particles are small enough to pass through the #200 sieve. Typical Fine-Grained soils are silts and clays. Silt particles typically range from 0.074 to 0.002 mm. Clay particles are less than 0.002 mm. It is not uncommon for clay particles to be less than 0.001 mm (colloidal size). Fine-grained soils are sometimes referred to as cohesive soils. The particles of cohesive soils tend to stick together due to molecular attraction.

For convenience in expressing the size characteristics of the various soil fractions, a number of particle-size classifications have been proposed by different agencies. Table 2-1 shows the category of various soil particles as proposed by the Unified Soil Classification System (USCS), which has gained wide recognition.

An effective way to present particle size data is to use grain-size distribution curves such as shown in Figure 2-3. Such curves are drawn on a semi-logarithmic scale, with the percentages finer than the grain size shown as the ordinate on the arithmetic scale. The shape of such curves shows at a glance the general grading characteristics of soil. For example, the dark line on Figure 2-3 represents a "Well-Graded" soil – with particles in a wide range. Well-graded soils consist of particles that fall into a broad range of sizes class, i.e., gravel, sand, silt-size, clay-size, and colloidal-size.

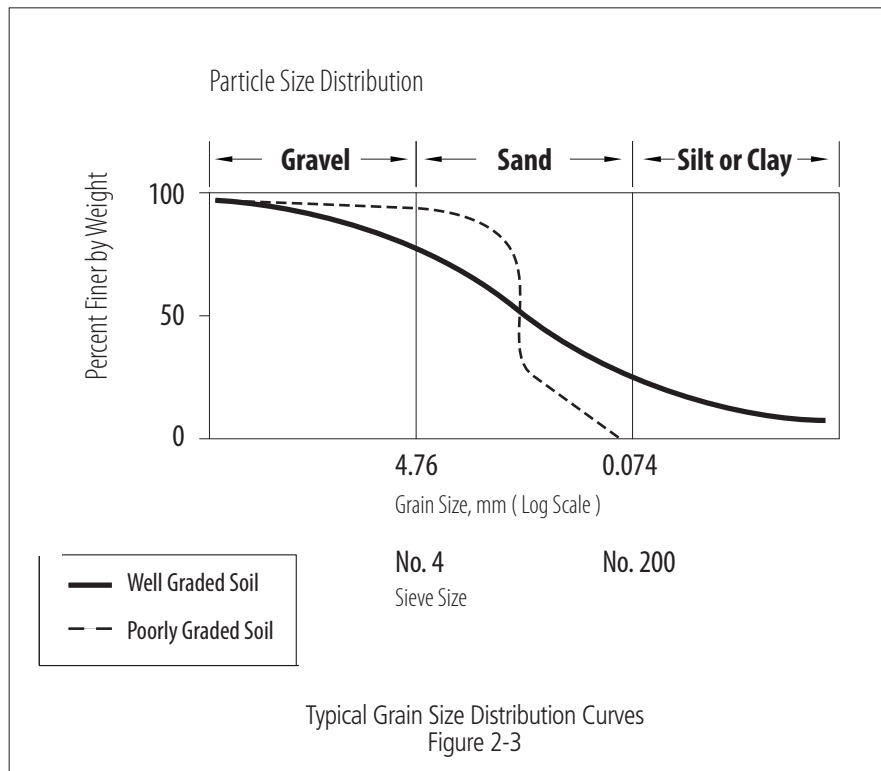
Soil Particle Sizes, Table 2-1

PARTICLE SIZE TERM	FRACTION	SIEVE SIZE	DIAMETER	FAMILIAR REFERENCE
Boulders	---	12" Plus	300 mm Plus	Volleyball
Cobbles	---	3" - 12"	75 - 300 mm	Baseball
Gravels	Coarse	0.75" - 3"	19 - 75 mm	Marbles & Peas
	Fine	No. 4 - 0.75"	4.76 - 19 mm	
Sand	Coarse	No. 10 - No. 4	2 - 4.76 mm	Rock Salt, Table Salt, Sugar
	Medium	No. 40 - No. 10	0.42 - 2 mm	
	Fine	No. 200 - No. 40	0.074 - .042 mm	
Fines (silts and clays)	---	Passing No. 200	0.074 mm	Flour

SOIL CONSISTENCY STATES and INDEX PROPERTIES

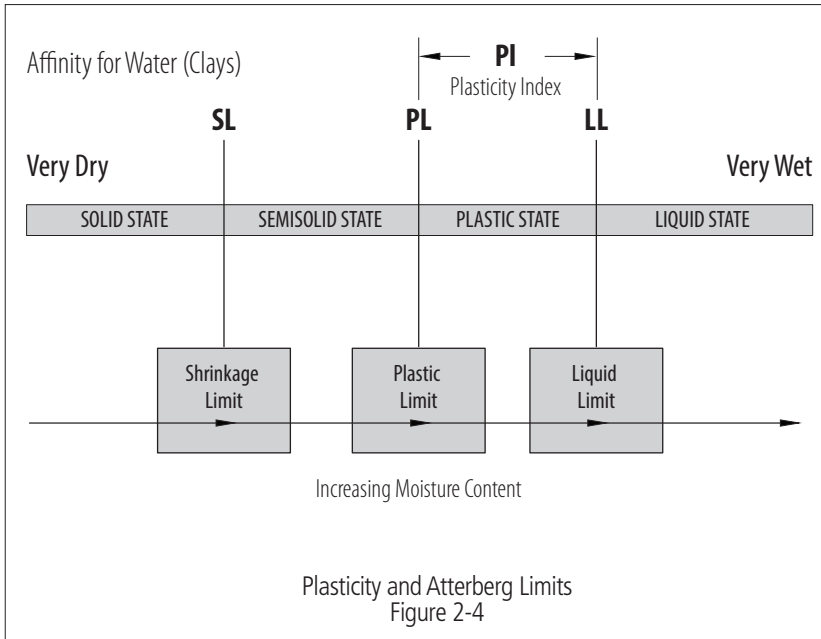
The consistency of fine-grained soils can range from a dry solid condition to a liquid form with successive addition of water and mixing as necessary to expand pore space for acceptance of water. The consistency passes from solid to semi-solid to plastic solid to viscous liquid as shown in Figure 2-4. In 1911, Atterberg, a Swedish soil scientist, defined moisture contents representing limits dividing the various states of consistency. These limits are known as Atterberg Limits. The shrinkage limit (SL) separates solid from semisolid behavior, the plastic limit (PL) separates semisolid from plastic behavior, and the liquid limit (LL) separates plastic from liquid state. Soils with water content above the liquid limit behave as a viscous liquid.

The width of the plastic state (LL-PL), in terms of moisture content, is defined as the plasticity index (PI). The PI is an important indicator of the plastic behavior a soil will exhibit. The Casagrande Plasticity Chart, shown in Figure 2-5, is a good indicator of the differences in plasticity that different fine-grained soils can have. The softness of saturated clay can be expressed numerically by the liquidity index (L.I.) defined as $L.I. = (w_n - P.L.)/(L.L. - P.L.)$. Liquidity Index is a very



useful parameter to evaluate the state of natural fine-grained soils and only requires measurement of the natural water content, the Liquid Limit and the Plastic Limit. Atterberg limits can be used as an approximate indicator of stress history of a given soil. Values of L.I. greater than or equal to one are indicative of very soft sensitive soils. In other words, the soil structure may be converted into a viscous fluid when disturbed or remolded by pile driving, caisson drilling, or the installation of CHANCE® Helical Piles/Anchors, or ATLAS RESISTANCE® Piers.

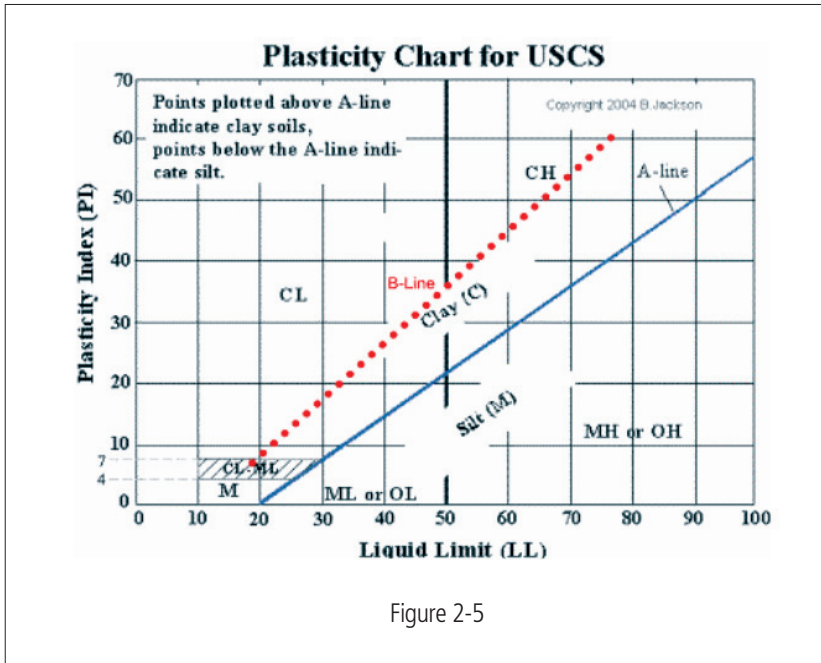
If the moisture content (w_n) of saturated clay is approximately the same as the L.L. ($L.I. = 1.0$), the soil is probably near normally consolidated. This typically results in an empirical torque multiplier for helical piles/anchors (K_t) = 10. If the w_n of saturated clay is greater than the L.L. ($L.I. > 1.0$), the soil is on the verge of being a



viscous liquid and K_t will be less than 10. If the w_n of saturated clay is close to the P.L. (L.I. = 0), the soil is dry and overconsolidated and K_t typically ranges between 12 and 14. If the w_n of a saturated clay is intermediate (between the PL and LL), the soil is probably over consolidated and K_t will be above 10. Many natural fine-grained soils are over consolidated, or have a history of having been loaded to a pressure higher than exists today. Some common causes are desiccation, the removal of overburden through geological erosion, or melting of overriding glacial ice.

Clays lying at shallow depth and above the water table often exhibit overconsolidated behavior known as desiccation. They behave as overconsolidated, but the overburden pressure required has never existed in the soil. Desiccated clays are caused by an equivalent internal tension resulting from moisture evaporation. This is sometimes referred to as negative pore pressure. The problems with desiccated or partly dry expansive clay are predicting the amount of potential expansion and the expansion or swell pressure so that preventive measures can be taken.

Sensitivity of fine grained soils is defined as the ratio of the undrained shear strength of a saturated soil in the undisturbed state to that of the soil in the remolded state $S_t = s_{u,und}/s_{u,rem}$. Most clays are sensitive to some degree, but highly sensitive soils cannot be counted on for shear strength after a CHANCE® Helical Pile, ATLAS RESISTANCE® Pier, drilled shaft, driven pile, etc. has passed through it. Some soils are "insensitive", that is, the remolded strength is about the same as the undisturbed strength. Highly sensitive soils include marine deposited in a salt water environment and subsequently subjected to



flushing by fresh water. Typical values of soil sensitivity are shown in Table 2-2.

ENGINEERING SOIL CLASSIFICATION

The engineering soil classification commonly used by Geotechnical Engineers is the Unified Soil Classification System (USCS). The Unified System incorporates the textural characteristics of the soil into engineering classification and utilizes results of laboratory grain-size data and Atterberg Limits shown in Table 2-1. The basics of the system are shown in Table 2-4. All soils are classified into 15 groups, each group being designated by two letters. These letters are abbreviations of certain soil characteristics as shown in Table 2-3.

Sensitivity of Soils, Table 2-2

Soil TYPE	Description	Sensitivity
Overconsolidated, Low to Medium Plastic Clays & Silty Clays	Insensitive	1-3
Normally Consolidated, Medium Plastic Clays	Medium Sensitivity	4-8
Marine Clays	Highly Sensitive	10-80

USCS Soil Group Symbol Characteristics, Table 2-3

	1st Symbol		2nd Symbol
G	Gravel	O	Organic
S	Sand	W	Well Graded
M	Non-plastic or Low Plasticity Fines	P	Poorly Graded
C	Plastic Fines	L	Low Liquid Limit
Pt	Peat, Humus, Swamp Soils	H	High Liquid Limit

COARSE-GRAINED SOILS (G & S)

GW and SW groups comprise well-graded gravelly and sandy soils that contain less than 5% of non-plastic fines passing the #200 sieve. GP and SP groups comprise poorly graded gravels and sands containing less than 5% of non-plastic fines. GM and SM groups generally include gravels or sands that contain more than 12% of fines having little or no plasticity. GC and SC groups comprise gravelly or sandy soils with more than 12% of fines, which exhibit either low or high plasticity.

FINE-GRAINED SOILS (M & C)

ML and MH groups include the predominately silty materials and micaceous or diatomaceous soils. An arbitrary division between the two groups is where the liquid limit is 50. CL and CH groups comprise clays with low (L.L. < 50) and high (L.L. > 50) liquid limits, respectively. They are primarily inorganic clays. Low plasticity clays are classified as CL and are usually lean clays, sandy clays, or silty clays. Medium-plasticity and high plasticity clays are classified as CH.

ORGANIC SOILS (O & Pt)

OL and OH groups are characterized by the presence of organic matter, including organic silts and clays. The Pt group is highly organic soils that are very compressible and have undesirable construction characteristics. Peat, humus, and swamp soils with a highly organic texture are typical.

Classification of a soil in the United Soil Classification System will require laboratory tests to determine the critical properties, but a tentative field classification is often made by drillers, geologists, or engineers; but considerable skill and experience are required. Soil boring logs often include the engineering classification of soils as described by the USCS.

Specifics of the Unified Soil Classification System (USCS), Table 2-4

Major Divisions			Group Symbols	Typical Descriptions
Coarse Grained Soils- more than 50% retained on #200 sieve.*	Gravels - 50% or more of coarse fraction retained on #4 sieve.	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures. Little or no fines.
			GP	Poorly graded gravels and gravel-sand mixtures. Little or no fines.
		Gravels with Fines.	GM	Silty gravels. Gravel-sand-silt mixtures.
			GC	Clayey gravels. Gravel-sand-clay mixtures.
	Sands - 50% or more of coarse fraction passes #4 sieve.	Clean Sands.	SW	Well-graded sands and gravelly sands. Little or no fines.
			SP	Poorly graded sands and gravelly sands. Little or no fines.
		Sand with Fines	SM	Silty sands. Sand-silt mixtures.
			SC	Clayey sands. Sand-clay mixtures.
Fine-Grained Soils - 50% or more passes #200 sieve.*	Silts and Clays - Liquid limit less than 50.	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.	
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	
		OL	Organic silts and organic silty clays of low plasticity.	
	Silts and Clays - Liquid limit 50 or more	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.	
		CH	Inorganic clays of high plasticity, fat clays.	
		OH	Organic clays of medium to high plasticity.	
Highly Organic Soils.			PT	Peat, muck and other highly organic soils.
*Based on the material passing the 3" (76 mm) sieve.				

SOIL MECHANICS

EFFECTIVE STRESS and PORE WATER PRESSURE

The total stress within a mass of soil at any point below a water table is equal to the sum of two components, which are known as effective stress and pore water pressure. Effective stress is defined as the total force on a cross section of a soil mass which is transmitted from grain to grain of the soil, divided by the area of the cross section, including both solid particles and void spaces. It sometimes is referred to as inter-granular stress. Pore water pressure is defined as the unit stress carried by the water in the soil pores in a cross section. Effective stress governs soil behavior and can be expressed as:

$$\sigma' = \sigma - u$$

Equation 2-1

where: σ' = the effective stress in the soil

σ = total (or applied) stress

u = pore water pressure

SOIL STRENGTH

One of the most important engineering properties of soil is its shearing strength, or its ability to resist sliding along internal surfaces within a given mass. Shear strength is the property that materially influences the bearing capacity of a foundation soil and the design of CHANCE® Helical Piles/Anchors, or ATLAS RESISTANCE® Piers. The basic principle is similar in many respects to an object that resists sliding when resting on a table.

The shear strength is the maximum shear resistance that the materials are capable of developing. Shear strength of soil consists of two parts. The first part is the friction between particles (physical property). The second part is called cohesion, or no-load shear strength due to a chemical bond between particles.

DRAINED SHEAR STRENGTH

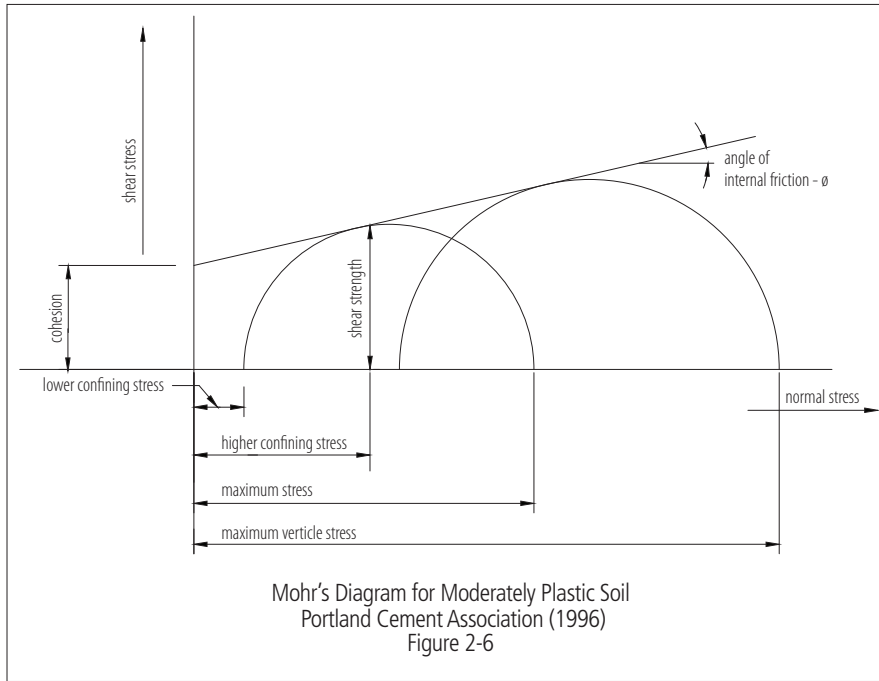
Most unsaturated coarse-grained soils and some mixed grain soils, have sufficiently high permeability that applied loads do not generate pore water pressures or any pore water pressures can dissipate during shear. This is also true if the load is applied very slowly and water is allowed to drain. The shear strength of these soils generally consists of both a "cohesive" component and a "frictional" component so that the shear strength may be reasonably described by the Mohr-Coulomb equation as shown in Equation 2-3.

UNDRAINED SHEAR STRENGTH

Saturated fine-grained soils, such as clays and silty clays subjected to rapid loading have a low enough permeability that excess pore water pressures cannot dissipate during shear. The behavior of these soils is controlled by undrained shear strength. The strength is composed of only a "cohesive" component and not a "frictional" component. The strength of these soils, is sometimes called "cohesion" (c), but a better term is simply undrained shear strength, s_u . The undrained shear strength is controlled by stress history, stress path, loading rate and vertical effective stress.

ANGLE of INTERNAL FRICTION

The shear strength of coarse-grained soils, such as sands, gravels and some silts, is closely analogous to the frictional resistance of solids in contact. The relationship between the normal stress acting on a plane in the soil and its shearing strength can be expressed by the following equation, in terms of stress:



$\tau = \sigma \tan \phi$ **Equation 2-2**

where: τ = the shearing stress at failure, or the shear strength
 σ = normal stress acting on the failure plane
 ϕ = friction angle

The internal friction of a given soil mass is related to the sliding friction between individual soil grains and the interlocking of soil particles. Shear strength attributable to friction requires a normal force (σ), and the soil material must exhibit friction characteristics, such as multiple contact areas. In dense soils, the individual soil grains can interlock, much like the teeth of two highly irregular gears. For sliding to occur, the individual grains must be lifted over one another

against the normal stress (σ). Therefore, the force required to overcome particle interlock is proportional to the normal stress, just the same as sliding friction is proportional to normal stress. In soil mechanics, ϕ is designated the angle of internal friction, because it represents the sum of sliding friction plus interlocking. The angle of internal friction (ϕ) is a function of density, roundness or angularity, and particle size.

COHESION

When saturated clay is consolidated, that is, when the volume of voids decreases as a result of water being squeezed out of the pores, the shear strength increases with normal stress. If the shear strength of clays which have a previous history of consolidation (i.e., pre-consolidated) is measured, the relationship between shear strength and normal stress is no longer a line intersecting the ordinate at zero. The clays exhibit a memory, or cohesive shear strength. In other words, the clays remember the pre-consolidation pressure they were previously subjected to. This means considerable shear strength is retained by the soil. Figure 2-6 is an example of the relationship between shear strength and normal stress for a pre-consolidated plastic clay as derived from a triaxial shear test. The intersection of the line at the ordinate is called the cohesion.

Cohesion is analogous to two sheets of flypaper with their sticky sides in contact. Considerable force is required to slide one over the other, even though no normal stress is applied. Cohesion is the molecular bonding or attraction between soil particles. It is a function of clay mineralogy, moisture content, particle orientation (soil structure), and density. Cohesion is associated with fine grain materials such as clays and some silts.

COULOMB EQUATION for SHEAR STRENGTH

The equation for shear strength as a linear function of total stress is called the Coulomb equation because it was first proposed by Coulomb in 1773.

$$\tau_f = c + \sigma \tan \phi$$

Equation 2-3

In terms of effective stress:

$$\tau_f = c' + (\sigma - u) \tan \phi'$$

Equation 2-4

where: τ_f = shear strength at failure
 c' = cohesion
 σ = total stress acting on the failure plane
 ϕ' = friction angle
 u = pore water pressure

Equations 2-3 and 2-4 are two of the most widely used equations in geotechnical engineering, since they approximately describe the shear strength of any soil under drained conditions. They are the basis for bearing capacity Equations 5-6 and 5-31 presented in Section 5.

SITE INVESTIGATIONS

To this point, various definitions, identification properties, limit states, engineering classifications, and soil strength properties have been discussed. This section details some of the more common soil exploration methods used to determine these various soil parameters.

The primary purpose of a geotechnical site investigation is to identify the subsurface stratification, and the key soil properties for design of the steel foundation elements. Such studies are useful for the following reasons:

ATLAS RESISTANCE® Piers:

- To locate the depth of a suitable bearing stratum for end bearing support of the underpinning pier.
- To establish the location of any weak or potentially liquefiable soil zones in which column stability of the pier shaft must be considered.
- To determine if there are any barriers to installing the pier to the required depth such as rubble fill, boulders, zones of chert or other similar rock, voids or cavities within the soil mass, any of which might require pre-drilling.
- To do a preliminary evaluation of the corrosion potential of the foundation soils as related to the performance life of the steel pier.

CHANCE® Helical Piles/Anchors, Tiebacks and SOIL SCREW® Anchors:

- To locate the depth and thickness of the soil stratum suitable for seating the helical plates of the pile and to determine the necessary soil strength parameters of that stratum.
- To establish the location of weak zones, such as peat type soils, or potentially liquefiable soils in which column stability of the pile for compression loading situations may require investigation.
- To locate the depth of the groundwater table (GWT).
- To determine if there are any barriers to installing the piles to the required depth such as fill, boulders or zones of cemented soils, or other conditions, which might require pre-drilling.
- To do a preliminary evaluation of the corrosion potential of the foundation soils as related to the performance life of the steel pile.

The extent to which a soil exploration program should reach depends on the magnitude of the project. If the proposed construction program involves only a small expenditure, the designer cannot afford to include more in the investigation than a small number of exploratory borings, test pits or helical trial probe piles and a few classification tests on representative soil samples. The lack of information about subsoil conditions must be compensated for by using a liberal factor of safety. However, if a large-scale construction operation is to be carried out under similar soil conditions,

the cost of a thorough and elaborate subsoil investigation is usually small compared to the savings that can be realized by utilizing the results in design and construction, or compared to the expense that would arise from a failure due to erroneous design assumptions. The designer must be familiar with the tools and processes available for exploring the soil, and with the methods for analyzing the results of laboratory and field tests.

A geotechnical site investigation generally consists of four phases: (1) Reconnaissance and Planning, (2) Test Boring and Sampling Program, (3) Laboratory Testing, and (4) a Geotechnical Report. A brief description of the requirements and procedures, along with the required soil parameters used in designing manufactured steel foundation products, is given in the following sections.

INITIAL RECONNAISSANCE and PLANNING

The first step in any subsoil exploration program should be an investigation of the general geological character of the site. The more clearly the site geology is understood, the more efficiently the soil exploration can be performed.

Reconnaissance and Planning includes: (1) review of the proposed project and structural load requirements and size of the structure and whether the project is new construction or structure repair, (2) a review of the general soil and geologic conditions in the proximity of the site, and (3) a site visit to observe topography and drainage conditions, rock outcrops if present, placement of borings, evidence of soil fill, including rubble and debris and evidence of landslide conditions. The planning portion includes making a preliminary determination of the number and depth of each boring as well as determining the frequency of soil sampling for laboratory testing and requesting the marking of all utilities in the zone in which borings will be conducted. Indicated below are recommended guidelines for determining the number of borings and the depth to which the boring should be taken based on the project type.

Minimum Number of Test Boring(s)

Whether the project involves underpinning/repair of an existing structure or new construction, borings should be made at each site where helical piles or resistance piers are to be installed. The recommended minimum number of borings necessary to establish a foundation soil profile is given below:

- Residential Home - One (1) boring for every 100 to 150 lineal feet of foundation.
- Commercial Building - One (1) boring for every 50 to 100 lineal feet for multistory-story structures, and every 100 to 150 lineal feet of foundation for other commercial buildings, warehouses and manufacturing buildings.
- Communication Towers - One (1) boring for each location of a cluster of piles or anchors, and one (1) boring at the tower center foundation footing.
- Sheet Pile/Earth Stabilization for Earth Cuts - One (1) boring for every 200 to 400 feet of project length.
- If the project is small or when the project has a restricted budget, helical trial probe piles installed at the site can provide information regarding the depth to the bearing strata and pile capacity.
- Or, boring number can be based on the overall project area, or based on minimum requirements per applicable building codes.

Depth of Test Boring(s)

The depth of each boring will vary depending on the project type, magnitude of foundation loads and area extent of the project structure. Some general guidelines for use in estimating required boring depths are given below:

- Residential Home - At least 15 feet deep with final 5 feet into good bearing stratum, generally "N" > 8 to 10 (See next section "Test Boring and Sampling Program" for a description of Standard Penetration Test and "N" values.)
- Commercial Building - For a single story structure at least 20 feet deep with final 5 to 10 feet into good bearing stratum (generally "N" > 15); add 5 foot depth for each additional story.



Auger Drilling Operation
Figure 2-7

- Communication Towers - Minimum of 35 feet for towers over 100 feet tall and at least 20 feet into a suitable bearing stratum (typically medium dense to dense for sands and stiff to very stiff for clays) for helical anchors/piles. The suitable bearing stratum should have a minimum “N” value of 12 for sands and a minimum of 10 for cohesive soils.
- Sheet Piling/Earth Stabilization - Boring should be taken to a depth that is at least as deep as the structure (sheet pile, retaining wall, etc.) to be anchored or until a suitable stratum is reached for seating the helical plates of the tiebacks (generally medium or denser sand or stiff clays).
- Active Seismic Areas - Depth per local codes.

TEST BORING and SAMPLING PROGRAM

In some cases, especially for small projects and shallow conditions, test borings may be conducted using hand augers or other portable equipment. In most cases, however, the site investigation will typically require drilling using a truck mounted drill rig.

The second step of the site investigation is to make exploratory boreholes or test pits that furnish more specific information regarding the general character and thickness of the individual soil strata. This step and an investigation of the general geological character of the site are recommended minimums. Other steps depend on the size of the project and the character of the soil profile.

Method of Boring and Frequency of Sampling

Drilling is typically the most economical and most expedient procedure for making borings although test pits can be an alternative for some projects. Three common types of borings obtained using truck or track mounted drill rigs are 1) wash borings (mud rotary), and 2) solid-stem continuous flight (CFA) auger drilling and 3) hollow stem flight auger (HSA) drilling. Any one of the three can be used, but CFA auger drilling is the most common – particularly for shallow borings. Wash borings or mud rotary drilling use casings to hold the borehole open and a drilling fluid to bring solid cuttings to the surface. The casing is either driven with a hammer or rotated mechanically while the hole is being advanced. The cutting bit and drill rods are inserted inside the casing and are rotated manually or mechanically. The cuttings allow the driller to visually classify the soil as to its type and condition and record the data on a log sheet at the depth of the cutting bit. Wash borings typically use water or drilling mud such as bentonite slurry depending on the soil. In some soil profiles, drilling mud prevents caving, making full-length casing unnecessary. While drilling proceeds, the driller observes the color and appearance of the mixture of soil and water/mud. This enables the driller to establish the vertical sequence of the soil profile. At 5 ft (1.5 m) intervals, or when a change in strata is noticed, the cutting bit is removed and a spoon sample is taken.

Auger drilling typically uses a continuous solid-stem flight auger rotated mechanically while the hole is being advanced. The continuous flight auger (CFA) often includes a hollow stem, which acts as a casing to hold the borehole open. Water or drilling mud is typically not used. Cuttings are carried to the surface by the auger flights, which allow visual

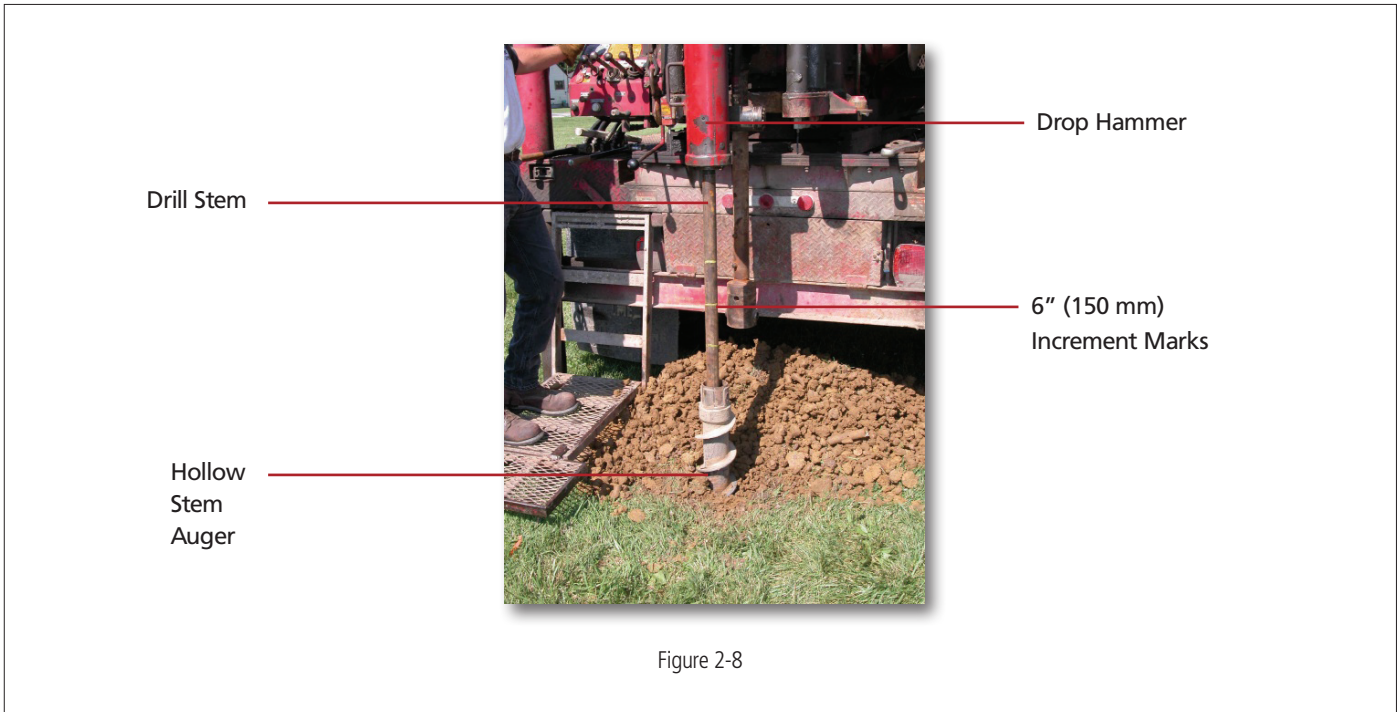


Figure 2-8

classification of the soil. The advantage of the hollow stem auger is to permit the sampler and rod to be inserted down through the auger without removing the auger sections each time a sampler is inserted. The auger acts as a temporary casing. Samplers are inserted inside the auger casing to retrieve disturbed and undisturbed soil samples typically at 5 ft (1.5 m) intervals. Figure 2-7 demonstrates an auger drilling operation. Solid-stem augers are designated by the outside diameter of the auger flights. Common sizes are 3 inch, 4 inch, and 6 inch. Hollow-stem augers are designated by the inside diameter of the pipe. 3-1/4 inch and 4-1/4 inch are common sizes.

Solid-stem continuous flight augers consist of a solid steel central shaft with a continuous auger, typically available in 5 foot sections. The borehole is advanced by rotating the auger, which brings soil cuttings to the ground surface. Disturbed samples of soil may be taken from the augers, but in order to obtain undisturbed samples, the augers must be removed and a sampling tool placed in the bottom of the borehole. Continuous Flight Augers work well in stiff to very stiff fine-grained soils that maintain an open borehole, but do not work in very soft clays or sands and loose silts below the water table. These conditions require either wash boring or the use of Hollow Stem Augers (HSA).

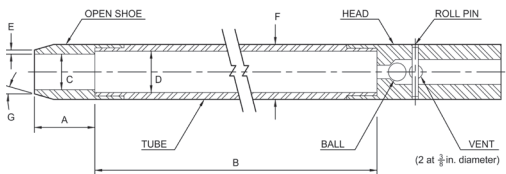
The groundwater table (GWT), or phreatic surface is defined as the elevation at which the pressure in the water is equal to that of the atmosphere. Information regarding the location of the groundwater table is very important to the design and construction of deep foundations – especially in granular soils. Careful observations should always be made and recorded, if circumstances permit, during exploratory drilling. It is customary to note the water level on completion of the hole and after allowing the hole to stand overnight or for 24 hours before backfilling. The use of drilling mud to stabilize the walls of the hole may preclude obtaining this information.

Soil Sampling

Geotechnical Site Investigations almost always include the collection of soil samples for identification and description, laboratory testing for soil classification and laboratory testing for soil strength and stiffness. There are two broad types of soil samples that are often collected; 1) disturbed samples, and 2) undisturbed samples. In general, disturbed samples may either be obtained from augers as previously discussed or more commonly they are obtained using the Standard Penetration Test (SPT). Undisturbed samples are typically obtained with thin-walled push tubes called Shelby Tubes (ST).

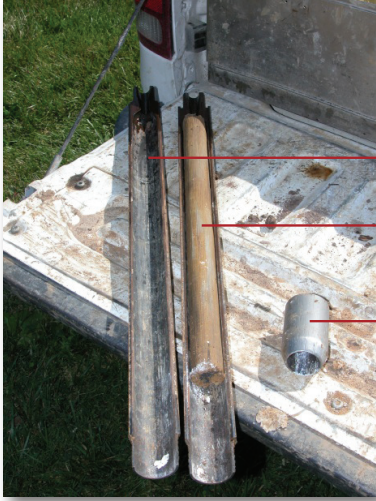
Standard Penetration Test and Sampling

The cuttings from exploratory drill holes are inadequate to furnish a satisfactory conception of the engineering characteristics of the soils encountered, or even the thickness and depths of the various strata. To obtain soil samples from test borings, a sampling spoon is attached to the drill rod and lowered to the bottom of the hole. The spoon is driven into the soil to obtain a sample and is then removed from the hole. The spoon is opened up and the recovery (soil sample length inside the spoon) is recorded. The soil is extracted from the spoon and inspected and described by the driller. A portion of the sample is placed in a glass jar and sealed for later visual inspection and laboratory determination of index properties.



$A = 1.0 \text{ to } 2.0 \text{ in (25 to 50 mm)}$
 $B = 18.0 \text{ to } 30.0 \text{ in (0.457 to 0.762 m)}$
 $C = 1.375 \pm 0.005 \text{ in (34.93 } \pm 0.13 \text{ mm)}$
 $D = 1.50 + 0.05 - 0.00 \text{ in (38.1 + 1.3 - 0.0 mm)}$
 $E = 0.10 \pm 0.02 \text{ in (2.54 } \pm 0.25 \text{ mm)}$
 $F = 2.00 + 0.05 - 0.00 \text{ in (50.8 + 1.3 - 0.0 mm)}$
 $G = 16.0^\circ \text{ to } 23.0^\circ$

Geometry of Standard Penetration Test Split-Barrel Sampler (ASTM D 1586)
Figure 2-9



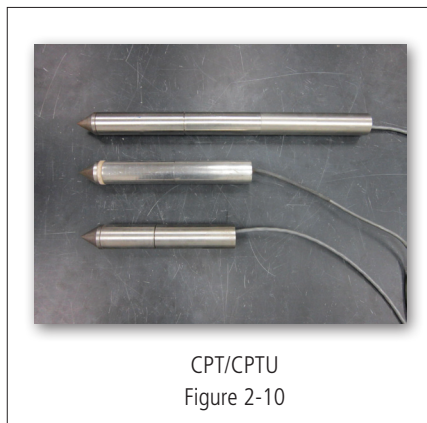
Split Barrel Tube
Recovered soil sample
Open Shoe

Split Spoon Sample

The 1½ in (38 mm) inside diameter split barrel may be used with a 16-gauge wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

The most common method of obtaining some information concerning relative density or the stiffness of in-situ soil consists of counting the number of blows of a drop weight required to drive the sampling spoon a specified distance into the ground. This dynamic sounding procedure is called the standard penetration test (SPT). The essential features include a drop hammer weighing 140 lb (63.5 kg) falling through a height of 30" (0.76 m) onto an anvil at the top of the drill rods, and a split spoon (SS) sampler having an external diameter of 2" (50.8 mm) and a length of 30" (0.76 m). The spoon is attached to the drill rods and lowered to the bottom of the drill hole. After the spoon reaches the

bottom, the number of blows of the hammer is counted to achieve three successive penetrations of 6" (0.15 m). The number of blows for the first 6" is disregarded because of the disturbance that exists at the bottom of the drill hole. The number of blows for the second and third 6" increments are added and designated the standard penetration test (SPT), "N" value, or blow count. The data obtained from SPT tests are commonly recorded on soil boring logs relative to the sounding depth where the sample was taken. SPT values are widely used to correlate the shearing strength of soil for the design of shallow and deep foundations – including CHANCE® Helical Piles and ATLAS RESISTANCE® Piers. The SPT values also can assist in determining the depth of installation requirements for ATLAS RESISTANCE® Piers. Values of soil friction angle "φ" and cohesion "c" can be selected through correlation with the SPT "N" values. Details of the equipment and standardized procedures are



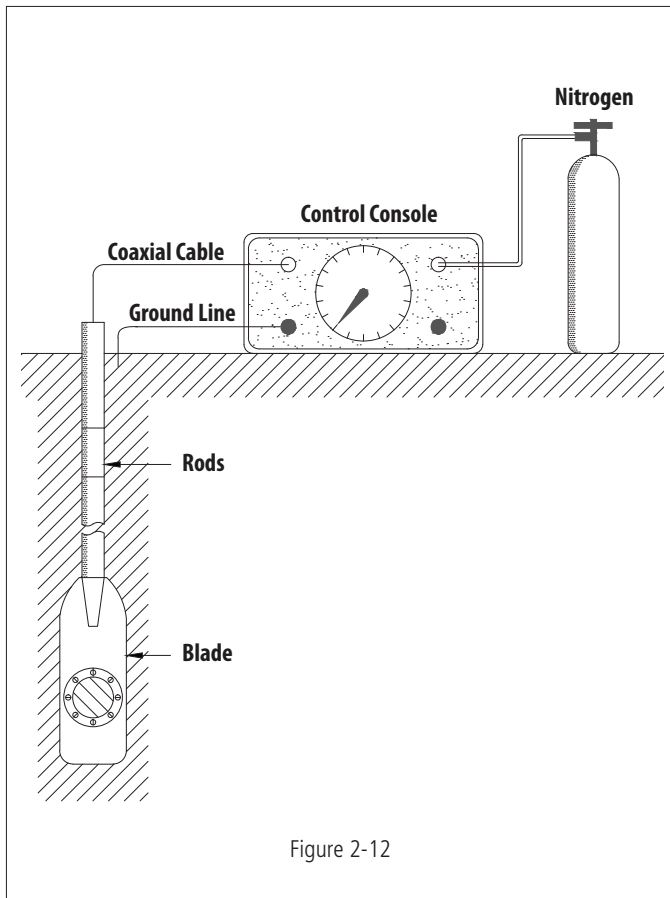


Figure 2-12

specified in ASTM D 1586. Figure 2-8 illustrates a drill crew conducting a Standard Penetration Test. The split spoon sampler is shown in Figure 2-9.

Undisturbed Samples

In general, soil samples taken from split spoon samplers are always considered disturbed to some degree for two reasons: 1) the sampler is driven into the soil, and 2) the split spoon is very thick. For soil samples to be used for laboratory analysis, the degree of disturbance of the samples must be reduced to a minimum. Reasonably satisfactory samples can be obtained in 50 and 76 mm samplers made of steel tubing about 1.5 mm thick. The lower ends are beveled to a cutting edge to give a slight inside clearance. This type of sampler is commonly referred to as a "Shelby tube". The Shelby tube is attached to the end of the drill rod and pushed vertically down into the soil to obtain an undisturbed sample. Hand samples or grab samples are sometimes taken from cuttings or test pits and are useful for soil classification and determining index properties. Details of the equipment and proper procedures for obtaining thin-walled Shelby Tube samples are specified in ASTM D1587.

IN-SITU TESTING METHODS

Cone Penetration Test (CPT) / Piezocone (CPTU)

The Cone Penetration Test consists of a cylindrical probe with a cone tip having an apex angle of 60° that is pushed slowly into the ground. The standard size cone has a diameter of 1.405 inch, which gives a projected end area of 10 cm². Most cones also have a short section behind the tip that is called the sleeve. The force on the tip and the sleeve are measured independently during penetration to give the cone tip resistance, q_c , and the sleeve resistance, f_s . These values may then be used to evaluate changes in soil layering at a site and to estimate individual soil properties, such as shear strength and stress history. Some cones are also equipped with a porewater pressure sensor to measure the excess porewater pressure as the cone advances. This is called a piezocone. The cone tip resistance obtained from a piezocone is defined as q_t , the "effective" or corrected cone tip resistance since it is corrected for porewater pressure. A figure of a CPT and CPTU are shown in Figure 2-10.

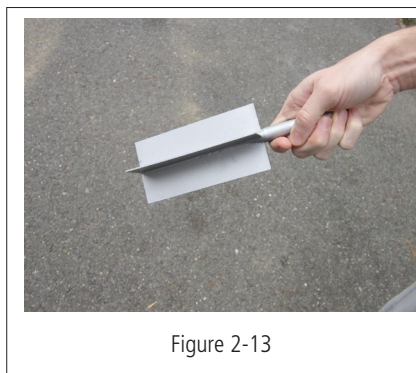


Figure 2-13

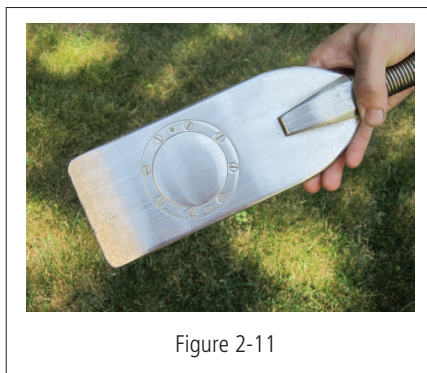


Figure 2-11

Cone penetrometers cannot penetrate more than a few meters in dense sand, but they have been used to depths up to 60 m or more in soft soils. The friction ratio, defined as the friction resistance divided as the tip resistance can be correlated with the type of soil encountered by the penetrometer. Since no samples are obtained by use of cone penetrometers, borings and sampling are usually needed for definitive information about the type of soil being investigated.

Dilatometer Test (DMT)

The Dilatometer Test consists of a flat stainless steel blade with a circular, flexible membrane mounted on one side of the blade, as shown on Figure 2-11. The blade is pushed into the ground, much like a CPT or CPTU, but instead of providing continuous data, pushing is stopped every 1 foot. Immediately after pushing is stopped, the flexible membrane is expanded into the soil using nitrogen gas and a control console at the ground surface. Two pressure readings are taken; 1) the A-Reading, which is the pressure required to just initiate movement of the membrane into the soil, and 2) the B-Reading, which is the pressure required to expand the center of the membrane 1 mm into the soil. The two Readings are corrected for the stiffness of the membrane to give two pressure readings, P_0 and P_1 . P_0 and P_1 are then used along with the soil effective stress at each test depth to obtain estimates of specific soil properties such as shear strength, modulus, stress history and in-situ lateral stress. The specific requirements of the test are given in ASTM D6635.

Field Vane Test (FVT)

The Field Vane Test (FVT) or Vane Shear Test (VST) is used to measure the undrained shear strength and Sensitivity of medium stiff to very soft saturated fine-grained soils. It is considered one of the most reliable and direct in-situ test methods for determining undrained shear strength and the only in-situ test that may be used to determine Sensitivity. The test consists of inserting a thin four-bladed vane into the soil and rotating slowly to create a shear failure in the soil. The vane is usually rectangular with a height to diameter ratio (H/D) of 2, as shown in Figure 2-13. Initially, the maximum torque is measured to obtain the peak or undisturbed undrained shear strength. Then, the vane is rotated 10 times and the test is repeated to obtain the remolded undrained shear strength. The ratio of undisturbed to remolded strength is defined as Sensitivity, as previously described. The specific requirements of the test are given in ASTM D2573.

Mechanical Properties of Various Rocks, Table 2-5

ROCK	YOUNG'S MODULUS AT ZERO LOAD (10^5 kg/cm ²)	BULK DENSITY (g/cm ³)	POROSITY (percent)	COMPRESSIVE STRENGTH (kg/cm ²)	TENSILE STRENGTH (kg/cm ²)
Granite	2 - 6	2.6 - 2.7	0.5 - 1.5	1,000 - 2,500	70 - 250
Microgranite	3 - 8				
Syenite	6 - 8				
Diorite	7 - 10			1,800 - 3,000	150 - 300
Dolerite	8 - 11	3.0 - 3.05	0.1 - 0.5	2,000 - 3,500	150 - 350
Gabbro	7 - 11	3.0 - 3.1	0.1 - 0.2	1,000 - 3,000	150 - 300
Basalt	6 - 10	2.8 - 2.9	0.1 - 1.0	1,500 - 3,000	100 - 300
Sandstone	0.5 - 8	2.0 - 2.6	5 - 25	200 - 1,700	40 - 250
Shale	1 - 3.5	2.0 - 2.4	10 - 30	100 - 1,000	20 - 100
Mudstone	2 - 5				
Limestone	1 - 8	2.2 - 2.6	5 - 20	300 - 3,500	50 - 250
Dolomite	4 - 8.4	2.5 - 2.6	1 - 5	800 - 2,500	150 - 250
Coal	1 - 2			50 - 500	20 - 50
Quartzite		2.65	0.1 - .05	1,500 - 3,000	100 - 300
Gneiss		2.9 - 3.0	0.5 - 1.5	500 - 2,000	50 - 200
Marble		2.6 - 2.7	0.5 - 2	1,000 - 2,500	70 - 200
Slate		2.6 - 2.7	0.1 - 0.5	1,000 - 2,000	70 - 200

Notes:

- 1) For the igneous rocks listed above, Poisson's ratio is approximately 0.25
- 2) For a certain rock type, the strength normally increases with an increase in density and increase in Young's Modulus (after Farmer, 1968)
- 3) Taken from Foundation Engineering Handbook , Winterkom and Fong, Van Nostrand Reinhold, page 72

The maximum torque (T) is measured during rotation and for a vane with H/D = 2 the undrained shear strength is determined from:

$$s_u = (0.273T)/D^3 \quad \text{Equation 2- 5}$$

Vanes are available in different sizes to suit the soil at a particular site. The Field Vane Test may be especially useful in evaluating sites for helical piles/anchors as it may give some insight to the engineer into the degree of disturbance and strength reduction that the soil may experience during installation, depending on the Sensitivity. It is important that the exact geometry of the vane (e.g., H, D, thickness of blades) and test procedures used be described in a Geotechnical Report so that the engineer may make any adjustments to the test results for the equipment used.

Helical Probe

Shear strength also can be estimated by installing a helical pile “probe” and logging installation torque vs. depth. The torque values can be used to infer shear strength based on the torque-to-capacity relationship discussed in Section 6.

Rock Coring and Quality of Rock Measurement

When bedrock is encountered, and rock anchors are a design consideration, a continuous rock core must be recovered to the depth or length specified. Typical rock anchors may be seated 20 ft. or 30 ft. into the rock formation.

In addition to conducting compressive tests on the recovered rock core samples (See Table 2-5), the rock core is examined and measured to determine the rock competency (soundness or quality). The rock quality designation (RQD) is the most commonly used measure of rock quality and is defined as:

$$RQD = \frac{\sum \text{Length of intact pieces of core (>100 mm)}}{\text{Length of core run}}$$

The values of RQD range between 0 and 1.0 where an RQD of 0.90 or higher is considered excellent quality rock.

Helical piles/anchors rotated or torqued into the ground cannot be installed into hard, competent bedrock. However, in upper bedrock surfaces comprised of weathered bedrock material such as weathered shale or sandstone, the helix plates can often be advanced if the RQD is 0.30 or less.

The presence of an intact bedrock surface represents the ideal ground condition for ATLAS RESISTANCE® Piers. In this ground condition, the ATLAS RESISTANCE® Pier is installed to the rigid bearing surface represented by the bedrock layer.

Laboratory Testing of Recovered Soil Samples

Laboratory testing is typically part of a subsurface investigation and may vary in scope depending upon project requirements or variability in soil conditions. Some of the more typical laboratory tests are described below:

Classification / Characterization Tests

- **Visual Classification** – Samples collected during the drilling operations should be visually classified. Every recovered sample from the field boring and sampling program is inspected visually and given a visual description as to its collection depth, percent recovery, moisture conditions, soil color, inclusion type and quantity, approximate strength, odor and composition (See Table 2-4). In addition to this visual classification, a representative number of samples are selected to conduct the following tests:
- **Water Content** – measures the amount of moisture in the soil. Moisture or water content is measured by weighing a soil sample taken from the field on a laboratory scale. The soil sample is then placed in a standard oven for a sufficient time to allow all the moisture to evaporate. After being removed from the oven, the soil sample is weighed again. The dried weight is subtracted from the original weight to determine the water weight of the sample. These methods are also used to determine the total (wet) unit weight and the dry unit weight.

SOIL MECHANICS

Sample Boring Log in Coarse-Grained Soil, Table 2-6

Project No.: 12-1122 **Boring Log** **Rig:** CME 75 with 140 lb Auto Hammer
Project: Doe Run Test Borings - 2012 **Location:** Leadwood, MO
Client: Hubbel Power Systems **Driller:** MAS
Boring No.: 1

SUBSURFACE PROFILE				SAMPLE				Standard Penetration Test blows/ft.	Water Content % Wp ----- WI
Depth (ft.)	Symbol	Description	Qp, T.S.F.	Dry Density, P.C.F.	Depth/Elev.	Number	Type		
0		Ground Surface			100.0				
		Crushed Stone: Poorly Graded Sand with Silt (SP-SM), Light Gray, Trace Gravel, Fine to Coarse, Dry				0	HA		
		(SP-SM), Trace Gravel, Fine to Coarse, Medium Dense, Dry Blow Sequence = 6-13-16 Recovery = 14"				1	SS	29	
		(SP-SM), Trace Gravel, Fine to Coarse, Medium Dense, Dry Blow Sequence = 10-13-14 Recovery = 18"				2	SS	27	
		(SP-SM), Fine to Medium, Medium Dense, Moist Blow Sequence = 8-8-7 Recovery = 16"				3	SS	15	
		(SP-SM), Fine to Medium, Medium Dense, Moist Blow Sequence = 3-5-5 Recovery = 19"				4	SS	10	
		(SP-SM), Fine to Medium, Loose, Moist Blow Sequence = 2-4-4 Recovery = 17"				5	SS	8	
		(SP-SM), Fine to Medium, Medium Dense, Moist Blow Sequence = 3-6-6 Recovery = 18"				6	SS	12	
		(SP-SM), Fine to Medium, Loose, Moist Blow Sequence = 2-3-4 Recovery = 15"				7	SS	7	
		(SP-SM), Fine to Medium, Loose, Moist/Wet Blow Sequence = 1-2-3 Recovery = 15"				8	SS	5	
		End of Boring @ 31½ Ft.			68.5 31.5				

SOIL MECHANICS

Drill Method: 3 1/4" HSA with AW Rod
Boring Started: 9-10-2012
Boring Completed: 9-10-2012
Tested By: N/A
Logging By: PEB



Groundwater Elev. During Drilling: 69.0
Groundwater Elev. @ Comp.:
Groundwater Elev. @ 1 Hrs.:
Boring Location: West Boring
 Sheet 1 of 1



- **Particle Size Analysis** – measures the distribution of particle sizes within the soil sample.
- **Atterberg Limits** – Liquid Limit (LL), Plastic Limit (PL), Shrinkage Limit (SL), and Plastic Index (PI) – applies to cohesive types of soil and is a measure of the relative stiffness of the soil and potential for expansion. Index properties (LL, PL, SL, and PI) are determined using specially developed apparatus and procedures for performing these tests. The equipment, specifications and procedures are closely followed in ASTM D 4318 Classification / Characterization Tests. The Liquid Limit and the Plastic Limit are particularly important since they may be used along with the natural water content to determine the Liquidity Index.

STRENGTH CHARACTERISTICS

In some instances undisturbed soil samples are recovered in the field using a thin wall Shelby tube. These recovered samples are tested either in triaxial or direct shear tests to determine directly the friction angle " ϕ " and the cohesion " c " of the soil. For cohesive (clay) soil samples, an unconfined compression test "UC" is often conducted. The unconfined compression test is used to determine the unconfined compression strength " q_u " of the clay soil. The cohesion of the clay sample is then taken to be one-half of " q_u ". The unconfined compression test is commonly performed due to its low cost; however the results tend to be conservative and simulate only total stress conditions with no confining pressure which may not be appropriate for the project. For granular soils, the Direct Shear test is a relatively inexpensive test to determine the soil friction angle and may also be used for undrained testing of cohesive samples. More refined laboratory testing may be appropriate for large projects and may offer a cost saving potential by justifying higher soil strength than using less sophisticated test methods. Some of the more complex strength tests include, Consolidated Drained (CD), Consolidated Undrained (CU) and Unconsolidated Undrained (UU) Triaxial tests for total and effective stress paths at project specific confining stresses.

THE GEOTECHNICAL REPORT

The geotechnical report provides a summary of the findings of the subsurface investigation, and the results of the laboratory testing. Geotechnical reports usually include an introduction detailing the scope of work performed, site history including geology, subsurface conditions, soil profile, groundwater location, potential design constraints such as seismic parameters and corrosion potential, foundation options, allowable load capacities, and an appendix which includes soil boring logs. Soil boring logs provide a wealth of information that is useful in the design of CHANCE® Helical Piles and ATLAS RESISTANCE® Piers. Boring logs come in variety of designs since there is no standard form, but they contain basically the same type of information – most of which has been discussed in this section. Items to expect on a soil boring are: total boring depth, soil profile, description of soil samples, sample number and type, Standard Penetration Test N-values, moisture content, Atterberg limits, unconfined compression strength or undrained shear strength (cohesion), groundwater table location, type of drilling used, type of SPT hammer used, and sample recovery. An example boring log is shown in Table 2-6 & 2-7. Table 2-6 is a soil boring taken in a coarse-grained sand soil. Table 2-7 is a soil boring taken in a fine-grained clay soil.

Sample Boring Log in Fine-grained Soil, Table 2-7

Project No.: 09-1219 **Boring Log** **Rig:** CME 55
Project: Mexico and Eaton Dam Drill Sites **Location:** Mexico/Park Hills, Missouri
Client: Chance Civil Construction **Driller:** MAS
Boring No.: Mexico

SUBSURFACE PROFILE				SAMPLE				Standard Penetration Test blows/ft.	Water Content % Wp —●— WI	
Depth (ft.)	Symbol	Description	Qp, t.s.f.	Dry Density, P.C.F.	Depth/Elev.	Number	Type			Blows/ft.
0		Ground Surface			0.0					
		Fill: Yellow Brown Silty Clay, w/Sand, (CL)			-2.5	0	HA			
		Fill: Yellow Brown Micaceous Clay, Trace Sand, Stiff, (CH)	3.50		2.5	1	SS	10		
5		Fill: Mottled Reddish Brown, Trace Sand and Gravel, Very Stiff, (CH)	3.50		-7.5	2	SS	18		
		Fill: Light Gray mottled Yellow Brown Clay, w/Sand and Gravel, Pieces of Coal and Shale, Very Stiff, (CH)	4.00		7.5	3	SS	16		
10		Fill: W/Pieces of Limestone, Stiff, (CH)			-12.5	4	SS	8		
		Light Gray Weathered Micaceous Clay (Shaly Residuum), Hard, (CH)	4.5+		12.5	5	SS	57		
15		Hard, (CH)				6	SS	53		
		Hard, (CH)				7	SS	105/10		
20		Hard, (CH)			-21.5	8	SS	50/4"		
		End of Boring @ 21 1/2 Ft.			21.5					

SOIL MECHANICS

Drill Method: 3 1/4" HSA
Boring Started: 11-23-2009
Boring Completed: 11-23-2009
Tested By:
Logging By: PEB/BJs

GEOTECHNICS
Soil & Material Testing

Groundwater Elev. During Drilling: ∇
Groundwater Elev. @ Comp.: ∇
Groundwater Elev. @ Hrs.: ∇
Boring Location: Client Provided



Problem Soil Conditions

All natural materials, such as soil, will exhibit conditions of variability that may make a single solution inadequate for inevitable problems that arise. It is wise to remember Dr. Terzaghi's emphasis to have a secondary solution ready when dealing with the variability of soils.

Deep Fill, Organic and Collapsible Soils

The existence of deep fills, organic and collapsible soils on a given project site are typically known before the start of the project. This is usually determined during the subsurface investigation by means of drilling or sounding. However, on large projects like an underground pipeline or transmission line that covers many miles, these soils may occur in undetected pockets and hence present a potential problem. The best solution is to be aware of the possibility of their existence and be prepared to install CHANCE® Helical Piles and ATLAS RESISTANCE® Piers deeper to penetrate through this material into better bearing soil. It is not recommended to locate the helical bearing plates or the tip of the ATLAS RESISTANCE® Pier in these soils.

Loose Liquefiable Soils

Some deposits of saturated sand and silty sand are naturally loose and may be prone to lose strength or liquefy during an earthquake or other dynamic loading. These soils are typically identified by very low SPT N-values (typically less than about 6) and should be viewed with caution.

Sensitive Clays

Some marine clay deposits are also very sensitive and can lose most of their shear strength when disturbed and when loaded dynamically. These deposits are typically identified with Liquidity Index greater than about 1.2.

Expansive Soils

Expansive soils exist all over the earth's surface, in nearly every region. These soils are often described as having high shrink-swell behavior since they can also shrink if dried out. The natural in-place weathering of rock produces sand, then silt, and finally clay particles – hence the fact that clay is a common soil type. Most clay soils exhibit volume change potential depending on moisture content, mineralogy, and soil structure. The upward forces (swell pressure) of expansive clay may far exceed the adfreeze forces generated by seasonally frozen ground, yet foundations continue to be founded routinely in expansive soil with no allowance for the potential expansion. Foundations should be designed to penetrate below the expansive soil's active zone, or be designed to withstand the forces applied the foundation, e.g., to prevent "slab dishing" or "doming." The active zone is defined as the depth of expansive soil that is affected by seasonal moisture variation. Another method used to design foundations on expansive soil is to prevent the soil's moisture content from changing. Theoretically, if the moisture content does not change, the volume of the clay soil will not change. This is typically difficult to control.

The tensile strength of deep foundations must be sufficient to resist the high tensile forces applied to the foundation by expansive soil via skin friction within the active zone. As an expansive soil swells or heaves, the adhesion force between the soil and the side of the foundation can be of sufficient magnitude to "jack" a foundation out of the ground. CHANCE® Helical Piles are a good choice in expansive soils due to their relatively small shaft size – which results in less surface area subjected to swell pressures and jacking forces. Isolating footings, slabs, and grade beams from subgrade soils by using void form is a typical detail used in areas like Denver, Colorado, where expansive soil is present. The void form isolates the structure from contact with the expansive soil, thereby eliminating the destructive effects of swell pressures.

A Plasticity Index (PI) greater than 25 to 30 is a red flag to the geotechnical engineer. A $PI \geq 25$ to 30 indicates the soil has significant volume change potential and should be investigated further. There are fairly simple tests (Atterberg, soil suction test, swell potential) that can be conducted but should be practiced by the informed designer.

Seasonally Frozen Ground

The most obvious soil in this category is the frost susceptible soils (typically, silt) as illustrated by the growth of frost needles and ice lenses in freezing weather. This leads to a commonly observed expansion phenomenon known as frost heave. Frost heave is typically observed on roadbeds, under concrete slabs, and along freshly exposed cuts. Capillary breaks and vapor barriers in conjunction with proper drainage will do much to control this problem, before CHANCE® Helical Piles or ATLAS RESISTANCE® Piers are installed.

A subcategory of this condition is seasonal permafrost. If possible, these ice lenses should be penetrated and not relied on for end bearing.

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SOIL MECHANICS





PRODUCT FEASIBILITY



PRODUCT FEASIBILITY SECTION 3

CONTENTS

FEASIBILITY of USING CHANCE® HELICAL or ATLAS RESISTANCE® PIER PRODUCTS	3-3
SHAFT SIZE SELECTION BASED on SOIL PARAMETERS	3-6
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SYMBOLS USED IN THIS SECTION

N	Blow Count	3-3
SPT	Standard Penetration Test	3-3
ASTM.....	American Society for Testing and Materials	3-3
C.....	Cohesion	3-3
ϕ	Friction Angle	3-3
FS.....	Factor of Safety	3-4
kip.....	Kilopound	3-4
SS.....	Square Shaft	3-6
RS	Round Shaft	3-6

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

Hubbell Power Systems, Inc., shall not be responsible for, or liable to you and/or your customers for the adoption, revision, implementation, use or misuse of this information. Hubbell, Inc., takes great pride and has every confidence in its network of installing contractors and dealers.

Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

FEASIBILITY of USING CHANCE® HELICAL or ATLAS RESISTANCE® PRODUCTS

Hubbell Power Systems, Inc. manufactures steel foundation products that can be designed for a wide range of soil conditions. In order to assist the designer/user in selecting the proper product for the application, Figure 3-1 shows the product type suitable for various soils and rock conditions. When reviewing Figure 3-1, the designer/user should note the following items:

- The most common selection of soil parameters for design is from field testing using the ASTM D 1586 Standard Penetration Test (SPT) and field or laboratory testing of shear strength (cohesion "c" and friction angle " ϕ "). Refer to Section 2 in this manual for a detailed discussion of geotechnical investigation requirements and to Section 4 for a detailed discussion of structural load requirements for projects using CHANCE® Helical Piles/ Anchors and/or ATLAS RESISTANCE® Piers.
- A range is noted based on SPT "N-" values where the ATLAS RESISTANCE® type of pier will provide the foundation underpinning support in an end-bearing mode. This "N-" value is generally above 30 to 35 in cohesionless (sands and gravels) soils and above 35 to 40 in cohesive clay soils.
- A range is indicated for use of the helical piles (compression) and helical anchors (tension). As noted on the chart, there are certain conditions for weathered rock and cemented sands where an initial predrilling will permit the installation of helical plates under relatively high installing torque (generally above 10,000 ft-lbs). Helical piles/ anchors have been successfully installed on projects where the target depth is not homogenous or consists of hard clays, cemented sands or weathered rock. These factors must be considered and evaluated before a design can be finalized. Modifications may have to be made to the design to be able to accomplish embedment into the target stratum such as:
 - Cutting a "sea shell" shape into the leading edge of one or more of the helical plates.
 - Predrilling prior to the installation of a helical pile/anchor.
 - Using a shaft configuration that provides adequate torques and resistance to "spikes" during installation.

The product selection chart shown in Figure 3-1 is intended for use on a preliminary basis. Hubbell Power Systems, Inc. assumes no responsibility for the accuracy of design when based solely on Figure 3-1. A Preliminary Design Request Form is provided at the end of this section. This form can be copied and then completed with the required information to request a preliminary design (application) by the Hubbell Power Systems, Inc. engineering department. The completed form can be sent to Hubbell Power Systems, Inc. or directly to your local CHANCE® Distributor.



All foundation systems should be designed under the direct supervision of a Registered Professional Engineer knowledgeable in product selection and application.

Hubbell Power Systems, Inc. steel foundation products offer simplicity in design and flexibility in adapting to the project. The design for ultimate and allowable bearing capacities, anchor or tieback loads for helical products, is established using classical geotechnical theory and analysis, and supplemented by empirical relationships developed from field load tests. In order to conduct the design, geotechnical information is required at the site. The design and data shown in this manual are not intended for use in actual design situations. Each project and application is different as to soils, structure, and all other related factors.

FACTORS of SAFETY

To recognize the variability of soil conditions that may exist at a site, as well as the varied nature of loading on structures and how these loads are transferred through foundations, Hubbell Power Systems, Inc. recommends an appropriate Factor of Safety (FS) when using CHANCE® Helical and ATLAS RESISTANCE® Pier foundation products. Generally, the minimum FS is 2 on all permanent loading conditions and 1.5 for any temporary load situation. National and local building codes may require more stringent Factors of Safety on certain projects. Refer to Section 5 for a discussion of Factors of Safety when using ATLAS RESISTANCE® Piers for underpinning (remedial repair) applications.

SITE ACCESS

The proximity to other structures, rights-of-way and obstructions are some of the first considerations for any construction or improvement. Equipment access may be restricted due to overhead limits and safety issues. The designer needs to consider all the possible limitations when selecting a foundation system. CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Piers can generally be used anywhere a soil boring can be taken and are virtually the most access-problem-free foundation systems available today. Restricted access and similar concerns should be shown on the bid documents with the usual notes concerning site conditions.

Vibration and noise can be another limitation to conventional deep foundations (i.e., driven piles, drilled piers). CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Piers have been installed inside office buildings, restaurants, retail shops and hospitals without interrupting their normal routines. CHANCE® Helical Pile and ATLAS RESISTANCE® Pier certified installers can assist the designer in determining the best type of product for the application.

WORKING LOADS

Helical piles have been used in the compressive mode to working (design) loads of 200 kip, in the form of the CHANCE HELICAL PULLDOWN® Micropile which is detailed later in this manual. In a “normal consolidated” soil, the working load per foundation is typically less than 100 kip, but special cases may apply.

Working tension loads are typically 100 kip or less. The soil is generally the limiting factor as the number and size of helical piles/anchors can be varied to suit the application. The designer should determine the shaft series of products to use from the information provided in Section 7 – Product Drawings and Ratings.

ATLAS RESISTANCE® Piers have been used in the compressive mode to working (design loads) of 70 kip+. The soil conditions, weight of the existing foundation, and type of foundation are generally the limiting factors when determining the number and size of ATLAS RESISTANCE Piers to use in a given application. The designer should determine the shaft series of products to use from the information provided in Section 7 - Product Drawings and Ratings.

SOILS

Soil may be defined for engineering purposes as the unconsolidated material in the upper mantle of the earth. Soil is variable by the nature of its weathering and/or deposition. The more accurately one can define the soil at a particular site; the better one can predict the behavior of any deep foundation, such as a CHANCE® Helical Pile, HELICAL PULLDOWN® Micropile or ATLAS RESISTANCE® Pier. In the absence of sufficient soil data, assumptions can be made by the designer. The field engineer or responsible person needs to be prepared to make changes in the field based on the soil conditions encountered during construction.

As noted earlier, ATLAS RESISTANCE® Piers will provide the foundation underpinning support in an end-bearing mode provided N-values are generally above 30 to 35 in cohesionless (sands and gravels) soils and above 35 to 40 in cohesive clay soils. CHANCE® Helical Piles can be installed into residual soil and virgin or undisturbed soils other than rock, herein defined as having a SPT “N-value” less than 80 to 100 blows per foot per ASTM D1586. This implies that the correct shaft series of helical piles must be chosen to match to the soil density. For example, a standard 1-1/2” shaft, Type SS helical pile with a total helix area of 1 square foot may require so much installing torque that it may have difficulty penetrating into the bearing stratum without exceeding the torsional strength of the shaft.

Water-deposited soil, marine, riverene (terraces or delta) and lacustrine have a high degree of variability. They may be highly sensitive and may regain strength with time. In these conditions, it is good practice to extend helical piles and resistance piers deeper into more suitable bearing soil.

Very soft or very loose natural, virgin or undisturbed soils overlying a very dense soil layer, such as unweathered rock, present an ideal situation for the installation of ATLAS RESISTANCE® Piers. Similar soil profiles could present a challenge to the installation of helical piles depending on the weathered nature of the underlying rock. The helices may not develop enough downward thrust in upper soils to penetrate into the hard underlying material. Down pressure is often applied to the shaft to assist in penetration of the helices into the hard underlying material.

The use of helical piles/anchors in controlled or engineered fill is another good application. For example, helical tiebacks are used in the controlled fills of roadway and railway fills to make improvements to the infrastructure.

Helical piles should be capable of penetrating the collapsible soils (such as loess) and poorly cemented granular soils in the southwestern United States.

EQUIPMENT

Equipment suitability consideration and selection is the domain of the contractor. Certified CHANCE® Installers are familiar with the various spatial requirements for his equipment and is best able to determine the type of mounted or portable equipment they can utilize to do the work. The designer may contact the local CHANCE® Distributor or certified installer for guidance on this matter. A wide variety of equipment can be utilized for projects based on such considerations as interior vs. exterior construction and headroom. Mini-excavators have been used indoors to install helical piles.

CONTRACTORS

Certified CHANCE® Installers are available in nearly all areas of North America. These installers should be experienced in the type of work specified. A current project list should be submitted as evidence of experience.

CODES

Building codes may have restrictions regarding the foundation type. Generally, CHANCE® Helical Piles and ATLAS RESISTANCE® Piers fall under the category of deep foundations, such as driven piles or drilled piers. The underpinning shaft series of CHANCE® Helical Piles and ATLAS RESISTANCE® Models AP-2-3500.165 and AP-2-3500.165 (M) have been evaluated to show compliance with past and also the latest revisions of the International Building Code (IBC). CHANCE® Type SS5 and SS175 helical piles and bracket assemblies have been evaluated per International Code Council Evaluation Services (ICC-ES) Acceptance Criteria AC358 for Helical Systems and Devices. In Canada, CCMC Report 13193-R shows compliance with the latest revisions of the Canadian Building Code (CBC). The current evaluation reports can all be found at www.abchance.com.

SHAFT SIZE SELECTION BASED on SOIL PARAMETERS

An additional condition that must be evaluated is the ability of the helical pile to penetrate soil to the required depth. For example, a foundation design may require an installation that penetrates a dense fill layer consisting of compacted construction debris (concrete, rubble, etc.) through a compressible organic layer below the fill and finally into the bearing strata. A helical pile shaft with a higher torque rating may be required to adequately penetrate through the fill even though a helical pile shaft with a lower torque rating would satisfy the ultimate capacity requirement. Table 3-1 outlines the maximum blow count or N-value that a particular shaft will typically penetrate. Note that the Type SS helical piles with higher strength shafts and helix material will penetrate harder/denser soils than the Type RS helical piles. Penetrating into harder/denser soils is generally required to support larger loads. The N-values listed in this table are intended to serve as a guide in the preliminary selection of the appropriate shaft series based on using multi-helix configurations. The limits are not intended to be absolute values and higher N-value soils may be penetrated by varying helix diameter, quantity and geometry. Therefore, local field installation experience may indicate more appropriate maximum N-values.

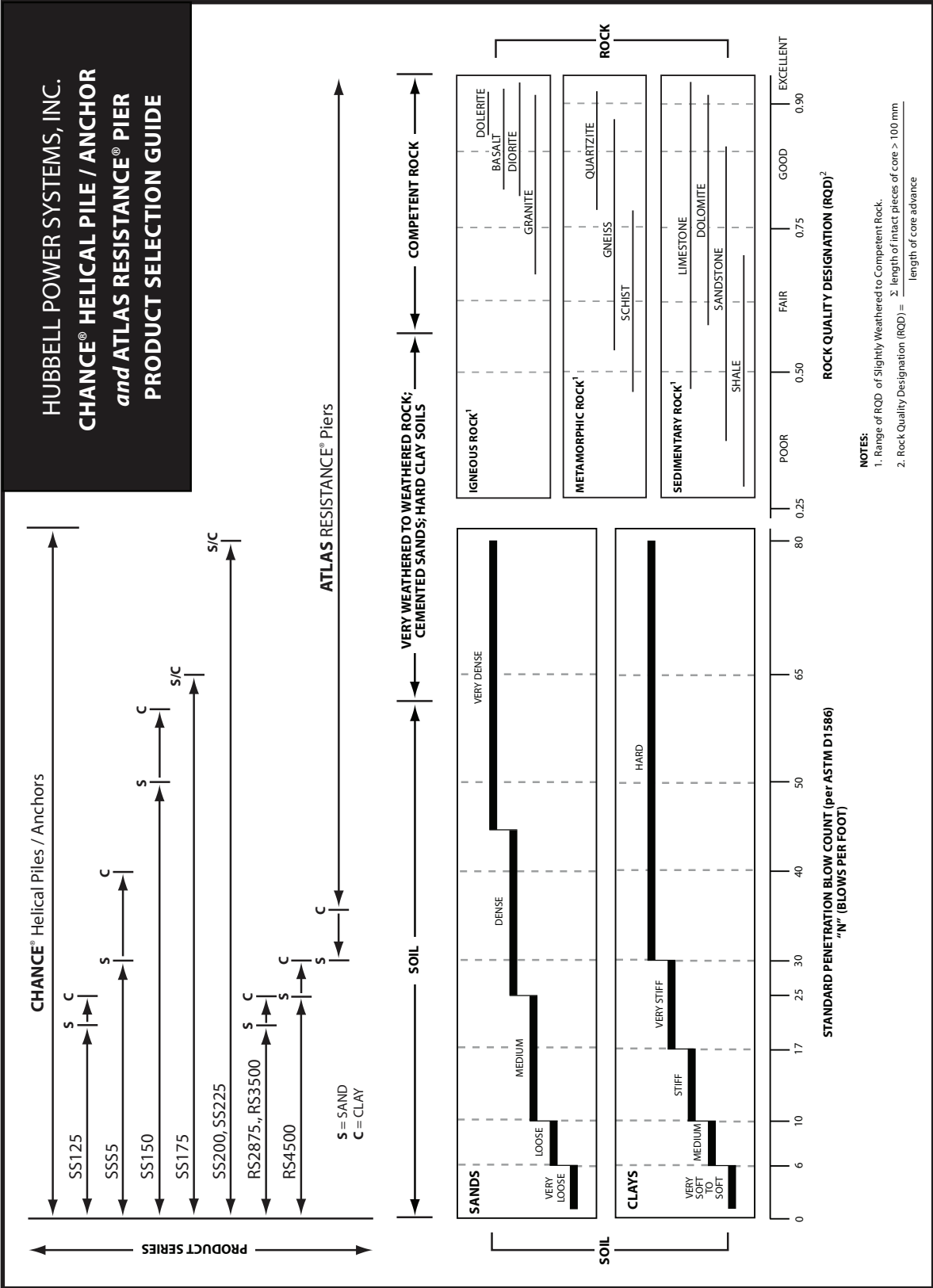
CHANCE® Helical Shaft Series Selection, Table 3-1

SHAFT SERIES	SHAFT SIZE in (mm)	TORQUE RATING Ft-lb (N-m)	MAX N-VALUE* Clay	MAX N-VALUE Sand
SS125	1-1/4 (32)	4,000 (5,400)	25	20
SS5	1-1/2 (38)	5,700 (7,730)	40	30
SS150	1-1/2 (38)	7,000 (9,500)	60	50
SS175	1-3/4 (44)	10,500 (14,240)	65	65
SS200	2 (51)	16,000 (21,700)	<80	<80
SS225	2-1/4 (57)	21,000 (28,475)	<80	<80
RS2875.203	2-7/8 (73)	5,500 (7,500)	25	20
RS2875.276	2-7/8 (73)	8,000 (10,847)	25	20
RS3500.300	3-1/2 (89)	13,000 (17,600)	25	20
RS4500.337	4-1/2 (114)	23,000 (31,200)	30	25
Large Diameter Pipe Pile (LDPP)		Varies based on Shaft Size	30	30

*N-value or Blow Count, from Standard Penetration Test per ASTM D 1586

Figure 3-1 on page 3-7 shows the same information as contained in the above table along with soil conditions suited for ATLAS RESISTANCE® Piers. This figure does not address the proper product selection based on its application. ATLAS RESISTANCE Piers are used primarily for remedial repair applications involving an existing structure. CHANCE® Helical Piles/Anchors are used for not only remedial repair applications, but for new commercial and residential construction, tieback walls, SOIL SCREW® walls, telecommunication towers, electric utility towers, pipeline buoyancy control, etc.

PRODUCT FEASIBILITY



Product Selection Guide, Figure 3-1

PRODUCT FEASIBILITY

PRELIMINARY CHANCE® HELICAL PILE/ANCHOR and ATLAS RESISTANCE® PIER DESIGN GUIDE

Hubbell Power Systems, Inc. manufactures CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Pier products for use as tension anchors and/or compression piles for varied foundation support applications. There are many different applications for these end bearing piles and each application will require:

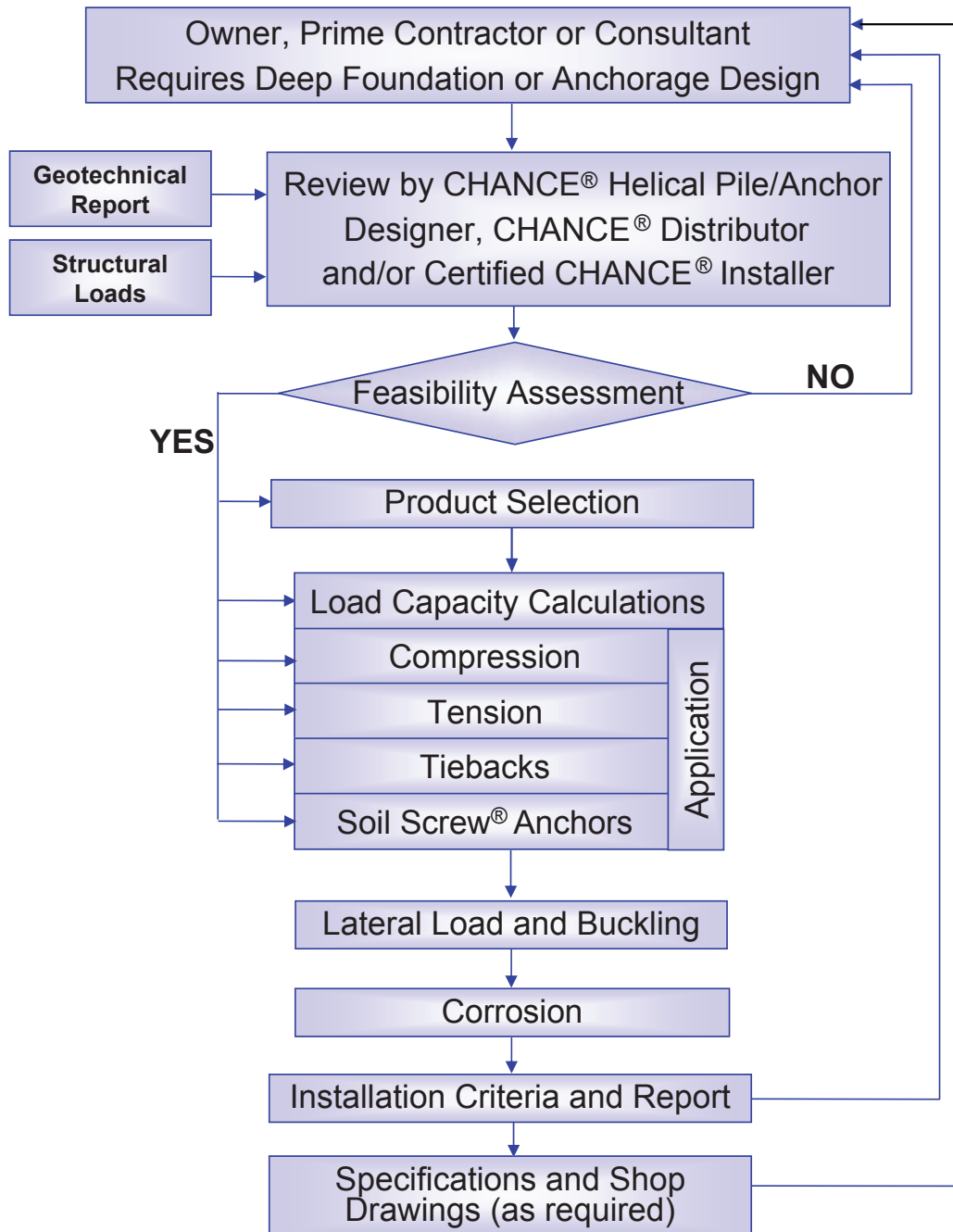
- An evaluation of the soil strata and soil characteristics of that stratum in which the helical plates or ATLAS RESISTANCE® Pier tip will be seated.
- A selection of the appropriate ATLAS RESISTANCE® Pier, including shaft type and bracket type or CHANCE® Helical Pile foundation, including shaft type, helical plate size, number and configuration. (Note: Type RS piles or CHANCE HELICAL PULLDOWN® Micropiles are strongly recommended in bearing/compression applications where the N-value of supporting soil around the shaft is less than 4. These piles have greater column stiffness relative to the standard CHANCE® Type SS piles. Refer to Buckling/Slenderness Considerations in Section 5 of this Technical Design Manual for a detailed discussion of this subject).
- A determination of the ultimate bearing capacity and suitable FS.

The preliminary design guide shown in Figures 3-2 and 3-3 is intended to assist certified installers, general contractors and consulting engineers in the selection of the appropriate CHANCE® Helical Pile or ATLAS RESISTANCE® Pier.

Design should involve professional geotechnical and engineering input. Specific information involving the structures, soil characteristics and foundation conditions must be used for the final design.

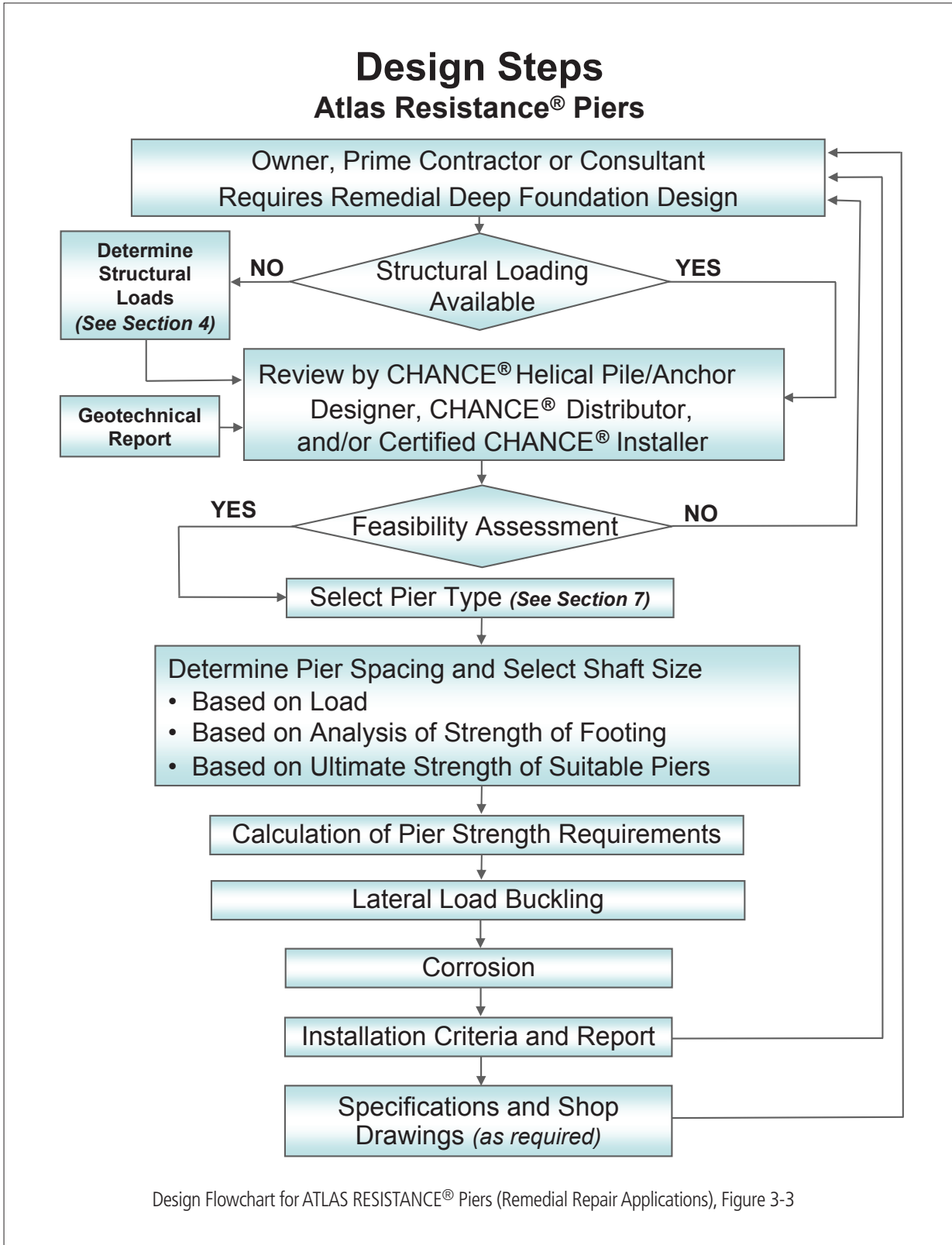
PRODUCT FEASIBILITY

Preliminary Design Flowchart for New Construction CHANCE® Helical Piles / Anchors



PRODUCT FEASIBILITY

Design Flowchart for CHANCE® Helical Piles and Anchors (New Construction), Figure 3-2



PRELIMINARY DESIGN REQUEST FORM

Contact at Hubbell Power Systems, Inc., CHANCE® Civil Construction: _____

Installing Contractor

Firm:	Contact:	
Phone:	Fax:	Cell:

Project

Name:	Type:	<input type="checkbox"/> Foundation	<input type="checkbox"/> Underpinning/Shoring
Address:		<input type="checkbox"/> New Construction	<input type="checkbox"/> Rock
		<input type="checkbox"/> Tieback Retaining	<input type="checkbox"/> Other:
		<input type="checkbox"/> Soil Nail Retaining	

Project Engineer? Yes No

Firm:	Contact:
Address:	Phone:
	Fax:
	Email:

Geotechnical Engineer? Yes No

Firm:	Contact:
Address:	Phone:
	Fax:
	Email:

Loads

	Design Load	FS (Mech) #1	FS (Geo) #1	Design Load	FS (Mech) #2	FS (Geo) #2
Compression						
Tension						
Shear						
Overturning						

Define the owner's expectations and the scope of the project:

The following are attached: Plans Soil Boring Soil Resistivity Soil pH

If any of the above are not attached, please explain:

Date: _____ Requested Response: _____ CHANCE® #: _____ Response: _____

Please copy and complete this form to submit a design request.

PRODUCT FEASIBILITY



PRODUCT FEASIBILITY





LOAD DETERMINATION



LOAD DETERMINATION SECTION 4

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STRUCTURAL LOADS	4-4
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CONCRETE PILE CAPS	

SYMBOLS USED IN THIS SECTION

FS	Factor of Safety	4-4
GWT	Ground Water Table	4-7
T.....	Tension Load	4-7
SL.....	Snow Load	4-11
S_K	Snow Load Factor	4-11
ksi.....	Kips (kilo-pounds) per square inch	4-11
ACI.....	American Concrete Institute	4-23
AISC.....	American Institute of Steel Construction	4-23

LOAD DETERMINATION

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

Hubbell Power Systems, Inc., shall not be responsible for, or liable to you and/or your customers for the adoption, revision, implementation, use or misuse of this information. Hubbell, Inc., takes great pride and has every confidence in its network of installing contractors and dealers.

Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

STRUCTURAL LOADS

TYPES of LOADS

There are generally four common loads that may be resisted by a given foundation element. These are compression, tension, lateral and moment loads. It is anticipated that anyone reading this manual will know the meanings of these loads, but for completeness we will describe them for our purposes here.

A compression load is one that will axially shorten a foundation and is typically considered to act vertically downward. The tension load tends to lengthen a foundation and is often taken to be acting vertically upward. A lateral load is one that acts parallel to the surface of the earth or perpendicular to a vertically installed foundation. The lateral load can also be referred to as a shear load. Moment load tends to bend the foundation about one of its transverse axis. A fifth load is torsion. It tends to twist the foundation about its longitudinal axis. This is a load that is seldom applied except during installation of a helical pile/anchor.

This design manual generally assumes the use of allowable strength design (ASD), i.e., the entire Factor of Safety (FS) is applied to the ultimate capacity of the steel foundation product in the soil to determine a safe (or design) strength. Section 7 of this Design Manual provides the Nominal, LRFD Design, and Allowable Strength of helical pile/anchor. Therefore, the designer can choose to use either limit states or allowable strength design for helical pile/anchor.

DESIGN or WORKING LOAD

The design load or working load is typically considered to be the same load. This is a combination of dead loads and live loads. The dead loads are simply the gravity load of structure, equipment, etc. that will always be there to be resisted by the foundation. The live load takes into account seismic events, wind load, snow load, ice, and occupancy activities. They are transient loads that are dynamic in nature. These loads are sometimes referred to as Unfactored Loads. They do not include any Factor of Safety.

Loads associated with backfill soil should be considered in any type of structural underpinning application. Soil load may be present in foundation lifting or restoration activities and can represent a significant percentage of the overall design load on an individual underpinning element, sometimes approaching as much as 50% of the total design load.

ULTIMATE LOAD

The ultimate load is the combination of the highest dead loads and live loads including safety factors. This load may or may not be the load used for foundation design.

FACTOR of SAFETY

Before a foundation design is complete a Factor of Safety (FS) must be selected and applied. In allowable strength design, the Factor of Safety (FS) is the ratio between the ultimate capacity of the foundation and the design load. A Factor of Safety of 2 is usual but can vary depending on the quality of the information available for the design process and if testing or reliable production control is used. Hubbell Power Systems, Inc. recommends a minimum Factor of Safety of 2 for permanent loading conditions and 1.5 for any temporary loading condition. See page 5-5 for a discussion of Factors of Safety when using ATLAS RESISTANCE® Piers for underpinning (remedial repair) applications.

NOTE: Ultimate load is not the same as ultimate capacity. A foundation has some finite capacity to resist load. The ultimate capacity may be defined as the minimum load at which failure of the foundation is likely to occur, and it can no longer support any additional load.

REVERSING LOADS

Foundation design must allow for the possibility that a load may reverse or change direction. This may not be a frequent occurrence, but when wind changes course or during seismic events, certain loads may change direction. A foundation may undergo tension and compression loads at different times or a reversal in the direction of the applied shear load. The load transfer of couplings is an important part of the design process for reversing loads.

DYNAMIC LOADS

Dynamic or cyclic loads are encountered when supporting certain types of equipment or conditions involving repetitive impact loads. They are also encountered during seismic events and variable wind events. These loads can prove destructive in some soil conditions and inconsequential in others. The designer must take steps to account for these possibilities. Research has shown that multi-helix anchors and piles are better suited to resist dynamic or cyclic loads. Higher factors of safety should be considered when designing for dynamic loads.

CODES and STANDARDS

The minimum load conditions, especially live loads for buildings are usually specified in the governing building codes. There are municipal, state and regional as well as model codes that are proposed for general usage. The designer must adhere to the codes for the project location. Chapter 18 of the IBC 2009 and 2012 contain Code sections for helical piles, as well as sections for general design of deep foundations. Section 4 of ICC-ES ESR-2794 provides guidelines for the design and installation of helical piles.

PRELIMINARY TIEBACK DESIGN GUIDE

Hubbell Power Systems, Inc. manufactures multi-helix products for use as tiebacks to assist in stabilizing and anchoring structures subjected to lateral loads from earth and water pressure. There are many applications for these tieback products and each application will require:

- An evaluation of the soil characteristics and the lateral earth and water loads on the retaining structure,
- A selection of the appropriate tieback product, including shaft type, helix size(s) and configuration, and
- A determination of the tension load capacity and suitable Factor of Safety.

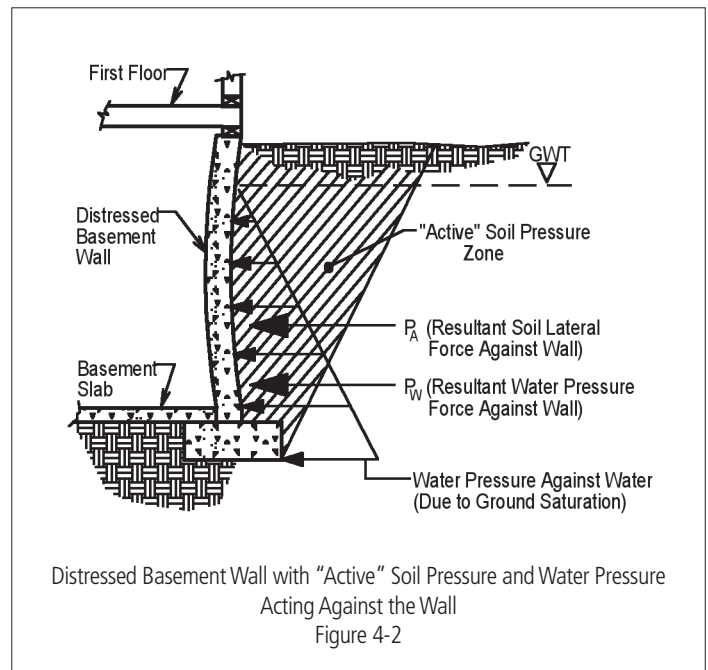
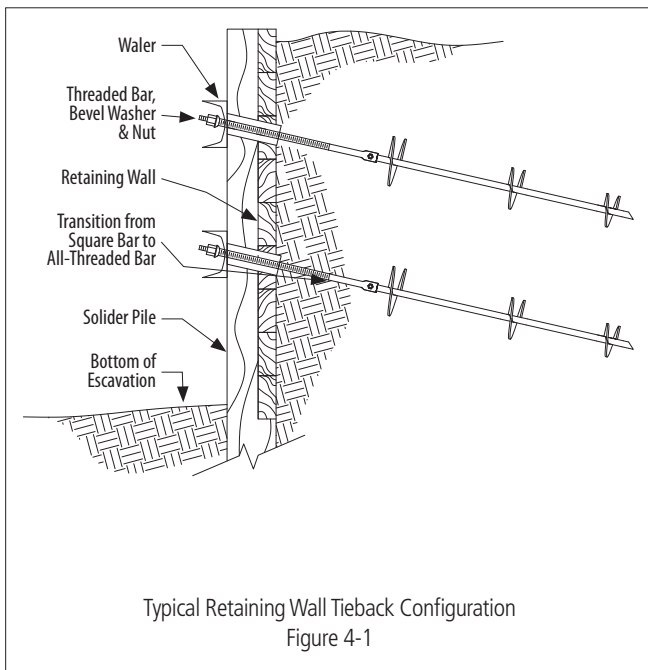
The following preliminary design guide information is intended to assist dealers, installing contractors, and consulting engineers in estimating the required tieback force and placement for the more common tieback applications and to select the appropriate CHANCE® Helical Tieback product. Figure 4-1 illustrates a typical temporary soldier beam and lagging retaining wall utilizing CHANCE® Helical Tiebacks. The commercial uses of CHANCE® Helical Tiebacks include both permanent and temporary sheet pile walls, bulkheads for marine applications, concrete reinforced walls, precast concrete panel walls, etc. They have been used in multi-tier tieback walls to heights of 50'-0.

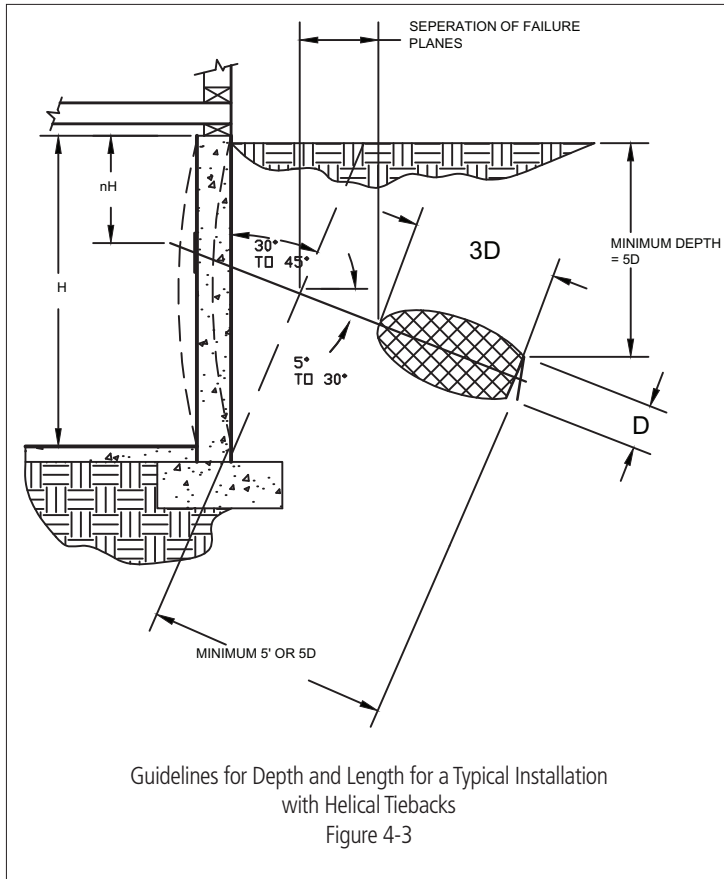
When using an external waler system consisting of double channels, WF or HP sections, these members shall be positioned relative to the wall face so that their webs are collinear with the tieback tendon. If the waler is not properly oriented with respect to the tieback tendon, then bending moments and shear loads could be introduced into the tieback tendon that could result in a premature failure of the tendon. The tieback tendon is intended to resist only axial loading.

LOAD DETERMINATION



It is recommended that a Registered Professional Engineer conduct the design.





TIEBACK DESIGN CONSIDERATIONS

Basement and Retaining Wall Applications

In most regions of the United States, many residential homes have basement walls below grade. Over time, the settling of the ground, plugging of drain tile, extensive rains, plumbing leaks and other environmental factors can cause these basement walls to inwardly bulge, crack, or be subjected to other forms of distress. The CHANCE® Helical Tieback can be an effective repair method for distressed basement walls (See Figure 4-2 and 4-3). There are, however, some general considerations that are important to understand and follow when specifying wall tiebacks.

Active and Passive Pressure Conditions

Figure 4-2 shows a distressed basement wall with the earth pressure “actively” pushing against the wall, as well as water pressure due to the indicated soil saturation condition. Most often it is the combined effect of “active” earth pressure and water pressure that leads to basement wall bulges and cracks. Active earth pressure is defined as the pressure exerted by the earth on a structure that causes movement of the structure away from the soil mass. When a helical tieback is installed and anchored in place, two options are available:

- A portion of the soil is removed, the helical tieback is used to restore the wall toward its original position and

the soil is backfilled against the wall, or

- The helical tieback is merely loaded and locked in position with no restoration. In this case, the wall is merely stabilized in its’ deflected position.

In either case, the soil will continue to exert an “active” pressure against the wall.

The installed helical tieback anchor develops anchoring resistance capacity through development of “passive” earth pressure against the helical plate. Passive earth pressure is defined as the pressure a structure exerts directly on the earth that causes the structure to move in the direction of the soil mass. Thus it is necessary that the helical tieback anchor be installed properly to ensure the ability to develop full “passive” pressure resistance.

It is very important that the basement wall repair should also include remedial drainage work in order to prevent any future condition of soil saturation and resulting water pressure against the wall and/or take into account the full effect of water pressure against the wall in the tieback design. (See Figure 4-2.)

Location and Placement of Tiebacks

Every tieback wall situation is unique, but there are some aspects that merit extra attention. The placement of the anchor is influenced by the height of the soil backfill against the wall. Figure 4-3 shows this condition and a guide for setting the location and minimum length of installation of the tieback. Experience indicates that the tieback should be located close to the point of maximum wall bulge and/or close to the most severe transverse crack. In cases where walls are constructed of concrete block walls or severe cracking occurred in solid concrete walls, a vertical and/or transverse steel channel (waler) or plate must be used to maintain wall integrity.

For other types of wall distress such as multiple cracking or differential settlement induced cracking, the tieback placement location must be selected on a case by case basis.

Another factor to consider is the height of soil cover over the helical tieback. Figure 4-3 shows the recommended minimum height of soil cover is five times the diameter of the largest helical plate. Finally, the helical anchor must

be installed a sufficient distance away from the wall in order that the helical plate(s) can fully develop an anchoring capacity by “passive” pressure as shown in Figure 4-3. This requires the length of installation to be related to the height of soil backfill also shown in Figure 4-3. The top-most or last helix installed must be located a minimum of five times its diameter beyond the assumed “active” failure plane.

Estimating Tieback Load Requirements

Estimating the lateral loads acting against basement walls or retaining walls as exerted by the earth requires knowledge of:

- The soil type and condition,
- The structural dimensions of the retaining structure, and.
- Other geotechnical conditions (e.g. ground water table).

Figures 4-4, 4-5, and 4-6 were prepared for preliminary design assistance for estimating tieback load requirements. Figures 4-5 and 4-6 illustrate cases where no ground water table (GWT) is present at the site. If hydrostatic water pressure is present, the magnitude of this pressure is determined and added to the tieback load requirement from the earth pressure.

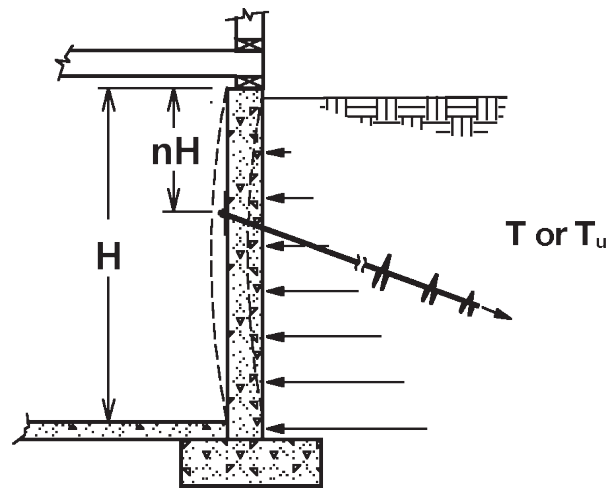
In those cases where the soil and subsurface drainage conditions are not known, it should be assumed in the design that water pressure will be present. As a guideline in preparing tieback load requirement estimates, one tieback row (tier) was used for walls of 15 feet of height or less and two tieback rows (tiers) for walls ranging in height from 15 feet to 25 feet. Individual project conditions and design considerations can cause changes in these guidelines.

PLACEMENT OF TIEBACK ANCHORS

TYPICAL BASEMENT WALL

- H = Height of backfill
- n = Tieback location from top of wall = 0.2 to 0.6
- FS = Factor of Safety = $1.5 < FS < 2.5$
- T = Tension load (lb/ft of wall)/cos ϕ . Assumes tieback provides 80% of lateral support.
- T_U = $18 \times (H^2) \times FS / \cos \phi$ (no water pressure present)
- T_U = $45 \times (H^2) \times FS / \cos \phi$ (water pressure present)

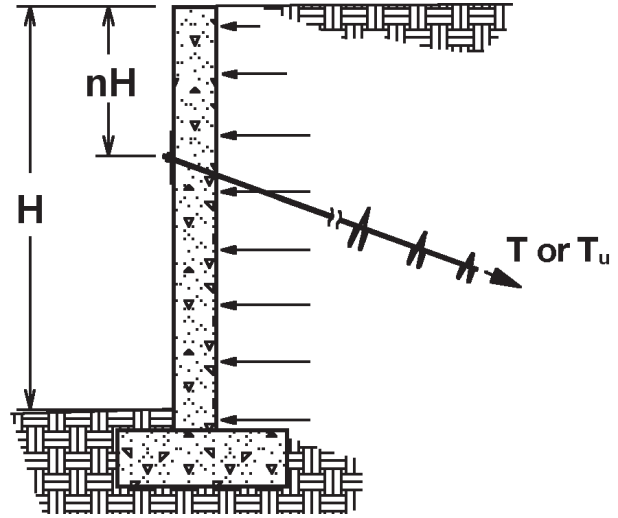
Note: Top of wall is assumed to be restrained in the lateral direction



Estimated Tieback Force Required for Basement Applications
Figure 4-4

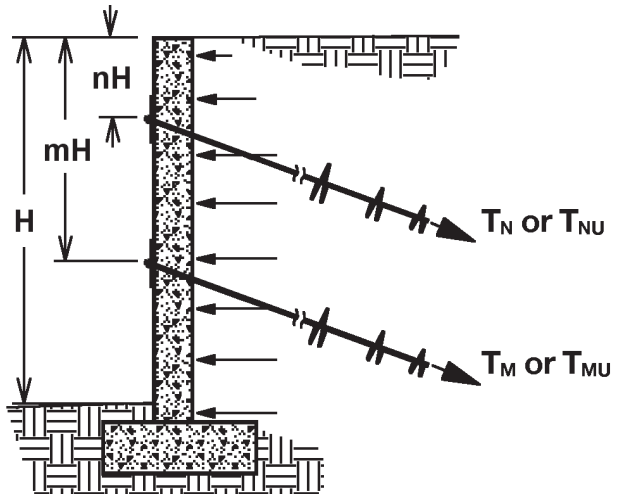
LOAD DETERMINATION

- H = Height of backfill (walls 15 ft or less)
- n = Tieback location from top of wall = 0.25 to 0.40
- FS = Factor of Safety = $1.5 < FS < 2.5$
- T = Tension Load (lb/ft of wall)/cos ϕ
- T_U = $25 \times (H^2) \times FS / \cos \phi$
- Note: Top of wall is assumed free to translate.



Estimated Tieback Force Required for Retaining Walls 15 Feet High or Less
Figure 4-5

- H = Height of backfill (walls 15 to 25 ft)
- n = Tieback location from top of wall = 0.20 to 0.30
- m = Lower tieback location from top of wall = 0.50 to 0.75
- FS = Factor of Safety = $1.5 < FS < 2.5$
- T = Tension Load (lb/ft of wall)/cos ϕ
- T_{NU} = $12 \times (H^2) \times FS / \cos \phi$
- T_{MU} = $18 \times (H^2) \times FS / \cos \phi$
- Note: Top of wall is assumed free to translate.



Estimated Tieback Force Required for Retaining Walls 15 Feet to 25 Feet
Figure 4-6

TECHNICAL DESIGN ASSISTANCE

The engineers at Hubbell Power Systems, Inc. have the knowledge and understand all of the elements of design and installation of CHANCE® Helical Piles/Anchors, Tiebacks, SOIL SCREW® Anchors and ATLAS RESISTANCE® Piers. Hubbell Power Systems, Inc. will prepare a complimentary product selection ("PRELIMINARY DESIGN") on a particular project for use by the engineer of record and our installing contractor or dealer.

If you require engineering assistance in evaluating an application, please contact your CHANCE® Distributor or Certified CHANCE® Installer in your area. These professionals will assist you in collecting the data required to submit the PRELIMINARY DESIGN INITIATION FORM and job specific data. The distributor, installing contractor or dealer will either send Preliminary Design requests to Hubbell Power System, Inc. or will provide the complimentary service themselves.

The PRELIMINARY DESIGN INITIATION FORM may be found on the last page of Section 3 in this manual. Please familiarize yourself with the information that you will need before calling for assistance.

TABLES for ESTIMATING DEAD LINE (DL) and LIVE LINE (LL) LOADS

Tables 4-1 through 4-5 below are provided solely as estimates of the dead and live line loads acting along a perimeter grade beam. It is recommended that a Registered Professional Engineer who is familiar with the site and site specific structural loading conduct the final analysis of the dead and live line loads acting along the perimeter grade beam.

Residential Buildings with Concrete Slab Floors, Table 4-1

BUILDING CONSTRUCTION	BUILDING DIMENSIONS (ft)								
	20' x 20'	20' x 30'	20' x 40'	30' x 30'	30' x 45'	30' x 60'	40' x 40'	40' x 60'	40' x 80'
	ESTIMATED DEAD LOAD at FOUNDATION, DL (lb/ft)								
One Story - Wood/metal/vinyl walls with wood framing on footing.	725	742	753	742	758	768	776	797	810
One Story - Masonry walls with wood framing on footing.	975	992	1003	992	1008	1018	1026	1047	1060
Two Story - Wood/metal/vinyl walls with wood framing on footing.	965	1004	1012	1004	1040	1063	1082	1129	1160
Two Story - First floor masonry, second floor wood/metal.	1215	1254	1280	1254	1290	1313	1332	1379	1410
Two Story - Masonry walls with wood framing on footing.	1465	1504	1530	1504	1540	1563	1582	1629	1660

LOAD DETERMINATION

Residential Buildings with Basements, Table 4-2

BUILDING CONSTRUCTION	BUILDING DIMENSIONS (ft)								
	20' x 20'	20' x 30'	20' x 40'	30' x 30'	30' x 45'	30' x 60'	40' x 40'	40' x 60'	40' x 80'
	ESTIMATED DEAD LOAD at FOUNDATION, DL (lb/ft)								
One Story - Wood/metal/vinyl walls with wood framing on footing.	1060	1092	1114	1092	1121	1140	1156	1195	1220
One Story - Masonry walls with wood framing on footing.	1310	1342	1364	1342	1371	1390	1406	1445	1470
Two Story - Wood/metal/vinyl walls with wood framing on footing.	1300	1354	1390	1354	1403	1435	1462	1528	1570
Two Story - First floor masonry, second floor wood/metal.	1550	1604	1640	1604	1653	1685	1712	1778	1820
Two Story - Masonry walls with wood framing on footing.	1800	1854	1890	1854	1903	1935	1962	2028	2070

Commercial Buildings, Table 4-3

BUILDING CONSTRUCTION	BUILDING DIMENSIONS (ft)								
	20' x 20'	20' x 30'	20' x 40'	30' x 30'	30' x 45'	30' x 60'	40' x 40'	40' x 60'	40' x 80'
	ESTIMATED DEAD LOAD at FOUNDATION, DL (lb/ft)								
One Story - Precast concrete walls on footing with slab floor.	2150	2175	2192	2175	2198	2213	2225	2255	2275
One Story - Precast concrete walls and basement on footing.	3130	3175	3205	3175	3217	3243	3265	3320	3355
Two Story - Precast concrete walls on footing with slab floor.	3425	3475	3508	3475	3521	3550	3611	3636	3675
Two Story - Precast concrete walls and basement on footing.	4490	4560	4607	4560	4624	4665	4700	4786	4840

LOAD DETERMINATION

Estimating Live Loads, Table 4-4

BUILDING CONSTRUCTION	BUILDING DIMENSIONS (ft)								
	20' x 20'	20' x 30'	20' x 40'	30' x 30'	30' x 45'	30' x 60'	40' x 40'	40' x 60'	40' x 80'
	ESTIMATED LIVE LOAD at FOUNDATION, LL (lb/ft)								
One Story - Residential on slab.	N/A								
One Story - Residential on basement.	250	300	333	300	346	375	400	461	500
One Story - Residential over crawl space.									
Two Story - Residential on slab.									
Two Story - Residential on basement.	500	600	667	600	692	750	800	923	1000
Two Story - Residential over crawl space.									
One Story - Commercial on slab.	N/A								
One Story - Commercial on basement.	450	540	600	540	623	675	720	831	900
Two Story - Commercial on slab.									
Two Story - Commercial on basement.	900	1080	1200	1080	1246	1350	1440	1662	1800

ESTIMATING SNOW LOADS (SL)

The required Snow Load Factor (S_K) can be determined from the locally approved building code. This factor will be given in pounds per square foot. To determine the Snow Load along the perimeter of the structure used the following:

$$SL = S_K \times [(w \times L) / 2 \times (w + L)]$$

NOTE: w = width of building, L = length of building

TABLES for ESTIMATING FREE SPANS BETWEEN SUPPORTS

Tables 4-6 through 4-9 are provided to help estimate spacing of CHANCE® Helical Piles or ATLAS RESISTANCE® Piers. One must clearly understand that the tables were calculated assuming that the foundation element was fabricated using proper construction techniques, with properly embedded reinforcing bars rated at 60 ksi and with high quality concrete having a 28-day compressive strength of 3,000 psi. After calculating maximum free span using Equation 4-1 below, the results were checked to ensure that beam shear did not yield a shorter maximum span. Keep in mind that poor construction techniques and/or substandard materials will shorten the allowable span. A Factor of Safety must be applied to the calculated maximum CHANCE® Helical Pile or ATLAS RESISTANCE® Pier spacing based upon experience and judgment.

$$L_s = [(F_y \times d \times A_s) / 1.875 \times P]^{1/2}$$

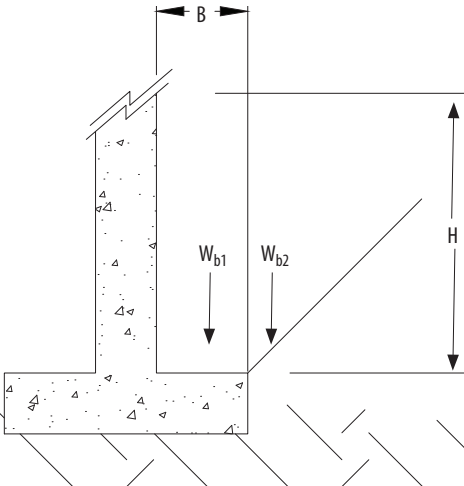
Equation 4-1

- where
- L_s = Maximum footing free span (ft)
 - F_y = Rebar yield strength = 24,000 psi
 - d = Moment arm distance (in)
 - A_s = Cross section area of steel (in²)
 - P = Structural line load (lb/ft)

LOAD DETERMINATION



Estimating Foundation Soil Load (W), Table 4-5

LOAD FROM SOIL OVERBURDEN	FOOTING TOE WIDTH B (in)	HEIGHT OF SOIL OVERBURDEN H (ft)	SOIL TYPE			
			COHESIVE		GRANULAR	
			W _{b1}	W _{b2}	W _{b1}	W _{b2}
 <p>Note: W_{b2} may be reduced or may not apply when only stabilizing the structure</p>	3	2	55	220	75	240
		4	110	880	125	960
		6	165	1980	188	2160
		8	220	3520	250	3840
	6	2	110	220	125	240
		4	220	880	250	960
		6	330	1980	375	2160
		8	440	3520	500	3840
	9	2	165	220	500	240
		4	330	880	1000	960
		6	495	1980	1500	2160
		8	660	3520	2000	3840
	12	2	220	220	250	240
		4	440	880	500	960
		6	660	1980	750	2160
		8	880	3520	1000	3840

Use Table 4-5 for structural underpinning applications.

$$x = \frac{(L_s + w_p/12)}{FS_f}$$

Equation 4-2

- where
- x = Pile/pier spacing
 - W_p = Width of foundation repair bracket (in)
 - FS_f = Factor of Safety based upon field conditions and engineering judgment.

Example: The structure has a 6" thick footing along with an 8" tall stem wall that was cast with the footing. It was reported that building code required a minimum of two #4 reinforcing bars spaced 3" from the bottom and sides of the concrete. The structure is a single story wood frame building with masonry veneer and a 4" concrete slab. The structural load on the perimeter footing was calculated at 1,020 lb/ft plus 250 lb/ft soil overburden.

$$\begin{aligned}
 L_S &= [(F_y \times d \times A_s) / 1.875 \times P]^{1/2} && \text{Equation 4-3} \\
 &= [(24,000 \times 11 \times 0.3926) / (1.875 \times 1270)]^{1/2} \\
 &= [43.526]^{1/2} \\
 L_S &= 6.6 \text{ ft} = \text{maximum free span} \\
 d &= (6'' - 3'') + 8'' = 11'' \\
 \text{where } A_s &= 2 \times 0.1963 = 0.3926 \text{ in}^2 \\
 P &= 1020 + 250 = 1270 \text{ lb/ft}
 \end{aligned}$$

$$x = \frac{(L_S + w_p/12)}{FS_f} \tag{Equation 4-4}$$

where

$$\begin{aligned}
 w_p &= 10'' \text{ (Atlas AP-2-UFB-3500.165 Pier Bracket)} \\
 &\text{or CHANCE}^\circ \text{ Underpinning Helical Pile Bracket C1500121} \\
 FS_f &= 1.2 \text{ (Inspection revealed a well built foundation)} \\
 x &= \frac{(6.6 + 10/12)}{FS_f} = \frac{7.43 \text{ ft}}{1.2} \\
 x &= 6.19 \text{ ft (specify pier spacing at 6 feet on center)}
 \end{aligned}$$

For this project specify the spacing at a maximum 6 feet on center to allow for unexpected defects in the beam or foundation loading, or for possible field adjustments caused by obstructions or utilities.

It is important to keep in mind when one wants to reduce the number of piles/piers on a project, the distances in the tables are for a free span between supports. A supplemental steel footing could be offered to the client, which will effectively expand the distance between piles/piers while maintaining the required free span distance.

If we consider the example above, depending upon the complexity of the architecture, the number of piles/piers could be reduced by perhaps 10% to 15% on the total project by simply installing a 24" long, 3/8" x 6" x 6" supplemental steel beam under the footing.

$$x = \frac{(L_S + L_b/12)}{FS_f} \tag{Equation 4-5}$$

where

$$\begin{aligned}
 L_b &= 24'' \text{ (supplemental steel beam length)} \\
 FS_f &= 1.2 \text{ (Inspection revealed a well built foundation)} \\
 x &= \frac{8.6 \text{ ft}}{1.2} = 7.17 \text{ ft (pier spacing can be increased to 7 ft on center)}
 \end{aligned}$$

The piles/piers could, if the architecture allows, be spaced on 7-foot centers, while still maintaining the desired 6-foot free span distance.

Tables 4-6 through 4-9 will assist the designer and installer to estimate the maximum free span allowable for some common foundation configurations.

LOAD DETERMINATION

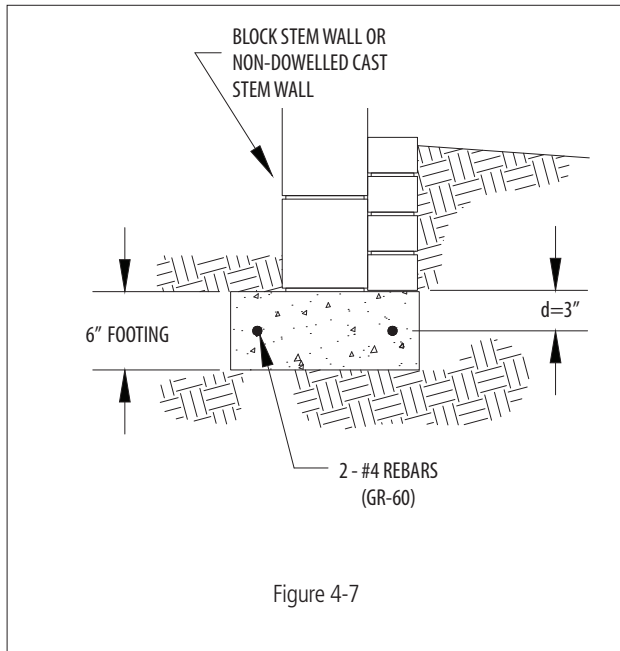


Figure 4-7

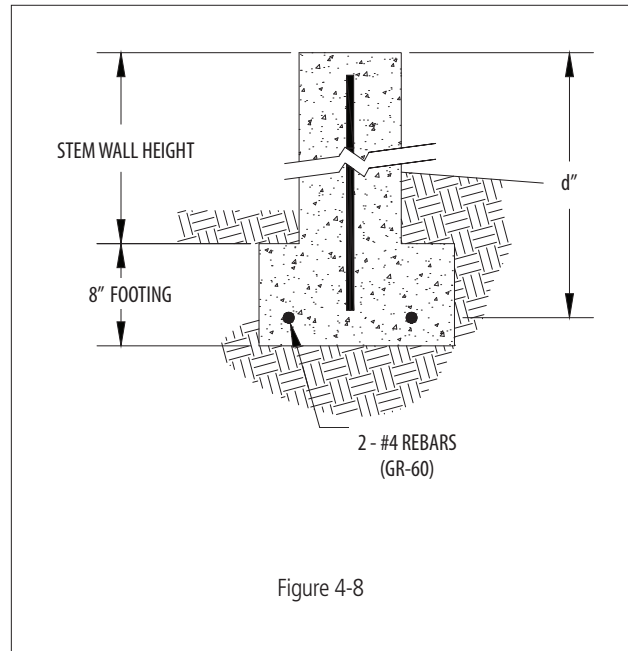


Figure 4-8

WARNING! THE DESIGNER MUST APPLY A FACTOR OF SAFETY TO THE MAXIMUM FREE SPAN WHEN PLANNING THE UNDERPINNING DESIGN SO THAT BEAM FAILURE IS NOT EXPERIENCED.

6" Thick Reinforced Concrete Spread Footings Maximum Free Spans, Table 4-6

6" THICK x 16" SPREAD FOOTING (See Figure 4-7)	BUILDING LINE LOAD (lb/ft.)											
	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500
	MAXIMUM FREE SPAN BETWEEN SUPPORTS											
2 - #4 Rebar (Gr 60): concrete block or cast stem wall (not dowelled) d = 3"	3'-11	3'-2	-	-	-	-	-	-	-	-	-	-
2 - #4 Rebar (Gr 60): 6" x 12" tall cast stem wall (dowelled or monolithic) d = 15"	8'-8	7'-1	6'-2	5'-6	5'-0	4'-8	4'-4	4'-1	-	-	-	-
2 - #4 Rebar (Gr 60): 6" x 18" tall cast stem wall (dowelled or monolithic) d = 21"	-	8'-5	7'-3	6'-6	5'-11	5'-6	5'-2	4'-10	4'-7	4'-5	4'-2	-
2 - #4 Rebar (Gr 60): 6" x 24" tall cast stem wall (dowelled or monolithic) d = 27"	-	-	8'-5	7'-4	6'-9	6'-3	5'-10	5'-6	5'-2	5'-0	4'-9	4'-7
2 - #4 Rebar (Gr 60): 6" x 48" tall cast stem wall (dowelled or monolithic) d = 51"	-	-	-	-	-	8'-7	8'-0	7'-7	7'-2	6'-10	6'-6	6'-3

LOAD DETERMINATION

8" Thick Reinforced Concrete Spread Footings Maximum Free Spans, Table 4-7

8" THICK x 16" SPREAD FOOTING (See Figure 4-8)	BUILDING LINE LOAD (lb/ft.)											
	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500	7,000
	MAXIMUM FREE SPAN BETWEEN SUPPORTS											
2 - #4 Rebar (Gr 60): concrete block or cast stem wall (not doweled) d = 5"	4'-6	3'-9	3'-6	-	-	-	-	-	-	-	-	-
2 - #4 Rebar (Gr 60): 8" x 12" tall cast stem wall (doweled or monolithic) d = 17"	7'-7	6'-6	5'-10	5'-4	4'-11	4'-7	4'-4	4'-2	3'-11	3'-9	3'-8	3'-5
2 - #4 Rebar (Gr 60): 8" x 18" tall cast stem wall (doweled or monolithic) d = 23"	-	7'-7	6'-10	6'-2	5'-9	5'-5	5'-1	4'-10	4'-7	4'-5	4'-3	4'-1
2 - #4 Rebar (Gr 60): 8" x 24" tall cast stem wall (doweled or monolithic) d = 29"	-	8'-6	7'-8	7'-0	6'-5	6'-0	5'-8	5'-5	5'-2	4'-11	4'-9	4'-7
2 - #4 Rebar (Gr 60): 8" x 48" tall cast stem wall (doweled or monolithic) d = 53"	-	-	-	-	-	8'-2	7'-8	7'-4	7'-0	6'-8	6'-5	6'-2

12" Thick Reinforced Concrete Spread Footings Maximum Free Spans, Table 4-8

12" THICK x 24" SPREAD FOOTING (See Figure 4-9)	BUILDING LINE LOAD (lb/ft.)											
	3,500	4,000	4,500	5,000	5,500	6,000	6,500	7,000	7,500	8,000	8,500	9,000
	MAXIMUM FREE SPAN BETWEEN SUPPORTS											
3 - #5 Rebar (Gr 60): 10" x 12" tall cast stem wall (doweled or monolithic) d = 21"	8'-4	7'-10	7'-2	7'-0	6'-8	6'-5	6'-2	5'-11	5'-9	5'-7	5'-5	5'-3
3 - #5 Rebar (Gr. 60): 10" x 18" tall cast stem wall (doweled or monolithic) d = 27"	-	-	8'-5	8'-0	7'-7	7'-3	7'-0	6'-9	6'-6	6'-4	6'-1	5'-11
3 - #5 Rebar (Gr. 60): 10" x 24" tall cast stem wall (doweled or monolithic) d = 33"	-	-	-	-	-	8'-0	7'-9	7'-5	7'-2	7'-0	6'-9	6'-7

LOAD DETERMINATION

Monolithic Reinforced Concrete Grade Beam Footing Maximum Free Spans, Table 4-9

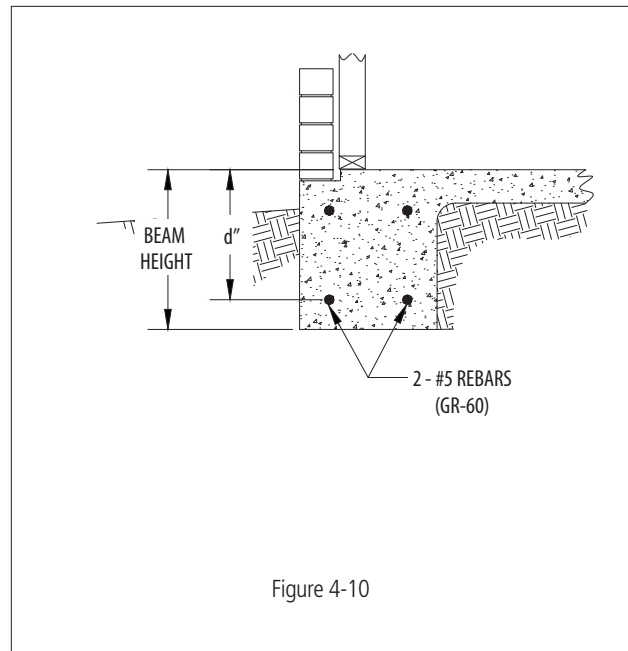
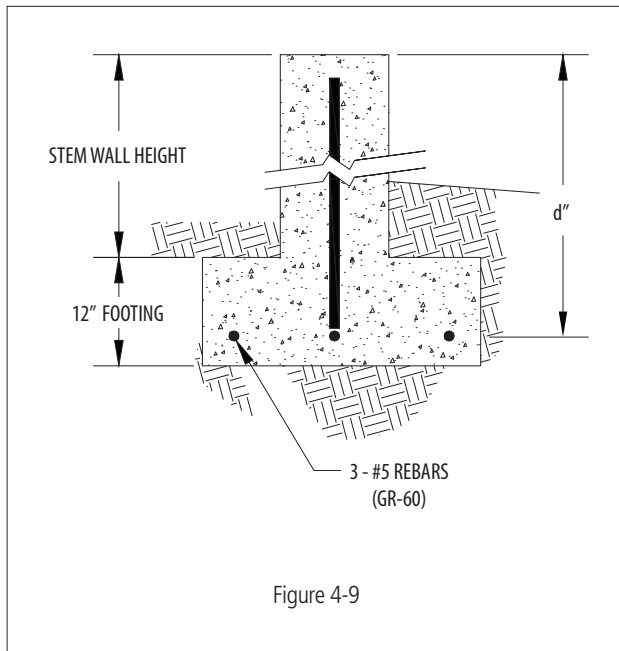
TURNED DOWN FOUNDATION CONSTRUCTION (See Figure 4-10)	BUILDING LINE LOAD (lb/ft.)											
	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500
	MAXIMUM FREE SPAN BETWEEN SUPPORTS											
12" high perimeter beam: 2-#4 bottom rebars (Gr 60) d = 9"	6'-9	5'-6	4'-9	4'-3	3'-11	3'-7	-	-	-	-	-	-
20" high perimeter beam: 2-#5 bottom rebars (Gr 60) d = 17"	-	-	8'-2	7'-5	6'-8	6'-2	5'-9	5'-6	5'-2	4'-11	4'-9	4'-6
24" high perimeter beam: 2-#5 bottom rebars (Gr 60) d = 21"	-	-	-	8'-1	7'-5	6'-10	6'-5	6'-1	5'-9	5'-6	5'-3	5'-0

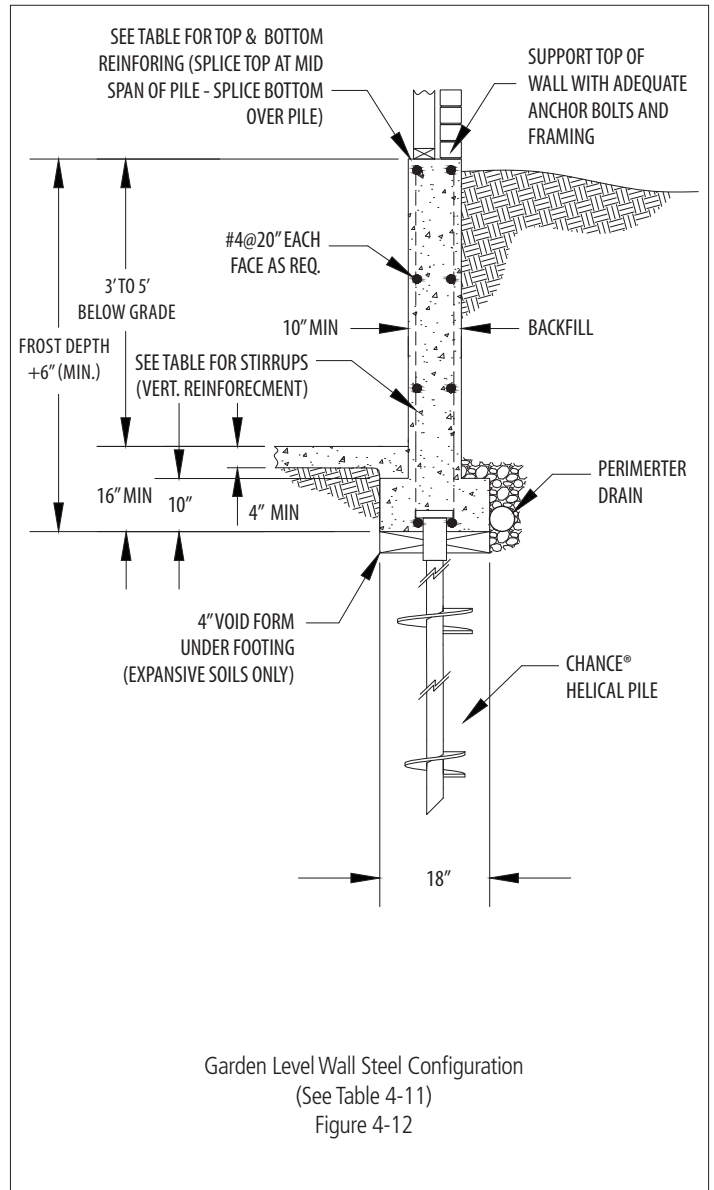
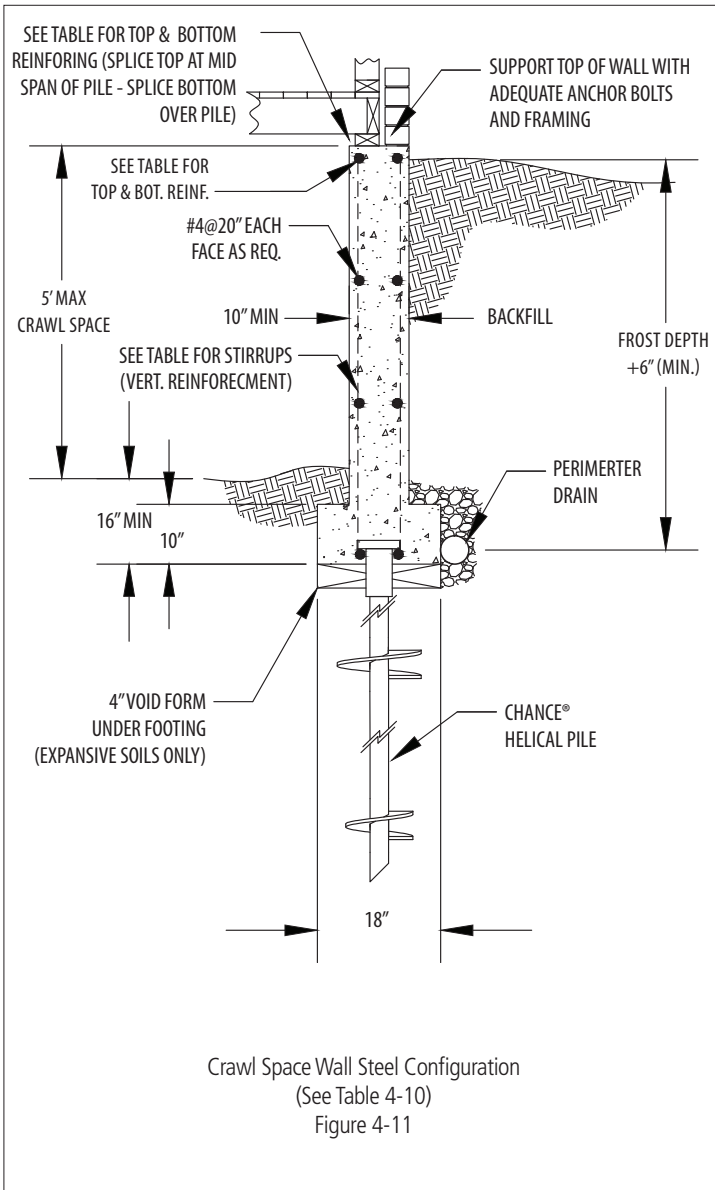
WARNING! THE DESIGNER MUST APPLY A FACTOR OF SAFETY TO THE MAXIMUM FREE SPAN WHEN PLANNING THE UNDERPINNING DESIGN SO THAT BEAM FAILURE IS NOT EXPERIENCED.

PRELIMINARY DESIGN GUIDELINES for REINFORCED CONCRETE GRADE BEAMS

Building loads are most commonly transferred to helical piles through concrete grade beams. Figures 4-11 through 4-15 below provide preliminary design guidance for grade beam sizing and steel reinforcement configuration. The grade beam sizing and selection of steel reinforcement tables below include the total line load for live loads on the beam and the dead load of the beam and structure. The 4" void under the grade beam is for illustration purposes only. The thickness of the void form will depend on site specific conditions. The final design should be conducted and approved by a Registered Professional Engineer.

LOAD DETERMINATION





LOAD DETERMINATION

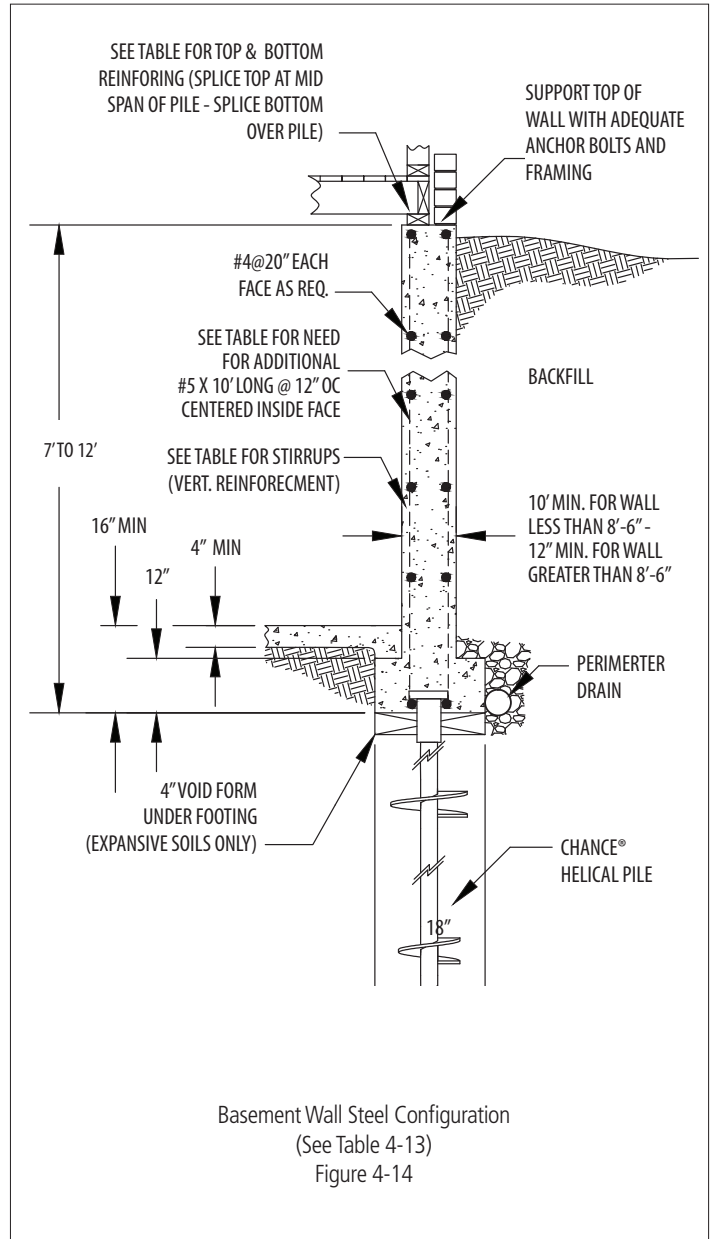
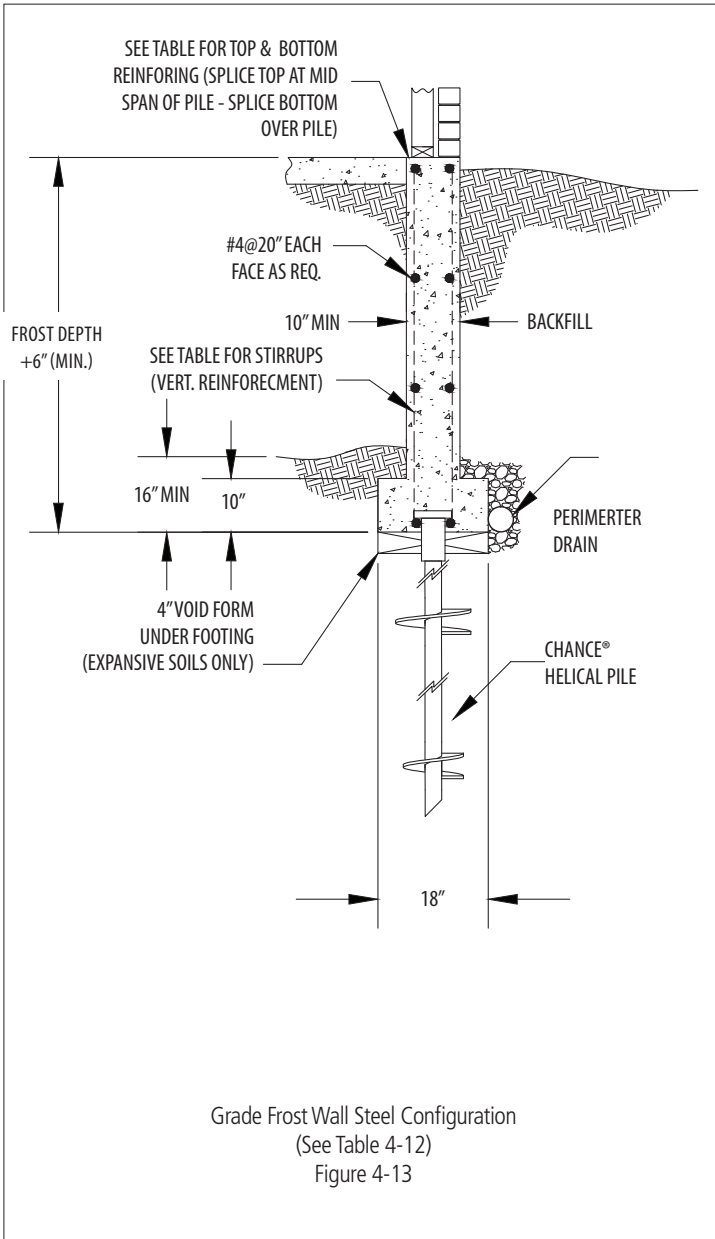
Crawspace Wall Reinforcing Steel, Table 4-10

PILE SPACING	WALL HEIGHT	TOTAL FOUNDATION LINE LOAD									
		3,000 (lb/ft)		4,000 (lb/ft)		5,000 (lb/ft)		6,000 (lb/ft)		7,000 (lb/ft)	
		STEEL REINFORCING BARS REQUIRED									
		Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)
8'	3'	2- #5		2- #6		2- #6		2 - #7		2 - #7	
	4'	2- #4	#3 @ 15"	2- #5	#3 @ 15"	2- #6	#3 @ 15"	2 - #6	#3 @ 15"	2 - #7	#3 @ 15"
	5'	2- #4		2- #4		2- #5		2 - #5		2 - #6	
10'	3'	2- #6		2- #7		2- #7		2 - #8		2 - #8	
	4'	2- #5	#3 @ 15"	2- #6	#3 @ 15"	2- #7	#3 @ 15"	2 - #8	#3 @ 15"	2 - #8	#3 @ 15"
	5'	2- #5		2- #5		2- #6		2 - #7		2 - #7	
12'	3'	2- #7		2- #7		2- #8		4 - #6		4 - #7	
	4'	2- #6	#3 @ 15"	2- #7	#3 @ 15"	2- #8	#3 @ 15"	4 - #6	#3 @ 15"	2 - #8	#3 @ 15"
	5'	2- #6		2- #7		2- #7		2 - #8		4 - #6	
15'	3'	2- #8		4- #6		4 - #7		4 - #8	#3 @ 11"	5 - #8	#3 @ 9"
	4'	2- #8	#3 @ 15"	2- #8	#3 @ 15"	4 - #6	#3 @ 15"	4 - #7	#3 @ 15"	4 - #8	#3 @ 15"
	5'	2- #7		2- #8		4 - #7		4 - #7		4 - #7	

Garden Level Wall Reinforcing Steel, Table 4-11

PILE SPACING	WALL HEIGHT	TOTAL FOUNDATION LINE LOAD									
		3,000 (lb/ft)		4,000 (lb/ft)		5,000 (lb/ft)		6,000 (lb/ft)		7,000 (lb/ft)	
		STEEL REINFORCING BARS REQUIRED									
		Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)
8'	3'	2- #5		2- #6		2- #6		2 - #7		2 - #7	
	4'	2- #4	#3 @ 15"	2- #5	#3 @ 15"	2- #6	#3 @ 15"	2 - #6	#3 @ 15"	2 - #7	#3 @ 15"
	5'	2- #4	#3 @ 12"	2- #4	#3 @ 12"	2- #5	#3 @ 12"	2 - #5	#3 @ 12"	2 - #6	#3 @ 12"
10'	3'	2- #6	#3 @ 15"	2- #7	#3 @ 15"	2- #7	#3 @ 15"	2 - #8	#3 @ 15"	2 - #8	#3 @ 15"
	4'	2- #5		2- #6		2- #7		2 - #8		2 - #8	
	5'	2- #5	#3 @ 12"	2- #6	#3 @ 12"	2- #6	#3 @ 12"	2 - #7	#3 @ 12"	2 - #7	#3 @ 12"
12'	3'	2- #7	#3 @ 15"	2- #7	#3 @ 15"	2- #8	#3 @ 15"	4 - #6	#3 @ 15"	4 - #7	#3 @ 15"
	4'	2- #6		2- #7		2- #8		2 - #8		2 - #8	
	5'	2- #6	#3 @ 12"	2- #7	#3 @ 12"	2- #7	#3 @ 12"	2 - #8	#3 @ 12"	4 - #6	#3 @ 12"
15'	3'	2- #8	#3 @ 15"	4- #6	#3 @ 15"	4 - #7	#3 @ 15"	4 - #8	#3 @ 10"	5 - #8	#3 @ 9"
	4'	2- #8		2- #8		4 - #6		4 - #7	#3 @ 15"	4 - #8	#3 @ 15"
	5'	2- #7	#3 @ 12"	2- #8	#3 @ 12"	4 - #7	#3 @ 12"	4 - #7	#3 @ 12"	4 - #7	#3 @ 12"

LOAD DETERMINATION



LOAD DETERMINATION

Grade Frost Wall Reinforcing Steel, Table 4-12

PILE SPACING	WALL HEIGHT	TOTAL FOUNDATION LINE LOAD									
		3,000 (lb/ft)		4,000 (lb/ft)		5,000 (lb/ft)		6,000 (lb/ft)		7,000 (lb/ft)	
		STEEL REINFORCING BARS REQUIRED									
		Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)
8'	3'	2- #5		2- #6		2- #6		2 - #7		2 - #7	
	4'	2- #4	#3 @ 15"	2- #5	#3 @ 15"	2- #6	#3 @ 15"	2 - #6	#3 @ 15"	2 - #7	#3 @ 15"
	5'	2- #4		2- #4		2- #5		2 - #5		2 - #6	
10'	3'	2- #6		2- #7		2- #7		2 - #8		2 - #8	
	4'	2- #5	#3 @ 15"	2- #6	#3 @ 15"	2- #7	#3 @ 15"	2 - #8	#3 @ 15"	2 - #8	#3 @ 15"
	5'	2- #5		2- #5		2- #6		2 - #7		2 - #7	
12'	3'	2- #7		2- #7		2- #8		4 - #6		4 - #7	
	4'	2- #6	#3 @ 15"	2- #7	#3 @ 15"	2- #8	#3 @ 15"	2 - #8	#3 @ 15"	2 - #8	#3 @ 15"
	5'	2- #6		2- #7		2- #7		2 - #8		4 - #6	
15'	3'	2- #8		4- #6		4 - #7		4 - #8	#3 @ 12"	4 - #8	#3 @ 9"
	4'	2- #8	#3 @ 15"	2- #8	#3 @ 15"	4 - #7	#3 @ 15"	4 - #7	#3 @ 15"	4 - #8	#3 @ 15"
	5'	2- #7		2- #8		4 - #7		4 - #7		4 - #7	

LOAD DETERMINATION

Basement Wall Reinforcing Steel Configuration, Table 4-13

PILE SPACING	WALL HEIGHT	TOTAL FOUNDATION LINE LOAD									
		3,000 (lb/ft)		4,000 (lb/ft)		5,000 (lb/ft)		6,000 (lb/ft)		7,000 (lb/ft)	
		STEEL REINFORCING BARS REQUIRED									
		Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)
8'	7'	2- #4	#3 @ 11"	2- #4	#3 @ 11"	2- #4	#3 @ 11"	2 - #5	#3 @ 11"	2 - #5	#3 @ 11"
	8'	2- #4	#3 @ 8"	2- #4	#3 @ 8"	2- #4	#3 @ 8"	2 - #4	#3 @ 8"	2 - #5	#3 @ 8"
	9'	2- #4	#4 @ 12"	2- #4	#4 @ 12"	2- #4	#4 @ 12"	2 - #4	#4 @ 12"	2 - #4	#4 @ 12"
	10'	2- #4	#4 @ 9"	2- #4	#4 @ 9"	2- #4	#4 @ 9"	2 - #4	#4 @ 9"	2 - #4	#4 @ 9"
	11'	2- #4	#4 @ 16" *	2- #4	#4 @ 16" *	2- #4	#4 @ 16" *	2 - #4	#4 @ 16" *	2 - #4	#4 @ 16" *
	12'	2- #4	#4 @ 12" *	2- #4	#4 @ 12" *	2- #4	#4 @ 12" *	2 - #4	#4 @ 12" *	2 - #4	#4 @ 12" *
10'	7'	2- #4	#3 @ 11"	2- #5	#3 @ 11"	2- #5	#3 @ 11"	2 - #6	#3 @ 11"	2 - #6	#3 @ 11"
	8'	2- #4	#3 @ 8"	2- #4	#3 @ 8"	2- #5	#3 @ 8"	2 - #5	#3 @ 8"	2 - #6	#3 @ 8"
	9'	2- #4	#4 @ 12"	2- #4	#4 @ 12"	2- #5	#4 @ 12"	2 - #5	#4 @ 12"	2 - #6	#4 @ 12"
	10'	2- #4	#4 @ 9"	2- #4	#4 @ 9"	2- #4	#4 @ 9"	2 - #5	#4 @ 9"	2 - #5	#4 @ 9"
	11'	2- #4	#4 @ 16" *	2- #4	#4 @ 16" *	2- #4	#4 @ 16" *	2 - #5	#4 @ 16" *	2 - #5	#4 @ 16" *
	12'	2- #4	#4 @ 12" *	2- #4	#4 @ 12" *	2- #4	#4 @ 12" *	2 - #4	#4 @ 12" *	2 - #5	#4 @ 12" *
12'	7'	2- #5	#3 @ 11"	2- #6	#3 @ 11"	2- #6	#3 @ 11"	2 - #7	#3 @ 11"	2 - #7	#3 @ 11"
	8'	2- #5	#3 @ 8"	2- #5	#3 @ 8"	2- #6	#3 @ 8"	2 - #6	#3 @ 8"	2 - #7	#3 @ 8"
	9'	2- #4	#4 @ 12"	2- #5	#4 @ 12"	2- #6	#4 @ 12"	2 - #6	#4 @ 12"	2 - #7	#4 @ 12"
	10'	2- #4	#4 @ 9"	2- #5	#4 @ 9"	2- #5	#4 @ 9"	2 - #6	#4 @ 9"	2 - #6	#4 @ 9"
	11'	2- #4	#4 @ 16" *	2- #5	#4 @ 16" *	2- #5	#4 @ 16" *	2 - #6	#4 @ 16" *	2 - #6	#4 @ 16" *
	12'	2- #4	#4 @ 12" *	2- #4	#4 @ 12" *	2- #5	#4 @ 12" *	2 - #5	#4 @ 12" *	2 - #6	#4 @ 12" *
15'	7'	2- #6	#3 @ 11"	2 - #7	#3 @ 11"	2 - #8	#3 @ 11"	4 - #6	#3 @ 11"	4 - #7	#3 @ 11"
	8'	2- #6	#3 @ 8"	2 - #7	#3 @ 8"	2 - #7	#3 @ 8"	2 - #8	#3 @ 8"	4 - #6	#3 @ 8"
	9'	2- #5	#4 @ 12"	2 - #6	#4 @ 12"	2 - #7	#4 @ 12"	2 - #8	#4 @ 12"	2 - #8	#4 @ 12"
	10'	2- #5	#4 @ 9"	2 - #6	#4 @ 9"	2 - #7	#4 @ 9"	2 - #7	#4 @ 9"	2 - #8	#4 @ 9"
	11'	2- #5	#4 @ 16" *	2 - #6	#4 @ 16" *	2 - #6	#4 @ 16" *	2 - #7	#4 @ 16" *	2 - #7	#4 @ 16" *
	12'	2- #5	#4 @ 12" *	2 - #5	#4 @ 12" *	2 - #6	#4 @ 12" *	2 - #7	#4 @ 12" *	2 - #7	#4 @ 12" *

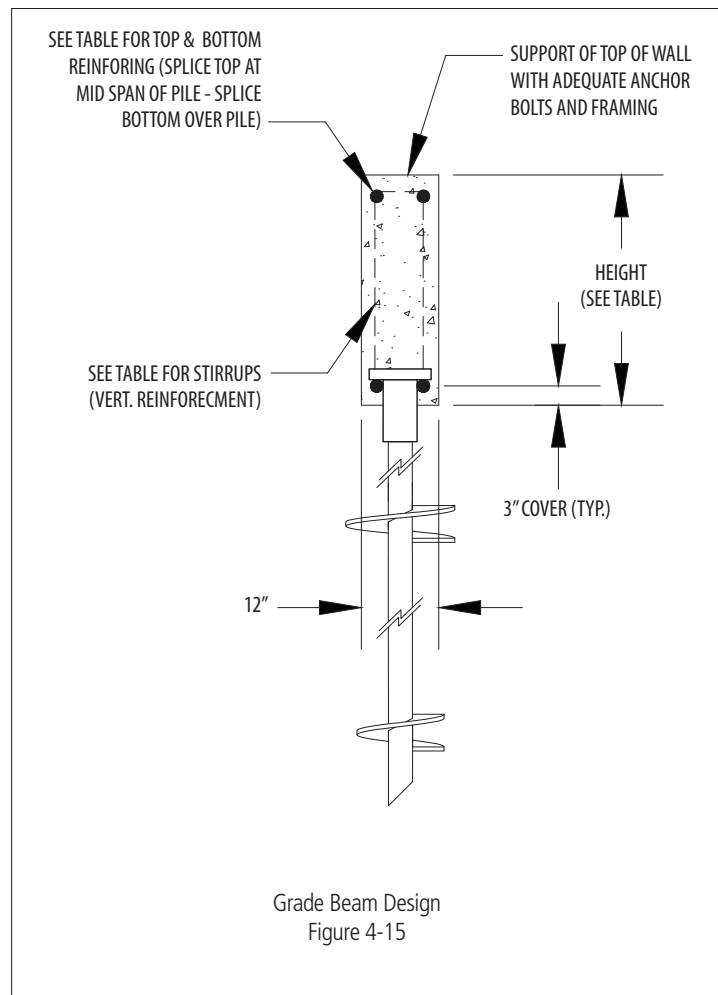
* Note: Requires added #5 x 10' long @ 12" O.C. bars centered vertically on inside wall face – See Figure 4-14.

LOAD DETERMINATION

Reinforcing Configuration Table, Table 4-14

Pile Spacing	TOTAL FOUNDATION LINE LOAD								
	2,000 (lb/ft)			3,000 (lb/ft)			4,000 (lb/ft)		
	STEEL REINFORCING BARS REQUIRED								
	Height	Top & Bottom	Stirrups (in. O.C.)	Height	Top & Bottom	Stirrups (in. O.C.)	Height	Top & Bottom	Stirrups (in. O.C.)
8'	18"	2 x #5	#3 @ 12"	20"	3 x #5	#3 @ 12"	24"	4 x #5	#3 @ 12"
10'	18"	3 x #5	#3 @ 12"	22"	3 x #5	#3 @ 12"	30"	4 x #5	#3 @ 15"
12'	24"	3 x #5	#3 @ 12"	27"	4 x #5	#3 @ 15"	30"	4 x #5	#3 @ 15"
15'	24"	4 x #5	#3 @ 12"	30"	4 x #5	#3 @ 15"	36"	4 x #6	#3 @ 18"

LOAD DETERMINATION



PRELIMINARY DESIGN GUIDELINES for REINFORCED PILE CAPS

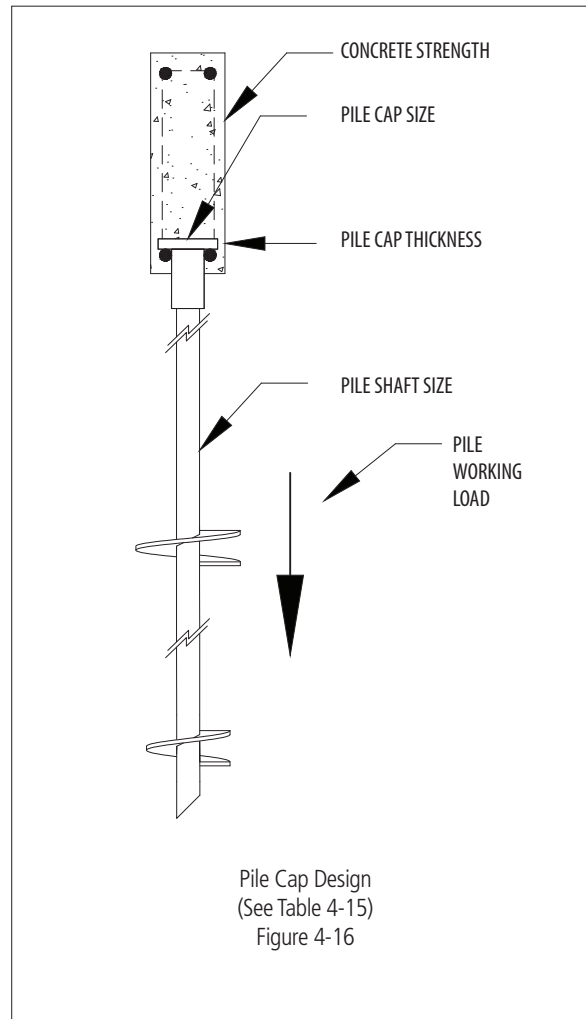
Pile cap configurations may be determined from Table 4-15. The table is based upon American Concrete Institute (ACI) criteria for concrete bearing stress from external bearing plates at working loads and from the American Institute of Steel Construction (AISC) criteria for bending stress in the steel plate overhang. Step 1 is based upon a yield-line theory whether bending is across a corner or parallel to an edge.

STEP 1. Select a pile cap plate size from Table 4-15 by looking at the proper row for applicable concrete strength. Locate the lowest value that exceeds the expected pile working load. The proper pile cap plate size is indicated at the bottom of the table.

STEP 2. The pile cap thickness is then determined from the lower portion of Table 4-15. Select the group of rows for the desired pile shaft size. Under the column for the desired pile cap plate size (as determined in Step 1), select the smallest pile cap thickness that exceeds the expected pile working load.



It is recommended that a Registered Professional Engineer conduct the design.



LOAD DETERMINATION

Pile Cap Configuration Table, Table 4-15

STEP 1		PILE CAP PLATE SIZE SELECTOR Limiting Pile Working Loads Controlled by Compressive Strength of Concrete			
Concrete Compressive Strength (psi)		Compressive Working Load on Helical Pile (lb)			
3,000		14,100	32,400	57,600	90,000
3,500		16,800	37,800	67,200	105,000
4,000		19,200	43,200	76,800	120,000
4,500		21,600	48,600	86,400	
5,000		24,000	54,000	96,000	
		RECOMMENDED PILE CAP SIZE			
		4" x 4"	6" x 6"	8" x 8"	10" x 10"
STEP 2		PILE CAP PLATE SIZE SELECTOR Limiting Pile Working Loads Controlled by Bending Stress in Plate Overhang			
Helical Pile Shaft Series	Pile Cap Thickness	PILE CAP SIZE (From Step 1 above)			
		4" x 4"	6" x 6"	8" x 8"	10" x 10"
		Compressive Working Load on Helical Pile (lb)			
RS2875.203 RS2875.262	1/4"	23,200	9,780	7,080	5,330
	3/8"	52,200	22,000	15,900	12,000
	1/2"		39,100	28,300	21,300
	3/4"		88,000	63,700	47,900
RS3500.300	1/4"		12,100	8,080	6,250
	3/8"		27,200	18,200	14,100
	1/2"		48,300	32,300	25,000
	3/4"		109,000	72,700	56,300
	1"				100,000
RS4500.337	1/4"		20,000	10,800	8,080
	3/8"		45,000	24,400	18,200
	1/2"		80,000	43,300	32,300
	3/4"			97,500	72,700
SS5 SS150	1/4"	10,000	6,000	5,000	4,000
	3/8"	21,000	12,000	10,000	9,000
	1/2"	40,000	25,000	18,000	16,000
	3/4"	85,000	50,000	40,000	35,000
	1"		90,000	75,000	65,000
SS175	1/4"	14,000	7,000	6,000	5,000
	3/8"	31,000	15,000	11,000	10,000
	1/2"	56,000	27,000	20,000	18,000
	3/4"		60,000	45,000	38,000
	1"		105,000	80,000	70,000
SS200	1/4"	21,000	9,000	6,500	5,500
	3/8"	45,000	18,000	13,000	11,000
	1/2"	82,000	32,000	22,000	19,000
	3/4"		71,000	50,000	42,000
	1"			90,000	75,000

LOAD DETERMINATION



DESIGN METHODOLOGY



DESIGN METHODOLOGY SECTION 5

CONTENTS

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SYMBOLS USED IN THIS SECTION

SPT	Standard Penetration Test	5-5
N	Standard Penetration Test Blow Count	5-5
FS	Factor of Safety	5-5
P	Line Load on Footing	5-6
P _w	Pier Working Load	5-7
DL	Dead Load	5-6
LL	Live Load	5-6
SL	Snow Load	5-6
W	Soil Load	5-6
X	Pier Spacing	5-6
FS _h	Factor of Safety (hardware)	5-6
R _w ULT	Minimum Ultimate Hardware Strength Requirement	5-6
R _h ULT	Ultimate Hardware Installation Force	5-6
X _{MAX}	Maximum Pier Spacing	5-6
R _p	Proof Resistance	5-7
FS _p	Proof Factor of Safety	5-7
R _h MAX	Maximum Pier Resistance	5-7
Q _{ULT}	Ultimate Capacity of the Soil	5-9

A_h	Projected Helix Area	5-9
c	Soil Cohesion	5-9
q'	Effective Overburden Pressure	5-9
B	Helix Diameter & Footing Width (Base)	5-9
γ'	Effective Unit Weight of the Soil	5-9
N_c	Bearing Capacity Factor for Cohesive Component of Soil	5-9
N_q	Bearing Capacity Factor for Non-Cohesive Component of Soil	5-9
N_γ	Bearing Capacity Factor for Soil Weight and Foundation Width	5-9
Q_t	Total Ultimate Multi-Helix Anchor/Pile Capacity	5-25
Q_h	Individual Helix Capacity	5-11
Q_s	Capacity Upper Limit	5-21
D	Vertical Depth to Helix Plate	5-10
ϕ	Angle of Internal Friction	5-11
γ	Effective Unit Weight of Soil	5-10
K_0	Coefficient of Earth Pressure at Rest	5-14
K_a	Coefficient of Active Earth Pressure	5-45
K_p	Coefficient of Passive Earth Pressure	5-45
H	Height of Wall or Resisting Element	5-46
P_a	Active Earth Pressure	5-46
P_p	Passive Earth Pressure	5-46
P_{crit}	Critical Compression Load	5-49
E	Modulus of Elasticity	5-49
I	Moment of Inertia	5-49
K	End Condition Parameter	5-49
L_u	Unsupported Length	5-49
Kl/r	Slenderness Ratio	5-49
P_{cr}	Critical Buckling Load	5-50
E_p	Modulus of Elasticity of Foundation Shaft	5-50
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d	Foundation Shaft Diameter	5-51
L	Foundation Shaft Length	5-51
U_{cr}	Dimensionless Ratio	5-51
y	Lateral Deflection of Shaft at Point x	5-51

X	Distance Along the Axis	5-51
EI	Flexural Rigidity of the Foundation Shaft	5-51
Q	Axial Compressive Load	5-51
E _s y	Soil Reaction per Unit Length	5-51
E _s	Secant Modulus of the Soil Response Curve	5-51
D	Diameter of Timber, Steel or Concrete Pile Column	5-38
f _s	Sum of Friction and Adhesion Between Soil and Pile	5-38
ΔL _f	Incremental Pile Length	5-38
C _a	Adhesion Factor	5-39
σ ₀	Mean Normal Stress	5-38
psf	Pounds per Square Foot	5-23
q	Effective Vertical Stress on Element	5-39
K	Coefficient of Lateral Earth Pressure	5-39
∅	Effective Friction Angle Between Soil & Pile Material	5-39
S	Average Friction Resistance on Pile Surface Area	5-39
P ₀	Average Overburden Pressure	5-39
s _u	Undrained Shear Strength	5-12
(N ₁) ₆₀	Normalized SPT N-value	5-32

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

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Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

5.1 ATLAS RESISTANCE® PIER CAPACITY

ATLAS RESISTANCE® Piers develop their capacity primarily through end bearing. The current accepted state of the art practice is for ATLAS RESISTANCE® Piers to be installed to a preset performance design criterion. The development of a theoretical capacity model is under study. Current and planned research projects and studies should provide meaningful data for the development of this model in the future.

In general, the tip of the ATLAS RESISTANCE® Pier should be embedded in cohesionless soils with Standard Penetration Test (SPT) “N” values above the 30 to 35 range and in cohesive soils with SPT “N” values above the 35 to 40 range. The ATLAS RESISTANCE® Pier will provide foundation underpinning support in end-bearing when positioned into these SPT “N” value ranges based on past installation experience. See Figures 5-1 and 5-2 for assumed failure patterns under a pile tip in dense sand.

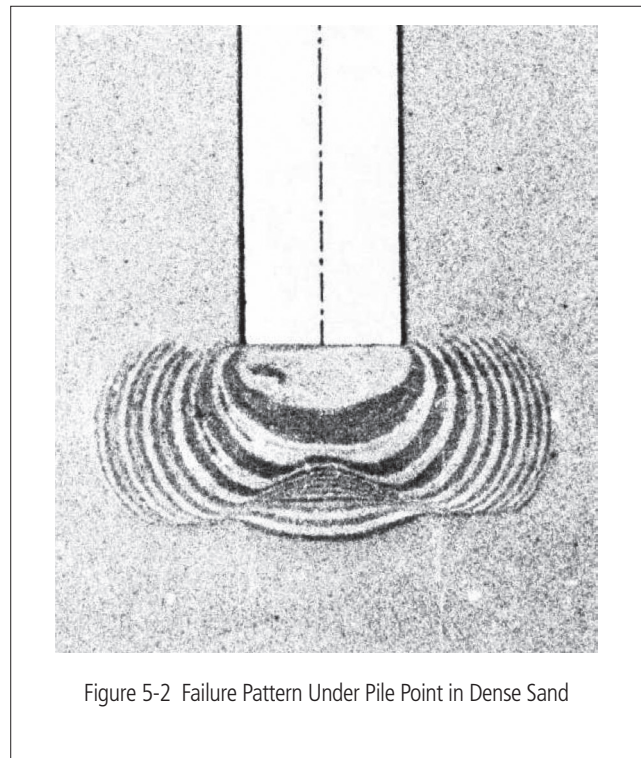
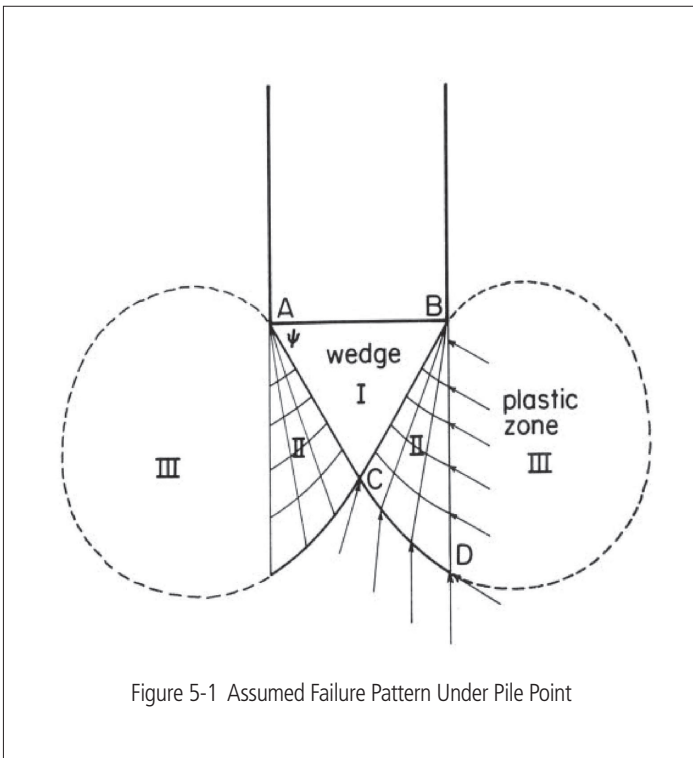
The ATLAS RESISTANCE® Pier is a manufactured, two-stage product designed specifically to produce structural support strength. First, the pier pipe is driven to a firm-bearing stratum then the lift equipment is combined with a manifold system to lift the structure. The ATLAS RESISTANCE® Pier System procedure provides measured support strength. ATLAS RESISTANCE® Piers are spaced at adequate centers where each pier is driven to a suitable stratum and then tested to a force greater than required to lift the structure. ***This procedure effectively load tests each pier prior to lift and provides a measured Factor of Safety (FS) on each pier at lift.***

Performance Design Criterion

The following guidelines are intended to serve as a basis for the selection and installation of a proper ATLAS RESISTANCE® Pier.

- Pier Spacing: The required working load per pier is calculated based on the dead loads and live loads and the ability of the existing foundation to span between the proposed pier locations.

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where

$$P = DL + LL + SL + W$$

$$P_w = (x) \times (P)$$

P = Line load on footing

P_w = Pier working load

DL = Dead load

LL = Live load

SL = Snow load

W = Soil load

x = Selected pier spacing

- Select Factor of Safety: Hubbell Power Systems, Inc. recommends a minimum Factor of Safety (FS_h) for mechanical strength of the hardware of 2.0.

where

$$FS_h = 2.0 \text{ (may be varied based on engineering judgment)}$$

$$R_{w \text{ ULT}} = P_w \times FS_h$$

$R_{w \text{ ULT}}$ = Minimum ultimate hardware strength based on structural weight

- Select a Pier System with an adequate minimum ultimate strength rating.

where

$$R_{h \text{ ULT}} \geq 2 \times P_w$$

$R_{h \text{ ULT}}$ = Minimum ultimate hardware strength based on the published strength rating found in Section 7 of this Technical Design Manual

- Check the maximum pier spacing (x_{MAX}) based upon the selected hardware capacity.

$$x_{MAX} = (R_{h \text{ ULT}}) / (FS_h) \times (P) \text{ (wall and footing must be structurally capable of spanning this distance)}$$

$$x \leq x_{MAX}$$

- Proof Load: ATLAS RESISTANCE® Piers are installed using a two-step process as noted above. First, the ATLAS RESISTANCE® Pier is driven to a firm bearing stratum. The resistance force applied during this step is called the Proof Load (R_p). Hubbell Power Systems, Inc. recommends a minimum Factor of Safety¹ (FS_p) of 1.5 at installation unless structural lift occurs first.

$$R_p = (FS_p) \times (P_W)$$

$$R_p = 1.5 \times (P_W)$$

$$R_{h \text{ MAX}} = (R_{h \text{ ULT}} / FS_h) \times 1.65$$

$$R_{h \text{ MAX}} = (R_{h \text{ ULT}} / 2.0) \times 1.65$$

$$R_p < R_{h \text{ MAX}}$$

where $R_{h \text{ MAX}} =$ Maximum installation force based on hardware ultimate capacity²

¹ Experience has shown that in most cases the footing and stem wall foundation system that will withstand a given long term working load will withstand a pier installation force of up to 1.5 times that long term working load. If footing damage occurs during installation, the free span between piers ($L_{p \text{ MAX}}$) may be excessive.

² It is recommended that $R_{h \text{ MAX}}$ not exceed $(R_{h \text{ ULT}} / 2) \times 1.65$ during installation without engineering approval.

Additional Notes:

Current practice by Hubbell Power Systems, Inc. is to limit the unsupported pier pipe exposure to a maximum of 2 feet at the published working loads for the standard pier systems. The soil must have a SPT “N” of greater than 4. The pier pipe must be sleeved for pier pipe exposures greater than 2 feet and up to 6 feet and/or through the depths where the SPT value “N” is 4 or less. Sleeve must extend at least 36” beyond the unsupported exposure and/or the area of weak soil. If the anticipated lift is to exceed 4”, then the ATLAS RESISTANCE® Continuous Lift Pier System should be used.

ATLAS RESISTANCE® Piers can be located as close as 12” (305 mm) between adjacent piers to develop a “cluster” of load bearing elements.

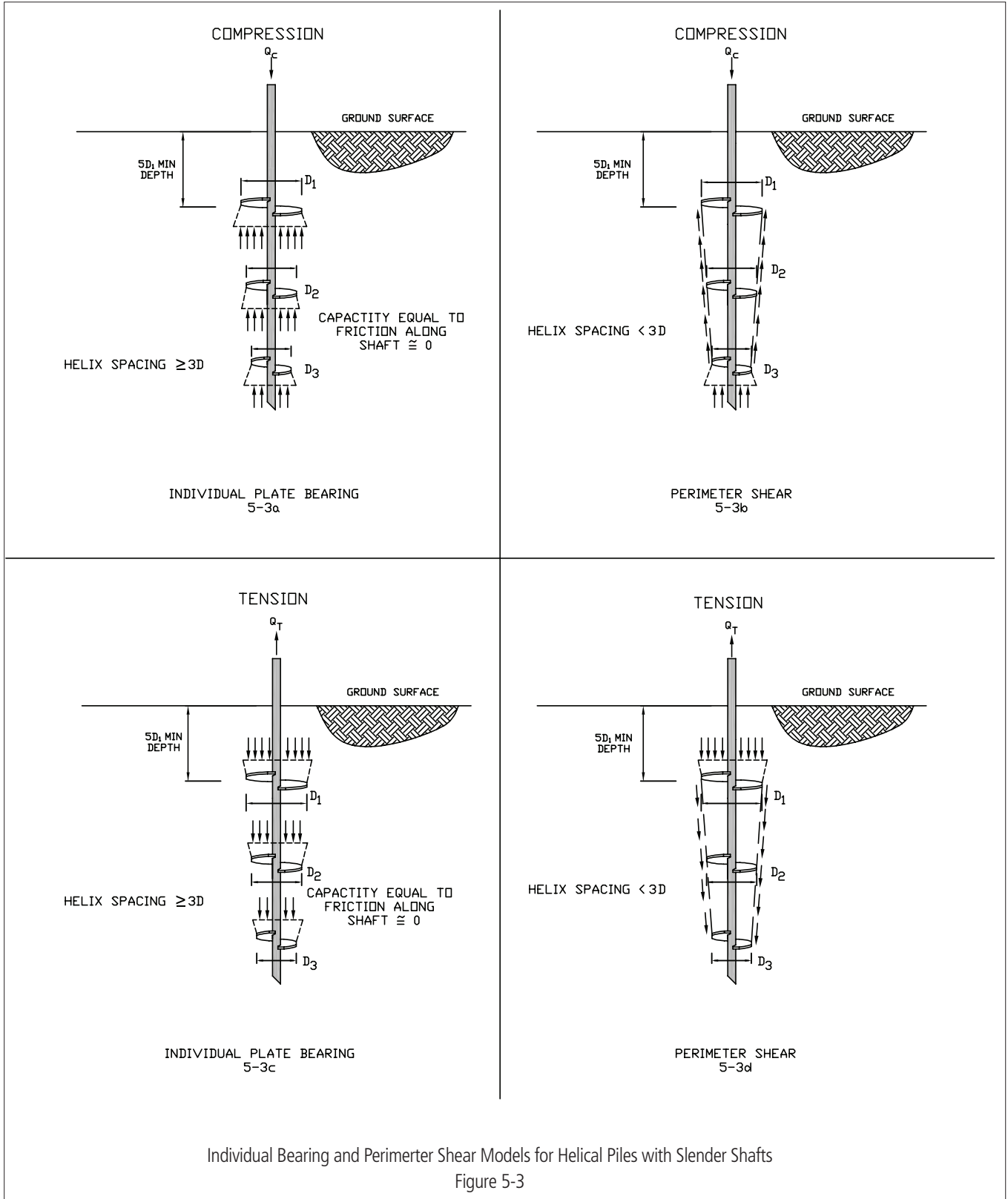
5.2 CHANCE® HELICAL PILE/ANCHOR ULTIMATE BEARING CAPACITY

The capacity of a helical pile/anchor is dependent on the strength of the soil, the projected area of the helix plate(s), and the depth of the helix plate(s) below grade. The soil strength can be evaluated by use of various field and lab techniques. The projected area is controlled by the size and number of helix plates. Helical anchors and screw piles may be used for a variety of applications involving both tension loading (helical anchors) and compression loading (screw piles or helical piles). Screw piles and helical anchors are generally classified as either “shallow” or “deep” depending on the depth of installation of the top helix below the ground surface, usually with respect to the helix diameter. There are some situations in which the installation may be considered partway between “shallow” and “deep”, or “intermediate”. In this Manual, only design procedures for “shallow” and “deep” installations will be described. Table 1 gives a summary of the most common design situations involving screw-piles and helical anchors that might be encountered. Note that the use of “shallow” multi-helix anchors for either compression or tension loading is not a typical application and is not covered in this Technical Design Manual.

The dividing line between shallow and deep foundations has been reported by various researchers to be between three and eight times the foundation diameter. To avoid problems with shallow installations, the minimum recommended embedment depth of helical piles and anchors is five helix diameters (5D). The 5D depth is the vertical distance from the surface to the top-most helix. Whenever a CHANCE® Helical Pile/Anchor is considered for a project, it should be applied as a deep foundation for the following reasons:

1. A deep bearing plate provides an increased ultimate capacity both in uplift and compression.
2. The failure at ultimate capacity will be progressive with no sudden decrease in load resistance after the ultimate capacity has been achieved.

The approach taken herein for single-helix piles/anchors assumes that the soil failure mechanism will follow the theory of general bearing capacity failure. For multi-helix helical piles and anchors, two possible modes of failure



are considered in design, depending on the relative spacing of the helix plates. For wide helix spacing ($s/B \geq 3$), the Individual Plate Bearing Method is used; for close helix spacing ($s/B < 3$), the Perimeter Shear Method is used. These two methods are illustrated in Figures 5-3a & c (Individual Plate Bearing) and 5-3b & d (Perimeter Shear). With Individual Plate Bearing, the helix capacity is determined by calculating the unit bearing capacity of the soil at each helix and then multiplying the result by the individual helix's projected area. Friction along the central shaft is typically not used to determine capacity, but may be included when the central shaft is round, as will be discussed later in this section. The Individual Plate Bearing Method assumes that load capacity will be developed simultaneously and independently by each helix; i.e. no interaction between helix plates. The Perimeter Shear Method assumes that because of the close helix spacing, a prism of soil will develop between the helix plates

Table 5-1 Typical Design Situations for Single-Helix and Multi-Helix Screw-Piles and Helical Anchors

Single-Helix				Multi-Helix			
Failure Condition				Failure Condition			
Shallow		Deep		Shallow		Deep	
C	T	C	T	C	T	C	T
Clay	Clay	Clay	Clay	N/A	N/A	Clay	Clay
Sand	Sand	Sand	Sand	N/A	N/A	Sand	Sand
Mixed Soils	Mixed Soils	Mixed Soils	Mixed Soils	N/A	N/A	Mixed Soils	Mixed Soils

C = Compression T = Tension

and failure in this zone occurs along a plane as shown in Figure 5-3b & d. In reality, the Perimeter Shear Method includes both plate bearing and perimeter shear failure as illustrated.

The following is Terzaghi's general bearing capacity equation, which allows determination of the ultimate capacity of the soil. This equation and its use will be discussed in this section, as it forms the basis of determining helix capacity in soil.

$$Q_{ult} = A_h (cN_c + q'N_q + 0.5 \gamma' BN_\gamma)$$

where

- Q_{ult} = Ultimate capacity of the soil
- A_h = Projected helix area
- c = Soil cohesion
- q' = Effective overburden pressure
- B = Footing width (base width)
- γ' = Effective unit weight of the soil

and N_c , N_q , and N_γ are bearing capacity factors

Terzaghi's Bearing Capacity Factors are shown in the Table 5-2.

Table 5-2. Terzaghi's Shallow Foundation Bearing Capacity Factors [from and Bowles (1988) and ASCE (1993a)]

ϕ'	N_c	N_γ	N_q
0	5.7	0.0	1.0
10	9.6	1.2	2.7
12	10.8	1.7	3.3
14	12.1	2.3	4.0
16	13.7	3.0	4.9
18	15.5	3.9	6.0
20	17.7	4.9	7.4
22	20.3	5.8	9.2
24	23.4	7.8	11.4
26	27.1	11.7	14.2
28	31.6	15.7	17.8
30	37.2	19.7	22.5
32	44.0	27.9	28.5
34	52.6	36.0	36.5
36	63.5	52.0	47.2
38	77.5	80.0	61.5
40	95.7	100.4	81.3
42	119.7	180.0	108.7
44	151.9	257.0	147.7
46	196.2	420.0	204.2
48	258.3	780.1	287.8

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Following is quoted from Bowles (1988) concerning the use of Equation 5-6 for deep foundations where the various terms of the bearing capacity equation are distinguished.

- “1. The cohesion term predominates in cohesive soil.
2. The depth term ($q'N_q$) predominates in cohesionless soil. Only a small D (vertical depth to footing or helix plate increases Q_{ult} substantially.
3. The base width term $0.5\gamma'BN_\gamma$ provides some increase in bearing capacity for both cohesive and cohesionless soils. In cases where B is less than about 2 feet (0.61 m), this term could be neglected with little error.”

The base width term of the bearing capacity equation is not used when dealing with helical anchors/piles because, as Bowles indicates, the resulting value of that term is quite small. The effective overburden pressure (q' , of consequence for cohesionless soils) is the product of depth and the effective unit weight of the soil. The water table location may cause a reduction in the soil bearing capacity. The effective unit weight of the soil is its in-situ unit weight when it is above the water table. However, the effective unit weight of soil below the water table is its in-situ unit weight less the unit weight of water.

Notes on use of Terzaghi’s Bearing Capacity equation:

1. Because helix plates are generally round, Terzaghi’s adjustment for round footings is sometimes used for compression loading:
 - a. $Q_H = A_H(1.3c'_Nc + q'_Nq + 0.6\gamma'BN\gamma)$
2. Because B is considered very small for screw-piles and helical anchors, relative to most concrete footings, most engineers choose to ignore the term $0.5\gamma'BN\gamma$ in design.
3. In saturated clays under compression loading, Skempton’s (1951) Bearing Capacity Factor for shallow round helical plates can also be used:
 - a. $N_c = 6.0(1 + 0.2D/B) \leq 9.0$
4. The unit weight of the soil is the total (wet) unit weight if the helical plate (s) is above the water table and the buoyant unit weight if the helical plate(s) is below the water table.
5. For saturated clay soils, $N_q = 1.0$; For sands, N_q is a function of the friction angle, ϕ' .
6. For square-shaft anchors/piles, the shaft resistance is generally ignored. For round shaft piles/anchors there may be a component of shaft resistance that contributes to capacity depending on the configuration of connections between extension sections.
7. In all cases, for both compression and tension loading, the upper limit of capacity is governed by the mechanical strength of the pile/anchor as provided by the manufacturer. See Section 7 of this Manual for mechanical strength ratings of CHANCE® Helical Piles/Anchors.

Concern can develop when a helical pile/anchor installation is terminated in sand above the water table with the likelihood that the water table will rise with time to be above the helix plates. In this situation, the helical pile/anchor lead section configuration and depth should be determined with the water at its highest anticipated level. Then the capacity of the same helical-pile/anchor should be determined in the same soil with the water level below the helical pile/anchor, which will typically produce higher load capacities and a more difficult installation, i.e., it will require more installation torque. It is sometimes the case that a larger helical pile/anchor product series, i.e., one with greater torque capacity, must be used in order to facilitate installation into the dry conditions.

5.2.1 Single-Helix Screw-Piles and Helical Anchors – Shallow Installation

5.2.1.1 Compression Loading (Shallow Single-Helix)

A shallow installation, like a shallow foundation, is one in which the ratio of depth (D) of the helix to diameter (B) of the helix is less than or equal to about 5, i.e., $D/B \leq 5$. In this case, the design is very analogous to compression loading of a shallow foundation.

5.2.1.1.a Saturated Clays $\phi' = 0$; $c > 0$

In saturated clays with $\phi' = 0$, the term $N_\gamma = 0$ and $N_q = 1.0$. The bearing capacity equation becomes:

$$Q_H = A_H(cN_C + \gamma'D) \quad \text{Equation 5-9}$$

where:

Q_H = Ultimate Bearing Capacity

A_H = Projected Helix Area

c = "cohesion"; for $\phi' = 0$; c = undrained shear strength = s_u

N_C = Bearing Capacity Factor for $\phi' = 0$; for round plates $N_C = 6.0(1 + 0.2D/B) \leq 9$

γ' = effective unit weight of soil above screw-pile

D = Depth

Note: The term $\gamma'D$ is sometimes ignored because it is very small.

5.2.1.1.b Sands $\phi' > 0$; $c' = 0$

In clean sands with zero cohesion, the cohesion term of the bearing capacity equation drops out and only two terms remain:

$$Q_H = A_H(q'N_q + 0.5\gamma'BN_\gamma) \quad \text{Equation 5-10}$$

where:

q' = effective surcharge (overburden pressure) = $\gamma'D$

N_q and N_γ are evaluated from the Table of Bearing Capacity Factors

Note: The term $0.5\gamma'BN_\gamma$ is typically ignored for helical piles because the helix plate is small

5.2.1.1.c Mixed Soils $\phi' > 0$; $c' > 0$

Many soils, such as mixed-grain silty sands, sandy silts, clayey sands, etc., have both a frictional and cohesive component of strength. In these cases, the bearing capacity equation includes all three terms:

$$Q_H = A_H(c'N_C + q'N_q + 0.5\gamma'BN_\gamma) \quad \text{Equation 5-11}$$

Note: The term $0.5\gamma'BN_\gamma$ is typically ignored for helical piles because the helix plate is small.

5.2.1.2 Tension Loading - Axial Uplift (Shallow Single Helix)

Under tension loading in axial uplift, the behavior of a shallow single-helix helical anchor is currently approached more-or-less as an "inverse" bearing capacity problem and the concern is for the failure surface to reach the ground surface, producing "breakout" of the helical plate. Helical anchors should not be installed at vertical depths less than 5 ft. for tension loading. The design approach is similar to that under compression loading, except that instead of using a Bearing Capacity Factor, N_C , a Breakout Factor, F_C , is used.

DESIGN METHODOLOGY

5.2.1.2.a Saturated Clays $\phi' = 0$; $c > 0$

Test results and analytical studies indicate that the Breakout Factor for saturated clays in undrained loading varies as a function of the Relative Embedment of the plate, i.e., D/B. This is much like the transition of shallow to deep foundation behavior under compression loading. Table 5-3 shows the variation in F_C vs. D/B for circular plates. This figure (from Das (1990) shows that $F_C = 1.2(D/B) \leq 9$, so that at $D/B > 7.5$, $F_C = 9$ (i.e., the transition from shallow to deep behavior under tension in clays occurs at about $D/B > 7.5$). In this case, the ultimate uplift capacity is similar to Equation 5-9 and is given as:

$$Q_{HU} = A_H(cF_C + \gamma'D)$$

where:

Q_{HU} = Ultimate Uplift Capacity

c = "cohesion"; for $\phi' = 0$ c = undrained shear strength = s_u

F_C = Breakout Factor for $\phi' = 0$; $F_C = 1.2(D/B) \leq 9$

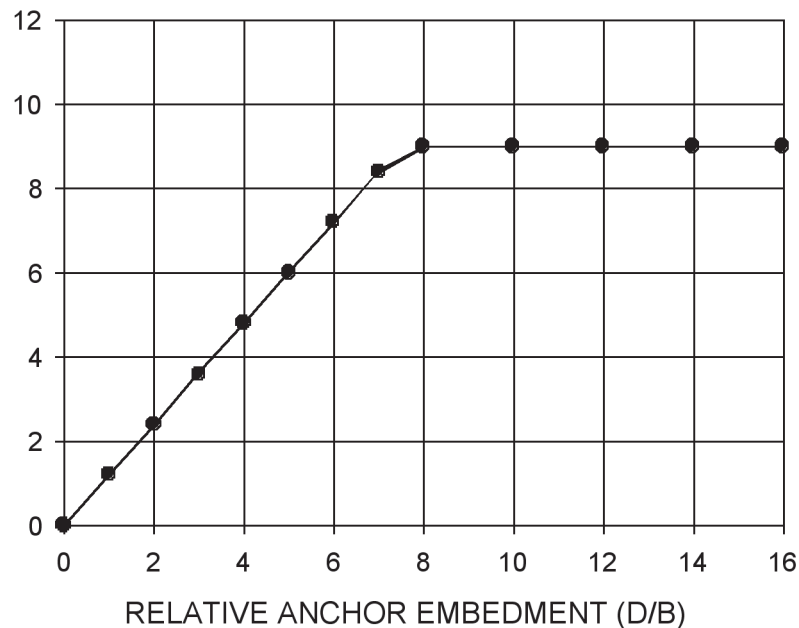
γ' = effective unit weight of soil above helical anchor plate

D = Depth

Note: The term $\gamma'D$ is sometimes ignored because it is very small.

In some situations the undrained shear strength of clays under tension loading may be reduced to account for some disturbance effects of the clay above the helical plate but this is a matter of engineering judgment.

Table 5-3 Variation in Uplift Breakout Factor for Shallow Single-Helix Anchors in Clay



5.2.1.2.b Sands $\phi' > 0$; $c' = 0$

In sands the uplift behavior of shallow (generally $D/B \leq 5$) single-helix anchors develops a failure zone that looks similar to an inverted truncated cone. The failure is assumed to take place by the perimeter shear acting along this failure surface, which is inclined from the vertical at an angle of about $\phi'/2$, as shown in Figure 5.4, and also includes the mass of the soil within the truncated cone. The Ultimate Uplift Capacity is calculated from:

$$Q_{HU} = W_S + \pi\gamma K_0(\tan\phi')(\cos^2\phi'/2) [(BD^2/2) + (D^3\tan\phi'/2)/3] \tag{Equation 5-13}$$

where:

- W_S = Mass of Soil in Truncated Cone = γV
- γ = Total (wet) Unit Weight
- V = Volume of Truncated Cone
- K_0 = At-Rest Lateral Earth Pressure Coefficient
- B = helix diameter
- D = vertical plate depth

The volume of the truncated cone is determined from:

$$V = [\pi D/3][B^2 + (B + 2D\tan\phi'/2)^2 + (B)(B + 2D \tan \phi'/2)] \tag{Equation 5-14}$$

Values of the at-rest lateral earth pressure coefficient for sands can reasonably be taken as:

$$K_0 = 1 - \sin\phi'$$

DESIGN METHODOLOGY

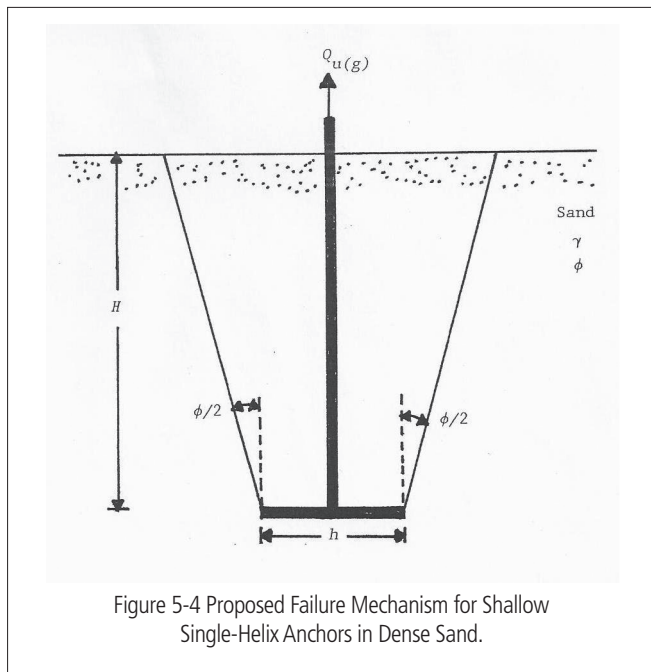


Figure 5-4 Proposed Failure Mechanism for Shallow Single-Helix Anchors in Dense Sand.

5.2.1.2.c Mixed Soils $\phi' > 0$; $c' = 0$

In mixed soils with both frictional and cohesive components of shear strength, there is an added resisting force in uplift for shallow installations above the value given by Equation 5-13. This added component results from cohesion acting along the surface of the truncated cone failure zone between the helical plate and the ground surface so that an additional term may be added to Equation 5-13 giving:

$$Q_{HU} = W_S + \pi\gamma K_0(\tan\phi')(\cos^2\phi'/2) [(BD^2/2) + (D^3\tan\phi'/2)/3] + (c)(A_C) \tag{Equation 5-15}$$

where:

A_C = Surface Area of Truncated Cone

The surface area of a truncated cone can be obtained from:

$$A_C = \pi[(R^2 + r^2) + [(R^2 - r^2) + (D(R + r))^2]^{0.5}] \tag{Equation 5-16}$$

where:

r = Radius of Helical Plate = $B/2$

R = Radius of Cone Failure Surface at the Ground Surface = $B/2 + (D)\tan(\phi'/2)$

The additional component of uplift resulting from soil cohesion, is sometimes ignored since soil cohesion is often lost from water infiltration or rising water table.

5.2.2 Single-Helix Screw-Piles and Screw-Anchors – Deep Installation

Deep installations of screw-piles and helical anchors are generally more common than shallow installations, provided there is sufficient soil depth to actually perform the installation. The reason is simply that higher load capacities are generally developed from a deeper installation in the same soil so it makes more sense economically to go for a deep installation when possible. Figure 5.5 below demonstrates the single-helix plate capacity model, where the soil failure mechanism will follow the theory of general bearing plate capacity. Compression capacity is mobilized from soil below the helix plate and tension capacity from soil above the helix plate.

5.2.2.1 Compression Loading (Deep Single-Helix)

A deep installation, like a deep foundation, is one in which the ratio of depth (D) of the helix to diameter (B) of the helix is greater than 5 - 7, i.e., $D/B > 5 - 7$. In this case, the design is very analogous to compression loading of deep end bearing foundation.

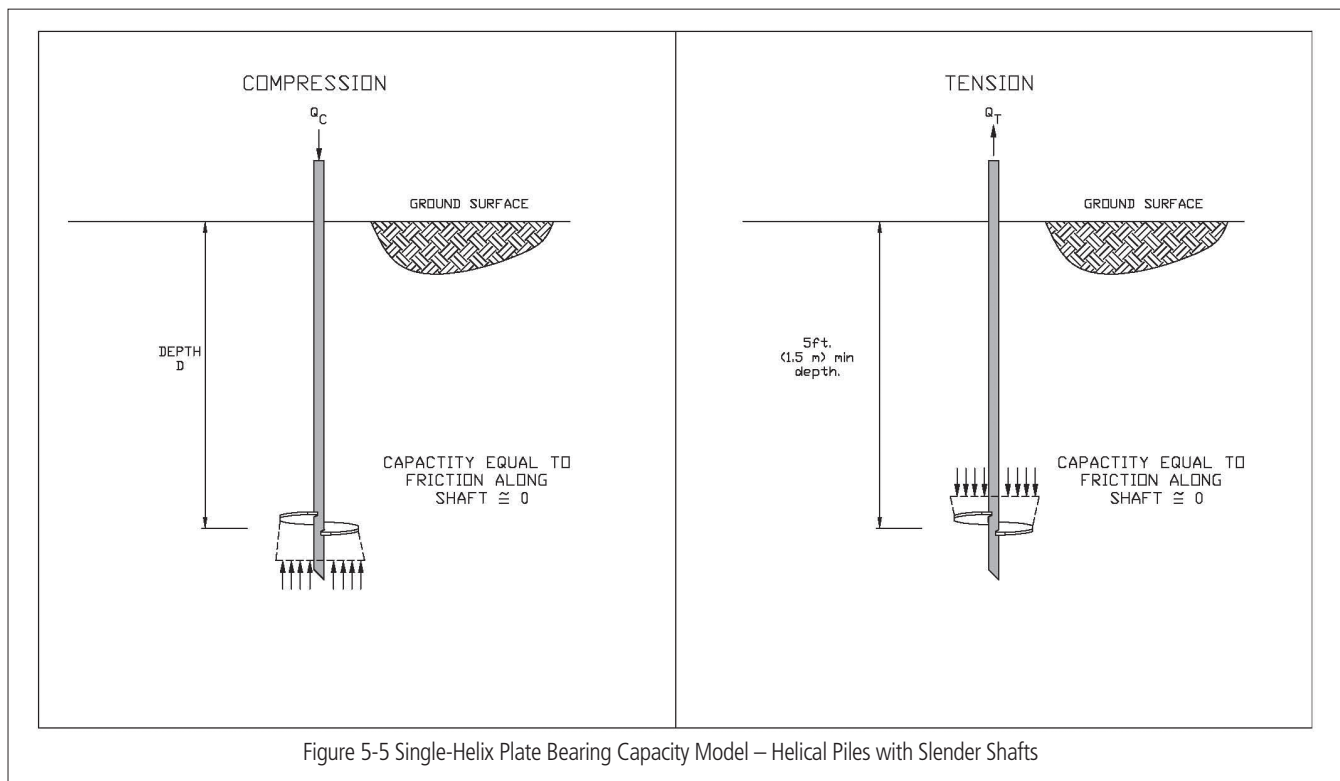


Figure 5-5 Single-Helix Plate Bearing Capacity Model – Helical Piles with Slender Shafts

5.2.2.1.a Saturated Clays $\phi' = 0$; $c' > 0$

Under compression loading, the ultimate capacity of a single-helix screw-pile in clay is calculated from Equation 5-9 as:

$$Q_H = A_H[(N_C)(s_u) + \gamma'D]$$

where:

$$N_C = \text{Bearing Capacity Factor for Deep Failure} = 9$$

Which gives:

$$Q_H = A_H[(9)(s_u) + \gamma'D]$$

Equation 5-17

5.2.2.1.b Sands $\phi' > 0$; $c' = 0$

For clean, saturated sands, the “cohesion” is normally taken as zero, reducing the ultimate capacity, as in Equation 5-10, to:

$$Q_H = A_H(q'N_q + 0.5\gamma'BN\gamma)$$

Even in moist sands or sand with a small amount of fines that may give some “cohesion”, this is usually ignored. Because the area of the plate is small, the contribution of the “width” term to ultimate capacity is also very small and the width term is often ignored leaving:

$$Q_H = A_H(q'N_q)$$

Equation 5-18

For deep installations, the bearing capacity factor N_q is usually obtained from values used for determining the end bearing capacity for deep pile foundations, which is different than the values used for shallow foundations. There are a number of recommendations for N_q available in foundation engineering textbooks as shown in Figure 5-6. The difference in N_q values shown in Figure 5-6 is largely related to the assumptions used in the failure mechanism. Figure 5-7 gives a reasonable chart of N_q values as a function of the friction angle of the soil, ϕ' , that may be used for screw-piles and helical anchors. The value of N_q in Figure 5-7 is obtained from:

$$N_q = 0.5 (12 \times \phi')^{\phi'/54}$$

Equation 5-19

Note: In some sands, the unit end bearing capacity of deep foundations may reach a limiting value. The point at which this occurs is generally termed the “critical depth”. Critical depth is defined as the depth at which effective vertical stress, a.k.a. overburden pressure, will not increase with depth. Critical depth is not specifically defined for screw-piles and helical anchors, but engineers often use it with deep installation in saturated sands.

5.2.2.1.c Mixed Soils $\phi' > 0$; $c' > 0$

The ultimate capacity of a deep single-helix screw-pile in mixed-grain soils can be taken from traditional bearing capacity theory using Equation 5-11:

$$Q_H = A_H(cN_c + q'N_q + 0.5\gamma'BN\gamma)$$

Note: The term $0.5\gamma'BN\gamma$ is typically ignored for helical piles because the helix plate is small.

5.2.2.2 Tension Loading –Axial Uplift (Deep Single-Helix)

5.2.2.2.a Saturated Clays $\phi' = 0$; $c' > 0$

Under tension loading, the ultimate capacity of a single-helix screw-anchor in clay the ultimate capacity is calculated using the same approach given in Section 5.2.2.1.a. In some cases a reduction may be made in the undrained shear strength to account for soil disturbance above the helical plate as a result of installation, depending on the Sensitivity of the clay. Also, as previously noted in Section 5.2.1.2.a, for a deep installation ($D/B > 7.5$) the Breakout Factor, F_C has a default value of 9. The bearing capacity equation becomes:

$$Q_{HU} = A_H[(9)s_u + \gamma'D]$$

5.2.2.2.b Sands $\phi' > 0$; $c' = 0$

In sands, the tension capacity of a helical anchor is generally assumed to be equal to the compression capacity provided that the soil above the helix is the same as the soil below the helix in a zone of about 3 helix diameters. Again, for clean, saturated sands, the “cohesion” is normally taken as zero, reducing the ultimate capacity to:

$$Q_H = A_H(q'N_q + 0.5\gamma'BN\gamma)$$

Also, because the area of the plate is small, the contribution of the "width" term to ultimate capacity is also very small and the width term is often ignored leaving:

$$Q_H = A_H(q'N_q)$$

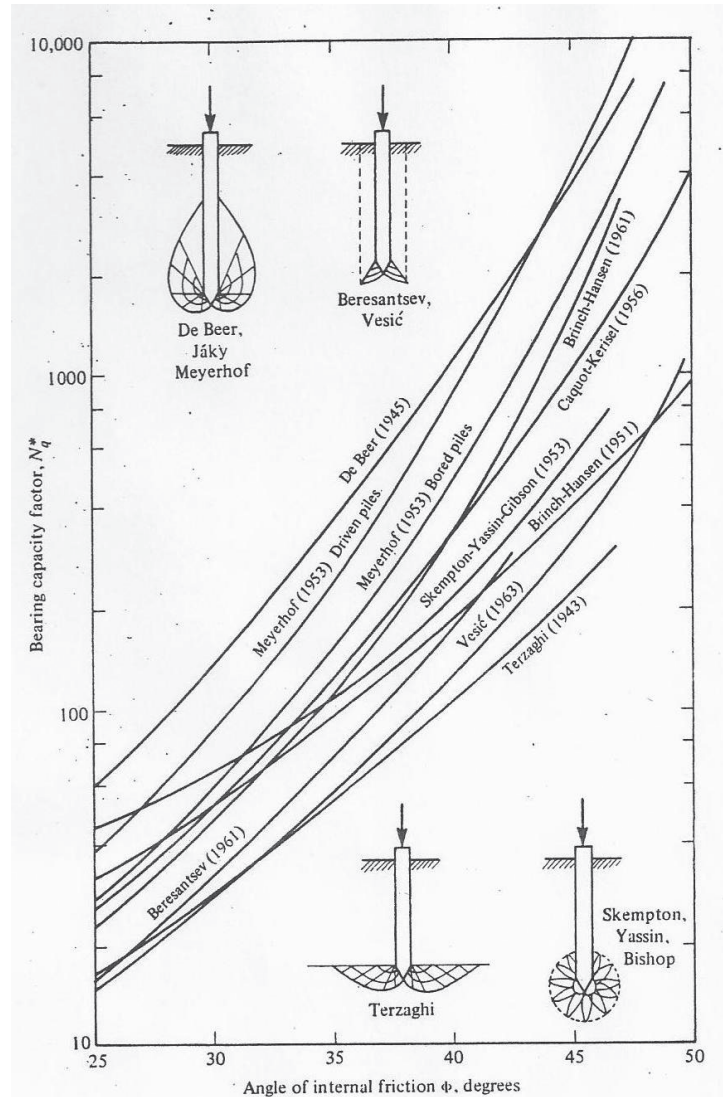
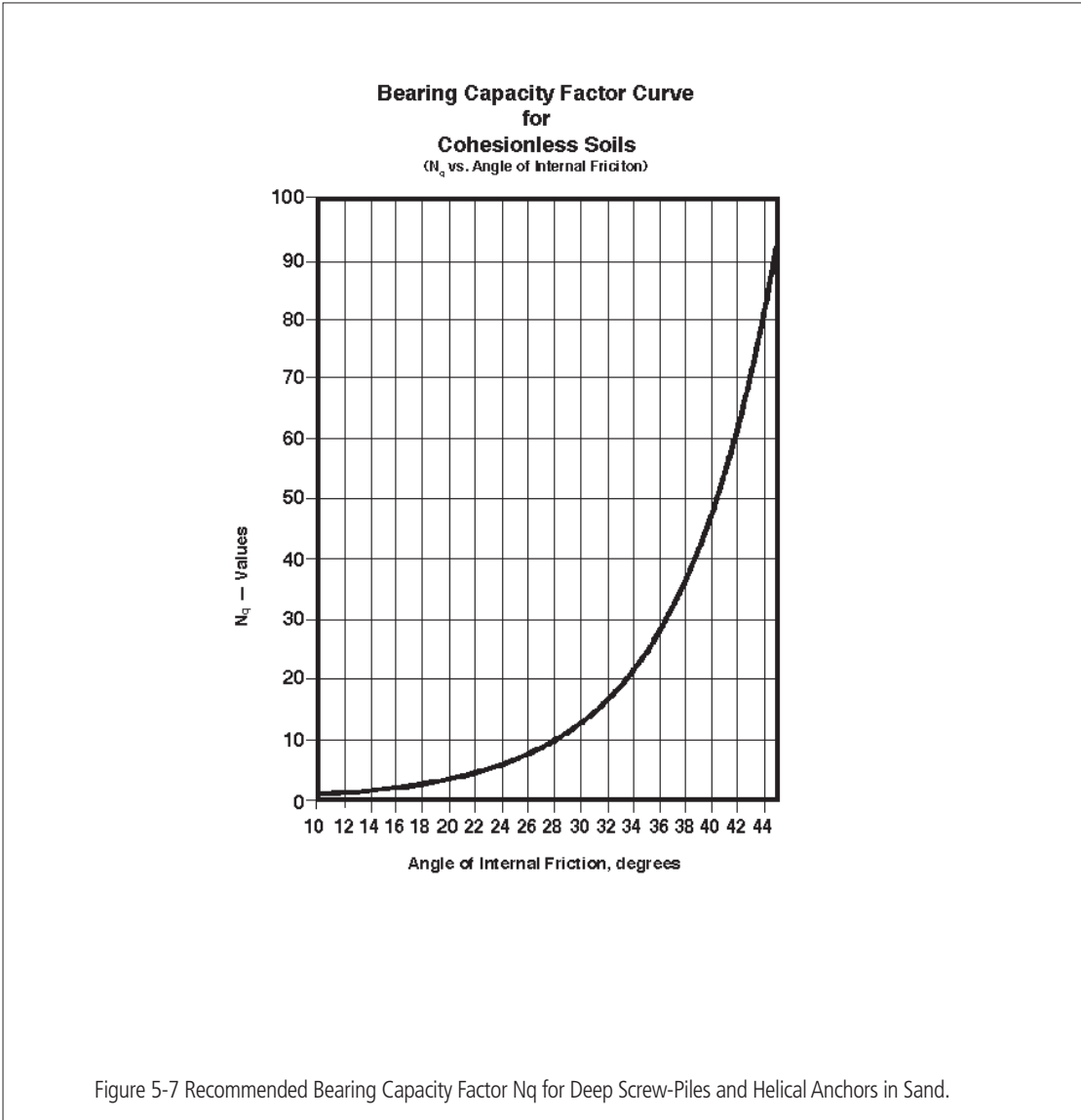


Fig. 19.49 Bearing capacity factors vs. angle of internal friction, according to various authors.

Figure 5-6 Reported Values of N_q for Deep Foundations in Sands [from Winterkorn & Fang (1983)].

DESIGN METHODOLOGY



5.2.2.2.c Mixed Soils $\phi' > 0$; $c' > 0$

The ultimate capacity of a deep screw-pile in mixed-grain soils can be taken from traditional bearing capacity theory using Equation 5-11:

$$Q_H = A_H(cN_c + q'N_q + 0.5\gamma BN_\gamma)$$

Note: The term $0.5\gamma'BN_\gamma$ is typically ignored for helical piles because the helix plate is small.

5.2.3 Multi-Helix Screw-Piles and Screw-Anchors – Deep Installation

The ultimate capacity of deep multi-helix screw-piles and screw-anchors depends on the geometry of the helical section, namely the size and number of helical plates and the spacing between the plates. As shown in Figure 5-3b and 5-3d, if the spacing of helix plates is close, the capacity is developed from a zone of failure between the helical plates and from end bearing from the end helix plate (either the lowest plate for compression loading or the top helix plate for tension loading), i.e., the helix plates interact with each other. If the spacing of the helix plates is sufficiently large, the capacity is taken as the sum of the capacity developed from the individual helix plates, i.e., there is no interaction between helix plates. Also, there is no capacity taken along the shaft between the helix plates.

In the U.S., most manufacturers of screw-piles and helical anchors produce elements with a standard helix spacing of 3 times the helix diameter. This spacing was originally used by CHANCE® over 30 years ago and is assumed to allow individual helix plates to develop full capacity with no interaction between helix plates and the total capacity is taken as the sum of the capacities from each plate as shown in Figure 5-3a and 5-3c. Most CHANCE® Screw-Piles and Helical Anchors use inter-helix spacing that is based on the diameter of the lower helix. For example, the distance between a 10 inch (254 mm) and a 12 inch (305 mm) helix is three times the diameter of the lower helix, or $10 \times 3 = 30$ inches (762 mm).

The first section, called the lead or starter, contains the helix plates. This lead section can consist of a single helix or multi-helices, typically up to four. Additional helix plates can be added, if required, with the use of helical extensions. Standard helix sizes and projected areas are shown in Table 5-4. Comprehensive tables of helix projected areas, showing both the full plate area and the area less the shaft for both square shaft and pipe shaft helical piles, is included in Section 7 of this Manual. The helix plates are usually arranged on the shaft such that their diameters stay the same size or increase as they get farther from the pilot point (tip). The practical limits on the number of helix plates per anchor/pile is usually four to five if placed in a fine-grained soils and six if placed in a coarse-grained or granular soils.

5.2.3.1 Compression Loading

The ultimate capacity of a multi-helix screw-pile with an inter-helix spacing greater than or equal to 3 ($s/B \geq 3$) is generally taken as the summation of the capacities of the individual plates:

Table 5-4 Standard Helix Sizes

LEAD SECTION AND EXTENSIONS	
DIAMETER in (cm)	AREA ft ² (m ²)
6 (15)	0.185 (0.0172)
8 (20)	0.336 (0.0312)
10 (25)	0.531 (0.0493)
12 (30)	0.771 (0.0716)
14 (35)	1.049 (0.0974)
16 (40)	1.385 (0.1286)

$$Q_M = \sum Q_H$$

Equation 5-20

where:

Q_M = Total Capacity of a Multi-Helix Screw-Pile/Helical Anchor

Q_H = Capacity of an Individual Helix

5.2.3.2 Tension Loading

As previously noted in soft clays, especially those with high Sensitivity, it may be appropriate to reduce the undrained shear strength of the undisturbed clay for design of anchors in tension to account for some disturbance of the clay as the helical plates have passed through. This is left to the discretion of the Engineer. Most of the evidence shows that in uniform soils, the tension capacity of multi-helix anchors is the same as in compression. This means that the ultimate capacity of a multi-helix helical anchor with plate spacing of 3B or more may be taken as

the summation of the capacities of the individual plates:

$$Q_M = \sum Q_H$$

There is some evidence that shows that in tension the unit capacity of the trailing helix plates is somewhat less than the leading helix. Engineers may wish to apply a reduction factor to account for this behavior; of about 10% for each additional helix on the helical anchor.

5.2.4. Round Shaft Screw-Piles and Helical Anchors

Screw-piles and helical anchors are available with both square shaft and round steel pipe shafts. Square shaft is used for tension applications and also for compression applications when shaft buckling or bracing is not an issue. Pipe shaft helical piles have become increasingly popular for use in compression loading for both new construction and remediation or underpinning of existing structures. They may be either single or multi-helix. Typical round shaft pile diameters range from 2-7/8 inches (73 mm) to 12 inches (305 mm). For the most part, the design is essentially the same as with square shaft screw-piles as previously described with two simple modifications: 1) some provision is usually made to include the additional load capacity developed via skin friction by the round shaft; and 2) in tension loading, the area of the helical plate is reduced to account for the central shaft as shown in Figure 5-11b. In compression loading, the full projected area of the helix plate develops capacity since the pipe generally plugs with soil.

Typically, the length of the shaft for about one helix diameter above the helix is not included in calculating shaft resistance due to skin friction. In addition, load capacity due to friction along the pile shaft is generally mobilized only if the shaft diameter is at least 3 inches (89 mm).

5.2.4.1 Shaft Resistance in Clay $\phi' = 0; c' > 0$

In clays, the shaft resistance developed by round shaft screw-piles and helical anchors is considered in much the same way that shaft resistance in a driven pile develops. In this traditional approach that is used for many driven piles in clays and available in most textbooks, the available "adhesion" between the shaft and the clay is obtained as a percentage of the undrained shear strength of the clay. This is the undrained or "Alpha" method in which:

$$\alpha = f_s / s_u$$

Equation 5-21

where:

α = Adhesion Factor

f_s = Unit Side Resistance

s_u = Undrained Shear Strength of the Clay

DESIGN METHODOLOGY

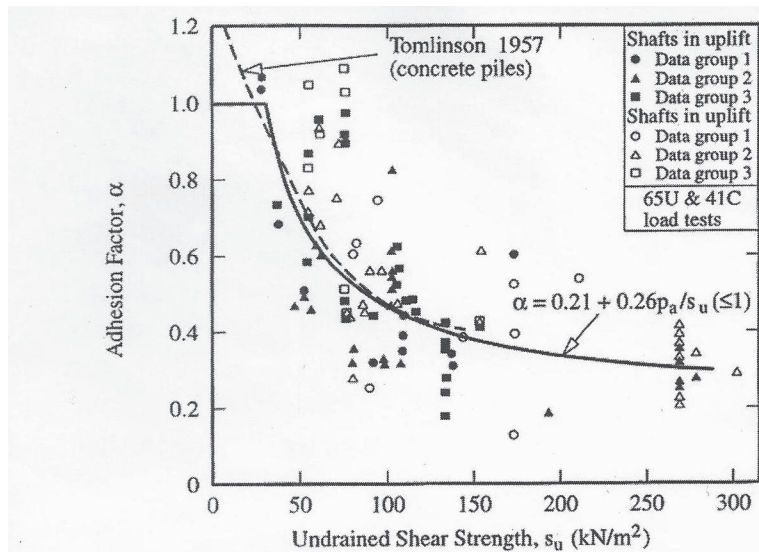


FIGURE 18.1 Adhesion as a function of undrained shear strength

Figure 5-8 Variation in Adhesion Factor with Undrained Shear Strength of Clays [from Canadian Foundation Manual (2006)].

The value of α is usually obtained from any one of a number of published charts and is typically related to the absolute value of the undrained shear strength of the clay. Figures 5-8 and 5-9 give typical plots of α vs. undrained shear strength for a number of cases in which f_s has been back calculated from actual pile load tests. Generally it is sufficient to select an average value of α for a given undrained shear strength for use in design.

The total shaft resistance is then obtained from:

$$Q_s = (f_s)(\pi)(d)(L)$$

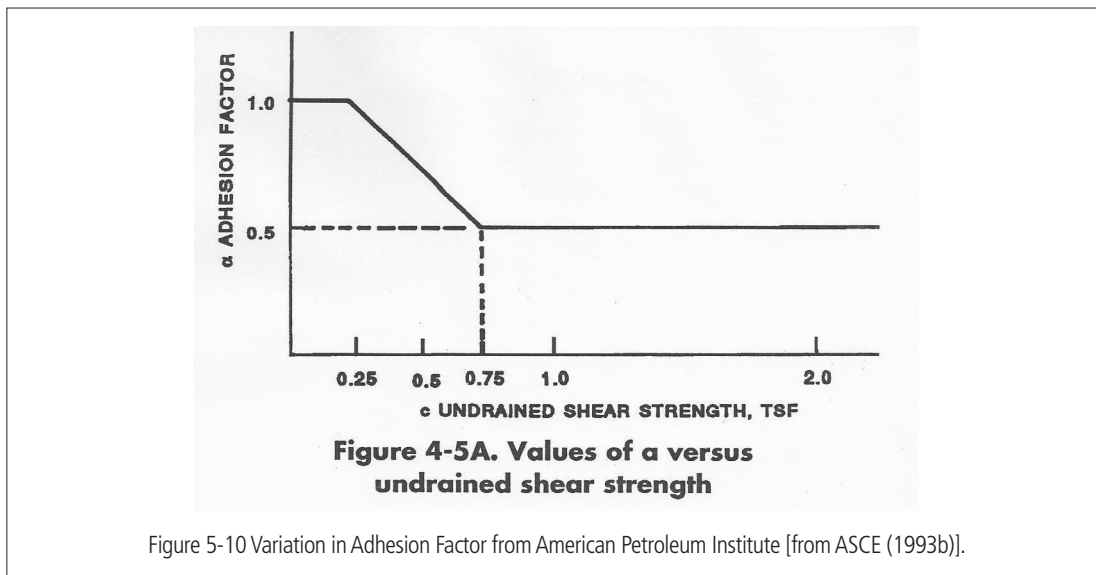
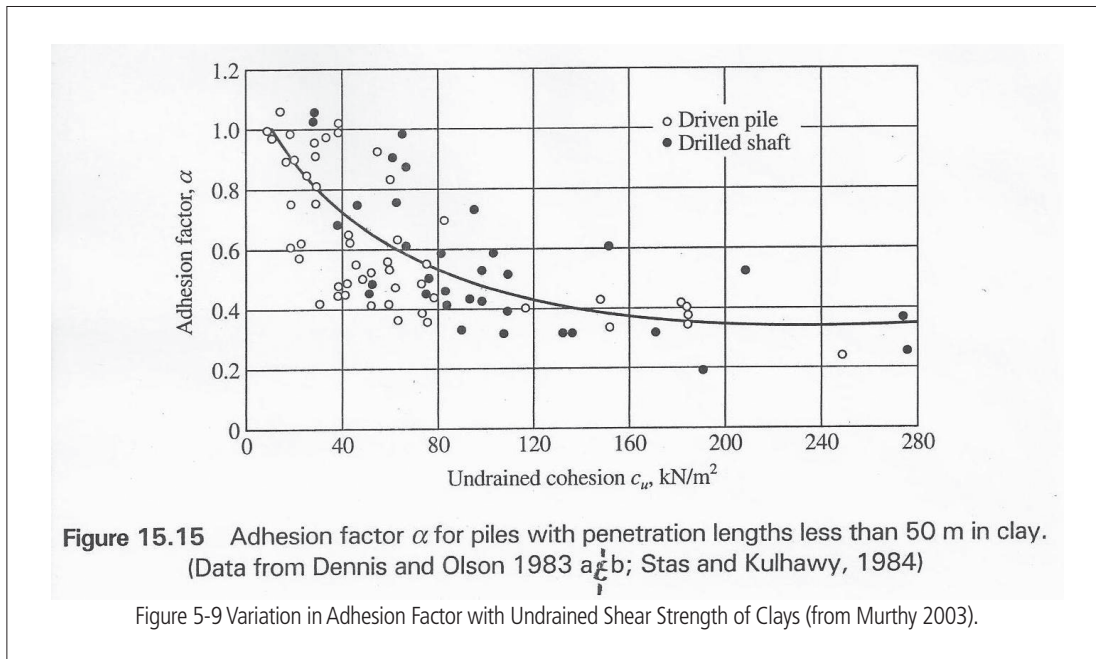
Equation 5-22

where:

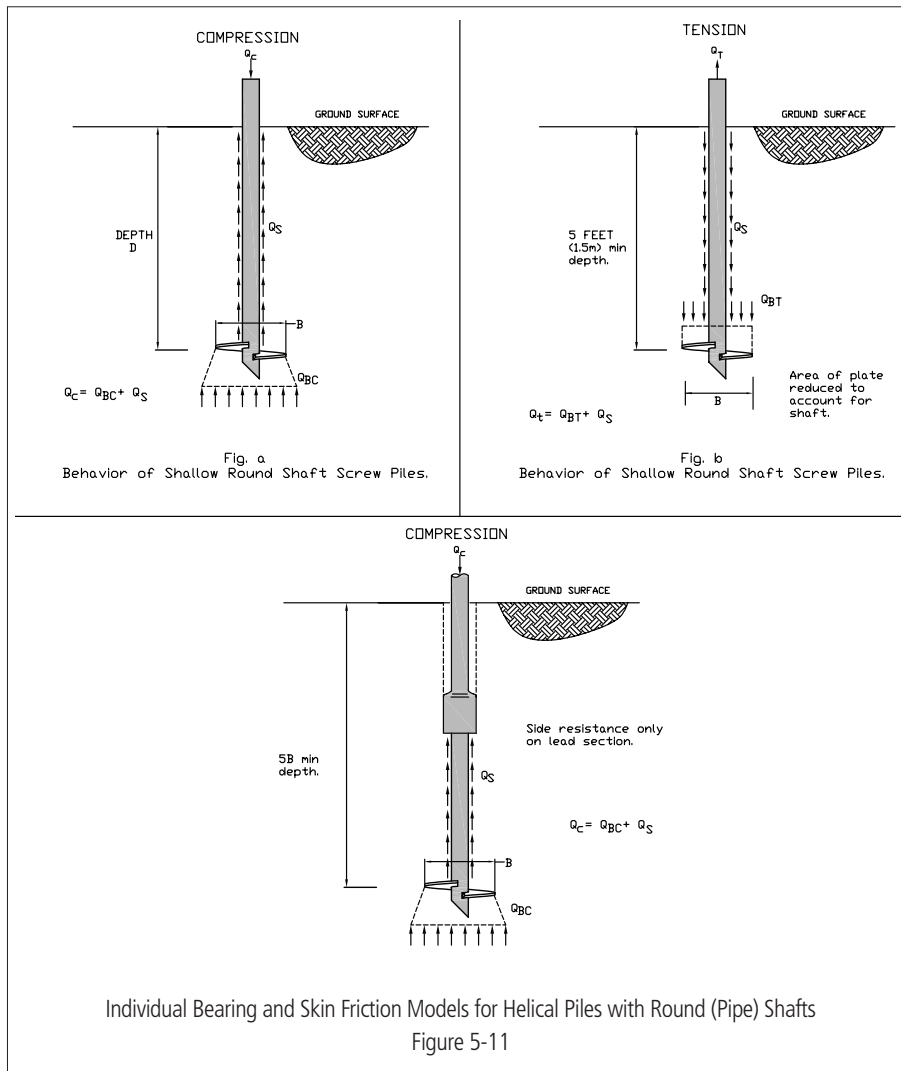
Q_s = Total Shaft Resistance

d = Diameter of Central Shaft

L = Length of Round Shaft in Contact with Soil



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The design line given by the American Petroleum Institute (API) shown Figure 5-10 may also be used in which:

For $s_u < 500$ psf; $\alpha = 1.0$

For $s_u > 1500$ psf; $\alpha = 0.5$

For $500 \text{ psf} < s_u < 1500 \text{ psf}$; α varies linearly between 1.0 and 0.5

The shaft resistance should only be calculated for that portion of the shaft length that is in full contact with the soil. This will depend on the length of the lead section, the design of the shaft couplings that connect the pile sections, and the type of soil. For example, flanged and bolted connections generally create an annulus between the shaft and the soil as the pile or anchor is installed as shown in Figure 5-11. This is because the coupling, being larger than the shaft, displaces and compacts soil. Generally, the length of the central shaft between couplings is not considered to develop shaft resistance unless the disturbed soil moves back against the shaft, or sufficient time is allowed for the soil to recover. In this situation, reduced shear strength should be used for shaft resistance capacity.

On the other hand, in the case of true flush connections between extension sections, the entire shaft may develop side resistance.

Table 5-5 Values of Unit Side Resistance for Steel Piles in Sand (from Navy Manual DM-7)

σ'_{vo} (psf)	Friction Angle of Soil ϕ'				
	20	25	30	35	40
	Unit Side Resistance f_s (psf)				
500	137	175	217	263	315
1000	273	350	433	525	629
1500	410	524	650	788	944
2000	546	700	866	1050	1259
2500	683	875	1082	1313	1574
3000	819	1049	1300	1575	1888
3500	956	1244	1516	1838	2203
4000	1092	1399	1732	2101	2517

5.2.4.2 Shaft Resistance in Sand and Mixed Soils $\phi' > 0$; $c' = 0$

The shaft resistance of steel pipe shaft piles in coarse-grained soils, such as sands and mixed soils is more complex than in clays but can still be determined using traditional deep foundation analyses. The Department of Navy Design Manual DM-7 also gives a simplified method for estimating the unit side resistance for straight shaft steel piles. The value of f_s is related to the friction angle of the soil, ϕ' , and the effective vertical stress, σ'_{vo} , as given in Table 5-5.

5.2.5 HELICAL ANCHOR/PILE SPACING & MINIMUM DEPTH

Reasonability Check

Consideration should be given to the validity of the values obtained when determining the bearing capacity and shaft resistance of the soil. The calculated theoretical ultimate capacity is no better than the data used to obtain that value. Data from soils reports, boring logs, the water table depth, and load information may not accurately represent actual conditions where the helical pile/anchor must function. Empirical values that are used and estimates of strength parameters, etc. that must be made because of lack of data affect the calculated bearing capacity and shaft resistance value. In those situations where soil data is insufficient or not available, a helical trial probe pile can help determine such items as, location of bearing strata, pile capacity, location of soft/loose soil, and the presence of obstructions, such as, cobbles, boulders, and debris.

An important step in the process of determining the capacity of a helical pile/anchor is to conduct a reasonability check. The engineer should use the best engineering judgment to perform the reasonability check. This should be based on experience, historical test data and consulting colleagues. This is easily overlooked but must be performed by the designer or by others.

Helical Pile/Anchor Spacing

Once the capacity of the helical pile/anchor is determined, concern may turn to location of the foundation element with respect to the structure and to other helical pile/anchors. It is recommended that the center-to-center spacing between adjacent anchors/piles be no less than five times the diameter of the largest helix. The minimum spacing is three feet (0.91 m). This latter spacing should be used only when the job can be accomplished no other way and should involve special care during installation to ensure that the spacing does not decrease with depth. Minimum spacing requirements apply only to the helix bearing plate(s), i.e., the pile/anchor shaft can be battered to achieve minimum spacing. Spacing between the helical anchors/piles and other foundation elements, either existing or future, requires special consideration and is beyond the scope of this section.

Group effect, or the reduction of capacity due to close spacing, has never been accurately measured with helical piles. However, bearing capacity theory would indicate that capacity reduction due to group effect is possible, so it's considered good practice to install helical piles into dense bearing stratum when center-to-center spacing is less than 4 feet (1.2 m).

Minimum Depth

As mentioned earlier, the minimum embedment depth recommended by Hubbell Power Systems, Inc. for a helical deep foundation is five helix diameters (5D), where D is the diameter of the largest helix. The 5D depth is the vertical distance from the surface to the top-most helix. Standard practice is to locate the top-most helix 6D to 8D vertical below the ground surface where practical. Minimum depth is also a function of other factors, such as seasonally frozen ground, "active" zones (depth of wetting) and depth of compressive soils. These factors are generally related to seasonal variations to soil strength parameters, but can also be related to long-term conditions, such as periods of drought or extended wet conditions. The minimum embedment depth recommended by Hubbell Power Systems, Inc. for a helical deep foundation due to seasonal variations is three diameters (3D) below the depth of soil where these seasonal variations will occur. For example, frost depths may require embedment depths that exceed the 5D minimum, depending on the project location. ICC-ES Acceptance Criteria AC308 has specified a minimum depth for helical tension anchors. AC308 states that for tension applications, as a minimum, the helical anchor must be installed such that the minimum depth from the ground surface to the uppermost helix is 12D, where D is the diameter of the largest helix. This disparity between minimum depth requirements can be reconciled by reviewing published literature on the subject, or by performing load tests.

Critical Depth

In granular soils, helical pile capacity is a function of both angle of internal friction (ϕ) and vertical effective overburden stress. Therefore, as a helical pile is extended deeper into soil, theoretical methods predict that the pile capacity would increase without limit as the effective vertical stress increases with increasing depth. In reality, there may be a critical depth where any further increase in depth results in only a small increase in the bearing capacity of the helical pile. Critical depth for helical piles is best determined by an experienced foundation engineer. Hubbell Power Systems, Inc. recommends critical depths of 20D to 30D be used in loose saturated soils at deep depth, where D is the diameter of the largest helix plate. The 20D to 30D length is the depth into a suitable bearing stratum, and is not necessarily measured from the ground surface.

Table 5-6 Soil Properties Required for Helical Pile/Anchor/Pile Design for Various Site Conditions

Soil Property Category	Required Soil Properties		
	Saturated Fine-Grained	Coarse-Grained	Unsaturated Fine-Grained, Mixed Soils
Shear Strength	s_u	ϕ'	c', ϕ'
Unit Weight	γ_{sat}	γ_{wet} OR γ_{buoy}	γ_{wet}

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5.3 EVALUATING SOIL PROPERTIES FOR DESIGN

The design of helical piles/anchors using the traditional soil mechanics approach described in the previous section requires evaluation of soil properties for input into the various bearing and friction capacity equations. Table 5-6 summarizes the soil properties for different site conditions for design of both single-helix and multi-helix helical piles/anchors.

Geotechnical design of helical piles/anchors requires information on the shear strength of saturated fine-grained soils, i.e., undrained shear strength, s_u , and the drained friction angle of coarse-grained soils, ϕ' . The best approach to evaluating these properties for design is a thorough site investigation and laboratory testing program on high quality undisturbed samples. However, this is not always possible or practical and engineers often rely on information obtained from field testing, such as the Standard Penetration Test (SPT). Whenever possible, other high quality field tests, such as Field Vane Tests (FVT), Cone Penetration Tests (CPT), Piezocone Tests (CPTU), Dilatometer Tests (DMT), Pressuremeter Tests (PMT) or Borehole Shear Tests (BST) are preferred. **THERE IS NO SUBSTITUTE FOR A SITE SPECIFIC GEOTECHNICAL INVESTIGATION.**

Estimating Undrained Shear Strength, s_u , in clays:

The undrained shear strength of saturated clays, silty clays and clayey silts is not a unique soil property, like Liquid Limit of clay content, but depends on the test method used for the measurement. Correlations are available for estimating undrained shear strength from the results obtained from several of the field tests noted above. The most common field results that may be available to engineers for design of helical piles/anchors are the SPT and CPT/CPTU.

s_u from SPT

A number of correlations exist for estimating both the undrained shear strength and unconfined compressive strength, q_u , of fine-grained soils from SPT results. Several of these correlations are given in Tables 5-7 and 5-8. The undrained shear strength is generally taken as one-half the unconfined compressive strength. Caution should be used when using these correlations since they have been developed for specific geologic deposits and the SPT field procedure used may not have been the same in all cases.

s_u from CPT/CPTU

The undrained shear strength may also be estimated from the tip resistance obtained from the total cone tip resistance from a CPT or the effective (net) cone tip resistance from a CPTU (e.g., Lunne et al. 1995).

Estimating s_u from the CPT total tip resistance is from a form of the bearing capacity equation as:

$$s_u = (q_c - \sigma_{vo})/N_k$$

Equation 5-23

where:

q_c = CPT tip resistance

σ_{vo} = total vertical stress at the cone tip = depth x total soil unit weight

N_k = empirical cone factor

The value of N_k varies somewhat with soil stiffness, plasticity, stress history and other factors, however many reported observations where s_u has been obtained from both laboratory triaxial tests and field vane tests suggest that a reasonable value of N_k for a wide range of soils is on the order of 16.

Estimating s_u from the CPTU effective tip resistance uses a modified approach since the tip resistance is corrected for pore pressure effects to give the effective tip resistance, q_t , as the undrained shear strength is obtained from:

$$s_u = (q_t - \sigma_{vo})/N_{kt}$$

Equation 5-24

where:

q_t = CPTU effective tip resistance

N_{kt} = empirical cone factor

Table 5-7. Reported Correlations Between SPT N-Value and Undrained Shear Strength, s_u

Correlation to Undrained Shear Strength	Units of s_u	Soil Type	Reference
$s_u = 29N^{0.72}$	kPa	Japanese cohesive soils	Hara et al. (1974)
$s_u = 4.5N$	tsf	Insensitive Overconsolidated Clays in U.K.	Stroud (1974)
$s_u = 8N$ $N < 10$ $s_u = 7N$ $10 < N < 20$ $s_u = 6N$ $20 < N < 30$ $s_u = 5N$ $30 < N < 40$	kPa	Guabiro tuba Clay	Tavares (1988)
$s_u = 1.39N + 74.2$	tsf	tropical soil	Ajayi & Balogun (1988)
$s_u = 12.5N$ $s_u = 10.5N_{60}$	kPa tsf	Sao Paulo overconsolidated clay	Decourt (1989)

Note: 1 kPa = 20.9 psf

Table 5-8. Reported Correlations Between SPT N-Value and Unconfined Compressive Strength, q_u

Correlation to Unconfined Compressive Strength	Units of q_u	Soil Type	Reference
$q_u = 12.5N$	kPa	Fine-Grained	Terzaghi & Peck (1967)
$q_u = N/8$	tsf	Clay	Golder (1961)
$q_u = 25N$ $q_u = 20N$	kPa kPa	Clay Silty Clay	Sanglerat (1972)
$q_u = 25N$ $q_u = 15N$ $q_u = 7.5N$	kPa	Highly Plastic Clay Medium Plastic Clay Low Plasticity Clay	Sowers (1979)
$q_u = 24N$	kPa	Clay	Nixon (1982)
$q_u = 62.5(N-3.4)$	kPa		Sarac & Popovic (1982)
$q_u = 15N$	kPa	CL and CL-ML	Behpoor & Ghahramani (1989)
$q_u = 58N^{0.72}$	kPa	Fine-Grained	Kulhawy & Mayne (1990)
$q_u = 13.6 N_{60}$ $q_u = 9.8N_{60}$ $q_u = 8.6N_{60}$ $q_u = (0.19PI + 6.2)N_{60}$	kPa	CH CL Fine-Grained Fine-Grained	Sivrikaya & Togrol (2002)

The value of N_{kt} also has been shown to vary for different soils but a reasonable conservative value for massive clays is on the order of 12. For very stiff, fissured clays, the value of N_{kt} may be as high as 30.

Other methods are available for estimating undrained shear strength from the pore pressure measurements from a CPTU or by first estimating the stress history from CPT/CPTU results and then converting to undrained shear strength, e.g., NCHRP (2007); Schnaid (2009), both of which are viable approaches.

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Estimating Shear Strength of Fine-Grained Soil – Other Methods

Vane Shear Test: Shear strength of fine-grained soils may be measured both in the field and in the laboratory. One of the most versatile devices for investigating undrained shear strength and sensitivity of soft clays is the vane shear test. It generally consists of a four-bladed rectangular vane fastened to the bottom of a vertical rod. The blades are pressed their full depth into the clay surface and then rotated at a constant rate by a crank handle. The torque required to rotate the vane is measured. The shear resistance of the soil can be computed from the torque and dimensions of the vane.

One such type of the portable vane shear test is the Torvane. It is a convenient hand-held device useful for investigating the strength of clays in the walls of test pits in the field or for rapid scanning of the strength of Shelby tubes or split spoon samples. A calibrated spring allows undrained shear strength (cohesion) to be read directly from the indicator.

Pocket Penetrometer Test: Another device used to estimate undrained shear strength in the laboratory or the field is the Pocket Penetrometer. As with the vane shear test, the pocket penetrometer is commonly used on Shelby tube and split spoon samples, and freshly cut test pits to evaluate the consistency and approximate unconfined compressive strength (q_u) of clay soils. The penetrometer's plunger is pushed into the soil $\frac{1}{4}$ " and a reading taken on the sliding scale on the side. The scale is a direct reading of shear strength. Pocket Penetrometer values should be used with caution. It is not recommended for use in sands or gravel soils.

Unconfined Compression Test: The unconfined compression (UC) test is used to determine the consistency of saturated clays and other cohesive soils. A cylindrical specimen is set up between end plates. A vertical load is applied incrementally at such a rate as to produce a vertical strain of about 1 to 2% per minute – which is rapid enough to prevent a volume change in the sample due to drainage. The unconfined compressive strength (q_u) is considered to be equal to the load at which failure occurs divided by the cross-sectional area of the sample at the time of failure. In clay soils where undrained conditions are expected to be the lower design limit (i.e. the minimum Factor of Safety), the undrained shear strength (i.e., cohesion) governs the behavior of the clay. This undrained shear strength is approximately equal to $\frac{1}{2}$ the unconfined compressive strength of undisturbed samples (see Laboratory Testing of Recovered Soil Samples in Section 2 of this Technical Manual).

The consistency of clays and other cohesive soils is usually described as soft, medium, stiff, or hard. Tables 5-9 and 5-10 can be found in various textbooks and are reproduced from Bowles, 1988. Values of consistency, overconsolidation ratio (OCR), and undrained shear strength (cohesion) empirically correlated to SPT N-values per ASTM D 1586 are given in Table 5-9. It should be noted that consistency correlations can be misleading because of the many variables inherent in the sampling method and the soil deposits sampled. As such, Table 5-9 should be used as a guide.

The relative density of sands, gravels, and other granular soils is usually described as very loose, loose, medium dense, dense, very dense, or extremely dense. The standard penetration test is a good measure of granular soil density. Empirical values for relative density, friction angle and unit weight as correlated to SPT "N" values per ASTM D 1586 are given in Table 5-10. It should be noted that SPT values can be amplified in gravel because a 1"+ gravel particle may get lodged in the opening of the sampler. This can be checked by noting the length of sample recovery on the soil boring log (see Table 2-6). A short recovery in gravelly soils may indicate a plugged sampler. A short or "low" recovery may also be indicated by loose sand that falls out of the bottom of the sampler during removal from the borehole.

Estimating Friction Angle, ϕ' , in sands

Results from both the SPT and CPT may be used to estimate the drained friction angle of sands and other coarse-grained soils. Generally, most site investigations involving coarse-grained soils will include the use of either the Standard Penetration Test (SPT) or the Cone Penetrometer (CPT).

ϕ' from SPT

Several correlations have been proposed to estimate the drained friction angle in sands from SPT results. A summary of several of the more popular correlations are given in Table 5-11. The correlation of Hatanaka & Uchida (1996) is shown in Figure 5-12, taken from FHWA Reference Manual on Subsurface Investigations (2002).

Table 5-9. Terms to Describe Consistency of Saturated Cohesive Soils

Consistency Term	Stress History	SPT N_{60} -Values	Undrained Shear Strength skf (kPa)	Comments
Very Soft	Normally Consolidated OCR = 1	0 - 2	<0.25 (12)	Runs through fingers.
Soft	Normally Consolidated OCR = 1 – 1.2	3 - 5	0.38 (18.2) to 0.63 (30.2)	Squeezes easily in fingers.
Medium	Normally Consolidated OCR = 1 to 2	6 - 9	0.75 (36) to 1.13 (54.1)	Can be formed into a ball.
Stiff	Normally Consolidated to OCR of 2-3.	10 - 16	1.25 (59.9) to 2 (95.8)	Hard to deform by hand squeezing.
Very Stiff	Overconsolidated OCR = 4 – 8	17 - 30	2.13 (102) to 3.75 (179.6)	Very hard to deform by hand.
Hard	Highly Overconsolidated OCR > 8	>30	>3.75 (179.6)	Nearly impossible to deform by hand.

ϕ' from CPT/CPTU

A similar approach may be used to estimate the friction angle of sands from the CPT/CPTU tip resistance based on a modified bearing capacity theory. Robertson and Campanella (1983) summarized a number of available calibration chamber tests on five sands and suggested a simple correlation between the normalized CPT tip resistance and a cone bearing capacity factor, N_q as:

$$N_q = (q_c/\sigma_{v0}') = 0.194\exp(7.63\tan\phi') \quad \text{Equation 5-26}$$

where:

σ_{v0}' = vertical effective (corrected for pore water pressure) stress at cone tip

This relationship is shown in Figure 5-14.

The friction angle may also be estimated from the effective tip resistance from the CPTU. Early calibration chamber data suggested a simple empirical correlation as:

$$\phi' = \arctan[0.1 + 0.38 \log (q_t/\sigma'_{v0})] \quad \text{Equation 5-27}$$

Equation 5-27 is shown in Figure 5-16.

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**Table 5-10. Empirical Values for Dr, Friction Angle and Unit Weight vs SPT
(Assuming a 20 ft (6 m) depth of overburden and 70% rod efficiency on hammer)**

Description		Very Loose	Loose	Medium	Dense	Very Dense
Relative Density (D_r) (%)		0	15	35	65	85
SPT (N_{70})	Fine	1-2	3-6	7-15	16-30	?
	Medium	2-3	4-6	8-20	21-40	40+
	Coarse	3-6	5-9	10-25	26-45	45+
Friction Angle (ϕ)	Fine	26-28	28-30	30-33	33-38	38+
	Medium	27-29	29-32	32-36	36-42	50+
	Coarse	28-30	30-34	34-40	40-50	50+
Total Unit Weight (g_{wet}) (PCF)		70-100	90-115	110-130	110-140	130-150

Additional test results from 24 different sands were compiled by Kulhawy and Mayne (1990) who proposed the following expression:

$$\phi' = 17.70 + 11.0 \log (q_{t1})$$

Equation 5-28

where:

$$(q_{t1}) = (q_t / \sigma_{atm}) / (\sigma'_{vo} / \sigma_{atm})^{0.5}$$

σ_{atm} = atmospheric pressure (1 atm = 1 bar = 100 kPa = 1tsf = 14.7 psi)

Table 5-11. Reported Correlations between SPT N-Value and ϕ' for Coarse-Grained Soils

Correlation	Reference
$\phi' = (0.3N)^{0.5} + 27^0$	Peck et al. (1953)
$\phi' = (10N)/35 + 27^0$	Meyerhof (1956)
$\phi' = (20N)^{0.5} + 15^0$	Kishida (1967)
$\phi' = (N/\sigma'_{vo})^{0.5} + 26.9^0$ (σ'_{vo} in MN/m ²)	Parry (1977)
$\phi' = (15N)^{0.5} + 15^0$	Shioi & Fukui (1982)
$\phi' = (15.4(N_1)_{60})^{0.5} + 20^0$	Hatanaka & Uchida (1996)

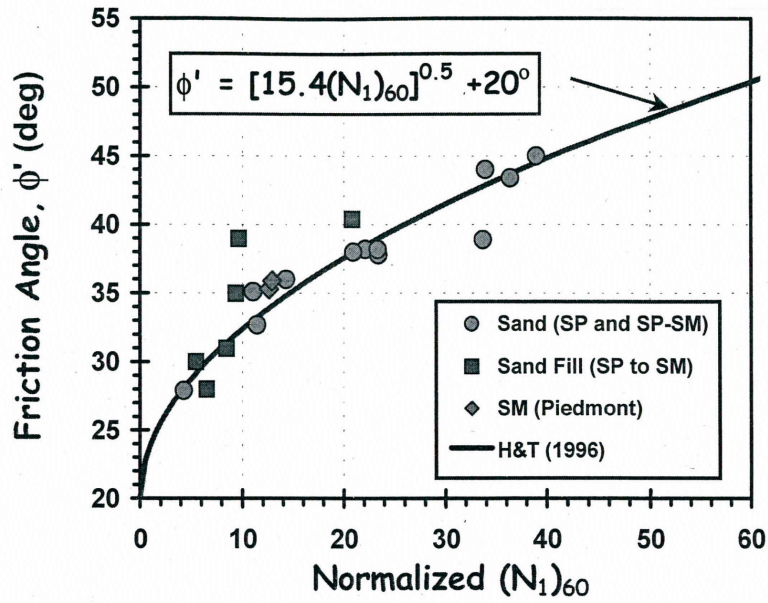
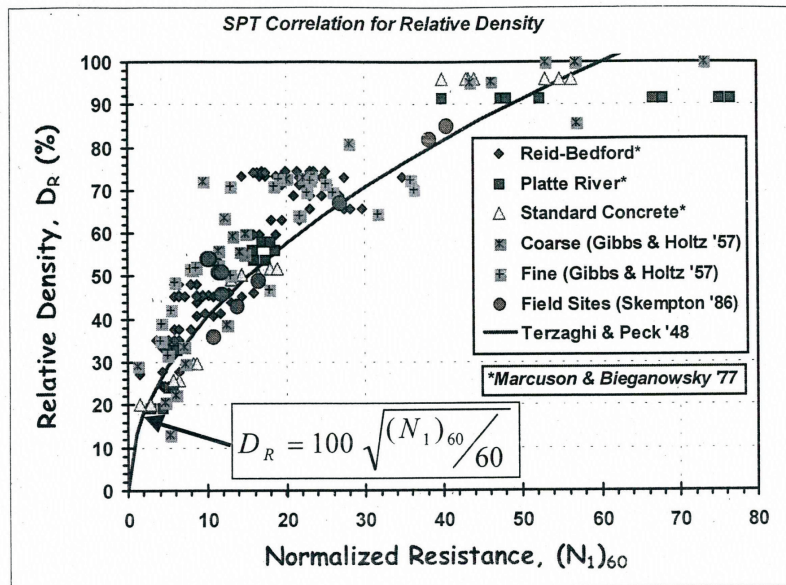


Figure 5-12 Peak Friction Angle of Sands from SPT Resistance - Correlation of Hatanaka & Uchida (1996) from FHWA Reference Manual on Subsurface Investigations (2002)



Direct Estimate of Unit Shaft Resistance, f_s , of Steel Round Shaft Piles and Grouted Helical Micropiles

Suggestions for estimating the unit side resistance, f_s , of deep foundations in a variety of soils have been presented. This approach is convenient for helical piles/anchors and reduces assumptions in first estimating shear strength and then estimating other factors to obtain f_s . Poulos (1989) summarized a number of reported correlations between pile unit side resistance and SPT N-value and suggested that most of these correlations could be expressed using the general equation:

$$f_s = \beta + \alpha N$$

Equation 5-29

Lutenegger (2011) presented a summary of more-or-less “global” reported correlations between SPT N-values and unit side resistance friction for both driven and bored piles in a number of different soil materials and shown in Table 5-12.

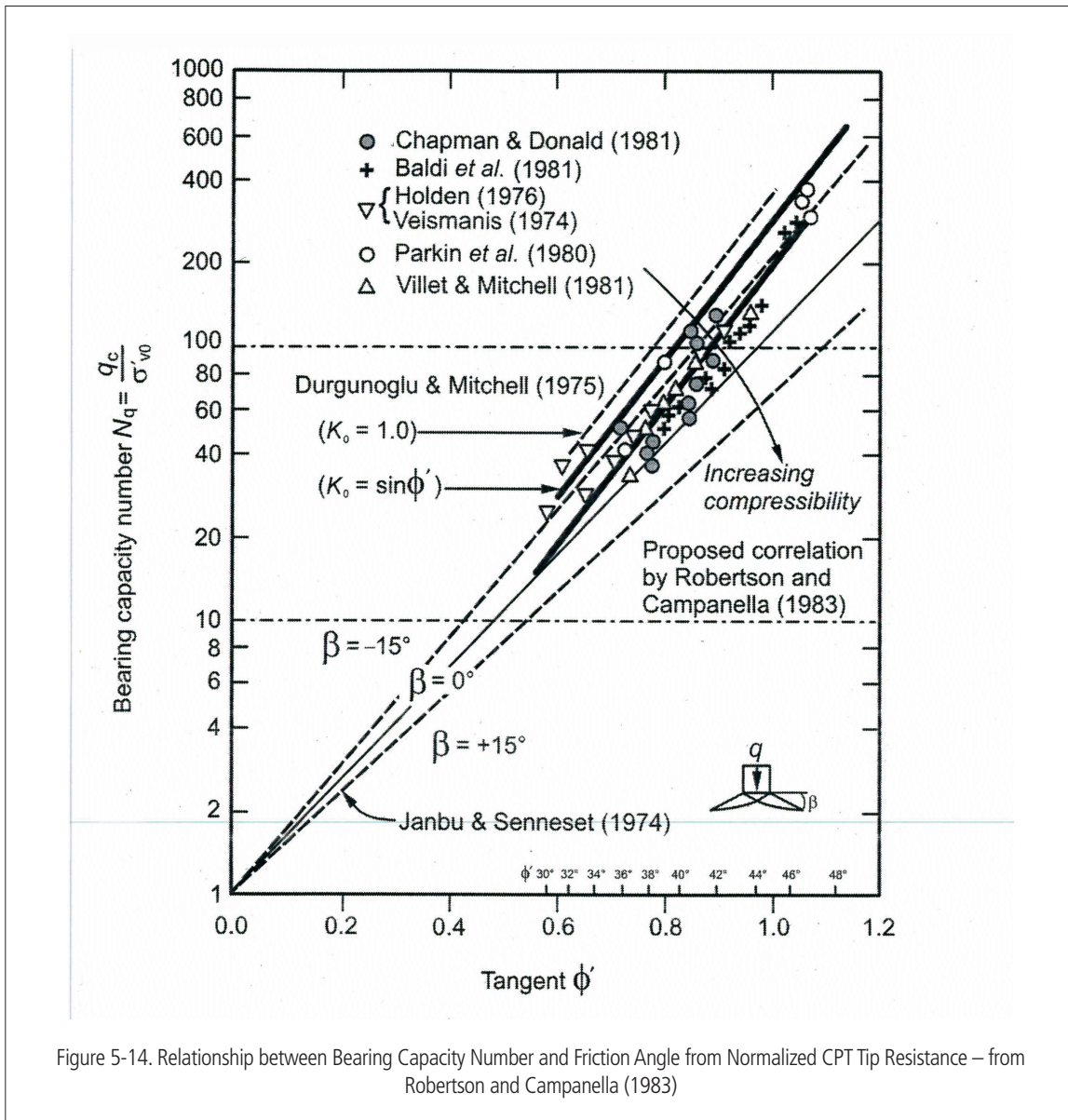


Figure 5-14. Relationship between Bearing Capacity Number and Friction Angle from Normalized CPT Tip Resistance – from Robertson and Campanella (1983)

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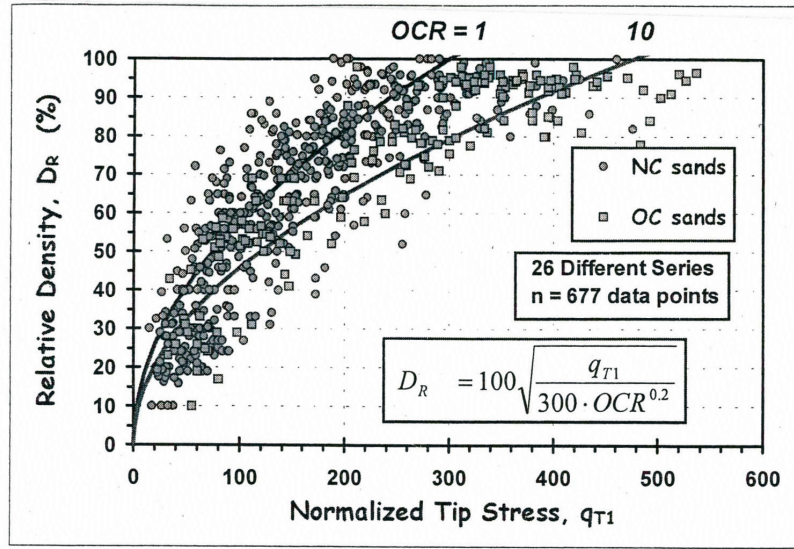


Figure 5-15. Relationship Between Relative Density for Normally Consolidated (NC) and Over Consolidated (OC) Sands from CPT Data.

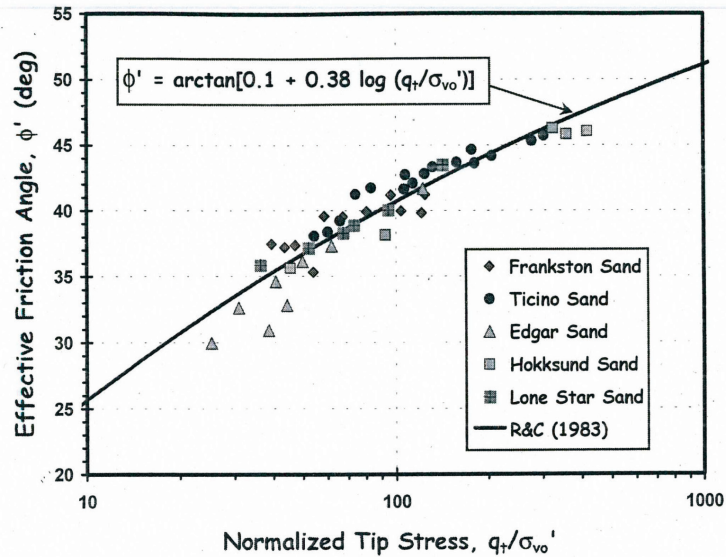


Figure 5-16. Relationship Between Friction Angle and the Effective Tip Resistance from CPTU Data

$$(N_1)_{60} = N_{60}/(\sigma'_{vo})^{0.5}$$

σ'_{vo} = effective overburden stress in tsf

Engineers might ask “Why should the SPT N-value correlate to pile side resistance?” Other than being purely coincidental, there must be a rational and logical explanation for such observations. The range in reported values of α given in Table 5-12 is quite large and the results might seem of limited use. Nonetheless, we can make some general observations and summarize these observations: 1) For most of these correlations, the value of β is very low and for practical purposes may be reasonably taken as zero with little effect on the correlation, which simplifies Eq. 5-29 to:

$$f_s = \alpha N$$

Equation 5-30

2) The value of α ranges from 0.3 to 12.5; 3) The observations presented in Table 5-12 generally suggest higher values of α for fine-grained soils as compared to coarse-grained soils; and 4) Values of α are generally higher for driven piles as compared to bored piles.

The values of α vary considerably for a number of obvious reasons, deriving from both the pile data as well as the SPT data. In regard to the pile data: 1) The data represent a wide range of pile types, i.e., different geometry, such as open and closed end pipe, H-Piles and construction practices; such as dry bored vs. wet bored as well as pile size, pile plugging, L/d, and other factors; 2) Different methods may have been used to interpret the ultimate capacity and to isolate the side resistance from end bearing; 3) The unit side resistance from pile tests is typically averaged over the length of the pile except in the case of well instrumented piles. Regarding the SPT data: 1) The results most likely represent a wide range in field practice including a wide range in energy or hammer efficiency; 2) It is likely that other variations in field practice or equipment such as spoon geometry are not consistent among the various studies and may affect results. Engineers should use the correlations in Table 5-12 with caution.

In fact, Equation 5-30 is similar to Equation 5-21, suggesting a correlation between SPT N-values and undrained shear strength (s_u) in fine-grained soils.

5.4 FACTOR of SAFETY

The equations discussed above are used to obtain the ultimate capacity of a helical anchor/pile. For working, or allowable stress design (ASD), an appropriate Factor of Safety must be applied to reduce the ultimate capacity to an acceptable design (or working) capacity. The designer determines the Factor of Safety to be used. In general, a minimum Factor of Safety of 2 is recommended. For tieback applications, the Factor of Safety typically ranges between 1.25 and 2.

Design or working loads are sometimes referred to as unfactored loads and do not include any Factor of Safety. They may arise from dead loads, live loads, snow loads and/or earthquake loads for bearing (compression) loading conditions; from dead loads, live loads, snow loads and/or wind loads for anchor loading conditions; and earth pressure, water pressure and surcharge loads (from buildings, etc.) for helical tieback or SOIL SCREW® earth retention conditions.

Ultimate loads, sometimes referred to as fully factored loads, already fully incorporate a Factor of Safety for the loading conditions described above. Hubbell Power Systems, Inc. recommends a minimum Factor of Safety of 2.0 for permanent loading conditions and 1.5 for temporary loading conditions. This Factor of Safety is applied to the

**Table 5-12. Reported Correlations between SPT N-Value and Pile Side Resistance
(from Lutenegeger 2011)**

Pile Type	Soil	β	α	Reference
driven displacement	granular	0	2.0	Meyerhof (1976)
	miscellaneous soils ($f_s < 170$ kPa)	10	3.3	Decourt (1982)
	cohesive	0	10	Shioi & Fukui (1982)
	cohesive cohesionless	0	3 1.8	Bazaraa & Kurkur (1986)
	sandy clayey	29 34	2.0 4.0	Kanai & Yubuuchi (1989)
	misc	0	1.9	Robert (1997)
bored	granular	0	1.0	Meyerhof (1976)
	granular	55	5.8	Fujita et al. (1977)
	cohesionless	0	3.3	Wright & Reese (1979)
	cohesive ($f_s < 170$ kPa)	10	3.3	Decourt (1982)
	cohesive	0	5.0	Shioi & Fukui (1982)
	cohesive cohesionless	0 0	1.8 0.6	Bazaraa & Kurkur (1986)
	residual soil & weathered rock	0	2.0	Broms et al. (1988)
	clay sand	0 0	1.3 0.3	Koike et al. (1988)
	sandy soil cohesive	35 24	3.9 4.9	Kanai & Yubuuchi (1989)
	residual soil	0	4.5	Winter et al. (1989)
	gravel sand silt clay	0 0 0 0	6.0 4.0 2.5 1.0	Hirayama (1990)
	residual soils	0	2.0	Chang & Broms (1991)
	clayey soil sandy soil	0 0	10.0 3.0	Matsui (1993)
	misc.	17.3 18.2	1.18 0.65	Vrymoed (1994)
	misc.	0	1.9	Robert (1997)
	sand	0	5.05	Kuwabara & Tanaka (1998)
	weathered rock	0	4	Wada (2003)
	cast-in-place	cohesionless cohesive	0 0	5.0 10.0
cohesionless ($f_s < 200$ kPa) cohesive ($f_s < 150$ kPa)		30 0	2.0 5.0	Yamashita et al.(1987)

Note: $f_s = \beta + \alpha N$ (f_s in units of kPa)

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design or working loads as defined above to achieve the ultimate load requirement. National and local building code regulations may require more stringent Factors of Safety on certain projects.

Most current structural design standards in Canada use a Limit States Design (LSD) approach for the structural design of helical piles/anchors rather than working or allowable stress design (WSD). All specified loads (dead, live, snow, wind, seismic, etc.) are factored in accordance with appropriate load factors and load combinations should be considered. In addition, the geotechnical resistance of the helical pile/anchor must be factored. Geotechnical resistance factors for helical piles/anchors are not yet clearly defined. Therefore, a rational approach should be taken by the designer and resistance factors should be considered that are suitable to specific requirements.

5.5 HeliCAP® HELICAL CAPACITY DESIGN SOFTWARE

Hubbell Power Systems, Inc. engineers developed HeliCAP® design software to determine the bearing capacity of helical piles and anchors in soil. Since then, it has been revised several times to provide additional features such as side resistance for steel pipe piles and grouted shaft helical piles. HeliCAP® software is available to engineers and designers upon request. The software uses the same theory of general bearing capacity as presented in Section 5.2 for deep foundations (minimum depth $\geq 5D$). A key feature of HeliCAP is it's designed to work with the information commonly available from soils reports. In North America, soil investigation usually includes a soil boring as described in Section 2 of this Technical Design Manual. The most common information available from the soils boring is the soil profile, groundwater location, and SPT blow count data per ASTM D-1586. As such, HeliCAP® includes blow count correlations for shear strength, angle of internal friction, and unit weight. These correlations are generally accepted as reasonable approximations given the available blow count data.

The following equations, factors, empirical values, etc., presented in this section are the algorithms used in the HeliCAP® v2.0 Helical Capacity Design Software. This program makes the selection of a helical anchor/pile much quicker than making hand calculations. It allows calculations to be made quickly while varying the different parameters to arrive at the most appropriate solution. As with any calculations, the results from this program are no better than the input data used to generate them.

The program will assist in determining an appropriate helical lead configuration and overall anchor/pile length. It also provides an estimate of the installation torque. The helical lead configuration can vary by the number and sizes of helix plates required to develop adequate capacity. Helical anchor/pile length may vary due to the combined effects of the lead configuration and soil strength. Generally speaking, the shorter the pile length for a given load, the better the performance will be in regard to deflection under load.

HeliCAP® BEARING CAPACITY METHODOLOGY

As detailed earlier in this Section, the Individual Plate Bearing Method states the capacity of a single or multi-helix anchor/pile is determined by summing the bearing capacity of the individual helix plate elements specific to a given pile. Thus:

$$Q_t = \sum Q_h$$

where:

Q_t = Total ultimate multi-helix anchor/pile capacity

Q_h = Individual helix capacity

HeliCAP determines the ultimate bearing capacity of an individual helix as per the following equation. An upper limit for this capacity is based on helix strength that can be obtained from the manufacturer. See Section 7 of this Technical Design Manual for the mechanical strengths of helix plates.

$$Q_h = A_h (cN_c + q'N_q) \leq Q_s$$

where:

A_h = Projected helix area

Q_s = Capacity upper limit, determined by the helix mechanical strength

Equation 5-31

Sands $\phi' > 0$; $c' = 0$

HeliCAP® determines the ultimate bearing capacity in a non-cohesive sand or gravel soil with Equation 5-32 in which the fine-grain (clay) term has been eliminated.

The bearing capacity factor N_q is dependent on the angle of internal friction (ϕ') of the non-cohesive sand or gravel soil. When a value is provided for the friction angle, HeliCAP uses Figure 5-7 (N_q vs ϕ') and Equation 5-19 to determine the value for N_q . When the angle of internal friction is not known, HeliCAP estimates it (and N_q) by using blow counts obtained from the Standard Penetration Test per ASTM D 1586. Equation 5-33 allows an estimate of the angle of internal friction from SPT blow count data. This equation is based on empirical data given by Bowles (1968) and its results should be used with caution. The graph in Figure 5-7 allows the determination of N_q for a specific angle of internal friction when measured in degrees. This curve was adapted from work by Meyerhof (1976). Equation 5-19 was written for the curve shown in Figure 5-7, which is Myerhof's N_q values divided by 2 for long term applications. **Note the correlated ϕ' and N_q values determined by HeliCAP® can be overridden. This is encouraged when more reliable soil data are available.**

$$Q_h = A_h q' N_q = A_h \gamma' D N_q \quad \text{Equation 5-32}$$

where:

A_h = Projected helix area

D = Vertical depth to helix plate

N_q = Bearing capacity factor for non-cohesive component of soil

γ' = Effective unit weight of the soil

$$\phi' = 0.28 N + 27.4 \quad \text{Equation 5-33}$$

where:

ϕ' = Angle of internal friction

N = Blow count per ASTM D 1586 Standard Penetration Test

Fine-Grain Cohesive Soil, $\phi' = 0$; $c' > 0$

HeliCAP® determines the ultimate bearing capacity in a cohesive or fine-grained soil with Equation 5-17 with the overburden term not used. The N_c factor is 9, provided the installation depth below grade is greater than five times the diameter of the top most helix.

$$Q_h = A_h c N_c = A_H [(9)(s_u)] \quad \text{Equation 5-34}$$

where:

A_h = Projected helix area

c = "cohesion"; for $\phi' = 0$; c = undrained shear strength = s_u

N_c = Bearing Capacity Factor for Deep Failure = 9 (minimum depth $\geq 5D$)

In the event that cohesion or undrained shear strength values are not available, HeliCAP® uses the following

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equation to obtain estimated undrained shear strength values when blow counts from ASTM D 1586 Standard Penetration Tests are available. This equation is based on empirical values and is offered only as a guide when undrained shear strength values are otherwise not available. It is suggested that results be used with caution. **(NOTE: The correlated undrained shear strength values determined by HeliCAP® can be overridden. This is encouraged when more reliable soil data are available.)**

$$c \text{ (ksf)} = N / 8 \text{ or } = 0.125(N)$$

Equation 5-35

$$c \text{ (kPa)} = 6N$$

where:

c = "cohesion"; for $\phi' = 0$; c = undrained shear strength = s_u

N = Blow count value per ASTM D 1586 Standard Penetration Test

Unit Weight Correlation

In the event unit weight values are not available, HeliCAP® uses the following equations to obtain estimated unit weight values when blow counts from ASTM D 1586 Standard Penetration Tests are available.

Clay (Fine-Grain) Soils:

$$N > 0 \text{ \& } N \leq 19: \quad \gamma = 80 + (2N) \text{ (lb/ft}^3\text{)}$$

$$N \geq 20 \text{ \& } N \leq 40 \quad \gamma = 120 \text{ (lb/ft}^3\text{)}$$

Equation 5-36

$$N \geq 41 \text{ \& } N < 50 \quad \gamma = 120 + 2(N-40) \text{ (lb/ft}^3\text{)}$$

$$N \geq 50 \quad \gamma = 140 \text{ (lb/ft}^3\text{)}$$

Equation 5-37

Sand (Coarse-Grain) Soils:

$$N = 0 \quad \gamma = 65 \text{ (lb/ft}^3\text{)}$$

$$N > 0 \text{ \& } N \leq 7 \quad \gamma = 60 + 5N \text{ (lb/ft}^3\text{)}$$

$$N \geq 8 \text{ \& } N \leq 10 \quad \gamma = 100 \text{ (lb/ft}^3\text{)}$$

Equation 5-38

$$N \geq 11 \text{ \& } N < 50 \quad \gamma = 90 + N \text{ (lb/ft}^3\text{)}$$

$$N \geq 50 \quad \gamma = 140 \text{ (lb/ft}^3\text{)}$$

Equation 5-39

These correlations were originally determined from Tables 3-2 and 3-3 in Bowles first edition of Foundation Analysis and Design. These relationships provide an approximation of the total unit weight. They have been modified slightly from how they were originally presented as experience has suggested. **(NOTE: The correlated total unit weight values determined by HeliCAP® can be overridden. This is encouraged when more reliable soil data are available.)**

Mixed Soils $\phi' > 0$; $c' > 0$

The determination of the bearing capacity of a mixed soil, one that exhibits both cohesion and friction properties, is accomplished by use of Equation 5-31. This is fairly uncomplicated when accurate values are available for both the cohesion (undrained shear strength) and friction terms (ϕ' & γ') of the equation. It is not possible to use ASTM D 1586 Blow Count correlations to determine all soil strength variables in the bearing capacity equation. Therefore, unless the designer is quite familiar with the project soil conditions, it is recommended that another approach be taken when accurate values are not available for both terms of the equation.

One suggestion is to first consider the soil as fine-grained (cohesive) only and determine capacity. Then consider the same soil as coarse-grained (cohesionless) only and determine capacity. Finally, take the lower of the two results and use that as the soil bearing capacity and apply appropriate Factors of Safety, etc.

HeliCAP® SHAFT RESISTANCE METHODOLOGY

As discussed earlier in this section, the shaft resistance developed by pipe shaft or grouted shaft screw-piles is considered in much the same way that shaft resistance in a driven pile develops. HeliCAP® uses this traditional approach that is available in most foundation design textbooks.

The general equation is:

$$Q_f = \sum[\pi(D)f_s(\Delta L_f)] \quad \text{Equation 5-40}$$

where:

D = Diameter of steel or concrete pile column

f_s = Sum of friction and adhesion between soil and pile

ΔL_f = incremental pile length over which πD and f_s are taken as constant

HeliCAP® uses two empirical methods to calculate shaft resistance - the Gouvenot Method and the US Department of Navy Method. The Gouvenot Method is named after the French researcher; who conducted tests on a variety of grouted shaft micropiles including gravity fed grout columns. HeliCAP® uses the Gouvenot method to calculate shaft resistance for grouted columns only (HELICAL PULLDOWN® Micropiles). The US Navy method uses the Dept. of Navy Design Manual 7, Soil Mechanics, Foundations and Earth Structures (1974). HeliCAP® uses the Navy method to calculate shaft resistance for both grouted columns and straight steel pipe shafts.

- Gouvenot reported a range of values for skin friction of concrete/grout columns based on a number of field load tests. The soil conditions are divided into three categories based on friction angle (ϕ) and cohesion (c). The equations used to calculate f_s are:

Type I: Sands and gravels with $35^\circ < \phi < 45^\circ$ and $c' = 0$:

$$f_s = \sigma_o \tan \phi$$

Equation 5-41

where: σ_o = Mean normal stress for the grout column

Type II: Mixed soils; fine loose silty sands with $20^\circ < \phi < 30^\circ$ and sandy clays with $205 \text{ psf} < C < 1024 \text{ psf}$ ($9.8 \text{ kPa} < c < 49 \text{ kPa}$)

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$$f_s = \sigma_o(\sin \varphi) + c(\cos \varphi)$$

Equation 5-42

Type III: Clays with 1024 psf < c < 4096 psf (49 kPa < c < 196 kPa)

$$f_s = C$$

Equation 5-43

where: 1024 psf < c < 2048 pfs (49 kPa < c < 98 kPa)
and:

$$f_s = 2048 \text{ psf (98 kPa)}$$

Equation 5-44

where: 2048 psf < c < 4096 psf (98 kPa < c < 196 kPa)

In HeliCAP® this analysis assumes a uniform shaft diameter for each soil layer and, if required, the friction capacity of the pile near the surface can be omitted.

- **Department of the Navy Design Manual 7 Method:**

For cohesive soils (α Method):

$$Q_f = \Sigma[\pi(D)C_a(\Delta L_f)]$$

Equation 5-45

where: C_a = Adhesion factor (See Table 5-13)

For cohesionless soils (α Method):

$$Q_f = \Sigma[\pi D(qK \tan \phi) \Delta L_f]$$

Equation 5-46

where: q = Effective vertical stress on element ΔL_f

K = Coefficient of lateral earth pressure ranging from K_o to about 1.75 depending on volume displacement, initial soil density, etc. Values close to K_o are generally recommended because of long-term soil creep effects. As a default, use $K_o = 1$.

φ = Effective friction angle between soil and plate material

$$Q_f = \Sigma[\pi D(S) \Delta L_f]$$

Equation 5-47

where: S = Average friction resistance on pile surface area = $P_o \tan \varphi$ (See Tables 5-5 & 5-14)

P_o = Average overburden pressure

For straight steel pipe shaft piles in sand, HeliCAP® uses Table 5-5 to calculate shaft resistance in sand layers using the Alternate Navy Method.

Tables 5-13, 5-14 and 5-5 are derived from graphs in the Department of the Navy Design Manual 7, Soil Mechanics, Foundations and Earth Structures (1974). Later editions of this manual limit the depth at which the average overburden pressure is assumed to increase. The following is an excerpt from the manual regarding this limiting depth:

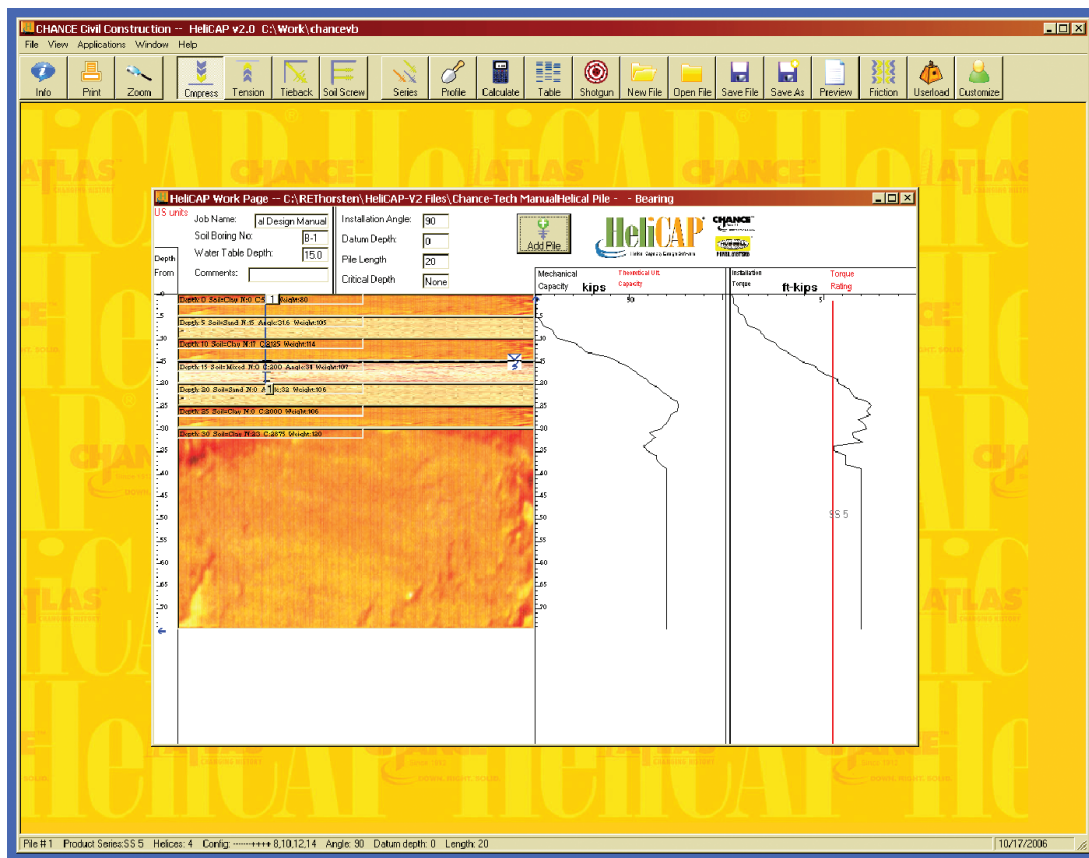
“Experimental and field evidence indicate that bearing pressure and skin friction increase with vertical effective stress (P_o) up to a limiting depth of embedment, depending on the relative density of the granular soil and position of the water table. Beyond this limiting depth ($10B \pm$ to $40B \pm$) there is very little increase in end bearing, and increase in side friction is directly proportional to the surface area of the pile. Therefore, if D is greater than $20B$, limit P_o at the pile tip to that value corresponding to $D = 20B$ ” where D = depth of the pile embedment over which side friction is considered and B = diameter of the pile.

Design Example 8-5 in Section 8 illustrates the use of the Navy Design Manual 7 method to calculate the friction capacity of a CHANCE HELICAL PULLDOWN[®] Micropile.

HeliCAP[®] v2.0 Helical Capacity Design Software calculates ultimate capacity and must have an appropriate Factor of Safety applied to the results. The program has additional features that allow it to be used for other applications, but it is beyond the scope of this manual to present all facets of the program. For additional assistance, refer to the Help screen or contact Hubbell Power Systems, Inc. application engineers.

The following screen is from HeliCAP[®] v2.0 Helical Capacity Design Software. It shows a typical workpage with the soil profile on the left and helical pile capacity on the right.

Design Examples 8-3 through 8-12 in Section 8 illustrate the use of the standard bearing equation to determine the bearing capacities of helical piles/anchors. These design examples are taken from actual projects involving residential and commercial new construction, boardwalks, tiebacks, telecommunication towers, pipeline buoyancy control, etc.



5.6 APPLICATION GUIDELINES for CHANCE® HELICAL PILES/ANCHORS

- The uppermost helix should be installed at least three diameters below the depth of seasonal variation in soil properties. Therefore, it is important to check the frost depth or “mud” line at the project site. Seasonal variation in soil properties may require the minimum vertical depth to exceed five helix diameters. The influence of the structure’s existing foundation (if any) on the helical pile/anchor should also be considered. Hubbell Power Systems, Inc. recommends helical piles/anchors be located at least five diameters below or away from existing foundation elements.
- The uppermost helix should be installed at least three helix diameters into competent load-bearing soil. It is best if all helix plates are installed into the same soil stratum.
- For a given shaft length, use fewer longer extensions rather than many shorter extensions. This will result in fewer connections and better load/deflection response.
- Check economic feasibility if more than one combination of helical pile/anchors helix configuration and overall length can be used.

Table 5-13. Recommended Adhesion Values in Clay*

PILE TYPE	SOIL CONSISTENCY	COHESION, c (psf)	ADHESION, Ca (psf)
Concrete	Very Soft	0 – 250	0 – 250
	Soft	250 – 500	250 – 480
	Medium Stiff	500 – 1000	480 – 750
	Stiff	1000 – 2000	750 – 950
	Very Stiff	2000 – 4000	950 – 1300
Steel	Very Soft	0 – 250	0 – 250
	Soft	250 – 500	250 – 460
	Medium Stiff	500 – 1000	460 – 700
	Stiff	1000 – 2000	700 – 720
	Very Stiff	2000 – 4000	720 - 750

* From Department of the Navy Design Manual 7, Soil Mechanics, Foundations and Earth Structures (1974).

Table 5-14. Straight Concrete Piles in Sand

P _o (psf)	Effective Angle of Internal Friction (degrees) (φ')				
	20	25	30	35	40
	S= Average Friction Resistance on Pile Surface (psf)				
500	182	233	289	350	420
1000	364	466	577	700	839
1500	546	699	866	1050	1259
2000	728	933	1155	1400	1678
2500	910	1166	1443	1751	2098
3000	1092	1399	1732	2100	2517
3500	1274	1632	2021	2451	2937
4000	1456	1865	2309	2801	3356

5.7 LATERAL CAPACITY OF HELICAL PILES

Introduction

The primary function of a deep foundation is to resist axial loads. In some cases they will be subjected to horizontal or lateral loads. Lateral loads may be from wind, seismic events, live loads, water flow, etc. The resistance to lateral loads is in part a function of the near surface soil type and strength, and the effective projected area of the structure bearing against these soils. This section provides a summarized description of the methods and procedures available to determine the lateral capacity of helical piles/anchors in soil.

The analysis of deep foundations under lateral loading is complicated because the soil reaction (resistance) at any point along the shaft is a function of the deflection, which in turn is dependent on the soil resistance. Solving for the response of a deep foundation under lateral loading is one type of soil-structure interaction problem best suited for numerical methods on a computer. Square shaft (SS) helical piles/anchor do not provide any significant resistance to lateral loads. However, Round Shaft (RS) helical piles/anchor and HELICAL PULLDOWN® Micropiles can provide significant resistance to lateral loads depending on the soil conditions. Over the past 7 seven years, there has been considerable research done on the lateral capacity of grouted shaft helical piles – both with and without casing. Abdelghany & Naggar (2010) and Sharnouby & Naggar (2011) applied alternating cyclic lateral loads to helical piles of various configurations in an effort to simulate seismic conditions. Their research showed that helical piles with grouted shafts retain all their axial load capacity after being subjected to high displacement lateral load.

Lateral Resistance - Methods Used

Most helical piles/anchors have slender shafts [less than 3 inch (89 mm)] that offer limited resistance to lateral loads when applied to vertically installed shafts. Load tests have validated the concept that vertical pile foundations are capable of resisting lateral loads via shear and bending. Several methods are available to analyze the lateral capacity of foundations in soil including: 1) Finite Difference method; 2) Broms' Method (1964a) and (1964b); 3) Murthy (2003) Direct Method; and 4) Evans & Duncan (1982) Method as presented by Coduto (2001). Each of these methods may be applied to Round Shaft helical piles..

Lateral resistance can also be provided by passive earth pressure against the structural elements of the foundation. The resisting elements of the structure include the pile cap, grade beams and stem walls. The passive earth pressure against the structural elements can be calculated using the Rankine Method.

Battered or inclined helical piles/anchors can be used to resist lateral loads by assuming that the horizontal load on the structure is resisted by components of the axial load. The implicit assumption in this is that inclined foundations do not deflect laterally, which is not true. Therefore, it is better practice to use vertically installed helical piles/anchors to resist only vertical loads and inclined helical piles/anchors to resist only lateral loads. When inclined piles are required to resist both vertical and lateral loads, it is good practice to limit the pile inclination angle to less than 15°.

Friction resistance along the bottom of a footing, especially in the case of a continuous strip footing or large pile cap, can be significant. The friction component in a sandy soil is simply the structure's dead weight multiplied by the tangent of the angle of internal friction. In the case of clay, cohesion times the area of the footing may be used for the friction component. When battered piles are used to prevent lateral movement, the friction may be included in the computation. The designer is advised to use caution when using friction for lateral resistance. Some building codes do not permit friction resistance under pile supported footings and pile caps due to the possibility the soil will settle away from the footing or pile cap. Shrink-swell soils, compressible strata, and liquefiable soil can result in a void under footings and pile caps.

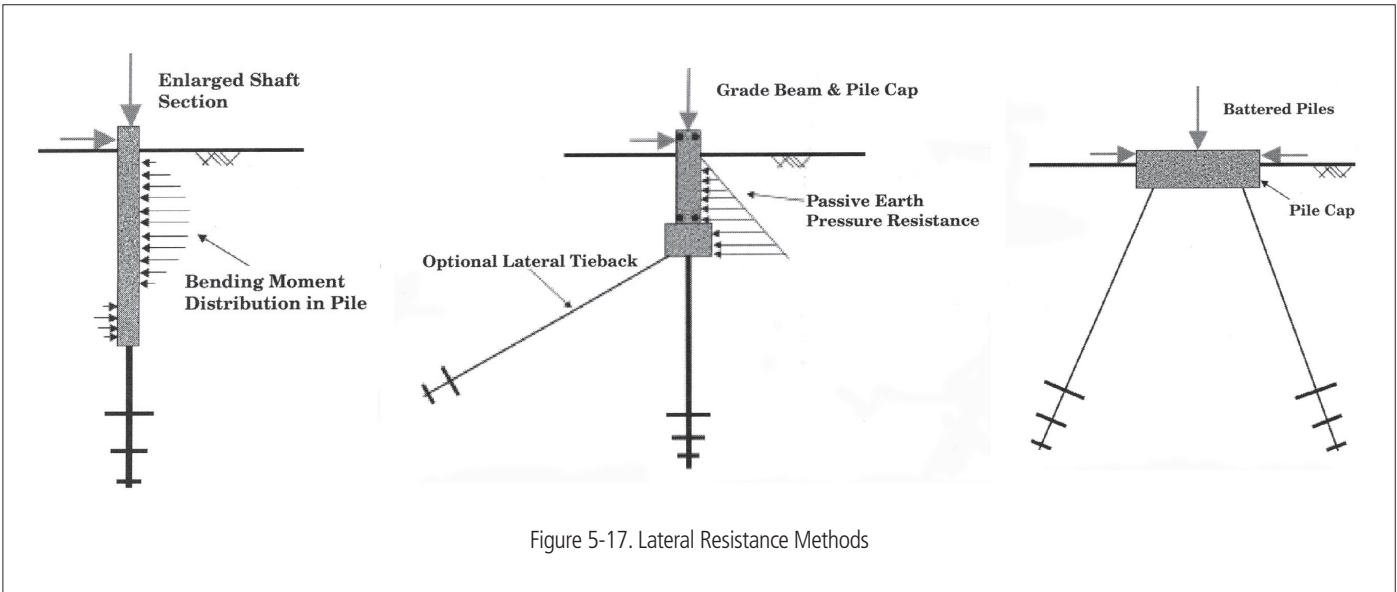


Figure 5-17. Lateral Resistance Methods

Finite Difference Method

Several computer programs, such as LPILEPLUS (ENSOFT, Austin, TX) are revisions of the COM624 program (Matlock and Reese) and its predecessor Beam-Column 28 (Matlock and Haliburton) that both use the p-y concept, i.e., soil resistance is a non-linear function of pile deflection, which was further developed by Poulos (1973). This method is versatile and provides a practical design method. This is made possible by the use of computers to solve the governing non-linear, fourth-order differential equation, which is explained in greater detail on page 5-20. Lateral load analysis software gives the designer the tools necessary to evaluate the force-deflection behavior of a helical pile/anchor embedded in soil.

Figures 5-18 and 5-19 are sample LPILEPLUS plots of lateral shaft deflection and bending moment vs. depth where the top of the pile is fixed against rotation. From results like these, the designer can quickly determine the lateral response at various horizontal loads up to the structural limit of the pile, which is typically bending. Many geotechnical consultants use LPILEPLUS or other soil-structure-interaction programs to predict soil-pile response to lateral loads.

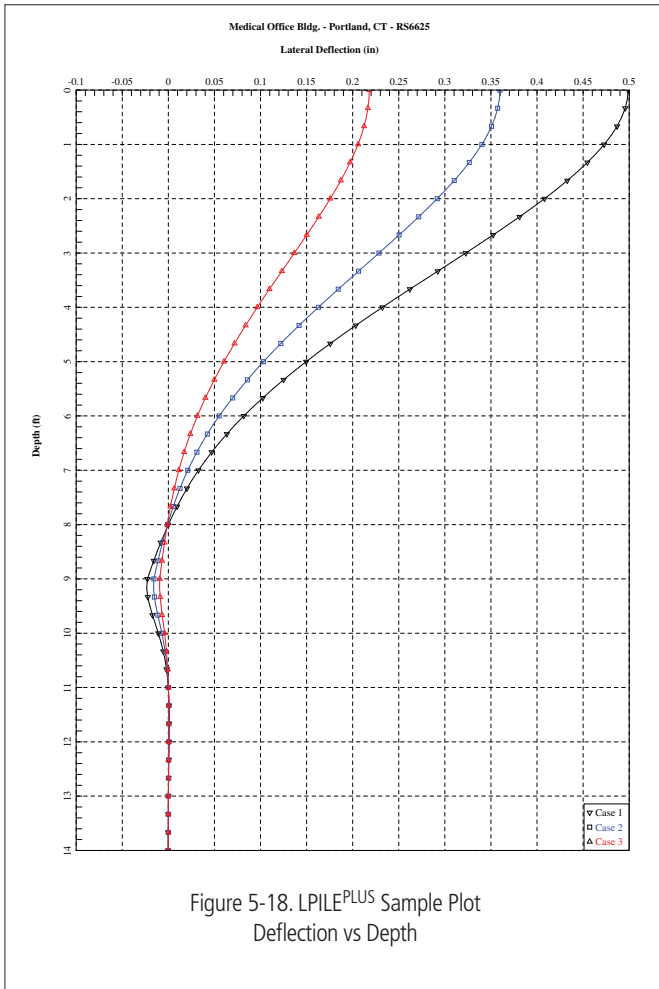


Figure 5-18. LPILEPLUS Sample Plot Deflection vs Depth

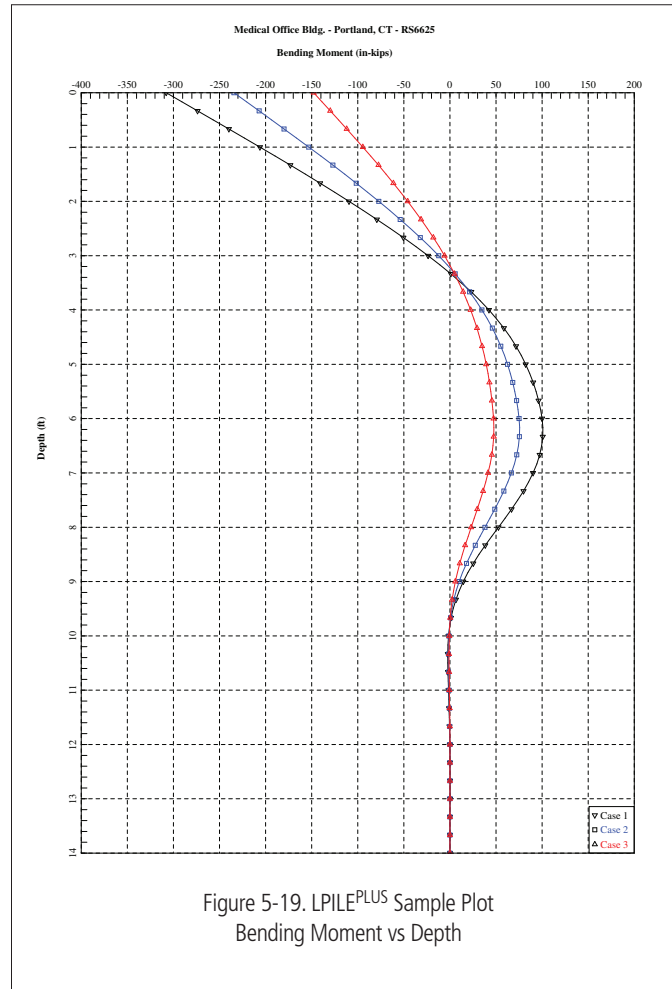


Figure 5-19. LPILEPLUS Sample Plot Bending Moment vs Depth

Brom's (1964a & 1964b) Method

Broms' Method is best suited for applications where the top section of the helical pile/anchor/pile is a greater diameter than the bottom section. Enlarged top sections are commonly used to increase the lateral capacity of the foundation shaft. Design Example 8-13 in Section 8 gives an example of this. It uses Broms' method for short piers in cohesive soil. A "short" pier is one that is rigid enough that it will move in the direction the load is tending by rotation or translation. A "long" pier is one that the top will rotate or translate without moving the bottom of the foundation, i.e., a plastic hinge will form.

Broms developed lateral capacity methods for both short and long piles in cohesive and non-cohesive soil. Broms theorized that a short free-headed pier rotates about a center, above the lower end of the foundation, without substantial deformation along its axis. The resistance is the sum of the net of the earth pressures above and the passive earth pressure below the center of rotation. The end bearing influence or effect is neglected. Likewise, the passive earth pressure on the uppermost 1.5 diameters of shaft and the active earth pressure on the back of the pile are neglected.

Figure 5-20 is a reaction/shear/moment diagram that demonstrates the Broms theory for laterally loaded short piles in cohesive soils. A simple static solution of these diagrams will yield the required embedment depth and shaft diameter of the top section required to resist the specified lateral load. It is recommended the designer obtain and review Broms' technical papers (see References at the end of this section) to familiarize themselves with the various solution methods in both cohesive and non-cohesive soils. The Broms Method was probably the most widely used method prior to the finite difference and finite element methods used today and gives fair agreement with field results for short piles.

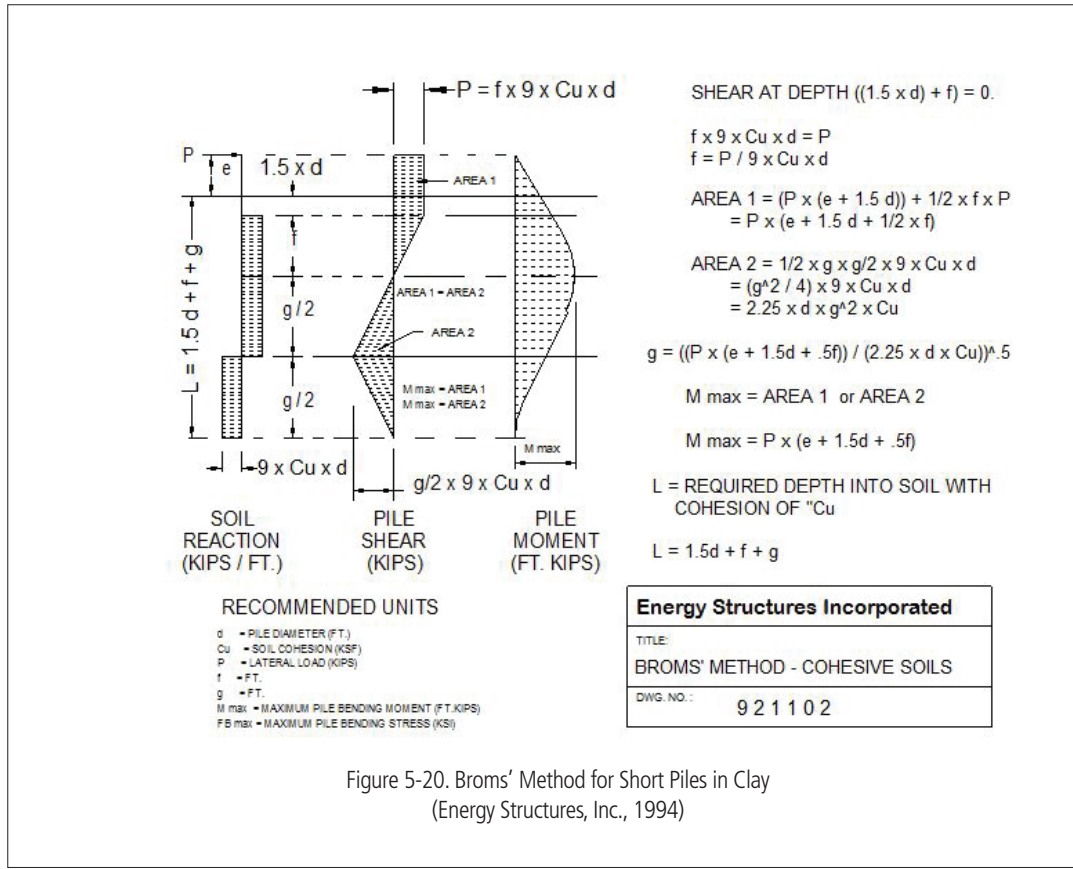


Figure 5-20. Broms' Method for Short Piles in Clay
(Energy Structures, Inc., 1994)

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Lateral Capacity By Passive Earth Pressure

Passive earth pressure on the projected area of the pile cap, grade beam, or stem wall can be calculated by the Rankine (ca. 1857) method, which assumes no soil cohesion or wall-soil friction. One can use known or assumed soil parameters to determine the sum of the passive earth pressure minus the active earth pressure on the other side of the foundation as shown in Figure 5-21. The following are general equations to calculate active and passive pressures on a wall for the simple case on a frictionless vertical face and a horizontal ground surface. Equations 5-51 and 5-52 are Rankine equations for sand. Equations 5-53 and 5-54 are the addition of the cohesion for clay or cohesive soils. Three basic conditions are required for validity of the equations:

1. The soil material is homogenous.
2. Sufficient movement has occurred so shear strength on failure surface is completely mobilized.
3. Resisting element is vertical; resultant forces are horizontal.

$K_0 = 1 - \sin \phi'$ Equation 5-48

$K_a = \tan^2 (45 - \phi'/2)$ Equation 5-49

$K_p = \tan^2 (45 + \phi'/2)$ Equation 5-50

For granular soil (sand):

$$P_a = \frac{1}{2}K_a\rho H^2 \quad \text{Equation 5-51}$$

$$P_p = \frac{1}{2}K_p\phi\rho H^2 \quad \text{Equation 5-52}$$

For cohesive soil (clay):

$$P_a = \frac{1}{2}K_a\rho H^2 - 2cH + 2c^2/\phi'\rho \quad \text{Equation 5-53}$$

$$P_p = \frac{1}{2}K_p\rho H^2 + 2cH \quad \text{Equation 5-54}$$

where: K_0 = Coefficient of earth pressure at rest
 K_a = Coefficient of active earth pressure
 K_p = Coefficient of passive earth pressure
 H = Height of wall or resisting element
 c = Cohesion
 ϕ' = Effective stress friction angle of soil
 P_a = Active earth pressure
 ρ = Unit weight of soil

Equations 5-48 through 5-54 are from NAVFAC Design Manual DM7, Foundations and Earth Structures (see References at the end of this section).

Table 5-15 is a tabulation of the coefficient for at rest, active, and passive earth pressure for various soil types, relative densities and consistencies.

Table 5-15 Coefficients of Earth Pressure (Das, 1987)

Soil	K_0 , Drained	K_0 , Total	K_a , Total	K_p , Total
Clay, soft *	0.6	1	1	1
Clay, hard *	0.5	0.8	1	1
Sand, loose	0.6	0.53	0.2	3
Sand, dense	0.4	0.35	0.3	4.6
* Assume saturated clays				

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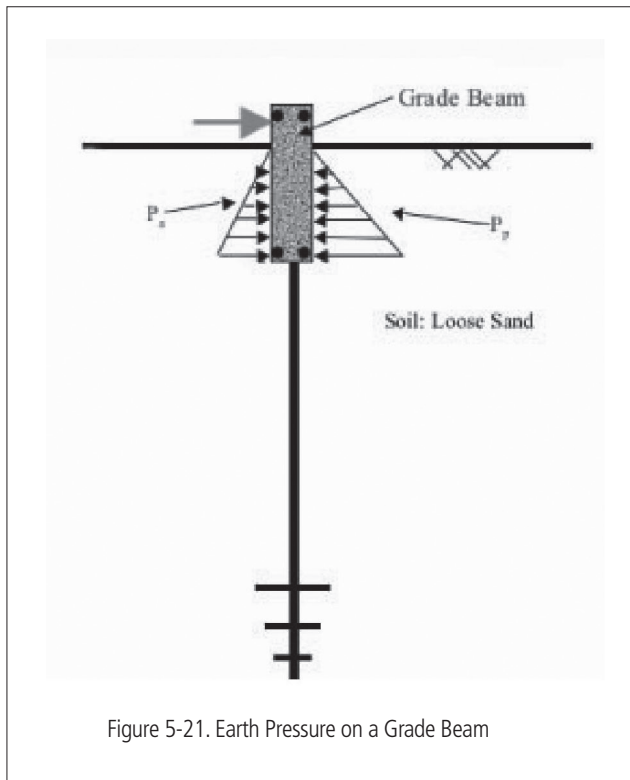


Figure 5-21. Earth Pressure on a Grade Beam

Using the Rankine solution may be an over-simplification of the problem but tends to be conservative since the height of the projected area of the footing or pile cap is not large and the cohesion term will generally be small. Design Example 8-15 in Section 8 illustrates the use of the Passive Resistance method to determine the lateral capacity of a foundation.

Battered CHANCE® Helical Piles/Anchors for Lateral Loading

Lateral loads are commonly resolved with battered helical piles and anchors. The method is to statically resolve the axial load capacity into its vertical and horizontal components. As stated earlier, it is best to use vertically installed helical piles and anchors to resist only vertical loads and battered helical piles and anchors to resist only lateral loads.

CHANCE® Helical Piles and Anchors and piles have been supplied to the seismic prone areas of the west coast of the United States and Canada for over 30 years for civil construction projects. In tension applications, they have been in service for over 50 years. They have been subjected to many earthquakes and aftershocks with good experience. Our helical pre-engineered products have been used far more extensively than any other manufacturer's

helical product in these areas. To date, there have been no ill effects observed using battered helical piles and anchors in seismic areas. These foundations, both vertically installed and battered, have been subjected to several earthquakes of magnitude 7+ on the Richter scale with no adverse affects. Anecdotal evidence indicates the structures on helical piles experienced less earthquake-induced distress than their adjacent structures on other types of foundations. Their performances were documented anecdotally in technical literature, including the *Engineering News Record*.

Additional Comments

The lateral capacity of round shaft (Type RS) helical piles and anchors is greater than the square shaft (Type SS) helical anchors and piles because of the larger section size. Typical pipe diameters of 2-7/8" (73mm), 3-1/2" (89 mm) and 4-1/2" (114 mm) OD are used for CHANCE® Helical Piles. As shown in Design Example 8-13 in Section 8, enlarged shaft sections are used for certain applications. From a practical standpoint, the largest diameter helical pile available from Hubbell Power Systems, Inc. is 10-3/4" diameter, but larger shaft diameters are available on a project specific basis.

As previously noted, there are several other methods used to analyze the lateral capacity of the shaft of piles. Murthy (2003) also presented a direct method for evaluating the lateral behavior of battered (inclined) piles.

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5.8 BUCKLING/BRACING/SLENDERNESS CONSIDERATIONS

Introduction

Buckling of slender foundation elements is a common concern among designers and structural engineers. The literature shows that several researchers have addressed buckling of piles and micropiles over the years (Bjerrum 1957, Davisson 1963, Mascardi 1970, and Gouvenot 1975). Their results generally support the conclusion that buckling is likely to occur only in soils with very poor strength properties such as peat, very loose sands, and soft clay.

However, it cannot be inferred that buckling of a helical pile will never occur. Buckling of helical piles in soil is a complex problem best analyzed using numerical methods on a computer. It involves parameters such as the shaft section and elastic properties, coupling strength and stiffness, soil strength and stiffness, and the eccentricity of the applied load. This section presents a description of the procedures available to evaluate buckling of helical piles, and recommendations that aid the systematic performance of buckling analysis. Buckling of helical piles under compression loads, especially square shaft helical piles, may be important in three situations:

1. When a pile is relatively long (>20 feet [6 m]) and is installed through very soft clay into a very hard underlying layer and is end-bearing.
2. When a pile is installed in loose, saturated clean sand that undergoes liquefaction during an earthquake event.
3. When a pile is subject to excessive eccentric load without adequate bracing.

Bracing

Bracing of pile foundation elements is a common concern among designers and structural engineers, especially for helical piles and resistance piers with slender shafts. Section 1810.2.2 of the 2009 & 2012 International Building Code requires deep foundations to be braced to provide lateral stability in all directions. Bracing can be provided many different ways – including pile groups of three or more, alternate lines of piles spaced apart, and using slabs, footings, grade beams and other foundation elements to provide lateral stability. When CHANCE® Helical Piles and ATLAS RESISTANCE® Piers are used for foundation repair, the piers must be braced as per situation 3 above. The following figures show two methods that are often used to ensure adequate bracing is used.

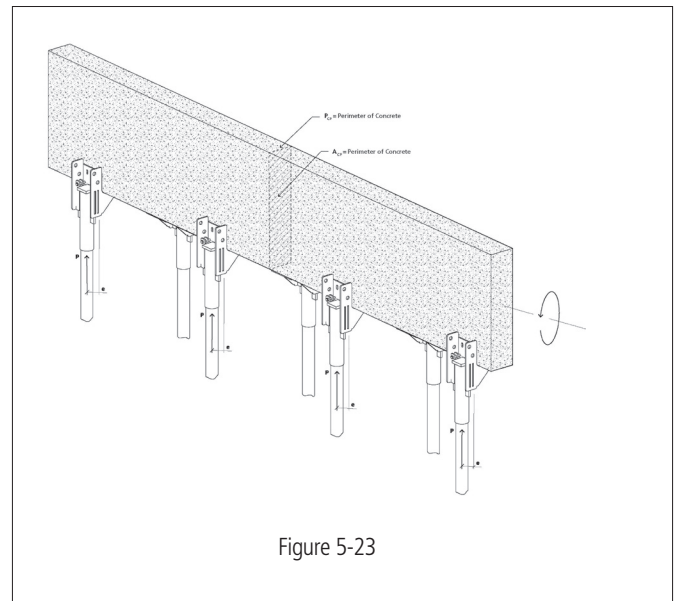
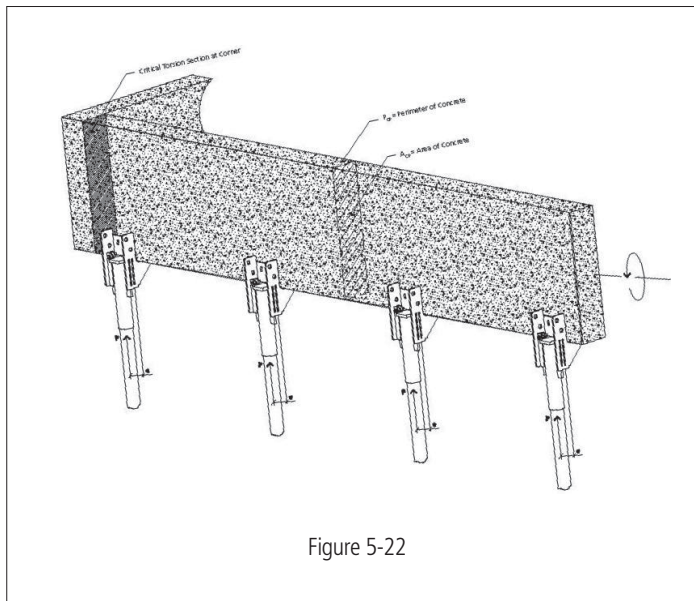


Figure 5-22 on the left is a portion of a grade beam foundation underpinned with ATLAS RESISTANCE® Piers. The grade beam provides torsional stiffness based on its section properties and steel reinforcement. The 90° foundation element on the left end also provides torsional and shear stiffness. Figure 5-23 on the right is a portion of a long continuous grade beam foundation underpinned with ATLAS RESISTANCE® Piers. The piers are staggered and alternated both on the inside and outside, which provides bracing.

Buckling Background

Buckling of columns most often refers to the allowable compression load for a given unsupported length. The mathematician Leonhard Euler solved the question of critical compression load in the 18th century with a basic equation included in most strength of materials textbooks.

	P_{crit}		$\pi^2 EI / (KL_u)^2$	Equation 5-55
	E	=	Modulus of elasticity	
where	I	=	Moment of inertia	
	K	=	End condition parameter that depends on fixity	
	L_u	=	Unsupported length	

Most helical piles have slender shafts which can lead to very high slenderness ratios (Kl/r), depending on the length of the foundation shaft. This condition would be a concern if the helical piles were in air or water and subjected to a compressive load. For this case, the critical buckling load could be estimated using the well-known Euler equation above.

However, helical piles are not supported by air or water, but by soil. This is the reason helical piles can be loaded in compression well beyond the critical buckling loads predicted by Equation 5-55. As a practical guideline, soil with N_{60} SPT blow counts per ASTM D-1586 greater than 4 along the entire embedded length of the helical pile shaft has been found to provide adequate support to resist buckling - provided there are no horizontal (shear) loads or bending moments applied to the top of the foundation. Only the very weak soils are of practical concern. For soils with N_{60} values of 4 blows/ft or less, buckling calculations can be done by hand using the Davison Method (1963) or by computer solution using the finite-difference technique as implemented in the LPILE^{PLUS} computer program (ENSOFT, Austin, TX). In addition, the engineers at Hubbell Power Systems, Inc. have developed a macro-based computer solution using the finite-element technique with the ANSYS® analysis software. If required, application engineers can provide project specific buckling calculations - given sufficient data relating to the applied loads and the soil profile. If you need engineering assistance, please contact your CHANCE® Distributor in your area. Contact information for CHANCE® Distributors can be found at www.abchance.com. These professionals will help you to collect the data required to perform a buckling analysis. The distributor will either send this data to Hubbell Power Systems, Inc. for a buckling analysis or provide this service themselves.

Buckling/Lateral Stability per International Building Code (IBC) Requirements

IBC 2009 Section 1810.2.1 - Lateral Support states that any soil other than fluid soil shall be deemed to afford sufficient lateral support to prevent buckling of deep foundation elements in accordance with accepted engineering practice and the applicable provisions of this code. Per IBC 2006 Section 1808.2.9.2 & IBC 2009 Section 1810.2.1, pier/piles driven into firm ground can be considered fixed and laterally supported at 5 feet below the ground surface and in soft material at 10 feet below the ground surface. The IBC does not specifically define fluid, soft, and firm soil. To remedy this, ICC-ES Acceptance Criteria AC358 defined these soil terms as follows:

Firm soils are defined as any soil with a Standard Penetration Test blow count of five or greater.

Soft soils are defined as any soil with a Standard Penetration Test blow count greater than zero and less than five.

Fluid soils are defined as any soil with a Standard Penetration Test blow count of zero [weight of hammer (WOH) or weight of rods (WOR)].

Therefore, one method to check the effects of buckling and lateral stability of helical piles and resistance piers is to assume the depth to fixity is either 5 feet in firm soil, or 10 feet in soft soil. The corresponding axial compression capacity of the pile shaft is determined based on either 5 feet or 10 feet of unsupported length. This is the method used to determine the nominal, LRFD design, and ASD allowable compression strengths of the helical pile product families provided in Section 7 of this manual.

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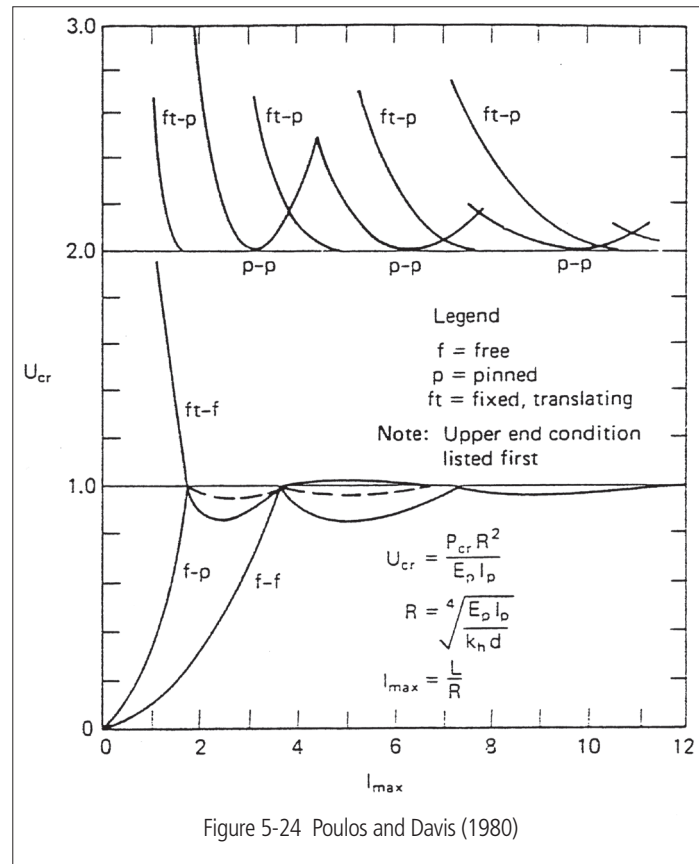


Figure 5-24 Poulos and Davis (1980)

Buckling Analysis by Davisson (1963) Method

A number of solutions have been developed for various combinations of pile head and tip boundary conditions and for the cases of constant modulus of sub grade reaction (k_h) with depth. One of these solutions is the Davisson (1963) Method as described below. Solutions for various boundary conditions are presented by Davisson in Figure 5-24. The axial load is assumed to be constant in the pile – that is no load transfer due to skin friction occurs and the pile initially is perfectly straight. The solutions shown in Figure 5-24 are in dimensionless form, as a plot of U_{cr} versus l_{max} .

where $U_{cr} = P_{cr}R^2/E_pI_p$ or $P_{cr} = U_{cr}E_pI_p/R^2$ Equation 5-56

where $R = \sqrt[4]{E_pI_p/k_h d}$ Equation 5-57

where $l_{max} = L/R$ Equation 5-58

- P_{cr} = Critical buckling load
- E_p = Modulus of elasticity of foundation shaft

- I_p = Moment of inertia of foundation shaft
- K_h = Modulus of sub grade reaction
- d = Foundation shaft diameter
- L = Foundation shaft length over which k_h is taken as constant
- U_{cr} = Dimensionless ratio

By assuming a constant modulus of sub grade reaction (k_h) for a given soil profile to determine R , and using Figure 5-24 to determine U_{cr} , Equation 5-56 can be solved for the critical buckling load. Typical values for k_h are shown in Table 5-16.

Table 5-16. Modulus of Sub Grade Reaction - Typical Values

Soil Description	Modulus of Subgrade Reaction (K_h) (pci)
Very soft clay	15 - 20
Soft clay	30 - 75
Loose sand	20

Figure 5-24 shows that the boundary conditions at the pile head and tip exert a controlling influence on U_{cr} , with the lowest buckling loads occurring for piles with free (unrestrained) ends. Design Example 8-16 in Section 8 illustrates the use of the Davisson (1968) method to determine the critical buckling load.

Another way to determine the buckling load of a helical pile in soil is to model it based on the classical Winkler (mathematician, circa 1867) concept of a beam-column on an elastic foundation. The finite difference technique can then be used to solve the governing differential equation for successively greater loads until, at or near the buckling load, failure to converge to a solution occurs. The derivation for the differential equation for the beam-column on an elastic foundation was given by Hetenyi (1946). The assumption is made that a shaft on an elastic foundation is subjected not only to lateral loading, but also to compressive force acting at the center of the gravity of the end cross-sections of the shaft, leading to the differential equation:

$$EI(d^4y/dx^4) + Q(d^2y/dx^2) + E_s y = 0$$

- y = Lateral deflection of the shaft at a point x along the length of the shaft
 - x = Distance along the axis, i.e., along the shaft
- where
- E = Flexural rigidity of the foundation shaft
 - Q = Axial compressive load on the helical pile
 - $E_s y$ = Soil reaction per unit length
 - E_s = Secant modulus of the soil response curve

The first term of the equation corresponds to the equation for beams subject to transverse loading. The second term represents the effect of the axial compressive load. The third term represents the effect of the reaction from the soil. For soil properties varying with depth, it is convenient to solve this equation using numerical procedures such as the finite element or finite difference methods. Reese, et al. (1997) outlines the process to solve Equation 5-59 using a finite difference approach. Several computer programs are commercially available that are applicable to piles subject to axial and lateral loads as well as bending moments. Such programs allow the introduction of soil and foundation shaft properties that vary with depth, and can be used advantageously for design of helical piles and micropiles subject to centered or eccentric loads.

To define the critical load for a particular structure using the finite difference technique, it is necessary to analyze the structure under successively increasing loads. This is necessary because the solution algorithm becomes unstable at loads above the critical. This instability may be seen as a convergence to a physically illogical configuration or failure to converge to any solution. Since physically illogical configurations are not always easily recognized, it is best to build up a context of correct solutions at low loads with which any new solution can be compared. Design

Example 8-17 in Section 8 illustrates the use of the Finite Difference method to determine the critical buckling load.

Buckling Analysis by Finite Elements

Hubbell Power Systems, Inc. has developed a design tool, integrated with ANSYS® finite element software, to determine the load response and buckling of helical piles. The method uses a limited non-linear model of the soil to simulate soil resistance response without increasing the solution time inherent in a full nonlinear model. The model is still more sophisticated than a simple elastic foundation model, and allows for different soil layers and types.

The helical pile components are modeled as 3D beam elements assumed to have elastic response. Couplings are modeled from actual test data, which includes an initial zero stiffness, elastic/rotation stiffness and a final failed condition – which includes some residual stiffness. Macros are used to create soil property data sets, helical pile component libraries, and load options with end conditions at the pile head.

After the helical pile has been configured and the soil and load conditions specified, the macros increment the load, solve for the current load and update the lateral resistance based on the lateral deflection. After each solution, the ANSYS® post-processor extracts the lateral deflection and recalculates the lateral stiffness of the soil for each element. The macro then restarts the analysis for the next load increment. This incremental process continues until buckling occurs. Various outputs such as deflection and bending moment plots can be generated from the results. Design Example 8-18 in Section 8 illustrates the use of the Finite Element method to determine the critical buckling load.

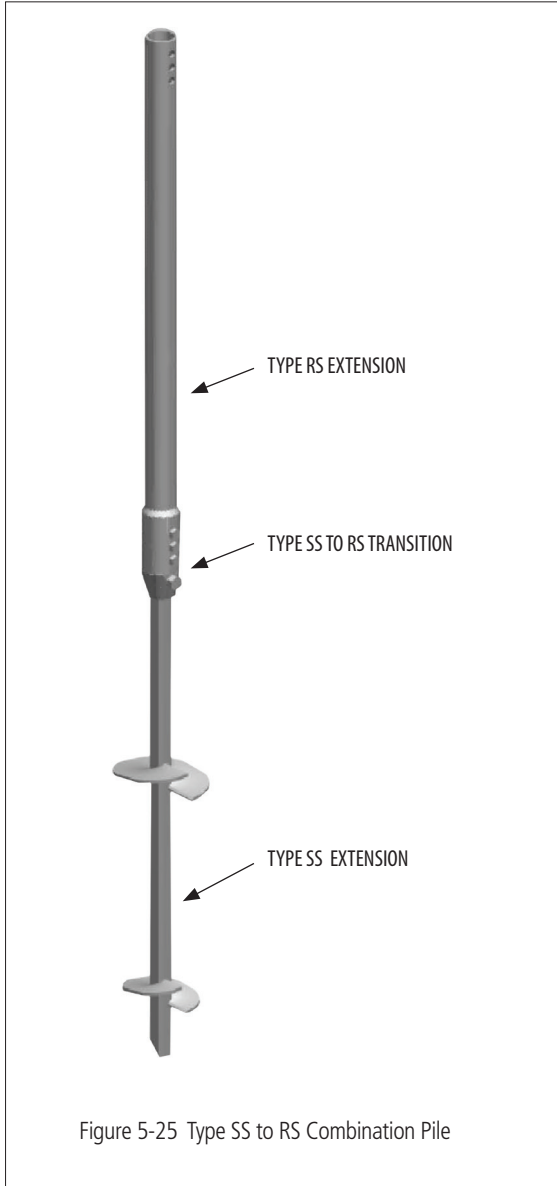
Practical Considerations – Buckling

As stated previously, where soft and/or loose soils (SPT N_{60} blow count ≤ 4) overlie the bearing stratum, the possibility of shaft buckling must be considered. Buckling also becomes a potential limiting factor where lateral loads (bending and shear) are present in combination with compressive loads. Factors that determine the buckling load include the helical pile shaft diameter, length, flexural stiffness and strength, the soil stiffness and strength, any lateral shear and/or moment applied at the pile head, and pile head fixity conditions (fixed, pinned, free, etc.). In addition, all extendable helical piles have couplings or joints used to connect succeeding sections together in order to install the helix plates into bearing soil. Bolted couplings or joints have a certain amount of rotational tolerance. This means the joint initially has no stiffness until it has rotated enough to act as a rigid element. This is analogous to saying the coupling or joint acts as a pin connection until it has rotated a specific amount, after which it acts as a rigid

element with some flexural stiffness.

Concern about slender shafts and joint stiffness, along with the fact that helical piles are routinely installed in soils with poor strength; are some of the reasons why helical piles are often installed with grouted shafts (helical pulldown piles) and are available with larger diameter pipe shafts (Type RS). Pipe shaft helical piles have better

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buckling resistance than plain square shaft (Type SS) because they have greater section modulus (flexural resistance), plus they have larger lateral dimensions, which means they have greater resistance to lateral deflection in soil. See the specifications section of the helical pile product family pages in Section 7 for the section properties and dimensions of both Type SS and RS helical piles/anchors.

Type SS helical piles/anchors provide the most efficient capacity-to-torque relationship (see Section 6, Installation Methodology). Type RS helical piles/anchors provide lateral capacity and better buckling resistance. A good compromise to address buckling in soft/loose soils is to use helical combination piles, or “combo piles” for short. A combo pile consists of Type SS square shaft material for the lead section and Type RS pipe shaft material for the extension sections (see Figure 5-25). The combo pile provides the advantages of both Type SS and RS material, which enables the helical pile/anchor to penetrate dense/hard soils, while at the same time provide a larger shaft section in the soft/loose soils above the bearing strata. See Section 7 for more information on combo piles.

The HELICAL PULLDOWN[®] Micropile is a method for constructing a grout column around the shaft of either a Type SS (square shaft) or RS (round shaft) helical pile installed in soft/loose soil. The installation process displaces soil around the central steel shaft and replaces it with a gravity fed, neat cement grout mixture. Upon curing, the grout forms a column that increases the section modulus of the pile shaft to the point that buckling is not the limiting condition. In addition to buckling resistance, the grout column increases axial load capacity due to skin friction or adhesion along the shaft; plus the load/deflection response of the helical pile is stiffer. See Section 7 for more information on CHANCE HELICAL PULLDOWN[®] Micropiles.

CHANCE HELICAL PULLDOWN[®] Micropiles cannot be installed in every soil condition. To date, grouted shaft helical piles have been successfully installed in overburden soil with SPT blow counts greater than 10 blows/ft. In those cases, the grouted shaft is being used to develop greater load capacity and a stiffer response, not necessarily to prevent buckling. Contractors have successfully installed pulldown micropiles in glacial tills (SPT $N_{60} > 50$) using special soil displacement methods. Increasingly dense soil makes installation more difficult for the displacement element, which has to force soil laterally outward away from the central steel shaft.

5.9 HELICAL PILE DEFLECTION AT WORKING LOAD

Most of the discussion thus far has focused on evaluating the ultimate load capacity of helical piles/anchors in axial compression or tension. This is considered as the Load Limit State and gives the upper bound on the load capacity. The displacements of the pile/anchor at this load state will be very large (> 2 inches [51 mm]) and technically the pile/anchor cannot sustain additional load but the deflection just keeps increasing. However, it is also of great interest to most engineers to consider the behavior of a helical pile/anchor at a lower working load or Serviceability State which will be well below the Load Limit State.

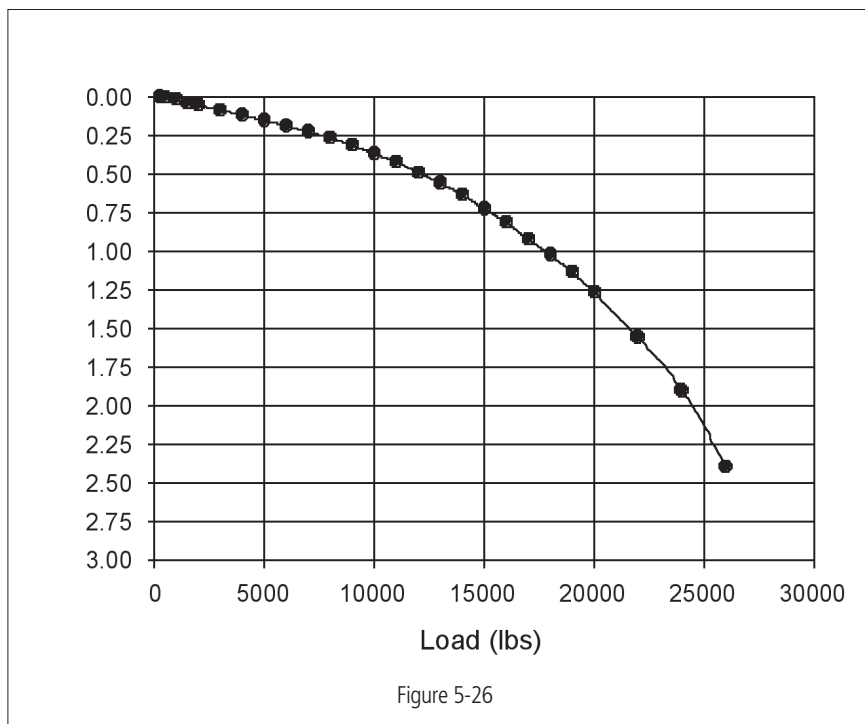


Figure 5-26

the pile/anchor cannot sustain additional load but the deflection just keeps increasing. However, it is also of great interest to most engineers to consider the behavior of a helical pile/anchor at a lower working load or Serviceability State which will be well below the Load Limit State.

We can consider a typical Load-Displacement curve as shown above. This plot is the test results of a 1.5 in. x 1.5 in. square-shaft helical anchor with a single 12 in. helix installed to a depth of 10 ft. in a medium dense silty sand. The test was performed in tension. According to the IBC, the Ultimate Capacity may be taken as the load producing a net displacement of 10% of the helix diameter or in this case the load at 1.20 in. which is 19,500 lbs. It is obvious that in this

case, as in most cases, the anchor can actually take more load, up to as much as 20% of the helix diameter.

Using a ASD Factor of Safety of 2.0, the working load for this anchors would be equal to 19,500 lbs/2.0 = 9,750 lbs. Because the load-displacement curve of most helical piles/anchors is generally nonlinear it would be expected that the displacement at the working load would be less than ½ of the displacement at 1.20 in. In this case, the displacement at the working load of 9,750 lbs is on the order of 0.36 in. Using a lower Factor of Safety gives a higher displacement. For example if a Factor of Safety of 1.5 is used, the working load becomes 19,500 lbs/1.5 = 13,000 lbs and the displacement corresponding to this load is on the order of 0.55 in.

Based on a review of a number of tests performed on single-helix pile/anchors in Colorado, Cherry and Perko (2012) recently suggested that for many anchors/piles, the displacement at the working loads (F.S. = 2) averaged about 0.25 in. Additional work is needed to determine how this may vary for multi-helix piles/anchors and if other soils show different behavior.

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INSTALLATION METHODOLOGY



INSTALLATION METHODOLOGY SECTION 6

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SYMBOLS USED IN THIS SECTION

DL	Dead Load	6-4
LL	Live Load	6-4
FS	Factor of Safety	6-4
SPT	Standard Penetration Test	6-5
N	SPT Blow Count	6-5
N_q	Bearing Capacity Factor	6-5
GWT	Ground Water Table	6-5
PL	Proof Load	6-6
Q_{ult}	Ultimate Uplift Capacity	6-8
K_t	Empirical Torque Factor	6-8
T	Average Installation Torque	6-8
SS	Square Shaft	6-8
RS	Round Shaft	6-8
H_d/S_d	Helix to Shaft Diameter Ratio	6-10
Q_{act}	Actual Capacity	6-12
Q_{calc}	Calculated Capacity	6-12
Q_{act}/Q_{calc}	Capacity Ratio	6-12
CID	Cubic Inch Displacement	6-16

INSTALLATION METHODOLOGY

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

Hubbell Power Systems, Inc., shall not be responsible for, or liable to you and/or your customers for the adoption, revision, implementation, use or misuse of this information. Hubbell, Inc., takes great pride and has every confidence in its network of installing contractors and dealers.

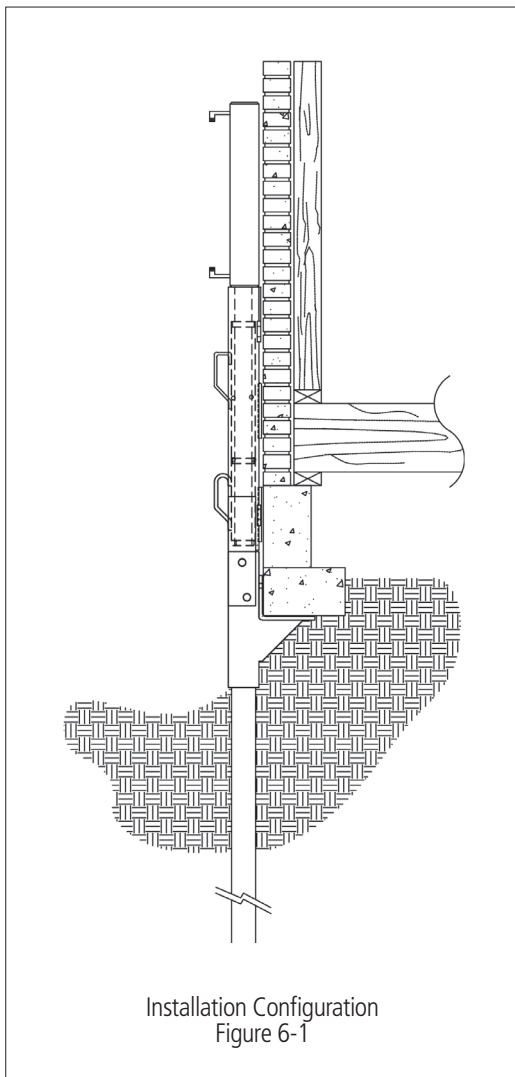
Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

ATLAS RESISTANCE® PIERS

ATLAS RESISTANCE® Piers develop their capacity as a result of a pile tip or end bearing reaction in soil or rock that is achieved by hydraulically driving hollow pier sections to suitable strata utilizing the reaction weight of an existing structure or any other mass or reaction assembly capable of resisting pushing loads in excess of design loads required. The friction reduction collar on the initial or starter section allows for an end bearing pile. Most ATLAS RESISTANCE® Piers are installed to a force equal to a minimum of 150% of the calculated total load at each pier placement. The total load condition is a sum of the structure Dead Loads (DL) and all known potential Live Loads (LL). In addition to the usual calculated loads, it is extremely important to include loads imposed from soil overburden over a projected area, primarily outside of the foundation wall footprint (toe or heel) of the footing. The area of the projection plus the height of soils above it produce a loading condition that is quite often in excess of the structure load itself. When lifting the structure is desired, an additional “soil wedge” area and/or volume should be considered relative to the soil type and its particular characteristics. To be conservative in design calculations it is prudent to consider the long term loading effect from soils outside of the vertical and horizontal plane of the soil overburden even when stabilization only is desired.

LOAD VERIFICATION

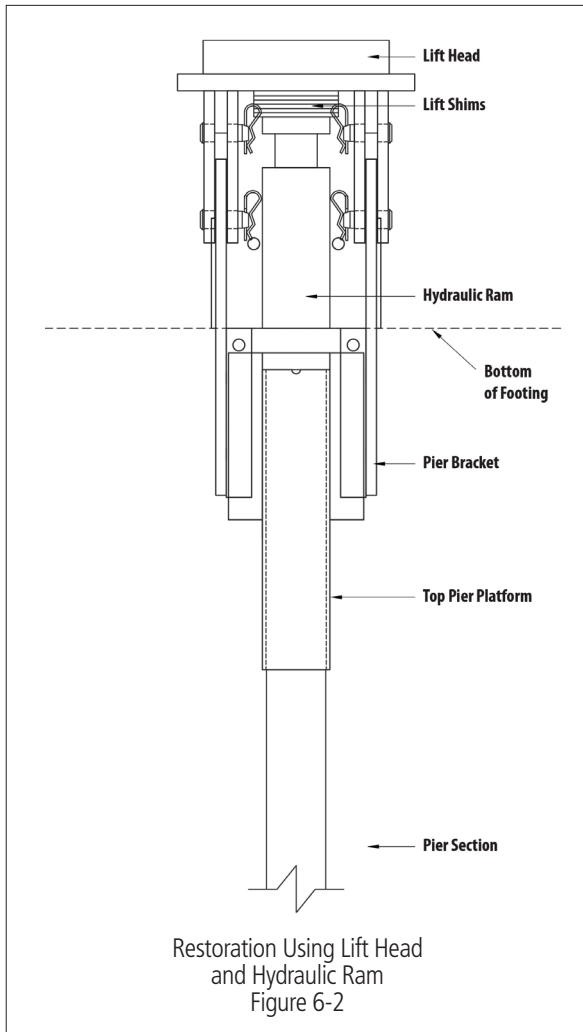
ATLAS RESISTANCE® Piers are installed using hydraulic cylinders with known effective areas. Although larger cylinders are available for extreme load conditions, the standard installation cylinders have an effective area of 8.29 in². The effective area of the cylinder is multiplied by the hydraulic pressure monitored by a gauge mounted between the hydraulic pump and the cylinder. The net result of this number is the actual force (in lbs) achieved as the pier sections are driven against the reaction weight of the structure until the required load is achieved or structure lift occurs. Additional pier sections are added as necessary until a competent bearing stratum is reached. The force is logged at the end of each pier section driven on the field installation log.



TWO STAGE SYSTEM METHODOLOGY

The installation of ATLAS RESISTANCE® Piers incorporates a two stage method that consists of driving each pier individually using the reaction from adjacent line loads. The integrity of the foundation determines the extent to which additional Factors of Safety (FS) can be achieved between the installation force and final lift loads. Figure 6-1 provides a schematic drawing that illustrates the installation of pier sections. The second stage occurs when all or the majority of the piers are loaded simultaneously using a manifold or series of manifolds and hydraulic rams placed at each pier. The manifolds and rams are connected to a pump or series of pumps depending on the number of piers being lifted. During the lifting stage the hydraulic pressure is monitored on each manifold system gauge. Typical 25 ton lifting rams have an effective area of 5.15 in². The load at each pier is monitored at the final lock off and noted on the field installation logs. The actual lift or lock off load at each pier can then be compared to the installation loads at each pier to determine the actual Factor of Safety developed between installation loads and actual loads required to produce structural lift and support. Figure 6-2 provides a schematic drawing illustrating the lift stage.

INSTALLATION METHODOLOGY

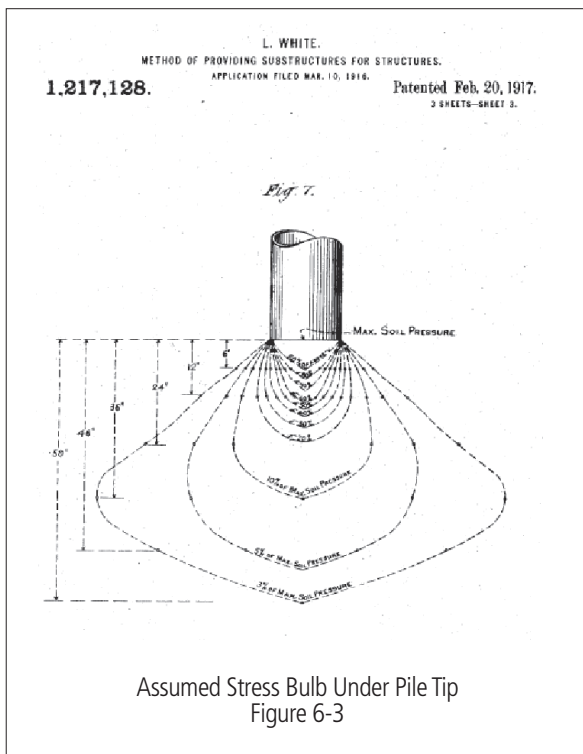


BEARING CAPACITY

The compressive bearing capacity of ATLAS RESISTANCE® Piers is developed predominantly by end-bearing due to the friction reduction collar at the lead end of the initial or starter section. Friction calculations do not normally enter into design steps unless required to comply with some older municipal codes. Increased tip areas (larger diameter pipe) will typically increase load resistance during installation of the pile. Standard pier section diameters are 2-7/8", 3-1/2", and 4-1/2". The selection of pier size is determined through consideration of pile load requirement, column stability (buckling concerns) structure integrity and the ability to drive the pile past seasonal zones of influence relative to available reaction forces. Bracket assemblies are coupled with the appropriate pier section size to service both the geotechnical and structural requirements.

CLAY SOILS

In clay soil conditions defined as very stiff to hard, i.e., Standard Penetration Test (SPT) "N" values in excess of 35-40 blows/foot, it has been shown empirically that an ATLAS RESISTANCE® Pier can generate substantial end-bearing capacity, often in excess of 50,000-60,000 lbs of bearing resistance. While the high capacities defy absolute calculation for both very dense sand and hard clay, empirical data developed over the last several decades gives evidence to this phenomenon. Data developed by A.S. Vesic (1972) for the Transportation Research Board suggests that hard/dense soil develops very high capacities due to the formation of a larger pile bulb at the base of an end-bearing foundation. This phenomenon results in higher values for the bearing capacity factor (Nq), especially for driven piles. Figure 6-3 is an excerpt from Patent 1.217.128 issued to L. White. It is a graphical rendition of the assumed large stress bulb formed under a pile tip.



SAND SOILS

ATLAS RESISTANCE® Piers also develop substantial end-bearing capacities in granular soils, but the sand or gravel must typically exhibit a high relative density with "N" values in excess of 30-35 blows/ft. The same pile bulb described above for clay soils will form at the base of an ATLAS RESISTANCE® Pier in sand soils. In granular soils, the overburden pressure (effective vertical confining stress) has a large influence on bearing capacity, so the deeper the pier tip is embedded, the higher the bearing capacity will be for a given sand deposit of uniform density. A design condition consisting of a shallow ground water table (GWT) will require ATLAS RESISTANCE® Piers to be installed to a sufficient depth to counteract the reduction in confining stress caused by the buoyancy effect of the water.

INSTALLATION METHODOLOGY



BEDROCK BEARING SURFACE

The presence of an intact bedrock surface represents an ideal ground condition for a totally end-bearing load transfer for any type of foundation. In this case the ATLAS RESISTANCE® Pier is installed to the rigid bearing surface represented by the bedrock layer, with load confirmation being verified by monitoring of the hydraulic pressure and effective area of the installation cylinder. The design capacity in this case is directly related to the structural strength of the pier shaft and bracket assembly.

INSTALLATION OVERVIEW

When the loading, structural and geotechnical conditions have been determined, the proper pier brackets and pier sections can be selected. Following excavation for the installation, the footing (if present) is notched to a point flush with the wall to be underpinned. Should steel reinforcement be encountered, notify the Engineer of Record prior to cutting. This procedure is performed to minimize the eccentricity of the pier assembly. In situations where notching the footing is prohibited, consideration needs to be given to the published pier capacity ratings if the footing extension from the wall is excessive, possibly increasing the eccentric load on the pier assembly resulting in a lower capacity. The bottom of the footing should be prepped and/or a load bearing grout added between the pier bracket and footing to provide a uniform bearing connection. This is a critical point, especially in high load conditions. Failure to comply with this step could result in a point load on the bracket and cause an early bracket failure.

When the bracket and installation equipment are properly positioned and anchored to the foundation or wall, the starter section can be placed in a vertical and plumb position. Activate the hydraulic pump to advance and retract the installation cylinder as necessary to drive the pier sections (see photo at top right). The pressure is recorded at the end of each 42" pier section. Continue driving pier sections until reaching strata capable of resisting the estimated Proof Load (PL) or until structure lift occurs. When approaching the end of the drive, a good rule of thumb is to drive pipe until either the structure begins to lift and/or the pressure continues to build. If a small amount of movement has occurred but the pressure remains constant, an experienced installer will continue to drive pipe until either a more significant movement is noted or a consistent build in pressure occurs. Depending on the integrity of the foundation and the comfort level of the installer, this will often result in substantial Factors of Safety in excess of 1.5. When driving the pier pipe is completed, the installation equipment is removed, pier sections are cut off to an appropriate elevation relative to the bracket type and load transfer components are set in place.

When all piers have been installed, the manifolds and hydraulics are loaded uniformly as much as possible (see photo at bottom right). Upon transfer of load to the entire pier assembly, lift pressures are noted at each pier and recorded on the field log. The actual verified Factor of Safety between installation pre-load and final lock off can then be confirmed. Table 6-1 is an example of the driving (installation) and lift forces that could be involved in the installation of ATLAS RESISTANCE® Piers.



Installation Load vs Lift Load, Table 6-1

FIRST STAGE			DRIVE	LIFT	SECOND STAGE			F/S DRIVE vs LIFT
INSTALLATION LOAD SUMMARY	STD. DRIVE CYLINDER EFFECTIVE AREA (SQ. IN)				PIER LIFT/LOCK SUMMARY	STD LIFT RAM EFFECTIVE AREA (SQ. IN)		
	8.29		←	→		5.15		
PIER NUMBER	PSI	LOAD			PIER NUMBER	PSI	LOAD	
1	4,200	34,818			1	4,000	20,600	1.7
2	4,600	38,134			2	4,000	20,600	1.9
3	4,600	38,134			3	4,500	23,175	1.6
4	4,800	39,792	←	→	4	4,500	23,175	1.7
5	5,000	41,450			5	4,800	24,720	1.7

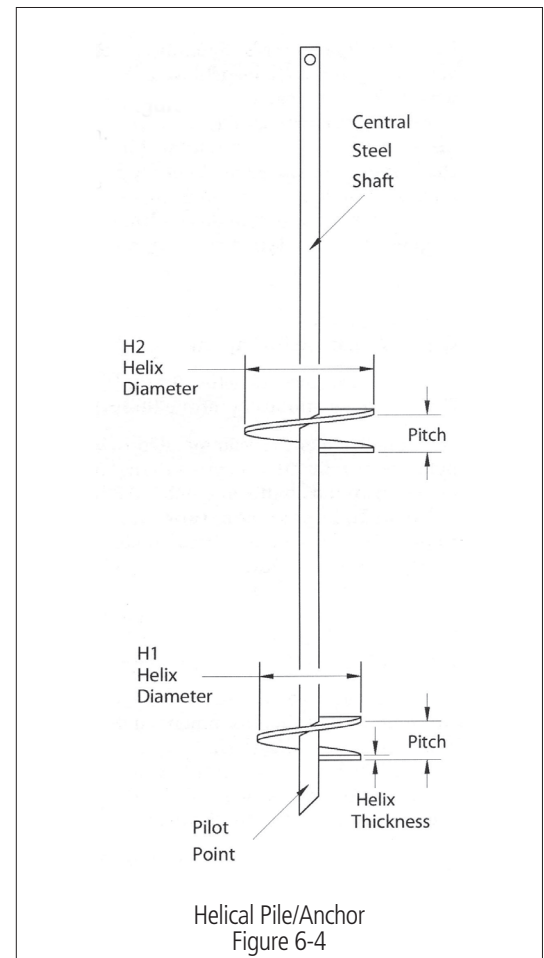
Refer to the *ATLAS RESISTANCE® Standard, Heavy Duty and Modified 2-Piece Pier Systems Model Specification* found under the Resources tab on www.abchance.com for detailed installation instructions.

CHANCE® HELICAL PILE/ANCHORS

By definition, a helical pile/anchor is a low soil displacement foundation element specifically designed to minimize disturbance during installation. In their simplest forms, helical pile/anchors consist of at least one helix plate and a central steel shaft (see Figure 6-4). The helix geometry is very important in that it provides the downward force or thrust that pulls a helical pile/anchor into the ground. The helix must be a true ramped spiral with a uniform pitch to maximize efficiency during installation. If the helix is not formed properly, it will disturb the soil more than if a true helix advances at a rate of one pitch per revolution. The central steel shaft transmits the rotational energy or torque from the machine to the helix plate(s). Most helical piles in North America use a low displacement (less than 4.5 inches (114 mm) diameter shaft in order to reduce friction and soil displacement during installation. A helical pile/anchor functions very similar to a wood screw except that it has a discontinuous thread-form and is made to a much larger scale.

INSTALLATION TORQUE/LOAD CAPACITY RELATIONSHIP

Before installation, a helical pile/anchor is simply a screw with a discontinuous thread and a uniform pitch. When installed into soil, a helical pile/anchors functions as an axially loaded end-bearing deep foundation. The helix plates serve a two-fold purpose. The first purpose is to provide the means to install the helical pile/anchor. The second purpose is to provide the bearing element means for load transfer to soil. As such, helical pile/anchor design is keyed to these two purposes, both of which can be used to predict the ultimate capacity.



INSTALLATION METHODOLOGY

Section 5 detailed how helix plates act as bearing elements. The load capacity is determined by multiplying the unit bearing capacity of the soil at each helix location by the projected area of each helix. This capacity is generally defined as the ultimate theoretical load capacity because it is based on soil parameters either directly measured or empirically derived from soil exploration sounding data.

The purpose of this section is to provide a basic understanding of how installation torque (or installation energy) provides a simple, reliable means to predict the load capacity of a helical pile/anchor. More importantly, this prediction method is independent of the bearing capacity method detailed in Section 5, so it can be used as a “field production control” method to verify load capacity during installation.

The installation torque-to-load capacity relationship is an empirical method originally developed by the A. B. Chance Company in the late 1950’s and early 1960’s. Hubbell Power Systems, Inc. has long promoted the concept that the torsion energy required to install a helical anchor/pile can be related to the ultimate load capacity of a pile/anchor. Precise definition of the relationship for all possible variables remains to be achieved. However, simple empirical relationships, originally derived for tension loads but also valid for compression loads, have been used for a number of years. The principle is that as a helical anchor/pile is installed (screwed) into increasingly denser/harder soil, the resistance to installation (called installation energy or torque) will increase. Likewise, the higher the installation torque, the higher the axial capacity of the installed pile/anchor. Hoyt and Clemence (1989) presented a landmark paper on this topic at the 12th International Conference on Soil Mechanics and Foundation Engineering. They proposed the following formula that relates the ultimate capacity of a helical pile/anchor to its installation torque:

$$Q_{ult} = K_t \times T \tag{Equation 6-1}$$

- where
- Q_{ult} = Ultimate uplift capacity [lb (kN)]
 - K_t = Empirical torque factor [ft^{-1} (m^{-1})]
 - T = Average installation torque [lb-ft (kN-m)]

Hoyt and Clemence recommended $K_t = 10 \text{ ft}^{-1}$ (33 m^{-1}) for square shaft (SS) and round shaft (RS) helical anchors less than 3.5” (89 mm) in diameter, 7 ft^{-1} (23 m^{-1}) for 3.5” diameter round shafts, and 3 ft^{-1} (9.8 m^{-1}) for 8-5/8” (219 mm) diameter round shafts. The value of K_t is not a constant - it may range from 3 to 20 ft^{-1} (10 to 66 m^{-1}), depending on soil conditions, shaft size and shape, helix thickness, and application (tension or compression). For CHANCE® Type SS Square Shaft Helical Piles/Anchors, K_t typically ranges from 10 to 13 ft^{-1} (33 to 43 m^{-1}), with 10 ft^{-1} (33 m^{-1}) being the recommended default value. For CHANCE® Type RS Pipe Shaft Helical Piles/Anchors, K_t typically ranges from 3 to 10 ft^{-1} (10 to 33 m^{-1}), with 9 ft^{-1} (30 m^{-1}) being the recommended default for Type RS2875; 7 ft^{-1} (23 m^{-1}) being the recommended default for Type RS3500.300; and 6 ft^{-1} (20 m^{-1}) being the recommended default for Type RS4500.337.

The Canadian Foundation Engineering Manual (2006) recommends values of $K_t = 7 \text{ ft}^{-1}$ for pipe shaft helical piles with 90 mm OD, and $K_t = 3 \text{ ft}^{-1}$ for pipe shaft helical piles approaching 200 mm OD.

The correlation between installation torque (T), and the ultimate load capacity (Q_{ult}) of a helical pile/anchor, is a simple concept but a complicated reality. This is partly because there are a large number of factors that can influence the determination of the empirical torque factor K_t . A number of these factors (not including soil), are summarized in Table 6.2.

It is important to understand that torque correlation is valid when the helical pile/anchor is advancing at a rate of penetration nearly equal to one helix pitch per revolution. Large displacement shafts [$>8\text{-}5/8$ ” (219mm)] are less likely to advance at this rate, which means torque correlation cannot be used as a means to determine capacity.

Factors Influencing K_t , Table 6-2

Factors Affecting Installation Torque (T)	Factors Affecting Ultimate Capacity (Q_{ult})
Method of Measuring Installation Torque (T)	Number and Size of Helix Plates
Installed Depth Used to Determine "Average" Torque	Direction of Loading (Tension or Compression)
Applied Down-Force or "Crowd"	Geometry of Couplings
Rate of Rotation	Spacing of Helix Plates
Alignment of Pile/Anchor	Shape and Size of Shaft
Rate of Advance	Time between Installation and Loading
Geometry of Couplings	
Shape and Size of Shaft	
Shape and Size of Shaft	
Number & Size of Helix Plates	
Pitch of Helix Plates	

The factors listed in Table 6-2 are some of the reasons why Hubbell Power Systems, Inc. has a dealer certification program. Contractors who install helical piles/anchors are trained in the proper methods and techniques before they are certified. In order for Equation 6-1 to be useful, installation torque must be measured. There are a variety of methods used to measure torque. Hubbell Power Systems, Inc. offers two in-line torque indicators; in-line indicators are the best method to determine torque for capacity prediction. Other useful methods to measure torque are presented later in this section. For torque correlation to be valid, the rate of penetration should be between 2.5" to 3" per revolution. The rotation speed should be consistent and in the range of 5 to 15 RPM. And, the minimum effective torsional resistance criterion (the average installation torque) should be taken over the last 3 feet of penetration; unless a single helix pile is used for compression load, where it is appropriate to use the final (last) installation torque.

ICC-ES Acceptance Criteria AC358 for Helical Pile Systems and Devices Section 3.13.2 provides torque correlation (K_t) values for conforming helical pile systems based on shaft size and shape. They are the same as recommended by Hubbell Power Systems, Inc. and by Hoyt and Clemence. Hubbell Power Systems, Inc. helical piles are conforming per AC358. The AC358 K_t values are the same for both tension and compression axial loads.

The International Building Code (IBC) 2009 & 2012 Section 1810.3.3.1.9 states there are three ways to determine the load capacity of helical piles – including well documented correlations with installation torque.

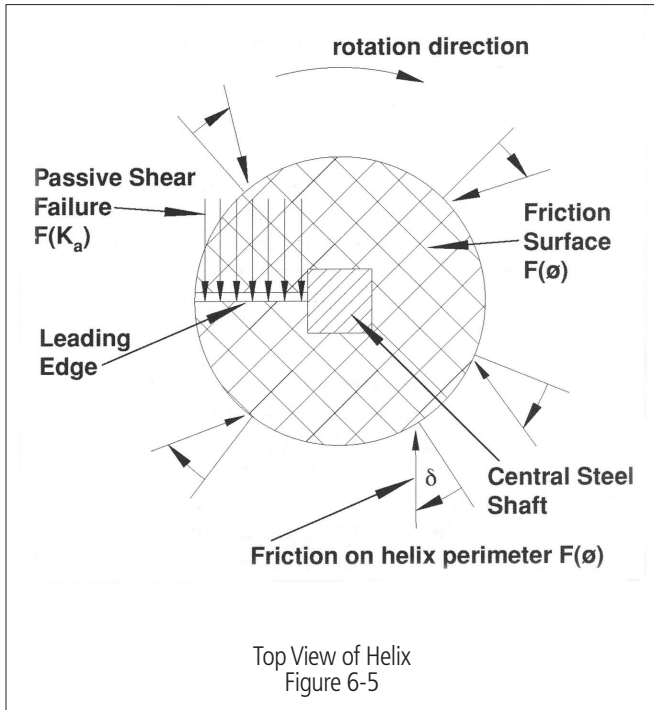
Soil Factors Influencing K_t

Locating helix bearing plates in very soft, loose, or sensitive soils will typically result in K_t values less than the recommended default. This is because some soils, such as salt leached marine clays and lacustrine clays, are very sensitive and lose considerable shear strength when disturbed. It is better to extend the helical pile/anchor beyond sensitive soils into competent bearing strata. If it's not practical to extend the helical pile/anchor beyond sensitive soils, testing is required to determine the appropriate K_t .

Full-scale load testing has shown that helical anchors/piles typically have at least the same capacity in compression as in tension. In practice, compression capacity is generally higher than tension capacity because the pile/anchor bears on soil below rather than above the helix plates, plus at least one helix plate is bearing on undisturbed soil. Soil above the bearing plates is disturbed by the slicing action of the helix, but not overly disturbed by being

“augured” and removed. Typically, the same values of K_t are used for both tension and compression applications. This generally results in conservative results for compression applications. A poorly formed helix shape will disturb soil enough to adversely affect the torque-to-capacity relationship, i.e., K_t is reduced. To prevent this, Hubbell Power Systems, Inc. uses matching metal dies to form helix plates which are as near to a true helical shape as is practically possible. To understand all the factors that K_t is a function of, one must first understand how helical piles/anchors interact with the soil during installation.

INSTALLATION METHODOLOGY



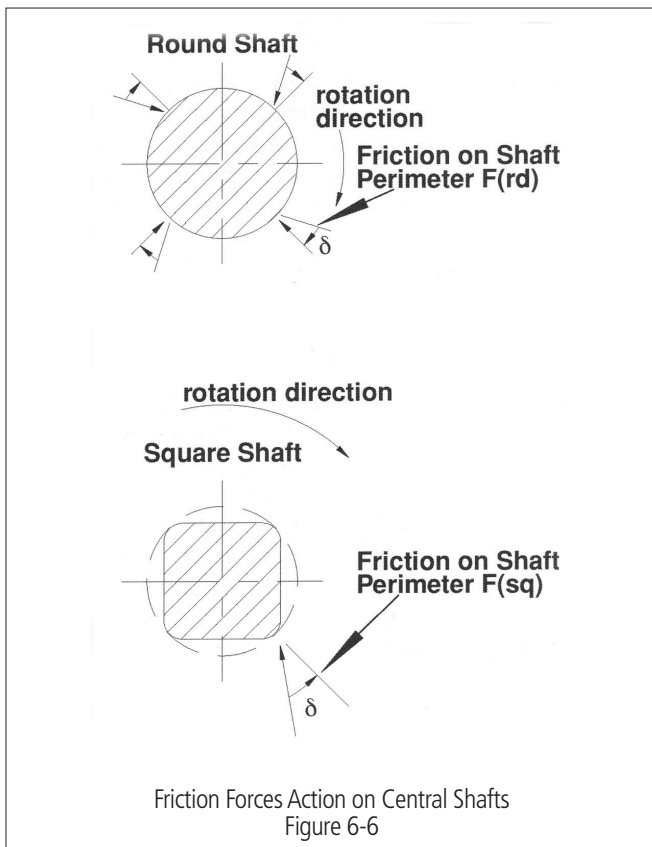
Torque Resistance Factors

There are two main factors that contribute to the torque resistance generated during a pile/anchor installation, friction and penetration resistance. Of the two factors, friction is the larger component of torque resistance.

Friction Has Two Basic Parts:

(1) Friction on the helix plate and friction along the central steel shaft. Friction resistance increases with helix size because the surface area of the helix in contact with the soil increases with the square of the diameter (see Figure 6-5). Likewise, friction resistance increases with pitch size, i.e., the larger the pitch, the greater the resistance. This is analogous to the difference between a coarse thread and a fine thread bolt. Basic physics tells us that “work” is defined as force time’s distance. A larger pitch causes the helix to travel a greater distance per revolution, thus more work is required.

(2) Friction along the central steel shaft is similar to friction on the helix plate. Friction resistance increases with shaft size because the surface area of the shaft in contact with the soil increases as the diameter increases. An important performance factor for helical pile/anchors is the helix to shaft diameter ratio (H_d/S_d). The higher the H_d/S_d ratio, the more efficient a given helical pile/anchor will be during installation. Friction resistance also varies with shaft shape (see Figure 6-6). A round shaft may be the most efficient section to transmit torque energy, but it has the disadvantage of full surface contact with the soil during installation. When the central steel shaft is large ($> 3"$ [76 mm] in diameter) the shaft friction resistance contributes significantly to the total friction resistance. However, a square shaft ($< 3"$ [76 mm] in diameter) has only the corners in full surface contact with the soil during installation, thus less shaft friction resistance. Friction energy (energy loss) required to install a helical pile/anchor is related to the helix and shaft size. The total energy loss due to friction is equal to the sum of the friction loss of all the individual helix plates plus the length of shaft subjected to friction via contact with the soil.



Penetration Resistance Has Two Basic Parts:

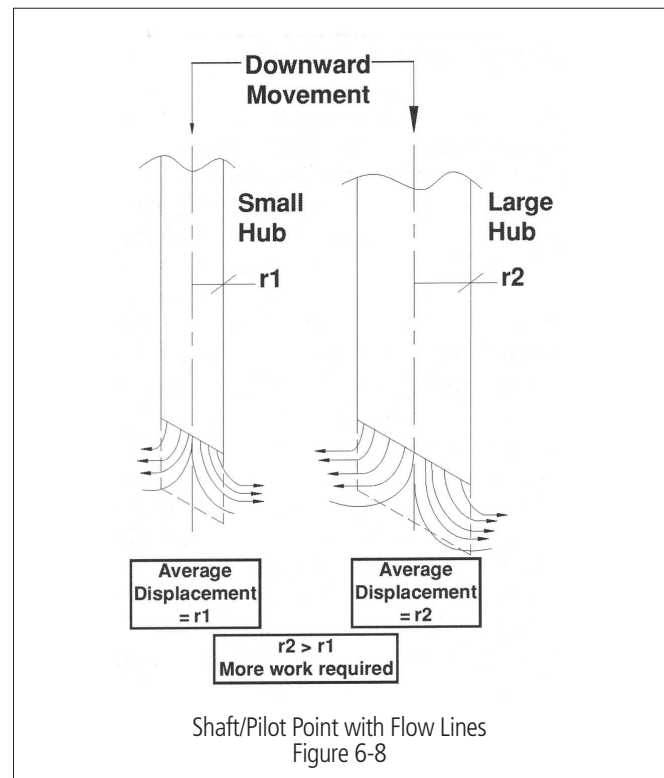
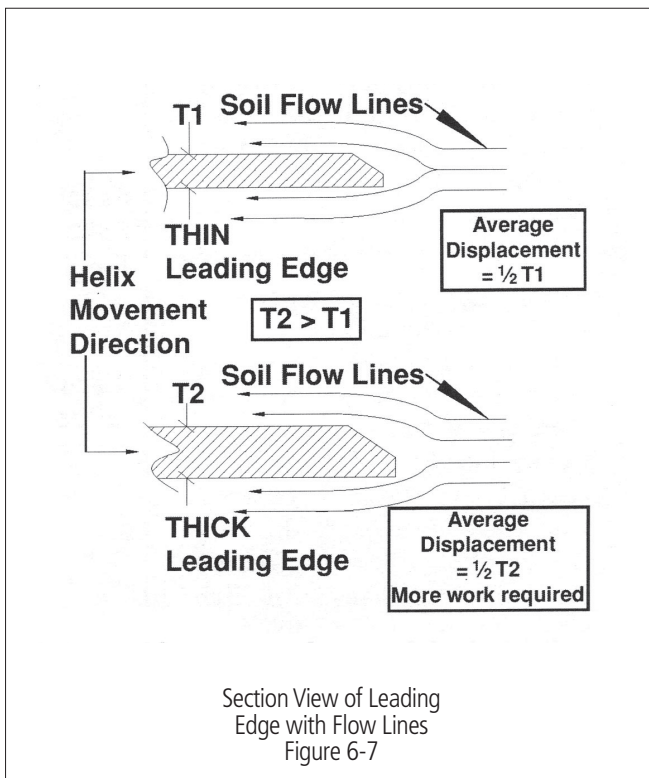
(1) Shearing resistance along the leading edge of the helix plate to allow passage of the helix plate and penetration resistance of the shaft/pilot point. Shearing resistance increases with helix size because leading edge length increases as the diameter increases. Shearing resistance also increases with helix thickness because more soil has to be displaced with a thick helix than with a thin helix (see Figure 6-7). The average distance the soil is displaced is equal to approximately 1/2 the helix thickness, so as the thickness increases the more work (i.e., energy) is required to pass the helix through the soil.

(2) Penetration resistance increases with shaft size because the projected area of the hub/pilot point increases with the square of the shaft radius (see Figure 6-8). The average distance the soil is displaced is approximately equal to the radius of the shaft, so as the shaft size increases, the more work (i.e., energy) is required to pass the hub/pilot point through the soil.

The penetration energy required to install a helical pile/anchor is proportional to the volume of soil displaced times the distance traveled. The volume of soil displaced by the anchor/pile is equal to the sum of the volumes of all the individual helix plates plus the volume of the soil displaced by the hub/pilot point in moving downward with every revolution.

Energy Relationships

Installation energy must equal the energy required to penetrate the soil (penetration resistance) plus the energy loss due to friction (friction resistance). The installation energy is provided by the machine and consists of two components, rotation energy supplied by the torque motor and downward force (or crowd) provided by the machine. The rotation energy provided by the motor along with the inclined plane of a true helical form generates the thrust necessary to overcome the penetration and friction resistance. The rotational energy is what is termed "installation torque." The downward force also overcomes penetration resistance, but its contribution is usually required only at the start of the installation, or when the lead helix is transitioning from a soft soil to a hard soil.



From an installation energy standpoint, the perfect helical pile/anchor would consist of an infinitely thin helix plate attached to an infinitely strong, infinitely small diameter central steel shaft. This configuration would be energy efficient because penetration resistance and friction resistance is low. Installation torque to capacity relationships would be high. However, infinitely thin helix plates and infinitely small shafts are not realistically possible, so a balanced design of size, shape, and material is required to achieve consistent, reliable torque to capacity relationships.

As stated previously, the empirical relationship between installation torque and ultimate capacity is well known, but not precisely defined. As one method of explanation, a theoretical model based on energy exerted during installation has been proposed [Perko (2000)]. The energy model is based on equating the energy exerted during installation with the penetration and friction resistance. Perko showed how the capacity of an installed helical pile/anchor can be expressed in terms of installation torque, applied downward force, soil displacement, and the geometry of the pile/anchor. The model indicates that K_t is weakly dependent on crowd, final installation torque, number of helix plates, and helix pitch. The model also indicates that K_t is moderately affected by helix plate radius and strongly affected by shaft diameter and helix plate thickness.

The important issue is energy efficiency. Note that a large shaft helical anchor/pile takes more energy to install into the soil than a small shaft pile/anchor. Likewise, a large diameter, thick helix takes more energy to install into the soil than a smaller diameter, thinner helix. The importance of energy efficiency is realized when one considers that the additional energy required to install a large displacement helical pile/anchor contributes little to the load capacity of the pile/anchor. In other words, the return on the energy "investment" is not as good. This concept is what is meant when Hubbell Power Systems, Inc. engineers say large shaft diameter and/or large helix diameter (>16" diameter) pile/anchors are not efficient "torque-wise." This doesn't mean large diameter or large helix plate piles are not capable of producing high load capacity, it just means the installation energy, i.e. machine, must be larger in order to install the pile.

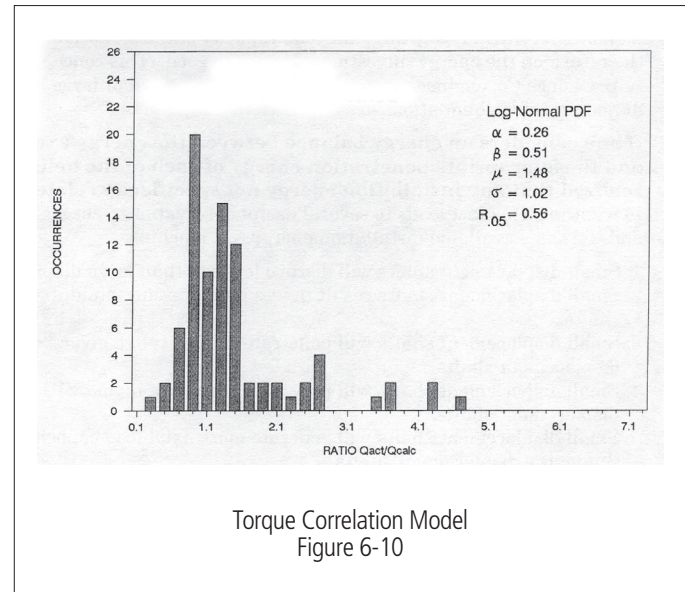
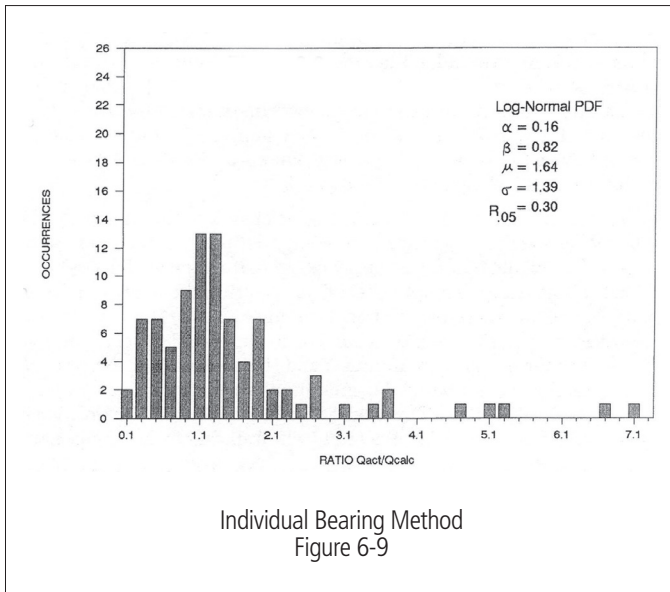
If one considers an energy balance between the energy exerted during loading and the appropriate penetration energy of each of the helix plates, then it can be realized that any installation energy not specifically related to helix penetration is wasted. This fact leads to several useful observations. For a given helix configuration and the same available installation energy (i.e., machine):

1. Small displacement shafts will disturb less soil than large displacement shafts.
2. Small displacement shafts result in less pore pressure buildup than large displacement shafts.
3. Small displacement shafts will penetrate farther into a given bearing strata than large displacement shafts.
4. Small displacement shafts will penetrate soils with higher SPT "N" values than large displacement shafts.
5. Small displacement shafts will generate more axial load capacity with less deflection than large displacement shafts.
6. K_t varies inversely with shaft diameter.

Reliability of Torque/Capacity Model

Hoyt and Clemence (1989) analyzed 91 tension load tests at 24 different sites with sand, silt and clay soils all represented. All of the tests used in the study were short term; most were strain controlled and included a final loading step of imposing continuous deflection at a rate of approximately 4 inches (102 mm) per minute. This final load was taken as the ultimate capacity. The capacity ratio Q_{act}/Q_{calc} was obtained for each test by dividing the actual capacity (Q_{act}) by the calculated capacity (Q_{calc}). Q_{calc} was calculated by using three different load capacity models: (1) Cylindrical shear, (2) Individual bearing, and (3) Torque correlation. These data were then compared and plotted on separate histograms (see Figures 6-9 and 6-10, cylindrical shear histogram not shown).

All three capacity models exhibited the capability of over-predicting pile/anchor capacity. This would suggest the use of appropriate Factors of Safety. However, the authors did not discriminate between "good" and "poor" bearing soils when analyzing the results. In other words, some of the test data analyzed were in areas where the helix plates were located in soils typically not suitable for end bearing, (i.e., sensitive) clays and loose sands.



All three capacity models' mean values were quite close, but the range and standard deviation were significantly lower for the torque correlation method than for the other two. This improved consistency is probably due to the removal of several random variables from the capacity model. Therefore, the installation torque correlation method yields more consistent results than either of the other two methods. The installation torque method does have one disadvantage, however, in that it cannot be used until after the helical pile/anchor has been installed. Therefore, it is better suited to on-site production control and termination criteria than design in the office.

Perko (2012) suggested that if both individual bearing capacity and torque correlation are used to determine the bearing capacity of a helical pile/anchor, the resulting capacity will be accurate to within 97.7% reliability.

Measuring Installation Torque

The torque correlation method requires the installation torque to be measured and recorded in the field. There are several methods that can be used to measure torque, and Hubbell Power Systems, Inc. has a complete line of torque indicators to choose from. Each one is described below along with its advantages and disadvantages:

• Shaft Twist

A.B. Chance Company stated in early editions of the Encyclopedia of Anchoring (1977) that for standard SS5 Anchors, "the most secure anchoring will result when the shaft has a 1 to 1-1/2 twist per 5-foot section." Shaft twist is not a true torque-indicating device. It has been used as an indication of "good bearing soil" since Type SS anchors were first introduced in the mid-1960's. Shaft twist should not be used exclusive of a true torque-indicating device. Some of the reasons for this are listed below.

Advantages:

- Simple, cheap, easy to use.
- Doesn't require any additional tooling.
- Visible indication of torque.



Disadvantages:

- Qualitative, not quantitative torque relationship.
- Not very accurate.
- Shaft twist can't be correlated to installation torque on a consistent basis.
- Type SS5, SS150, SS175, SS200, and SS225 shafts twist, or wrap-up, at different torque levels.
- Shaft twist for a round shaft is not obvious without other means of reference.

• **Shear Pin Torque Limiter**

A shear pin torque limiter is a mechanical device consisting of two shear halves mounted to a central pin such that the shear halves are free to rotate (see Figure 6-11). Shear pins inserted into perimeter holes prevent the shear halves from rotating and are rated to shear at 500 ft-lb of torque per pin. Required torque can be achieved by loading the shear halves with the appropriate number of pins, i.e., 4000 ft-lb = 8 pins. The shear pin torque limiter is mounted in line with the torque motor and pile/anchor tooling.

Advantages:

- Simple design, easy to use.
 - Tough and durable, will take a lot of abuse and keep working.
 - Accurate within ± 5% if kept in good working condition.
- Torque limiter - used to prevent exceeding a specified torque.
 - Relatively inexpensive to buy and maintain.
 - Easy interchange from one machine to another.

Disadvantages:

- Point-wise torque indicator, i.e., indicates torque at separate points, not continuously.
- Requires constant unloading and reloading of shear pins.
- Limited to 10,000 ft-lb.
- Sudden release of torsional (back-lash) energy when pins shear.
- Fits tools with 5-1/4" bolt circle only.

• **Digital Torque Indicator**

A digital torque indicator is a device consisting of strain gauges mounted to a torsion bar located between two bolt flanges (see Figure 6-12). This tool measures installation torque by measuring the shear strain of the torsion bar. The digital display reads torque directly. The digital torque indicator is mounted in-line with the torque motor and pile/anchor tooling.

Advantages:

- Simple torsion bar & strain gauge design, easy to use.
- Continuous reading torque indicator.
- Digital display reads torque directly.



Mechanical Dial Torque Indicator
Figure 6-12



Wireless Remote Display
Figure 6-13



Remote Data Logger
Figure 6-14

- Accurate within $\pm 2\%$ if kept in good working condition.
- Fits tools with 5-1/4" and 7-5/8" bolt circles.
- Calibrated with equipment traceable to US Bureau of Standards before leaving plant.
- Can be used as a calibration tool for other types of torque indicators.
- Easy interchange from one machine to another.
- Reliable, continuous duty torque indicator.
- Comes with wireless remote display and an optional remote data logger.

Disadvantages:

- Drive tools must be switched out when installing different types of helical pile/anchor.

• DP-1 Differential Pressure Torque Indicator

A differential pressure torque indicator is a hydraulic device consisting of back-to-back hydraulic pistons; hoses, couplings, and a gauge (see Figure 6-15). Its' operation is based on the principle that the work output of a hydraulic torque motor is directly related to the pressure drop across the motor. The DP-1 hydraulically or mechanically "subtracts" the low pressure from the high to obtain the "differential" pressure. Installation torque is calculated using the cubic inch displacement and gear ratio of the torque motor. The DP-1 piston block and gauge can be mounted anywhere on the machine. Hydraulic hoses must be connected to the high and low pressure lines at the torque motor.

Advantages:

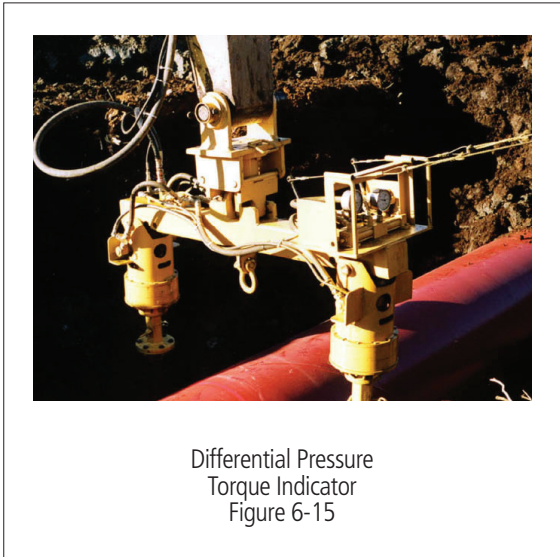
- Indicates torque by measuring pressure drop across hydraulic torque motor.
- No moving parts.
- Continuous reading torque indicator.
- Very durable - the unit is not in the tool string.
- Pressure gauge can be located anywhere on the machine.
- Analog type gauge eliminates "transient" torque peaks.

- Pressure gauge can be overlaid to read torque (ft-lb) instead of pressure (psi).
- Accurate within $\pm 5\%$ if kept in good working condition.
- After mounting, it is always ready for use.
- Can be provided with multiple readout gauges.

Disadvantages:

- Requires significant initial installation setup time and material, i.e., hydraulic fittings, hoses, oil.
- Requires a hydraulic pressure-to-torque correlation based on the torque motor's cubic inch displacement (CID) and gear ratio.
- For two-speed torque motors, pressure-to-torque correlation changes depending on which speed the motor is in (high or low).
- Requires periodic recalibration against a known standard, such as the digital torque indicator, or shear pin torque limiter.
- Sensitive to hydraulic leaks in the lines that connect the indicator to the torque motor.
- Relatively expensive.
- Difficult interchange from one machine to another.

INSTALLATION METHODOLOGY



Differential Pressure
Torque Indicator
Figure 6-15

TORQUE INDICATOR and MOTOR CALIBRATION

All torque indicators require periodic calibration. Hubbell Power Systems, Inc. recommends that torque indicators be calibrated at least once per year. The digital torque indicator can be used in the field to calibrate other indicators, such as hydraulic pressure gauges and the DP-1. As torque motors age, the relationship between hydraulic pressure and installation torque will change. Therefore, it is recommended that hydraulic torque motors be periodically checked for pressure/torque relationship throughout their service life. Hubbell Power Systems, Inc. has torque test equipment available to recalibrate torque indicators and torque motors.

INSTALLATION TERMINATION CRITERIA

The Engineer of Record can use the relationship between installation torque and ultimate load capacity to establish minimum torque criteria for the installation of production helical

piles/anchor. The recommended default values for K_t of [10ft⁻¹ (33m⁻¹)] for CHANCE® Type SS, [9ft⁻¹ (30m⁻¹)] for Type RS2875, [7ft⁻¹ (23m⁻¹)] for Type RS3500 and [6ft⁻¹ (20m⁻¹)] for Type RS4500 will typically provide conservative results.

For large projects that merit the additional effort, a pre-production test program can be used to establish the appropriate torque correlation factor (K_t) for the existing project soils. It is recommended that K_t be determined by dividing the ultimate load capacity determined by load test by the average installation (effective) torque taken over the last 3 feet (1 meter) of penetration into the bearing strata. The minimum effective torsional resistance criterion applies to the "background" resistance; torque spikes resulting from encounters with obstacles in the ground must be ignored in determining whether the torsional resistance criterion has been satisfied. The minimum effective torsional resistance criterion (the average installation torque taken over the last 3 feet of penetration) may not be applicable in certain soil profiles, such as, a relatively soft stratum overlying a very hard stratum. Engineering judgment must be exercised. See Appendix B for more detailed explanation of full-scale load tests. Large-scale projects warrant more than one pre-production test.

Whatever method is used to determine K_t , the production helical piles/anchors should be installed to a specified minimum torque and overall minimum depth. These termination criteria should be written into the construction documents. See www.abchance.com for model specifications that contain sections on recommended termination criteria for helical piles/anchors.

ICC-Evaluation Services ESR-2794 requires the following installation termination criteria:

- When installing single-helix anchors/piles that will be loaded in tension and all multi-helix anchors/piles, torsional resistance must be recorded at the final tip embedment minus 2 feet (710 mm) and final embedment minus 1 foot (305 mm), in addition to the resistance at final embedment.
- For single-helix compression piles, the final torsional resistance reading must be equal to or exceed the specified minimum.
- For multi-helix anchors and piles, the average of the final three torsional resistance readings must be equal to or exceed the specified minimum.
- The tip embedment and torsional resistance readings must be verified to meet or exceed the specified termination criteria before terminating installation.

Minimum Bearing Depth of Top-Most Helix

For deep foundation behavior, Hubbell Power Systems, Inc. recommends the minimum vertical depth of the top-most helix plate should be at least five times the diameter of the top-most helix. Natural factors such as frost depth and active zones (expansive soil) can also affect minimum depth. Hubbell Power Systems, Inc. recommends the minimum vertical depth of the top-most helix plate should be at least three times the diameter of the top most helix below the maximum frost depth or depth of active zone. For example, if the frost depth is 4 feet and the top-most helix plate is 12 in (305 mm), then the minimum depth to the top-most helix is $4 + 3 \times (12 \text{ in}) = 7 \text{ ft}$ (2.1 m).

Tolerances

It is possible to install helical piles/anchors within reasonable tolerance ranges. For example, it is common to locate and install an pile/anchor within 1 inch (25 mm) of the staked location. Plumbness can usually be held within $\pm 1^\circ$ of design alignment. For vertical installations a visual plumbness check is typically all that's required. For battered installations, an inclinometer can be used to establish the required angle. See www.abchance.com for model specifications that contain sections on recommended termination criteria for helical piles/anchors.

Torque Strength Rating

Torque strength is important when choosing the correct helical pile/anchor for a given project. It is a practical limit since the torque strength must be greater than the resistance generated during installation. In fact, the central steel shaft is more highly stressed during installation than at any other time during the life of the helical pile/anchor. This is why it is important to control both material strength variation and process capability in the fabrication process. Hubbell Power Systems, Inc. designs and manufactures helical piles/anchors to achieve the torque ratings published in the product family sections in Section 7. The ratings are listed based on product series, such as SS5, SS175, RS3500, etc.

The torque rating is defined as the maximum torque energy that should be applied to the helical pile/anchor during installation in soil. It is not the ultimate torque strength, defined as the point where the central shaft experiences torsion fracture. It is best described as an allowable limit, or "safe torque" that can be applied to the helical pile/anchor. Some other manufacturers publish torque ratings based on ultimate torque strength.

The designer should select the product series that provides a torque strength rating that meets or exceeds the anticipated torsion resistance expected during the installation. HeliCAP® Engineering Software (see Section 5) generates installation torque vs. depth plots that estimate the torque resistance of the defined soil profile. The plotted torque values are based on a K_t of 10 for Type SS and 9, 7 or 6 for Type RS. The torque ratings published in the product family sections in Section 7 are superimposed on the HeliCAP® Torque vs Depth plot, so the user can see at a glance when the estimated torque resistance equals or exceeds the torque rating of a given product series.

In some instances, it may be necessary to exceed the torque rating in order to achieve the minimum specified depth, or to install the helical pile/anchor slightly deeper to locate the helix plates farther into bearing stratum. This “finishing torque limit” should never exceed the published torque rating by more than 10%. To avoid fracture under impact loading due to obstruction laden soils, choose a helical product series with at least 30% more torque strength rating than the expected torque resistance. Note that the possibility of torsion fracture increases significantly as the applied torque increases beyond the published ratings. The need to install helical pile/anchors deeper is better accomplished by reducing the size and/or number of helix plates, or by choosing a helical product series with a higher torque rating.

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DRAWINGS & RATINGS



PRODUCT DRAWINGS AND RATINGS

Section 7

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DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

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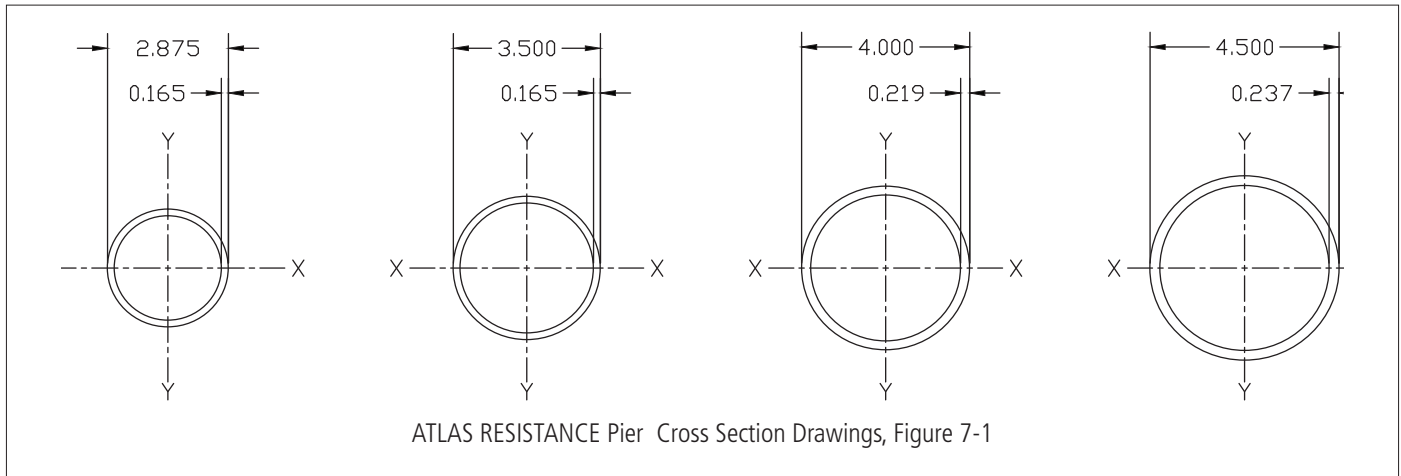
Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.



ATLAS RESISTANCE® PIERS

The ATLAS RESISTANCE® Pier is an assembly of structural steel components that includes a steel bracket attached to the foundation or slab, which is then mounted on a steel pier that is installed to bedrock or firm bearing stratum. The lead pier starter section includes a unique friction reduction collar that reduces skin friction on the pier pipe during installation. Hubbell Power Systems, Inc. offers a broad range of pier pipe sizes and remedial repair brackets for both foundation and slab underpinning applications. This section will discuss those products in detail along with their capacity ratings.

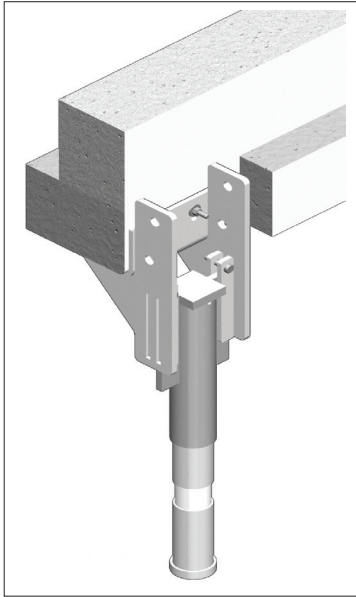
PIER PIPE SHAFTS



ATLAS RESISTANCE® Pier Section Properties, Table 7-1

PRODUCT SERIES	SHAFT SIZE in (mm)	WALL THICKNESS in (mm)	METAL AREA in ² (cm ²)	PERIMETER in (cm)	MOMENT OF INERTIA in ⁴ (cm ⁴) <i>I_{x-x}, I_{y-y}, I_{x-y}</i>	SECTION MODULUS in ³ (cm ³)	
						<i>S_{x-x}</i> <i>S_{y-y}</i>	<i>S_{x-y}</i>
RS2875.165	2.875 (73)	0.165 (4.2)	1.4 (9.0)	9.0 (22.9)	1.29 (53.7)	0.90 (14.7)	0.90 (14.7)
RS3500.165	3.5 (89)	0.165 (4.2)	1.7 (11.0)	11.0 (27.9)	2.41 (100.3)	1.38 (22.6)	1.38 (22.6)
RS4000.219	4.0 (101)	0.219 (5.6)	2.6 (16.8)	12.6 (32.0)	4.66 (194.0)	2.33 (38.2)	2.33 (38.2)
RS4500.237	4.5 (114)	0.237 (6.0)	3.2 (20.6)	14.1 (35.9)	7.23 (301.0)	3.21 (52.6)	3.21 (52.6)

REMEDIAL REPAIR BRACKETS for ATLAS RESISTANCE® PIERS



ATLAS RESISTANCE® Standard and Modified 2-Piece Systems

- Use for lifts up to 4"
- All 2-piece pier systems include:
 - Pier bracket
 - Top pier platform
 - Pier Starter with Friction Reduction Collar
 - Pier Section
 - "M" designates one modified sleeve included

Order Separately: Two pier pins (two Grade 8 bolts for 4-1/2" pier) and pier shims. Each pier requires a minimum of four anchor bolts. NOTE: Anchor bolts not supplied by Hubbell Power Systems, Inc.

See Note 3 at bottom of table for available finishes.

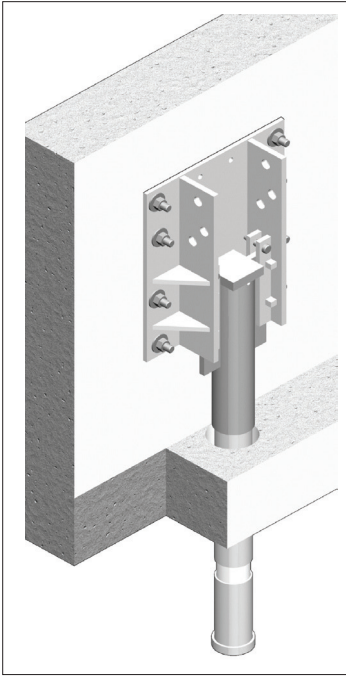
DRAWINGS & RATINGS

ATLAS RESISTANCE® STANDARD AND MODIFIED 2-PIECE PIER DESIGNATORS

Pier Designation	Ultimate Capacity ¹	Max Working Capacity ¹	Pier Dia	Features
AP-2-UF-2875.165	60,000#	30,000#	2-7/8"	Lowest cost
AP-2-UF-2875.165M	70,000#	35,000#	2-7/8"	Lowest cost, Increased rotational stiffness, Recommended for weak surface soils
AP-2-UF-3500.165	85,000#	42,500#	3-1/2"	"Flow Coat" pier pipe standard (NER579) ²
AP-2-UFVL-3500.165	86,000#	43,000#	3-1/2"	Has additional mounting plate for two additional anchor bolts
AP-2-UF-3500.165M	91,000#	45,500#	3-1/2"	"Flow Coat" pier pipe standard (NER579) ² , Increased rotational stiffness. Recommended for weak surface soils
AP-2-UFVL-3500.165M	91,000#	45,500#	3-1/2"	Has additional mounting plate for two additional anchor bolts, Increased rotational stiffness
AP-2-UF-4000.219	98,000#	49,000#	4"	Higher capacity, Easier installation than AP2-3500M
AP-2-UFVL-4000.219	110,000#	55,000#	4"	Has additional mounting plate for two additional anchor bolts
AP-2-UF-4500.237	141,000#	70,500#	4-1/2"	Highest capacity

Notes:

1. Capacities based upon maximum pipe exposure of 2 feet and soil strength having a minimum Standard Penetration Test (SPT) Blow Count "N" of 4. The capacities are based on a pier depth to fixity of 5'-6.
2. Complies with the structural provisions of the most recent editions of BOCA National Code, ICBO Uniform Code, SBCCI Standard Code and 2000 International Building and Residential Code (2002 Accumulative Supplement).
3. Available finishes: P = Entire product supplied mill finish steel. G = Entire product supplied galvanized. PA = Plain steel bracket assy; "Flow Coat" corrosion protection on pier pipe. GA = HDG bracket assy; "Flow Coat" corrosion protection on pier pipe.



ATLAS RESISTANCE® 2-Piece Plate Pier Systems

- Easy surface mount installation.
- May be used for round columns (custom manufactured - see information below).
- Use for lifts up to 4"
- All plate pier systems include:
 - Pier bracket
 - Top pier platform
 - Pier Starter with Friction Reduction Collar
 - Pier Section

Order separately: Two pier pins (two Grade 8 bolts for 4-1/2" pier) and pier shims. Six or eight anchor bolts per pier are required (consult specification drawings on abchance.com for anchor bolt specifications). NOTE: Anchor bolts not supplied by Hubbell Power Systems, Inc.

See Note 3 at bottom of table for available finishes.

DRAWINGS & RATINGS

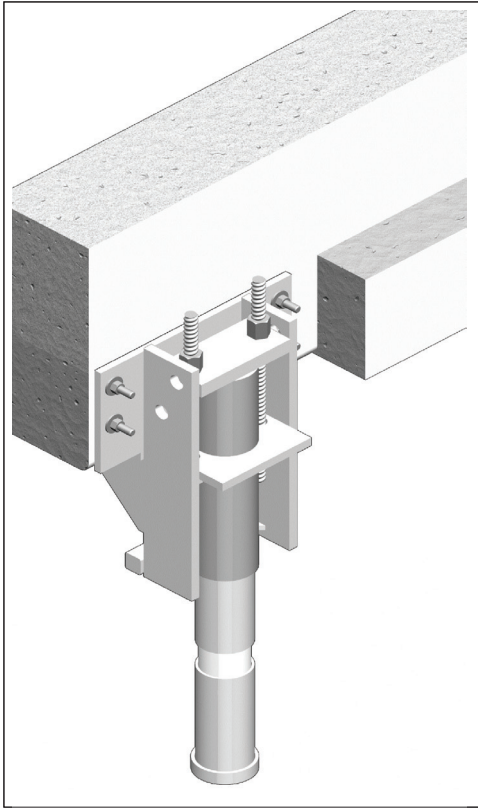
ATLAS RESISTANCE® 2-PIECE PIER PLATE PIER DESIGNATORS				
Pier Designation	Ultimate Capacity ¹	Max Working Capacity ¹	Pier Dia	Features
AP-2-PP-2875.165	60,000#	30,000#	2-7/8"	Lowest cost
AP-2-PP-2875.165M	70,000#	35,000#	2-7/8"	Lowest cost, Increased rotational stiffness, Recommended for weak surface soils
AP-2-PP-3500.165	86,000#	43,000#	3-1/2"	Standard pier for most applications, "Flow Coat" pier pipe standard
AP-2-PP-3500.165M	90,000#	45,000#	3-1/2"	"Flow Coat" pier pipe standard, Increased rotational stiffness, Recommended for weak surface soils
AP-2-PP-4000.219	103,000#	51,500#	4"	Larger pier pipe, Higher capacity
AP-2-PP-4500.237	112,000#	56,000#	4-1/2"	Commercial and Industrial applications, Greater pier pipe diameter, Highest capacity

Notes:

1. Capacities based upon maximum pipe exposure of 2 feet and soil strength having a minimum Standard Penetration Test (SPT) Blow Count "N" of 4. The capacities are based on a pier depth to fixity of 5'-6.
2. Mounting distance from bottom of stem wall to bottom of plate pier bracket must be greater than 5".
3. Available Finishes: P = Entire product supplied mill finish steel. G = Entire product supplied galvanized. PA = Plain steel bracket assy; "Flow Coat" corrosion protection on pier pipe. GA = HDG bracket assy; "Flow Coat" corrosion protection on pier pipe.

ROUND COLUMN APPLICATIONS

Where a plate pier must be attached to a round column, the pier bracket can be custom manufactured at extra cost to match the radius of the column and the side rail width will be extended for clearance. Please provide diameter of column when ordering. Specify: AP-2-PPRC-2875.165, AP-2-PPRC-3500.165M or AP-2-PPRC-4000.219.



ATLAS RESISTANCE® Continuous Lift Pier Systems

- Use for lifts exceeding 4"
- Exceptional, extended lift capabilities
- All Continuous Lift Pier Systems include:
 - Continuous lift pier bracket assembly
 - Cap plate assembly
 - Top pier sleeve (Not applicable on AP-CL-UF-4000.219)
 - Pier Starter with Friction Reduction Collar
 - Pier Section

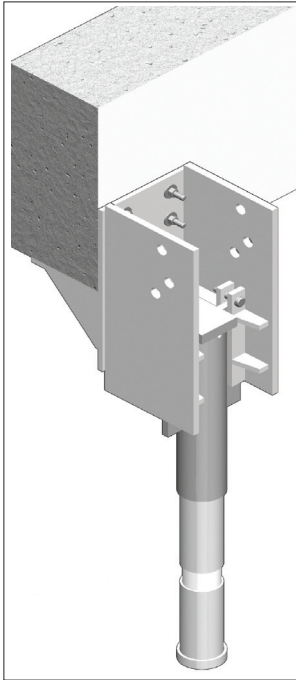
Order separately: Re-useable lift head, continuous thread rebar, nuts, and 6 anchor bolts.

See Note 2 at bottom of table for available finishes.

ATLAS RESISTANCE® Continuous Lift Pier Designators				
Pier Designation	Ultimate Capacity ¹	Max Working Capacity ¹	Pier Dia	Features
AP-CL-UF-2875.165	40,000#	20,000#	2-7/8"	Lowest cost
AP-CL-UF-3500.165	61,000#	30,500#	3-1/2"	"Flow Coat" pier pipe standard
AP-CL-UF-4000.219 (Similar to illustration)	100,000#	50,000#	4"	Higher capacity

Notes:

1. Capacities based upon maximum pipe exposure of 2 feet and soil strength having a minimum Standard Penetration Test (SPT) Blow Count "N" of 4. The capacities are based on a pier depth to fixity of 5'-6.
2. Available Finishes: P = Entire product supplied mill finish steel. G = Entire product supplied galvanized. PA = Plain steel bracket assy; "Flow Coat" corrosion protection on pier pipe. GA = HDG bracket assy; "Flow Coat" corrosion protection on pier pipe.



ATLAS RESISTANCE® 2-Piece Predrilled Pier Systems

- Use for lifts up to 4"
- Drilled pier access hole required where unsuitable rock is near surface
- Use where designer requires penetration into bearing rock
- Eccentricity from wall to C-L pipe is 6-3/4"
 - All pre-drilled piers include:
 - Pier bracket
 - Top pier platform
 - Pier Starter with Friction Reduction Collar
 - Pier Section

Order separately: Two pier pins and four anchor bolts per pier, and shims as required.

See Note 2 at bottom of table for available finishes.

DRAWINGS & RATINGS

ATLAS RESISTANCE® 2-Piece Predrilled Pier Designators

Pier Designation	Ultimate Capacity ¹	Max Working Capacity ¹	Pier Dia	Features
AP-2-UFPDVL-2875.165M	58,000#	29,000#	2-7/8"	Lowest cost
AP-2-UFPDVL-3500.165M	62,000#	31,000#	3-1/2"	Low cost, Corrosion resistant, "Flow Coat" pier pipe standard
AP-2-UFPDVL-4000.219	76,000#	38,000#	4"	Higher capacity
AP-2-UFPD-4500.237	92,000#	46,000#	4-1/2"	Highest capacity, Commercial and Industrial applications

Notes:

1. Capacities based upon maximum pipe exposure of 2 feet and soil strength having a minimum Standard Penetration Blow Count (SPT) of 4. The capacities are based on a pier depth to fixity of 5'-6.
2. Available Finishes: P = Entire product supplied mill finish steel. G = Entire product supplied galvanized. PA = Plain steel bracket assy; "Flow Coat" corrosion protection on pier pipe. GA = HDG bracket assy; "Flow Coat" corrosion protection on pier pipe.

ATLAS RESISTANCE® 2-Piece Predrilled Plate Pier Designators (Special Order-Not Shown)
 Note: Mounting distance from bottom of stem wall to bottom of plate pier bracket must be greater than 5".

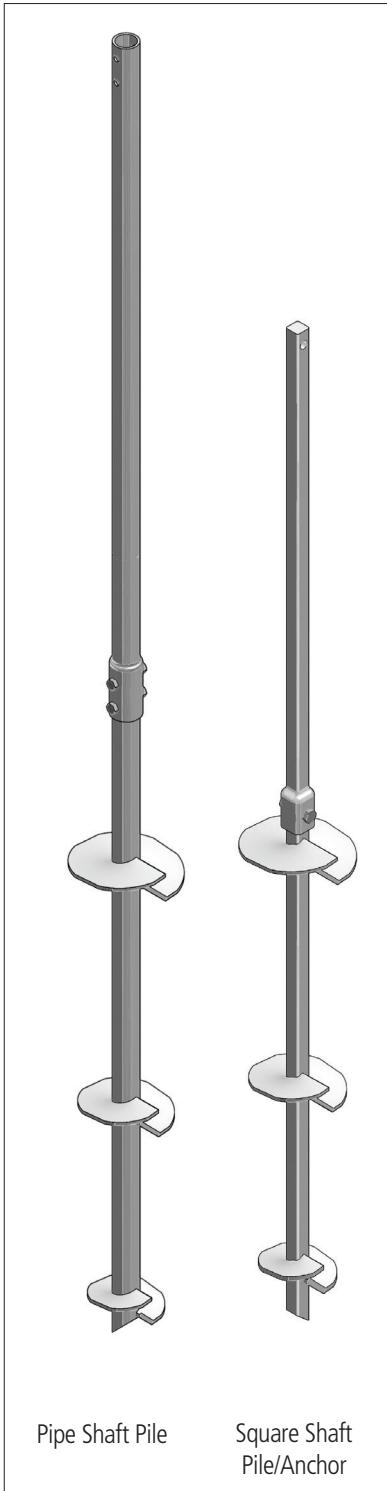
AP-2-PPPD-3500.165	76,000#	38,000#	3-1/2"	Lowest cost, Corrosion resistant, "Flow Coat" pier pipe standard
AP-2-PPPD-3500.165M	80,000#	40,000#	3-1/2"	Low cost, Corrosion resistant, "Flow Coat" pier pipe standard
AP-2-PPPD-4000.219	83,000#	41,500#	4"	Higher capacity
AP-2-PPPD-4500.237	95,000#	47,500#	4-1/2"	Highest capacity, Commercial and Industrial applications

CHANCE® HELICAL PILES/ANCHORS

Introduction

A helical pile/anchor is a factory-manufactured steel deep foundation system designed to resist axial compression, axial tension, and/or lateral loads from structures. It consists of a central steel shaft with one or more helical-shaped bearing plates welded to the central steel shaft. The central steel shaft can be one-piece (non-extendable) or fully extendable with one or more extension shafts, couplings, and a bracket/termination that allows for connection to building structures. A helical pile/anchor is screwed into the ground by application of torsion and can be extended until a required depth or a suitable bearing soil stratum is reached. Load is transferred to the soil through the helix bearing plates. Central steel shafts are available in either Type SS (Square Shaft) series or Type RS (Round Shaft) series. The Type SS series are available in 1-1/4" to 2-1/4" square sizes. The Type RS series are available in 2-7/8" to 8" diameter sizes. Type SS/RS Combo Piles are available for compression applications in soil conditions where dense/hard soils must be penetrated with softer/loose soils above the bearing strata. The grouted shaft CHANCE HELICAL PULLDOWN® Micropile series is also used in applications similar to those requiring the use of the Type SS/RS Combo Piles, but have the additional benefit of generating capacity via skin friction along the grout-soil interface in a suitable bond zone stratum. For a complete list of mechanical ratings and section properties of the central steel shafts, see the Tables found in each helical pile/anchor Product Family in this Section. Refer to Section 3, Product Feasibility and Section 6, Installation Methodology for guidelines on the proper shaft selection based on application, soil conditions, site accessibility, etc.

Helical pile/anchor sections are joined with bolted couplings. Installation depth is limited only by soil density and practicality based on economics. A helical bearing plate or "helix" is one pitch of a screw thread. Most helical piles include more than one helix plate, and the plates are arranged in a "tapered" configuration with the smallest helix being in the bottom and the largest helix being on the top. The large majority of CHANCE® helix plates, regardless of their diameter, have a standard 3" pitch. Being a true helical shape, the helix plates do not auger into the soil but rather screw into it with minimal soil disturbance. CHANCE helix plates are "pre-qualified" per the requirements of Table 3 in ICC-ES AC308 Acceptance Criteria for Helical Pile Systems and Devices, meaning they are generally circular in plan, have a true helix shape, and are attached perpendicular to the central steel shaft with the leading and trailing edges parallel. Helix plates are spaced at distances far enough apart that they function independently as individual bearing elements; consequently, the capacity of a particular helix on a helical pile/anchor shaft is not influenced by the helix above or below it.



Pipe Shaft Pile

Square Shaft Pile/Anchor

Lead Section and Extensions

The starter section or “lead” section contains the helix plates. This lead section can consist of a single helix or up to four helices. Additional helix plates can be added, if required, with the use of helical extensions. Standard helix sizes and areas are shown in Table 7-2 and 7-3 below. Tables 7-2 and 7-3 provide the projected areas of the most common helix plate diameters. Table 7-2 provides helix areas for Type Square Shaft Helical Piles, and Table 7-3 provides helix areas for Type Round Shaft Helical Piles. The full plate projected area includes the area occupied by the central steel shaft. The “area less shaft” is the projected area of the helix plates less the area occupied by the center shaft. Most all CHANCE® helix plates are provided with a sharp leading edge, which is the front edge of the helix that penetrates the soils as the helical anchor/pile is advanced clockwise through soil. The sharp leading edge enables the helix to better slice through tough soils, roots, and seasonally frozen ground. Hubbell Power Systems, Inc. offers several helix plates with “sea shell” leading edges as special options to the product series. Our standard “sea shell” configuration that works best in most tough soils conditions is the 90° design as shown below. The sea shell cut is a leading edge with a “spiral” cut that is very effective when installing helical piles/anchors in debris laden soils, cobbles, and weathered rock.

However, it is important to remember that the bearing capacity of the helical pile/anchor is reduced because the bearing surface area is reduced. Therefore, larger helix diameters or additional helix plates may be required when using “sea shell” cut plates. Tables 7-2 and 7-3 include the projected areas of helix plates offered with the sea shell cut. The helix plates are arranged on the shaft such that their diameters increase as they get farther from the pilot point. The practical limits on the number of helices per pile/anchor is four to five if placed in a cohesive soil and six if placed in a cohesionless or granular soil.

Plain extensions are then added in standard lengths of 3, 5, 7 and 10 feet until the lead section penetrates into the bearing strata. Standard helix configurations are provided in the product series tables in this section. Note that lead time will be significantly reduced if a standard helix configuration is selected.

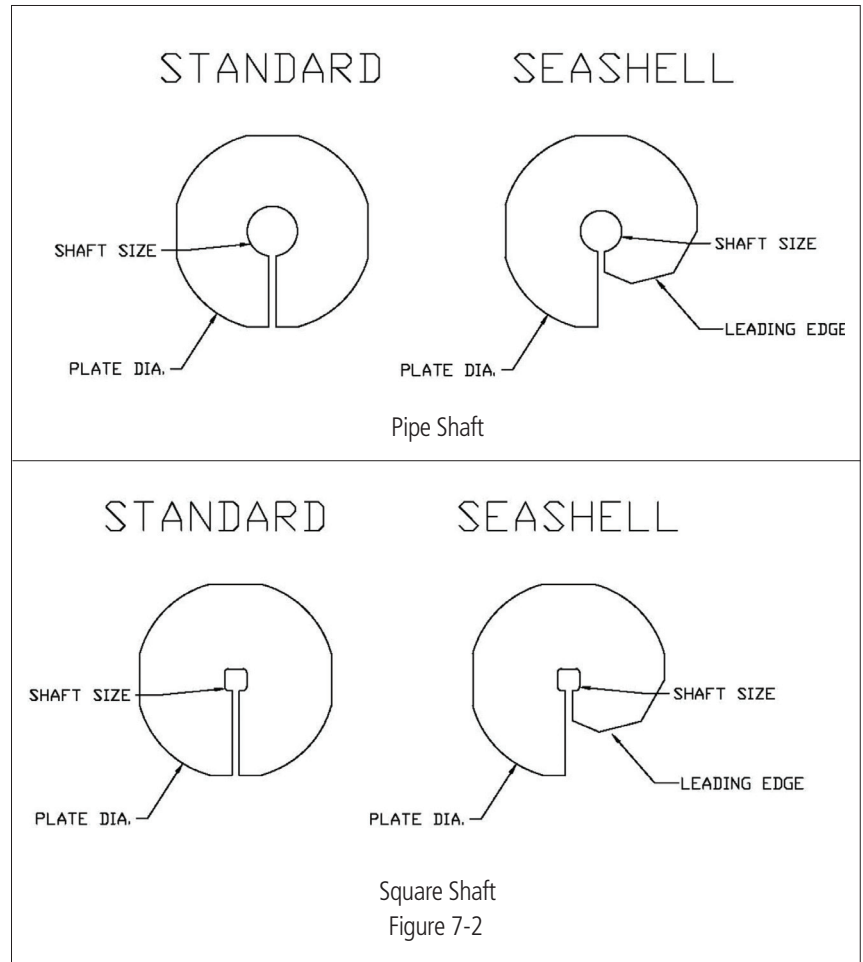


Table 7-2: CHANCE® Square Shaft Helix Plate Sizes and Projected Areas by Product Family

	SQUARE SHAFTS				
	Diameter in. (mm)	STANDARD		SEASHELL	
		AREA w/o HOLE ft ² (m ²)	FULL PLATE AREA ft ² (m ²)	AREA w/o HOLE ft ² (m ²)	FULL PLATE AREA ft ² (m ²)
SS125	6 (150)	0.174 (0.0162)	0.185 (0.0172)	N/A	N/A
	8 (200)	0.324 (0.0301)	0.336 (0.0312)	0.304 (0.0282)	0.316 (0.0294)
	10 (250)	0.519 (0.0482)	0.531 (0.0493)	0.468 (0.0435)	0.479 (0.0445)
	12 (300)	0.759 (0.0705)	0.771 (0.0716)	0.668 (0.0621)	0.679 (0.0631)
	14 (350)	1.037 (0.0963)	1.049 (0.0975)	0.903 (0.0839)	0.915 (0.0850)
	16 (406)	1.366 (0.1269)	1.378 (0.128)	N/A	N/A
SS5/ SS150	6 (150)	0.169 (0.0157)	0.185 (0.0172)	0.156 (0.0145)	0.172 (0.0160)
	8 (200)	0.320 (0.0297)	0.336 (0.0312)	0.300 (0.0279)	0.316 (0.0294)
	10 (250)	0.515 (0.048)	0.531 (0.0493)	0.463 (0.0430)	0.479 (0.0445)
	12 (300)	0.755 (0.0701)	0.771 (0.0716)	0.663 (0.0616)	0.679 (0.0631)
	14 (350)	1.033 (0.0960)	1.049 (0.0975)	0.899 (0.0835)	0.915 (0.0850)
	16 (406)	1.362 (0.1265)	1.378 (0.128)	N/A	N/A
SS175	6 (150)	0.163 (0.151)	0.185 (0.0172)	N/A	N/A
	8 (200)	0.314 (0.0292)	0.336 (0.0312)	0.293 (0.0272)	0.316 (0.0294)
	10 (250)	0.509 (0.0473)	0.531 (0.0493)	0.457 (0.0425)	0.479 (0.0445)
	12 (300)	0.749 (0.0696)	0.771 (0.0716)	0.658 (0.0611)	0.679 (0.0631)
	14 (350)	1.027 (0.0954)	1.049 (0.0975)	N/A	N/A
	16 (406)	1.356 (0.126)	1.378 (0.128)	N/A	N/A
SS200	6 (150)	0.154 (0.0143)	0.185 (0.0172)	0.143 (0.0133)	0.172 (0.0160)
	8 (200)	0.305 (0.0283)	0.336 (0.0312)	N/A	N/A
	10 (250)	0.500 (0.0465)	0.531 (0.0493)	0.450 (0.0418)	0.479 (0.0445)
	12 (300)	0.740 (0.0687)	0.771 (0.0716)	N/A	N/A
	14 (350)	1.018 (0.0946)	1.049 (0.0975)	N/A	N/A
	16 (406)	1.349 (0.1253)	1.378 (0.128)	N/A	N/A
SS225	6 (150)	0.149 (0.0138)	0.185 (0.0172)	N/A	N/A
	8 (200)	0.300 (0.0279)	0.336 (0.0312)	N/A	N/A
	10 (250)	0.495 (0.0460)	0.531 (0.0493)	N/A	N/A
	12 (300)	0.735 (0.0683)	0.771 (0.0716)	N/A	N/A
	14 (350)	1.013 (0.0941)	1.049 (.0975)	N/A	N/A
	16 (406)	1.341 (0.125)	1.378 (0.128)	N/A	N/A

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Table 7-3: CHANCE® Pipe Shaft Helix Plate Sizes and Projected Areas by Product Family

		PIPE SHAFTS			
		STANDARD		SEASHELL	
	Diameter in. (mm)	AREA w/o HOLE ft ² (m ²)	FULL PLATE AREA ft ² (m ²)	AREA w/o HOLE ft ² (m ²)	FULL PLATE AREA ft ² (m ²)
RS2875	8 (200)	0.290 (0.0269)	0.336 (0.0312)	0.270 (0.0251)	0.316 (0.0294)
	10 (250)	0.485 (0.0451)	0.531 (0.0493)	0.433 (0.0402)	0.479 (0.0445)
	12 (300)	0.725 (0.0674)	0.771 (0.0716)	0.633 (0.0588)	0.680 (0.0632)
	14 (350)	1.003 (0.0932)	1.049 (0.0975)	0.869 (0.0807)	0.915 (0.0850)
	16 (406)	1.31 (0.122)	1.378 (0.128)	N/A	N/A
RS3500	8 (200)	0.268 (0.0249)	0.336 (0.0312)	N/A	N/A
	10 (250)	0.463 (0.0430)	0.531 (0.0493)	N/A	N/A
	12 (300)	0.703 (0.0653)	0.771 (0.0716)	0.612 (0.0569)	0.680 (0.0632)
	14 (350)	0.981 (0.0911)	1.049 (0.0975)	N/A	N/A
	16 (406)	1.312 (0.122)	1.378 (0.128)	N/A	N/A
RS4500	8 (200)	0.224 (0.0208)	0.336 (0.0312)	N/A	N/A
	10 (250)	0.419 (0.0389)	0.531 (0.0493)	0.367 (0.0341)	0.479 (0.0445)
	12 (300)	0.659 (0.0612)	0.771 (0.0716)	N/A	N/A
	14 (350)	0.937 (0.0871)	1.049 (0.0975)	N/A	N/A
	16 (406)	1.266 (0.1176)	1.378 (0.128)	N/A	N/A
	20 (508)	2.034 (0.1889)	2.146 (0.1994)	N/A	N/A

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Table 7-4 is a quick reference guide for the design professional. It relates ASTM D1586 SPT “N₆₀” values for cohesive and non-cohesive soils to the expected load capacity of various CHANCE Type Square Shaft (SS) and Round Shaft (RS) Helical Piles. It is intended to be used as a reference guide to enable the designer to quickly determine which helical pile systems to use for project specific soil conditions and load requirements.

Table 7-4: CHANCE® Helical Pile/Anchor Load Capacity Table

Soil Type		Product Family		Axial Compression / Tension Capacity*	
“N ₆₀ ” - Value** Cohesive	“N ₆₀ ” - Value** Non-Cohesive	Helical Pile Shaft Size Inches (mm)	Torque Rating Ft-lb (N-m)	Ultimate Capacity [P _u] Kip (kN)	Allowable Capacity [P _a = 0.5 P _u] Kip (kN)
25 – 35	25 - 30	SS5 1-1/2 (38)	5,700 (7,730)	57 (254)	28.5 (127)
25 - 40	25 - 35	SS150 1-1/2 (38)	7,000 (9,500)	70 (312)	35 (156)
35 - 50	35 -40	SS175 1-3/4 (44)	10,500 (14,200)	105 (467)	52.5 (234)
50 - 70	40 - 60	SS200 2 (51)	16,000 (21,700)	160 (712)	80 (356)
70 - 90	60 - 80	SS225 2-1/4 (57)	21,000 (28,475)	210 (934)	105 (467)
20 - 25	15 - 20	RS2875.203 2-7/8 (73)	5,500 (7,500)	49.5 (220)	24.75 (110)
25 - 35	20 - 30	RS2875.276 2-7/8 (73)	8,000 (10,850)	72 (320)	36 (160)
35 - 40	30 – 35	RS3500.300 3-1/2 (89)	13,000 (17,600)	91 (405)	45.5 (202)
35 – 40	30 – 35	RS4500.337 4-1/2 (114)	23,000 (31,200)	138 (614)	69 (307)

* Based on Torque Rating – Axial Compression / Tension Capacity = Torque Rating x K_t. Well documented correlations with installation torque are recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. “Default” K_t for Type SS = 10 ft⁻¹ (33 m⁻¹). “Default” K_t for Type RS2875 Series = 9 ft⁻¹ (30 m⁻¹); for Type RS3500.300 = 7 ft⁻¹ (23 m⁻¹); for Type RS4500.337 = 6 ft⁻¹ (20 m⁻¹).

** “N₆₀” Values or Blow Count from the Standard Penetration Test per ASTM D1586.

NOTES:

1. The table above is given as a guideline only. The capacity of CHANCE Helical Pile/Anchors may vary depending on, but not limited to, water table elevation and changes to that elevation, changes in soil conditions and soil layer thicknesses.
2. Achievable capacities could be higher or lower than stated in the table depending on:
 - a. Site specific conditions
 - b. On-site testing verification
 - c. HELICAL PULLDOWN® Micropiles can achieve higher capacities in compression. On-site testing should be performed to verify additional pile capacity.
 - d. This chart is to be used for preliminary design assessment only. Capacities should be verified on per project, site-specific basis by a registered design professional.
3. The above chart represents the hardest or densest soil conditions that the helical pile can be installed into. The helical pile will likely achieve its torque rating quickly upon encountering the highest N values indicated above.

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CHANCE® Type SS125 Helical Piles and Anchors

40 kip Ultimate – 20 kip Allowable Capacity

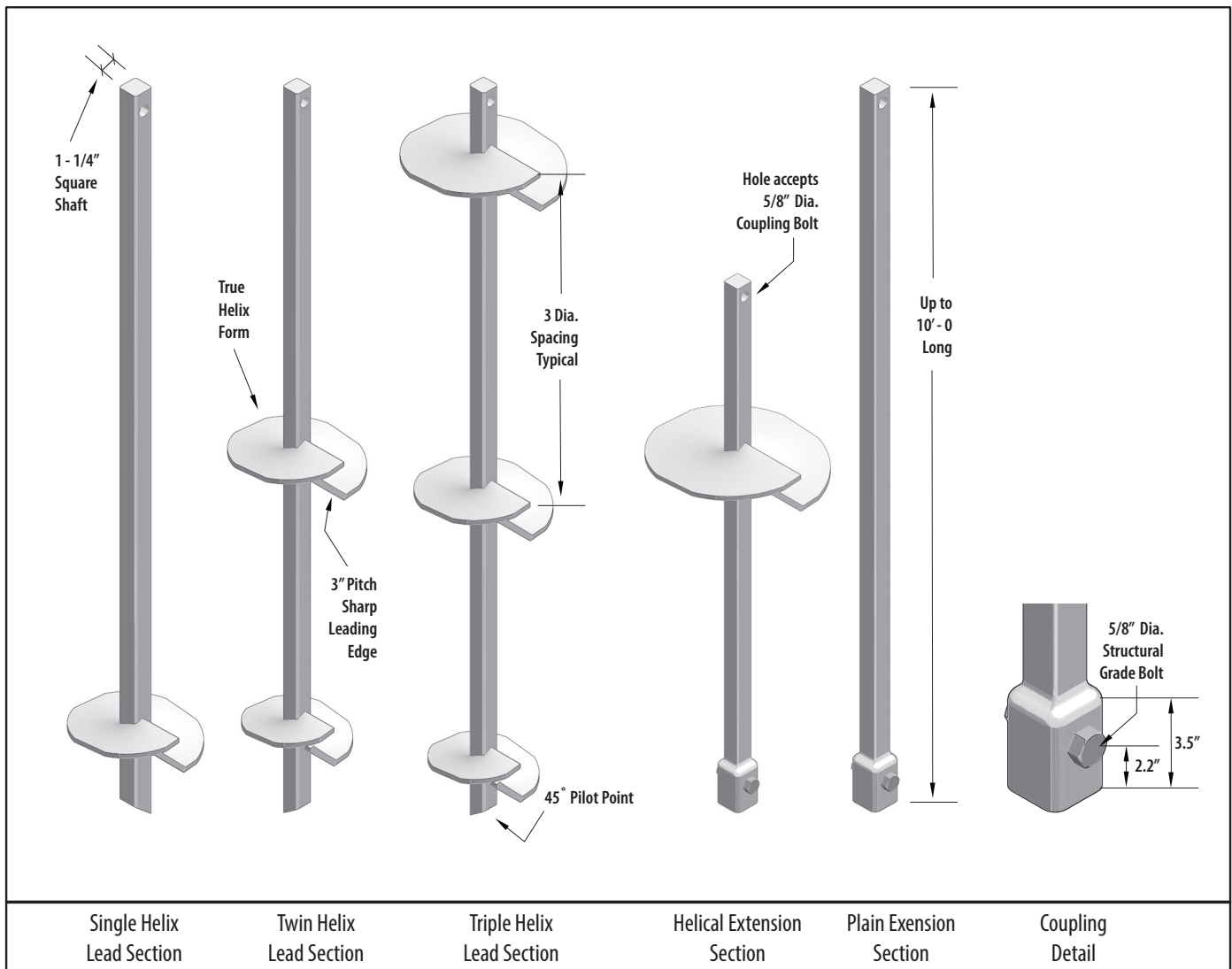
Installation Torque Rating – 4,000 ft-lb

Multi-Purpose 1-1/4 inch Solid Round-Cornered-Square Steel Shaft with integrally formed square upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type SS125 Helical Piles and Anchors have 40 kip ultimate capacity and 20 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Solid square shaft helical piles and anchors provide greater penetration into bearing soils and increased axial capacity in firm soils compared to pipe shaft helical piles with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type SS Helical Piles and Anchors have a longer service life than do pipe shaft piles because of their reduced surface area. CHANCE Type SS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with “sea-shell” cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

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All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

SS125 Helical Pile and Anchor Specifications & Available Configurations

Shaft – Round-Cornered-Square (RCS) 1-1/4 inch solid steel shaft produced exclusively for CHANCE products.

Coupling - forged as a deep socket from the steel shaft material as an integral part of the extension, connected with structural bolts.

Helix - 3/8 inch Thick: ASTM A572, or A1018, or A656 with minimum yield strength of 50 ksi.

3 inch Helix Pitch – a standard established by Hubbell Power Systems, Inc. for Helical Piles and Anchors.

Available Helix Diameters: 6, 8, 10, 12, or 14 inches.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

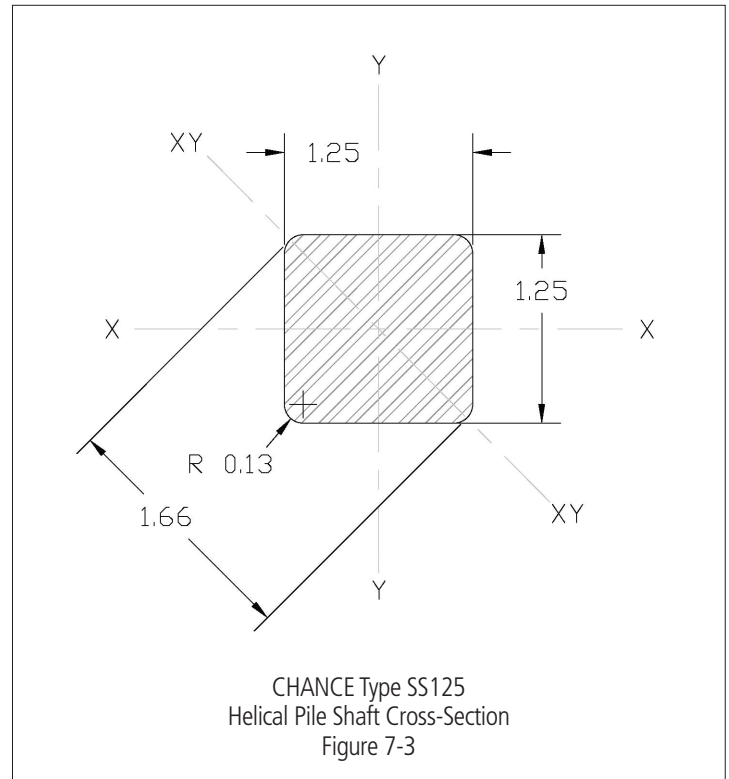
The standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

- Single, double, and triple Lead Sections, 1 and 5 feet long
- Plain Extensions, 3, 5, 7, and 10 feet long
- Extensions with Helix Plates, 3-1/2 feet long, single and double helix

Helical products are Hot Dip Galvanized per ASTM A153 Class B-1.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



Nominal, LRFD Design and ASD Allowable Strengths of SS125 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength kip (kN)	LRFD Design Strength kip (kN)	ASD Allowable Strength kip (kN)
6 (150)	0.375 (9.5)	37.4 (166.3)	33.7 (149.9)	18.7 (83.2)
8 (200)	0.375 (9.5)	37.4 (166.3)	33.7 (149.9)	18.7 (83.2)
10 (250)	0.375 (9.5)	46.6 (207.3)	41.9 (186.4)	23.3 (103.6)
12 (300)	0.375 (9.5)	44.1 (196.2)	39.7 (176.6)	22.1 (98.3)
14 (350)	0.375 (9.5)	36.0 (160.1)	32.4 (144.1)	18.0 (80.1)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

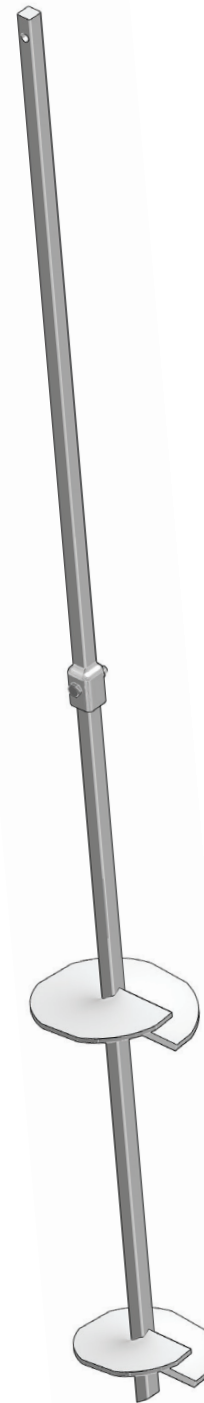
Nominal and LRFD Design Compression Strengths of CHANCE® Type SS125 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	Nominal & LRFD Design Compression Strengths kip (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	See Helix Strength Table		27.3 (121.4)	24.6 (109.4)	13.4 (59.6)	12.0 (53.4)	6.8 (30.2)	6.2 (27.6)
Lead, Multi-Helix	53.6 (238.4)	48.2 (214.4)	27.3 (121.4)	24.6 (109.4)	13.4 (59.6)	12.0 (53.4)	6.8 (30.2)	6.2 (27.6)
Extension	53.6 (238.4)	48.2 (214.4)	27.3 (121.4)	24.6 (109.4)				

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.



Assembly of SS125
Figure 7-4

SS125 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled Round-Cornered-Square (RCS) Solid Steel Bars per ASTM A29; modified AISI 1530 with 90 ksi minimum yield strength			
Shaft Size	1.25 in	32 mm	Corroded	
			1.237 in	31.4 mm
Moment of Inertia (I)	0.20 in ⁴	8.3 cm ⁴	Corroded	
			0.191 in ⁴	7.95 cm ⁴
Shaft Area (A)	1.55 in ²	10.0 cm ²	Corroded	
			1.52 in ²	9.81 cm ²
Section Modulus (S _{x-x})	0.32 in ³	5.3 cm ³	Corroded	
			0.31 in ³	5.1 cm ³
Perimeter	4.79 in	12.17 cm	Corroded	
			4.74 in	12.0 cm
Coupling	Integral Forged Square Deep Socket			
Coupling Bolts	One 5/8 inch Diameter ASTM A325 Type 1 Hex Head Bolt with Threads Excluded from Shear Planes			
Helix Plates	0.375 inch Thick, Formed on Matching Metal Dies, ASTM A572 Grade 50 or better			
Coatings	Hot Dip Galvanized per ASTM A153 Class B-1, 3.1 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	10 ft ⁻¹		33 m ⁻¹	
Torque Rating	4,000 ft-lb		5,400 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	50 kip	222 kN	37.5 kip	167 kN
Allowable Tension Strength	25 kip		111 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	40 kip	178 kN	20 kip	89 kN

ASD Allowable Compression Strengths of CHANCE® Type SS125 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength kip (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	<i>See Helix Strength Table</i>		8.0 (35.6)	4.1 (18.2)
Lead, Multi-Helix	32.1 (142.8)	16.4 (72.9)	8.0 (35.6)	4.1 (18.2)
Extension	32.1 (142.8)	16.4 (72.9)	8.0 (35.6)	4.1 (18.2)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

CHANCE® Type SS5 Helical Piles and Anchors

57 kip Ultimate – 28.5 kip Allowable Capacity

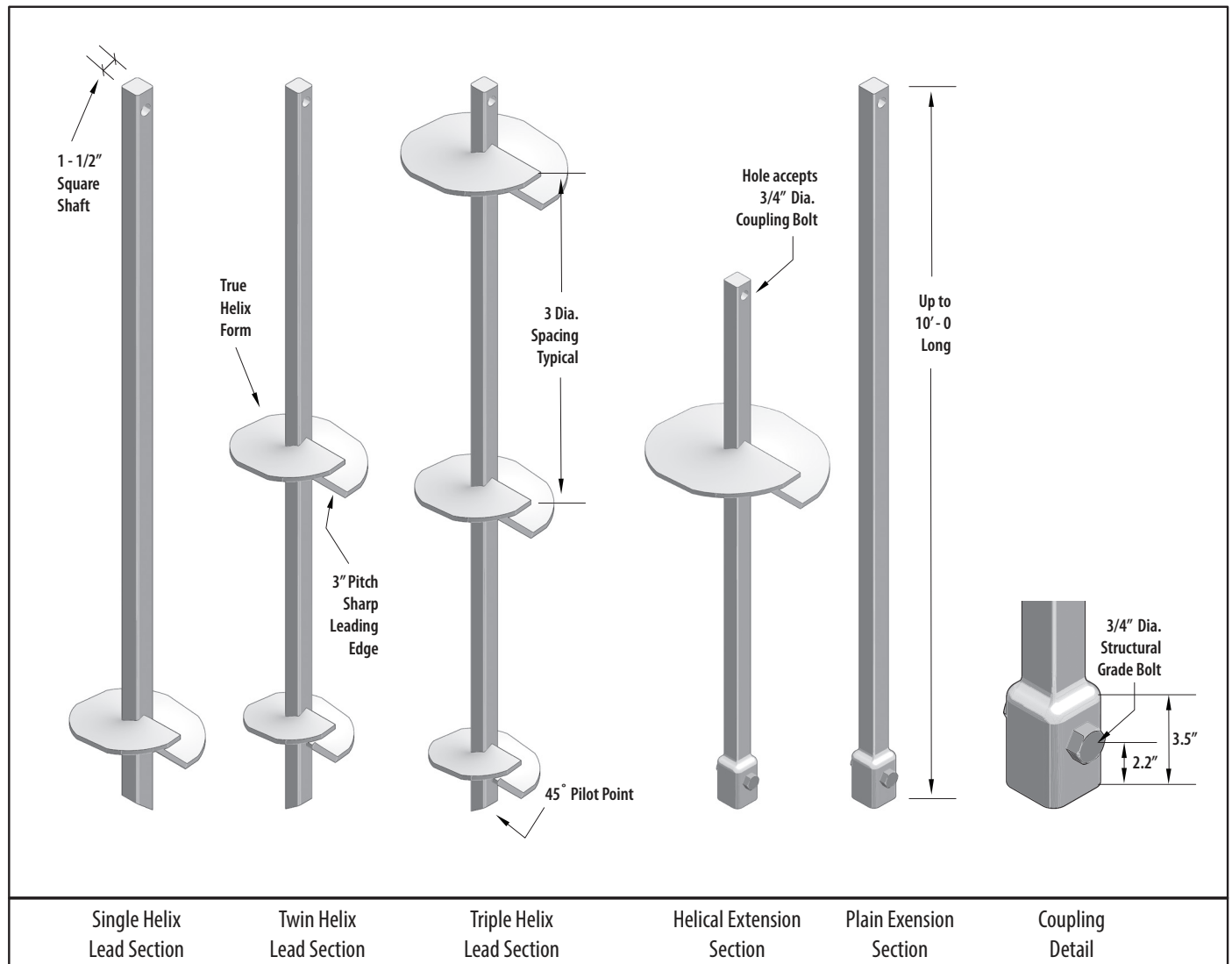
Installation Torque Rating – 5,700 ft-lb

Multi-Purpose 1-1/2 inch Solid Round-Cornered-Square Steel Shaft with integrally formed square upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type SS5 Helical Piles and Anchors have 57 kip ultimate capacity and 28.5 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Solid square shaft helical piles and anchors provide greater penetration into bearing soils and increased axial capacity in firm soils compared to pipe shaft helical piles with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type SS Helical Piles and Anchors have a longer service life than do pipe shaft piles because of their reduced surface area. CHANCE Type SS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with "sea-shell" cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

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All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

SS5 Helical Pile and Anchor Specifications & Available Configurations

Shaft – Round-Cornered-Square (RCS) 1-1/2 inch solid steel shaft produced exclusively for CHANCE products.

Coupling - forged as a deep socket from the steel shaft material as an integral part of the extension, connected with structural bolts.

Helix - 3/8 inch Thick: ASTM A572, or A1018, or A656 with minimum yield strength of 50 ksi.

3 inch Helix Pitch – a standard established by Hubbell Power Systems, Inc. for Helical Piles and Anchors.

Available Helix Diameters: 6, 8, 10, 12, 14, or 16 inches.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

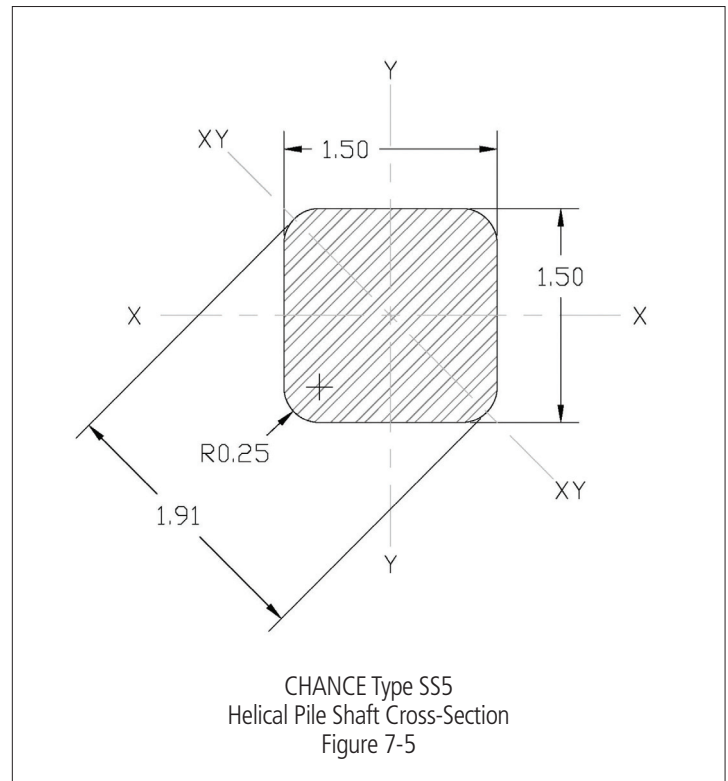
The standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

- Single, double, triple, and quad helix Lead Sections, 3, 5, 7, and 10 feet long
- Plain Extensions, 3, 5, 7, and 10 feet long
- Extensions with Helix Plates, 3 and 5 feet long, single helix

Helical products are Hot Dip Galvanized per ASTM A153 Class B-1.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



Nominal, LRFD Design and ASD Allowable Strengths of SS5 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength kip (kN)	LRFD Design Strength kip (kN)	ASD Allowable Strength kip (kN)
6 (150)	0.375 (9.5)	57.3 (254.9)	51.6 (229.5)	28.7 (127.7)
8 (200)	0.375 (9.5)	57.3 (254.9)	51.6 (229.5)	28.7 (127.7)
10 (250)	0.375 (9.5)	47.7 (212.2)	42.9 (190.8)	23.8 (105.6)
12 (300)	0.375 (9.5)	44.2 (196.6)	39.8 (177.0)	22.1 (98.3)
14 (350)	0.375 (9.5)	54.1 (240.7)	48.7 (216.6)	27.1 (120.6)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

Nominal and LRFD Design Compression Strengths of CHANCE® Type SS5 Helical Pile Lead & Extension Sections^{1,2}

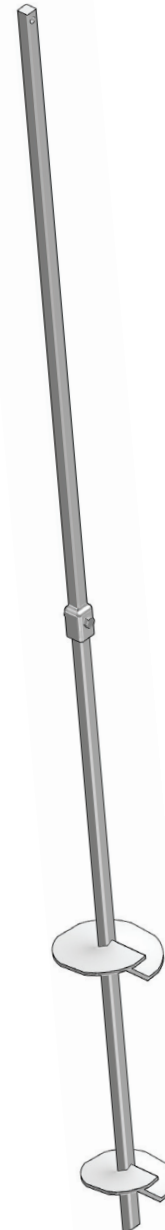
Section Type & Helix Count	Nominal & LRFD Design Compression Strengths kip (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	See Helix Strength Table		Single 6 & 8 in	Single 6 & 8 in	26.6 (118.3)	24.0 (106.8)	13.6 (60.5)	12.2 (54.3)
			54.4 (242.0)	48.9 (217.5)				
			For Other Helix Diameters, See Helix Strength Table					
Lead, Multi-Helix	89.8 (399.5)	80.8 (359.4)	54.4 (242.0)	48.9 (219.5)	26.6 (118.3)	24.0 (106.8)	13.6 (60.5)	12.2 (54.3)
Extension	89.8 (399.5)	80.8 (359.4)	54.4 (242.0)	48.9 (219.5)	26.6 (118.3)	24.0 (106.8)	13.6 (60.5)	12.2 (54.3)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

SS5 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled Round-Cornered-Square (RCS) Solid Steel Bars per ASTM A29; modified AISI 1044 with 70 ksi minimum yield strength			
Shaft Size	1.50 in	38 mm	Corroded	
			1.487 in	37.8 mm
Moment of Inertia (I)	0.40 in ⁴	16.5 cm ⁴	Corroded	
			0.38 in ⁴	15.6 cm ⁴
Shaft Area (A)	2.2 in ²	14.2 cm ²	Corroded	
			2.16 in ²	13.94 cm ²
Section Modulus (S _{x-x})	0.53 in ³	8.7 cm ³	Corroded	
			0.40 in ³	6.6 cm ³
Perimeter	5.6 in	14.2 cm	Corroded	
			5.5 in	14 cm
Coupling	Integral Forged Square Deep Socket			
Coupling Bolts	One ¾ inch Diameter ASTM A325 Type 1 Hex Head Bolt with Threads Excluded from Shear Planes			
Helix Plates	0.375 inch Thick, Formed on Matching Metal Dies, ASTM A572 Grade 50 or better			
Coatings	Hot Dip Galvanized per ASTM A153 Class B-1, 3.1 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	10 ft ⁻¹		33 m ⁻¹	
Torque Rating	5,700 ft-lb		7,730 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	70 kip	312 kN	52.5 kip	234 kN
Allowable Tension Strength	35 kip		156 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	57 kip	254 kN	28.5 kip	127 kN



Assembly of SS5
Figure 7-6

ASD Allowable Compression Strengths of CHANCE® Type SS5 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength kip (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	<i>See Helix Strength Table</i>		16 (71.2)	8.1 (36.0)
Lead, 2-Helix 8"-10"	52.5 (233.5)	32.6 (145.0)	16 (71.2)	8.1 (36.0)
Lead, 2-Helix 10"-12"	45.9 (204.2)			
Lead, 2-Helix 12"-14"	49.9 (222.0)			
Lead, 2-Helix 14"-14"	53.8 (239.3)			
Lead, Multi-Helix	53.8 (239.3)	32.6 (145.0)	16 (71.2)	8.1 (36.0)
Extension	53.8 (239.3)	32.6 (145.0)	16 (71.2)	8.1 (36.0)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

CHANCE® Type SS150 Helical Piles and Anchors

70 kip Ultimate – 35 kip Allowable Capacity

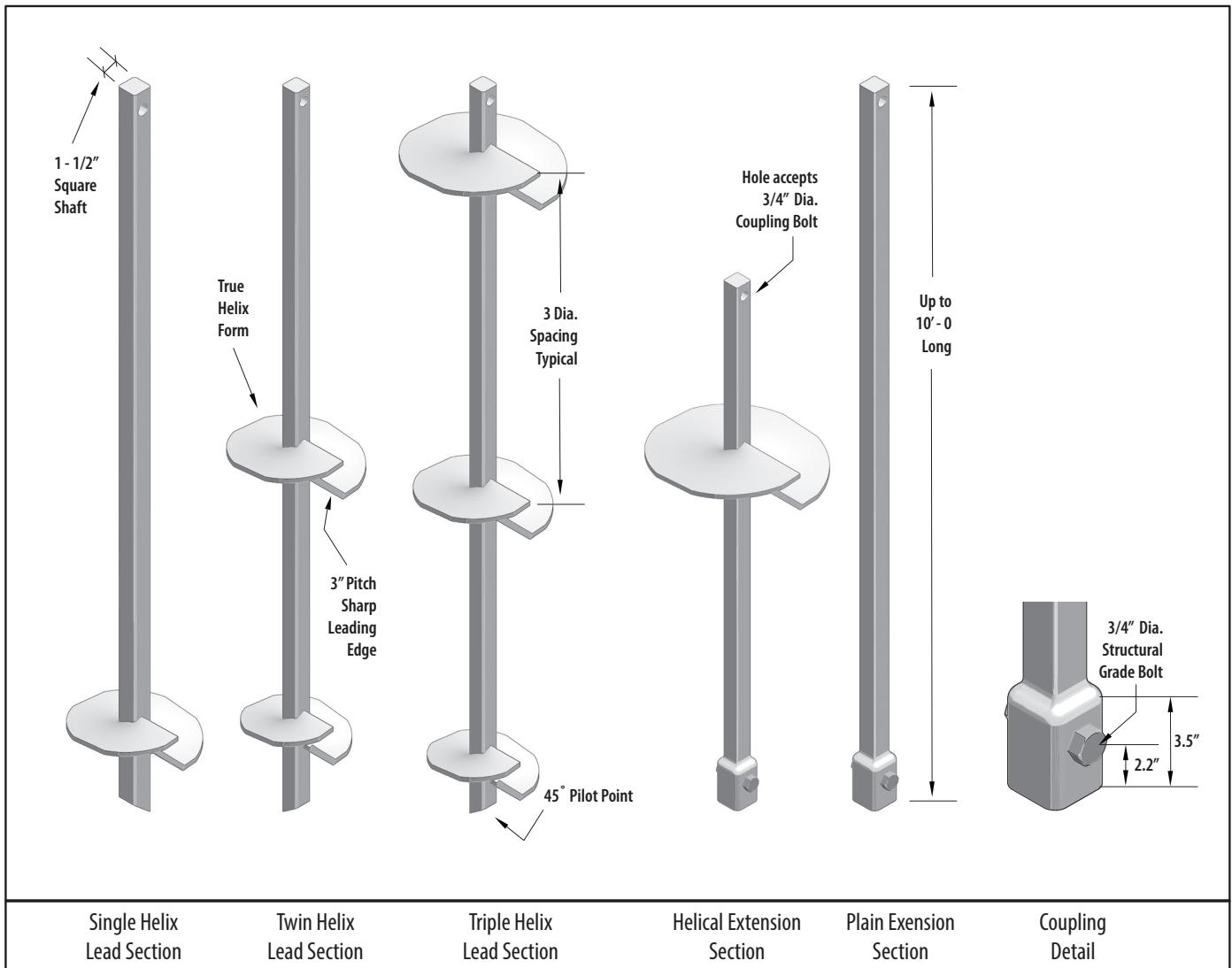
Installation Torque Rating – 7,000 ft-lb

Multi-Purpose 1-1/2 inch Solid Round-Cornered-Square Steel Shaft with integrally formed square upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type SS150 Helical Piles and Anchors have 70 kip ultimate capacity and 35 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Solid square shaft helical piles and anchors provide greater penetration into bearing soils and increased axial capacity in firm soils compared to pipe shaft helical piles with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type SS Helical Piles and Anchors have a longer service life than do pipe shaft piles because of their reduced surface area. CHANCE Type SS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with “sea-shell” cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

DRAWINGS & RATINGS



All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

SS150 Helical Pile and Anchor Specifications & Available Configurations

Shaft – Round-Cornered-Square (RCS) 1-1/2 inch solid steel shaft produced exclusively for CHANCE products.

Coupling - forged as a deep socket from the steel shaft material as an integral part of the extension, connected with structural bolts.

Helix - 3/8 inch Thick: ASTM A656 or A1018, with minimum yield strength of 80 ksi.

3 inch Helix Pitch – a standard established by Hubbell Power Systems, Inc. for Helical Piles and Anchors.

Available Helix Diameters: 6, 8, 10, 12, and 14 inch.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

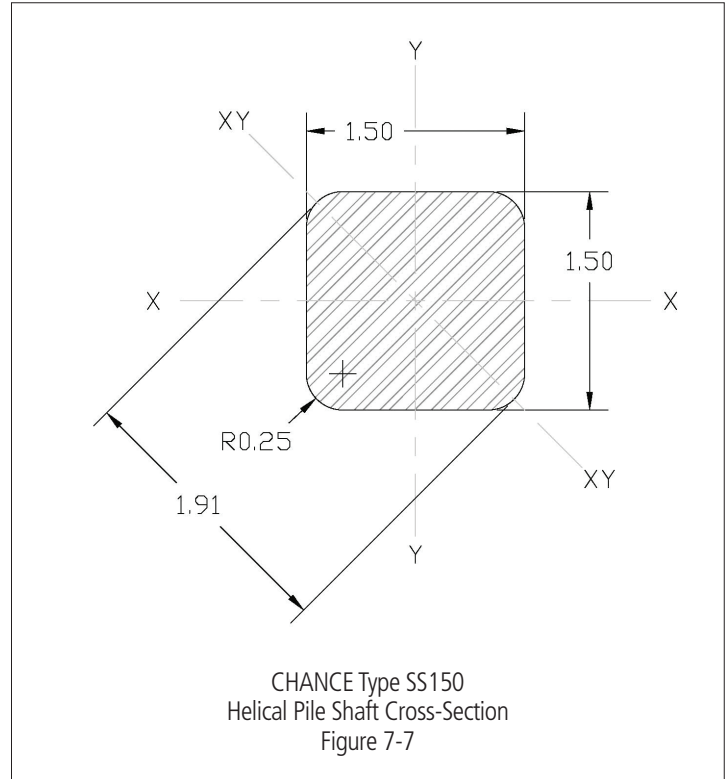
Single, double, triple, and quad helix Lead Sections, 3, 5, 7, and 10 feet long

Plain Extensions, 3, 5, 7, and 10 feet long

Extensions with Helix Plates, 5, 7, and 10 feet long, single and multi-helix

Helical products are Hot Dip Galvanized per ASTM A153 Class B-1.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Axial Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



Nominal, LRFD Design and ASD Allowable Strengths of SS150 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength, kip (kN)	LRFD Design Strength, kip (kN)	ASD Allowable Strength, kip (kN)
6 (150)	0.375 (9.5)	57.7 (257)	51.9 (231)	28.8 (128)
8 (200)	0.375 (9.5)	57.7 (257)	51.9 (231)	28.8 (128)
10 (250)	0.375 (9.5)	61.9 (275)	55.7 (248)	30.9 (137)
12 (300)	0.375 (9.5)	49.7 (221)	44.7 (199)	24.8 (110)
14 (350)	0.375 (9.5)	52.9 (235)	47.7 (212)	26.5 (118)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

Nominal and LRFD Design Compression Strengths of CHANCE® Type SS150 Helical Pile Lead & Extension Sections^{1,2}

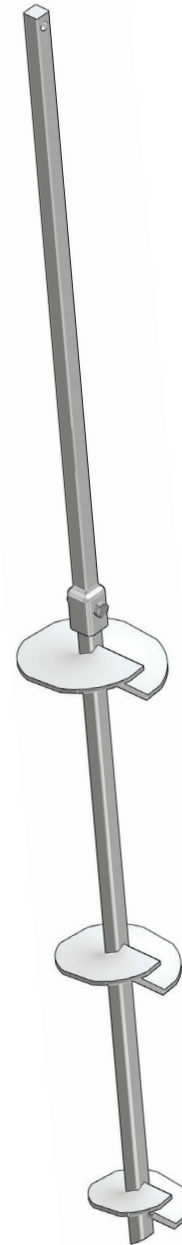
Section Type & Helix Count	Nominal & LRFD Design Compression Strengths, kip (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	See Helix Strength Table		Single 6, 8, or 10 inch – 54.4 (242)	Single 6, 8, or 10 inch – 48.9 (218)	26.6 (118)	24.0 (107)	13.6 (60.5)	12.2 (54)
			For Other Helix Diameters, See Helix Strength Table					
Lead, Multi-Helix Extension	99.5 (443)	89.5 (398)	54.4 (242)	48.9 (218)	26.6 (118)	24.0 (107)	13.6 (60.5)	12.2 (54)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

SS150 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled Round-Cornered-Square (RCS) Solid Steel Bars per ASTM A29; modified AISI 1530 with 90 ksi minimum yield strength			
Shaft Size	1.50 in	38 mm	Corroded	
			1.487 in	37.8 mm
Moment of Inertia (I)	0.40 in ⁴	16.5 cm ⁴	Corroded	
			0.38 in ⁴	15.6 cm ⁴
Shaft Area (A)	2.2 in ²	14.2 cm ²	Corroded	
			2.16 in ²	13.94 cm ²
Section Modulus (S _{x-x})	0.53 in ³	8.7 cm ³	Corroded	
			0.40 in ³	6.6 cm ³
Perimeter	5.6 in	14.2 cm	Corroded	
			5.5 in	14.0 cm
Coupling	Integral Forged Square Deep Socket			
Coupling Bolts	One 3/4 inch Diameter ASTM A325 Type 1 Hex Head Bolt with Threads Excluded from Shear Planes			
Helix Plates	0.375 inch Thick, Formed on Matching Metal Dies, ASTM A656 Grade 80 or better			
Coatings	Hot Dip Galvanized per ASTM A153 Class B-1, 3.1 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	10 ft ⁻¹		33 m ⁻¹	
Torque Rating	7,000 ft-lb		9,500 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	70 kip	312 kN	52.5 kip	234 kN
Allowable Tension Strength	35 kip		156 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	70 kip	312 kN	35 kip	156 kN



Assembly of SS150
Figure 7-8

ASD Allowable Compression Strengths of CHANCE® Type SS150 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength, kip (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	See Helix Strength Table Above		16 (71)	8.1 (36)
Lead, 2-Helix 8"-10"	59.6 (265)		16 (71)	8.1 (36)
Lead, 2-Helix 10"-12"	55.7 (248)			
Lead, 2-Helix 12"-14"	51.3 (228)			
Lead, 2-Helix 14"-14"	53.0 (236)			
Lead, Multi-Helix	59.6 (265)			
Extension	59.6 (265)			

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

CHANCE® Type SS175 Helical Piles and Anchors

105 kip Ultimate – 52.5 kip Allowable Capacity

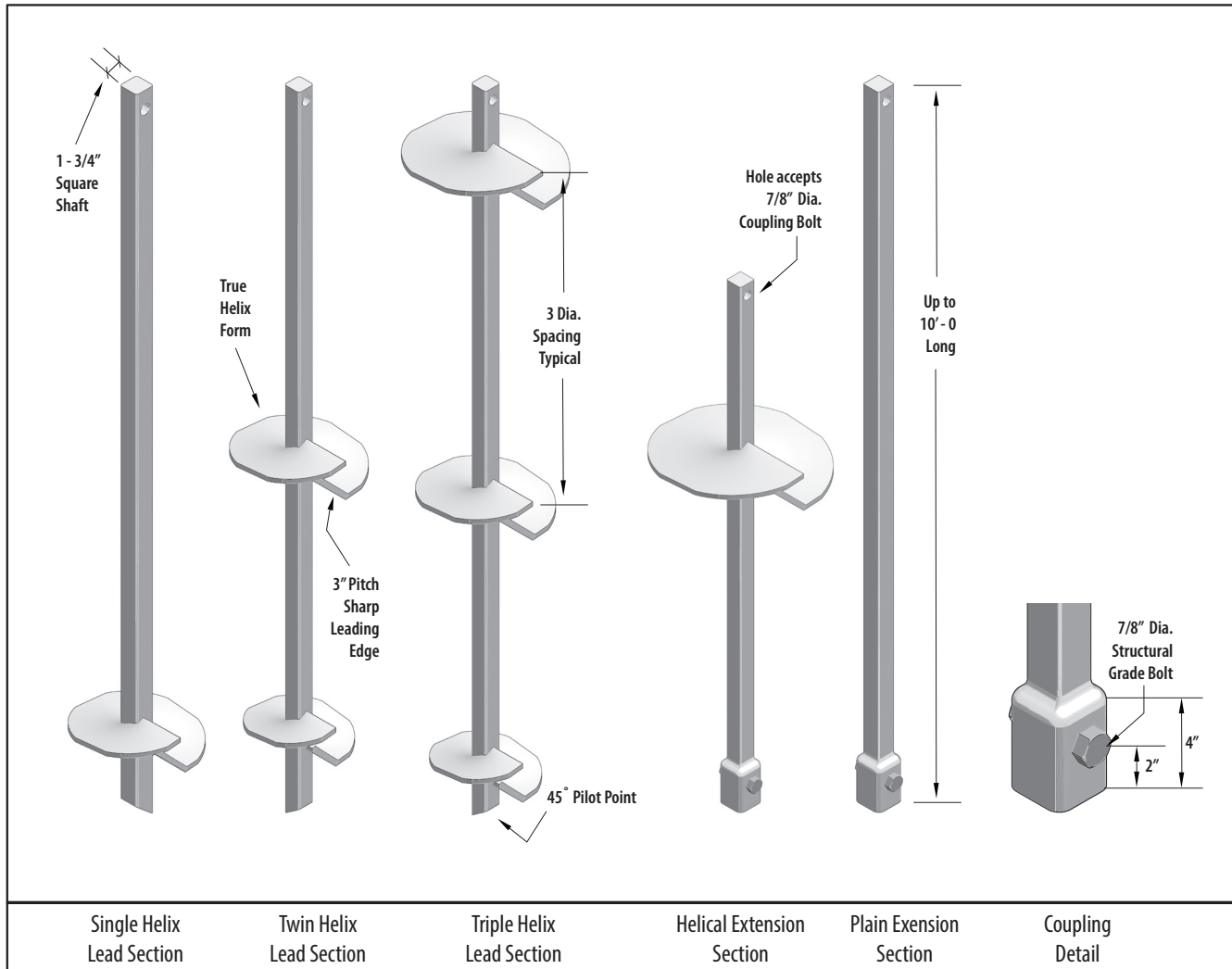
Installation Torque Rating – 10,500 ft-lb

Multi-Purpose 1-3/4 inch Solid Round-Cornered-Square Steel Shaft with integrally formed square upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type SS175 Helical Piles and Anchors have 105 kip ultimate capacity and 52.5 kip working or allowable capacity in compression and 100 kip ultimate capacity and 50 kip working or allowable capacity in tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Solid square shaft helical piles and anchors provide greater penetration into bearing soils and increased axial capacity in firm soils compared to pipe shaft helical piles with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type SS Helical Piles and Anchors have a longer service life than do pipe shaft piles because of their reduced surface area. CHANCE Type SS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with “sea-shell” cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

DRAWINGS & RATINGS



All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

SS175 Helical Pile and Anchor Specifications & Available Configurations

Shaft – Round-Cornered-Square (RCS) 1-3/4 inch solid steel shaft produced exclusively for CHANCE products.

Coupling – forged as a deep socket from the steel shaft material as an integral part of the extension, connected with structural bolts.

Helix - 3/8 & 1/2 inch Thick: ASTM A656, or A1018 with minimum yield strength of 80 ksi.

3 inch Helix Pitch – a standard established by Hubbell Power Systems, Inc. for Helical Piles and Anchors.

Available Helix Diameters: 6, 8, 10, 12, or 14 inches.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

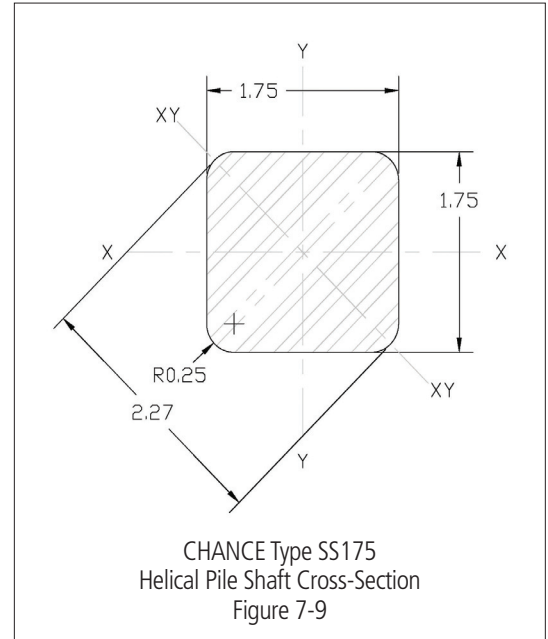
Configurations:

Single, double, triple, and quad helix Lead Sections, 3, 5, 7, and 10 feet long

Plain Extensions, 3, 5, 7, and 10 feet long

Extensions with Helix Plates, 3, 5, 7, and 10 feet long, single and multi-helix
Helical products are Hot Dip Galvanized per ASTM A153 Class B-1.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



Nominal, LRFD Design and ASD Allowable Strengths of SS175 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength, kip (kN)	LRFD Design Strength, kip (kN)	ASD Allowable Strength, kip (kN)
6 (150)	0.5 (13)	123.3 (548.5)	111 (493.8)	61.6 (274)
8 (200)	0.5 (13)	123.3 (548.5)	111 (493.8)	61.6 (274)
10 (250)	0.375 (9.5)	66.1 (294)	59.5 (264.7)	33.1 (147.2)
12 (300)	0.375 (9.5)	57.5 (255.8)	51.7 (230)	28.7 (127.7)
14 (350)	0.375 (9.5)	51.8 (230.4)	46.7 (207.7)	25.9 (115.2)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

Nominal and LRFD Design Compression Strengths of CHANCE® Type SS175 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	Nominal & LRFD Design Compression Strengths, kip (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	See Helix Strength Table		See Helix Strength Table		50.5 (224.6)	45.4 (201.9)	25.8 (114.8)	23.2 (103.2)
Lead, 2-Helix 8"-10"	164.3 (730.8)	147.8 (657.4)	103.0 (458.2)	92.7 (412.4)	50.5 (224.6)	45.4 (201.9)	25.8 (114.8)	23.2 (103.2)
Lead, 2-Helix 10"-12"	123.6 (549.8)	111.2 (494.6)						
Lead, 2-Helix 12"-14"	109.3 (486.2)	98.4 (437.7)						
Lead, 2-Helix 14"-14"	103.6 (460.8)	93.4 (415.5)						
Lead, Multi-Helix	164.3 (730.8)	147.8 (657.4)						
Extension	164.3 (730.8)	147.8 (657.4)						

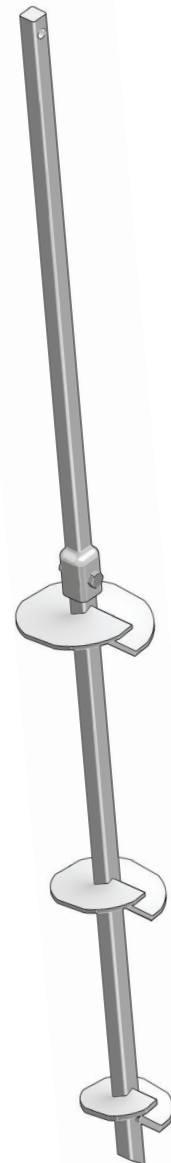
For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

DRAWINGS & RATINGS

SS175 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled Round-Cornered-Square (RCS) Solid Steel Bars per ASTM A29; modified AISI 1530 with 90 ksi minimum yield strength			
Shaft Size	1.75 in	44.4 mm	Corroded	
			1.737 in	44 mm
Moment of Inertia (I)	0.75 in ⁴	31.1 cm ⁴	Corroded	
			0.725 in ⁴	30.1 cm ⁴
Shaft Area (A)	3.1 in ²	19.4 cm ²	Corroded	
			2.97 in ²	19.16 cm ²
Section Modulus (S _{x-x})	0.85 in ³	13.9 cm ³	Corroded	
			0.835 in ³	13.65 cm ³
Perimeter	6.6 in	16.7 cm	Corroded	
			6.5 in	16.5 cm
Coupling	Integral Forged Square Deep Socket			
Coupling Bolts	One 7/8 inch Diameter ASTM A193 Grade B7 Hex Head Bolt with Threads Excluded from Shear Planes			
Helix Plates	0.375 & 0.5 inch Thick, Formed on Matching Metal Dies, ASTM A656 Grade 80 or better			
Coatings	Hot Dip Galvanized per ASTM A153 Class B-1, 3.1 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	10 ft ⁻¹		33 m ⁻¹	
Torque Rating	10,500 ft-lb		14,240 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	100 kip	445 kN	75 kip	334 kN
Allowable Tension Strength	50 kip		222 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	105 kip	467 kN	52.5 kip	234 kN



Assembly of SS175
Figure 7-10

ASD Allowable Compression Strengths of CHANCE® Type SS150 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength, kip (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	See Helix Strength Table Above	See Helix Strength Table Above	30.2 (134.3)	15.4 (68.5)
Lead, Single 12" Helix			28.7 (127.7)	
Lead, Single 14" Helix			25.9 (115.2)	
Lead, 2-Helix 8"-10"	94.7 (421.2)	61.7 (274.5)	30.2 (134.3)	15.4 (68.5)
Lead, 2-Helix 10"-12"	61.8 (274.9)	61.7 (274.5)		
Lead, 2-Helix 12"-14"	54.6 (242.9)	54.6 (242.9)		
Lead, 2-Helix 14"-14"	51.8 (230.4)	51.8 (230.4)		
Lead, Multi-Helix	98.4 (437.7)	61.7 (274.5)	30.2 (134.3)	15.4 (68.5)
Extension	98.4 (437.7)	61.7 (274.5)	30.2 (134.3)	15.4 (68.5)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

CHANCE® Type SS200 Helical Piles and Anchors

160 kip Ultimate – 80 kip Allowable Capacity

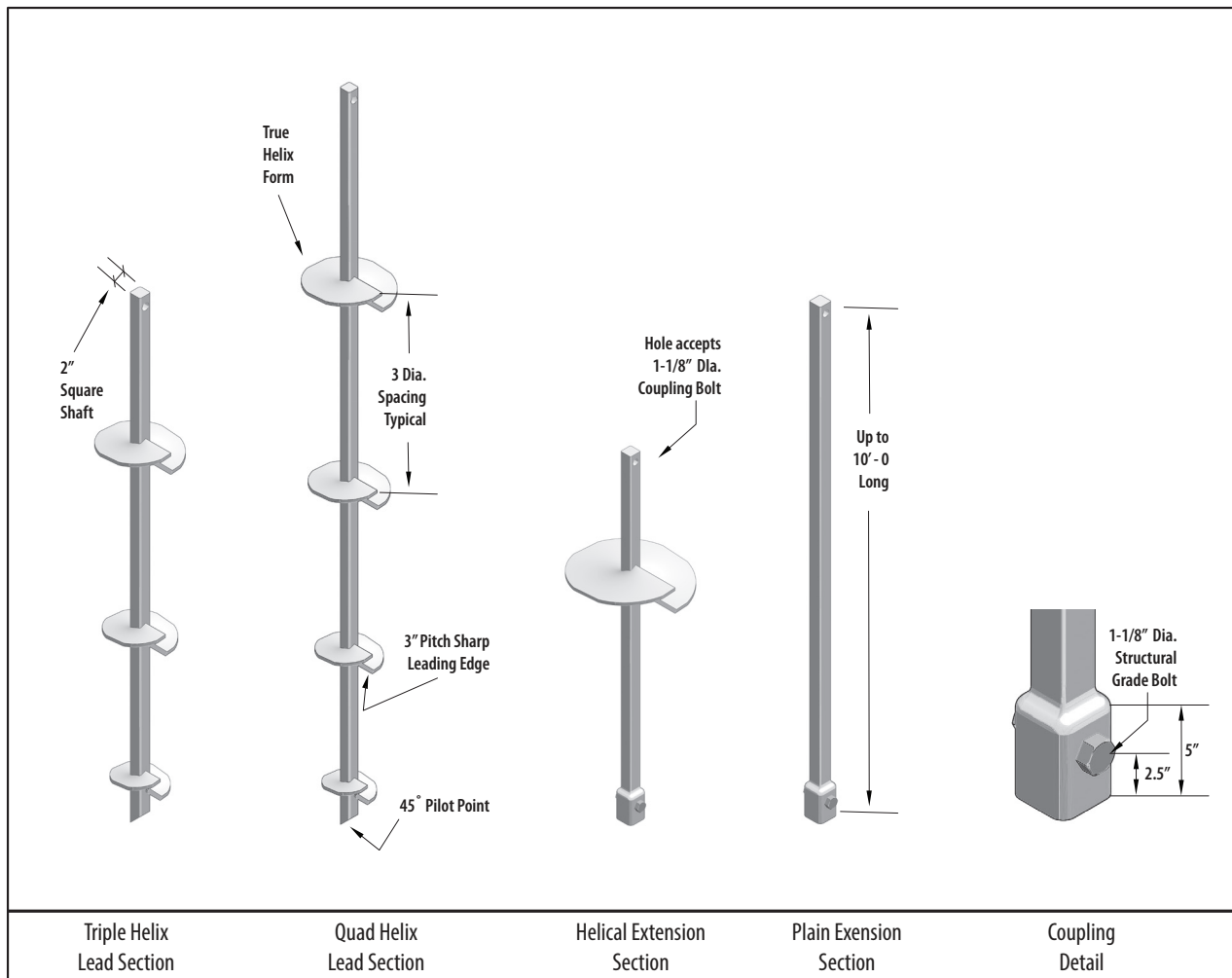
Installation Torque Rating – 16,000 ft-lb

Multi-Purpose 2 inch Solid Round-Cornered-Square Steel Shaft with integrally formed square upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type SS200 Helical Piles and Anchors have 160 kip ultimate capacity and 80 kip working or allowable capacity in compression and 150 kip ultimate capacity and 75 kip working or allowable capacity in tension. This capacity is based on structural strength ratings and well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Solid square shaft helical piles and anchors provide greater penetration into bearing soils and increased axial capacity in firm soils compared to pipe shaft helical piles with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type SS Helical Piles and Anchors have a longer service life than do pipe shaft piles because of their reduced surface area. CHANCE Type SS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with "sea-shell" cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

DRAWINGS & RATINGS



All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

SS200 Helical Pile and Anchor Specifications & Available Configurations

Shaft – Round-Cornered-Square (RCS) 2 inch solid steel shaft produced exclusively for CHANCE products.

Coupling - forged as a deep socket from the steel shaft material as an integral part of the extension, connected with structural bolts.

Helix – ½ inch Thick: ASTM A656, or A1018 with minimum yield strength of 80 ksi.

3 inch Helix Pitch – a standard established by Hubbell Power Systems, Inc. for Helical Piles and Anchors.

Available Helix Diameters: 6, 8, 10, 12, and 14 inch.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

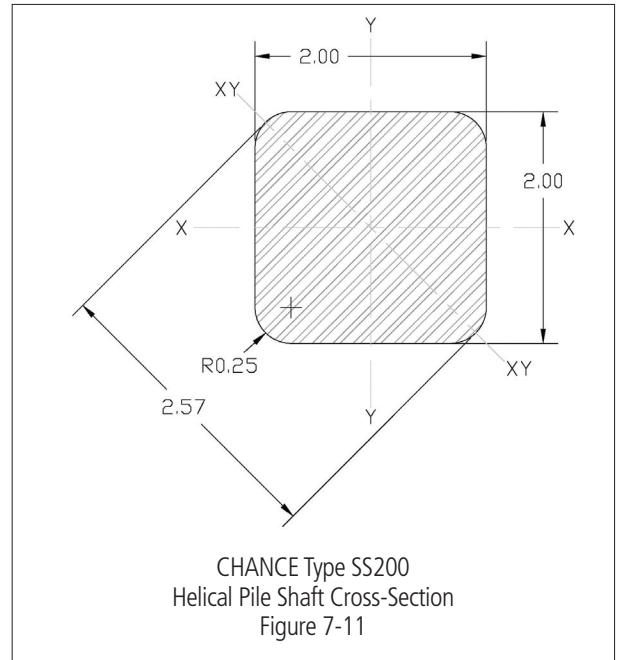
Triple, and quad helix Lead Sections, 5, 7, 8, and 10 feet long

Plain Extensions, 3, 5, 7, and 10 feet long

Extensions with Helix Plates, 3, 7, and 10 feet long, single and multi-helix

Helical products are Hot Dip Galvanized per ASTM A153 Class B-1.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Axial deflections of 0.25 to 0.50 inches are typical at allowable capacity.



Nominal, LRFD Design and ASD Allowable Strengths of SS220 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength, kip (kN)	LRFD Design Strength, kip (kN)	ASD Allowable Strength, kip (kN)
6 (150)	0.5 (13)	154 (685)	138.5 (616.1)	77 (342.5)
8 (200)	0.5 (13)	154 (685)	138.5 (616.1)	77 (342.5)
10 (250)	0.5 (13)	122.8 (546.2)	110.5 (491.5)	61.4 (273.1)
12 (300)	0.5 (13)	131.3 (584)	118.1 (525.3)	65.6 (291.8)
14 (350)	0.5 (13)	115.3 (512.9)	103.8 (461.7)	57.6 (256.2)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

Nominal and LRFD Design Compression Strengths of CHANCE® Type SS200 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	Nominal & LRFD Design Compression Strengths, kip (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	See Helix Strength Table		See Helix Strength Table		85.6 (380.8)	77.1 (342.9)	43.7 (194.4)	39.3 (174.8)
Lead, 2-Helix 8"-10"	239.6 (1065.8)	215.6 (959)	167.5 (745)	150.8 (670.8)	86.6 (385.2)	77.1 (342.9)	43.7 (194.4)	39.3 (174.8)
Lead, 2-Helix 10"-12"	239.6 (1065.8)	215.6 (959)						
Lead, 2-Helix 12"-14"	239.6 (1065.8)	215.6 (959)						
Lead, 2-Helix 14"-14"	230.6 (1025.8)	207.6 (923.5)						
Lead, Multi-Helix	239.6 (1065.8)	215.6 (959)						
Extension	239.6 (1065.8)	215.6 (959)						

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

DRAWINGS & RATINGS

SS200 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled Round-Cornered-Square (RCS) Solid Steel Bars per ASTM A29; modified AISI 1530 with 90 ksi minimum yield strength			
Shaft Size	2 in	51 mm	Corroded	
			1.971 in	50 mm
Moment of Inertia (I)	1.26 in ⁴	52.4 cm ⁴	Corroded	
			1.19 in ⁴	49.53 cm ⁴
Shaft Area (A)	3.9 in ²	25.3 cm ²	Corroded	
			3.81 in ²	24.58 cm ²
Section Modulus (S _{x-x})	1.26 in ³	20.6 cm ³	Corroded	
			1.21 in ³	19.83 cm ³
Perimeter	7.5 in	18.9 cm	Corroded	
			7.36 in	18.69 cm
Coupling	Integral Forged Square Deep Socket			
Coupling Bolts	One 1-1/8 inch Diameter ASTM A193 Grade B7 Hex Head Bolt with Threads Excluded from Shear Planes			
Helix Plates	0.5 inch Thick, Formed on Matching Metal Dies, ASTM A656 or A1018 Grade 80			
Coatings	Hot Dip Galvanized per ASTM A153 Class B-1, 3.1 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	10 ft ⁻¹		33 m ⁻¹	
Torque Rating	16,000 ft-lb		21,700 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	150 kip	668 kN	112.5 kip	500 kN
Allowable Tension Strength	75 kip		334 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	160 kip	712 kN	80 kip	356 kN



Assembly of SS200
Figure 7-12

ASD Allowable Compression Strengths of CHANCE® Type SS200 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength kip (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	See Helix Strength Table Above		51.3 (228.2)	26.2 (116.5)
Lead, 2-Helix 8"-10"	138.4 (615.6)		51.3 (228.2)	26.2 (116.5)
Lead, 2-Helix 10"-12"	127.0 (765.1)			
Lead, 2-Helix 12"-14"	123.2 (548)			
Lead, 2-Helix 14"-14"	115.2 (512.4)		51.3 (228.2)	26.2 (116.5)
Lead, Multi-Helix	143.5 (638.3)			
Extension	143.5 (638.3)		51.3 (228.2)	26.2 (116.5)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

CHANCE® Type SS225 Helical Piles and Anchors

210 kip Ultimate – 105 kip Allowable Capacity

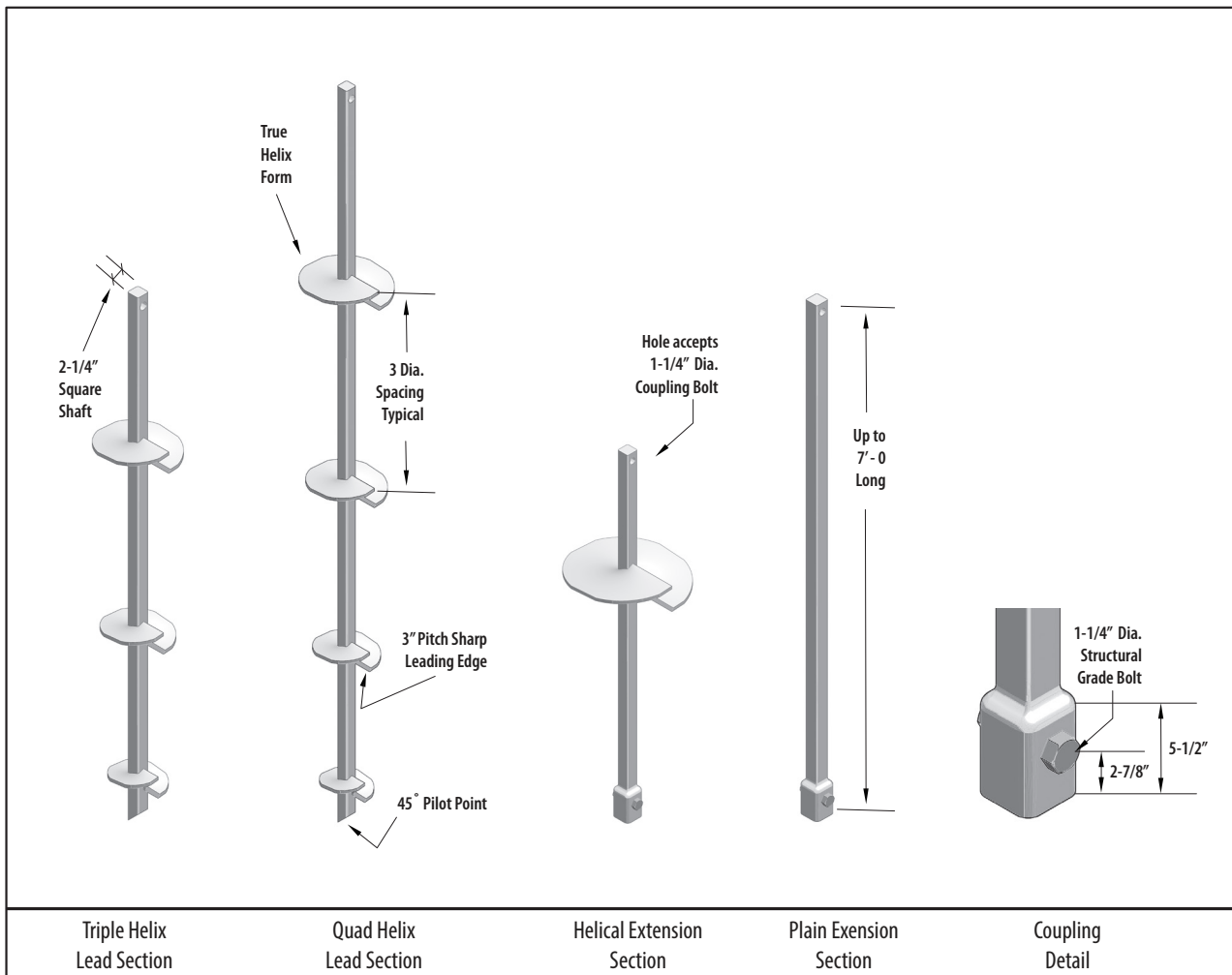
Installation Torque Rating – 21,000 ft-lb

Multi-Purpose 2-1/4 inch Solid Round-Cornered-Square Steel Shaft with integrally formed square upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type SS225 Helical Piles and Anchors have 210 kip ultimate capacity and 105 kip working or allowable capacity in compression and 200 kip ultimate capacity and 100 kip working or allowable capacity in tension. This capacity is based on structural strength ratings and well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Solid square shaft helical piles and anchors provide greater penetration into bearing soils and increased axial capacity in firm soils compared to pipe shaft helical piles with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type SS Helical Piles and Anchors have a longer service life than do pipe shaft piles because of their reduced surface area. CHANCE Type SS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with "sea-shell" cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

DRAWINGS & RATINGS



All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

SS225 Helical Pile and Anchor Specifications & Available Configurations

Shaft – Round-Cornered-Square (RCS) 2-1/4 inch solid steel shaft produced exclusively for CHANCE products.

Coupling - forged as a deep socket from the steel shaft material as an integral part of the extension, connected with structural bolts.

Helix - 1/2 inch Thick: ASTM A656, or A1018 with minimum yield strength of 80 ksi. 3 inch Helix Pitch – a standard established by Hubbell Power Systems, Inc. for Helical Piles and Anchors.

Available Helix Diameters: 6, 8, 10, 12, and 14 inch.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

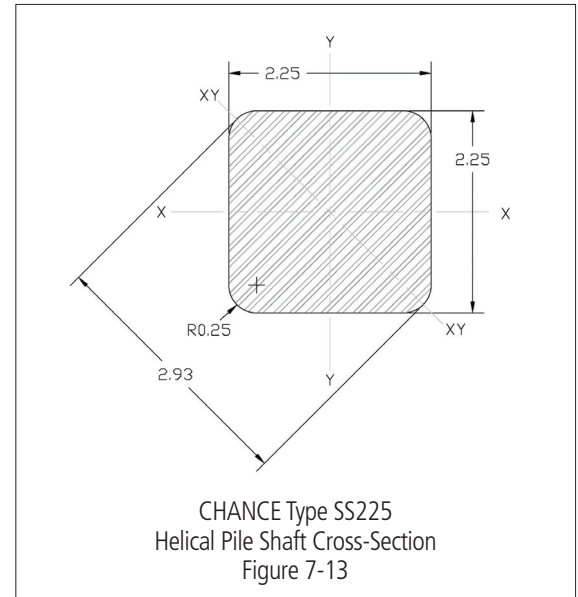
Configurations:

Triple, and quad helix Lead Sections, 5, 7 and 10 feet long

Plain Extensions, 5 and 7 feet long

Extensions with Helix Plates, 5, and 7 feet long, single and multi-helix

Helical products are Hot Dip Galvanized per ASTM A153 Class B-1.



NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Axial deflections of 0.25 to 0.50 inches are typical at allowable capacity.

Nominal, LRFD Design and ASD Allowable Strengths of SS225 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength kip (kN)	LRFD Design Strength kip (kN)	ASD Allowable Strength kip (kN)
6 (150)	0.5 (13)	188 (836.3)	169.1 (752.2)	94 (418.1)
8 (200)	0.5 (13)	188 (836.3)	169.1 (752.2)	94 (418.1)
10 (250)	0.5 (13)	151.8 (675.2)	136.6 (607.6)	75.9 (337.6)
12 (300)	0.5 (13)	141.3 (628.5)	127.2 (565.8)	70.6 (314)
14 (350)	0.5 (13)	126.3 (561.8)	113.7 (505.8)	63.2 (281.1)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

Nominal and LRFD Design Compression Strengths of CHANCE® Type SS225 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	Nominal & LRFD Design Compression Strengths, kip (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	See Helix Strength Table		See Helix Strength Table		139.0 (618.3)	125.1 (556.5)	70.9 (315.4)	63.8 (283.8)
					Single 14 inch – 126.3 (561.8)	Single 14 inch – 113.7 (505.8)		
Lead, 2-Helix 8"-10"	331.6 (1475)	298.4 (1327.3)	250.1 (1112.5)	225.1 (1001.3)	139.0 (618.3)	125.1 (556.5)	70.9 (315.4)	63.8 (283.8)
Lead, 2-Helix 10"-12"	293.1 (1303.8)	263.8 (1173.4)						
Lead, 2-Helix 12"-14"	267.6 (1190.3)	240.9 (1071.6)						
Lead, 2-Helix 14"-14"	252.6 (1123.6)	227.4 (1011.5)						
Lead, Multi-Helix	331.6 (1475)	298.4 (1327.3)						
Extension	331.6 (1475)	298.4 (1327.3)						

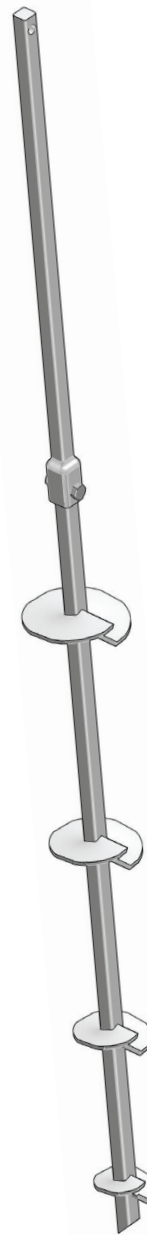
For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

SS225 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS

SHAFT	Hot Rolled Round-Cornered-Square (RCS) Solid Steel Bars per ASTM A29; modified AISI 1530 with 90 ksi minimum yield strength			
Shaft Size	2.25 in	57 mm	Corroded	
			2.237 in	56.8 mm
Moment of Inertia (I)	2.04 in ⁴	84.9 cm ⁴	Corroded	
			1.99 in ⁴	82.83 cm ⁴
Shaft Area (A)	5.0 in ²	32.1 cm ²	Corroded	
			4.93 in ²	31.81 cm ²
Section Modulus (S _{x-x})	1.81 in ³	29.7 cm ³	Corroded	
			1.79 in ³	29.37 cm ³
Perimeter	8.5 in	21.5 cm	Corroded	
			8.43 in	21.41 cm
Coupling	Integral Forged Square Deep Socket			
Coupling Bolts	One 1-1/4 inch Diameter ASTM A193 Grade B7 Hex Head Bolt with Threads Excluded from Shear Planes			
Helix Plates	0.5 inch Thick, Formed on Matching Metal Dies, ASTM A656 or A1018 Grade 80			
Coatings	Hot Dip Galvanized per ASTM A153 Class B-1, 3.1 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	10 ft ⁻¹		33 m ⁻¹	
Torque Rating	21,000 ft-lb		28,475 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	200 kip	890 kN	150 kip	667 kN
Allowable Tension Strength	100 kip		445 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	210 kip	934 kN	105 kip	467 kN


 Assembly of SS225
Figure 7-14

ASD Allowable Compression Strengths of CHANCE® Type SS225 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength kip (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	See Helix Strength Table Above	See Helix Strength Table Above	See Helix Strength Table Above, except single 6 & 8 inch - 83.2 (370.1)	42.5 (189)
Lead, 2-Helix 8"-10"	169.9 (755.8)	149.8 (666.3)	83.2 (370.1)	42.5 (189)
Lead, 2-Helix 10"-12"	146.5 (651.6)	146.5 (650.7)		
Lead, 2-Helix 12"-14"	133.8 (595.1)	133.8 (595.1)		
Lead, 2-Helix 14"-14"	126.4 (562.2)	126.4 (562.3)		
Lead, Multi-Helix	198.6 (883.4)	149.8 (666.3)	83.2 (370.1)	42.5 (189)
Extension	198.6 (883.4)	149.8 (666.3)	83.2 (370.1)	42.5 (189)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

CHANCE® Type RS2875.203 Helical Piles

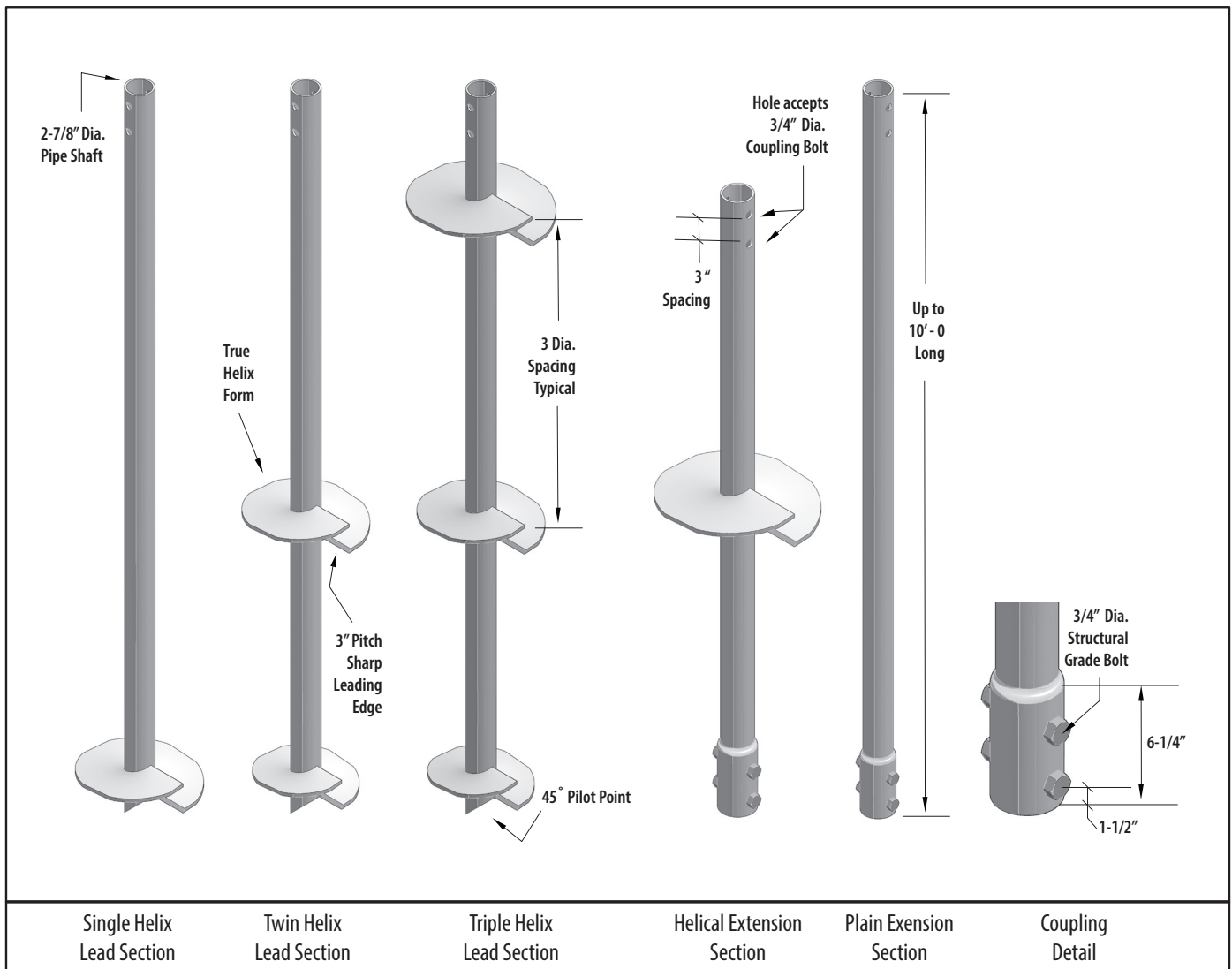
49.5 kip Ultimate – 24.75 kip Allowable Capacity

Installation Torque Rating – 5,500 ft-lb

Multi-Purpose 2-7/8" Diameter, 0.203" Wall, Round HSS Shaft with integrally formed upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type RS2875.203 Helical Piles have 49.5 kip ultimate capacity and 24.75 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Round shaft helical piles offer increased lateral and buckling resistance compared to solid square shafts with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type RS Helical Piles can be coupled with square shaft lead sections (Combo Piles) to provide greater penetration into bearing soils. CHANCE Type RS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with "sea-shell" cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.



DRAWINGS & RATINGS

All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

RS2875.203 Helical Pile Specifications & Available Configurations

Shaft – HSS 2-7/8 inch OD x 0.203 inch (schedule 40) wall steel shaft produced exclusively for CHANCE products.

Coupling – forged as an integral part of the plain and helical extension material as round deep sockets connected with multiple structural bolts.

Helix – 3/8 inch Thick: ASTM A572, or A1018, or A656 with minimum yield strength of 50 ksi.

3 inch Helix Pitch – a standard established by Hubbell Power Systems, Inc. for Helical Piles and Anchors.

Available Helix Diameters: 8, 10, 12, or 14 inches.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

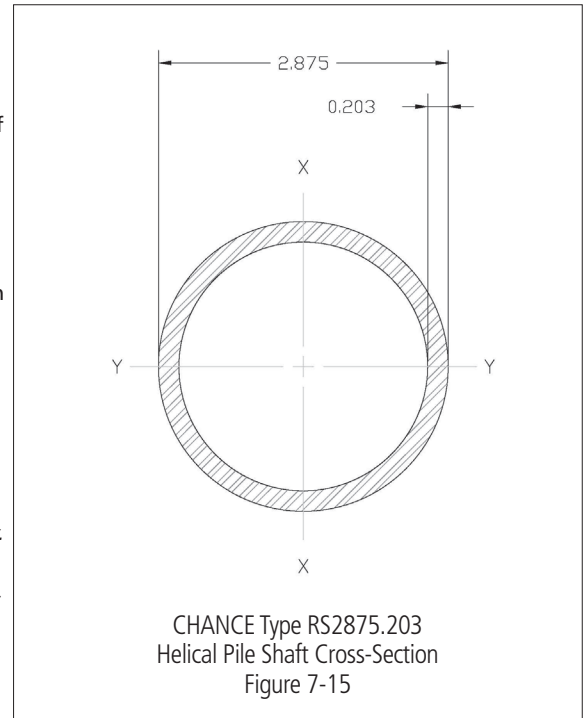
Single, double, and triple helix Lead Sections, 5, 7, and 10 feet long

Plain Extensions, 3, 5, 7, and 10 feet long

Extensions with Helix Plates, 5 and 7 feet long

Helical products are Hot Dip Galvanized per ASTM A153 Class B-1.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



Nominal, LRFD Design and ASD Allowable Strengths of RS2875.203 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength kip (kN)	LRFD Design Strength kip (kN)	ASD Allowable Strength kip (kN)
8 (200)	0.375 (9.5)	85.8 (381.7)	77.2 (343.4)	42.9 (190.8)
10 (250)	0.375 (9.5)	73.6 (327.4)	66.3 (294.9)	36.8 (163.7)
12 (300)	0.375 (9.5)	75.6 (336.3)	68.0 (302.5)	37.8 (168.1)
14 (350)	0.375 (9.5)	61.0 (271.3)	54.9 (244.2)	30.5 (135.7)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

Nominal and LRFD Design Compression Strengths of CHANCE® Type RS2875.203 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	Nominal & LRFD Design Compression Strengths kips (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	69.0 (306.9)	62.1 (276.2)	64.3 (286.0)	57.9 (257.6)	55.5 (246.9)	49.9 (222.0)	42.0 (186.8)	37.8 (168.1)
	For Single 14"– 61 (271.3)	For Single 14"– 54.9 (244.2)	For Single 14"– 61.0 (271.3)	For Single 14"– 57.9 (257.6)				
Lead, Multi-Helix	69.0 (306.9)	62.1 (276.2)	64.3 (286.0)	57.9 (257.6)	55.5 (246.9)	49.9 (222.0)	42.0 (186.8)	37.8 (168.1)
Extension	69.0 (306.9)	62.1 (276.2)	64.3 (286.0)	57.9 (257.6)				

For SI: 1 kip = 4.448 kN.

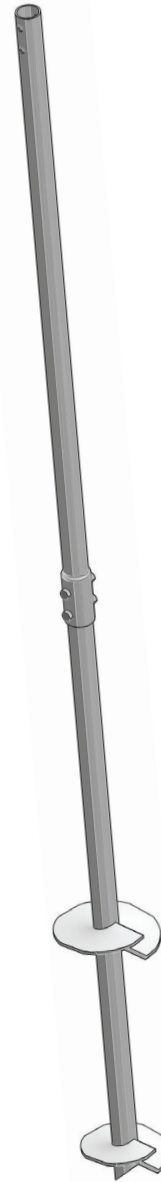
¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

DRAWINGS & RATINGS

RS2875.203 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled HSS 2-1/2 inch Nominal Schedule 40 (0.203 inch nominal wall) per ASTM A500 Grade B/C with 50 ksi minimum yield strength			
Shaft Size, OD	2.875 in	73 mm	Corroded	
			2.862 in	72.7 mm
Shaft Size, ID*	2.497 in	63.4 mm	Corroded	
			2.510 in	63.75 mm
Moment of Inertia (I)*	1.44 in ⁴	59.9 cm ⁴	Corroded	
			1.344 in ⁴	55.9 cm ⁴
Shaft Area (A)*	1.59 in ²	10.3 cm ²	Corroded	
			1.48 in ²	9.57 cm ²
Section Modulus (S _{x-x})*	1.0 in ³	16.4 cm ³	Corroded	
			0.939 in ³	15.4 cm ³
Perimeter	9.0 in	22.8 cm	Corroded	
			8.99 in	22.8 cm
Coupling	Integral Forged Round Deep Socket Sleeve			
Coupling Bolts	Two ¾ in Diameter SAE J429 Grade 5 Hex Head Bolts with Threads Excluded from Shear Planes			
Helix Plates	0.375 inch Thick, Formed on Matching Metal Dies, ASTM A572 Grade 50 or better			
Coatings	Hot Dip Galvanized per ASTM A153 Class B-1, 3.1 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	9 ft ⁻¹		30 m ⁻¹	
Torque Rating	5,500 ft-lb		7,500 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	60 kip	267 kN	45 kip	200 kN
Allowable Tension Strength	30 kip		133 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	49.5 kip	220 kN	24.75 kip	110 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS2875.203
Figure 7-16

ASD Allowable Compression Strengths of CHANCE® Type RS2875.203 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength kips (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	For Single 8" – 41.3 (183.7)		For Single 8" – 38.5 (171.3)	
	See Helix Strength Table Above for 10", 12" & 14"		See Helix Strength Table Above for 10", 12" & 14"	
Lead, 2-Helix 8"-10"	41.3 (183.7)	38.5 (171.3)	33.2 (147.7)	25.1 (111.7)
Lead, 2-Helix 10"-12"			33.2 (147.7)	
Lead, 2-Helix 12"-14"				33.2 (147.7)
Lead, 2-Helix 14"-14"			25.1 (111.7)	
Lead, Multi-Helix	41.3 (183.7)	38.5 (171.3)	33.2 (147.7)	25.1 (111.7)
Extension	41.3 (183.7)	38.5 (171.3)	33.2 (147.7)	25.1 (111.7)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

CHANCE® Type RS2875.276 Helical Piles

72 kip Ultimate – 36 kip Allowable Capacity

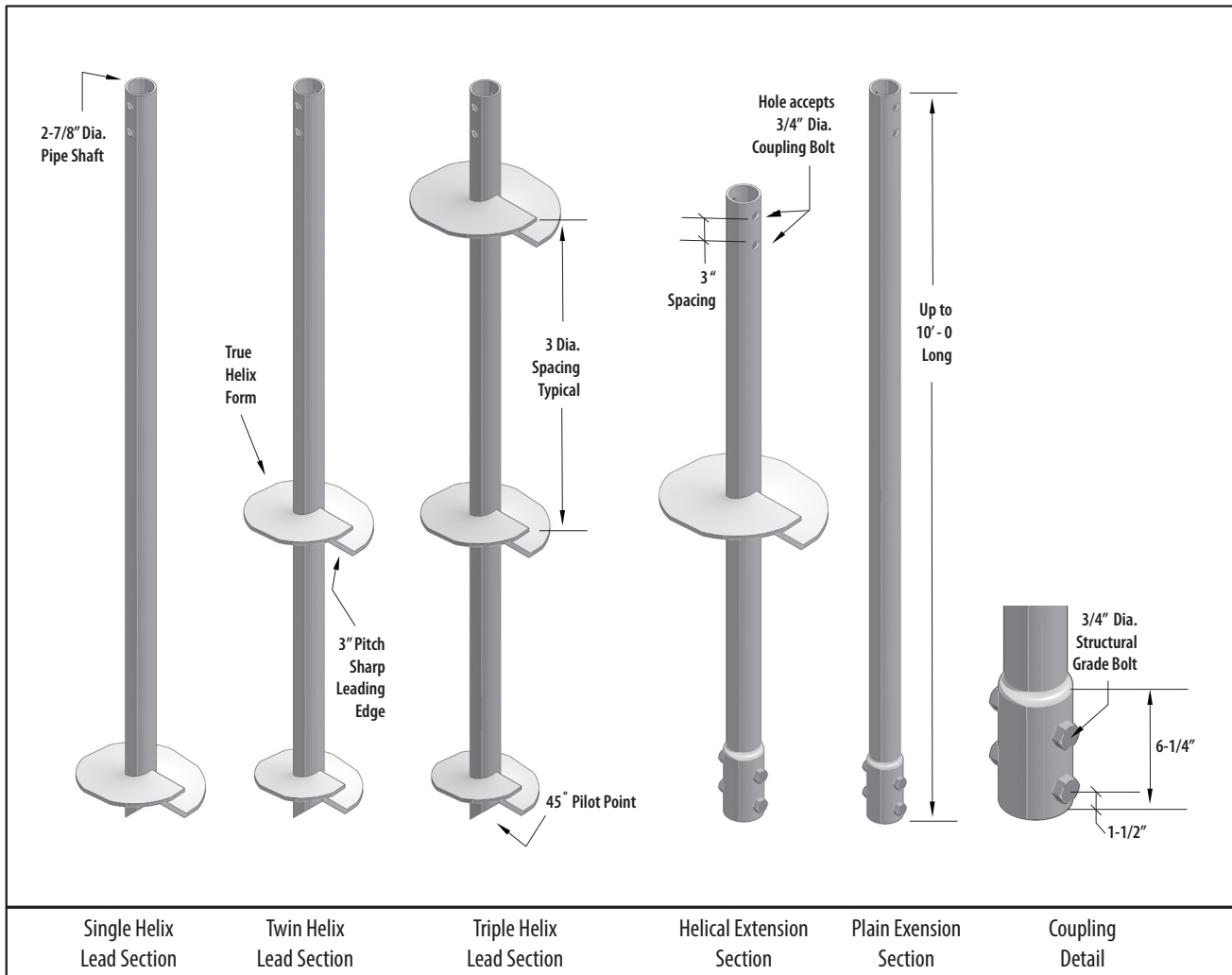
Installation Torque Rating – 8,000 ft-lb

Multi-Purpose 2-7/8" Diameter, 0.276" Wall, Round HSS Shaft with integrally formed upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type RS2875.276 Helical Piles have 72 kip ultimate capacity and 36 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Round shaft helical piles offer increased lateral and buckling resistance compared to solid square shafts with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type RS Helical Piles can be coupled with square shaft lead sections (Combo Piles) to provide greater penetration into bearing soils. CHANCE Type RS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with "sea-shell" cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

DRAWINGS & RATINGS



All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

RS2875.276 Helical Pile Specifications & Available Configurations

Shaft – HSS 2-7/8 inch OD x 0.276 inch (schedule 80) wall steel shaft produced exclusively for CHANCE products.

Coupling – forged as an integral part of the plain and helical extension material as round deep sockets connected with multiple structural bolts.

Helix – 3/8 inch Thick: ASTM A656, or A1018 with minimum yield strength of 80 ksi.

3 inch Helix Pitch – a standard established by Hubbell Power Systems, Inc. for CHANCE Helical Piles and Anchors.

Available Helix Diameters: 8, 10, 12, or 14 inches.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

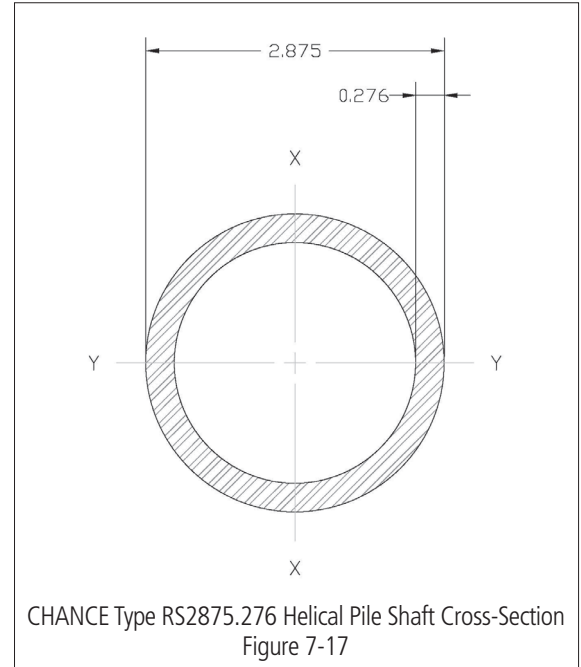
Single, double, and triple and quad helix Lead Sections, 3.5, 5, 7, and 10 feet long

Plain Extensions, 3, 5, 7, and 10 feet long

Extensions with Helix Plates, 3 feet long

Helical products are Hot Dip Galvanized per ASTM A153 Class B-1.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



Nominal, LRFD Design and ASD Allowable Strengths of RS2875.276 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength kip (kN)	LRFD Design Strength kip (kN)	ASD Allowable Strength kip (kN)
8 (200)	0.375 (9.5)	121.4 (540.0)	109.3 (486.2)	60.7 (270.0)
10 (250)	0.375 (9.5)	98.9 (439.9)	89.0 (395.9)	49.5 (220.2)
12 (300)	0.375 (9.5)	85.3 (379.4)	76.8 (341.6)	42.7 (189.9)
14 (350)	0.375 (9.5)	53.7 (238.9)	48.3 (214.9)	26.9 (119.7)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

Nominal and LRFD Design Compression Strengths of CHANCE® Type RS2875.276 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	Nominal & LRFD Design Compression Strengths kips (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	92.9 (413.2)	83.6 (371.9)	86.3 (383.9)	77.7 (345.6)	73.9 (328.7)	66.5 (295.8)	55.2 (245.5)	49.7 (221.1)
	See Helix Table Above For Single 12" & 14"				See Helix Table Above For Single 14"			
Lead, Multi-Helix	92.9 (413.2)	83.6 (371.9)	86.3 (383.9)	77.7 (345.6)	73.9 (328.7)	66.5 (295.8)	55.2 (245.5)	49.7 (221.1)
Extension	92.9 (413.2)	83.6 (371.9)	86.3 (383.9)	77.7 (345.6)				

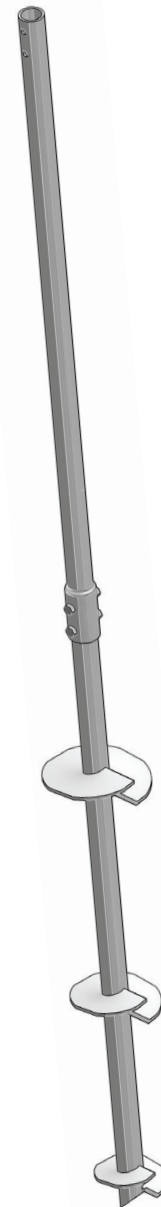
For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

RS2875.276 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled HSS 2-1/2 inch Nominal Schedule 80 (0.276 inch nominal wall) per ASTM A500 Grade B/C with 50 ksi minimum yield strength			
Shaft Size, OD	2.875 in	73 mm	Corroded	
			2.862 in	72.7 mm
Shaft Size, ID*	2.36 in	60 mm	Corroded	
			2.375 in	60.3 mm
Moment of Inertia (I)*	1.83 in ⁴	76.2 cm ⁴	Corroded	
			1.733 in ⁴	72.1 cm ⁴
Shaft Area (A)*	2.11 in ²	13.6 cm ²	Corroded	
			2.0 in ²	12.9 cm ²
Section Modulus (S _{x-x})*	1.27 in ³	20.8 cm ³	Corroded	
			1.21 in ³	19.8 cm ³
Perimeter	9.0 in	22.8 cm	Corroded	
			8.99 in	22.8 cm
Coupling	Integral Forged Round Deep Socket Sleeve			
Coupling Bolts	Two 3/4 in Diameter SAE J429 Grade 5 Hex Head Bolts with Threads Excluded from Shear Planes			
Helix Plates	0.375 inch Thick, Formed on Matching Metal Dies, ASTM A656 Grade 80 or better			
Coatings	Hot Dip Galvanized per ASTM A153 Class B-1, 3.1 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	9 ft ⁻¹		30 m ⁻¹	
Torque Rating	8,000 ft-lb		10,846 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	90 kip	400 kN	67.5 kip	300 kN
Allowable Tension Strength	45 kip		200 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	72 kip	320 kN	36 kip	160 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS2875.276
Figure 7-18

ASD Allowable Compression Strengths of CHANCE® Type RS2875.276 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength kips (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	For Single 8" – 55.6 (247.3)	For Single 8" – 51.7 (230.0)	44.3 (197.1)	33.0 (146.8)
	See Helix Strength Table Above for 10", 12" & 14"	See Helix Strength Table Above for 10", 12" & 14"	See Helix Strength Table Above for 12" & 14"	For Single 14" – 26.9
Lead, 2-Helix 8"-10"	55.6 (247.3)	51.7 (230.0)	44.3 (197.1)	33.0 (146.8)
Lead, 2-Helix 10"-12"				
Lead, 2-Helix 12"-14"				
Lead, 2-Helix 14"-14"				
Lead, Multi-Helix	55.6 (247.3)	51.7 (230.0)	44.3 (197.1)	33.0 (146.8)
Extension	55.6 (247.3)	51.7 (230.0)	44.3 (197.1)	33.0 (146.8)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

CHANCE® Type RS3500.300 Helical Piles

91 kip Ultimate – 45.5 kip Allowable Capacity

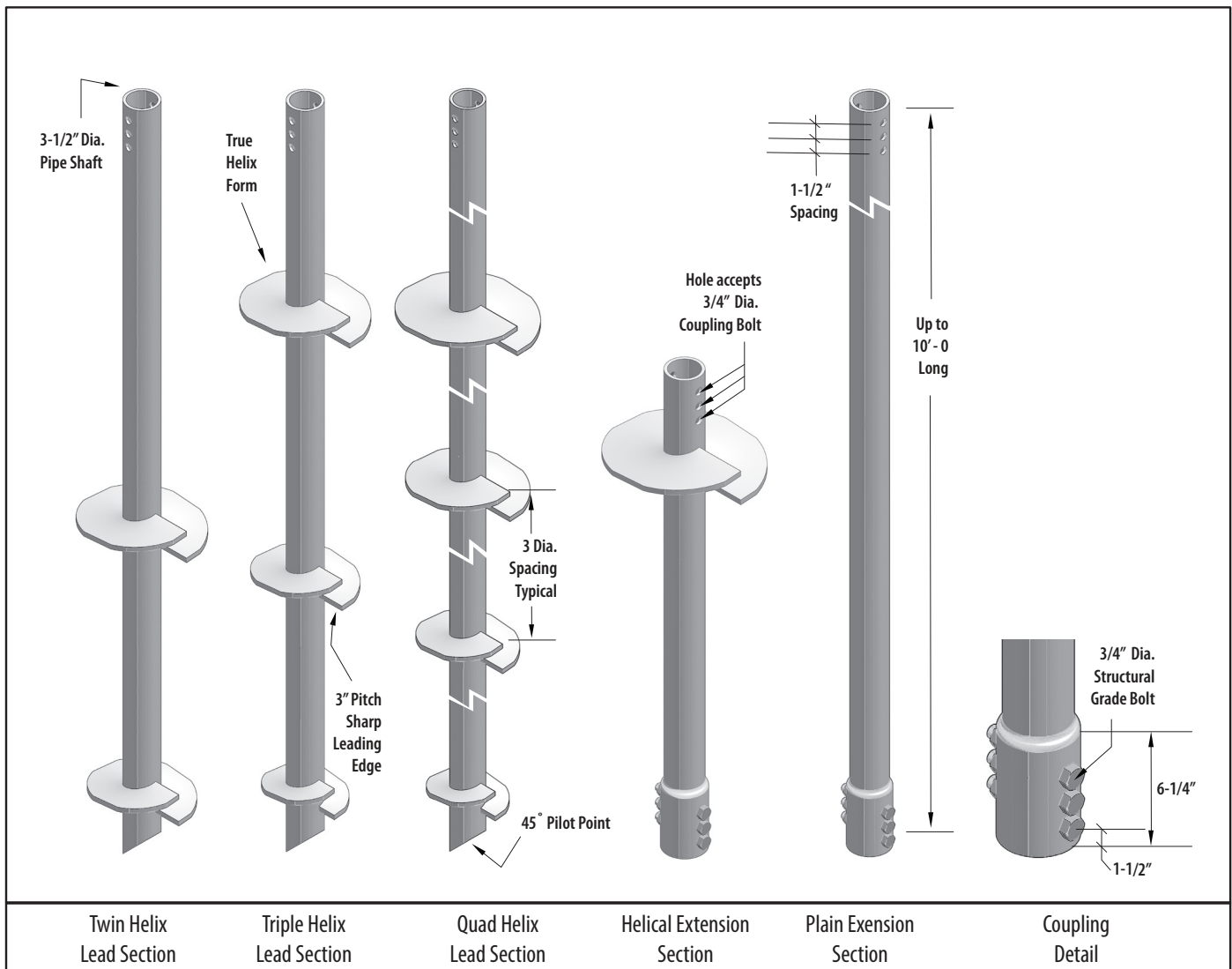
Installation Torque Rating – 13,000 ft-lb

Multi-Purpose 3-1/2" Diameter, 0.300" Wall, Round HSS Shaft with integrally formed upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type RS3500.300 Helical Piles have 91 kip ultimate capacity and 45.5 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Round shaft helical piles offer increased lateral and buckling resistance compared to solid square shafts with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type RS Helical Piles can be coupled with square shaft lead sections (Combo Piles) to provide greater penetration into bearing soils. CHANCE Type RS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with "sea-shell" cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

DRAWINGS & RATINGS



All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

RS3500.300 Helical Pile Specifications & Available Configurations

Shaft – HSS 3-1/2 inch OD x 0.300 inch (schedule 80) wall steel shaft produced exclusively for CHANCE products.

Coupling - forged as an integral part of the plain and helical extension material as round deep sockets connected with multiple structural bolts.

Helix – 1/2 inch Thick: ASTM A572, or A1018, or A656 with minimum yield strength of 50 ksi.

3 inch Helix Pitch – a Standard established by Hubbell Power Systems, Inc. for CHANCE Helical Piles and Anchors.

Available Helix Diameters: 8, 10, 12, 14 or 16 inches.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

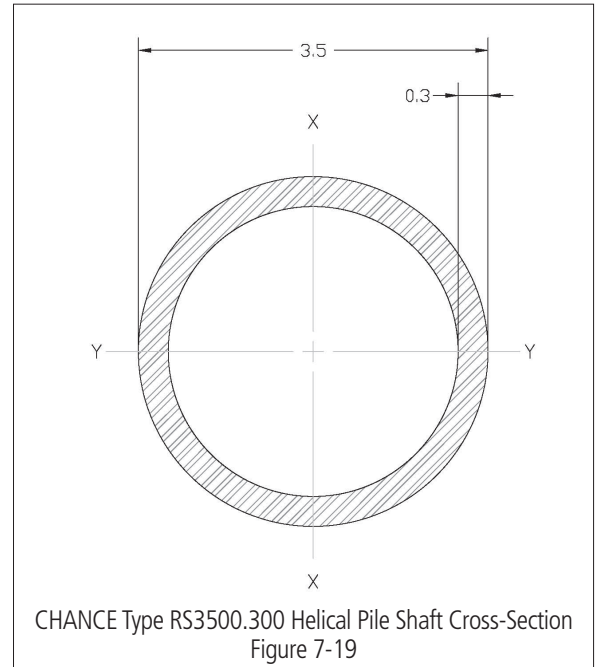
Single, double, triple, and quad helix Lead Sections, 3, 5, 7, and 10 feet long

Plain Extensions, 3, 5, 7, and 10 feet long

Extensions with Helix Plates, 3-1/2 7 and 10 feet long

Helical products are Hot Dip Galvanized per ASTM A123 Grade 75.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



DRAWINGS & RATINGS

Nominal, LRFD Design and ASD Allowable Strengths of RS3500.300 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength kip (kN)	LRFD Design Strength kip (kN)	ASD Allowable Strength kip (kN)
8 (200)	0.5 (13)	158.3 (704.2)	142.4 (633.4)	79.1 (351.9)
10 (250)	0.5 (13)	132.5 (589.3)	119.3 (530.7)	66.3 (294.9)
12 (300)	0.5 (13)	98.4 (437.7)	88.6 (394.1)	49.2 (187.7)
14 (350)	0.5 (13)	132.3 (588.5)	119.0 (529.3)	66.2 (294.5)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

Nominal and LRFD Design Compression Strengths of CHANCE® Type RS3500.300 Helical Pile Lead & Extension Sections^{1,2}

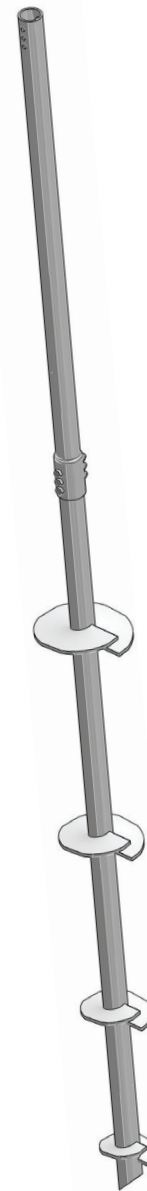
Section Type & Helix Count	Nominal & LRFD Design Compression Strengths kips (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	128.0 (569.4)	115.2 (512.4)	121.9 (542.2)	109.7 (488.0)	110.0 (489.3)	99.0 (440.3)	90.7 (403.5)	81.6 (363.0)
	For Single 12" – 98.4 (437.7)	For Single 12" – 88.6 (394.1)	For Single 12" – 98.4 (437.7)	For Single 12" – 88.6 (394.1)	For Single 12" – 98.4 (437.7)	For Single 12" – 88.6 (394.1)		
Lead, Multi-Helix	128 (569.4)	115.2 (512.4)	121.9 (542.2)	109.7 (488.0)	110.0 (489.3)	99.0 (440.4)	90.7 (403.5)	81.6 (363.0)
Extension	128.0 (569.4)	115.2 (512.4)	121.9 (542.2)	109.7 (488.0)				

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

RS3500.300 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled HSS 3 inch Nominal Schedule 80 (0.300 inch nominal wall) per ASTM A500 Grade B/C with 50 ksi minimum yield strength			
Shaft Size, OD	3.5 in	89 mm	Corroded	
			3.487 in	63.2 mm
Shaft Size, ID*	2.942 in	74.7 mm	Corroded	
			2.955 in	75.1 mm
Moment of Inertia (I)*	3.69 in ⁴	153.6 cm ⁴	Corroded	
			3.514 in ⁴	146.3 cm ⁴
Shaft Area (A)*	2.82 in ²	18.2 cm ²	Corroded	
			2.692 in ²	17.4 cm ²
Section Modulus (S _{x-x})*	2.11 in ³	34.5 cm ³	Corroded	
			2.016 in ³	33.0 cm ³
Perimeter	11.0 in	27.9 cm	Corroded	
			10.95 in	27.8 cm
Coupling	Integral Forged Round Deep Socket Sleeve			
Coupling Bolts	Three ¾ in Dia. SAE J429 Grade 5 Hex Head Bolts with Threads Excluded from Shear Planes			
Helix Plates	0.5 inch Thick, Formed on Matching Metal Dies, ASTM A572 Grade 50 or better			
Coatings	Hot Dip Galvanized per ASTM A123 Grade 75, 3.0 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	7 ft ⁻¹		23 m ⁻¹	
Torque Rating	13,000 ft-lb		17,600 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	120 kip	534 kN	90 kip	400 kN
Allowable Tension Strength	60 kip		261 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	91 kip	405 kN	45.5 kip	202.5 kN



Assembly of RS3500.300
Figure 7-20

DRAWINGS & RATINGS

* computed with 93% of wall thickness per AISC 360-10, B4.2

ASD Allowable Compression Strengths of CHANCE® Type RS3500.300 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength kips (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	For Single 8" – 76.6 (340.7)	For Single 8" – 73.0 (324.7)	65.9 (293.1)	54.3 (241.5)
	See Helix Strength Table Above for 10", 12" & 14"	See Helix Strength Table Above for 10", 12" & 14"	For Single 12" – 49.2 (218.9)	For Single 12" – 49.2 (218.9)
Lead, 2-Helix 8"-10"	76.6 (340.7)	73.0 (324.7)	65.9 (293.1)	54.3 (241.5)
Lead, 2-Helix 10"-12"				
Lead, 2-Helix 12"-14"				
Lead, 2-Helix 14"-14"				
Lead, Multi-Helix	76.6 (340.7)	73.0 (324.7)	65.9 (293.1)	54.3 (241.5)
Extension	76.6 (340.7)	73.0 (324.7)	65.9 (293.1)	54.3 (241.5)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

CHANCE® Type RS4500.337 Helical Piles

138 kip Ultimate – 69 kip Allowable Capacity

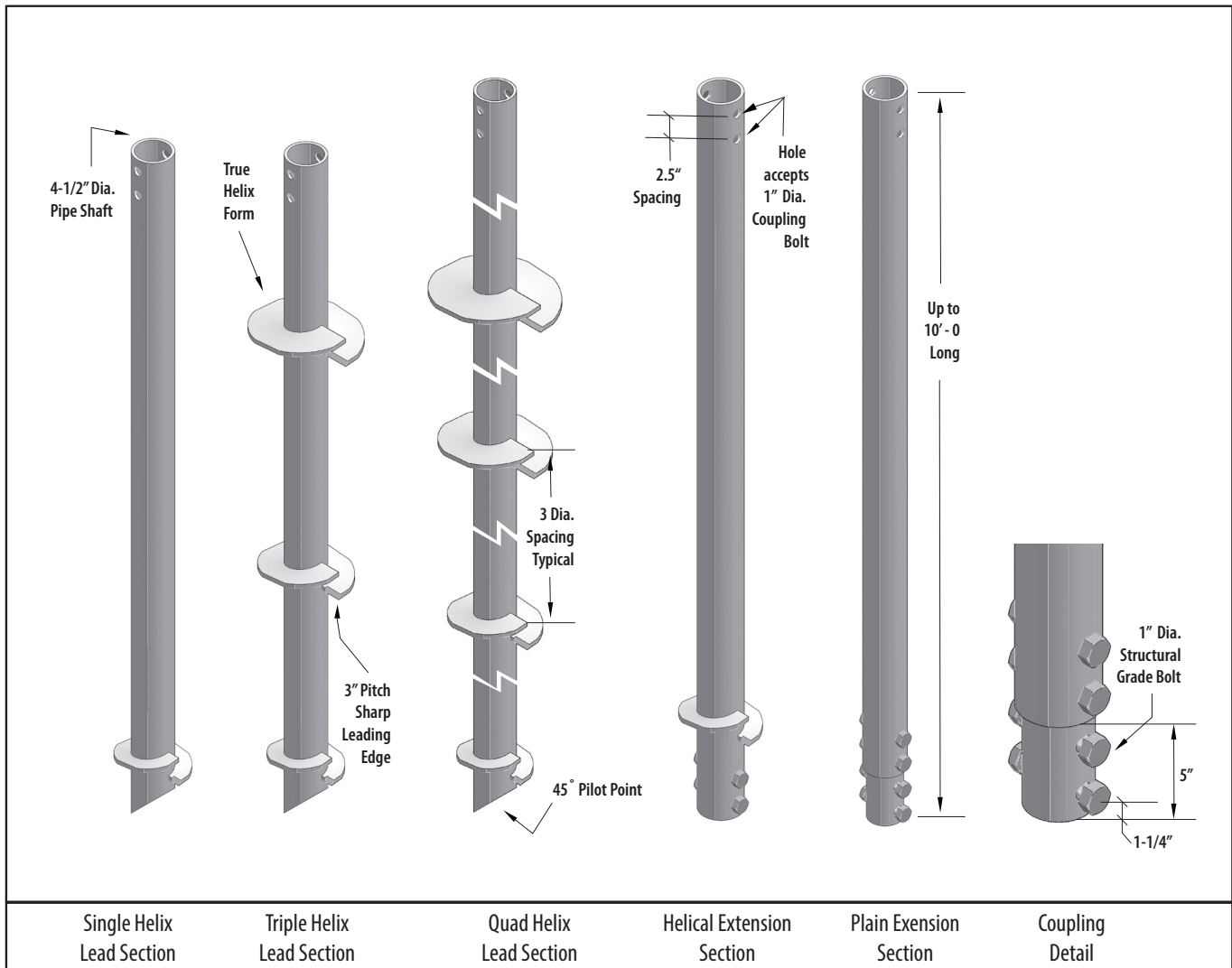
Installation Torque Rating – 23,000 ft-lb

Multi-Purpose 4-1/2" Diameter, 0.337" Wall, Round HSS Shaft with integrally formed upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type RS4500.337 Helical Piles have 138 kip ultimate capacity and 69 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Round shaft helical piles offer increased lateral and buckling resistance compared to solid square shafts with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type RS Helical Piles can be coupled with square shaft lead sections (Combo Piles) to provide greater penetration into bearing soils. CHANCE Type RS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with "sea-shell" cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

DRAWINGS & RATINGS



All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

RS4500.337 Helical Pile Specifications & Available Configurations

Shaft – HSS 4-1/2 inch OD x 0.337 inch (schedule 80) wall steel shaft produced exclusively for CHANCE products.

Coupling – internal sleeve consisting of precision matched steel tube section connected with multiple structural bolts.

Helix – 1/2 inch Thick: ASTM A572, or A1018, or A656 with minimum yield strength of 80 ksi.

3 inch Helix Pitch – a Standard established by Hubbell Power Systems, Inc. for CHANCE Helical Piles and Anchors.

Available Helix Diameters: 8, 10, 12, 14, 16, or 20 inches.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The Standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

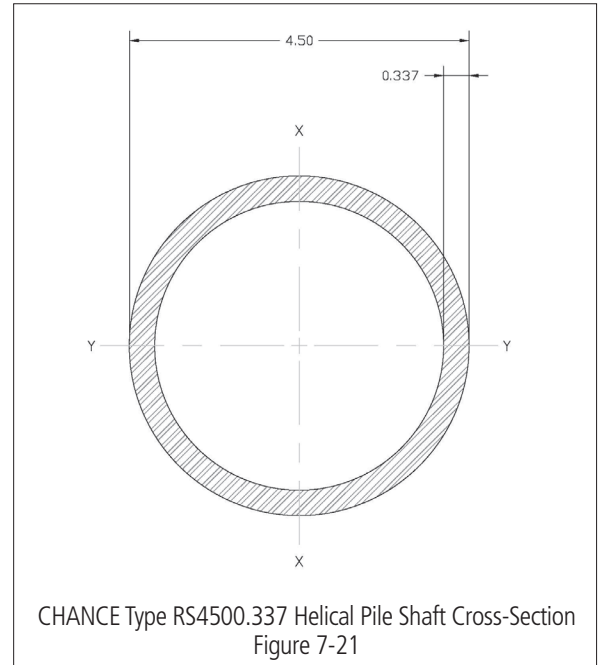
Single, double, triple, and quad helix Lead Sections, 7 and 10 feet long

Plain Extensions, 3, 5, 7, and 10 feet long

Extensions with Helix Plates, 5, 7 and 10 feet long

Helical products are Hot Dip Galvanized per ASTM A123 Grade 75.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



Nominal, LRFD Design and ASD Allowable Strengths of RS4500.337 Helix Plates for Shaft Axial Tension and Compression¹

Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength kip (kN)	LRFD Design Strength kip (kN)	ASD Allowable Strength kip (kN)
8 (200)	0.5 (13)	244.5 (1087.6)	220.1 (979.1)	122.3 (499.5)
10 (250)	0.5 (13)	200.3 (891.0)	180.3 (802.0)	100.2 (445.7)
12 (300)	0.5 (13)	168.5 (749.5)	151.7 (674.8)	84.3 (375.0)
14 (350)	0.5 (13)	133.0 (591.6)	119.7 (532.5)	66.5 (295.8)

For SI: 1 kip = 4.448 kN.

¹Capacities based on a design corrosion level of 50-years.

Nominal and LRFD Design Compression Strengths of CHANCE® Type RS4500.337 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	Nominal & LRFD Design Compression Strengths kips (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design	Nominal	Design	Nominal	Design	Nominal	Design
Lead, Single Helix	191.7 (852.7)	172.6 (767.7)	186.3 (828.7)	167.7 (746.0)	175.3 (779.8)	157.8 (701.9)	156.3 (695.3)	140.7 (625.9)
	See Helix Strength Table Above For Single 12" & 14"						For Single 14" – 133.0 (591.6)	For Single 14" – 119.7 (532.5)
Lead, Multi-Helix	191.7 (852.7)	172.6 (767.8)	186.3 (828.7)	167.7 (746.0)	175.3 (779.8)	157.8 (701.9)	156.3 (695.3)	140.7 (625.9)
Extension	191.7 (852.7)	172.6 (767.8)	186.3 (828.7)	167.7 (746.0)				

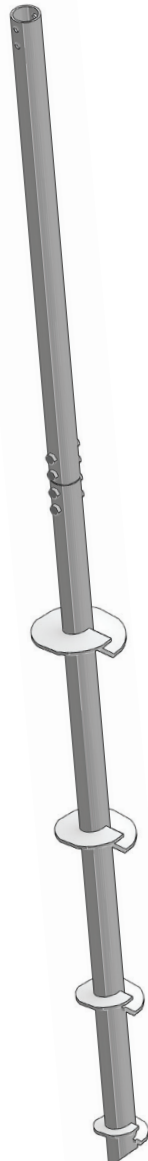
For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

RS4500.337 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS

SHAFT	Hot Rolled HSS 4 inch Nominal Schedule 80 (0.337 inch nominal wall) per ASTM A500 Grade B/C with 50 ksi minimum yield strength			
Shaft Size, OD	4.5 in	114 mm	Corroded	
			4.487 in	114 mm
Shaft Size, ID*	3.874 in	98.4 mm	Corroded	
			3.886 in	98.7 mm
Moment of Inertia (I)*	9.07 in ⁴	377.5 cm ⁴	Corroded	
			8.701 in ⁴	362.2 cm ⁴
Shaft Area (A)*	4.12 in ²	26.6 cm ²	Corroded	
			3.951 in ²	25.5 cm ²
Section Modulus (S _{x-x})*	4.03 in ³	66.1 cm ³	Corroded	
			3.878 in ³	63.6 cm ³
Perimeter	14.1 in	35.9 cm	Corroded	
			14.09 in	35.8 cm
Coupling	Internal Sleeve Steel Tube Section			
Coupling Bolts	Four 1 in Dia. SAE J429 Grade 8 Hex Head Bolts			
Helix Plates	0.5 inch Thick, Formed on Matching Metal Dies, ASTM A572 Grade 80 or better			
Coatings	Hot Dip Galvanized per ASTM A123 Grade 75, 3.0 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	6 ft ⁻¹		20 m ⁻¹	
Torque Rating	23,000 ft-lb		31,200 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	160 kip	712 kN	120 kip	534 kN
Allowable Tension Strength	80 kip		356 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	138 kip	614 kN	69 kip	307 kN


 Assembly of RS4500.337
Figure 7-22

* computed with 93% of wall thickness per AISC 360-10, B4.2

ASD Allowable Compression Strengths of CHANCE® Type RS4500.337 Helical Pile Lead & Extension Sections^{1,2}

Section Type & Helix Count	ASD Allowable Axial Compression Strength kips (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	For Single 8" – 114.8 (551.7)	For Single 8" – 111.6 (496.4)	105.0 (467.1)	93.6 (416.4)
	See Helix Strength Table Above for 10", 12" & 14"	See Helix Strength Table Above for 10", 12" & 14"	See Helix Strength Table Above for 10", 12" & 14"	See Helix Strength Table Above for 12" & 14"
Lead, 2-Helix 8"-10"	114.8 (551.7)	111.6 (496.4)	105.0 (467.1)	93.6 (416.4)
Lead, 2-Helix 10"-12"				
Lead, 2-Helix 12"-14"				
Lead, 2-Helix 14"-14"	114.8 (551.7)	111.6 (496.4)	105.0 (467.1)	93.6 (416.4)
Lead, Multi-Helix				
Extension	114.8 (551.7)	111.6 (496.4)	105.0 (467.1)	93.6 (416.4)

For SI: 1 kip = 4.448 kN.

¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.


CHANCE® Type RS6625.280 Helical Piles

200 kip Ultimate – 100 kip Allowable Capacity

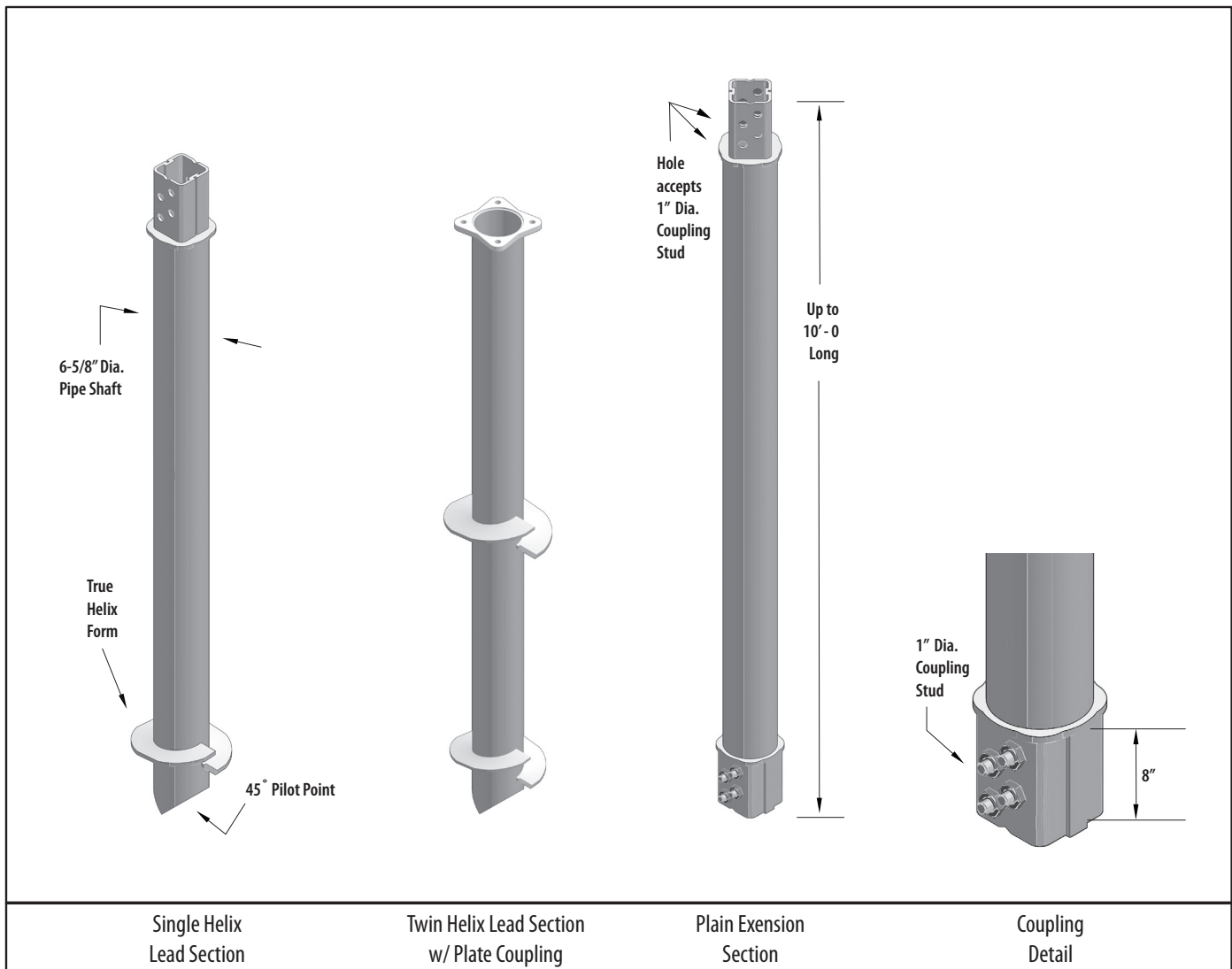
Installation Torque Rating – 40,000 ft-lb

Multi-Purpose 6-5/8" Diameter, 0.280" Wall, Round HSS Shaft with welded square formed couplings

Description:

Hubbell Power Systems, Inc., CHANCE Type RS6625.280 Helical Piles have 200 kip ultimate capacity and 100 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Round shaft helical piles offer increased lateral and buckling resistance compared to solid square shafts with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type RS Helical Piles can be coupled with square shaft lead sections (Combo Piles) to provide greater penetration into bearing soils. CHANCE Type RS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with "sea-shell" cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.

DRAWINGS & RATINGS



All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

RS6625.280 Helical Pile Specifications & Available Configurations

Shaft – HSS 6-5/8 inch OD x 0.280 inch (schedule 40) wall steel shaft produced exclusively for CHANCE products.

Coupling – formed and welded as a deep square socket, connected with multiple threaded studs & nuts.

Helix – 1/2 inch Thick: ASTM A572, or A1018, or A656 with minimum yield strength of 80 ksi.

3 inch Helix Pitch – a Standard established by Hubbell Power Systems, Inc. for CHANCE Helical Piles and Anchors.

Available Helix Diameters: 12, 14, and 16 inches.

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The Standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

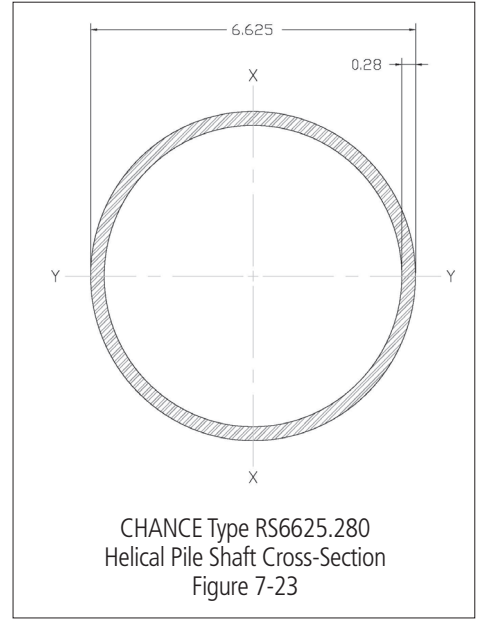
Single, double, triple, Lead Sections, 7, 10, and 15 feet long

Plain Extensions, 5, 7, and 10 feet long

Extensions with Helix Plates, 5, 7 and 10 feet long

Helical products are Hot Dip Galvanized per ASTM A123 Grade 75.

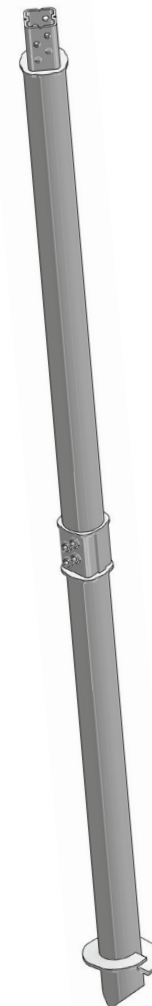
NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



DRAWINGS & RATINGS

RS6625.280 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled HSS 6 inch Nominal Schedule 40 (0.280 inch nominal wall) per ASTM A500 Grade B/C with 50 ksi minimum yield strength			
Shaft Size, OD	6.625 in	168 mm	Corroded	
			6.612 in	167.95 mm
Shaft Size, ID*	6.10 in	155.1 mm	Corroded	
			6.118 in	155.4 mm
Moment of Inertia (I)*	26.37 in ⁴	1096.1 cm ⁴	Corroded	
			25.05 in ⁴	1041.2 cm ⁴
Shaft Area (A)*	5.2 in ²	33.55 cm ²	Corroded	
			4.94 in ²	31.9 cm ²
Section Modulus (S _{x-x})*	7.96 in ³	130.2 cm ³	Corroded	
			7.58 in ³	124 cm ³
Perimeter	20.8 in	52.8 cm	Corroded	
			20.77 in	52.7 cm
Coupling	Formed and Welded Square Socket			
Coupling Bolts	Four 1 in Dia. Grade 2 Studs			
Helix Plates	0.5 inch Thick, Formed on Matching Metal Dies, ASTM A572 Grade 80 or better			
Coatings	Hot Dip Galvanized per ASTM A123 Grade 75, 3.0 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	5 ft ⁻¹		13 m ⁻¹	
Torque Rating	40,000 ft-lb		54,233 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	200 kip	890 kN	150 kip	667 kN
Allowable Tension Strength	100 kip		445 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	200 kip	890 kN	100 kip	445 Kn

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS6625.280
Figure 7-24

CHANCE® Type RS8625.250 Helical Piles

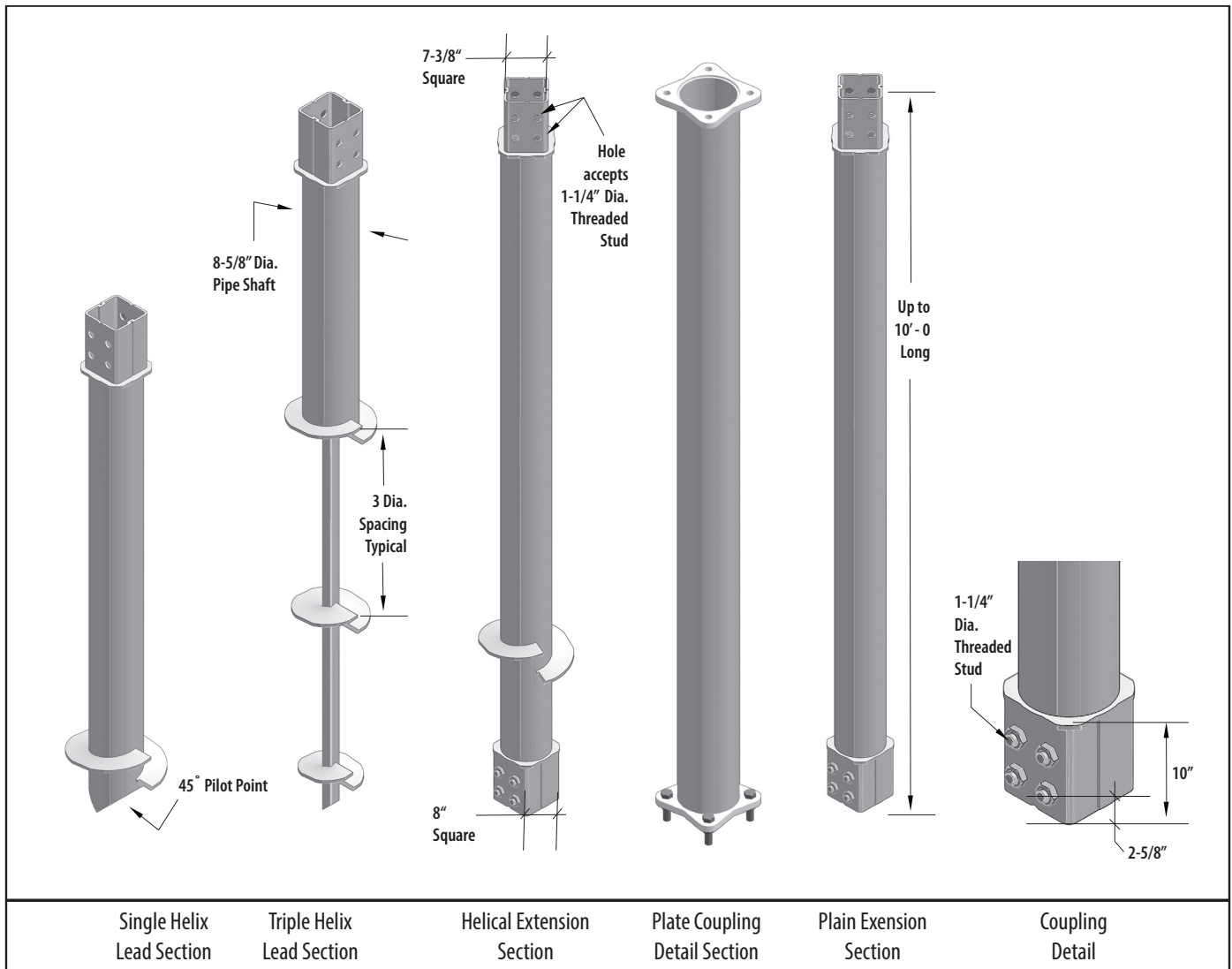
300 kip Ultimate – 150 kip Allowable Capacity

Installation Torque Rating – 60,000 ft-lb

Multi-Purpose 8-5/8" Diameter, 0.250" Wall, Round HSS Shaft with welded square formed couplings

Description:

Hubbell Power Systems, Inc. , CHANCE Type RS8625.280 Helical Piles have 300 kip ultimate capacity and 150 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity per IBC Section 1810.3.3.1.9. Lead sections and extensions couple together to extend the helix bearing plates to the required load bearing stratum. Round shaft helical piles offer increased lateral and buckling resistance compared to solid square shafts with similar torque strength. Strength calculations are based on a design corrosion level of 50 years for most soil conditions. CHANCE Type RS Helical Piles can be coupled with square shaft lead sections (Combo Piles) to provide greater penetration into bearing soils. CHANCE Type RS Helical Piles and Anchors feature sharpened leading edge helix plates that are circular in plan to provide uniform load bearing in most soil conditions. Helix plates can be equipped with "sea-shell" cuts on the leading edge to enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See below for additional information and other sections of this Technical Manual for specifications and design details.



DRAWINGS & RATINGS

All Hubbell Power Systems, Inc. CHANCE Helical Products are MADE IN THE U.S.A.

RS8625.250 Helical Pile Specifications & Available Configurations

Shaft – HSS 8-5/8 inch OD x 0.250 inch (schedule 20) wall steel shaft produced exclusively for CHANCE products.

Coupling – formed and welded as a deep square socket, connected with multiple threaded studs and nuts.

Helix – 1/2, 5/8, and 3/4 inch Thick: ASTM A572, or A1018, or A656 with minimum yield strength of 50 and 80 ksi, depending on helix diameter.

6 inch Helix Pitch – a standard established by Hubbell Power Systems, Inc. for larger diameter CHANCE Helical Anchors and Piles.

Available Helix Diameters: 16, 18, and 24 inches

All helix plates are spaced 3 times the diameter of the preceding (lower) helix unless otherwise specified.

The Standard helix plate has straight sharpened leading edges or can be ordered with a “sea shell” cut. The “sea shell” cut is best suited when it is necessary to penetrate soils with fill debris, cobbles, or fractured rock.

Configurations:

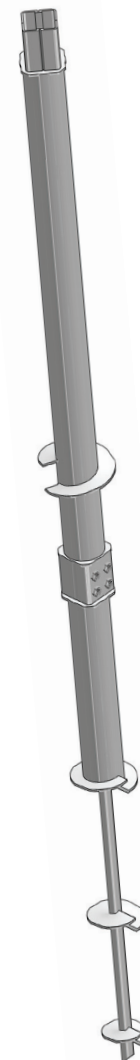
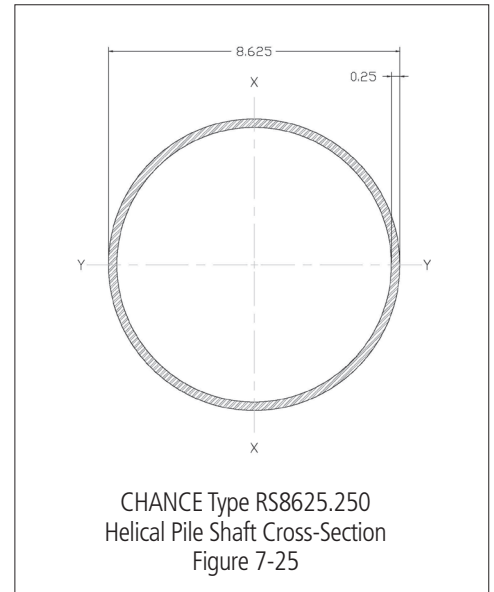
Single, double, triple, Lead Sections, 5, 7, 10, 15, and 20 feet long

Plain Extensions, 5, 7, 10, 15, and 10 feet long

Extensions with Helix Plates, 10 feet long

Helical products are Hot Dip Galvanized per ASTM A123 Grade 75.

NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum factor of safety of 2 is recommended for determining allowable capacity from correlations. Deflections of 0.25 to 0.50 inches are typical at allowable capacity.



Assembly of RS8625.250
Figure 7-26

RS8625.250 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled HSS 8 inch Nominal Schedule 20 (0.250 inch nominal wall) per ASTM A500 Grade B/C with 50 ksi minimum yield strength			
Shaft Size, OD	8.625 in	219 mm	Corroded	
			8.612 in	218.7 mm
Shaft Size, ID*	8.16 in	207.3 mm	Corroded	
			8.172 in	207.5 mm
Moment of Inertia (I)*	54.12 in ⁴	2249.5 cm ⁴	Corroded	
			51.09 in ⁴	2123.6 cm ⁴
Shaft Area (A)*	6.14 in ²	39.6 cm ²	Corroded	
			5.80 in ²	37.4 cm ²
Section Modulus (S _{x-x})*	12.55 in ³	205.2 cm ³	Corroded	
			11.87 in ³	194.1 cm ³
Perimeter	27.1 in	68.8 cm	Corroded	
			27.05 in	68.1 cm
Coupling	Formed and Welded Square Socket			
Coupling Bolts	Four 1-1/4 in Dia. Grade 2 Studs			
Helix Plates	0.5 - 0.75 inch Thick, Formed on Matching Metal Dies, ASTM A572 Grade 80 or better			
Coatings	Hot Dip Galvanized per ASTM A123 Grade 75, 3.0 mil minimum thickness or Bare Steel			
TORQUE PROPERTIES				
Torque Correlation Factor	5 ft ⁻¹		13 m ⁻¹	
Torque Rating	60,000 ft-lb		81,349 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	300 kip	1334 kN	225 kip	1001 kN
Allowable Tension Strength	150 kip		667 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	300 kip	1334 kN	150 kip	667 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2

TYPE SS/RS COMBINATION HELICAL PILES

CHANCE® Helical Transition Coupler

Adapts Type SS to Type RS Pile Shafts

The Type SS/RS Combination Pile is used mainly in compression applications in areas where soft/loose soils are located above the bearing strata (hard/dense soils) for the helices. The Type RS material with its much greater section modulus will resist columnar buckling in the soft/loose soil. Its larger shaft diameter also provides for lateral load resistance. Due to its slender size, the Type SS material provides the means for the helix plates to penetrate deeper into hard/dense soil stratum than if the helical pile shaft was pipe shaft only. For a given helix configuration and same available installation energy (i.e. machine), a small displacement shaft will penetrate farther into a soil bearing strata than a large displacement shaft and will disturb less soil.

It is recommended that a CHANCE SS/RS Combination Helical Pile be used in all projects where pipe shaft is being used. The square shaft lead section will provide better load capacity and less settlement than a comparable straight pipe shaft pile.

The transition section (see Figure 7-27) adapts Type SS helical lead sections to Type RS plain extensions. Installation of this combination pile is the same as a standard helical pile. Table 7-9 provides the various standard transition couplers that are available along with their ratings. Special transition couplers, such as RS2875 to RS4500, are also available. Please contact your area CHANCE® Distributor for availability and delivery times.

Table 7-5: Transition Couplers

CATALOG NUMBER	DESCRIPTION	TORQUE RATINGS
C1500896	SS5/SS150 square shaft to a RS2875.203 round shaft	5,500 ft-lb
C1500896	SS5/SS150 square shaft to a RS2875.276 round shaft	7,000 ft-lb
C1500895	SS175 square shaft to a RS3500.300 dia round shaft	10,500 ft-lb
C1500937	SS200 square shaft to a RS3500.300 dia round shaft	13,000 ft-lb



Pile Assembly with Transition Coupler Figure 7-27

CHANCE HELICAL PULLDOWN® Micropiles

The CHANCE HELICAL PULLDOWN® Micropile (HPM) is a patented (U.S. patent 5,707,180) method used to form a grout column around the shaft of a standard square shaft or pipe shaft helical pile/anchor. The installation process can employ grout only (see Figure 7-28) or grout in combination with either steel or PVC casing (see Figure 7-29). The result is a helical pile with grouted shaft similar, in terms of installation, to drilled and grouted anchors or auger cast-in-place piles using gravity grouting.

The initial reason for developing the HPM was to design a helical pile with sufficient shaft size to resist buckling. However, since its inception, the method has demonstrated more advantages than simply buckling resistance. The advantages and limitations, based on the results of field tests, are summarized herein:

1. Increase buckling capacity of a helical pile shaft in soft/loose overburden soils to the point that end-bearing controls failure.
2. Increased compression capacity due to the mobilization of skin friction at the grout/soil interface. Total capacity is a function of both skin friction and end-bearing.

3. Provides additional corrosion protection to anchor shaft in aggressive soils. The grout column provides additional corrosion protection to the steel pile shaft from naturally occurring aggressive soils with high metal loss rates, organic soils such as peat or other corrosive environments like slag, ash, swamp, chemical waste, or other man-made material.
4. Stiffens the load/deflection response of helical piles. Axial deflection per unit load is typically less than with un-grouted shafts.

The installation procedure for CHANCE HELICAL PULLDOWN® Micropiles is rather unique in that the soil along the sides of the shaft is displaced laterally and then replaced and continuously supported by the flowable grout as the pile is installed. To begin the installation process, a helical pile/anchor is placed into the soil by applying torque to the shaft. The helical shape of the bearing plates creates a significant downward force that keeps the pile advancing into the soil. After the Lead Section with the helical plates penetrates the soil, a Lead Displacement Plate and Extension are placed onto the shaft. Resuming torque on the assembly advances the helical plates and pulls the displacement plate downward, forcing soil outward to create a cylindrical void around the shaft. From a reservoir at the surface, a flowable grout is gravity fed and immediately fills the void surrounding the shaft. Additional extensions and displacement plates are added until the helical bearing plates reach the minimum depth required or competent load-bearing soil. This displacement pile system does not require removing spoils from the site.

DRAWINGS & RATINGS

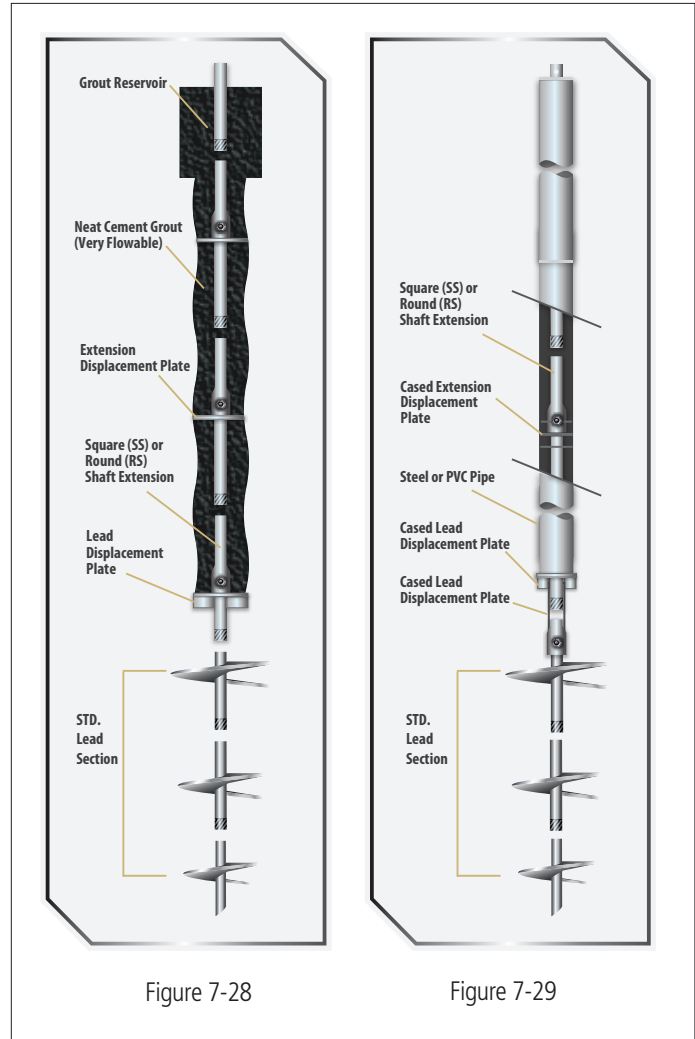


Figure 7-28

Figure 7-29

THEORETICAL GROUT VOLUME PER FOOT (METER)

Grout Column Diameter inches (mm)	Pile Shaft Size inches (mm)	Grout Volume ft ³ /ft (m ³ /m)
4 (102)	1-1/2 (38) solid square	0.071 (0.007)
5 (127)	1-1/2 (38) solid square	0.120 (0.011)
	1-3/4 (44) solid square	0.115 (0.011)
6 (152)	1-1/2 (38) solid square	0.181 (0.017)
	1-3/4 (44) solid square	0.175 (0.016)
	2 (51) solid square	0.169 (0.016)
	2-1/4 (57) solid square	0.161 (0.015)
	2-7/8 x 0.203 (73 x 5.2) pipe shaft	0.185 (0.017)
	2-7/8 x 0.276 (73 x 7) pipe shaft	0.181 (0.017)
	3-1/2 x 0.300 (89 x 7.6) pipe shaft	0.176 (0.016)
	4-1/2 x 0.337 (114 x 8.6) pipe shaft	0.166 (0.015)
7 (178)	1-1/2 (38) solid square	0.249 (0.023)
	1-3/4 (44) solid square	0.246 (0.023)
	2 (51) solid square	0.240 (0.022)
	2-1/4 (57) solid square	0.232 (0.022)
	3-1/2 x 0.300 (89 x 7.6) pipe shaft	0.246 (0.023)
	4-1/2 x 0.337 (114 x 8.6) pipe shaft	0.237 (0.022)
8 (203)	1-3/4 (44) solid square	0.328 (0.030)
	2-7/8 x 0.203 (73 x 5.2) pipe shaft	0.337 (0.031)
	2-7/8 x 0.276 (73 x 7) pipe shaft	0.333 (0.031)
	3-1/2 x 0.300 (89 x 7.6) pipe shaft	0.328 (0.030)
	4-1/2 x 0.337 (114 x 8.6) pipe shaft	0.319 (0.029)
8.5 (216)	2 (51) solid square	0.367 (0.034)
	2-1/4 (57) solid square	0.359 (0.033)
10 (254)	1-3/4 (44) solid square	0.524 (0.049)
	2 (51) solid square	0.517 (0.048)
	2-1/4 (57) solid square	0.511 (0.047)
	3-1/2 x 0.300 (89 x 7.6) pipe shaft	0.525 (0.049)
	4-1/2 x 0.337 (114 x 8.6) pipe shaft	0.515 (0.048)

Multiply volume in chart by grout column length to get total volume.

Grout volume per length of shaft extension can easily be calculated by multiplying the shaft length by the volume in the chart. Be sure to convert your units to feet or meters.

Note that if the piles are un-cased, more grout may be required due to irregularities in the column, and subsurface voids. Also, don't forget to add for the grout bath and waste when bidding the job.

Higher Compression Strengths with Grouted Shafts

The following tables provide the nominal, LRFD design, and ASD allowable compression strengths of helical piles with various diameter grouted shafts. The strengths listed are based on an unsupported shaft length of 10 feet (3 meters) with either a fixed or pinned end condition at the pile head. The grout column diameters listed are the most common used per each helical product family. Each table includes the compression strengths of shafts without grout for comparison.

Per the International Building Code (IBC) 2006 Section 1808.2.9.2 & IBC 2009 Section 1810.2.1, the depth to fixity of piles driven into soft ground can be considered fixed and laterally supported at 10 feet below the ground surface.

Nominal, LRF Design, and ASD Allowable Compression Strengths of CHANCE® Type SS5 Grouted Shaft Piles in Soft Soil^{1,2,3}

Grout Column Diameter	Nominal, LRF Design, and ASD Allowable Compression Strengths kip (kN)					
	Soft Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	13.6 (60)	12.2 (54)	8.1 (36)	26.6 (118)	24.0 (107)	16.0 (71)
4" OD	30.2 (134)	22.6 (101)	15.1 (67)	59.2 (263)	44.4 (198)	29.6 (132)
5" OD	54.9 (244)	41.2 (183)	27.4 (122)	104.5 (465)	78.3 (348)	52.2 (232)
6" OD	86.2 (383)	64.6 (287)	43.1 (192)	148.3 (660)	111.2 (495)	74.1 (330)
7" OD	126.2 (561)	94.6 (421)	63.1 (281)	194.6 (866)	145.9 (649)	97.3 (433)

Nominal, LRF Design, and ASD Allowable Compression Strengths of CHANCE® Type SS150 Grouted Shaft Piles in Soft Soil^{1,2,3}

Grout Column Diameter	Nominal, LRF Design, and ASD Allowable Compression Strengths kip (kN)					
	Soft Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	13.6 (60)	12.2 (54)	8.1 (36)	26.6 (118)	24.0 (107)	16.0 (71)
4" OD	30.2 (134)	22.6 (101)	15.1 (67)	59.2 (263)	44.4 (198)	29.6 (132)
5" OD	54.9 (244)	41.2 (183)	27.4 (122)	104.5 (465)	78.3 (348)	52.2 (232)
6" OD	86.2 (383)	64.6 (287)	43.1 (192)	148.3 (660)	111.2 (495)	74.1 (330)
7" OD	126.8 (564)	95.1 (423)	63.4 (282)	208.4 (927)	156.3 (695)	104.2 (464)

Nominal, LRF Design, and ASD Allowable Compression Strengths of CHANCE® Type SS175 Grouted Shaft Piles in Soft Soil^{1,2,3}

Grout Column Diameter	Nominal, LRF Design, and ASD Allowable Compression Strengths kip (kN)					
	Soft Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	25.8 (115)	23.2 (103)	15.4 (69)	50.5 (225)	45.4 (202)	30.2 (134)
5" OD	66.6 (296)	49.9 (222)	33.3 (148)	127.2 (566)	95.4 (424)	63.6 (283)
6" OD	111.5 (496)	83.6 (372)	55.7 (248)	185.6 (826)	139.2 (619)	92.8 (413)
7" OD	158.3 (704)	118.7 (528)	79.1 (352)	236.2 (1051)	177.2 (788)	118.1 (525)
8" OD	209.2 (931)	156.9 (698)	104.6 (465)	290.4 (1292)	217.8 (969)	145.2 (646)

Nominal, LRF Design, and ASD Allowable Compression Strengths of CHANCE® Type SS200 Grouted Shaft Piles in Soft Soil^{1,2,3}

Grout Column Diameter	Nominal, LRF Design, and ASD Allowable Compression Strengths kip (kN)					
	Soft Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	43.7 (194)	39.3 (175)	26.2 (117)	85.6 (381)	77.1 (343)	51.3 (228)
6" OD	128.7 (572)	96.6 (430)	64.4 (286)	233.9 (1040)	175.4 (780)	116.9 (520)
7" OD	201.9 (898)	151.4 (673)	101.0 (449)	312.9 (1392)	234.6 (1044)	156.4 (696)
8.5" OD	294.7 (1311)	221.0 (983)	147.4 (656)	407.6 (1813)	305.7 (1360)	203.8 (907)
10" OD	401.4 (1786)	301.1 (1339)	200.7 (893)	513.6 (2285)	385.2 (1713)	256.8 (1142)

DRAWINGS & RATINGS

Nominal, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type SS225 Grouted Shaft Piles in Soft Soil^{1,2,3}

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Soft Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	70.9 (315)	63.8 (284)	42.5 (189)	139.0 (618)	125.1 (556)	83.2 (370)
6" OD	154.9 (689)	116.2 (517)	77.5 (345)	281.8 (1254)	211.4 (940)	140.9 (627)
7" OD	228.8 (1018)	171.6 (763)	114.4 (509)	363.2 (1171)	272.4 (1212)	181.6 (808)
8.5" OD	354.3 (1576)	265.7 (1182)	177.1 (788)	482.3 (2145)	361.7 (1609)	241.1 (1072)
10" OD	466.1 (2073)	349.6 (1555)	233.1 (1037)	591.3 (2630)	443.5 (1973)	295.7 (1315)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type RS2875.203 Grouted Shaft Piles in Soft Soil^{1,2,3}

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Soft Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	42.0 (187)	37.8 (168)	25.1 (112)	55.5 (247)	49.9 (222)	33.2 (148)
6" OD	95.7 (426)	71.8 (319)	47.8 (213)	125.7 (559)	94.3 (419)	62.8 (279)
8" OD	160.1 (712)	120.1 (534)	80.1 (356)	203.2 (904)	152.4 (678)	101.6 (452)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type RS2875.276 Grouted Shaft Piles in Soft Soil^{1,2,3}

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Soft Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	55.2 (246)	49.7 (221)	33.0 (147)	73.9 (329)	66.5 (296)	44.3 (197)
6" OD	114.3 (508)	85.7 (381)	57.1 (254)	147.7 (657)	110.8 (493)	73.9 (329)
8" OD	181.4 (807)	136.0 (605)	90.7 (403)	226.9 (1009)	170.2 (757)	113.5 (505)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type RS3500.300 Grouted Shaft Piles in Soft Soil^{1,2,3}

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Soft Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	90.7 (403)	81.6 (363)	54.3 (242)	110.0 (49)	99.0 (440)	65.9 (293)
6" OD	145.1 (645)	108.8 (484)	72.5 (322)	175.6 (781)	131.7 (586)	87.8 (391)
7" OD	179.3 (798)	134.4 (598)	89.6 (399)	214.1 (952)	160.6 (714)	107.0 (476)
8" OD	216.7 (964)	162.5 (723)	108.4 (482)	257.3 (1145)	193.0 (859)	128.6 (572)
10" OD	314.4 (1399)	235.8 (1049)	157.2 (699)	365.6 (1626)	274.2 (1220)	182.8 (813)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type RS4500.337 Grouted Shaft Piles in Soft Soil^{1,2,3}

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Soft Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	156.3 (695)	140.7 (626)	93.6 (416)	175.3 (780)	157.8 (702)	105.0 (467)
6" OD	195.3 (869)	146.5 (652)	97.6 (434)	220.6 (981)	165.5 (736)	110.3 (491)
7" OD	230.4 (1025)	172.8 (769)	115.2 (512)	259.6 (1155)	194.7 (866)	129.8 (577)
8" OD	274.2 (1220)	205.6 (915)	137.1 (610)	306.4 (1363)	229.8 (1022)	153.2 (681)
10" OD	372.8 (1658)	279.6 (1244)	186.4 (829)	415.0 (1846)	311.3 (1385)	207.5 (923)

For SI: 1 kip = 4.448 kN.

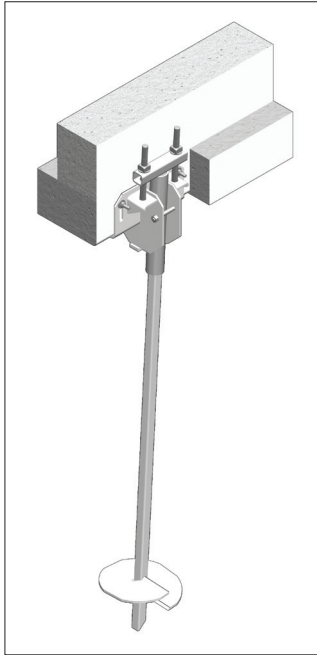
¹ Refer to Section 4.1.3 of ESR-2794 for descriptions of fixed condition, pinned condition, soft soil.

² Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with IBC Section 1808.2.5, and the lead section with which the extension is used will provide sufficient helix capacity to develop the full shaft capacity.

³ Column length to "fixity" of shaft in soil = 10 feet (3 meters)

DRAWINGS & RATINGS





REMEDIAL REPAIR BRACKETS for CHANCE® HELICAL PILES

CHANCE® Helical C1500121 Standard Bracket and T-pipe System

- Used with CHANCE Type SS5 & SS150 1-1/2" Square Shaft Helical Piles and Type RS2875.203 and RS2875.276 2-7/8" OD Pipe Shaft Helical Piles
- Use for lifts up to 4" (10 cm)
- All C1500121 Standard Systems include:
 - Foundation bracket
 - T-pipe
 - Hardware

Order separately: Two 5/8" (16 mm) diameter concrete anchor bolts per pile as required.

Standard finish is Hot-Dip Galvanized per ASTM A153.

Ultimate mechanical strength of bracket body is 80,000 lbs (356 kN). Working mechanical strength of bracket body is 40,000 lbs (178kN).

See table below for system (bracket/pile shaft) ratings.

CHANCE® Helical C1500121 Standard Bracket and T-Pipe Ratings

T-Pipe Designations for the C150-0121 Bracket	Ultimate Mechanical Strength ^{1,3} lbs (kN)	Pile Size in (mm)	Product Series	Max Working Capacity ^{2,3} based on Product Series lbs (kN)	Features
C150-0486	40,000 (178)	1-1/2 (38) Square	SS5 SS150	20,000 (89) 20,000 (89)	Lowest cost with square shaft.
C150-0487	80,000 (356)	1-1/2 (38) Square	SS5 SS150	20,000 (89) 25,000 (111)	Higher capacity with SS150.
C278-0001	40,000 (178)	2-7/8 (73) Round	RS2875.203	20,000 (89)	Lowest cost with round shaft.
C278-0002	80,000 (356)	2-7/8 (73) Round	RS2875.203	25,000 (111)	Higher capacity with stronger T-pipe
C278-8012	40,000 (178)	2-7/8 (73) Round	RS2875.276	20,000 (133)	Higher capacity with RS2875.203
C278-8011	80,000 (356)	2-7/8 (73) Round	RS2875.276	30,000 (133)	Higher capacity with RS2875.276

Notes:

1. Ultimate mechanical strength is for the bracket body and T-pipe combination.
2. The capacity of CHANCE® Helical Pile Systems is a function of many individual elements, including the capacity of the foundation, bracket, pile shaft, helix plate and bearing stratum, as well as the strength of the foundation-to-bracket connection, and the quality of the helical pile installation. The fifth column shows typical working capacities of the CHANCE® Helical Pile System based upon maximum shaft exposure of 2 feet and soil strength having a minimum Standard Penetration Test (SPT) Blow Count "N₆₀" of 4. Actual capacities could be higher or lower depending on the above factors.
3. The ultimate capacity of the system, i.e., bracket, T-pipe, and pile shaft, can be increased to the pile shaft compression capacity limit as shown on the product data pages provided the pile shaft is reinforced using a pipe sleeve or grout column. The maximum working capacity shall not be greater than one half the ultimate mechanical strength of the bracket and t-pipe combination given above.

Building Code Compliance per ICC-ES ESR-2794

The following tables provide the nominal, LRFD design, and ASD allowable compression strengths of C150-0121 Foundation Repair Brackets, T-pipes, and both Type SS5 and SS150 helical piles as evaluated per ICC-ES Acceptance Criteria AC358. These strengths are published in ICC-ES ESR-2794. The strengths listed are based on three different concrete foundation strengths, two different soils conditions - firm and soft. The pile head is assumed to be fixed within the bracket assembly, and the piles are assumed to be braced.

Per the International Building Code (IBC) 2006 Section 1808.2.9.2 & IBC 2009 Section 1810.2.1, the depth to fixity of piles driven into firm ground can be considered fixed and laterally supported at 5 feet below the ground surface and in soft material at 10 feet.

Nominal Strengths of C1500121 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	Nominal Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500121	C1500486	SS5/150	36.3 (161)	26.6 (118)	36.3 (161)	26.6 (118)	36.3 (161)	26.6 (118)
C1500121	C1500487	SS5	74.6 (332)	26.6 (118)	82.9 (369)	26.6 (118)	89.8 (399)	26.6 (118)
C1500121	C1500487	SS150	78.7 (350)	26.6 (118)	87.1 (387)	26.6 (118)	99.5 (443)	26.6 (118)

LRFD Design Strengths of C150-0121 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	LRFD Design Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500121	C1500486	SS5/150	32.6 (145)	24.0 (107)	32.6 (145)	24.0 (107)	32.6 (145)	24.0 (107)
C1500121	C1500487	SS5	52.2 (232)	24.0 (107)	58.0 (258)	24.0 (107)	62.8 (279)	24.0 (107)
C1500121	C1500487	SS150	55.1 (245)	24.0 (107)	60.9 (271)	24.0 (107)	69.6 (310)	24.0 (107)

ASD Allowable Strengths of C150-0121 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	ASD Allowable Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500121	C1500486	SS5/150	21.7 (97)	16.0 (71)	21.7 (97)	16.0 (71)	21.7 (97)	16.0 (71)
C1500121	C1500487	SS5	32.8 (146)	16.0 (71)	36.4 (162)	16.0 (71)	39.4 (175)	16.0 (71)
C1500121	C1500487	SS150	34.6 (154)	16.0 (71)	38.2 (170)	16.0 (71)	43.7 (194)	16.0 (71)

For SI: 1 kip = 4.448 Kn.

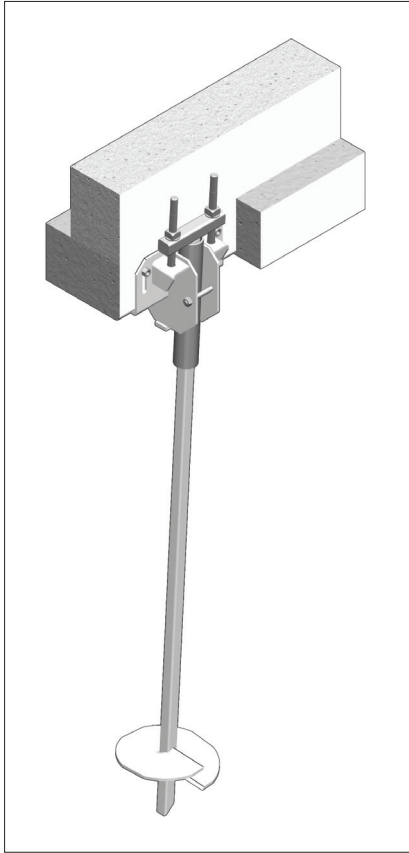
¹Refer to Section 4.1.3 of ICC-ES ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

²Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with Section 1810.2.2 of the 2012 & 2009 IBC (Section 1808.2.5 of the 2006 IBC).

³Strength ratings apply to the specific bracket, T-pipe and pile/anchor models listed.

⁴See Section 4.1.2 of ICC-ES ESR-2794 for applicable limit states that must be evaluated by a registered design professional.

⁵Refer to the specified compressive strength of concrete at 28 days.



CHANCE® Helical C1500299 Standard Bracket and T-Pipe System

- Used with CHANCE Type SS175 1-3/4" Square Shaft Helical Piles
- Use for lifts up to 4" (10 cm)
- All C1500299 Standard Systems include:
 - Foundation bracket
 - T-pipe
 - Hardware

Order separately: Two 5/8" (16 mm) diameter concrete anchor bolts per pile as required.

Standard finish is Hot-Dip Galvanized per ASTM A153.

Ultimate mechanical strength of bracket body is 80,000 lbs (356 kN). Working mechanical strength of bracket body is 40,000 lbs (178kN).

See table below for system (bracket/pile shaft) ratings.

CHANCE® Helical C1500299 Standard Bracket and T-Pipe Ratings

T-Pipe Designations for the C150-0299 Bracket	Ultimate Mechanical Strength ^{1,3} lbs (kN)	Pile Size in (mm)	Product Series	Max Working Capacity ^{2,3} based on Product Series lbs (kN)	Features
C150-0488	80,000 (356)	1-3/4 (44) Square	SS175	30,000 (133)	Lowest cost with Type SS175 Product Series.

Notes:

1. Ultimate mechanical strength is for the bracket body and T-pipe combination.
2. The capacity of CHANCE® Helical Pile Systems is a function of many individual elements, including the capacity of the foundation, bracket, pile shaft, helix plate and bearing stratum, as well as the strength of the foundation-to-bracket connection, and the quality of the helical pile installation. The fifth column shows typical working capacities of the CHANCE® Helical Pile System based upon maximum shaft exposure of 2 feet and soil strength having a minimum Standard Penetration Test (SPT) Blow Count " N₆₀" of 4. Actual capacities could be higher or lower depending on the above factors.
3. The ultimate capacity of the system, i.e., bracket, T-pipe, and pile shaft, can be increased to the pile shaft compression capacity limit as shown on the product data pages provided the pile shaft is reinforced using a pipe sleeve or grout column. The maximum working capacity shall not be greater than one half the ultimate mechanical strength of the bracket and t-pipe combination given above.

Building Code Compliance per ICC-ES ESR-2794

The following tables provide the nominal, LRFD design, and ASD allowable compression strengths of C1500299 Foundation Repair Brackets, T-pipes, and Type SS175 Helical Piles as evaluated per ICC-ES Acceptance Criteria AC358. These strengths are published in ICC-ES ESR-2794. The strengths listed are based on three different concrete foundation strengths, two different soils conditions - firm and soft. The pile head is assumed to be fixed within the bracket assembly, and the piles are assumed to be braced.

Per the International Building Code (IBC) 2006 Section 1808.2.9.2 & IBC 2009 Section 1810.2.1, the depth to fixity of piles driven into firm ground can be considered fixed and laterally supported at 5 feet below the ground surface and in soft material at 10 feet.

Nominal Strengths of C1500299 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	Nominal Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500299	C1500488	SS175	83.8 (373)	50.5 (225)	91.4 (407)	50.5 (225)	99.0 (440)	50.5 (225)

LRFD Design Strengths of C1500299 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	LRFD Design Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500299	C1500488	SS175	58.6 (261)	42.9 (191)	66.5 (296)	45.4 (202)	74.2 (330)	45.4 (202)

ASD Allowable Strengths of C1500299 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	ASD Allowable Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500299	C1500488	SS175	36.8 (164)	27.7 (123)	41.7 (185)	30.2 (134)	49.5 (220)	30.2 (134)

For SI: 1 kip = 4.448 Kn.

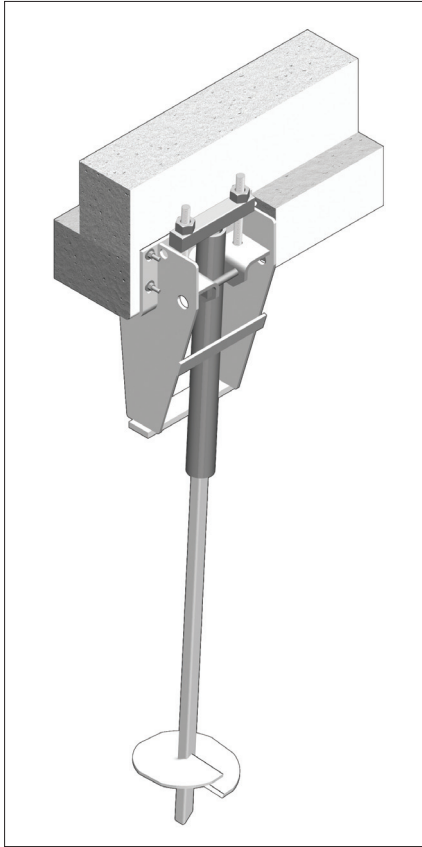
¹Refer to Section 4.1.3 of ICC-ES ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

²Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with Section 1810.2.2 of the 2012 & 2009 IBC (Section 1808.2.5 of the 2006 IBC).

³Strength ratings apply to the specific bracket, T-pipe and pile/anchor models listed.

⁴See Section 4.1.2 of ICC-ES ESR-2794 for applicable limit states that must be evaluated by a registered design professional.

⁵Refer to the specified compressive strength of concrete at 28 days.



CHANCE® Helical C1500147 Heavy Duty Bracket and T-Pipe System

- Used with CHANCE Type SS175 1-3/4" Square Shaft Helical Piles, Type SS200 2" Square Shaft Helical Piles, and Type RS3500.300 3-1/2" OD Round Shaft Helical Piles
- Use for lifts up to 4" (10 cm)
- All C150-0147 Standard Systems include:
 - Foundation bracket
 - T-pipe
 - Hardware

Order separately: Four 5/8" (16 mm) diameter concrete anchor bolts per pile as required.

Standard finish is HOT-DIP GALVANIZED per ASTM A153.

Ultimate mechanical strength of bracket body is 120,000 lbs (534 kN).
Working mechanical strength of bracket body is 60,000 lbs (267kN).

See table below for system (bracket/pile shaft) ratings.

CHANCE® Helical C1500147 Standard Bracket and T-Pipe Ratings					
T-Pipe Designations for the C150-0147 Bracket	Ultimate Mechanical Strength ^{1,3} lbs (kN)	Pile Size in (mm)	Product Series	Max Working Capacity ^{2,3} based on Product Series lbs (kN)	Features
C1500474	120,000 (534)	1-3/4 (44) Square	SS175	40,000 (178)	Lowest cost with square shaft.
C1500475	120,000 (534)	3-1/2 (89) Round	RS3500.300	50,000 (222)	Higher capacity with RS3500.300.
C1500508	120,000 (534)	2 (51) Square	SS200	50,000 (222)	Highest capacity with square shaft.

Notes:

1. Ultimate mechanical strength is for the Bracket Body and T-Pipe combination.
2. The capacity of CHANCE® Helical Pile Systems is a function of many individual elements, including the capacity of the foundation, bracket, pile shaft, helix plate and bearing stratum, as well as the strength of the foundation-to-bracket connection, and the quality of the helical pile installation. The fifth column shows typical working capacities of the CHANCE® Helical Pile System based upon maximum shaft exposure of 2 feet and soil strength having a minimum Standard Penetration Test (SPT) Blow Count " N₆₀" of 4. Actual capacities could be higher or lower depending on the above factors.
3. The ultimate capacity of the system, i.e., bracket, T-pipe, and pile shaft, can be increased to the pile shaft compression capacity limit as shown on the product data pages provided the pile shaft is reinforced using a pipe sleeve or grout column. The maximum working capacity shall not be greater than one half the ultimate mechanical strength of the bracket and t-pipe combination given above.

Building Code Compliance per ICC-ES ESR-2794

The following tables provide the nominal, LRFD design, and ASD allowable compression strengths of C150-0147 Foundation Repair Brackets, T-pipes, and Type SS175 Helical Piles as evaluated per ICC-ES Acceptance Criteria AC358. These strengths are published in ICC-ES ESR-2794. The strengths listed are based on three different concrete foundation strengths, two different soils conditions - firm and soft. The pile head is assumed to be fixed within the bracket assembly, and the piles are assumed to be braced.

Per the International Building Code (IBC) 2006 Section 1808.2.9.2 & IBC 2009 Section 1810.2.1, the depth to fixity of piles driven into firm ground can be considered fixed and laterally supported at 5 feet below the ground surface and in soft material at 10 feet.

Nominal Strengths of C150-0147 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	Nominal Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500147	C1500474	SS175	100 (445)	50.5 (225)	100 (445)	50.5 (225)	100 (445)	50.5 (225)

LRFD Design Strengths of C150-0147 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	LRFD Design Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500147	C1500474	SS175	86.7 (386)	45.4 (202)	88.4 (393)	45.4 (202)	90 (400)	45.4 (202)

ASD Allowable Strengths of C150-0147 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	ASD Allowable Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500147	C1500474	SS175	54.4 (242)	30.2 (134)	57.0 (254)	30.2 (134)	60.0 (267)	30.2 (134)

For SI: 1 kip = 4.448 Kn.

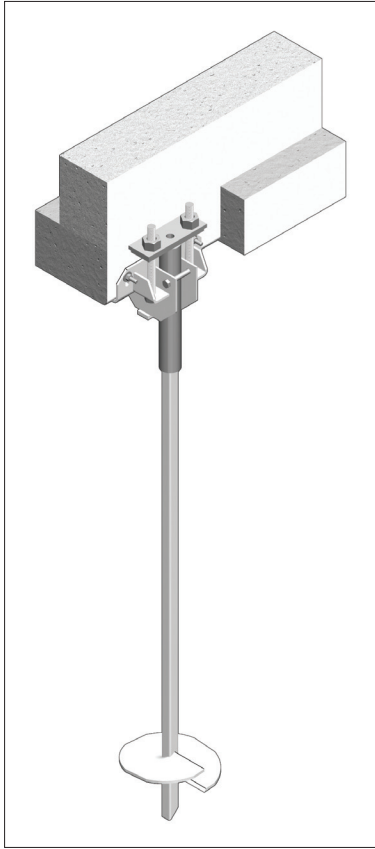
¹Refer to Section 4.1.3 of ICC-ES ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

²Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with Section 1810.2.2 of the 2012 & 2009 IBC (Section 1808.2.5 of the 2006 IBC).

³Strength ratings apply to the specific bracket, T-pipe and pile/anchor models listed.

⁴See Section 4.1.2 of ICC-ES ESR-2794 for applicable limit states that must be evaluated by a registered design professional.

⁵Refer to the specified compressive strength of concrete at 28 days.



CHANCE® Helical PSAC1500499 Low Profile Bracket and T-Pipe System

- Used with CHANCE Type SS5 & SS150 1-1/2" Square Shaft Helical Piles and Type RS2875.203 and RS2875.276 2-7/8" OD Pipe Shaft Helical Piles
- Use for lifts up to 4" (10 cm)

All PSAC1501500499 Low Profile Systems include:

- Foundation bracket
- T-pipe
- Hardware

Order separately: Two 1/2" (13 mm) diameter concrete anchor bolts per pile as required.

Standard finish is Hot-Dip Galvanized per ASTM A153.

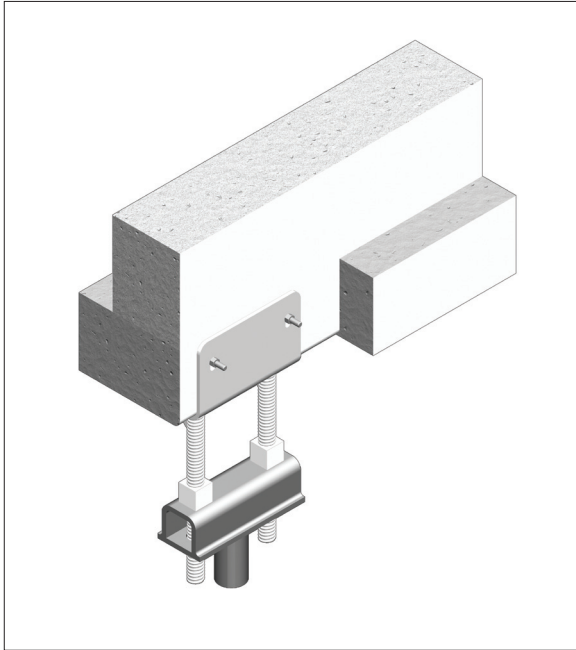
Ultimate mechanical strength of bracket body is 30,000 lbs (133 kN). Working mechanical strength of bracket body is 15,000 lbs (67 kN).

See table below for system (bracket/pile shaft) ratings.

CHANCE® Helical PSAC1500499 Low Profile Bracket and T-Pipe Ratings					
T-Pipe Designations for the PSA1500499 Bracket	Ultimate Mechanical Strength ^{1,3} lbs (kN)	Pile Size in (mm)	Product Series	Max Working Capacity ^{2,3} based on Product Series lbs (kN)	Features
PSAC150-0503	30,000 (133)	1-1/2 (38) Square	SS5 SS150	15,000 (67)	Lowest cost with Type SS5 Product Series
PSAC278-0003	30,000 (133)	2-7/8 (73) Round	RS2875.203	15,000 (67)	Lowest cost with Type RS2875.203 Product Series

Notes:

1. Ultimate mechanical strength is for the bracket body and T-pipe combination.
2. The capacity of CHANCE® Helical Pile Systems is a function of many individual elements, including the capacity of the foundation, bracket, pile shaft, helix plate and bearing stratum, as well as the strength of the foundation-to-bracket connection, and the quality of the helical pile installation. The fifth column shows typical working capacities of the CHANCE® Helical Pile System based upon maximum shaft exposure of 2 feet and soil strength having a minimum Standard Penetration Test (SPT) Blow Count "N₆₀" of 4. Actual capacities could be higher or lower depending on the above factors.
3. The ultimate capacity of the system, i.e., bracket, T-pipe, and pile shaft, can be increased to the pile shaft compression capacity limit as shown on the product data pages provided the pile shaft is reinforced using a pipe sleeve or grout column. The maximum working capacity shall not be greater than one half the ultimate mechanical strength of the bracket and t-pipe combination given above.



CHANCE® Helical Direct Jack Underpinning Brackets

- Used with CHANCE Type SS5 & SS150 1-1/2" and SS175 1-3/4" Square Shaft Helical Piles, Type RS2875.276 2-7/8" OD Pipe Shaft Helical Piles, and Type RS3500.300 3-1/2" OD Pipe Shaft Helical Piles
- Use for lifts up to 4" (10 cm)
- All Direct Jack Underpinning Brackets include:
 - Foundation bracket
 - T-pipe
 - Two Thread Bar Nuts

Order separately: Two 1/2" (13 mm) diameter concrete anchor bolts per pile as required.

Standard finish is Hot-Dip Galvanized per ASTM A153

The bracket body and T-pipe are packaged together.

See table below for system (bracket/pile shaft) ratings.

CHANCE® Helical Direct Jack Underpinning Brackets					
Direct Jack Catalog Number	Ultimate Mechanical Strength ^{1,3} lbs (kN)	Pile Size in (mm)	Product Series	Max Working Capacity ^{2,3} based on Product Series lbs (kN)	Features
C150-0738	70,000 (356)	1-1/2 (38) Square	SS5 SS150	35,000 (133)	Lowest cost
C150-0733	100,000 (445)	1-3/4 (44) Square	SS175	50,000 (222)	Highest Capacity
C150-0840	72,000 (320)	2-7/8 (73) Round	RS2875.276	36,000 (160)	
C150-0841	91,000 (405)	3-1/2 (89) Round	RS3500.300	45,500 (202)	

Notes:

1. Ultimate mechanical strength is for the bracket body and T-pipe combination.
2. The capacity of CHANCE® Helical Pile Systems is a function of many individual elements, including the capacity of the foundation, bracket, pile shaft, helix plate and bearing stratum, as well as the strength of the foundation-to-bracket connection, and the quality of the helical pile installation. The fifth column shows typical working capacities of the CHANCE® Helical Pile System based upon maximum shaft exposure of 2 feet and soil strength having a minimum Standard Penetration Test (SPT) Blow Count " N₆₀" of 4. Actual capacities could be higher or lower depending on the above factors.
3. The ultimate capacity of the system, i.e., bracket, T-pipe, and pile shaft, can be increased to the pile shaft compression capacity limit as shown on the product data pages provided the pile shaft is reinforced using a pipe sleeve or grout column. The maximum working capacity shall not be greater than one half the ultimate mechanical strength of the bracket and t-pipe combination given above.

DRAWINGS & RATINGS

Building Code Compliance per ICC-ES ESR-2794

The following tables provide the nominal, LRFD design, and ASD allowable compression strengths of C1500738 Foundation Repair Bracket, T-pipe, and Type SS5 Helical Piles as evaluated per ICC-ES Acceptance Criteria AC358. These strengths are published in ICC-ES ESR-2794. The strengths listed are based on three different concrete foundation strengths, two different soils conditions - firm and soft. The pile head is assumed to be fixed within the bracket assembly, and the piles are assumed to be braced.

Per the International Building Code (IBC) 2006 Section 1808.2.9.2 & IBC 2009 Section 1810.2.1, the depth to fixity of piles driven into firm ground can be considered fixed and laterally supported at 5 feet below the ground surface and in soft material at 10 feet.

Nominal Strengths of C1500738 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	Nominal Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500738	Incl w/ Brkt	SS5	50.9 (226)	23.1 (103)	50.9 (226)	23.1 (103)	50.9 (226)	23.1 (103)

LRFD Design Strengths of C1500738 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	LRFD Design Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500738	Incl w/ Brkt	SS5	45.8 (204)	20.8 (93)	45.8 (204)	20.8 (93)	45.8 (204)	20.8 (93)

ASD Allowable Strengths of C1500738 Remedial Repair Brackets & Helical Piles^{1,2,3,4}

Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	ASD Allowable Strength in Axial Compression kip (kN)					
			2500 psi Concrete ⁵		3000 psi Concrete ⁵		4000 psi Concrete ⁵	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500738	Incl w/ Brkt	SS5	30.5 (136)	13.8 (61)	30.5 (136)	13.8 (61)	30.5 (136)	13.8 (61)

For SI: 1 kip = 4.448 Kn.

¹Refer to Section 4.1.3 of ICC-ES ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

²Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with Section 1810.2.2 of the 2012 & 2009 IBC (Section 1808.2.5 of the 2006 IBC).

³Strength ratings apply to the specific bracket, T-pipe and pile/anchor models listed.

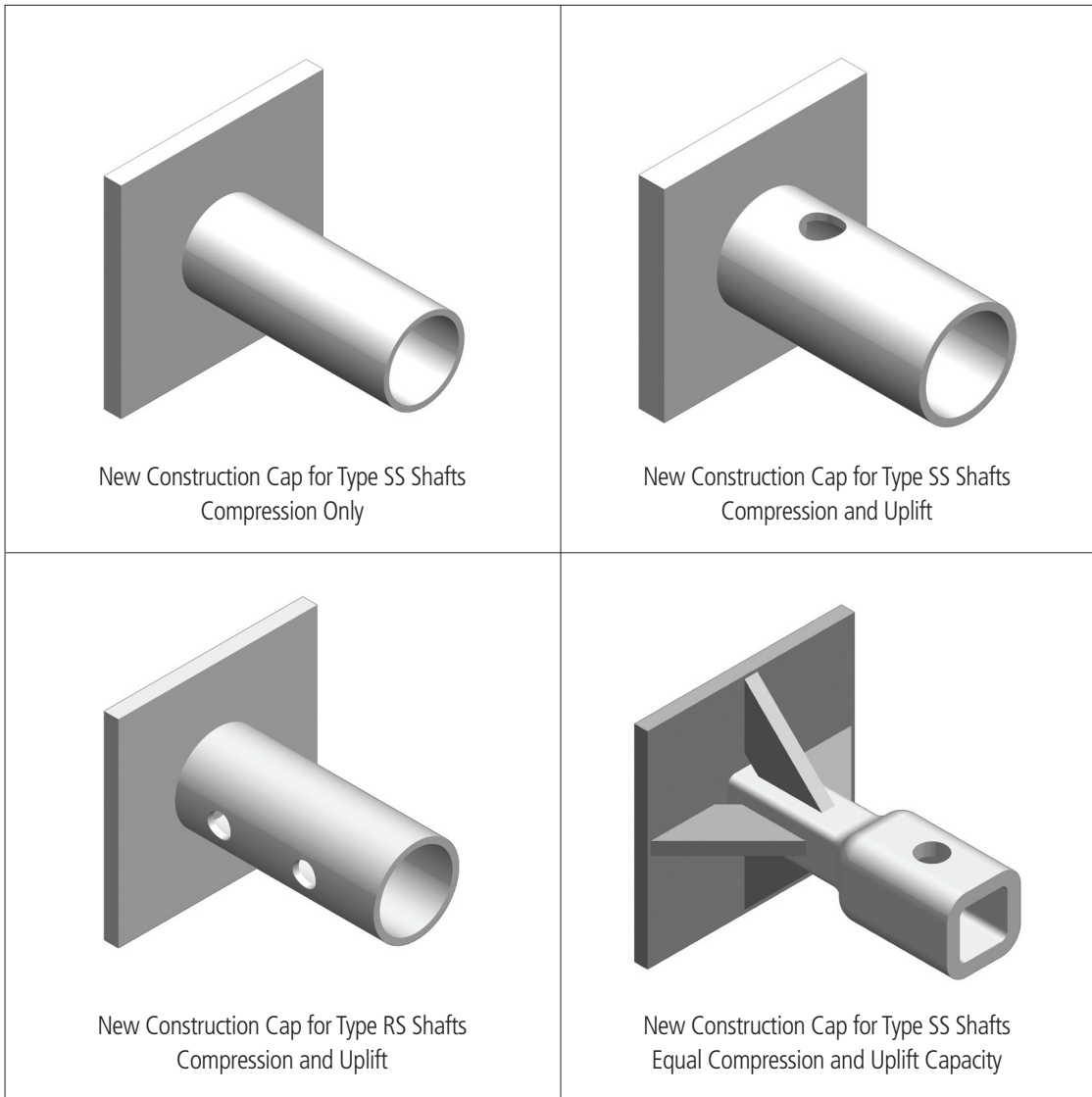
⁴See Section 4.1.2 of ICC-ES ESR-2794 for applicable limit states that must be evaluated by a registered design professional.

⁵Refer to the specified compressive strength of concrete at 28 days.

DRAWINGS & RATINGS

NEW CONSTRUCTION PILE CAPS

The CHANCE® New Construction Pile Caps are designed for use with the CHANCE® Type SS Square Shaft and RS Round Shaft helical piles and for embedment in cast-in-place concrete foundations. Each new construction pile cap consists of either one bearing plate and one steel tube sleeve that are factory-welded together to form the cap, or one bearing plate, two re-bars and one steel tube sleeve that are factory-welded together. The plate type pile caps are designed to be used in spread footings, grade beams, structural slabs, and reinforced concrete pile caps. The re-bar cap is designed to be used in grade beams and reinforced pile caps. The concrete foundation and interaction of pile shaft, new construction pile cap, and concrete footing for moment transfer, as applicable, must be designed and justified with due consideration to all applicable limit states and the direction and eccentricity of applied loads, including reactions provided by the brackets, acting on the concrete foundation. For preliminary design guidelines for reinforced pile caps refer to Section 4.



CHANCE® Helical New Construction Pile Caps

Pile Cap Designation	Design (Working) Load kip (kN)	Plate Size (square)	Pipe OD & Length	Description
C150-0458	40 (178) compression	6" x 6" x 1/2"	2-1/2" x 6"	Fits SS5/SS150 and RS2875.165/RS2875.203; use for compression only.
C150-0459	60 (267) compression	6" x 6" x 3/4"	3" x 6"	Fits SS175; use for compression only.
C150-0465	40 (178) compression 20 (89) uplift	6" x 6" x 1/2"	2-1/2" x 6"	Fits SS5/SS150; use for uplift and compression.
C150-0467	60 (267) compression 30 (133) uplift	6" x 6" x 3/4"	3" x 6"	Fits SS175; use for uplift and compression.
C150-0777	35 (156) compression	7" x 7" x 1/2"	2-1/2" x 6"	Fits SS5/SS150; use for compression only
C150-0778	52.5 (234) compression	8" x 8" x 1/2"	2-7/8" x 6"	Fits SS175; use for compression only
C150-0779	75 (334) compression	12" x 12" x 1/2"	3-1/2" x 6"	Fits SS200; use for compression only
C150-0780	100 (445) compression	12" x 12" x 1/2"	3-1/2" x 6"	Fits SS225; use for compression only
C150-0781	36 (160) compression	7" x 7" x 1/2"	3-1/2" x 6"	Fits RS2875; use for compression only
C150-0782	50 (222) compression	10" x 10" x 1/2"	4-1/2" x 6"	Fits RS3500; use for compression only
C150-0783	70 (311) compression	12" x 12" x 1/2"	5-9/16" x 6"	Fits RS4500; use for compression only
C150-0793	35 (156) compression 23 (102) uplift	7" x 7" x 1/2"	2-1/2" x 6"	Fits SS5/150; use for uplift and compression
C150-0794	52.5 (234) compression 37 (165) uplift	8" x 8" x 1/2"	2-7/8" x 6"	Fits SS175; use for uplift and compression
C150-0795	75 (334) compression 45 (200) uplift	12" x 12" x 1/2"	3-1/2" x 6"	Fits SS200; use for uplift and compression
C150-0796	100 (445) compression 40 (178) uplift	12" x 12" x 1/2"	3-1/2" x 6"	Fits SS225; use for uplift and compression
C150-0797	36 (160) compression 36 (160) uplift	7" x 7" x 1/2"	3-1/2"	Fits RS2875; use for uplift and compression
C150-0798	50 (222) compression 50 (222) uplift	10" x 10" x 1/2"	4-1/2"	Fits RS3500; use for uplift and compression
C150-0799	70 (311) compression 70 (311) uplift	12" x 12" x 1/2"	5-9/16"	Fits RS4500; use for uplift and compression

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Building Code Compliance per ICC-ES ESR-2794

The following tables provide the nominal, LRFD design, and ASD allowable compression strengths of C1500458G and C1500465G pile caps used with Type SS5 helical piles; and the C1500459G and C1500467G pile caps used with Type SS175 helical piles as evaluated per ICC-ES Acceptance Criteria AC358. The last table on page 7-64 provides the nominal, LRFD design, and ASD allowable tension strengths of C1500465G pile cap used with Type SS5 helical piles; and C1500467G pile cap used with Type SS175 helical piles as evaluated per ICC-ES Acceptance Criteria AC358. These strengths are published in ICC-ES ESR-2794. The strengths listed are based on three different concrete foundation strengths, two different soils conditions - firm and soft. The pile head is assumed to be either pinned or fixed within the concrete foundation depending on cover and reinforcing; and the piles are assumed to be braced. The helical pile must be embedded at least 7.5 inches into the concrete foundation when designed as fixed end condition.

Per the International Building Code (IBC) 2006 Section 1808.2.9.2 & IBC 2009 Section 1810.2.1, the depth to fixity of piles driven into firm ground can be considered fixed and laterally supported at 5 feet below the ground surface and in soft material at 10 feet.

Nominal Strengths of New Construction Pile Caps Loaded in Compression^{1,2,3,4,5,6}

Catalog Number	Pile Model	Nominal Compression Strength kip (kN)											
		2500 psi Concrete ⁶				3000 psi Concrete ⁶				4000 psi Concrete ⁶			
		Firm Soil		Soft Soil		Firm Soil		Soft Soil		Firm Soil		Soft Soil	
		Pinned	Fixed	Pinned	Fixed	Pinned	Fixed	Pinned	Fixed	Pinned	Fixed	Pinned	Fixed
C150-0458G	SS5	54.4 (242)	60.0 (267)	13.6 (60)	26.6 (118)	54.4 (242)	62.3 (277)	13.6 (60)	26.6 (118)	54.4 (242)	66.9 (298)	13.6 (60)	26.6 (118)
C150-0459G	SS175	100 (445)	100 (445)	25.8 (115)	50.5 (225)	100 (445)	100 (445)	25.8 (115)	50.5 (225)	100 (445)	100 (445)	25.8 (115)	50.5 (225)
C150-0465G	SS5	54.4 (242)	60.0 (267)	13.6 (60)	26.6 (118)	54.4 (242)	62.3 (277)	13.6 (60)	26.6 (118)	54.4 (242)	66.9 (298)	13.6 (60)	26.6 (118)
C150-0467G	SS175	100 (445)	100 (445)	25.8 (115)	50.5 (225)	100 (445)	100 (445)	25.8 (115)	50.5 (225)	100 (445)	100 (445)	25.8 (115)	50.5 (225)

LRFD Design Strengths of New Construction Pile Caps Loaded in Compression^{1,2,3,4,5,6}

Catalog Number	Pile Model	LRFD Design Compression Strength kip (kN)											
		2500 psi Concrete ⁶				3000 psi Concrete ⁶				4000 psi Concrete ⁶			
		Firm Soil		Soft Soil		Firm Soil		Soft Soil		Firm Soil		Soft Soil	
		Pinned	Fixed	Pinned	Fixed	Pinned	Fixed	Pinned	Fixed	Pinned	Fixed	Pinned	Fixed
C150-0458G	SS5	48.9 (218)	50.6 (225)	12.2 (54)	24.0 (107)	48.9 (218)	52.0 (231)	12.2 (54)	24.0 (107)	48.9 (218)	54.7 (243)	12.2 (54)	24.0 (107)
C150-0459G	SS175	79.2 (352)	79.2 (352)	23.2 (103)	45.4 (202)	90 (400)	90 (400)	23.2 (103)	45.4 (202)	90 (400)	90 (400)	23.2 (103)	45.4 (202)
C150-0465G	SS5	48.9 (218)	50.6 (225)	12.2 (54)	24.0 (107)	48.9 (218)	52.0 (231)	12.2 (54)	24.0 (107)	48.9 (218)	54.7 (243)	12.2 (54)	24.0 (107)
C150-0467G	SS175	79.2 (352)	79.2 (352)	23.2 (103)	45.4 (202)	90 (400)	90 (400)	23.2 (103)	45.4 (202)	90 (400)	90 (400)	23.2 (103)	45.4 (202)

DRAWINGS & RATINGS

ASD Allowable Strengths of New Construction Pile Caps Loaded in Compression^{1,2,3,4,5,6}

Catalog Number	Pile Model	ASD Allowable Compression Strength kip (kN)											
		2500 psi Concrete ⁶				3000 psi Concrete ⁶				4000 psi Concrete ⁶			
		Firm Soil		Soft Soil		Firm Soil		Soft Soil		Firm Soil		Soft Soil	
		Pinned	Fixed	Pinned	Fixed	Pinned	Fixed	Pinned	Fixed	Pinned	Fixed	Pinned	Fixed
C1500458G	SS5	32.6 (145)	33.7 (150)	8.1 (36)	16.0 (71)	32.6 (145)	34.6 (154)	8.1 (36)	16.0 (71)	32.6 (145)	36.4 (162)	8.1 (36)	16.0 (71)
C1500459G	SS175	52.7 (234)	52.7 (234)	15.4 (69)	30.2 (134)	60.0 (267)	60.0 (267)	15.4 (69)	30.2 (134)	60.0 (267)	60.0 (267)	15.4 (69)	30.2 (134)
C1500465G	SS5	32.6 (145)	33.7 (150)	8.1 (36)	16.0 (71)	32.6 (145)	34.6 (154)	8.1 (36)	16.0 (71)	32.6 (145)	36.4 (162)	8.1 (36)	16.0 (71)
C1500467G	SS175	52.7 (234)	52.7 (234)	15.4 (69)	30.2 (134)	60.0 (267)	60.0 (267)	15.4 (69)	30.2 (134)	60.0 (267)	60.0 (267)	15.4 (69)	30.2 (134)

For SI: 1 inch = 25.4 mm, 1 kip = 4.448 kN, 1lbf-ft = 1.356 N-m.

¹Refer to Section 4.1.3 of ICC-ES ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

²Strength ratings are based on a design corrosion level of 50-years and presume the supported structure is braced in accordance with Section 1810.2.2 of the 2012 & 2009 IBC (Section 1808.2.5 of the 2006 IBC).

³Capacities apply to the specific pile cap and pile models listed.

⁴The fixed end condition requires that the foundation itself be fixed and that pile and pile cap be embedded in the foundation with adequate concrete cover and reinforcing to resist 56.4 kip-in or 116 kip-in nominal bending moment for SS5 and SS175 pile models, respectively. The center of shaft must be at least 6-in away from the end/corner of the concrete footing.

⁵See Section 4.1.2 of ICC-ES ESR-2794 for applicable limit states that must be evaluated by a registered design professional.

⁶Refer to the specified compressive strength of concrete at 28 days.

Nominal, LRFD Design and ASD Allowable Strengths of New Construction Pile Caps Loaded in Tension^{1,2,3,4}

Catalog Number	Pile Model	Nominal, LRFD Design and ASD Allowable Strengths in Tension kip (kN)								
		2500 psi Concrete ⁵			3000 psi Concrete ⁵			4000 psi Concrete ⁵		
		Nom Str	Design Str	Allow Str	Nom Str	Design Str	Allow Str	Nom Str	Design Str	Allow Str
C1500465G	SS5	56.2 (250)	42.1 (187)	28.1 (125)	56.2 (250)	42.1 (187)	28.1 (125)	56.2 (250)	42.1 (187)	28.1 (125)
C1500467G	SS175	78.9 (351)	59.2 (263)	39.5 (176)	78.9 (351)	59.2 (263)	39.5 (176)	78.9 (351)	59.2 (263)	39.5 (176)

For SI: 1 inch = 25.4 mm, 1 kip = 4.448 kN.

¹Refer to Section 4.1.3 of ICC-ES ESR-2794 for descriptions of fixed condition, pinned condition, soft soil and firm soil.

²Strength ratings are based on a design corrosion level of 50-years.

³Capacities apply to the specific pile cap and pile models listed.

⁴See Section 4.1.2 of ICC-ES ESR-2794 for applicable limit states that must be evaluated by a registered design professional.

⁵Refer to the specified compressive strength of concrete at 28 days.

DRAWINGS & RATINGS



DESIGN EXAMPLES



DESIGN EXAMPLES SECTION 8

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DESIGN EXAMPLES

SYMBOLS USED IN THIS SECTION

(Symbols Used are listed separately for each Design Example)

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

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DESIGN EXAMPLE 1 ATLAS RESISTANCE® PIERS

SYMBOLS USED IN THIS DESIGN EXAMPLE

SPT	Standard Penetration Test	8-4
N.....	Standard Penetration Test Blow Count	8-4
P	Total Live Load	8-5
DL.....	Dead Load	8-5
LL.....	Live Load	8-5
SL	Snow Load	8-5
W.....	Soil Load	8-5
S_K	Snow Load Requirement Factor	8-5
P_w	Working Pier Load	8-5
X.....	Pier Spacing	8-5
FS.....	Factor of Safety	8-5
FS_h	Factor of Safety for Mechanical Strength of Hardware	8-5
$R_{w\text{ ULT}}$	Ultimate Hardware Strength based on Structural Weight	8-5
$R_{h\text{ ULT}}$	Ultimate Hardware Strength	8-5
X_{max}	Maximum Pier Spacing Based on Hardware Capacity	8-5
FS_p	Proof Load Factor of Safety	8-6
R_p	Installation Force to Achieve Proof Load	8-6
$R_{h\text{ MAX}}$	Maximum Installation Force Based on Ultimate	
.....	Capacity of Hardware	8-6
$L_{p\text{ MAX}}$	Maximum Free Span Between Piers	8-6

DESIGN EXAMPLES

Type of Structure

The structure is a two-story, 20' x 40' frame residence with full brick veneer siding located in the Midwest. The house sits on 8" thick by 8' high cast concrete basement walls with steel reinforced concrete footings 1'-8" wide by 1'-0" thick. The roof is composition shingles over 1/2" plywood decking and felt underlayment. There is six feet of peaty clay soil overburden present.

Preliminary Investigation

Settlement is evident in portions of the structure of 2-1/2". Checking with local building officials reveals no special controlling codes for underpinning existing structures that must be observed. Preliminary geotechnical information indicates the footing is situated in peaty clay type soil with Standard Penetration Test (SPT) "N" values of six and higher. This soil extends to a depth of 15 feet where a dense glacial till exists. It is determined that the glacial till layer will serve as an adequate bearing stratum for the ATLAS RESISTANCE® Piers.



Preliminary Estimate of Total Live Load on Footing

$$P = \text{Dead Load (DL)} + \text{Live Load (LL)} + \text{Snow Load (SL)} + \text{Soil Load (W)} \quad \text{Equation 8-1}$$

$$P = (1,890 + 667 + 120 + 2,310) = 4,987 \text{ lb/ft}$$

(See Tables 4-2, 4-4 and 4-5 in Section 4 for DL, LL and W).

where:

$$\begin{aligned} \text{DL} &= 1,890 \text{ lb/ft} \\ \text{LL} &= 667 \text{ lb/ft} \\ \text{SL} &= S_K \times [(l \times w) / 2 (l + w)] \\ &\quad \text{where } l \text{ and } w \text{ are the building dimensions} \\ S_K &= \text{Snow load requirement factor} = 18 \text{ lb/ft}^2 \text{ (for this example)} \\ \text{SL} &= 18 \text{ lb/ft}^2 \times (800 / 120) \text{ ft} = 120 \text{ lb/ft} \\ \text{W} &= W_1 + W_2 = (330 + 1,980) \text{ lb/ft} = 2,310 \text{ lb/ft} \end{aligned}$$

ATLAS RESISTANCE® Pier Selection

While the ATLAS RESISTANCE® Continuous Lift Pier could be used for this application, the small lift required makes it unnecessary. The ATLAS RESISTANCE® Predrilled Pier is not a good choice here due to the absence of a hard, impenetrable layer above the intended bearing stratum. Therefore, the ATLAS RESISTANCE® 2-Piece Standard Pier is selected for strength and economy. The more expensive ATLAS RESISTANCE® Plate Pier could also be attached to the concrete basement wall and used for this application. Since there are suitable soils with “N” counts above four, there is no need to sleeve the pier pipe for added stiffness.

Pier Spacing

Using the information obtained about the stem wall and footing to be supported, and applying sound engineering judgment, the nominal pier spacing based on the foundation system’s ability to span between piers is estimated at about eight feet. This puts the nominal working pier load (P_W) at:

$$P_W = (x) \times (P) = 8 \text{ ft} \times 4,987 \text{ lb/ft} = 39,896 \text{ lbs} \quad \text{Equation 8-2}$$

where:

$$\begin{aligned} x &= \text{Selected pier spacing} = 8 \text{ ft} \\ P &= \text{Line load on footing} = 4,987 \text{ lb/ft} \end{aligned}$$

Factor of Safety

Hubbell Power Systems, Inc. recommends a minimum Factor of Safety (FS) for the mechanical strength of the hardware of 2.0.

$$\begin{aligned} \text{FS}_h &= 2.0 \text{ (may be varied based on engineering judgment)} \\ R_{W \text{ ULT}} &= \text{Minimum ultimate hardware strength requirement} \\ &\quad \text{based on structural weight} \\ &= P_W \times \text{FS}_h = (39,896 \text{ lb}) \times 2 = 79,792 \text{ lb} \end{aligned} \quad \text{Equation 8-3}$$

Select a pier system with an adequate minimum ultimate strength rating:

$$\begin{aligned} R_{h \text{ ULT}} &= 86,000 \text{ lb - Choose AP-2-UFVL3500.165M[*][14'-0]} \\ &\quad \text{Modified 2-Piece Pier System} \\ X_{\text{max}} &= \text{Maximum pier spacing based on hardware capacity} \\ &= (R_{h \text{ ULT}}) / [(FS_h) \times (P)] \\ &= (86,000 \text{ lb}) / [(2) \times (4,987)] \\ &= 8.6 \text{ ft (Use 9.0 ft. Wall and footing are judged able} \\ &\quad \text{to span this distance)} \end{aligned} \quad \text{Equation 8-4}$$

Proof Load

Hubbell Power Systems, Inc. recommends a minimum Factor of Safety of 1.5 at installation unless structural lift occurs first.

FS_p R_p $R_{h\ MAX}$	$=$ Proof Load Factor of Safety ¹ = 1.5 $=$ Installation force based on weight of structure to achieve Proof Load verification $= (FS_p) \times (P_W) = (1.5) (8.6 \times 4987) = 64,332\ lb$ $=$ Maximum installation force based on hardware ultimate capacity ² $= (R_{h\ ULT}/2) (1.65) = (86,000/2) (1.65) = 70,950\ lb$ $= R_{W\ MIN} < R_{h\ MAX} = OK, \text{ where } R_{W\ MIN} = R_p$	Equation 8-5
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- 1 Experience has shown that in most cases the footing and stem wall foundation system that will withstand a given long term working load will withstand a pier installation force of up to 1.5 times that long term working load. If footing damage occurs during installation, the free span ($L_{P\ MAX}$) may be excessive.
- 2 It is recommended that $R_{h\ MAX}$ not exceed $(R_{h\ ULT} / 2) \times (1.65)$ during installation without engineering approval.

Design Recommendations

The result of the analysis provides the following design specifications:

- Underpinning product: ATLAS RESISTANCE® Modified 2-Piece Pier AP-2-UF-3500.165M[*][14'-0]
- Pier spacing: 8.6' on center
- Installation Proof Load: 64,332 lbs ± (unless lift of the structure occurs first)
- Working load is anticipated to be 42,900 lbs ± (4,987 lb/ft x 8.6 ft)
- Anticipated pier depths: 15 ft ±

DESIGN EXAMPLES

DESIGN EXAMPLE 2
ATLAS RESISTANCE® PIERS WITH INTEGRATED TIEBACK
SYMBOLS USED IN THIS DESIGN EXAMPLE

kip	Kilopound	8-8
SPT	Standard Penetration Test	8-8
N.....	SPT Blow Count	8-8
bpf.....	Blows per Foot	8-8
bgs	Below Ground Surface	8-8
P	Compression Loading	8-8
x.....	Pier Spacing	8-8
$P_{w\ min}$	Minimum Working Pier Load	8-8
klf	Thousand per Lineal Foot	8-8
DL_h	Horizontal Design Load	8-8
D	Diameter(s)	8-8
c.....	Cohesion	8-8
ϕ	Friction Angle	8-8
N_q	Bearing Capacity Factor	8-8
γ	Unit Weight of Soil	8-8
pcf	Pounds per Cubic Foot	8-8
FS.....	Factor of Safety	8-8
UC_r	Ultimate Tension Capacity	8-8
Q_t	Ultimate Bearing Capacity	8-8
T_u	Ultimate Capacity of Helical Tieback	8-9
A_h	Area of Helix	8-9
K_t	Empirical Torque Factor	8-9
R_p	Proof Load	8-9
FS_p	Proof Load Factor of Safety	8-9
DS.....	Minimum Installing Force	8-9
$R_{h\ max}$	Maximum Installation Force	8-9
FS_h	Hardware Factor of Safety	8-9

DESIGN EXAMPLES

Project Information

An existing three-story commercial building located within a hurricane prone region requires foundation retrofitting for potential scour activity and lateral load forces from hurricane force winds. The structure sits on a shallow foundation system consisting of a 4' high 10" thick stem wall and a 4' wide 12" thick spread footing with three #5 reinforcement bars (Grade 60). The structural Engineer of Record has requested a new foundation system capable of withstanding 2 kips per lineal foot design lateral forces and temporary scour depths to 1' below the existing spread footing. The estimated design compression loading is 5 kips per lineal ft for the existing structure. The structural engineer has determined that the existing foundation system can handle underpinning support spans of 8' or less.

Geotechnical Investigation

A geotechnical investigation was performed to determine the soil types and strengths at the project location. The soil borings advanced near the project location show medium dense silty sand with SPT "N" values ranging from 15 to 25 bpf to a depth of 20 ft bgs. This medium dense silty sand layer is underlain by dense sand and weathered limestone bedrock with SPT "N" values greater than 40 bpf. Groundwater was observed at 18' bgs during the investigation.

Underpinning System Selection

The availability of a dense stratum with "N" values greater than 40 bpf allows the use of the ATLAS RESISTANCE® Pier. The additional lateral loading can be designed for using a helical tieback anchor and the integrated ATLAS RESISTANCE® Pier bracket. Based on the design compression loading (P) of 5 kips per lineal ft and the allowable pier spacing (x) of 8' the required minimum design capacity of the ATLAS RESISTANCE® Pier ($P_{w \min}$) is $(x) \times (P) = 8.0 \times 5.0$ or 40 kips.

The AP-2-UF-3500.165 system could be used since it has a maximum working (design) capacity of 42.5 kips. However, due to the possibility of scour and subsequent lack of soil support the modified pier with a working capacity of 45.5 kips is recommended (AP-2-UF-3500.165M) with at least three modified pier sections to increase the rotational stiffness of the bracket.

Helical Tieback Design and Installation

With a maximum spacing of 8' and an estimated design lateral line load of 2 klf, the horizontal design load (DL_H) at the tieback anchor location is 16 kips. The tieback anchors are typically installed between 15° to 25° from horizontal. An installation angle of 20° was chosen after determining that there are no underground structures/ conduits that may interfere with the tieback installation. The tieback must be designed with a minimum embedment depth of 5D (distance from the last helical plate to the ground surface) where D = diameter of the helical plate. The tieback will be designed to bear in the silty sand with "N" values of 20 bpf observed at 5 to 10 feet bgs. Based on the SPT "N" values and soil descriptions, the following parameters are used in the design:

- Cohesion (c) = 0
- Friction angle (ϕ) = 34°
- Bearing capacity factor (N_q) = 21
- Unit weight of soil (γ) = 115 pcf

Using a Factor of Safety (FS) = 2 on the design load and an installation angle of 20°, the required ultimate tension capacity of the tieback (UC_t) is $(FS \times DL_H) / \cos 20^\circ = (2 \times 16) / \cos 20^\circ = 34$ kip. The ultimate bearing capacity (Q_t) of a helical tieback can be determined from:

$$Q_t = A_n (cN_c + qN_q)$$

Equation 8-6

Try a Type SS5 series (12"-14" Lead) with a length of 15 ft:

Check depth criteria based on:

- A starting depth of 4 ft below the ground surface
- tieback length of 15 ft
- An installation angle of 20°

The length to the top of the lead helix is $15 \text{ ft} - 3(12/12) - 4/12 = 11.7 \text{ ft}$. The depth of embedment would be $4 + 11.7\sin(20) = 4 \text{ ft} + 4 \text{ ft} = 8 \text{ ft}$ which is greater than $5D$ (6 ft), so the depth criteria is met.

Check the ultimate capacity of the helical tieback (T_u) using:

- $N_q = 21$

$$d_{\text{avg}} = 4 \text{ ft} + \frac{15 \text{ ft} - 1}{2} \left[\frac{3(12 \text{ in}) + 4 \text{ in}}{12 \text{ in/ft}} \right] \sin(20) = 8.6 \text{ ft}$$

Equation 8-7

- $\gamma' = 115 \text{ pcf}$
- $\Sigma A_n = A_{12} + A_{14} = 0.77 \text{ ft}^2 + 1.05 \text{ ft}^2 = 1.82 \text{ ft}^2$

$$Q_t = 1.82 \text{ ft}^2 (8.6 \text{ ft})(115 \text{ pcf})(21) = 37.8 \text{ kips}$$

Equation 8-8

Since the ultimate bearing capacity (37.8 kips) is greater than the required ultimate capacity of 34 kips, the Type SS5 (12"-14") tieback is acceptable. The average minimum installation torque would be UC_r/K_t or $34,000/10 = 3400 \text{ ft-lbs}$. This minimum installation torque is less than the torque rating of the SS5 and SS125 bar; therefore, either shaft size would be acceptable. K_t = empirical torque factor (default value = 10 for the SS series).

The distance from the assumed "active" failure plane to the 14" helix must be at least 5 times its diameter or 6'-0". Both the minimum length and estimated installation torque must be satisfied prior to the termination of tieback installation.

ATLAS RESISTANCE® Pier Underpinning Installation

Given a design load of 40 kips and the potential for 1 ft of temporary exposed pier section due to scour, use the AP-2-UF-3500.165[M]:

- The AP-2-UF-3500.165M pier has a working (design) load capacity of 45.5 kips. The estimated line load (P) is 5 klf, therefore with a maximum pier c-to-c spacing (x) of 8 ft, the piers will experience a design load (P_w) of 40 kips. The spacing may need to be decreased based upon field conditions.
- Use a minimum 3 modified pier sections (10.5 ft) offset halfway from the inner sleeve sections
- The depth to a suitable stratum for ATLAS RESISTANCE® Pier placement is approximately 20 ft bgs
- Install each pier to a minimum installing force, (Proof Load) $R_p = 1.50 \times P_w$ (estimated Factor of Safety (FS_p) of 1.5 on the design load) which makes the minimum installing force $DS=60,000 \text{ lbs}$ (based on an 8 ft spacing) or imminent lift, whichever occurs first. The maximum installation force ($R_{h \text{ max}}$) shall not exceed $R_{h \text{ ULT}}/2 \times F_{sh}$ or $(91,000/2) \times 1.65 = 75,000 \text{ lbs}$ (estimated Factor of Safety (FS_h) of 1.65 of the design load for hardware).

DESIGN EXAMPLE 3

HELICAL PILE FOUNDATION FOR NEW CONSTRUCTION

SYMBOLS USED IN THIS DESIGN EXAMPLE

L/W	Length to Width Ratio	8-10
P	Total Live Load	8-10
DL	Dead Load	8-10
LL	Live Load	8-10
SL	Snow Load	8-10
FS	Factor of Safety	8-10
P_w	Working Pier Load	8-10
x	Pile Spacing	8-10
Q_t	Ultimate Pile Capacity	8-11
A	Area of Helix Plate	8-11
c	Cohesion of Soil	8-11
N_c	Bearing Capacity	8-11
T	Torque	8-11
K_t	Empirical Torque Factor	8-11

DESIGN EXAMPLES

Building Type

- Two story residence
- Slab on grade
- Masonry wall, wood frame
- Width = 30 ft, L/W = 1-1/2

Structural Loads

- Total Live Load on perimeter footing = P **Equation 8-9**
- $P = \text{Dead Load (DL)} + \text{Live Load (LL)} + \text{Snow Load (SL)}$
- $P = 1540 + 346 + 162 = 2,048 \text{ lbs/ft}$ (See Tables 4-1 and 4-4 in Section 4 for DL and LL)
- Factor of Safety (FS) = 2.0 (minimum)

Pile Spacing

- Estimated working load (P_w) = (x) x (P) **Equation 8-10**
- Estimated pile spacing (x) = 6.0 ft
- $P_w = 6.0 \times 2,048 = 12,288 \text{ lbs}$



CHANCE® Helical Pile Selection

RS2875.203 with 8-10-12 helix configuration

Ultimate Pile Capacity

- $Q_t = (A_8 + A_{10} + A_{12}) c N_c$ **Equation 8-11**
 $A_8, A_{10}, A_{12} =$ Projected area of helical plates
 $A_8 = 0.34 \text{ ft}^2$ $A_{10} = 0.53 \text{ ft}^2$ $A_{12} = 0.77 \text{ ft}^2$
 $c = 2,000 \text{ psf}$ (based on $N=16$ – Equation, 5-35)
 $N_c =$ Bearing capacity = 9.0
- $Q_t = (1.64) (2,000) (9.0)$
- $Q_t = 29,520 \text{ lb}$ (installation depth is over 20 ft)

Check Q_t

- Conduct Field Load Test (if required per specifications)

Estimate Installation Torque

$$T = (P_w \times FS) / K_t = (12,288 \times 2) / 9 = 2,750 \text{ ft-lb} \quad \text{Equation 8-12}$$

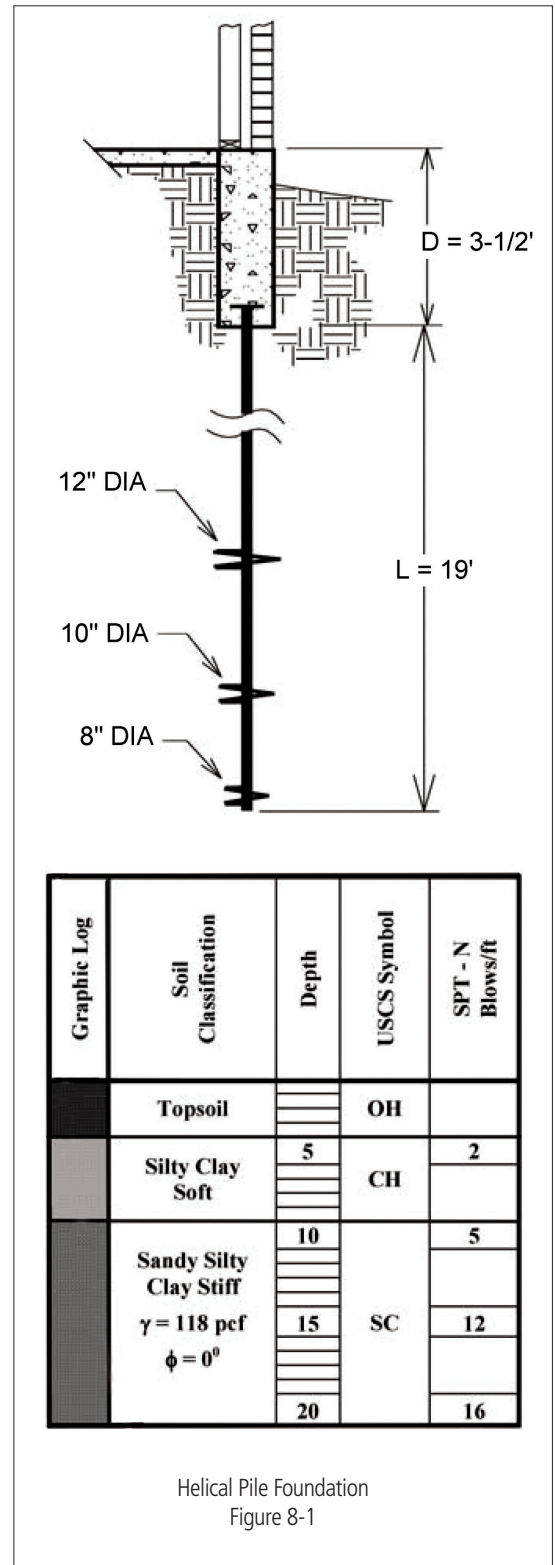
$K_t =$ empirical torque factor (default value = 9 for the R2875 series)

The rated installation torque of the RS2875.203 series is 5500 ft-lb, which is greater than the required estimated installation torque of 2,750 ft-lb. (OK)

NOTE: If during installation $T = 2,750 \text{ ft-lb.}$ is not achieved, then two options are available: (1) reduce pile spacing (x), or (2) change helix configuration to a larger combination, i.e., (10"-12"-14")

Factor of Safety

- Theoretical Ultimate Capacity:** **Equation 8-13**
 $FS = (Q_t / P_w)$
 $FS = 29,520 / 12,288 = 2.4$ (OK)
- Torque Correlation:**
 $FS = (T \times K_t) / P_w$
 $FS = (2,750 \times 9) / 12,288 = 2.01$ (OK)



DESIGN EXAMPLES

DESIGN EXAMPLE 4
LIGHT COMMERCIAL STRUCTURE
SYMBOLS USED IN THIS DESIGN EXAMPLE

CH.....	Highly Plastic Clay	8-13
PI.....	Plasticity Index	8-13
C.....	Cohesion of Soil	8-13
γ	Unit Weight of Soil	8-13
pcf.....	Pounds per Cubic Foot	8-13
CL.....	Low Plasticity Clay	8-13
SPT.....	Standard Penetration Test	8-13
N.....	SPT Blow Count	8-13
kip.....	Kilopound	8-13
P.....	Total Live Load	8-13
P_w	Working Load	8-13
FS.....	Factor of Safety	8-13
U_{Cr}	Required Ultimate Capacity	8-13
Q_{ult}	Ultimate Bearing Capacity	8-14
A_h	Area of Helix	8-14
N_c	Bearing Capacity	8-14
N_q	Bearing Capacity Factor	8-14
B.....	Footing Width	8-14
ϕ	Angle of Internal Friction	8-14
ksf.....	Kilo Square Feet	8-14
CMP.....	Corrugated Metal Pipe	8-15
DOT.....	Department of Transportation	8-15
K_t	Torque Factor	8-15
T.....	Torque	8-16

DESIGN EXAMPLES

Problem

Build a new (lightly loaded single story) commercial building on a typical clay soil profile as given on a single boring. The profile consists of the upper 10'-0 of highly plastic clay (CH), Plasticity Index (PI) = 35; cohesion (c) = 2000 psf; unit weight (γ) of 105 pcf. The swell potential of this layer is estimated to be 2". The top 10'-0 layer is underlain by 20' of stiff to very stiff low plasticity clay (CL) that has an Standard Penetration Test (SPT) blow count "N" = 20. The boring was terminated at 30 feet without encountering the water table. No further soil parameters or lab data given.

Possible Solution

Support the structure on a grade beam and structural slab, which is in turn supported by helical piles. Isolate the foundation and slab from the expansive subgrade by forming a 2" void, using a cardboard void form. Assume the water table is at the soil boring termination depth. This is typically a conservative design assumption when the water table is not encountered. The stiff to very stiff clay soil in the 20-foot thick layer is probably at or near 100% saturation (volume of water is the same as the volume of the voids).

Step 1: Feasibility

- Site Access – The site is road accessible, with no overhead or underground obstructions, but the owner is concerned about potential damage to neighboring sites due to vibration and noise.
- Working Loads – The structure is single story, so the working loads are probably considerably less than 100 kip per pile.
- Soils – Boulders, large cobbles, or other major obstructions are not present in the bearing stratum. The clay soil does not appear to be too hard to penetrate with helical piles. See Table 3-1 (Helical Shaft Series Selection) or Figure 3-1 (Product Selection Guide) in Section 3 to determine if helical piles are feasible, and if so, which product series to use.
- Qualified Installers – Local Certified CHANCE® Installers are available and can get competitive bids from a second certified installer 20 miles away.
- Codes – Local building codes allow both shallow and deep foundations.

Cost-bid must be competitive with other systems. Owner may pay a small premium to "protect" the investment in the structure.

Step 2: Soil Mechanics

See Problem section above.

Step 3: Loads

- Exterior Grade Beam – The dead and live loads result in a total live load (P) of 3 kips per lineal foot on the perimeter grade beam (12" wide x 18" deep). The grade beam is designed to span between piles on 8'-0 centers. Therefore, the design or working load per pile (P_w) is 3 kip/ft x 8 ft = 24 kip. A Factor of Safety (FS) of 2.0 is recommended. Therefore, the required ultimate capacity (UC_r) per exterior pile is 24 x 2 = 48 kip compression.
- Interior Columns – The dead load results in 9 kips per column. The live load results in 20 kip per column. The total dead and live load per column is 9 + 20 = 29 kip/column design or working load. A Factor of Safety of 2 is recommended. Therefore, the required ultimate capacity per interior pile is 29 x 2 = 58 kip compression. The required ultimate loads for both the exterior grade beam and interior columns are well within the load ratings of the Hubbell Power Systems, Inc., CHANCE® product series.
- Lateral Loads – The piles are not required to resist any lateral loads.

Step 4: Bearing Capacity

Find the ultimate bearing capacity in the stiff to very stiff clay using hand calculations.

$$\text{Bearing Capacity: } Q_{ult} = A_h (cN_c + q'N_q + 0.5\gamma'BN_\gamma) \quad \text{Equation 8-14}$$

For saturated clay soils, the second term of Equation 8-14 becomes zero since the angle of internal friction (ϕ) is assumed to be zero for saturated clays, thus $N_q = 0$. The third term (base term) may be dropped because B is relatively small. The simplified equation becomes:

$$Q_{ult} = A_h c N_c = A_h c 9 \quad \text{Equation 8-15}$$

$$c \text{ (ksf)} = N/8 \quad \text{Equation 8-16}$$

From Equation 5-35, $c \text{ (ksf)} = 20/8 = 2.5 \text{ ksf}$. At this point, an iterative process is required. Select a helix configuration that is believed can develop the required ultimate capacity. Try a 10"-12" twin helix with a minimum of 5'-0" embedded into the bearing stratum which is the stiff low plasticity clay starting 10 ft below grade. From Table 8-1, the helix area of a 10" helix is 76.4 in² or 0.531 ft²; the helix area of a 12" helix is 111 in² or 0.771 ft².

Substituting:

$$Q_{10} = 0.531 \text{ ft}^2 \times 2.5 \text{ ksf} \times 9 = 11.95 \text{ kips} \quad \text{Equation 8-17}$$

$$Q_{12} = 0.771 \text{ ft}^2 \times 2.5 \text{ ksf} \times 9 = 17.35 \text{ kips}$$

$$Q_t = \Sigma Q_h = 11.95 + 17.35 = 29.3 \text{ kips}$$

Standard Helix Sizes, Table 8-1

DIAMETER in (cm)	AREA ft ² (m ²)
6 (15)	0.185 (0.0172)
8 (20)	0.336 (0.0312)
10 (25)	0.531 (0.0493)
12 (30)	0.771 (0.0716)
14 (35)	1.049 (0.0974)

Another trial is required because the total ultimate capacity ($Q_t = 29.3 \text{ kip}$) is less than required. Try a three-helix configuration (10"-12"-14") with a minimum of 5'-0" embedded in the bearing stratum. From Table 8-1, the helix area of a 14" helix is 151 in² or 1.05 ft².

$$Q_{14} = 1.05 \text{ ft}^2 \times 2.5 \text{ ksf} \times 9 = 23.63 \text{ kips} \quad \text{Equation 8-18}$$

$$Q_t = \Sigma Q_h = 11.95 + 17.35 + 23.63 = 52.93 \text{ kips}$$

To achieve the necessary Factor of Safety of 2, two helical piles with a 10"-12" helical configuration can be used under the interior columns ($29.3 \times 2 = 58.6 \approx 59 \text{ kips}$ ultimate capacity) and a single helical pile with a 10"-12"-14" helical configuration can be used under the perimeter grade beam. The termination of the helical pile in a concrete cap or grade beam should be made with an appropriately designed pile cap or an available "new construction" bracket from Hubbell Power Systems, Inc. This will allow the foundation to rise up, should the swell ever exceed the 2" void allowance, but to shrink back and rest on the pile tops.

DESIGN EXAMPLES

Checking Bearing Capacity Using HeliCAP® Engineering Software

A sample tabular data printout is shown in Figure 8-2, where the twin helix (10"-12") $Q_{ult} = 29.2 \text{ kip} \approx 29.3 \text{ kip}$, OK; and the triple helix (10"-12"-14") $Q_{ult} = 52.8 \text{ kip} \approx 52.93 \text{ kip}$, OK

Steps 5 and 6: Lateral Capacity and Buckling

- Lateral Capacity – None is required in the statement of the problem. In reality, horizontal loads due to wind will be resisted by net earth pressure (passive-active) on the grade beam and/or caps. See Section 5 for an explanation of earth pressure resistance.
- Buckling Concerns – The soil density and shear strength is sufficient to provide lateral confinement to the central steel shaft. This is supported by the fact that the SPT blow count is greater than four for the top clay layer. Should analysis be required, the Davisson method described in Section 5 may be used to determine the critical load.

Step 7: Corrosion

No electrochemical properties were given for the clay soil. Generally, undisturbed, i.e., non-fill, material tends to be benign as little oxygen is present and the ions that are present in solution are not washed away due to flowing water or fluctuating water level. In the absence of soil data, a useful guide is to observe the use of corrugated metal pipe (CMP) by the local Department of Transportation (DOT). If the DOT uses CMP, the likelihood is that the local soils are not very aggressive.

Step 8: Product Selection

Ultimate capacity for a 10"-12" configuration per Step 4 above was 29 kip, and the ultimate capacity for a 10"-12"-14" configuration was 53 kip. Table 8-2 shows that both CHANCE® Helical Type SS5 and Type RS2875.276 product series can be used, since 53 kip is within their allowable load range. Note that Table 8-2 assumes a K_t of 10 ft^{-1} for the Type SS product series and K_t of 9 ft^{-1} for the Type RS2875 product series. In this case, use the Type SS5 product series because shaft buckling is not a practical concern and the required capacity can be achieved with less installation torque.

Practical Guidelines for Foundation Selection, Table 8-2

INSTALLATION TORQUE	ULTIMATE LOAD ¹		DESIGN LOAD ²		HELICAL PILE PRODUCT SERIES
	kip	kN	kip	kN	
5,500	55	244	27.5	110	SS5
5,500	49.5	202	24.75	110	RS2875.203
7,000	70	312	35	156	SS150
8,000	72	320	36	160	RS2875.276

¹ Based on a torque factor (K_t) = 10 for SS Series and K_t = 9 for RS2875 Series.

² Based on a Factor of Safety of 2.

For the 10"-12" configuration, the minimum depth of 18'-0 can be achieved by using a lead section, which is the first pile segment installed and includes the helix plates, followed by two or three plain extensions. For the 10"-12"-14" configuration, the minimum depth of 21'-0 can be achieved by using a lead section followed by three or four plain extensions. The exact catalog items to use for a specific project are usually the domain of the contractor. Your Certified CHANCE® Installer is familiar with the standard catalog items and is best able to determine which ones to use based on availability and project constraints. For your reference, catalog numbers with product descriptions are provided in Section 7 of this design manual.

The head of the helical pile is to be approximately 1'-0 below grade in the grade beam or cap excavation, which will put the twin-helix pile tip 18'-0 below the original ground level and the three-helix screw foundation tip 21'-0. These are minimum depths, required to locate the helix plates at least 5'-0 into the bearing stratum. On large projects, it is advisable to add 3% to 5% extra extensions in case the soil borings vary considerably or if widely spaced borings fail to indicate differences in bearing depths.

Step 9: Field Production Control

Use $K_t = 10 \text{ ft}^{-1}$ for CHANCE® Helical Type SS material if verification testing is not done prior to production work. The minimum depth and minimum installing torque must both be achieved. If the minimum torque requirement is not achieved, the contractor should have the right to load test the helical pile to determine if K_t is greater than 10 ft^{-1} . Verification testing is often done in tension since it's simpler and less costly to do than compression testing, and the compressive capacity is generally higher than tension capacity, which results in a conservative site-specific K_t value.

Estimate installing torque for field production control and specifying the minimum allowable without testing.

$$Q_{ult} = K_t T, \text{ or } T = Q_{ult} / K_t \tag{Equation 8-19}$$

where: $Q_{ult} = UC_r$ in this example

Interior columns: $T = Q_{ult} / K_t = (58,000 \text{ lbs} / 2 \text{ piles}) / 10 \text{ ft}^{-1} = 2,900 \text{ ft-lb} \approx 3,000 \text{ ft-lb}$ for the minimum average torque taken over the last three readings.

Perimeter grade beam: $T = Q_{ult} / K_t = 48,000 \text{ lb} / 10 \text{ ft}^{-1} = 4,800 \text{ ft-lb}$ for the minimum average torque taken over the last three readings.

Note that the torque rating for the CHANCE® Helical Type SS5 product series is 5,500 ft-lb – OK.

Step 10: Product Specifications

See Section 7, Product Drawings and Ratings and Appendix C for Hubbell Power Systems, Inc. model specifications.

Step 11: Load Test

Since this is a small project with low loads in “normal” soils, it is acceptable to use the torque correlation method as the driving criteria and omit the “optional” load test.

DESIGN EXAMPLES

HeliCAP SUMMARY REPORT

Job Name: Design Manual for New Construction

C:\Documents and Settings\glseider\My Documents

Job Number: Example 2

5/19/2003 3:06:57 PM

Water Table Depth: None

Boring No: B-1

Anchor Use: Compression

Capacity Summary

Anchor Number	Anchor Family	Helix Depth (ft)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 90 Datum Depth: 0 Length: 18					
12" helix	SS 5	15	17.3t 17.3c	29.2t	29.2t	2925
10" helix	SS 5	17.5	11.9t 11.9c	29.2c	29.2c	
Anchor 2	Angle: 90 Datum Depth: 0 Length: 21					
14" helix	SS 5	15	23.6t 23.6c	52.8t 52.8c	52.8t 52.8c	5287
12" helix	SS 5	18	17.3t 17.3c			
10" helix	SS 5	20.5	11.9t 11.9c			

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (lb/ft ²)	N	Angle of Internal Friction (Degrees)	Unit Weight (lb/ft ³)
0	Clay	2000	0	0	105
10	Clay	2500	20	0	120

HeliCAP® Summary Report
Figure 8-2

DESIGN EXAMPLES

DESIGN EXAMPLE 5

HELICAL PULLDOWN® MICROPILES for NEW CONSTRUCTION

SYMBOLS USED IN THIS DESIGN EXAMPLE

HPM	CHANCE HELICAL PULLDOWN® Micropile	8-18
ΣQ_h	Compression Capacity	8-18
Q_f	Friction Capacity	8-18
Q_t	Total Capacity	8-18
D_h	Diameter of Helix	8-18
PL/AE	Elastic Compression Line	8-18
N	Standard Penetration Test Blow Count	8-19
ϕ	Angle of Internal Friction	8-19
C	Cohesion of Soil	8-19

Problem

Determine the capacity of the following CHANCE HELICAL PULLDOWN® Micropile (HPM) installed into the soil described in Figure 8-4.

- SS5 1-1/2" x 1-1/2" square shaft
- Helix configuration: 8"-10"-12"
- Total depth: 40 ft
- Grout column: 5" dia x 31 ft

Calculations

End bearing calculations from the HeliCAP® Engineering Software. See Table 8-3 below for the ultimate end bearing capacity of the proposed 8"-10"-12" lead configuration.

Summary: Compression Capacity (ΣQ_h) = 44.7 kip

Summary: Friction Capacity (Q_f) = 22.1 kip (see Table 8-4)

Total Capacity (Q_t) = $\Sigma Q_h + Q_f = 44.7 + 22.1 = 66.8$ kip

Review of Compression Test

Figure 8-3 is a load deflection plot from the actual compression test on the HPM installed into the soil described in Figure 8-4. From the plotted data, the ultimate capacity (based on $0.08D_h + PL/AE$) was 80 kip, compared to the calculated total capacity of 66.8 kip. This calculated value provides a conservative approach to determining the ultimate capacity of an HPM.

DESIGN EXAMPLES

HeliCAP® Summary Report, Table 8-3

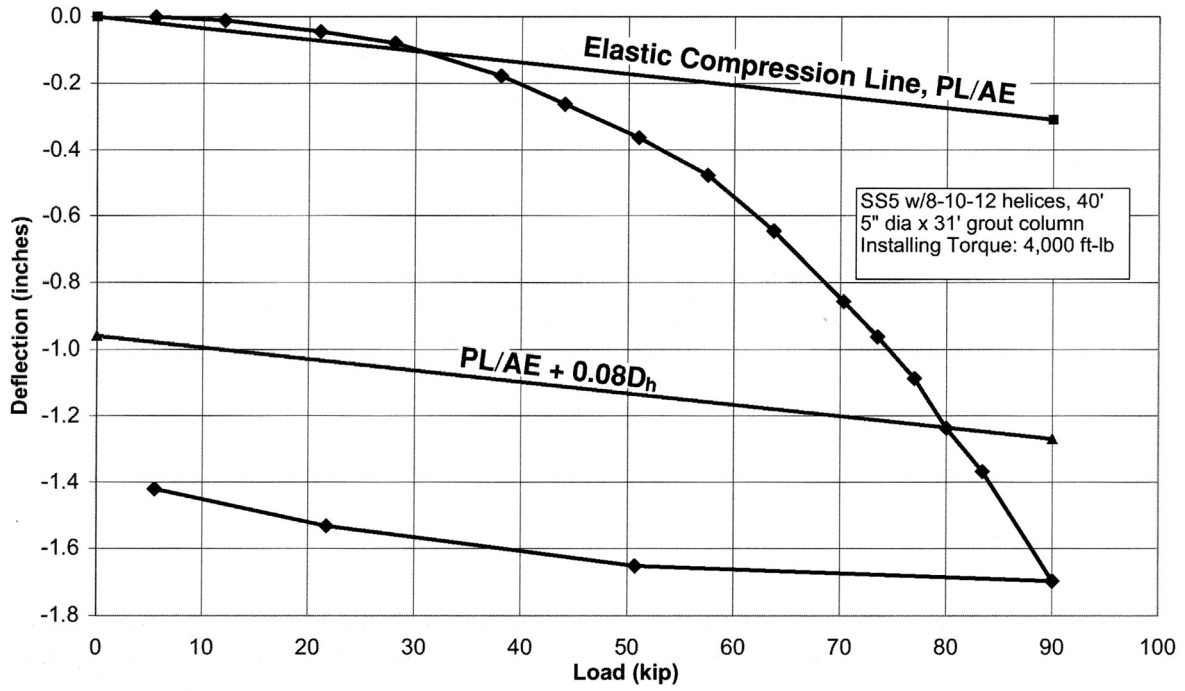
Job Name: Medina, MN Demonstration						
Job Number: Stannard Soil Anchor Systems				Water Table Depth: 15 ft		
Boring No: B-1						
Anchor Use: Compression						
Capacity Summary						
Anchor Number	Anchor Family	Helix Depth (ft)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 90 Datum Depth: 0 Length: 40					
12" helix	SS 5	35	17.9t 19.9c			
10" helix	SS 5	37.5	14.3t 14.8c	41.9t	41.9t	4263
8" helix	SS 5	39.5	9.6t 9.8c	44.7c	44.7c	

DESIGN EXAMPLES

Friction Calculation (See Soil Boring Log in Figure 8-4), Table 8-4

DEPTH (ft)	SOIL	"N"	ESTIMATED		EFFECTIVE UNIT WEIGHT (lb/ft ³)	AVERAGE OVERBURDEN (lb/ft ²)	ADHESION/FRICTION (lb/ft ²)	SIDE FRICTION (lb)
			COHESION (lb/ft ²)	φ				
0 - 9	CLAY	6	750	-	92	-	682	8040
9 - 15	CLAY	2	250	-	84	-	250	1965
15 - 18	CLAY	1	125	-	20	-	125	491
18 - 22	SAND	5	-	29	23	1438	798	3192
22 - 28	CLAY	7	875	-	32	-	682	5364
28 - 31	SAND	8	-	30	38	1733	1001	3003
TOTAL								22055

Notes: (1) $\phi = 0.28N + 27.4$ (2) $c = (N \times 1000) / 8$ (3) Area/ft of pile = $\pi \times d = \pi (5/12) = 1.31\text{ft}^2/\text{ft}$



Helical Pulldown® Micropile Compression Test
Figure 8-3

DESIGN EXAMPLES

MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION
 LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION



UNIQUE NUMBER
 U.S. Customary Units

State Project		Bridge No. or Job Desc.		Trunk Highway/Location		Boring No.	Ground Elevation			
				Anchor Demonstration - Medina, MN		1				
Location					Drill Machine 91		SHEET 1 of 2			
Co. Coordinate: X= Y= (ft.)					Hammer CME Automatic Calibrated		Drilling Completed 7/16/01			
Latitude (North)= Longitude (West)=										
DEPTH	Depth	Lithology	Classification	Drilling Operation	SPT	MC	COH	γ	Soil	Other Tests Or Remarks
	Elev.				N ₆₀	(%)	(psf)	(pcf)		
					REC (%)	RQD (%)	AGL (ft)	Core Breaks	Rock	Formation or Member
	5		FILL, mixture of sandy lean clay, clayey sand, a little gravel, brown and gray							
	9.5		SAPRIC PEAT, black, soft (PT)							
	12.0		ORGANIC CLAY, grayish brown, very soft (OH)							
	15			WH						
	18.0		SILTY SAND, fine grained, gray, waterbearing, loose, lenses of lean clay (SM)							
	22.0		LEAN CLAY, gray, firm (CL)							
	28.0		CLAYEY SAND, a little gravel, gray, firm to stiff to very stiff, lenses of sand (SC/CL)							
	35									

Index Sheet Code 3.0

(Continued Next Page)

Soil Class:LR Rock Class:LR Edit: Date 7/19/01
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Soil Boring Log
 Figure 8-4
 (Sheet 1 of 2)

DESIGN EXAMPLES



MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION
 LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION



UNIQUE NUMBER
 U.S. Customary Units

Mn/DOT GEOTECHNICAL SECTION - LOG & TEST RESULTS							SHEET 2 of 2			
State Project		Bridge No. or Job Desc.		Trunk Highway/Location		Boring No.	Ground Elevation:			
				Anchor Demonstration - Medina, MN		1				
DEPTH	Depth	Lithology	Classification	Drilling Operation	SPT	MC	COH	γ	Soil	Other Tests
	Elev.				N ₆₀	(%)	(psf)	(pcf)		Or Remarks
					REG (%)	RQD (%)	ACL (%)	Core Breaks	Rock	Formation or Member
					11					
	40		CLAYEY SAND, a little gravel, gray, firm to stiff to very stiff, lenses of sand (SC/CL)		11					
	45				12					
	50				15					
	55				17					
	60				20					
	64.0									
Bottom of Hole - 64'										

Soil Class. LR Rock Class. LR Edit Date: 7/19/07
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Soil Boring Log
 Figure 8-4
 (Sheet 2 of 2)

DESIGN EXAMPLES

DESIGN EXAMPLE 6

HELICAL PILES for BOARDWALKS

SYMBOLS USED IN THIS DESIGN EXAMPLE

SPT	Standard Penetration Test	8-23
N	SPT Blow Count	8-23
WOH	Weight of Hammer	8-23
P_w	Working Pier Load	8-23
FS	Factor of Safety	8-23
UC_r	Required Ultimate Capacity	8-23
Q_h	Ultimate Capacity of Helix Plate	8-24
A	Projected Area of Helix Plate	8-24
D	Vertical Depth to Helix Plate	8-24
γ'	Effective Unit Weight of Soil	8-24
N_q	Bearing Capacity Factor	8-24
K	End Condition Parameter	8-25
P_{crit}	Critical Load	8-25
E	Modulus of Elasticity	8-25
I	Moment of Inertia	8-25
L_u	Unsupported Length	8-25
K_t	Empirical Torque Factor	8-25

DESIGN EXAMPLES

Soils

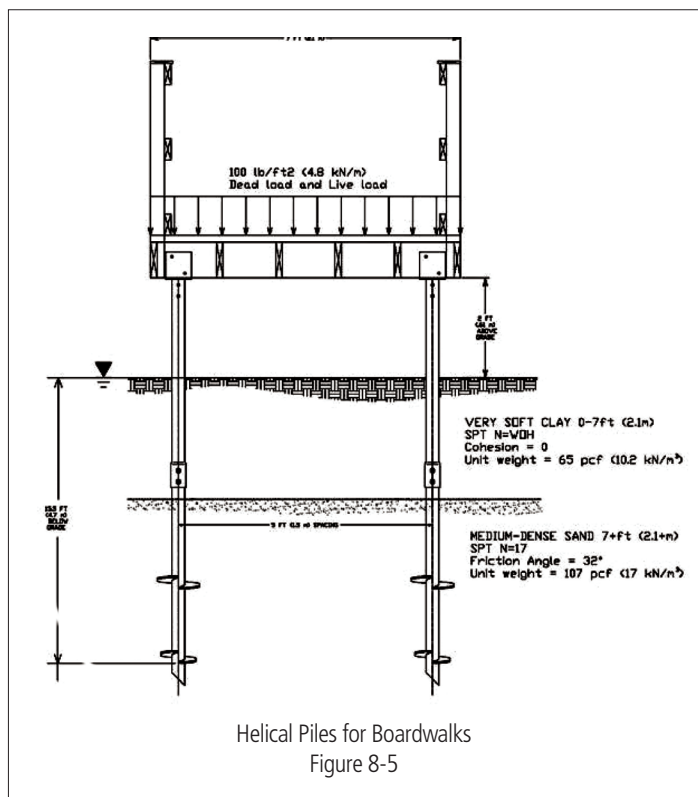
A helical pile foundation is proposed to support a pedestrian walkway. The soil profile consists of 7'-0 (2.1 m) of very soft clay with a reported Standard Penetration Test (SPT) blow count “N” equal to weight of hammer (WOH) and a unit weight of 65 lb/ft³ (10.2 kN/m³). Below the very soft clay is a thick layer of medium-dense sand with a SPT blow count value of 17. The correlated friction angle is 32° and the unit weight is 107 lb/ft³ (16.8 kN/m³). The water table is located at the surface. The proposed helical pile is connected to the walkway with a CHANCE® Walkway Support Bracket. The helical piles must be checked for lateral stability in the very soft clay.

Walkway

- The helical piles are spaced 5 ft (1.5 m) apart and are exposed 2 ft (0.61 m) above grade as shown in Figure 8-5.
- The walkway is 7 ft (2.1 m) wide; each pile group or “bent” is spaced 10'-0 apart.

Structural Loads

- The dead and live vertical load is 100 lb/ft² (4.8 kN/m²). Lateral loads are negligible.
- The required compression load per helical pile (P_w) is 100 lb/ft² x 7'-0 x 10'-0 = 7000 lb/2 helical piles = 3500 lb (15.6 kN) per pile.
- Using a Factor of Safety (FS) of 2, the required ultimate capacity (UC_r) per helical pile is 3500 lb x 2 = 7000 lb (31.1 kN).



CHANCE® Helical Pile Selection

- Try a twin-helix configuration with 10" (254 mm) and 12" (305 mm) diameters.
- Try either Type SS5 1-1/2" (38 mm) Square Shaft or Type RS2875.203 2-7/8" (73 mm) Round Shaft material.

Ultimate Pile Capacity

The top-most helix should be at least three diameters into a suitable bearing soil; which in this example is the medium-dense sand starting 7 ft (2.1 m) below grade. The spacing between helix plates is also three diameters; which is $3 \times 10'' = 2.5$ ft (0.8 m) for a 10"-12" (254 mm – 305 mm) configuration. Finally, the distance from the bottom-most helix to the pile tip is 0.5 ft (0.15 m). Therefore, the minimum overall length for a 10"-12" helix configuration in this soil profile is $7 \text{ ft} + (3 \times 12 \text{ inch}) + 2.5 \text{ ft} + 0.5 \text{ ft} = 13 \text{ ft}$ (4 m). The effective unit weight is the submerged unit weight in this case, because the water table is at the ground surface. The general bearing capacity equation (simplified for cohesionless soils) is:

$$Q_h = AD\gamma'N_q$$

Equation 8-20

where:

Q_h = Ultimate capacity of helix plate

A = Projected area of helix plate

D = Vertical depth to helix plate

γ' = Effective unit weight of soil = 2.6 lb/ft^3 (0.4 kN/m^3) for the very soft clay and 44.6 lb/ft^3 (7.1 kN/m^3) for the medium-dense sand

N_q = Bearing capacity factor for cohesionless soils = 17 for 32° sand

For a 10"-12" configuration, the bearing capacity equation is:

$$\Sigma Q_h = A_{10}D_{10}\gamma'N_q + A_{12}D_{12}\gamma'N_q$$

Equation 8-21

$$\text{where: } \Sigma Q_h = 0.531 \text{ ft}^2[(7 \text{ ft} \times 2.6 \text{ lb/ft}^3) + (5.5 \text{ ft} \times 44.6 \text{ lb/ft}^3)]17 + 0.771 \text{ ft}^2[(7 \text{ ft} \times 2.6 \text{ lb/ft}^3) + (3 \text{ ft} \times 44.6 \text{ lb/ft}^3)]17$$

$$\Sigma Q_h = 4371 \text{ lb (19.4 kN)}$$

4371 lb is less than the required ultimate capacity (7000 lb) needed for the vertical piles. Greater capacity can be obtained by extending the helix plates deeper into the medium-dense sand. Try extending the pile length 3 ft (0.9 m) deeper so that the tip is 16 ft (4.9 m).

$$\begin{aligned} \Sigma Qh &= 0.531 \text{ ft}^2[(7 \text{ ft} \times 2.6 \text{ lb/ft}^3) + (8.5 \text{ ft} \times 44.6 \text{ lb/ft}^3)]17 \\ &\quad + 0.771 \text{ ft}^2[(7 \text{ ft} \times 2.6 \text{ lb/ft}^3) + (6 \text{ ft} \times 44.6 \text{ lb/ft}^3)]17 \\ \Sigma Qh &= 7332 \text{ lb (32.6 kN)} \end{aligned} \tag{Equation 8-22}$$

7332 lb is greater than the required ultimate capacity needed for the vertical piles, so 16 ft (4.9 m) pile length will work.

Buckling

Check for buckling on Type SS5 1-1/2" (38 mm) square shaft and Type RS2875.203 2-7/8" (73 mm) OD pipe shaft material with 2 ft (0.61 m) of exposed shaft above grade. Assume a free-fixed ($K = 2$) end-condition. Assume the very soft clay provides no lateral support, i.e., the pile shaft is unsupported above the sand, so the unsupported (effective) length (L_u) of the "column" is 2 ft + 7 ft = 9 ft (2.7 m).

Euler's Equation: $P_{crit} = \pi^2 EI / [KL_u]^2$

For Type SS5 square shaft material:

$$\begin{aligned} P_{crit} &= \pi^2 [30 \times 10^6 \text{ lb/in}^2] [.396 \text{ in}^4] / [2 \times 108 \text{ in}]^2 \\ P_{crit} &= 2513 \text{ lb (11.2 kN)} \end{aligned} \tag{Equation 8-23}$$

The critical load for the Type SS5 series is less than the required 7000 lb (31.1 kN) ultimate capacity, so a shaft with greater stiffness is required.

For Type RS2875.203 pipe shaft material:

$$\begin{aligned} P_{crit} &= \pi^2 [30 \times 10^6 \text{ lb/in}^2] [1.53 \text{ in}^4] / [2 \times 108 \text{ in}]^2 \\ P_{crit} &= 9710 \text{ lb (42.2 kN)} \end{aligned} \tag{Equation 8-24}$$

The critical load for Type RS2875.203 pipe shaft is greater than the required 7000 lb (31.1 kN) ultimate capacity. Use the RS2875.203 series (2-7/8 inch (73 mm) OD pipe shaft material).

Torque

$$\begin{aligned} \text{Torque required} &= \text{Required ultimate capacity} / K_t \\ \text{where:} &= K_t = 9 \text{ (26) for RS2875 round shaft} \\ \text{Torque required} &= 7000 \text{ lb} / 9 \\ \text{Torque required} &= 778 \text{ ft-lb (1186 N-m)} \end{aligned} \tag{Equation 8-25}$$

The torque strength rating for RS2875.203 material is 5,500 ft-lb (7,500 N-m) - OK.

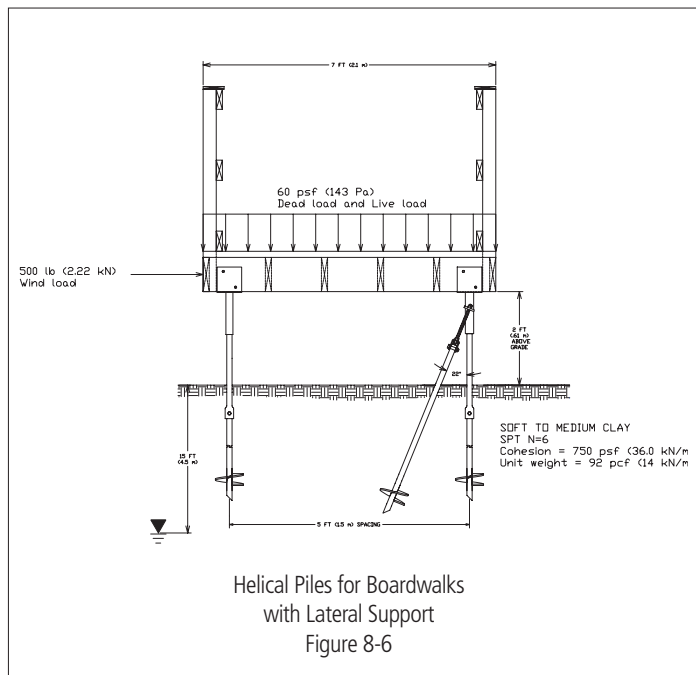
DESIGN EXAMPLE 7

HELICAL PILES for BOARDWALKS with LATERAL SUPPORT

SYMBOLS USED IN THIS DESIGN EXAMPLE

SPT	Standard Penetration Test	8-26
N	SPT Blow Count	8-26
psf	Pounds per Square Foot	8-26
GWT	Ground Water Table	8-26
FS	Factor of Safety	8-26
UC_r	Required Ultimate Capacity	8-26
Q_t	Total Capacity	8-27
A	Area of Helix	8-27
c	Cohesion of Soil	8-27
N_c	Bearing Capacity	8-27
P_{crit}	Critical Load	8-27
K_t	Empirical Torque Factor	8-27

A CHANCE® Helical Type SS5 square shaft is proposed as the foundation for a pedestrian walkway. The pier is connected to the walkway with a CHANCE® Helical Walkway Support Bracket with lateral support. The soil is a soft to medium clay with a Standard Penetration Test (SPT) "N" value of 6, cohesion of 750 psf (36.0 kN/m²) and unit weight of 92 lb/ft³ (14 kN/m³). The ground water table (GWT) is 15 ft (4.5 m) below grade.



Walkway:

- The piles are spaced 5 ft (1.5 m) apart and are exposed 2 ft (0.61 m) above grade.
- The walkway is 7 ft (2.1 m) wide and pier sets are 5 ft (1.5 m) apart.
- The battered pile is at an angle of 22°.

Structural Loads:

- Using a Factor of Safety (FS) of 2, the required ultimate capacity (UC_r) per vertical pile is 4550 lb (20 kN).
- Using a Factor of Safety of 2, the required ultimate capacity (UC_r) per battered pile is 2646 lb (12 kN).

CHANCE® Helical Pile Selection:

- Try a Type SS5 square shaft with a 12" (305 mm) diameter helix.

CHANCE® Helical Pile Selection

- Try a Type SS5 square shaft with a 12" (305 mm) diameter helix.

Ultimate Pile Capacity:

The pile depth needs to be at least 5 diameters into the soft to medium clay layer. Therefore the vertical pile length should be at least 5 ft (1.5 m) below grade.

$$\begin{aligned}
 Q_t &= AcN_c && \text{Equation 8-26} \\
 Q_t &= [.771 \text{ ft}^2][750 \text{ psf}][9] \\
 &= 5,204 \text{ lb (23 kN)}
 \end{aligned}$$

where: A = Projected area of helical plates
 c = Cohesion of soil
 N_c = Bearing capacity

5,204 lb is greater than UC_r for the vertical pile. The battered pile depth needs to be at least 5 diameters below grade. Therefore the battered pile length should be 6 ft (1.8 m) below grade.

Buckling:

Check for buckling on the SS5 square shaft with 2 ft (0.61 m) of exposed shaft above grade. Assume a pin-pin (K = 1) connection.

Euler's Equation:

$$\begin{aligned}
 P_{crit} &= \pi^2 EI / [KL_u]^2 && \text{Equation 8-27} \\
 P_{crit} &= \pi^2 [30 \times 10^6] [.396] / [1 \times 24]^2 \\
 P_{crit} &= 203,354 \text{ lb (904 kN)}
 \end{aligned}$$

The critical load is greater than the ultimate vertical load so buckling is not a concern.

Torque:

$$\begin{aligned}
 \text{Torque required} &= \text{Required load} / K_t && \text{Equation 8-28} \\
 \text{where:} &= K_t = 10 (33) \text{ for square shaft} \\
 \text{Torque required} &= 5,204 \text{ lb} / 10 \\
 \text{Torque required} &= 520 \text{ ft-lb (705 N-m)}
 \end{aligned}$$

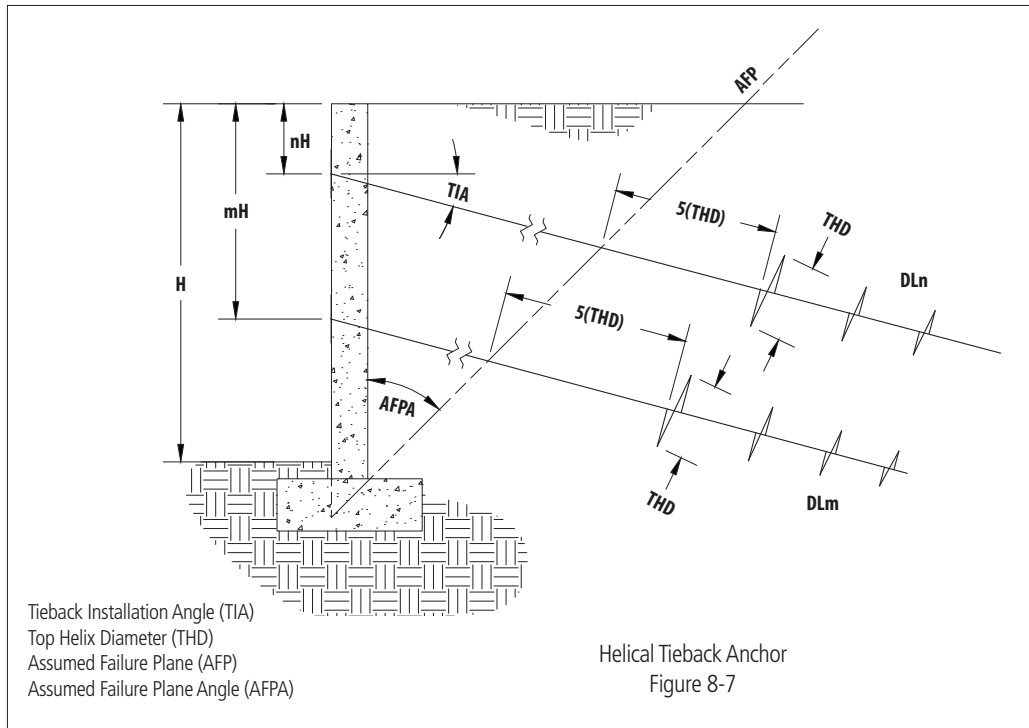
This does not exceed the SS5 torque rating of 5,500 ft-lb (7,500 N-m).

DESIGN EXAMPLES

DESIGN EXAMPLE 8
HELICAL TIEBACK ANCHORS IN CLAY
SYMBOLS USED IN THIS DESIGN EXAMPLE

H.....	Height of Wall	8-29
nH.....	Height of Upper Anchor	8-29
mH.....	Height of Lower Anchor	8-29
GWT.....	Ground Water Table	8-29
DL _N	Design Load for Upper Anchor	8-29
DL _M	Design Load for Lower Anchor	8-29
Q _{tn}	Ultimate Tension Capacity for Upper Anchor	8-29
Q _{tm}	Ultimate Tension Capacity for Lower Anchor	8-29
A.....	Area of Helix Plate	8-29
N _c	Bearing Capacity Factor	8-29
c.....	Cohesion of Soil	8-29
T _u	Ultimate Capacity of Anchors	8-29
FS.....	Factor of Safety	8-30
T _N	Installation Torque for Upper Anchor	8-30
T _M	Installation Torque for Lower Anchor	8-30
K _t	Empirical Torque Factor	8-30

DESIGN EXAMPLES



Structure Type

- Cast concrete retaining wall
- Height (H) = 18 ft, thickness = 2'-0
- $nH = 0.25H = 4.5$ ft, $mH = 0.63H = 11.3$ ft
- Residual soils: stiff clay with $N = 28$. No ground water table (GWT) present.
- Tieback installation angle = 15°

Structural Design Loads (See Figure 4-6 in Section 4)

- $DL_N/ft = (12 \times H^2) / \cos 15^\circ$
- $DL_N/ft = (12 \times 18^2) / \cos 15^\circ$
- $DL_N/ft = 4,025$ lb/lin ft
- $DL_M/ft = (18 \times H^2) / \cos 15^\circ$
- $DL_M/ft = (18 \times 18^2) / \cos 15^\circ$
- $DL_M/ft = 6,040$ lb/lin ft

CHANCE® Helical Product Selection

- Wall height ≥ 15 ft; use two rows of tiebacks
- Try Type SS150 series, C150-0169 (8"-10"-12" Lead) for DL_N .
- Try Type SS175 series, C110-0247 (8"-10"-12"-14" Lead) for DL_M .

Ultimate Tension Capacity (Using Bearing Capacity Approach)

$$Q_{tn} = (A_8 + A_{10} + A_{12}) \times (c N_c)$$

A_8, A_{10}, A_{12} = Projected area of helical plates (8", 10", and 12")

N_c = Bearing capacity factor related to the residual soil, clay

$A_8 = 0.336$ ft²

$A_{10} = 0.531$ ft²

$A_{12} = 0.771$ ft²

$N_c = 9$

$c = N / 8 = 28 / 8 = 3.5$ ksf or 3,500 psf (see Equation 5-35)

$Q_{tn} = (0.336 + 0.531 + 0.771) \times 3,500 \times 9$

$Q_{tn} = 51,600$ lbs

Equation 8-29

$$Q_{tm} = (A_8 + A_{10} + A_{12} + A_{14}) \times (c N_c)$$

$A_8, A_{10}, A_{12}, A_{14}$ = Projected area of helical plates (8", 10", 12", and 14")

$A_{14} = 1.049$ ft²

$Q_{tm} = (0.336 + 0.531 + 0.771 + 1.049) \times 3,500 \times 9$

$Q_{tm} = 84,640$ lbs

Equation 8-30

Check Ultimate Anchor Capacity (T_u)

Compare Q_{tN} and Q_{tM} to field load tension tests if required by specifications.

Tieback Spacing

$$\text{Spacing}_N = (Q_{tN} / FS) / DL_N = (51,600 / 2) / (4,025) = 6.4 \text{ ft}$$

$$\text{Spacing}_M = (Q_{tM} / FS) / DL_M = (84,640 / 2) / (6,040) = 7.0 \text{ ft}$$

(use 6'-6" center to center spacing for both rows of tiebacks)

where: FS = 2.0

Estimate Installation Torque

$$T = (DL \times \text{Spacing} \times FS) / K_t$$

Equation 8-31

$$T_N = (DL_N \times \text{Spacing}_N \times FS) / K_t = (4,025 \times 6.5 \times 2) / 10 = 5,300 \text{ ft-lb}$$

$$T_M = (DL_M \times \text{Spacing}_M \times FS) / K_t = (6,040 \times 6.5 \times 2) / 10 = 7,850 \text{ ft-lb}$$

where: K_t = Empirical torque factor (default value = 10 for Type SS series)

Check Installation Torque Ratings

The rated installation torque of the Type SS150 series is 7,000 ft-lbs, which is greater than the required installation torque (T_N) of 5,300 ft-lbs.

The rated installation torque of the Type SS175 series is 10,500 ft-lbs, which is greater than the required installation torque (T_M) of 7,850 ft-lbs.

Minimum Tieback Length

The distance from the assumed "active" failure plane to the 12" helix must be at least 5 x its diameter or 5'-0". The distance from the assumed "active" failure plane to the 14" helix must be at least 5 x its diameter or 6'-0". Both the minimum length and estimated installation torque must be satisfied prior to the termination of tieback installation.

DESIGN EXAMPLES

DESIGN EXAMPLE 9

HELICAL TIEBACK ANCHORS IN SAND

SYMBOLS USED IN THIS DESIGN EXAMPLE

φ	Angle of Internal Friction	8-31
γ	Unit Weight of Soil	8-31
pcf.....	Pounds per Cubic Foot	8-31
K_a	Active Earth Pressure Coefficient	8-31
DL.....	Design Load	8-31
DL_t	Tieback Design Load	8-31
Q_t	Ultimate Tension Capacity	8-32
A.....	Area of Helix Plate	8-32
N_q	Bearing Capacity Factor	8-32
Q_t	Total Capacity	8-32
T_u	Ultimate Anchor Capacity	8-32
FS.....	Factor of Safety	8-32
T.....	Installation Torque	8-32
K_t	Empirical Torque Factor	8-32

DESIGN EXAMPLES

Structure Type

- Cast concrete retaining wall
- Granular backfill for wall $\varphi = 35^\circ$ $\gamma = 120$ pcf
- Height = 15 ft, thickness = 1-1/2 ft
- Anchor Height = 1/3H = 5 ft
- Residual soils: silty coarse sand; medium to dense $\varphi = 31^\circ$ $\gamma = 118$ pcf. No ground water table present.
- Tieback installation angle = 25°

Structural Design Loads

- Use backfill $\varphi = 35^\circ$
- $K_a = (1 - \sin \varphi) / (1 + \sin \varphi) = 0.27$
- $DL/ft = (1/2 \gamma H^2 K_a) / \cos 25^\circ$
 $= [1/2 (120) (15)^2 (0.27)] / \cos 25^\circ$
 $= 4,000$ lb/lin ft
- Assume tieback carries 80%; therefore, $DL_t / ft = 0.80 \times 4,000 = 3,200$ lb/lin ft

CHANCE® Helical Product Selection

- Wall height ≤ 15 ft; use single row of tiebacks
- Try Type SS5 series, C1500007 (8"-10"-12" Lead)

Ultimate Tension Capacity (Using Bearing Capacity Approach)

$$\begin{aligned}
 Q_t &= (A_8 + A_{10} + A_{12}) \times (q_h N_q) && \text{Equation 8-32} \\
 A_8, A_{10}, A_{12} &= \text{Projected area of helical plates (8", 10" and 12")} \\
 N_q &= \text{Bearing capacity factor related to } \varphi \text{ of residual soil (31}^\circ\text{)} \\
 A_8 &= 0.336 \text{ ft}^2 \\
 A_{10} &= 0.531 \text{ ft}^2 \\
 A_{12} &= 0.771 \text{ ft}^2 \\
 N_q &= 15 \text{ (from Equation 5-19)} \\
 q_h &= \gamma \times D_h \text{ (depth of helix below ground line, ft)} \\
 q_8 &= 118 \text{ pcf (5' + 25' sin 25}^\circ\text{)} = 1836 \text{ psf} \\
 q_{10} &= 118 \text{ pcf (5' + 23' sin 25}^\circ\text{)} = 1736 \text{ psf} \\
 q_{12} &= 118 \text{ pcf (5' + 20.5' sin 25}^\circ\text{)} = 1612 \text{ psf} \\
 Q_t &= [(0.336 \times 1836) + (0.531 \times 1736) + (0.771 \times 1612)] \times 15 \\
 Q_t &= 41,725 \text{ lbs}
 \end{aligned}$$

Check Ultimate Anchor Capacity (T_u)

Compare Q_t to field load tension tests if required by specifications.

Tieback Spacing

$$\begin{aligned}
 \text{where: } \text{Spacing}_N &= (Q_t / FS) / DL_t = (41,725 / 2) / (3,200) = 6.5 \text{ ft} && \text{Equation 8-33} \\
 &= \text{(use 6'-6 center to center spacing)} \\
 FS &= 2.0
 \end{aligned}$$

Estimate Installation Torque

$$\begin{aligned}
 \text{where: } T &= (DL_t \times \text{spacing} \times FS) / K_t = (3,200 \times 6.5 \times 2.0) / 10 = 4,200 \text{ ft-lb} && \text{Equation 8-34} \\
 K_t &= \text{Empirical torque factor (default value = 10 for Type SS series)}
 \end{aligned}$$

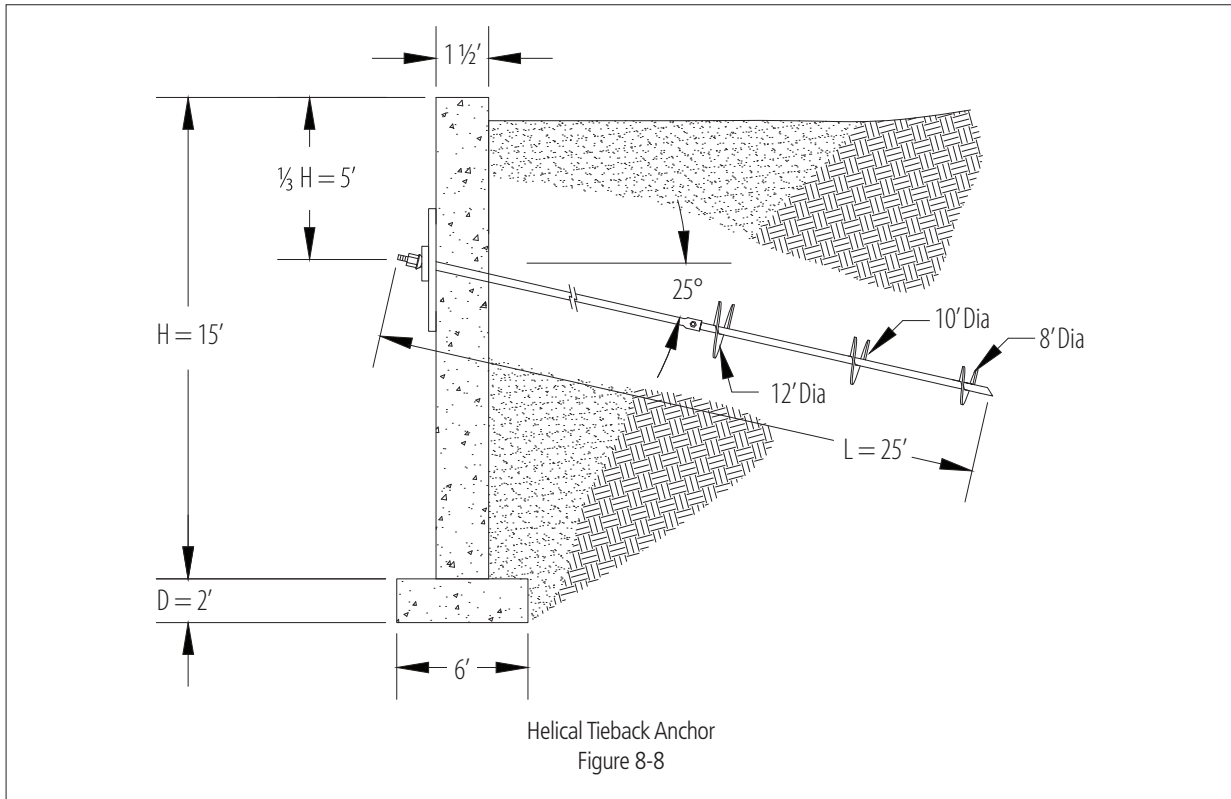
Check Installation Torque Ratings

The rated installation torque of the Type SS5 series is 5,500 ft-lbs, which is greater than the required installation torque (T) of 4,200 ft-lbs.

Minimum Tieback Length

The distance from the assumed "active" failure plane to the 12" helix must be at least 5 times its diameter or 5'-0". Both the minimum length and estimated installation torque must be satisfied prior to the termination of tieback installation.

DESIGN EXAMPLES



SOIL BORING LOG				
Graphic Log	Soil Classification	Depth	USCS Symbol	SPT - N Blows/ft
	Topsoil		OH	
	Silty Sand	5	SM	17
	Silty Coarse Sand $\gamma = 118 \text{ pcf}$ $\phi = 31^\circ$	10	SM	30
		15		32
		20		34

Soil Boring Log
Figure 8-9

DESIGN EXAMPLES

DESIGN EXAMPLE 10
SOIL SCREW® RETENTION WALL SYSTEM
SYMBOLS USED IN THIS DESIGN EXAMPLE

S_v	Vertical SOIL SCREW® Spacing	8-35
S_H	Horizontal SOIL SCREW® Spacing	8-35
L	Length of SOIL SCREW® Anchor	8-35
FS	Factor of Safety	8-35
γ	Unit Weight of Soil	8-35
ϕ	Internal Angle of Friction	8-35
pcf	Pounds per Cubic Foot	8-35
psf	Pounds per Square Foot	8-35
Ω	Ohms	8-35
ppm	Parts per Million	8-35
GWT	Ground Water Table	8-36
H	Height of Wall	8-36
K_a	Active Earth Pressure Coefficient	8-36
F_1	Horizontal Force from Retained Soil	8-36
F_2	Horizontal Force from Surcharge Load	8-36
L_x	Horizontal Length of SOIL SCREW® Anchor	8-37
e	Eccentricity of Vertical Force	8-37
σ_v	Vertical Stress	8-37
Q_{allow}	Allowable Bearing Capacity	8-37
kip	Kilopound	8-38
N_q	Bearing Capacity Factor	8-39
P	Ultimate Tension Capacity	8-39
A	Area of Helix	8-39
y	Difference in Depth of SOIL SCREW® Anchor from End to End	8-39
θ	Angle of SOIL SCREW® Anchor (from horizontal)	8-39
psi	Pounds per Square Inch	8-40
ksi	Kilopounds per Square Inch	8-40
d	Diameter of Welded Fabric Wire	8-40
D	Diameter of Rebar	8-40
A_s	Area of Steel	8-40
m_v	Vertical Moment Resistance	8-41

DESIGN EXAMPLES

T_{FN}	Maximum Helical Anchor Head Load	8-41
C_F	Facing Pressure Factor	8-41
V_N	Punching Shear Strength of Facing	8-41
f'_c	Compressive Strength of Concrete	8-41
h_c	Thickness of Facing	8-41
D'_c	Effective Cone Diameter at Center of Facing	8-41
$FS_{internal}$	Internal Factor of Safety	8-42
FS_{global}	Global Factor of Safety	8-43
M_c	Cantilever Moment	8-43
FS_{MC}	Factor of Safety for Cantilever Moment	8-44
S_c	Shear Force	8-44
FS_{shear}	Factor of Safety for Shear Force	8-44

Problem

Determine the SOIL SCREW® Anchor spacing (S_V , S_H), SOIL SCREW® Anchor length (L) and facing requirements for an excavation support system for a 23 foot deep excavation in a silty sand. The required design Factor of Safety (FS) for internal stability is 1.5, and for global stability is 1.3.

Step 1 - Define Design Parameters

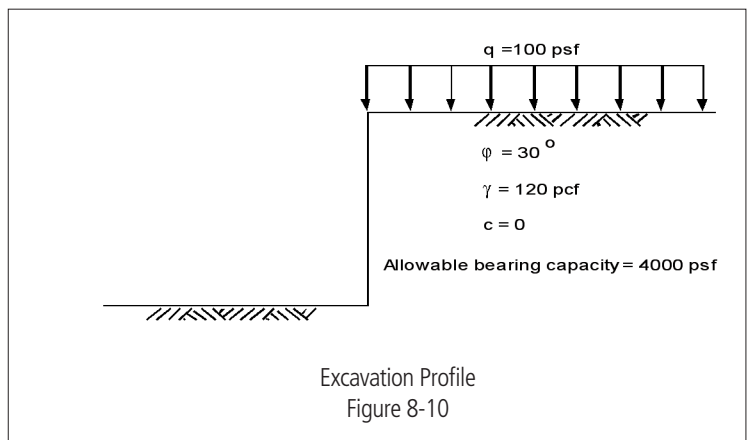
Given: The unit weight (γ) and friction angle (ϕ) of the silty sand is 120 pcf and 30° respectively. The allowable bearing capacity of the silty sand at the bottom of the excavation is 4000 psf. The electrochemical properties of the silty sand are listed below:

- Resistivity 4000 Ω/cm
- pH 7
- Chlorides 50 ppm
- Sulfates 100 ppm

A design live surcharge load of 100 psf is considered to be applied uniformly across the ground surface at the top of the wall. The wall face is vertical. Groundwater is located 60 feet below the ground surface.

CHANCE® Type SS5 Helical SOIL SCREW® Anchors, for which lead sections and extensions are available in 5' and 7' lengths, are to be used for the SOIL SCREW® Anchors.

The design life of the structure is one year. Design SOIL SCREW® Anchor lengths will be governed by the lead and extension pieces and thus will be 10', 12', 14', 15', 17', 19', etc.

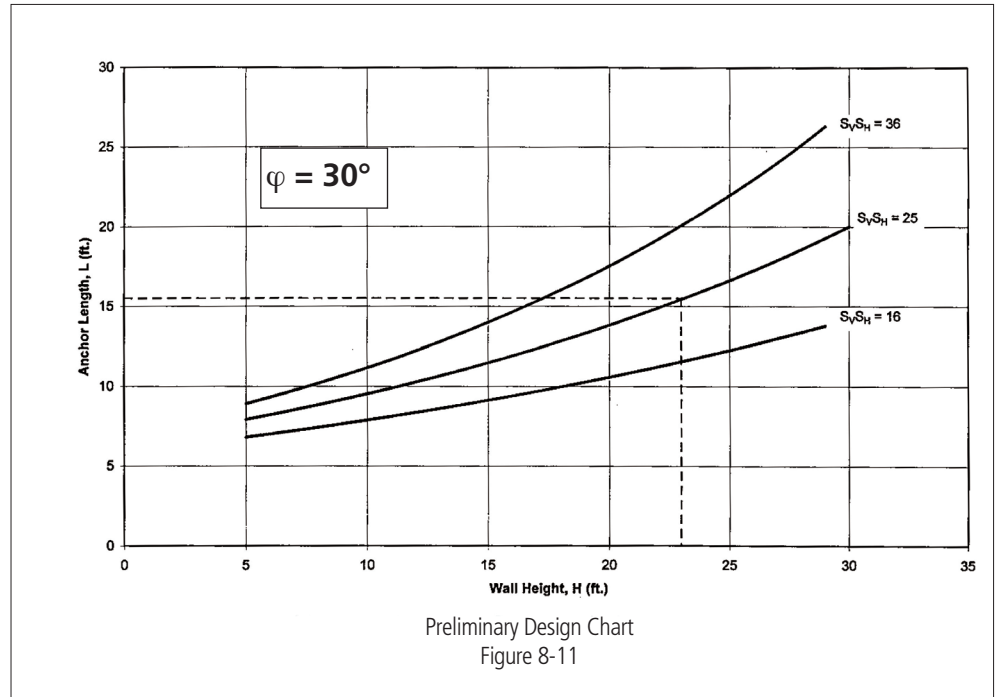


Step 2 - Check the Preliminary Feasibility of the SOIL SCREW® Retention Wall System

The medium dense, silty sands at this site are well suited for the SOIL SCREW® Retention Wall System (i.e., good stand up time). The ground water table (GWT) is well below the bottom of the excavation. The conditions at the site are therefore favorable for the SOIL SCREW® Retention Wall System.

Design charts are used to determine preliminary SOIL SCREW® Anchor spacing and lengths for the given wall geometry, loading and soil conditions. For the soil conditions, $\phi = 30^\circ$, enter the Preliminary Design Chart

(Figure 8-11) along the x-axis at a wall height (H) = 23 ft. A typical SOIL SCREW® Anchor spacing for soils with "good" stand up time is 5 ft. x 5 ft. Therefore, use the $S_V S_H = 25$ curve to determine the preliminary SOIL SCREW® Anchor length (L) = 16 ft.



Step 3 - Determine External Earth Pressures

Use Equation 8-35 to determine the active earth pressure (K_a) at the back of the reinforced soil mass.

$$K_a = \tan^2 [45 - (\phi/2)]$$

Equation 8-35

$$K_a = \tan^2 [45 - (30/2)] = 0.33$$

Step 4 - Check Preliminary SOIL SCREW® Anchor Length with Respect to Sliding

Available SOIL SCREW® Anchor lengths for CHANCE® Helical Type SS5 anchors are 10', 12', 14', 15', 17', 19', etc. The 16 foot preliminary length determined in Step 2 does not account for surcharge loading, which tends to increase SOIL SCREW® Anchor lengths. Try 19' SOIL SCREW® Anchors (length to height ratio of 0.83). For preliminary designs for walls with the given soil and loading conditions, a length to height ratio of 0.8 to 1.0 is a starting point for the analysis and appears to be conservative.

The horizontal force from the retained soil (F_1) is determined using Equation 8-36.

$$F_1 = 1/2 K_a \gamma H^2$$

Equation 8-36

$$F_1 = 1/2 (0.33) (120) 23^2 = 10474 \text{ lb/lf of wall}$$

The horizontal force from the surcharge load (F_2) is determined using Equation 8-37.

$$F_2 = K_a qH = 0.33 (100) 23 = 759 \text{ lb/lf of wall}$$

Equation 8-37

Using 19' SOIL SCREW® Anchors installed at a 15° angle, the horizontal length (L_x) of the SOIL SCREW® Anchor is determined using Equation 8-38.

$$L_x = L \cos 15^\circ \quad \text{Equation 8-38}$$

$$L_x = 19 \cos 15^\circ = 18.4 \text{ ft}$$

The Factor of Safety against sliding is determined using Equation 8-39.

$$FS = \frac{\gamma HL_x \tan \phi}{F_1 + F_2} = \frac{120 (23) 18.4 \tan 30}{10474 + 759} \quad \text{Equation 8-39}$$

$$FS = 2.61$$

Step 5 - Check Required Bearing Capacity at the Base of the Wall

Determine the eccentricity (e) of the resultant vertical force using Equation 8-40.

$$e = \frac{[F_1 (H/3)] + [F_2 (H/2)]}{\gamma HL_x} \quad \text{Equation 8-40}$$

$$= \frac{[10474 (23/3)] + [759 (23/2)]}{120 (23) 18.4}$$

$$= 1.75 < (L_x/6) = (18.4/6) = 3.06$$

The vertical stress (σ_v) of the bottom of the wall is determined using Equation 8-41.

$$\sigma_v = \frac{\gamma HL_x + qL_x}{L_x - 2e} = \frac{120 (23) 18.4 + 100 (18.4)}{18.4 - 2 (1/75)} = 3532 \text{ psf} \quad \text{Equation 8-41}$$

Given the allowable bearing capacity (Q_{allow}) is 4000 psf:

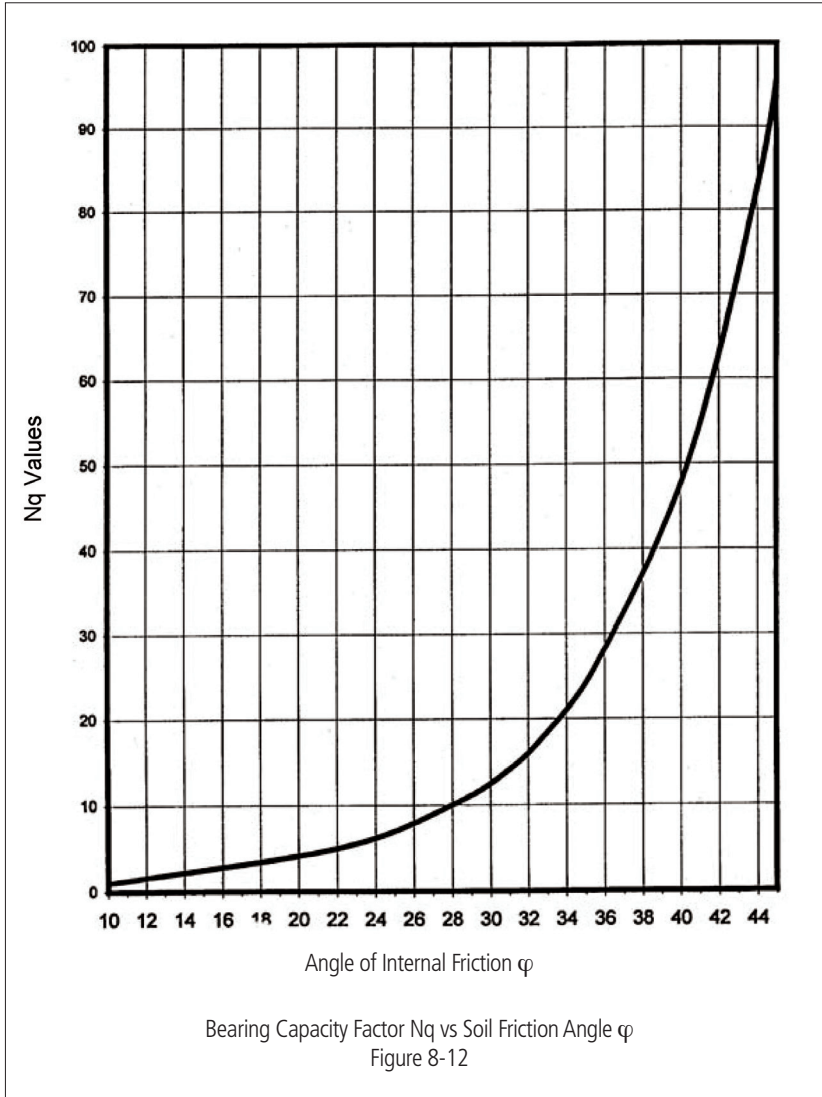
$$Q_{\text{allow}} = 4000 \text{ psf} > \sigma_v = 3532 \text{ psf} \quad \text{Equation 8-42}$$

Step 6 - Determine the Allowable Helical Anchor Strength

Allowable Design Strength of Type SS5 Helical Anchor (Service Life = 75 Years), Table 8-5

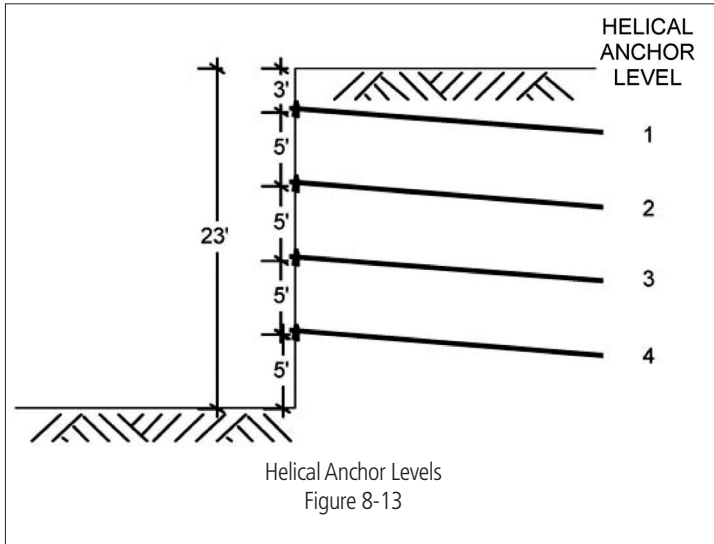
Ta 75 yrs (kips)	V 75 yrs (kips)	ALLOWABLE DESIGN STRENGTH (TEMPORARY STRUCTURES) (kips)	ALLOWABLE DESIGN STRENGTH 75 yrs (kips)
50	37	45	37

DESIGN EXAMPLES



The SOIL SCREW® Anchor wall is a temporary structure with a design life of one year. From Table 8-5, the allowable design strength of the CHANCE® Helical SS5 Anchor is 45 kips. This table is based on the following electrochemical properties of soil:

- Resistivity: >3000 Ω/cm
- pH: >5<10
- Chlorides: 100 ppm
- Sulfates: 200 ppm
- Organic content: 1% max



Step 7 - Estimate the Tension Capacity of the SOIL SCREW® Anchors

Determine the bearing capacity factor (N_q) for helical anchors for a sand with an effective friction angle, $\phi = 30^\circ$. From Figure 8-12, $N_q = 14$. Assumed vertical spacing is 5 feet (see Figure 8-13). Nail pattern is as shown in Figure 8-13. There are eight helices per anchor, as shown in Figure 8-14.

The ultimate tension capacity (P) of the Helical SOIL SCREW® Anchor at Level 1 is determined using Equation 8-43.

$$P = \sum_{i=1}^8 A_i q_i N_q \quad \text{Equation 8-43}$$

Helical anchors have 8" diameter helices. The helix area (A) can be calculated using Equation 8-44.

$$\begin{aligned} A &= \pi (0.33)^2 \\ &= 0.336 \text{ ft}^2 \text{ (use } 0.34 \text{ ft}^2) \end{aligned} \quad \text{Equation 8-44}$$

The ultimate tension capacities for the helical anchors at the various levels are determined using Equation 8-45.

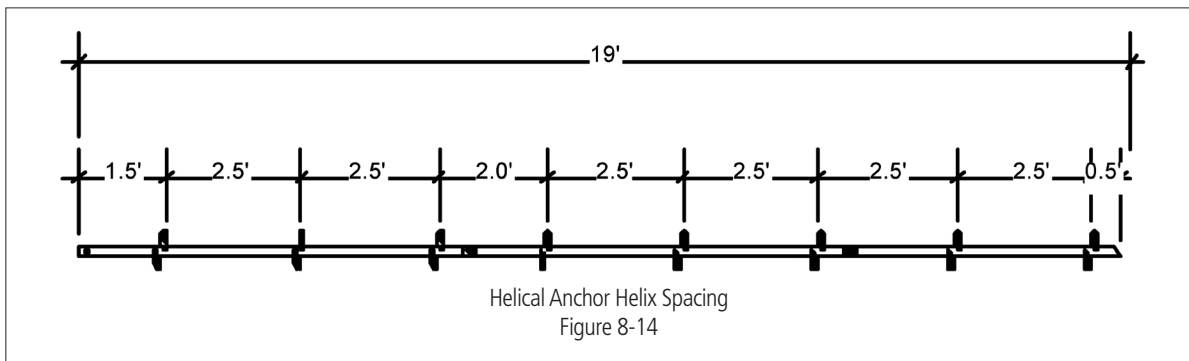
$$\begin{aligned} y &= L (\sin \theta) \\ &= 19 (\sin 15^\circ) \end{aligned} \quad \text{Equation 8-45}$$

where:

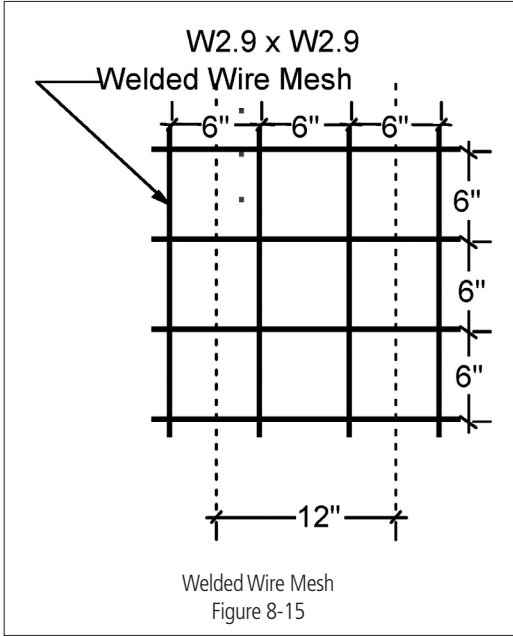
- = 4.9 ft
- L = Length of SOIL SCREW® Anchor
- θ = Installation angle (from horizontal)

$$\text{Average Overburden Depth} = 3 + (y/2) = 5.5 \text{ ft at Level 1}$$

- $P_{\text{LEVEL1}} = 8 (0.34) 5.5 (120) 14 = 25 \text{ kips}$
- $P_{\text{LEVEL2}} = 8 (0.34) 10.5 (120) 14 = 48 \text{ kips}$
- $P_{\text{LEVEL3}} = 8 (0.34) 15.5 (120) 14 = 71 \text{ kips}$
- $P_{\text{LEVEL4}} = 8 (0.34) 20.5 (120) 14 = 94 \text{ kips}$



DESIGN EXAMPLES



Step 8 - Define a Trial Facing System

Try a 4" thick, 4000 psi shotcrete face with 6 x 6, W2.9 x W2.9 welded wire mesh reinforcing and two #4 vertical rebars at the helical anchor locations. Try a helical anchor spacing of 5 feet vertically and horizontally and an 8" square by 3/4" thick bearing plate with a steel yield stress of 36 ksi.

Step 9 - Determine the Allowable Flexural Strength of the Facing

For typical helical anchor wall construction practice, the facing is analyzed using vertical strips of width equal to the horizontal anchor spacing. For facing systems involving horizontal nail spacings that are larger than the vertical spacing or unit horizontal moment capacities that are less than the vertical unit moment capacities, horizontal strips of width equal to the vertical anchor spacing should be used.

The area of steel (A_s) for a vertical beam of width 5 feet ($S_H = 5$ feet) with the anchor on the beam's centerline is determined using Equation 8-46. Diameter (d) of the welded fabric wire is 0.192". Diameter (D) of the rebar is 0.500". For a 5 foot wide vertical beam centered between the anchors, the rebars are located at the beam edges and should be ignored. A_s is calculated using Equation 8-47.

The corresponding average nominal unit moment resistances are determined using Equation 8-48.

Equation 8-46

$$A_{s,neg} = \left(\frac{pd^2}{4} \right) \left(\frac{\text{in}^2}{\text{wire}} \right) \times \left(\frac{2 \text{ wires}}{\text{ft}} \right) (5 \text{ ft}) + \left(\frac{pD^2}{4} \right) \left(\frac{\text{in}^2}{\text{rebar}} \right) \times \left(\frac{2 \text{ rebars}}{5 \text{ ft}} \right) (5 \text{ ft})$$

$$= \left(\frac{p(0.192^2)}{4} \right) (2) (5) + \left(\frac{p(0.500^2)}{4} \right) (2)$$

$$= 0.682 \text{ in}^2$$

Equation 8-47

$$A_{s,pos} = \left(\frac{\pi D^2}{4} \right) \left(\frac{\text{in}^2}{\text{wire}} \right) \times \left(\frac{2 \text{ wires}}{\text{ft}} \right) (5 \text{ ft})$$

$$= \frac{\pi (0.192)^2}{4} (2) (5)$$

$$= 0.289 \text{ in}^2$$

Equation 8-48

$$m_v = \frac{A_s F_y \left(d - \frac{A_s F_y}{1.7 f_{cb}} \right)}{b}$$

$$m_{v,neg} = \frac{0.682 (60) \left(2 - \frac{0.682 (60)}{1.7 (4) (5 \times 12)} \right)}{5 (12)}$$

$$= 1.30 \text{ k} - \text{in/in}$$

$$= 1.30 \text{ k} - \text{ft/ft}$$

$$m_{v,pos} = \frac{0.289 (60) \left(2 - \frac{0.289 (60)}{1.7 (4) (5 \times 12)} \right)}{5 (12)}$$

$$= 0.566 \text{ k-ft/ft}$$

DESIGN EXAMPLES

Step 10 - Determine the Maximum Helical Anchor Head Load

Determine the maximum helical anchor head load that will produce the allowable moments determined in Step 9 using Equation 8-49. Using Table 8-6, determine the facing pressure factor (C_F) for temporary shotcrete facing 4" thick.

$$T_{FN, \text{ flexure}} = C_F (m_{v, \text{ neg}} + m_{v, \text{ pos}}) 8 (SH/SV) \quad \text{Equation 8-49}$$

$$T_{FN, \text{ flexure}} = 2.0 (1.30 + 0.57) 8 (5 \text{ ft}/5 \text{ ft}) = 29.8 \text{ kips}$$

Facing Pressure Factor, Table 8-6

NOMINAL FACING THICKNESS (in)	TEMPORARY FACING C_F	PERMANENT FACING C_F
4	2.0	1.0
6	1.5	1.0
8	1.0	1.0

Step 11 - Determine the Allowable Punching Shear Strength of the Facing

The punching shear strength (V_N) is determined using Equation 8-50.

$$V_N = 0.125 \sqrt{f'_c} p D'_c h_c \quad \text{Equation 8-50}$$

$$V_N = 0.125 \sqrt{4} \pi (12) (4) = 38 \text{ kips}$$

where:

$$f'_c = 4,000 \text{ psi} = 4 \text{ ksi}$$

$$h_c = 4 \text{ in}$$

$$D'_c = 8 + 4 = 12 \text{ in}$$

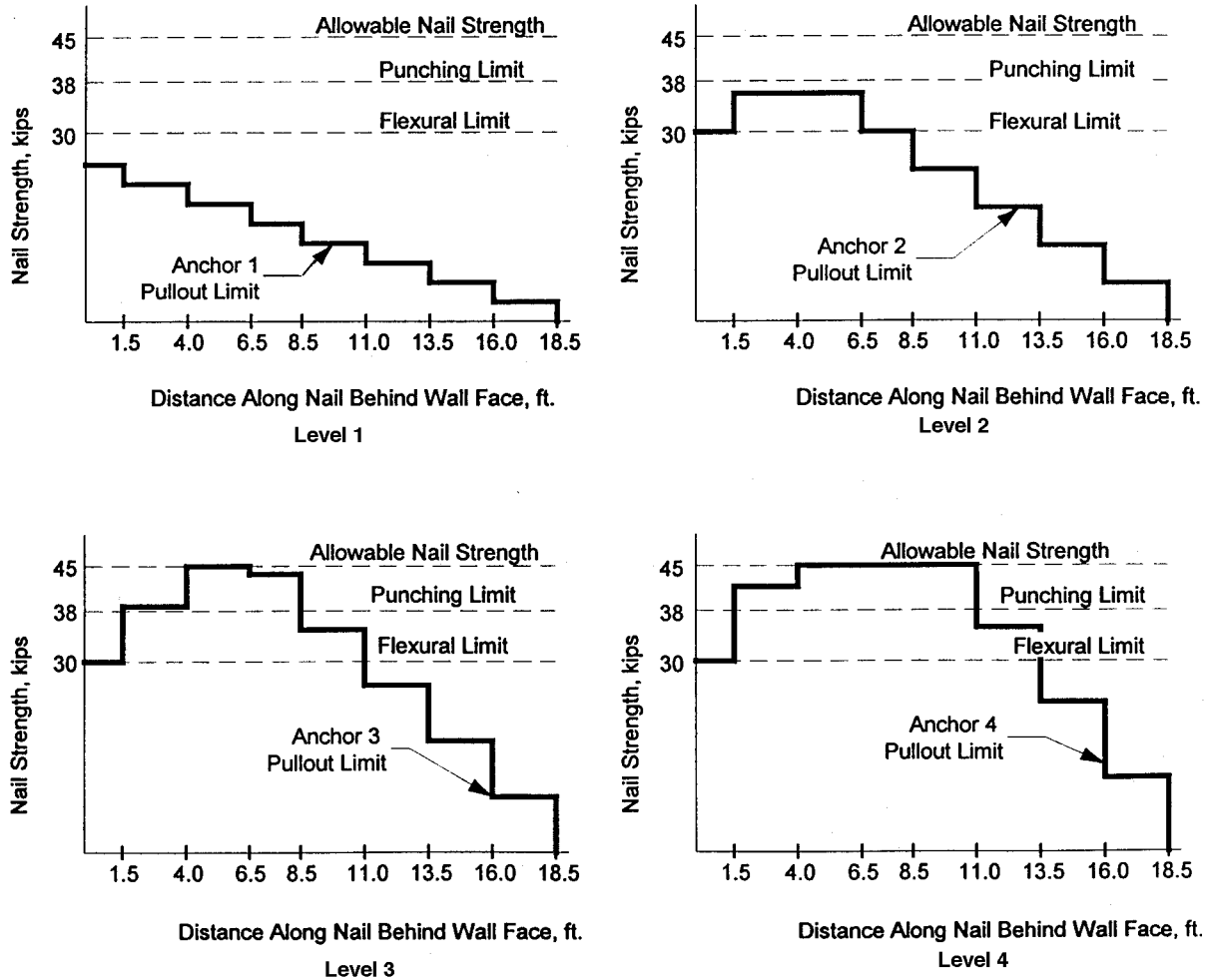
Step 12 - Determine Critical Helical Anchor Head Load for Punching

Determine the critical helical anchor head load (T_{FN}) for punching using Equation 8-51.

$$T_{FN, \text{ punching}} = V_N = 38 \text{ kips} \quad \text{Equation 8-51}$$

Step 13 - Construct SOIL SCREW® Anchor Strength Envelope

Construct the strength envelope at each anchor level as shown in Figure 8-16. At the wall face, the anchor head flexural strength is less than the anchor head punching strength and therefore controls. There are eight helices per anchor. Each step in strength equals the single-helix bearing capacity for the anchor layer (Step 7). From the last helix (working from right to left) increase the pullout capacity in a stepwise fashion. If the pullout envelope working from the back of the nail does not intersect the flexural limit line, the strength envelope will look like that shown for Anchor 1. If the pullout envelope working from the back of the nail exceeds the flexural limit, then construct a pullout envelope working from the flexural limit at the head of the nail.



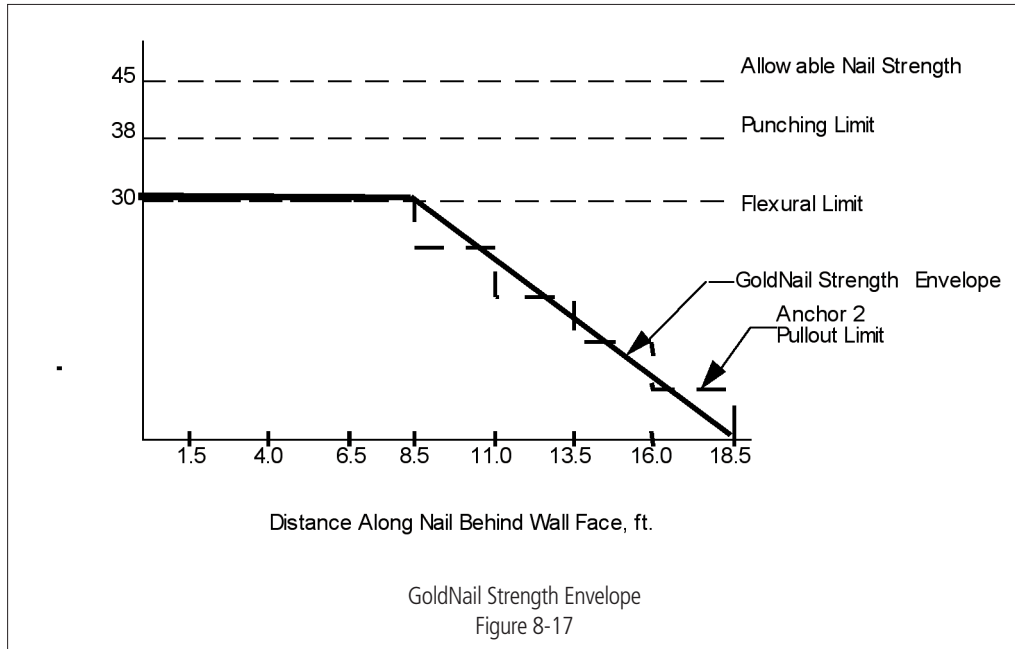
Anchor Pullout Limits
Figure 8-16

Step 14 - Evaluate Internal and Compound Stability

GoldNail 3.11, "A Stability Analysis Computer Program for Soil Nail Wall Design," developed by Golder and Associates, was used to perform the internal and compound stability analysis. Refer to Attachment EX1 in the CHANCE® SOIL SCREW® Retention Wall System Design Manual for printout result of this stability analysis. The following discussion is based on these results.

The anchor strength envelope developed in Step 13 needs to be modified for GoldNail. The increase in pullout capacity along the length of the nail is estimated for GoldNail as straight lines, not step functions. An example of this modification for Anchor Level 2 is shown in Figure 8-17.

Within GoldNail there are several analysis options. The option used for this example is "Factor of Safety." Using this option, the Internal Factor of Safety (FS_{internal}) = 2.11 for the anchor pattern defined in Step 7. The GoldNail output printout lists "Global Stability" not "Internal Stability." However, the location of the critical failure surface (Circle #13) indicates an internal mode of failure, as shown on the GoldNail geometry printout.



DESIGN EXAMPLES

Step 15 - Check Global Stability

Analysis was performed for the given slope geometry by the computer program PCSTABL6H, developed by Purdue University and modified by Harald Van Aller, and the pre-processor STED, developed by Harald Van Aller. The resulting Global Factor of Safety (FS_{global}) = 1.93. Refer to Attachment EX2 in the CHANCE® SOIL SCREW® Retention Wall System Design Manual for printout results of this global stability analysis.

Step 16 - Check Cantilever at Top of Wall

In Step 7 the layout of anchors was assumed. The cantilever at the top of the wall from Step 7 is 3 feet. Check cantilever moment (M_c) using Equation 8-52.

Equation 8-52

$$\begin{aligned}
 M_c &= K_a \gamma \left[\left(\frac{H_1^2}{2} \right) \left(\frac{H_1}{3} \right) + q \left(\frac{H_1^2}{2} \right) \right] \\
 &= 0.33 (120) \left[\left(\frac{3^2}{2} \right) \left(\frac{3}{3} \right) + 100 \left(\frac{3^2}{2} \right) \right] \\
 &= 326.7 \text{ lb} - \text{ft/ft}
 \end{aligned}$$

Maximum allowable moment at midspan (Step 9) is 566 lb-ft/ft., therefore:

$$FS_{MC} = (566 / 327) = 1.73 \quad \text{OK} \quad \text{Equation 8-53}$$

Check shear force at cantilever (S_c) using Equation 8-54.

$$\begin{aligned} &= K_a [\gamma (H_1^2 / 2) + qH_1] && \text{Equation 8-54} \\ S_c &= 0.33 [120 (3^2 / 2) + 100 (3)] \\ &= 277 \text{ lb/ft} \end{aligned}$$

Determine allowable shear using Equation 8-55

$$\begin{aligned} V_N &= 0.125 \sqrt{f'_c} h_c && \text{Equation 8-55} \\ &= 0.125 \sqrt{4} (4) = 1000 \text{ lb/lf} \end{aligned}$$

$$FS_{\text{shear}} = (1000 / 277) = 3.6 \quad \text{OK} \quad \text{Equation 8-56}$$

DESIGN EXAMPLES

DESIGN EXAMPLE 11

HELICAL PILES/ANCHORS for TELECOMMUNICATION TOWERS

SYMBOLS USED IN THIS DESIGN EXAMPLE

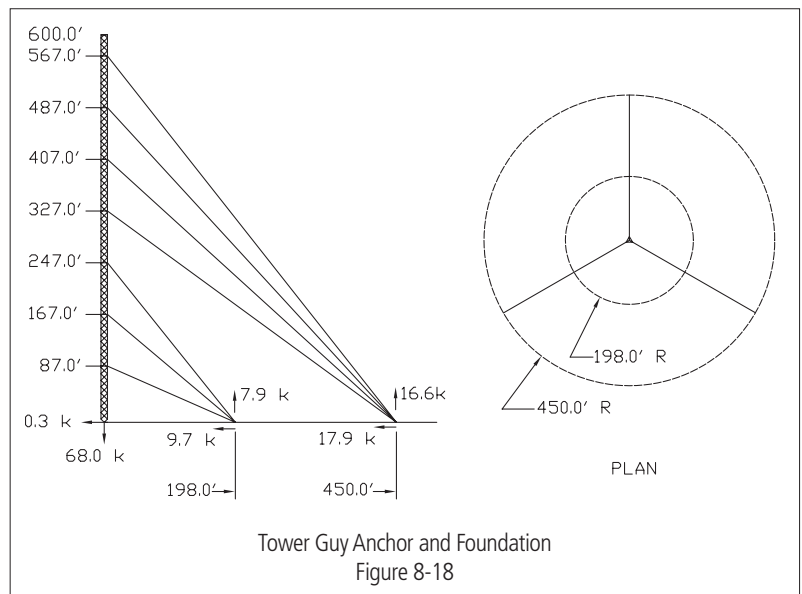
SST	Self-Supporting Tower	8-45
T_{ug}	Upper Guywire Anchor Tension	8-46
$I_{A_{ug}}$	Upper Guywire Installation Angle	8-46
T_{lg}	Lower Guywire Anchor Tension	8-46
$I_{A_{lg}}$	Lower Guywire Installation Angle	8-46
C	Compression	8-46
V	Horizontal Shear	8-46
FS	Factor of Safety	8-46
kip	Kilopound	8-46
R_{uc}	Recommended Ultimate Capacity	8-46
K_t	Empirical Torque Factor	8-46
T	Minimum Installation Torque	8-46
DL	Resultant Axial Load	8-47

Purpose

This Design Example provides an aid in the selection of appropriate helical guywire anchors and center mast helical piles for telecommunication towers.

The guywire loads are to be resisted by a helical tension anchor. When the vertical and horizontal components are provided the resultant must be determined as well as the angle between the resultant load and the horizontal, (this is the angle the helical anchor should be installed at to properly resist the guywire load(s)). There may be one or more guywires that come to the ground to be restrained by one or more helical anchors depending on the magnitude of the load and/or the soil strength. Helical piles can be used to resist the loads from the structure mast. These loads will generally be composed of a vertical load and a lateral load at the base of the mast or pole.

If the structure is a self supporting tower (SST), the loads from each leg of the tower must be resisted. These generally consist of vertical uplift and compression loads and a horizontal shear load at the ground line. These three loads can be dealt with in a number of ways. Typically one or more helical piles are used for each leg of the tower and may be installed at a batter to better resist the horizontal shear loads. Steel grillages and reinforced concrete caps have been used to facilitate load transfer from the structure to the helical piles. This type design will not be covered in this design example since the intent is to focus on the guyed mast tower structure.



DESIGN EXAMPLES

Figure 8-18 shows the tower that will be used for these sample calculations. It will be noted that the four upper guywires come to the ground at a single guywire point and that the three lower guywires come to ground at a different guywire point. There must be at least a single helical anchor installed at each of these points to provide restraint for the guywires which in turn stabilize the tower by resisting lateral loads on the structure.

For this tower, the vertical and horizontal components of the guywire loads are given and must be resolved into the tension load the helical guywire anchor is to resist.

Upper Guywire Loads

- Vertical load component = 16.6 k
- Horizontal load component = 17.9 k
- Tension in the upper guywire anchor = $T_{ug} = (16.6^2 + 17.9^2)^{0.5} = 24.4$ k
- Helical guywire anchor installation angle = $IA_{ug} = \tan^{-1} (16.6/17.9) = 43^\circ$

Lower Guywire Loads

- Vertical load component: 7.9 k
- Horizontal load component: 9.7 k
- Tension in the lower guywire anchor = $T_{lg} = (7.9^2 + 9.7^2)^{0.5} = 12.5$ k
- Helical guywire anchor installation angle = $IA_{lg} = \tan^{-1} (7.9/9.7) = 39^\circ$

Mast Foundation Loads

- Compression (C) = 68.0 k
- Horizontal shear (V) = 0.3 k

Selecting Helical Guywire Anchors

Hubbell Power Systems, Inc. HeliCAP® Engineering Software will be utilized to determine the appropriate helical anchor/pile sizes for this tower. Soil conditions are shown in the Sample Boring Log in Figure 8-19. The soil data and guywire anchor data was input into the HeliCAP® Engineering Software to get an appropriate output. The minimum acceptable Factor of Safety (FS) = 2.

Upper Guywire Helical Anchor

The HeliCAP® Summary Report for the upper guywire helical anchor is shown in Figure 8-20. This report provides the following information:

- Helical Anchor: SS5 (1.5" square shaft, 5500 ft-lbs torque rating, 70 kips ultimate tension rating)
- Lead Section: 4 helix (8"-10"-12"-14")
- Installation Angle: 43°
- Datum Depth (depth below grade where installation starts): 0 ft
- Length: 45 (ft along the shaft at the 43° installation angle)
- Recommended Ultimate Capacity (R_{uc}): 50.2t (kips tension)

The Factor of Safety for this tension anchor is $R_{uc} / T_{lg} = 50.2 / 24.4 = 2.05 > 2$ (OK). Use this helical anchor at each of three upper guywire anchor locations per tower.

The required average minimum installation torque (T) is:

$$\begin{aligned}
 T &= (T_{ug} \times FS) / K_t && \text{Equation 8-57} \\
 &= (24,400 \times 2.0) / 10 \\
 &= 4,900 \text{ ft-lbs}
 \end{aligned}$$

where: $K_t =$ Empirical torque factor = 10 (default value for Type SS5 series)

T = 4,900 ft-lbs is less than the rated torque (5,500 ft-lbs) of the Type SS5 series. (OK).



Lower Guywire Helical Anchor

The HeliCAP® Summary Report for the lower guywire helical anchor is shown in Figure 8-21. This report provides the following information:

- Helical Anchor: SS5 (1.5" square shaft, 5500 ft-lbs torque rating, 70 kips ultimate tension rating)
- Lead Section: 4 helix (8"-10"-12"-14")
- Installation Angle: 39°
- Datum Depth (depth below grade where installation starts): 0 ft
- Length: 25 ft (along the shaft at the 39° installation angle)
- Recommended Ultimate Capacity (R_{uc}): 26.6t (kips tension)

The Factor of Safety for this tension anchor is $R_{uc} / T_{ug} = 26.6 / 12.5 = 2.12 > 2$ (OK) Use this helical anchor at each of three lower guywire anchor locations per tower.

$$\begin{aligned}
 T &= (T_{lg} \times FS) / K_t && \text{Equation 8-58} \\
 &= (12,500 \times 2.0) / 10 \\
 &= 2,500 \text{ ft-lbs}
 \end{aligned}$$

where: K_t = Empirical torque factor = 10 (default value for Type SS5 series)

$T = 2,500$ ft-lbs is less than the rated torque (5,500 ft-lbs) of the Type SS5 series. (OK).

Helical Pile

Given:

- Compression Load = 68.0 k
- Shear Load = 0.3 k

Assume three helical piles installed at 120° intervals in plan view with each pile battered away from vertical at a 10° angle:

68/3 piles = 22.67k ultimate/pile element.

Assume entire shear (0.3 k) is taken by one battered pile. Therefore, the resultant axial load (DL) to a battered pile is:

$$DL = (22.67^2 + 0.3^2)^{0.5} = 22.7k$$

The HeliCAP® Summary Report for the helical piles is shown in Figure 8-22. This report provides the following information:

- Helical Pile: SS175 (1.75" square shaft, 10,500 ft-lbs torque rating, 100 kips ultimate tension rating)
- Lead Section: 4 helix (8"-10"-12"-14")
- Installation Angle: 80° below horizontal (10° away from vertical)
- Datum Depth: (depth below grade where installation starts): 0 ft
- Length: 34 ft (along the shaft at the 80° installation angle)
- Recommended Ultimate Capacity (R_{uc}): 50.7c (kips compression)

The Factor of Safety for this compression pile is $R_{uc} / DL = 50.7 / 22.7 = 2.23 > 2$ (OK) Use three SS175 helical piles per tower base. The three helical piles must be captured in a "pile cap." This may be a reinforced concrete cap, the design of which is beyond the scope of this design example. The design of this concrete pile cap is left to the structural engineer.

$$T = (DL \times FS) / K_t$$

$$= (22,700 \times 2.0) / 10$$

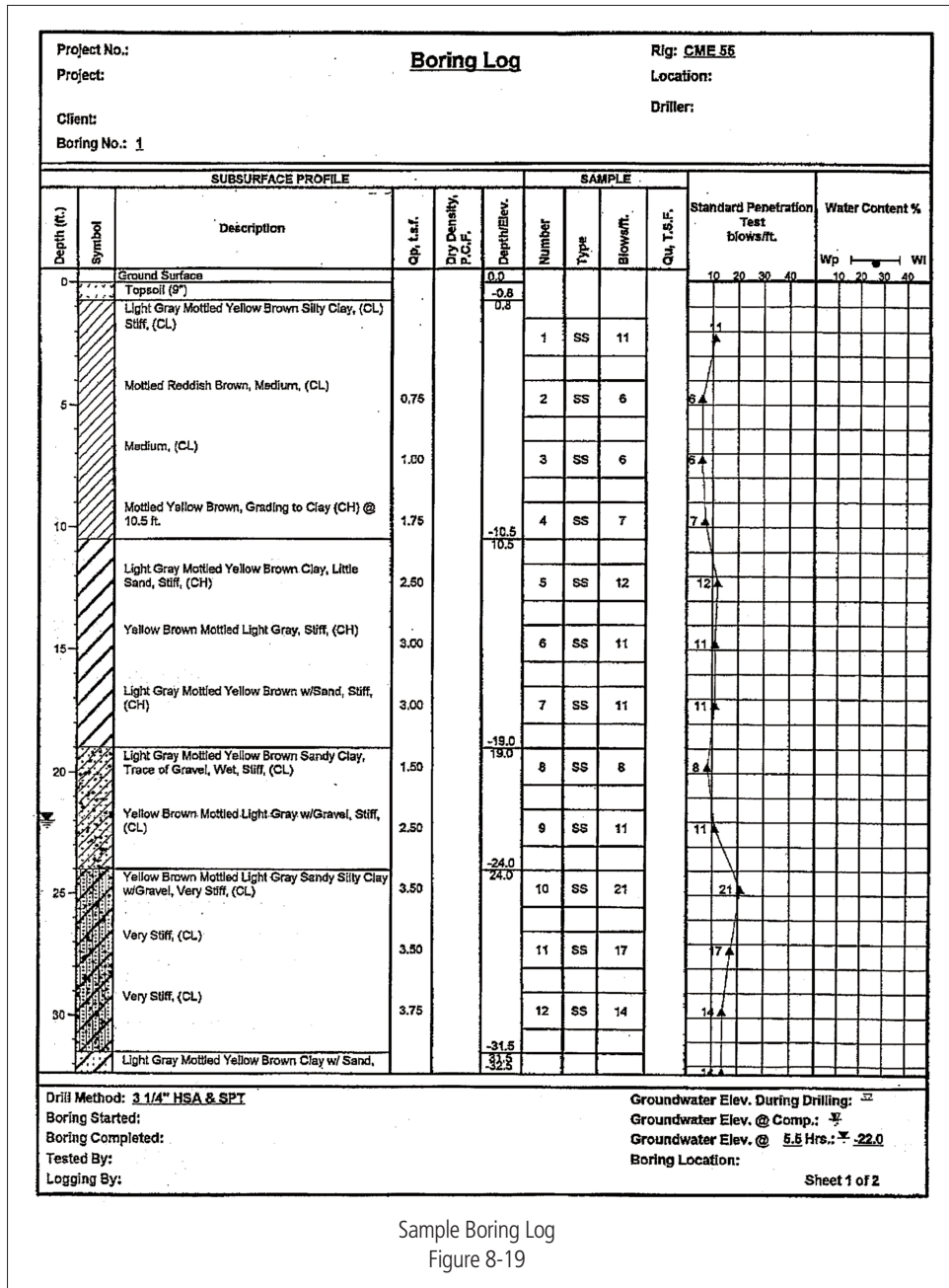
$$= 4,500 \text{ ft-lbs}$$

Equation 8-59

where: K_t = Empirical torque factor = 10 (default value for Type SS175 series)

T = 4,500 ft-lbs is less than the rated torque (10,500 ft-lbs) of the Type SS175 series. (OK).

DESIGN EXAMPLES



Sample Boring Log
Figure 8-19

HeliCAP SUMMARY REPORT

b Name: Tower Guy Calculations

C:\Documents and Settings\jgoen\Desktop\Tow

b Number: Upper Guy

6/1/2006 8:43:36 AM

Water Table Depth: 22 ft

ring No: 1

Anchor Use: Tension

Capacity Summary

Anchor Number	Anchor Family	Helix Depth (ft)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 43 Datum Depth: 0 Length: 45					
14" helix	SS 5	25.2	16.9t 24.8c			
12" helix	SS 5	27.2	17t 14.7c			
10" helix	SS 5	28.9	10.1t 9.5c	50.2t	50.2t	5502
8" helix	SS 5	30.3	6.1t 5.3c	54.4c	54.4c	

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (lb/ft ²)	N	Angle of Internal Friction (Degrees)	Unit Weight (lb/ft ³)
0	Clay	1375	11	0	102
5	Clay	750	6	0	92
7	Clay	750	6	0	92
10	Clay	875	7	0	94
12	Clay	1500	12	0	104
15	Clay	1375	11	0	102
17	Clay	1375	11	0	102
20	Clay	1000	8	0	96
22	Clay	1375	11	0	102
25	Clay	2625	21	0	120
27	Clay	2125	17	0	114
30	Clay	1750	14	0	108
32	Clay	1750	14	0	108
35	Clay	1500	12	0	104
37	Clay	1625	13	0	106
40	Clay	1500	12	0	104
42	Clay	1375	11	0	102
45	Clay	2125	17	0	114
47	Clay	2500	20	0	120
50	Clay	6125	49	0	138

HeliCAP® Summary Report for Upper Guywires

Figure 8-20

DESIGN EXAMPLES



HeliCAP SUMMARY REPORT

Job Name: Tower Guy Calculations

C:\Documents and Settings\jlgoben\Desktop\Tower
6/1/2006 8:31:40 AM

Job Number: Lower Guy

Water Table Depth: 22 ft

Boring No: 1

Anchor Use: Tension

Capacity Summary

Anchor Number	Anchor Family	Helix Depth (ft)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 39 Datum Depth: 0 Length: 25					
14" helix	SS 5	10.6	7.4t 10.2c			
12" helix	SS 5	12.5	7.5t 10.3c			
10" helix	SS 5	14.1	7.1t 6.9c	26.6t	26.6t	3002
8" helix	SS 5	15.4	4.4t 4.2c	31.7c	31.7c	

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (lb/ft2)	N	Angle of Internal Friction (Degrees)	Unit Weight (lb/ft3)
0	Clay	1375	11	0	102
5	Clay	750	6	0	92
7	Clay	750	6	0	92
10	Clay	875	7	0	94
12	Clay	1500	12	0	104
15	Clay	1375	11	0	102
17	Clay	1375	11	0	102
20	Clay	1000	8	0	96
22	Clay	1375	11	0	102
25	Clay	2625	21	0	120
27	Clay	2125	17	0	114
30	Clay	1750	14	0	108
32	Clay	1750	14	0	108
35	Clay	1500	12	0	104
37	Clay	1625	13	0	106
40	Clay	1500	12	0	104
42	Clay	1375	11	0	102
45	Clay	2125	17	0	114
47	Clay	2500	20	0	120
50	Clay	6125	49	0	138

HeliCAP® Summary Report for Lower Guywires
Figure 8-21

DESIGN EXAMPLES

HeliCAP SUMMARY REPORT

Job Name: Tower Foundation Calculations

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6/1/2006 9:27:53 AM

Job Number: Three Foundations per Tower Base

Water Table Depth: 22 ft

Boring No: 1

Anchor Use: Compression

Capacity Summary

Anchor Number	Anchor Family	Helix Depth (ft)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 80 Datum Depth: 0 Length: 34					
14" helix	SS 175	25.6	16.9t 23.2c			
12" helix	SS 175	28.5	15.8t 13.8c			
10" helix	SS 175	31	8.9t 8.3c	47.1t	47.1t	5323
8" helix	SS 175	32.9	5.3t 5.3c	50.7c	50.7c	

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (lb/ft ²)	N	Angle of Internal Friction (Degrees)	Unit Weight (lb/ft ³)
0	Clay	1375	11	0	102
5	Clay	750	6	0	92
7	Clay	750	6	0	92
10	Clay	875	7	0	94
12	Clay	1500	12	0	104
15	Clay	1375	11	0	102
17	Clay	1375	11	0	102
20	Clay	1000	8	0	96
22	Clay	1375	11	0	102
25	Clay	2625	21	0	120
27	Clay	2125	17	0	114
30	Clay	1750	14	0	108
32	Clay	1750	14	0	108
35	Clay	1500	12	0	104
37	Clay	1625	13	0	106
40	Clay	1500	12	0	104
42	Clay	1375	11	0	102
45	Clay	2125	17	0	114
47	Clay	2500	20	0	120
50	Clay	6125	49	0	138

HeliCAP® Summary Report for Foundations
Figure 8-22

DESIGN EXAMPLE 12
HELICAL ANCHORS for PIPELINE BUOYANCY CONTROL
SYMBOLS USED IN THIS DESIGN EXAMPLE

OD.....	Outside Diameter	8-53
T_w	Pipe Wall Thickness	8-53
F_y	Minimum Yield Strength of Pipe	8-53
P_d	Pipe Design Pressure	8-53
P_m	Pipe Maximum Operating Pressure	8-53
T_m	Pipe Maximum Operating Temperature	8-53
F.....	Construction Type Design Factor	8-53
E.....	Longitudinal Joint Factor	8-53
T.....	Temperature Factor	8-53
D_c	Density of Coating	8-53
T_c	Thickness of Coating	8-53
D_b	Density of Backfill	8-53
FS.....	Factor of Safety	8-53
W_p	Weight of Pipe per Linear Foot	8-54
I.....	Moment of Inertia	8-54
S.....	Section Modulus	8-54
W_c	Weight of Coating per Linear Foot	8-55
W_g	Gross Buoyancy	8-55
W_n	Net Buoyancy	8-55
L_b	Allowable Span Length Based on Bending Stress	8-55
P.....	Maximum Design Pressure	8-55
F_h	Hoop Stress	8-55
F_l	Longitudinal Stress	8-55
F_b	Allowable Longitudinal Bending Stress	8-55
M_{max}	Maximum Moment at Mid-Span Between Pipeline Anchor Sets	8-56
L_d	Mid-Span Vertical Displacement Based on Mid-Span Deflection	8-56
Y.....	Mid-Span Vertical Displacement	8-56
L_p	Allowable Span Length Based on Mechanical Strength of Pipeline Bracket	8-56
UC_p	Ultimate Mechanical Strength of Pipeline Bracket	8-56
WC_p	Working Capacity of Pipeline Bracket	8-56
L_a	Allowable Span Length Based on Uplift Capacity of Anchors in Boring	8-56

DESIGN EXAMPLES

UC _a	Ultimate Uplift Capacity	8-56
WC _a	Working Uplift Capacity	8-56
WC _s	Total Working Uplift Capacity	8-56

PURPOSE

This Design Example provides an aid in the selection of appropriate helical anchors for pipeline buoyancy control.

ASSUMPTIONS

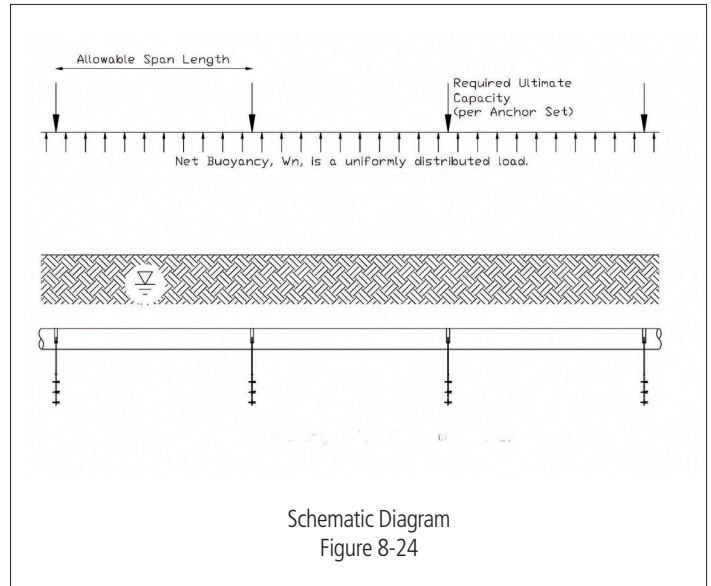
- Pipe contents: Natural gas
- Pipe Outside Diameter (OD): 42"
- Pipe Wall Thickness (T_w): 0.938"
- Grade of Pipe: API 5L, Grade X65
- Minimum Yield Strength Of Pipe (F_y): 65,000 psi
- Pipe design pressure (P_d): 1,440 psi
- Maximum Operating Pressure (P_m): 1,440 psi
- Maximum Operating Temperature (T_m): 85° F
- Construction type design factor (F): 0.50
- Longitudinal joint factor (E): 1.0
- Temperature Factor (T): T_m < 250°F
- Coating: Fusion Bonded Epoxy
- Density of coating (D_c): 70.0 pcf
- Coating thickness (T_c): 16 mils
- Pipeline placement: Land Based in Trench with 4'-0 of Cover above Top of Pipe
- Backfill material: Loose, Poorly Graded Silty Sand
- Specific Gravity of Backfill Material: 1.44
- Density of backfill material (D_b) = 1.44 x 62.4 pcf = 89.9 pcf (use 90.0 pcf)
- Span between anchor sets: Simple Span with Pin-Pin Ends
- Maximum vertical displacement at Mid-Span between Anchor Sets = L_g/360
- Minimum Factor of Safety (FS) for Mechanical Strength Of Hardware/Anchors = 2.0
- Minimum Factor of Safety (FS) for Anchor Soil Capacity = 2.0
- Soil data: As shown in Figure 8-23

DESIGN EXAMPLES



Sample Problem - Natural Gas Pipeline			
Borehole BH-1			
HeliCAP® Software Input Values			
Depth (ft)	Clay Cohesion (psf)	Sand N-Value (SPT)	Soil
0		7	sand
3		7	sand
5		28	sand
7		21	sand
10		30	sand
12		21	sand
13	60		clay
15	60		clay
20	380		clay
25	500		clay
30	250		clay
35	460		clay
40	1250		clay
45	2000		clay
50	1560		clay
55	1250		clay
60	2250		clay
65	1320		clay
70	750		clay
75	750		clay

Borehole BH-1 Sample Data
Figure 8-23



SOLUTION

Net Buoyancy (W_n)

Properties of pipe:

- Weight per linear foot (W_p):

$$\begin{aligned}
 W_p &= [D_s \times \pi \times (42.0^2 - 40.124^2)] / (4 \times 144) \\
 &= [490.0 \times \pi \times (1764.0 - 1609.935)] / (576) \\
 &= 411.74 \text{ plf}
 \end{aligned}$$

Equation 8-60

- Moment of inertia (I) = 25515.8 in⁴
- Section modulus (S) = 0.7032 ft³

Properties of coating:

- Weight per linear foot (W_c):

$$\begin{aligned} W_c &= [D_c \times \pi \times (42.032^2 - 42.0^2)] / (4 \times 144) && \text{Equation 8-61} \\ &= [70.0 \times \pi \times (42.032^2 - 42.0^2)] / (4 \times 144) \\ &= 1.03 \text{ plf} \end{aligned}$$

Buoyancy:

- Gross buoyancy (W_g):

$$\begin{aligned} W_g &= [D_b \times \pi \times (42.032^2/12^2)] / 4 && \text{Equation 8-62} \\ &= [90.0 \times \pi \times (42.032^2/12^2) / 4 \\ &= 865.8 \text{ plf} \end{aligned}$$

- Net buoyancy (W_n):

$$\begin{aligned} W_n &= W_g - W_p - W_c && \text{Equation 8-63} \\ &= 865.8 - 411.74 - 1.03 \\ &= 453.03 \text{ plf (use 453.0 plf)} \end{aligned}$$

Allowable Span Length (L_b) Based on Bending Stress

- Maximum design pressure (P):

$$\begin{aligned} P &= [(2 \times f_y \times T_w)/OD] \times F \times E \times T && \text{Equation 8-64} \\ &= [(2 \times 65,000 \times 0.938)/42.0] \times 0.5 \times 1.0 \times 1.0 \\ &= 1451.7 \text{ psi (use given } P_d \text{ of 1440.0 psi)} \end{aligned}$$

- Hoop stress (F_h):

$$\begin{aligned} F_h &= (P_d \times OD)/(2 \times T_w) && \text{Equation 8-65} \\ &= (1440.0 \times 42.0)/(2 \times 0.938) \\ &= 32,238.8 \text{ psi} \end{aligned}$$

- Longitudinal stress (F_l):

$$\begin{aligned} F_l &= (0.25 \times P_d \times OD)/T_w && \text{Equation 8-66} \\ &= (0.25 \times 1440.0 \times 42.0)/0.938 \\ &= 16,119.4 \text{ psi} \end{aligned}$$

- Allowable longitudinal bending stress (F_b):

$$\begin{aligned} F_b + F_l &= 0.75 \times (F \times E \times T) \times F_y && \text{Equation 8-67} \\ F_b &= [0.75 \times (0.5 \times 1.0 \times 1.0) \times 65,000] - 16,119.4 \\ &= 8,255.6 \text{ psi} \end{aligned}$$

DESIGN EXAMPLES

$$F_b = M_{\max}/S \quad \text{Equation 8-68}$$

M_{\max} = Maximum moment at mid-span between pipeline anchor sets

where: $= (W_n \times L_b^2)/8$

$$L_b = [(8 \times S \times F_b)/W_n]^{1/2}$$

$$= [(8 \times 0.7032 \times 8255.6 \times 144)/453.0]^{1/2}$$

$$= 121.5 \text{ ft}$$

Allowable Span Length (L_d) Based on Mid-Span Deflection

- Mid-span vertical displacement (Y) at center of span:

$$Y = L_d/360 \quad \text{Equation 8-69}$$

$$L_d/360 = (5 \times W_n \times L_d^4) / (384 \times E \times I)$$

$$L_d = [(384 \times E \times I) / (360 \times 5 \times W_n)]^{1/3}$$

$$L_d = [(384 \times 29,000,000 \times 25525.8/144) / (360 \times 5 \times 453.0)]^{1/3}$$

$$L_d = 134.2 \text{ ft}$$

$$Y = (134.2/360) \times 12 = 4.5 \text{ in}$$

Allowable Span Length (L_p) Based on the Mechanical Strength of Pipeline Bracket

- Rated ultimate mechanical strength (UC_p) of pipeline bracket = 80,000 lbs
- Rated mechanical working capacity (WC_p) of pipeline bracket (using FS_m of 2.0):

$$WC_p = UC_p/FS_m \quad \text{Equation 8-70}$$

$$= 80,000/2$$

$$= 40,000 \text{ lbs}$$

$$WC_p = (W_n \times L_p/2) \times 2 \quad \text{Equation 8-71}$$

$$L_p = WC_p/W_n$$

$$= 40,000/453.0$$

$$= 88.3 \text{ ft}$$

Allowable Span Length (L_a) Based on the Uplift Capacity of Anchors in Soil (Boring B-1)

- Ultimate uplift capacity (UC_a) ranges from 45,900 to 41,700 lbs with overall anchor depths below ground line of 51'-0 to 60'-0. See Figure 8-25. Use $UC_a = 40,000$ lbs.
- Working uplift capacity (WC_a) (using FS_s of 2.0):

$$WC_a = UC_a/FS_s \quad \text{Equation 8-72}$$

$$= 40,000/2$$

$$= 20,000 \text{ lbs}$$

- There are two anchors located at each anchor support location along the pipeline, therefore, the total working uplift capacity (WC_s) per anchor set = $WC_a \times 2$ anchors = $20,000 \times 2 = 40,000$ lbs.

$$L_a = WC_s/W_n \quad \text{Equation 8-73}$$

$$= 40,000/453.0$$

$$= 88.3 \text{ ft}$$

SUMMARY

The uplift capacity plot data was obtained from the soil strength parameters shown in Figure 8-23 and capacities generated by HeliCAP® Engineering Software. The maximum span length between anchor sets is limited to 88 ft based on the ultimate mechanical strength of the pipeline brackets and the ultimate uplift capacity of the anchors in the soil boring shown in Figure 8-25.

Only one soil boring was provided along this proposed section of pipeline. If the soil conditions vary at the anchor set locations and the required average installation torque of 4,000 ft-lbs for a span length of 88 ft cannot be achieved at reasonable anchor depths, the span lengths should be reduced as shown in Table 8-8.

Hubbell Power Systems, Inc. manufactures two band types for use with pipeline buoyancy control systems. See Figure 8-26. Each system has advantages depending on the application and local acceptance. Both systems will provide adequate buoyancy control with industry accepted Factors of Safety.

Summary of Design Criteria, Table 8-7

	MAXIMUM ALLOWABLE SPAN LENGTH (ft)	REQUIRED UC _s PER ANCHOR SET (lbs) ²	REQUIRED UC _a PER ANCHOR SET (lbs) ²	MINIMUM INSTALLATION TORQUE (ft-lbs) ^{1,2}
Longitudinal Bending	121.5	110,080	55,040	5,500
Mid-Span Deflection	134.2	121,585	60,793	6,100
Mechanical Strength of Bracket	88.3	80,000	40,000	4,000
Anchor Capacity	88.3	80,000	40,000	4,000

Notes:

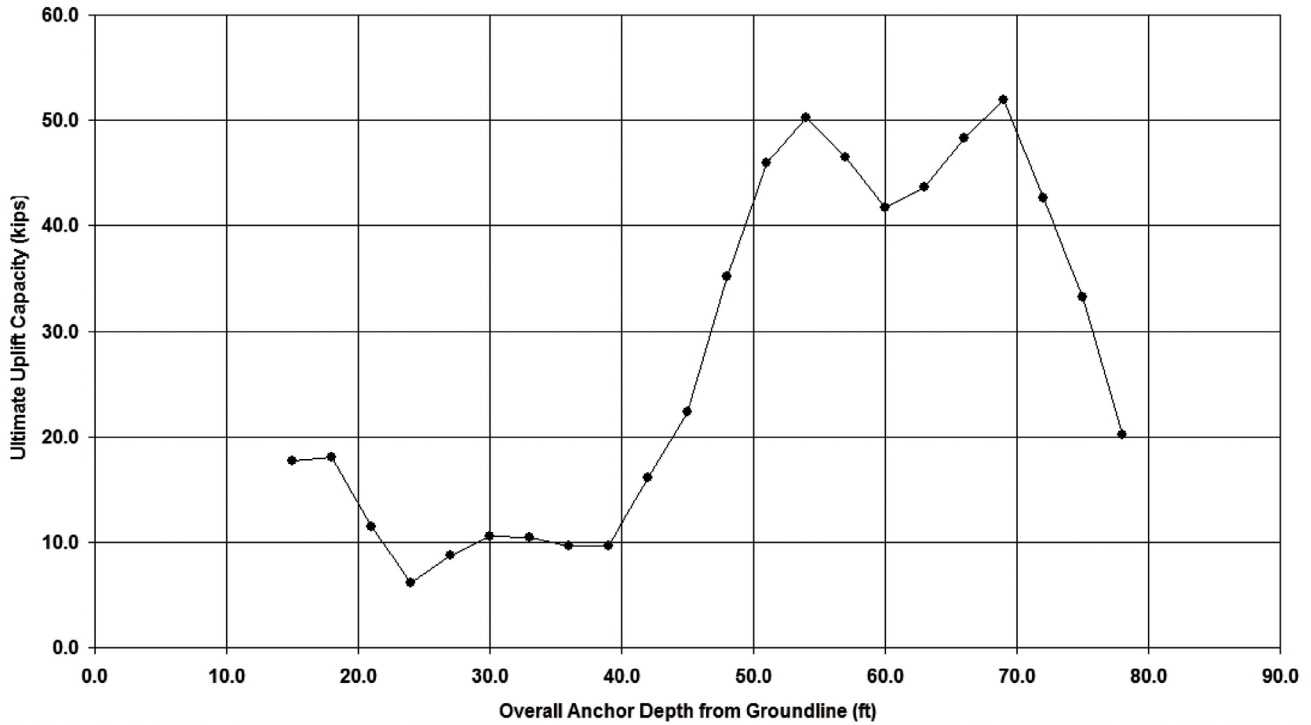
- The required average minimum installation torque is based on using the published installation torque to ultimate capacity ratio (K_t) of 10:1 for the Type SS series anchor material. $Torque = UC_a / K_t$.
- These values include a minimum acceptable industry standard Factor of Safety of 2 for helical anchors/piles when used in permanent applications. These pipeline anchors are considered by Hubbell Power Systems, Inc. to be a permanent application. If the client or their representative opts to use a lower Factor of Safety these values will have to be reduced accordingly. For example, at a span length of 88.3 ft, the working capacity per anchor set is $453.0 \text{ plf} \times 88.3 \text{ ft} = 40,000 \text{ lbs}$. Applying an FS of only 1.5, the required UC_s is $1.5 \times 40,000 = 60,000 \text{ lbs}$. The required UC_a is $60,000 \text{ lbs} / 2 \text{ anchors} = 30,000 \text{ lbs}$. The required minimum installation torque is $30,000 / 10 = 3,000 \text{ ft-lbs}$.

Span Reduction Schedule, Table 8-8

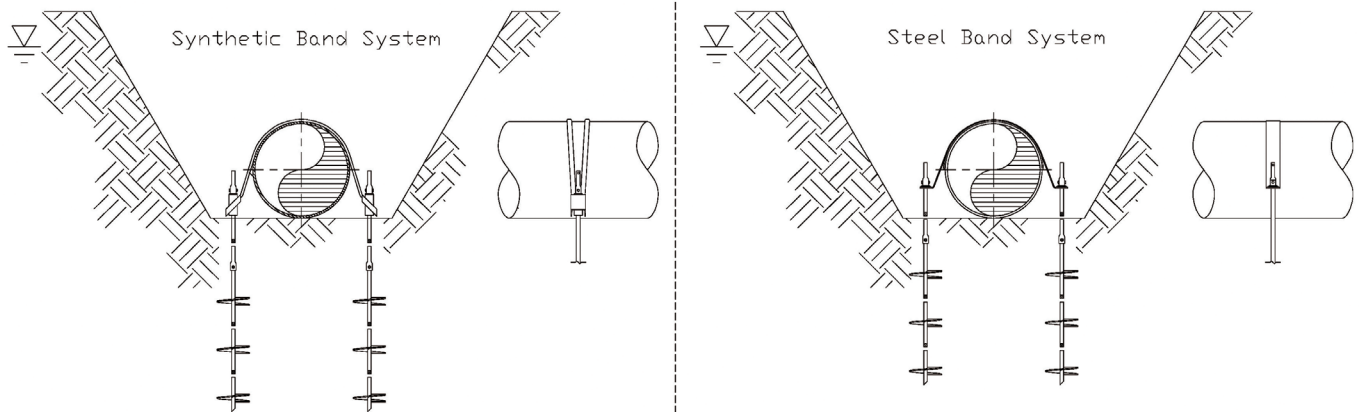
SPAN LENGTH (ft)	REQUIRED UC _s PER ANCHOR SET (lbs)	REQUIRED UC _a PER ANCHOR (lbs)	MINIMUM INSTALLATION TORQUE (ft-lbs)
88	80,000	40,000	4,000
77	70,000	35,000	3,500
66	60,000	30,000	3,000
55	50,000	25,000	2,500
44	40,000	20,000	2,000

Sample Problem - Natural Gas Pipeline Project

Ultimate Uplift Capacity using a 14",14",14" Helical Lead Section - Boring B-1



Ultimate Uplift Capacity
Figure 8-25



Band Systems
Figure 8-26

DESIGN EXAMPLE 13

TYPE RS HELICAL PILES for LATERAL SUPPORT

SYMBOLS USED IN THIS DESIGN EXAMPLE

C	Cohesion Factor of Soil	8-59
P	Applied Horizontal Shear Load	8-59
C_u	Cohesion of Clay	8-59
D	Diameter of Foundation	8-59
e	Eccentricity	8-59
L	Minimum Length of Foundation	8-59
f	Bending Stress	8-59
M^{POS}_{MAX}	Maximum Bending Moment	8-60
L	Required Depth into Soil	8-60

PROBLEM

A CHANCE® Helical Type SS175 1-3/4" square shaft helical anchor/pile is proposed for a pedestrian bridge abutment. The top section of the shaft is to be encased in a 6" nominal steel pipe and grout to provide lateral resistance. The top ten feet of the soil profile is medium-stiff clay with a cohesion factor (c) of 1000 psf. Determine what length of 6" diameter steel case is required to resist 4400 lbs of lateral load using the Broms' Method.

Assumptions

- The 1-3/4" square shaft below the 6" cased section provides no lateral resistance.
- The solution method used is shown in Figure 8-27.
- Eccentricity is assumed to be 1 ft.

Solution

Applied horizontal shear load: Use 4400 lbs. Include a Factor of Safety of 2 in the calculations, thus doubling the horizontal shear load; $P = 2 \times 4400 = 8800$ lbs.

C_u = Cohesion of clay: Use $C_u = 1000$ psf

D = Diameter of foundation: Use $D = 6.625$ " (6" nominal pipe size)

e = Eccentricity; distance above grade to resolved load:
Use $e = 1$ ft

L = Minimum length of foundation based on above criteria.

f = $P/9 (C_u) D$
= $8800 \text{ lbs}/9 (1000 \text{ psf}) (6.625 \text{ in}/12)$
= 1.771 ft

Equation 8-74

DESIGN EXAMPLES

$$\begin{aligned}
 M_{MAX}^{POS} &= P [e + 1.5(d) + 0.5(f)] \\
 &= 8800 \text{ lbs} [1 \text{ ft} + 1.5 (6.625 \text{ in}/12) + 0.5 (1.771 \text{ ft})] \\
 &= 23,880 \text{ ft-lbs}
 \end{aligned}$$

Equation 8-75

$$\begin{aligned}
 M_{MAX}^{POS} &= 2.25 (d) g^2 (Cu) \\
 23,880 \text{ ft-lbs} &= 2.25 (6.625 \text{ in}/12) g^2 (1000 \text{ psf}) \\
 g^2 &= 19.22 \text{ ft}^2 \\
 g &= \sqrt{19.22} \\
 &= 4.38 \text{ ft}
 \end{aligned}$$

Equation 8-76

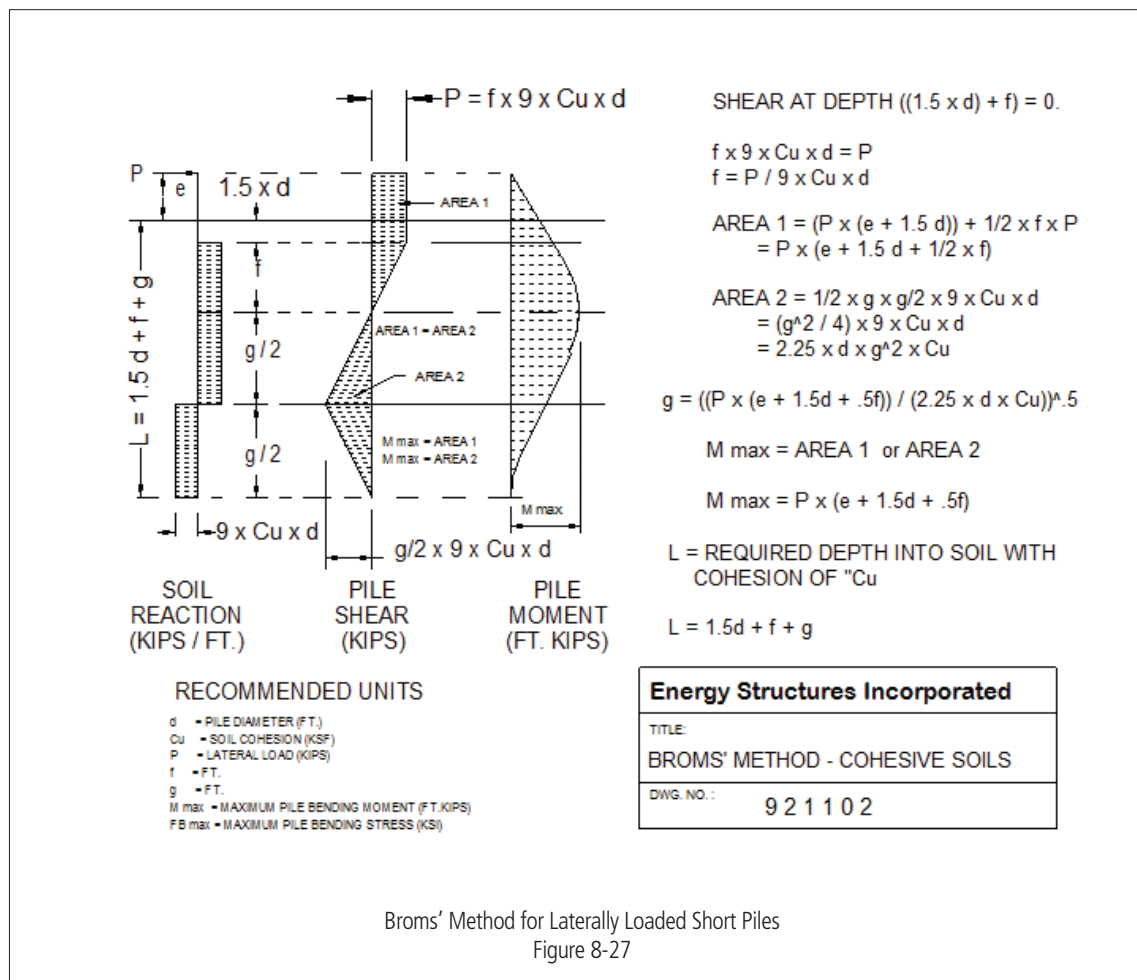
$$\begin{aligned}
 L &= 1.5D + f + g \\
 &= 1.5 (6.625 \text{ in}/12) + 1.771 \text{ ft} + 4.38 \text{ ft} \\
 &= 6.98 \text{ ft}
 \end{aligned}$$

Equation 8-77

Summary

The 6" nominal steel case should be at least 7'-0 long to resist the 4400 lb lateral load.

DESIGN EXAMPLES



DESIGN EXAMPLE 14

INSTANT FOUNDATIONS® for STREET LIGHT SUPPORTS

SYMBOLS USED IN THIS DESIGN EXAMPLE

SLF	Street Light Foundation	8-61
DL.....	Dead or Down Load	8-61
V.....	Horizontal or Lateral Shear Load	8-61
M.....	Moment Loads	8-61
AASHTO	American Association of State Highway and Transportation Officials	8-61
L.....	Required Length	8-63
c.....	Cohesion of Soil	8-63
FS.....	Factor of Safety	8-63
V_F	Applied Shear at Groundline including Factor of Safety	8-63
V_M	Applied Moment at Groundline including Factor of Safety	8-63
D.....	Diameter of Foundation	8-63
q.....	Broms' Coefficient	8-63
M_{MAX}	Maximum Moment Applied to Foundation	8-63
φ	Internal Angle of Friction	8-64
γ	Unit Weight of Soil	8-64
K_p	Passive Earth Pressure Coefficient	8-64

DESIGN EXAMPLES

PURPOSE

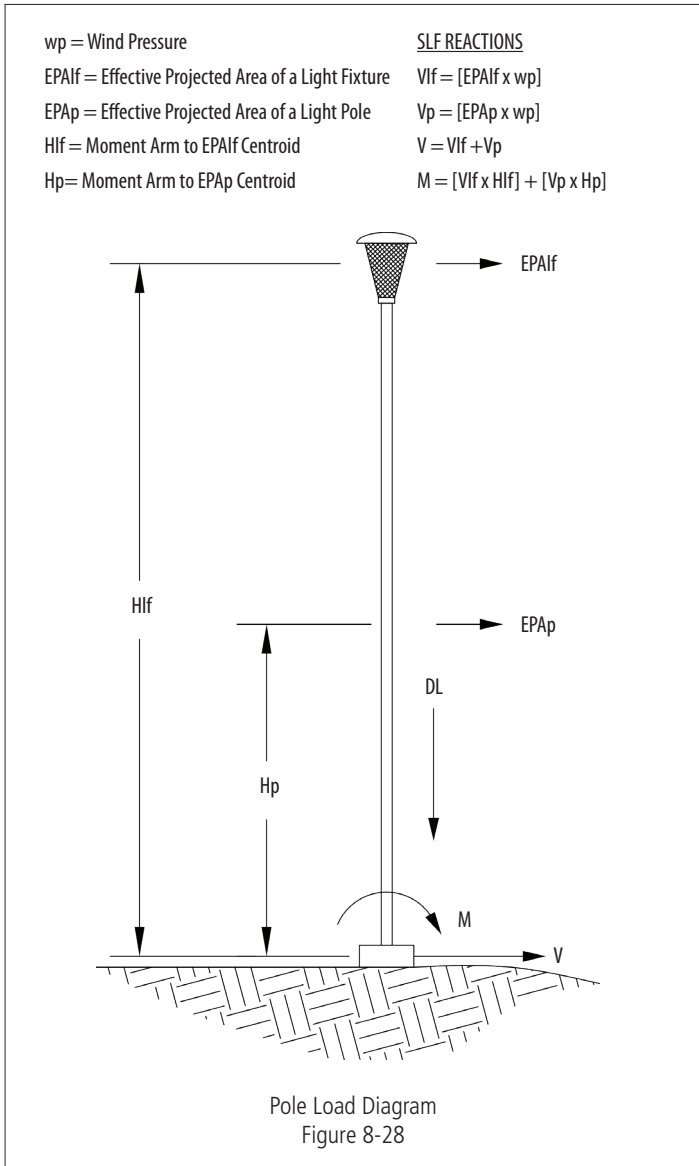
This Design Example provides example solutions to aid in the selection of appropriate CHANCE® Helical Instant Foundation® products for different job parameters.

SLF LOADS

The resulting pole loads to be resisted by a street light foundation (SLF) are dead or vertical down loads (DL), horizontal, lateral or shear loads (V) due to wind on the pole and luminaire (light fixture), and overturning moment loads (M) resulting from the tendency to bend at or near the ground line as the wind causes the pole to displace and the foundation restrains the pole base at one location (see Figure 8-28).

The DL for an SLF application is so small that a foundation sized to resist V and M will typically be much more than adequate to resist DL. Therefore, DL will not control the SLF design and will not be considered here. If DL is large enough to be of concern for an application where an SLF will be used, it may be evaluated based on bearing capacity equations applied to the soil around the helical bearing plate and friction along the shaft. These evaluations are beyond the scope of this design example, which will only deal with SLF applications.

Since SLF products are used as lighting foundations along public highways, it is appropriate to mention the American Association of State Highway and Transportation Officials (AASHTO) publication *Standard Specifications for Structural Support for Highway Signs, Luminaires and Traffic Signals*. This document is often taken as the controlling specification for jobs using SLF's and will be referenced throughout this discussion.

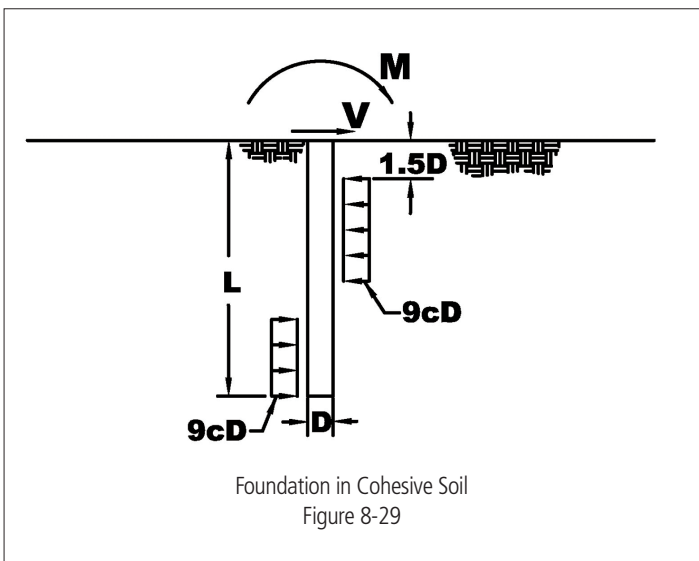


SLF SELECTION

The SLF selection process is a trial and error procedure that may require more than one iteration. First, select an SLF diameter based on the applied bending moment (M) that must be resisted. That is, ensure that the applied moment is less than the allowable moment on the shaft. Determining the allowable moment requires a structural analysis of the pipe shaft section capacities (often based on a reduced cross section through cable ways, bolt slots, base plate size, welds, etc). This effort should be familiar to engineers engaged in design work, so a sample of this process will not be given here.

The foundation shaft diameter will often be as large as or larger than the base diameter of the pole to be supported. Allowable moment capacities for CHANCE® Helical Instant Foundation® products are provided in Table 10-2 in Section 10 of this Technical Design Manual. These capacities, when compared to the ground line reactions of the pole, can be used to choose a starting diameter to resist the applied loads. In this regard, shear is usually not the controlling factor for SLF shaft size but rather the moment load. (Note: The starting size may change as the given soil conditions for a job may dictate the final SLF size required.)

The design or selection of a foundation size to resist light pole loads in a given soil may be determined by various methods. Numerical methods using finite element and finite difference techniques may be used but have proven to be somewhat sophisticated for the rather simple SLF application. The Fourth Edition of the AASHTO specification lists a number of preliminary design methods that can be employed in the design process. Among those listed and discussed are the methods developed by Bengt B. Broms for embedment lengths in cohesive and cohesionless soils and a graphical method dealing with the embedment of lightly loaded poles and posts. The Broms method will be used for this design example as experience has shown these methods to both useable and appropriate. Calculations are provided for both cohesive soil (clay) and cohesionless soil (sand).



COHESIVE SOIL (see Figure 8-29)

Assumed values:

- Applied shear load at the groundline (V) = 460 lbs.
- Applied moment at the groundline (M) = 8600 ft-lbs.
- Foundation diameter is 6" nominal Schedule 40. Use 6.625" as the actual pipe size in calculations. Cableway openings are 2.5" wide by 12" high. The allowable moment capacity of this foundation shaft size and cableway opening is 10,860 ft-lbs.
- The required length (L) will be determined using the Broms method.
- Cohesion (c) = 1000 psf.
- Factor of Safety = 2.

$$\begin{aligned}
 V_F &= V (FS) && \text{Equation 8-78} \\
 &= 460 (2) \\
 &= 920 \text{ lbs}
 \end{aligned}$$

$$\begin{aligned}
 V_M &= M (FS) && \text{Equation 8-79} \\
 &= 8600 (2) \\
 &= 17,200 \text{ ft-lbs}
 \end{aligned}$$

$$\begin{aligned}
 L &= 1.5D + q [1 + \{ 2 + (4H + 6D)/q \}^{0.5}] && \text{Equation 8-80} \\
 &= 1.5 (6.625/12) + 0.185157 \times [1 + \{ 2 + (4 \times 18.69565 + 6 \\
 &\quad \times (6.625/12)) / (0.185157) \}^{0.5}] \\
 &= 4.82 \text{ ft}
 \end{aligned}$$

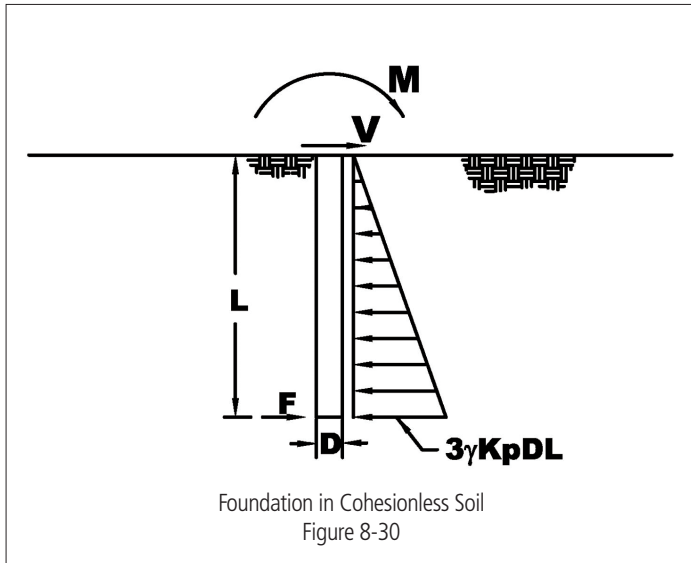
- where:
- D = Diameter of foundation = 6.625 inches
 - q = $V_F / 9cD = 920 / (9 \times 1000 \times 6.625/12) = 0.185157 \text{ ft}$
 - c = Shear strength of cohesive soil = 1000 psf
 - H = Moment / Shear = $M/V = V_M / V_F = 17200 \text{ ft-lbs} / 920 \text{ lbs} = 18.69565 \text{ ft}$
 - L = Calculated Foundation Length to Provide a SF of 2 Against Soil Failure.

The length required to provide a Factor of Safety of 2 against soil failure is 4.82 ft. Since SLF lengths are provided in even foot lengths, use L = 5 ft. For the required embedment length, the maximum moment in the shaft is:

$$\begin{aligned}
 M_{MAX} &= V (H + 1.5D + 0.5q) && \text{Equation 8-81} \\
 &= 460 (18.69565 + (1.5 \times 6.625/12) + (0.5 \times 0.185157)) \\
 &= 9023.5 \text{ ft-lbs}
 \end{aligned}$$

Maximum moment can be compared with the allowable moment capacity of the foundation shaft to determine adequacy. For this example the allowable moment in the 6" pipe shaft is given as 10,860 ft-lbs, which is greater than the applied moment. Therefore, the 6" diameter by 5' long SLF is adequate for the applied loads in the clay soil.

DESIGN EXAMPLES



COHESIONLESS SOIL (See Figure 8-30)

Assumed values:

- Applied shear load at the groundline (V) = 460 lbs.
- Applied moment at the groundline (M) = 8600 ft-lbs.
- Foundation diameter is 6" nominal Schedule 40. Use 6.625" as the actual pipe size in calculations. Cableway openings are 2.5" wide by 12" high. The allowable moment capacity of this foundation shaft size and cableway opening is 10,860 ft-lbs.
- The required length (L) will be determined using the Broms method.
- $\phi = 30^\circ$
- $\gamma = 100 \text{ lbs/ft}^3$
- Factor of Safety = 2.

DESIGN EXAMPLES

$$V_F = V (FS) = 460 (2) = 920 \text{ lbs} \quad \text{Equation 8-78}$$

$$V_M = M (FS) = 8600 (2) = 17,200 \text{ ft-lbs} \quad \text{Equation 8-79}$$

Broms equation for cohesionless soil requires a trial and error solution. For the trial and error solution, start by assuming the foundation diameter (D) is 6.625" and the length (L) is 6 feet:

$$0 \leq L^3 - (2V_F L / K_p \gamma D) - (2VM / K_p \gamma D) \quad \text{Equation 8-82}$$

$$= 6^3 - [2 \times 920 \times 6 / (3 \times 100 \{6.625/12\})] - [(2 \times 17200) / (3 \times 100 \times \{6.625/12\})]$$

where: $= -58.35$

$$0 > -58.35$$

$$K_p = \tan^2 (45 + \phi/2) = 3.0$$

$$\gamma = \text{Effective unit weight of soil} = 100 \text{ lbs/ft}^3$$

The 6 foot length is too short so we will try a 7 foot length and repeat the calculation:

$$0 = 7^3 - [2 \times 920 \times 7 / (3 \times 100 \{6.625/12\})] - [(2 \times 17200) / (3 \times 100 \times \{6.625/12\})]$$

$$= 57.53$$

$$0 < 57.53$$

A 7 foot long SLF will be adequate. The maximum moment in the foundation shaft can be determined with the following equation:

$$M_{MAX} = V (H + 0.54 \times (V / \gamma DK_p)^{0.5}) \quad \text{Equation 8-83}$$

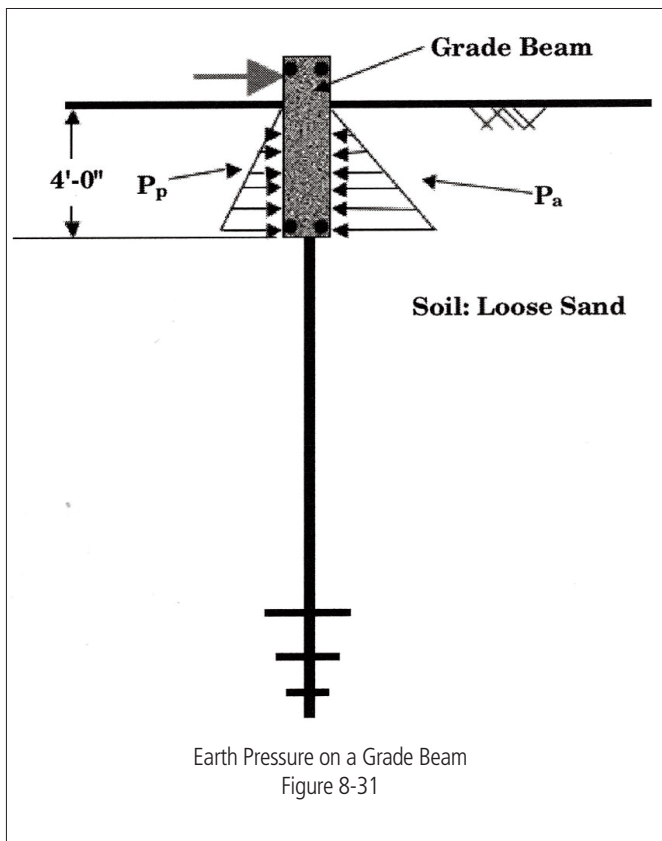
$$= 460 (18.69565 + 0.54 \times (460/100 \times (6.625/12) \times 3)^{0.5})$$

$$= 9013.968 \text{ ft-lbs}$$

This is less than the allowable moment capacity of 10,860 ft-lbs, therefore a 6" diameter by 7' long SLF is adequate for the applied load in the sandy soil.

DESIGN EXAMPLE 15
FOUNDATION EARTH PRESSURE RESISTANCE
SYMBOLS USED IN THIS DESIGN EXAMPLE

pcf	Pounds per Cubic Foot	8-65
K_a	Active Earth Pressure Coefficient	8-65
K_p	Passive Earth Pressure Coefficient	8-65
P_a	Active Load	8-66
P_p	Passive Load	8-66



PROJECT

A CHANCE® Helical Type SS5 1-1/2" square shaft helical anchor is proposed as part of a pier and beam foundation for a residential structure (see Figure 8-31). The top of the helical anchor is fixed in a concrete grade beam that extends 4'-0 below grade. The surface soils are loose sands. Determine the lateral capacity of the grade beam using the Rankine earth pressure method.

ASSUMPTIONS

- The lateral capacity of the 1-1/2" square shaft helical anchor is limited based on shaft size. It is generally not assigned any contribution to the lateral capacity of a foundation
- The effective length of the grade beam for lateral resistance is 25'-0
- Assume a unit weight of 95 pcf
- The water table is well below the bottom of the grade beam
- There are no surcharge loads
- From Table 8-9, $K_a = 0.2$, $K_p = 3$

DESIGN EXAMPLES

SOLUTION

$$\begin{aligned}
 P_a &= 0.5K_a\gamma H^2 \\
 &= 0.5 \times 0.2 \times 95 \times 42 \\
 &= 152 \text{ lb/ft}
 \end{aligned}$$

Equation 8-84

$$\begin{aligned}
 P_p &= 0.5K_p\gamma H^2 \\
 &= 0.5 \times 3 \times 95 \times 42 \\
 &= 2280 \text{ lb/ft}
 \end{aligned}$$

$$\begin{aligned}
 P_p - P_a &= 2280 - 152 \\
 &= 2128 \text{ lb/ft}
 \end{aligned}$$

$$\text{Total lateral resistance} = 2128 \times 25' - 0 = 53,200 \text{ lbs}$$

NOTE: In this example, more than 1" of movement will probably be required to fully mobilize the total lateral resistance. Partial mobilization requires less deflection.

Coefficients of Earth Pressure (Das, 1987), Table 8-9

SOIL	K_0' DRAINED	K_0' TOTAL	K_a' TOTAL	K_p' TOTAL
Clay, soft ¹	0.6	1	1	1
Clay, hard ¹	0.5	0.8	1	1
Sand, loose	0.6	0.53	0.2	3
Sand, dense	0.4	0.35	0.3	4.6

Note:
¹ Assume saturated clays.

DESIGN EXAMPLES

DESIGN EXAMPLE 16

BUCKLING EXAMPLE USING the DAVISSON METHOD

SYMBOLS USED IN THIS DESIGN EXAMPLE

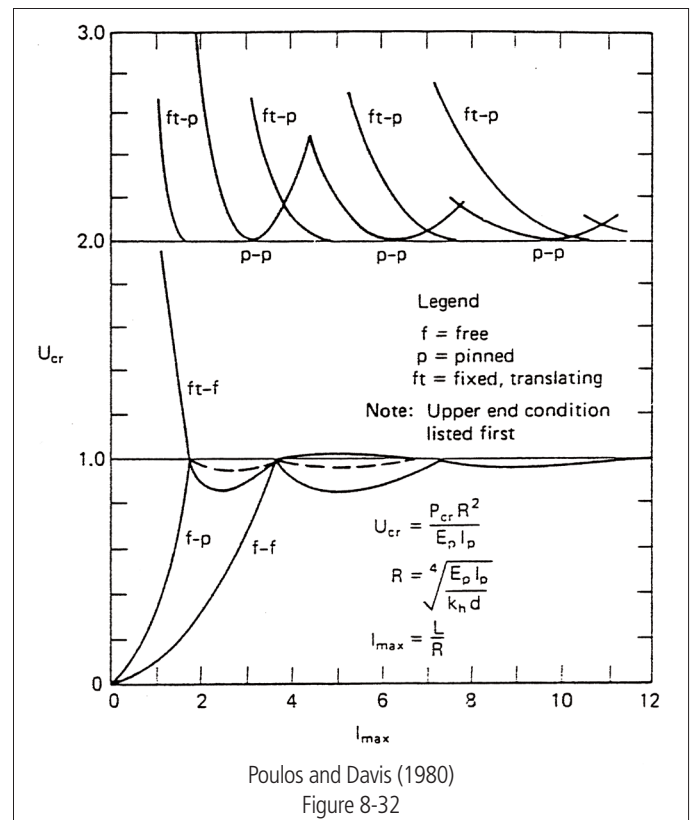
k_h	Empirical Torque Factor for Helix	8-67
U_{cr}	Critical Capacity	8-67
R	Resistance	8-68
I_{max}	Maximum Moment of Inertia	8-68
P_{cr}	Critical Pressure	8-68
E_p	Modulus of Elasticity	8-68
I_p	Moment of Inertia	8-68
D	Shaft Diameter	8-68
kip.....	Kilopound	8-68

PROJECT

A three-helix CHANCE® Helical Type SS150 1-1/2" square shaft helical pile is to be installed into the soil profile as shown in Figure 8-33. The top three feet is uncontrolled fill and is assumed to be soft clay. The majority of the shaft length (12 feet) is confined by soft clay with a $k_h = 15$ pci. The helix plates will be located in stiff clay below 15 feet. The buckling model assumes a pinned-pinned end condition for the helical pile head and tip. Determine the critical buckling load using the Davisson method.

ASSUMPTIONS

- k_h is constant, i.e., it does not vary with depth. This is a conservative assumption because k_h usually varies with depth, and in most cases increases with depth.
- Pinned-pinned end conditions are assumed. In reality, end conditions are more nearly fixed than pinned, thus the results are generally conservative.
- From Figure 8-32, $U_{cr} \approx 2$



DESIGN EXAMPLES

$$R = \sqrt[4]{(30 \times 10^6 \times 0.396) / (15 \times 1.5)} = 26.96$$

$$I_{max} = (15 \times 12) / 26.96 = 6.7$$

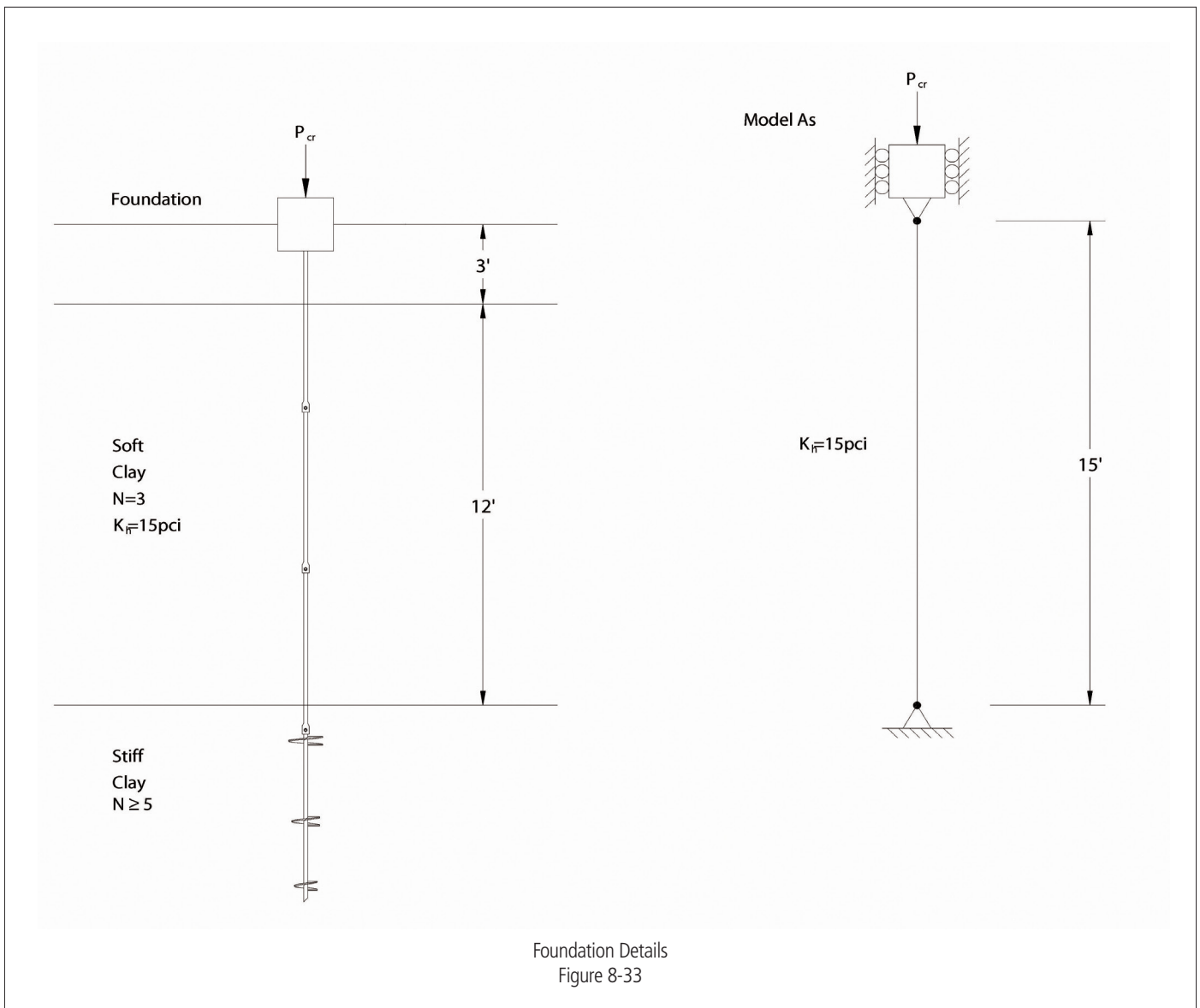
$$P_{cr} = (2 \times 30 \times 106 \times 0.396) / 26.96^2 = 32.69 \text{ kips}$$

Equation 8-85

CHANCE® Helical Type SS150 Square Shaft Foundations Physical Properties, Table 8-10

MODULUS of ELASTICITY (E_p)	MOMENT of INERTIA (I_p)	SHAFT DIAMETER (D)
30 x 10 ⁶ psi	0.396 in ⁴	1.5 in

DESIGN EXAMPLES

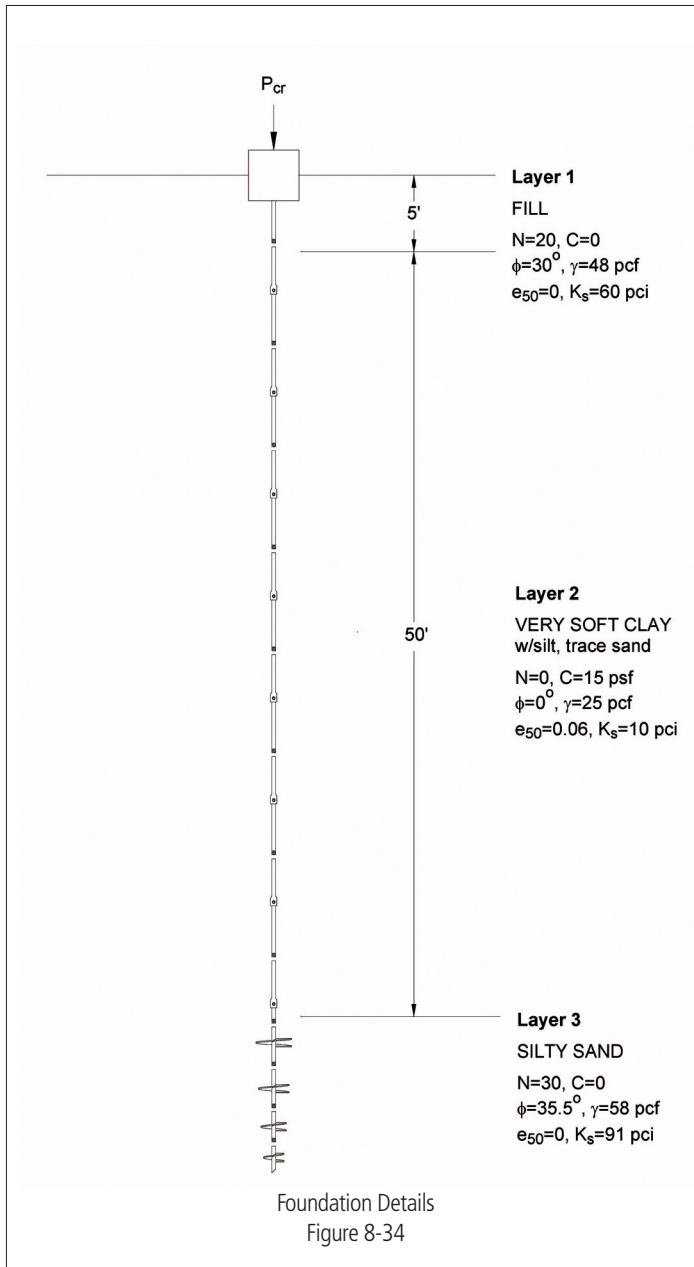


DESIGN EXAMPLE 17

BUCKLING EXAMPLE USING the FINITE DIFFERENCE METHOD

SYMBOLS USED IN THIS DESIGN EXAMPLE

WOH	Weight of Hammer	8-69
WOR.....	Weight of Rod	8-69
psf	Pounds per Square Foot	8-69
ID.....	Inside Diameter	8-70
HPM.....	CHANCE HELICAL PULLDOWN® Micropile	8-70



A four-helix CHANCE® Helical Pile is to be installed into the soil profile as shown in Figure 8-34. The top five feet is compacted granular fill and is considered adequate to support lightly loaded slabs and shallow foundations. The majority of the shaft length (50 feet) is confined by very soft clay described by the borings as “weight of hammer” (WOH) or “weight of rod” (WOR) material. WOH or WOR material means the weight of the 130-lb drop hammer or the weight of the drill rod used to extend the sampler down the borehole during the standard penetration test is enough to push the sampler down 18+ inches. As a result, a low cohesion value (15 psf) is assumed. The helix plates will be located in dense sand below 55 feet. Determine the critical buckling load of a Type SS175 1-3/4” square shaft and Type RS3500.300 round shaft piles using LPILEPLUS 3.0 for Windows® (ENSOFT, Austin, TX).

When the computer model is completed, the solution becomes an iterative process of applying successively increasing loads until a physically logical solution converges. At or near the critical buckling load, very small increasing increments of axial load will result in significant changes in lateral deflection – which is a good indication of elastic buckling. Figure 8-35 is an LPILEPLUS output plot of lateral shaft deflection vs depth. As can be seen by the plot, an axial load of 14,561 lb is the critical buckling load for a Type SS175 1-3/4” square shaft because of the dramatic increase in lateral deflection at that load compared to previous lesser loads. Figure 8-36 indicates a critical buckling load of 69,492 lb for Type RS3500.300 round shaft.

Note that over the same 50-foot length of very soft clay, the well-known Euler equation predicts a critical buckling load for Type SS175 of 614 lb with pinned-pinned end conditions and 2,454 lb with fixed-fixed end conditions. The Euler critical buckling load for

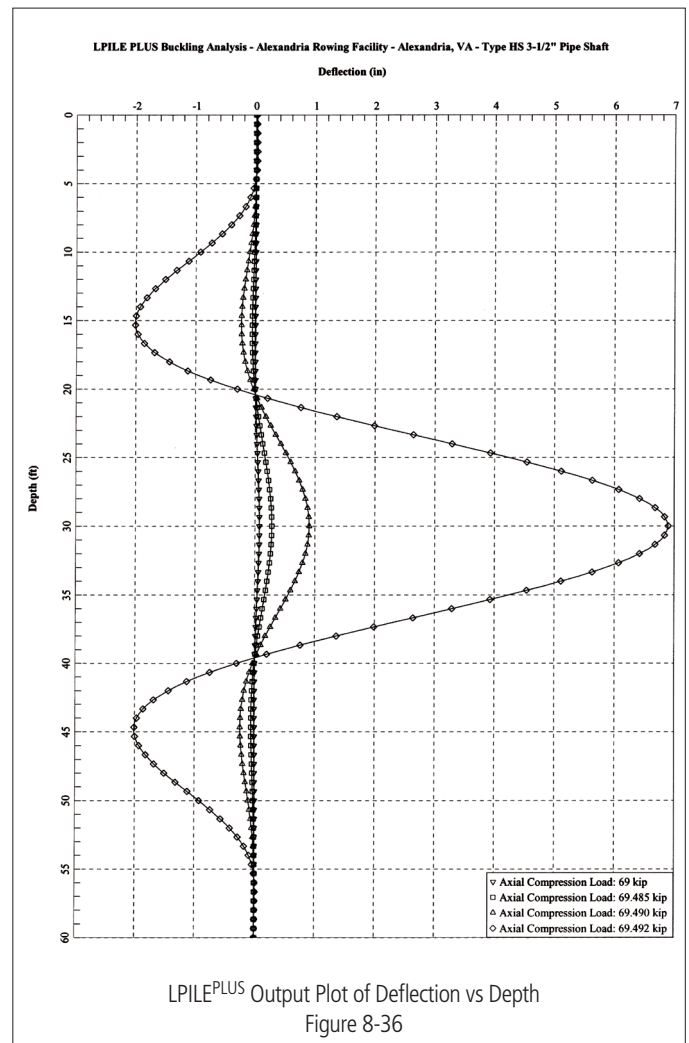
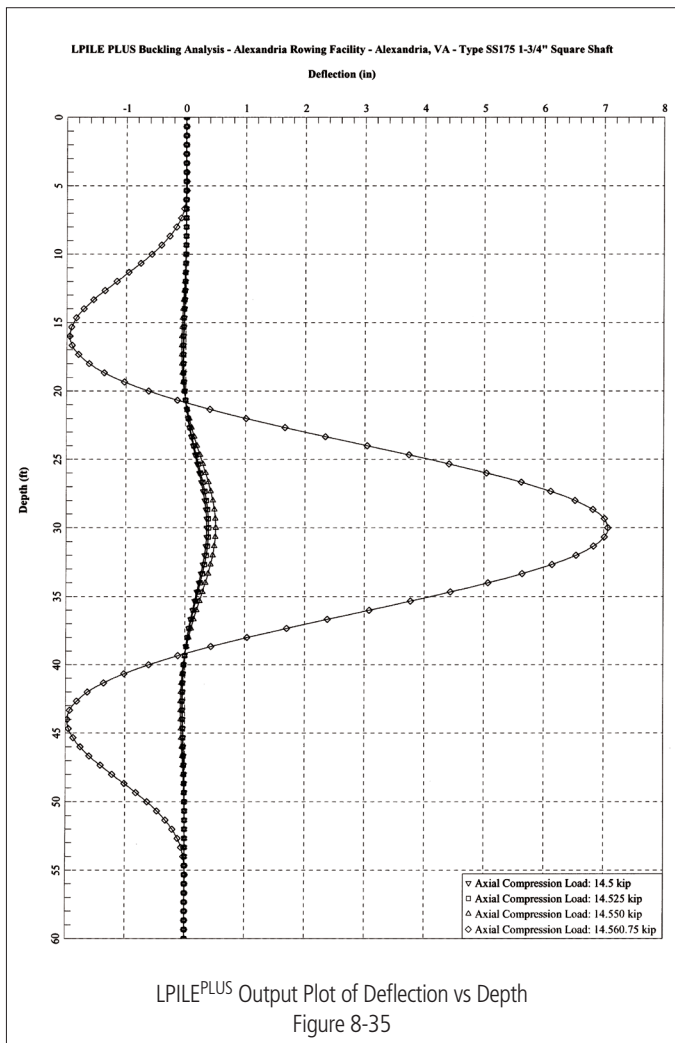
DESIGN EXAMPLES

Type RS3500.300 is 3,200 lb for pinned-pinned and 12,800 lb for fixed-fixed. This is a good indication that shaft confinement provided by the soil will significantly increase the buckling load of helical piles. This also indicates that even the softest materials will provide significant resistance to buckling.

All extendable helical piles have couplings or joints used to connect succeeding sections together in order to install the helix plates in bearing soil. One inherent disadvantage of using the finite difference method is its inability to model the effects of bolted couplings or joints that have zero joint stiffness until the coupling rotates enough to bring the shaft sides into contact with the coupling walls. This is analogous to saying the coupling or joint acts as a pin connection until it has rotated a specific amount, after which it acts as a rigid element with some flexural stiffness. All bolted couplings or joints, including square shaft and round shaft piles, have a certain amount of rotational tolerance. This means the joint initially has no stiffness until it has rotated enough to act as a rigid element. In these cases, it is probably better to conduct buckling analysis using other means, such as finite element analysis, or other methods based on empirical experience as mentioned earlier.

If couplings are completely rigid, i.e., exhibit some flexural stiffness even at zero joint rotation, axial load is transferred without the effects of a pin connection, and the finite difference method can be used. An easy way to accomplish rigid couplings with round shaft piles is to pour concrete or grout down the ID of the pipe after installation. Another method is to install a grout column around the square or round shaft of the foundation using the CHANCE HELICAL PULLDOWN[®] Micropile (HPM) method. The HPM is a patented (U.S. Patent 5,707,180) installation method initially developed to install helical anchor foundations in very weak soils where buckling may be anticipated.

DESIGN EXAMPLES

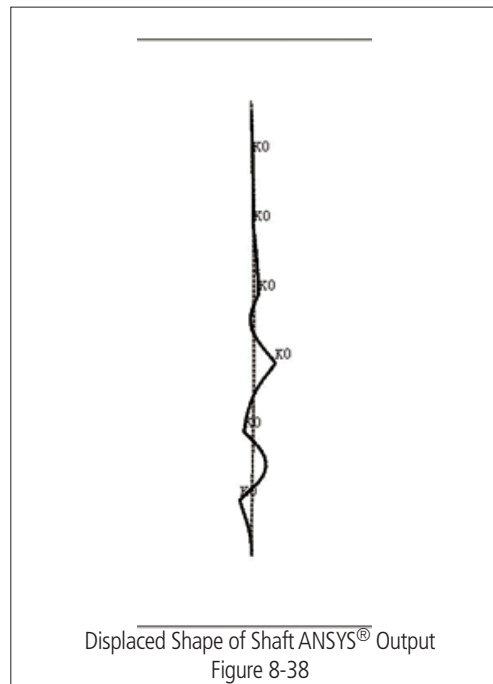
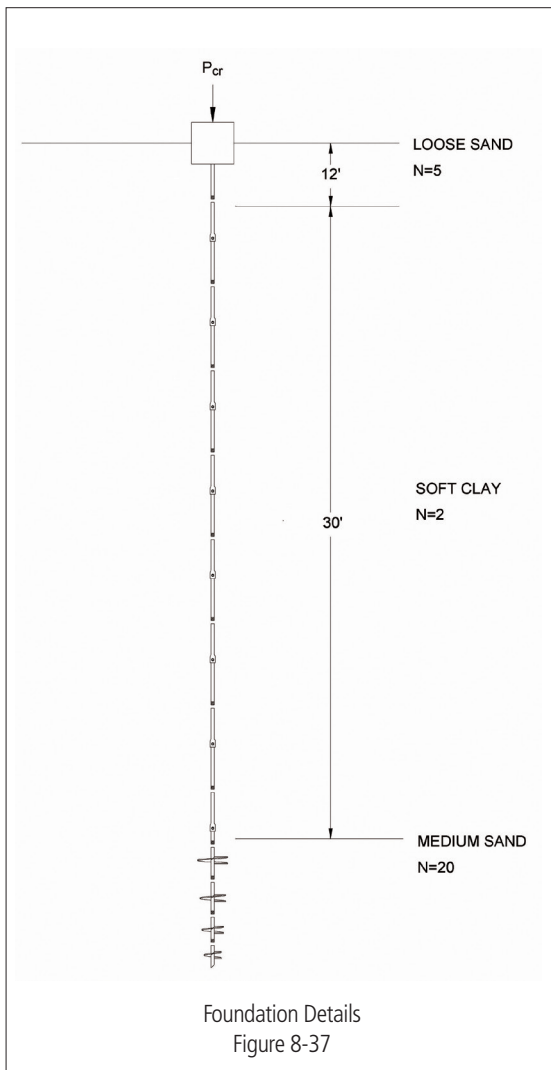


DESIGN EXAMPLE 18

BUCKLING EXAMPLE USING the FINITE DIFFERENCE METHOD

SYMBOLS USED IN THIS DESIGN EXAMPLE

SPT	Standard Penetration Test	8-71
N	SPT Blow Count	8-71
psf	Pounds per Square Foot	8-71
kip	Kilopound	8-71
HPM	CHANCE HELICAL PULLDOWN® Micropile	8-71



A three-helix CHANCE® Helical Type SS5 1-1/2" square shaft helical pile is to be used to underpin an existing townhouse structure that has experienced settlement (see Figure 8-37 for soil profile details). The top 12 feet is loose sand fill, which probably contributed to the settlement problem. The majority of the shaft length (30 feet) is confined by very soft clay with an SPT blow count "N" of 2. As a result, a cohesion value (250 psf) is assumed. The helix plates will be located in medium-dense sand below 42 feet. Determine the critical buckling load using the ANSYS integrated file element model.

Output indicates the Type SS5 1-1/2" square shaft buckled at around 28 kip. Figure 8-38 shows the displaced shape of the shaft (exaggerated for clarity). The "K0" in Figure 8-38 are the locations of the shaft couplings. Note that the deflection response is controlled by the couplings, as would be expected. Also note that the shaft deflection occurs in the very soft clay above the medium-dense bearing stratum. Since the 28 kip buckling load is considerably less than the bearing capacity (55+ kip) it is recommended to install a grout column around the 1-1/2" square shaft using the CHANCE HELICAL PULLDOWN® Micropile (HPM) method.

DESIGN EXAMPLES

DESIGN EXAMPLES





RETENTION WALL SYSTEM



SOIL SCREW® RETENTION WALL SYSTEM SECTION 9

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RETENTION WALL SYSTEM

SYMBOLS USED IN THIS SECTION

FS	Factor of Safety	9-5
AWS.....	American Welding Society	9-7
SPT	Standard Penetration Test	9-8
N.....	SPT Blow Count	9-8
LI.....	Liquidity Index	9-8
K_t	Empirical Torque Factor	9-11
c.....	Cohesion of Soil	9-15
φ	Angle of Internal Friction	9-15
θ	Failure Plane Angle	9-16
RF	Resisting Force	9-17
DF	Driving Force	9-17
SSCF.....	SOIL SCREW® Anchor Component Force	9-17
WWF	Welded Wire Fabric	9-17
GWT	Ground Water Table	9-19
P_{des}	Design Load per Pier	9-15
DS.....	Design Load	9-15
T.....	Indicated Force	9-20

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

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Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

INTRODUCTION

Hubbell Power Systems, Inc. provides the SOIL SCREW® Retention Wall System as an efficient and economical system to retain soil during excavation and construction of structures below grade. The following are some of the advantages of this system over other soil retention methods:

- Fast installation without specialized equipment;
- Immediate support without curing time;
- Reduced installation time - post-tensioning not required;
- No need for H-piles, walers and heavy reinforced walls;
- Immediate on-site capacity verification; and
- Excavations adjacent to existing structures are possible when used with ATLAS RESISTANCE® Piers or CHANCE® Helical Piles;

The CHANCE® Underpinning/Shoring system provides for underpinning existing shallow footings, permitting excavation adjacent to the existing structure to a depth that would otherwise undermine the existing footing. The system allows excavation to proceed directly adjacent to an existing building without fear of vibration or structural damage to the building.

Commercial property owners often want to construct buildings with maximum possible footprints and a basement to maximize the potential of the site. If there is an existing building with a shallow footing adjacent to the proposed construction site, that building will need to be protected against damage from settlement due to removal of the soil that is laterally supporting the existing footing. Similar protection is required when a sloping excavation is cut next to an existing shallow footing in order to construct a building, parking lot, or roadway adjacent and down-slope of this footing.

The SOIL SCREW® Retention Wall System is designed to provide protection to the existing structure by using a combination of foundation support products. ATLAS RESISTANCE® Piers or CHANCE® Helical Piles are used to underpin the foundation of the existing structure. The structural load from the shallow footing is transferred down to a suitable bearing stratum below the depth of the intended excavation. The SOIL SCREW® Retention Wall System, combined with a reinforced shotcrete retaining wall is then used to maintain stability of the cut slope and the underpinning system as the excavation proceeds. For some conditions CHANCE® Helical Tieback Anchors can be used at the underpinning bracket to further ensure against lateral footing movement of existing buildings.

Other methods require the use of impact driven "soldier" piles. The major disadvantages to this system are the equipment size, noise and vibrations caused by the installation of the piles. This can be bothersome, annoying and stressful to the occupants of surrounding buildings, could damage sensitive electronics and/or could cause settlement of the building being protected. Because the CHANCE® Foundation Stabilization System and support uses hydraulic power for driving the underpinning, helical tieback anchors, and Helical SOIL SCREW® Anchors, it is extremely quiet and practically vibration free, thus allowing full use of neighboring buildings during the construction process.

PRODUCT BENEFITS

CHANCE SOIL SCREW® Retention Wall Systems offer the following benefits:

- Low installed cost
- No vibration
- Shorter installation lengths
- Ease of installation in limited access areas
- Minimum disturbance to site
- Immediate loading
- On-site load test capability
- Reusable in temporary stabilization applications

RETENTION WALL SYSTEM

SYSTEM DESCRIPTION

The CHANCE SOIL SCREW® Retention Wall System creates an internally reinforced soil mass when closely spaced in a regular geometric pattern and protected by a reinforced facing of shotcrete. It differs from helical tieback anchors even though the appearance of the products is similar.

A tieback restrained wall is generally constructed by installing a structural wall facing system that is anchored to the earth by means of high strength helical anchors that are installed to a stratum of soil of sufficient strength to resist the forces placed upon the wall by the retained earth. The helical tieback anchor experiences a tension load equal to the retained earth forces. The structural retaining wall must be designed with sufficient strength to be able to support the soil load between tiebacks without excessive deformation.

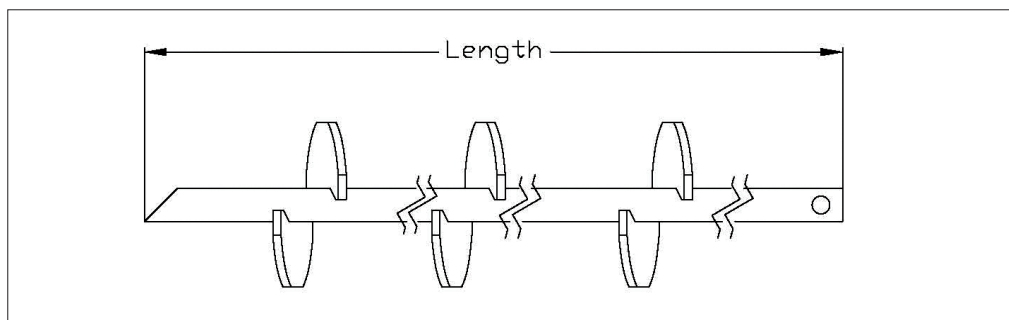
CHANCE® Helical SOIL SCREW® Anchors are designed and installed differently than helical tieback anchors. They are generally seated at a shallower depth than helical tieback anchors when installed to retain similar soil masses. Most importantly, the Helical SOIL SCREW® Anchors are not tensioned after installation; they are passive elements. When the SOIL SCREW® Retention Wall System is installed it holds the soil as a single mass of sufficient internal stability to provide a suitable Factor of Safety (FS) against failure. The load on the Helical SOIL SCREW® Anchors is created across the movement plane as the soil mass moves slightly downward due to gravity.

Many projects require that excavations be extremely close to existing structures. By combining ATLAS RESISTANCE® Modified Piers, or CHANCE® Helical Piles, CHANCE® Helical Tieback Anchors, and the CHANCE SOIL SCREW® Retention Wall System together, the designer is able to safely support an existing structure and the underlying soil mass during adjacent excavations. ATLAS RESISTANCE® Piers or CHANCE® Helical Piles support the structural load of the perimeter of the building, thus dramatically reducing the surcharge on the soil mass that must be retained. CHANCE® Helical Tieback Anchors are used for lateral support of the building's footing in projects where deep, adjacent excavations are required and/or for buildings with perimeter weights exceeding 4,000 pounds per linear foot. With the surcharge loads properly transferred away from the soil mass under the building, the design for soil retention using CHANCE® Helical SOIL SCREW® Anchors is greatly simplified and requires fewer Helical SOIL SCREW® Anchors. In many instances, this method is the only economical way to accomplish this task. This method of structure/soil mass support prevents structure distress that may manifest itself during potential settlement as the soil mass loads the CHANCE SOIL SCREW® Retention Wall System.

SOIL SCREW® RETENTION WALL SYSTEM SELECTION GUIDELINES

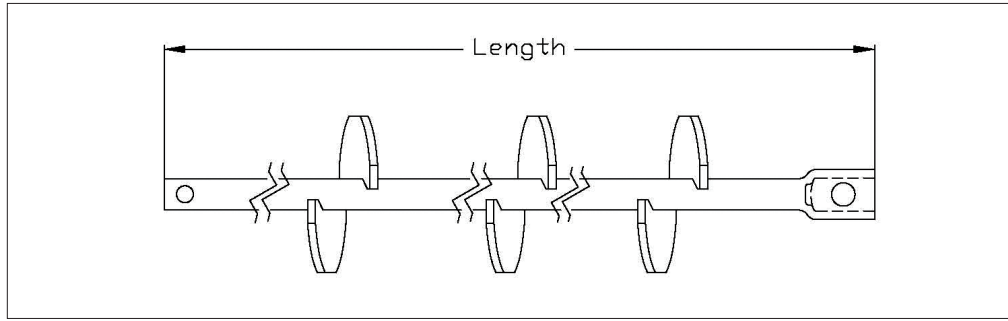
The CHANCE SOIL SCREW® Retention Wall System is available in two shaft sizes and two helix diameters. A variety of shaft lengths are offered to provide a designer an adequate selection for any application and load requirements. Design and installation requires input and supervision by a professional engineer and adequate site specific soil information.

CHANCE SOIL SCREW® Retention Wall System (Type SS5 and SS175 Series) Lead Sections



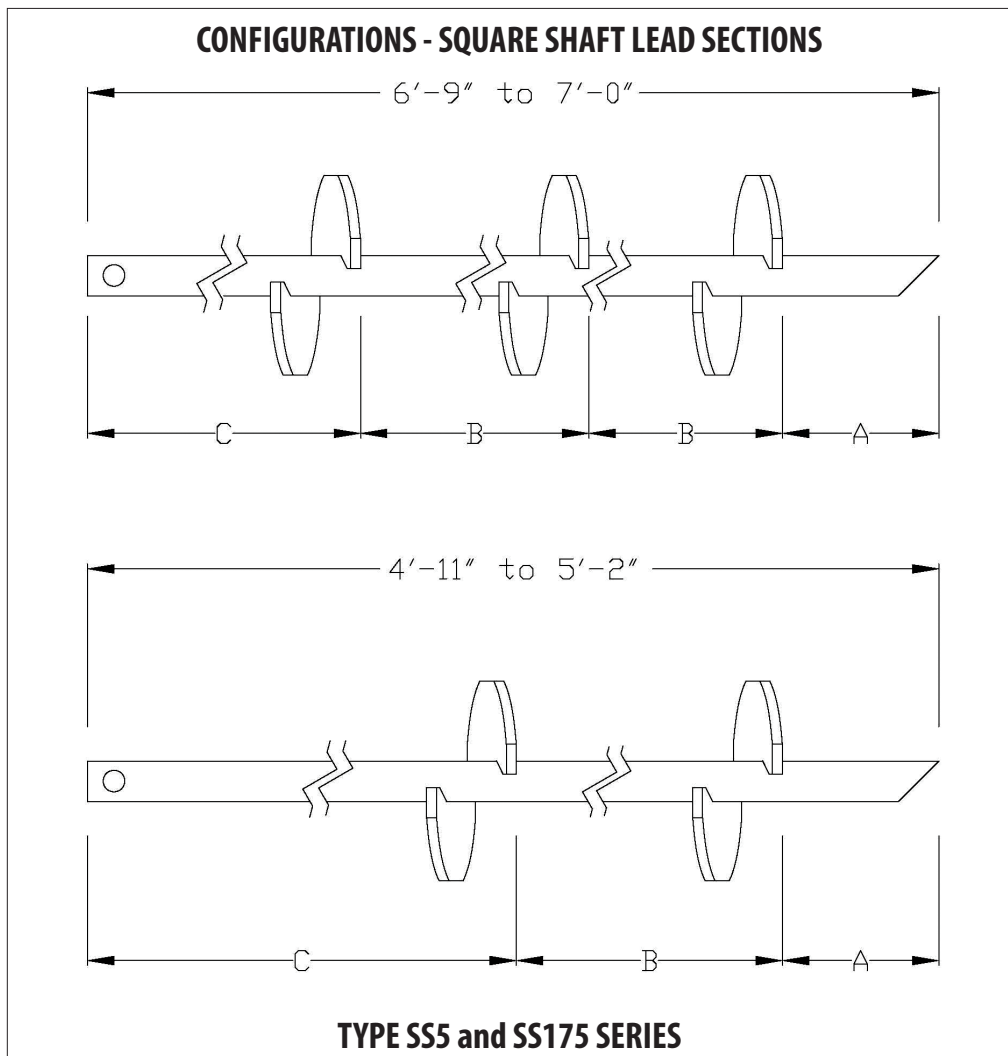
Product Designation	Product Series	Length	No. Plates	Plate Size	Weight lb.
C1100692	SS5	4'-11	2	8" Dia.	49
C1100691	SS5	7'-0	3	8" Dia.	69
C11002350301	SS175	5'-2	2	8" Dia.	62
T11006740302	SS175	6'-9	3	6" Dia.	75

CHANCE SOIL SCREW® Retention Wall System (Type SS5 and SS175 Series) Extension Sections



Product Designation	Product Series	Length	No. Plates	Plate Size	Weight lb.
C1100690	SS5	4'-9"	2	8" Dia.	42
C1100689	SS5	6'-9"	3	8" Dia.	50
C11004500301	SS175	6'-11"	2	6" Dia.	70
C11004500302	SS175	6'-10"	3	8" Dia.	75

RETENTION WALL SYSTEM

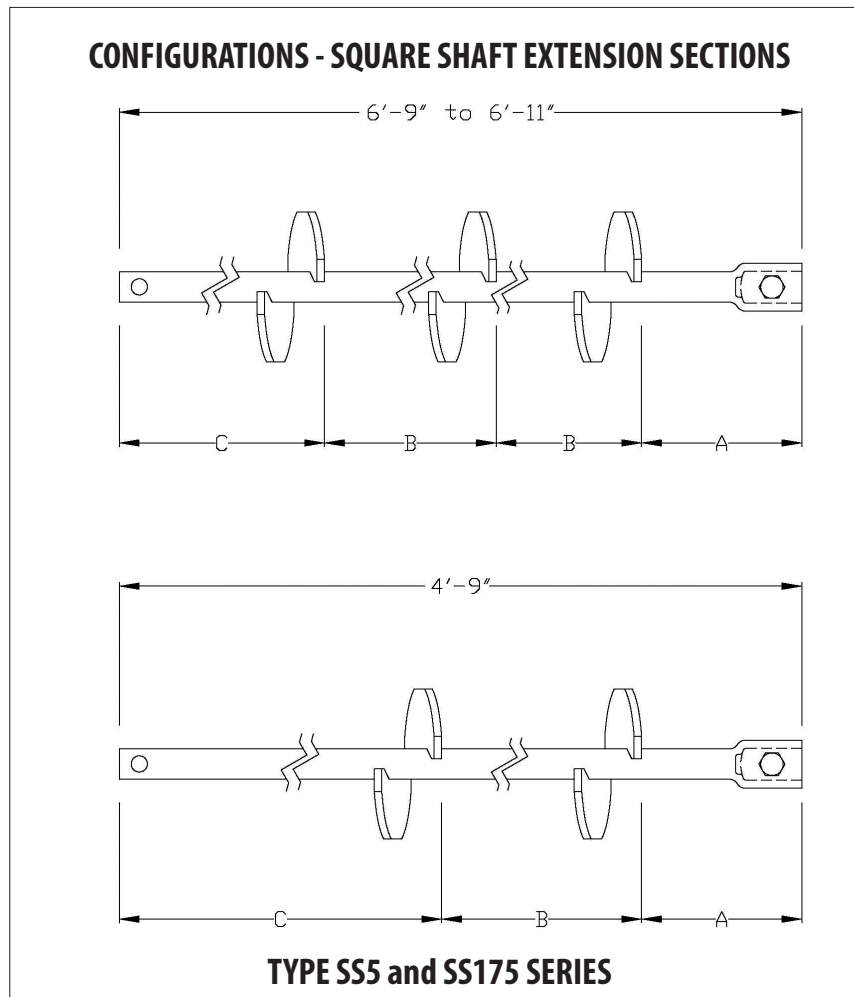


CHANCE SOIL SCREW® Retention Wall System (Type SS5 and SS175 Series) Lead Sections

CONFIGURATION TABLE (Leads and Extensions)						
Bar Size	Plate Size	Length	Dim A	Dim B	Dim C	No. Plates
1-1/2" Square Soil Screw® Lead Section	8" Dia.	4'-11	6"	29"	24"	2
		7'-0	6"	29"	20"	3
1-1/2" Square Soil Screw® Extension	8" Dia.	4'-9	5"	29"	23"	2
		6'-9	6"	29"	17"	3
1-3/4" Square Soil Screw® Lead Section	6" Dia.	5'-2	8"	30"	24"	2
	8" Dia.	6'-9	6"	30"	15"	3
1-3/4" Square Soil Screw® Extension	6" Dia.	6'-11	6"	30"	17"	3
	8" Dia.	6'-10	9"	29"	15"	3

NOTES – SOIL SCREW® ANCHOR PRODUCTS (Type SS5 and SS175 Series):

- Refer to the schematic drawings at the bottom of page 9-6 and below for Dimensions A, B and C.
- All extensions include integrally forged couplings, machine bolts and hex nuts
- All helical plates are welded to the shaft in conformance to the American Welding Society (AWS) Structural Welding Code AWS D1.1" and applicable revisions.
- Available Finish: Hot Dip Galvanized (HDG)



RETENTION WALL SYSTEM

PRELIMINARY DESIGN CONSIDERATIONS

The following requirements must be considered:

1. An evaluation of: (a) the foundation soil strata (below the reinforced soil mass), (b) the soil stratum into which the helix plates will be located, and (c) the soil behind the reinforced soil mass to be retained by the SOIL SCREW® Retention Wall System.
2. A selection of the appropriate Helical SOIL SCREW® Anchor including shaft size, helix plate diameter and length of embedment.
3. A determination of the ultimate tension capacity of the Helical SOIL SCREW® Anchors with a suitable Factor of Safety.

The following preliminary design guide for Helical SOIL SCREW® Anchors is intended to provide a basic understanding of SOIL SCREW® Retaining Wall theory.

SOIL SCREW® Anchor wall design requires professional geotechnical and engineering input. Specific information involving the structures, soil characteristics and foundation conditions must be used for the final design.

PRELIMINARY DESIGN RECOMMENDATIONS

- The top of the Helical SOIL SCREW® Anchor wall typically moves in the range of 0.1% to 0.3% of the wall height. Vertical and lateral movements are expected to be approximately 1/4" for a ten-foot cut and 1/2" for a 20-foot cut. This lateral movement is of concern when there is a structure located at the top of the proposed cut. It is therefore required that either ATLAS RESISTANCE® Piers or CHANCE® Helical Piles underpin the existing structure. It is recommended to use CHANCE® Helical Tieback Anchors at each underpinning placement location whenever the cut exceeds 12 feet and/or the existing structural line load is greater than 4,000 lb/ft.
- Surcharge loads due to slabs, column footings, overburden soils, vehicular traffic, or other structures behind the wall must be considered when calculating the soil loads to be retained by the Helical SOIL SCREW® Anchors.
- The CHANCE® SOIL SCREW® Retention Wall System is best suited to cemented or medium-dense to dense sand and to low plasticity clay soils with Standard Penetration Test (SPT) N values ≥ 8 . Use caution in highly plastic clays and silts.
- The CHANCE® SOIL SCREW® Retention Wall System is poorly suited for jointed weathered rock material that dips into the excavation, loose sand with SPT N values ≤ 7 and in those cohesive soils with SPT N values of ≤ 6 (clays with cohesion < 850 psf or an allowable bearing stress $< 2,000$ psf) anywhere in the depth profile of soil that is to be excavated.
- Clean to relatively clean cohesionless soils with poor stand-up time typically require a 1" (\pm) flash shotcrete coating to be placed simultaneously with the excavation. The maximum recommended incremental face cut height is four feet or less. Use CHANCE® Helical Tieback Anchors when underpinning/shoring next to an existing structure.
- Use of the underpinning/shoring system is permissible for excavations of up to 20 feet and under extremely favorable conditions shall not exceed 25 feet.
- The underpinning/shoring system is a temporary support system. Creep is generally not a problem, however, the system is not recommended when the Liquidity Index (LI) is >0.2 .
- SOIL SCREW® Anchors must have helix plates of the same diameter continuously along the installed length.
- SOIL SCREW® Anchors must be installed at a minimum downward angle of 5° from horizontal and typically do not exceed 15° downward angle.
- Engineering design shall include verification of several levels of design analysis:
 - Internal stability: The soil mass acts as a coherent mass
 - External stability: The ability to resist lateral sliding
 - Global stability: The ability to resist massive rotational failure outside the "internally stabilized soil" mass

RETENTION WALL SYSTEM

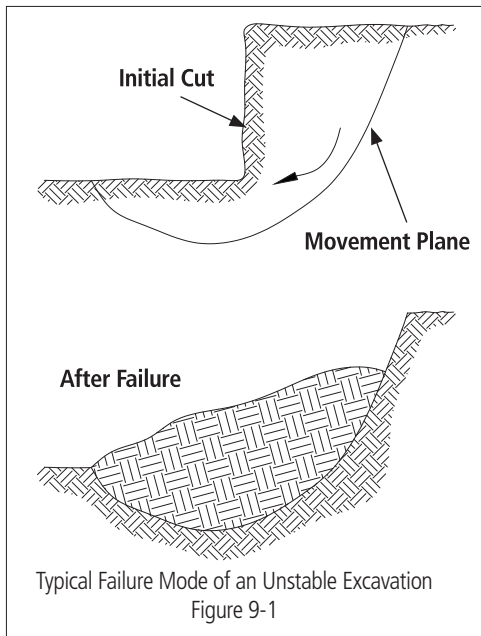


Figure 9-1

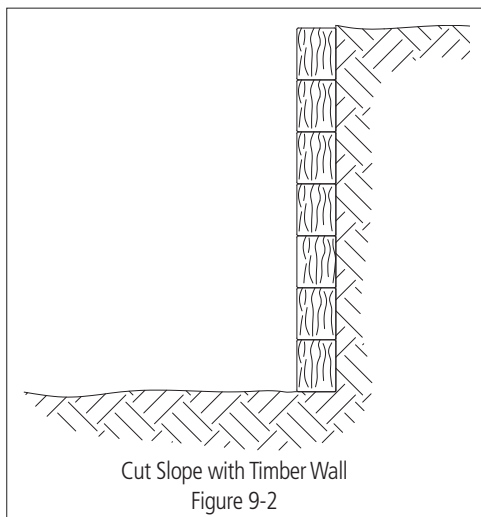


Figure 9-2

IMPORTANT NOTICE

A Registered Professional Engineer shall design the CHANCE SOIL SCREW® Retention Wall System. The installation shall be performed by trained and certified installing contractors/dealers.

GEOTECHNICAL and STRUCTURAL ENGINEERING

For an introduction and guidance on how to design retention walls using the CHANCE SOIL SCREW® Retention Wall System, refer to the SOIL SCREW® Retention Wall System Design Manual. For a copy of this manual, please contact your area CHANCE® Distributor or visit the Hubbell Power Systems, Inc. website at www.abchance.com.

Design Example 10 in Section 8 provides a detailed wall design using the CHANCE SOIL SCREW® Retention Wall System.

CHANCE Helical SOIL SCREW® Anchors look similar to helical tieback anchors, but they are different and they act differently to stabilize a slope. To understand how Helical SOIL SCREW® Anchors act and the differences between the two products, we must examine a cut slope that is unable to stand for an extended time on its own (see Figure 9-1).

A simple method to improve stability of the slope would be to stack railroad ties against the cut face so that the soil would have to push the ties over in the process of failing (see Figure 9-2). If this proves insufficient, driving "soldier" piles in front of the railroad ties (now termed "lagging") enhances the stability. Now the soil must push the lagging and the soldier piles over before failure can occur (see Figure 9-3).

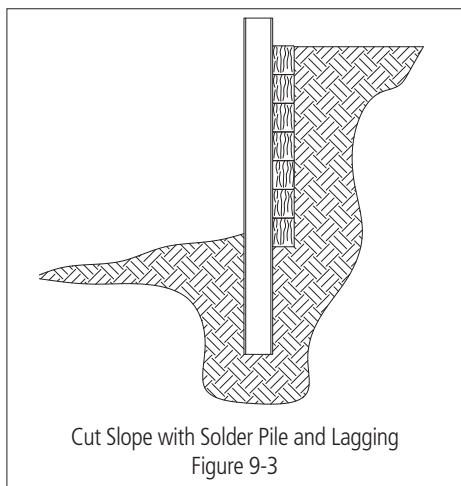
If this is still insufficient to stabilize the soil, a beam can be installed along the wall connecting the soldier piles. This beam is called a "waler" and it is anchored by helical tieback anchors to a stable portion of the soil mass behind the failure plane (see Figure 9-4). Now as the slope attempts to fail, the sliding soil pushes against the lagging, the lagging pushes against the soldier piles, the soldier piles push against the waler, and the waler pulls on the tiebacks. If the helical tieback anchors provide enough resistance, the whole system is stable. The design of the wall system (the lagging, soldier piles and the waler) brings the distributed soil force against the lagging toward, and concentrates the load at, the helical tieback anchors. After the tiebacks are installed, they are usually post-tensioned. When helical tiebacks are used

for this type of application, they are typically concentrated in a few tiers, and are designed so that all tension resistance is attained within the stable soil mass behind the potential movement plane.

Helical SOIL SCREW® Anchors differ from helical tieback anchors because they are designed to attain pullout resistance within the sliding soil mass as well as the stable mass behind the movement plane. For Helical SOIL SCREW® Anchors to be effective, they must have helices along the whole length of the shaft. When the unstable soil mass begins to slide, it moves against the helices buried within this unstable mass (see Figure 9-5). The resistance generated on the helices within the unstable mass secures the soil directly and reduces the resulting soil pressure against the wall. The net effect is that Helical SOIL SCREW® Anchors reduce the structural requirements for the wall system. In most cases the Helical SOIL SCREW® Anchors are connected directly to the wall without the use of soldier piles or walers. The retaining wall is therefore thinner than a wall required when using tieback anchors.

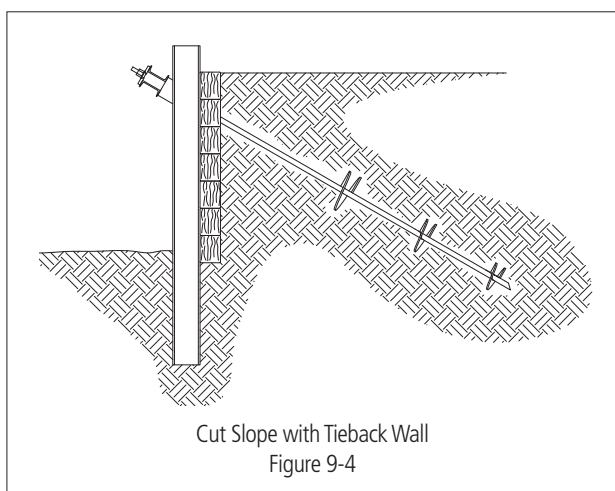
Helical SOIL SCREW® Anchors are more evenly distributed on the wall and therefore carry lighter loads than helical tieback anchors. Helical SOIL SCREW® Anchors should not be post-tensioned as post-tensioning puts bearing stresses on the wrong side of the helices that are embedded in the unstable soil mass. Some engineers require that a small load (1000 pounds or less) be applied to newly installed Helical SOIL SCREW® Anchors to remove any slack in the connections.

RETENTION WALL SYSTEM



Cut Slope with Solder Pile and Lagging
Figure 9-3

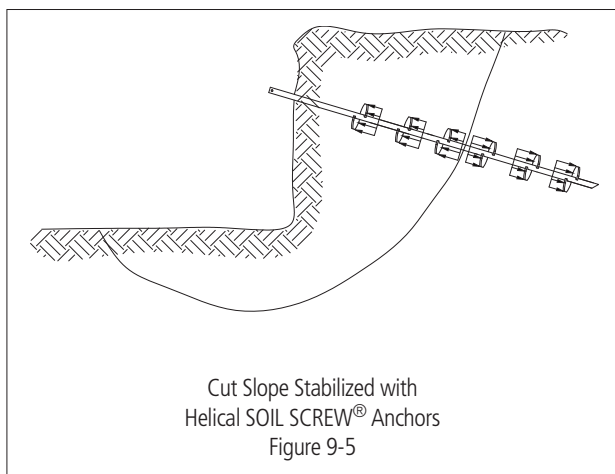
Because Helical SOIL SCREW® Anchors are not post-tensioned, the unstable soil mass has to slump slightly before the SOIL SCREW® System can develop resistance. SOIL SCREW® Retaining Walls deflect both vertically downward and laterally outward during this slumping process. The magnitudes of both deflections typically vary from 0.1% to 0.3% of the wall height (see Figure 9-6). For example, the top of a 12-foot high wall will typically deflect from 1/8" to 3/8" downward and outward. Because 3/8" settlement approaches the level that can cause damage in some structures, the Hubbell Power Systems, Inc. Underpinning/Shoring System includes helical tieback anchors at the underpinning bracket whenever excavation depths exceed 12 feet or structural footing loads exceed 4,000 lb/ft. Post-tensioning these tieback anchors prior to excavation allows the deflections at the footing to be controlled to an acceptable level.



Cut Slope with Tieback Wall
Figure 9-4

Because of the potential severity of a structural failure involving one of these systems, Hubbell Power Systems, Inc. recommends that a staff application

engineer, or an engineer from an authorized CHANCE® Distributor perform a preliminary design and make a final wall design review. The preliminary design will give recommendations for the Helical SOIL SCREW® Anchors and, if the project requires, specific underpinning piers/piles and/or helical tieback anchors to be used on the specific project. Details for the placement of the products, the required embedment depths and minimum installation resistances and torques will be recommended. These preliminary recommendations, estimates of installation depths and wall thickness will aid in preparing cost estimates. Both the installing contractor/dealer and the Engineer of Record shall review these recommendations. The CHANCE® Distributor or Hubbell Power Systems, Inc. Engineer will work with the Engineer of Record as required to resolve any issues regarding the preliminary design. The Engineer of Record must accept and approve the final design before construction can begin.



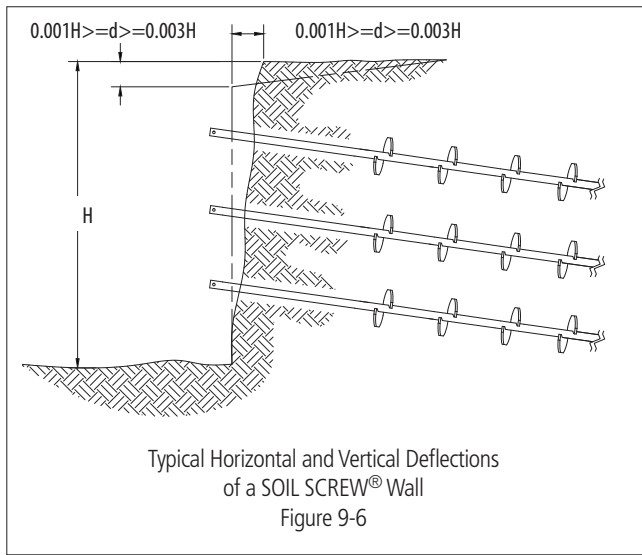
Cut Slope Stabilized with
Helical SOIL SCREW® Anchors
Figure 9-5

Shotcrete

Shotcrete is portland cement concrete or mortar propelled at high velocity (typically by air pressure) onto a surface. With wet process shotcrete, the dry materials are mixed with water and pumped to a nozzle, where air is added to project the material onto the surface. Dry process shotcrete, also known as "gunite", delivers the dry material to the nozzle by air pressure where water is added at the point of discharge. The water and dry materials mix during deposition. Each process has its own advantages and disadvantages, but either, or both, may be used to construct the wall facing for the CHANCE SOIL SCREW® Retention Wall System.

The wet process allows for high deposition rates up to three times the rate attainable with gunite with less rebound (5% vs. 15% for gunite). In addition, the nozzleman need not be as

highly skilled for this process. The major disadvantages to the shotcrete wet process are the extensive cleanup required and the difficulty scheduling ready-mix deliveries. The gunite (dry) process has the advantage of easy clean up and the ability to mix materials on site. Gunite has more disadvantages than shotcrete. Gunite has a relatively low deposition rate (slower application), has more rebound and requires highly skilled operators.



The functions of shotcrete in the CHANCE SOIL SCREW® Retention Wall System are:

- To prevent sloughing and spalling of the excavated soil face.
- To prevent buckling of the underpinning pier/pile, if required on the project.
- To transfer the earth pressures to the Helical SOIL SCREW® Anchors instead of the inner wall face.

In some instances, the system is exposed only temporarily. The excavation is usually filled in after the basement wall is constructed or permanent facing is built in front of the system's wall. In some cases, however, the system wall will be permanently exposed and must also perform cosmetic functions.

Flexural strength, shear strength and ductility are the important characteristics of the wall in this application. The wall must resist the movement of the retained soil and restrain the underpinning pier/pile (if used on the project) from buck-

ling, both of which require flexural strength. The wall must also transfer load to the SOIL SCREW® Anchor head, which requires both shear and flexural strength. Because deformation is necessary to generate the resistance that makes the system stable, the wall must tolerate some deformation without losing its strength. The properties of the shotcrete that contribute to these wall characteristics are compressive strength and bond strength.

A structural engineer employed by the owner will typically prepare the final shotcrete wall design. Hubbell Power Systems, Inc. suggests that the wall design be reviewed by one of their staff application engineers or authorized Distributors.

LIMITING LOAD CAPACITIES

Ultimate Tension Strength

The ultimate tension strengths indicated in Table 9-1 represent the net tension strengths of the Helical SOIL SCREW® Anchor shaft/coupling systems. The designer must use an adequate Factor of Safety in the design to preclude Helical SOIL SCREW® Anchor failure in tension. A Factor of Safety of 2:1 is often used.

Torque Strength Rating

The torque ratings indicated in Table 9-1 represent the maximum torque that should be applied to the Helical SOIL SCREW® Anchor during installation in homogeneous soils. The risk of torsional fracture increases significantly as the applied torque increases beyond these limits. In obstruction-laden soils, the maximum torques that should be applied during installation are 80% of the table limits due to the increased risk of torsional fracture posed by impact loading. The designer must consider these torque ratings in evaluating whether the Helical SOIL SCREW® Anchors can be installed to the required depths. In addition, these torque ratings pose practical limits to the ultimate tension capacities that can be developed by limiting the strengths of soils into which the Helical SOIL SCREW® Anchors can be installed. The practical limit to the ultimate tension capacities that can be achieved (in lbs) is about ten times the installation torques (in ft-lbs) that may be applied during installation using a torque factor (K_t) of 10. See Section 6 for a detailed discussion of the correlation of installation torque of a helical anchor to its ultimate tension capacity.

Ultimate Tension Strengths and Torque Ratings for CHANCE® Helical SOIL SCREW® Anchors, Table 9-1

CHANCE® SOIL SCREW® PRODUCT	ULTIMATE TENSION STRENGTH	TORQUE RATING
SS5 Series 1-1/2" (38 mm) Round Corner Sq	70,000 lbs	5,700 ft-lbs*
SS175 Series 1-3/4" (45 mm) Round Corner Sq	100,000 lbs	10,500 ft-lbs*

*Refer to Ultimate Tension Strength and Torque Rating in the text. Practical load limits in the field may be limited due to the factors discussed in the above paragraph.

RETENTION WALL SYSTEM

GENERAL CONSTRUCTION CONSIDERATIONS of UNDERPINNING/SHORING SYSTEMS

The CHANCE SOIL SCREW® Retention Wall System for underpinning/shoring next to an existing structure is a specialized construction process and must be installed by Certified CHANCE® Installer. Listed below are some general items regarding the construction procedures:

WARNING! DURING THE COURSE OF CONSTRUCTION, THE FOOTING AND FACE OF THE SHORING SHOULD BE CONTINUOUSLY MONITORED FOR ANY MOVEMENTS. IF MOVEMENTS ARE NOTED, THE CONSTRUCTION PROCESS SHOULD BE STOPPED, TEMPORARY BRACING INSTALLED AND THE ENGINEER AND/OR GEOTECHNICAL ENGINEER SHOULD BE IMMEDIATELY NOTIFIED FOR FURTHER DIRECTION.

1. As is the case in conventional underpinning of buildings using ATLAS RESISTANCE® Modified Piers or CHANCE® Helical Piles, the footing must be properly prepared so that the pier/pile bracket can be positioned under the footing with a minimum of eccentricity with the wall load. This process may involve chipping the concrete to provide a proper bearing surface and creating a notch in the spread footing to reduce pier/pile eccentricity.
2. For those projects requiring underpinning and CHANCE® Helical Tieback Anchors at the pier/pile bracket, the tieback must be installed to the required length and torque prior to installing the underpinning system.
3. If ATLAS RESISTANCE® Modified Piers are used as the underpinning system, the process requires the use of pier sleeving to prevent buckling at the joints of the pier pipe. Every sleeve joint must be at least 18" away from a pier pipe joint. In some cases grouting of the pier pipe along with the insertion of a steel reinforcement bar may be specified.
4. The pier sleeving must be installed to a minimum of 2 feet below the deepest excavation (cut).
5. If using ATLAS RESISTANCE® Modified Piers, the piers shall be driven to the required depth and load tested to 150% of the design load. Then each pier shall be preloaded to at least 95% of the design load and locked off. If using CHANCE® Helical Piles as the underpinning system, the helical piles shall be installed to the required minimum depths and minimum average installation torques.
6. When the ATLAS RESISTANCE® Pier or CHANCE® Helical Pile underpinning system installation is complete, the helical tieback anchor shall be attached to the pier/pile bracket and preloaded. Normally the tieback is preloaded to the design load.
7. Upon completion of all of the underpinning and tieback operations, the wall face excavation can commence. If the soils are generally cohesionless (sands, etc.) or there is any danger of the soil face sloughing off, a 1" thick flash coat of shotcrete shall be immediately placed against the face of the cut as the excavation proceeds. If the cut soil is capable of standing by itself, then the first layer of shotcrete can be applied after the initial cut is complete. The same procedure shall be followed for subsequent incremental excavations. Under no circumstances should a cut of any height be left open at the face for more than two hours.
8. The depth of cut on the first excavation, as well as on subsequent incremental excavations shall be at least one foot deeper than the depth of the row of Helical SOIL SCREW® Anchors. See Figure 9-13, which shows a 6-foot cut and 5-foot deep row of Helical SOIL SCREW® Anchors.
9. When the first excavation is complete (with or without shotcrete flash coating), the first row of CHANCE® Helical SOIL SCREW® Anchors is installed to the requirements indicated in the design specifications (length of installation, minimum torque, installation angle, etc.). A Helical SOIL SCREW® Anchor shall be positioned immediately adjacent to each underpinning pier/pile. Shotcrete is placed onto the cut face to 1/2 of the total specified shotcrete thickness.
10. The welded wire mesh reinforcement is set against the face of the wet shotcrete along the cut face of the wall with excess reinforcement turned outward at the bottom of the cut to allow for overlap of reinforcement on successive stages.
11. Welded rebar assemblies with bearing plates are positioned over each Helical SOIL SCREW® Anchor and secured against the welded wire mesh reinforcement and (still) wet shotcrete face.
12. The remaining shotcrete is installed to provide the total thickness specified.
13. Steps 7 through 12 above are repeated after each incremental excavation. Stabilization continues until all of the Helical SOIL SCREW® Anchors are installed and the reinforced shotcrete wall is completed to the design depth.

RETENTION WALL SYSTEM

CONCEPTS and APPLICATIONS of UNDERPINNING/SHORING SYSTEMS

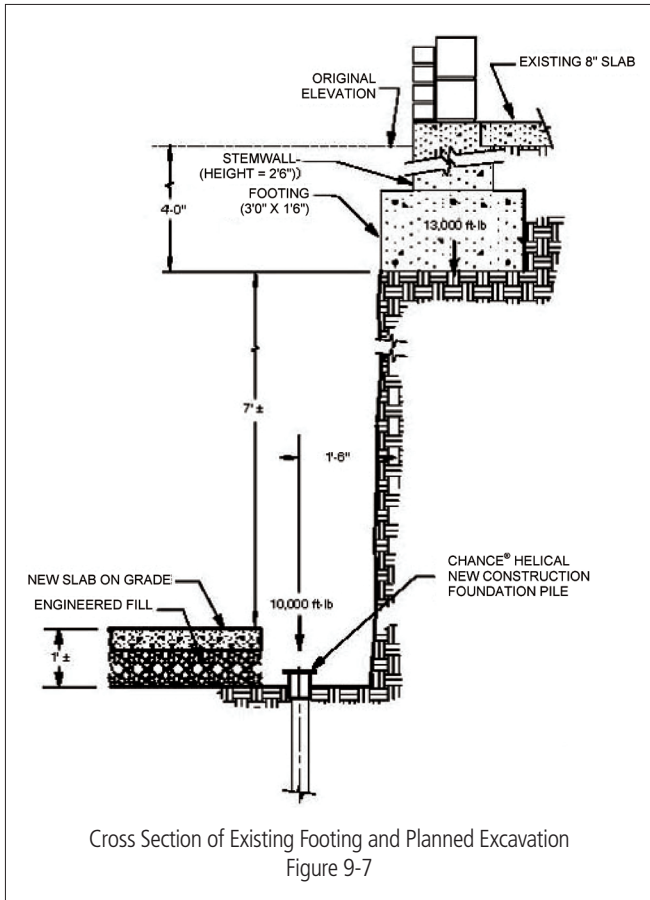
BACKGROUND

The construction of additions to office and commercial buildings or new construction adjacent to existing buildings requires earth excavation much deeper than the footing elevation of the immediately adjacent building(s). The use of sheet pile and/or H-piles with wood lagging to prevent adjacent footing subsidence requires the use of dynamic pile driving equipment with the attendant vibrations and noise levels. There are decided disadvantages to these traditional approaches since the vibrations may cause movement of the existing building foundation and subsequent structural damage. Additionally, the vibration levels can often lead to a shutdown of business operations if conducted during normal working hours.

Hubbell Power Systems, Inc. offers an underpinning/shoring system that not only avoids the vibrations and noise level issues, but also permits the shoring and excavation to proceed at a more rapid pace. In many cases this results in an overall cost savings to the prime contractor and owner. The examples covered below are intended to illustrate some of the design concepts and applications of this system.

In conducting preliminary designs for projects using the underpinning/shoring system and in the development of the case studies that follow, Hubbell Power Systems, Inc. uses certain guidelines. These guidelines are briefly summarized below:

1. Hubbell Power Systems, Inc. does not currently recommend using the underpinning/shoring system for excavations exceeding 25 feet.
2. Although ATLAS RESISTANCE® Piers or CHANCE® Helical Foundation Piles can be used for the underpinning stage; it is preferred to use the ATLAS RESISTANCE® Pier if "hard stratum" is within a reasonable depth at the proposed construction site.
3. The ATLAS RESISTANCE® Piers used for underpinning the existing building foundation must be sleeved with the joints of the sleeves offset from the joints of the underpinning pier pipe.
4. It is recommended in cases where the line load equals or exceeds 4,000 pounds per lineal foot and/or the depth of cut exceeds 12 feet to use a CHANCE® Helical Tieback integrated at the pier bracket level. This requirement uses the pier and tieback combination as illustrated in Figure 9-11. This helical product is used as a tieback anchor and not a SOIL SCREW® Anchor.
5. Helical SOIL SCREW® Anchors must be installed at a minimum downward angle of 5° and generally not to exceed 15°.
6. All Helical SOIL SCREW® Anchors have the same size helix plates continuously along the installed length of the shaft.
7. The bottom cantilever of shotcrete wall should be limited to 2/3 of the typical spacing for the Helical SOIL SCREW® Anchor row, but should not exceed 3 feet.
8. If the foundation soils to be excavated contain cohesionless soils (sands, silts and gravels and gravel and silty sands) a "flash coat" of shotcrete should be applied immediately as the cut is made.
9. CHANCE® Installers must receive formal training in the "concept" and "field installation technique" prior to using the underpinning/shoring system on an actual project.



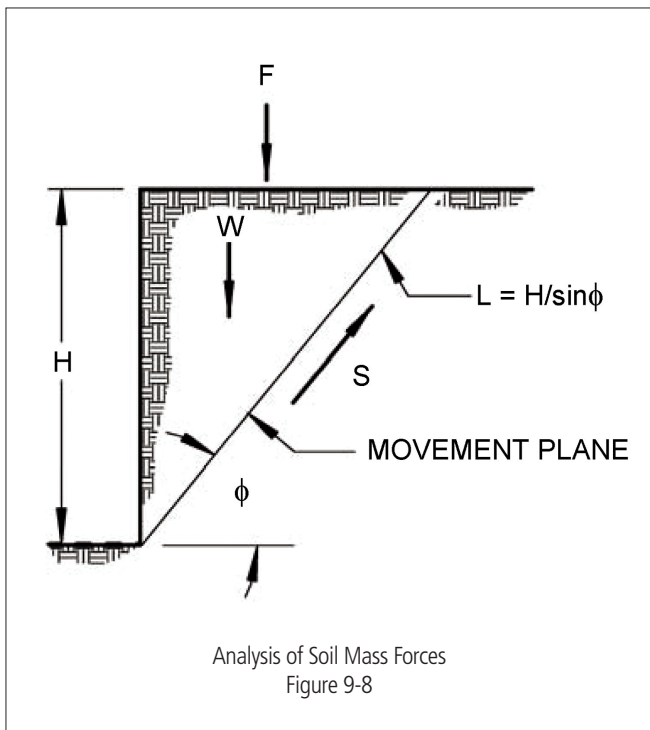
Cross Section of Existing Footing and Planned Excavation
Figure 9-7

NOTE: The designs and data shown in the following examples are not intended for use in actual design situations. Each project and application is different as to soils, structure and related factors.

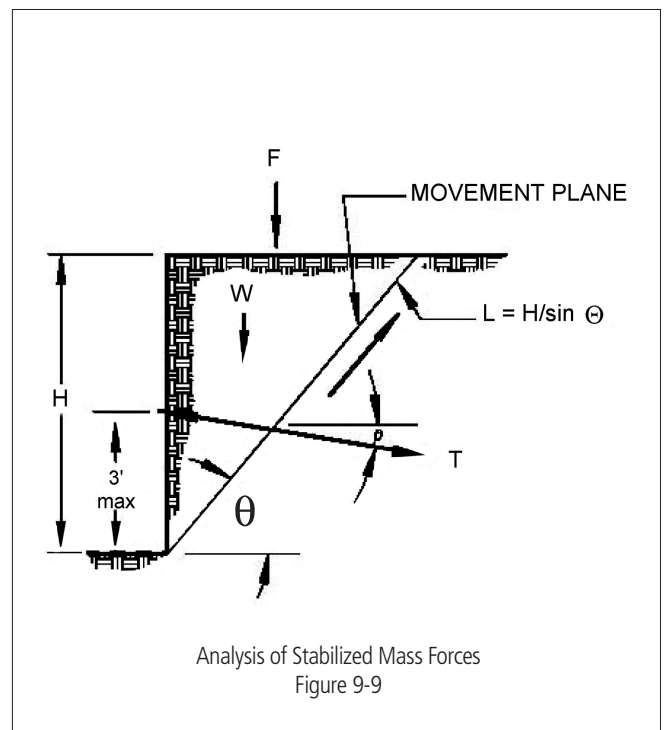
CASE STUDY 1 - HIGH FOUNDATION LINE LOAD with SHALLOW CUT

Northern Excellence University is planning to construct an addition to the existing Book Science Building. The existing building has a continuous perimeter footing as shown in Figure 9-7. The building is a 3-story structure and has a foundation line load of 13,000 pounds per lineal foot. This reinforced concrete footing is seated about 4 feet below the existing ground line as noted in Figure 9-7. There are no column footings at the exterior wall of the existing building immediately adjacent to the proposed addition.

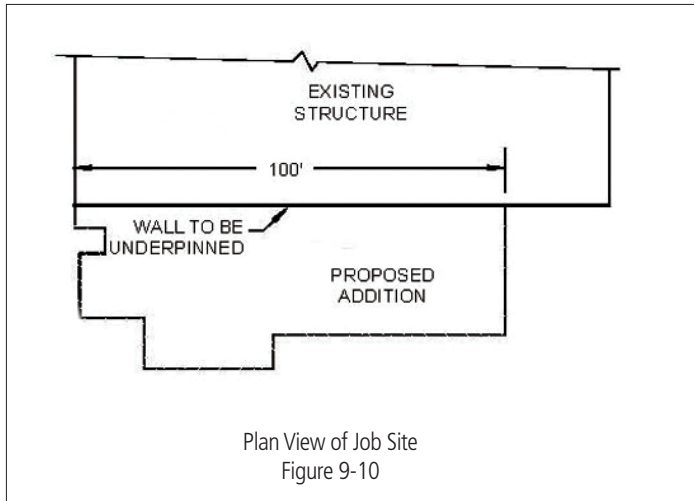
The proposed building addition will be placed immediately adjacent to a 100-foot section of one wall of the existing building as shown in Figure 9-10. The foundation for the new building will also be a reinforced concrete continuous footing, but it will be set eight feet below the bottom of the existing building footing as shown in Figure 9-7. The estimated footing load for the new addition is 10,000 pounds per lineal foot. As noted in Figure 9-7, a surcharge load will exist arising from the Live Load on the floor slab (100 lb/ft²), the weight of the concrete slab and the overburden pressure from approximately 3-1/2 feet of soil cover over the top of the existing footing.



Analysis of Soil Mass Forces
Figure 9-8



Analysis of Stabilized Mass Forces
Figure 9-9



A geotechnical investigation was conducted at the site and the results showed that below the first foot of topsoil, a stratum of silty to sandy clay existed to a depth of 18 feet. The Standard Penetration Test (SPT) blow count, "N" for this soil was consistently in the 9 to 10 range through the 18 feet. Both by correlation with the "N" values and from the results of hand held penetrometer tests on the soil, this silty to sandy clay was determined to have a cohesion, "c" of 1,000 pounds per square foot and a friction angle, "φ" of 10°. Below the 18 feet of silty to sandy clay a stratum of weathered sandstone was encountered to the bottom of the borings at 20 feet at which the driller experienced auger refusal. No ground water was encountered during the soil borings.

Underpinning System - ATLAS RESISTANCE® Modified Piers

As noted above, a stratum of sandstone exists at the site beginning at a depth of 18 feet. Auger refusal was experienced at a depth of 20 feet. Allowing for four feet from the ground elevation of the boring log to the bottom of the footing to be underpinned indicates that the length of the underpinning pier pipe will be 16 feet. The existing footing line load is:

$$p = 13,000 \text{ lb/ft} \quad \text{Equation 9-1}$$

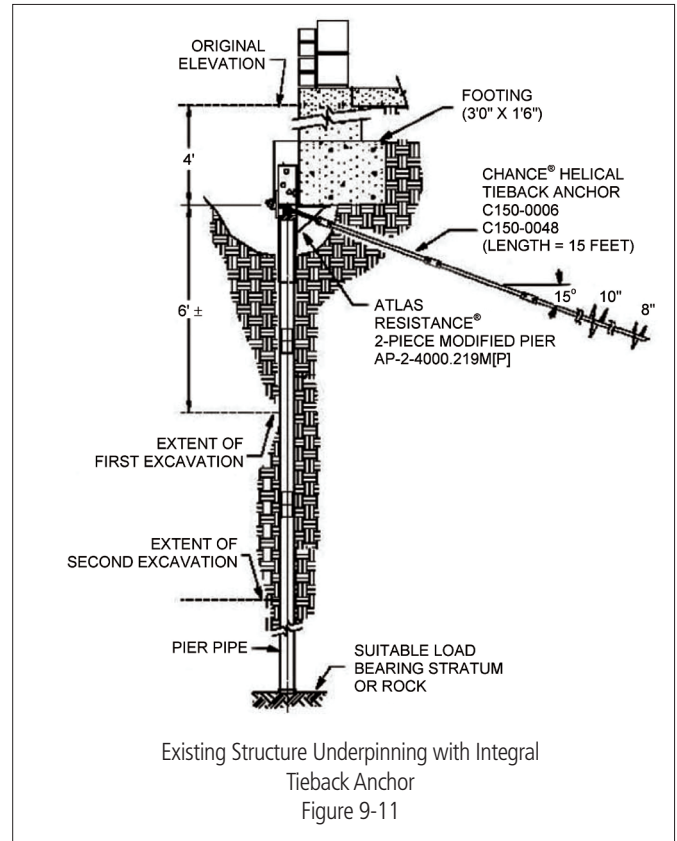
If we assume a pier spacing of 4 ft, center to center, the load per pier becomes:

$$P_{des} = 13,000 \text{ lb (4 ft)} = 52,000 \text{ lbs} \quad \text{Equation 9-2}$$

Based on a requirement of installing an ATLAS RESISTANCE® Pier to a tested load resistance of at least 50% higher than the design load leads to:

$$DS = 52,000 (1.5) = 78,000 \text{ lbs} \quad \text{Equation 9-3}$$

An ATLAS RESISTANCE® 2-Piece Modified Pier part number AP-2-4000.219[M] is selected. This pier is designed with a 4" diameter pier pipe and has an ultimate capacity of 98,000 lbs. The "M" indicates the use of 4-1/2" diameter sleeving over the pier pipe. The sleeved portion of the pier shall extend down to a depth of 10'-6" (three lengths of sleeve pipe). Since this is temporary construction, corrosion protection is unnecessary. Details of the underpinning and tieback anchorage are shown in Figure 9-11.



RETENTION WALL SYSTEM

INTEGRATED TIEBACK SYSTEM - CHANCE® Helical Tieback Anchors

Following the recommendation of using an integrated tieback whenever the line load exceeds 4,000 lbs/ft, a CHANCE® Helical Tieback Anchor must be selected for used with each ATLAS RESISTANCE® 2-Piece Modified Pier placement. For this situation, the C1500006 Tieback Anchor Lead Section and C1500048 Tieback Extension with coupling and hardware is recommended.

The installed length is estimated to be 15 feet. The installed angle is 15° down from horizontal. The lead section consists of one 8-inch and one 10-inch diameter plate welded to a 1-1/2" square solid steel shaft. Installed torque is estimated to be 2,000 ft-lbs, minimum. No corrosion protection is required because the construction is temporary.

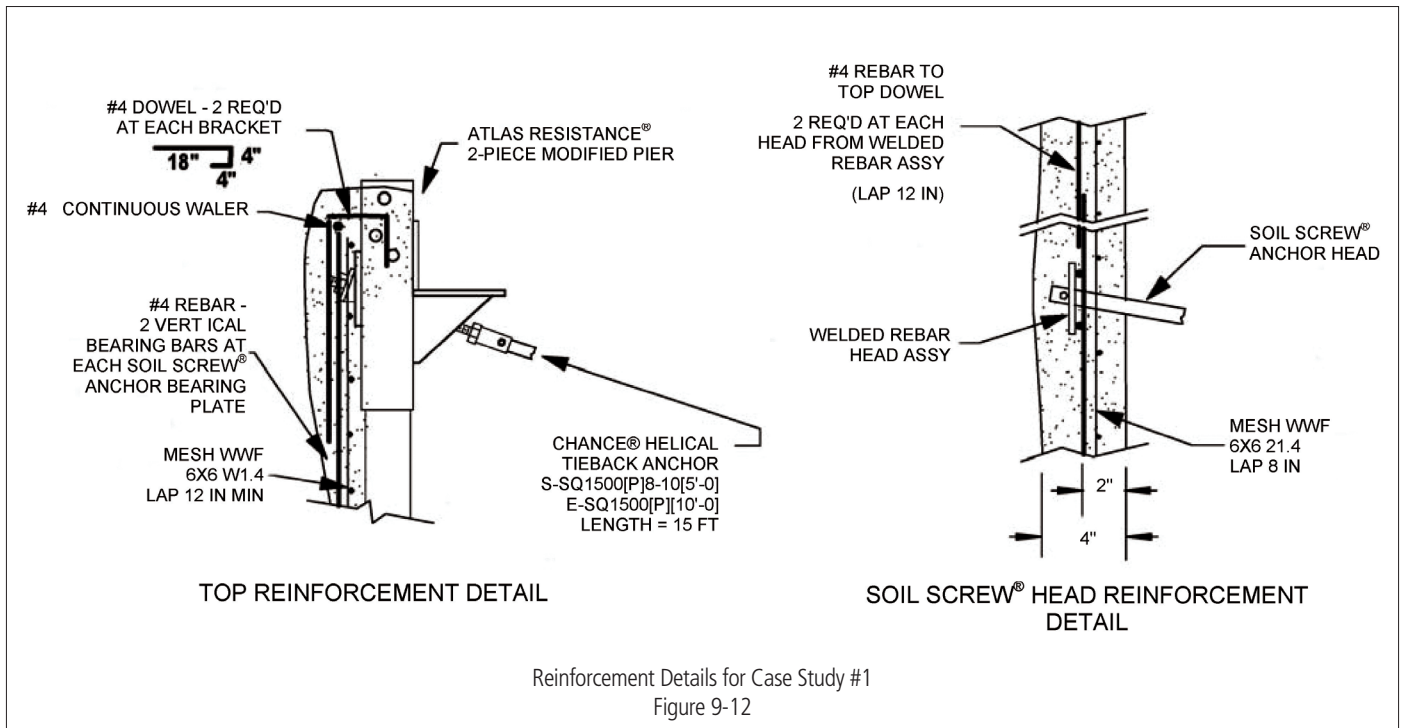
SOIL SCREW® RETENTION WALL SYSTEM

The body mass of soil that would slide along the movement plane if failure were to occur as excavation takes place is illustrated in Figure 9-8. If one uses the soil properties previously listed with an assumed failure plane angle (θ) of 51°, the driving force and resisting force may be calculated. In order to provide a Factor of Safety against failure of the body mass, a single line of CHANCE® Helical SOIL SCREW® Anchors will be used. A minimum Factor of Safety of 2.0 is required against such a failure. (Note that the typical design Factor of Safety for Helical SOIL SCREW® Anchors ranges from 1.3 to 2.0.) A Factor of Safety of 2.0 was selected because of the very high foundation line load of the existing footing above the excavation. In conducting the SOIL SCREW® Anchor analysis, it assumed that the CHANCE® Helical tieback anchors did not contribute to the holding capacity of the body mass of soil even though the tieback prevents cantilever at the top of the wall.

Also shown in Figure 9-8 is the resistance to movements that occur along the movement plane arising from the shear strength of the soil. This shear strength is made up of both the cohesion and friction acting along that plane.

In Figure 9-9 the same body mass of soil is shown, but now the single Helical SOIL SCREW® Anchor shown provides additional resistance to sliding that develops along the movement plane. If the installation angle of the Helical SOIL SCREW® Anchor is 10°, the new driving force and new resisting force may be calculated.

RETENTION WALL SYSTEM

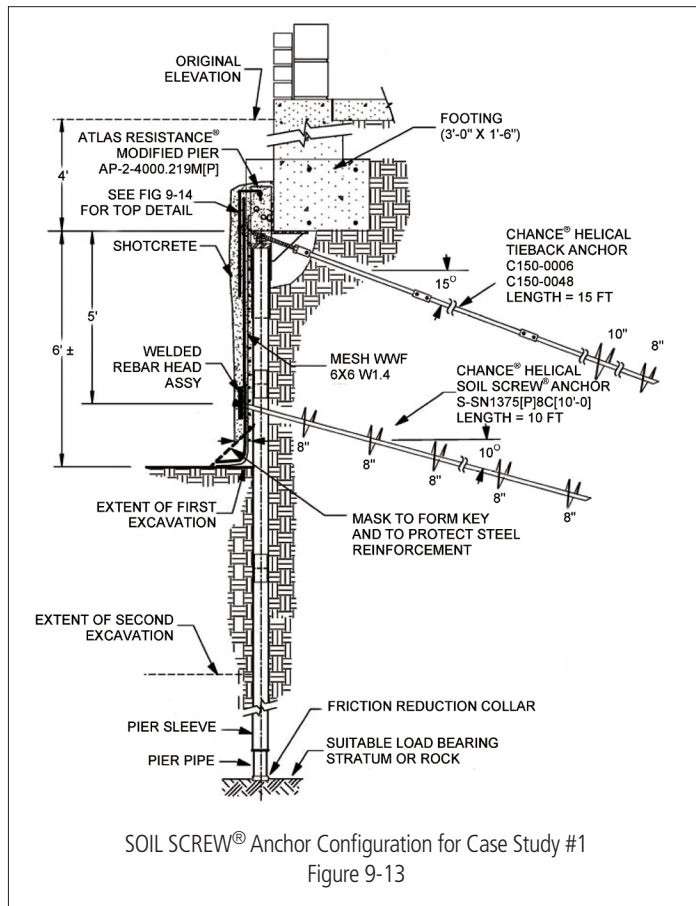


Generally, the Factor of Safety is illustrated by the following equation:

$$FS = RF / (DF - SSCF) \quad \text{Equation 9-4}$$

where

- FS = Factor of Safety
- RF = Resisting force
- DF = Driving force
- SSCF = SOIL SCREW® Anchor component force



Resisting Force (RF) arises from the shear strength of the soil (c and ϕ) along the movement plane and the Helical SOIL SCREW® Anchor component parallel to the movement plane. Driving Force (DF) is the component of the soil body mass (weight) in the direction of the movement plane. Helical SOIL SCREW® Anchor Component Force (SSCF) is the component of the total Helical SOIL SCREW® Anchor holding capacity (ultimate capacity) in the direction of the movement plane. Internal stability analysis as described herein is typically done with commercially available software such as SNAILZ (Caltrans) or Gold Nail (Golder Associates); see the CHANCE® Soil Screw® Retention Wall System Design Manual for an example. Helical SOIL SCREW® Anchor tension capacity is calculated with HeliCAP® Helical Capacity Design Software and input into the stability analysis software.

For the specific conditions defined above, the CHANCE® Helical SOIL SCREW® Anchor Lead Section C1100692 and C1100690 Extension is selected. The Helical SOIL SCREW® Anchor lead section consists of 8" diameter plates welded along the entire length of a 1-1/2" square shaft. Minimum installed length is 10 feet. Installed angle is 10° down from horizontal. Installed torque is estimated to be 1,500 ft-lb minimum. The single row of Helical SOIL SCREW® Anchors is set immediately adjacent to each underpinning pier pipe at a depth of 5 feet below the integrated tieback anchor (this will maintain the 3 foot maximum allowable bottom cantilever). No corrosion protection is required.

SHOTCRETE WALL

The shotcrete wall is a temporary facing for the excavation. Since there is a CHANCE® Helical Tieback Anchor at the top, the wall will be laterally anchored at the pier brackets to allow longer spacing for the single row of Helical SOIL SCREW® Anchors. The bottom cantilever should be 3 feet.

The vertical bearing bars are extended from the welded rebar head assembly to the dowels and waler at the top of the wall in order to augment the welded wire fabric reinforcing (see Figures 9-13 and 9-14).

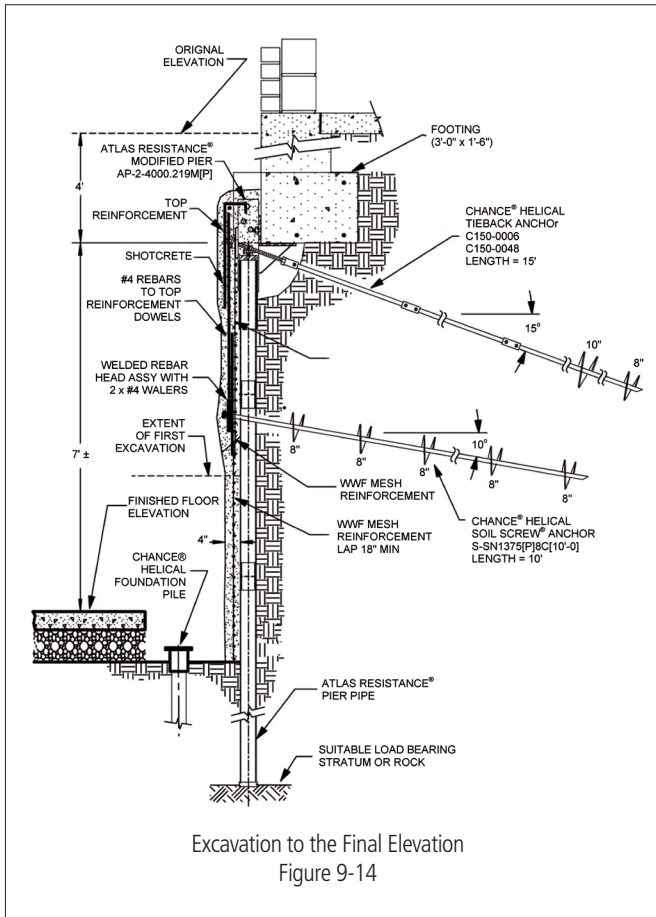
The top wall segment is checked for flexure and shear using the distributed SOIL SCREW® Anchor head forces and one-way beam action. Two #4 reinforcing bar walers shall be placed continuously along the SOIL SCREW® Anchor row. The selected wall thickness is 4". Reinforcing is a welded wire fabric (WWF 6x6 W.14 or equivalent) spaced midway in the shotcrete wall at a 2" nominal depth.

RETENTION WALL SYSTEM

SOIL SCREW® ANCHOR HEAD DESIGN

The shotcrete wall design is critical to the punching shear of the SOIL SCREW® Anchor heads and flexural strength of the all face between the SOIL SCREW® Anchor heads. The SOIL SCREW® Anchor head forces are expected to be approximately 1/2 of the total SOIL SCREW® Anchor tension load. The shotcrete facing is checked for flexure and punching shear using two-way slab action. This information is used in the internal stability analysis. A welded rebar head assembly can be used at each placement to provide local reinforcement. It is spliced to the horizontal walers and the vertical bearing bars previously described. To accomplish the proper positioning of the welded rebar head assembly and rebar, the welded wire fabric must be pushed into the initial 2" face coat of shotcrete approximately 1/2" at each SOIL SCREW® Anchor head. The 4" wall thickness and reinforcement selected above are adequate.

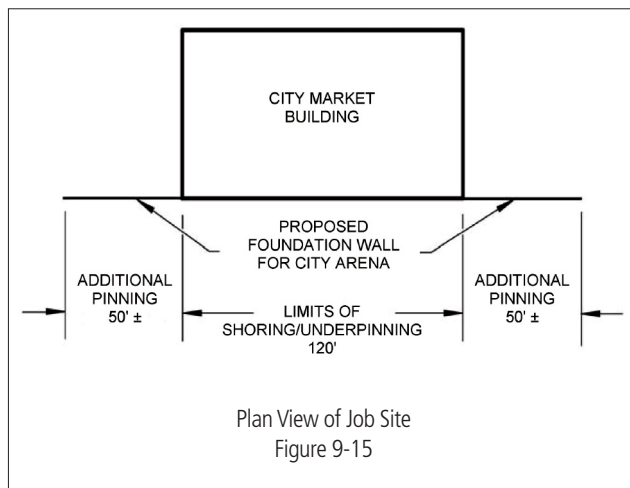
The first 6 feet of soil is excavated and the soil body mass is stabilized. Figure 9-13 shows the installation of a CHANCE® Helical SOIL SCREW® Anchor, welded wire reinforcement, welded rebar head assembly and shotcrete. Note that the shotcrete stops short of the bottom of the excavation to allow for splicing the welded wire reinforcement and a suitable shotcrete joint. Figure 9-14 show excavation to the final elevation along with continued stabilization of the soil mass. Construction of the new foundation begins with the installation of CHANCE® New Construction Helical Piles.



Excavation to the Final Elevation
Figure 9-14

CASE STUDY 2 - LOW FOUNDATION LINE WITH DEEP CUT

The City of High Hope is planning to build a new multi-purpose arena that will seat 8,000 people. The arena will be located within the downtown district. A 20-foot deep cut will be required for the new construction to provide sufficient elevation for the arena seating yet maintain a low ground level building profile. A portion of the arena wall will be immediately adjacent to the existing historic city market building (see Figure 9-15). The city market building is a single story warehouse that measures 60 by 120 feet. The back wall of the market building will abut the new arena wall. The market building was constructed in the early 1900s and has an unreinforced concrete grade beam foundation that measures three feet wide by two feet deep. The grade beam, seated three feet below the existing grade, has a line load of 3,000 lbs per lineal foot. The general configuration of the footing along with installed underpinning and tieback is shown in Figure 9-16.



A geotechnical investigation conducted at the site found a 30-foot thick stratum of silty sand below approximately two feet of topsoil and fill material that consisted of silt, sand and cinders. The Standard Penetration Test (SPT) blow count “N” in this silty sand increased with depth from N=13 to N=18. Sufficient silt is present in the sand to hold a shallow vertical cut for a short period of time. Below the silty sand stratum at a depth of 32 feet the borings encountered a hard glacial till of clayey sand and gravel. The SPT value recorded were N=50+. By correlating the N values, the friction angle of the silty sand (ϕ) was estimated to be 30°. The ground water table (GWT) was located at 15 feet which means dewatering will be required prior to excavation.

Based on discussion with the designer and contractor, a decision was made to use the CHANCE® Helical underpinning/shoring technique in the immediate vicinity of the city market building. The Helical SOIL SCREW® Anchors will continue for an additional 50 feet on each side of the market building as the slope is cut in a benched pattern. Beyond this zone, adequate clear distance exists to back-slope the cut side without providing any wall retaining system.

Underpinning System - ATLAS RESISTANCE® Modified Piers

As noted above, a hard glacial till exists at a depth of 29 feet below the bottom of the market building footing. The estimated length of the underpinning pier pipe is 32 feet. The existing line load is 3,000 lb/ft. Although the footing line load is relatively light, the fact that the 24” thick footing is not reinforced will limit the spacing of the piers to five feet on center. Based on this spacing, the design load per pier becomes:

$$P_{des} = 3,000 \text{ lb (5 ft)} \quad \text{Equation 9-5}$$

$$P_{des} = 15,000 \text{ lbs}$$

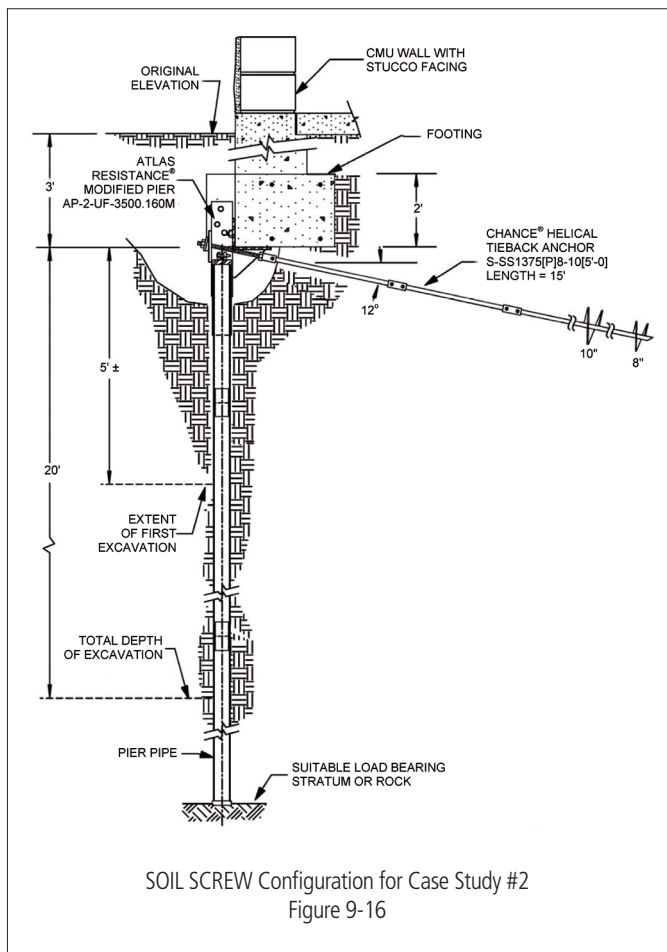
Based on the requirement of installing ATLAS RESISTANCE® Modified Piers to a tested load resistance of at least 50% higher than the design load leads to:

$$DS = 15,000 (1.5) \quad \text{Equation 9-6}$$

$$DS = 22,500 \text{ lbs}$$

For this requirement, the ATLAS RESISTANCE® AP-2-3500.165[PA] M 2-Piece Modified Pier is selected. The modified pier has a 3-1/2” diameter pier pipe and has an ultimate capacity of 91,000 lbs. “M” indicates the use of 4” diameter sleeving over the pier pipe. The sleeved portion of the pier shall extend down to a depth of 21 feet (six lengths of sleeve pipe). “PA” indicates the product is manufactured of mill finish steel (plain) with flow coated corrosion protection of the pier pipe. Since this is temporary construction, the corrosion protection is unnecessary; however this product is supplied with corrosion protected pipe as standard. Details of the underpinning and tieback anchorage are shown in Figure 9-16.

RETENTION WALL SYSTEM



Integrated Tieback System - CHANCE® Helical Tieback Anchors

Although the footing line load is less than the 4,000 lb/ft criteria, the depth of the cut to be shored is 20 feet. This exceeds the recommended 12 foot limitation and as such a CHANCE® Helical Tieback Anchor must be selected for use with each modified pier placement. For this situation Type SS5 1-1/2" square shaft Lead Section and Extension are the recommended components.

The lead section consists of one 8" and one 10" diameter plate welded to a 1-1/2" square shaft. Minimum installed length is estimated to be 15 feet. Installed angle is 12° down from horizontal. Installed torque is estimated to be 1,800 ft-lb minimum. No corrosion protection is required since the construction is temporary.

SOIL SCREW® Shoring System - CHANCE® Helical SOIL SCREW® Anchors

Because the depth of cut is 20 feet from grade (17 feet below the bottom of the footing of the market building), three Helical SOIL SCREW® Anchors are required. In this case a Factor of Safety of 1.5 was used because the existing market building is relatively light. In conducting the soil analysis, it was assumed that the CHANCE® Helical Tieback Anchor does not contribute to the holding capacity of the body mass of soil. As in Case Study 1, internal stability analysis is typically done with commercially available software such as SNAILZ (Caltrans) or GoldNail (Golder Associates), and SOIL SCREW® Anchor tension capacity is calculated with HeliCAP® Helical Capacity Design Software and input

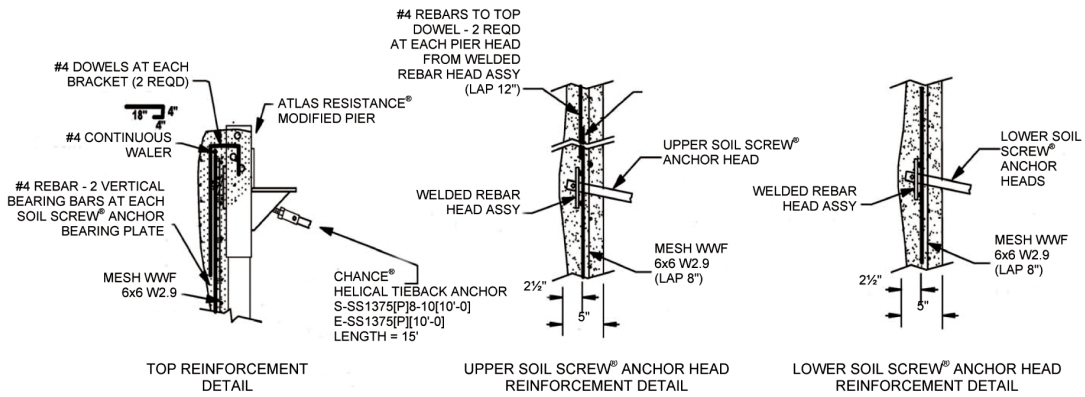
into the stability analysis software. In this project, the shear strength is from the frictional nature of the cohesionless soil (silty sand) and its magnitude is related to the friction angle ($\varphi = 30^\circ$ in this case).

As described in the CHANCE® SOIL SCREW® Retention Wall System Design Manual, SOIL SCREW® Anchors add to the resisting force along the movement plane. In this case, however, the indicated force (T) is the resultant of all three rows of Helical SOIL SCREW® Anchors. Placement of the three rows of Helical SOIL SCREW® Anchors is shown in Figure 9-18. The value for the ultimate holding capacity required (including the Factor of Safety) is:

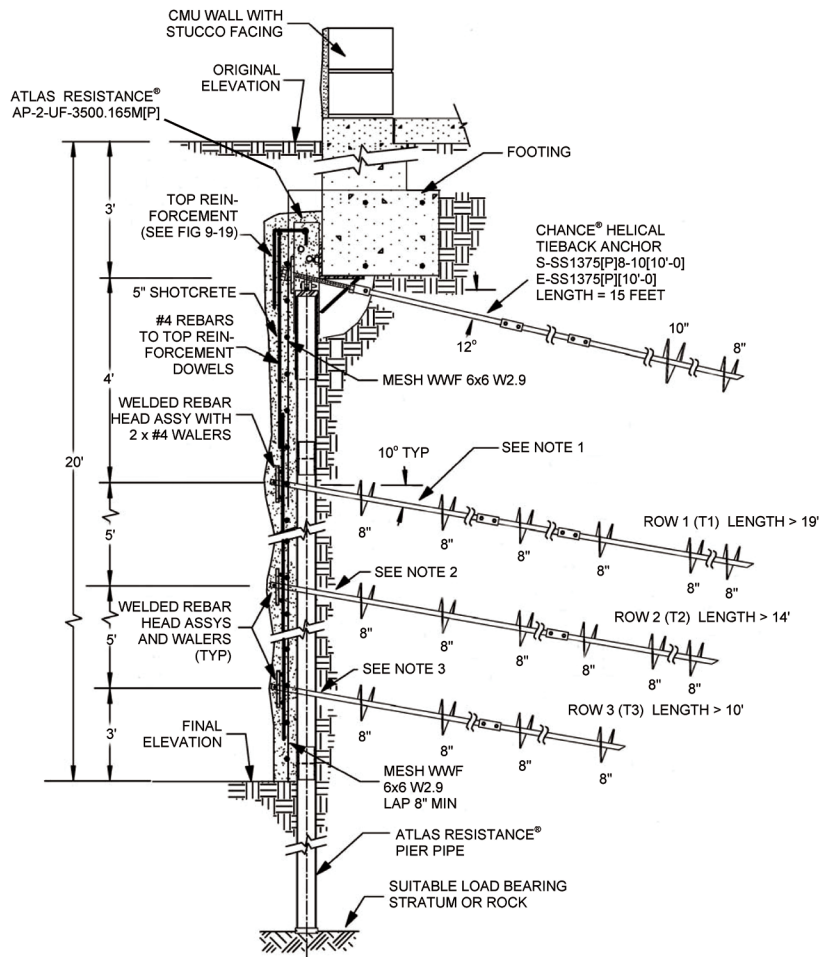
$$T = T_1 + T_2 + T_3 \quad \text{Equation 9-7}$$

The results of extensive testing of soil nail walls indicate that the top row of soil nails or screws is most heavily loaded with the successively lower rows having lesser holding capacity requirements. The following are the recommended CHANCE® Helical SOIL SCREW® Systems for this project:

- SOIL SCREW® Anchor Row #1 (T_1): C2200691 Lead and two C1100689 Extensions. The SOIL SCREW® Anchor has continuously spaced 8" diameter plates along the entire length of a 1-1/2" solid square steel shaft. The SOIL SCREW® Anchor will be installed to a minimum length of 19 feet, 10° down from horizontal and to an estimated torque of 2,500 ft-lbs.
- SOIL SCREW® Anchor Row #2 (T_2): C2200691 Lead and one C1100689 Extension. The SOIL SCREW® Anchor has continuously spaced 8" diameter plates along the entire length of a 1-1/2" solid square steel shaft. The SOIL SCREW® Anchor will be installed to a minimum length of 14 feet, 10° down from horizontal and to an estimated torque of 1,800 ft-lbs.
- SOIL SCREW® Anchor Row #3 (T_3): C1100692 Lead and C1100690 Extension. The SOIL SCREW® Anchor has continuously spaced 8" diameter plates along the entire length of a 1-1/2" solid square steel shaft. The SOIL SCREW® Anchor will be installed to a minimum length of 10 feet, 10° down from horizontal and to an estimated torque of 1,000 ft-lbs.



Reinforcement Details for Case Study #2
Figure 9-17



- NOTE 1: CHANCE® HELICAL SOIL SCREW® - S-SN1375[P]8C[10'-0] - E-SN1375[P]10[10'-0] - LENGTH = 20'
- NOTE 2: CHANCE® HELICAL SOIL SCREW® - S-SN1375[P]8C[10'-0] - E-SN1375[P]6[6'-8] - LENGTH = 16'-8"
- NOTE 3: CHANCE® HELICAL SOIL SCREW® - S-SN1375[P]8C[10'-0] - E-SN1375[P]6[6'-8] - LENGTH = 13'-4"

Excavation and Stabilization
Figure 9-18

RETENTION WALL SYSTEM

Shotcrete Wall

The shotcrete wall is a temporary facing for the excavation. Since the soil analysis assumed that the CHANCE® Helical Tieback Anchors do not contribute to the holding capacity of the body mass of soil (see Figure 9-8), the CHANCE® Helical SOIL SCREW® Anchors were designed to hold the total body mass. The bottom cantilever should be limited to 2/3 of the typical spacing for the SOIL SCREW® Anchor row, but should not exceed 3 feet. In this case the cantilever is 3 feet.

Vertical bearing bars are extended from the welded rebar head assemblies at the upper row of SOIL SCREW® Anchors to the dowels and waler at the top of the wall in order to augment the selected shotcrete wall thickness (5"). Welded wire fabric reinforcing (WWF 6x6 W2.9 or equivalent) is spaced midway within the shotcrete wall at a 2-1/2" nominal depth. The top wall segment is checked for flexure and shear using the distributed SOIL SCREW® Anchor head forces and one-way beam action. Two #4 reinforcing bar walers are placed continuously along each SOIL SCREW® Anchor row (see Figures 9-17 and 9-18).

SOIL SCREW® Anchor Head Design

The SOIL SCREW® Anchor head forces are expected to be approximately 1/2 of the SOIL SCREW® Anchor tension load. The shotcrete facing is checked for flexure and punching shear using two-way slab action. This information is used in the internal stability analysis. A wall plate could have been placed at the wall face to maximize punching shear resistance, but in this example a welded rebar head assembly that includes a wall plate is placed on each Helical SOIL SCREW® Anchor at the middle of the shotcrete wall as shown in Figure 9-18 (refer to SOIL SCREW® Anchor Wall Accessories for details of the welded rebar head assembly). The welded rebar head assembly shall be spliced to the horizontal walers at each row of Helical SOIL SCREW® Anchors and to the vertical bearing bars between the upper row of Helical SOIL SCREW® Anchors and the dowels at the pier brackets. To properly position and embed the welded rebar head assembly and rebar, the welded wire fabric must be pushed into the initial 2-1/2" face coat of shotcrete approximately 1/2" at each SOIL SCREW® Anchor head. The 5" wall thickness and reinforcement described above are adequate.

References:

1. AASHTO Highway Subcommittee on Bridges and Structures, Manual on Foundation Investigations, American Association of State Highway and Transportation Officials, 1978.
2. Federal Highway Administration Publication No. FHWA-SA93-026, Recommendations Clouterre, English Translation, 1993.
3. Federal Highway Administration Publication No. FHWA-SA-96-069, Manual for Design and Construction Monitoring of Soil Nail Walls, 1996.
4. Federal Highway Administration Publication No. FHWA-SA-96-071, Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines, 1996.
5. Federal Highway Administration Publication No. FHWA-SA-96-072, Corrosion/Degradation of Soil Reinforcement for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, 1996.



LIGHTING AND SIGNS



FOUNDATION LIGHTING AND SIGNS SYSTEM SECTION 10

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SYMBOLS USED IN THIS SECTION

FS	Factor of Safety	10-5
AASHTO	American Association of State Highway and Transportation Officials	10-7
EPA	Effective Projected Area	10-7

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

Hubbell Power Systems, Inc., shall not be responsible for, or liable to you and/or your customers for the adoption, revision, implementation, use or misuse of this information. Hubbell, Inc., takes great pride and has every confidence in its network of installing contractors and dealers.

Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

INTRODUCTION

Hubbell Power Systems, Inc. manufactures the Foundation Lighting and Signs System to provide resistance to lateral loads and moment loads due to wind and other load conditions. The versatility and ease of construction of the CHANCE® Foundation Lighting and Signs System permits great flexibility in a number of applications. Typical uses for these products are foundations for equipment pads, foundation supports for signs, supports for light standards and decorative poles, and other eccentric load applications.

PRODUCT BENEFITS

The Foundation Lighting and Signs System offers the following benefits:

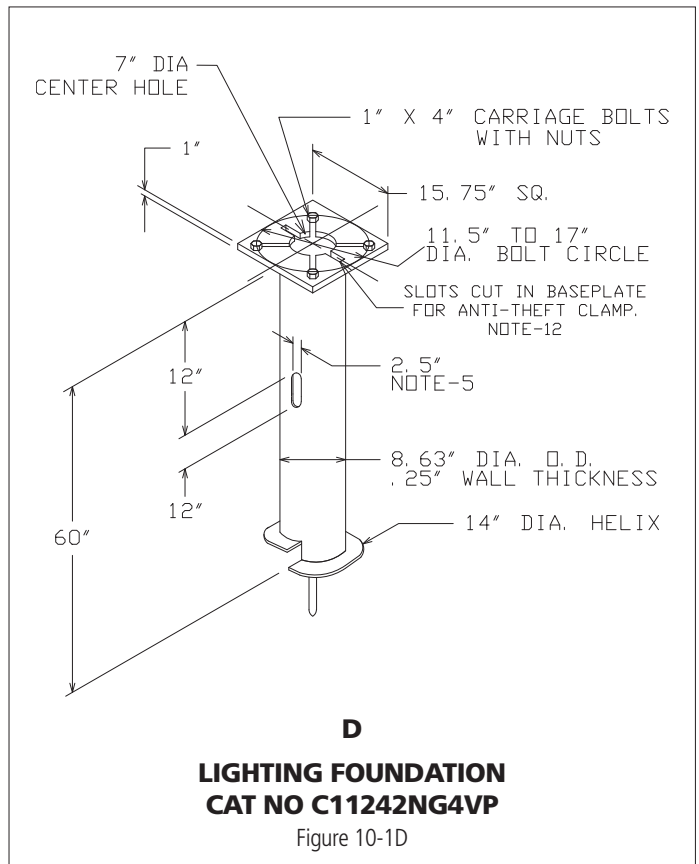
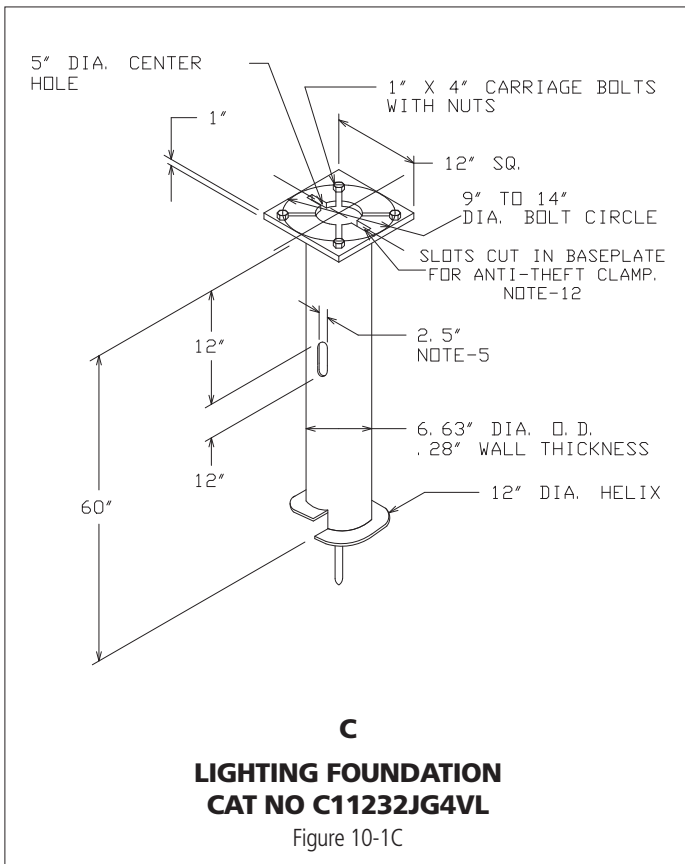
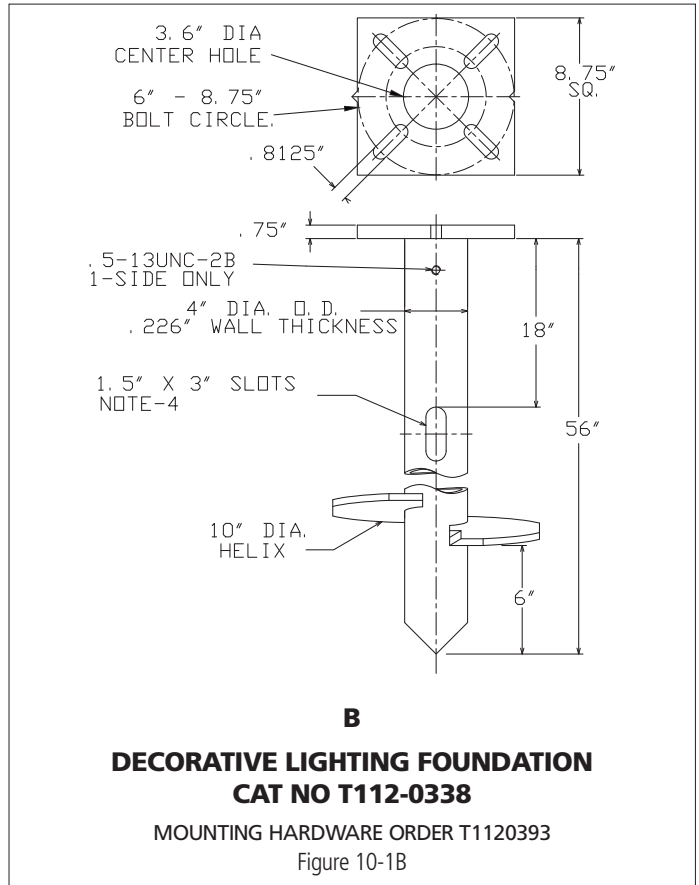
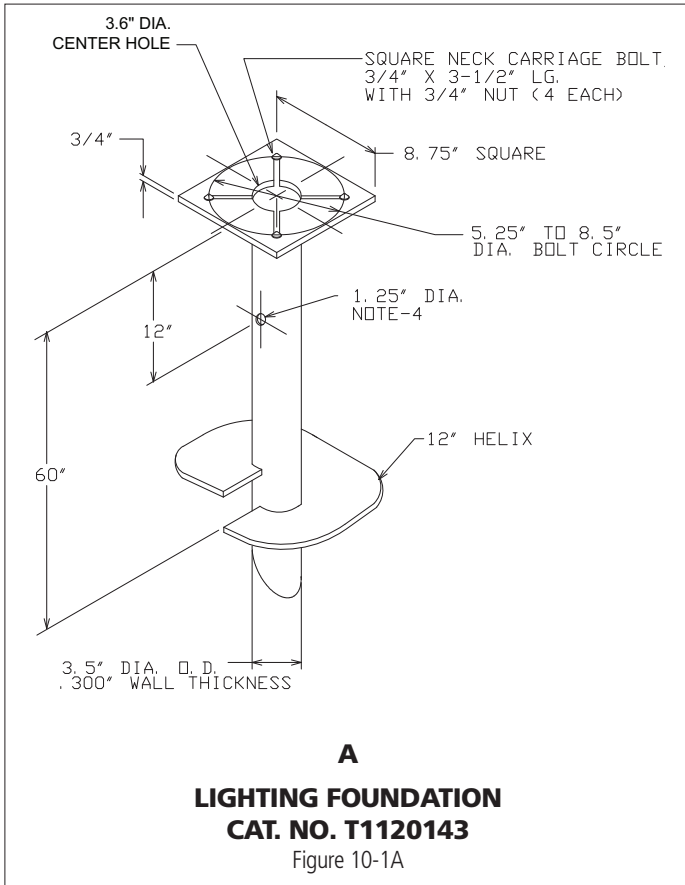
- Fast installation.
- No vibration.
- Ease of installation in limited access areas.
- Minimum disturbance to site.
- No excavation required.
- All steel foundation.
- Immediate structure installation.
- Ready for immediate wiring.
- All weather installation.
- On-site load test capability.

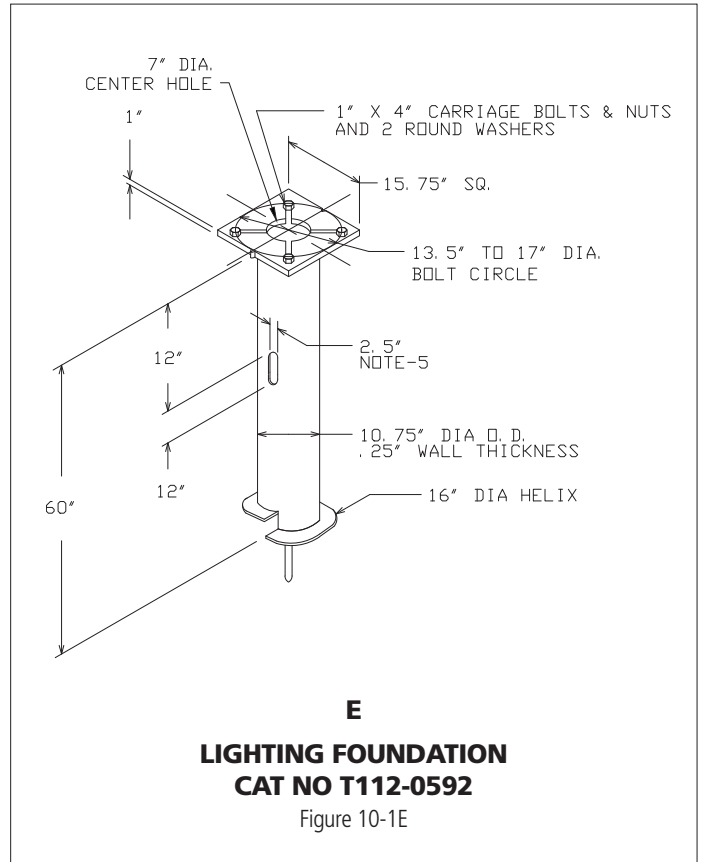
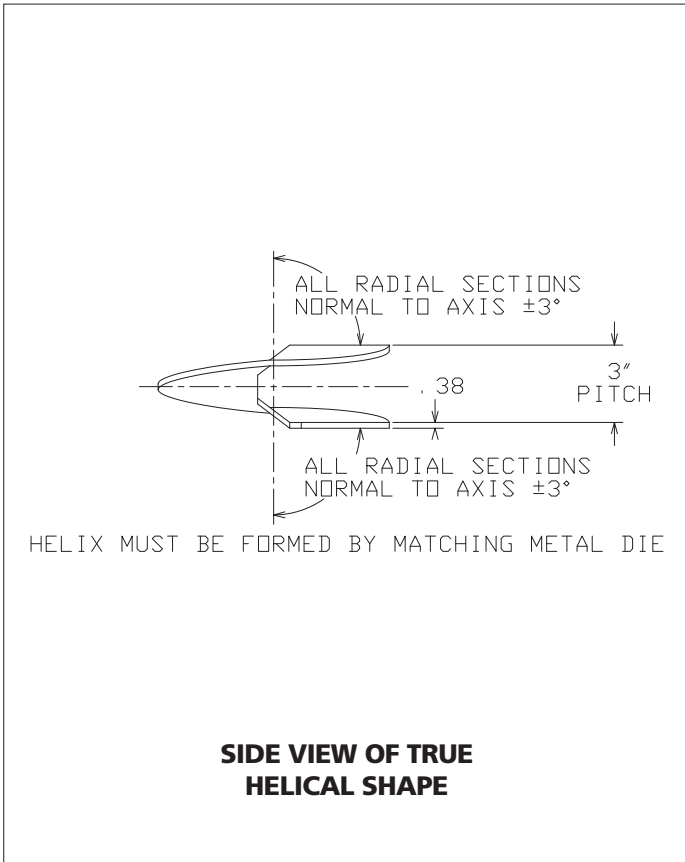
This section describes the CHANCE® Foundation Lighting and Signs System products for overturning moment loads and lateral support that are typically maintained in stock to provide quick delivery to the project site. Table 10-1 and Figure 10-1 illustrate just a few of the Foundation Lighting and Signs products that are available in each of the product series. Our manufacturing facility is capable of rapidly fabricating products to suit the application.

FOUNDATION LIGHTING AND SIGNS System Product Selection, Table 10-1

DETAIL	CATALOG NO	PILE DIA	LENGTH	NOTES
A	T1120143	3-1/2"	5' - 0"	1. Manufacturer to have in effect industry recognized written quality control for all materials and manufacturing processes. 2. All material to be new, unused and mill traceable meeting specifications found on product drawing. 3. Additional lengths and configurations are available as standard catalog numbers.
B	T1120338	4"	4' - 8"	
C	C11232JG4VL	6-5/8"	5' - 0"	
D	C11242NG4VP	8-5/8"	5' - 0"	
E	T1120592	10-3/4"	5' - 0"	

LIGHTING AND SIGNS





LIGHTING AND SIGNS

RECOMMENDED FACTORS of SAFETY for DESIGN

The variability of soil conditions that may exist at a project site, plus the varied nature of loading on structures and how these loads are transferred through foundation elements, requires the consulting engineer and/or dealer/installing contractor to use an appropriate Factor of Safety (FS) in design for use with the Chance® Foundation Lighting and Signs System. Generally this Factor of Safety is a minimum of 2:1 on all permanent loading conditions and a minimum of 1.5:1 for any temporary load situation. National and local building code regulations may require more stringent Factors of Safety on certain projects.



DESIGN GUIDELINES

The Foundation Lighting and Signs System provides manufactured single helix fixed length products for use as foundations for varied applications such as light poles, signs and equipment supports. There are many applications for these tubular helical specialty products. Each application will require:

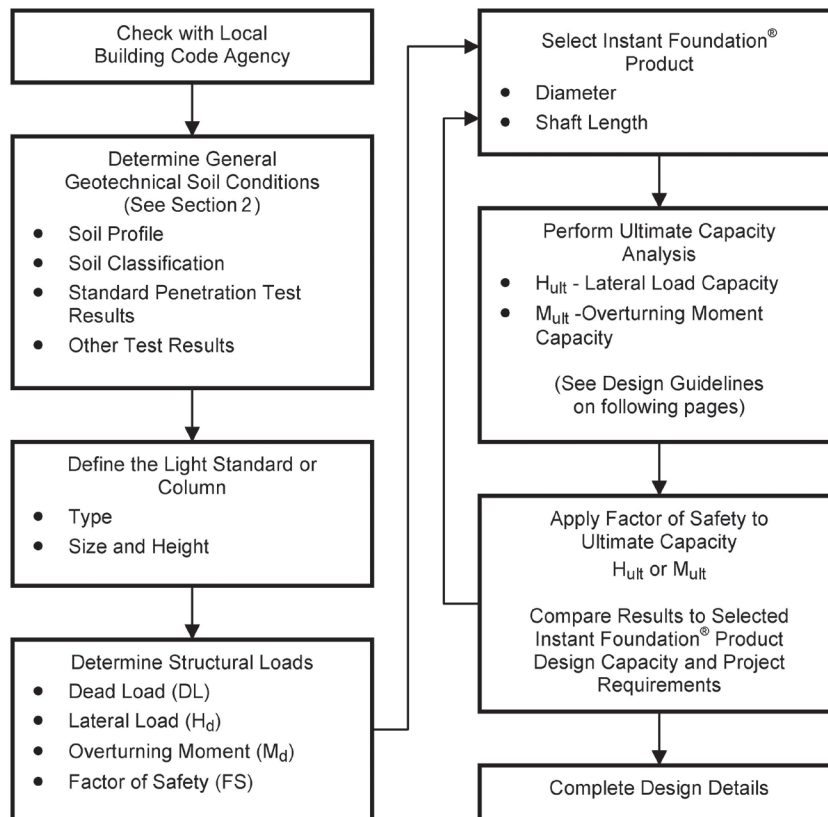
1. An evaluation of the soil strata and soil characteristics of that stratum in which the product will be installed.
2. A selection of the appropriate Foundation Lighting and Signs Product shaft diameter, shaft length, base plate size, bolt diameter and bolt circle diameter.
3. A determination of the ultimate bearing capacity and suitable Factor of Safety.

NOTE: The design should involve professional geotechnical and engineering input. Specific information involving the structures, soil characteristics and foundation conditions must be used for the final design.

The following preliminary design guide information is intended to assist dealers, installing contractors, and consulting engineers to select the appropriate CHANCE® Foundation Lighting and Signs Product to resist overturning moment and lateral load.

The Hubbell Power Systems, Inc. Pole Load Determination Data Sheet is provided on page 10-9. This can be used to gather and record the information required to determine the loads to be applied to a light pole foundation. The loads and given soil conditions are then used to determine the appropriate Foundation Lighting and Signs Product size required for the job. The SELECT-A BASE™ Lighting Base Program is an on-line program used for preliminary foundation selection. The program incorporates a database of CHANCE® Lighting Bases. The program inputs include loading conditions (wind, moment, and/or lateral), pole/pole arm details and soil data. The software is free and easy to use on-line at www.abchance.com.

INSTANT FOUNDATION® SYSTEM DESIGN STEPS

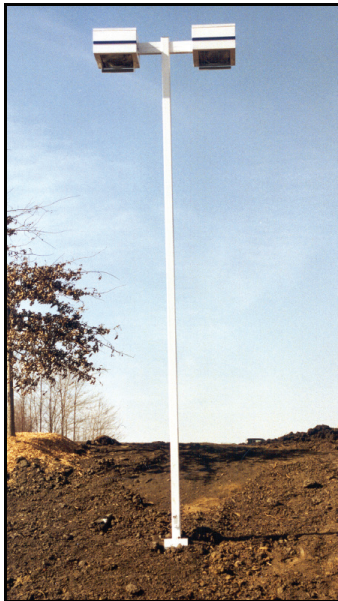


LIGHTING AND SIGNS

LIGHT POLE STANDARDS PRODUCTS

CHANCE® Foundation Lighting and Signs® Products for light pole standards are designed to resist both the lateral forces and overturning moments from wind loads. Controlling design standards for wind loads can be determined either by consulting local or national building codes or conformance to standards set by the American Association of State Highway and Transportation Officials (AASHTO). These standards will provide the required design wind load based on geographic region and the factors associated with the shape and type of structure in order to determine the resulting wind pressure. This wind pressure is then applied to the effective projected area (EPA) of the light pole, arm and fixture. These lateral forces can be used to determine the resultant lateral force and overturning moment applied to the foundation as shown in Figure 10-4. The luminaire or fixture supplier may be consulted to determine the actual effective projected area for the specific light assembly.

Table 10-2 provides the suggested shaft diameter and installation requirements for various lateral load-overturning moment ranges. Table 10-3 provides the minimum recommended design life based on the structure type. This has been reproduced from AASHTO Specification, 4th Edition, 2001. The designer can make a site-specific analysis, or an analysis can be obtained by completing the Pole Load Determination Data Sheet on page 10-9 and submitting it to Hubbell Power Systems, Inc. to determine the most appropriate Instant Foundation® Product.



Installed Light Standard
Figure 10-2



Foundation Lighting and Signs® Products are Easily Installed Using
Common Construction Equipment.
Figure 10-3

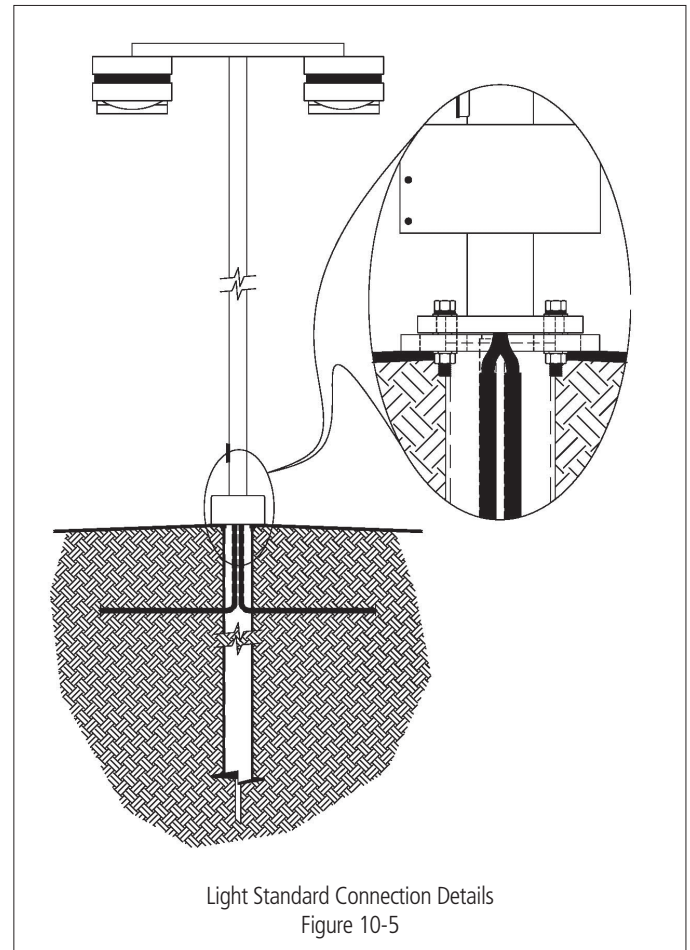
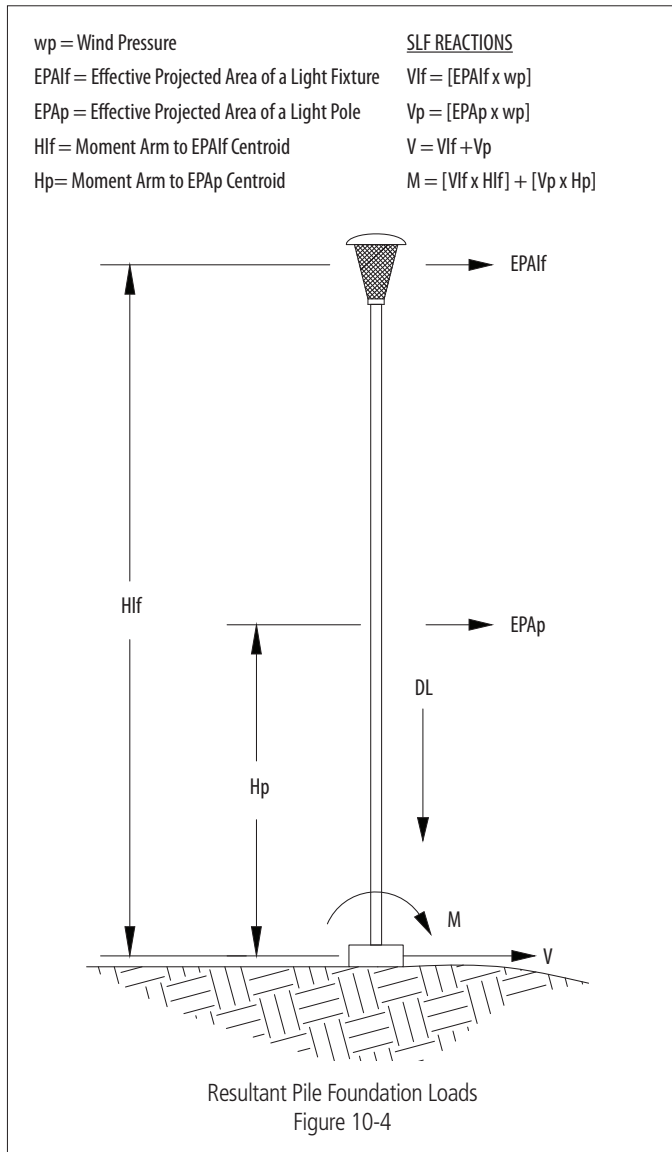
CHANCE® Foundation Lighting and Signs® System for Light Standards, Table 10-2

DESIGN LATERAL LOAD ²	DESIGN OVERTURNING MOMENT ²	RECOMMENDED HELICAL FOUNDATION ²	PRODUCT PART NUMBER
150 – 500 lb.	≤ 2,800 ft-lb.	3.5" Dia x 5' Long	T1120143
150 – 500 lb.	≤ 3,500 ft-lb.	4" Dia x 4'-8" Long	T1120338
500 – 1,000 lb.	≤ 10,500 ft-lb.	6-5/8" Dia x 5' Long	C11232JG4VL
1,000 – 1,200 lb.	≤ 21,000 ft-lb.	8-5/8" Dia x 5' Long	C11242NG4VP
1,200 – 1,500 lb.	≤ 37,000 ft-lb.	10-3/4" Dia x 5' Long	T1120592

Notes:

1. The above lateral loads and overturning moments are mechanical ratings of the indicated foundation. Project soil conditions must be evaluated during preliminary design.
2. These design loads are based on allowable bending in the pipe shaft with cableway widths of 1.25" in 3.5" dia, 1.5" in 4" dia and 2.5" in all other foundations.

LIGHTING AND SIGNS



Recommended Minimum Design Life, Table 10-3

DESIGN LIFE	STRUCTURE TYPE
50 Years	<ul style="list-style-type: none"> • Luminaire support structures exceeding 15m (49.2 ft) in height. • Overhead sign structures.
25 Years	<ul style="list-style-type: none"> • Luminaire support structures less than 15m (49.2 ft) in height. • Traffic signal structures.
10 Years	<ul style="list-style-type: none"> • Roadside sign structures.

(Reproduced from AASHTO Specification, 4th Edition, 2001)

LATERALLY LOADED FOUNDATIONS

Certain projects require a rapidly installed foundation that must resist lateral loads. Examples of these projects include:

- Equipment platforms for communication towers or mechanical systems.
- Seaside structures subjected to wave action.
- Temporary classroom/mobile building foundations.
- Solar Panels

Each project must be evaluated and designed and should include geotechnical and professional engineering input. Hubbell Power Systems, Inc. offers a "Preliminary Design Service" for evaluating the feasibility of using Foundation Lighting and Signs® Products on such specific projects.

FOUNDATION LIGHTING AND SIGNS® SYSTEM SPECIFICATIONS

The Specification at the end of this section provides a typical specification for the CHANCE® Foundation Lighting and Signs® System.

1. American Association of State Highway and Transportation Officials (AASHTO) Specification, 4th Edition, 2001.
2. Uniform Building Code, Volume 2 - Division 3, 1997.

POLE LOAD DETERMINATION DATA SHEET

Luminaire mounting height:		<input type="checkbox"/> m	<input type="checkbox"/> ft
Height of pole:		<input type="checkbox"/> m	<input type="checkbox"/> ft
Outside diameter of pole top:		<input type="checkbox"/> cm	<input type="checkbox"/> in
Outside diameter of pole bottom:		<input type="checkbox"/> cm	<input type="checkbox"/> in
Arm length:		<input type="checkbox"/> m	<input type="checkbox"/> ft
Arm tip outside diameter:		<input type="checkbox"/> cm	<input type="checkbox"/> in
Arm bottom outside diameter:		<input type="checkbox"/> cm	<input type="checkbox"/> in
Luminaire weight:		<input type="checkbox"/> kg	<input type="checkbox"/> lb
Luminaire EPA (projected area x C_d):		<input type="checkbox"/> m ²	<input type="checkbox"/> ft ²
Basic wind speed:		<input type="checkbox"/> kph	<input type="checkbox"/> mph
Minimum design life (Default design life is 25 yrs. See Table 10-3):		<input type="checkbox"/> 10 <input type="checkbox"/> 25 <input type="checkbox"/> 50 yrs	
Number of arms:			
Number of luminaires:			
Pole shape:	<input type="checkbox"/> Cylinder <input type="checkbox"/> Flat <input type="checkbox"/> Hexdecagonal (16 sides) <input type="checkbox"/> Dodecagonal (12 sides) <input type="checkbox"/> Octagonal (8 sides) <input type="checkbox"/> Square (4 sides) <input type="checkbox"/> Diamond		
Arm shape:	<input type="checkbox"/> Cylinder <input type="checkbox"/> Flat <input type="checkbox"/> Hexdecagonal (16 sides) <input type="checkbox"/> Dodecagonal (12 sides) <input type="checkbox"/> Octagonal (8 sides) <input type="checkbox"/> Square (4 sides) <input type="checkbox"/> Diamond		
Is this pole/foundation in Alaska?		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Required foundation bolt diameter:		<input type="checkbox"/> cm	<input type="checkbox"/> in
Required foundation bolt circle diameter:		<input type="checkbox"/> cm	<input type="checkbox"/> in
Site Soil Data (if available):			

SPECIFICATION

CHANCE® Foundation Lighting and Signs® System

- 3-1/2" Dia x 0.300" Wall
- 6-5/8" Dia x 0.280 Wall
- 10-3/4" Dia x 0.250" Wall
- 4" Dia x 0.226" Wall
- 8-5/8" Dia x 0.250" Wall

The usual application for this foundation is where loads are moderate and the project requires greater column stiffness than is possible with the typical square shaft helical pile. Examples of applications are: Light Standards, Curbside Business Sign Support, Electrical/Mechanical Equipment Pad Support, Cantilevered Loads, etc.

PART 1 – GENERAL

1.1 SCOPE OF WORK

This work consists of furnishing labor, tools, equipment and materials associated with the preparation and installation of the CHANCE® Foundation Lighting and Signs® System for structural foundation support according to the specifications contained herein. The work includes, but is not limited to, the following:

1. Diligent investigation of the possible existence and location of underground utilities situated at or near the area of work;
2. Excavation and preparation of foundation soil to grade for foundation installation;
3. Mounting of the hydraulic gear motor on a backhoe unit or similar auxiliary powered equipment, and the installation of the Foundation Lighting and Signs® Product to the required torque resistance at the required depth (if torque resistance measurement is required).
4. Removal of the hydraulic gear motor.
5. Conducting an optional Field Load Test on one or more Foundation Lighting and Signs® Products.
6. Clean Up.

1.2 REFERENCES

1. Building Officials and Code Administrators International, Inc. (BOCA) Basic National Building Code.
2. American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals.

1.3 DELIVERY, STORAGE AND HANDLING

All foundation products shall be handled and transported carefully to prevent any deformation or damage. Care should be taken to prevent the accumulation of dirt, mud or other foreign matter on the steel materials. Such accumulation shall be completely removed prior to installation.

PART 2 - MATERIAL

2.1 HYDRAULIC GEAR MOTOR

The torque rating of the hydraulic gear motor used to install the Foundation Lighting and Signs® Product shall be adequate to install the required foundation. It is suggested that the torque rating be 25 percent higher than the planned installation torque. Depending upon the soil conditions and pile configuration, different hydraulic gear motors may be required.

2.2 3-1/2" and 4" DIAMETER HELICAL FOUNDATION LIGHTING AND SIGNS® SERIES

2.2.1 Foundation Shaft Section

The shaft section consists of a tubular hot rolled steel pile section 3-1/2" in diameter with a 0.300" wall thickness, or 4" diameter with a wall thickness of 0.226" conforming to ASTM A-53, A-252 and A-500. The length of the foundation shall be as specified: 4', 4'-8", 5', etc. The lead end of the 3.5" and 4" foundations shall have a single or double bevel cut to aid in starting the foundation installation. Welded to the shaft shall be one ASTM A-635 steel helical plate with a thickness of 3/8" and a 3" pitch.

2.2.2 Foundation System Base Mounting Plates

Foundation base plates may be round or square, of various sizes in plan view and may vary in thickness from 1/2" to 1-1/2" depending on job requirements.

2.3 6-5/8", 8-5/8" and 10-3/4" DIAMETER HELICAL FOUNDATION LIGHTING AND SIGNS® SERIES

2.3.1 Foundation Shaft Section

The shaft section consists of 6" diameter (6-5/8" outside diameter with 0.280" wall), 8" diameter (8-5/8" outside diameter with 0.250" wall) or 10" (10-3/4" outside diameter with 0.250" wall) steel pipe conforming to ASTM A-53, A-252 or A-500. The length of the foundation may be 4', 5', 7', 8' or 10' long as required by the application. The pile section shall have two wire access slots located 1800 from each other. The integral foundation cap plate shall have an alignment notch located directly above one of the wire access slots. Welded to the lead end of the foundation shaft shall be a steel helical plate with a 3" pitch. To aid in starting the pile, a 1-1/4" diameter steel rod shall extend beyond the center of the helix to provide a pilot.

2.3.2 Foundation System Base Mounting Plates

Foundation base plates may be round or square, of various sizes in plan view and may vary in thickness from 3/4" to 1-1/2" depending on job requirements.

2.4 WELDMENTS

All welded connections shall conform to the requirements of the American Welding Society Structural Welding Code, AWS D1.1 and applicable revisions.

PART 3 - EXECUTION

The following is intended to provide the controlling specification for the major steps undertaken in the installation of the CHANCE® FOUNDATION LIGHTING AND SIGNS® Systems. Variations in the installation procedure may occur depending on the application and the structural support required.

WARNING! THOROUGHLY INVESTIGATE THE POSSIBLE EXISTENCE AND LOCATION OF ALL UNDERGROUND UTILITIES SITUATED AT OR NEAR THE AREA OF WORK BEFORE PROCEEDING. SERIOUS INJURY MAY RESULT FROM FAILURE TO LOCATE ALL UNDERGROUND UTILITIES.

3.1 PREPARATION

The soil shall be excavated to the proper grade for placement of the CHANCE® Foundation Lighting and Signs® Product. Stakes should be set at each foundation location prior to commencement of work. The foundation layout and staking should be under the supervision of the responsible structural engineer and be accomplished using fully qualified and trained technicians familiar with foundation layout.

3.2 INSTALLATION OF THE FOUNDATION LIGHTING AND SIGNS® PRODUCT

The hydraulic gear motor shall be installed on a backhoe or other suitable pile installation unit. Mount the Foundation Lighting and Signs® Product to the hydraulic gear motor via the appropriate kelly bar adapter and installing tool using two structural grade bolts and nuts. The foundation is positioned vertically over a marked pile location and driven into the soil by means of the hydraulic gear motor. Rotary installation continues until the required design torque is achieved at or below the predetermined depth. The baseplate

is typically installed to grade or slightly above to allow clearance for bolt mounting of the pole base. It is important that the installation torque remain at or above the predetermined value during this process. Details of the installation shall be provided to the supervising engineer for review.

3.3 DOCUMENTATION

When required, the dealer/installing contractor shall monitor the torque applied to the foundation during installation. It is recommended that the installation torque be recorded at one-foot intervals throughout the installation. The installation torque may be measured with a calibrated torque indicator. At the conclusion of the installation, a copy of the foundation installation record shall be provided to the engineer for review.

3.4 LOAD TEST (Optional)

A detailed description on the requirements and procedures for conducting a Load Test may be found in Appendix B (LOAD TESTS). The results of the Field Load Test provide guidance for determining the ultimate and allowable foundation loads.

Load testing should be conducted under the supervision of the responsible engineer.

Depending on the project specifications, a Working Load Test may be required. Normally, the first installed foundation is selected for this test; however, some specifications require ultimate loading of the foundation. If an Ultimate Load Test is required, a test foundation must be installed in an alternate location on the site in addition to the pile locations marked. After the Ultimate Load Test is completed, the test foundation may be removed from the soil and used on the project, provided it is not damaged.

3.5 CLEAN UP

Upon completion of the installation of the CHANCE® Foundation Lighting and Signs® Product, all equipment shall be removed from the site. Any disturbed soils in the area of the foundation shall be restored to the dimensions and condition specified by the engineer.

END OF SPECIFICATION

LIGHTING AND SIGNS





CORROSION



CORROSION - AN OVERVIEW APPENDIX A

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CORROSION THEORY	A-4
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DESIGN EXAMPLES	A-21

SYMBOLS USED IN THIS SECTION

pH.....	Acidity or Alkalinity of a Solution	A-7
ASTM.....	American Society for Testing and Materials	A-7
V	Voltage	A-7
I.....	Electrical Current	A-25
R	Resistance or Resistivity	A-8
L.....	Pin spacing	A-8
NBS.....	National Bureau of Standards	A-8
FHWA	Federal Highway Administration	A-9
AASHTO	American Association of State Highway and Transportation Officials	A-9
R_{meter}	Resistivity Indication from Nillson Resistivity Meter	A-13
WSF.....	Wenner Spacing Factor	A-13
CL.....	Corrosion Weight Loss	A-17
GWT	Ground Water Table	A-19
ppm.....	Parts per Million	A-9
ASL	Allowable Steel Loss	A-21
SL.....	Service Life	A-22
G	Amount of Galvanized Coating	A-23
W_s	Weight of Steel Pile	A-24
K_2	Weight Loss by Corrosion	A-24

CORROSION

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

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Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

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INTRODUCTION

Corrosion is defined as the degradation of a material or its properties due to a reaction with the environment. Corrosion exists in virtually all materials, but is most often associated with metals. Metallic corrosion is a naturally occurring process in which the surface of a metallic structure is oxidized or reduced to a corrosion product such as rust by chemical or electrochemical reaction with the environment. The surface of metallic structures is attacked through the migration of ions away from the surface, resulting in material loss over time. Given enough time, the material loss can result in significant reduction of area, which in turn leads to a reduction in the structural capacity of a given metallic element. When corrosion eventually destroys a sufficient amount of the structure's strength, a failure will occur.

The corrosion mechanisms involved with buried metallic structures are generally understood, but accurate prediction of metal loss rates in soil is not always easily determined. This appendix provides an introduction to the concepts of underground corrosion and the factors that influence this corrosion in disturbed and undisturbed soils. A few design examples are provided to give the reader a better understanding as to whether corrosion is a critical factor in a CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Pier application. This section is not intended to be a rigorous design guide, but rather a "first check" to see if corrosion is a practical concern given the specific project site conditions. A qualified corrosion engineer should be consulted for a site specific recommendation if steel foundation products are to be used in a known corrosive soil.

Experience over the past 50 years has shown the vast majority of square shaft and round shaft helical anchors/piles have a calculated service life well in excess of the design life of the structure (typically 50 to 75 years in the United States). In highly corrosive soils and areas of stray currents (e.g., underground transmission pipelines, DC railroads) additional measures must be taken to protect steel foundation products. In these cases, active protective measures such as sacrificial anodes are employed.

CORROSION THEORY

To understand why metallic corrosion occurs, it is necessary to understand how a metal, such as carbon steel, is formed. During the steel making process, natural low energy iron ore is refined into metal. This process adds a great deal of energy to the metal. When the steel is placed into a corrosive environment, it will, by natural processes, return to its low energy state over time. To make the return trip, the steel must give up the energy gained at the mill. This is the essence of the reduction process that we call corrosion.

Mechanical strength, physical size and shape, and chemical composition of the steel are all properties that must be considered when designing CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Piers. Mechanical and physical properties are well defined and controlled during the manufacturing process. This is also true of the chemical composition, primarily due to the superior process controls used by the steel mills. Of the three properties, chemical composition is the primary factor with respect to corrosion.

Corrosion of steel is an electrochemical process. Romanoff (1957) stated:

"For electrochemical corrosion to occur there must be a potential difference between two points that are electrically connected and immersed in an electrolyte. Whenever these conditions are fulfilled, a small current flows from the anode area through the electrolyte to the cathode area and then through the metal to complete the circuit, and the anode area is the one that has the most negative potential, and is the area that becomes corroded through loss of metal ions to the electrolyte. The cathode area, to which the current flows through the electrolyte, is protected from corrosion because of the deposition of hydrogen or other ions that carry the current.

"The electrochemical theory of corrosion is simple, i.e., corrosion occurs through the loss of metal ions at anode points or areas. However, correlation of this theory with actual or potential corrosion of metals underground is complicated and difficult because of the many factors that singly or in combination affect the course of the electrochemical reaction. These factors not only determine the amount or rate at which corrosion occurs but also the kind of corrosion."

Depending on the many factors that affect the electrochemical reaction, corrosion can affect a metal in several different ways. Some of these types are listed below:

Corrosion Types, Table A-1

TYPE	CHARACTERISTICS
Uniform or Near Uniform	Corrosion takes place at all area of the metal at the same or a similar rate.
Localized	Some areas of the metal corrode at different rates than other areas due to heterogeneities in the metal or environment. This type of attack can approach pitting.
Pitting	Very highly localized attack at specific areas resulting in small pits that may penetrate to perforation.

Considerations need to be applied as to the types and rates of corrosion anticipated. Current theory does not permit accurate prediction of the extent of expected corrosion unless complete information is available regarding all factors. Therefore, uniform corrosion will be the corrosion type discussed herein.

Romanoff states there are several conditions that must be met before the corrosion mechanism takes place. These are:

Electrical Factors

Two points (anode and cathode) on a metallic structure must differ in electrical potential. The anode is defined as the electrode of an electrochemical cell at which oxidation occurs, i.e., the negative terminal of a galvanic cell. The cathode is defined as the electrode of an electrochemical cell at which reduction occurs, i.e., the positive terminal of a galvanic cell. An electrical potential can be caused by differences in grain orientation within the steel structure, i.e., different orientations of the steel grain structure can cause some grains to act as anodes while others act as cathodes, while the rest of the steel material exhibits excellent electrical conductivity. In addition, chemical anisotropy, non-metallic inclusions, strained and unstrained areas, and other imperfections on the surface of a metal can create potential differences that drive the corrosion process.

Metallic Path

The anode and the cathode must be electrically bonded or connected to complete the circuit.

Electrolyte

The principle function of soil moisture is to furnish the electrolyte for carrying current. The ions in the electrolyte may be hydrogen and hydroxyl ions from the water itself and a variety of cations and anions, which depend upon the number and amount of soluble salts dissolved in the water. The presence of these ions determines the electrical conductivity, expressed as resistivity (measured in ohms/cm), of the electrolyte, as well as chemical properties such as acidity or alkalinity, and the development of chemical reactions between the primary products of corrosion and the electrolyte. For example, ferrous material is corroded by electrolytes that contain sulfates or chlorides from the soil because the corrosion products formed at the anode and the cathode are both soluble.

Aeration

Aeration affects the access of oxygen and moisture to the metal. Oxygen, either from atmospheric sources or from oxidizing salts or compounds, stimulates corrosion by combining with metal ions to form oxides, hydroxides, or metal salts. If corrosion products are soluble or are otherwise removed from the anodic areas, corrosion proceeds, but if the products accumulate, they may reduce corrosion by providing a barrier that is more noble (cathodic) than the bare metal. The aeration characteristics of a soil are dependent upon physical characteristics such as the particle size, particle size distribution, and unit weight. In volume change soils such as clay, a reduction in moisture content results in cracks that provide effective channels for the oxygen of the air to reach buried metal. Disturbed soils such as fill result in oxygen being more readily available. In some instances, atmospheric oxygen can become trapped in isolated pockets or cells creating the potential for localized anodic regions.



SOIL ENVIRONMENTS

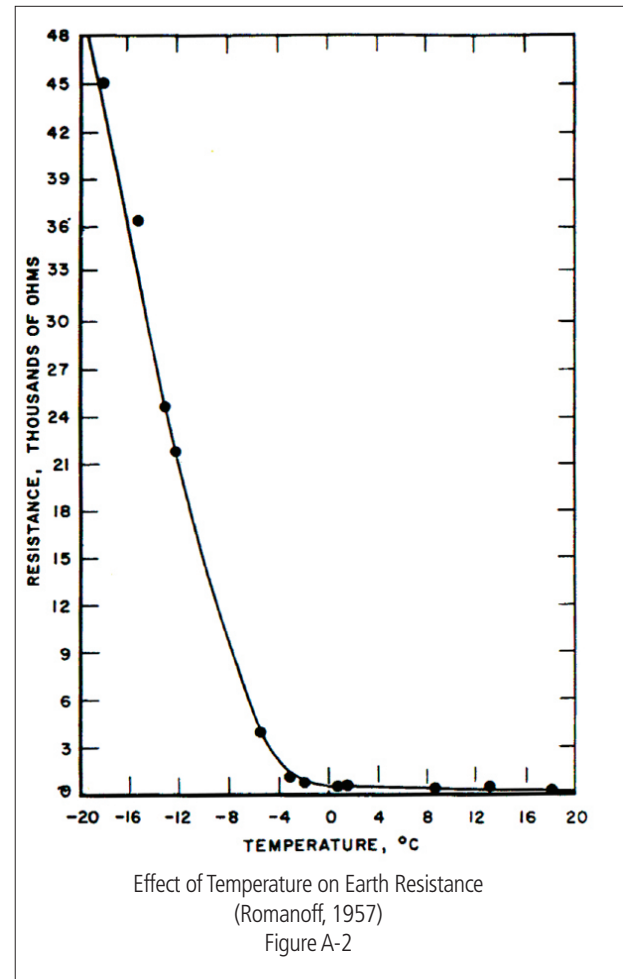
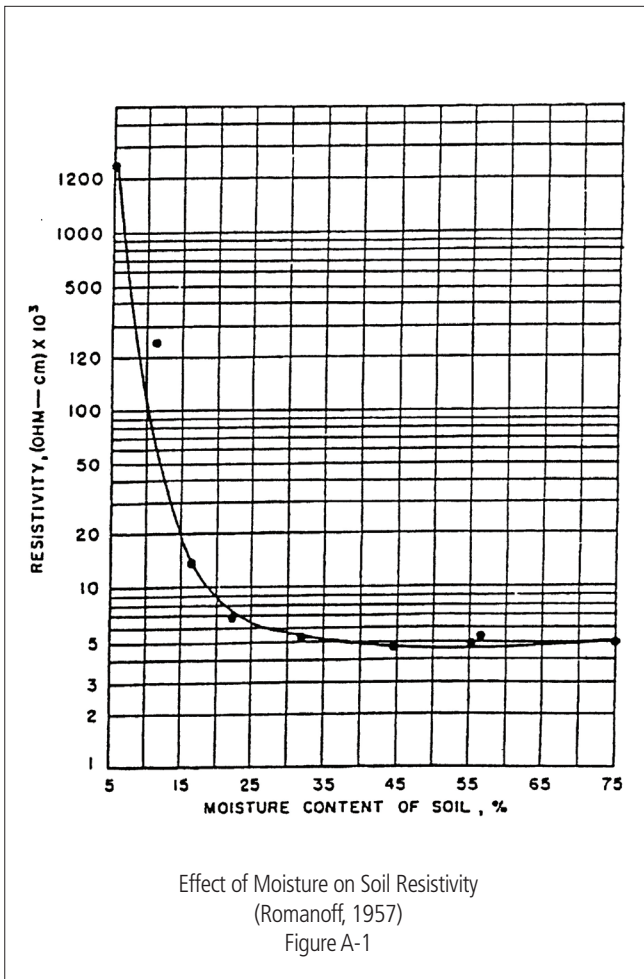
SOIL TYPE

Soils constitute the most complex environment known to metallic corrosion. Corrosion of metals in soil can vary from relatively rapid material loss to negligible effects. Obviously, some soil types are more corrosive than others. The origin of soils, along with climate, geologic location, plant and animal life, and the effects of man all influence the corrosive potential of a given soil. Chemical analysis of soils is usually limited to determinations of the constituents that are soluble in water under standardized conditions. The elements that are usually determined are the base-forming elements, such as sodium, potassium, calcium, and magnesium; and the acid-forming elements, such as carbonate, bicarbonate, chloride, nitrate, and sulfate. The nature and amount of soluble salts, together with the moisture content of the soil, largely determine the ability of the soil to conduct an electric current. Therefore, fine-grained soils such as clays and some silts are considered to have a greater corrosion potential because they typically have lower hydraulic conductivity resulting in the accumulation of acid and base forming materials, which cannot be leached out very quickly. However, granular soils such as sands and gravels are considered to have a reduced corrosion potential because they typically have increased hydraulic conductivity, resulting in the leaching of accumulated salts.

GROUND WATER

Moisture content in soil will probably have the most profound effect when considering corrosion potential than any other variable. No corrosion will occur in environments that are completely dry. The effect of moisture content on the resistivity of a clay soil is shown in Figure A-1. When the soil is nearly dry, its resistivity is very high (i.e., no corrosion potential). However, the resistivity decreases rapidly with increases in moisture content until the saturation point is reached, after which further additions of moisture have little or no effect on the resistivity. Figure A-2 shows the effect of temperature on the resistivity of a soil. As the temperature decreases down to the freezing point (32°F or 0°C), the resistivity increases gradually. At temperatures below the freezing point, the soil resistivity increases very rapidly.

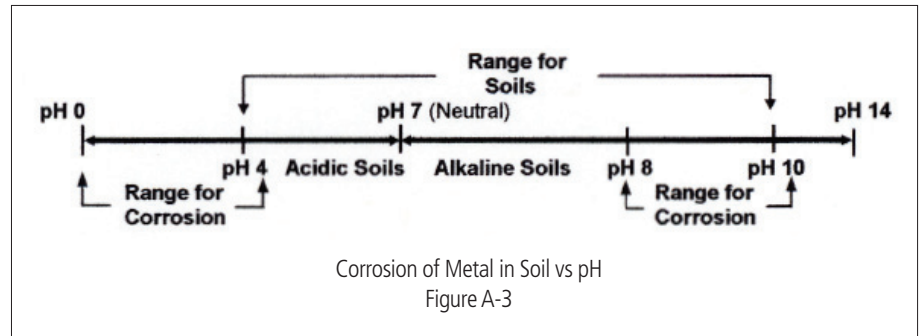
CORROSION



SOIL pH

Soil pH can be used as an indicator of corrosion loss potential for metals in soil. The term “pH” is defined as the acidity or alkalinity of a solution that is assigned a number on a scale from 0 to 14. A value of 7 represents neutrality, lower numbers indicate increasing acidity and higher numbers increasing alkalinity. Each unit of change represents a ten-fold change in acidity or alkalinity which is the negative logarithm of the effective hydrogen-ion concentration or hydrogen-ion activity in gram equivalents per liter of solution. The development of acidity in soils is a result of the natural processes of weathering under humid conditions. Acidic soils are those that have had soluble salts and other materials removed, usually by moderate to high rainfall. In general, the soils of the Midwest and Eastern United States are acid to a considerable depth, whereas the soils whose development has been retarded by poor drainage or other conditions are alkaline. Most soils fall within a pH range that is strongly acid to mildly alkaline.

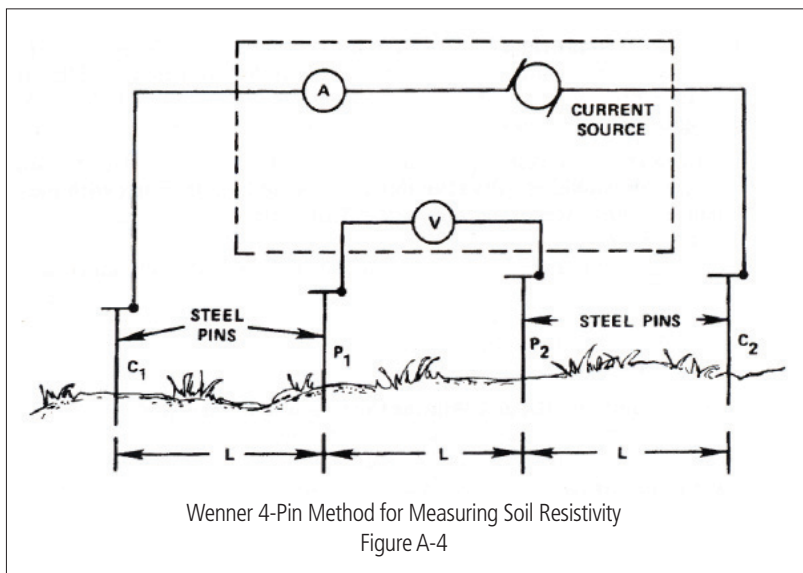
Extremely acid soils (below pH 4.5) and very strongly alkaline soils (above pH 9.1) have significantly high corrosion loss rates when compared to other soils (see Figure A-3). Soil pH is best measured in the field using a pH meter and following the methods defined in ASTM G 51 – 77.



SOIL RESISTIVITY

Soil resistivity (the reciprocal of conductivity) is the one variable that has the greatest influence on corrosion rate. However, other factors such as hydrogen-ion concentration, soluble salts and total acidity are interrelated, and it is difficult to control conditions so that there is only one variable. In general, the lower the resistivity, the higher the corrosion rate. Metals buried in low resistivity soils will generally be anodic, whereas metals buried in adjacent high resistivity soils will generally be cathodic.

As shown in Figure A-1, moisture content has a profound effect on resistivity. Soil that is completely free of water has extremely high resistivity. For example, sandy soils that easily drain water away are typically non-corrosive; clayey soils that hold water have low resistivity and are typically corrosive. Backfill material will generally be more corrosive than native earth because the backfill soil has a higher moisture content. In addition, backfill material typically never reconsolidates back to the same degree as native soil, allowing more penetration and retention of water.



Soil resistivity is typically measured using one or both of two methods: (1) testing onsite with the Wenner four-pin method, and/or (2) taking a soil sample to a laboratory for a soil box resistivity test. The recommended practice is the onsite Wenner four-pin method per ASTM G57-78. The four-pin method is recommended because it measures the average resistivity of a large volume of earth with relative ease. As Figure A-4 shows, this method places four pins at equal distances from each other. A current is then sent through the two outer pins. By measuring the voltage across the two inner pins, the soil resistance can be calculated using Ohm's Law ($V = IR$). Soil resistivity can be determined using Equation A-1.

CORROSION

$$\text{Resistivity} = 191.5 (R) (L) \text{ (ohms/cm)} \quad \text{Equation A-1}$$

where R = Resistance measured with a soil resistivity meter
 L = Pin spacing (ft)

The soil box resistivity test is not recommended because it requires taking large number of samples for an accurate map of soil resistivities in a given area. The soil box test is also much more time-consuming than the four-pin method. Table A-2 is offered as a guide in predicting the corrosion potential of a soil with respect to resistivity alone.

Soil Resistivity and Potential Corrosion Rate, Table A-2

RESISTANCE CLASSIFICATION	SOIL RESISTIVITY (ohms/cm)	CORROSION POTENTIAL
Low	0 - 2000	Severe
Medium	2000 - 10,000	Moderate
High	10,000 - 30,000	Mild
Very High	Above 30,000	Unlikely

PREDICTING CORROSION LOSS

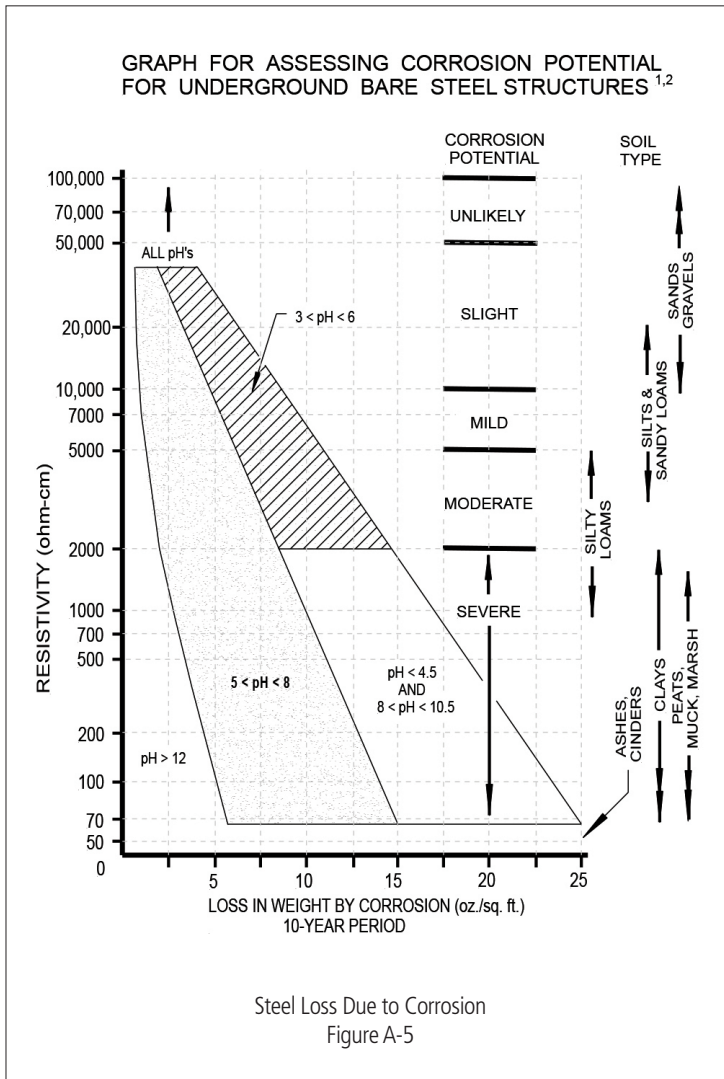
BARE STEEL

The National Bureau of Standards (NBS) performed extensive studies of underground corrosion between 1910 and 1955. More than 36,500 metal samples were exposed at 128 test locations throughout the United States. In 1957, Romanoff presented the results of these investigations in *Underground Corrosion* (1957). The studies showed that most underground corrosion was a complex electrochemical process dependent on the various properties discussed previously. The NBS studies were primarily concerned with buried pipeline corrosion. Since pipes are installed in backfilled trenches, the NBS work was performed on specimens placed in trenches ranging from 18 in (0.46 m) to 6 ft (1.8 m) deep. The following conclusions can be drawn from these studies:

- The metal loss rates reported were from samples placed in backfilled, i.e., disturbed soils.
- Atmospheric oxygen or oxidizing salts stimulate corrosion by combining with metal ions to form oxides, hydroxides, or metallic salts. This is particularly true in disturbed soils at or near the soil surface.
- The least corrosive soils had resistivities above 3,000 ohms/cm and low soluble salt concentrations.
- Metal loss rates in disturbed soils can be determined by assuming they will be similar to the loss rates found at test sites with similar pH and resistivity levels as provided in NBS Circular 579, Tables 6, 8 and 13.

Hubbell Power System, Inc. bulletin 01-9204, *Anchor Corrosion Reference and Examples*, contains extensive metal loss rate data derived from Romanoff's work. It is recommended that this information be used to determine the service life of non-galvanized steel in disturbed soil. The service life for most structures in the United States is 50 to 75 years. Assuming a corrosion allowance for steel piles/piers, Romanoff's metal loss rate data for specific soil types and locations can be used to determine if the required service life can be achieved.

CORROSION



Romanoff's data can also be arranged in easy-to-use graphs or tables. Figure A-5 provides a preliminary estimate for metal corrosion loss of bare steel if specific information is available on the soil (soil type, pH and resistivity). Figure A-5 provides a technique for quickly assessing those situations for which concern and design consideration for corrosion must be taken into account when metallic structures are placed below ground. For example, a clay soil with resistivity of 2000 ohms/cm and a pH of 6 will have an average metal loss rate of approximately 5 oz/ft²/10yrs, or 0.5 oz/ft²/yr. This figure was developed from the results of the NBS studies in addition to similar field experimentation results as presented in the Proceedings, Eighth International Ash Utilization Symposium, Volume 2, American Coal Ash Association, Washington, DC, 1987.

The Federal Highway Administration (FHWA) has proposed uniform corrosion loss rates based on a simple assessment of the electrochemical index properties. Per FHWA-RD-89-198, the ground is considered aggressive if any one of the critical indicators in Table A-3 shows critical values.

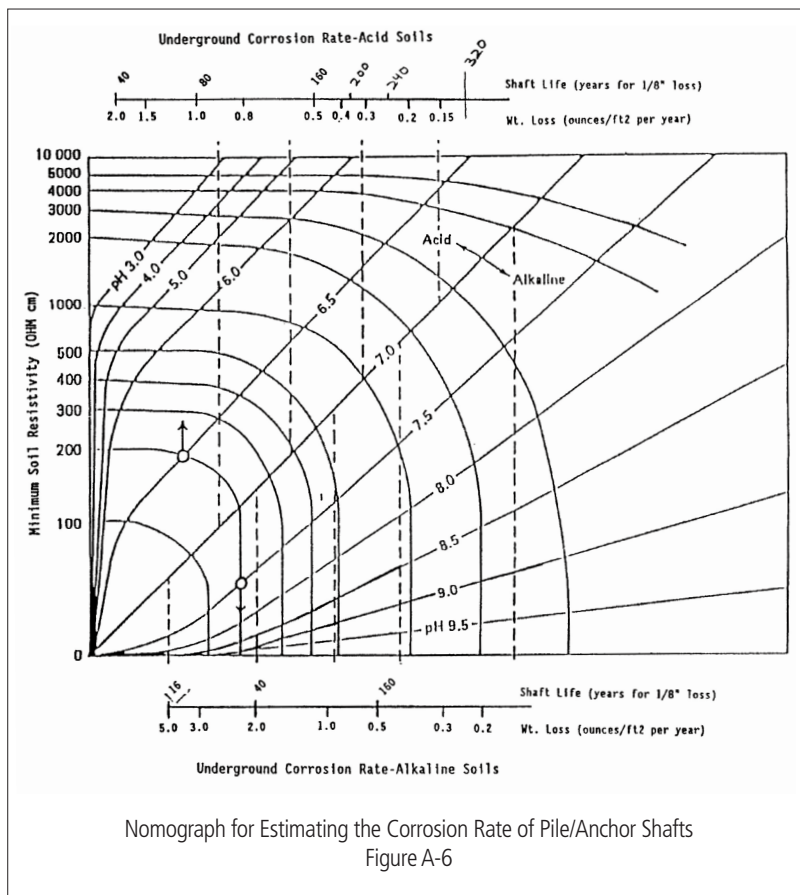
CORROSION

Electromechanical Properties of Mildly Corrosive Soils, Table A-3

PROPERTY	TEST DESIGNATION	CRITERIA
Resistivity	AASHTO T-288-91	> 3000 ohm/cm
pH	AASHTO T-289-91	>5 < 10
Sulfates	AASHTO T-290-91	200 ppm
Chlorides	AASHTO T-291-91	100 ppm
Organic Content	AASHTO T-267-86	1% maximum

The design corrosion rates, per FHWA-SA-96-072, suitable for use in mildly corrosive soils having the electrochemical properties listed in Table A-3 are:

- For zinc:
 - 15 μm/year (0.385oz/ft²/yr) for the first two years
 - 4 μm/year (0.103 oz/ft²/yr) thereafter
- For carbon steel: 12 μm/year (0.308 oz/ft²/yr)



Examples:

- For pH of 6.5 and resistivity of 200 ohms/cm weight loss is approximately 1.3 oz/ft²/yr and expected life (for 1/8" shaft loss) is approximately 65 years.
- For pH of 7.5 and resistivity of 200 ohms/cm weight loss is approximately 2.3 oz/ft²/yr and expected life (for 1/8" shaft loss) is approximately 38 years.

Other methods are available to predict corrosion loss rates. Figure A-6 is a nomograph for estimating the corrosion rate of helical anchor/pile/pier shafts. It is a corrosion nomograph adapted from the British Corrosion Journal (King, 1977). Its appeal is its ease of use. If the resistivity and soil pH are known, an estimate of the service life (defined as 1/8" material loss, for example) of a CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Pier shaft can be obtained for either an acidic or alkaline soil.

CORROSION LOSS RATES

WATER/MARINE ENVIRONMENT

Factors other than resistivity and pH can have a strong influence on corrosion loss rates. It is well known that marine environments can be severely corrosive to unprotected steel, particularly in tidal and splash zones. Corrosion loss rates in these environments can be quite high, averaging 6.9 oz/ft² (Uhlig, Corrosion Handbook, 2000). Salt spray, sea breezes, topography, and proximity all affect corrosion rate. Studies have shown that the corrosion rate for zinc exposed 80 ft (24.4 m) from shore was three times that for zinc exposed 800 ft (244 m) from shore.

Seawater immersion is less corrosive than tidal or splash zones. This is because seawater deposits protective scales on zinc and is less corrosive than soft water. Hard water is usually less corrosive than soft water toward zinc because it also deposits protective scales on the metallic surface. Table A-4 provides corrosion loss rates of zinc in various waters. In most situations, zinc coatings would not be used alone when applied to steel immersed in seawater, but would form the first layer of a more elaborate protective system, such as active protection using sacrificial anodes.

**Corrosion of Zinc in Various Waters (Corrosion Handbook, Volume 13 Corrosion, ASM International),
Table A-4**

WATER TYPE	μ m/yr	mils/yr	oz/ft ²
Seawater			
Global oceans, average	15 - 25	0.6 - 1.0	0.385 - 0.642
North Sea	12	0.5	0.308
Baltic Sea and Gulf of Bothnia	10	0.4	0.257
Freshwater			
Hard	2.5 - 5	0.1 - 0.2	
Soft river water	20	0.8	0.513
Soft tap water	5 - 10	0.2 - 0.4	0.128 - 0.257
Distilled water	50 - 200	2.0 - 8.0	1.284 - 5.130

CORROSION in UNDISTURBED SOIL

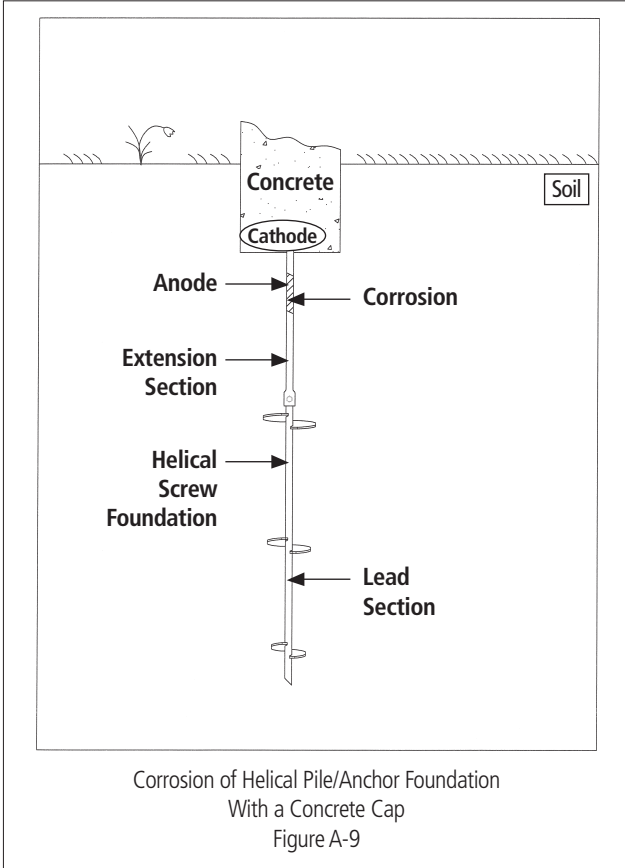
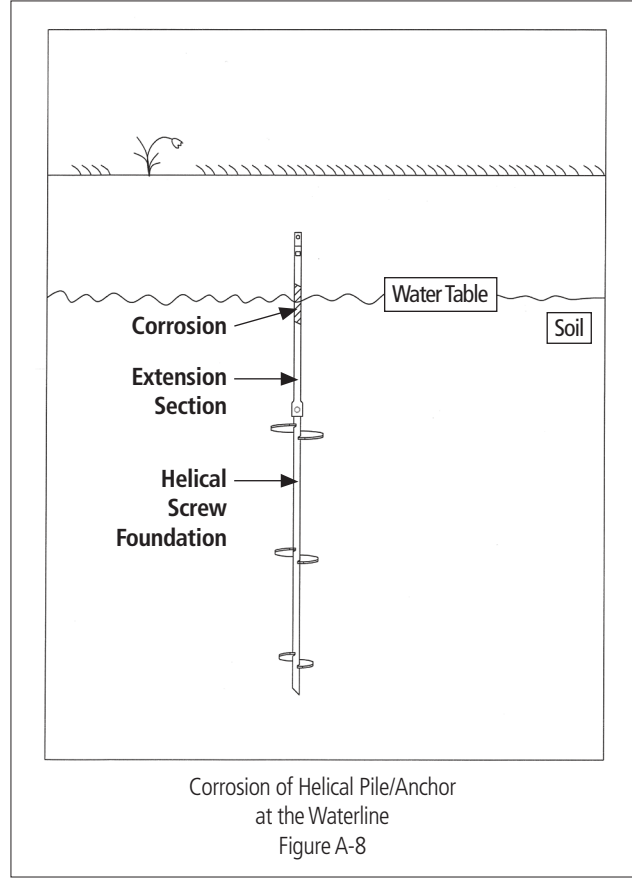
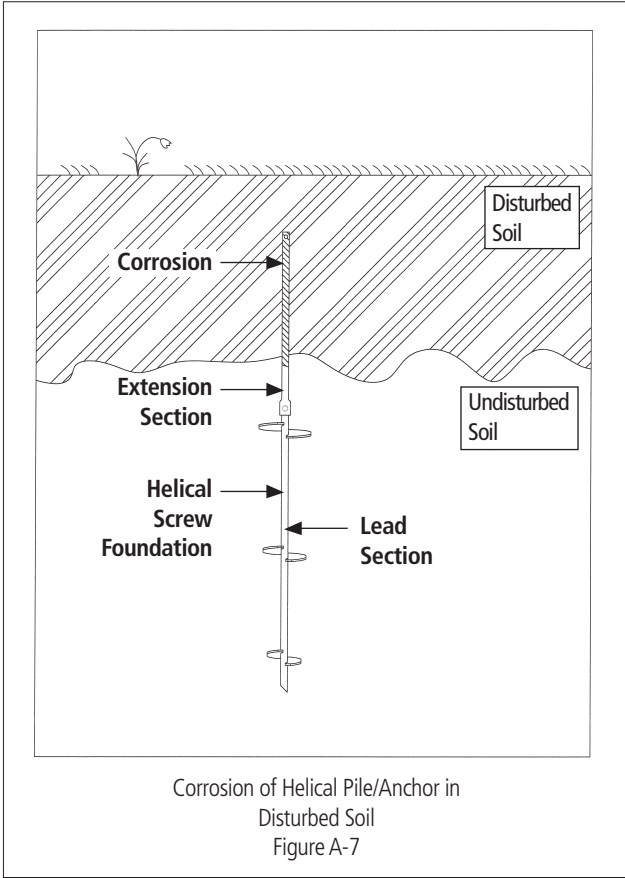
In NBS Monograph 127, (*Underground Corrosion of Steel Pilings*) (Romanoff, 1972), it was reported that driven steel piles did not experience appreciable corrosion when driven into undisturbed soils. These findings were obtained during NBS studies of steel pile corrosion. Romanoff also stated that the NBS corrosion data for steel exposed in disturbed soils was not applicable to steel piles driven in undisturbed soil. He concluded:

“... that soil environments which are severely corrosive to iron and steel buried under disturbed conditions in excavated trenches were not corrosive to steel piling driven in the undisturbed soil. The difference in corrosion is attributed to the differences in oxygen concentration. The data indicates that undisturbed soils are so deficient in oxygen at levels a few feet below the ground line or below the water table zone that steel pilings are not appreciably affected by corrosion, regardless of the soil types or the soil properties. Properties of soils such as type, drainage, resistivity, pH, or chemical composition are of no practical value in determining the corrosiveness of soils toward steel pilings driven underground.”

The following conclusions can be drawn from these studies:

- Oxygen is required at cathodic sites to support underground corrosion of a steel foundation product.
- Disturbed soils (fill) contain an adequate supply of oxygen to support underground corrosion, at least at shallow depths. Thus, the top-most extension(s) of the CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Pier central steel shaft merits corrosion protection, either using passive protection like zinc, epoxy or teflon coatings or active protection like sacrificial anodes.
- The aggressiveness of disturbed soils can be measured, and they can be classified as aggressive and non-aggressive (see Table A-2).
- Undisturbed soils were deficient in oxygen a few feet below the ground surface, or below the water table. It is recommended to install the helical bearing plates of a helical pile/anchor into de-aerated soil.





The role of oxygen in an undisturbed soil overrides the effects of soil resistivity, pH, etc. In those situations where a steel foundation product is installed into a soil profile where a disturbed soil layer overlies undisturbed soil, the section of the central shaft in the disturbed soil is cathodic to the rest of the foundation in the undisturbed region as illustrated in Figure A-7. As a result, the most severe corrosion occurs on the section of the central shaft just below the disturbed layer.

Similarly, a steel foundation product located in undisturbed soil with a high water table can suffer some corrosion attack at the waterline as illustrated in Figure A-8. This combination does not result in serious attack, but it is believed that the situation is aggravated by a continuously changing water table, which would draw in oxygen as the waterline dropped. The section of the central shaft above the waterline acts as a weak cathode to the anode below the waterline.

Helical piles are commonly terminated in concrete cap or grade beams. The area of steel in the concrete forms a passive oxide film generated by the action of the highly alkaline environment, and this area is cathodic to the rest of the helical pile in the soil. However, the high resistivity of the concrete limits the effectiveness of the cathode, thereby limiting the small amount of corrosion attack to the region of the helical pile immediately outside the concrete as illustrated in Figure A-9.

FIELD MEASUREMENT of SOIL RESISTIVITY

Field measurement of soil resistivity is not a difficult or time consuming process and results in the most accurate assessment of corrosion potential for the site. Hubbell Power Systems, Inc. recommends the use of the Nillson Model 400 Soil Resistance Meter System. The depth of the soil resistivity measurement is directly related to the pin spacing on the surface. The most accurate assessment is obtained by performing the test using a pin spacing of 5-20 foot intervals. In addition, the test should be repeated at a right angle to the original test to ensure that stray currents are not influencing the readings.

A. Equipment Set-Up

1. Insert the four sensor pins into the soil in a straight line leading away from the Resistivity Meter at a center-to-center distance of five feet (see Figure A-10).
2. Connect one wire to each pin and to the appropriate terminal on the Nillson meter.

B. Resistivity Measurement

1. Adjust the OHMS resistivity dial and the MULTIPLIER dial to the maximum setting (turned fully to the right) (see Figure A-11).
2. Place the SENSITIVITY switch in the LOW position and rotate the MULTIPLIER dial to the left until the meter needle goes past the NEUTRAL point, then rotate the MULTIPLIER one position to the right. Note the MULTIPLIER (M) amount on the field notes.
3. Move the OHMS dial to the left until the meter needle is at NEUTRAL.
4. Adjust the SENSITIVITY switch to HIGH position and adjust the OHMS dial to refine the reading.
5. Record the reading (R_{meter})
6. Return the OHMS and MULTIPLIER to the maximum settings and repeat the test.
7. Repeat the test with the pins spaced at 10-feet on center, then at 15-feet and 20-feet on center. Record the readings

C. Calculation of Soil Resistivity

$$R = R_{\text{meter}} (M) (\text{WSF})$$

Equation A-2

where: R_{meter} = Meter resistance reading (ohms)

M = Meter MULTIPLIER reading

WSF = Wenner spacing factor = $191.5L$ (ft) = $628L$ (m)

L = Pin spacing

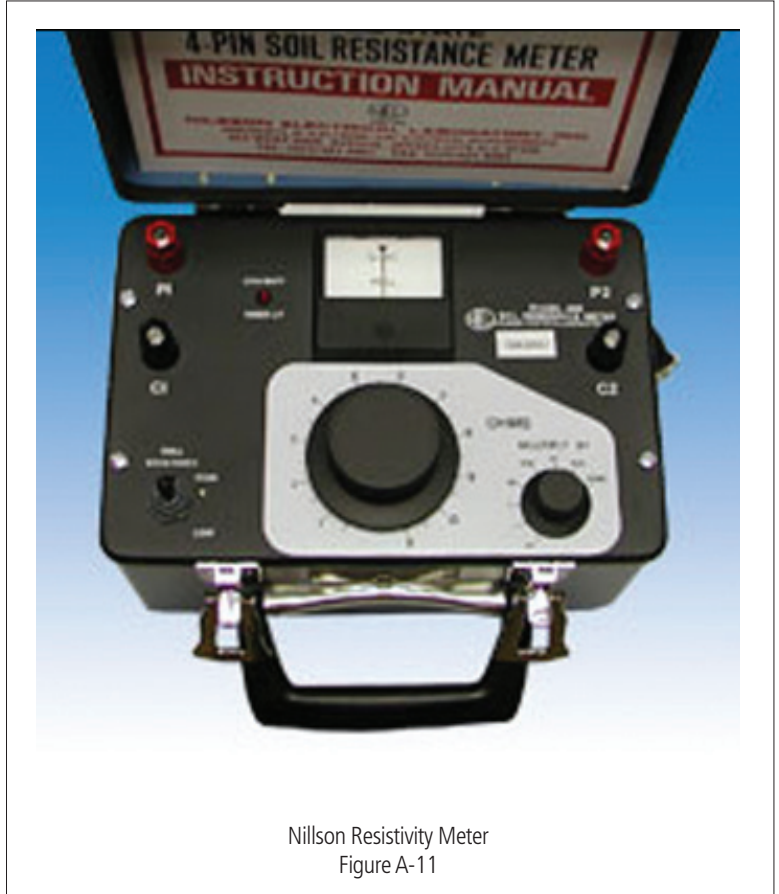
R = Soil resistivity (ohms/cm)

D. Additional Resistivity Measurements

1. The soil resistivity (R) is the average value over the depth of soil equal to the spacing of the pins. Therefore, to get a profile of the soil resistivity one must repeat the procedures in paragraph B above with the pins spaced at 10, 15 and 20 feet on center.
2. Repeat the entire test at right angles to the original alignment.



Sensor Pin Installation
Figure A-10



Nillson Resistivity Meter
Figure A-11

E. Documentation

Record the field data and the calculations onto the Soil Resistivity Log. A sample log is presented below (See Figure A-12).

F. Evaluate Results

When the Soil Resistivity (R) has been determined, refer to Figure A-5 to determine an estimate of the loss of weight by corrosion over a 10-year period for underground bare steel structures.

COMBINED WENNER 4-PIN SOIL RESISTIVITY LOG				
Location:		Job No.		
Date:	Weather Conditions:	Orientation of Pins:		
WENNER METHOD OF SOIL RESISTIVITY				
PIN SPACING (Depth in Feet)	METER RESISTANCE (R _{Meter}) (ohms)	METER MULTIPLIER (M)	WENNER SPACING FACTOR (WSF) (191.5* x Pin Spacing)	SOIL RESISTIVITY R = (R _{Meter}) x M x WSF

* If pin spacing is measured in meters, use WENNER SPACING FACTOR (WSF) of 628 instead of 191.5

Sample Resistivity Log
Figure A-12

CORROSION CONTROL TECHNIQUES

The amount and type of corrosion control is a function of structure type, service life, and the overall aggressiveness of the project soils. The following requirements are typical. The specifier should review and edit as appropriate for the project.

- **Structure Type:** Temporary structures generally do not require corrosion protection. A temporary structure is defined within a specified time frame (i.e., months rather than years). In general, permanent structures have a service life greater than 24 months.
- **Service Life:** A typical service life of 50 to 75 years should be used unless otherwise specified. If the service life of a temporary CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Pier is likely to be extended due to construction delays, it should be considered permanent. For a service life of less than 20 years in non-aggressive soil, corrosion protection is not recommended.
- **Soil:** Soil can be classified as aggressive or non-aggressive. See Guide to Model Specification - Helical Piles for Structural Support and Model Specification - Helical Tieback Anchors for Earth Retention in Appendix C of this Technical Design Manual for examples of aggressiveness classifications. It is recommended that steel foundation elements installed into soils classified as aggressive be provided with some type of corrosion protection.

Several alternatives are available to protect steel foundation products against corrosion and can be roughly categorized in terms of cost. Because of the added cost, the need for corrosion protection must be carefully determined and specified as necessary. Depending upon the classification as to the corrosion potential for a soil environment, several alternatives are available to deter the corrosion cycle and extend the performance life of the underground steel element. These control measures can be split into categories:

- **Passive Control:** For use in soils classified as mild to moderate corrosion potential. It typically consists of a metal loss allowance (i.e., 1/8") and/or coatings – such as galvanization or epoxy. Passive control is relatively inexpensive.
- **Active Control:** For use in soils classified as moderate to severe corrosion potential. It typically consists of cathodic protection via the use of sacrificial anodes. Active control is relatively expensive and is used in permanent applications.

PASSIVE CONTROL

Allowable Metal Loss Rate

As mentioned previously, Hubbell Power Systems, Inc. bulletin 01-9204, Anchor Corrosion Reference and Examples, contains extensive metal loss rate data derived from Romanoff's work. Other metal loss rate data is presented on pages A-8 through A-12. The design examples at the end of this section demonstrate passive control calculations that estimate the service life of helical pile shafts in soil using these metal loss rates. Design Example 1 uses the metal loss rates from Romanoff (Bulletin 01-9204). The service life is defined as the estimated length of time required for 1/8" of material loss to occur on the helical pile/anchor shaft. Design Example 2 uses the metal loss rates from Figure A-5 in conjunction with Equation A-2. The service life in this example is defined as the estimated length of time required for a 10% material loss to occur on the helical pile shaft. Design Example 3 uses the design corrosion rates per FHWA-SA-96-072 (as quoted here on page A-8) and an assumed service life of 85 years.

The amount of loss in these design examples is strictly arbitrary, but the assumed material loss of 1/8" in Design Example 1 is common for pile evaluation.

Galvanization (Passive Control)

Aggressive soils, and the conditions illustrated in Figures A-7, A-8, and A-9 demonstrate the need to coat the section of the steel foundation product above the waterline in the disturbed soil and, in particular, the area of the central shaft in the concrete cap or grade beam. Thus, by removing the cathode, the anode/cathode system is disrupted resulting in reduced corrosion. If it were possible to apply a coating capable of guaranteed isolation of the steel surface from the electrolyte (soil), all corrosion concerns would be solved. However, a coating capable of 100% guaranteed isolation has yet to be developed. Epoxy coatings provide excellent electrical isolation, but will chip and abrade easily during handling and installation. The same holds true for

CORROSION

porcelain, teflon, and polyurethane coatings. A small chip or crack in the protective coating can cause corrosion activity to be highly localized, possibly leading to severe damage. **The single best coating for steel foundation products is hot dip galvanizing.**

The first step in the galvanizing process is pickling the steel in dilute acid. This removes any rust, scale, oil or other surface contaminants. The clean steel is then dipped in a vat of molten zinc for time periods ranging up to several minutes for the more massive steel foundations. After the hold period, the zinc-coated steel is withdrawn from the vat at a controlled rate, which allows the coating to quickly cool and harden. The result is a tough, combined zinc and zinc-iron coating which metallurgically bonds to the steel. Other galvanization processes, such as mechanical galvanizing and electroplating, do not form a coating that is metallurgically bonded to the steel.

Hubbell Power System, Inc. galvanizes to the latest ASTM standards – either ASTM A153 class B or ASTM A123. ASTM A153 Class B requires an average weight of zinc coating to be 2.0 oz./ft² (3.4 mils) and any individual specimen to be no less than 1.8 oz./ft² (3.1 mils). ASTM A123 can be used to specify thicker zinc coatings – up to 2.3 oz./ft² (3.9 mils) depending on the coating thickness grade used. Regardless of which ASTM galvanizing specification is used, typical zinc coating thickness for hot-dip galvanized CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Piers ranges between 4 and 6 mils.

CORROSION

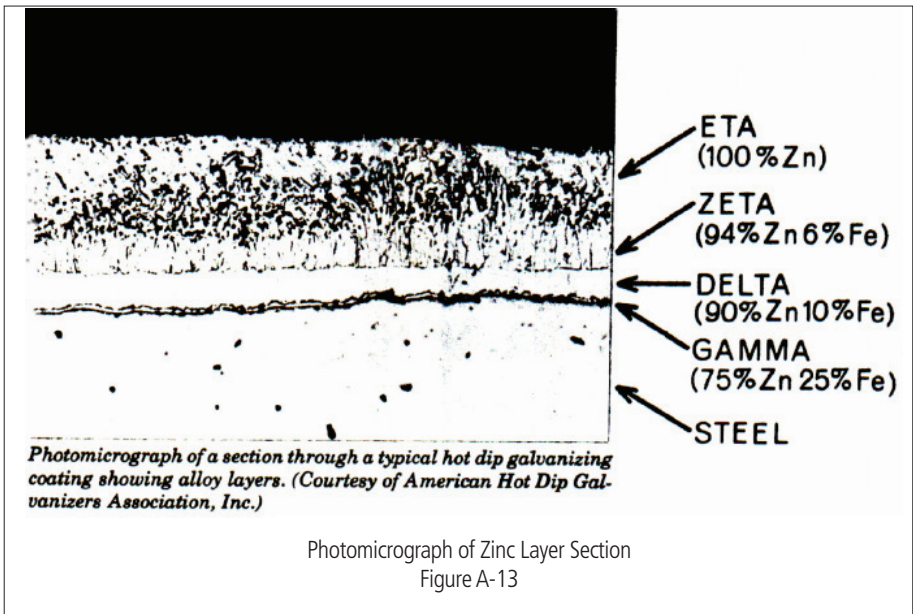


Figure A-13 illustrates how zinc and steel react to form zinc-iron alloy layers. The bottom of the picture shows the base steel, then a series of alloy layers and, on the outside, the relatively pure outer zinc layer. The underlying zinc-iron alloy layers are actually harder than the base steel. Therefore, below the relatively soft pure zinc layer, the zinc-alloy layers provide protection in abrasive conditions such as dense sands and gravels.

Hot dip galvanized coatings protect the carbon steel shaft in two ways. First, the zinc coating provides a protective layer between the foundation's central shaft and the environment. Second, if the zinc coating is scratched and the steel surface exposed, the zinc, not the steel, will corrode. This is because zinc is a dissimilar metal in electrical contact with the steel, thus the difference in potential between the two metals and their relative chemical performance (anode or cathode) can be judged by examining a galvanic series as shown in Table A-5. The materials at the top of the list are most active (anodic) compared to the noble (cathodic) materials at the bottom of the list. Steel is more noble than zinc, thus the more active zinc coating will act as an anode and corrode while the more noble steel will be the cathode and be protected.

Service Life Increase Through Galvanization

Hubbell Power Systems, Inc. bulletin 01-9204, Anchor Corrosion Reference and Examples, contains extensive metal loss rate data on galvanized steel derived from Romanoff's work. It is recommended that this information be used to determine the service life of the hot dipped galvanized coating in disturbed soil. When hot-dip galvanized steel is used, the total service life should be increased by the time it takes the zinc coating to be lost due to corrosion. Another method for estimating service life increase is presented in the following paragraphs.

The results of the studies conducted by the National Bureau of Standards and by Porter indicated that a galvanized coating (zinc) was effective in delaying the onset of corrosion in the buried steel structures. Typical conclusions drawn from this study for 5 mil (3 oz/ft²) galvanized coatings include:

- It is adequate for more than 10 years corrosion protection for inorganic oxidizing soils.
- It is adequate for more than 10 years corrosion protection for inorganic reducing soils.
- It is insufficient for corrosion protection in highly reducing organic soils (pH<4), inorganic reducing alkaline soils and cinders, typically offering 3 to 5 years of protection in such cases.

It was also noted, however, that the use of a galvanized coating significantly reduces the rate of corrosion of the underlying steel structure once the zinc coating was destroyed.

The observed rates of corrosion for the galvanized coating were different (less) than that for bare steel in the NBS study. For galvanized coatings (zinc) of 5 mils, Equation A-3 can be used to estimate the corrosion (weight loss) rate.

$$\begin{aligned}
 CL_1 &= 0.25 - 0.12 \log_{10} (R/150) && \text{Equation A-3} \\
 CL_1 &= \text{Weight loss (oz/ft}^2\text{/yr)} \\
 R &= \text{Soil resistivity (ohms/cm)}
 \end{aligned}$$

NOTE: For thinner galvanized coatings, the rate of galvanized coating loss is two to three times the rate determined from Equation A-3.

Manufactured Metallic Coating (Passive Control)

Hubbell Power Systems, Inc. provides triple coat corrosion protection as a standard feature on the 3-1/2" diameter by 0.165" wall (3500.165 series) ATLAS RESISTANCE® Pier pipe and as an optional feature on the 2-7/8" diameter 0.165 wall (2875.165 series) ATLAS RESISTANCE® Pier pipe. The triple coating consists of:

- Hot-dipped uniform zinc galvanizing
- Chromate conversion coating
- Clear organic polymer coating

The triple coating can significantly reduce the corrosion process by mechanically preventing access of oxygen to the steel surface of the pipe. Data from the manufacturer indicates that this corrosion protection is equivalent to 3 mil (1.8 oz/ft²) of hot dip galvanizing. Because of the thinness of this film and possible scratching of the coating, this corrosion protection technique should not be used in soils classified as severe.

Galvanic Series in Seawater, Table A-5

ACTIVE PASSIVE	Magnesium
	Zinc
	Beryllium
	Aluminum Alloys
	Cadmium
	Mild Steel, Cast Iron
	300 Series Stainless Steel (Active)
	Aluminum Bronze
	Naval Brass
	Tin
	Copper
	Lead-Tin Solder (50/50)
	90-10 Copper Nickel
	Lead
	Silver
	300 Series Stainless Steel (Passive)
	Titanium
	Platinum
	Graphite

Bituminous and Other Coatings (Passive Control)

Bituminous as well as other materials have been used as coatings on buried steel elements for years as a corrosion protection technique. The primary requirements of a bituminous coating are good adherence (permanence), continuous coating and resistance to water absorption. The bituminous coating can either be heat baked onto the shaft or field applied just prior to installation. As is the case for the manufactured coatings, this coating technique prevents oxygen and water from contacting the metal surface, thus preventing or retarding the corrosion process.

Bituminous or asphaltic coatings or paints only provide physical protection from the environment. They will wear off quickly due to the abrasive action during installation of CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Piers. Extension sections are typically hot-dip galvanized, but other coatings can be specified. Practical application of asphaltic coatings is generally limited to the extension sections located at or near the surface where the coating will provide the greatest benefit. Bituminous and other coatings are best applied in severely corrosive conditions where part of the helical anchor/pile is exposed above grade. Examples are steel foundations used in tidal marshes, coastal regions, and contaminated soils.

A limited amount of available data indicates that bituminous coatings can extend the performance life of underground steel piles and piers by 5 to 15 years, depending on the soil environment and the thickness of the coating. For the vast majority of CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Pier applications, the use of coating techniques (galvanized and/or bituminous) will provide a sufficiently long-term solution for corrosion protection.

Cathodic Protection (Active Control)

As indicated previously, corrosion is an electrochemical process that involves a flow of direct electrical current from the corroding (anodic) areas of the underground metallic structure into the electrolyte and back onto the metallic structure at the non-corroding (cathodic) areas. In situations where metallic structures such as Hubbell Power Systems, Inc. foundation products are to be placed in a severe corrosive soil environment, an active corrosion control technique should be used. This active control technique is termed cathodic protection. Cathodic protection is a method of eliminating corrosion damage to buried steel structures by the application of DC current. The effect of the DC current is to force the metallic surface to become cathodic (i.e., collecting current). If the current is of sufficient magnitude, all metallic surfaces will become cathodic to the external anode.

Both sacrificial anode and impressed current (rectifier and ground bed) cathodic protection systems are used to provide the required current. If the current source is derived from a sacrificial metal (magnesium and zinc are the two most common galvanic anodes used in soils), the effectiveness will depend on the soil properties in which it is placed. More available current is generated from a sacrificial anode in low resistance soils than high resistance soils. It is also best to place impressed current anode beds in lower resistant soils. However, since the available driving potential is greater (rectifier control), the soil resistivity is less significant.

Current requirements needed to protect a steel structure from corrosion will vary due to physical and environmental factors. These requirements could range from 0.01ma/ft² of metal surface for a well-applied, high-dielectric-strength plastic coating to 150 ma/ft² for bare steel immersed in a turbulent, high velocity, salt-water environment. In soil, 1 to 3 ma/ft² is typically used as the required current to protect carbon steel.

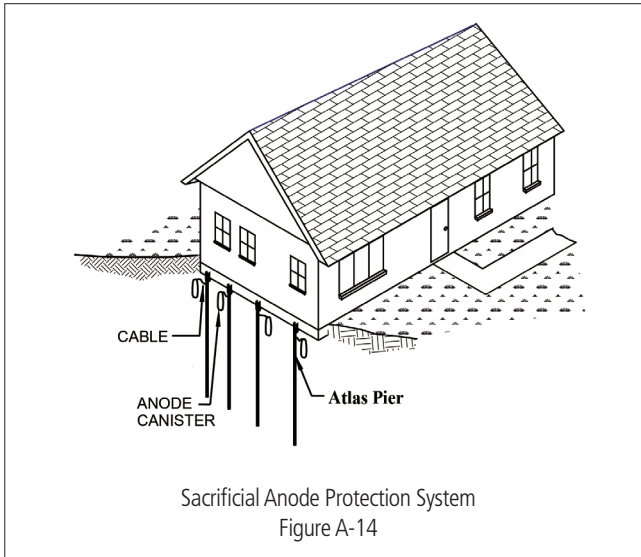
The basic principle in cathodic protection is to apply a direct current of higher electromotive potential than that generated by the corroding metallic structure, thus effectively eliminating the corrosion process.

Sacrificial Anodes (Active Control)

In the case of CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Piers, sacrificial anodes are the most common method of cathodic protection used. This is done by electrically connecting the steel to a properly selected anode of a less noble metal such as zinc or magnesium. The dissimilar metals buried in a common electrolyte (soil) form a galvanic cell. The cell works much like the battery in the family car; the less noble anode corrodes or sacrifices itself while the more noble cathode is protected. For steel to be cathodically protected, it is generally recognized that at least one of the following conditions must be met:

- The potential of the steel must be at -0.85 volts or more negative with respect to a saturated copper-copper sulfate half-cell in contact with the electrolyte, or
- A potential shift of -0.3 volts or more negative upon connection of the cathodic protection.

Magnesium, zinc and aluminum are the most commonly used galvanic sacrificial anodes. The sacrificial anode (galvanic) is attached to each underground metallic structure by a metallic conductor (cable) and placed within the common electrolyte (soil medium). The sacrificial anode works best when a small amount of current is needed and/or when the soil resistivities are low. Anodes are installed normally 3 feet below the surface and 3 to 7 feet from the CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Pier.



In designing and using sacrificial anode systems, the soil profile conditions as to the type of soil, resistivities, soil pH and location of the ground water table (GWT), if present, must be determined. Among the design considerations for the system:

- Use of wire type or canister type anode
- Selection of the appropriate anode material (magnesium, titanium, etc.)
- Designing the ground bed (location, dimensions, horizontal vs. vertical, depth of placement, type of backfill, etc.)
- Determining the number of piles/piers per anode
- Type, size and connections between pile(s) and the sacrificial anode.

The application of cathodic protection using galvanic sacrificial anode bags to underground metallic structures offers the following advantages:

- No external power supply required
- Low system cost (bags and installation)
- Minimum maintenance costs

CATHODIC PROTECTION PRODUCTS


Hubbell Power Systems, Inc. recommends a selection of magnesium anodes (9, 17, 32, and 48-pound bag sizes) for cathodic protection of foundation support systems. Cathodic protection is generally used to extend the life of a steel product in corrosive soil beyond the added life available by hot dip galvanizing the components. While it is possible to protect mill finish steel, the engineer usually calls for the cathodic protection in addition to zinc galvanizing.

FACTORS INFLUENCING ANODE OUTPUT:

- **Soil Resistivity:** Current output from the magnesium anode increases as the soil resistivity decreases. Therefore, magnesium anodes are usually specified in applications where the soil resistivity is 5,000 ohms/cm or less. The effectiveness of this type of cathodic protection decreases as the resistivity increases above 5,000 ohms/cm. Above 10,000 ohms/cm resistivity, magnesium anodes are not effective.

- Anode Surface Area: The amount of current output generated by an anode is directly proportional to the surface area of the anode. Different manufacturers of cathodic protection produce anodes with different surface areas. Just because magnesium anodes from different manufacturers weigh the same is not to be assumed that the current output will be the same. The data presented here is representative for the products identified here.
- Alloy Potential: H-1 magnesium alloy has an open circuit potential of -1.53 to -1.55 volts, which works well with vertically installed foundation support systems. High potential anodes are available from other sources. These high cost, high potential anodes are generally used along horizontal pipelines where the higher potential produced by the anode translates to fewer anodes being required. Table A-5 provides estimates of current output from a single, standard potential H-1 magnesium alloy anode as related to soil resistivity.

Magnesium Anodes, Table A-5

	MAGNESIUM ANODES TYPE H-1 STANDARD POTENTIAL MAGNESIUM			
	Item No	Magnesium Weight	Package Size	Unit Weight
	PSA4438	9 lb.	6" Dia. x 17" Tall	27
	PSA4439	17 lb.	6-1/2" Dia. x 24" Tall	45
	PSA5106	32 lb.	8" Dia. x 28" Tall	72
	PSA4440	48 lb.	8" Dia. x 38" Tall	100

MAGNESIUM ANODE CURRENT OUTPUT – mA					
Resistivity – ohm-cm	1,000	2,000	3,000	4,000	5,000
9# Anode	106.5	53.3	35.5	26.6	21.3
17# Anode	150	75	50	37.5	30
32# Anode	159	79.5	53	39.8	31.8
48# Anode	163.5	81.8	54.5	40.9	32.7

Design Example 4 at the end of this section provides a method for estimating the service life of a sacrificial magnesium anode. For additional information on anode selection, refer to Hubbell Power Systems, Inc. bulletin 2-8307, Cathodic Protection of Anchors – A Basic Guide to Anode Selection and Hubbell Power Systems, Inc. bulletin 01-9204, Anchor Corrosion Reference and Examples.

Impressed Current (Active Control)

In areas of the most severe corrosion potential, where a larger current is required and/or in high resistance electrolytes, an impressed current system is generally recommended which requires a power source, rectifier and a ground bed of impressed current anodes. These systems require a continuous external power source.

The majority of applications where Hubbell Power Systems, Inc. foundation products may be specified will not require an active corrosion protection system. In those cases where the combination of soil and electrolyte conditions requires an active system, the sacrificial anode protection system will likely be the most economical approach.

Active cathodic protection systems must be individually designed to the specific application. The major variables are soil moisture content, resistivity of soil and pH. Each of these items influences the final selection of the cathodic protection system. Typical design life for the cathodic protection is 10 to 20 years, depending upon the size and length of the anode canister.

CORROSION

DESIGN EXAMPLES

Design Example 1:

- Project: Santa Rosa, CA Residence

The purpose of the calculations is to estimate the service life of Type SS Helical Pile Shafts on the subject project. Service life is defined as the estimated length of time required for 1/8" of material loss to occur on the helical pile shaft. This amount of loss is strictly arbitrary, but is common for pile evaluation.

- Given:

Helical piles galvanized to ASTM A153 (Minimum Zinc Coating = 1.8 oz/ft²)

Soil resistivity is 760 ohms/cm minimum

Soil pH - 7.70

Water soluble chloride – 11 ppm

Water soluble sulfate – 417 ppm

- Assumptions:

It is assumed that the material loss rates will be similar to the loss rates found at test sites with similar pH and resistivity levels as given in Romanoff's Underground Corrosion, NBS Circular #579 (1957), Tables 6, 8 and 13.

In Circular #579, Site #5 is indicated as having a resistivity of 1,315 ohms/cm and a pH of 7.0. This soil is Dublin Clay Adobe and is located around Oakland, California. In addition, Site #2 is indicated as having a resistivity of 684 ohms/cm and a pH of 7.3. This soil is Bell Clay and is located around Dallas, Texas. The corrosion rates for these two sites will be used to estimate the life of the Type SS helical pile shaft material.

- Allowable Steel Loss:

Based on the loss of 1/8" thickness of the helical pile shaft, calculate the allowable steel loss (ASL) in terms of weight per unit area:

$$\begin{aligned}
 \text{ASL} &= (0.125 \text{ in}) (0.283 \text{ lb/in}^3) (16) \\
 &= (0.566 \text{ oz/in}^2) (144 \text{ in}^2/\text{ft}^2) \\
 &= 81.5 \text{ oz/ft}^2
 \end{aligned}$$

- Average Metal Loss per Year:

From Site #5: (Dublin Clay Adobe)

EXPOSURE DURATION (years)	WEIGHT LOSS (oz/ft ²)	LOSS PER YEAR (oz/ft ²)
1.9	1.4	0.737
4.1	2.2	0.585
6.2	4.8	0.774
8.1	5.2	0.642
12.1	5.4	0.446
17.5	8.3	0.474

The average metal loss per year is 0.61 oz/ft². Note that as the duration of exposure increases, the material loss per year generally decreases.

- Pile Shaft Life:

To determine the pile shaft service life (SL), the allowable steel loss is divided by the average loss per year:

$$\begin{aligned} \text{SL} &= (81.5 \text{ oz/ft}^2) / (0.61 \text{ oz/ft}^2) \\ &= 133.6 \text{ years} \end{aligned}$$

- Total Zinc Coating Loss:

CHANCE® Helical Piles/Anchors are typically provided already hot dip galvanized per ASTM A153. The coating thickness for ASTM A153 class B = 1.8 oz/ft². From Romanoff, NBS Circular #579, Page 110, Table 65 gives the following average loss rates for Site #5 soils:

EXPOSURE DURATION (years)	WEIGHT LOSS (oz/ft ²)	LOSS PER YEAR (oz/ft ²)
10.17	2.66	0.262

- Estimated Life of Zinc: $1.8 \text{ oz/ft}^2 / 0.262 \text{ oz/ft}^2 = 6.9 \text{ years}$
- Total Estimated Service Life of Helical Pile Shaft: $133.6 + 6.9 = 140.5 \text{ years}$
- From Romanoff Site #2 (Bell Clay):

EXPOSURE DURATION (years)	WEIGHT LOSS (oz/ft ²)	LOSS PER YEAR (oz/ft ²)
2.1	2.4	1.143
4.0	3.0	0.750
5.9	3.4	0.576
7.9	3.6	0.456
12.0	5.9	0.492
17.6	8.1	0.460

The average loss per year is 0.65 oz/ft². Note that as the duration of exposure increases, the material loss per year generally decreases.

- Helical Pile Shaft Life:

To determine the helical pile shaft's service life (SL), the allowable steel loss is divided by the average loss per year.

$$\begin{aligned} \text{SL} &= (81.5 \text{ oz/ft}^2) / (0.65 \text{ oz/ft}^2) \\ &= 125.4 \text{ years} \end{aligned}$$

- Total Zinc Coating Loss:

CHANCE® Civil Construction helical anchors/piles are already provided hot dip galvanized per ASTM A153. The coating thickness for ASTM A153 class B = 1.8 oz/ft². From Romanoff, NBS Circular #579, Page 110, Table 65 gives the following average loss rates for site #2 soils.

EXPOSURE DURATION (years)	WEIGHT LOSS (oz/ft ²)	LOSS PER YEAR (oz/ft ²)
9.92	0.44	0.044

- Estimated Life of Zinc: $1.8 \text{ oz/ft}^2 / 0.044 \text{ oz/ft}^2 = 40.9 \text{ years}$
- Total Estimated Service Life of Helical Pile Shaft: $125.4 + 40.9 = 166.3 \text{ years}$

CORROSION

- Summary:

Total estimated service life of helical pile shaft in Site #5 soils = 140.5 years

Total estimated service life of helical pile shaft in Site #2 soils = 166.3 years

These calculations are an estimate of the service life only (1/8" material loss from shaft) and are based upon loss rates obtained from Romanoff's disturbed soil sites. It is generally accepted that the majority of any corrosion will occur at or near the surface. Therefore, it is very likely that helical pile shaft metal loss will control the design. In the event the estimated service life does not meet the design requirements, one option is to use a larger sized helical pile shaft.

Design Example 2:

- Project: An access bridge designed to cross a wetland area.

The purpose of the calculations is to estimate the service life of Type RS3500.300 Helical Piles on this project. The service life is defined as the estimated length of time required for a 10% metal loss to occur to the helical pile shaft.

- Given:

1. Helical Piles will receive a hot dipped galvanized coating (G) of 5-mil thick (3-oz/ft²)
2. Soil Resistivity (R) – 1,000 ohms/cm
3. Soil pH – 6.0
4. Soil type – organic silt in top 10' with SPT blow counts of 2 to 4 blows per foot.

- Assumptions:

1. The metal loss rates will be based on the values given in Figure A-5 with a pH of 6.0 and a resistivity of 1,000 ohms/cm. These values place the organic silt in the severe corrosion environment region.
2. The galvanized coating loss rates will be based on Equation A-3 as shown on page A-17.

- Estimated Life of Galvanized Coating:

To estimate average life for galvanized coating in a location with a soil resistivity of 1000 ohms/cm, Equation A-3 is used:

$$\begin{aligned}
 CL_1 &= 0.25 - 0.12 \log_{10} (R/150) \\
 &= 0.25 - 0.12 \log_{10} (1000/150) \\
 &= 0.25 - 0.12 (0.824) \\
 &= 0.15 \text{ oz/ft}^2/\text{yr}
 \end{aligned}$$

where: CL_1 = Weight loss per year

The estimated life of the galvanized coat is:

$$\begin{aligned}
 L_1 &= G/CL_1 && \text{Equation A-4} \\
 &= (3 \text{ oz/ft}^2) / (0.15 \text{ oz/ft}^2) \\
 &= 20 \text{ years}
 \end{aligned}$$

where: G = Amount of galvanized coating = 3.0 oz/ft² for typical hot dipped galvanized coating (5 mil)
 L_1 = Life expectancy (yrs)

- Estimated Life of of Steel:

The formula for estimating average life for loss in steel wall thickness is given in Equation A-5 below:

$$L_2 = W_s / K_2 \quad \text{Equation A-5}$$

where:

- L_2 = Life expectancy (yrs)
- W_s = Weight of steel pile (oz/ft²)
- K_2 = Loss in weight by corrosion (oz/ft²/yr) as determined from Figure A-5

Reference to Figure A-5 indicates a corrosion weight loss range for bare steel of approximately 3 to 10 oz/ft² for a 10-year period. In this case (also checking the NBS data) an estimate was used of 8 oz/ft² for 10 years. Therefore $K_2 = 8.0 \text{ oz/ft}^2$ per 10 years or $0.8 \text{ oz/ft}^2/\text{year}$.

A 10% weight loss of the wall thickness of the steel for the RS3500.300 pile results in:

$$W_s = 0.1 (0.300 \text{ in}/12 \text{ in}/\text{ft}) (489.6 \text{ lb}/\text{ft}^3) (16 \text{ oz}/\text{lb}) = 20 \text{ oz}/\text{ft}^2$$

The estimated additional life becomes:

$$L_2 = W_s / K_2 = (20 \text{ oz}/\text{ft}^2) / (0.8 \text{ oz}/\text{ft}^2/\text{yr}) = 25 \text{ yrs}$$

- Life Estimate Summary (Galvanized Steel Round Shaft):

Based upon the assumptions, the results of this analysis indicate that the CHANCE® Type RS3500.300 helical pile as specified for the bridge foundation will experience an average 40 to 45 year estimated life.

Design Example 3:

Extendable helical piles/anchors consist of segmented elements that are coupled together with structural bolts. It is possible for coupling bolts to be located near the surface in disturbed soils. Therefore, it is recommended that the coupling bolt service life be calculated based on corrosion loss rates. This can be accomplished using methods similar to those shown in Design Example 1.

- Determine the diameter reduction of Type SS5/150 coupling bolts using corrosion loss rates per FHWA-SA-96-072. Type SS5/150 Helical Piles/Anchors use 3/4" diameter bolts per ASTM A325. Assume a service life of 85 years.

- Total Zinc Coat Loss:

Hubbell Power Systems, Inc. provided fasteners are hot dip galvanized per ASTM A153. The coating thickness for ASTM A153 class B = $1.8 \text{ oz}/\text{ft}^2$.

Zinc loss the first two years: $= 0.385 \text{ oz}/\text{ft}^2/\text{year} \times 2 \text{ years} = 0.77 \text{ oz}/\text{ft}^2$

Estimated life of zinc coating = $[1.8 \text{ oz}/\text{ft}^2 - 0.77 \text{ oz}/\text{ft}^2 = 1.03 \text{ oz}/\text{ft}^2 / 0.103 \text{ oz}/\text{ft}^2 = 10 \text{ years}] + 2 \text{ years} = 12 \text{ years}$

- Total Steel Loss:

Coupling bolt steel loss will occur after the zinc coating is lost. The exposure time to corrosion for the bolt steel is: $85 \text{ years} - 12 \text{ years} = 73 \text{ years}$.

Bolt steel loss over 73 years: $= 0.308 \text{ oz}/\text{ft}^2/\text{year} \times 73 \text{ years} = 22.5 \text{ oz}/\text{ft}^2$

$22.5 \text{ oz}/\text{ft}^2 / 144 \text{ in}^2/\text{ft}^2 \times 16 \text{ oz}/\text{lb} \times 0.283 \text{ lb}/\text{in}^3 = 0.035" (0.9 \text{ mm})$

Diameter reduction after 85 years is $0.75" - 2 \times 0.035" = 0.68" (17.3 \text{ mm})$

CORROSION

- Determine the tensile load capacity reduction of Type SS5/150 Coupling Bolts: The minimum ultimate tensile strength for CHANCE® Type SS5/150 Helical Piles/Anchors is 70 kip. The failure mechanism is double shear of the coupling bolt. Assuming a linear relationship between diameter and shear capacity, the bolt diameter reduction from an 85-year exposure per FHWA-SA-96-072 corrosion loss rates suitable for use in mildly corrosive soils will result in a reduced tension load capacity, i.e., $0.68 \times 70/0.75 = 63.5$ kips.

Design Example 4:

1. Estimated Average Life of Sacrificial Magnesium Type Anode:

The formula for estimating average life for sacrificial magnesium anode life is given in Equation A-6 below:

	L_3	=	$[57.08 (K_3) (W_a)] / I$	Equation A-6
where:	L_3	=	Life expectancy of magnesium or zinc anode (yrs)	
	K_3	=	Efficiency of anode bag (60%-70%)	
	W_a	=	Weight of anode (lbs)	
	I	=	Current output of anode (mA). Available from Table A-5 for CHANCE® Civil Construction supplied anodes or from the vendor when using other anodes.	

NOTE: Equation A-6 is not unit consistent.

Assume that in the previous Design Example 2, the pile performance life is to be further extended (beyond 40 to 45 years) by use of a 48-pound magnesium sacrificial anode for each pile. For this size bar and soil resistivity condition ($R = 1000$ ohms/cm), the vendor indicates $I = 163.5$ mA and $K = 65\%$. Therefore, Equation A-12 becomes:

$$\begin{aligned}
 L_3 &= [57.08 (0.65) (48)] / 163.5 \\
 &= 11 \text{ yrs}
 \end{aligned}$$



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18. Winterkorn, Hans F., and Hsai-Yang Fang, Foundation Engineering Handbook, Van Nostrand Reinhold Company, New York, NY, 1962.
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CORROSION



CORROSION





LOAD TESTS



LOAD TESTS APPENDIX B

CONTENTS

STATIC LOAD TESTS (TIEBACKS)	B-3
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SYMBOLS USED IN THIS SECTION

FS	Factor of Safety	B-3
P_T	Test Pressure	B-3
DL	Design Load	B-3
A	Effective Cylinder Area	B-3
AL	Alignment Load	B-4
ASTM.....	American Society for Testing and Materials	B-6
D	Diameter	B-6

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

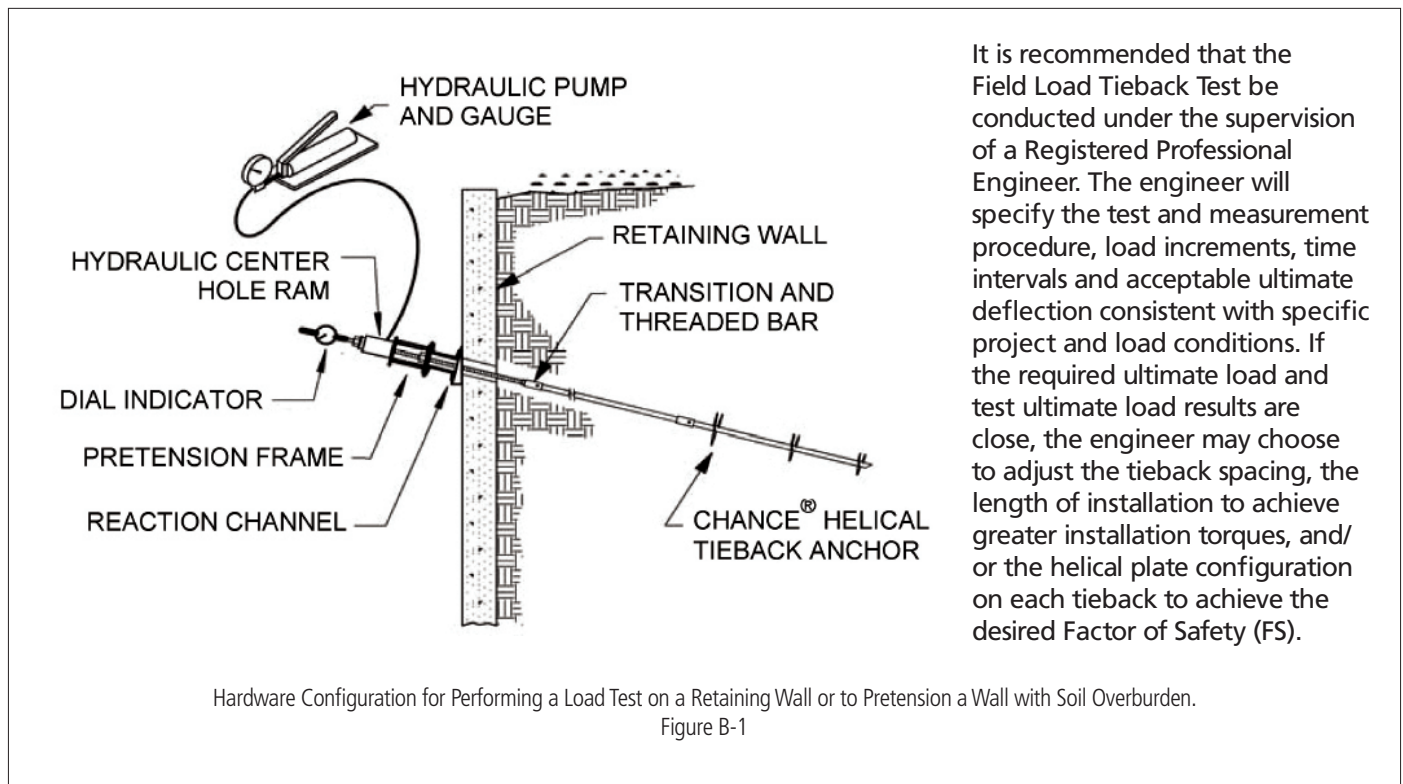
Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

Hubbell Power Systems, Inc., shall not be responsible for, or liable to you and/or your customers for the adoption, revision, implementation, use or misuse of this information. Hubbell, Inc., takes great pride and has every confidence in its network of installing contractors and dealers.

Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

STATIC LOAD TESTS (TIEBACKS)



TEST PROCEDURE

WARNING! DO NOT ALLOW ANYONE TO STAND BEHIND OR IN LINE WITH THE THREADED BAR AND JACK DURING THIS TEST. SERIOUS INJURY MAY OCCUR IF A COMPONENT FAILS DURING TESTING.

1. Determine the required length of the helical tieback anchor to locate the helix plates into the target soil stratum as determined from the project boring logs. Use this data to select the tieback design and ultimate tension capacity and the estimated installation torque. Install the helical tieback anchor to the determined length and torque requirements.
2. If the soil overburden has not been excavated from behind the wall, connect the thread bar adapter/transition to the helical tieback by reaching through the hole in the wall. Install the continuously threaded bar, reaction channel, hydraulic ram (loading device), pretension frame (if required), dial indicator (or other measuring device such as Total Station Unit), hydraulic pump and gauge (see Figure B-1). The magnitude of the test pressure is determined as follows:

$$P_T \text{ (test pressure) psi} = \frac{DL \text{ (design load) lbs} \times FS \text{ (Factor of Safety} = 1.25 \text{ to } 2.5)}{A \text{ (effective cylinder area) in}^2}$$

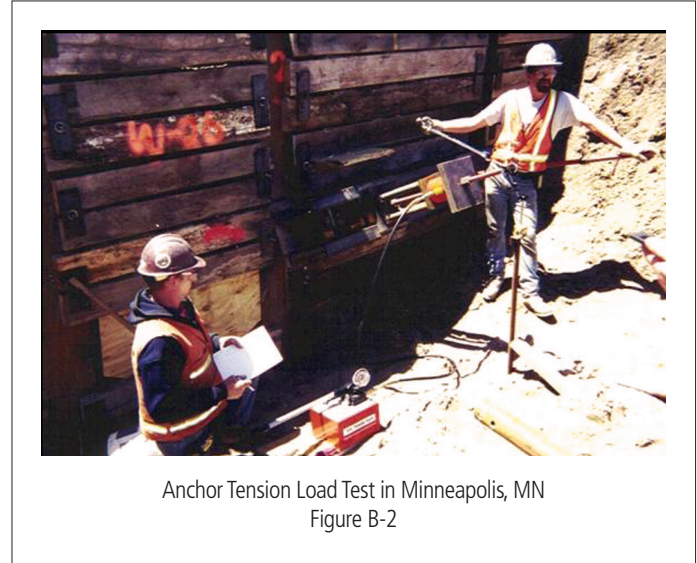
NOTE: The effective cylinder areas (A) are available from the manufacturers of center hole rams (i.e., Enerpac, Power Team, Simplex, etc).

The load application system, i.e., center hole ram and pump, shall be calibrated by an independent testing agency prior to the load testing of any tiebacks. For additional details, refer to the Model Specification - Helical Tieback Anchors for Earth Retention at <http://www.abchance.com/resources/specifications>.

An Alignment Load (AL), usually 5% to 10% of the Design (Working) Load (DL), should be applied to the helical tieback anchor prior to the start of field load tests. The initial alignment load helps to remove any looseness in the tieback shaft couplings and thread bar transition system.

3. Pre-Production Tests (Optional):

Load tests shall be performed to verify the suitability and capacity of the proposed helical tieback anchor, and the proposed installation procedures prior to the installation of production tiebacks. The owner shall determine the number of pre-production tests, their location and acceptable load, and movement criteria. Such tests shall be based, as a minimum, on the principles of the performance test as described below. If pre-production tiebacks are to be tested to their ultimate capacity, then an additional purpose of the pre-production tests is to empirically verify the ultimate capacity to average installing torque relationship of the helical tiebacks for the project site. Testing above the performance test maximum applied load of 125% x DL should follow the loading procedures and increments as given in the Static Axial Load Tests (Compression/Tension) section to follow.



Anchor Tension Load Test in Minneapolis, MN
Figure B-2

4. Performance Tests:

The number of tiebacks that require performance testing shall be defined in the project specifications. The minimum number of tiebacks for performance testing shall be two (2). Helical tieback anchors shall be performance tested by incrementally loading and unloading the tieback in accordance with the Performance Test Schedule (see Table B-1). The applied load shall be increased from one increment to the next immediately after recording the anchor movement. The load shall be held long enough to obtain and record the movement reading at all load increments other than the maximum test load. The maximum test load (1.25 x DL) shall be held for a minimum of 10 minutes. Anchor movements shall be recorded at 0.5, 1, 2, 3, 4, 5, 6, and 10 minutes. Refer to Acceptance Criteria on page B-12 for additional hold periods, if required, and acceptable movement criteria.

5. Proof Testing:

All anchors which are not performance tested shall be proof tested. The proof test shall be performed by incrementally loading the helical anchor in accordance with the Proof Test Schedule (see Table B-2). The load shall be raised from one increment to another after an observation period. At load increments other than the maximum test load, the load shall be held for a period not to exceed two (2) minutes. The two minute observation period shall begin when the pump begins to load the anchor to the next load increment. Movement readings shall be taken at the end of the two minute observation period.

The dealer/installing contractor or engineer shall plot the helical anchor displacement vs. load for each load increment in the proof test. The 1.25DL test load shall be maintained for five (5) minutes. This five minute observation period shall commence as soon as 1.25DL is applied to the anchor. Displacement readings shall be recorded at 0.5, 1, 2, 3, 4, and 5 minutes. Refer to Acceptance Criteria on page B-12 for additional hold periods, if required, and acceptable displacement criteria.

Performance Test Schedule, Table B-1

PERFORMANCE TEST SCHEDULE				
CYCLICAL LOAD INCREMENTS (%DL/100)				
AL	AL	AL	AL	AL
0.25DL*	0.25DL	0.25DL	0.25DL	0.25DL
	0.25DL	0.50DL	0.50DL	0.50DL
		0.75DL*	0.75DL	0.75DL
			1.00DL*	1.00DL
				1.25DL*
				Reduce to lock-off load#

AL = Alignment Load, usually 10 to 15% of DL.
 DL = Design (Working) Load
 * The dealer/installing contractor shall plot the helical anchor movement for each load increment marked with an asterisk (*) in the performance schedule and plot the residual displacement at each alignment load versus the highest previously applied load.
 # Helical tieback anchors which are performance tested may be completely unloaded prior to the lock-off load procedure. Final adjusting to the lock-off load does not require further movement readings.
 See the Performance Testing Procedures in the Model Specification - Helical Tieback Anchors for Earth Retention at <http://www.abchance.com/resources/specifications> for further information regarding load test equipment, load test set-up, dial gauges for monitoring anchor displacement, etc.

Proof Test Schedule, Table B-2

PROOF TEST SCHEDULE	
LOAD TEST SCHEDULE (%DL/100)	OBSERVATION PERIOD (MIN.)
AL	AL
0.25DL	2.0
0.50DL	2.0
0.75DL	2.0
1.00DL	2.0
1.25DL	5.0
Reduce to lock-off load#	

AL = Alignment Load, usually 10 to 15% of DL.
 DL = Design (Working) Load
 # Helical tieback anchors which are proof tested may be completely unloaded prior to the lock-off load procedure. Final adjusting to the lock-off load does not require further displacement readings.
 See the Proof Testing Procedures in the Model Specification - Helical Tieback Anchors for Earth Retention at <http://www.abchance.com/resources/specifications> for further information regarding load test equipment, load test set-up, dial gauges for monitoring anchor displacement, etc.

LOAD TESTS

STATIC AXIAL LOAD TESTS (COMPRESSION/TENSION)

PRE-PRODUCTION LOAD TESTS

Load tests shall be performed to verify the suitability and capacity of the proposed helical anchor/pile, and the proposed installation procedures prior to installation of production helical anchors/piles. These load tests shall be performed prior to the installation of the production helical anchors/piles. The Owner shall determine the number of pre-production load tests, their location, acceptable load and displacement criteria, and the type(s) of load direction (i.e., tension, compression, or both). An additional purpose of pre-production tests is to empirically verify the ultimate capacity to the average installing torque relationship of the helical pile/anchor for the project site with the torque measurement equipment used for the project. Pre-production helical pile/anchor installation methods, procedures, equipment, and overall length shall be identical to the production helical anchors/piles to the extent practical except where approved otherwise by the Owner.

It is recommended that any field load test for compression or tension be conducted under the supervision of a Registered Professional Engineer. The engineer will specify the test and measurement procedure, load increments, time intervals, and acceptable ultimate displacement consistent with specific project and load conditions. Test procedures shall conform to ASTM D-1143-07, Standard Test Method for Pile under Static Axial Compressive Load and/or ASTM D3689-07, Standard Test Method for Pile under Static Axial Tension Load unless otherwise specified by the engineer. These ASTM specifications do not specify a particular method to be used, but rather provide several slow-testing and quick-testing optional methods.

Citing the Canadian Foundation Engineering Manual, 2007:

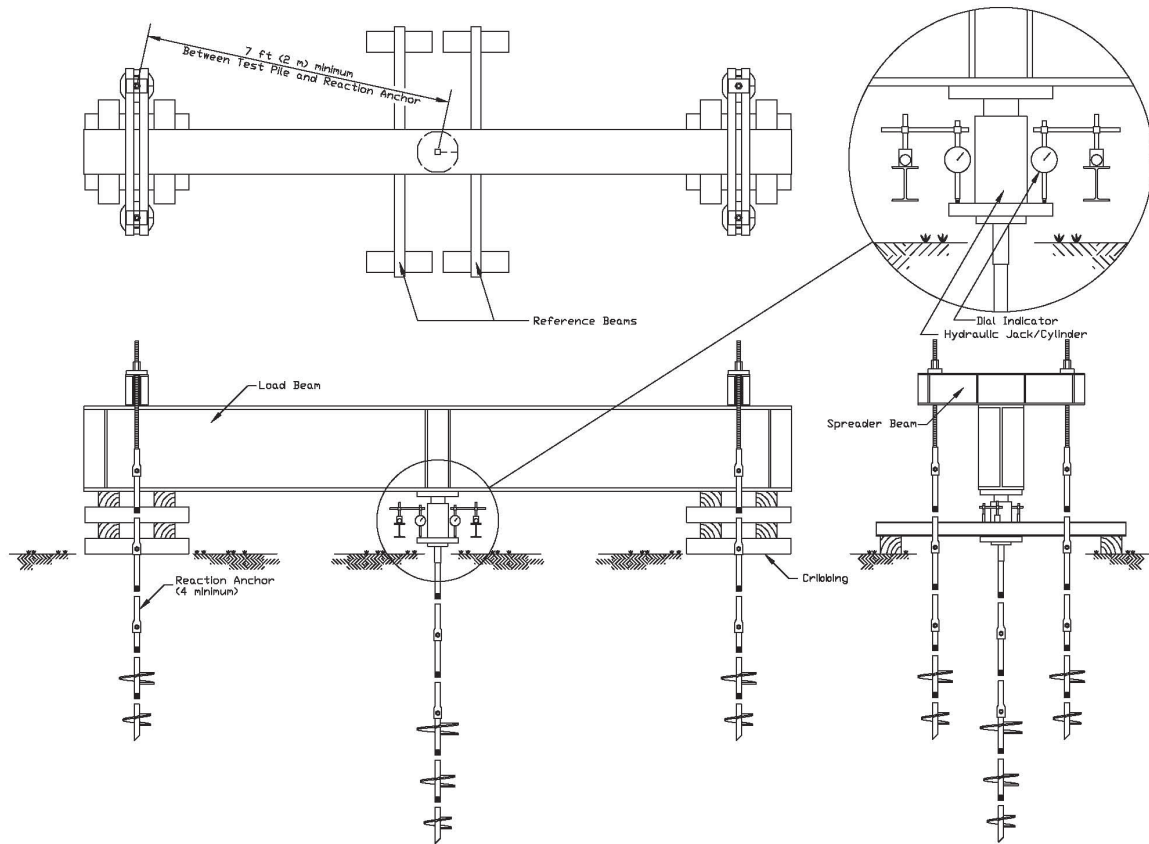
“The slow-testing methods . . . (outlined by the ASTM D1143-07. . . are very time-consuming. When the objective of the test is to determine the bearing capacity of the pile, these methods can actually make the data difficult to evaluate and disguise the pile true load movement behavior, thereby counteracting the objective of the test. The benefit of the (slow) test methods lies in the additional soil-pile behavior information, occasionally obtained, which the interpreting engineer can use, when required, in an overall evaluation of the piles.

“. . . For routine testing and proof testing purposes, the quick methods . . . are sufficient. Where the objective is to determine the bearing capacity of the pile . . . the quick test is technically preferable to the slow methods.”

Therefore, the following test procedure is based on the “Quick Load Test Method for Individual Piles”. This test procedure shall be considered to meet the minimum requirements for load testing. It is not intended to preclude local building codes, which may require the use of other testing methods as described in the ASTM specifications..

PRE-PRODUCTION LOAD TESTS

1. Determine the depth to the target stratum of soil from the geotechnical site investigation report that includes boring logs. Use these data to select an pile/anchor design capacity, ultimate capacity and estimate the installation torque at the target stratum and depth.
2. Set the spacing and install the four reaction anchors at the test site (see Figure B-3). The recommended spacing between the test pile and the reaction anchors is at least 5D, where D = diameter of the largest helical plate. For tension only tests, the reaction anchors are not required.
3. Install the test helical pile at the centroid of the reaction anchors to the target depth and torque resistance. For tension tests, install the test anchor at the desired location to the target depth and torque resistance.
4. Mount the two anchor beams on the four reaction anchors/piles and the reaction beam between the anchor beams (see Figure B-3). For tension tests, center the reaction beam over the anchor and support each end of the beam on cribbing or dunnage. The helical reaction piles are not required if the surface soils have sufficient bearing strength to support the cribbing/dunnage under the applied loading without excessive deflections.
5. Install a load cell, hydraulic load jack, actuator and pressure gauge. The center hole load jack will be mounted below the reaction beam for a bearing (compression) test (see Figure B-3) and above the reaction beam for an anchor (tension) test. A solid core hydraulic jack can be used for compression tests.
6. Set the displacement measuring devices. Deflection measuring devices can include analog dial or electronic digital



Basic Compression Field Test Set-up
Figure B-3



Indoor Compression Test
Figure B-4

gauges (must be accurate to .001") mounted on an independent reference beam, a transit level surveying system, or other types of devices as may be specified by the engineer.

7. Apply and record a small alignment or seating load, usually 5% to 10% of the design load. Unless otherwise defined, the ultimate test load shall be assumed equal to 200% of the design load. Hold the seating load constant for 10 minutes or until no further displacement is measured.

8. Set the displacement measuring device(s) to zero.

9. Axial compression or tension load tests shall be conducted by loading the helical anchor/pile in step-wise fashion as shown in Table B-3 to the extent practical. Pile/anchor head displacement shall be recorded at the beginning of each step and after the end of the hold time. The beginning of the hold time shall be defined as the moment when the load equipment achieves the required load step. There is a generalized form for

recording the applied load, hold periods, and pile/anchor head deflections provided at the end of this Section.

10. Test loads shall be applied until continuous jacking is required to maintain the load step or until the test load increment equals 200% of the design load (i.e., 2.0 x DL), whichever occurs first. The observation period for this last load increment shall be 10 minutes or as otherwise specified. Displacement readings shall be recorded at 1, 2, 3, 4, 5 and 10 minutes (load increment maxima only).
11. The applied test load shall be removed in four approximately equal decrements per the schedule in Table B-3. The hold time for these load decrements shall be 1 minute, except for the last decrement, which shall be held for 5 minutes. Refer to Acceptance Criteria on page B-13 for acceptable movement criteria.

NOTE: Refer to Helical Pile Load Tests in the Model Specification - Helical Piles for Structural Support at <http://www.abchance.com/resources/specifications> for further information regarding load test equipment, load test setup, dial gauges for monitoring anchor displacement, etc..

PRODUCTION LOAD TEST PROCEDURES (OPTIONAL - AS SPECIFIED)

1. Follow the test setup procedures listed under Pre-Production Load Test Procedures (Items 1 through 7), **except** the maximum test load to be applied to the pile/anchor is the Design Load (DL). (This may be the only type of load test conducted depending on the conditions.)
2. The Contractor shall perform axial load tests on the number and location of helical piles as specified by the Owner. At the Contractor’s suggestion, but with the Owner’s permission, tension tests may be performed in lieu of compression tests up to 1.00 DL for helical piles with sufficient structural tension capacity. The requirements of Table B-4 may be regarded as a minimum, however, it is not recommended to test production helical piles to values of up to 2.0 DL unless the helical pile’s failure load is significantly higher than 2.0 DL. The maximum production helical pile test load shall be determined by the Owner. For example, ASTM D1143 stipulates testing to 2.0 DL.

Pre-Production Test Schedule, Table B-3

PRE-PRODUCTION TEST SCHEDULE			
CYCLICAL LOAD INCREMENTS (%DL/100)			
Load Increment	Hold Period (Min.)	Load Increment	Hold Period (Min.)
AL	1.0	AL	1.0
0.20DL	4.0	0.50DL	4.0
0.40DL	4.0	1.00DL	4.0
0.60DL	4.0	1.20DL	4.0
0.80DL	4.0	1.40DL	4.0
1.00DL	4.0	1.60DL	4.0
0.75DL	4.0	1.80DL	4.0
0.50DL	4.0	2.00DL	10.0
0.25DL	4.0	1.50DL	4.0
		1.00DL	4.0
		0.50DL	4.0
		AL	5.0

AL = Alignment Load, usually 10% of DL; DL = Design (Working) Load

LOAD TESTS

3. Axial compression or tension load tests shall be conducted by loading the helical pile/anchor in the load sequence as shown in Table B-4. Anchor/pile head displacement shall be recorded at the beginning of each step and after the end of the hold time. The beginning of the hold time shall be defined as the moment when the load equipment achieves the required load step. The observation period for this last load increment shall be 5 minutes or as otherwise specified. Displacement readings shall be recorded at 0.5, 1, 2, 3, 4, and 5 minutes (load increment maxima only).
4. The applied test load shall be removed in four approximately equal decrements per the schedule in Table B-4. The hold time for these load decrements shall be 1 minute, except for the last decrement, which shall be held for 5 minutes. Refer to Acceptance Criteria on page B-13 for acceptable displacement criteria.

STATIC LOAD TESTS (LATERAL)

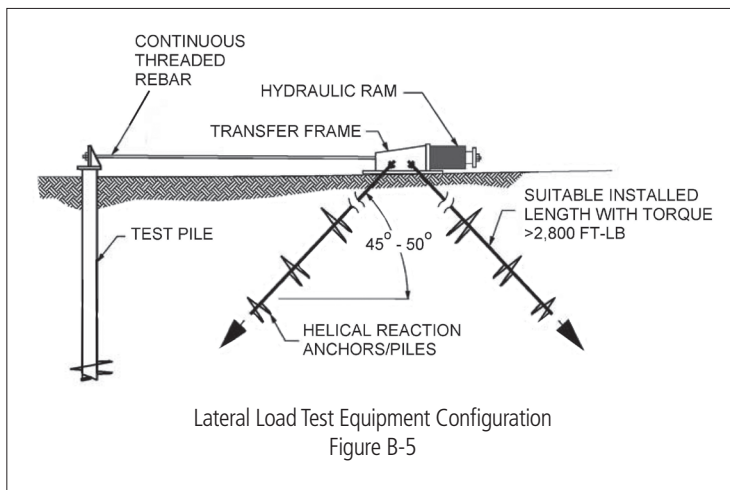
Helical pile/anchor offer maximum benefits structurally when loaded axially (centrically) either in tension or compression. In certain design situations, the anchors/piles may be subjected to lateral loads and it is important to establish their lateral load capacity. Such applications may include support for communication equipment platforms, foundations for light poles, and sign standards or use as foundation systems for modular homes. It is recommended that the Field Lateral Load Test on pile/anchor be conducted under the supervision of a Registered Professional Engineer. The engineer will specify the test and measurement procedure, load increments, time intervals, and acceptable ultimate deflection consistent with specific project and load conditions. If the desired ultimate lateral load capacity and test lateral load capacity results are close, the engineer may choose to increase the diameter of the anchor/pile shaft and/or use a concrete collar on the anchor/pile head in order to achieve the desired Factor of Safety. Lateral load tests shall be conducted in accordance with ASTM D-3966-07, Standard Test Method for Piles under Lateral Load.

LOAD TESTS

Production Test Schedule (Optional - as Specified), Table B-4

PRODUCTION TEST SCHEDULE	
LOAD INCREMENT	HOLD PERIOD (MIN.)
AL	0
0.20 DL	4.0
0.40 DL	4.0
0.60 DL	4.0
0.80 DL	4.0
1.00 DL	5.0
0.60 DL	1.0
0.40 DL	1.0
0.20 DL	1.0
AL	5.0

AL = Alignment Load, usually 10 of DL.
DL = Design (Working) Load



TEST PROCEDURE

1. In order to conduct a lateral load test on an installed pile/anchor, it is necessary to install a reaction anchor system. The reaction anchor system consists of helical pile/anchor installed at a battered angle, and using a test apparatus setup such as shown in Figure B-5. Once the reaction anchor system is installed, the test pile/anchor is installed to the specified estimated depth and design torque.

2. Threaded steel bar or cable shall be used to connect the test pile to the reaction anchor frame. A hydraulic ram and pressure gauge is installed to apply the test load(s) and to measure the applied force.

3. Set the displacement measuring devices. Displacement measuring devices can include analog dial or electronic digital gauges (must be accurate to 0.001") mounted on a reference beam, a transit surveying system, or other type of device as specified by the engineer.

4. For the Load Capacity Tests, follow steps 7 through 11 in the Static Axial Load Tests on page B-6 & B-7.

5. A failure criterion is often established by the project engineer and will reflect project specific conditions. The load versus lateral deflection is plotted. Interpretation of these results to determine the ultimate and working lateral load capacities often requires engineering judgment. Refer to Acceptance Criteria on page B-14 for acceptable displacement criteria.



Lateral Load Test Apparatus
Figure B-6

CAPACITY VERIFICATION FOR ATLAS® RESISTANCE PIERS

On occasion, a building owner or engineer may want confirmation that existing ATLAS RESISTANCE® Pier underpinning is supporting the load as initially designed. Many times this request comes as a result of a client seeing tension cracks in the drywall or masonry. Many such requests are generated as a result of the owner failing to improve a poor drainage situation, from a failure to maintain the soil moisture around the perimeter of the structure or from leaks in the plumbing system. It is possible that the stratum upon which the pier is founded is receding. Changes can also occur that increase subsurface water near the structure such as a drainage system becoming clogged or an inoperative sump pump. In partial underpinning situations, additional loads may be imposed from adjacent areas experiencing further settlement resulting in a much greater load from the time of the previous installation. In these conditions, additional piers will be required along with adjustment of affected earlier installed piers.

The following gives the dealer/installing contractor and engineer guidance for answering these concerns and the engineer assistance with specifications for pier bearing verification.

TEST AND ADJUSTMENT PROCEDURE

1. Excavate and expose the top half of the pier bracket at each location to be tested and adjusted.
2. Check the pier pins to see if they are tight by tapping the heads of the pier pins with a hammer and then attempting to remove the pins using pliers.
 - a. If the pier pins are loose:
 - The pier may be bearing on a stratum that is receding or that has deteriorated. Load test the pier.
 - The pier pipe or pier bracket component may have failed. If inspection of the components reveals a failure, replace the failed component and return it to Hubbell Power Systems, Inc. for evaluation. Load test the pier.
 - The footing may have heaved from expansion of the underlying soil if the floor slopes toward the interior. If evaluation of the structural elements, elevation measurements, drainage, and soil moisture content reveals heaving, then correcting the drainage or plumbing may allow the pier to return to the desired elevation. Schedule another inspection after the remedial work is complete and the soil has stabilized.
 - b. If the pier pins are tight but the floor slopes toward the perimeter:
 - The interior floor may be heaving. If an evaluation of the structural elements and elevations reveal interior heaving, a plumbing test, an evaluation of the surface drainage, and subsurface soil conditions should be performed and the deficiencies must be corrected before any attempt to adjust the perimeter is performed.
 - The bearing stratum may be receding or compressing under the pier load as the structure continues to settle. Load test the pier.
3. Load testing procedure for ATLAS RESISTANCE® Piers:
 - a. Install a lift head onto the pier bracket and place a 25 ton hydraulic ram with hose, gauge, and hand pump on the top pier platform.
 - b. Slowly advance the ram while monitoring the top pier platform for creep.
 - c. If little or no movement is observed, then the end of the pier is probably still founded upon competent material. Continue to increase the force on the ram until the structure begins to lift. (If the pier advances into the soil more than the stroke of the ram, skip to step f below.)
 - d. Record the load test force that was required to begin to lift the structure. The formula for this force is: Gauge Pressure x 5.15 = Verification or Test Force (verify effective area of ram).
 - e. Compare this force to the force indicated on the original pier log. (Variation of ±15% is acceptable.) (Skip to step i below.)
 - f. Remove lift head assembly and top pier platform and install the pier driving equipment, drive stand, hydraulic drive cylinder, gauge, and gasoline or electric pump. Drive the pier pipe as if this was a new installation until suitable bearing is obtained. Record the driving force. The formula for this force is: Gauge Pressure x 8.29 = Driving Force (verify effective area of drive cylinder).
 - g. Cut the added pier pipe to proper length and record the added length required at this pier.
 - h. Install the top pier platform and lift head.
 - i. Repeat steps a through e for **each pier that requires load bearing verification**.
4. Procedure for Adjusting Piers:
 - a. Prepare a system of hydraulic rams and manifold(s) that are connected to all of the piers that need to be adjusted. Follow the normal elevation recovery procedure as described in the Typical Specification for the ATLAS RESISTANCE® Pier system being tested. Typical Specifications are available on the Hubbell Power Systems, Inc. website, www.abchance.com.

- b. Carefully apply pressure using the hand pump to restore the lost elevation. Valve off each ram as the foundation elevation reaches the target. Record the lifting force and the amount of lift at each placement. The formula is: Gauge Pressure x 5.15 = Lifting Force.
 - c. Once the structure has reached the target elevation, install pier shims and pier pins as described in the Typical Specification for the ATLAS RESISTANCE® Pier system being tested. The Typical Specifications are available on the Hubbell Power Systems, Inc. website, www.abchance.com.
 - d. Carefully reduce the hydraulic pressure at each ram, remove the rams and lift heads
 - e. Replace and compact the excavated soil and leave the area clean and neat.
5. Report the results:
- a. A Pier Installation Report shall be prepared that includes:
 - A pier layout of the area of work with each pier location indicated,
 - The verification or test force,
 - The amount of downward movement required before reaching this force,
 - The lifting force, and
 - The amount of lift that was required to restore the foundation to the target elevation.
 - b. Report to the engineer or owner any surface or subsurface drainage conditions observed and any suspected plumbing problems (such as water seeping into all or only several excavations). It is important that the Owner understand that any plumbing leaks or drainage deficiencies that are observed at the time of the adjustment be corrected immediately, otherwise stability issues may continue.

ACCEPTANCE CRITERIA

Static Load Tests (Tiebacks)

PRE-PRODUCTION AND PERFORMANCE TESTS

The net displacement shall not exceed 0.05" during the first log cycle of time, i.e., 1 min to 10 min. If the anchor movement between the one (1) minute and ten (10) minute readings exceeds 0.05", then the 1.25 DL test load shall be maintained for an additional 20 minutes. Displacements shall be recorded at 15, 20, 25, and 30 minutes. Net displacement is the difference between the movement recorded at the initial time increment and the final time increment of the log cycle of time. The initial time increment is 1 min and the final time increment is 10 min for the first log cycle of time for Pre-Production and Performance Tests.

The net displacement shall not exceed 0.10" during the final log cycle of time (examples, 3 min to 30 min, 6 min to 60 min, etc). If the acceptance criteria is not satisfied, then the anchor test shall be continued for an additional 30 minutes. Displacements shall be recorded at 45 and 60 minutes. If the acceptance criteria is not satisfied after this extended observation period, then the contractor shall exercise one of the options as provided in Section 6.5, Acceptance Criteria, in the Model Specification - Helical Tieback Anchors for Earth Retention found on www.abchance.com.

PROOF TESTS

The net movement shall not exceed 0.05" during the first log cycle of time, i.e., 0.5 min to 5 min. If the anchor movement between the one-half (1/2) minute and five (5) minute readings exceeds 0.05", then the 1.25 DL test load shall be maintained for an additional 5 minutes. Displacements shall be recorded at 6 and 10 minutes.

The net displacement shall not exceed 0.10" during the final log cycle of time (examples, 1 min to 10 min, 3 min to 30 min, etc). If the acceptance criteria is not satisfied, then the anchor test shall be continued for an additional 20 minutes. Displacements shall be recorded at 15, 20, 25, and 30 minutes. If the acceptance criteria is not satisfied after this extended observation period, then the contractor shall exercise one of the options as provided in Section 6.5, Acceptance Criteria, in the Model Specification - Helical Tieback Anchors for Earth Retention found on www.abchance.com.

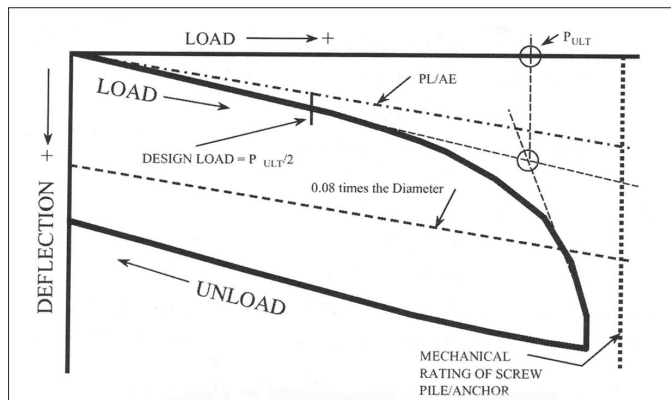
Static Axial Load Tests (Compression/Tension)

PRE-PRODUCTION LOAD TESTS

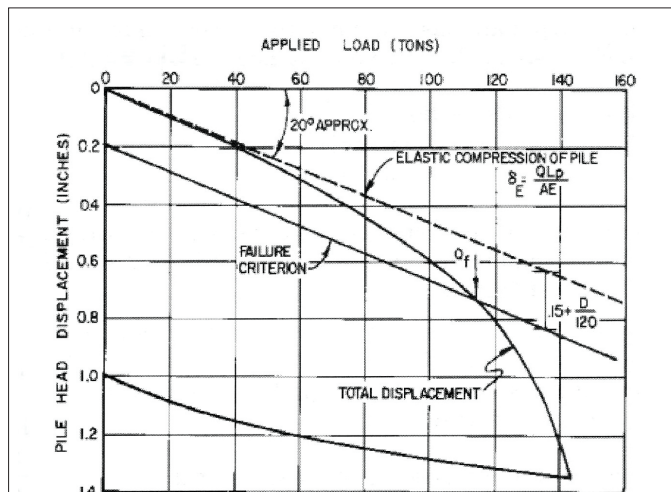
Acceptance of the load test results is generally governed by the building code for that jurisdiction and is subject to review by the structural designer. The structural designer determines the maximum displacement the structure can withstand without undue loss of function or distress. The acceptance criteria must be defined prior to conducting the load test.

The load displacement data may be plotted for a quick overview of the results. Figure B-7 shows a sample test plot. Various building codes have their own acceptance criteria, which is generally a limit on deflection at the factored load. A fast way to determine the ultimate geotechnical capacity is by use of a technique called the “intersection of tangents.” This is accomplished by graphically constructing two tangent lines. One line is drawn tangent to the second “straight line” portion of the load curve, which is beyond the curved or non-linear portion of the load deflection curve. The other line is drawn tangent to the initial “straight line” portion of the load deflection curve. The point where the two tangents intersect identifies an estimate of the ultimate capacity.

An example of a Code-based acceptance criteria for the allowable capacity is the Chicago and New York City Code, which calls for the design load to be the lesser of:



Sample Compression Test Load-Deflection Curve
Figure B-7



Davisson Method for Determining Net Displacement
Figure B-8

1. 50% of the applied load causing a net displacement (total displacement less rebound) of the pile of 0.01" per ton of applied load, or
2. 50% of the applied load causing a net displacement of the pile of 1/2". Net displacement is defined as the gross displacement at the test load less the elastic compression.

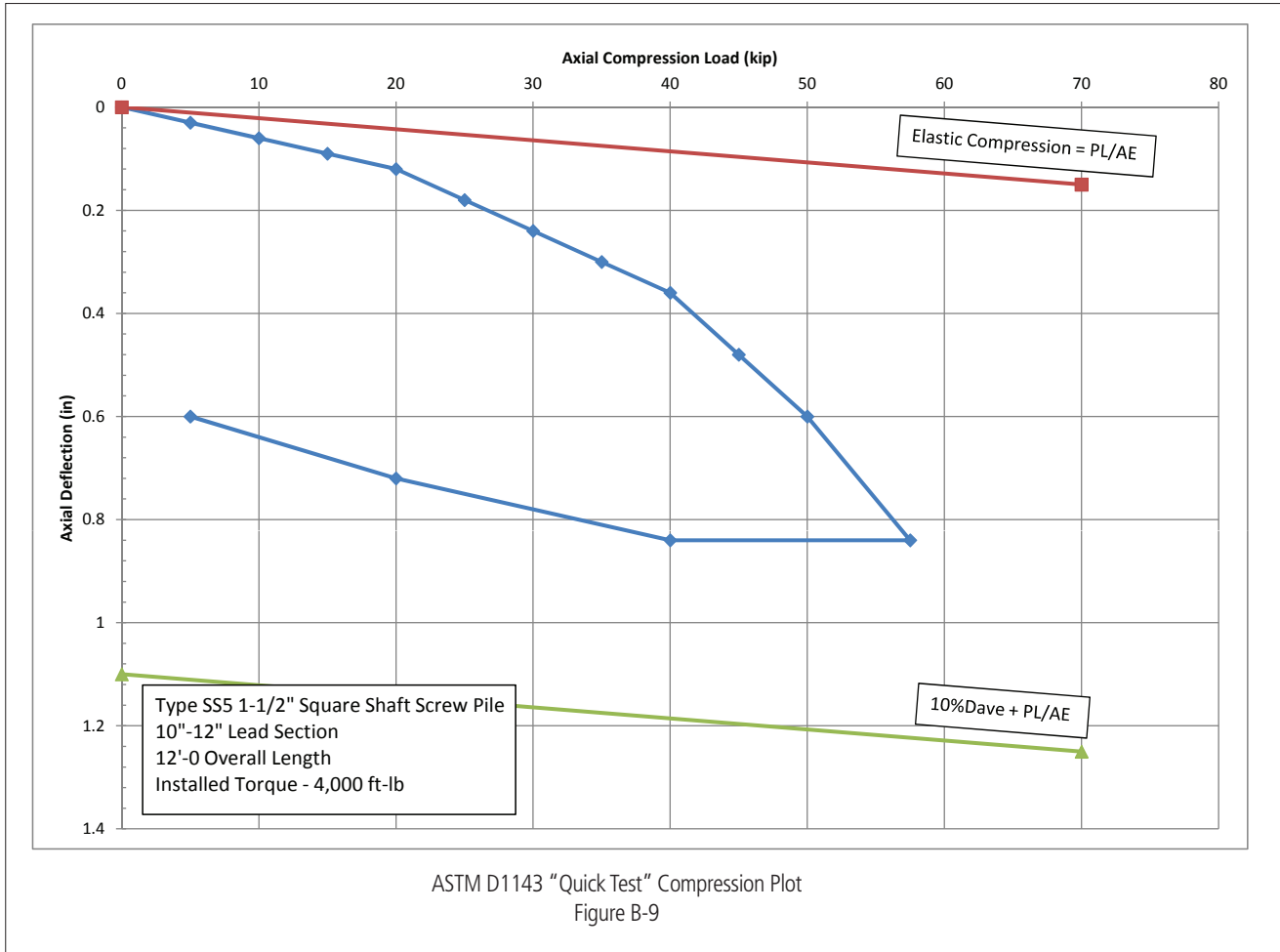
Other allowable capacity acceptance criteria include:

- Maximum total displacement under a specified load.
- Maximum net displacement after the test load.
- Maximum displacement under the design load, or various techniques such as that defined by the Davisson Method (1973) and shown in Figure B-8.

The recommended acceptance criteria for the allowable geotechnical capacity for helical piles/anchors is 1/2 of the applied test load causing a net displacement (gross displacement less the elastic compression/tension) not to exceed 0.10 times the average diameter of the helix plate(s). This is the acceptance criteria used in ICC-ES Acceptance Criteria AC358 for Helical Systems and Devices, per Section 4.4.1.2.

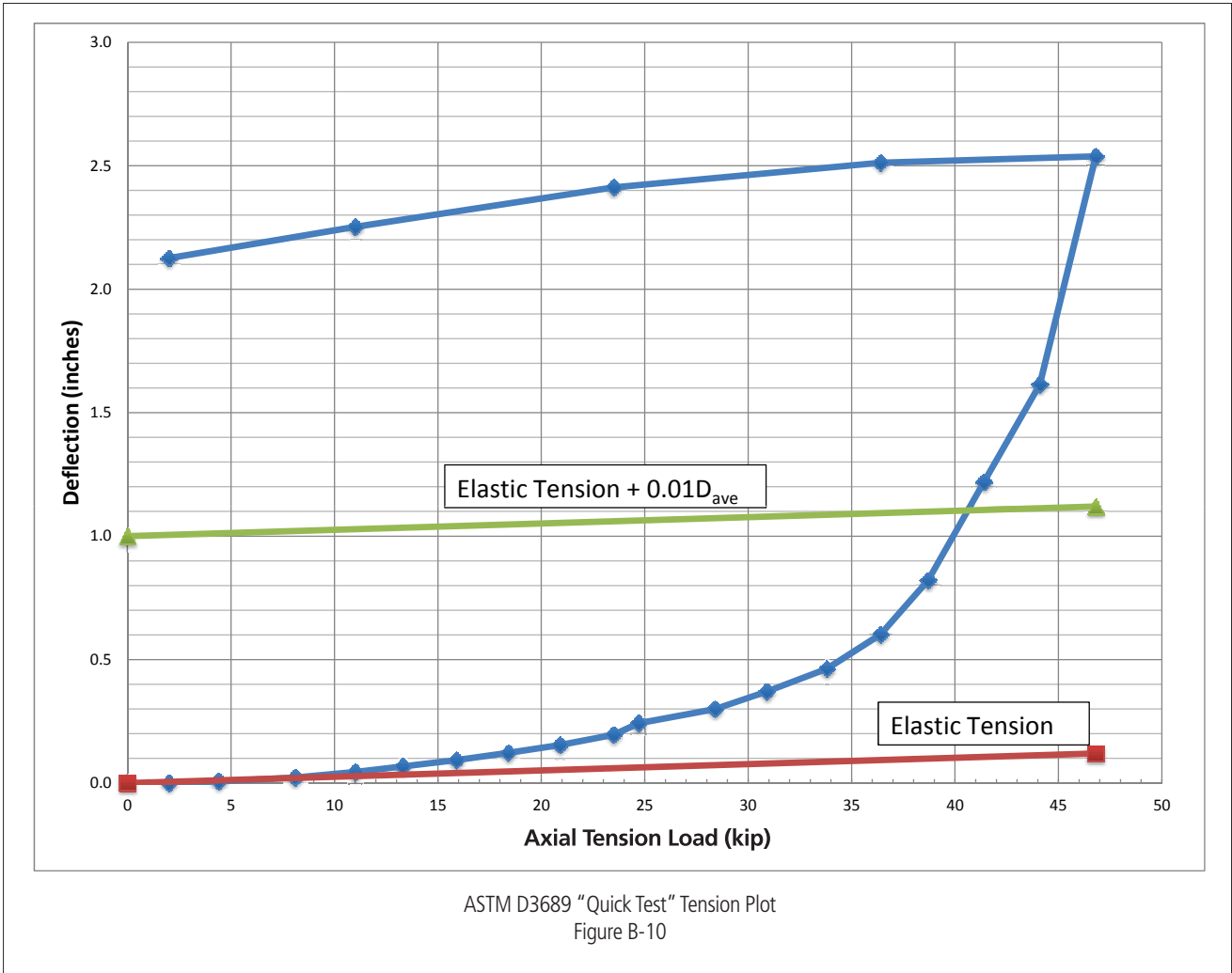
When relatively low foundation capacities are required, the allowable capacity for helical piles/anchors might be based on minimum depth and minimum torque criteria. This is similar to what the New York City code for driven piles up to 30 tons requires, which is to define capacity by the minimum “blows per foot of set.” The subject of load tests and acceptance criteria are discussed by Crowther (1988) and may be referred to for a more complete treatment of the subject.

Figure B-9 is a plot of results from a compression “quick test” per ASTM D1143-07 of a 12 ft long, 1-1/2" square shaft helical pile having 10" and 12" helix plates. It was installed in the residual fine grained soils of Roanoke,



Virginia and tested immediately after installation. The load-displacement curve is completely below the elastic compression line, indicating no skin friction was acting on the shaft during the test. The load-displacement curve does not cross the $PL/AE + 0.01D_{ave}$, which indicates the maximum test load is less than the ultimate geotechnical capacity of the helical pile.

Figure B-10 is a plot of results from a tension "quick test" per ASTM D3689-07 of a 16 foot long, 1-1/2" square shaft helical anchor having 8", 10" and 12" helix plates. It was installed in the residual fine grained soils of Centralia, MO and tested immediately after installation. The load-displacement curve is completely above the elastic tension line (red line), indicating no skin friction was acting on the shaft during the test. The load-displacement curve crosses the $PL/AE + 0.01D_{ave}$ line at approximately 41 kip. The average installation torque over the last three readings was 3,450 ft-lb. The torque correlation method (K_t) of capacity prediction says the ultimate geotechnical capacity is $3,450 \times 10 = 34,500$ lb (34.5 kip), using a K_t of 10 ft^{-1} as outlined in Section 6. The tested ultimate geotechnical capacity based on 10% average helix diameter net displacement is 41 kip. Therefore, the K_t based on the load test is $41,000/3450 = 11.9 \approx 12$.



PRODUCTION LOAD TESTS (OPTIONAL)

Some projects are large enough in size to justify the expense of several production tests. Production tests are useful to verify helical anchor/pile capacity at multiple locations across the project site, especially with varying soil conditions. The net displacement of helical anchor/piles at the allowable load (1/2 the geotechnical capacity) typically ranges between 0.25 inches (25 mm) and 0.5 inches (51 mm) total vertical movement as measured relative to the top of the helical anchor/pile prior to the start of testing. The Owner or structural engineer usually determines what the allowable displacement is, and it must be defined prior to conducting the Production Load Test. Limiting axial net deflections of 1" to 1-1/2" at the ultimate geotechnical capacity are typical.

STATIC LOAD TESTS (LATERAL)

Acceptance Criteria for Helical Systems and Devices AC358 states the allowable load capacity shall be equal to half the load required to cause 1 inch (25 mm) of lateral deflection as measured from the ground surface. The acceptance criteria must be defined prior to conducting the Lateral Load Test. The acceptance criteria must be realistic in its magnitude so as not to potentially damage the structure. Limiting lateral deflections of 1"+ at the ultimate load capacity have been used on some projects. It is suggested that large lateral loads be resisted through some other means (such as helical anchors, battered helical piles, or enlarged concrete pile caps/grade beams).

References

1. AC308 Acceptance Criteria for Helical Systems and Devices, ICC-Evaluation Services, June 2013 Revision.
2. ASTM D1143-07, Static Load Test Method for Piles under Static Axial Compressive Load, American Society for Testing and Materials, Philadelphia, PA.
3. ASTM D3689-07, Standard Test Method for Pile under Static Axial Tension Load, American Society for Testing and Materials, Philadelphia, PA.
4. ASTM D-3966-07, Standard Test Method for Piles under Lateral Load, American Society for Testing and Materials, Philadelphia, PA.
5. Canadian Foundation Engineering Manual, Canadian Geotechnical Society, 1985.
6. Crowther, Carroll L., Load Testing of Deep Foundations, John Wiley and Sons, 1988.
7. Davisson, M.T., High Capacity Piles, Department of Civil Engineering, Illinois Institute of Technology, Chicago, IL, 1973.

LOAD TESTS





HELICAL PILES & ANCHORS



HELICAL PILES & ANCHORS

A BASIC GUIDELINE FOR DESIGNERS

APPENDIX C

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HELICAL PILES & ANCHORS

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

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Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

Helical Piles & Anchors:

A Basic Guideline for Designers

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Edited by Hubbell Power Systems, Inc.

I. INTRODUCTION

Helical piles and anchors have made tremendous gains in popularity and acceptance in the first part of the 21st century. They are used increasingly in varied applications such as underpinning settling foundations, new construction piles, tiebacks, guy anchors, pipe supports, solar panel foundations, thrust restraints, and street light foundations. They are gaining acceptance and are used in residential, commercial, industrial and heavy civil markets.

Many consulting engineers will not use helical products in their everyday design and application jobs. They may have gone through training or become familiar with design for a specific project but have lost that ability through infrequent use and choose to either not relearn and/or not use the helical products or to “leave it to the specialty contractor.” This Guideline is to help shorten and refresh the process so engineers can efficiently design with helical piles and anchors to be profitable and add value for their clients.

The goal of this Guideline is to bring the design, selection, and procurement of helical piles and anchors into a practical perspective. This Guideline will not focus on academic theory, but will present practical solutions to problems involving helical piles and anchors. The intent is to provide this information to engineers to help them solve problems on projects that they are involved with in an effective manner.

II. DESIGN REQUIREMENTS

A. Shaft Type of Helical Pile/Anchor

There are 4 basic types of helical piles available. The following is a brief summary of the 4 different types of helicals.

- **Type 1 - Square Shaft**

Square shaft piles are more efficient than pipe shaft helical piles in regards to capacity derived from installation energy. A square shaft helical pile will have more axial capacity than a pipe shaft helical pile installed with the same amount of torsional energy into the same soil profile.

Square shaft helical piles are better at penetrating dense material than pipe shaft helical piles.

The square shaft piles have slender cross sections. Therefore, they do not have a large section modulus/stiffness to resist buckling under compressive loads without support from the surrounding soil. As long as there is sufficient passive soil pressure around the pile to prevent buckling, square shaft piles are suitable for compressive loads. As a general rule, if the soil profile has ASTM D1586 SPT N_{60} value of 5 or greater, there is sufficient passive soil pressure to prevent the square shafts from buckling at the compressive loads that they are rated for. If SPT N_{60} values are 4 or less, then buckling may be a concern and is a complex problem dependent on a number of variables. A rigorous analysis can be done if enough reliable soil data is available, but the problem can normally be more efficiently solved by selecting another shaft type with a larger section modulus.

- **Type 2 - Pipe Shaft**

Pipe shaft helical piles are not as efficient in regard to load capacity derived from installation energy, but have a larger section modulus when buckling of the square shafts or potential unsupported length is a concern.

Pipe shaft helical lead sections do not penetrate dense material as effectively as square shaft lead sections.

- **Type 3 - Combo Pile**

A combo pile (Combination Pile) is a helical pile that has both the advantages of square shaft and pipe shaft helicals. A combo pile has a square shaft lead section that is better at penetrating dense material and generating load capacity, and is then transitioned to a pipe shaft for the plain extensions where overburden soils are softer and a larger section modulus is desired for buckling resistance, or when lateral load resistance is required.

- **Type 4 – HELICAL PULLDOWN® Micropile**

A HELICAL PULLDOWN® Micropile is a square shaft helical foundation or anchor that has the plain extension sections encased in a small diameter grout column, typically 5" – 7" in diameter. Pipe shaft helical piles can also be encased in a grout column, but that is less common. Similar to the combo pile, it has the advantage of the square shaft lead section to penetrate dense material. The added grout column provides a larger section modulus for buckling resistance and lateral resistance in softer soils. Lateral load resistance with grouted shafts requires a steel case. The grout in contact with the soil will develop friction capacity via a bond zone in suitable soil stratum. This can greatly increase the total axial capacity of the pile (end-bearing and skin friction) as well as stiffen the load response of the pile. The grout column also provides additional corrosion protection to the steel shaft. The HELICAL PULLDOWN® Micropile is a patented technology exclusive to Hubbell Power Systems, Inc. installing contractors.

There are a minimum of 6 design considerations that should be taken into account when choosing the required shaft type. This is often the most important aspect of specifying a helical pile and too often receives the least amount of attention prior to installation.

A.1. Axial Capacity of Shaft

**Reference: Section 5
Section 7**

Is the shaft section sufficient to carry the intended axial load? This will have a great deal to do with the selection of the shaft type. There are four basic types of helical piles. See above for brief description.

- Type 1 - Square Shaft
- Type 2 - Pipe Shaft
- Type 3 - Combo Pile (Square shaft lead with pipe shaft extensions)
- Type 4 - Grouted HELICAL PULLDOWN® Micropiles.

If SPT N_{60} values are 4 or less, the section modulus should be increased by choosing a pipe shaft or encasing the square shaft within a grout column, i.e. HELICAL PULLDOWN® Micropile. Another benefit of choosing a grouted shaft pulldown pile is that it is a composite pile rather than an end bearing only pile. It can generate capacity from both end bearing of the helical plates as well as friction capacity from the grout. Often the torque correlated axial capacities listed in Section 7 of the square shaft product family can be exceeded for compressive loads because of the enlargement of the section modulus and the addition of the friction capacity resulting from the addition of the grout column. Tension loads are controlled by the mechanical limits of the couplings. The increase in compression capacity can be verified with a load test. A further benefit of grouted shaft piles is they will have a stiffer load/deflection response than an end bearing only pile.

A.2. Penetration into Desired Geologic Strata

Reference: p. 5-52

The helical plates must generate the thrust required to advance the shaft through the soil profile. The helical plate or screw thread is an inclined plane. Helical piles (i.e. screw piles) are displacement piles that have the advantage of no spoils. The soil that is displaced by the shaft during installation is displaced to the side. The smaller the shaft size relative to the size of the helical plates (low displacement pile), the more efficient the pile will be in regards to capacity derived from the same installation energy. A helical pile that has a smaller shaft size relative to the size of the helical plates will be better at penetrating dense soil than one with a larger shaft size relative to the size of the helical plates (high displacement pile). Displacing more soil will require more installation energy, i.e. additional installation torque. The greater the installation energy, the larger the required equipment to install the pile.

Square shaft helicals are better at penetrating dense material than pipe shaft helical piles. Where penetration into dense material is required, and a larger section is needed in the upper portions of the pile for buckling reasons, a Combo Pile or a HELICAL PULLDOWN® Micropile are good choices as the square shaft lead sections will penetrate into the dense material better than a pile with a pipe shaft lead. If a soil strata is too dense or the shaft too large relative to the size of the helical plates, the pile could “spin-out”. “Spin-out” means that the pile is still being rotated but is not advancing, and installation torque drops dramatically. This is similar to “stripping” a screw. **The capacity-to-torque correlation is no longer valid for spun-out piles.** (Note: see Section 6 – Installation Methodology for a complete explanation of torque correlation for helical anchors and piles) Now, rather than having a helical pile where torque is used as an indicator of the pile capacity, it is just an end bearing pile that was advanced to depth via a screw mechanism. This does not mean that the pile has no capacity, but rather that the capacity cannot be estimated by the installation energy as is normally done for a low-displacement helical pile. The pile’s capacity will depend on the type of material the helical plates are in, how much the soil was disturbed, and whether or not the shaft tip, or pilot point, contributes to the capacity in end bearing. High capacities can be possible if the shaft tip is sitting on rock.

HELICAL PILES & ANCHORS



A.3. Lateral Loading

Reference: p. 5-42
thru 5-47

Helical piles, whether they be square shaft, pipe shaft or HELICAL PULLDOWN® Micropiles, are generally slender members (low displacement pile). Lateral capacity of piles is dependent on the flexural stiffness of the pile, and the resistance of the soil the pile shaft will be bearing against as it deflects. Due to their slender size, helical pile shafts have a small effective projected area for the soil to bear against. Therefore, low displacement helical piles do not have much lateral capacity at typical tolerances for allowable lateral displacement. Square shaft piles don't have any significant lateral capacity. Pipe shaft and HELICAL PULLDOWN® Micropiles have a limited amount. A grouted shaft HELICAL PULLDOWN® Micropile with a steel casing at the top of the pile will offer the stiffest pile section and the most resistance to lateral loads. Lateral capacity ranges from 2 to 4 kip for 3" to 4" diameter piles to 10 kip for 6" to 10" diameter helical piles at typical lateral displacement tolerances. The use of battered (inclined) piles can be utilized to resist lateral loads if needed and are discussed in Section 5 of this Manual.

A.4. Corrosion Potential

Reference: App. A

There is extensive information on corrosion of steel piling in soils. In most conditions, corrosion is not a practical concern of either square shaft or pipe shaft helical piles. Corrosion is the oxidation of the steel members of a helical pile/anchor. There is typically little to no oxygen in undisturbed soils, especially below the water table. Driven steel piles have been installed with pile hammers for more than a century and are still commonly used today. The vast majority of interstate highway bridges in the Piedmont regions of the southeast United States are bearing on steel H-piles. If corrosion is a concern for a given project, then a square shaft helical pile is a solid cross section and has much less perimeter surface area for corrosion to occur compared to a pipe shaft; which is hollow and has much more perimeter surface area (inside and out) compared to the cross-sectional area of steel. A HELICAL PULLDOWN® Micropile, where the solid square shaft is encased in a very dense grout mixture, provides the most resistance to corrosion. Cathodic protection, or corrosion allowance (sacrificial steel) are also options in aggressive environments or applications.

A.5. Tension Only Loads.

For tension only members, square shaft (Type SS) is always the logical choice. As noted above, square shaft helicals are more efficient in regards to load capacity versus installation energy (torque correlation), are better at penetrating dense soils, and have less surface area for corrosion potential. There is more sacrificial steel (relative to total cross-sectional area) available when considering corrosion in square shafts. The size and strength of the shaft is governed by the required installation torque; there is more steel section available than is required to carry the rated axial tension load. The reason for this is because the steel in the shaft is subjected to more stress during installation than it will ever see while in service. Once the helical anchor is installed, the ultimate mechanical tension strength is governed by the shear strength of the coupling bolt. The square shaft has more available steel cross-section (compared to pipe shaft) that can be sacrificed before the tensile strength is reduced.

A.6. Reversing Loads.

For piles that are required to resist compression and tension loads, the designer must recognize that helical piles are a manufactured product with bolted connections. There is manufacturing tolerance in each connection. For example, most helical piles have up to 1/8" axial tolerance in each connection. If the manufacturer did not allow for that tolerance, connections would often not fit together in the field. If the load reverses, the top of the pile will displace (up or down) a distance equaling the sum of the bolt tolerance in all of the bolted connections before it can resist the reversed load. This may or may not be of concern to the designer and is dependent on the type of structure that is being

supported with the piles. The grout column of a HELICAL PULLDOWN® Micropile fills those connections, thereby removing the bolt tolerance as well as stiffening the load response. That is why grouted shafts are often utilized for piles with reversing load conditions. Grouting the inside of pipe shaft helicals will also stiffen the coupling movements for reversing load conditions.

B. Shaft Size

There are a minimum of 2 design considerations that must be accounted for when choosing the required shaft size.

1. Torsional Capacity of Shaft

Reference: Section 7

Basic helical design methodology states that installation energy has a direct relationship to pile capacity. The shaft selected must be able to withstand the expected installation torque required for the pile to reach the intended capacity and the required depth or specific soil strata. If a dense layer must be penetrated prior to reaching the required termination depths, the shaft must have enough torsional capacity to pass through the dense layer. Otherwise pre-drilling through the dense layer may be required.

2. Axial Capacity of Shaft

Reference: Section 7
Section 5

The shaft section must be capable of withstanding the required axial load. This will have a great deal to do with the selection of the shaft type and size. If the torsional strength is sufficient to reach the required depth and torque-correlated capacity, the shaft section will be sufficient to carry the axial load. The load capacities listed in the Specifications Table for each Product Family in Section 7 of this Manual are limited by torque for compressive loads and by the coupling strength for tension. The exception to this are when there are soft or very loose soils that do not provide sufficient passive soil pressure via confinement to prevent buckling under compression loads, (SPT N_{60} values of 4 or less). A square shaft can be up-sized to a pipe shaft to prevent buckling for lighter loads, or a grout column may be added with a HELICAL PULLDOWN® Micropile to provide increased section modulus that would allow the axial capacities in the Product Family Specifications Table in Section 7 to be exceeded. See the increased compression load capacity tables for HELICAL PULLDOWN® Micropiles with various diameter grout columns in Section 7.

C. Helical Configuration

There is a minimum of 1 design element that must be considered when choosing the suggested/required helical configuration for a performance-based specification or 2 design elements if using a prescriptive-based specification.

1. Mechanical Capacity of Individual Helical Plates

Reference: Section 7

The mechanical capacity or strength of an individual helical plate is dependent on the thickness, grade of steel, and diameter; and strength of the weld that connects it to the pile/anchor shaft. In most cases, the mechanical capacity of a given diameter helix plate will increase with increasing shaft diameter. As a minimum, there must be enough helical plates so that the sum of their individual capacities can share the load that is required of the pile/anchor. A performance-based specification would only require that the minimum number of helical plates be provided that is necessary to share the load. The size of each plate would be left up to the installation contractor as long as the minimum number is provided and that other requirements are met, such as minimum depth and torque. For example, if 60 kips capacity is required, and the individual helix capacity is 40 kips, then a minimum of two helices would be required to share the 60 kip load. A prescriptive-based specification would be explicit on the exact number and size of the helix plates.

2. Size of Helical Plates

Reference: Section 7

The size of helical plates can have a significant influence on the installation and performance of a helical pile/anchor. The helical configuration (smaller or larger diameter helix plates) required can change from pile to pile. If the specifier is not comfortable with a performance-based specification, (minimum number of helical plates, minimum torque capacity, minimum depth), then a more prescriptive approach can be given. This may also be required for comparative bid reasons and is fine as long as a payment mechanism for adjustment is provided. Typically, the denser the soil, the smaller the helical plates must be. Alternately, the softer or less dense the terminating soil strata, the larger the helical plates will need to be to generate the required torque/capacity.

Typical helical sizes range from 8" to 14" diameter. 16" diameter helix plates are available, but are not as common. It is important that the smallest helix be the first or penetrating helix. A multi-helix lead will then have subsequent helices increasing in size. Generally, the same size helix is not repeated until the largest size available is reached. For example, a typical three-helix configuration would be an 8"/10"/12" on all square shaft sizes (1.5" and larger), or a 10"/12"/14" helical configuration on smaller square shaft sizes (1.25" and 1.5") or pipe shaft. Generally, larger square shaft sizes would only be used to generate larger load capacities; hence are generally not used unless being installed into dense material. Therefore, a smaller 8" helix is needed to better penetrate the dense material. A pipe shaft has a larger section/cross sectional area, which results in small remaining area of an 8" helix plate. Therefore, the smallest helix plate typically used on pipe shaft is generally a 10" diameter.

Helical plates are inclined planes and provide the driving mechanism for the rotational advancement of the pile/anchor. Helical configurations with multiple helical plates will drive straighter, and are more likely to advance properly than single helix configurations, and perform better. If too few helical plates are used, the most likely installation problem is "spinning out" (See above: Shaft Type, Penetration into desired geologic strata). This can be solved by adding more helix plates, larger helix plates, and/or more crowd pressure (downward force from installing equipment). Increasing crowd pressure may require a larger piece of equipment (excavator, backhoe etc.). Generally, adding more helical plates is more economical compared to upsizing to larger equipment. If too many helical plates are used, the likely installation problem is that the torque capacity of the shaft is reached prior to reaching the desired depth. Helical extensions can be removed by unscrewing the pile/anchor, taking them off and reinstalling the pile/anchor. If helical plates on the lead section need to be removed, it will require the installation contractor to supply a different helical lead or remove helical plates in the field with a torch or saw. Removal of helix plates in the field is done quite often, but for cost/time reasons the installing contractor would prefer not have to remove helical plates regardless of the method.

If there is limited risk in exceeding the torque capacity of the shaft prior to the required/desired depth, and that depth exceeds approximately 30', it is more economical to have enough helical plates - either to generate the required capacity (in the case of soft to medium bearing strata) or to penetrate the bearing strata (in the case of dense bearing strata) in the beginning rather than run the risk of either not getting the capacity at a reasonable length or "spinning out" trying to penetrate something dense. Extracting a pile/anchor and then reinstalling it at those lengths, while very do-able, generally have time costs that far exceed the cost of providing a helical extension on the first attempt.

D. Pile/Anchor Length

There are a minimum of 2 design elements that should be considered when requiring/estimating a pile/anchor length, whether using a performance or prescriptive based specification.



1. Minimum Length

Reference: Section 5

Compression Only Piles – For helicals used as compression piles, often there is a geotechnical reason that the piles be a minimum length to ensure that the pile is deep enough to achieve required capacity needed for the long term. For example, if it is known that a compressible peat layer exists between 15' and 20' depths, then it is important for the piles to have bearing capacity in soil strata below the peat layer. Therefore, a minimum depth should be required to ensure that the piles are bearing below the peat layer and will not settle over time as the peat consolidates.

If there is no geotechnical reason to require a deeper minimum length, the minimum length for the pile to behave as a deep foundation is that the upper-most helix (the plate closest to the ground surface) is a minimum depth of 5 diameters (5D) of the helix plate below grade or subgrade. If the helical plate is not installed to this depth, the failure mode will be similar to a shallow foundation. This could cause a rupture of soil at the surface if there is not enough confining pressure. For example, if a site has loose overburden sand that trends to medium-dense sand with varying depth, with little risk of the sand getting looser with depth, the minimum length requirement may be “the uppermost helix must be 5D below sub-grade”. Most specifications simplify this to 5 feet below subgrade.

Tension Piles/Anchors – The 5D requirement over the uppermost helix for tension elements is extremely important. If this requirement is not met, there is not enough confining pressure and a wedge or plug of soil can erupt to the surface as the anchor fails. For helical tieback anchors, the 5D requirement is 5D beyond the active failure plane, which is dependent on the friction (ϕ) angle of the soil and the wall height. It is important that the helical plates are not stressing soil in the active failure wedge. If this happens, the wall could experience a global type failure. Again, most specifications simplify this dimension to 5 feet beyond the active failure plane. Therefore, the minimum length requirement for helical tiebacks should be “the uppermost helix must be 5 feet beyond the active failure plane”. There should be a schedule, table, or formula for determining this in the field to ensure that the minimum length is achieved.

2. Cost

The total installed length has a direct impact on the cost of the pile/anchor in both material cost and installation time. The designer must always keep this in mind. The length defined (or undefined) by the bidding documents has enormous ramifications on the cost. Well written bidding documents should define the piles well enough to obtain the pile/anchor performance that the owner requires, as well as obtain competitive pricing from the installing contractor. If the piles are not well defined, the installation contractor that leaves the most out of his bid will likely get the job. This is not good for the owner as it increases the likelihood that the owner is not going to get the performance from the piles that is needed; or be presented with an expensive change order after construction has begun. Bidding should be based upon a minimum estimated bid length with some method for adjustment for differing lengths. This approach better utilizes the flexibility of helicals, which is one of their advantages. A thorough discussion of bidding and construction documents and strategies is discussed in Section III of this Appendix, titled “Construction Documents”.

E. Pile/Anchor Minimum Capacity or Installation Torque

Whether using a performance or prescriptive specification, the pile/anchor capacity should be specified in order to ensure that the desired pile/anchor capacity is achieved and that one of the primary advantages of helicals is utilized, which is measuring installation energy (torque).

1. Minimum Capacity

All structural members, regardless of the method of determining the load capacity or strength that the member is designed to resist, are designed with a factor of safety to provide for possible overload conditions; or for the possibility that the member is understrength for some unknown or unforeseen reason. This normal use load is commonly referred to by names such as service, design, working, or un-factored load.

A factor of safety is applied to this load to provide a reserve load capacity beyond that which it is expected see under normal use. This safety factor may be prescribed by building code, but is often left up to the engineer-of-record. A proper factor of safety is a combination of economics and statistics. It is not typically economically feasible to design for zero probability of failure. Generally the more uncertainty, the higher the factor of safety applied. Conversely, the less uncertainty, the lower the factor of safety applied. The industry standard for helical piles is a factor of safety of 2 for permanent applications. Generally, for tieback anchors that are going to be individually post-tensioned and tested, a factor of safety of 1.5 is used. A lower factor of safety is justified since there is less uncertainty (the tieback is tested). This load that contains the safety factor is usually referred to as either the ultimate or factored load.

One of the biggest problems with construction documents regarding helical piles/anchors is clearly identifying the load required. The best method is to clearly define the loads as ultimate/factored loads on the construction documents. If not, then the loads should be clearly identified as (service/design/working/un-factored loads) and clearly state what the required factor of safety is.

OR

2. Installation Torque

**Reference: Section 6
Section 7**

Installation torque can also be specified as the minimum requirement as it relates to the pile/anchor capacity required. This should only be done for piles/anchors that will not receive a proof test. This should not be done for tieback anchors where each anchor will be post tensioned and proof tested. In that case, passing the proof test is the only criteria that matters and obtaining a minimum torque is really a convenience for the contractor to ensure that he does not fail the proof test.

If the minimum torque approach is utilized, the specifier should be aware that torque capacity correlations differ depending on the type and size of shaft used. Please refer to Section 6 for a full discussion of Torque/Capacity (K_t) relationships. Empirical Torque Factors are soil dependent. Unless on-site testing is performed to obtain a site specific Empirical Torque Factor, statically conservative default values are typically used. A table of recommended default values for K_t is provided for your convenience.

<u>Shaft Type</u>	<u>Shaft Size</u>	<u>K_t</u>
Square	1.25"	10 ft ⁻¹
Square	1.5"	10 ft ⁻¹
Square	1.75"	10 ft ⁻¹
Square	2.0"	10 ft ⁻¹
Square	2.25"	10 ft ⁻¹
Pipe	2-7/8" OD	9 ft ⁻¹
Pipe	3.5" OD	7 ft ⁻¹
Pipe	4.5" OD	6 ft ⁻¹

Also, tension capacities should correspond to the average torque measured over the last three average helix diameters of installed length. Most specifications simplify this to 3 feet. This is because in tension, the helical plates are bearing against the soil that they have already passed through. So depending on how fast the torque increased, this could have a significant impact on the capacity of the anchor. Obviously, it is virtually impossible to average a helical anchor/pile's maximum torque rating over the last three average helix diameters.

III. CONSTRUCTION DOCUMENTS

A. Construction Plans

The previous section defined the design elements that should be considered when electing to use helical piles/anchors. Each one of these should be defined in the construction plans on a well-engineered project.

- Shaft Type
- Shaft Size
- Helical Configuration
- Pile/Anchor Length
- Minimum Capacity or Torque

By defining the parameters that will be acceptable for each of these design elements, more favorable results will be obtained from both a pricing and performance perspective. It is the writer's experience that summarizing the pile/anchor parameters in a format similar as listed above works well.

For example; consider using the following format or similar plans:

Helical Pile Data Summary

Pile Type:	Square Shaft Helical Pile
Shaft Material:	SS175 (1.75" x 1.75" solid square shaft)
Helical Configuration:	8"/10"/12" helices
Bid Length:	28'-0
Minimum Capacity:	80 kips ultimate capacity

Other parameters can also be added such as grout column diameter for grouted HELICAL PULLDOWN® Micropiles, minimum length (if different from bid length), termination type, angle of installation, or required casing.

The above summary provides enough information for bidders to aggressively bid on the same items as other bidders. It reduces their risk of being undercut by a contractor bidding with either lesser material or a lesser estimated length. This also gives the owner and the engineer a comparative basis for their bid analysis. A method for payment should also be established for deviations from the bid length and should be considered in the bid analysis.

B. Bidding Documents

Well-crafted construction documents will allow installation contractors to accurately bid and properly install piles to serve their intended purpose. It is in the owner's and engineer's best interest for contractors to have the proper information to be able to accurately bid and properly install the piles/anchors. Poorly-crafted construction documents with lack of definition will result either in high pricing because the contractor has to assume an inordinate amount of risk, less than desired performance from the piles/anchors, installation problems, or change orders from the contractor. None of these things make the engineer-of-record, or helical piles attractive to the owner for future projects.

Bid processes can be handled in several different ways, and are dependent on the particular aspects and needs of each project. No two projects are exactly the same. Therefore, different aspects of the project may be the driving force behind the bid process or bid structure. These could be price, speed, or function. Helical piles/anchors are used in design/build projects, lump sum bids and projects with a unit pricing structure. It is the writer's experience that unless there is a wealth of geotechnical information that is available to the bidders, lump sum pricing is generally not in the owner's best interest. A pricing structure that shares some of the risk with the owner and the contractor tends to result in better overall pricing. One exception to this would be if the bidders are allowed access to the site to install probe or exploratory piles prior to bidding. Helical piles/anchors are well suited to exploratory installations because of the torque to capacity relationships, the pile/anchor material can be recovered, and there is minimal disruption to the site. The less risk the contractor assumes, the better pricing will be.

Generally, a pricing structure that allows for a per/pile price to a specified bid depth with unit pricing for additional/deductible length works best. For example, if the geotechnical information available indicated that the average pile/anchor depth to be between 25'-0 and 30'-0 then a bid length of 28'-0 might be established with unit pricing by the foot for piles that exceed or are short of that length. Unit pricing would likely be even better if it is established in increments of 7'-0 rather than 1' increments since 7'-0 is the length of most common material plain extensions. This is because the same amount of material is likely to be used once the contractor has to add an additional piece. In other words, if the pile depth exceeds 28'-0, there is an additional unit cost per unit additional 7'-0 extension. Some situations may lend themselves to providing a unit price for helical extensions also. Many tieback projects have benefited by utilizing this approach.

Another unit pricing strategy that is used effectively is to have the bidders provide a unit price per foot for the entire length of piling or anchorage on the project and not have a price per pile/anchor. In other words, the construction plans might show 100 piles at an average 50' depth and the bid quantity would be set up for unit pricing by the foot, (or 7' increments) for 500 lineal feet (LF) of piling. Payment would be made by the unit price for the quantity of piling installed, whether it is 450 LF or 550 LF.

C. Technical Specifications

Technical Specifications are an important part of well-crafted construction documents and should further define the details regarding the helical piles or anchors. Technical Specifications should define anything that affects the pricing or performance of the piles or anchors. At a minimum, the following should be defined:

- Pile materials
- Installation tools and equipment
- Quality control methods
- Installation records required
- Installation tolerances and techniques
- Load testing requirements, procedures, and acceptance criteria (if any)

Model specifications for helical piles, anchors, and tiebacks that can be used as templates and edited for your specific project needs are included on www.abchance.com.



FORMS



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FORMS

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

Hubbell Power Systems, Inc., shall not be responsible for, or liable to you and/or your customers for the adoption, revision, implementation, use or misuse of this information. Hubbell, Inc., takes great pride and has every confidence in its network of installing contractors and dealers.

Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.



PRELIMINARY DESIGN REQUEST FORM

Contact at Hubbell Power Systems, Inc.:

Installing Contractor

Firm: _____ Contact _____
 Phone: _____ Fax: _____ Cell: _____

Project

Name: _____ Type: Foundation Underpinning/Shoring
 Address: _____ New Construction Rock
 _____ Tieback Retaining Other:
 _____ Soil Nail Retaining

Project Engineer ? Yes No

Firm: _____ Contact: _____
 Address: _____ Phone: _____
 _____ Fax: _____
 _____ Email: _____

Geotechnical Engineer ? Yes No

Firm: _____ Contact: _____
 Address: _____ Phone: _____
 _____ Fax: _____
 _____ Email: _____

Loads

	Design Load	FS (Mech) #1	FS (Geo) #1	Design Load	FS (Mech) #2	FS (Geo) #2
Compression	_____	_____	_____	_____	_____	_____
Tension	_____	_____	_____	_____	_____	_____
Shear	_____	_____	_____	_____	_____	_____
Overturning	_____	_____	_____	_____	_____	_____

Define the owner's expectations and the scope of the project: _____

The following are attached: Plans Soil Boring Soil Resistivity Soil pH

If any of the above are not attached, please explain: _____

Date: _____ Requested Response: _____

Please copy and complete this form to submit a design request.

FORMS



HeliCAP® Helical Capacity Design Software Buyer Qualification and Order Form

<u>Qty</u>	<u>Description</u>	<u>Price Each</u>	<u>Hard Drive Serial # (see instructions on next page)</u>
------------	--------------------	-------------------	--

1	HeliCAP® Helical Capacity Design Software	_____	_____
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Please send me a copy of HeliCAP® on CD.

Three additional licenses are available per copy. Go to www.abchance.com or contact Hubbell Power Systems, Inc. for more information.

BACKGROUND INFORMATION

Engineer

- Structural
- Geotechnical
- Civil
- Mechanical
- Electrical
- Registered professional
- Previous helical experience
- Other _____

Contractor

- General
- Sub
- Design-Build
- Other _____

- Architect**
- Distributor**
- Government Agency**
- Educational Institute**
- Student**
- Power Utility**
- End User**
- Other** _____

APPLICATION REFERENCE

UTILITY

- Guy Anchors (Transmission Line)
- Telecommunication Towers
- DOT/FFA
- Registered Professional
- Other _____

RESIDENTIAL

- Underpinning (Foundation Repairs)
- Basement Wall Anchors
- Other _____

COMMERCIAL

- Underpinning (Foundation Repairs)
- Deep Foundations
- Pipeline Anchors (Buoyancy)
- Earth Retention (Tiebacks and Soil Nails)
- Tiedowns (Uplift Restraint)
- Boardwalks - Walkways
- Other _____

FORMS

System Requirements

- Windows® XP/7/8
- Pentium® 100 MHz processor
- 32 Mb RAM
- 35 Mb free hard disk space
- 2X CD-ROM drive
- MAC users must have Virtual PC installed.

How to Find Your Hard Drive Serial Number

Your hard drive serial number is required in order to issue a license key for the HeliCAP® Helical Capacity Design Software. To find your hard drive serial number:

- Click the Start button at the lower left corner of the desktop.
- In the search prompt, type "cmd".
- A dialog box will pop up that should have "CMD". It should be near the top of the box and it should be highlighted. Press Enter.
- A DOS window should appear and display a DOS prompt. The DOS prompt will normally start with "C:", which is the default drive. If you want to install HeliCAP® on a different drive, type the drive letter followed by a colon (e.g., "d:") at the prompt and press Enter.
- Type "vol" at the DOS prompt and press Enter. The hard drive serial number (or Volume Serial Number) will be displayed. The Volume Serial Number is 8 digits, with a dash in between. The characters are alpha numeric.
- Record the serial number and close the DOS prompt window.

ATLAS RESISTANCE® Piers Installation Log

Project:	Sheet of
Pier Number:	
Pier Designator:	Installation Date:
Maximum Work Capacity:	Installation Technician:
Installation Cylinder Effective Area:	

DEPTH (ft)	PIER SECTION	PRESSURE (psi)	LOAD (lbs)	NOTES
3'-6	1			
7'-0	2			
10'-6	3			
14'-0	4			
17'-6	5			
21'-0	6			
24'-6	7			
28'-0	8			
31'-6	9			
35'-0	10			
38'-6	11			
42'-0	12			
45'-6	13			
49'-0	14			
52'-6	15			
56'-0	16			
59'-6	17			
63'-0	18			
66'-6	19			
70'-0	20			
73'-6	21			
77'-0	22			
80'-6	23			
84'-0	24			
87'-6	25			

Total Full Section Length:	Length of Cut-Off Section:
Depth to Pier:	Total Depth from Grade:

LIFTING LOG

Lift Ram Effective Area:				Date of Lift:
Final Lift	Lift Amount (in)	Pressure (psi)	Load (lbs)	Comments:

FORMS



ATLAS RESISTANCE® Piers - Project Summary Log

Project:					Project Completion Date:				
					Sheet of				
Pier Number	Date	Total Depth	Install Pressure	Install Load	Stage	Final Lift Pressure	Final Lift Load	Final Lift Amount	FS Drive vs Lift
1									
2									
3									
4									
5					←				
6									
7									
8									
9									
10					DRIVE				
11									
12					←				
13									
14									
15									
16									
17					→				
18									
19									
20					LIFT				
21									
22									
23									
24									
25									
26					→				
27									
28									
29									
30									
Report Prepared By:					Date:				

FORMS





GLOSSARY



GLOSSARY of TERMS

Alignment Load (AL)	A low magnitude load applied to a pile/anchor at the start of the load test to keep the testing equipment correctly positioned and to remove any slack in the reaction system.
Allowable Capacity	The geotechnical capacity of a pile/anchor or pier as determined by a reduction of the ultimate capacity with an appropriate factor of safety or resistance factor.
Anchor or Anchorage	A combination of anchor and the soil or deeply weathered rock into which it is installed that together resist tension loads applied to the anchor.
ATLAS RESISTANCE® Pier	An assembly of structural steel components that includes a foundation bracket assembly attached to the concrete foundation, which is then mounted to a steel pier that is installed to bedrock or dense bearing stratum via hydraulic jacking of the pipe shaft segments.
Axial Load (P)	An axially oriented compression or uplift (tension) load supported by an pile/anchor or pier resulting from dead, live and seismic loads.
Bearing Load	A load generally regarded as an axial compressive load on a pile or pier.
Bearing Stratum	Soil layers of sufficient strength to be capable of resisting the applied axial load transferred by a pile or pier.
Contractor	The person or firm responsible for performing the required construction, i.e., installation of CHANCE® Helical Piles/Anchors or ATLAS RESISTANCE® Piers.
Coupling	A central steel shaft connection for CHANCE® Type SS and RS helical piles. Couplings may be either separable sleeve couplings or integral forged sockets.
Coupling Bolts	High strength structural steel fasteners used to connect helical anchor/pile segments together. For CHANCE® Type SS segments the coupling bolt transfers axial loads. For CHANCE® Type RS segments the coupling bolt transfers both axial and torsional loads.
Coupling, Pier Sleeve	A steel tubing of suitable outside diameter to fit into a pier starter and extension section to provide a means for attaching the various pier sections together for ATLAS RESISTANCE® Piers. It allows for extending the pier to the required depth.
Creep	The movement that occurs during the Creep Test of a pile/anchor or pier under a constant load.
Dead Load (DL)	Generally, vertical loads comprised of the weight of the structure plus various fixed assets, such as equipment, machinery, walls and other permanent items.

GLOSSARY

Design Load (Pd)	The maximum anticipated service load applied to a pile or pier, comprised of calculated dead and live loads. Also known as Working Load.
Effective Stress	The total force on a cross section of a soil mass that is transmitted from grain to grain of the soil, divided by the area of the cross section. Also known as Intergranular Stress.
Elastic Movement	The recoverable movement measured during a pile/pier load test resulting from the elastic shortening or lengthening of the pile/pier shaft material.
End Bearing	The transfer of axial loads to the soil at the tip of a helical pile via helix plates or at the tip of a pier.
Evaluation Services Report (ESR)	The evaluation of a manufactured product or building component by the evaluation services of the various model code agencies (ICC). The report outlines the requirements that must be met to satisfy the intent of the Building Code.
Extension Pier Section	With reference to an ATLAS RESISTANCE® Pier, the pipe sections following the starter pier section that extend the starter section to the load bearing stratum. The extension pier sections are equipped with a pier sleeve that allows for coupling the extensions to the starter section or other extensions.
Failure Criteria	A method used to determine the ultimate capacity of a pile/anchor based on a load test. A typical failure criteria for helical piles is the load where the pile head displacement is equal to 10% of the average helix diameter plus the elastic movement.
Foundation Soil Load	The load from soil overburden on the outstanding toe of a footing. This soil load is in addition to the existing structure weight supported by the footing. It increases the dead load used as a reaction to install a push pier and therefore aids the installation. However, it may work to defeat attempts to lift a structure and may require reduction or removal if a lift is required.
Friction Reduction Collar	The enlarged section at the bottom of the pipe starter section of an ATLAS RESISTANCE® Pier. The collar diameter is larger than the following pipe shaft, thus forcing the displaced soil away from the pipe shaft.
Gunite	A dry concrete mixture that is carried to a nozzle in moving air where it is mixed with water. The operator controls the water-cement ratio.
Helical Extension	A helical pile/anchor component installed immediately following the lead section (if required) to increase the bearing area of the foundation. This component consists of one or more helical plates welded to a central steel shaft.
Helical Pile	A bearing type foundation consisting of a lead section, helical extension (if required by site conditions), plain extension section(s) and a pile cap. Also known as a screw pile or helical screw foundation.

HELICAL PULLDOWN® Micropile	A small diameter, soil displacement, cast-in-place helical pile in which the applied load is resisted by both end bearing and friction. The design is protected under United States Patent 5,707,180, Method and Apparatus for Forming Piles In-Situ.
Helix Plate	A round steel plate formed into a ramped spiral. The helical shape provides the downward force used to install a helical pile/anchor, plus the plate transfers the load to the soil in end bearing. Helical plates are available in various diameters and thicknesses.
Impact Driven	A pile driven with a pile hammer.
In-Situ	In the natural or original position. Used in soil mechanics to describe the original state of soil condition prior to disturbance from field testing or sampling methods.
Installation Torque	The resistance generated by a helical pile/anchor when installed into soil. The installation resistance is a function of the soil plus the size and shape of the various components of the helical pile/anchor. The installation energy must equal the resistance to penetrate the soil (penetration energy) plus the energy loss due to friction (friction energy).
Kip	One thousand pounds of force, or a "kilopound."
Lagging	Horizontal members, usually of timber or concrete, spanning between soldier piles to retain the soil between pile locations. They transfer the load directly from the soil to the soldier piles.
Lateral Load (V)	A load applied perpendicular to the longitudinal axis of a pile or pier resulting from live and seismic loads. Also called a shear load.
Lead Section	The first helical pile/anchor component installed into the soil, consisting of single or multiple helix plates welded to a central steel shaft. The helical plates transfer the axial load to bearing stratum.
Live Load (LL)	A load comprised of roof, wind, floor, and in some cases, seismic loads. Floor loads include people, temporary or non-fixed equipment, furniture and machinery. Roof loads include ice and snow.
Load Bearing Stratum	See Bearing Stratum.
Net Settlement	The non-elastic (non-recoverable) movement or displacement of a pile/pier measured during load testing.
Open Specification	An arrangement in which the contractor is given the responsibility for the scope and design of the pile or pier installation. The construction, capacity and performance of the pile or pier are the sole responsibility of the contractor. This specification is most common for securing bids on temporary projects, and is not recommended for permanent applications. See also Performance Specification and Prescriptive Specification.
Overburden	Natural or placed material that overlies the load bearing stratum.

GLOSSARY

Performance Specification	An arrangement in which the contractor is given the responsibility for certain design and/or construction procedures, but must demonstrate to the owner through testing and/or mutually agreed upon acceptance criteria that the production piles/piers meet or exceed the specified performance parameters. The contractor and owner share responsibility for the work. See also Open Specification and Prescriptive Specification.
Pier Head Assembly	An ATLAS RESISTANCE® Pier bracket or other termination device that allows attachment to an existing footing or floor slab.
Pile Cap	A means of connection through which structural loads are transferred to a pile or pier. The type of connection varies depending on the requirements of the project and the type of pile/pier material used. NOTE: Care must be used in the design of pile caps to ensure adequate structural load transfer. Design constraints such as expansive soils, compressible soils and seismic loads must be accounted for in pile cap design.
Pipe Shaft	A central shaft element made from hollow, steel, round pipe, ranging in diameter from 2" to 10". Also known as Hollow Shaft, Round Shaft (Type RS), Type T/C and Type PIF for CHANCE® Helical Piles.
PISA® System	The acronym for Power Installed Screw Anchor. The PISA® System was originally developed for the power utility industry in the late 1950's.
Plain Extension	A central steel shaft segment without helical plates. It is installed following the installation of the lead section or helical extension (if used). The units are connected with separable sleeve couplings or integral forged couplings and bolts. Plain extensions are used to extend the helical plates beyond the specified minimum depth into competent load bearing stratum.
Pore Pressure	Unit stress carried by the water in the soil pores in a cross section.
Post Tensioning	The stressing of a structure after all structural elements are in place (e.g., loading a tieback anchor to post tension a retaining wall).
Preloading	A load applied to a pile prior to connection to a structure to minimize structural movement in service. Also known as Prestressing.
Prescriptive Specification	An arrangement in which the owner has the sole responsibility for the scope and design of the pile or pier installation and specifies the procedures that must be followed. Prescriptive specifications mandate the owner to be responsible for the proper performance of the production piles/piers. The contractor is responsible for fulfilling the obligations/details as specified in the construction documents.

Pretensioning	The prestressing of an anchor or foundation prior to the service load being applied.
Proof Test	The incremental loading of a pile or pier, where the load is held for a period of time and the total movement is recorded at each load increment. The maximum applied load is generally 1.0 to 1.25 times the design load.
Rebound	Waste created by sprayed concrete falling to the floor or ground below the intended target location. Rebound is usually half for shotcrete compared to gunite.
Reinforced Earth	A soil mass whose overall shear strength has been increased via some reinforcing technique (e.g., SOIL SCREW® Anchor, soil nail, geofabric, etc.).
Round Shaft	Hollow steel, round pipe, central shaft elements ranging in diameter from 2" to 10". Also known as Hollow Shaft, Round Shaft (Type RS), Type T/C and Type PIF for CHANCE® Helical Piles.
Safety Factor (SF)	The ratio of the ultimate capacity to the working or design load used for the design of any structural element. Also referred to as a factor of safety.
Seismic Load	A load induced on a structure caused by ground motions resulting from a seismic event (earthquake). Usually included as part of the live load.
Shaft	A steel or composite steel/grout shaft or rod used to transfer load from the surface to the bearing plates.
Shotcrete	A wet concrete mixture that is pumped to a nozzle where air is added to carry the concrete mix to the application. Often used to quickly provide a facing on soil nail or SOIL SCREW® Anchor reinforced retaining walls.
Soil Nail	A steel rod driven or drilled and grouted into the ground to reinforce, stabilize, or strengthen soil such as the soil mass behind a retaining wall.
SOIL SCREW® Anchor	A CHANCE® Helical Anchor with helices welded along the entire length of the shaft. A SOIL SCREW® Anchor is used to engage the soil and serves the same function as a soil nail, i.e., soil reinforcement.
Soldier Pile	An H or WF section normally driven (or placed in a drilled hole and backfilled with weak grout or concrete) vertically at intervals of several feet to resist the load on the lagging of a retaining wall. It is the main structural element of a retaining wall. Also known as an h-pile.
Square Shaft (SS)	A solid steel, round-cornered-Square central Shaft element ranging in size from 1-1/4" to 2-1/4". Also known as Type SS for CHANCE® Helical Anchors.
Starter Pier Section	With reference to an ATLAS RESISTANCE® Pier, the first pipe section to be placed in the ground. It is usually equipped with a friction reduction collar.
Starter Section	With reference to a CHANCE® Helical Pile, a lead section, but usually used in reference to a SOIL SCREW® Anchor.
Test Load	The maximum load applied to a pile or pier during testing.

GLOSSARY

Thread Bar Adapter	A section of central steel shaft that can be used to connect a tiedown or ground anchor to a new or existing concrete foundation/pile cap via a high tensile strength pre-stressing thread bar.
Tieback	A tension anchor used to resist the loads on a retaining wall due to the earth pressure and other loads at or near the top of a wall.
Tiedown	A device used to transfer tensile loads to soil. Tiedowns are used for seismic retrofit. They consist of a central steel shaft, helix bearing plates, coatings, corrosion protection, a means of connection, etc. Also known as a ground anchor.
Top Pier Platform	The top section of an ATLAS RESISTANCE® Pier equipped with vertical stabilizers that facilitate attachment to the pier bracket.
Torque Rating	The maximum torque energy that can be applied to a helical anchor/pile during installation in soil. Also known as allowable torque or safe torque.
Ultimate Capacity (Qu)	The limit state based on the structural and/or geotechnical capacity of a pile or pier, defined as the point at which no additional capacity can be justified.
Ultimate Load (Pu)	The load determined by applying a safety factor to the working load. The ultimate load applied to a structural element must be less than the ultimate capacity of that same element or a failure limit state may occur.
Underpinning Bracket	A bracket used to connect an existing strip or spread foundation or footing to a CHANCE® Helical Pile or ATLAS RESISTANCE® Pier.
Uplift Load	Generally, an axial tensile load on an anchor.
Verification Test	Similar to the Proof Test except a cyclic loading method is used to analyze total, elastic and net movement of the pile. Used for pre-contract or pre-production pile load tests.
Vertical Stabilizer	A steel plate element, welded to the side of the top pier platform, which prevents lateral movement within the pier bracket. Vertical stabilizers will allow the pier bracket to move vertically up from the top pier platform but prevent the bracket from moving below a previously set elevation.
Waler	A horizontal structural member placed along soldier piles to accept the load from the piles and transmit it to struts, shoring or tieback anchors.
Working Load	Another term for Design Load.

GLOSSARY

