CHANCE®

Transmission and Substation Foundations

Technical Design Manual

HUBBELL®

TRANSMISSION AND SUBSTATION FOUNDATIONS
TECHNICAL DESIGN MANUAL

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INTRODUCTION
SECTION 1

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SYMBOLS USED IN THIS SECTION

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RR	Round Rod	1-5
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kips	Kilopound	1-10

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.

DEFINITION OF HELICAL PILES/ANCHORS

The helical pile/anchor is 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 balances the capacities of its three basic parts and maximizes the efficient use of their materials.

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 Sytems, 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-lbs 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 1½" 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). 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 3½"-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.

- **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.

- **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.

CHANCE® CIVIL CONSTRUCTION SOIL CLASSIFICATION , TABLE 1-1

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.

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**

SoftwareHubbell 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 utility 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 commercial construction. The product's versatility allows for application in limited and remote access. Helical piles/anchors are a great solution for telecommunicat and transmission towers as well as for tie downs in windy or seismic areas. 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

CHANCE® HELICAL PILE/ANCHOR ADVANTAGES TABLE 1-2

Advantages of CHANCE® Helical Pile/Anchors

- 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
- Install in inclement weather
- Solution for:
  - Restricted access sites
  - High water table
  - Weak surface soils
- Environmentally friendly
- No vibration
- No spoils to remove

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 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.

- **Inclement weather installation**

Because helical piles/anchors can be installed in inclement 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.

- **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 pile 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 installers.

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

CONTENTS

SYMBOLS USED IN THIS SECTION

w_n	Moisture Content	2-6
M	Mass	2-5
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
USCS	Unified Soil Classification System	2-6
γ_s	Saturated Unit Weight (Saturated Density)	2-6
SL	Shrinkage Limit	2-7
PL	Plastic Limit	2-7
LL	Liquid Limit	2-7
PI	Plasticity Index	2-7
L.I.	Liquidity Index	2-7
S_t	Soil Sensitivity	2-8
K_t	Torque Multiplier for Helical Piles/Anchors	2-8
σ`	Effective Stress	2-11
σ	Total Stress	2-11
u	Pore Water Pressure	2-11
c	Cohesion	2-11

s_u	Undrained Shear Strength	2-11
τ_f	Shear Strength	2-12
φ	Friction Angle	2-12
GWT	Ground Water Table	2-13
CFA	Continuous Flight Auger	2-15
HSA	Hollow Stem Auger	2-15
SPT	Standard Penetration Test	2-16
ST	Shelby Tube	2-16
SS	Split Spoon	2-17
N	Field Blowcount Value from Standard Penetration Test	2-17
DMT	Dilatometer Test	2-18
CPT	Cone Penetration Test	2-18
CPTU	Piezocone Penetration Test	2-18
FVT	Field Vane Test	2-19
VST	Vane Shear Test	2-19
RQD	Rock Quality Desigination	2-20
q_u	Unconfined Compressive Strength	2-22
UC	Unconfined Compression Test	2-22

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® helical piles are utilized for communication towers, transmission and distribution power lines, signs and 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.

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.

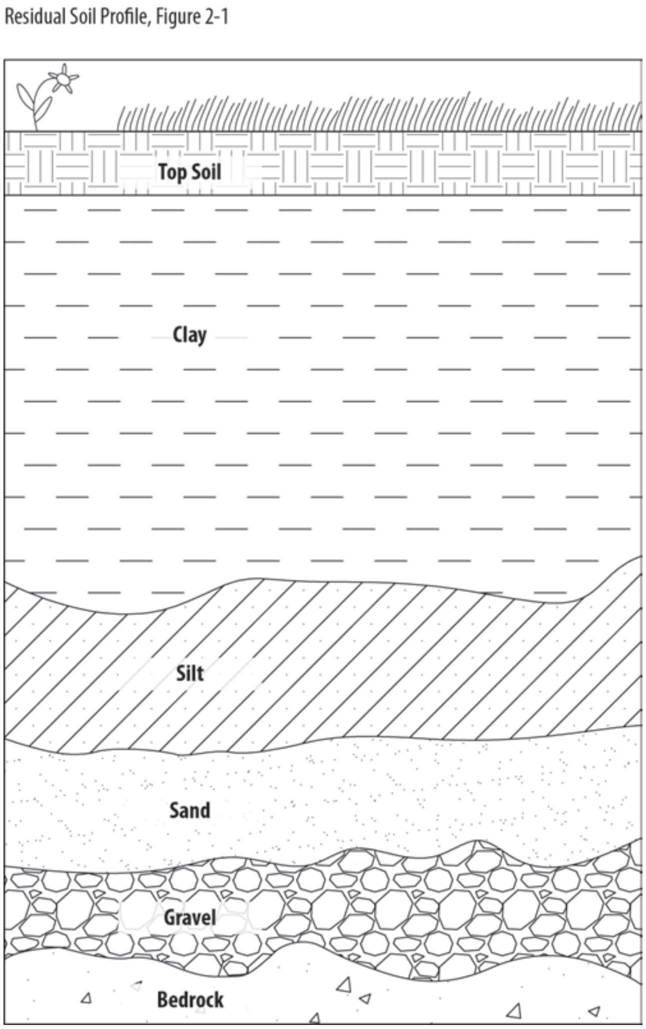
DEFINITION OF SOIL

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.

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.

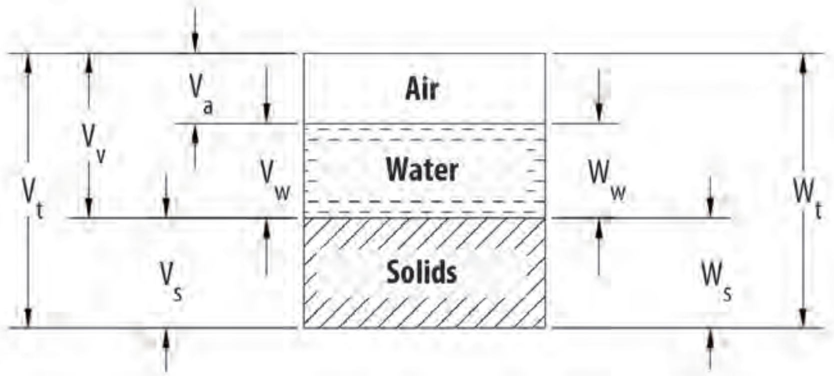
A soil mass is a porous material containing solid particles interspersed with pores or voids. These voids may be filled with air, water, or both. Figure 2-2 shows a conceptual block diagram of relative volumes of air, water, and soil solids in a given volume of soil. Pertinent volumes are indicated by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



Generalized Soil Profile
Figure 2-1

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.



Mositure Content	W_n	W_w / W_s
Degree of Saturation	S	V_w / V_v
Void Ratio	e	V_v / V_s
Porosity	n	V_v / V_t
Dry Unit Weight (Dry Density)	γ_d	W_s / V_t
Total Unit Weight	γ_t	$(W_s + W_w) / V_t$
Saturated Unit Weight	γ_s	$(W_s + V_v \gamma_w) V_t$
Effective (Submerged) Unit Weight	γ^1	$\gamma_s - \gamma_w$

Soil Phases and Index Properties
Figure 2-2

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.

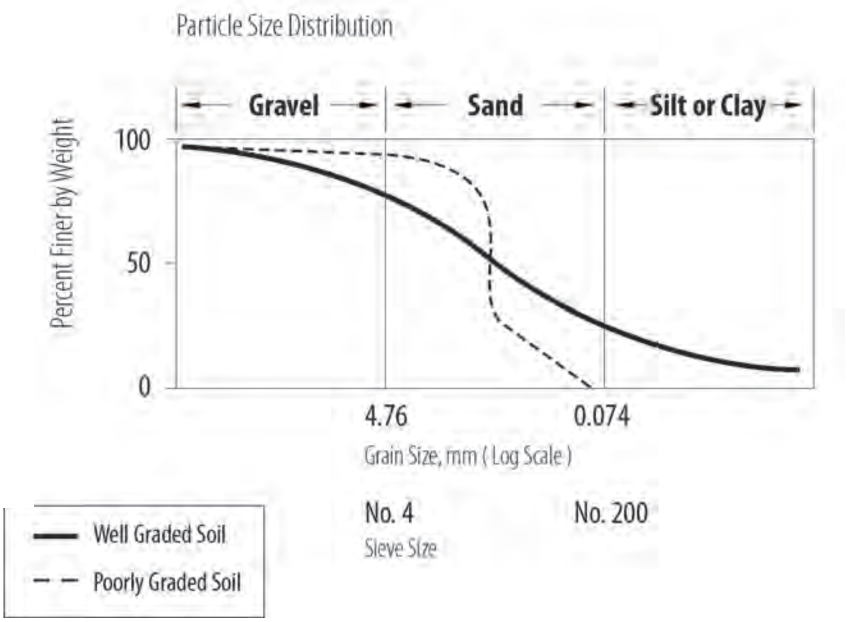
SOIL PARTICLE SIZES, TABLE 2-1

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 Fine	0.75”- 3” No. 4 - 0.75”	19 - 75 mm 4.76 - 19 mm	Marbles & Peas
Sand	Coarse Medium Fine	No. 10 - No. 4 No. 40 - No. 10 No. 200 - No. 40	2 - 4.76 mm 0.42 - 2 mm 0.074 - .042 mm	Rock Salt, Table Salt, Sugar
Fines (silts and clays)	---	Passing No. 200	0.074 mm	Flour

SOIL CONSISTENCY STATES AND INDEX PROPERTIES

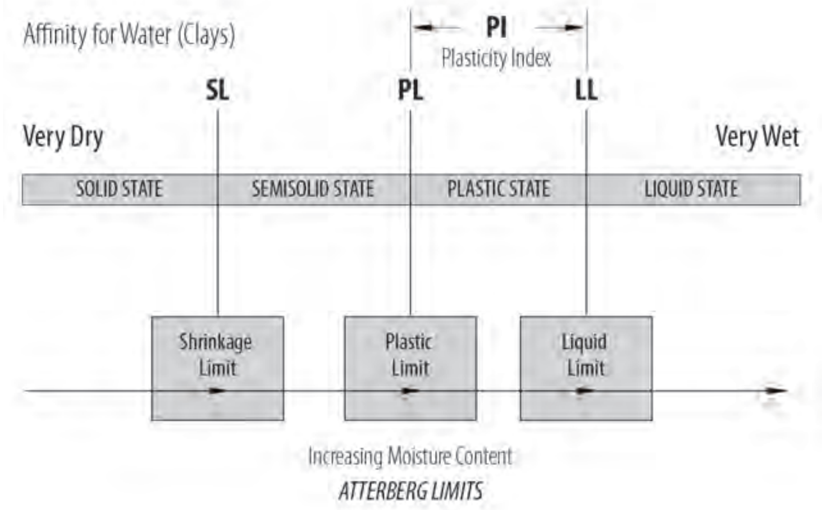
The consistency of fine-grained soils can range from a dry solid condition to a liquid form with successive addition of water and mixing as necessary to expand pore space for acceptance of water. The consistency passes from solid to semi-solid to plastic solid to viscous liquid as shown in Figure 2-4. 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.



Typical Grain Size Distribution Curves
Figure 2-3

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



Plasticity and Atterberg Limits
Figure 2-4

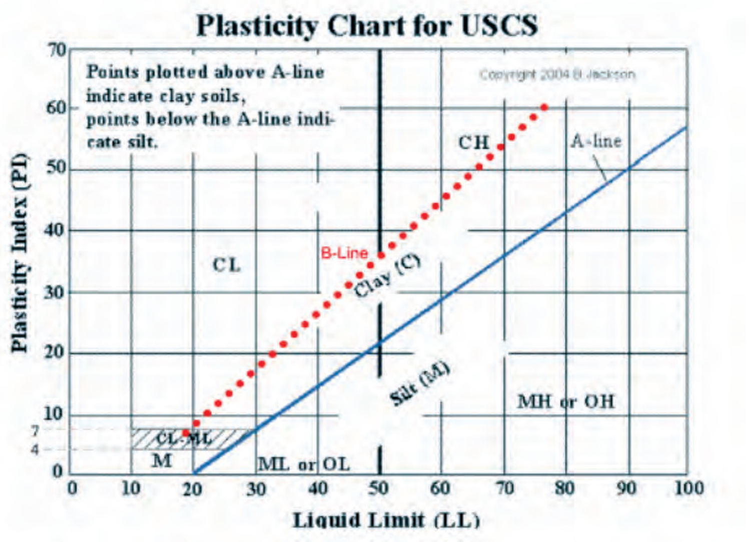


Figure 2-5

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 Kt 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 $S_t = su_{und}/su_{rem}$. Most clays are sensitive to some degree, but highly sensitive soils cannot be counted on for shear strength after a CHANCE® helical pile, 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 gravely 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

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 find 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.

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:

$$\sigma` = s - u \qquad \text{Equation 2-1}$$

where: $\sigma`$ = 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. 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

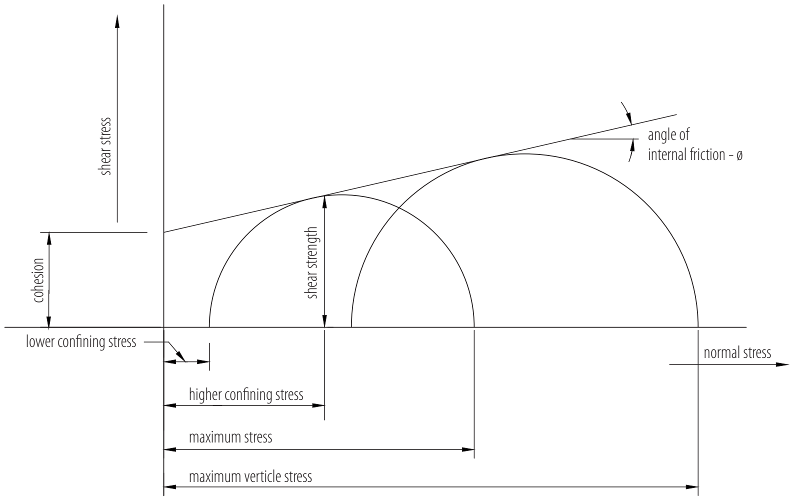
Most unsaturated coarse-grained soils and some mixed grain soils, have sufficiently high permeability that applied loads do not generate pore water pressures or any pore water pressures can dissipate during shear. This is also true if the load is applied very slowly and water is allowed to drain. The 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:



Mohr's Diagram for Moderately Plastic Soil
Portland Cement Association (1996)
Figure 2-6

$\tau = \sigma \tan \varphi$ **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 (s), 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.

$\tau_f = c + \sigma \tan \varphi$ **Equation 2-3**

In terms of effective stress:

$\tau_f = c' + (\sigma - u) \tan \varphi'$ **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:

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:

- 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.

- 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:

- 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.

- 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 typicallyrequire 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 Operation
Figure 2-7

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 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.

Figure 2-8

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.

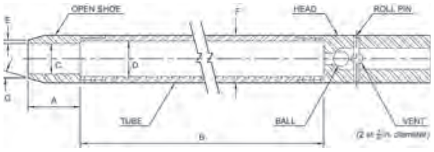
Soil Sampling

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

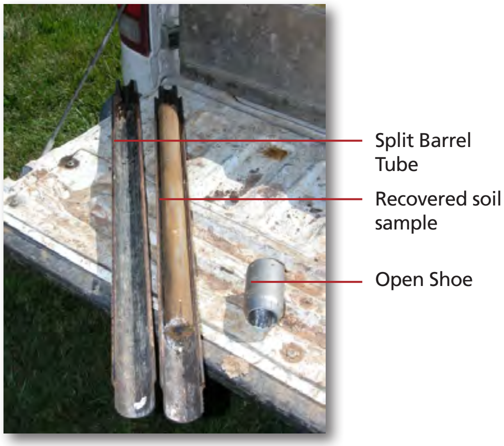
The cuttings from exploratory drill holes are inadequate to furnish a satisfactory conception of the engineering characteristics of the soils encountered, or even the thickness and depths of the various strata. To obtain soil samples from test borings, a sampling spoon is attached to the drill rod and 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.

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. 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 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.



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

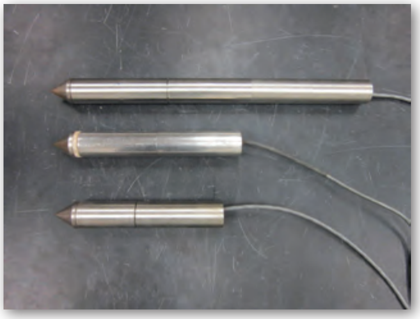
Geometry of Standard Penetration Test
Split-Barrel Sampler (ASTM D 1586)
Figure 2-9



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.

Undisturbed Samples



CPT/CPTU

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.

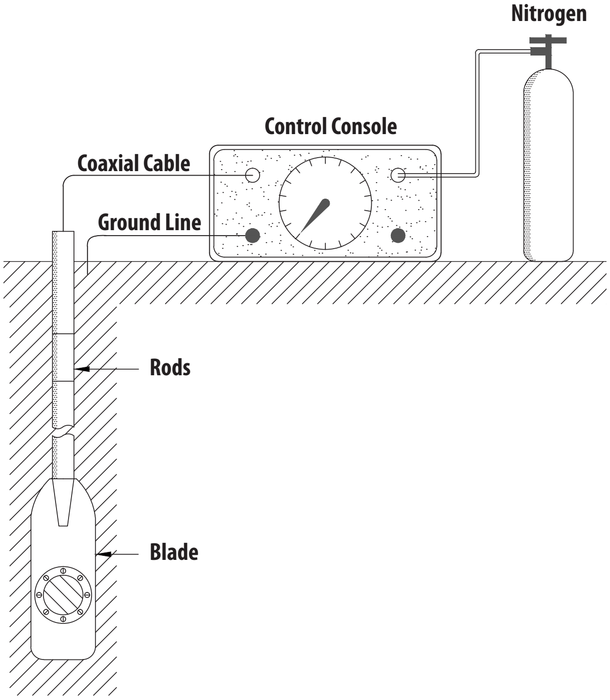


Figure 2-12

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 cm^2. 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.

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.

Figure 2-13

Figure 2-11

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.

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

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

Vanes are available is 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.

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

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:

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

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.

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.

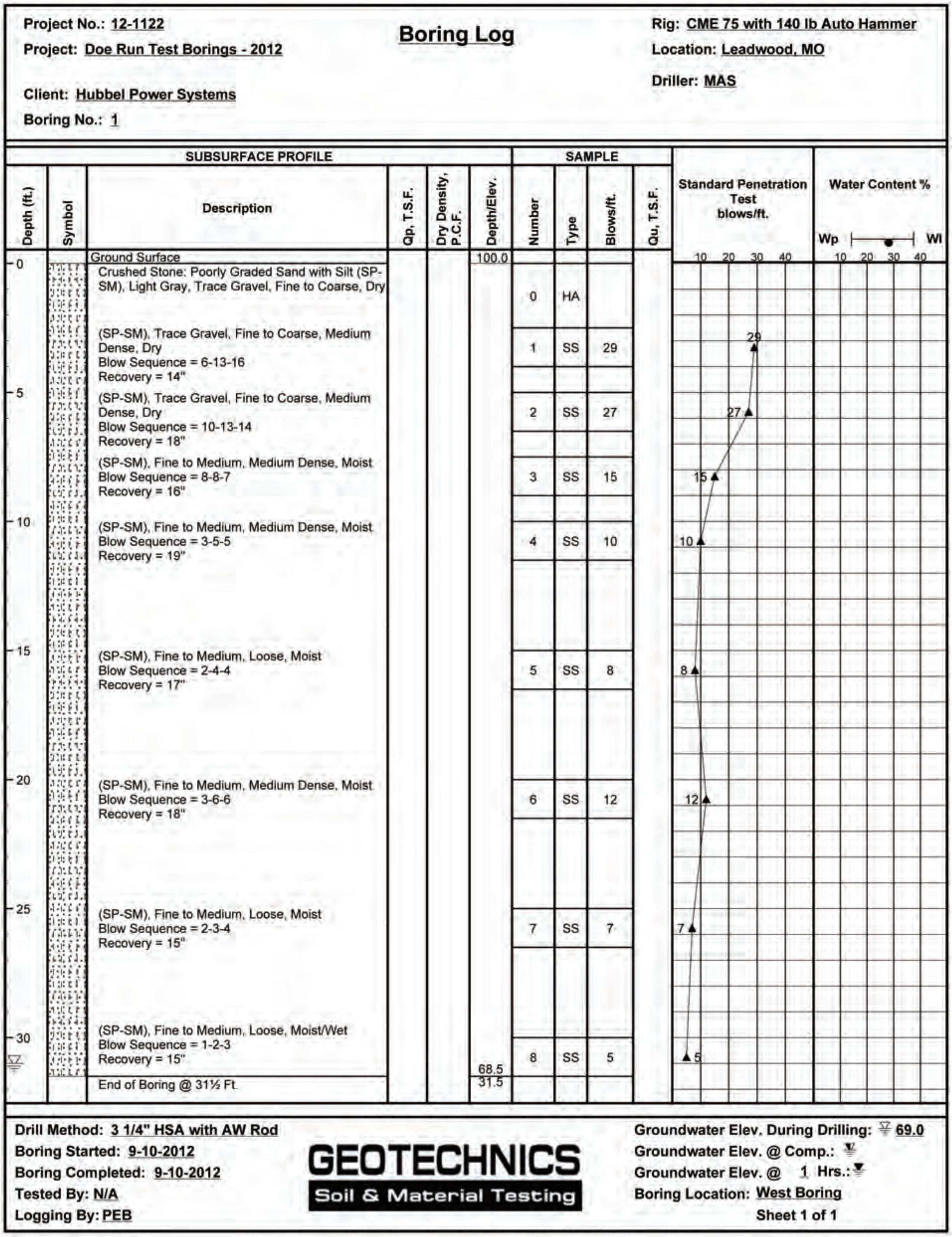
- **Particle Size Analysis**

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 tests. The liquidlimit and the plastic limit are particularly important since they may be used along with the natural water content to determine the liquidity Index.

SAMPLE BORING LOG IN COARSE-GRAINED SOIL, TABLE 2-6



Project No.: 12-1122
Project: Doe Run Test Borings - 2012
Client: Hubbel Power Systems
Boring No.: 1

Boring Log

Rig: CME 75 with 140 lb Auto Hammer
Location: Leadwood, MO
Driller: MAS

SUBSURFACE PROFILE						SAMPLE					
Depth (ft.)	Symbol	Description	Qp, T.S.F.	Dry Density, P.C.F.	Depth/Elev.	Number	Type	Blows/ft.	Qu, T.S.F.	Standard Penetration Test blows/ft. (10 20 30 40)	Water Content % (Wp ● Wl; 10 20 30 40)
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		29	
5		(SP-SM), Trace Gravel, Fine to Coarse, Medium Dense, Dry Blow Sequence = 10-13-14 Recovery = 18"				2	SS	27		27	
		(SP-SM), Fine to Medium, Medium Dense, Moist Blow Sequence = 8-8-7 Recovery = 16"				3	SS	15		15	
10		(SP-SM), Fine to Medium, Medium Dense, Moist Blow Sequence = 3-5-5 Recovery = 19"				4	SS	10		10	
15		(SP-SM), Fine to Medium, Loose, Moist Blow Sequence = 2-4-4 Recovery = 17"				5	SS	8		8	
20		(SP-SM), Fine to Medium, Medium Dense, Moist Blow Sequence = 3-6-6 Recovery = 18"				6	SS	12		12	
25		(SP-SM), Fine to Medium, Loose, Moist Blow Sequence = 2-3-4 Recovery = 15"				7	SS	7		7	
30 ▽		(SP-SM), Fine to Medium, Loose, Moist/Wet Blow Sequence = 1-2-3 Recovery = 15"			68.5 31.5	8	SS	5		5	
		End of Boring @ 31½ Ft.									

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

GEOTECHNICS
Soil & Material Testing

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

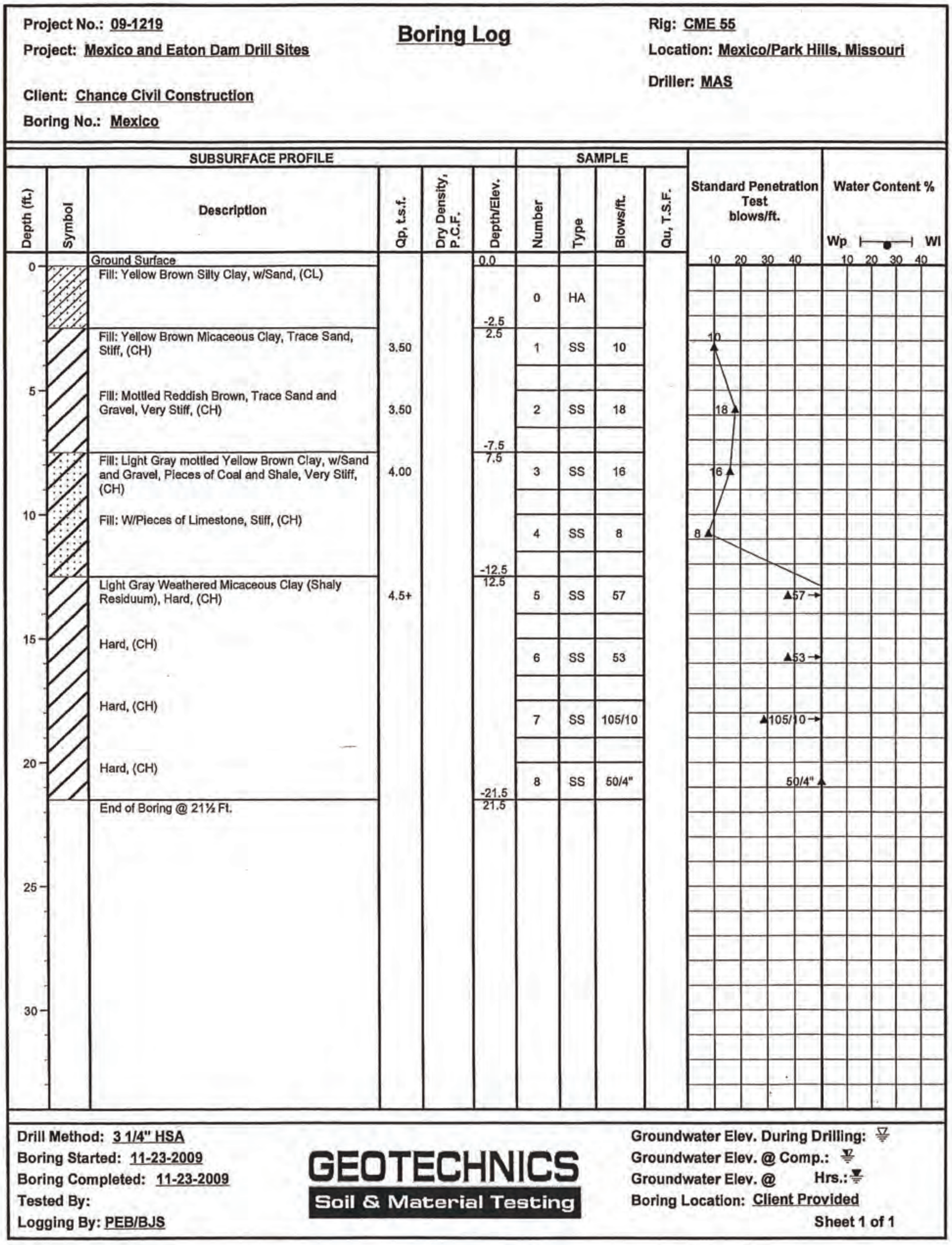
Strength Characteristics

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 "qu". 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. 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
Project: Mexico and Eaton Dam Drill Sites
Client: Chance Civil Construction
Boring No.: Mexico

Boring Log

Rig: CME 55
Location: Mexico/Park Hills, Missouri
Driller: MAS

SUBSURFACE PROFILE						SAMPLE			
Depth (ft.)	Symbol	Description	Qp, t.s.f.	Dry Density, P.C.F.	Depth/Elev.	Number	Type	Blows/ft.	Qu, T.S.F.
		Ground Surface			0.0				
0		Fill: Yellow Brown Silty Clay, w/Sand, (CL)				0	HA		
					-2.5 2.5				
		Fill: Yellow Brown Micaceous Clay, Trace Sand, Stiff, (CH)	3.50			1	SS	10	
5		Fill: Mottled Reddish Brown, Trace Sand and Gravel, Very Stiff, (CH)	3.50			2	SS	18	
					-7.5 7.5				
		Fill: Light Gray mottled Yellow Brown Clay, w/Sand and Gravel, Pieces of Coal and Shale, Very Stiff, (CH)	4.00			3	SS	16	
10		Fill: W/Pieces of Limestone, Stiff, (CH)				4	SS	8	
					-12.5 12.5				
		Light Gray Weathered Micaceous Clay (Shaly Residuum), Hard, (CH)	4.5+			5	SS	57	
15		Hard, (CH)				6	SS	53	
		Hard, (CH)				7	SS	105/10	
20		Hard, (CH)				8	SS	50/4"	
		End of Boring @ 21½ Ft.			-21.5 21.5				
25									
30									

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

Sheet 1 of 1

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 deeper to penetrate through this material into better bearing soil. It is not recommended to locate the helical bearing plates.

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 indentified 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." 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.

A plasticity index (PI) greater than 25 to 30 is a red flag to the geotechnical engineer. A PI ≥ 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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PRODUCT FEASABILITY
SECTION 3

CONTENTS

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
FS	Factor of Safety	3-3
kip	Kilopound	3-3
SS	Square Shaft	3-5
RS	Round Shaft	3-5

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 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.
- 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 or anchor 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 foundation products. Generally, the minimum FS is 2 on all permanent loading conditions and 1.5 for any temporary load situation. Certain applications may require more stringent Factors of Safety on certain projects.

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 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 have been installed inside office buildings, restaurants, retail shops and hospitals without interrupting their normal routines. CHANCE helical pile 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.

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 or Helical Pulldown micropile. 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.

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 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, 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 piles are used in the controlled fills of roadways 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. 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 contractor for guidance on this matter. A wide variety of equipment can be utilized for projects based on such considerations as headroom.

In the utility industry digger derricks, line trucks, bobcats, and small excavators are used for installation of helical piles.

SHAFT SIZE SELECTION BASED ON SOIL PARAMETERS

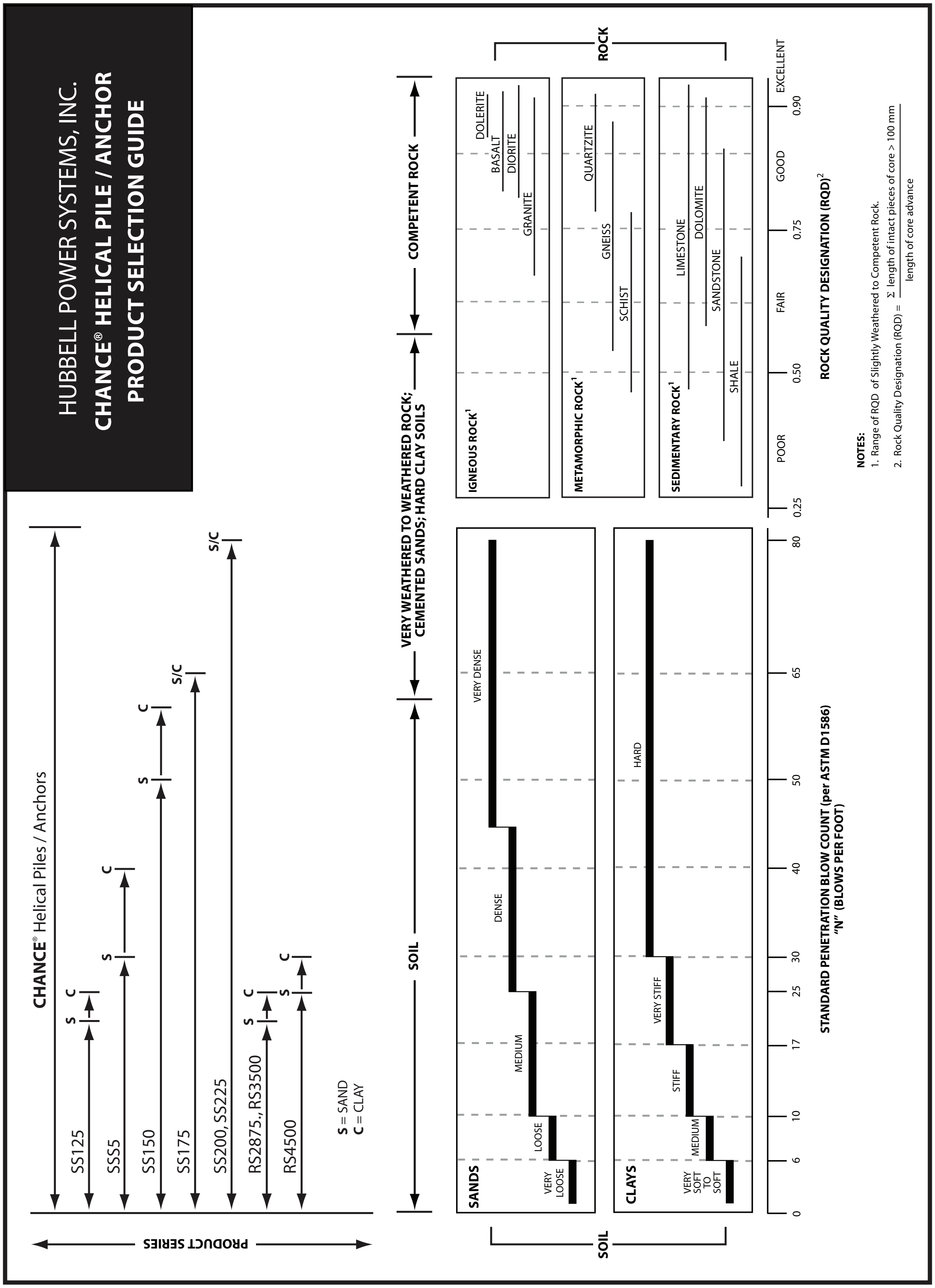
An additional condition that must be evaluated is the ability of the helical pile to penetrate soil to the required depth. For example, a foundation design may require an installation that penetrates a dense fill layer consisting of compacted construction debris (concrete, rubble, etc.) through a compressible 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. This figure does not address the proper product selection based on its application.



Product Selection Guide, Figure 3-1

PRELIMINARY CHANCE® HELICAL PILE/ANCHOR DESIGN GUIDE

Hubbell Power Systems, Inc. manufactures CHANCE® helical piles/anchors 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:

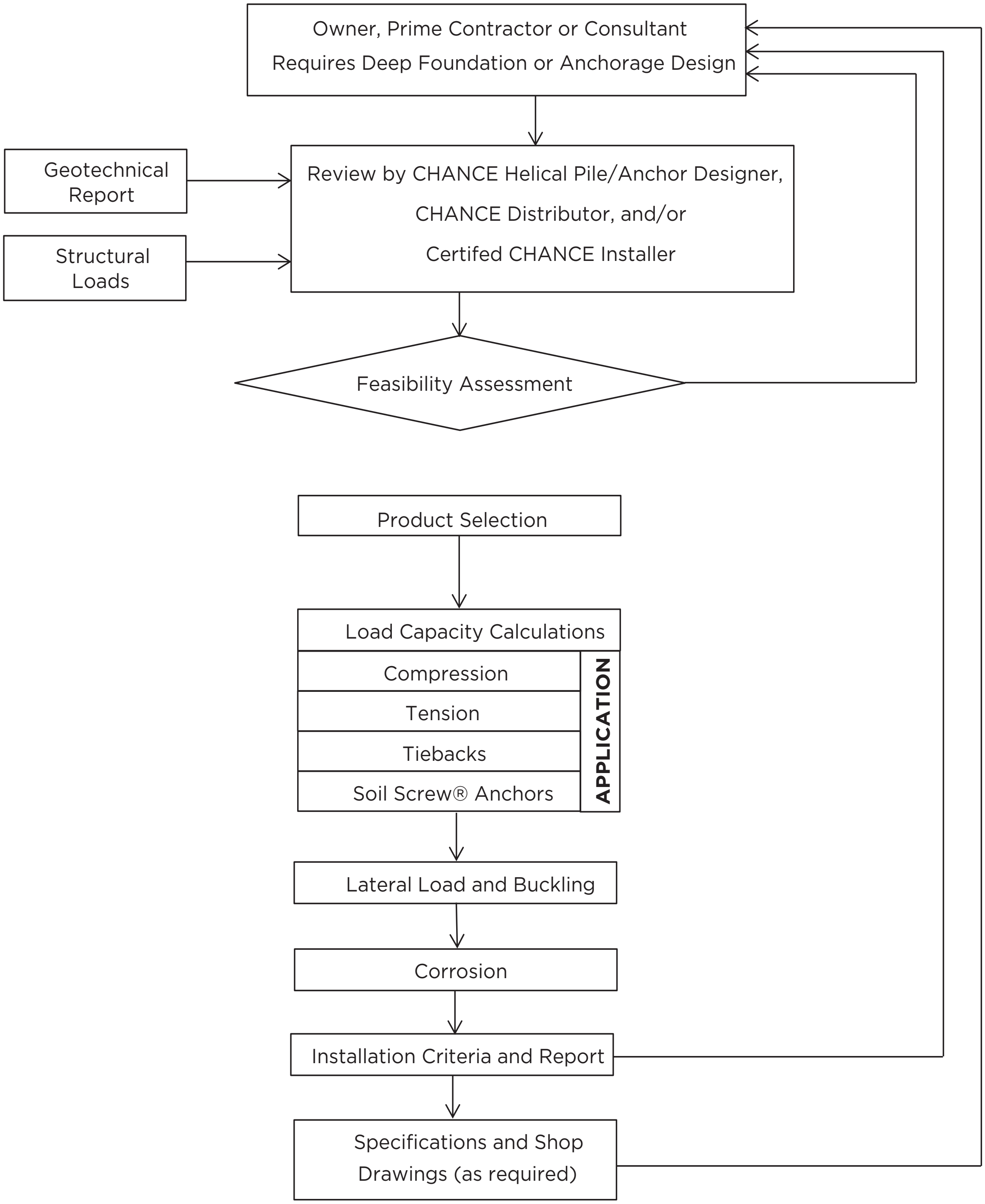
- An evaluation of the soil strata and soil characteristics of that stratum in which the helical plates or tip will be seated.
- A selection of the appropriate CHANCE® helical pile foundation, including shaft type, helical plate size, number and configuration. (Note: Type RS piles or CHANCE HELICAL PULLDOWN® 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 mManual 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.

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.

Preliminary Design Flowchart for New Construction

CHANCE® Helical Piles/Anchors



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:	○ 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:__________________________ CHANCE® #:____________ Response:____________

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

DESIGN METHODOLOGY
SECTION 4

CONTENTS

SYMBOLS USED IN THIS SECTION

Pw	Pier Working Load	4-5
DL	Dead Load	4-5
LL	Live Load	4-5
SL	Snow Load	4-5
W	Soil Load	4-5
FS_h	Factor of Safety (hardware)	4-5
B	Helix Diameter & Footing Width (Base)	4-6
x	Helix Spacing	4-6
Q_{ULT}	Ultimate Capacity of the Soil	4-8
A_h	Projected Helix Area	4-8
c	Soil Cohesion	4-8
q'	Effective Overburden Pressure	4-8
γ '	Effective Unit Weight of the Soil	4-8
N_c	Bearing Capacity Factor for Cohesive Component of Soil	4-8
N_q	Bearing Capacity Factor for Non-Cohesive Component of Soil	4-8

$N\gamma$	Bearing Capacity Factor for SoiL Weight and Foundation Width	4-8
Q_H	Individual Helix Capacity	4-10
D	Vertical Depth to Helix Plate	4-10
φ	Angle of Internal Friction	4-11
γ	Effective Unit Weight of Soil	4-11
s_u	Undrained Shear Strength	4-12
F_c	Breakout Factor	4-12
K_O	Coefficient of Earth Pressure at Rest	4-13
A_c	Surface Area of Truncated Cone	4-13
S_a	Undrained Shear Strength of Clay	4-14
Q_M	Total Bearing Capacity of Multi Screw Pile/ Helical Anchor	4-18
α	Adhesion Factor	4-19
Q_s	Capacity Upper Limit	4-21
psf	Pounds per Square Foot	4-23
Q_t	Total Ultimate Multi-Helix Anchor/Pile Capacity	4-27
$\sigma`_{vo}$	Effective Overburden Stress	4-31
$(N_1)_{60}$	Normalized SPT N-value	4-32
σ_o	Mean Normal Stress for Grout Column	4-37
D	Diameter of Timber, Steel or Concrete Pile Column	4-37
f_s	Sum of Friction and Adhesion Between Soil and Pile	4-37
ΔL_f	Incremental Pile Length	4-37
C_a	Adhesion Factor	4-38
s_o	Mean Normal Stress	4-37
q	Effective Vertical Stress on Element	4-38
K	Coefficient of Lateral Earth Pressure	4-38
ø	Effective Friction Angle Between Soil & Pile Material	4-38
S	Average Friction Resistance on Pile Surface Area	4-40
P_o	Average Overburden Pressure	4-40
K_p	Coefficient of Passive Earth Pressure	4-45
K_a	Coefficient of Active Earth Pressure	4-46
H	Height of Wall or Resisting Element	4-46
P_a	Active Earth Pressure	4-46

P_p	Passive Earth Pressure	4-46
P_{crit}	Critical Compression Load	4-49
E	Modulus of Elasticity	4-49
I	Moment of Inertia	4-49
K	End Condition Parameter	4-49
L_u	Unsupported Length	4-49
d	Foundation Shaft Diameter	4-50
L	Foundation Shaft Length	4-50
Kl/r	Slenderness Ratio	4-51
P_{cr}	Critical Buckling Load	4-51
E_p	Modulus of Elasticity of Foundation Shaft	4-51
I_p	Moment of Inertia of Foundation Shaft	4-51
k_h	Modulus of Subgrade Reaction	4-51
U_{cr}	Dimensionless Ratio	4-51
y	Lateral Deflection of Shaft at Point x	4-51
x	Distance Along the Axis	4-51
EI	Flexural Rigidity of the Foundation Shaft	4-51
Q	Axial Compressive Load	4-51
$E_s y$	Soil Reaction per Unit Length	4-51
E_s	Secant Modulus of the Soil Response Curve	4-51
C_a	Adhesion Factor	4-40

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.

4.1 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.

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.

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.

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. Hubbell Power Systems, Inc. will prepare a complimentary product selection ("Preliminary Design") on a particular project

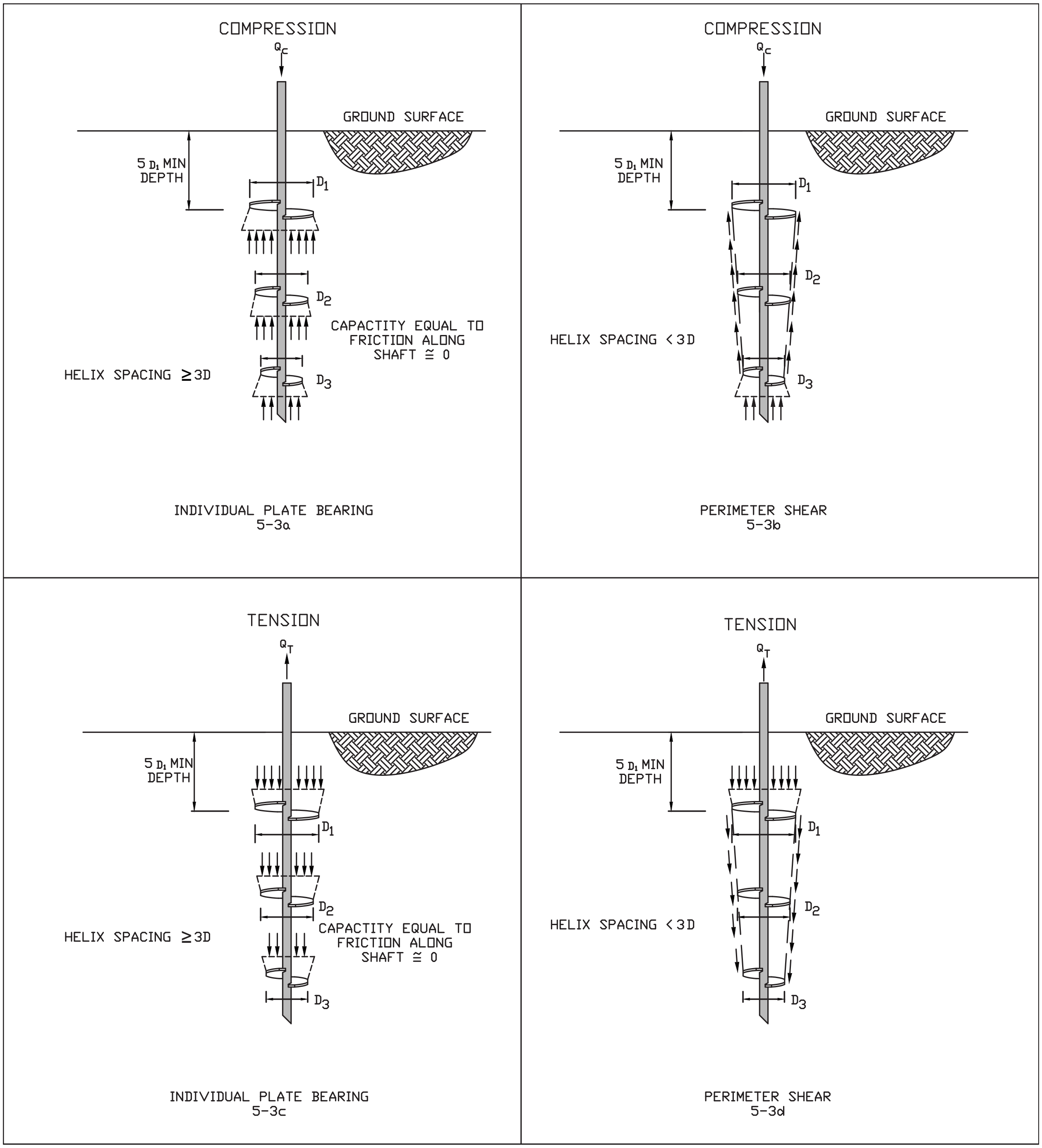
4.2 CHANCE® HELICAL PILE/ANCHOR ULTIMATE BEARING CAPACITY

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.



Individual Bearing and Perimerter Shear Models for Helical Piles with Slender Shafts
Figure 4-1

These two methods are illustrated in Figures 4-1a & c (Individual Plate Bearing) and 4-1b & 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 and failure in this zone occurs along a plane as shown in Figure 4-1b & 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.

TABLE 4-2 TYPICAL DESIGN SITUATIONS FOR SINGLE-HELIX & 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

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 Nc, Nq, and Nγ are bearing capacity factors

Terzaghi's Bearing Capacity Factors are shown in the Table 4-2.

TABLE 4-3. TERZAGHI’S SHALLOW FOUNDATION BEARING CAPACITY FACTORS [FROM AND BOWLES (1988) AND ASCE (1993A)]

φ ’	Nc	Nγ	Nq
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

Following is quoted from Bowles (1988) concerning the use of Equation 4-6 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:

   $Q_H = A_H(1.3c'N_C + q'N_q + 0.6\gamma'BN\gamma)$

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:

   $N_C = 6.0(1 + 0.2D/B) \leq 9.0$
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.

4.3 SINGLE-HELIX SCREW-PILES AND HELICAL ANCHORS SHALLOW INSTALLATION

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.

Saturated Clays $\varphi' = 0; c > 0$

In saturated clays with $\varphi' = 0$, the term $N\gamma = 0$ and $Nq = 1.0$. The bearing capacity equation becomes:

$$Q_H = A_H(cN_C + \gamma' D) \qquad \textbf{Equation 4-9}$$

where:

Q_H = Ultimate Bearing Capacity
A_H = Projected Helix Area
c = "cohesion"; for $\varphi' = 0$; c = undrained shear strength = s_u
N_C = Bearing Capacity Factor for $\varphi' = 0$; 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.

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

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

$$Q_H = A_H(q'N_q + 0.5\gamma' BN\gamma) \qquad \textbf{Equation 4-10}$$

where:

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

N_q and $N\gamma$ 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

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

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:

$$Q_H = A_H(c'N_C + q'N_q + 0.5\gamma' BN\gamma) \qquad \textbf{Equation 4-11}$$

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

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.

Saturated Clays $\varphi' = 0; c > 0$

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 $\varphi' = 0$ c = undrained shear strength = s_u

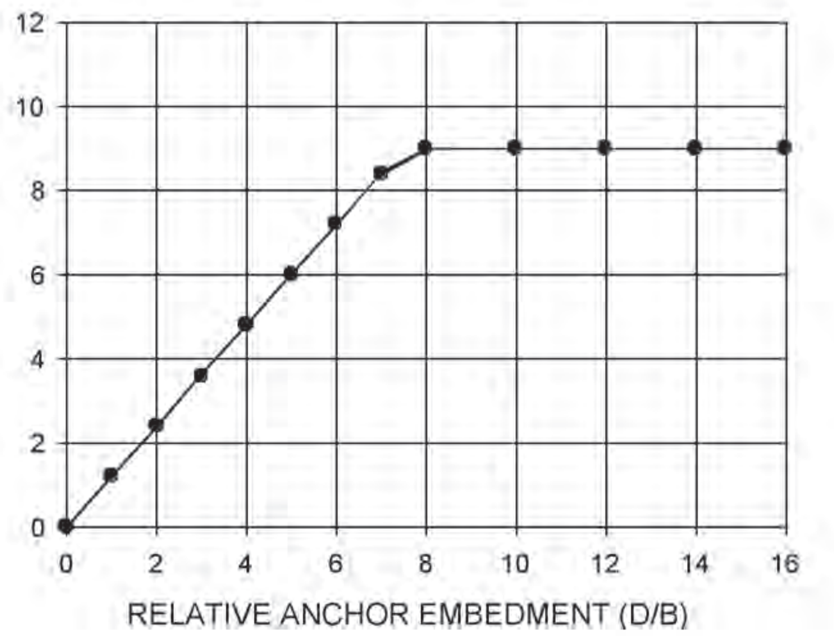
F_C = Breakout Factor for $\varphi' = 0$; $F_C = 1.2(D/B) \leq 9$

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 4-3 VARIATION IN UPLIFT BREAKOUT FACTOR FOR SHALLOW SINGLE-HELIX ANCHORS IN CLAY



Sands φ’ > 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 φ’/2, as shown in Figure 4.2, and also includes the mass of the soil within the truncated cone. The Ultimate Uplift Capacity is calculated from:

$$Q_{HU} = W_S + \pi g K_0(\tan\varphi')(\cos^2\varphi'/2)\ [(BD^2/2) + (D^3\tan\varphi'/2)/3)]$$ **Equation 4-13**

where:

W_S = Mass of Soil in Truncated Cone = gV

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:

$$V = [\pi D/3][B^2 + (B + 2D\tan\varphi'/2)^2 + (B)(B + 2D\tan\varphi'/2)]$$ **Equation 4-14**

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

$K_0 = 1 - \sin\varphi'$

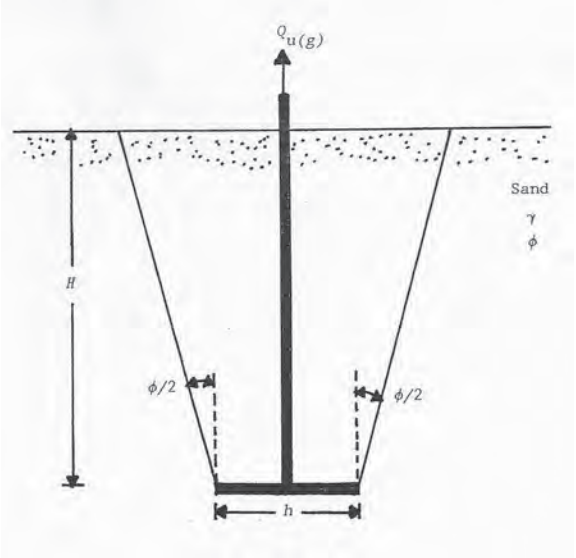


Figure 4-2 Proposed Failure Mechanism for Shallow Single-Helix Anchors in Dense Sand.

Mixed Soils φ’ > 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 4-13. 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:

$$Q_{HU} = W_S + \pi g K_0(\tan\varphi')(\cos^2\varphi'/2)\ [(BD^2/2) + (D^3\tan\varphi'/2)/3)] + (c)(A_C)$$ **Equation 4-15**

where:

A_C = Surface Area of Truncated Cone

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

$$A_C = \pi[(R^2 + r^2) + [(R^2 - r^2) + (D(R + r))^2]^{0.5}]$$ 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(φ’/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.

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.

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.

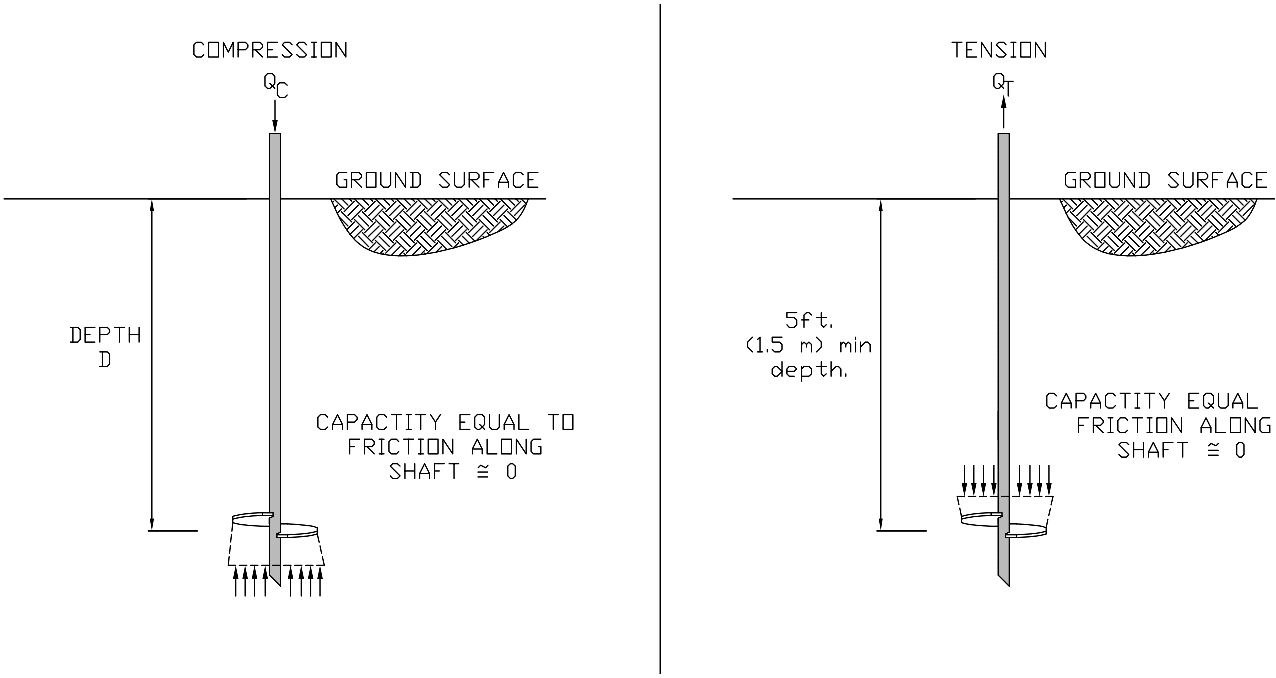


Figure 4-5 Single-Helix Plate Bearing Capacity Model – Helical Piles with Slender Shafts

Saturated Clays φ' = 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 = Bearing Capacity Factor for Deep Failure = 9

Which gives:

$$Q_H = A_H[(9)(s_u) + \gamma' D] \qquad \textbf{Equation 4-17}$$

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

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:

$$Q_H = A_H(q'N_q) \qquad \textbf{Equation 4-18}$$

For deep installations, the bearing capacity factor Nq 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 Nq available in foundation engineering textbooks as shown in Figure 4-6. The difference in Nq values shown in Figure 4-6 is largely related to the assumptions used in the failure mechanism. Figure 4-7 gives a reasonable chart of Nq 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 Nq in Figure 5-7 is obtained from:

$$Nq = 0.5\ (12 \times \varphi')^{\varphi'/54} \qquad \textbf{Equation 4-19}$$

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.

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

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.

TENSION LOADING – AXIAL UPLIFT (DEEP SINGLE-HELIX)

Saturated Clays $\varphi' = 0; c' > 0$

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:

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

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

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:

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

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:

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

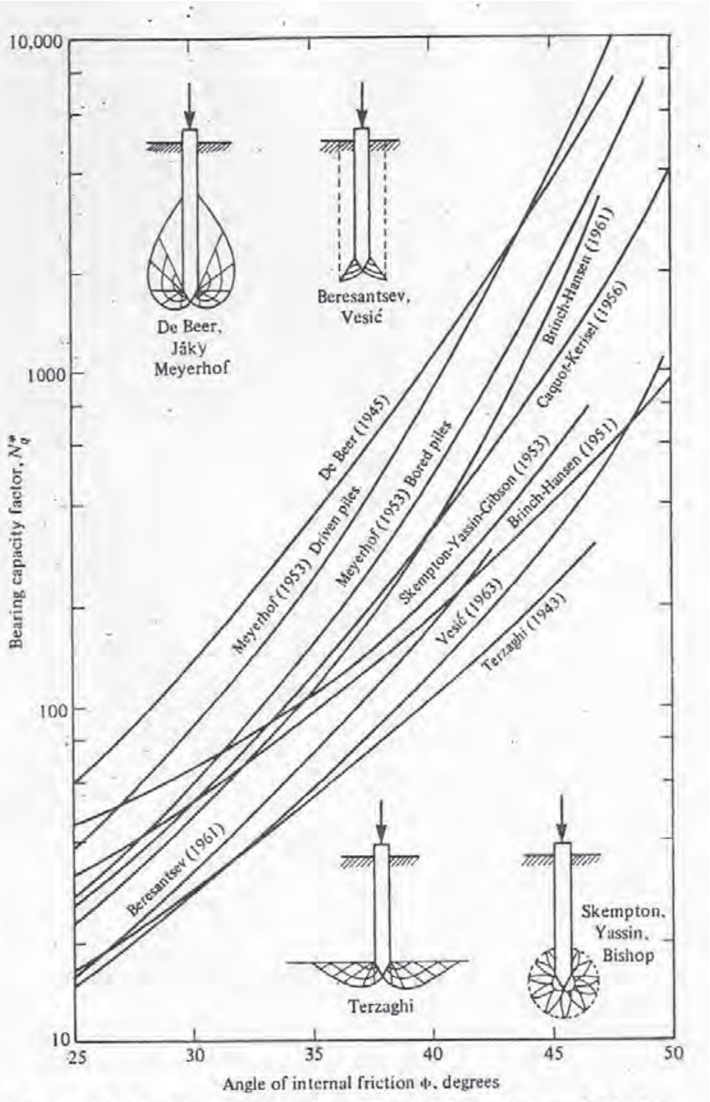


Fig. 19.49 Bearing capacity factors vs. angle of internal friction, according to various authors.

Figure 4-4 Reported Values of Nq for Deep Foundations in Sands [from Winterkorn & Fang (1983)].

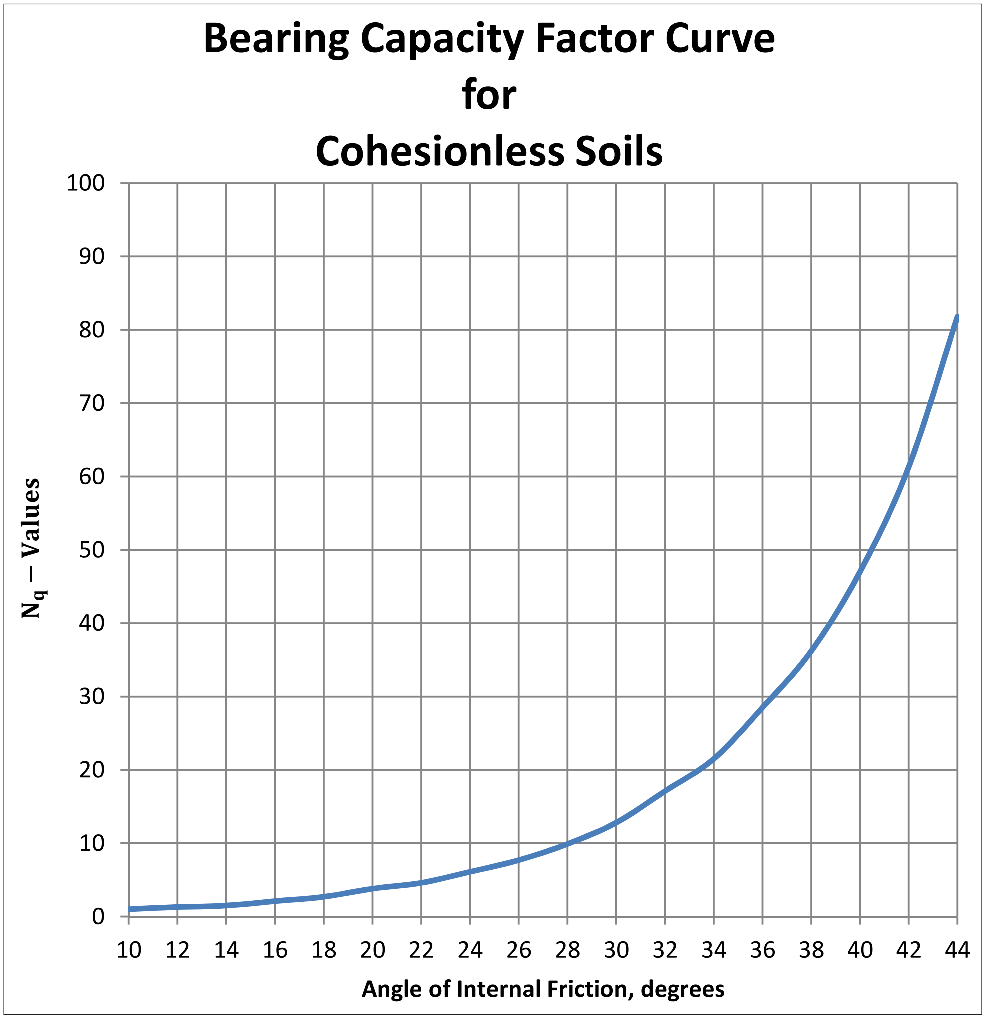


Figure 4-5 Recommended Bearing Capacity Factor Nq for Deep Screw-Piles and Helical Anchors in Sand.

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

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

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

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

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 x 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 4-4. 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.

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 4-4 STANDARD HELIX

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 4-20**

where:

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

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.

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 4-9b. 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).

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

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 4-21**

where:

α = Adhesion Factor
f_S = Unit Side Resistance
s_u = Undrained Shear Strength of the Clay

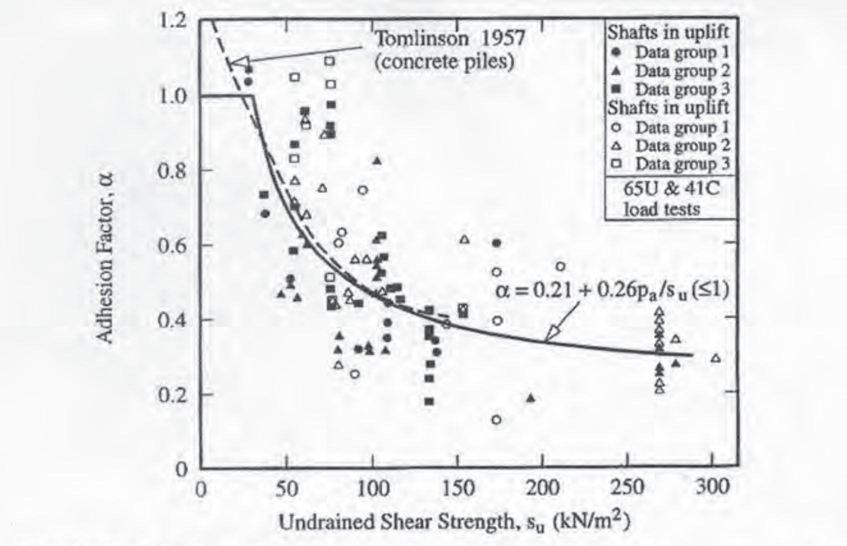


FIGURE 18.1 *Adhesion as a function of undrained shear strength*

Figure 4-6 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 4-6 and 4-7 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:

$$Q_S = (f_S)(\pi)(d)(L) \qquad \textbf{Equation 4-22}$$

where:

Q_S = Total Shaft Resistance
d = Diameter of Central Shaft

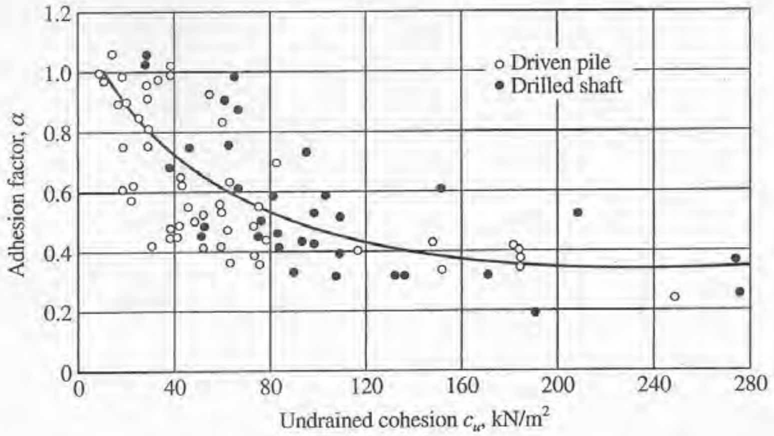


Figure 15.15 Adhesion factor α for piles with penetration lengths less than 50 m in clay. (Data from Dennis and Olson 1983 a, b; Stas and Kulhawy, 1984)

Figure 4-7 Variation in Adhesion Factor with Undrained Shear Strength of Clays (from Murthy 2003).

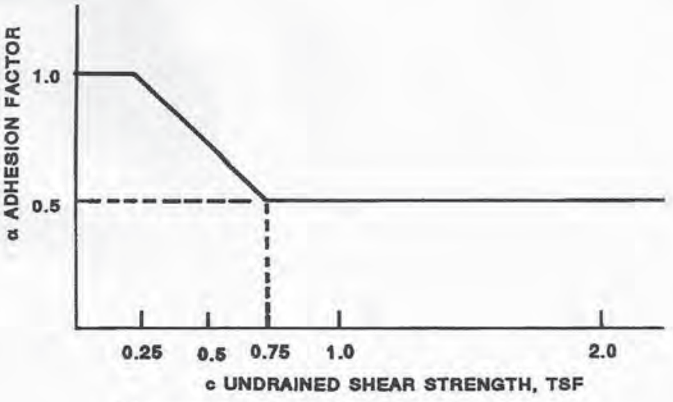


Figure 4-5A. Values of α versus undrained shear strength

Figure 4-8 Variation in Adhesion Factor from American Petroleum Institute [from ASCE (1993b)].

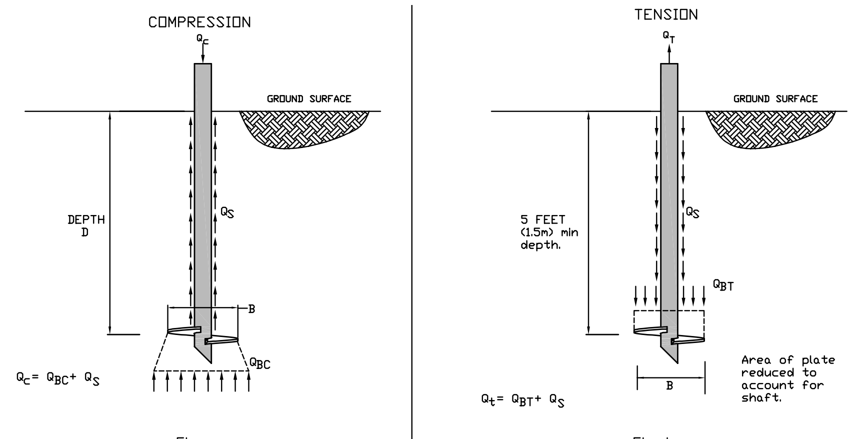
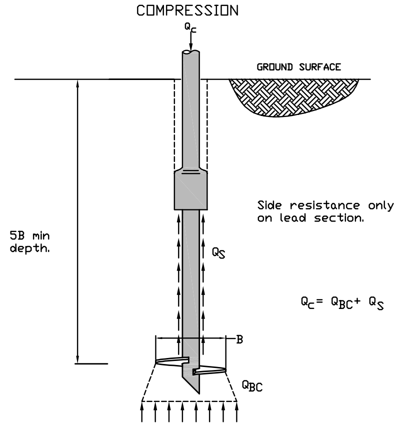


Fig. a
Behavior of Shallow Round Shaft Screw Piles.

Fig. b
Behavior of Shallow Round Shaft Screw Piles.



Individual Bearing and Skin Friction Models for Helical Piles with Round (Pipe) Shafts
Figure 4-9

L = Length of Round Shaft in Contact with Soil

The design line given by the American Petroleum Institute (API) shown Figure 4-10 may also be used in which:

For s_u < 500 psf; α = 1.0

For s_u > 1500 psf; α = 0.5

For 500 psf < su < 1500 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 4-9. 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

TABLE 4-5 VALUES OF UNIT SIDE RESISTANCE FOR STEEL PILES IN SAND (FROM NAVY MANUAL DM-7)

s'_{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

develop side resistance.

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

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 4-5.

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 AC358 has specified a minimum depth for helical tension anchors. AC358 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 4-6 SOIL PROPERTIES REQUIRED FOR HELICAL PILE/ANCHOR/PILE DESIGN FOR VARIOUS SITE CONDITIONS

	Required Soil Properties		
Soil Property Category	**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}

4.4 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 6-6 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 4-7 and 4-8. 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:

$$s_u = (q_c - \sigma_{vo})/N_k \qquad \textbf{Equation 4-23}$$

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:

$$s_u = (q_t - \sigma_{vo})/N_{kt} \qquad \textbf{Equation 4-24}$$

where:

q_t = CPTU effective tip resistance
N_{kt}= empirical cone factor

TABLE 4-7. 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	Guabirotuba 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 4-8. REPORTED CORRELATIONS BETWEEN SPT N-VALUE AND UNCONFINED COMPRESSIVE STRENGTH, QU

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.

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 ¼" 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 ½ 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 4-9 and 4-10 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 4-9. 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 4-9 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 4-11. The correlation of Hatanaka & Uchida (1996) is shown in Figure 4-10, taken from FHWA Reference Manual on Subsurface Investigations (2002).

TABLE 4-9. 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:

$$N_q = (q_c/s_{v0}') = 0.194\exp(7.63\tan\varphi') \qquad \textbf{Equation 4-26}$$

where:

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

This relationship is shown in Figure 4-14.

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:

$$\varphi' = \arctan[0.1 + 0.38 \log (q_t/\sigma'_{vo})] \qquad \textbf{Equation 4-27}$$

Equation 4-27 is shown in Figure 4-16.

TABLE 4-10. 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 (f)	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:

$$\varphi' = 17.70 + 11.0 \log (q_{t1})$$ **Equation 4-28**

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

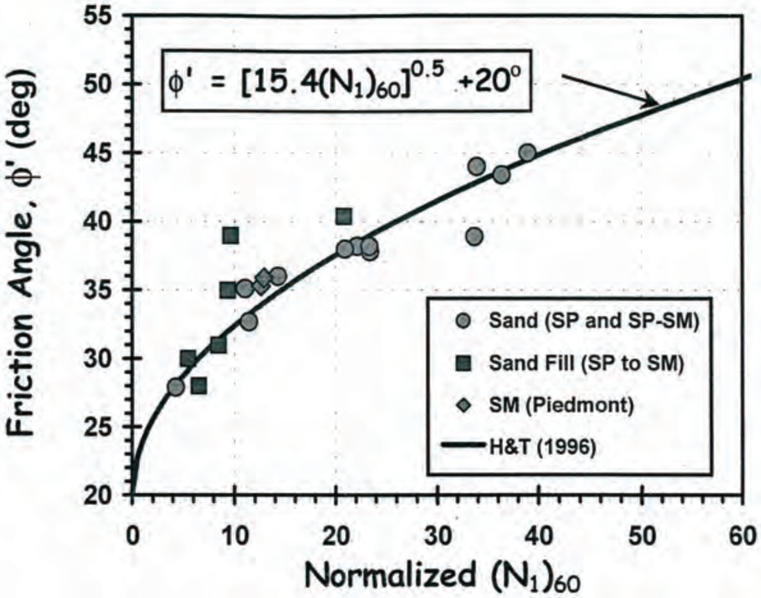


Figure 4-10 Peak Friction Angle of Sands from SPT Resistance - Correlation of Hatanaka & Uchida (1996) from FHWA Reference Manual on Subsurface Investigations (2002)

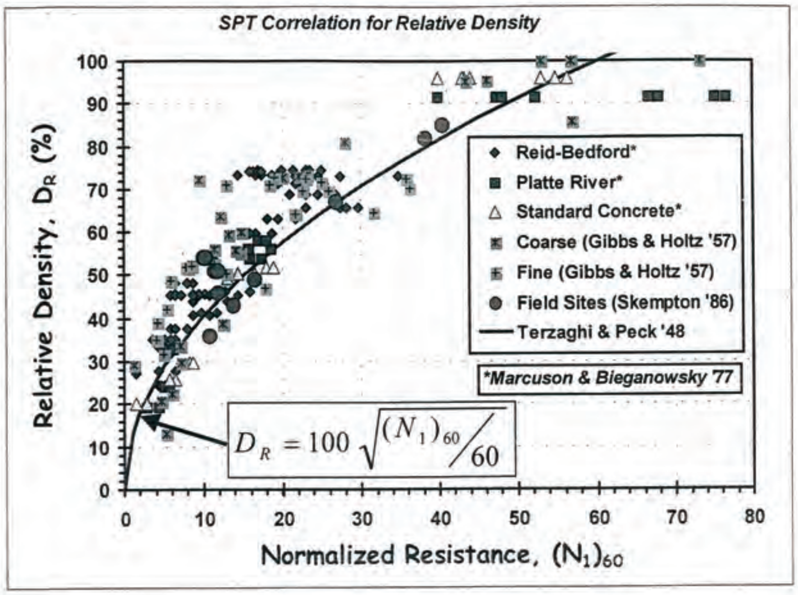


Figure 4-11

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:

$$f_s = \beta + \alpha N \qquad \textbf{Equation 4-29}$$

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 4-12.

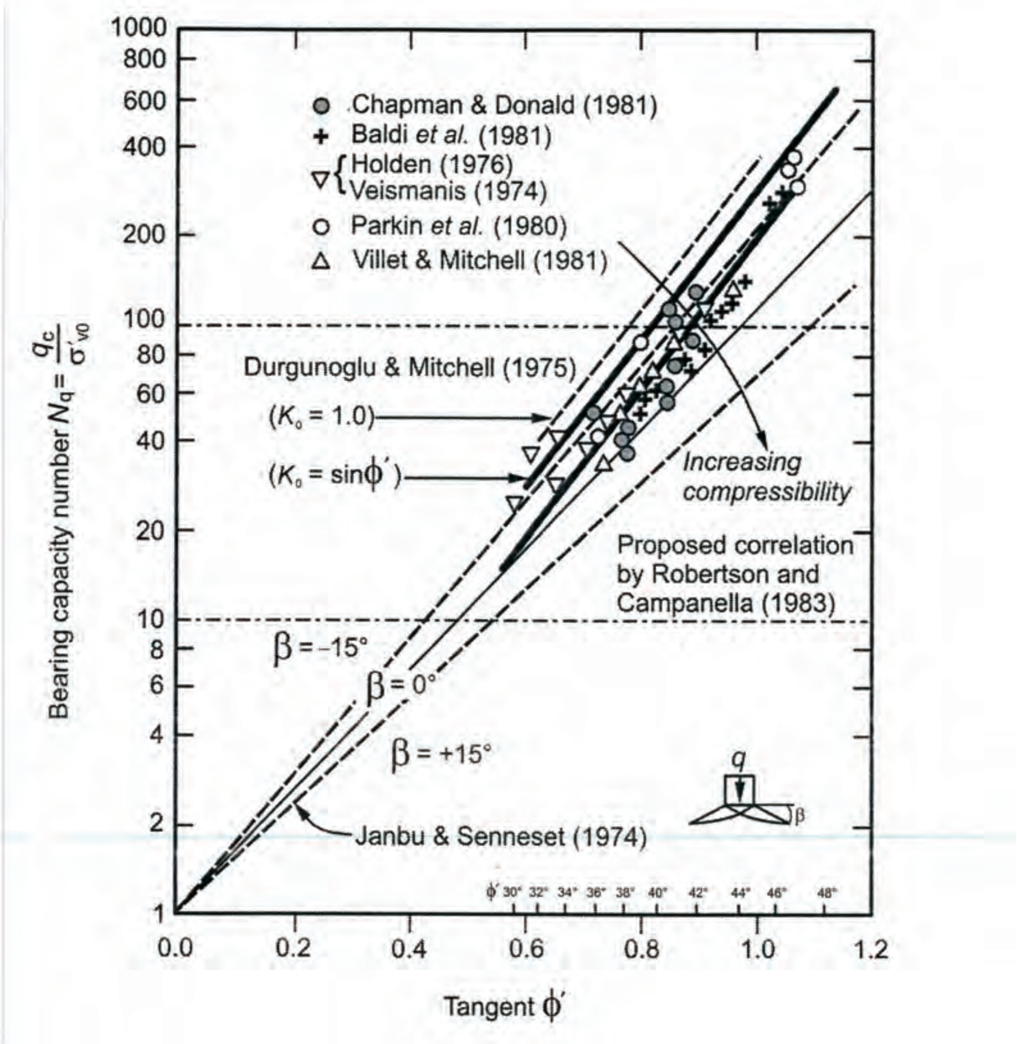


Figure 4-12. Relationship between Bearing Capacity Number and Friction Angle from Normalized CPT Tip Resistance – from Robertson and Campanella (1983)

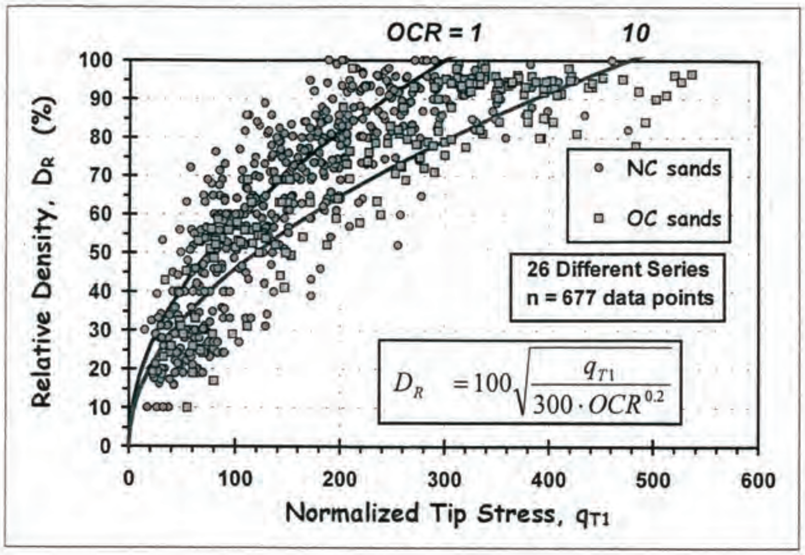


Figure 4-13. Relationship Between Relative Density for Normally Consolidated (NC) and Over Consolidated (OC) Sands from CPT Data.

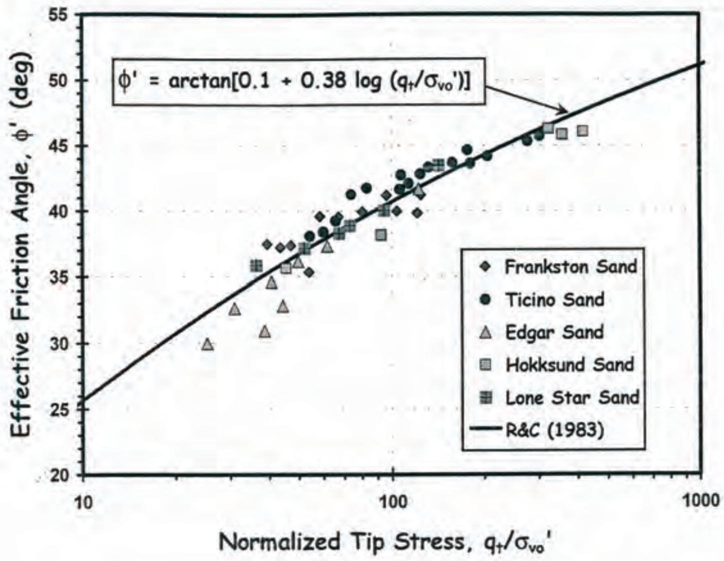


Figure 4-14. Relationship Between Friction Angle and the Effective Tip Resistance from CPTU Data

$(N_1)_{60} = N_{60}/(\sigma'_{vo})^{0.5}$ 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 4-12 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:

$$fs = \alpha N \qquad \textbf{Equation 4-30}$$

2) The value of α ranges from 0.3 to 12.5; 3) The observations presented in Table 4-12 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 4-12 with caution.

In fact, Equation 4-30 is similar to Equation 4-21, suggesting a correlation between SPT N-values and undrained shear strength (s_u) in fine-grained soils.

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 Srew® 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 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 (ASD). 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.

TABLE 4-12. REPORTED CORRELATIONS BETWEEN SPT N-VALUE AND PILE SIDE RESISTANCE (FROM LUTENEGGER 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 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	Shoi & Fukui (1982)
	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)

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 4.3 for deep foundations (minimum depth ≥ 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 3 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:

$$Q_t = SQ_h$$

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.

$$Q_h = A_h (cN_c + q'N_q) \leq Qs \qquad \textbf{Equation 4-31}$$

where:

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

Sands φ’ > 0; c’ = 0

HeliCAP® determines the ultimate bearing capacity in a non-cohesive sand or gravel soil with Equation 4-32 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 4-7 (Nq vs φ’) and Equation 4-19 to determine the value for N_q. When the angle of internal friction is not known, HeliCAP estimates it (and Nq) by using blow counts obtained from the Standard Penetration Test per ASTM D 1586. Equation 4-33 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 4-7 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 4-19 was written for the curve shown in Figure 4-7, which is Myerhof’s N_q values divided by 2 for long term applications. **Note the correlated φ’ and Nq values determined by HeliCAP® can be overridden. This is encouraged when more reliable soil data are available.**

$$Q_h = A_h q' N_q = Ah\,\gamma' D N_q$$ **Equation 4-32**

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

$$\varphi' = 0.28\,N + 27.4$$ **Equation 4-33**

where:

φ’ = Angle of internal friction
N = Blow count per ASTM D 1586 Standard Penetration Test

Fine-Grain Cohesive Soil, φ’ = 0; c’ > 0

HeliCAP determines the ultimate bearing capacity in a cohesive or fine-grained soil with Equation 4-17 with the overburden term not used. The Nc factor is 9, provided the installation depth below grade is greater than five times the diameter of the top most helix.

$$Qh = A_h c N_c = A_H[(9)(s_u)]$$ **Equation 4-34**

where:

A_h = Projected helix area
c = “cohesion”; for φ’ = 0; c = undrained shear strength = s_u
N_c = Bearing Capacity Factor for Deep Failure = 9 (minimum depth ≥ 5D)

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

$c\ (\text{ksf}) = N / 8$ or $= 0.125(N)$ **Equation 4-35**

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

where:

c = "cohesion"; for $\varphi' = 0$; 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: **Equation 4-36**
$N > 0\ \&\ N \leq 19$: $\gamma = 80 + (2N)\ (\text{lb/ft}^3)$
$N \geq 20\ \&\ N \leq 40$ $\gamma = 120\ (\text{lb/ft}^3)$

$N \geq 41\ \&\ N < 50$ $\gamma = 120 + 2(N-40)\ (\text{lb/ft}^3)$ **Equation 4-37**
$N \geq 50$ $\gamma = 140\ (\text{lb/ft}^3)$

Sand (Coarse-Grain) Soils:
$N = 0$ $\gamma = 65\ (\text{lb/ft}^3)$

$N > 0\ \&\ N \leq 7$ $\gamma = 60 + 5N\ (\text{lb/ft}^3)$ **Equation 4-38**
$N \geq 8\ \&\ N \leq 10$ $\gamma = 100\ (\text{lb/ft}^3)$

$N \geq 11\ \&\ N < 50$ $\gamma = 90 + N\ (\text{lb/ft}^3)$ **Equation 4-39**
$N \geq 50$ $\gamma = 140\ (\text{lb/ft}^3)$

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 $\varphi' > 0; c' > 0$

The determination of the bearing capacity of a mixed soil, one that exhibits both cohesion and friction properties, is accomplished by use of Equation 4-31. 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:

$$Qf = \Sigma[\pi(D)fs(\Delta Lf)] \qquad \textbf{Equation 4-40}$$

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 fs 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 (f) and cohesion (c). The equations used to calculate f_s are:

  Type I: Sands and gravels with $35° < \varphi < 45°$ and $c' = 0$:

$$f_s = \sigma_o \tan \varphi \qquad \textbf{Equation 4-41}$$

  where: σ_o = Mean normal stress for the grout column

  Type II: Mixed soils; fine loose silty sands with $20° < \varphi < 30°$ and sandy clays with 205 psf < C < 1024 psf (9.8 kPa < c < 49 kPa)

$f_s = \sigma_o(\sin \varphi) + c(\cos \varphi)$ **Equation 4-42**

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

$f_s = c$ **Equation 4-43**

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

f_s = 2048 psf (98 kPa) **Equation 4-44**

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 (a Method):

$Q_f = \Sigma[\pi(D)C_a(\Delta L_f)]$ **Equation 4-45**

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

For cohesionless soils (a Method):

$Q_f = \Sigma[\pi D(qK\tan f)\Delta L_f]$ **Equation 4-46**

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 4-47**

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

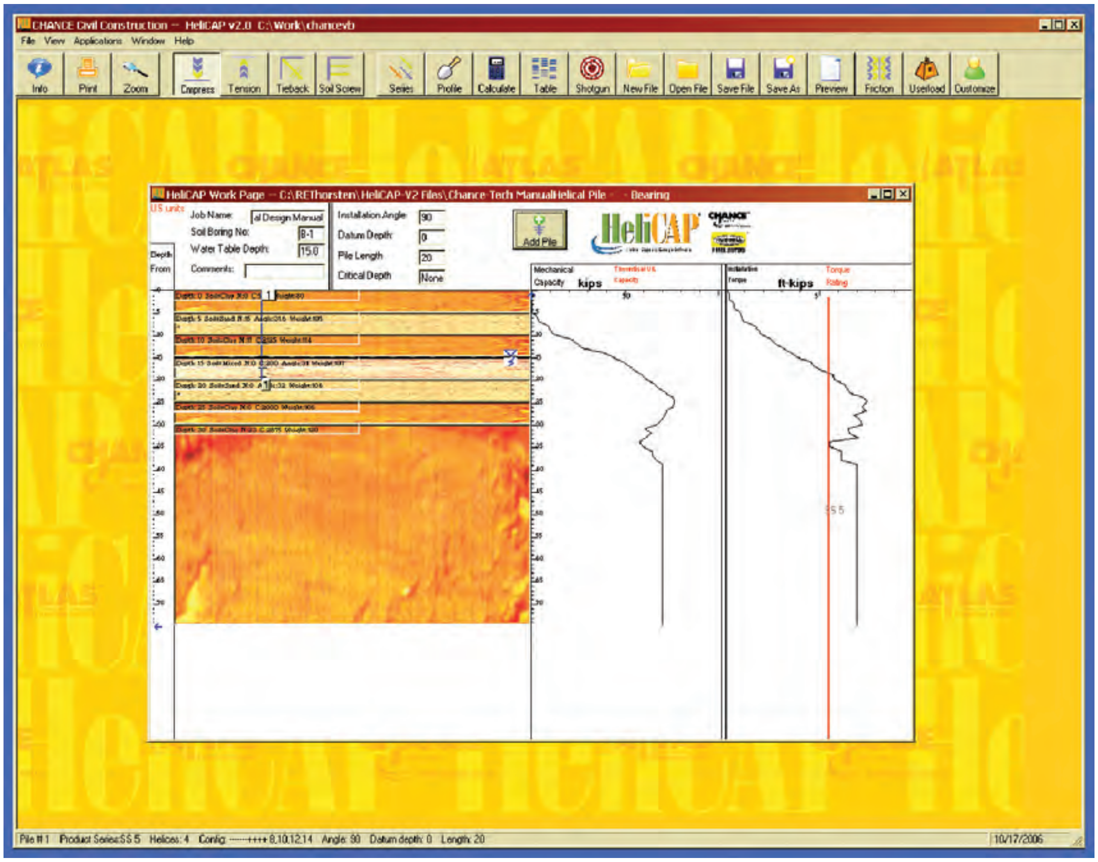
For straight steel pipe shaft piles in sand, HeliCAP® uses Table 5-5 to calculate shaft resistance in sand layers using the Alternate Navy Method.

Tables 4-13, 4-14 and 4-5 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± to 40B±) 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.

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.



Job Name: al Design Manual
Soil Boring No: B-1
Water Table Depth: 15.0
Comments:
Installation Angle: 90
Datum Depth: 0
Pile Length: 20
Critical Depth: None

Pile #1 Product Series:SS 5 Helices: 4 Config: ------++++ 8,10,12,14 Angle: 90 Datum depth: 0 Length: 20 10/17/2006

4.7 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 4-13. 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 4-14. STRAIGHT CONCRETE PILES IN SAND

P_o (psf)	Effective Angle of Internal Friction (degrees) (γ')				
	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

4.8 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); (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.

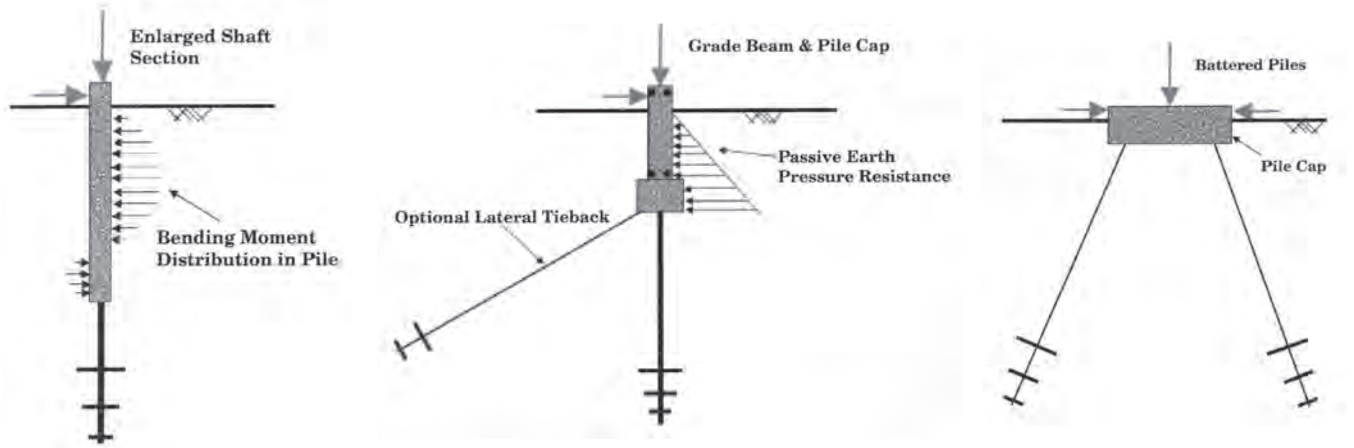


Figure 5-17. Lateral Resistance Methods

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 4-20. 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 4-18 and 4-19 are sample LPILE^{PLUS} 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 LPILE^{PLUS} or other soil-structure-interaction programs to predict soil-pile response to lateral loads.

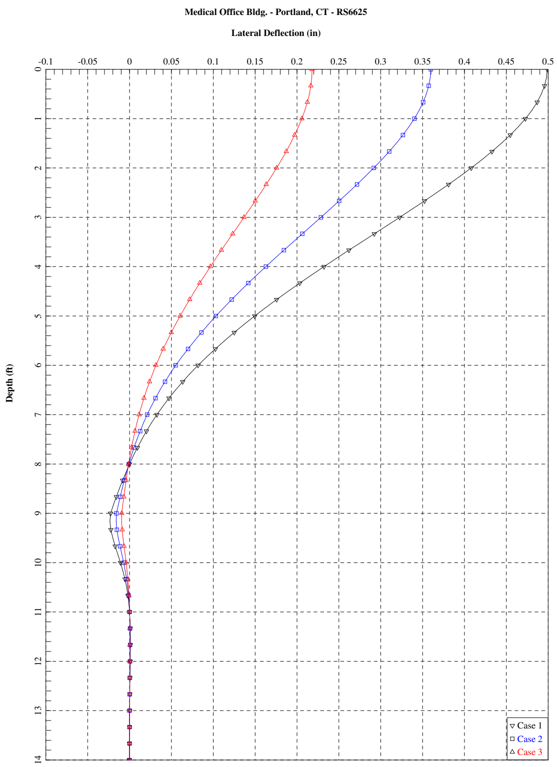


Figure 4-16. LPILE^{PLUS} Sample Plot
Deflection vs Depth

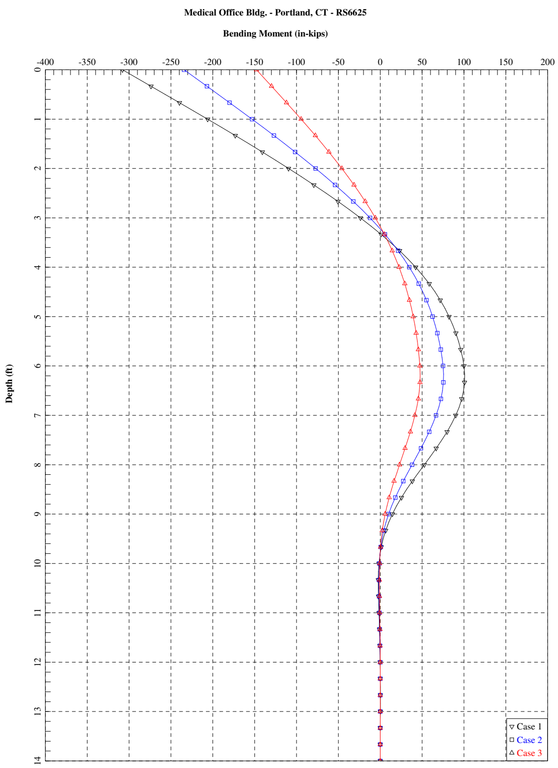


Figure 4-17. LPILE^{PLUS} Sample Plot
Bending Moment vs Depth

LPILEPLUS and similar computer programs work well in evaluating a single pile. When designing for helical piles for larger shear and moment loads it is beneficial to use a pile group modeling computer program, such as GROUP (ENSOFT, Austin, TX). This program uses similar non-linear functions of pile deflection but in two and three dimensions over multiple piles in the form of t-z and Q-w curves for axial loading, p-y curves for lateral loading, and T-q curves for torsional loading. This analysis makes gives a model of the total pile interaction and the ability to design battered piles while monitoring the stress and moment imparted on individual piles.

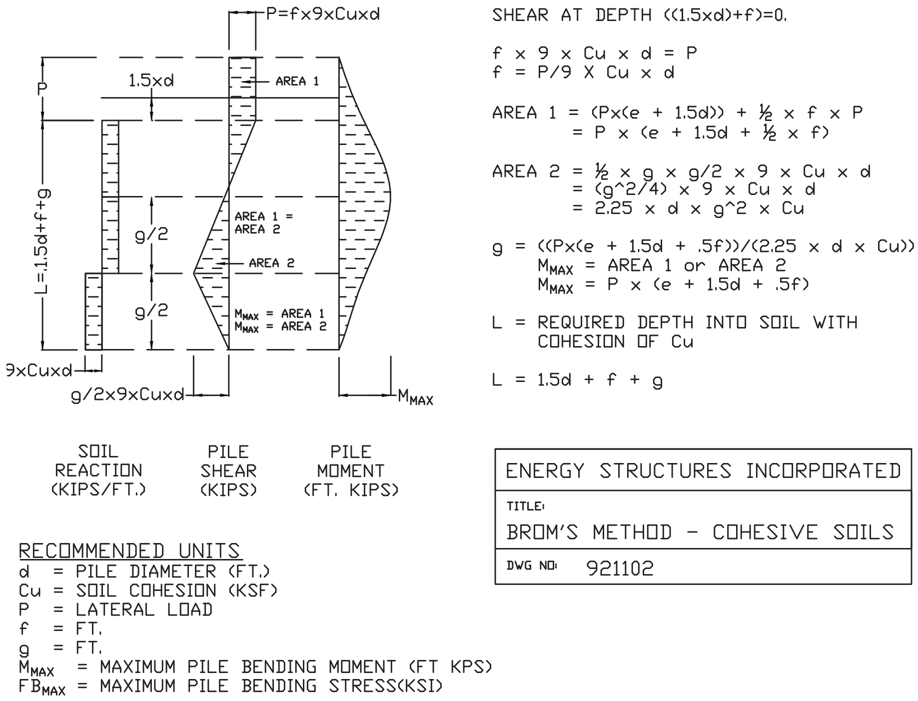
Similar to LPILEPLUS plots of the lateral shaft deflection and bending moment vs. depth are generated from the software. Figures 4-18 and 4-19 are samples plots of GROUP

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 7-13 in Section 7 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 4-20 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.



SHEAR AT DEPTH ((1.5xd)+f)=0.

f x 9 x Cu x d = P
f = P/9 X Cu x d

AREA 1 = (Px(e + 1.5d)) + ½ x f x P
= P x (e + 1.5d + ½ x f)

AREA 2 = ½ x g x g/2 x 9 x Cu x d
= (g^2/4) x 9 x Cu x d
= 2.25 x d x g^2 x Cu

g = ((Px(e + 1.5d + .5f))/(2.25 x d x Cu))
M_{MAX} = AREA 1 or AREA 2
M_{MAX} = P x (e + 1.5d + .5f)

L = REQUIRED DEPTH INTO SOIL WITH
COHESION OF Cu

L = 1.5d + f + g

ENERGY STRUCTURES INCORPORATED
TITLE:
BROM'S METHOD - COHESIVE SOILS
DWG NO: 921102

RECOMMENDED UNITS
d = PILE DIAMETER (FT.)
Cu = SOIL COHESION (KSF)
P = LATERAL LOAD
f = FT.
g = FT.
M_{MAX} = MAXIMUM PILE BENDING MOMENT (FT KPS)
FB_{MAX} = MAXIMUM PILE BENDING STRESS(KSI)

Figure 4-20. Broms' Method for Short Piles in Clay
(Energy Structures, Inc., 1994)

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 4-21. 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 4-51 and 4-52 are Rankine equations for sand. Equations 4-53 and 4-54 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.

$$K_O = 1-\sin \phi'$$ **Equation 4-48**

$$K_a = \tan^2 (45-\phi'/2)$$ **Equation 4-49**

$$K_p = \tan^2 (45+\phi'/2)$$ **Equation 4-50**

For granular soil (sand):

$$P_a = ½K_a\rho H^2$$ **Equation 4-51**

$$P_p = ½K_p\phi\rho H^2$$ **Equation 4-52**

For cohesive soil (clay):

$$P_a = ½K_a r H^2 - 2cH + 2c^2/\phi\rho$$ **Equation 4-53**

$$P_p = ½K_p\rho H^2 + 2cH$$ **Equation 4-54**

where:
K_O = 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 4-48 through 4-54 are from NAVFAC Design Manual DM7, Foundations and Earth Structures (see References at the end of this section).

Table 4-15 is a tabulation of the coefficient for at rest, active, and passive earth pressure for various soil types, relative densities and consistencies.

TABLE 4-15 COEFFICIENTS OF EARTH PRESSURE (DAS, 1987)

Soil	K_O, Drained	K_O, 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

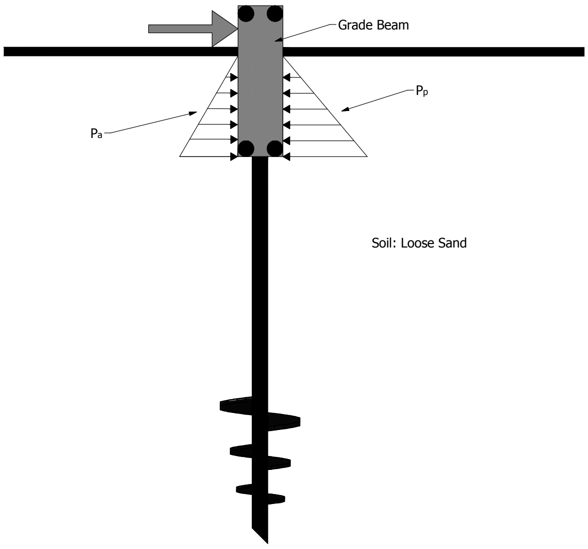


Figure 4-21. Earth Pressure on a Grade Beam

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.

Batters

Lateral loads are commonly resolved with battered helical piles and anchors. Battered piles are used when passive lateral resistance of the surrounding soil is inadequate to transmit the lateral loads required by a structure, or the greater rigidity of the foundation is required.

CHANCE ® Helical Piles and Anchors have been supplied to the seismic prone areas of the west coast of the United States and Canada for over 30 years for 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. Due to the increased foundation stiffness design engineers must take in account the increased foundation stiffness of battered pile foundations when designing where dynamic horizontal loads are present.

It is common practice to assume that all lateral loads are transferred to the lateral component of the piles axial capacity, but this assumption is not a complete model of how battered piles behave. A portion of the lateral load is transferred to the lateral component of the pile's axial capacity but a load is also transferred passively to the surrounding soil. Allowable bending moment of the pile must be taken into account when designing a group. The bending moment induced typically will be less than that of a vertical pile under similar shear loads, but can excessive if a large enough shear load is applied to the pile group.

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.

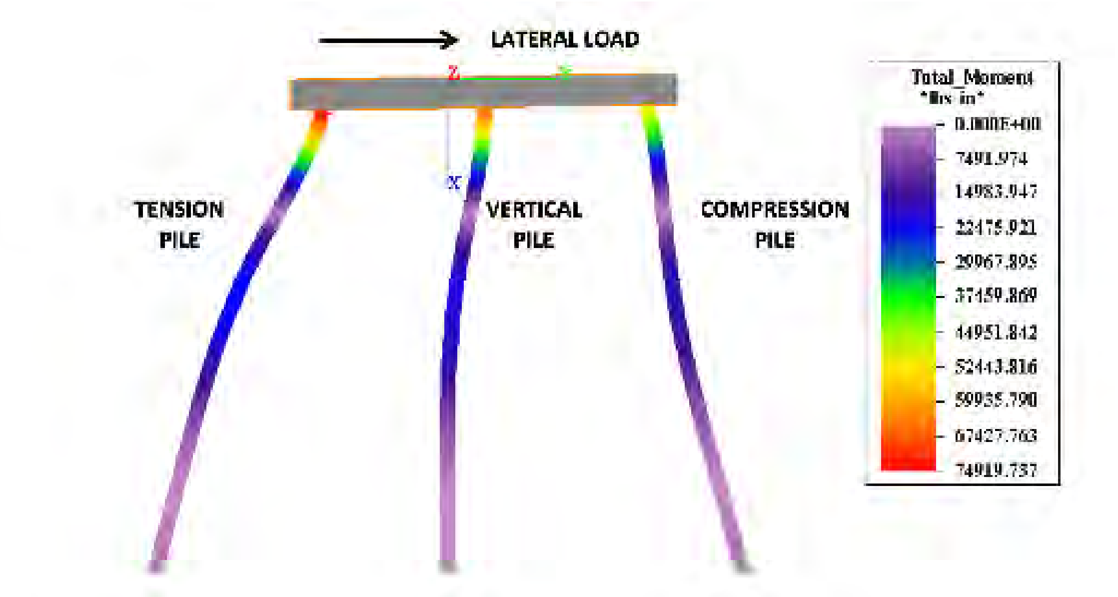


Figure 4-22.Group Box Pile Deflection

Figure 4-22 shows 30 times the deflection of an RS3500 pile group within allowable bending moment. The actual deflection of the pile group is approximatly 5/16." The tension and compression battered piles both resist the shear axially and passively while the vertical pile is only resisting lateral load passively. The lateral load causes the tension pile to be pushed downward into the soil and compression pile is pushed upward. This behavior is shown in Figure 4-23.

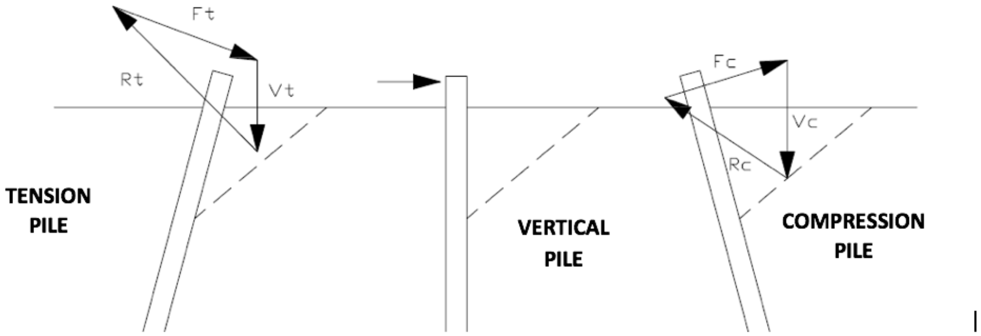


Figure 4-23 Behavior of Battered Piles

The tension pile sees large passive resistance than the compression pile due to the force pushing the pile downward (Ft). The compression piles transfers a greater portion of the lateral load axially.

The pile head amount of fixity is a critical component when designing battered piles. For lateral deflection a fixed head creates the stiffest load response, but will induce the highest bending moments within the piles. Fixed head conditions are typical of concrete or moment resistant caps and grillages. A pinned head condition will induce lower bending moments, but will allow much higher deflections. This typically results in a less efficient pile cap that can withstand less shear load. Pinned head conditions are typical of non-moment resistant caps and grillages.

4.9 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.

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.

$$P_{crit} \qquad \pi^2EI/(KL_u)^2$$

Equation 4-55

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 4-55. 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 Davisson 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 6 of this manual.

Buckling Analysis by Davisson (1963) Method

A number of solutions have been developed for various combinations of pile head and tip boundary

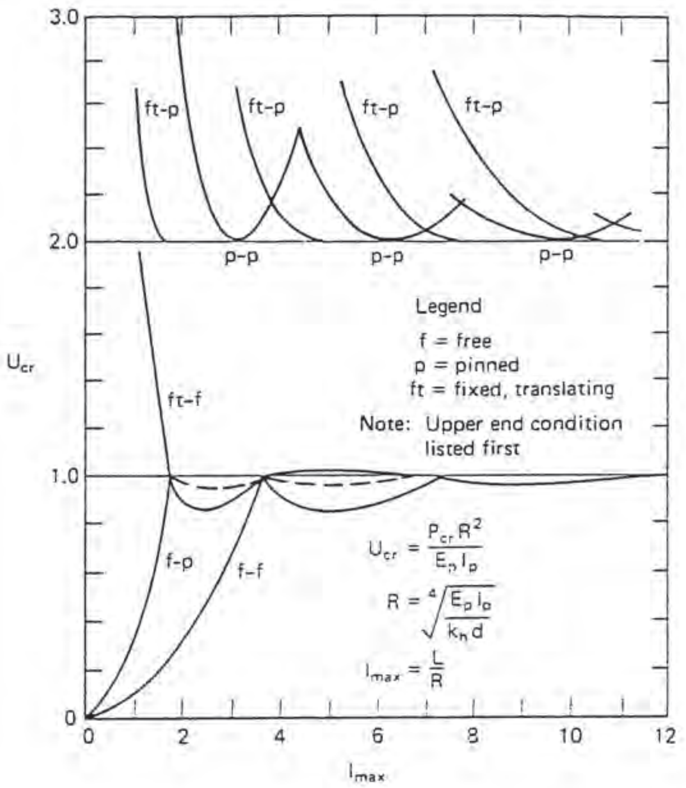


Figure 5-24 Poulos and Davis (1980)

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 4-24. 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 4-24 are in dimensionless form, as a plot of U_{cr} versus I_{max}.

where $U_{cr} = P_{cr}R^2/E_pI_p$ or $P_{cr} = U_{cr}E_pI_p/R^2$ **Equation 4-56**

where $R = {}^4\sqrt{E_pI_p/k_hd}$ **Equation 4-57**

where I_{max} = L/R **Equation 4-58**

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 (kh) for a given soil profile to determine R, and using Figure 4-24 to determine U_{cr}, Equation 4-56 can be solved for the critical buckling load. Typical values for k_h are shown in Table 4-16.

TABLE 4-16. MODULUS OF SUB GRADE REACTION - TYPICAL VALUES

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

Figure 4-24 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:

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

where

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

E = Flexural rigidity of the foundation shaft

Q = Axial compressive load on the helical pile

E_sy = 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 4-59 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.

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.

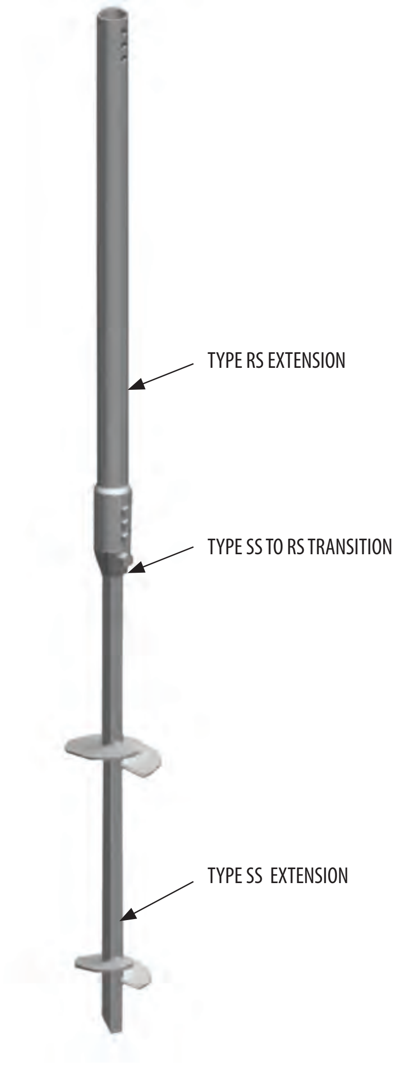


Figure 5-25 Type SS to RS Combination Pile

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.

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 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 6 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 5, 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 4-25). 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 6 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.

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.

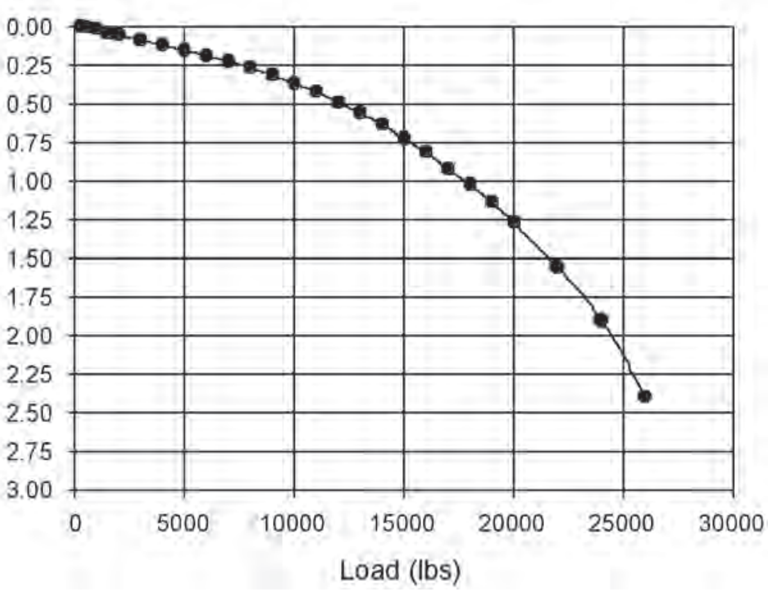


Figure 4-26

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
SECTION 5

CONTENTS

SYMBOLS USED IN THIS SECTION

Qult	Ultimate Uplift Capacity	5-5
Kt	Empirical Torque Factor	5-5
T	Average Installation Torque	5-5
SS	Square Shaft	5-5
RS	Round Shaft	5-5
Hd/Sd	Helix to Shaft Diameter Ratio	5-7
Qact	Actual Capacity	5-9
Qcalc	Calculated Capacity	5-9
Qact/Qcalc	Capacity Ratio	5-9
CID	Cubic Inch Displacement	5-12

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.

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 5-4). 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.

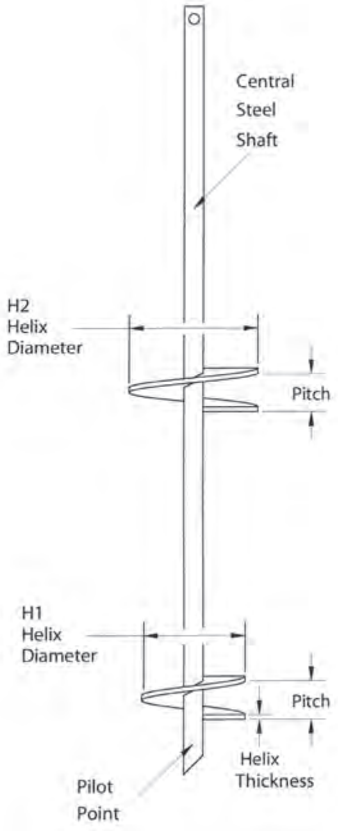
INSTALLATION TORQUE/LOAD CAPACITY RELATIONSHIP

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.

Section 4 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 4, 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:



Helical Pile/Anchor
Figure 6-4

$$Q_{ult} = K_t \times T$$ **Equation 5-1**

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 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 ft^{-1} for pipe shaft helical piles with 90 mm OD, and K_t = 3 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 5-1.

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 [>8-5/8" (219mm)] are less likely to advance at this rate, which means torque correlation cannot be used as a means to determine capacity.

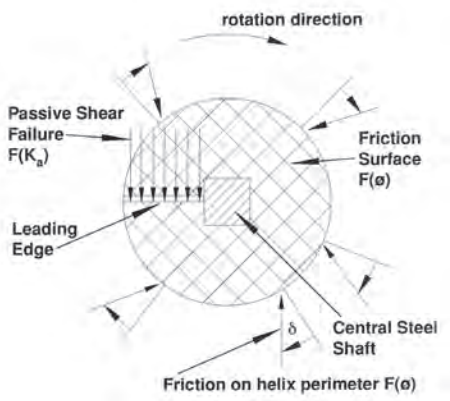
FACTORS INFLUENCING K_T, TABLE 5-1

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	

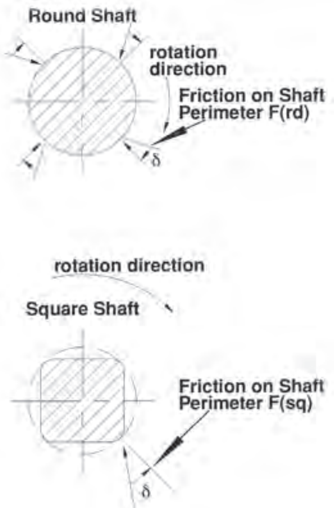
In order for Equation 5-1 to be useful, installation torque must be measured. There are a variety of methods used to measure torque. Hubbell Power Systems, Inc. offers two in-line torque indicators; in-line indicators are the best method to determine torque for capacity prediction. Other useful methods 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 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.



Top View of Helix
Figure 5-2



Friction Forces Action on Central Shafts
Figure 5-3

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.

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 5-2). 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.

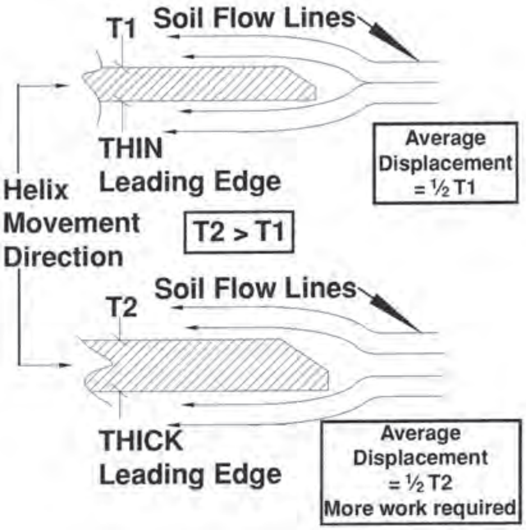
(2) Friction along the central steel shaft is similar to friction on the helix plate. Friction resistance increases with shaft size because the surface area of the shaft in contact with the soil increases as the diameter increases. An important performance factor for helical pile/anchors is the helix 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 5-3). 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 5-4). 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.

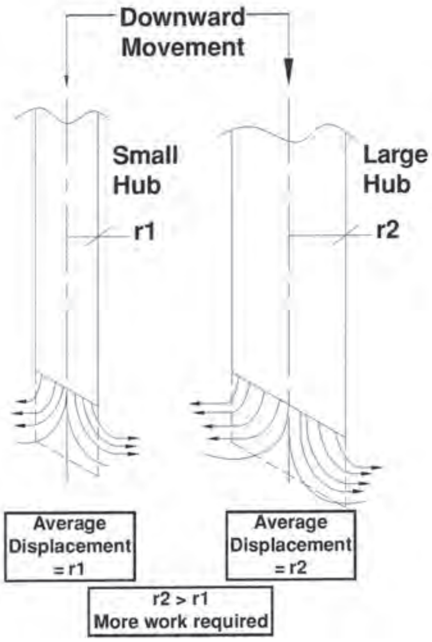
(2) Penetration resistance increases with shaft size because the projected area of the hub/pilot point increases with the square of the shaft radius (see Figure 5-5). The average distance the soil is displaced is approximately equal to the radius of the shaft, so as the shaft size increases, the more 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.



Section View of Leading
Edge with Flow Lines
Figure 5-4



Shaft/Pilot Point with Flow Lines
Figure 5-5

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 others 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.

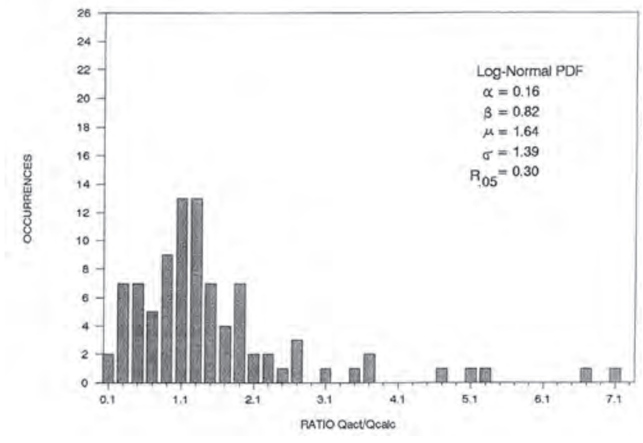
If one considers an energy balance between the energy exerted during loading and the appropriate penetration energy of each of the helix plates, then it can be realized that any installation energy not specifically related to helix penetration is wasted. This fact leads to several useful observations. 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.

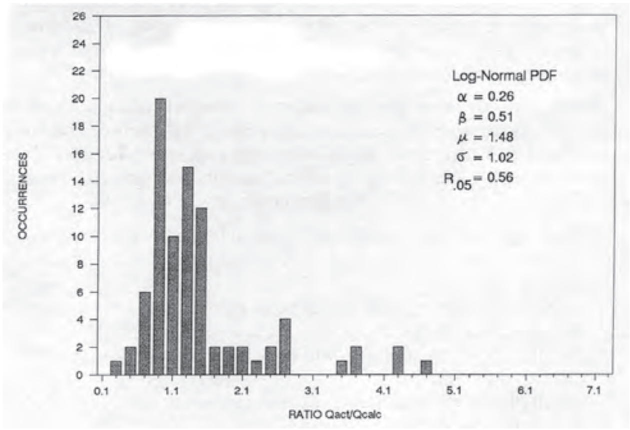
Reliability of Torque/Capacity Model

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 5-6 and 5-7, 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.



Individual Bearing Method
Figure 5-6



Torque Correlation Model
Figure 5-7

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
Figure 5-8

- **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 5-8). 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.

Mechanical Dial Torque Indicator
Figure 5-9

Wireless Remote Display
Figure 5-10

Remote Data Logger
Figure 5-11

- 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 5-9). 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.
- Accurate within ± 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**

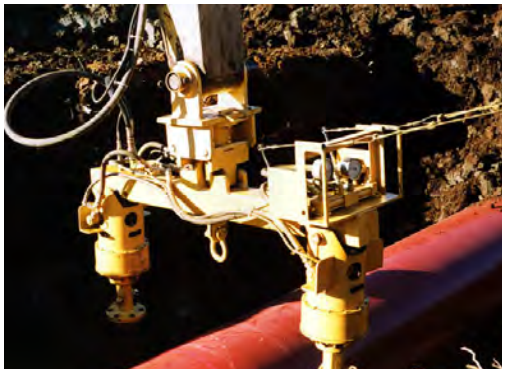
A differential pressure torque indicator is a hydraulic device consisting of back-to-back hydraulic pistons; hoses, couplings, and a gauge (see Figure 5-12). Its' operation is based on the principle that the work output of a hydraulic torque motor is directly related to the pressure drop across the motor. 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 ± 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.



Differential Pressure
Torque Indicator
Figure 5-12

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 x (12 in) = 7 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 ± 1° 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 6. 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 4) 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 6 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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PRODUCT DRAWINGS AND RATINGS
Section 6

CONTENTS

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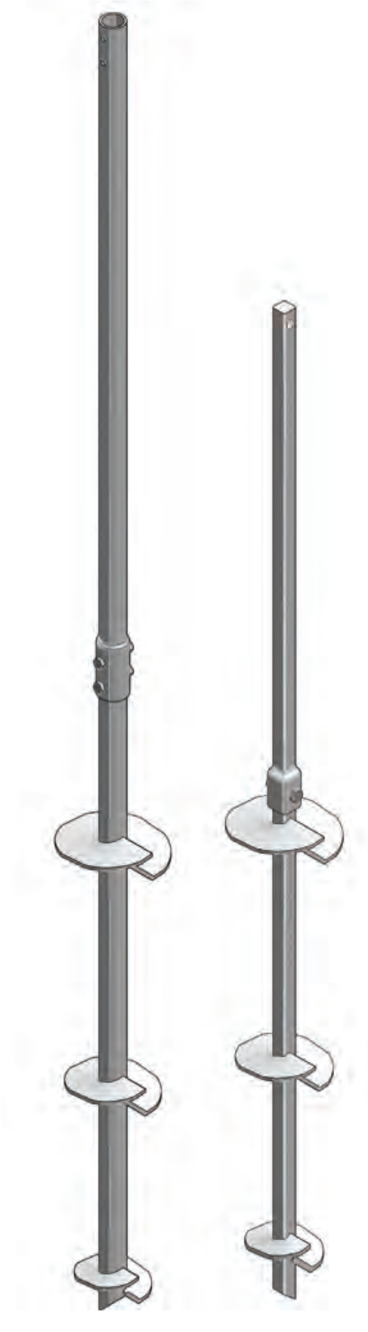
Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.



Pipe Shaft Pile Square Shaft Pile/Anchor

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.

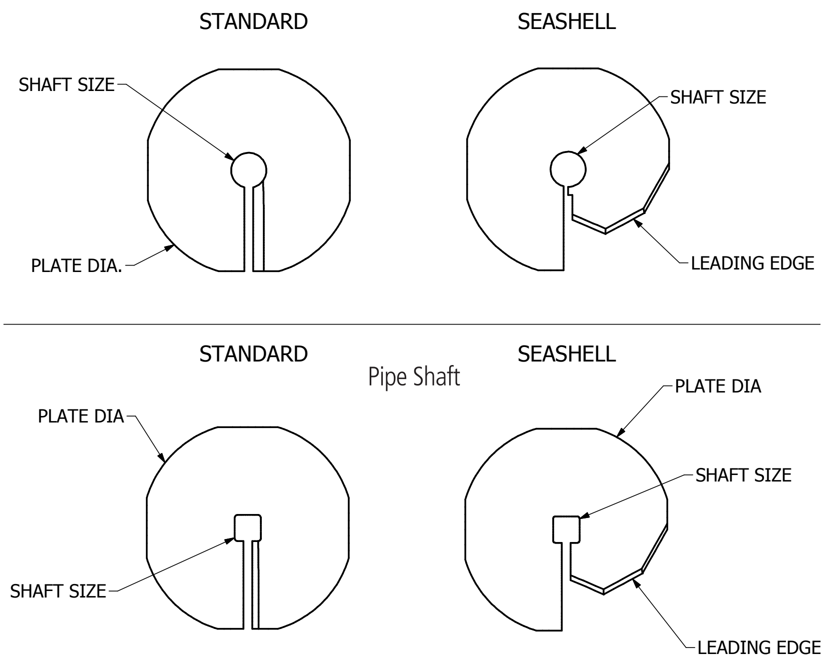
Helical pile/anchor sections are joined with bolted couplings. Installation depth is limited only by soil density and practicality based on economics. A helical bearing plate or “helix” is one pitch of a screw thread. Most helical piles include more than one helix plate, and the plates are arranged in 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 AC358 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.

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 6-2 and 6-3 below. Tables 6-2 and 6-3 provide the projected areas of the most common helix plate diameters. Table 6-2 provides helix areas for Type Square Shaft Helical Piles, and Table 6-3 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 though 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 6-2 and 6-3 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.



Square Shaft
Figure 6-2

TABLE 6-2: CHANCE® SQUARE SHAFT HELIX PLATE SIZES AND PROJECTED AREAS BY PRODUCT FAMILY

		SQUARE 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)
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

TABLE 6-3: 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

		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)
RS6625	12 (300)	0.532 (0.0494)	0.771 (0.0716)	N/A	N/A
	14 (350)	0.810 (0.0753)	1.049 (0.0975)	N/A	N/A
	16 (406)	1.139 (0.1058)	1.378 (0.1281)	N/A	N/A
	18 (457)	1.508 (0.1402)	1.748 (0.1624)	N/A	N/A
	20 (508)	1.922 (0.1786)	2.146 (0.1994)	N/A	N/A
	22 (559)	2.379 (0.1786)	2.618 (0.2434)	N/A	N/A
RS8626	14 (350)	0.643 (0.0598)	1.049 (0.0975)	N/A	N/A
	16 (406)	0.972 (0.0904)	1.378 (0.1281)	N/A	N/A
	18 (457)	1.342 (0.1247)	1.748 (0.1624)	N/A	N/A
	20 (508)	1.755 (0.1632)	2.146 (0.1994)	N/A	N/A
	22 (559)	2.212 (0.2056)	2.618 (0.2434)	N/A	N/A
	24 (610)	2.713 (0.2522)	3.119 (0.2899)	N/A	N/A
RS1075	16 (406)	0.748 (0.0695)	1.378 (0.1281)	N/A	N/A
	18 (457)	1.117 (0.1039)	1.748 (0.1624)	N/A	N/A
	20 (508)	1.531 (0.1423)	2.146 (0.1994)	N/A	N/A
	22 (559)	1.988 (0.1848)	2.618 (0.2434)	N/A	N/A
	24 (610)	2.489 (0.2313)	3.119 (0.2899)	N/A	N/A

Table 6-4 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 6-4: 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}).

** “N_{60}” Values or Blow Count from the Standard Penetration Test per ASTM D1586.

NOTES:

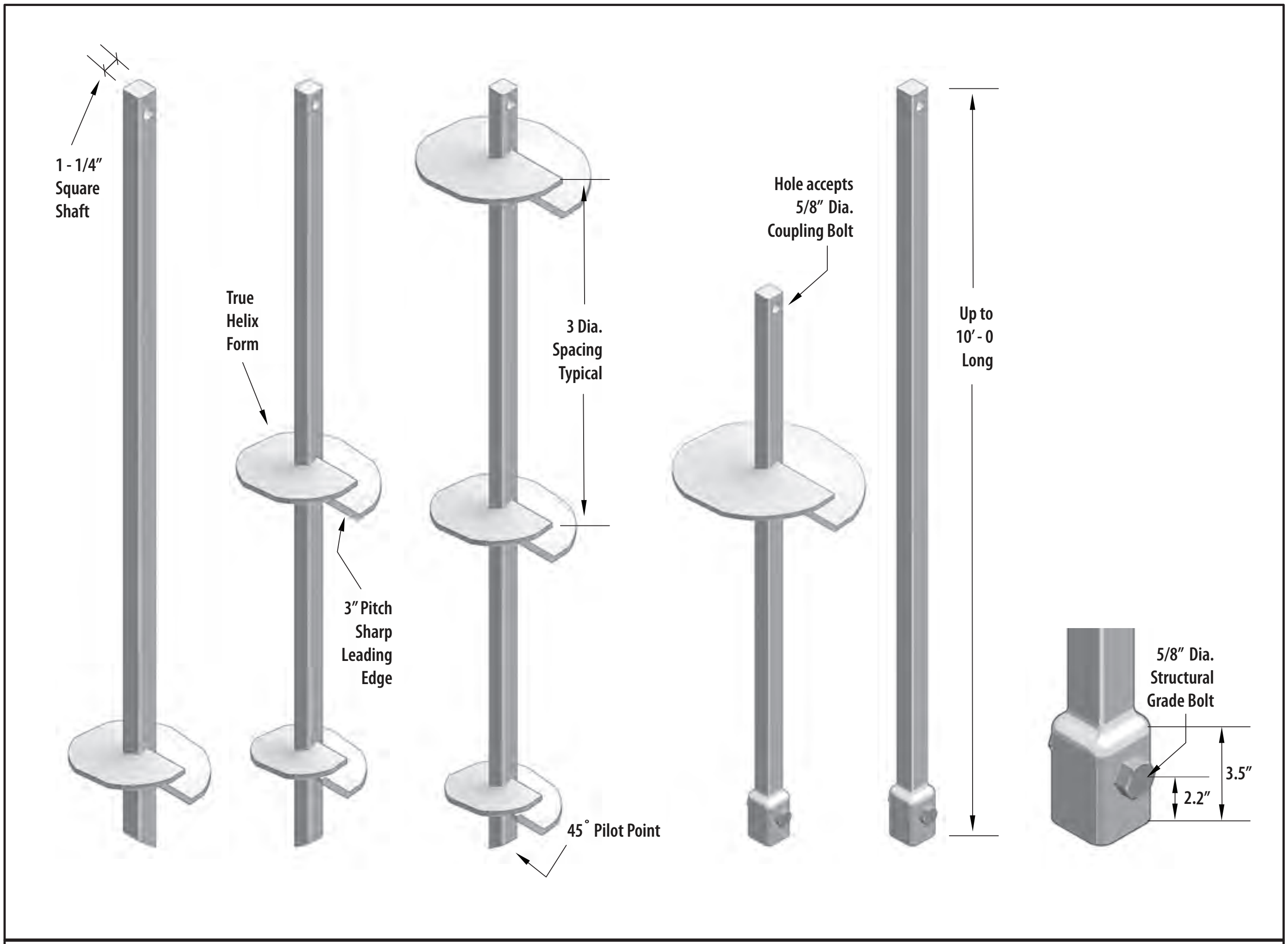
1. The table above is given as a guideline only. The capacity of CHANCE Helical Pile/Anchors may vary depending on, but not limited to, water table elevation and changes to that elevation, changes in soil conditions and soil layer thicknesses.
2. Achievable capacities could be higher or lower than stated 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.

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.



Single Helix Lead Section	Twin Helix Lead Section	Triple Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

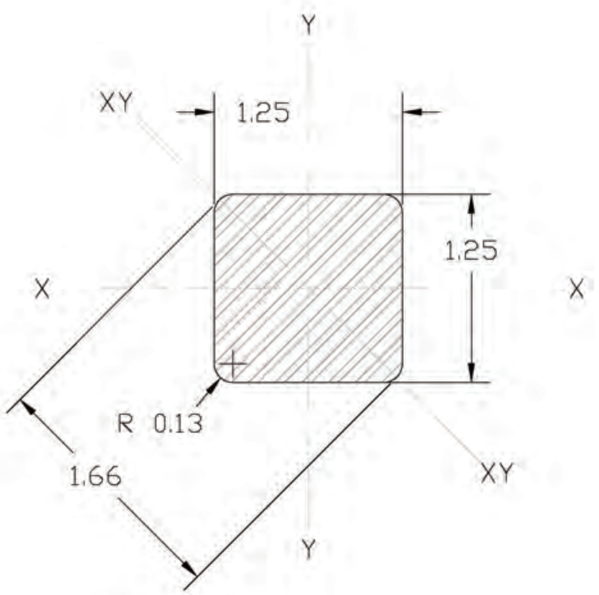
SS125 Helical Pile and Anchor Specifications & Available Configurations

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.



CHANCE Type SS125
Helical Pile Shaft Cross-Section
Figure 6-3

Nominal, LRFD Design and ASD Allowable Strengths of SS125 Helix Plates for Shaft Axial Tension and Compression[1]

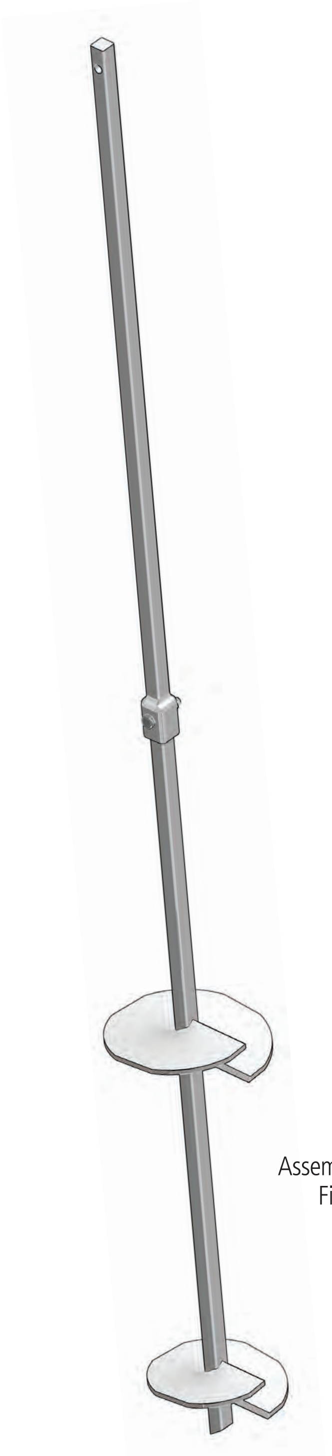
Helix Diameter in (mm)	Thickness in (mm)	Nominal Strength kip (kN)	LRFD Design Strength kip (kN)	ASD Allowable Strength kip (kN)
6 (150)	0.375 (9.5)	37.4 (166.3)	28.05 (124.7)	18.7 (83.2)
8 (200)	0.375 (9.5)	37.4 (166.3)	28.05 (124.7)	18.7 (83.2)
10 (250)	0.375 (9.5)	46.6 (207.3)	34.9 (155.5)	23.3 (103.6)
12 (300)	0.375 (9.5)	44.1 (196.2)	33.1 (147.2)	22.1 (98.3)
14 (350)	0.375 (9.5)	36.0 (160.1)	27.0 (120.1)	18.0 (80.1)

For SI: 1 kip = 4.448 kN.
[1]Capacities 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 6-4

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	*See Helix Strength Table*	16.4 (72.9)	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

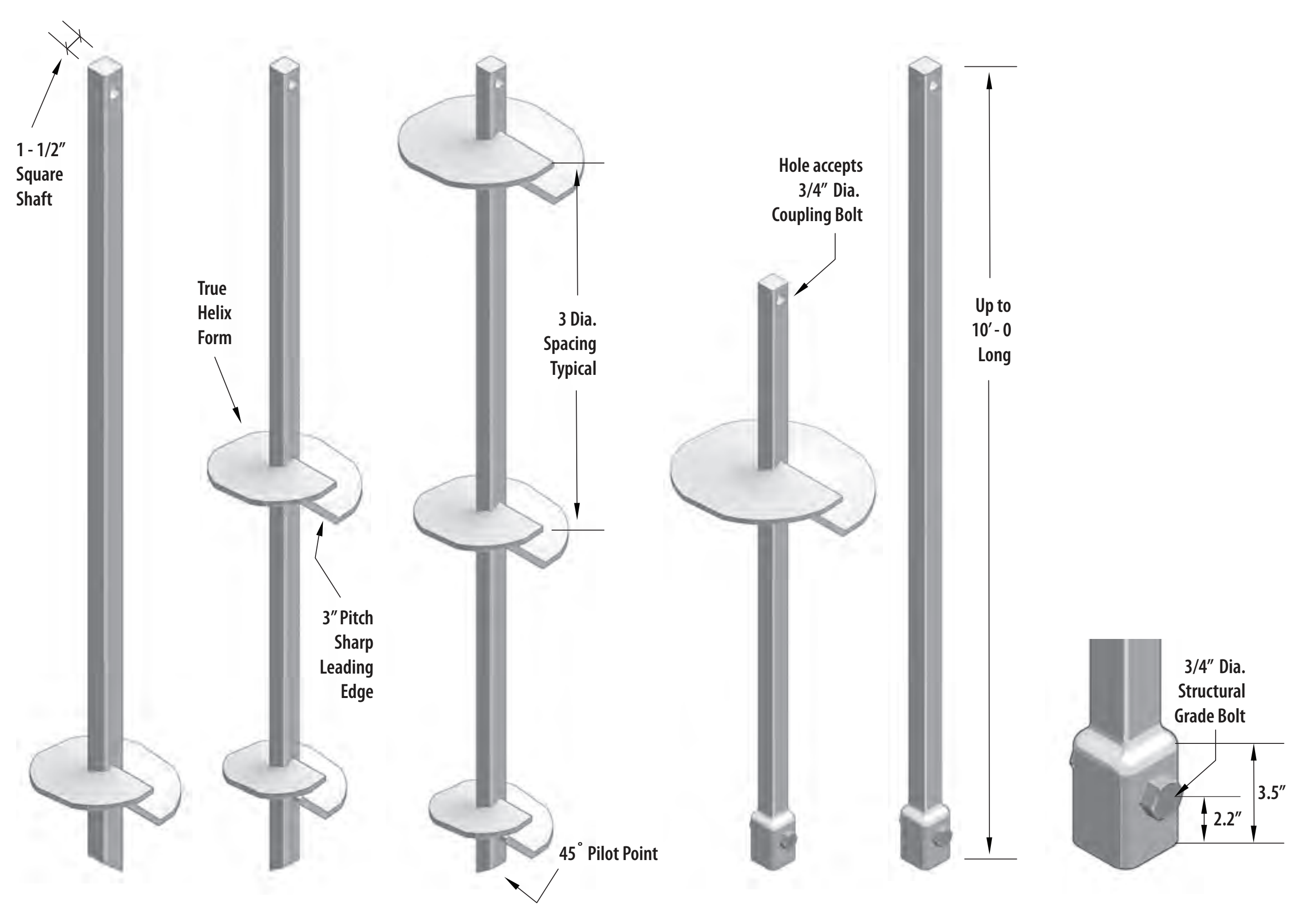
57 kip Ultimate – 28.5 kip Allowable Capacity

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.



Single Helix Lead Section	Twin Helix Lead Section	Triple Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

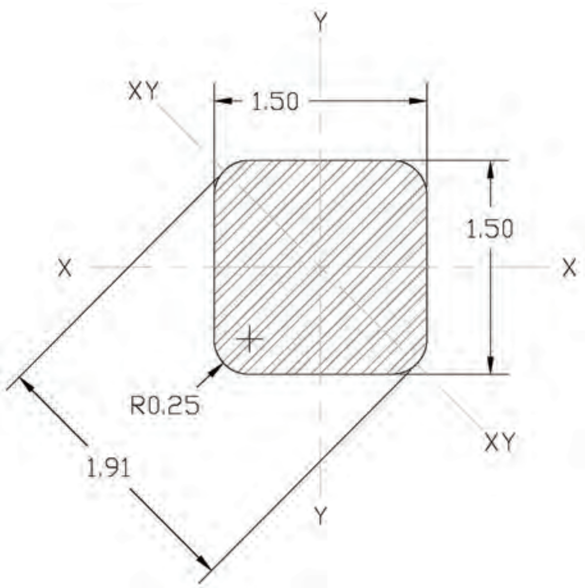
SS5 Helical Pile and Anchor Specifications & Available Configurations

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.



CHANCE Type SS5
Helical Pile Shaft Cross-Section
Figure 6-5

Nominal, LRFD Design and ASD Allowable Strengths of SS5 Helix Plates for Shaft Axial Tension and Compression[1]

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)	43.0 (191.2)	28.7 (127.7)
8 (200)	0.375 (9.5)	57.3 (254.9)	43.0 (191.2)	28.7 (127.7)
10 (250)	0.375 (9.5)	47.7 (212.2)	35.8 (159.2)	23.8 (105.6)
12 (300)	0.375 (9.5)	44.2 (196.6)	33.2 (147.5)	22.1 (98.3)
14 (350)	0.375 (9.5)	54.1 (240.7)	40.6 (180.5)	27.1 (120.6)

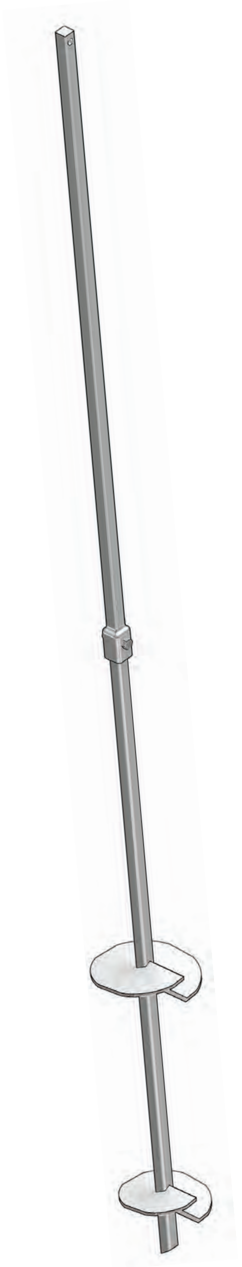
For SI: 1 kip = 4.448 kN.
[1] Capacities based on a design corrosion level of 50-years.

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 54.4 (242.0)	Single 6 & 8 in 48.9 (217.5)	26.6 (118.3)	24.0 (106.8)	13.6 (60.5)	12.2 (54.3)
			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)				

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 6-6

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	*See Helix Strength Table*	*See Helix Strength Table*	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

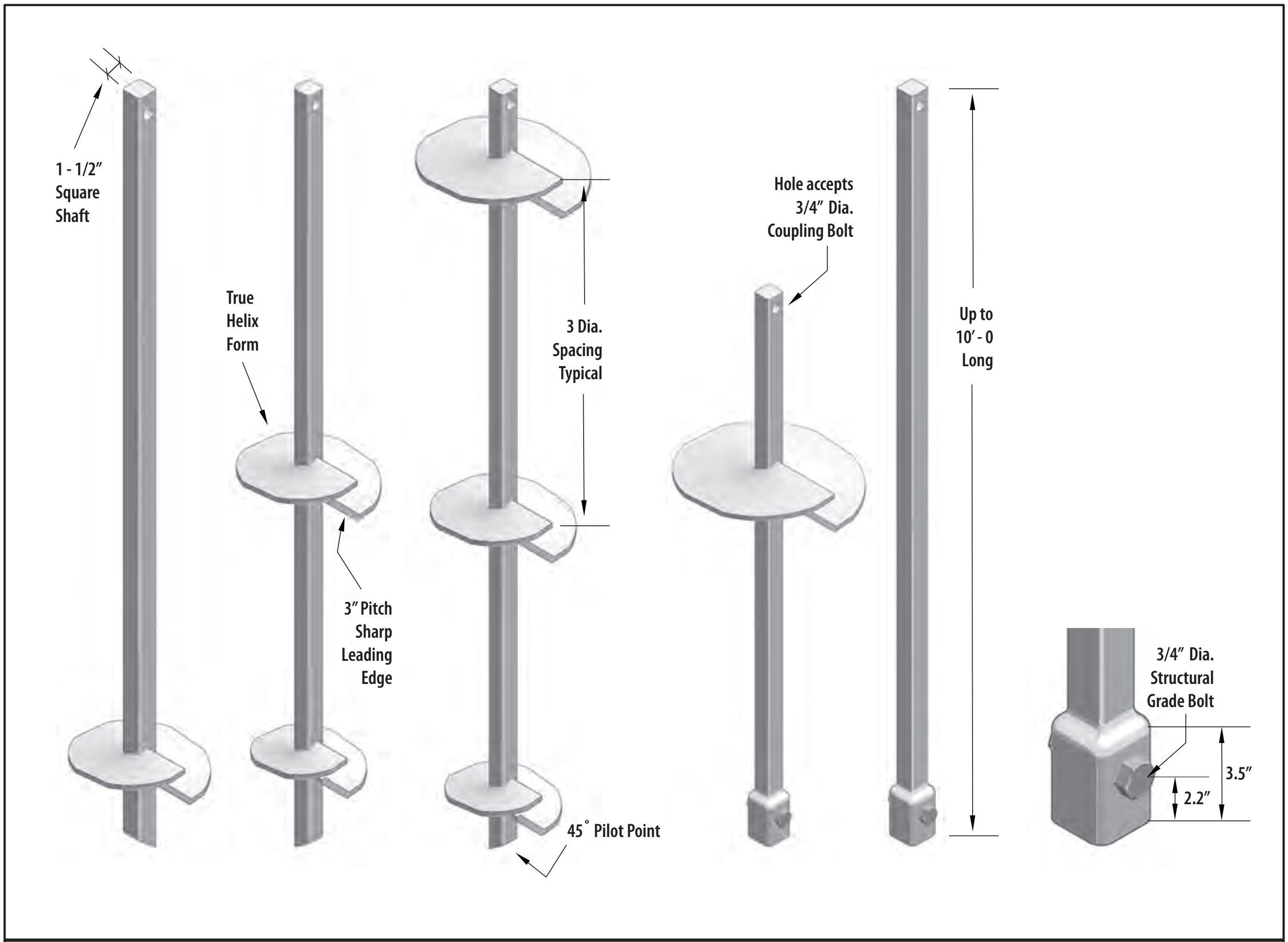
70 kip Ultimate – 35 kip Allowable Capacity

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.

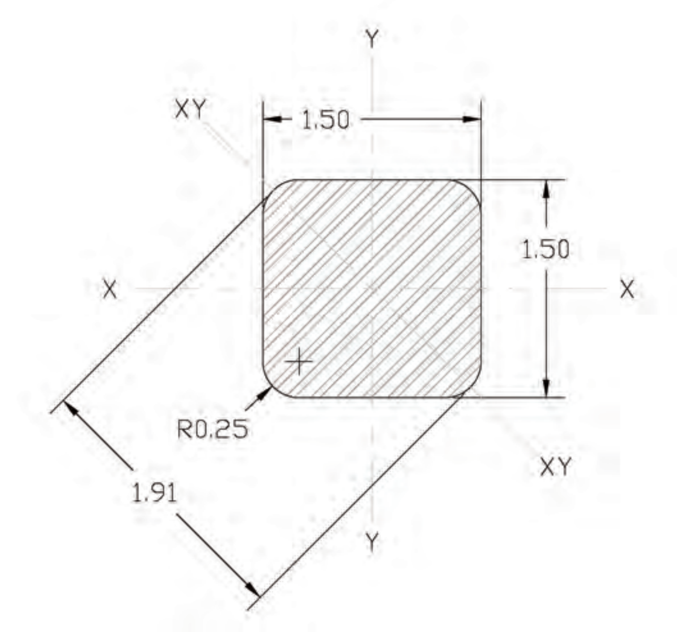


Single Helix Lead Section	Twin Helix Lead Section	Triple Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

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.



CHANCE Type SS150
Helical Pile Shaft Cross-Section
Figure 6-7

Nominal, LRFD Design and ASD Allowable Strengths of SS150 Helix Plates for Shaft Axial Tension and Compression[1]

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)	43.3 (192.8)	28.8 (128)
8 (200)	0.375 (9.5)	57.7 (257)	43.3 (192.8)	28.8 (128)
10 (250)	0.375 (9.5)	61.9 (275)	46.4 (206.3)	30.9 (137)
12 (300)	0.375 (9.5)	49.7 (221)	37.3 (165.8)	24.8 (110)
14 (350)	0.375 (9.5)	52.9 (235)	39.7 (176.3)	26.5 (118)

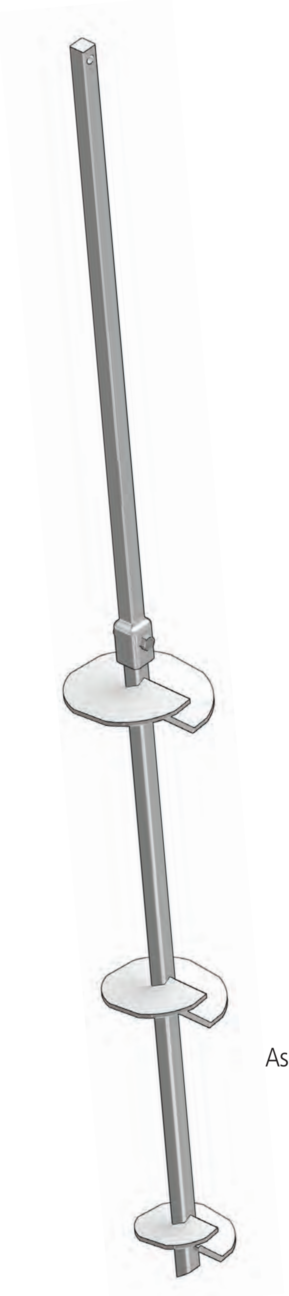
For SI: 1 kip = 4.448 kN.
[1]Capacities based on a design corrosion level of 50-years.

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) *For Other Helix Diameters, See Helix Strength Table*	Single 6, 8, or 10 inch – 48.9 (218)	26.6 (118)	24.0 (107)	13.6 (60.5)	12.2 (54)
Lead, Multi-Helix	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)
Extension								

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 ($S_{x\text{-}x}$)	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 6-8

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	See Helix Strength Table Above	16 (71)	8.1 (36)
Lead, 2-Helix 8”-10”	59.6 (265)	32.6 (145)	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

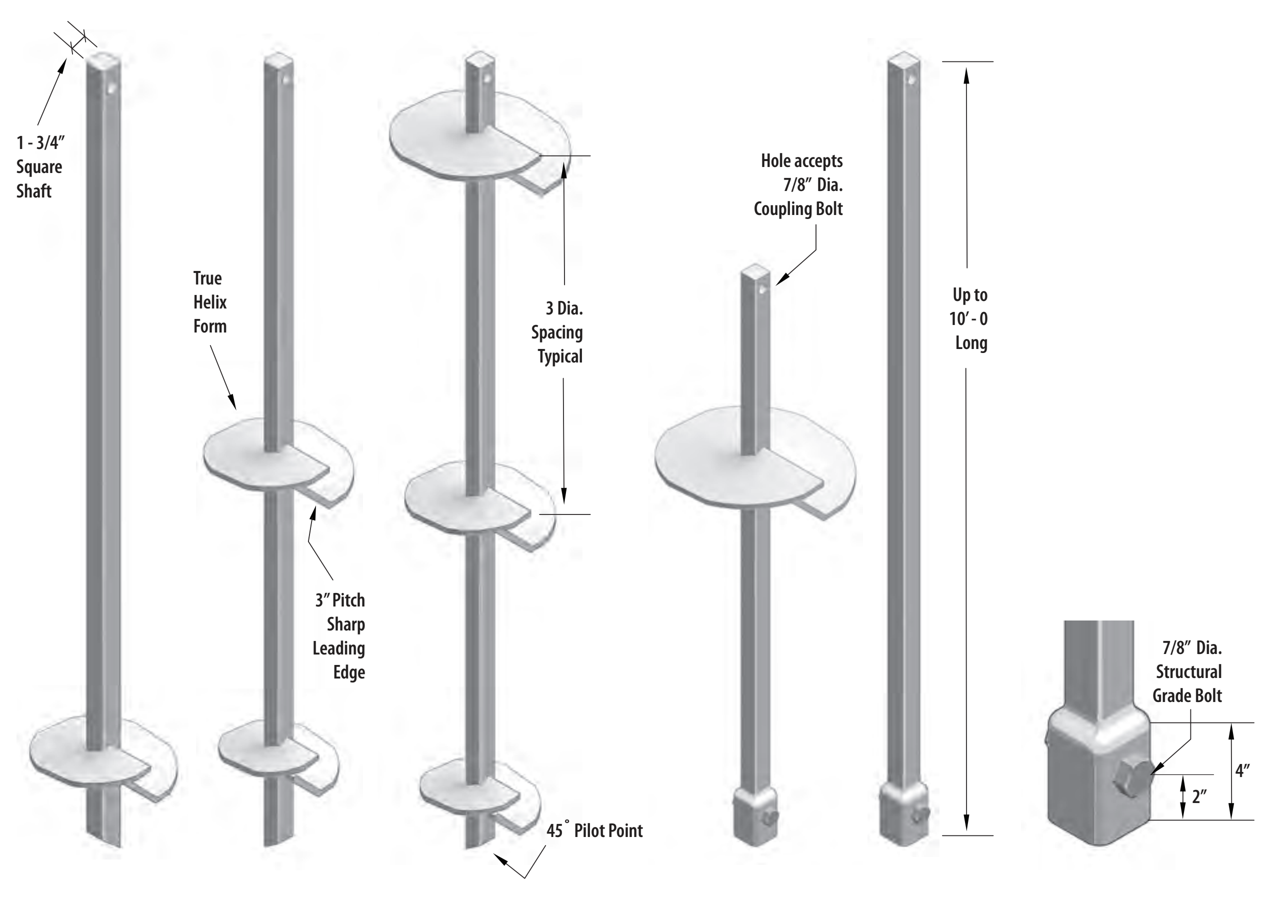
105 kip Ultimate – 52.5 kip Allowable Capacity

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.

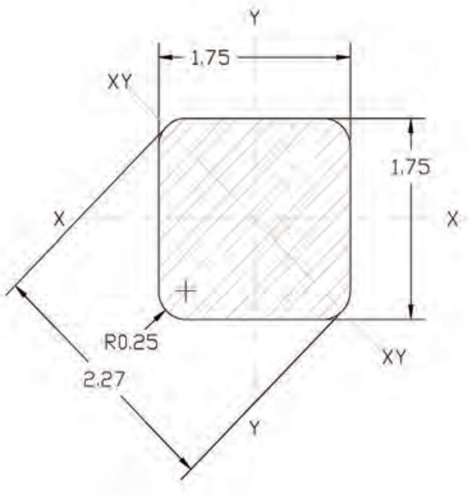


Single Helix Lead Section	Twin Helix Lead Section	Triple Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

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.



CHANCE Type SS175
Helical Pile Shaft Cross-Section
Figure 6-9

Nominal, LRFD Design and ASD Allowable Strengths of SS175 Helix Plates for Shaft Axial Tension and Compression[1]

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)	92.5 (411.4)	61.6 (274)
8 (200)	0.5 (13)	123.3 (548.5)	92.5 (411.4)	61.6 (274)
10 (250)	0.375 (9.5)	66.1 (294)	49.6 (220.5)	33.1 (147.2)
12 (300)	0.375 (9.5)	57.5 (255.8)	43.1 (191.9)	28.7 (127.7)
14 (350)	0.375 (9.5)	51.8 (230.4)	38.9 (172.8)	25.9 (115.2)

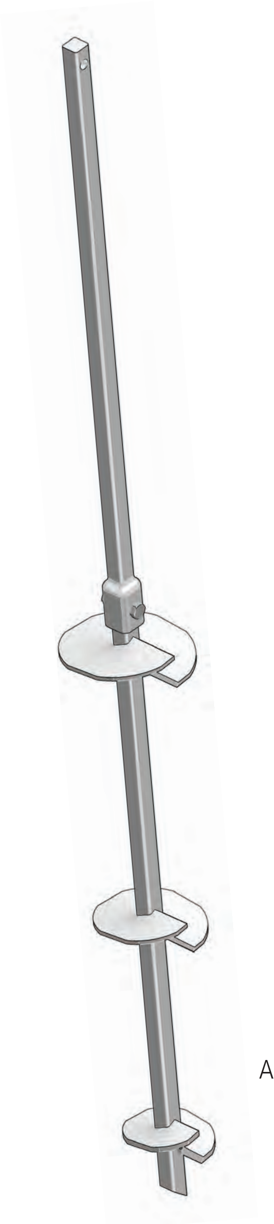
For SI: 1 kip = 4.448 kN.
[1]Capacities based on a design corrosion level of 50-years.

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.

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 ($S_{x\text{-}x}$)	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 6-10

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

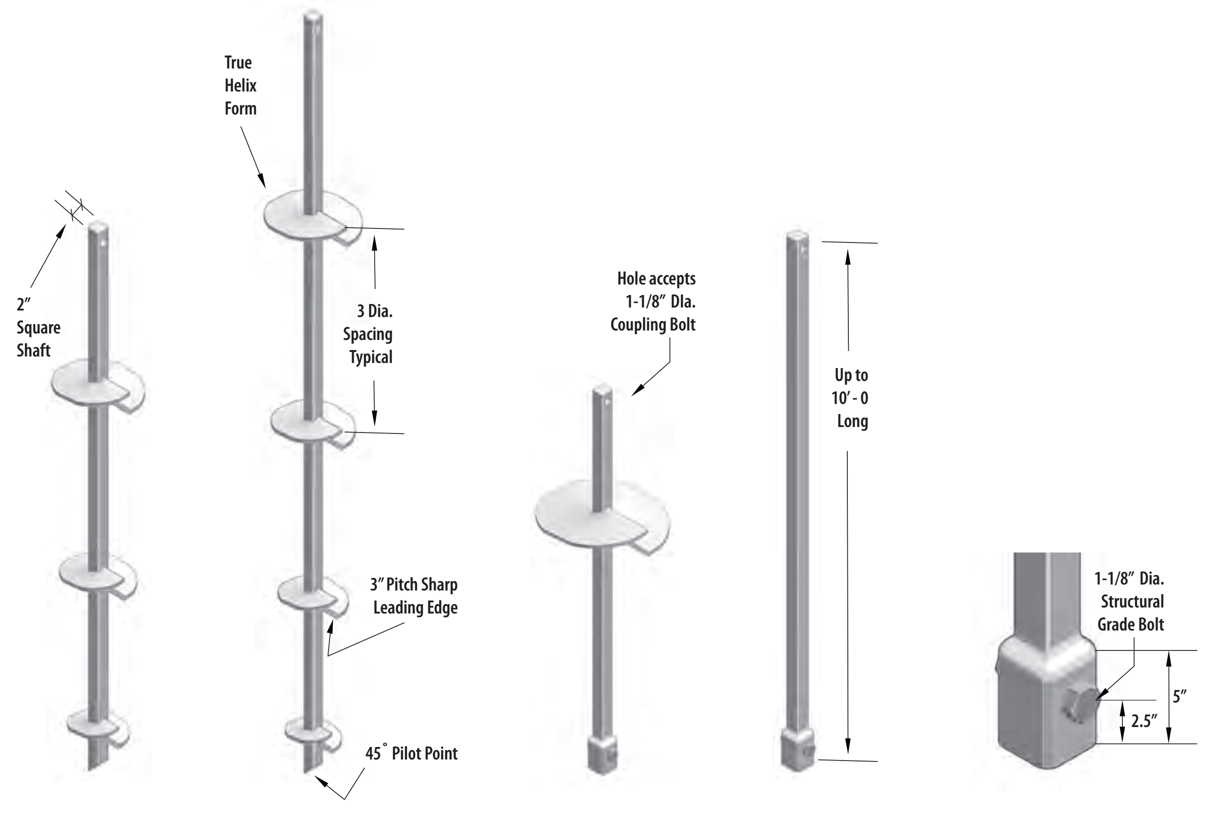
160 kip Ultimate – 80 kip Allowable Capacity

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.

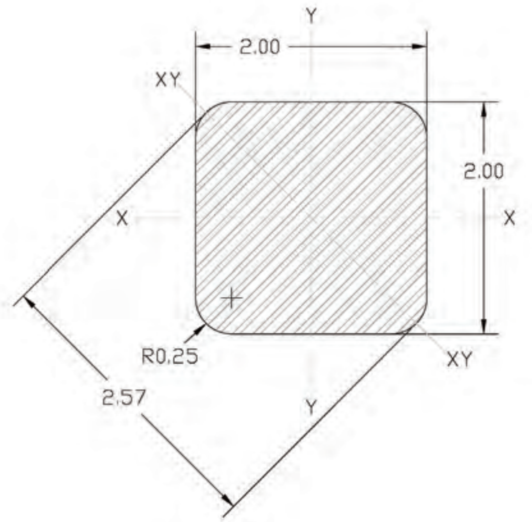


Triple Helix Lead Section	Quad Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

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.



CHANCE Type SS200
Helical Pile Shaft Cross-Section
Figure 6-11

Nominal, LRFD Design and ASD Allowable Strengths of SS220 Helix Plates for Shaft Axial Tension and Compression[1]

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)	115.5 (513.8)	77 (342.5)
8 (200)	0.5 (13)	154 (685)	115.5 (513.8)	77 (342.5)
10 (250)	0.5 (13)	122.8 (546.2)	92.1 (409.7)	61.4 (273.1)
12 (300)	0.5 (13)	131.3 (584)	98.5 (438)	65.6 (291.8)
14 (350)	0.5 (13)	115.3 (512.9)	86.5 (384.7)	57.6 (256.2)

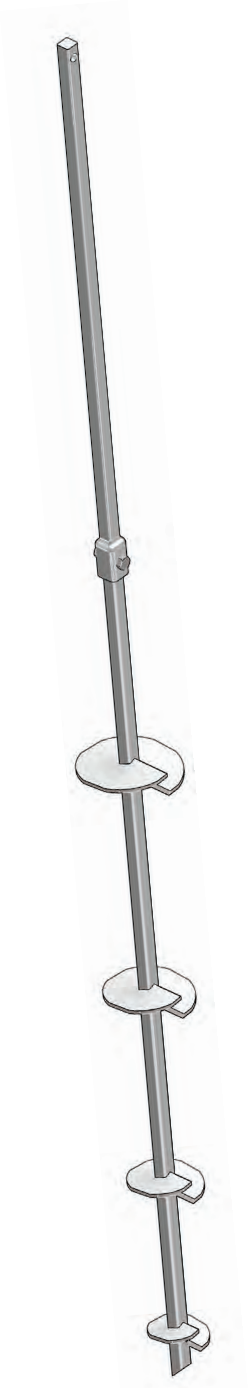
For SI: 1 kip = 4.448 kN.
[1]Capacities based on a design corrosion level of 50-years.

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.

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 6-12

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	See Helix Strength Table Above	51.3 (228.2)	26.2 (116.5)
Lead, 2-Helix 8”-10”	138.4 (615.6)	100.3 (446.1)	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)			
Lead, Multi-Helix	143.5 (638.3)	100.3 (446.1)	51.3 (228.2)	26.2 (116.5)
Extension	143.5 (638.3)	100.3 (446.1)	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

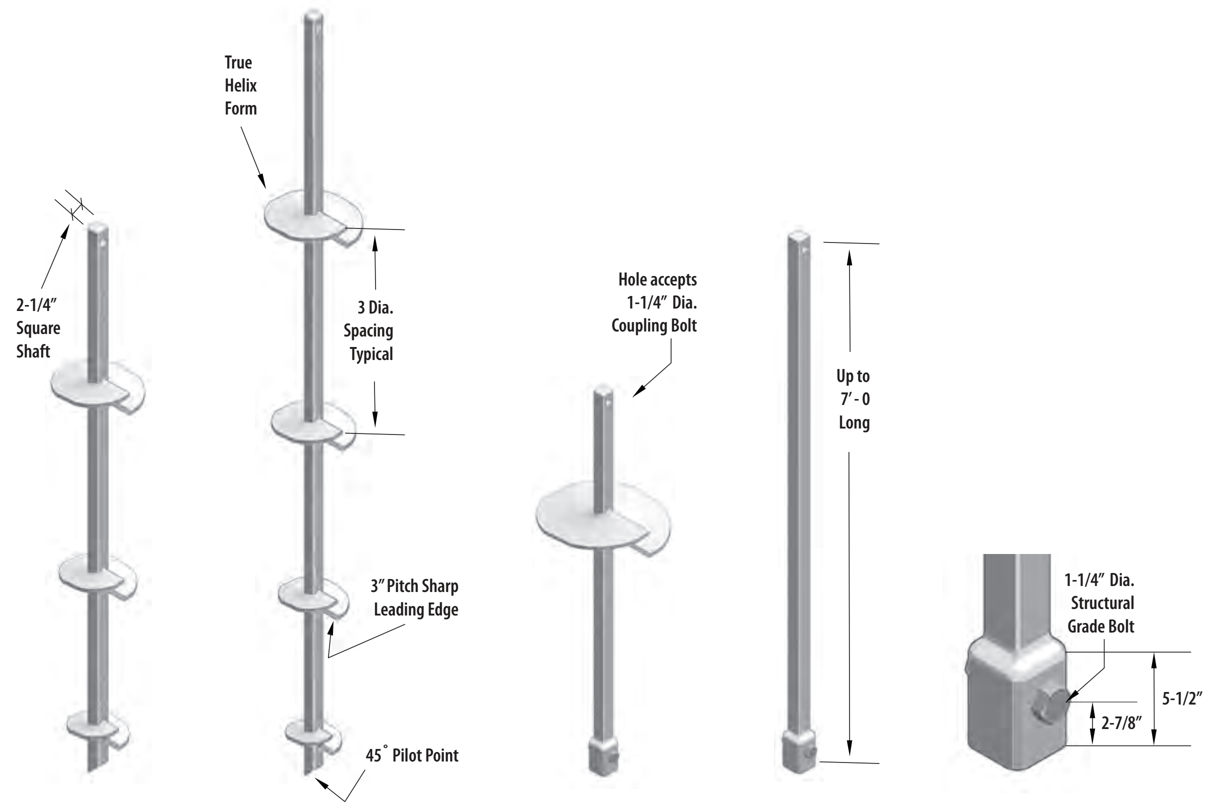
210 kip Ultimate – 105 kip Allowable Capacity

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:

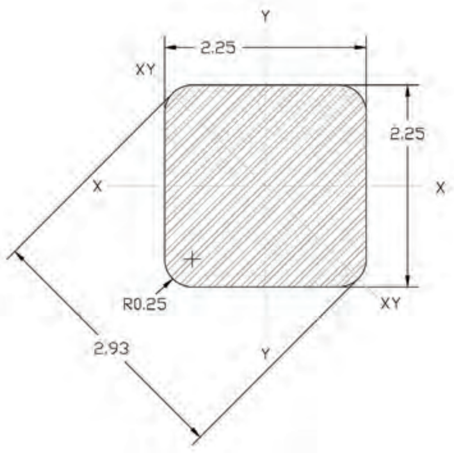
Hubbell Power Systems, Inc., CHANCE Type SS225 Helical Piles and Anchors have 210 kip ultimate capacity and 105 kip working or allowable capacity in compression and 200 kip ultimate capacity and 100 kip working or allowable capacity in tension. This capacity is based on structural strength ratings and 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.



Triple Helix Lead Section	Quad Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

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 - 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 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.



CHANCE Type SS225
Helical Pile Shaft Cross-Section
Figure 6-13

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 Compression[1]

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)	141 (627.2)	94 (418.1)
8 (200)	0.5 (13)	188 (836.3)	141 (627.2)	94 (418.1)
10 (250)	0.5 (13)	151.8 (675.2)	113.9 (506.4)	75.9 (337.6)
12 (300)	0.5 (13)	141.3 (628.5)	106 (471.4)	70.6 (314)
14 (350)	0.5 (13)	126.3 (561.8)	94.7 (421.4)	63.2 (281.1)

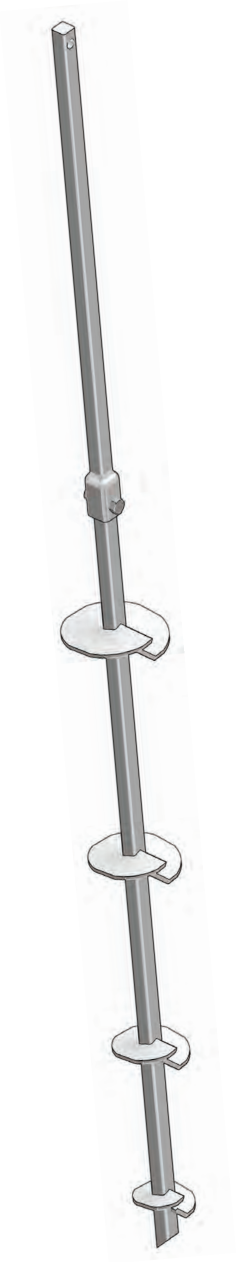
For SI: 1 kip = 4.448 kN.
[1] Capacities based on a design corrosion level of 50-years.

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) Single 14 inch – 126.3 (561.8)	125.1 (556.5) Single 14 inch – 113.7 (505.8)	70.9 (315.4)	63.8 (283.8)
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 6-14

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

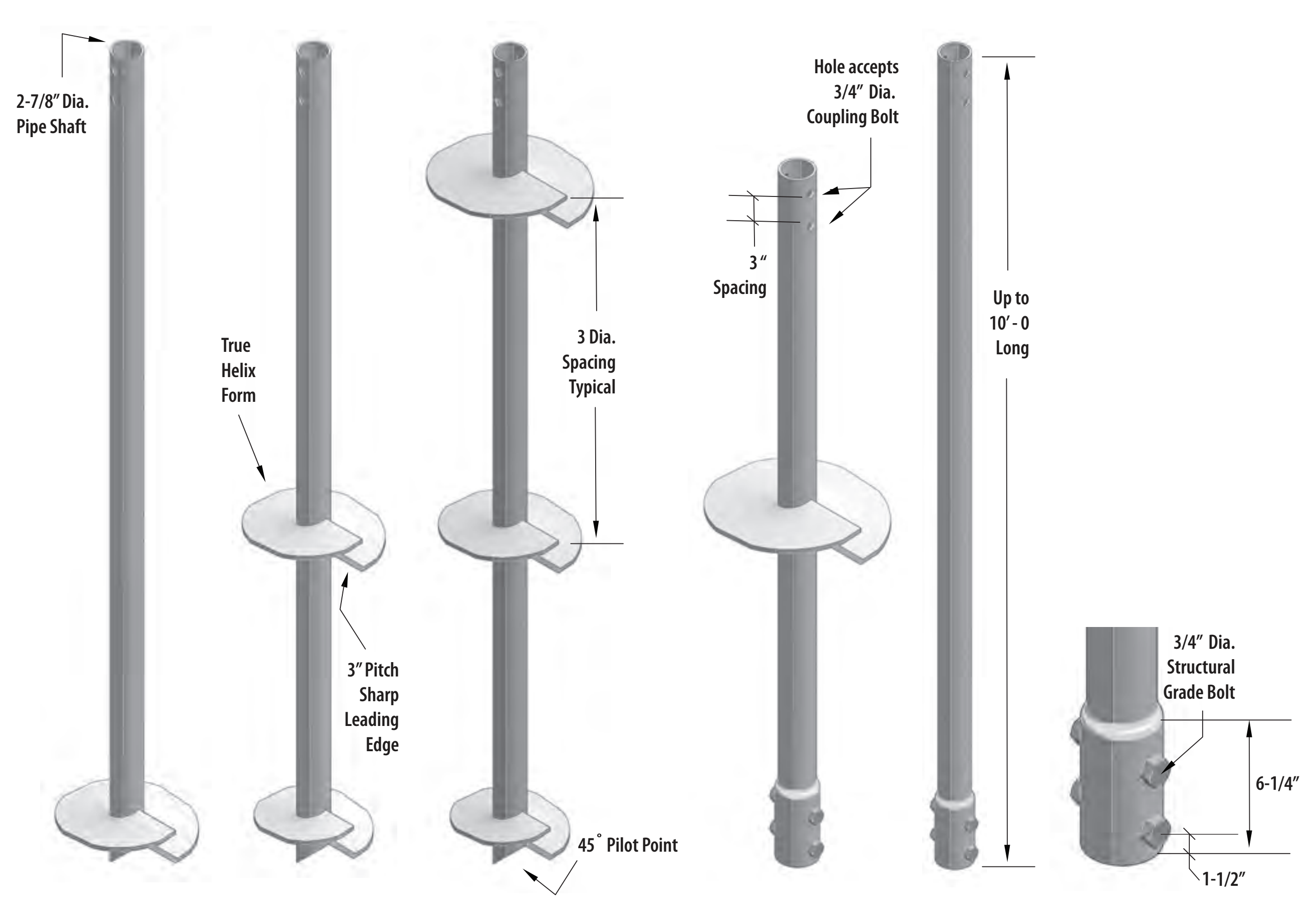
63 kip Ultimate – 31.5 kip Allowable Capacity

Installation Torque Rating – 7,000 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 63 kip ultimate capacity and 31.5 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.

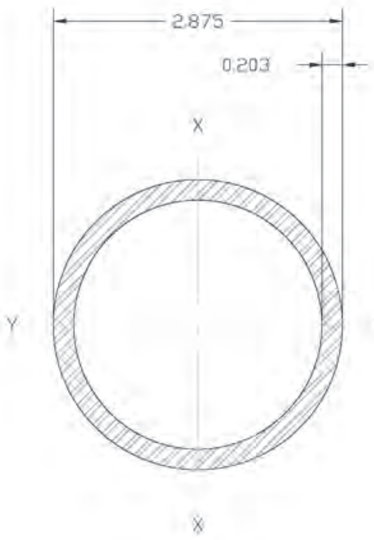


Single Helix Lead Section | Twin Helix Lead Section | Triple Helix Lead Section | Helical Extension Section | Plain Exension Section | Coupling Detail

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.



CHANCE Type RS2875.203
Helical Pile Shaft Cross-Section
Figure 6-15

Nominal, LRFD Design and ASD Allowable Strengths of RS2875.203 Helix Plates for Shaft Axial Tension and Compression[1]

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)	64.4 (286.3)	42.9 (190.8)
10 (250)	0.375 (9.5)	73.6 (327.4)	55.2 (245.6)	36.8 (163.7)
12 (300)	0.375 (9.5)	75.6 (336.3)	56.7 (252.2)	37.8 (168.1)
14 (350)	0.375 (9.5)	61.0 (271.3)	45.8 (203.5)	30.5 (135.7)

For SI: 1 kip = 4.448 kN.
[1]Capacities based on a design corrosion level of 50-years.

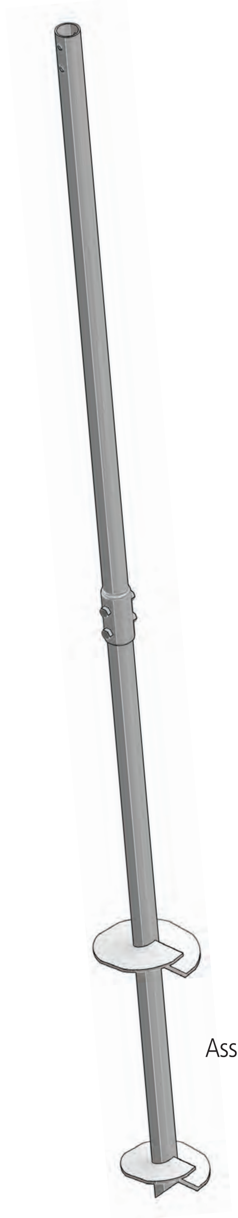
Nominal and LRFD Design Compression Strengths of CHANCE® Type RS2875.203 Helical Pile Lead & Extension Sections[1,2]

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.

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 65 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	7,000 ft-lb		9,491 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	
	63 kip	280 kN	31.5 kip	140 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS2875.203
Figure 6-16

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)**	**33.2 (147.7)**	**25.1 (111.7)**
	See Helix Strength Table Above for 10", 12" & 14"	See Helix Strength Table Above for 10", 12" & 14"	For Single 14" – 30.5 (135.7)	
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"				
Lead, 2-Helix 12"-14"				
Lead, 2-Helix 14"-14"				
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 RS2875.203 HELICAL PILES PER ICC-ES AC 358 FOR BUILDING CODE EVALUATION

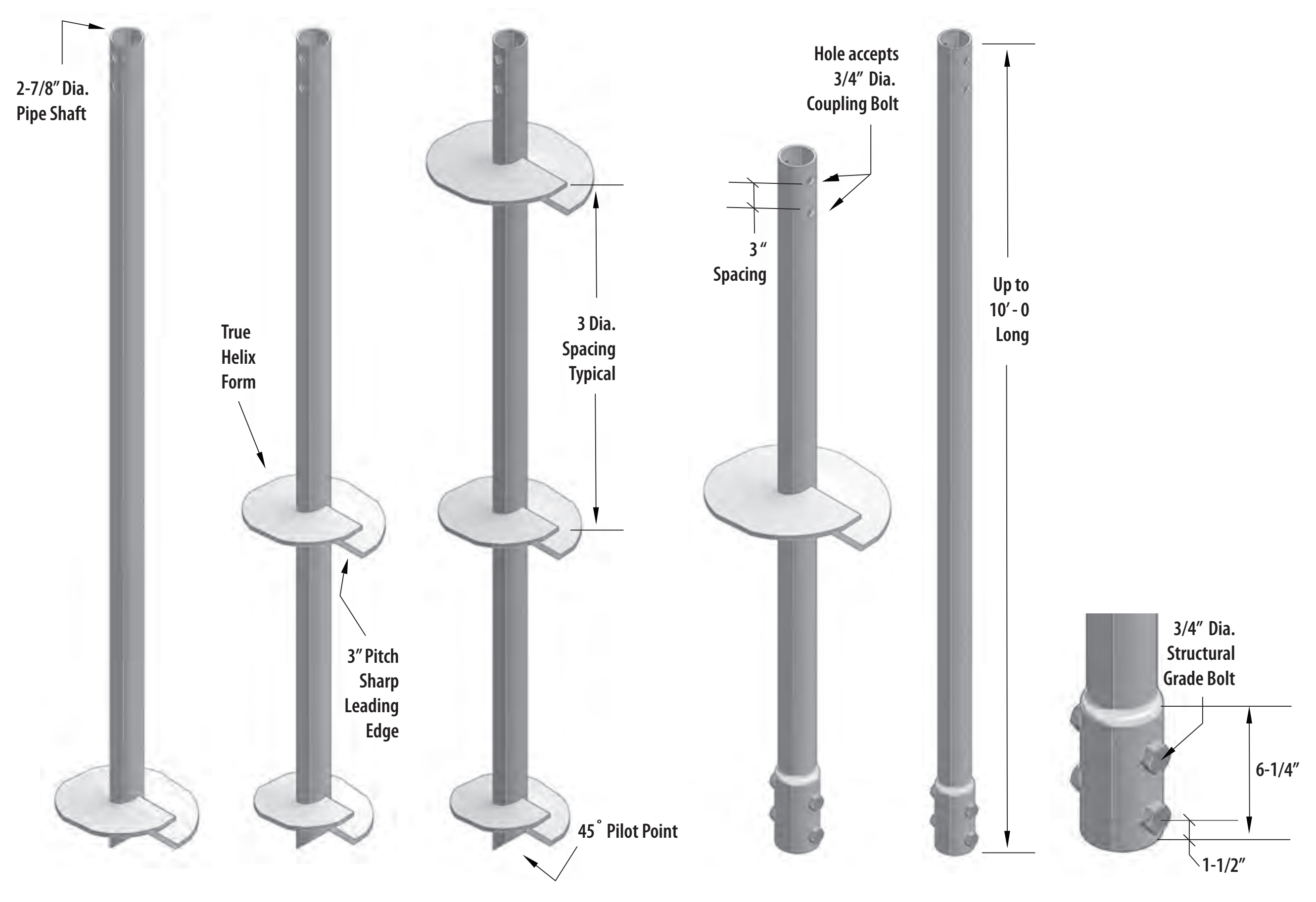
60.4 kip Ultimate – 30.2 kip Allowable Capacity

Installation Torque Rating – 6,710 ft-lb

Multi-Purpose 2-7/8" Diameter, 0.203" Wall, Round HSS Shaft with sleeve couplings

Description:

Hubbell Power Systems, Inc., CHANCE Type RS2875.203 Helical Piles have 60.4 kip ultimate capacity and 30.2 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.

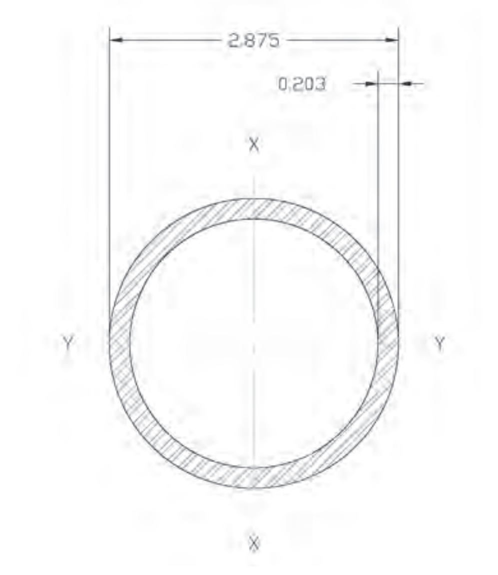


Single Helix Lead Section	Twin Helix Lead Section	Triple Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

RS2875.203 Building Code 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 – welded sleeve forming a socket 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.



CHANCE Type RS2875.203
Helical Pile Shaft Cross-Section
Figure 6-17

Nominal, LRFD Design and ASD Allowable Strengths of RS2875.203 Helix Plates for Shaft Axial Tension and Compression[1]

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)	135.0 (600.5)	101.3 (450.6)	67.5 (300.3)
10 (250)	0.375 (9.5)	122.7 (545.8)	92.0 (409.2)	61.4 (273.1)
12 (300)	0.375 (9.5)	127.1 (565.4)	95.3 (423.9)	63.6 (282.9)
14 (350)	0.375 (9.5)	124.9 (555.6)	93.7 (416.8)	62.4 (277.6)

For SI: 1 kip = 4.448 kN.
[1] Capacities based on a design corrosion level of 50-years.

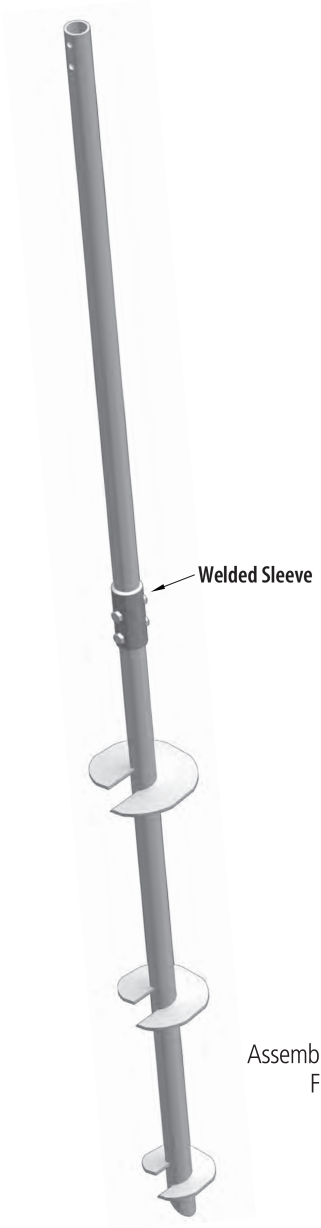
Nominal and LRFD Design Compression Strengths of CHANCE® Type RS2875.203 Helical Pile Lead & Extension Sections[1,2]

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	87.1 (387.4)	65.3 (290.5)	80.1 (356.3)	65.3 (290.5)	66.1 (294.0)	59.5 (264.7)	45.2 (201.1)	41.4 (184.2)
Lead, Multi-Helix								
Extension								

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.

RS2875.203 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 65 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	Welded 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	6,710 ft-lb		9,100 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	87 kip	387 kN	65.3 kip	290.5 kN
Allowable Tension Strength	43.5 kip		193.5 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	60.4 kip	269 kN	30.2 kip	134 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS2875.203
Figure 6-18

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	43.5 (193.5)	43.5 (193.5)	39.6 (176.1)	27.5 (122.3)
Lead, 2-Helix 8”-10”	43.5 (193.5)	43.5 (193.5)	39.6 (176.1)	27.5 (122.3)
Lead, 2-Helix 10”-12”				
Lead, 2-Helix 12”-14”				
Lead, 2-Helix 14”-14”				
Lead, Multi-Helix	43.5 (193.5)	43.5 (193.5)	39.6 (176.1)	27.5 (122.3)
Extension	43.5 (193.5)	43.5 (193.5)	39.6 (176.1)	27.5 (122.3)

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.

CHANCE® TYPE RS2875.276 HELICAL PILES

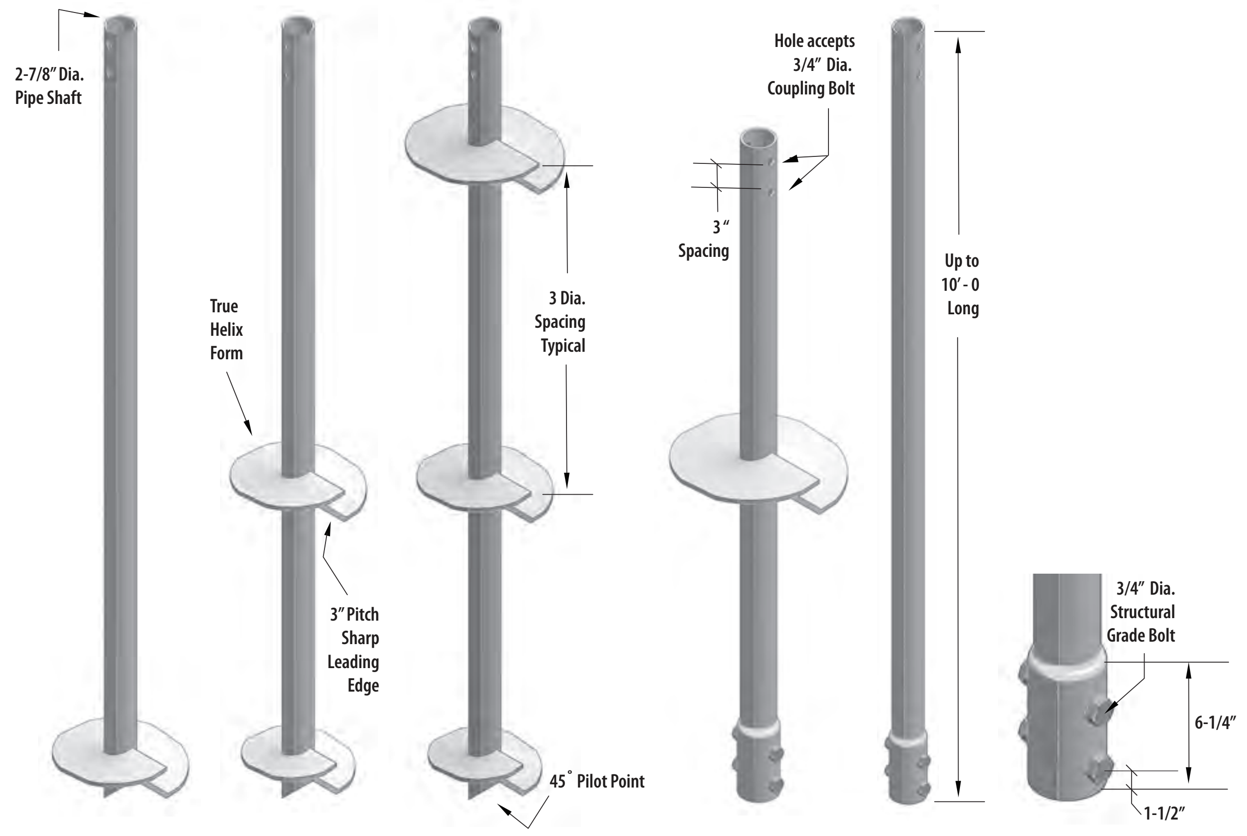
72 kip Ultimate – 36 kip Allowable Capacity

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.

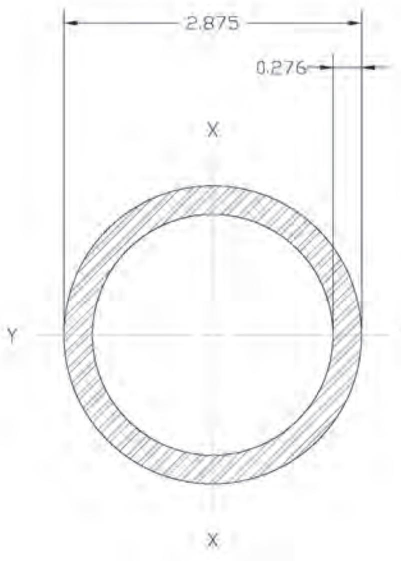


Single Helix Lead Section	Twin Helix Lead Section	Triple Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

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.



CHANCE Type RS2875.276 Helical Pile Shaft Cross-Section
Figure 6-19

Nominal, LRFD Design and ASD Allowable Strengths of RS2875.276 Helix Plates for Shaft Axial Tension and Compression[1]

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)	91.1 (378)	60.7 (270.0)
10 (250)	0.375 (9.5)	98.9 (439.9)	74.2 (330)	49.5 (220.2)
12 (300)	0.375 (9.5)	85.3 (379.4)	63.9 (284.6)	42.7 (189.9)
14 (350)	0.375 (9.5)	53.7 (238.9)	40.3 (179.2)	26.9 (119.7)

For SI: 1 kip = 4.448 kN.
[1] Capacities based on a design corrosion level of 50-years.

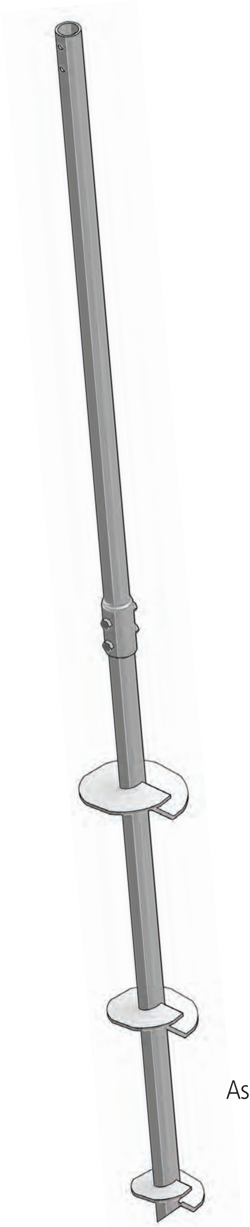
Nominal and LRFD Design Compression Strengths of CHANCE® Type RS2875.276 Helical Pile Lead & Extension Sections[1,2]

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 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 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 6-20

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 RS2875.276 HELICAL PILES PER ICC-ES AC358 FOR BUILDING CODE EVALUATION

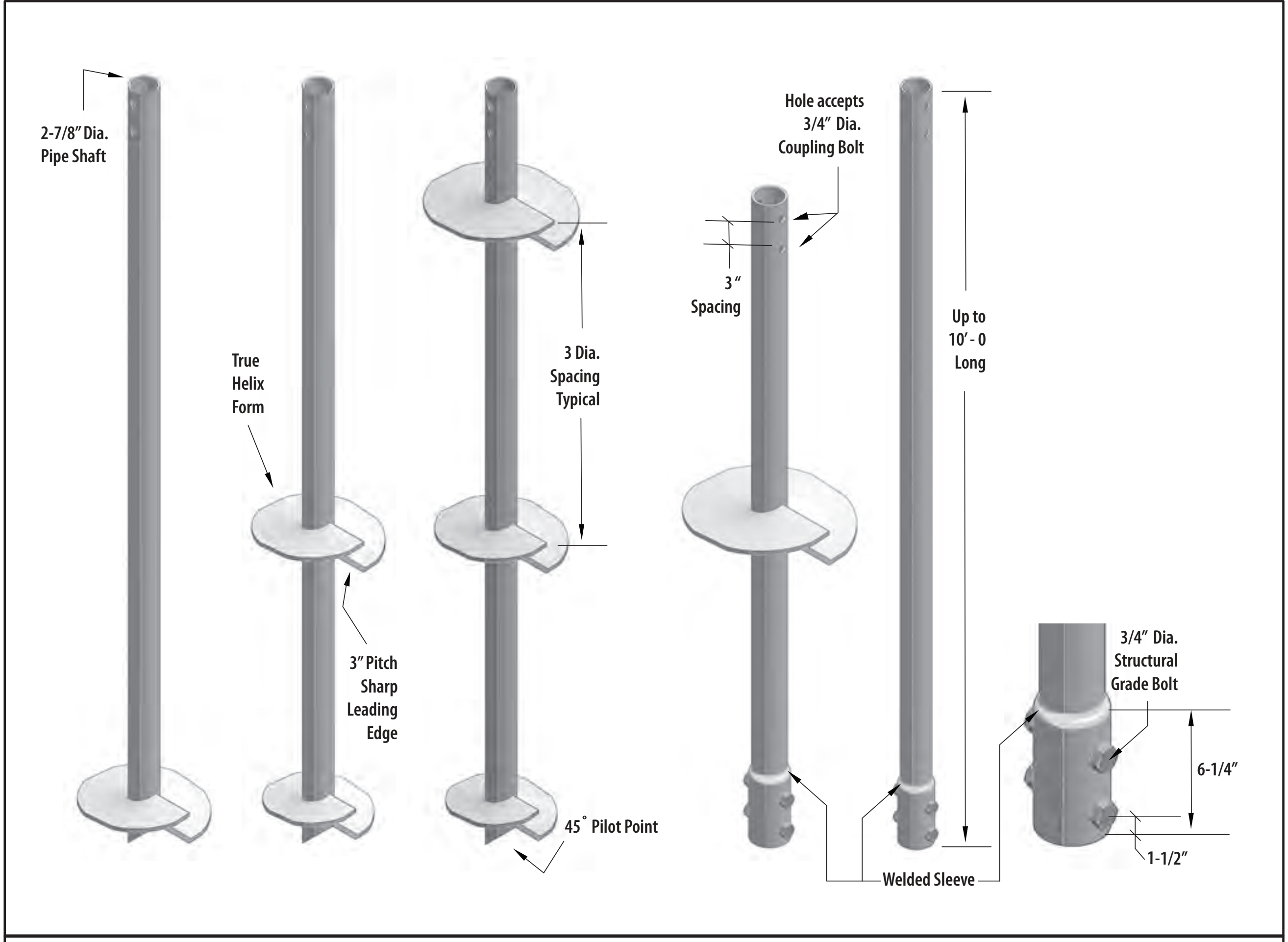
80.1 kip Ultimate – 40.05 kip Allowable Capacity

Installation Torque Rating – 8,900 ft-lb

Multi-Purpose 2-7/8” Diameter, 0.276” Wall, Round HSS Shaft with Sleeve Couplings

Description:

Hubbell Power Systems, Inc., CHANCE Type RS2875.276 Helical Piles have 80.1 kip ultimate capacity and 40.05 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.

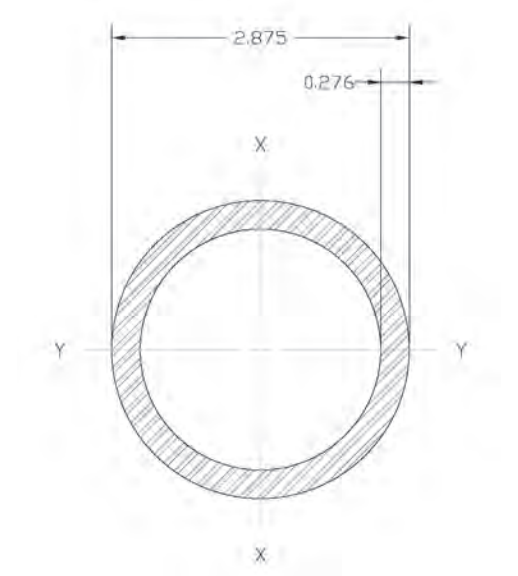


Single Helix Lead Section	Twin Helix Lead Section	Triple Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

RS2875.276 Building Code 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 – Welded sleeve forming a socket 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.



CHANCE Type RS2875.276 Helical Pile Shaft Cross-Section
Figure 6-21

Nominal, LRFD Design and ASD Allowable Strengths of RS2875.276 Helix Plates for Shaft Axial Tension and Compression[1]

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)	113.9 (504.4)	85.4 (378.3)	56.9 (253.1)
10 (250)	0.375 (9.5)	94.5 (420.4)	70.9 (315.3)	47.3 (210.4)
12 (300)	0.375 (9.5)	93.0 (413.7)	69.8 (310.3)	46.5 (206.8)
14 (350)	0.375 (9.5)	100.3 (446.2)	75.2 (334.7)	50.2 (223.3)

For SI: 1 kip = 4.448 kN.
[1] Capacities based on a design corrosion level of 50-years.

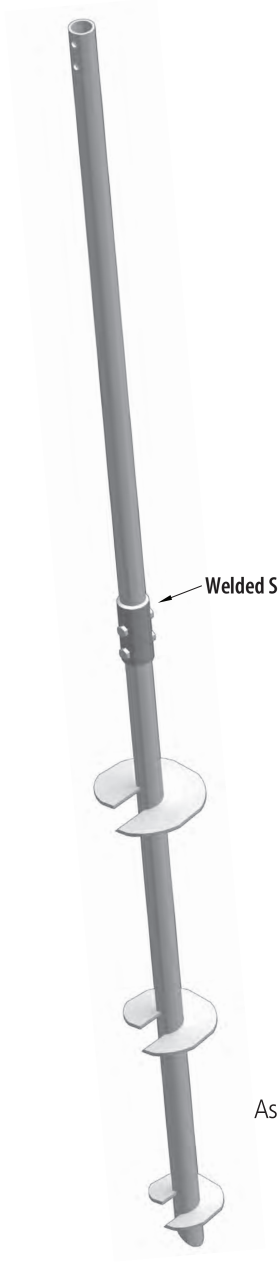
Nominal and LRFD Design Compression Strengths of CHANCE® Type RS2875.276 Helical Pile Lead & Extension Sections[1,2]

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)
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	Welded 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 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	8,900 ft-lb		12,067 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	97.9 kip	453.3 kN	73.4 kip	326.5 kN
Allowable Tension Strength	48.9 kip		217.5 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	80.1 kip	356.3 kN	40.05 kip	178.2 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS2875.276
Figure 6-22

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

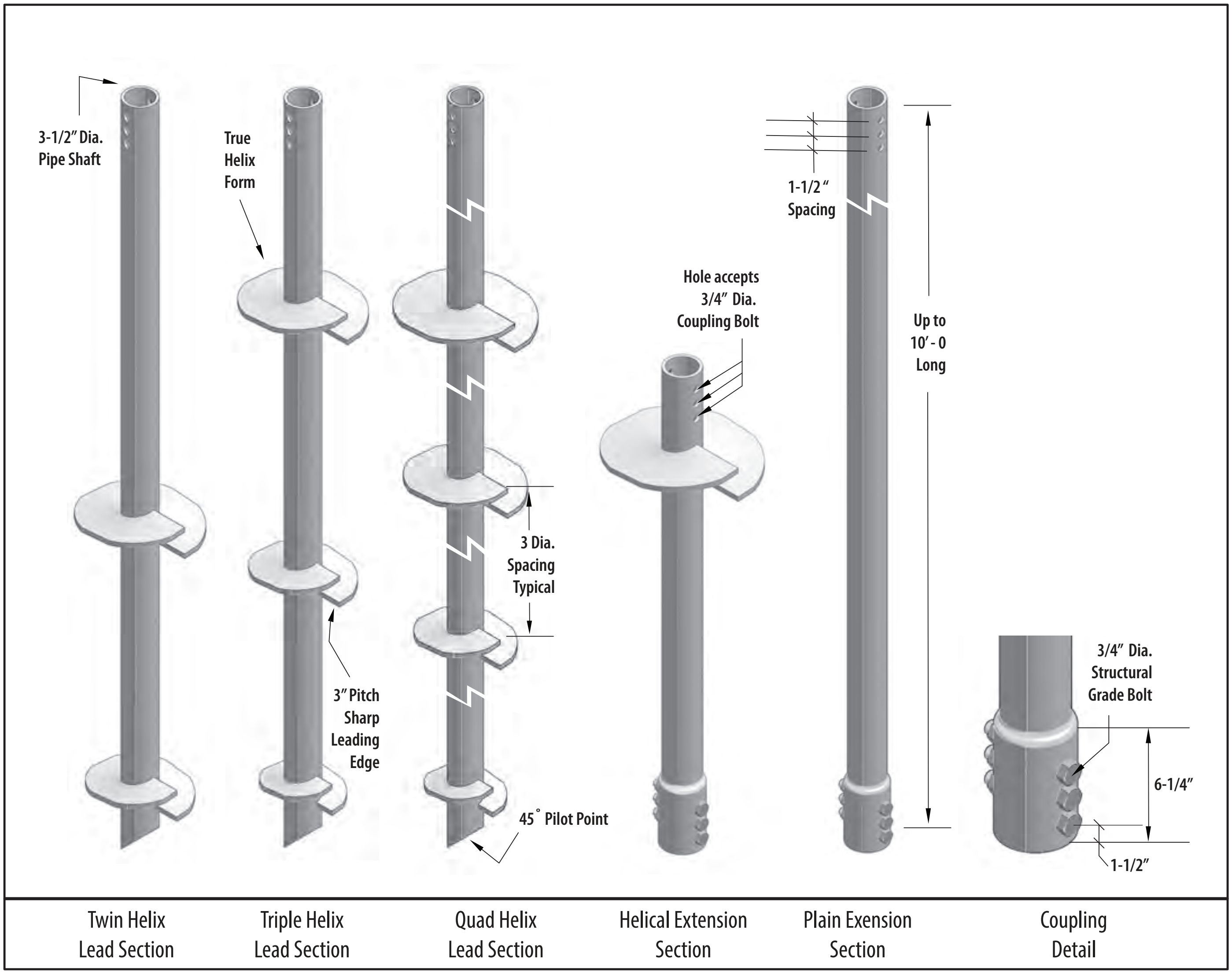
91 kip Ultimate – 45.5 kip Allowable Capacity

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:

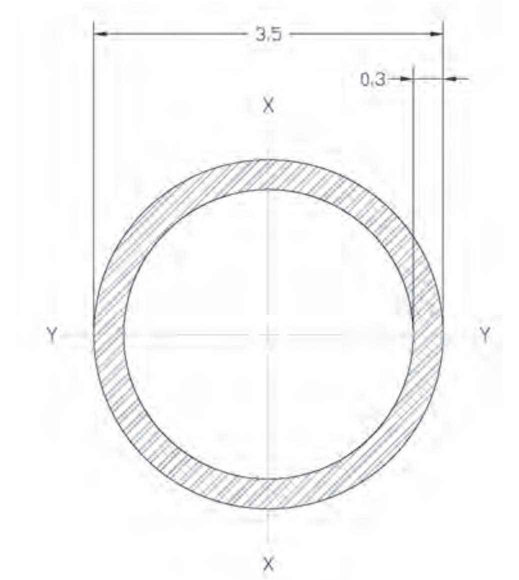
Hubbell Power Systems, Inc., CHANCE Type RS3500.300 Helical Piles have 91 kip ultimate capacity and 45.5 kip working or allowable capacity in compression or tension. This capacity is based on well documented correlations with installation torque, which is recognized as one method to determine capacity 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.



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.



CHANCE Type RS3500.300 Helical Pile Shaft Cross-Section
Figure 6-23

Nominal, LRFD Design and ASD Allowable Strengths of RS3500.300 Helix Plates for Shaft Axial Tension and Compression[1]

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)	118.7 (528.2)	79.1 (351.9)
10 (250)	0.5 (13)	132.5 (589.3)	99.4 (442)	66.3 (294.9)
12 (300)	0.5 (13)	98.4 (437.7)	73.8 (328.3)	49.2 (187.7)
14 (350)	0.5 (13)	132.3 (588.5)	99.2 (441.4)	66.2 (294.5)

For SI: 1 kip = 4.448 kN.
[1]Capacities based on a design corrosion level of 50-years.

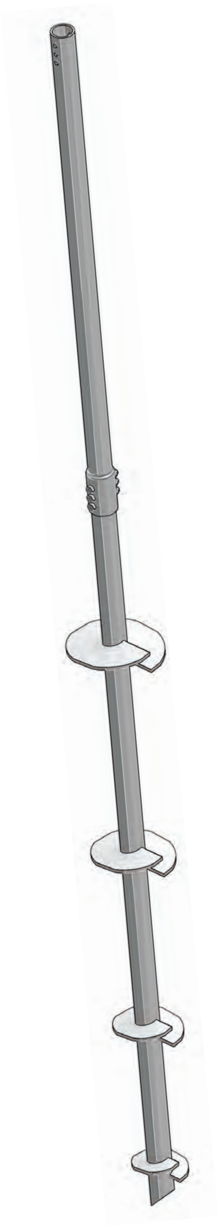
Nominal and LRFD Design Compression Strengths of CHANCE® Type RS3500.300 Helical Pile Lead & Extension Sections[1,2]

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

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS3500.300
Figure 6-24

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) See Helix Strength Table Above for 10”, 12” & 14”	For Single 8” – 73.0 (324.7) See Helix Strength Table Above for 10”, 12” & 14”	65.9 (293.1) For Single 12” – 49.2 (218.9)	54.3 (241.5) 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 RS3500.300 HELICAL PILES PER ICC-ES AC358 FOR BUILDING CODE EVALUATION

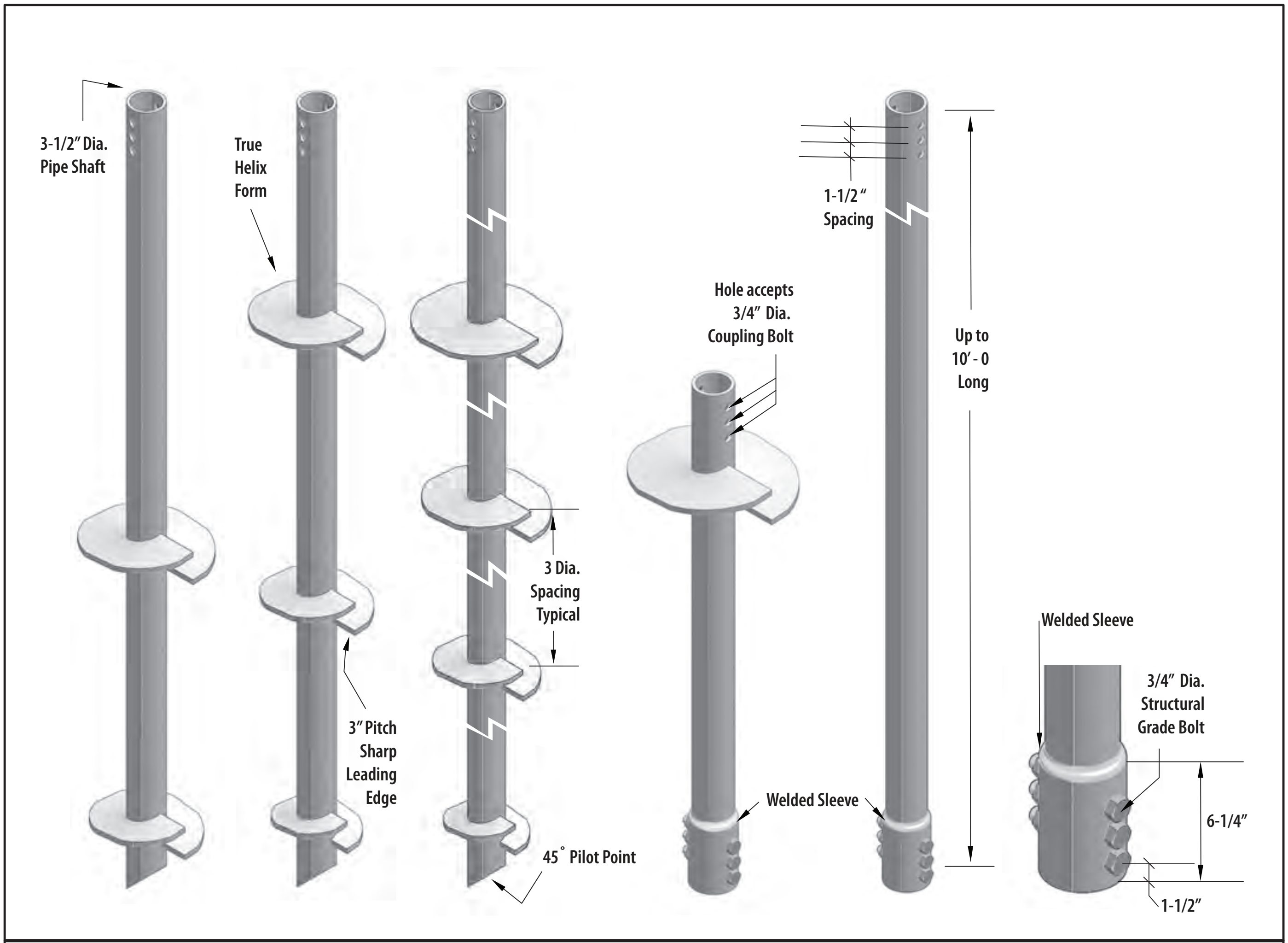
87.5 kip Ultimate – 43.75 kip Allowable Capacity

Installation Torque Rating – 12,500 ft-lb

Multi-Purpose 3-1/2" Diameter, 0.300" Wall, Round HSS Shaft with Welded Sleeve Coupling

Description:

Hubbell Power Systems, Inc., CHANCE Type RS3500.300 Helical Piles have 87.5 kip ultimate capacity and 43.75 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

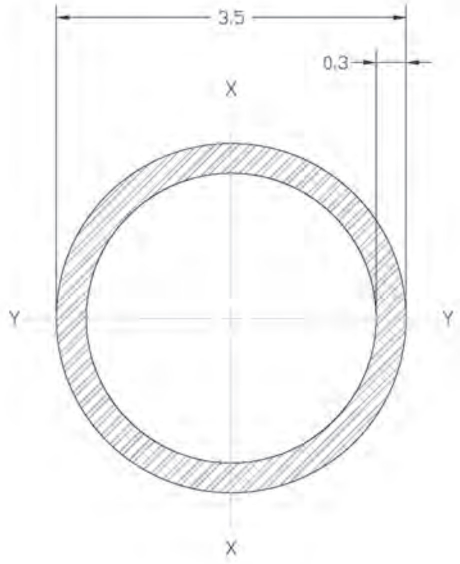


Twin Helix Lead Section	Triple Helix Lead Section	Quad Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

RS3500.300 Building Code 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 – Welded sleeve forming a socket 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, 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, 3-1/2 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.



CHANCE Type RS3500.300 Helical Pile Shaft Cross-Section
Figure 6-25

Nominal, LRFD Design and ASD Allowable Strengths of RS3500.300 Helix Plates for Shaft Axial Tension and Compression[1]

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)	141.1 (627.6)	105.8 (470.7)	70.6 (314.0)
10 (250)	0.5 (13)	155.1 (689.9)	116.3 (517.4)	77.6 (345.2)
12 (300)	0.5 (13)	159.6 (709.9)	119.7 (532.4)	79.8 (354.9)
14 (350)	0.5 (13)	139.4 (620.1)	104.6 (465.1)	69.7 (301.1)

For SI: 1 kip = 4.448 kN.
[1] Capacities based on a design corrosion level of 50-years.

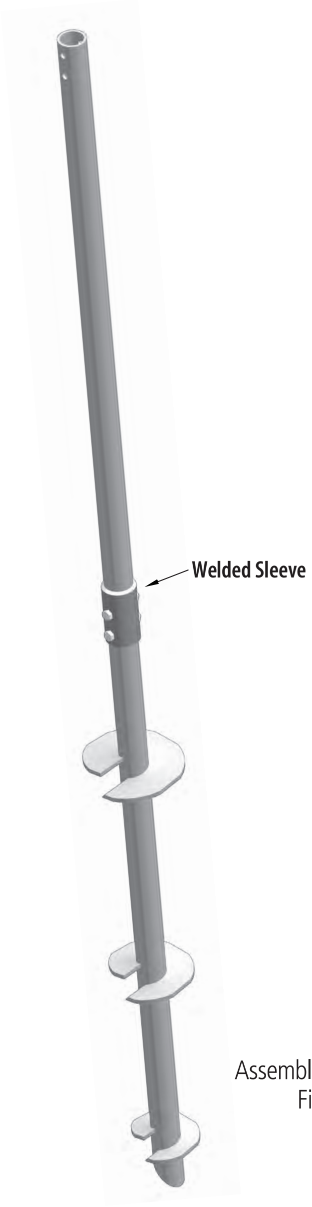
Nominal and LRFD Design Compression Strengths of CHANCE® Type RS3500.300 Helical Pile Lead & Extension Sections[1,2,3]

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	100 (444.8)	90 (400.3)	100 (444.8)	90 (400.3)	100 (444.8)	90 (400.3)	90.7 (403.5)	81.6 (363.0)
Lead, Multi-Helix	100 (444.8)	90 (400.3)	100 (444.8)	90 (400.3)	100 (444.8)	90 (400.3)	90.7 (403.5)	81.6 (363.0)
Extension	100 (444.8)	90 (400.3)	100 (444.8)	90 (400.3)	100 (444.8)	90 (400.3)		

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.
[3] Nominal strengths are limited to 100 kip (444.8 kN) per AC358 Section 3.8.

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	Welded Round Deep Socket			
Coupling Bolts	Two 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	12,500 ft-lb		16,947.7 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	100 kip	444.8 kN	86.1 kip	383.0 kN
Allowable Tension Strength	57.4 kip		255.3 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	87.5 kip	389.2 kN	43.75 kip	194.6 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS3500.300
Figure 6-26

ASD Allowable Compression Strengths of CHANCE® Type RS3500.300 Helical Pile Lead & Extension Sections[1,2,3]

Section Type & Helix Count	ASD Allowable Axial Compression Strength kips (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	60.0 (266.9)	60.0 (266.9)	60.0 (266.9)	54.3 (241.5)
Lead, 2-Helix 8”-10”	60.0 (266.9)	60.0 (266.9)	60.0 (266.9)	54.3 (241.5)
Lead, 2-Helix 10”-12”				
Lead, 2-Helix 12”-14”				
Lead, 2-Helix 14”-14”				
Lead, Multi-Helix	60.0 (266.9)	60.0 (266.9)	60.0 (266.9)	54.3 (241.5)
Extension	60.0 (266.9)	60.0 (266.9)	60.0 (266.9)	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.

[3] ASD allowable strengths are limited to 60 kip (266.9 kN) per AC358 Section 3.8.

CHANCE® TYPE RS4500.237 HELICAL PILES

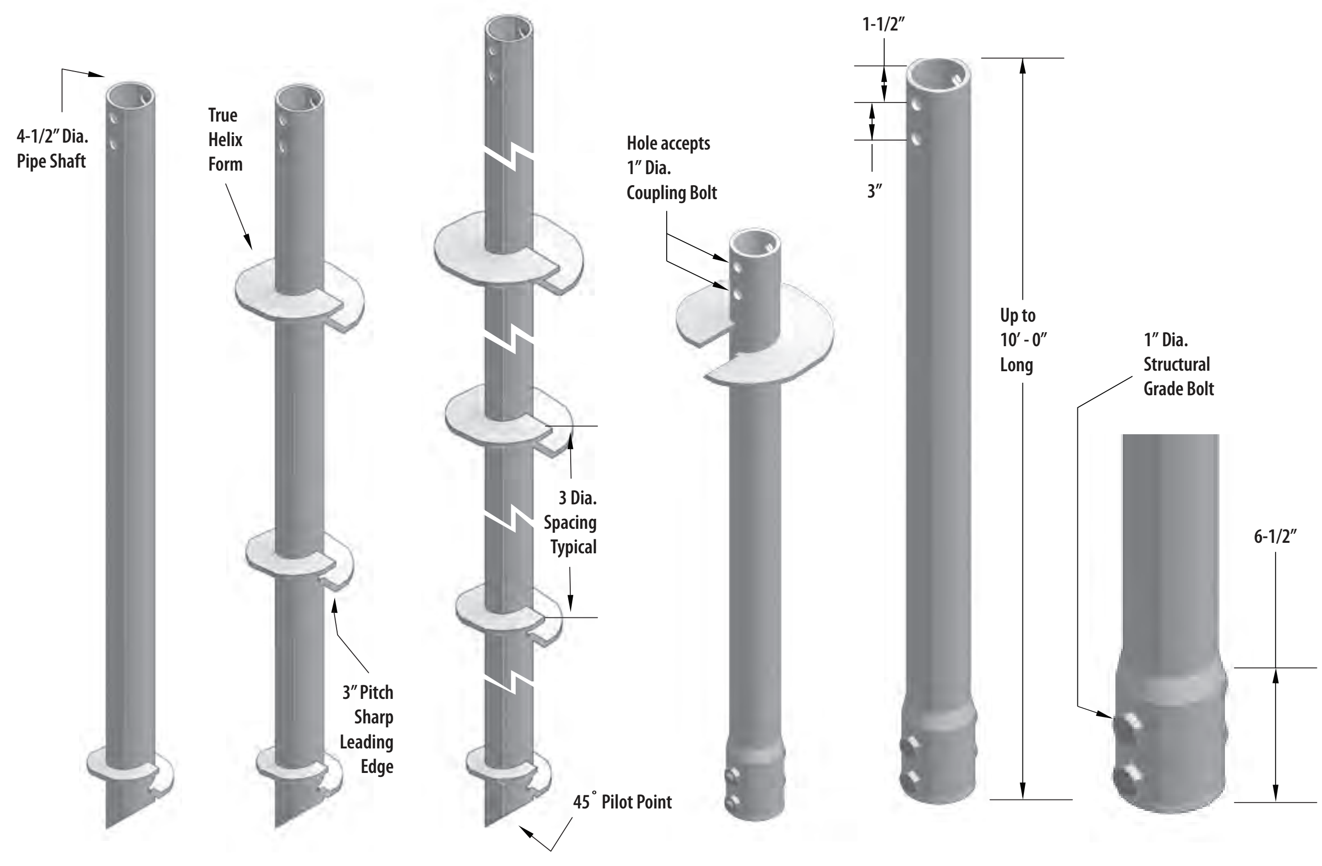
108 kip Ultimate – 54 kip Allowable Capacity

Installation Torque Rating – 18,000 ft-lb

Multi-Purpose 4-1/2” Diameter, 0.237” Wall, Round HSS Shaft with integrally formed upset sockets

Description:

Hubbell Power Systems, Inc., CHANCE Type RS4500.337 Helical Piles have 108 kip ultimate capacity and 54 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.

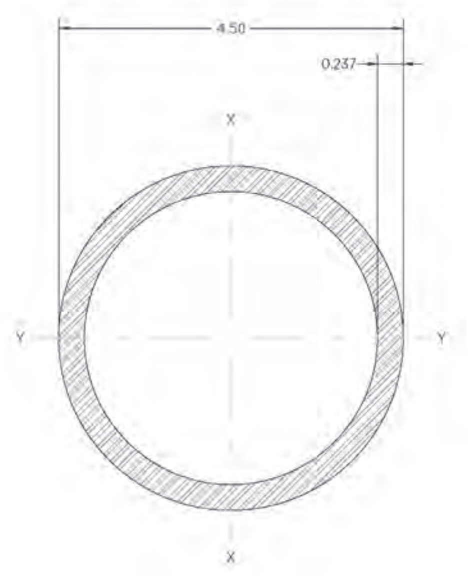


Single Helix Lead Section	Triple Helix Lead Section	Quad Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

RS4500.237 Helical Pile Specifications & Available Configurations

Shaft – HSS 4-1/2 inch OD x 0.237 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 – 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.



CHANCE Type RS4500.337 Helical Pile Shaft Cross-Section
Figure 6-27

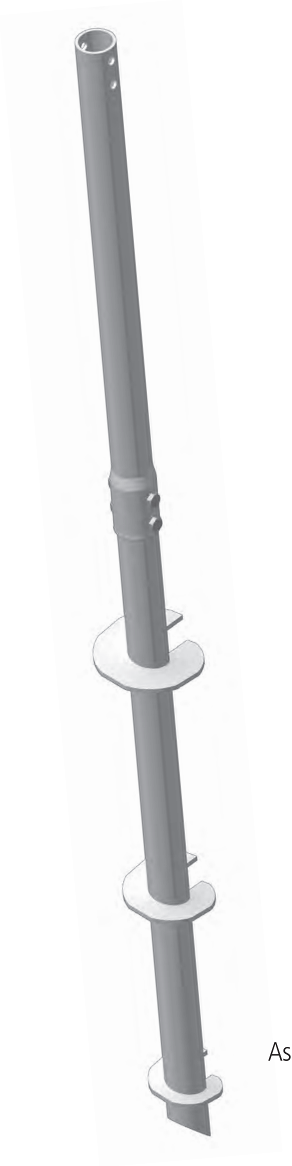
Nominal, LRFD Design and ASD Allowable Strengths of RS4500.237 Helix Plates for Shaft Axial Tension and Compression[1]

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)	183.4 (815.7)	122.3 (499.5)
10 (250)	0.5 (13)	200.3 (891.0)	150.2 (608.3)	100.2 (445.7)
12 (300)	0.5 (13)	168.5 (749.5)	126.4 (562.1)	84.3 (375.0)
14 (350)	0.5 (13)	133.0 (591.6)	99.8 (443.7)	66.5 (295.8)

For SI: 1 kip = 4.448 kN.
[1] Capacities based on a design corrosion level of 50-years.

RS4500.237 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled HSS 4 inch Nominal Schedule 40 (0.237 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*	4.059 in	103.4 mm	Corroded	
			4.071 in	103.4 mm
Moment of Inertia (I)*	6.79 in^4	282.6 cm^4	Corroded	
			6.415 in^4	267.9 cm^4
Shaft Area (A)*	2.96 in^2	19.1 cm^2	Corroded	
			2.786 in^2	18.09 cm^2
Section Modulus (S_{x-x})*	3.02 in^3	49.6 cm^3	Corroded	
			2.859 in^3	47.0 cm^3
Perimeter	14.1 in	35.9 cm	Corroded	
			14.09 in	35.8 cm
Coupling	Integral Forged Round Deep Socket Sleeve			
Coupling Bolts	Two 1 in Dia. ASTM A193 Grade B7 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	18,000 ft-lb		31,200 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	120 kip	712 kN	90 kip	534 kN
Allowable Tension Strength	60 kip		356 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	108 kip	614 kN	54 kip	307 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS4500.337
Figure 6-28

CHANCE® TYPE RS4500.337 HELICAL PILES

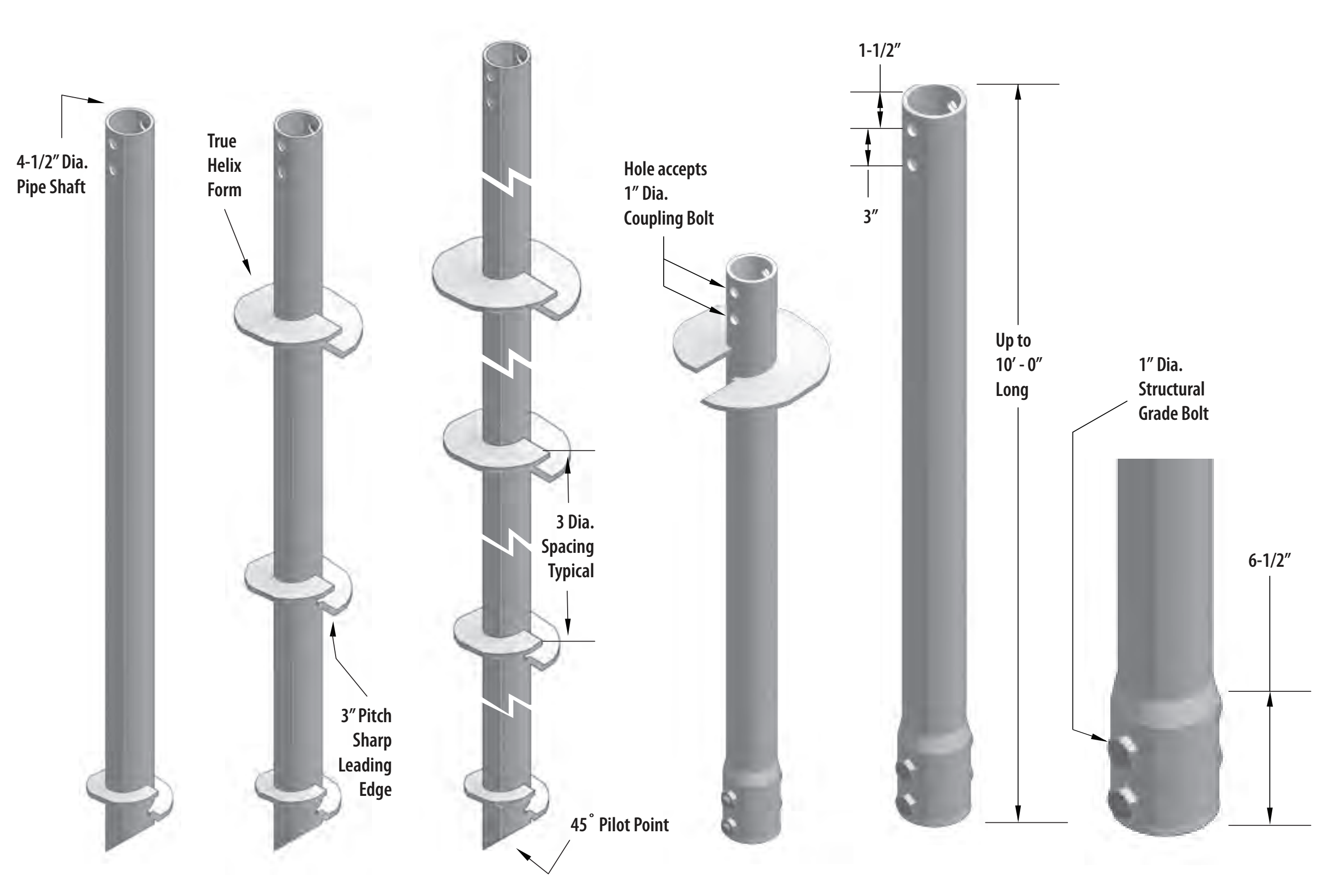
150 kip Ultimate – 75 kip Allowable Capacity

Installation Torque Rating – 25,000 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 150 kip ultimate capacity and 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.

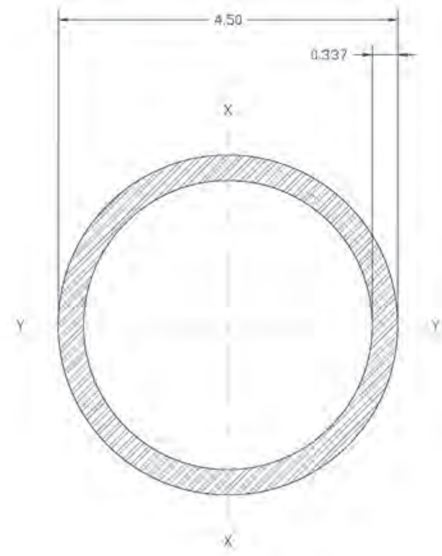


Single Helix Lead Section | Triple Helix Lead Section | Quad Helix Lead Section | Helical Extension Section | Plain Exension Section | Coupling Detail

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 – forged as an integral part of the plain and helical extension material as round deep pockets 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.



CHANCE Type RS4500.337 Helical Pile Shaft Cross-Section
Figure 6-29

Nominal, LRFD Design and ASD Allowable Strengths of RS4500.337 Helix Plates for Shaft Axial Tension and Compression[1]

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)	183.4 (815.7)	122.3 (499.5)
10 (250)	0.5 (13)	200.3 (891.0)	150.2 (668.3)	100.2 (445.7)
12 (300)	0.5 (13)	168.5 (749.5)	126.4 (562.1)	84.3 (375.0)
14 (350)	0.5 (13)	133.0 (591.6)	99.75 (443.7)	66.5 (295.8)

For SI: 1 kip = 4.448 kN.
[1]Capacities 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)
	For Nominal, see Helix Strength Table above for Single 12" & 14" For LRFD design, see Helix Strength Table above for 10", 12" & 14"						For Single 14" – 133.0 (591.6)	For Single 12" & 14" see Helix Table
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.

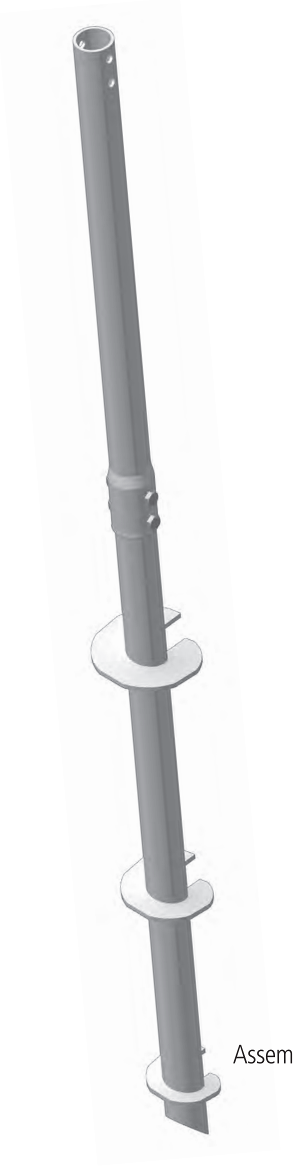
RS4500.337 HELICAL PILE AND ANCHOR PRODUCT SPECIFICATIONS				
SHAFT	Hot Rolled HSS 4 inch Nominal Schedule 80 (0.337 inch nominal wall) per ASTM A500 Grade B/C with 50 ksi minimum yield strength			
Shaft Size, OD	4.5 in	114 mm	Corroded	
			4.487 in	114 mm
Shaft Size, ID*	3.874 in	98.4 mm	Corroded	
			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 ($S_{x\text{-}x}$)*	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	Integral Forged Round Deep Socket Sleeve			
Coupling Bolts	Two 1 in Dia. ASTM A193 Grade B7 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	25,000 ft-lb	33,900 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	
	150 kip	667 kN	75 kip	334 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2



Assembly of RS4500.337
Figure 6-30

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"				
Lead, Multi-Helix	114.8 (551.7)	111.6 (496.4)	105.0 (467.1)	93.6 (416.4)
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 RS4500.337 HELICAL PILES PER ICC-ES AC358 FOR BUILDING CODE EVALUATION

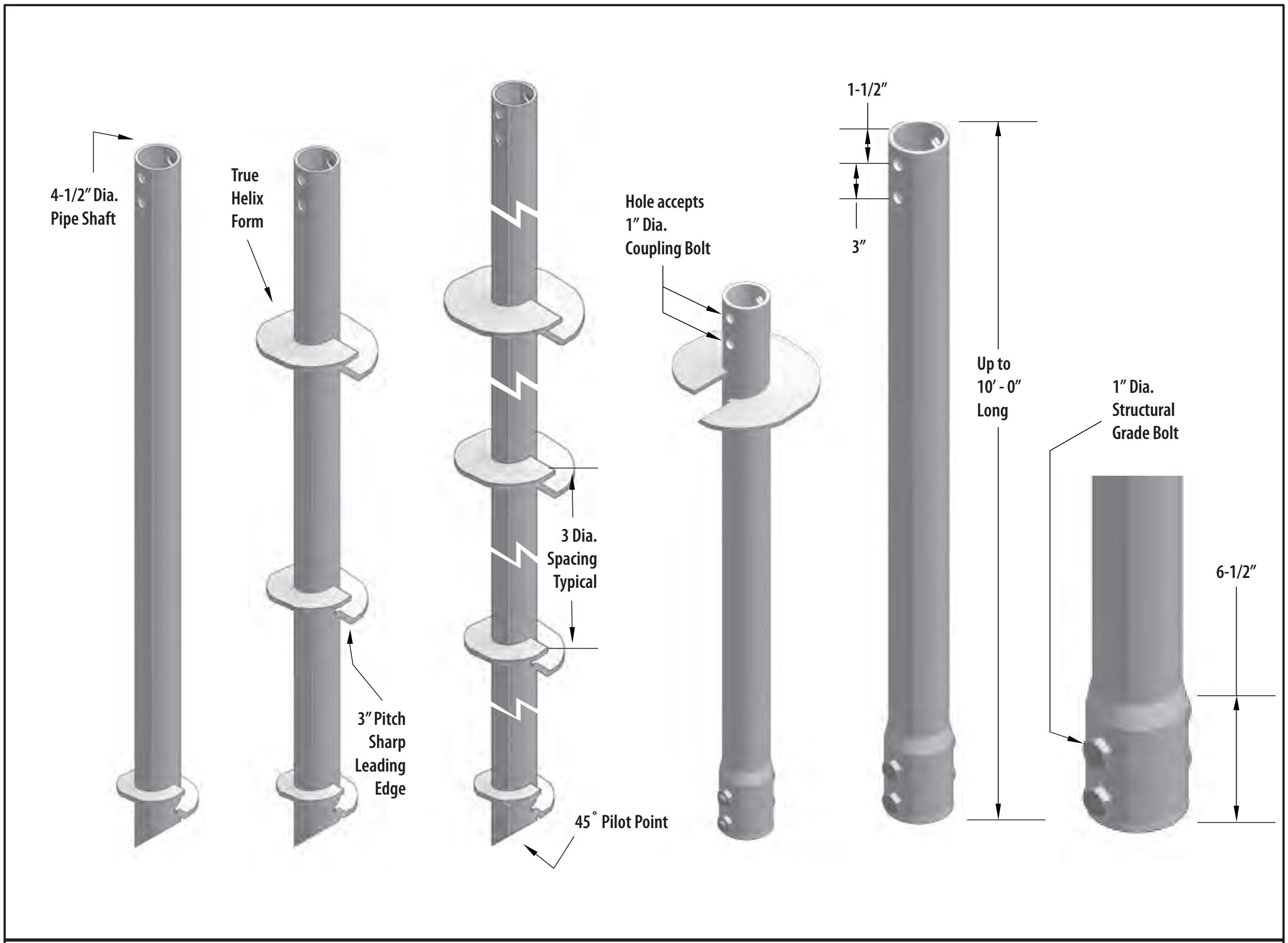
136.1 kip Ultimate – 68.1 kip Allowable Capacity

Installation Torque Rating – 24,300 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 136.1 kip ultimate capacity and 68.1 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

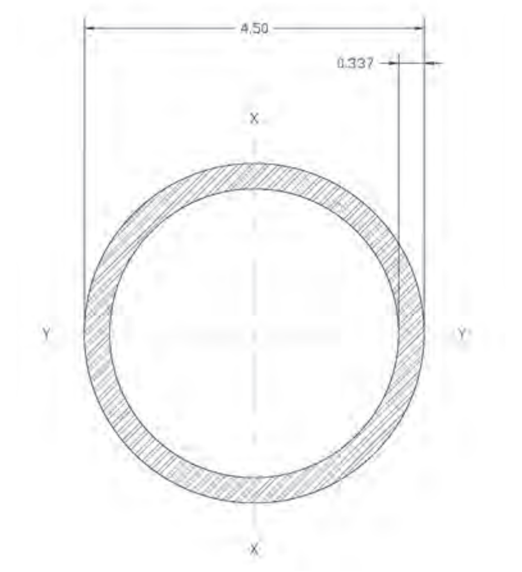


Single Helix Lead Section	Triple Helix Lead Section	Quad Helix Lead Section	Helical Extension Section	Plain Exension Section	Coupling Detail

RS4500.337 Building Code 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 – 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 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.



CHANCE Type RS4500.337 Helical Pile Shaft Cross-Section
Figure 6-31

Nominal, LRFD Design and ASD Allowable Strengths of RS4500.337 Helix Plates for Shaft Axial Tension and Compression[1]

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)	180.2 (801.6)	135.2 (601.4)	90.2 (401.2)
10 (250)	0.5 (13)	180.2 (801.6)	135.2 (601.4)	90.2 (401.2)
12 (300)	0.5 (13)	180.2 (801.6)	135.2 (601.4)	90.2 (401.2)
14 (350)	0.5 (13)	180.2 (801.6)	135.2 (601.4)	90.2 (401.2)

For SI: 1 kip = 4.448 kN.
[1]Capacities based on a design corrosion level of 50-years.

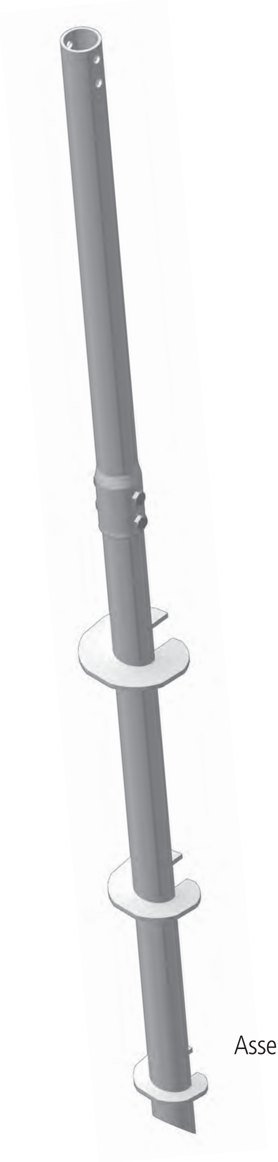
Nominal and LRFD Design Compression Strengths of CHANCE® Type RS4500.337 Helical Pile Lead & Extension Sections[1,2,3]

Section Type & Helix Count	Nominal & LRFD Design Compression Strengths kips (kN)							
	Firm Soil				Soft Soil			
	Fixed		Pinned		Fixed		Pinned	
	Nominal	Design[3]	Nominal	Design[3]	Nominal	Design[3]	Nominal	Design
Lead, Single Helix	See Helix Strength Table Above				175.3 (779.8)		156.3 (695.3)	
Lead, Multi-Helix	191.7 (852.7)	145.33 (646.5)	186.3 (828.7)	145.33 (646.57)	175.3 (779.8)	145.33 (646.57)	156.3 (695.3)	140.67 (625.7)
Extension								

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.
[3] Limited by Coupling Bolt Shear

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	Integral Forged Round Deep Socket Sleeve			
Coupling Bolts	Two 1 in Dia. ASTM A193 Grade B7 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†	5.6 ft^{-1}		18.5 m^{-1}	
Torque Rating	24,300 ft-lb		32,946 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	150 kip	667.2 kN	112.5 kip	500.2 kN
Allowable Tension Strength	75 kip		333.6 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	136.1 kip	605.4 kN	68.1 kip	302.9 kN

* computed with 93% of wall thickness per AISC 360-10, B4.2
† per ICC-ES AC358 Section 3.13.1.1



Assembly of RS4500.337
Figure 6-32

ASD Allowable Compression Strengths of CHANCE® Type RS4500.337 Helical Pile Lead & Extension Sections[1,2,3]

Section Type & Helix Count	ASD Allowable Axial Compression Strength kips (kN)			
	Firm Soil		Soft Soil	
	Fixed	Pinned	Fixed	Pinned
Lead, Single Helix	See Helix Strength Table Above for 8”, 10”, 12” & 14”	See Helix Strength Table Above for 8”,10”, 12” & 14”	See Helix Strength Table Above for 8”, 10”, 12” & 14”	See Helix Strength Table Above for 8”, 10”, 12” & 14”
Lead, 2-Helix 8”-10”	96.9 (431)	96.9 (431)	96.9 (431)	93.6 (416.4)
Lead, 2-Helix 10”-12”				
Lead, 2-Helix 12”-14”				
Lead, 2-Helix 14”-14”				
Lead, Multi-Helix	96.9 (431)	96.9 (431)	96.9 (431)	93.6 (416.4)
Extension	96.9 (431)	96.9 (431)	96.9 (431)	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.

[3] Limited by Bolt Shear

CHANCE® TYPE RS6625.280 HELICAL PILES

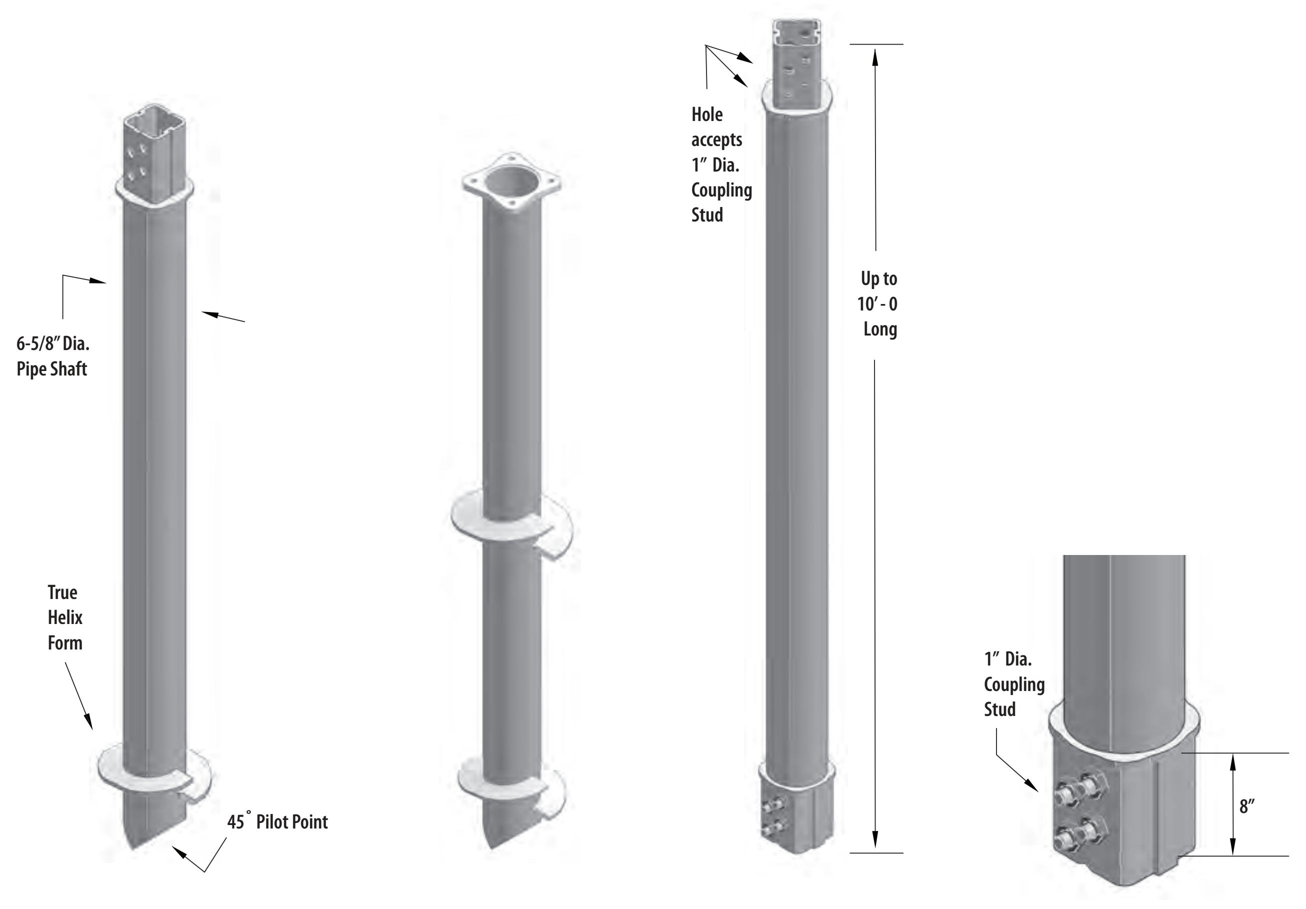
200 kip Ultimate – 100 kip Allowable Capacity

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.

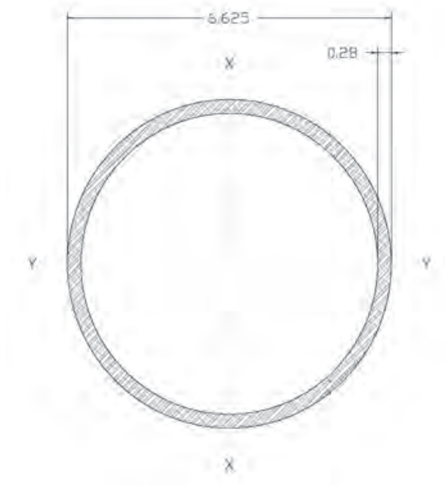


Single Helix Lead Section	Twin Helix Lead Section w/ Plate Coupling	Plain Exension Section	Coupling Detail

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.

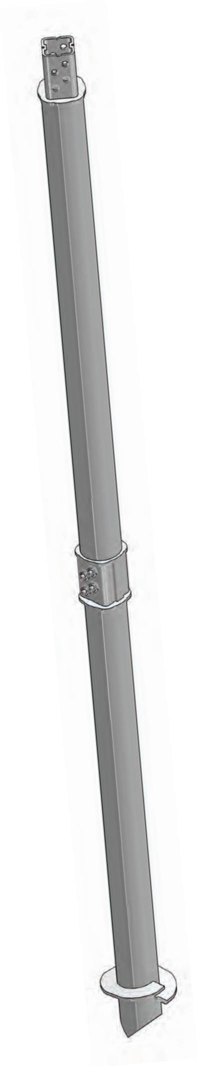
NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum 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.



CHANCE Type RS6625.280
Helical Pile Shaft Cross-Section
Figure 6-33

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 6-34

CHANCE® TYPE RS8625.250 HELICAL PILES

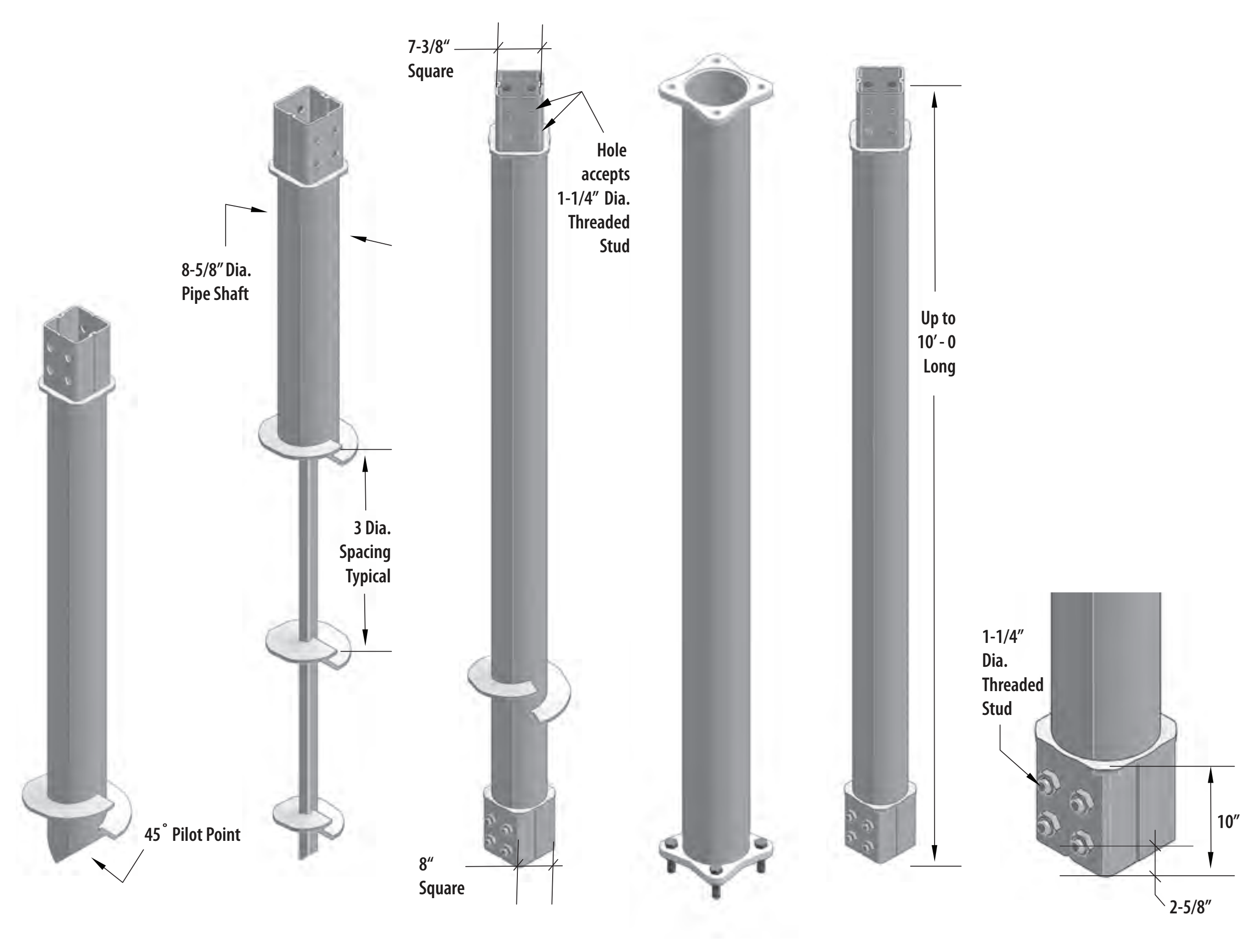
300 kip Ultimate – 150 kip Allowable Capacity

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.

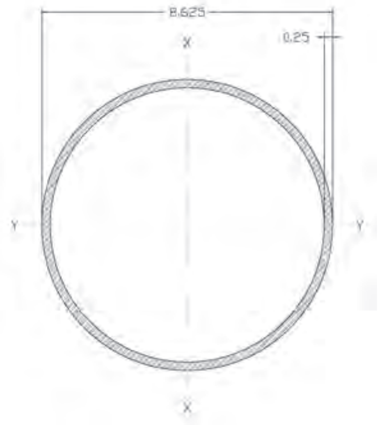


Single Helix Lead Section	Triple Helix Lead Section	Helical Extension Section	Plate Coupling Detail Section	Plain Exension Section	Coupling Detail

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 – ½, 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.

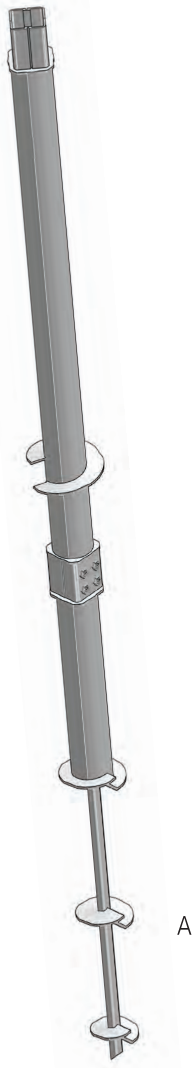
NOTE: Helical piles shall be installed to appropriate depth in suitable bearing stratum as determined by the geotechnical engineer or local jurisdictional authority. Torque correlated capacities are based on installing the pile to its torque rating, using consistent rate of advance and RPM. A minimum 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.



CHANCE Type RS8625.250
Helical Pile Shaft Cross-Section
Figure 6-35

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



Assembly of RS8625.250
Figure 6-36

CHANCE® ROCK-IT™ HELICAL LEAD

Description:

The ROCK-IT™ Lead Section is an innovative solution to penetrate rocky or high blow count soils without pre-drilling or field modification. The single carbide, patent pending design was developed after site testing of several rock anchor configurations to provide an economical, yet proven solution to reach load-bearing depths in high blow count material.

Key Benefits:

- Wear resistant, offset carbide tip designed to break through rocky soil
- Reduced installation time to save time and money
- Reduced spiking of torque and chatter during installation for better pile performance and a safer alternative

Figure 6-37

CATALOG NO.	ANCHOR FAMILY	DESCRIPTION*
C1101290	SS5 or SS150	Square Shaft Anchor, SS5 or SS150, 6/8 x 3 ft. ROCK-IT
C1101291	SS5 or SS150	Square Shaft Anchor, SS5 or SS150, 8/10 x 3 ft. ROCK-IT
C1101292	SS5 or SS150	Square Shaft Anchor, SS5 or SS150, 8/10 x 5 ft. ROCK-IT
C1101293	SS175	Square Shaft Anchor, SS175, 8/10/12 x 5 ft. ROCK-IT
C1101294	SS175	Square Shaft Anchor, SS175, 8/10 x 5 ft. ROCK-IT
C1101295	SS175	Square Shaft Anchor, SS175, 6/8 x 3 ft. ROCK-IT
C1101296	SS175	Square Shaft Anchor, SS175, 8/10 x 3 ft. ROCK-IT
C1101297	SS200	Square Shaft Anchor, SS200, 8/10/12 x 7 ft. ROCK-IT
C1101298	SS225	Square Shaft Anchor, SS225, 8/10/12 x 7 ft. ROCK-IT

*See helical pile and anchor specifications of the product family for torque rating, helix strengths and pile capacities.

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 6-38) 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 6-5 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.

Pile Assembly with
Transition Coupler
Figure 6-38

TABLE 6-5: TRANSITION COUPLERS

CATALOG NUMBER	DESCRIPTION	TORQUE RATINGS	KT			
			SAND		CLAY	
			< 30′	≥ 30′	< 30′	≥ 30′
C1071639	SS5/SS150 SQUARE SHAFT TO RS2875.203 ROUND SHAFT	5,500 ft-lbs	10	9.5	9.5	9.5
C1071639	SS150 SQUARE SHAFT TO RS2875.276 ROUND SHAFT	7,000 ft-lbs	10	9.5	9.5	9.5
C1072501	SS175 SQUARE SHAFT TO RS2875.276 ROUND SHAFT	8,000 ft-lbs	10	9.5	9.5	9.5
C1071515	SS175 SQUARE SHAFT TO RS3500.300 ROUND SHAFT	10,500 ft-lbs	9.5	9	9	8.5
C1072502	SS200 SQUARE SHAFT TO RS3500.300 ROUND SHAFT	13,000 ft-lbs	9.5	8.5	9	8

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 6-39) or grout in combination with either steel or PVC casing (see Figure 6-40). 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.

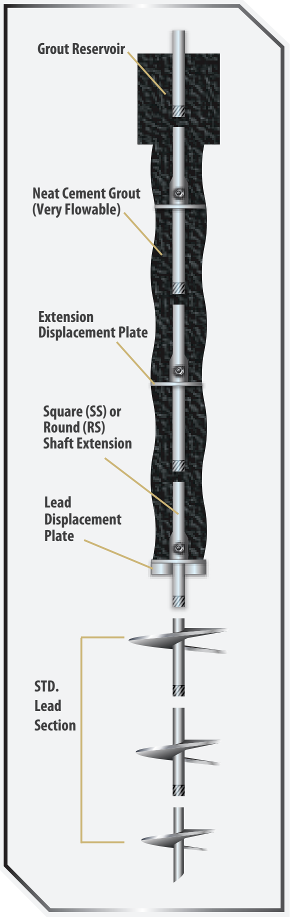


Figure 6-39

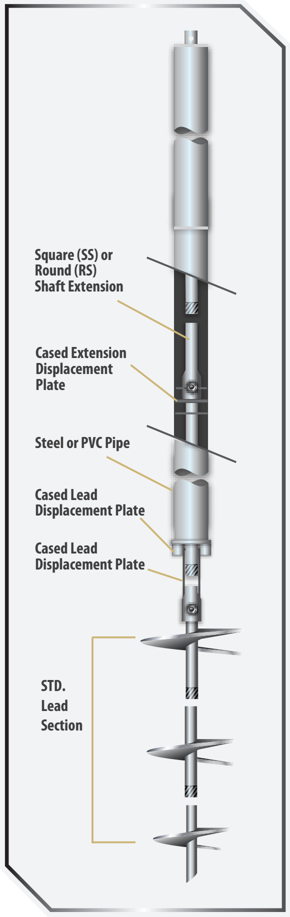


Figure 6-40

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.

TABLE 6-6: 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, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type SS5 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	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, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type SS150 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	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, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type SS175 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	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, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type SS200 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	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)

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)

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)

CHANCE® DRIVECAST™ SCREW DISPLACEMENT PILES

The CHANCE Drivecast screw displacement pile utilizes soil displacement methodology which allows the pile to be advanced into the soil by rotation. Pile sections are comprised of a centralized steel shaft and a patented displacement assembly placed at regular intervals from the pile tip. By design, the pile establishes a cylindrical void which allows a column of grout to be immediately pulled down from a gravity-fed reservoir, creating a grouted, high capacity pile.

Drivecast piles are made from structural steel meeting the requirements of ASTM A500, A572, A656, and A1018. The displacement paddle extends from the perimeter of the central shaft to the outer edge of the lower helix. Depth requirements are achieved by adding 5’ or 10’ extension sections via couplings and structural grade bolts.

DISPLACEMENT PLATES FOR CASED GROUT COLUMNS

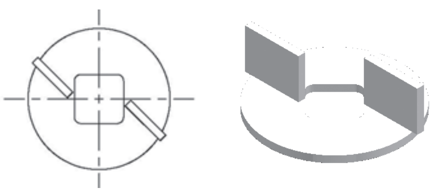
Lead Displacement Plates

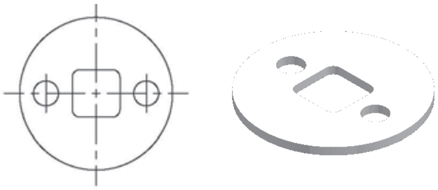
Catalog Number	Plate Dia (in)	Casing Dia (in)	Product Series
T1100911	5	4	SS5/SS150
C1100912	7	6	SS175

Extension Displacement Plates

Catalog Number	Plate Dia (in)	Casing Dia (in)	Product Series
T1100913	5	4	SS5/SS150
C1100914	7	6	SS175

DISPLACEMENT PLATES FOR UNCASED GROUT COLUMNS





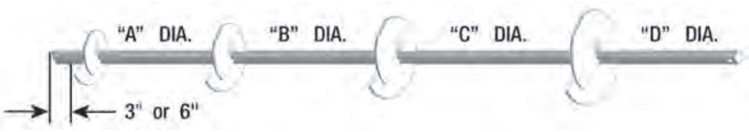
Lead Displacement Plates

Catalog Number	Plate Dia (in)	Product Series
T1100915	5	SS5/SS150
C1100916	5	SS175

Lead Displacement Plates

Catalog Number	Plate Dia (in)	Product Series
T1100917	5	SS5/SS150
C1100918	5	SS175

COMMON LEAD CONFIGURATIONS



CHANCE Helical Round-Cornered Square Shaft Leads used with HELICAL PULLDOWN® Micropile (1)

Type	Catalog Number	Helix Plate Diameter (in)				Nominal Length (ft)	Effective Length (ft)	Weight	Helix Grade
		A	B	C	D				
SS5	C1100921	8	10	12	-	7	76.2	79	50
SS175	C1100922	8	10	12	-	7	76.2	100	50

Figure 6-41

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(1) HELICAL PULLDOWN® Micropiles use Standard Exten-

HIGH COMPRESSION STRENGTH WITH DRIVECAST™ PILES IN SOFT SOIL

The following tables provide the nominal, LRFD design, and ASD allowable compression strengths of Drivecast piles with various diameter grout shafts in soft soils. The strengths listed are based on an unsupported length of 10 feet (3 meters) with either a fixed or pinned end condition at the pile head. The grout column diameters listed reflect the results in various soil conditions. In clay, the grout column is generally close to the diameter of the small plate on the displacement assembly. In sand, the grout column ranges between the small and large diameter plates on the displacement assembly. In loose sand fill, the grout column can exceed the diameter of the large plate on the displacement assembly. Each table includes the compression strengths of shafts without external grout for comparison.

Per the International Building Code(IBC) 2015 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 ground surface.

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type SS175 Central Shafts 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	25.8 (155.6)	23.2 (103.9)	15.4 (69.0)	50.5 (226.3)	45.4 (203.4)	30.2 (135.3)
8” OD	217.4 (974.4)	163.1 (731.0)	108.7 (487.2)	316.5 (1418.6)	237.3 (1063.6)	158.2 (709.0)
9” OD	280.6 (1257.7)	210.5 (943.5)	140.3 (628.8)	381.2 (1708.6)	285.9 (1281.4)	190.6 (854.3)
10” OD	350.2 (1569.6)	262.7 (1177.4)	175.1 (784.8)	451.4 (2023.2)	338.5 (1517.2)	225.7 (1011.6)
11” OD	426.0 (1909.4)	319.5 (1432.0)	213.0 (954.7)	527.1 (2362.5)	395.3 (1771.8)	263.6 (1181.5)
12” OD	507.9 (2276.5)	380.9 (1707.2)	253.9 (1138.0)	608.6 (2727.8)	456.5 (2046.1)	304.3 (1363.9)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type SS200 Central Shafts 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	43.7 (195.8)	39.3 (176.1)	26.2 (117.4)	85.6 (383.6)	77.1 (345.5)	51.3 (229.9)
8” OD	262.2 (1175.2)	196.6 (881.2)	131.1 (587.6)	374.8 (1679.9)	281.1 (1259.9)	187.4 (839.9)
9” OD	328.8 (1473.7)	246.6 (1105.3)	164.4 (736.8)	441.6 (1979.3)	331.2 (1484.5)	220.8 (989.6)
10” OD	401.4 (1799.1)	301.1 (1349.5)	200.7 (899.5)	513.6 (2302.0)	385.2 (1726.5)	256.8 (1151.0)
11” OD	479.8 (2150.5)	359.9 (1613.1)	239.9 (1075.2)	590.9 (2648.5)	443.2 (1986.5)	295.5 (1324.4)
12” OD	564.0 (2527.9)	423.0 (1895.9)	282.0 (1263.9)	673.8 (3020.1)	505.3 (2264.8)	336.9 (1510.0)
13” OD	654.1 (2931.8)	490.5 (2198.5)	327.0 (1465.6)	762.3 (3416.7)	571.8 (2562.9)	381.2 (1708.6
14” OD	749.9 (3361.2)	562.5 (2521.2)	375.0 (1680.8)	856.8 (3840.3)	642.6 (2880.2)	428.4 (1920.1)
15” OD	851.8 (3817.9)	638.8 (2863.2)	425.9 (1908.9)	957.3 (4290.8)	718.0 (3218.2)	478.7 (2145.6)
16” OD	959.7 (4301.5)	719.7 (3225.8)	479.8 (2150.5)	1063.9 (4768.6)	798.0 (3576.8)	532.0 (2384.5)

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.

[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)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type RS3500.300 Central Shafts 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	90.66 (403.3)	81.59 (362.9)	54.28 (241.4)	110.01 (489.3)	99.01 (440.4)	65.88 (293.0)
Grout Inside	104.27 (463.8)	78.20 (347.9)	52.14 (231.9)	131.39 (584.5)	98.55 (438.4)	65.70 (292.2)
8” OD	227.20 (1010.6)	170.40 (758.0)	113.60 (505.3)	275.51 (1225.5)	206.63 (919.1)	137.75 (612.7)
9” OD	273.01 (1214.4)	207.76 (924.2)	136.50 (607.2)	326.56 (1452.6)	244.92 (1089.5)	163.28 (726.3)
10” OD	326.90 (1454.1)	245.18 (1090.6)	163.45 (727.1)	385.18 (1713.4)	288.88 (1285.0)	192.59 (856.7)
11” OD	388.90 (1729.9)	291.68 (1297.5)	194.45 (865.0)	451.33 (2007.6)	338.50 (1505.7)	225.67 (1003.8)
12” OD	458.90 (2041.3)	344.17 (1530.9)	229.45 (1020.6)	524.92 (2335.0)	393.69 (1751.2)	262.46 (1167.5)
13” OD	536.72 (2387.4)	402.54 (1790.6)	268.36 (1193.7)	605.82 (2694.8)	454.36 (2021.1)	302.91 (1347.4)
14” OD	622.20 (2767.7)	466.65 (2075.8)	311.10 (1383.8)	693.90 (3086.6)	520.43 (2315.0)	346.95 (1543.3)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type RS4500.337 Central Shafts 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	156.30 (700.5)	140.67 (630.5)	93.59 (419.4)	175.30 (785.7)	157.77 (707.1)	104.97 (470.4)
Grout Inside	190.46 (853.6)	142.84 (640.2)	95.23 (426.8)	219.25 (982.7)	164.44 (737.0)	109.63 (491.3)
8” OD	302.24 (1354.7)	226.68 (1016.0)	151.12 (677.3)	344.32 (1543.3)	258.24 (1157.4)	172.16 (771.6)
9” OD	347.89 (1559.3)	260.92 (1169.4)	173.94 (779.6)	395.11 (1770.9)	296.33 (1328.2)	197.56 (885.5)
10” OD	440.88 (1976.1)	300.66 (1347.6)	200.44 (898.4)	453.02 (2030.5)	339.76 (1522.8)	226.51 (1015.2)
11” OD	461.50 (2068.5)	346.12 (1551.3)	230.75 (1034.2)	518.18 (2322.5)	388.64 (1741.9)	259.09 (1161.2)
12” OD	529.87 (2374.9)	397.41 (1781.2)	264.94 (1187.5)	590.67 (2647.5)	443.00 (1985.6)	295.33 (1323.7)
13” OD	606.03 (2965.76)	454.53 (2021.85)	303.02 (1347.9)	670.46 (2982.36)	502.85 (2236.79)	335.23 (1491.18)
14” OD	689.92 (3068.92)	517.44 (2301.69)	344.96 (1534.46)	757.52 (3369.62)	568.14 (2527.21)	378.76 (1684.81)
15” OD	781.42 (3475.93)	586.06 (2606.93)	390.71 (1737.97)	851.77 (3788.86)	638.83 (2841.66)	425.88 (1894.41)
16” OD	880.42 (3916.30)	660.32 (2947.25)	440.21 (1958.15)	953.14 (4239.78)	714.85 (3179.81)	476.57 (2119.89)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type RS8625.250 Central Shafts 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	272.91	245.62	163.42	280.85	252.76	168.17
Grout Inside	490.33	367.75	245.17	513.39	385.04	256.69
12” OD	674.76	506.07	337.38	708.49	531.37	354.24
13” OD	749.04	561.78	374.52	787.13	590.35	393.56
14” OD	830.02	622.52	415.01	872.47	654.35	436.23
15” OD	917.93	688.45	458.97	964.63	723.47	482.31
16” OD	1012.92	759.69	506.46	1063.69	797.76	531.84
17” OD	1115.13	836.34	557.56	1169.72	877.29	584.86
18” OD	1224.62	918.46	612.31	1282.76	962.07	641.38
19” OD	1341.44	1006.08	670.72	1402.82	1052.12	701.41
20” OD	1465.58	1099.19	732.79	1529.92	1147.44	764.96
21” OD	1597.04	1197.78	798.52	1664.02	1248.02	832.01
22” OD	1735.76	1301.82	867.88	1805.12	1353.84	902.56

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)

HIGH COMPRESSION STRENGTH WITH DRIVECAST™ PILES IN FIRM SOILS

The following tables provide the nominal, LRFD design, and ASD allowable compression strengths of Drivecast piles with various diameter grout shafts in firm soils. The strengths listed are based on an unsupported length of 5 feet (3 meters) with either a fixed or pinned end condition at the pile head. The grout column diameters listed reflect the results in various soil conditions. In clay, the grout column is generally close to the diameter of the small plate on the displacement assembly. In sand, the grout column ranges between the small and large diameter plates on the displacement assembly. In loose sand fill, the grout column can exceed the diameter of the large plate on the displacement assembly. Each table includes the compression strengths of shafts without external grout for comparison.

Per the International Building Code (IBC) 2015 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 ground surface.

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type SS175 Central Shafts in Firm Soil[1,2,3]

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Firm Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	103.02 (461.7)	92.82 (416.0)	61.69 (276.5)	164.26 (736.2)	147.83 (662.6)	98.36 (440.8)
8” OD	386.26 (1731.3)	289.6 (1298.4)	193.13 (865.6)	424.24 (1901.5)	318.18 (1426.1)	212.12 (950.7)
9” OD	448.60 (2010.7)	336.4 (1508.0)	224.30 (1005.3)	484.31 (2170.7)	363.24 (1628.1)	242.16 (1085.4)
10” OD	516.53 (2315.1)	387.40 (1736.4)	258.26 (1157.5)	550.36 (2466.8)	412.77 (1850.1)	275.18 (1233.4)
11” OD	590.27 (2645.7)	442.7 (1984.2)	295.13 (1322.8)	622.55 (2790.4)	466.91 (2092.7)	311.27 (1395.1)
12” OD	670.00 (3003.0)	502.5 (2252.3)	335.00 (1501.5)	701.01 (3142.0)	525.76 (2356.5)	350.50 (1571.0)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type SS200 Central Shafts in Firm Soil[1,2,3]

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Firm Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	167.34 (750.0)	150.60 (675.0)	100.20 (449.1)	239.01 (1071.2)	215.11 (964.1)	143.12 (641.4)
8” OD	453.11 (2030.9)	339.83 (1523.1)	226.55 (1015.4)	495.45 (2220.7)	371.59 (1665.5)	247.72 (1110.3)
9” OD	516.55 (2315.2)	387.42 (1736.5)	258.28 (1157.6)	556.10 (2492.5)	417.07 (1869.3)	278.05 (1246.2)
10” OD	585.45 (2624.1)	439.08 (1968.0)	292.72 (1312.0)	622.66 (2790.8)	466.99 (2093.1)	311.33 (1395.4)
11” OD	660.02 (2958.3)	495.02 (2218.7)	330.01 (1479.1)	695.29 (3116.4)	521.47 (2337.3)	347.64 (1558.1)
12” OD	740.48 (3318.9)	555.36 (2489.2)	370.24 (1659.4)	774.13 (3469.8)	580.60 (2602.3)	387.06 (1734.8)
13” OD	826.98 (3706.7)	620.24 (2780.0)	413.49 (1853.3)	859.27 (3851.4)	644.46 (2888.6)	429.64 (1925.7)
14” OD	919.66 (4122.1)	689.74 (3091.5)	459.83 (2061.0)	950.81 (4261.7)	713.10 (3196.2)	475.40 (2130.8)
15” OD	1018.6 (4565.5)	763.95 (3424.1)	509.30 (2282.7)	1048.78 (4700.8)	786.59 (3525.6)	524.39 (2350.4)
16” OD	1123.8 (5037.4)	842.91 (3778.1)	561.94 (2518.7)	1153.25 (5169.1)	864.94 (3876.8)	576.62 (2584.5)

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 & 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.

[3] Column length to “fixity” of shaft in soft soil = 10 feet (3 meters), and 5 feet (1.5 meters).

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type RS3500.300 Central Shafts in Firm Soil[1,2,3]

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Firm Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	121.92 (546.4)	109.73 (491.8)	73.01 (327.2)	127.97 (573.5)	115.17 (516.2)	76.63 (343.4)
Grout Inside	148.57 (665.9)	111.43 (499.4)	74.28 (332.9)	157.41 (705.5)	118.06 (529.1)	78.70 (352.7)
8″ OD	305.22 (1368.0)	228.92 (1026.0)	152.61 (684.0)	320.30 (1435.6)	240.22 (1076.7)	160.15 (717.8)
9″ OD	359.15 (1609.7)	269.37 (1207.3)	179.58 (804.9)	375.60 (1683.5)	281.70 (1262.6)	187.80 (841.7)
10″ OD	420.25 (1883.6)	315.19 (1412.7)	210.13 (941.8)	437.84 (1962.4)	328.38 (1471.8)	218.92 (981.2)
11″ OD	488.48 (2189.4)	366.36 (1642.1)	244.24 (1094.7)	507.01 (2272.5)	380.26 (1704.4)	253.50 (1136.2)
12″ OD	563.78 (2526.9)	422.84 (1895.2)	281.89 (1263.4)	583.05 (2613.3)	437.29 (1960.0)	291.53 (1306.7)
13″ OD	646.08 (2895.8)	484.56 (2171.9)	3233.04 (14491.1)	665.94 (2984.8)	499.45 (2238.6)	332.97 (1492.4)
14″ OD	735.30 (3295.7)	551.48 (2471.8)	367.65 (1647.8)	755.63 (3386.8)	566.72 (2540.1)	377.81 (1693.4)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type RS4500.337 Central Shafts in Firm Soil[1,2,3]

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Firm Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	186.32 (835.1)	167.69 (751.6)	111.57 (500.0)	191.74 (859.4)	172.57 (773.4)	114.82 (514.6)
Grout Inside	236.28 (1059.0)	177.21 (794.2)	118.14 (529.5)	244.7 (1097.0)	183.56 (822.7)	122.37 (548.4)
8″ OD	369.00 (1653.9)	276.75 (1240.4)	184.50 (826.9)	381.23 (1708.7)	285.92 (1281.5)	190.61 (854.3)
9″ OD	422.75 (1894.8)	317.07 (1421.1)	211.38 (947.4)	436.42 (1956.1)	327.32 (1467.1)	218.21 (978.0)
10″ OD	483.42 (2166.7)	362.57 (1625.1)	241.71 (1083.3)	498.43 (2234.0)	373.82 (1675.5)	249.21 (1117.0)
11″ OD	551.08 (2470.0)	413.31 (1852.5)	275.54 (1235.0)	567.27 (2542.6)	425.46 (1907.0)	283.64 (1271.3)
12″ OD	625.75 (2804.7)	469.31 (2103.5)	312.88 (1402.3)	642.98 (2881.9)	482.23 (2161.4)	321.49 (1440.9)
13″ OD	707.43 (3146.8)	530.57 (2360.1)	353.72 (1573.4)	725.53 (3227.3)	544.15 (2420.5)	362.76 (1613.6)
14″ OD	796.09 (3541.2)	597.07 (2655.9)	398.05 (1770.6)	814.91 (3624.9)	611.19 (2718.7	407.46 (1812.5)
15″ OD	891.69 (3966.4)	668.76 (2974.8)	445.84 (1983.2)	911.11 (4052.8)	683.33 (3039.6)	455.56 (2026.4)
16″ OD	994.18 (4422.3)	745.63 (3316.7)	497.09 (2211.2)	1014.1 (4510.9)	760.57 (3383.2)	507.05 (2255.4)

Nominal, LRFD Design, and ASD Allowable Compression Strengths of Drivecast Piles, Type RS8625.250 Central Shafts in Firm Soil[1,2,3]

Grout Column Diameter	Nominal, LRFD Design, and ASD Allowable Compression Strengths kip (kN)					
	Firm Soil					
	Pinned			Fixed		
	Nominal	Design	Allowable	Nominal	Design	Allowable
No Grout	285.16	256.64	170.75	287.21	258.49	171.98
Grout Inside	526.07	394.55	263.03	532.15	399.11	266.07
12″ OD	727.09	545.32	363.54	736.01	552.01	368.01
13″ OD	808.15	606.11	404.07	818.23	613.67	409.12
14″ OD	895.89	671.92	447.95	907.13	680.35	453.57
15″ OD	990.39	742.79	495.20	1002.75	752.06	501.38
16″ OD	1091.68	818.76	545.84	1105.11	828.83	552.55
17″ OD	1199.79	899.85	599.90	1214.22	910.66	607.11
18″ OD	1314.75	986.07	657.38	1330.09	997.57	665.04
19″ OD	1436.57	1077.43	718.28	1452.73	1089.55	726.36
20″ OD	1565.23	1173.93	782.62	1582.14	1186.60	791.07
21″ OD	1700.75	1275.56	850.37	1718.31	1288.73	859.15
22″ OD	1843.09	1382.32	921.55	1861.23	1395.93	930.62

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 & 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.

[3] Column length to “fixity” of shaft in soft soil = 10 feet (3 meters), and 5 feet (1.5 meters).

TABLE 6-8

DRIVECAST™ PILE THEORETICAL GROUT VOLUME PER FOOT (METER)

PILE SHAFT DIAMETER in. (mm)	GROUT COLUMN DIAMETER in. (mm)	GROUT VOLUME (ft3/ft (m3/m)
1.75 (44)	8 (203.2)	0.321 (0.030)
	9 (228.6)	0.413 (0.038)
	10 (254)	0.517 (0.048)
	11 (279.4)	0.632 (0.059)
	12 (304.8)	0.781 (0.073)
2.00 (51)	8 (203.2)	0.304 (0.028)
	9 (228.6)	0.396 (0.037)
	10 (254)	0.500 (0.046)
	11 (279.4)	0.614 (0.0570
	12 (304.8)	0.774 (0.072)
	13 (330.2)	0.876 (0.081)
	14 (355.6)	1.051 (0.098)
	15 (381)	1.182 (0.110)
	16 (406.4)	1.351 (0.126)
3.5 (89)	8 (203.2)	0.270 (0.025)
	9 (228.6)	0.363 (0.034)
	10 (254)	0.466 (0.043)
	11 (279.4)	0.581 (0.054)
	12 (304.8)	0.706 (0.066)
	13 (330.2)	0.843 (0.078)
	14 (355.6)	0.990 (0.092)
4.5 (114)	8 (203.2)	0.222 (0.021)
	9 (228.6)	0.315 (0.029)
	10 (254)	0.419 (0.039)
	11 (279.4)	0.533 (0.050)
	12 (304.8)	0.659 (0.061)
	13 (330.2)	0.795 (0.074)
	14 (355.6)	0.942 (0.088)
	15 (381)	1.100 (0.102)
	16 (406.4)	1.269 (0.118)
5.5	10 (254)	0.365 (0.034)
	11 (279.4)	0.480 (0.045)
	12 (304.8)	0.605 (0.056)
	13 (330.2)	0.741 (0.069)
	14 (355.6)	0.889 (0.083)
	15 (381)	1.047 (0.097)
	16 (406.4)	1.216 (0.113)
8.625	12 (304.8)	0.359 (0.033)
	13 (330.2)	0.495 (0.046)
	14 (355.6)	0.642 (0.060)
	15 (381)	0.800 (0.074)
	16 (406.4)	0.969 (0.090)
	17 (431.8)	1.149 (0.107)
	18 (457.2)	1.340 (0.124)

REINFORCEMENT FOR UPPER 6’-0 OF DRIVECAST™ PILE GROUT COLUMNS

This table provides basic information about the option to add steel reinforcement to the grout column outside the central steel shaft (hollow pipe or solid square) in the upper 6’-0 of soils with minimum 2” cover.

$$Asr = 0.004(Ag)$$

$$\text{Max} = 0.004 \; \frac{(\pi)(16'')^2}{4} \; 0.804 \text{ in}^2$$

Perimeter or Reing’g (w/2” Clr) = πDr

Hoops = 0.009 in^2/in of spacing = 0.009 in^2/(”12”) = 0.11in^2

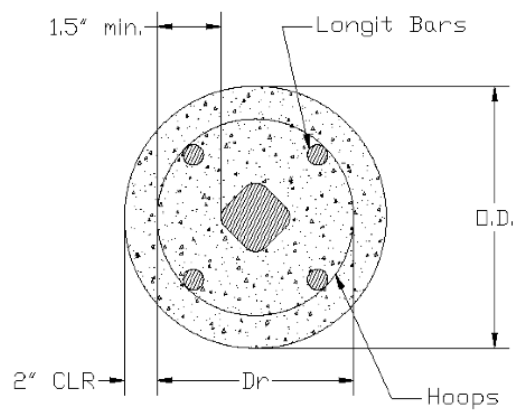


Figure 6-42

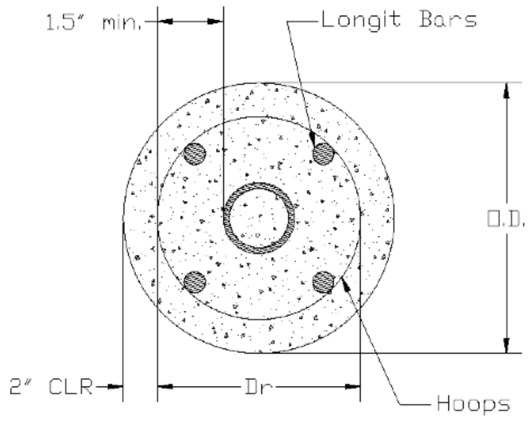


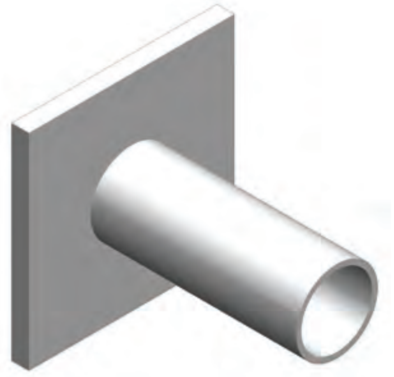
Figure 6-43

TABLE 6-9: STEEL REINFORECEMENT - DRIVECAST™ PILES

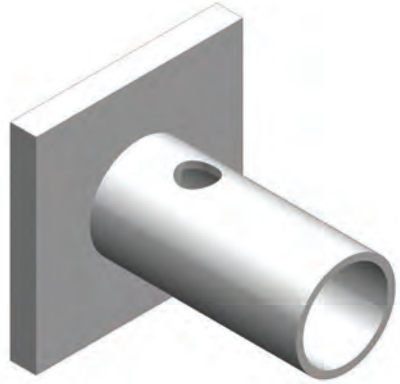
PILES	O.D.	Asr (in2)	REINF’G PERIMETER (in)	LONGIT BARS	HOOPS
SS	10”	0.314	18.85	(3) #3	“3@12”
SS	11”	0.380	21.99	(4) #3	“3@12”
SS, RS	12”	0.452	25.13	(4) #3	“3@12”
SS, RS	13”	0.531	28.27	(5) #3	“3@12”
SS, RS	14”	0.616	31.42	(4) #4	“3@12”
SS, RS	15”	0.707	34.56	(4) #4	“3@12”
SS, RS	16”	0.804	37.70	(4) #4	“3@12”
SS, RS	17”	0.908	40.84	(4) #4	“3@12”
SS, RS	18”	1.018	43.98	(4) #5	“3@12”
SS, RS	19”	1.134	59.69	(4) #5	“3@12”
SS, RS	20”	1.257	62.83	(4) #5	“3@12”
SS, RS	21”	1.385	65.97	(4) #5	“3@12”
SS, RS	22”	1.520	69.12	(5) #5	“3@12”

NEW CONSTRUCTION PILE CAPS

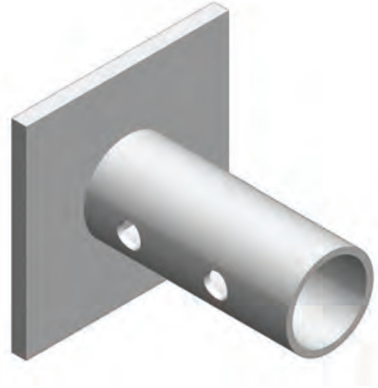
The CHANCE® new construction pile caps are designed for use with the CHANCE Type SS square shaft and RS round shaft helical piles and for embedment in cast-in-place concrete foundations. Each new construction pile cap consists of either one bearing plate and one steel tube sleeve that are factory-welded 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.



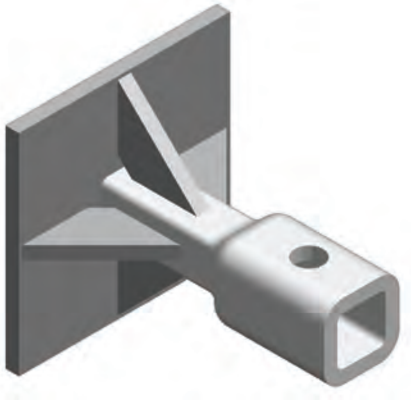
New Construction Cap for Type SS Shafts
Compression Only
Figure 6-44



New Construction Cap for Type SS Shafts
Compression and Uplift
Figure 6-45



New Construction Cap for Type RS Shafts
Compression and Uplift
Figure 6-46



New Construction Cap for Type SS Shafts
Equal Compression and Uplift Capacity
Figure 6-47

TABLE 6-10

CHANCE® helical New Construction Pile Caps			
Design (Working) Load kip (kN)	**Plate Size (square)**	**Pipe OD & Length**	**Description**
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.
60 (267) compression	6” x 6” x 3/4”	3” x 6”	Fits SS175; use for compression only.
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.
60 (267) compression 30 (133) uplift	6” x 6” x 3/4”	3” x 6”	Fits SS175; use for uplift and compression.
35 (156) compression	7” x 7” x 1/2”	2-1/2” x 6”	Fits SS5/SS150; use for compression only
52.5 (234) compression	8” x 8” x 1/2”	2-7/8” x 6”	Fits SS175; use for compression only
75 (334) compression	12” x 12” x 1/2”	3-1/2” x 6”	Fits SS200; use for compression only
100 (445) compression	12” x12” x 1/2”	3-1/2” x 6”	Fits SS225; use for compression only
36 (160) compression	7” x 7” x 1/2”	3-1/2” x 6”	Fits RS2875; use for compression only
50 (222) compression	10” x 10” x 1/2”	4-1/2” x 6”	Fits RS3500; use for compression only
70 (311) compression	12” x 12” x 1/2”	5-9/16” x 6”	Fits RS4500; use for compression only
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
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
75 (334) compression 45 (200) uplift	12” x 12” x 1/2”	3-1/2” x 6”	Fits SS200; use for uplift and compression
100 (445) compression 40 (178) uplift	12” x 12” x 1/2”	3-1/2” x 6”	Fits SS225; use for uplift and compression
36 (160) compression 36 (160) uplift	7” x 7” x 1/2”	3-1/2”	Fits RS2875; use for uplift and compression
50 (222) compression 50 (222) uplift	10” x 10” x 1/2”	4-1/2”	Fits RS3500; use for uplift and compression
70 (311) compression 70 (311) uplift	12” x 12” x 1/2”	5-9/16”	Fits RS4500; use for uplift and compression

DESIGN EXAMPLES

DESIGN EXAMPLES
SECTION 7

CONTENTS

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.

DESIGN EXAMPLE 1

HELICAL PILES/ANCHORS FOR TELECOMMUNICATION TOWERS

SYMBOLS USED IN THIS DESIGN EXAMPLE

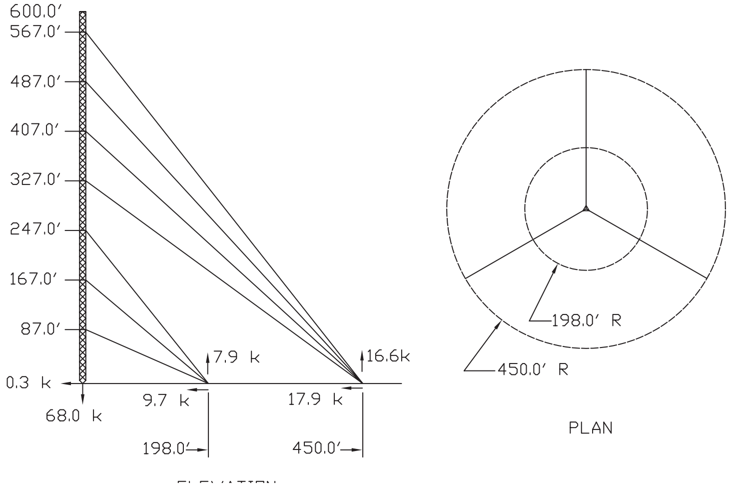
SST	SELF SUPPORTING TOWER	7-4
T_{ug}	UPPER GUYWIRE TENSION	7-5
IA_{ug}	UPPER GUYWIRE INSTALLATION ANGLE	7-5
T_{lg}	LOWER GUYWIRE TENSION	7-5
IA_{lg}	LOWER GUYWIRE INSTALLATION ANGLE	7-5
C	COMPRESSION	7-5
FS	FACTOR OF SAFETY	7-5
kip	KILOPOUND	7-5
R_{uc}	RECOMENDED ULTIMATE CAPACITY	7-5
K_t	TORQUE TO CAPACITY RATIO	7-6
T	MINIMUM INSTALATION TORQUE	7-7
DL	RESULTANT AXIAL LOAD	7-7

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



Tower Guy Anchor and Foundation
Figure 7-1

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.

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 kip
- Horizontal load component = 17.9 kip
- Tension in the upper guywire anchor = $T_{ug} = (16.6^2 + 17.9^2)^{0.5} = 24.4$ k
- Helical guywire anchor installation angle = $IA_{ug} = \tan^{-1} (16.6/17.9) = 43°$

Lower Guywire Loads

- Vertical load component: 7.9 kip
- Horizontal load component: 9.7 kip
- Tension in the lower guywire anchor = $T_{lg} = (7.9^2 + 9.7^2)^{0.5} = 12.5$ k
- Helical guywire anchor installation angle = $IA_{lg} = \tan^{-1} (7.9/9.7) = 39°$

Mast Foundation Loads

- Compression (C) = 68.0 kip
- Horizontal shear (V) = 0.3 kip

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 7-2. 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:

$$T = (T_{ug} \text{ x } FS) / K_t \qquad \textbf{Equation 7-1}$$

$$= (24{,}400 \text{ x } 2.0) / 10$$

$$= 4{,}900 \text{ ft-lbs}$$

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.

$$T = (T_{lg} \text{ x } FS) / K_t \qquad \textbf{Equation 7-2}$$

$$= (12{,}500 \text{ x } 2.0) / 10$$

$$= 2{,}500 \text{ ft-lbs}$$

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.

$$T = (DL \times FS) / K_t$$

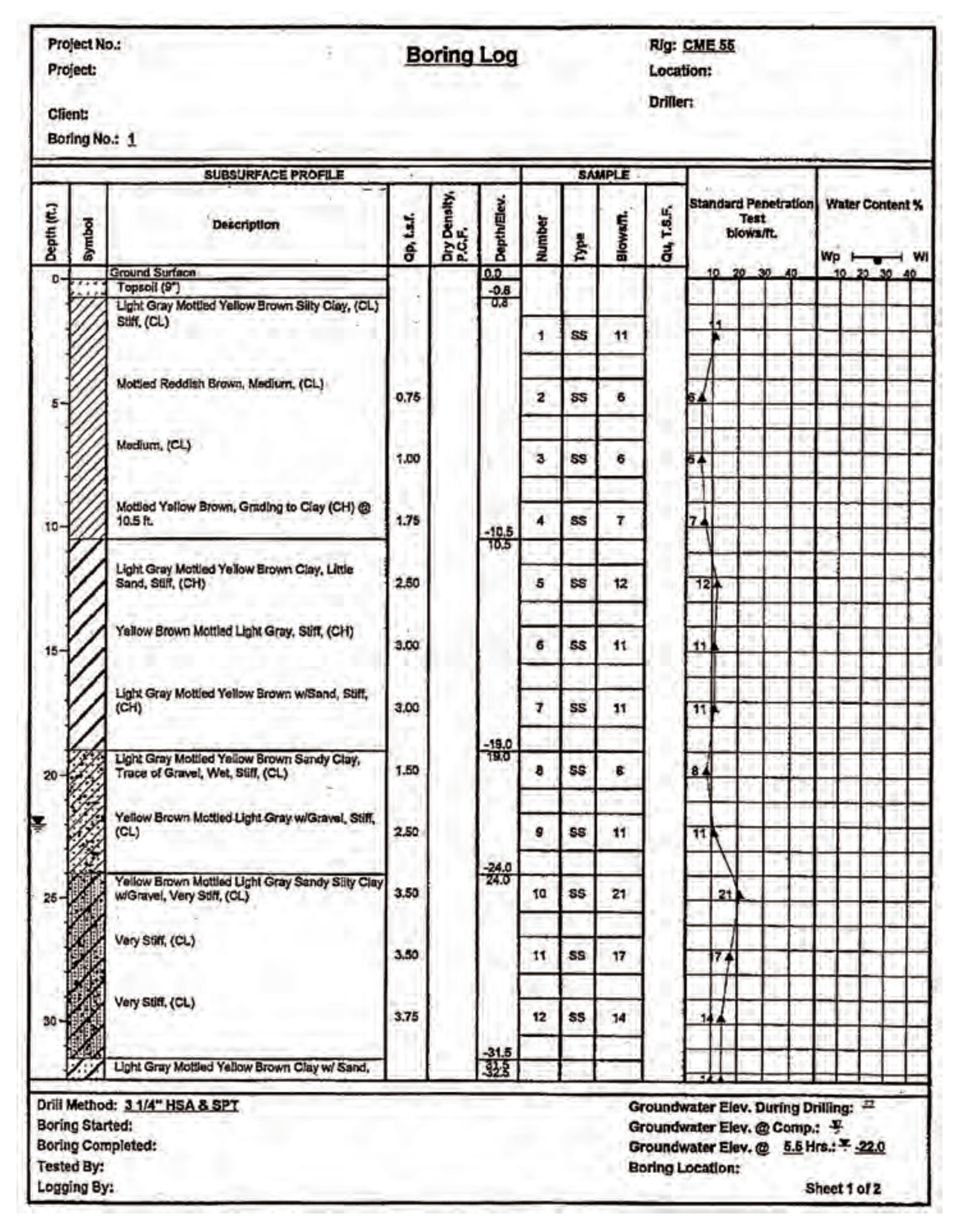
Equation 7-3

$$= (22{,}700 \times 2.0) / 10$$

$$= 4{,}500 \text{ ft-lbs}$$

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).



Boring Log

Project No.:
Project:
Client:
Boring No.: 1

Rig: CME 55
Location:
Driller:

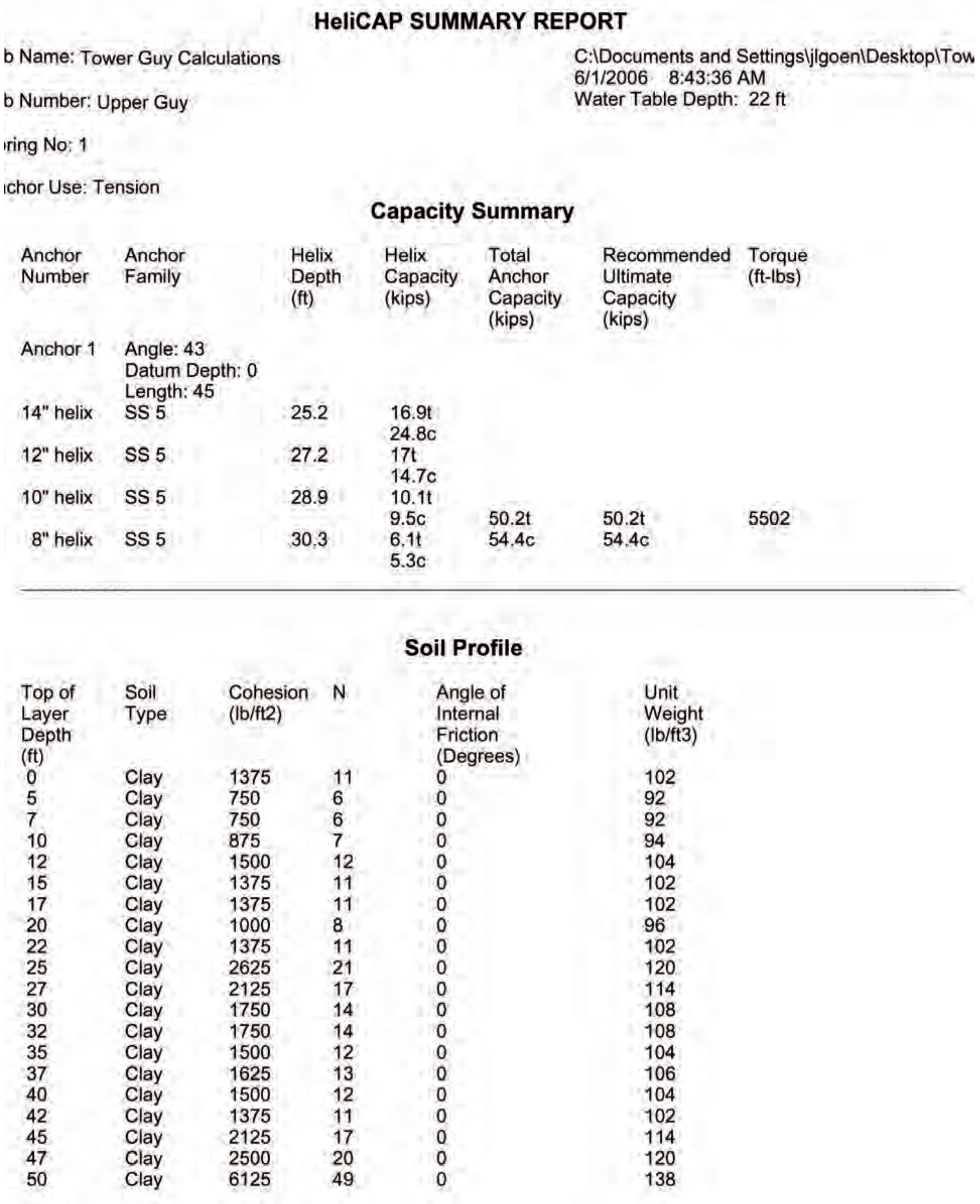
SUBSURFACE PROFILE						SAMPLE			
Depth (ft.)	Symbol	Description	Qp, t.s.f.	Dry Density, P.C.F.	Depth/Elev.	Number	Type	Blows/ft.	Qu, T.S.F.
0		Ground Surface			0.0				
		Topsoil (9")			-0.8 0.8				
		Light Gray Mottled Yellow Brown Silty Clay, (CL) Stiff, (CL)				1	SS	11	
5		Mottled Reddish Brown, Medium, (CL)	0.75			2	SS	6	
		Medium, (CL)	1.00			3	SS	6	
10		Mottled Yellow Brown, Grading to Clay (CH) @ 10.5 ft.	1.75		-10.5 10.5	4	SS	7	
		Light Gray Mottled Yellow Brown Clay, Little Sand, Stiff, (CH)	2.50			5	SS	12	
15		Yellow Brown Mottled Light Gray, Stiff, (CH)	3.00			6	SS	11	
		Light Gray Mottled Yellow Brown w/Sand, Stiff, (CH)	3.00		-19.0 19.0	7	SS	11	
20		Light Gray Mottled Yellow Brown Sandy Clay, Trace of Gravel, Wet, Stiff, (CL)	1.50			8	SS	8	
		Yellow Brown Mottled Light Gray w/Gravel, Stiff, (CL)	2.50		-24.0 24.0	9	SS	11	
25		Yellow Brown Mottled Light Gray Sandy Silty Clay w/Gravel, Very Stiff, (CL)	3.50			10	SS	21	
		Very Stiff, (CL)	3.50			11	SS	17	
30		Very Stiff, (CL)	3.75		-31.5	12	SS	14	
		Light Gray Mottled Yellow Brown Clay w/ Sand,			31.5 -32.5				

Drill Method: 3 1/4" HSA & SPT
Boring Started:
Boring Completed:
Tested By:
Logging By:

Groundwater Elev. During Drilling:
Groundwater Elev. @ Comp.:
Groundwater Elev. @ 5.5 Hrs.: -22.0
Boring Location:

Sheet 1 of 2

Sample Boring Log
Figure 7-2



HeliCAP SUMMARY REPORT

b Name: Tower Guy Calculations

b Number: Upper Guy

ring No: 1

chor Use: Tension

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6/1/2006 8:43:36 AM
Water Table Depth: 22 ft

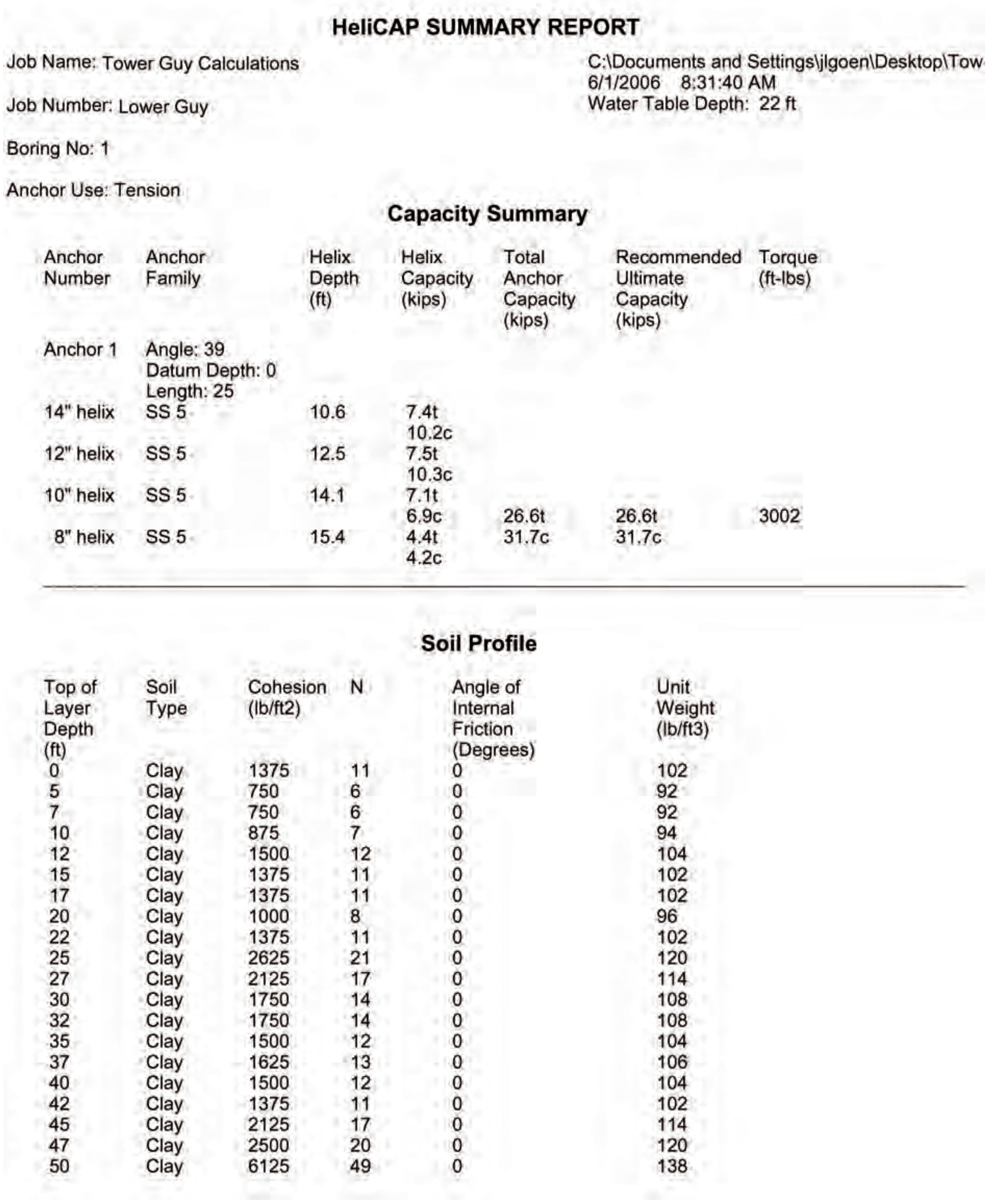
Capacity Summary

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/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 Upper Guywires
Figure 7-3



HeliCAP SUMMARY REPORT

Job Name: Tower Guy Calculations

Job Number: Lower Guy

Boring No: 1

Anchor Use: Tension

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Water Table Depth: 22 ft

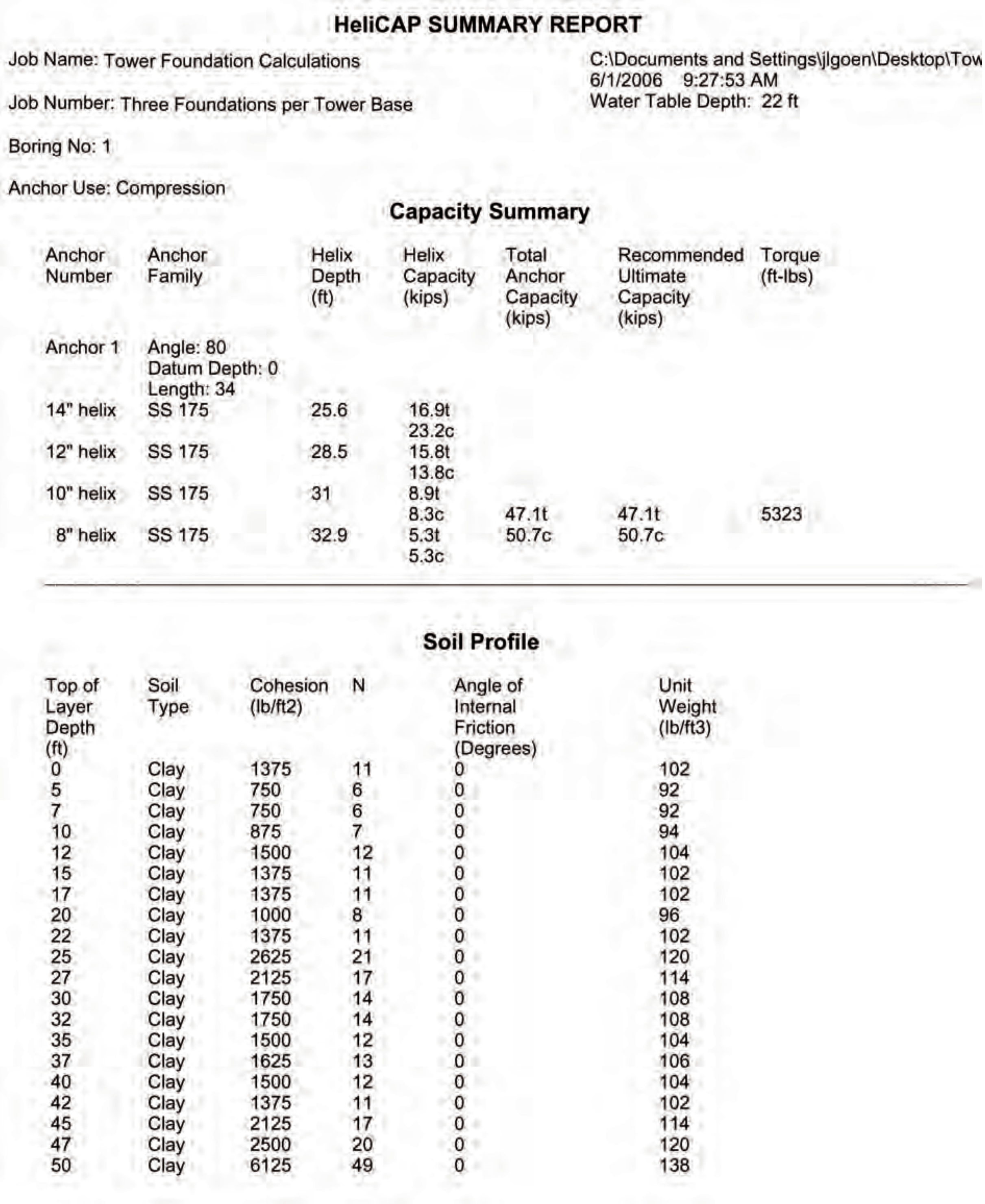
Capacity Summary

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 7-4



HeliCAP SUMMARY REPORT

Job Name: Tower Foundation Calculations

Job Number: Three Foundations per Tower Base

Boring No: 1

Anchor Use: Compression

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Water Table Depth: 22 ft

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	50.7c	50.7c	
			5.3c			

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 Foundations
Figure 7-5

DESIGN EXAMPLE 2

SELF SUPPORT TOWER DESIGN WITH FIXED HEAD GRILLAGE DESIGN

SYMBOLS USED IN THIS DESIGN EXAMPLE

T-Z CURVE	AXIAL DISPLACEMENT VS LOAD PLOT	7-13
Mp	PLASTIC MOMENT	7-14
FS	FACTOR OF SAFETY	7-14
K_t	TORQUE TO CAPACITY RATIO	7-15

Purpose

This design example is intended to assist with the design of Self Support Structure foundations using Chance® RS3500.300 Helical Piles and Can Grillages where reveal is required. The basic principles used in this example can be used for any Self Support Structure.

In this example, each leg of the Self Support Structure will be supported by a grillage on helical piles. This type of structure will generally have tension, compression, and shear loads that will need to be calculated or provided by the tower manufacturer. Generally all moment loads are transferred to the structure by Tension/Compression force couples (One side has a tension load while the other side is compressed).

After the loads for the structure have been determined, it is possible to design the piles.

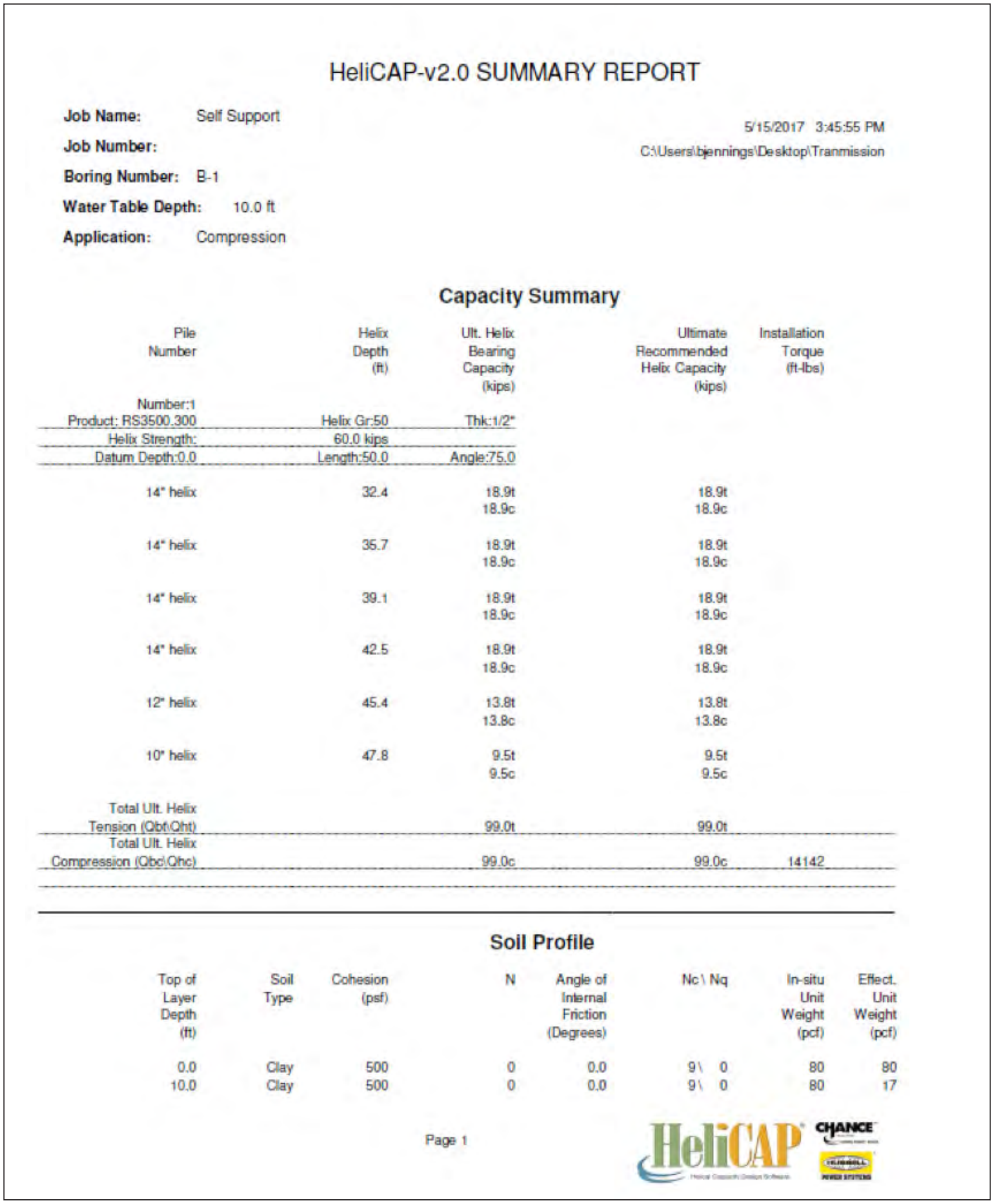
Loads For This Example

- Compression: 130 kip
- Tension: 100 kip
- Shear:
  - Transverse: 11 kip
  - Longitudinal: 10 kip

Soils

- Layers
  - 0-15ft: 500 psf clay (500 psf is the cohesion of the clay)
  - 15-30ft: 1000 psf clay
  - >30ft: 2000 psf clay
- Water Table: 10 ft below surface
- Required Reveal Height: 1 ft.

Pile Capacity:
The first step in the design is to calculate the estimated axial capacity of the pile. This is done by putting the boring into Helicap®, selecting the product line you wish to use (RS3500.300 for Can style grillage), and helix configuration. This value is generally the maximum capacity of the pile type you wish to use, but can be lower if the soils are not very good. This value is used for the initial T-Z curve in the group model. In this example with a 10/12/14/14/14/14, a 90 kip pile can be attained (See Figure 1).



HeliCAP-v2.0 SUMMARY REPORT

Job Name: Self Support
Job Number:
Boring Number: B-1
Water Table Depth: 10.0 ft
Application: Compression

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Capacity Summary

Pile Number	Helix Depth (ft)	Ult. Helix Bearing Capacity (kips)	Ultimate Recommended Helix Capacity (kips)	Installation Torque (ft-lbs)
Number:1 Product: RS3500.300	Helix Gr:50	Thk:1/2"		
Helix Strength:	60.0 kips			
Datum Depth:0.0	Length:50.0	Angle:75.0		
14" helix	32.4	18.9t 18.9c	18.9t 18.9c	
14" helix	35.7	18.9t 18.9c	18.9t 18.9c	
14" helix	39.1	18.9t 18.9c	18.9t 18.9c	
14" helix	42.5	18.9t 18.9c	18.9t 18.9c	
12" helix	45.4	13.8t 13.8c	13.8t 13.8c	
10" helix	47.8	9.5t 9.5c	9.5t 9.5c	
Total Ult. Helix Tension (Qbt\Qht)		99.0t	99.0t	
Total Ult. Helix Compression (Qbc\Qhc)		99.0c	99.0c	14142

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (psf)	N	Angle of Internal Friction (Degrees)	Nc \ Nq	In-situ Unit Weight (pcf)	Effect. Unit Weight (pcf)
0.0	Clay	500	0	0.0	9 \ 0	80	80
10.0	Clay	500	0	0.0	9 \ 0	80	17

Page 1

Figure 7 -6: Helicap Printout

At this point, the data is input into Group®. Some of the inputs include: the soils, the loads (including different load cases for tension/compression as well as different directions the loads can act), T-Z curve, and the pile configuration/properties (Pile configuration for grillages can be found in the grillage section under the products tab and pile properties/capacities can be found in the same section under the section for the desired pile.

Generally the loads put into GROUP® are working loads. Because GROUP® is estimating lateral deflection; the best way to get a factor of safety is to apply it to the Group results. Please consult the Group® Manual for any questions about how to use Group®.

Here are the results of this analysis for these piles.

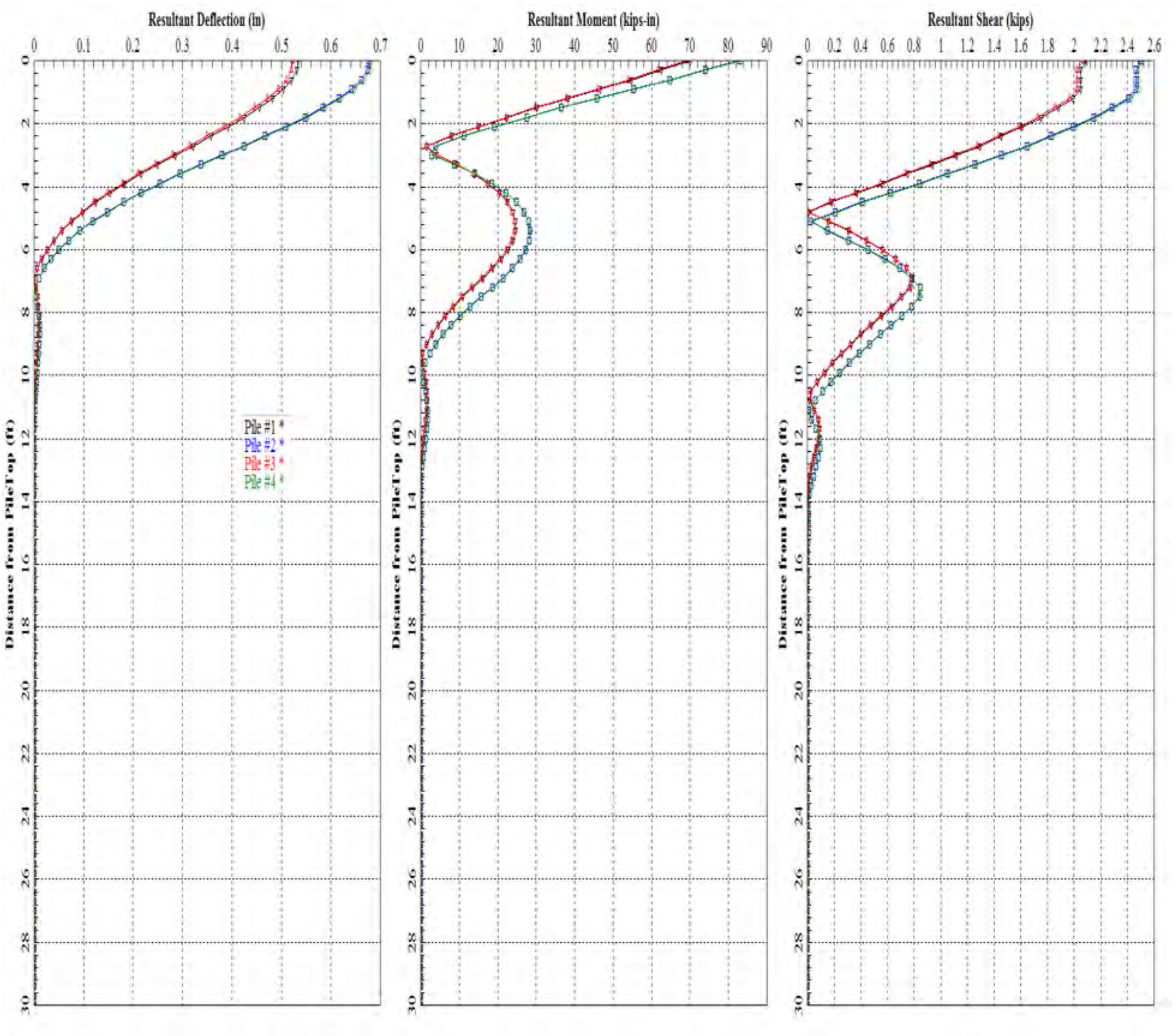
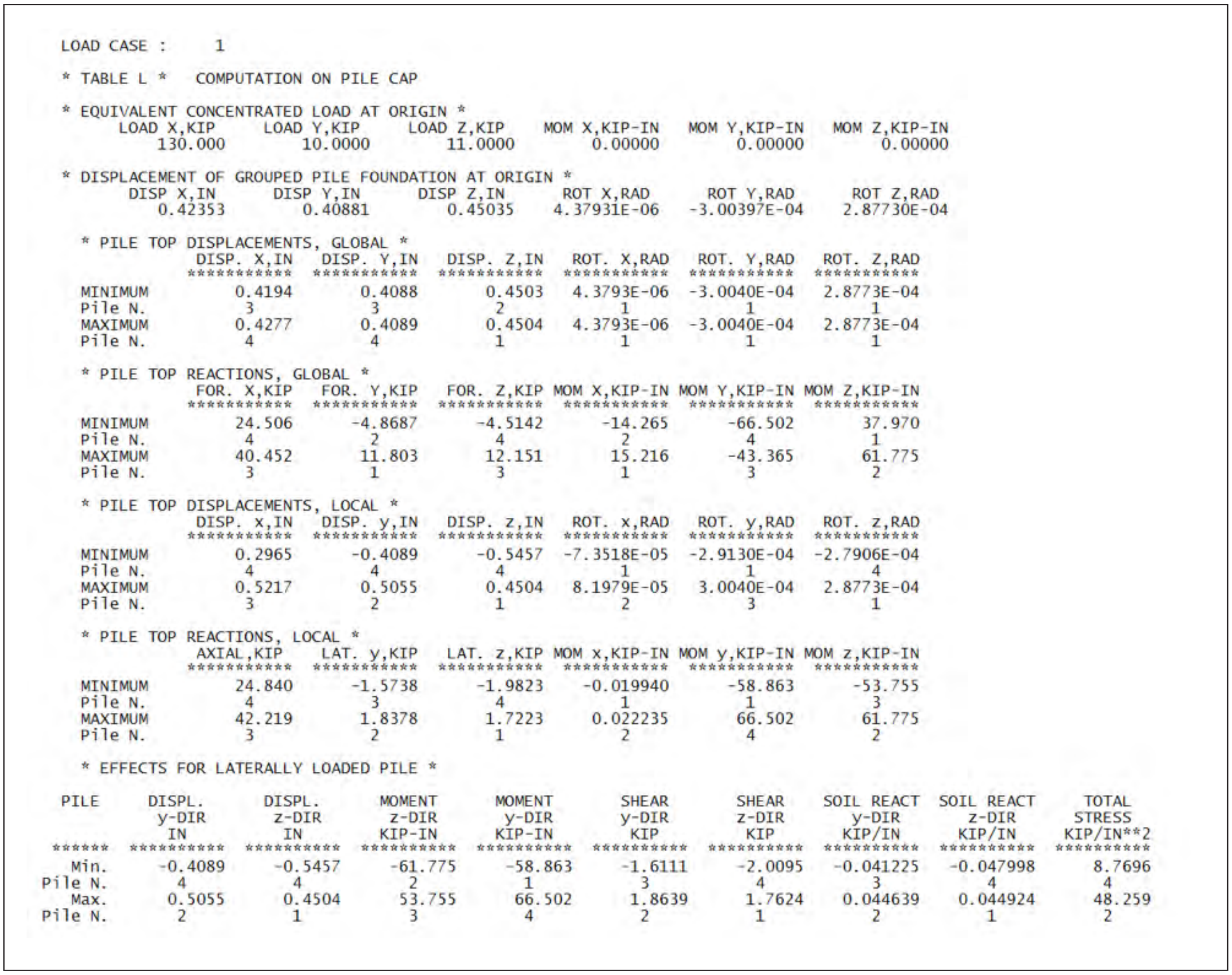


Figure 7-7: Resultant Deflection, Moment, and Shear

When looking at the GROUP® results, the important things to look for in Figure 2 are: Is the resultant deflection greater than acceptable? Is the moment greater than 0.6 Mp? Generally with a Self Support Structure, 1" lateral defection at working loads is acceptable and 0.6 Mp for resolved is 87 kip-in.

The minimum embedment for the helical piles (or minimum amount of pipe for the piles in Combo piles) is where the resultant shear reaches and stays very close to 0 kip. In this case, it would be 14 ft. There are some scenarios that can increase minimum embedment. If there is a soft layer of soil, the minimum embedment can require bearing below that layer. It can also be used to ensure the last helix plate is a minimum of 5 helix diameters below the surface.



```
 LOAD CASE :      1

 * TABLE L *    COMPUTATION ON PILE CAP

 * EQUIVALENT CONCENTRATED LOAD AT ORIGIN *
      LOAD X,KIP     LOAD Y,KIP     LOAD Z,KIP    MOM X,KIP-IN   MOM Y,KIP-IN   MOM Z,KIP-IN
         130.000        10.0000        11.0000        0.00000        0.00000        0.00000

 * DISPLACEMENT OF GROUPED PILE FOUNDATION AT ORIGIN *
       DISP X,IN      DISP Y,IN      DISP Z,IN      ROT X,RAD      ROT Y,RAD      ROT Z,RAD
         0.42353        0.40881        0.45035    4.37931E-06   -3.00397E-04    2.87730E-04

   * PILE TOP DISPLACEMENTS, GLOBAL *
             DISP. X,IN   DISP. Y,IN   DISP. Z,IN   ROT. X,RAD   ROT. Y,RAD   ROT. Z,RAD
            ***********  ***********  ***********  ***********  ***********  ***********
   MINIMUM       0.4194       0.4088       0.4503   4.3793E-06  -3.0040E-04   2.8773E-04
   Pile N.       3            3            2            1            1            1
   MAXIMUM       0.4277       0.4089       0.4504   4.3793E-06  -3.0040E-04   2.8773E-04
   Pile N.       4            4            1            1            1            1

   * PILE TOP REACTIONS, GLOBAL *
             FOR. X,KIP   FOR. Y,KIP   FOR. Z,KIP MOM X,KIP-IN MOM Y,KIP-IN MOM Z,KIP-IN
            ***********  ***********  ***********  ***********  ***********  ***********
   MINIMUM       24.506      -4.8687      -4.5142      -14.265      -66.502       37.970
   Pile N.       4            2            4            2            4            1
   MAXIMUM       40.452       11.803       12.151       15.216      -43.365       61.775
   Pile N.       3            1            3            1            3            2

   * PILE TOP DISPLACEMENTS, LOCAL *
             DISP. x,IN   DISP. y,IN   DISP. z,IN   ROT. x,RAD   ROT. y,RAD   ROT. z,RAD
            ***********  ***********  ***********  ***********  ***********  ***********
   MINIMUM       0.2965      -0.4089      -0.5457  -7.3518E-05  -2.9130E-04  -2.7906E-04
   Pile N.       4            4            4            1            1            4
   MAXIMUM       0.5217       0.5055       0.4504   8.1979E-05   3.0040E-04   2.8773E-04
   Pile N.       3            2            1            2            3            1

   * PILE TOP REACTIONS, LOCAL *
             AXIAL,KIP    LAT. y,KIP   LAT. z,KIP MOM x,KIP-IN MOM y,KIP-IN MOM z,KIP-IN
            ***********  ***********  ***********  ***********  ***********  ***********
   MINIMUM       24.840      -1.5738      -1.9823    -0.019940      -58.863      -53.755
   Pile N.       4            3            4            1            1            3
   MAXIMUM       42.219       1.8378       1.7223     0.022235       66.502       61.775
   Pile N.       3            2            1            2            4            2

   * EFFECTS FOR LATERALLY LOADED PILE *

 PILE      DISPL.      DISPL.      MOMENT      MOMENT       SHEAR       SHEAR    SOIL REACT  SOIL REACT     TOTAL
           y-DIR       z-DIR       z-DIR       y-DIR        y-DIR       z-DIR       y-DIR       z-DIR       STRESS
            IN          IN        KIP-IN      KIP-IN         KIP         KIP       KIP/IN      KIP/IN     KIP/IN**2
******  **********  **********  **********  **********  **********  **********  **********  **********  **********
  Min.     -0.4089     -0.5457     -61.775     -58.863     -1.6111     -2.0095   -0.041225   -0.047998      8.7696
Pile N.      4           4           2           1           3           4           3           4           4
  Max.      0.5055      0.4504      53.755      66.502      1.8639      1.7624    0.044639    0.044924      48.259
Pile N.      2           1           3           4           2           1           2           1           2
```

Figure 7 -8: GROUP® Results

From Figure 7-8, the important things to look for include, is the total stress greater than the yield stress and is the required axial capacity smaller than half the capacity of the T-Z curve (for a FS=2). In this case the maximum total stress is 48.3 ksi which is less than (50 ksi) and the axial load is 42.2 kip which is less than 90/2=45.

At this point, if the axial capacity from the T-Z curve is considerably larger than double the required by the model, the T-Z curve is adjusted to be closer and the helical configuration is also adjusted in the Helicap model until the right capacity is found.

With the final ultimate capacity known, the torque required for installation can be calculated. Equation 7-4 shows the equation for calculating installation torque.

Installation Torque (ft-lbs)=required Capacity(kip)*1000/k_t **Equation 7-4**

- k_t=7 for RS3500
- Required Capacity is 90 kip
- Installation torque: 1000*90/7=12,900 ft-lbs

Recommendation:

1. **Install 4-RS3500.300 helical piles**
    a. Helix Configuration: 10/12/14/14/14/14
    b. Installation Torque: 12,900 ft-lbs
    c. Estimated Embedment: 50 ft.
    d. Minimum embedment: 14 ft.
2. **Assumptions**
    a. Boring B-1 is representative of the site
        1. Water table: 10 ft.
    b. Loads given:
        a. 130kip Comp
        b. 100kip Tension
        c. Shear:
            1. Transverse 10kip
            2. Longitudinal 10kip
    c. Piles are installed at ground level
    d. Pile Revea: 1 ft.
    e. Torque to Capacity Ratio: 7:1
    f. Fixed Head Condition
    g. Axial FS: 2.0
    i. Amount of Lateral deflection acceptable at working loads: 0.7"
3. **Notes**
    a. May reach installation torque before reaching minimum embedment. Adhere to minimum embedment
    b. Maximum torque for RS3500.300 is 13,000 ft-lbs. Do not Overtorque!

DESIGN EXAMPLE 3

H-FRAME STRUCTURE DESIGN WITH CONCRETE CAP AND MICROPILE DESIGN

SYMBOLS USED IN THIS DESIGN EXAMPLE

T-Z CURVE	AXIAL DISPLACEMENT VS LOAD PLOT	7-17
Mp	PLASTIC MOMENT	7-19
FS	FACTOR OF SAFETY	7-20
K_t	TORQUE TO CAPACITY RATIO	7-21

Purpose

This design example is intended to assist with the design of H-Frame Structure foundations. This example will show how to design using GROUP® and a concrete cap. A grillage can be used for an H-frame structure, and an example of how to design for a grillage is given in Design Example 2

Each leg of the H-Frame Structure will be supported by a concrete pile cap. This type of structure will generally have tension, compression, shear, and moment loads that will need to be calculated or provided by the tower manufacturer

After the loads for the structure have been determined, it is possible to design the piles.

For this example the loading soil is as follows:

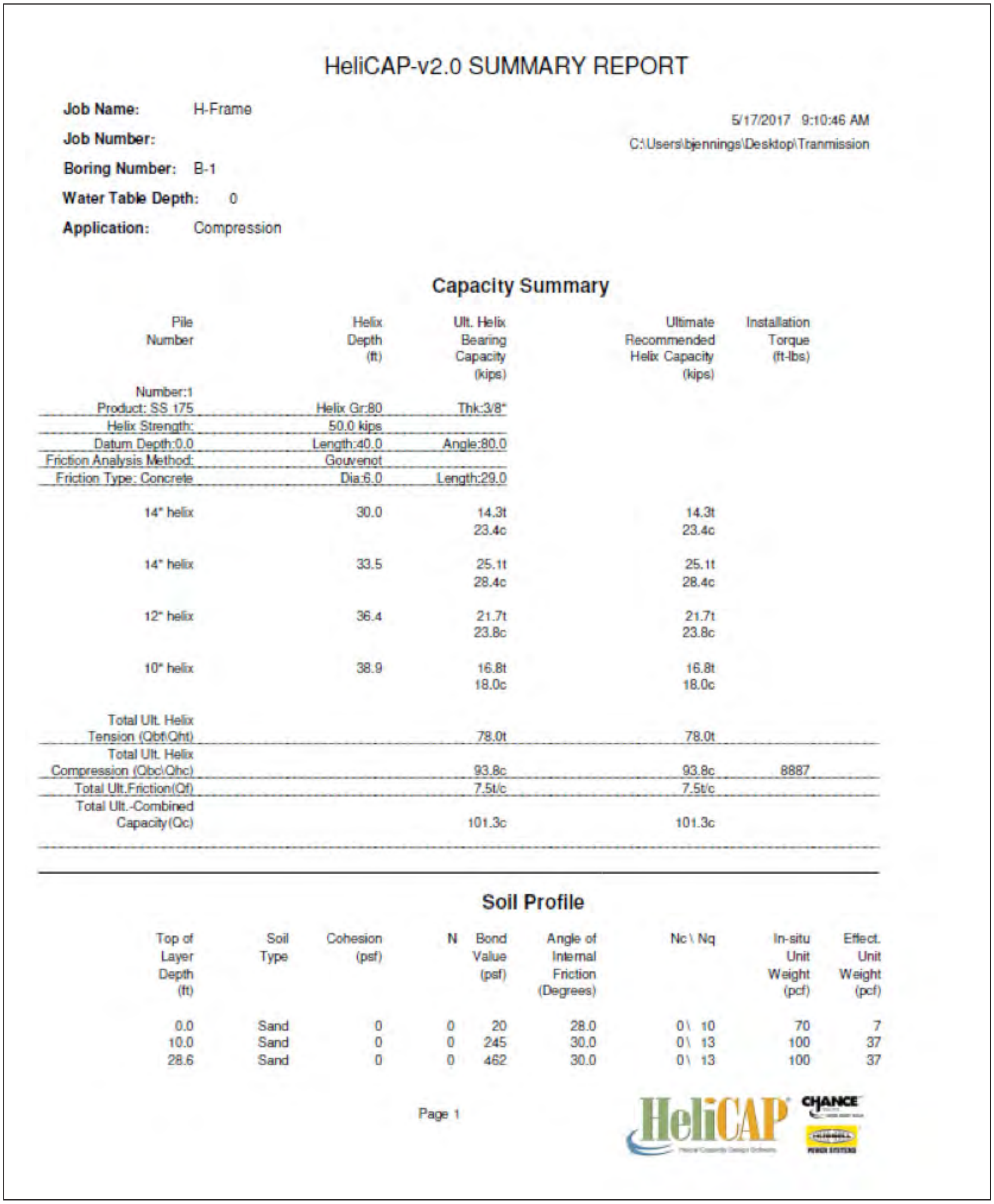
Loads

- Compression: 100 kip
- Tension: 80 kip
- Shear:
  - Transverse: 9.5 kip
  - Longitudinal: 1 kip
- Moment
  - Longitudinal: 150 kip-ft

Soil Profile:

- Layers
  - 0-10 ft: 28° Friction Angle Sand
  - 10-30 ft: 30° Friction Angle Sand
  - >30ft: 35° Friction Angle Sand
- Water Table: Surface (0 ft)

Pile Capacity:
The first step in the design is to look at the soil profile and estimate a maximum ultimate axial capacity that can be attained. This is done by putting the boring into Helicap®, selecting the product line you wish to use, and helix configuration. This value is generally the maximum capacity for the pile you wish to use (the axial capacities of shafts can be found in the Drawings and Ratings section), but can be lower if the soils are not very good. You will use this value for the initial T-Z curve in the group model. In this example, we will use a SS175 pulldown pile with helical configuration 10/12/14/14. The estimated capacity is 100 kip (See Figure 7-9).



HeliCAP-v2.0 SUMMARY REPORT

Job Name: H-Frame
Job Number:
Boring Number: B-1
Water Table Depth: 0
Application: Compression

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Capacity Summary

Pile Number	Helix Depth (ft)	Ult. Helix Bearing Capacity (kips)	Ultimate Recommended Helix Capacity (kips)	Installation Torque (ft-lbs)
Number:1				
Product: SS 175	Helix Gr:80	Thk:3/8"		
Helix Strength:	50.0 kips			
Datum Depth:0.0	Length:40.0	Angle:80.0		
Friction Analysis Method:	Gouvenot			
Friction Type: Concrete	Dia:6.0	Length:29.0		
14" helix	30.0	14.3t 23.4c	14.3t 23.4c	
14" helix	33.5	25.1t 28.4c	25.1t 28.4c	
12" helix	36.4	21.7t 23.8c	21.7t 23.8c	
10" helix	38.9	16.8t 18.0c	16.8t 18.0c	
Total Ult. Helix Tension (Qbt\Qht)		78.0t	78.0t	
Total Ult. Helix Compression (Qbc\Qhc)		93.8c	93.8c	8887
Total Ult.Friction(Qf)		7.5t/c	7.5t/c	
Total Ult.-Combined Capacity(Qc)		101.3c	101.3c	

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (psf)	N	Bond Value (psf)	Angle of Internal Friction (Degrees)	Nc \ Nq	In-situ Unit Weight (pcf)	Effect. Unit Weight (pcf)
0.0	Sand	0	0	20	28.0	0\ 10	70	7
10.0	Sand	0	0	245	30.0	0\ 13	100	37
28.6	Sand	0	0	462	30.0	0\ 13	100	37

Page 1

Figure 7-9: Helicap Printout

There are a few options for consideration at this point in design. Are the piles going to have a fixed or pinned end condition? Batter or no batter? Embed the pile cap or not? A fixed head condition will make the foundation more rigid and result in smaller defections with lateral loads. However, it also results in greater moments. Battered piles will also make a foundation more rigid and result in less deflection. This results in the ability to uses smaller shafts to resist lateral loads, but also required an axial load to work. It is acceptable to embed the pile cap, but there are many variables that have to be considered before doing so. Can it be guaranteed that the cap will always have soil around it? Will the soil around it have the same properties as has been assumed for the top layer/is the soil disturbed? These are just a few of the items that need to be considered before GROUP®.

At this point, the data is input into Group®. Some of the inputs include: the soils, the loads (including different load cases for tension/compression as well as different directions the loads can act), T-Z curve, and the pile configuration/properties. The pile configuration is going to be made up of 2 sections. The first is a cased pulldown pile (to resist moment) and the next will be an uncased pulldown pile. You want the cut off between the two to be at the point where estimated moment in the pile is less than the cracking moment of the uncased column.

Generally the loads put into GROUP® are working loads. Because GROUP® is estimating lateral deflection; the best way to get a factor of safety is to apply it to the GROUP® results. Please consult the GROUP® Manual for any questions about how to use GROUP®.

With the data in GROUP®, the design becomes an iterative process to come up with a pile configuration that works well. If the piles have too much moment, they can be spaced further apart or battered at a different angle to relieve it. If the piles have too much axial loading, spacing a little closer together can fix that issue. Sometimes, the loads will just require larger diameter pipe, greater diameter column, or more piles to have an acceptable model. If the axial capacity from the T-Z curve is considerably larger than double the required by the model, the T-Z curve can be adjusted down to get a more cost effective pile. In this case the T-Z curve was adjusted from 100 to 85 kips.

Here are the results of the analysis with the T-Z curve capacity of 85 kips on 4 piles battered 10 degrees from vertical, away from the center, and spaced on the corners of a 5’ square.

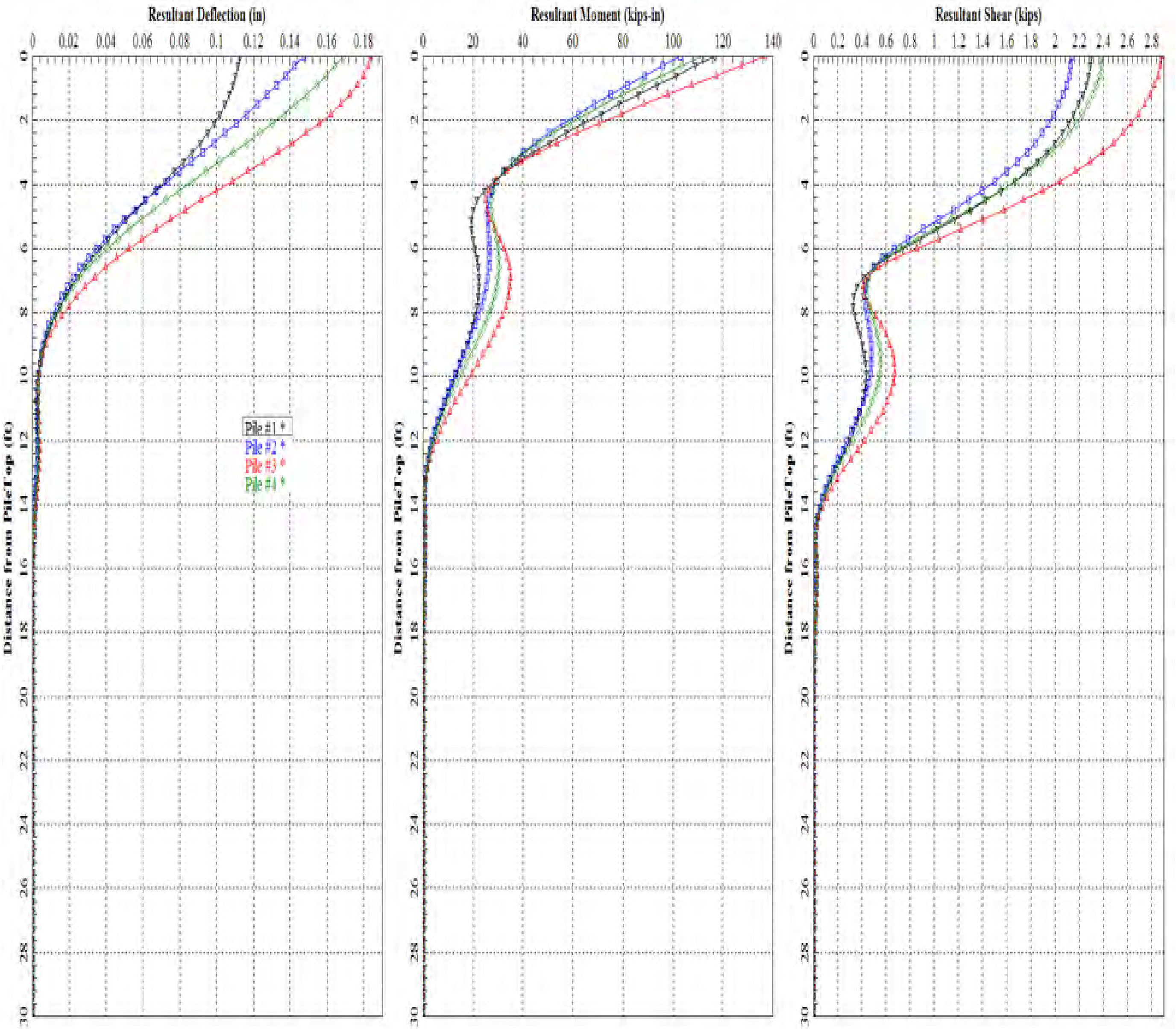
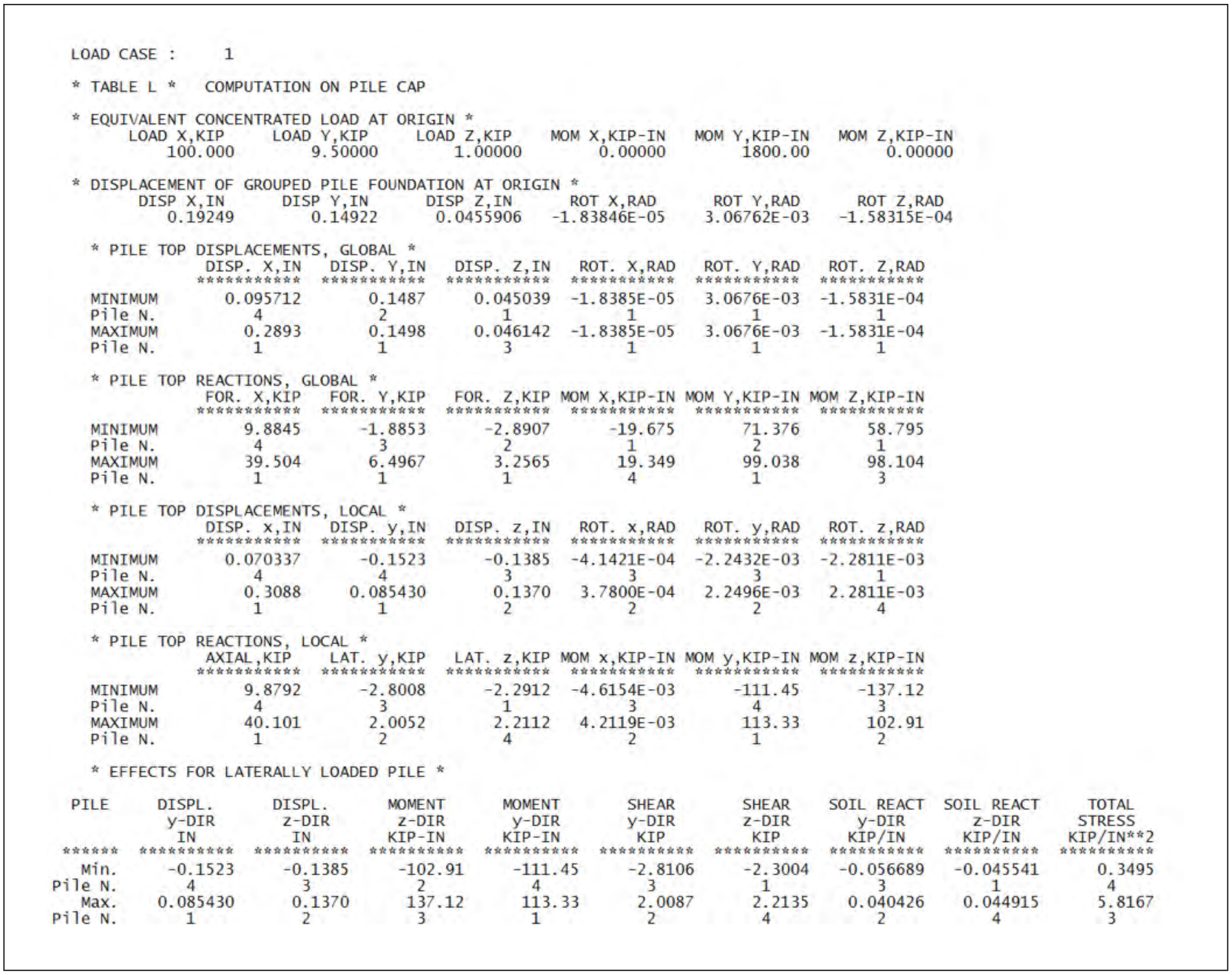


Figure 7-10: Resultant Deflection, Moment, and Shear

When looking at the GROUP® results, the important things to look for in Figure 7-10 are: Is the resultant deflection greater than acceptable and is the moment greater than allowable. For a pulldown pile, the acceptable moment is either 0.6 Mp of the casing or the cracking moment. In this case, the cracking moment is 10.6 kip-in.

The minimum depth of grout for the piles is where the resultant shear becomes very close to 0 (less than 50 lbs). This is the location where the square shaft no longer requires the grout column (assuming the soil is greater than 4 blow materials). The minimum depth of the grout column in this example is 16 ft. The minimum depth of casing is the deepest depth at which the resultant moment is equal to the cracking moment of the uncased shaft. In this case the minimum cased depth is 14 ft.

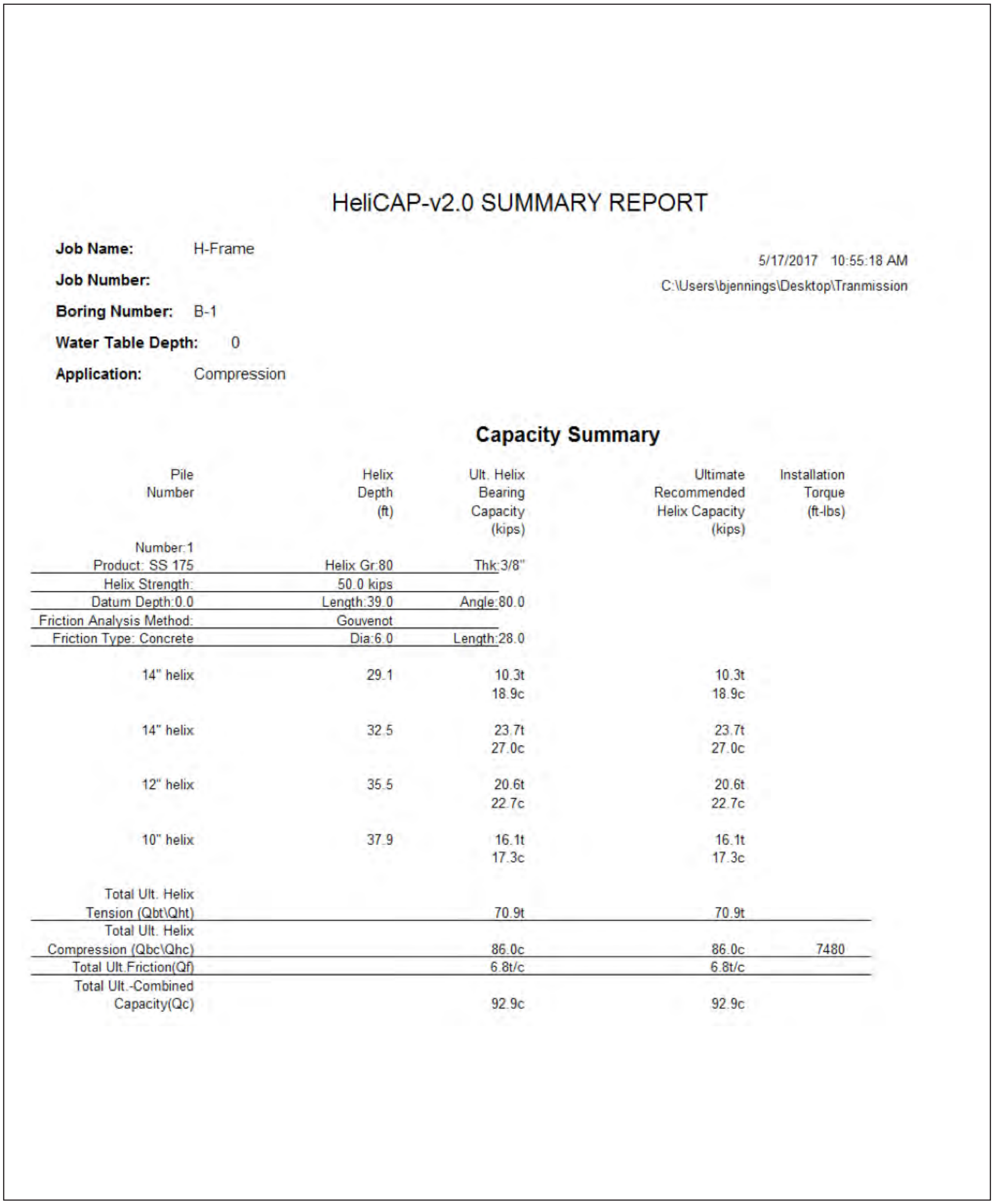


```
LOAD CASE :      1

* TABLE L *    COMPUTATION ON PILE CAP

* EQUIVALENT CONCENTRATED LOAD AT ORIGIN *
      LOAD X,KIP     LOAD Y,KIP     LOAD Z,KIP   MOM X,KIP-IN   MOM Y,KIP-IN   MOM Z,KIP-IN
        100.000        9.50000        1.00000        0.00000        1800.00        0.00000

* DISPLACEMENT OF GROUPED PILE FOUNDATION AT ORIGIN *
       DISP X,IN      DISP Y,IN      DISP Z,IN      ROT X,RAD      ROT Y,RAD      ROT Z,RAD
         0.19249        0.14922      0.0455906   -1.83846E-05    3.06762E-03   -1.58315E-04

  * PILE TOP DISPLACEMENTS, GLOBAL *
              DISP. X,IN   DISP. Y,IN   DISP. Z,IN   ROT. X,RAD   ROT. Y,RAD   ROT. Z,RAD
             ***********  ***********  ***********  ***********  ***********  ***********
  MINIMUM       0.095712       0.1487     0.045039  -1.8385E-05   3.0676E-03  -1.5831E-04
  Pile N.           4            2            1            1            1            1
  MAXIMUM         0.2893       0.1498     0.046142  -1.8385E-05   3.0676E-03  -1.5831E-04
  Pile N.           1            1            3            1            1            1

  * PILE TOP REACTIONS, GLOBAL *
              FOR. X,KIP   FOR. Y,KIP   FOR. Z,KIP MOM X,KIP-IN MOM Y,KIP-IN MOM Z,KIP-IN
             ***********  ***********  ***********  ***********  ***********  ***********
  MINIMUM         9.8845      -1.8853      -2.8907      -19.675       71.376       58.795
  Pile N.           4            3            2            1            2            1
  MAXIMUM         39.504       6.4967       3.2565       19.349       99.038       98.104
  Pile N.           1            1            1            4            1            3

  * PILE TOP DISPLACEMENTS, LOCAL *
              DISP. x,IN   DISP. y,IN   DISP. z,IN   ROT. x,RAD   ROT. y,RAD   ROT. z,RAD
             ***********  ***********  ***********  ***********  ***********  ***********
  MINIMUM       0.070337      -0.1523      -0.1385  -4.1421E-04  -2.2432E-03  -2.2811E-03
  Pile N.           4            4            3            3            3            1
  MAXIMUM         0.3088     0.085430       0.1370   3.7800E-04   2.2496E-03   2.2811E-03
  Pile N.           1            1            2            2            2            4

  * PILE TOP REACTIONS, LOCAL *
               AXIAL,KIP   LAT. y,KIP   LAT. z,KIP MOM x,KIP-IN MOM y,KIP-IN MOM z,KIP-IN
             ***********  ***********  ***********  ***********  ***********  ***********
  MINIMUM         9.8792      -2.8008      -2.2912  -4.6154E-03      -111.45      -137.12
  Pile N.           4            3            1            3            4            3
  MAXIMUM         40.101       2.0052       2.2112   4.2119E-03       113.33       102.91
  Pile N.           1            2            4            2            1            2

  * EFFECTS FOR LATERALLY LOADED PILE *

 PILE      DISPL.      DISPL.      MOMENT      MOMENT       SHEAR       SHEAR  SOIL REACT  SOIL REACT     TOTAL
            y-DIR       z-DIR       z-DIR       y-DIR       y-DIR       z-DIR       y-DIR       z-DIR     STRESS
             IN          IN        KIP-IN      KIP-IN        KIP         KIP       KIP/IN      KIP/IN   KIP/IN**2
 ******  **********  **********  **********  **********  **********  **********  **********  **********  **********
   Min.     -0.1523     -0.1385     -102.91     -111.45     -2.8106     -2.3004   -0.056689   -0.045541      0.3495
Pile N.        4           3           2           4           3           1           3           1           4
   Max.    0.085430      0.1370      137.12      113.33      2.0087      2.2135    0.040426    0.044915      5.8167
Pile N.        1           2           3           1           2           4           2           4           3
```

Figure 7 -11: GROUP® Results

From Figure 7-11, the important thing to look for is that the axial capacity of the pile (from the T-Z curve) is greater than or equal to 2 times the axial reactions (for an axial FS of 2.0). In this case the 85 kips from the T-Z curve is greater than 40*2= 80 kips.

Since the T-Z curve was changed during design, the Helicap® run needs to be run again to get an 85 kip pile. Here are the results.



HeliCAP-v2.0 SUMMARY REPORT

Job Name: H-Frame

Job Number:

Boring Number: B-1

Water Table Depth: 0

Application: Compression

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Capacity Summary

Pile Number	Helix Depth (ft)	Ult. Helix Bearing Capacity (kips)	Ultimate Recommended Helix Capacity (kips)	Installation Torque (ft-lbs)
Number:1				
Product: SS 175	Helix Gr:80	Thk:3/8"		
Helix Strength:	50.0 kips			
Datum Depth:0.0	Length:39.0	Angle:80.0		
Friction Analysis Method:	Gouvenot			
Friction Type: Concrete	Dia:6.0	Length:28.0		
14" helix	29.1	10.3t 18.9c	10.3t 18.9c	
14" helix	32.5	23.7t 27.0c	23.7t 27.0c	
12" helix	35.5	20.6t 22.7c	20.6t 22.7c	
10" helix	37.9	16.1t 17.3c	16.1t 17.3c	
Total Ult. Helix Tension (Qbt\Qht)		70.9t	70.9t	
Total Ult. Helix Compression (Qbc\Qhc)		86.0c	86.0c	7480
Total Ult.Friction(Qf)		6.8t/c	6.8t/c	
Total Ult.-Combined Capacity(Qc)		92.9c	92.9c	

Figure 7-9: Helicap Final Run

With a final ultimate capacity known, it is time to determine the installation requirements. With the helix configuration being a 10/12/14/14, the length of the lead is 11 ft. Therefore the grout will start 11 ft from the start of the pile. From the Helicap® report, it is known that in the 28 ft length, 6.8 kips of ultimate friction were developed a the estimated friction bearing capacity per foot is .242 kip/ft. Therefore, for every foot the pile is longer than 11 ft, it will require 0.242 kips less capacity per foot. So for example at 39 ft, it will only require 78.2 kip of bearing capacity. Being as torque to capacity ration Kt is 10:1, therefore, only 7,900 ft-lbs of torque is required instead of the 8,500 had friction not been included. With this known, it is possible to plot the required torque on a chart vs. depth as seen in Figure 7-13.

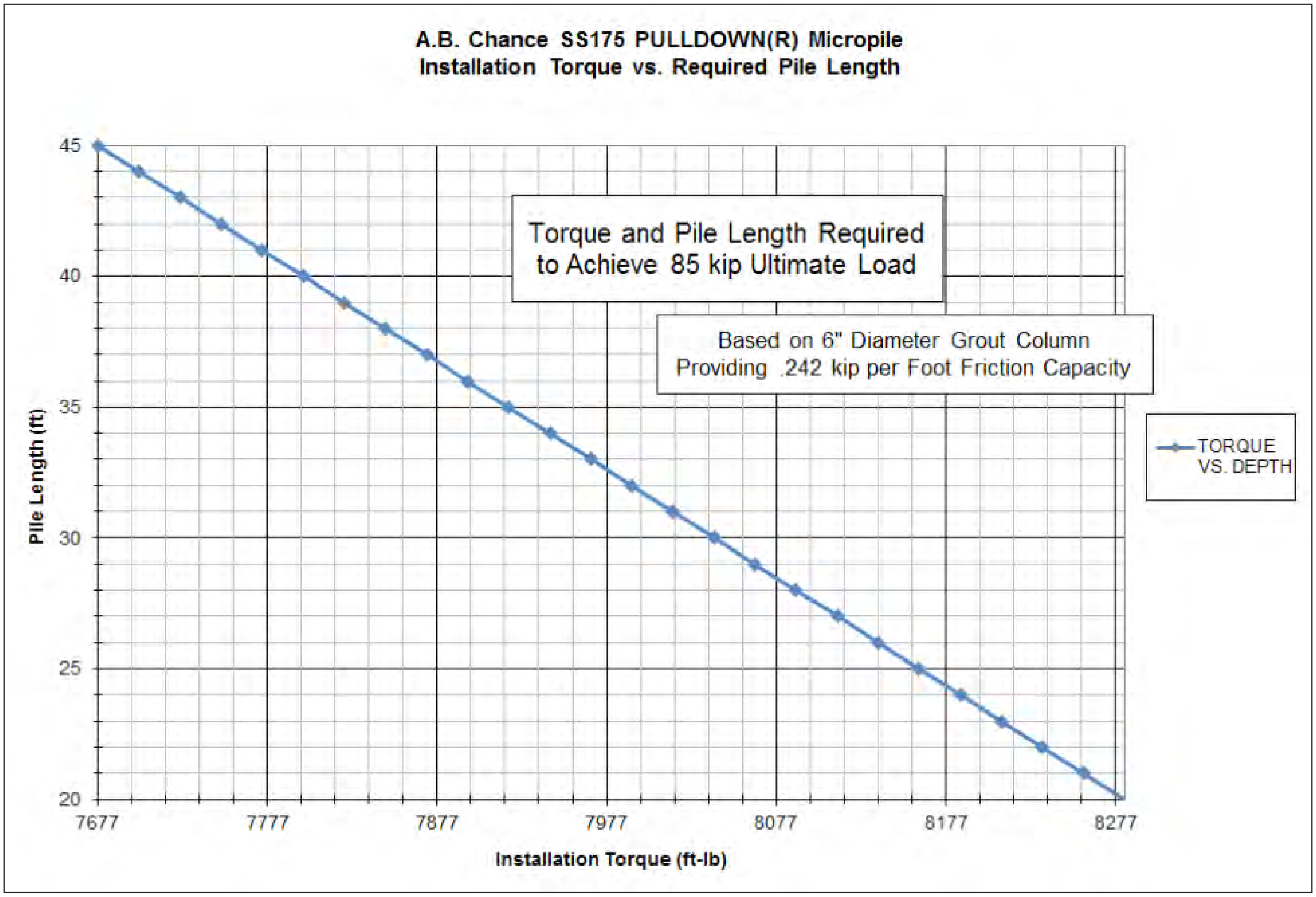


Figure 7 -13: Torque vs. Required Length

You will also want to include a pile layout for your design to make it a little less confusing. A simple pile layout for this design is included in Figure 7-14.

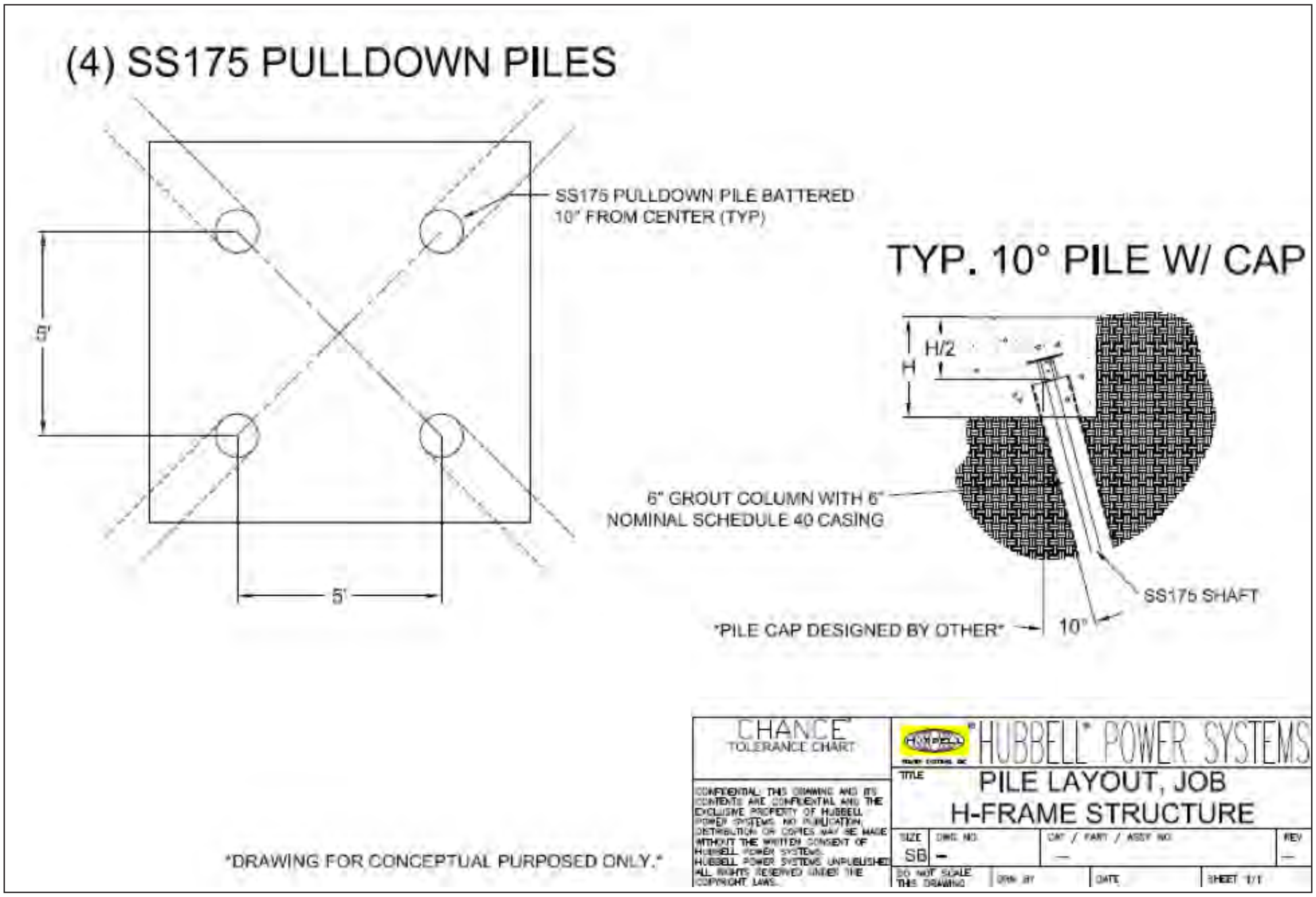


Figure 7 -14: Pile Layout

Recommendation:

1. **Install a SS175 Helical Pulldown Micropile**
    a. 6” Grout Column
    b. Case first 12 ft with minimum 6” Nominal Schedule 40 pipe per ASTM A500 GRD B
    c. Helix Configuration: 10/12/14/14
    d. Installation torque and length per attached installation torque vs required pile length plot Figure 7-13
    e. Locate piles per attached Pile Layout (Figure 7-14)
    f. Estimated Embedment: 40 ft
    g. Minimum embedment: 27 ft (16+11)

2. **Assumptions**
   a. Boring is representative of the site
      1. Water table depth: 0 ft.
   b. Loads given:
      i. 10kip Comp
      ii. 80kip Tension
      iii. Shear
         1. Transverse: 9.5kip
         2. Longitudinal 4kip
      iv. Moment:
         1. Longitudinal: 150kip ft.
   c. Piles are installed at ground level
   d. Torque to Capacity Ratio: 10:1
   d. Head Condition: Fixed
   e. Axial FS: 2.0
   f. Amount of Lateral deflection acceptable at working loads: 0.2

3. **Notes**
   i. May reach installation torque before reaching minimum embedment. Adhere to minimum embedment requirements
   ii. Ensure final torque is greater than required installation torque at given depth
   iii. Maximum torque for SS175 is 10,500 ft-lbs. Do not Overtorque! (Torque capacities can be found in the Drawings and Ratings section)

DESIGN EXAMPLE 4

MONOPOLE DESIGN WITHOUT GROUP

SYMBOLS USED IN THIS DESIGN EXAMPLE

Mp	PLASTIC MOMENT	7-30
FS	FACTOR OF SAFETY	7-28
K_t	TORQUE TO CAPACITY RATIO	7-31

Purpose

This design example is intended to assist with the design of small Monopole Structures. It will go through the basic design using hand calculations/L-pile. GROUP® can also be used for this eample.

The leg of the Monopole Structure will be supported by a concrete pile cap. This type of structure will generally have compression, shear, and moment loads that will need to be calculated or provided by the tower manufacturer

After the loads for the structure have been determined, it is possible to design the piles.

For this example the loading is as follows:

Loads

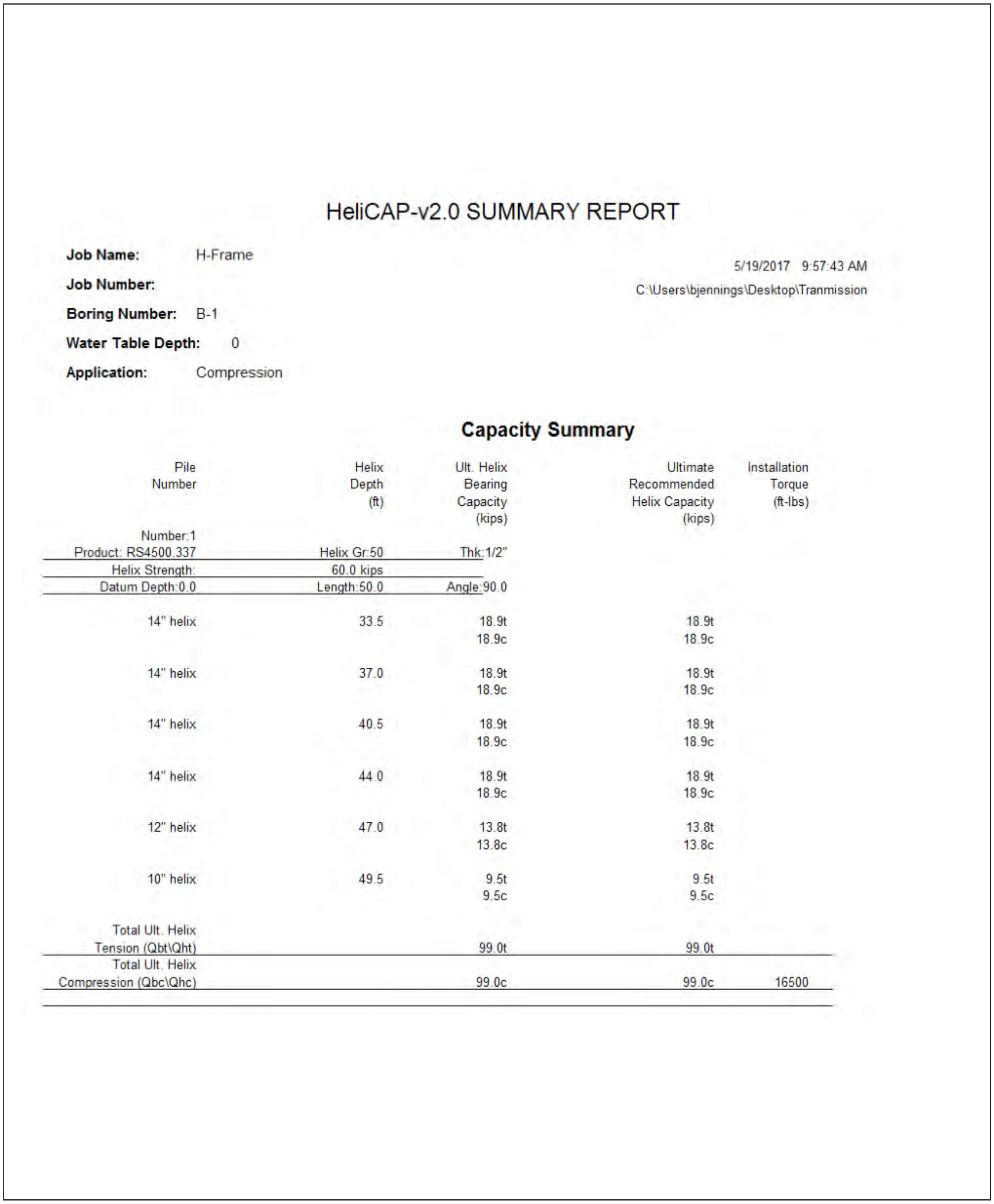
- Compression:
  - 50 kip
- Shear:
  - 40 kip
- Moment
  - 200 ft-kip

Soil Profile:

- Layers
  - 0-15 ft: 1000 psf clay
  - 15-30 ft: 1500 psf clay
  - >30ft: 2000 psf clay
- Water Table: Surface (0 ft)

Pile Capacity:

The first step in the design is to look at the soil profile and estimate a maximum ultimate axial capacity that can be attained. This is done by putting the boring into Helicap® and selecting the product line and helix configuration you wish to use. This value is generally the maximum capacity for the pile you wish to use (the axial capacities of shafts can be found in the Drawings and Ratings section), but can be lower if the soils are not very good.



HeliCAP-v2.0 SUMMARY REPORT

Job Name: H-Frame

Job Number:

Boring Number: B-1

Water Table Depth: 0

Application: Compression

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Capacity Summary

Pile Number	Helix Depth (ft)	Ult. Helix Bearing Capacity (kips)	Ultimate Recommended Helix Capacity (kips)	Installation Torque (ft-lbs)
Number:1				
Product: RS4500.337	Helix Gr:50	Thk:1/2"		
Helix Strength:	60.0 kips			
Datum Depth:0.0	Length:50.0	Angle:90.0		
14" helix	33.5	18.9t 18.9c	18.9t 18.9c	
14" helix	37.0	18.9t 18.9c	18.9t 18.9c	
14" helix	40.5	18.9t 18.9c	18.9t 18.9c	
14" helix	44.0	18.9t 18.9c	18.9t 18.9c	
12" helix	47.0	13.8t 13.8c	13.8t 13.8c	
10" helix	49.5	9.5t 9.5c	9.5t 9.5c	
Total Ult. Helix Tension (Qbt\Qht)		99.0t	99.0t	
Total Ult. Helix Compression (Qbc\Qhc)		99.0c	99.0c	16500

Figure 7-15: Helicap Printout

As can be seen from the Helicap® model, 99 kip can be attained using an RS4500.337.

L-pile/Hand Calc Method

For this analysis, the cap is going to be considered fully rigid. The first step is to determine a pile configuration and spacing, then ensure the load to the piles is not greater than allowable. In this case, the wanted configuration includes 9 piles (all with 100 kip capacity) and located on a 3x3 grid. A sample pile layout can be seen in Figure 7-16.

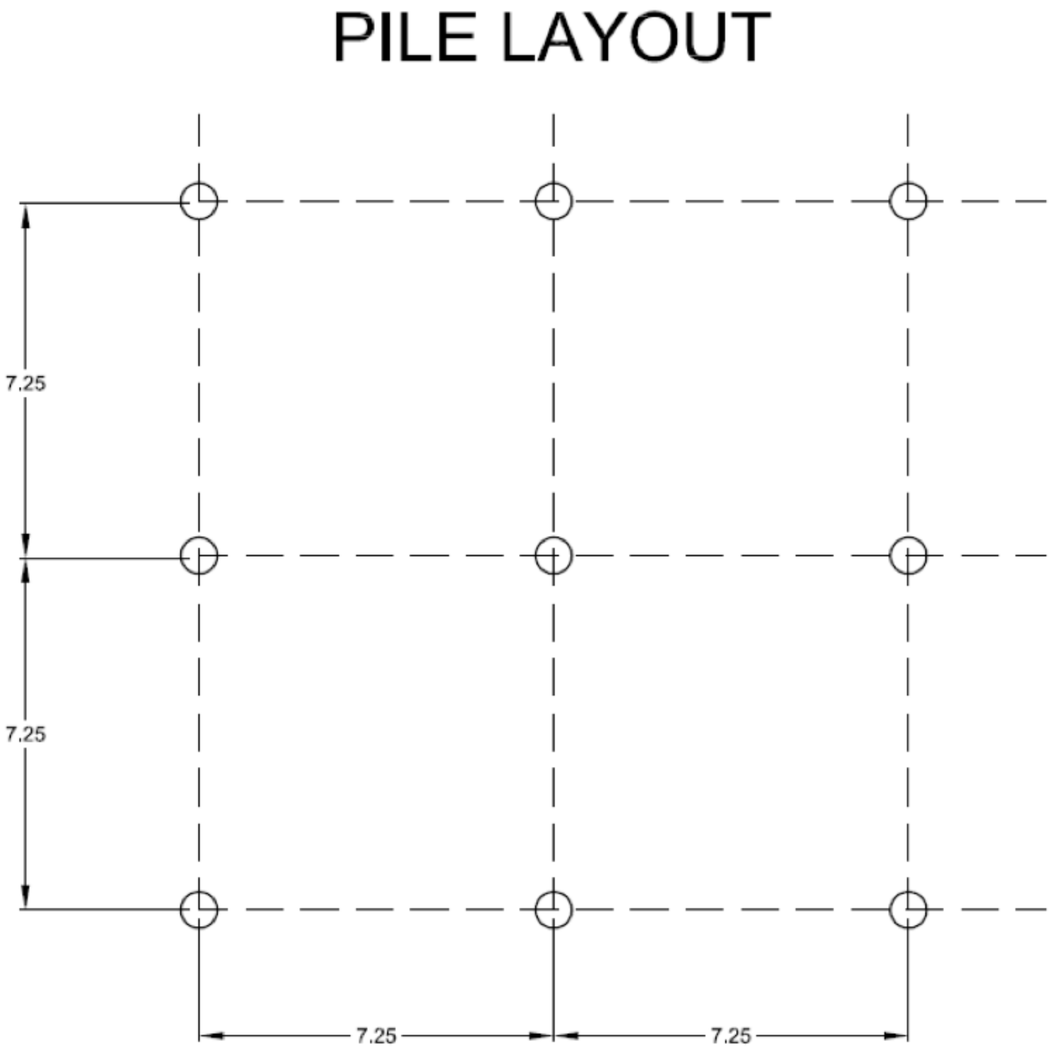


Figure 7-16: Anticipated Pile Layout

Because this example assumes the load can act in any direction, it is necessary to determine the worst case loading for this pile layout. In this case, two scenarios will be evaluated. In one case, the load acts along the lines in the grid. In the second case, it acts at a 45 to the first case. The two layouts can be seen in Figures 7-17.

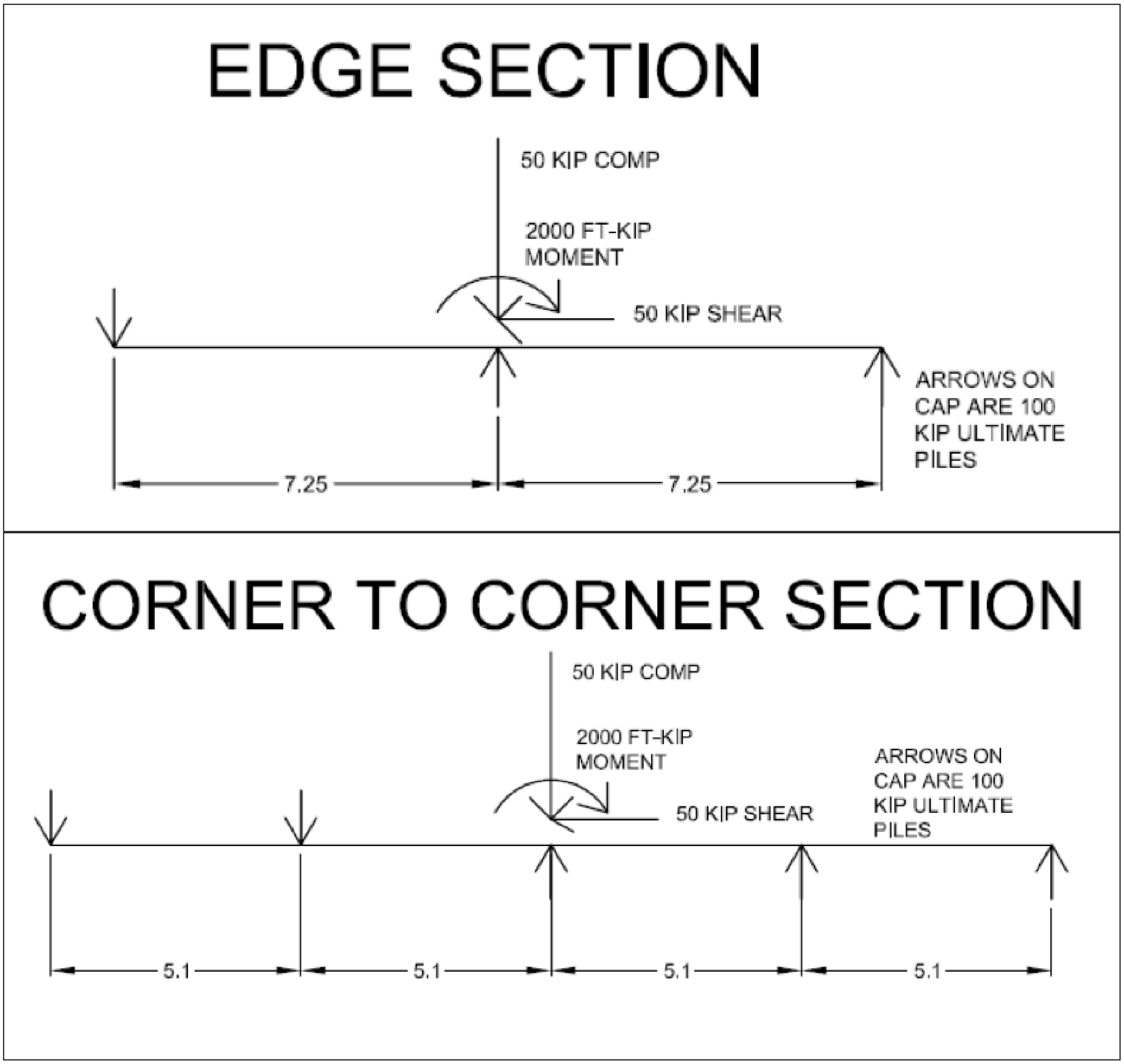


Figure 7-17 GROUP® Results

With the two layouts determined, it is now possible to analyze and ensure that the piles have the required capacity with the intended spacing. Because the pile cap will not be truly rigid and the fact that the piles can continue to deflect and carry their ultimate capacities, beyond the location they reach ultimate capacity, it will be assumed the capacity of each pile is 100 kips ultimate (50 kip working). To ensure the FS=2 kip will be used as the capacity of each of the 9 piles.

Because there are 3 piles that will not be taking any axial load from the moment in both cases, it is assumed that that axial load will be transferred through these piles and not through the other piles in the concrete cap.

It is now possible to calculate the amount of moment that can be resisted by the layout. This can be conducted by using a summation of moments about the center of the cap (location where load is applied).

Moment=Load*perpindicular distance **Equation 7-5**

Along the grid, the summation of moments would look like this (positive is resistance and negative is load):

$$\sum Moments = 7.25ft*50kip*3piles+7.25ft*50kip*3piles-2000kip\ ft=175\ kip\ ft$$

Therefore, the piles can resist an additional 175 kip-ft of moment with a FS of 2.0.

For the corner to corner analysis, the summation of moments looks like this:

$$\sum Moments = (10.3ft*50kip*1\ pile+5.1ft*50kip*2pile)*2-2000kip\ ft=50\ kip\ ft$$

Therefore, the piles can resist the moment and axial loads in both directions.

With the axial design completed, it is time to ensure the piles can take the shear loads. It is assumed that the piles will have a pinned pile head condition and the shear load is distributed to each pile evenly.

$$\frac{\text{Shear}}{\text{Pile}} = \frac{\text{Shear Force}}{\text{Number of Piles}} = \frac{\text{40 kip}}{\text{9 Piles}} = \text{4.44 kip/pile}$$

This shear load as well as an axial load of 50 kips are input into L-pile along with the pile properties for R345001337 (found in the Drawings and Ratings section of this manual) and soil properties. See the Design Methodology section for assistance as well as the L-pile manual for assistance in using L-pile. The resulting deflection curve is included in Figure 7-18 and the moment curve is included in Figure 7-19.

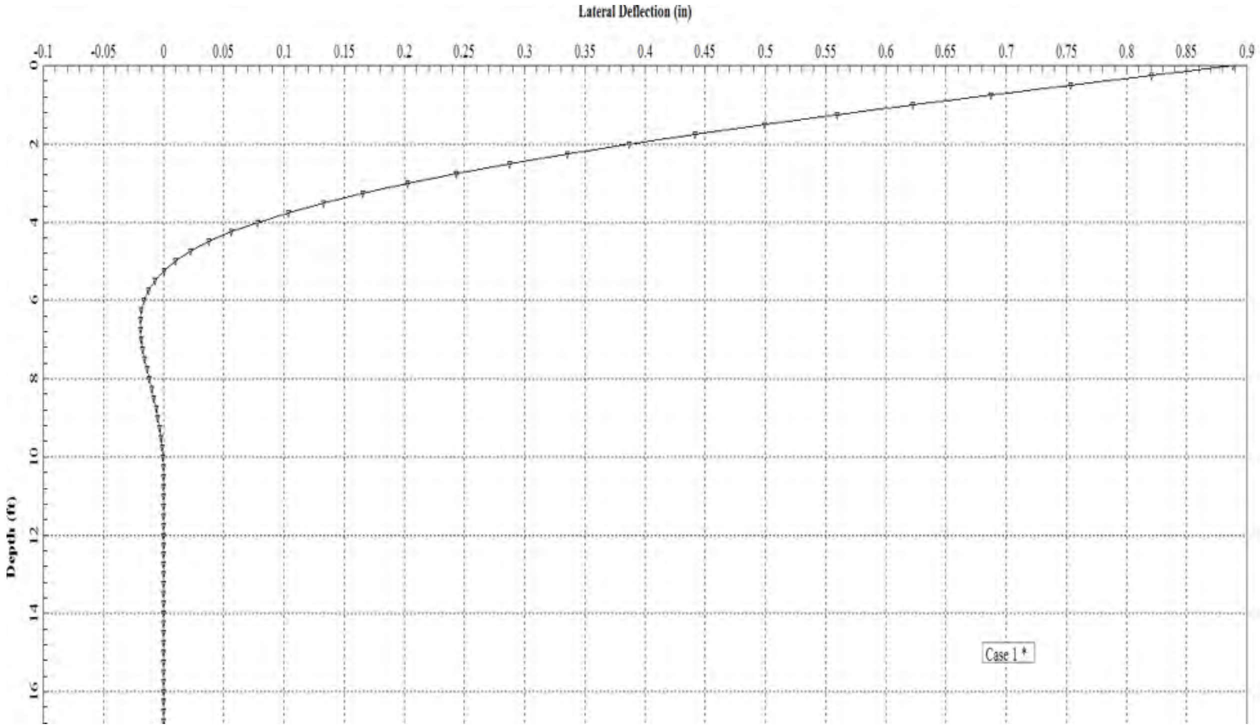


Figure 7-18: Lateral Deflection vs Depth

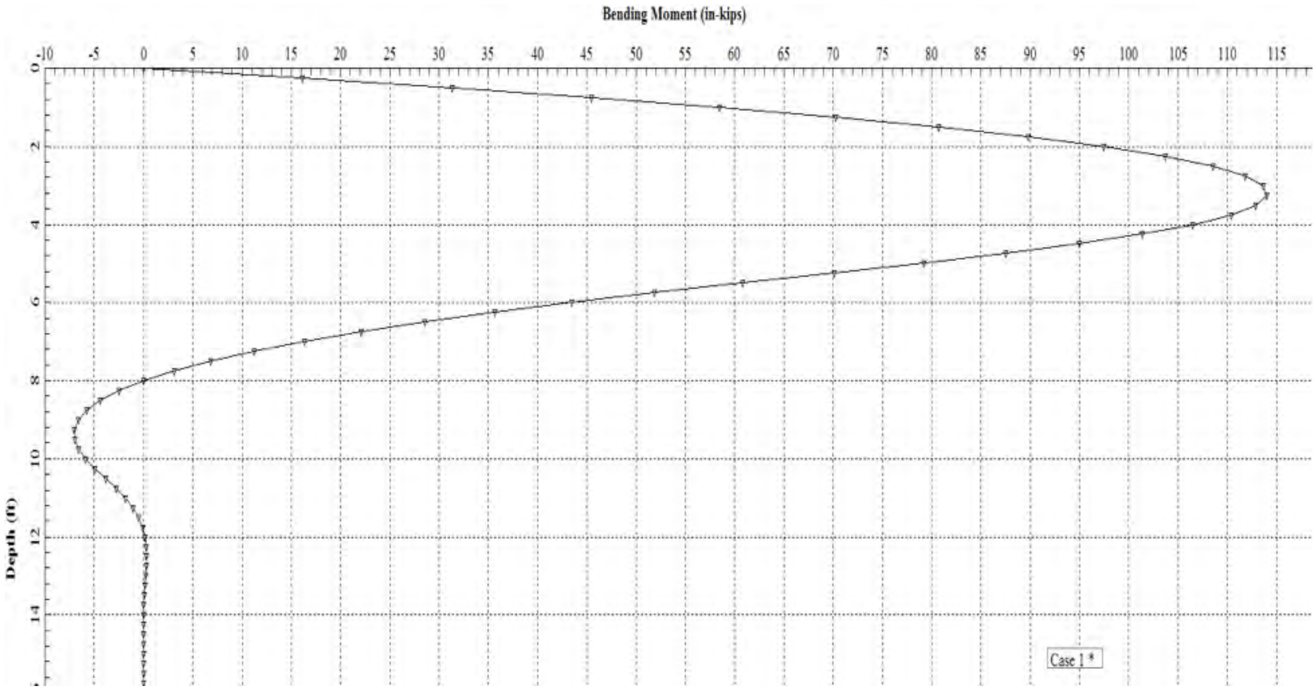


Figure 7-19: Bending Moment vs Depth

These results show that the piles will be able to carry the required shear capacity with 0.9” deflection and 114 kip-in of moment. This deflection is generally acceptable for transmission structures and the moment is less than the 0.6 Mp used in standard design.

Recommendation:

1. **Install 9-RS4500.337 Helical Piles**
    a. Helix Configuration: 10/12/14/14/14/14
    b. Installation torque: 16,700 ft-lbs
    c. Locate piles per attached Pile Layout (Figure 2)
    d. Estimated Embedment: 50 ft
    e. Minimum embedment: 20 ft

2. **Assumptions**
    a. Boring is representative of the location
        i. Water table depth is deeper than 50 ft
    b. Given loads are working (moment and shear can act in any direction)
        i. Compression: 50 kip
        ii. Moment: 2000 kip-ft
        iii. Shear: 40 kip
    c. Piles are installed at ground level
    d. Torque to Capacity Ratio for RS4500 is 6:1
    e. Pinned Head Condition
    f. Axial FS=2.0
    g. 1" of Lateral deflection acceptable at working loads

3. **Notes**
    a. May reach installation torque before reaching minimum embedment. Adhere to minimum embedment requirement
        i. Ensure final torque is greater than installation torque
    b. Maximum torque for RS4500.337 is 21,000 ft-lbs. Do not overtorque!

DESIGN EXAMPLE 5

GUYED TRANSMISSION STRUCTURE DESIGN

SYMBOLS USED IN THIS DESIGN EXAMPLE

Mp	PLASTIC MOMENT	7-34
FS	FACTOR OF SAFETY	7-34
K_t	TORQUE TO CAPACITY RATIO	7-35

Purpose

This design example is intended to assist with the design of Guyed Transmission Structure foundation. This example will show how to design using L-pile® and a pinned head condition grillage. This type of structure will generally have tension, compression, and shear loads that will need to be calculated or provided by the tower manufacturer.

After the loads for the structure have been determined, it is possible to design the piles.

For this example the working loading and soil profile is as follows:

Loads

- Center Base
  - Compression: 100 kip
  - Shear:
    - 1 kip
- Guyes
  - 30 kip

Soil Profile:

- Layers
  - 0-10 ft: 200 psf clay
  - 10-30 ft: 1000 psf clay
  - >30ft: 2000 psf clay
- Water Table: Surface (0 ft)

Pile Capacity:

The first step in the design is to determine the pipe shaft diameter or Micropile required to resist the lateral load. To do this, the pile properties, soil properties, and loads are put into L-pile. The pipe properties can be calculated for all pipe products with the information found in the Drawings and Ratings section of this manual. Generally working loads will be input into L-pile so that failure criteria of x lateral deflection at working loads can be used. In this example, 2R78625, 188 Pipe Piles will be used. The results are plotted in Figure 7-20 and Figure 7-21.

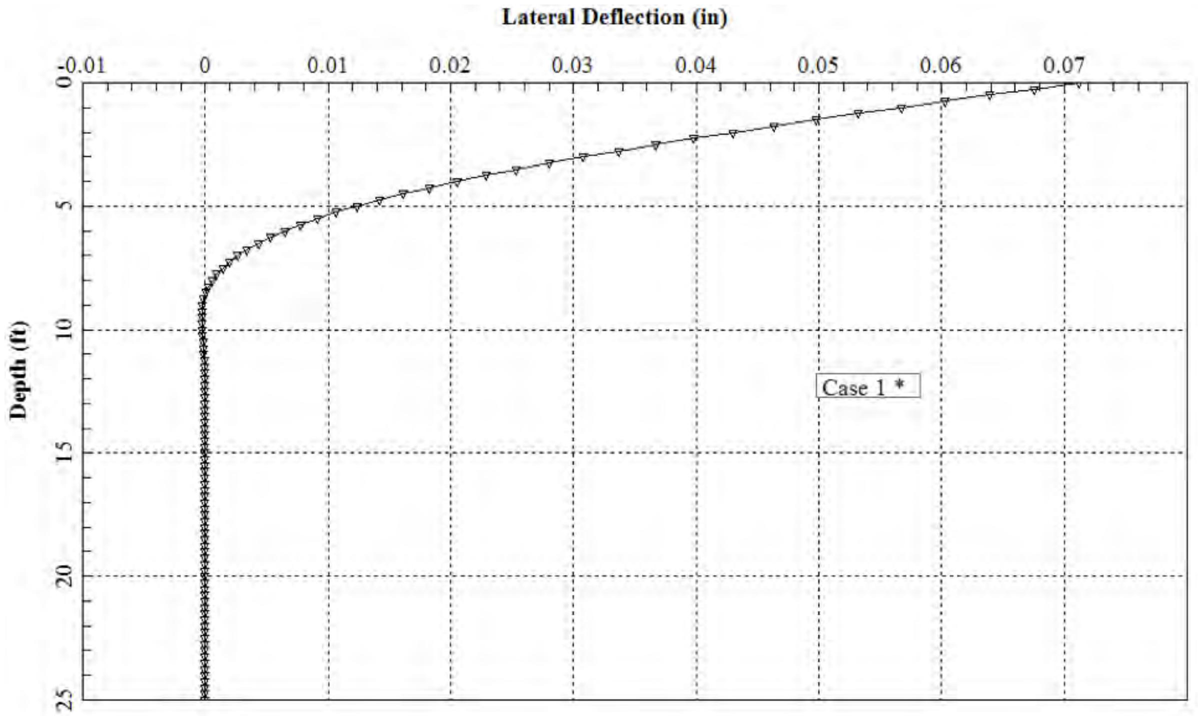


Figure 7-20: Lateral Deflection vs Depth

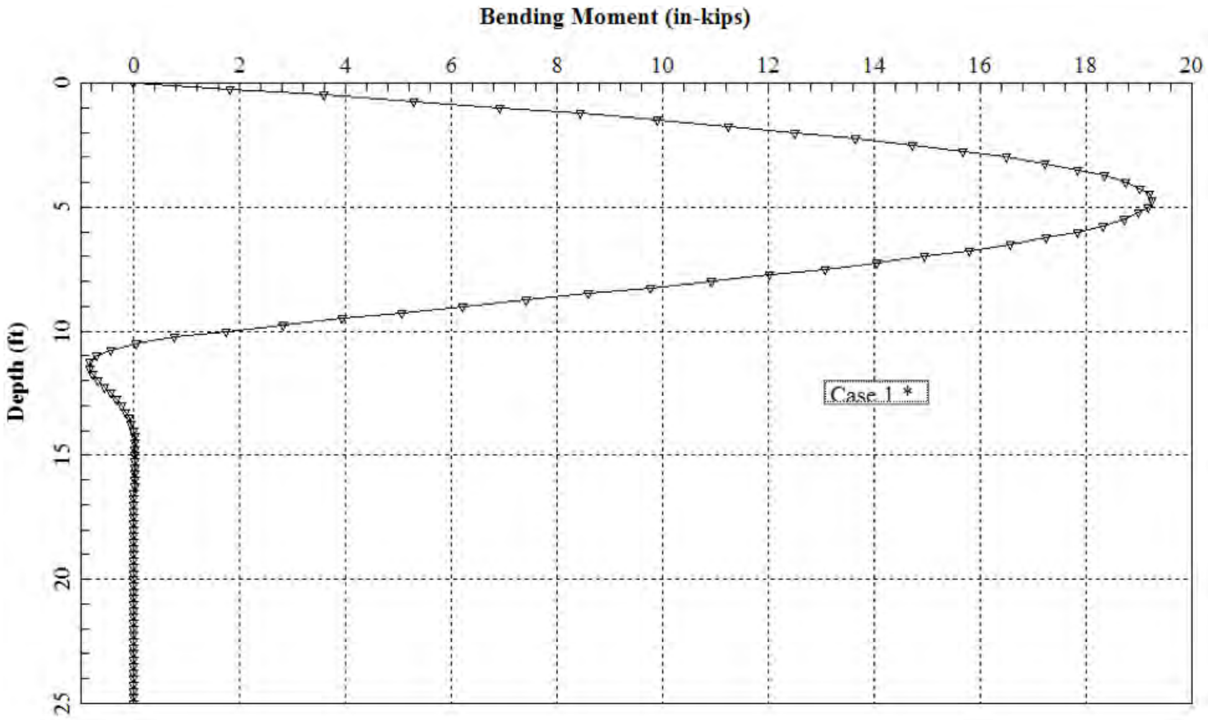
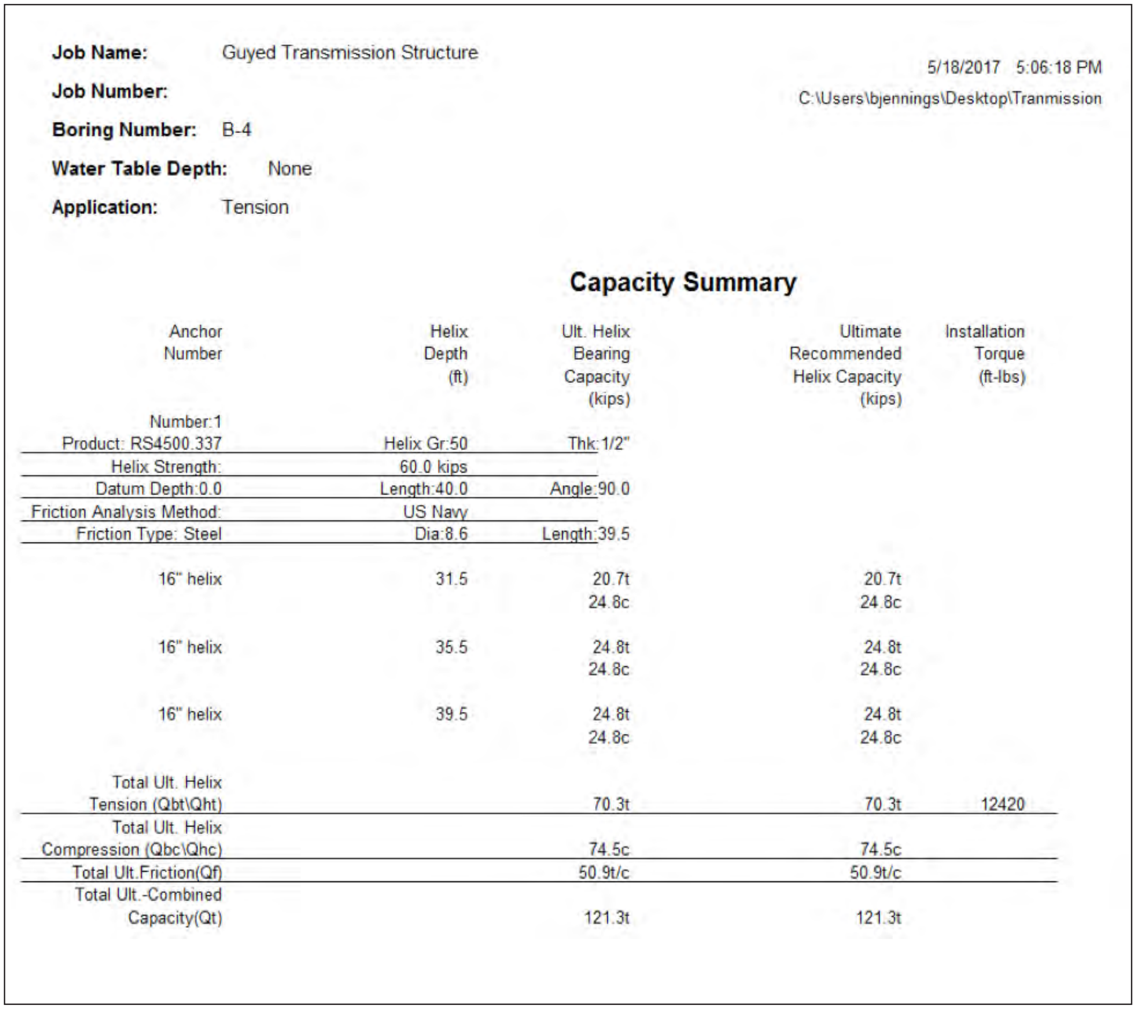


Figure 7-21: Lateral Deflection vs Depth

When looking at L-pile results, the goal is to have the deflection below what is allowable for the design and the moment less than 0.6Mp. These results show that 2-RS8625.188 wall pipes will carry the lateral load with an estimated 0.07" deflection and 20 kip-in of moment.

With the intended pipe shaft determined, Helicap® is now used to get a helix configuration and estimated installation depth for both the center piles as well as the guy anchors. Figure 3 is the Helicap® report for the center piles.



Job Name: Guyed Transmission Structure

Job Number:

Boring Number: B-4

Water Table Depth: None

Application: Tension

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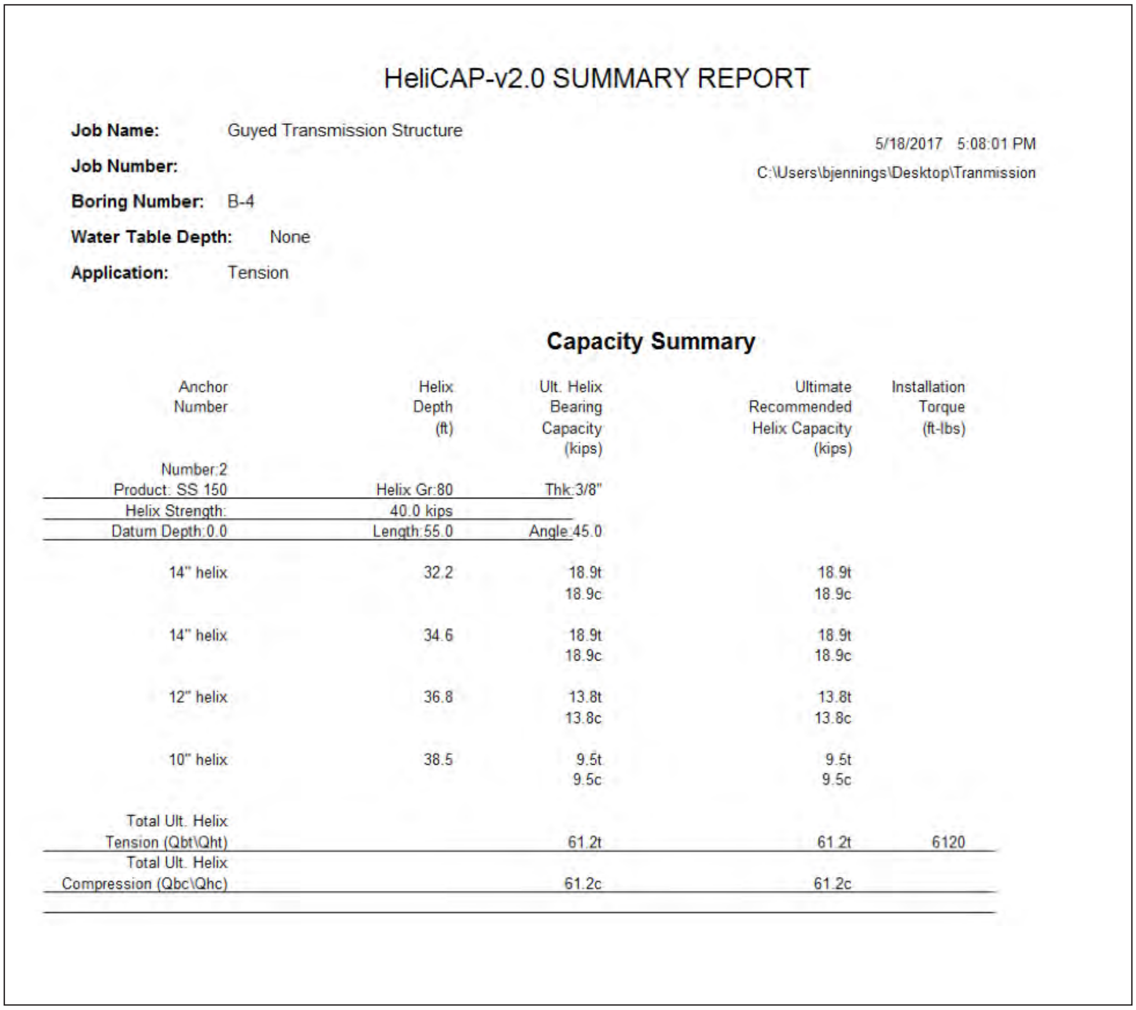
Capacity Summary

Anchor Number	Helix Depth (ft)	Ult. Helix Bearing Capacity (kips)	Ultimate Recommended Helix Capacity (kips)	Installation Torque (ft-lbs)
Number:1				
Product: RS4500.337	Helix Gr:50	Thk:1/2"		
Helix Strength:	60.0 kips			
Datum Depth:0.0	Length:40.0	Angle:90.0		
Friction Analysis Method:	US Navy			
Friction Type: Steel	Dia:8.6	Length:39.5		
16" helix	31.5	20.7t 24.8c	20.7t 24.8c	
16" helix	35.5	24.8t 24.8c	24.8t 24.8c	
16" helix	39.5	24.8t 24.8c	24.8t 24.8c	
Total Ult. Helix Tension (Qbt\Qht)		70.3t	70.3t	12420
Total Ult. Helix Compression (Qbc\Qhc)		74.5c	74.5c	
Total Ult.Friction(Qf)		50.9t/c	50.9t/c	
Total Ult.-Combined Capacity(Qt)		121.3t	121.3t	

Figure 7-22: RS8625.188 Helicap® Report

For the guy anchors, with the ultimate capacity known (FS*working), it is possible to design the anchor using Helicap®. See Figure 7-23 for results.



HeliCAP-v2.0 SUMMARY REPORT

Job Name: Guyed Transmission Structure

Job Number:

Boring Number: B-4

Water Table Depth: None

Application: Tension

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Capacity Summary

Anchor Number	Helix Depth (ft)	Ult. Helix Bearing Capacity (kips)	Ultimate Recommended Helix Capacity (kips)	Installation Torque (ft-lbs)
Number:2 Product: SS 150	Helix Gr:80	Thk:3/8"		
Helix Strength:	40.0 kips			
Datum Depth:0.0	Length:55.0	Angle:45.0		
14" helix	32.2	18.9t 18.9c	18.9t 18.9c	
14" helix	34.6	18.9t 18.9c	18.9t 18.9c	
12" helix	36.8	13.8t 13.8c	13.8t 13.8c	
10" helix	38.5	9.5t 9.5c	9.5t 9.5c	
Total Ult. Helix Tension (Qbt\Qht)		61.2t	61.2t	6120
Total Ult. Helix Compression (Qbc\Qhc)		61.2c	61.2c	

Figure 7-23: Guy Piles Helicap® Report

With these results, it is possible to calculate the required installation torques for the piles. For an 8" diameter pipe, the Kt is 4:1 and for SS150, Kt is 10:1. To calculate required torque, equation:

Installation Torque (ft-lbs)=required Capacity(kip)*1000/Kt **Equation 7-6**

The required installation torque for the RS8625 piles is 25,000 ft-lbs and for the guy anchors is 6,000 ft-lbs.

Recommendation:

1. **Center Piles**
    - a. Install 2-RS8625.188
        - i. Minimum spacing is 48" (6*largest helix dia)
        - ii. Installation Torque=25,000 ft-lbs
        - iii. Estimated embedment=40 ft
        - iv. Minimum embedment=15 ft

2. **Guy Anchors**
    - a. Install SS150 Helical Anchors
        - i. Minimum effective installation torque: 6,000 ft-lbs
        - ii. Estimated Embedement=55 ft
        - iii. Batter piles within ±5° of guy wires

2. **Assumptions**
        - i. Boring is representative of the location
        - 1. Water table deeper than 40 ft
    - ii. Loads given are working loads
        - 1. Center Base
            - a. Compression: 100 kip
            - b. Shear: 1 kip
        - 2. Guyes
            - a. 30 kip
    - iii. Piles are installed at ground level
    - iv. Torque to Capacity Ratio:
        - 1. RS8625 is 4:1
        - 2. SS150 is 10:1
    - v. RS8625 piles have pinned head condition
    - vi. Require an axial factor of safety of 2.0
    - vii. ½" of lateral deflection acceptable at working loads

3. **Notes**
    - a. May reach installation torque before reaching minimum embedment. Adhere to minimum embedment
        - i. Ensure final torque is greater than required installation torque at given depth
    - b. Maximum torque for RS8625.188 is 50,000 ft-lbs. Do not overtorque
    - c. Maximum torque for SS150 is 7,000 ft-lbs. Do not overtorque

DESIGN EXAMPLE 6

HELICAL PILE FOUNDATION FOR NEW SUBSTATION CONSTRUCTION

SYMBOLS USED IN THIS DESIGN EXAMPLE

P	ALLOWABLE DESIGN LOAD	7-38
FS	FACTOR OF SAFETY	7-38
Q_t	ULTIMATE PILE CAPACITY	7-38
K_t	TORQUE TO CAPACITY RATIO	7-38
A	AREA OF HELIX PLATE	7-38
C	COHESION OF SOIL	7-38
N_c	BEARING CAPACITY FACTOR	7-38
T	TORQUE	7-38
N	SPT BLOW COUNTS	7-38

Purpose

This design example is intended to assist with the design of new construction substation structures that require deep piles beneath a concrete cap for compression capacity. This example will show how to calculate the bearing capacity of four piles beneath a 10 feet square concrete cap holding an oil filled transformer.

After the loads for the structure have been determined, it is possible to design the piles.

For this example the working load is as follows:

- Compression: 56 kip (Load includes weight of concrete cap)
- Shear loads are assumed to be taken by up by passive pressure and fiction along the bottom of the concrete cap.

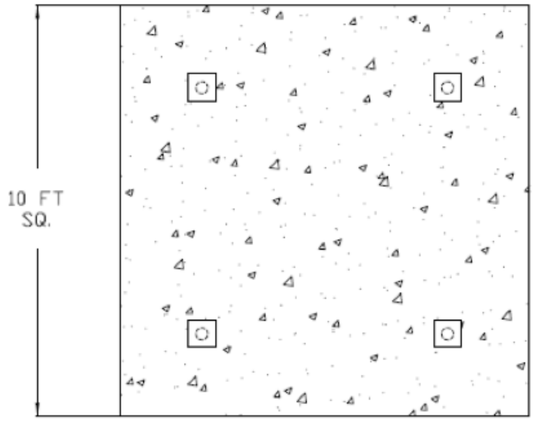


Figure 7-24

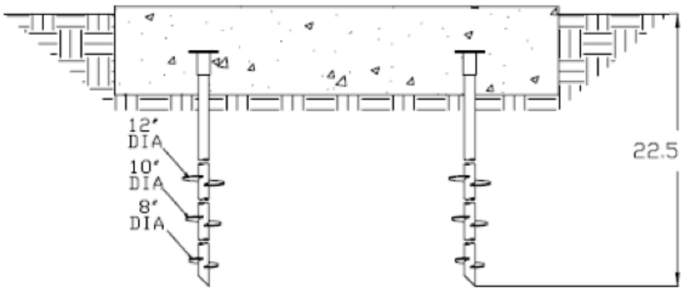
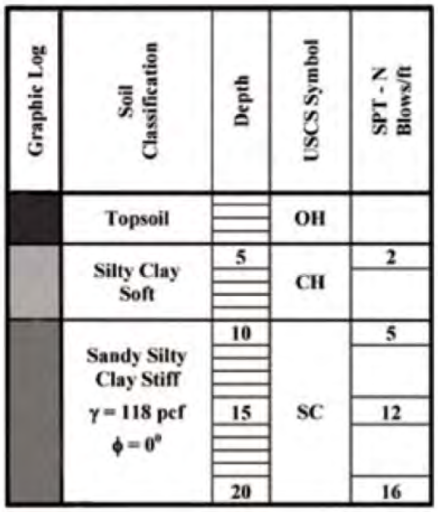


Figure 7-25

Soil Profile:



Graphic Log	Soil Classification	Depth	USCS Symbol	SPT - N Blows/ft
	Topsoil		OH	
	Silty Clay Soft	5	CH	2
	Sandy Silty Clay Stiff $\gamma = 118$ pcf $\phi = 0^\circ$	10 15 20	SC	5 12 16

Figure 7-26

CHANCE® Helical Pile Selection

RS2875.203 with 8-10-12 helix configuration

Ultimate Pile Capacity **Equation 7-7**

- $Q_t = (A_8 + A_{10} + A_{12})\ c\ N_c$

  A_8, A_{10}, A_{12} = Projected area of helical plates.

  $A_8 = 0.34\text{ft}^2$ $A_{10} = 0.53\text{ ft}^2$ $A_{12} = 0.77\text{ ft}^2$

  N_c = Bearing Capacity Factor = 9.0

  C = N/8 = 16/8 = 2 ksf
- $Q_t = (1.64\text{ft}^2)(2{,}000\text{ psf})(9.0)$
- $Q_t = 29{,}520$ lb (installed depth is over 20 ft)

Check Qt

- Conduct Field Load Test (if required per specifications)

Estimate installation Torque **Equation 7-8**

P = 56,000lb/4 Piles = 14,000 lb

$T = (P \text{ X } FS)/K_t = (14{,}000\text{ lb} \times 2)/9 = 3{,}150$ ft-lb

K_t = empirical torque factor (default value =9 for the RS2875 series)

The rated installation torque of the RS2875.203 series is 5500 ft-lb, which greater than the required estimated installation torque of 3,150 ft-lb. (OK)

NOTE: If during installation T = 3,150 ft-lb is not achieved then two options are available: (1) add piles if spacing allows, or (2) change helix configuration to a larger combination, i.e, (10-12-14) (3) Install Deeper

Factor of Safety **Equation 7-9**

- Theoretical Ultimate Capacity

  $FS = (Q_t/P) = 29{,}520/14{,}000 = 2.1$ (OK)
- Torque Correlation:

  $FS = (T \times K_t)/P$

  $FS = (3{,}150 \times 9)/14{,}000 = 2.03$ (OK)

DESIGN EXAMPLE 7

TYPE RS HELICAL PILES FOR SUBSTATION LATERAL SUPPORT

SYMBOLS USED IN THIS DESIGN EXAMPLE

C	COHESION FACTOR OF SOIL	7-40
P_s	APPLIED HORIZONTAL SHEAR LOAD	7-40
C_u	COHESION OF CLAY	7-40
D	DIAMETER OF FOUNDATION	7-40
L	MINIMUM LENGTH OF FOUNDATION	7-40
e	ECCENTRICITY	7-40
F	BENDING STRESS	7-40
M^{POS}_{mAX}	MAXIMUM BENDING MOMENT	7-40
FS	FACTOR OF SAFETY	7-40

Purpose

This design example is intended to assist with the design of new construction substation structures that requires a low axial load with high shear load on a single pile. This example will show how to calculate the lateral capacity of a single pile using the Broms' Method for a 345KV medium switch support.

After the loads for the structure have been determined, it is possible to design the piles.

For this example the working loading is as follows:

Loads

- Shear: 2300 lbs
- Shear applied to switch 10 feet above grade.

Soil Profile:

- Soil is a clay with a cohesion of 0.5 ksf.

Solution

P = Applied horizontal shear load: Use 2300 lbs. Include a Factor of Safety of 2 in the calculations, thus doubling the horizontal shear load; P = 2 x 2300 lbs = 4600 lbs

C_u = Cohesion of Clay: 500 psf

D = Diameter of foundation: Use D = 10.75” (10” nominal pipe size)

e = Eccentricity; distance above grad to resolve load: Given e = 10 ft.

L = Minimum Length of foundation based on above criteria.

$F = P/ [9 (C_u) D]$ **Equation 7-11**

$= 4600 \text{ lbs}/ [9 (500 \text{ psf}) (10.75\text{in}/12)]$

$= 1.141 \text{ ft}$

$M^{POS}_{mAX} = P (e +1.5D + 0.5F)$

$= 4600 \text{ lbs} [10 + 1.5(10.75 \text{ in} /12) + 0.5 (1.141 \text{ ft})]$

$= 54{,}806 \text{ ft-lbs}$

$M^{POS}_{mAX} = 2.25\ D \text{ x } g2 \text{ x } {}_{Cu}$

$54{,}806 \text{ ft-lb} = 2.25 (10.75 \text{ in}/12)\ g^2 (500 \text{ psf})$

$g^2 = 54.38$

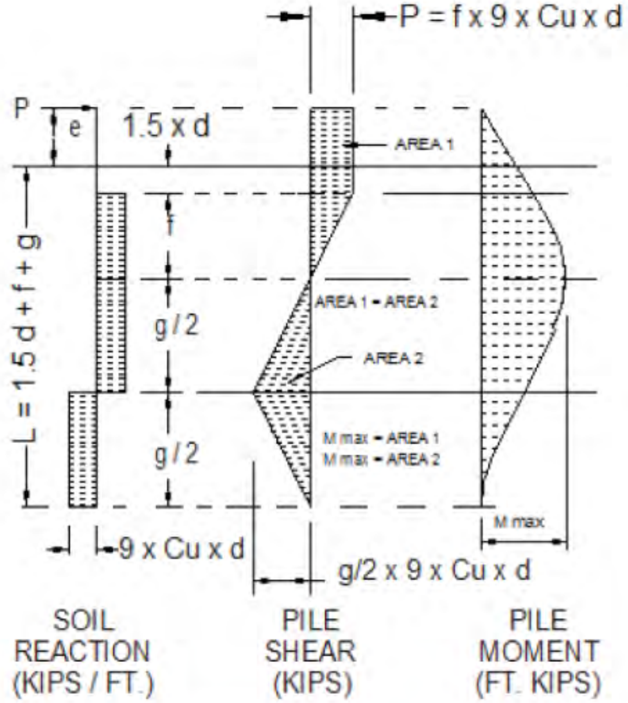
$g = 7.38 \text{ ft}$

$L = 1.5D + F + G$

$= 1.5 (10.75 \text{ in}/12) + 1.141\text{ft} + 7.38\text{ft}$

$= 9.87 \text{ FT}$

Summary
The 10” Nominal Round Shaft helical pile should be at least 10’-0 long to resist the 2300 lb lateral load applied 10 feet above grade



SHEAR AT DEPTH ((1.5 x d) + f) = 0.

f x 9 x Cu x d = P
f = P / 9 x Cu x d

AREA 1 = (P x (e + 1.5 d)) + 1/2 x f x P
= P x (e + 1.5 d + 1/2 x f)

AREA 2 = 1/2 x g x g/2 x 9 x Cu x d
= (g^2 / 4) x 9 x Cu x d
= 2.25 x d x g^2 x Cu

g = ((P x (e + 1.5d + .5f)) / (2.25 x d x Cu))^.5

M max = AREA 1 or AREA 2

M max = P x (e + 1.5d + .5f)

L = REQUIRED DEPTH INTO SOIL WITH COHESION OF "Cu

L = 1.5d + f + g

RECOMMENDED UNITS

d = PILE DIAMETER (FT.)
Cu = SOIL COHESION (KSF)
P = LATERAL LOAD (KIPS)
f = FT.
g = FT.
M max = MAXIMUM PILE BENDING MOMENT (FT.KIPS)
FB max = MAXIMUM PILE BENDING STRESS (KSI)

Energy Structures Incorporated
TITLE:
BROMS' METHOD - COHESIVE SOILS
DWG. NO.: 921102

Broms’ Method for Laterally Loaded Short Piles

Figure 7-26

DESIGN EXAMPLE 8

HELICAL PILE FOUNDATION FOR REMEDIATION OF SUBSTATION BUS SUPPORT

SYMBOLS USED IN THIS DESIGN EXAMPLE

ϕ	ANGLE OF INTERNAL FRICTION	7-43
γ	UNIT WEIGHT OF SOIL	7-43
N	SPT BLOW COUNTS	7-43
PC	ALLOWABLE DESIGN LOAD IN COMPRESSION	7-45
P_t	ALLOWABLE DESIGN LOAD IN TENSION	7-45
FS	FACTOR OF SAFETY	7-45
Q_t	ULTIMATE PILE CAPACITY	7-45
K_t	TORQUE TO CAPACITY RATIO	7-45
A	AREA OF HELIX PLATE	7-45
N_c	BEARING CAPACITY FACTOR	7-45
T	TORQUE	7-45

Purpose

This design example is intended to assist with the remediation design of a substation bus support that has settled. The plan of repair is to replace the central drilled concrete shaft beneath each leg with two type RS (Round Shaft) piles with a steel grade beam. The central concrete shaft will be demolioshed as well during pile install. This example will show how to calculate the axial capacity of the type RS piles and the lateral capacity of the type RS pile, using L-pile.

After the loads for the structure have been determined, it is possible to design the piles.

For this example the loading is as follows:

Loads

- Compression: 5,000 lbs
- Tension: 2,000 lbs
- Shear Long Direction: 1,200 lbs
- Shear Trans Direction: 1, 200 lbs
- Moment About Long Axis: 10,000 ft-lbs
- Moment About Trans Axis: 0 ft-lbs

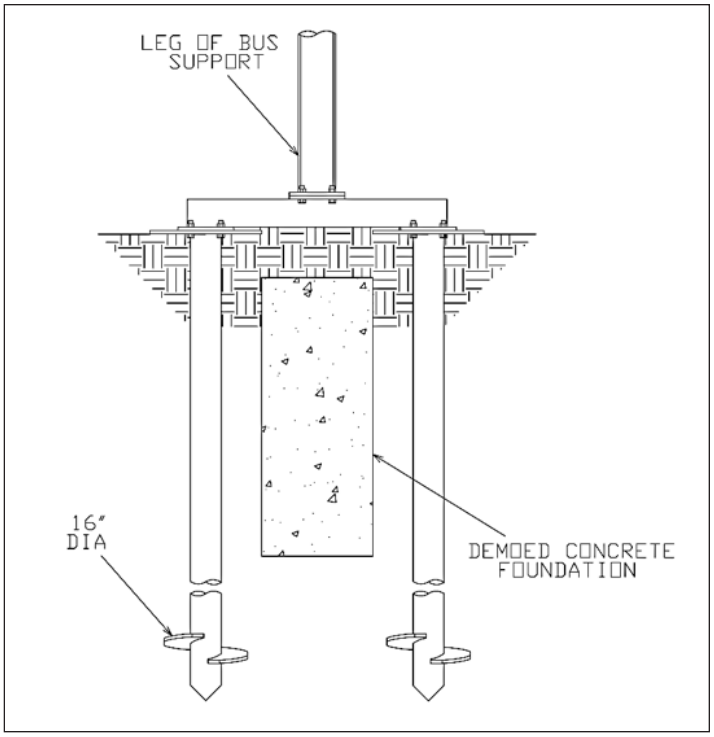


Figure 7-27

Soil Profile:

Soil Description	Depth ft.	SPT -N Blows/ft
Silty Sand Loose γ=90lb/ft3 ϕ=27°	0	4
Sand γ=120lb/ft3 Φ=30°	5	10

Note: Water Table = 0 FT

Figure 7-28

CHANCE® Helical Pile Selection
RS6625.280 with a single 16” diameter helix

Lateral Capacity Analysis using L-Pile
Moment load about the longitudinal axis is assumed to be transferred to the piles in tension and compression. The piles will require passive resistance of the resultant shear load of $(1,200^2 + 1,200^2)^{1/2}$= 1,698 lbs with a maximum deflection under this load of 1/2” that is typical for substation structures. L-Pile yields the following output for this shaft that is within the design parameters and requires a minimum embedment of 14 feet.

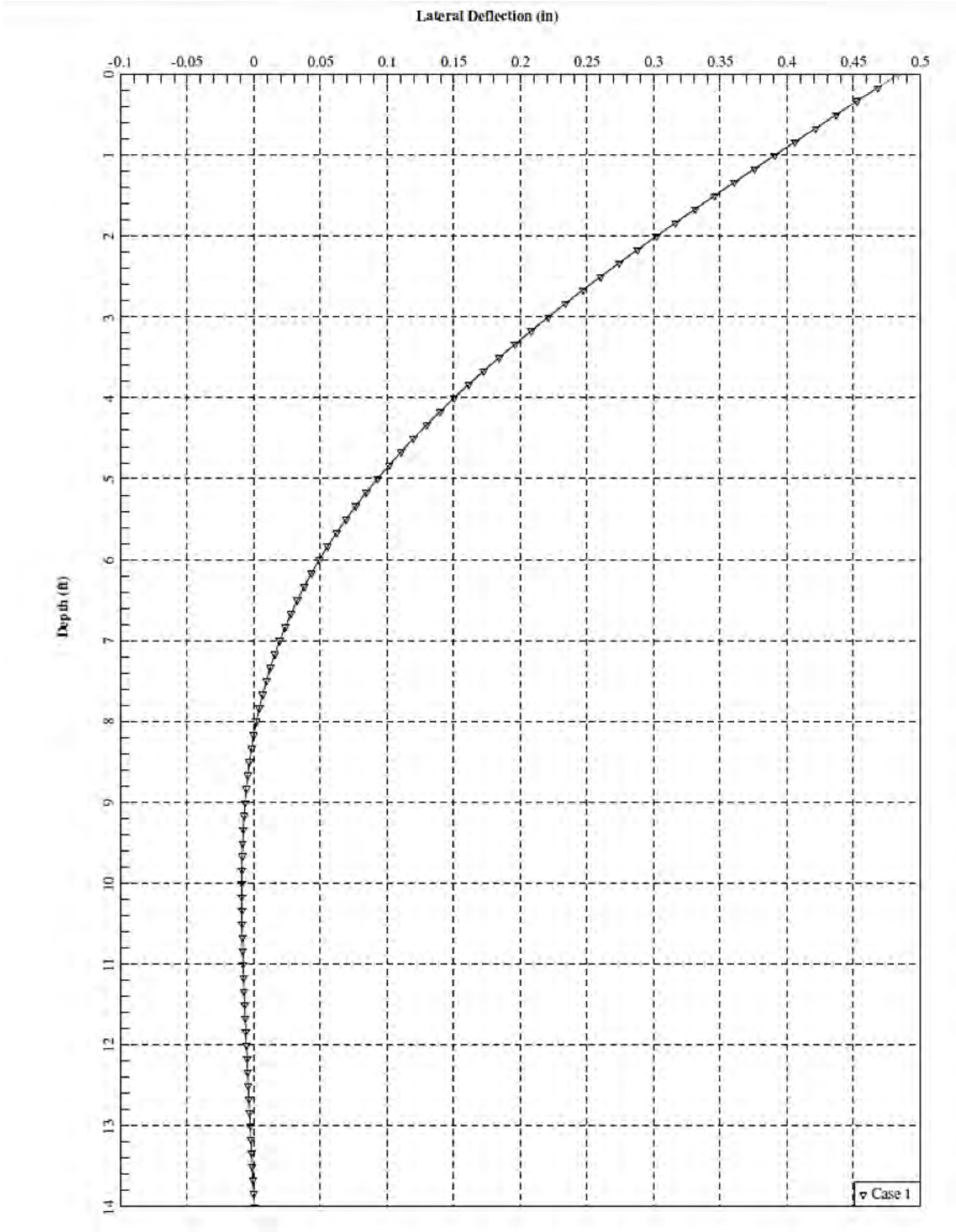


Figure 7-28

Ultimate Pile Capacity

- Pc= Compression/2 piles + 10,000 ft-lbs/4 ft spacing
  = (5000 lbs / 2) + 2,500 lbs
  = 5,000 lbs
- P_t= Tension/2 piles + 10,000 ft-lbs/4 ft spacing
  = (2000 lbs / 2) + 2,500 lbs
  = 3,500 lbs
- $Q_t = (A_{16})\ q_h\ N_q$
  A_{14} = Projected area of helical plates.
  Compression will have full helix area = A_{16C} = 1.281 ft^2
  Tension will area will be full helix area minus pipe shaft = A_{16T} = 0.972 ft^2
  N_q = Bearing Capacity Factor related to ϕ of residual soil (30°) = $0.5\ (12 \text{ x } \Phi)\ \Phi^{/54} = 13$
- $q_h = \gamma' \text{ x } D_h$ (Effective unit weight times depth of helix below ground line, ft)
  = (90 pcf – 62.4pcf) (5ft) + (120 pcf – 62.4pcf) (8.5ft)
  = 627 psf
- QtC = (1.281 ft^2) (627 psf) (13) = 10,441 lbs (Ultimate Compression Capacity)
- QtT = (0.972 ft^2) (627 psf) (13) = 7,922 lbs (Ultimate Tension Capacity)

Check Qt

- Conduct Field Load Test (if required per specifications)

Estimate installation Torque

P = 5000 lbs
$T = (P \text{ X } FS)/K_t$ = (5,000 lb x 2)/5 = 2,000 ft-lb
K_t = empirical torque factor (default value =5 for the RS6625 series)

NOTE: If during installation T = 2,000 ft-lb is not achieved then two options are available: (1) install piles deeper, or (2) change helix configuration to a larger combination, i.e, (16-18)

Factor of Safety

- Theoretical Ultimate Bearing Capacity
  FS = (Q_{tC}/P) = 10,441/ 5,000 = 2.09 (OK Compression)
  FS = (Q_{tT}/P) = 7,922 / 3,500 = 2.26 (OK Tension)

DESIGN EXAMPLE 9

INSTANT FOUNDATIONS® for STREET LIGHT SUPPORTS

SYMBOLS USED IN THIS DESIGN EXAMPLE

SLF	STREET LIGHT FOUNDATION	7-46
DL	DEAD OR DOWN LOAD	7-47
V	HORIZONTAL OR LATERAL SHEAR LOAD	7-47
M	MOMENT LOADS	7-47
AASHTO	AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS	7-47
L	REQUIRED LENGTH	7-48
C	COHESION OF SOIL	7-48
FS	FACTOR OF SAFETY	7-48
V_F	APPLIED SHEAR AT GROUNDLINE INCLUDING FACTOR OF SAFETY	7-48
V_M	APPLIED MOMENT AT GROUNDLINE INCLUDING FACTOR OF SAFETY	7-48
D	DIAMETER OF FOUNDATION	7-48
q	BROMS' COEFFICIENT	7-48
M_{MAX}	MAXIMUM MOMENT APPLIED TO FOUNDATION	7-48
φ	INTERNAL ANGLE OF FRICTION	7-49
γ	UNIT WEIGHT OF SOIL	7-49
K_P	PASSIVE EARTH PRESSURE COEFFICIENT	7-49

Purpose

This design example provides example solutions to aid in the selection of appropriate CHANCE® 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 7-30).

wp = Wind Pressure

EPAlf = Effective Projected Area of a Light Fixture

EPAp = Effective Projected Area of a Light Pole

Hlf = Moment Arm to EPAlf Centroid

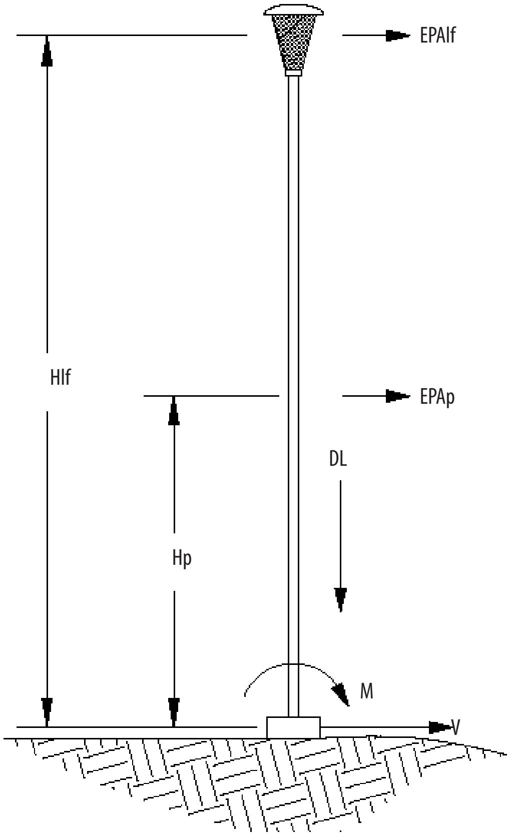
SLF REACTIONS

Vlf = [EPAlf x wp]

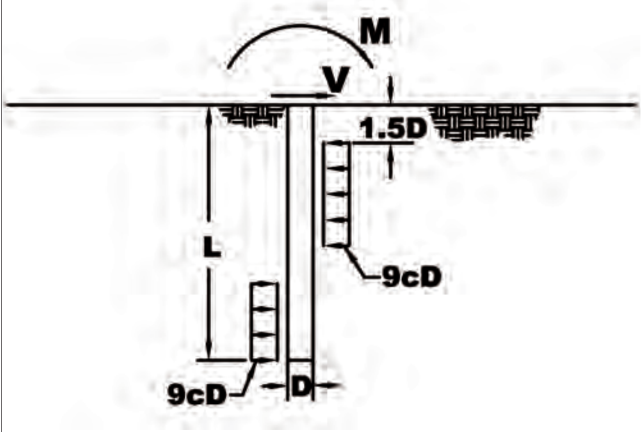
Vp = [EPAp x wp]

V = Vlf + Vp

M = [Vlf x Hlf] + [Vp x Hp]



Pole Load Diagram
Figure 7-30



Foundation in Cohesive Soil
Figure 7-31

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 that 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 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 7-31)

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.

V_F = V (FS) **Equation 7-12**

= 460 (2)

= 920 lbs

V_M = M (FS) **Equation 7-13**

= 8600 (2)

= 17,200 ft-lbs

L = 1.5D+q [1+{ 2 + (4H+6D)/q} $^{0.5}$] **Equation 7-14**

= 1.5 (6.625/12) + 0.185157 x [1 + { 2+ (4 x 18.69565 + 6 x (6.625/12)) / (0.185157)} $^{0.5}$]

= 4.82 ft

where:

D = Diameter of foundation = 6.625 inches

q = V_F/9cD = 920 / (9 x 1000 x 6.625/12) = 0.185157ft

c = Shear strength of cohesive soil = 1000 psf

H = Moment / Shear = M/V = V_M / V_F = 17200 ft-lbs / 920 lbs = 18.69565 ft

L = Calculated Foundation Length to Provide a SF of 2 Against Soil Failure.

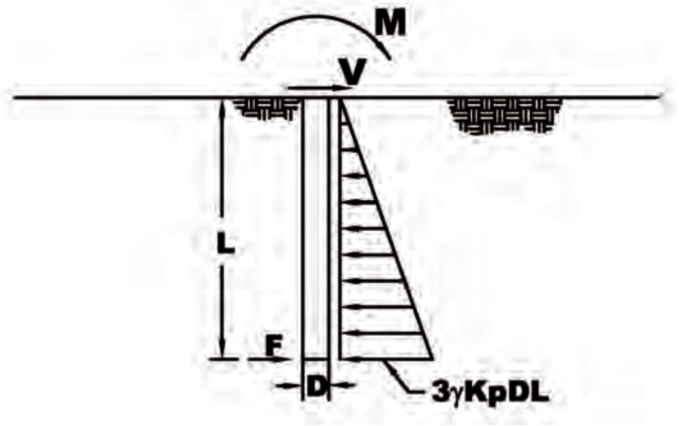
The length required to provide a Factor of Safety of 2 against soil failure is 4.82 ft. Since SLF lengths are provided in even foot lengths, use L = 5 ft. For the required embedment length, the maximum moment in the shaft is:

M_{MAX} = V (H + 1.5D + 0.5q) **Equation 7-15**

= 460 (18.69565 + (1.5 x 6.625/12) + (0.5 x 0.185157)

= 9023.5 ft-lbs

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.



Foundation in Cohesionless Soil
Figure 7-32

Cohesionless Soil (See Figure 7-32)

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.
- $\phi = 30°$
- $\gamma = 100$ lbs/ft3
- Factor of Safety = 2.

$= V\ (FS)$ **Equation 7-16**

$V_F = 460\ (2)$

$= 920$ lbs

$= M\ (FS)$ **Equation 7-17**

$V_M = 8600\ (2)$

$= 17{,}200$ ft-lbs

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:

$0 \leq L^3 - (2V_F L / K_{P_\gamma} D) - (2VM / K_{P_\gamma} D)$ **Equation 7-18**

$= 6^3 - [2 \times 920 \times 6) / (3 \times 100 \{6.625/12\})] - [(2 \times 17200) / (3 \times 100 \times \{6.625/12\})]$

$= -58.35$

where:

$0 > -58.35$

$K_P = \tan^2 (45 + \varphi/2) = 3.0$

γ = Effective unit weight of soil = 100 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:

$M_{MAX} = V(H + 0.54 \times (V / \gamma D K_P)^{0.5})$ **Equation 7-19**

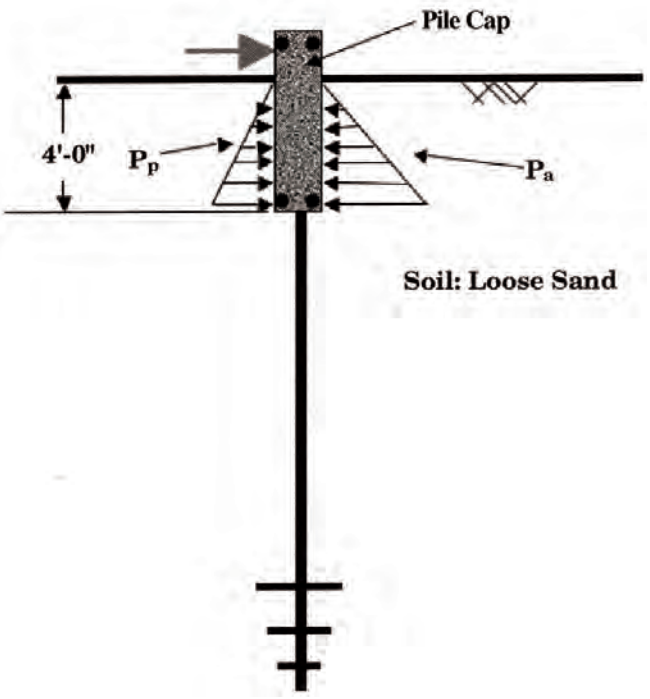
$= 460\ (18.69565 + 0.54 \times (460/100 \times (6.625/12) \times 3)^{0.5})$

$= 9013.968$ 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 10
FOUNDATION EARTH PRESSURE RESISTANCE
SYMBOLS USED IN THIS DESIGN EXAMPLE

PCF	POUNDS PER CUBIC FOOT	7-50
K_A	ACTIVE EARTH PRESSURE COEFFICIENT	7-50
K_P	PASSIVE EARTH PRESSURE COEFFICIENT	7-50
P_A	ACTIVE LOAD	7-51
P_P	PASSIVE LOAD	7-54



Earth Pressure on a Grade Beam
Figure 7-33

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, $K_a = 0.2$, $K_p = 3$

Solution

$P_a = 0.5K_a\gamma H^2$ **Equation 7-20**

$= 0.5 \times 0.2 \times 95 \times 42$

$= 152$ lb/ft

$P_p = 0.5K_p\gamma H^2$

$= 0.5 \times 3 \times 95 \times 42$

$= 2280$ lb/ft

$P_p - P_a = 2280 - 152$

$= 2128$ lb/ft

Total lateral resistance = 2128 x 25'-0 = 53,200 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)

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.

Figure 7-34

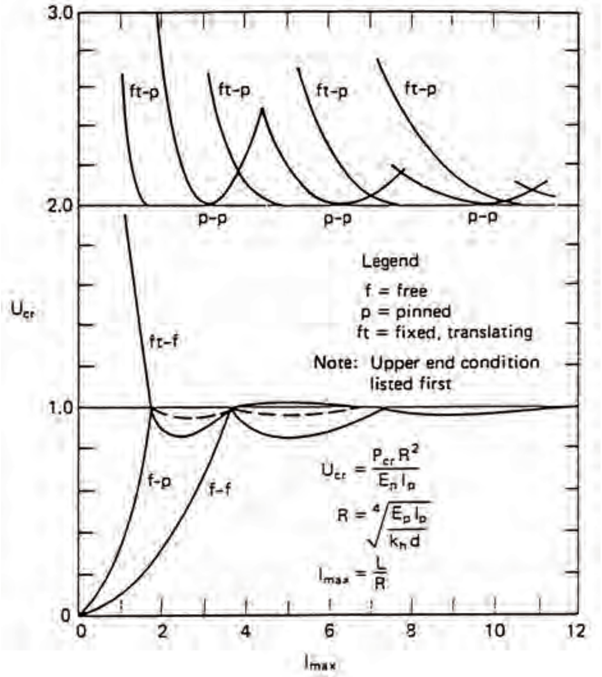
DESIGN EXAMPLE 11
BUCKLING EXAMPLE USING THE DAVISSON METHOD
SYMBOLS USED IN THIS DESIGN EXAMPLE

k_h	Empirical Torque Factor for Helix	7-52
U_{cr}	Critical Capacity	7-52
R	Resistance	7-53
I_{max}	Maximum Moment of Inertia	7-53
P_{cr}	Critical Pressure	7-53
E_p	Modulus of Elasticity	7-53
I_p	Moment of Inertia	7-53
D	Shaft Diameter	7-53
kip	Kilopound	7-53

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 7-35, $U_{cr} \approx 2$



Poulos and Davis (1980)
Figure 7-32

$R = {}^4\sqrt{}(30 \times 10^6 \times 0.396) / (15 \times 1.5) = 26.96$ **Equation 7-21**

$I_{max} = (15 \times 12) / 26.96$

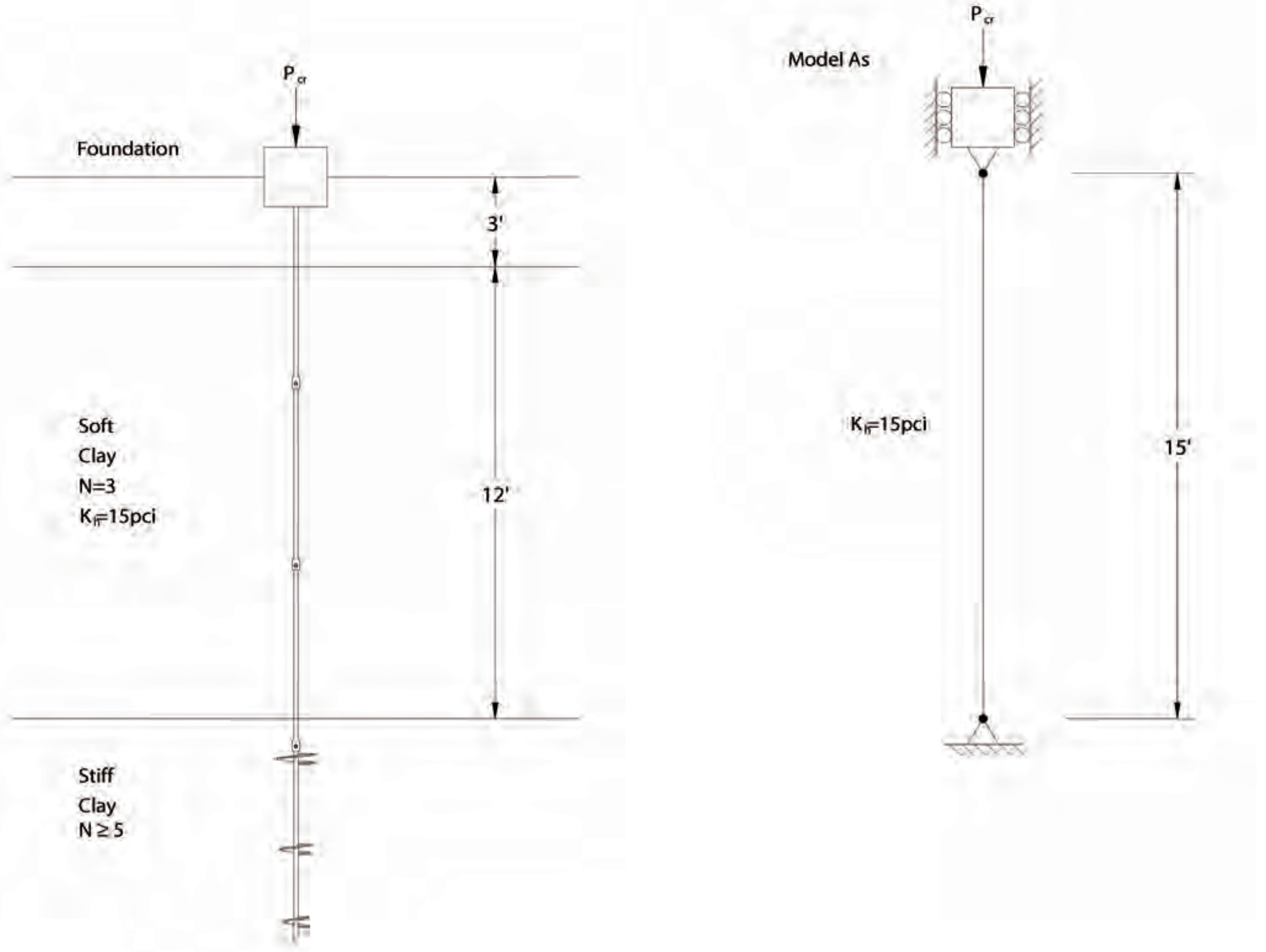
$= 6.7$

$P_{cr} = (2 \times 30 \times 106 \times 0.396) / 26.96^2$

$= 32.69$ kips

CHANCE® HELICAL TYPE SS150 SQUARE SHAFT FOUNDATIONS PHYSICAL PROPERTIES, TABLE 7-1

MODULUS of ELASTICITY (E_p)	MOMENT of INERTIA (I_p)	SHAFT DIAMETER (D)
30×10^6 psi	0.396 in^4	1.5 in



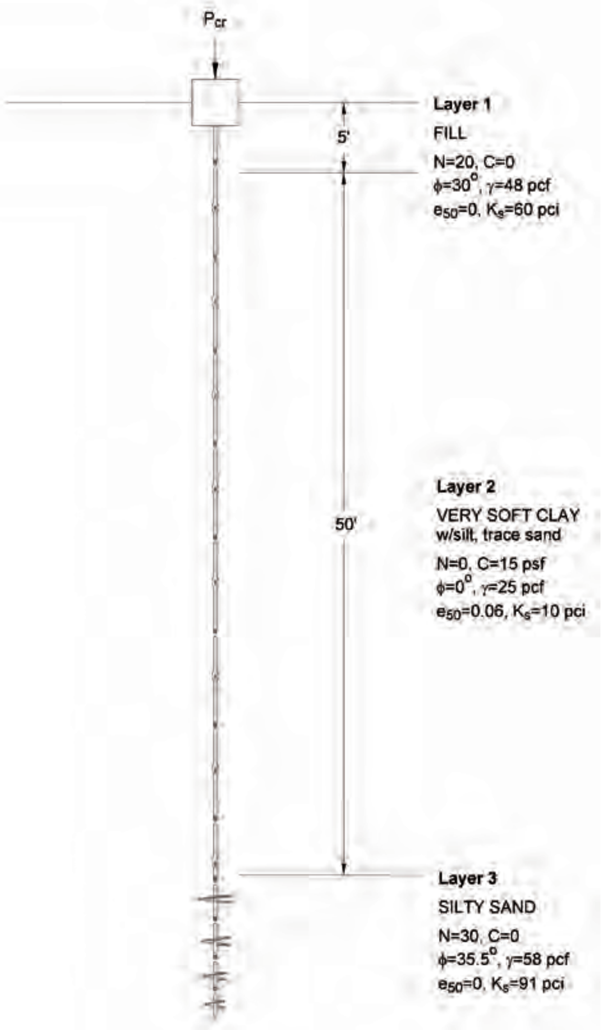
Foundation Details
Figure 7-36

DESIGN EXAMPLE 12

BUCKLING EXAMPLE USING THE FINITE DIFFERENCE METHOD

SYMBOLS USED IN THIS DESIGN EXAMPLE

WOH	Weight of Hammer	7-54
WOR	Weight of Rod	7-54
psf	Pounds per Square Foot	7-55
ID	Inside Diameter	7-55
HPM	CHANCE HELICAL PULLDOWN® Micropile	7-55



Foundation Details
Figure 7-37

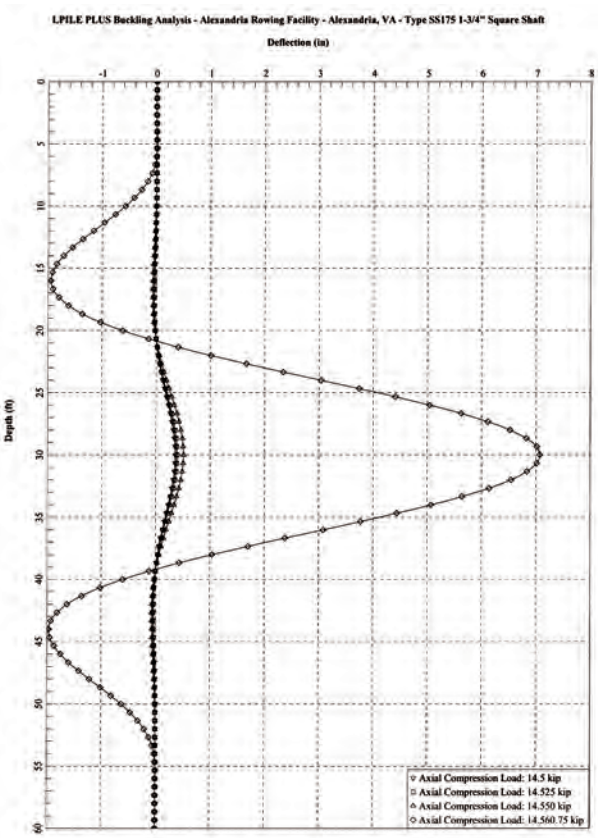
A four-helix CHANCE® Helical Pile is to be installed into the soil profile as shown in Figure 8-34. The top five feet is compacted granular fill and is considered adequate to support lightly loaded slabs and shallow foundations. The majority of the shaft length (50 feet) is confined by very soft clay 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 7-38 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.

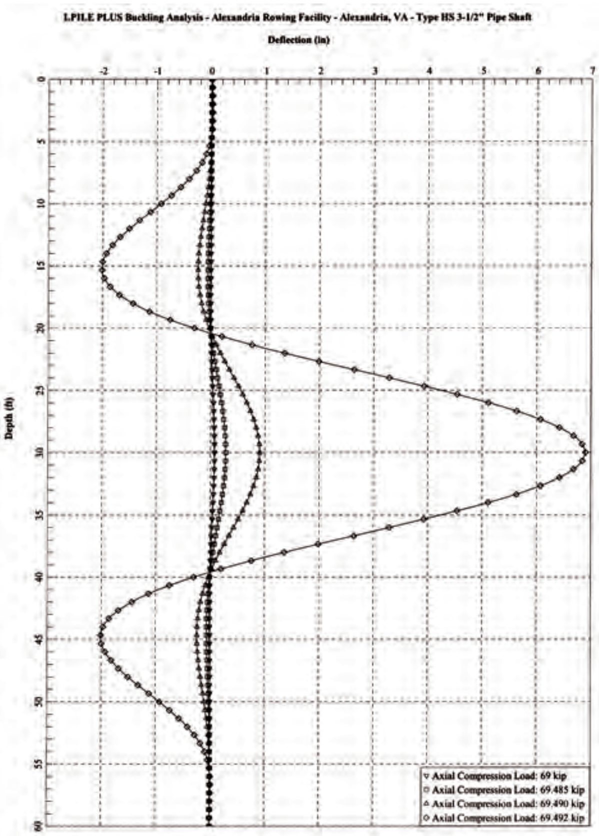
Note that over the same 50-foot length of very soft clay, the well-known Euler equation predicts a critical buckling load for Type SS175 of 614 lb with pinned-pinned end conditions and 2,454 lb with fixed-fixed end conditions. The Euler critical buckling load for Type RS3500.300 is 3,200 lb for pinned-pinned 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.



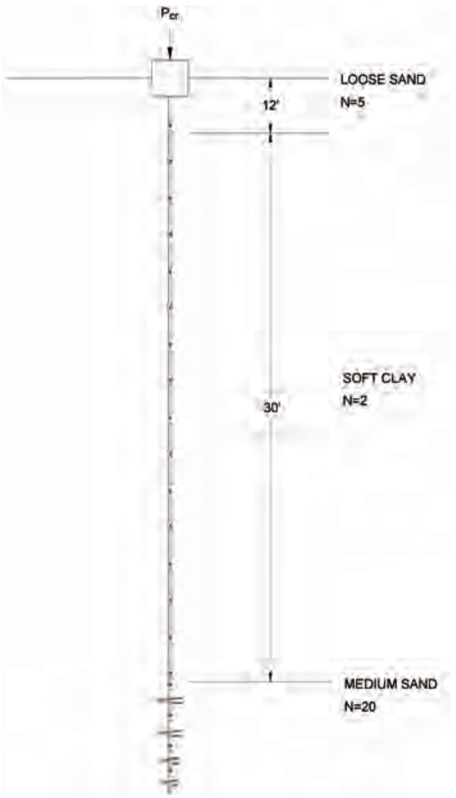
LPILE^{PLUS} Output Plot of Deflection vs Depth
Figure 7-37



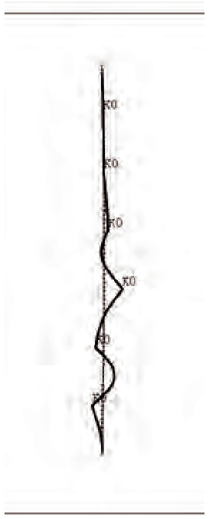
LPILE^{PLUS} Output Plot of Deflection vs Depth
Figure 7-37

DESIGN EXAMPLE 13
BUCKLING EXAMPLE USING THE FINITE ELEMENT METHOD
SYMBOLS USED IN THIS DESIGN EXAMPLE

SPT	Standard Penetration Test	7-56
N	SPT Blow Count	7-56
psf	Pounds per Square Foot	7-56
kip	Kilopound	7-56
HPM	CHANCE HELICAL PULLDOWN® Micropile	7-56



Foundation Details
Figure 7-40



Displaced Shape of Shaft ANSYS® Output
Figure 7-41

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 "KO" 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.

CORROSION

CORROSION - AN OVERVIEW
APPENDIX A

CONTENTS

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

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

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 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/anchors. 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 deter-

mine 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.

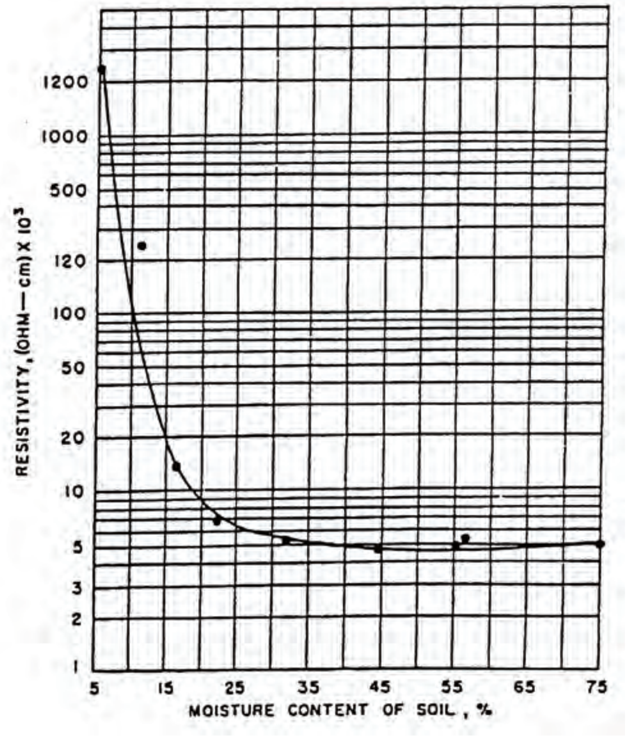
SOIL ENVIRONMENTS

Soil Type

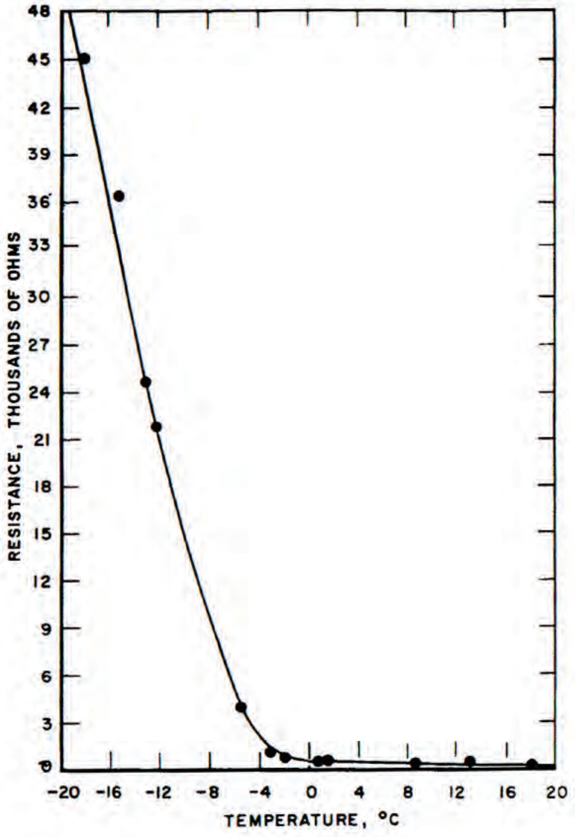
Soils constitute the most complex environment known to metallic corrosion. Corrosion of metals in soil can vary from relatively rapid material loss to negligible effects. Obviously, some soil types are more corrosive than others. The origin of soils, along with climate, geologic location, plant and animal 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



Effect of Moisture on Soil Resistivity
(Romanoff, 1957)
Figure A-1

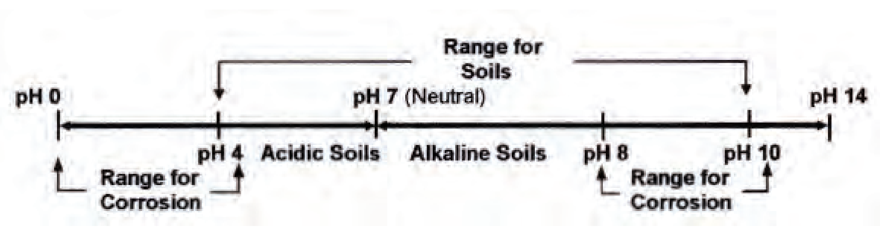


Effect of Temperature on Earth Resistance
(Romanoff, 1957)
Figure A-2

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.

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.



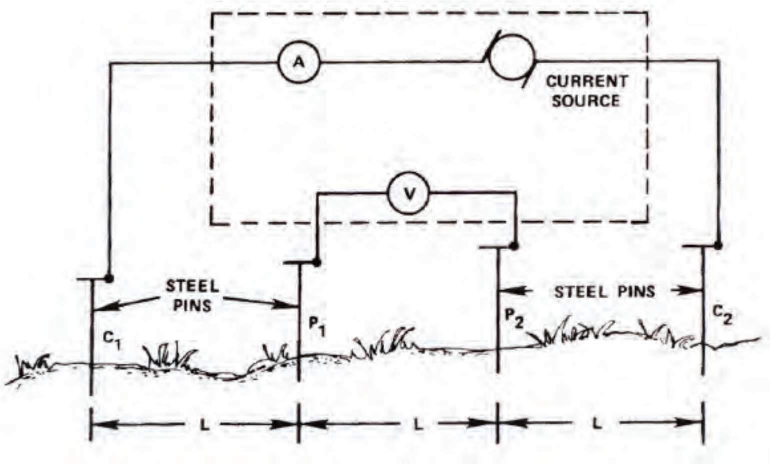
Corrosion of Metal in Soil vs pH
Figure A-3

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.



Wenner 4-Pin Method for Measuring Soil Resistivity
Figure A-4

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.

Resistivity = 191.5 (R) (L) (ohms/cm) **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

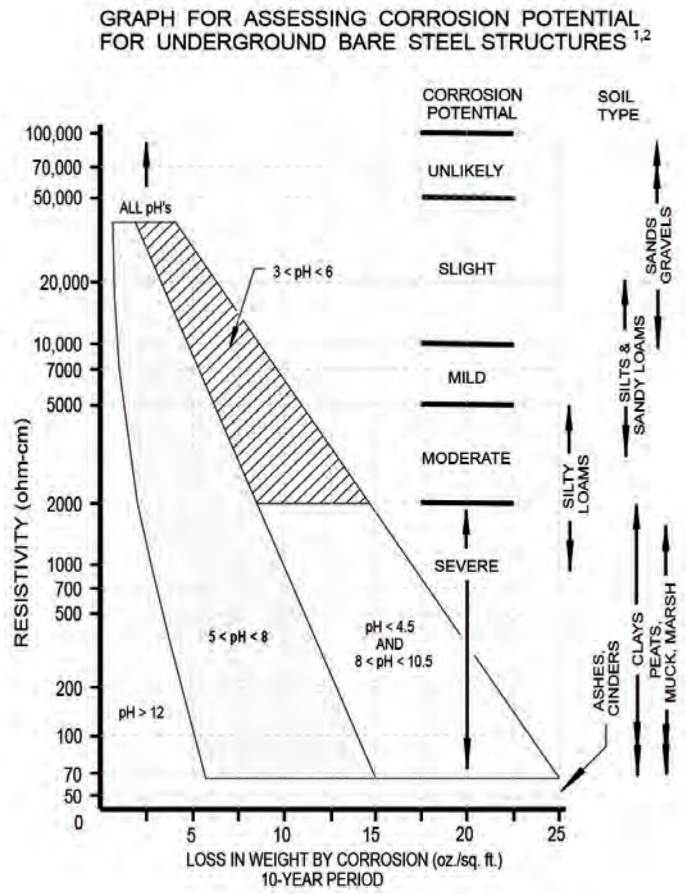
PREDICTING CORROSION LOSS

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.



Steel Loss Due to Corrosion
Figure A-5

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/ft^2/10yrs, or 0.5 oz/ft^2/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.

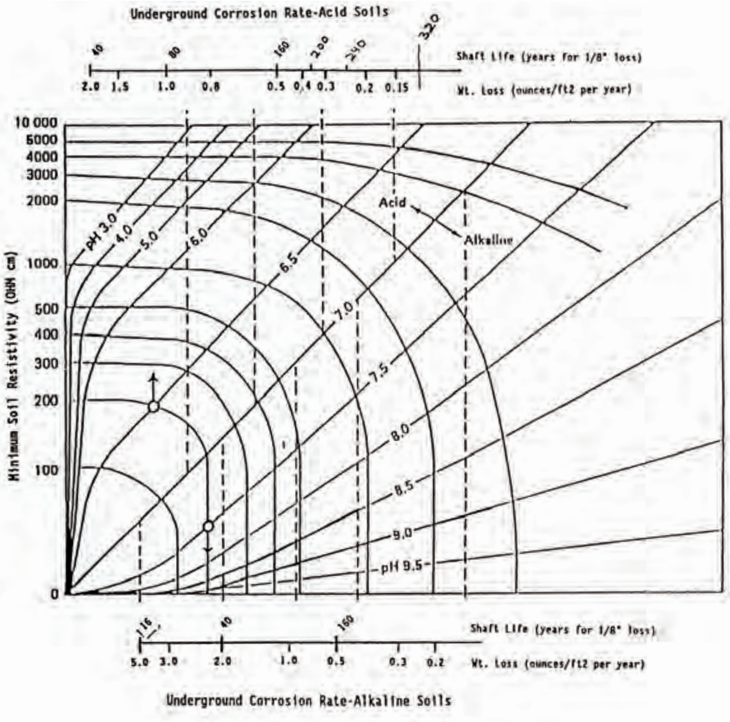
The Federal Highway Administration (FHWA) has proposed uniform corrosion loss rates based on a simple assessment of the electrochemical index properties. Per FHWA-RD-89-198, the ground is considered aggressive if any one of the critical indicators in Table A-3 shows critical values.

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/ft^2/yr) for the first two years
	4 µm/year (0.103 oz/ft^2/yr) thereafter
For carbon steel:	12 µm/year (0.308 oz/ft^2/yr)



Nomograph for Estimating the Corrosion Rate of Pile/Anchor Shafts
Figure A-6

Examples:

- For pH of 6.5 and resistivity of 200 ohms/cm weight loss is approximately 1.3 oz/ft^2/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/ft^2/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 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/ft.2 (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

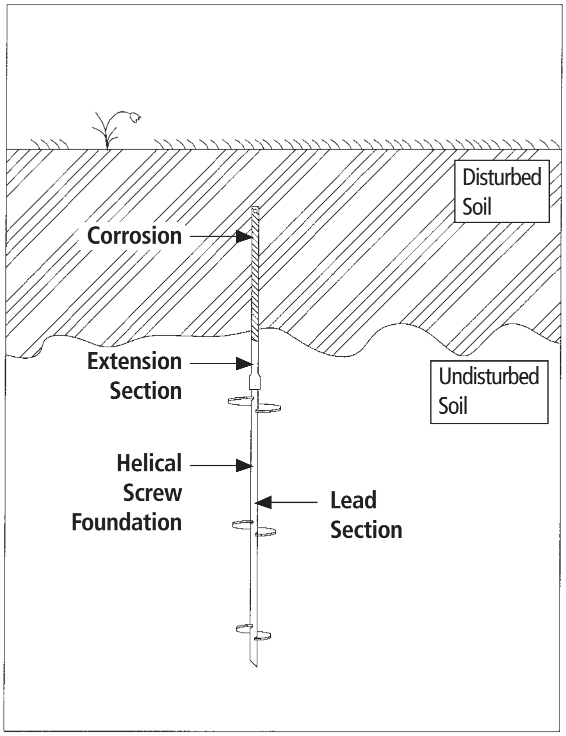
Corrosion in undisturbed soil

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:

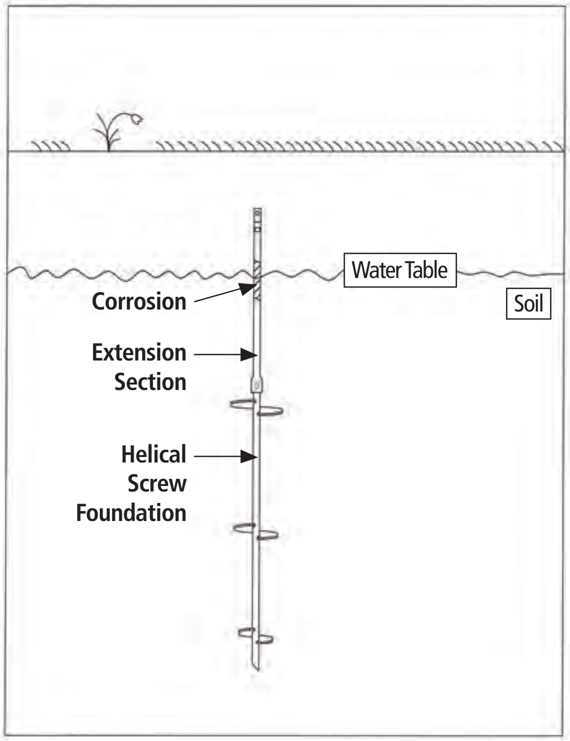
> “. . . that soil environments which are severely corrosive to iron and steel buried under disturbed conditions in excavated trenches were not corrosive to steel piling driven in the undisturbed soil. The difference in corrosion is attributed to the differences in oxygen concentration. The data indicates 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:

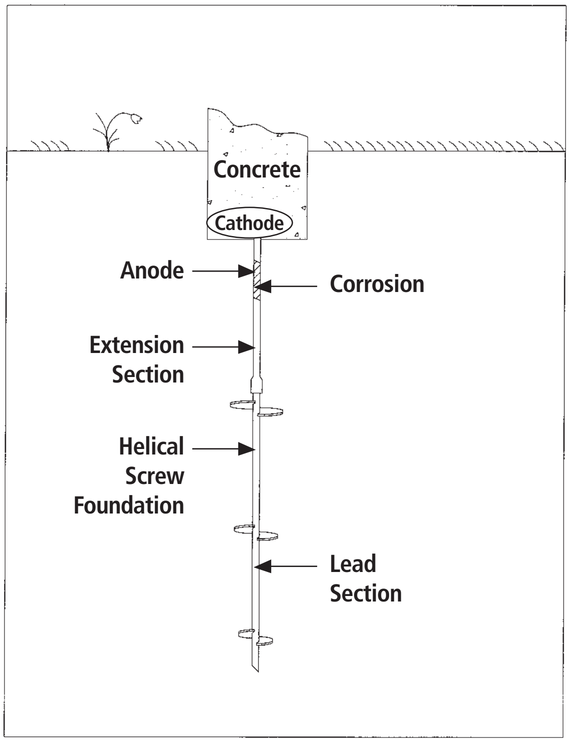
- Oxygen is required at cathodic sites to support underground corrosion of a steel foundation product.
- Disturbed soils (fill) contain an adequate supply of oxygen to support underground corrosion, at least at shallow depths. Thus, the top-most extension(s) of the CHANCE® helical pile/anchor central 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.



Corrosion of Helical Pile/Anchor in
Disturbed Soil
Figure A-7



Corrosion of Helical Pile/Anchor
at the Waterline
Figure A-8



Corrosion of Helical Pile/Anchor Foundation
With a Concrete Cap
Figure A-9

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

$$R = R_{meter}\,(M)\,(WSF) \qquad \textbf{Equation A-2}$$

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 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.

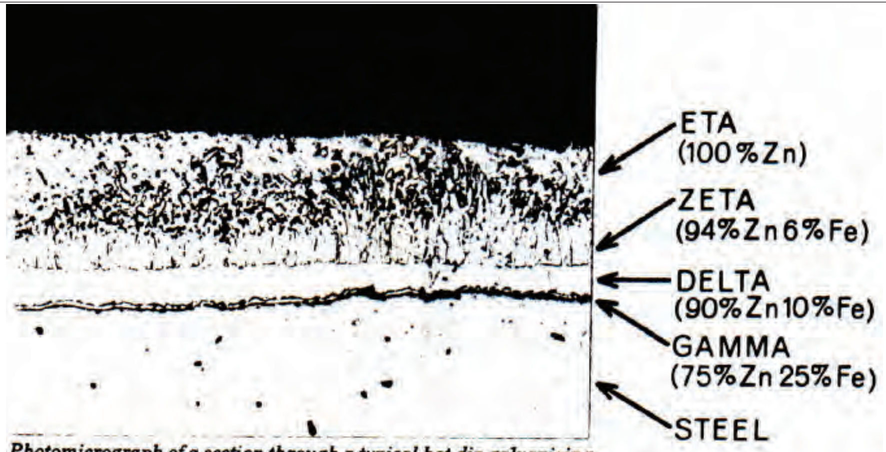
The amount of loss in these design examples is strictly arbitrary, but the assumed material loss of 1/8" in Design Example 1 is common for pile evaluation.

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 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./ft^2 (3.4 mils) and any individual specimen to be no less than 1.8 oz./ft^2 (3.1 mils). ASTM A123 can be used to specify thicker zinc coatings – up to 2.3 oz./ft^2 (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.



Photomicrograph of a section through a typical hot dip galvanizing coating showing alloy layers. (Courtesy of American Hot Dip Galvanizers Association, Inc.)

Photomicrograph of Zinc Layer Section
Figure A-13

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/ft^2) 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.

$CL_1 = 0.25 - 0.12 \log_{10} (R/150)$ **Equation A-3**

CL_1 = Weight loss (oz/ft^2/yr)

R = Soil resistivity (ohms/cm)

NOTE: For thinner galvanized coatings, the rate of galvanized coating loss is two to three times the rate determined from Equation A-3.

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. 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 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/ft^2 of metal surface for a well-applied, high-dielectric-strength plastic coating to 150 ma/ft^2 for bare steel immersed in a turbulent, high velocity, salt-water environment. In soil, 1 to 3 ma/ft^2 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, 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.

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.

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/ft^2)

  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/ft^2. Note that as the duration of exposure increases, the

CORROSION

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:

  $$SL = (81.5\ \text{oz/ft}^2) / (0.61\ \text{oz/ft}^2) = 133.6\ \text{years}$$

- 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/ft^2. 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 oz/ft^2 / 0.262 oz/ft^2 = 6.9 years
- Total Estimated Service Life of Helical Pile Shaft: 133.6 + 6.9 = 140.5 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/ft^2. 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.

  $$SL = (81.5\ \text{oz/ft}^2) / (0.65\ \text{oz/ft}^2) = 125.4\ \text{years}$$

- 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/ft^2. 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 oz/ft^2 / 0.044 oz/ft^2 = 40.9 years
- Total Estimated Service Life of Helical Pile Shaft: 125.4 + 40.9 = 166.3 years

- 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/ft^2)
  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:

$$\begin{aligned} L_1 &= G/CL_1 \\ &= (3 \text{ oz/ft}^2) / (0.15 \text{ oz/ft}^2) \\ &= 20 \text{ years} \end{aligned} \qquad \textbf{Equation A-4}$$

where: G = Amount of galvanized coating = 3.0 oz/ft^2 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:

  $L_2 = W_s/K_2$ **Equation A-5**

  where:
  L_2 = Life expectancy (yrs)
  W_s = Weight of steel pile (oz/ft^2)
  K_2 = Loss in weight by corrosion ($oz/ft^2/yr$) 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/ft^2 for a 10-year period. In this case (also checking the NBS data) an estimate was used of 8 oz/ft^2 for 10 years. Therefore K_2 = 8.0 oz/ft^2 per 10 years or 0.8 $oz/ft^2/year$.

  A 10% weight loss of the wall thickness of the steel for the RS3500.300 pile results in:

  W_s = 0.1 (0.300 in/12 in/ft) (489.6 lb/ft^3) (16 oz/lb)
  = 20 oz/ft^2

  The estimated additional life becomes:

  $L_2 = W_s / K_2$
  = (20 oz/ft^2) / (0.8 $oz/ft^2/yr$)
  = 25 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 oz/ft^2.

  Zinc loss the first two years: = 0.385 $oz/ft^2/year$ x 2 years = 0.77 oz/ft^2

  Estimated life of zinc coating = [1.8 oz/ft^2 - 0.77 oz/ft^2 = 1.03 oz/ft^2/0.103 oz/ft^2 = 10 years] + 2 years = 12 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 years – 12 years = 73 years.

  Bolt steel loss over 73 years: = 0.308 $oz/ft^2/year$ x 73 years = 22.5 oz/ft^2

22.5 oz/ft^2/144 in^2/ft^2 x 16 oz/lb x 0.283 lb/in^3 = 0.035” (0.9 mm)

Diameter reduction after 85 years is 0.75”– 2 x 0.035” = 0.68” (17.3 mm)

- 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 x 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:

$$L_3 = [57.08 (0.65) (48)] / 163.5$$

$$= 11 \text{ yrs}$$

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19. Various Cathodic Protection System Vendors.

LOAD TESTS
APPENDIX B

CONTENTS

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.

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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.

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:

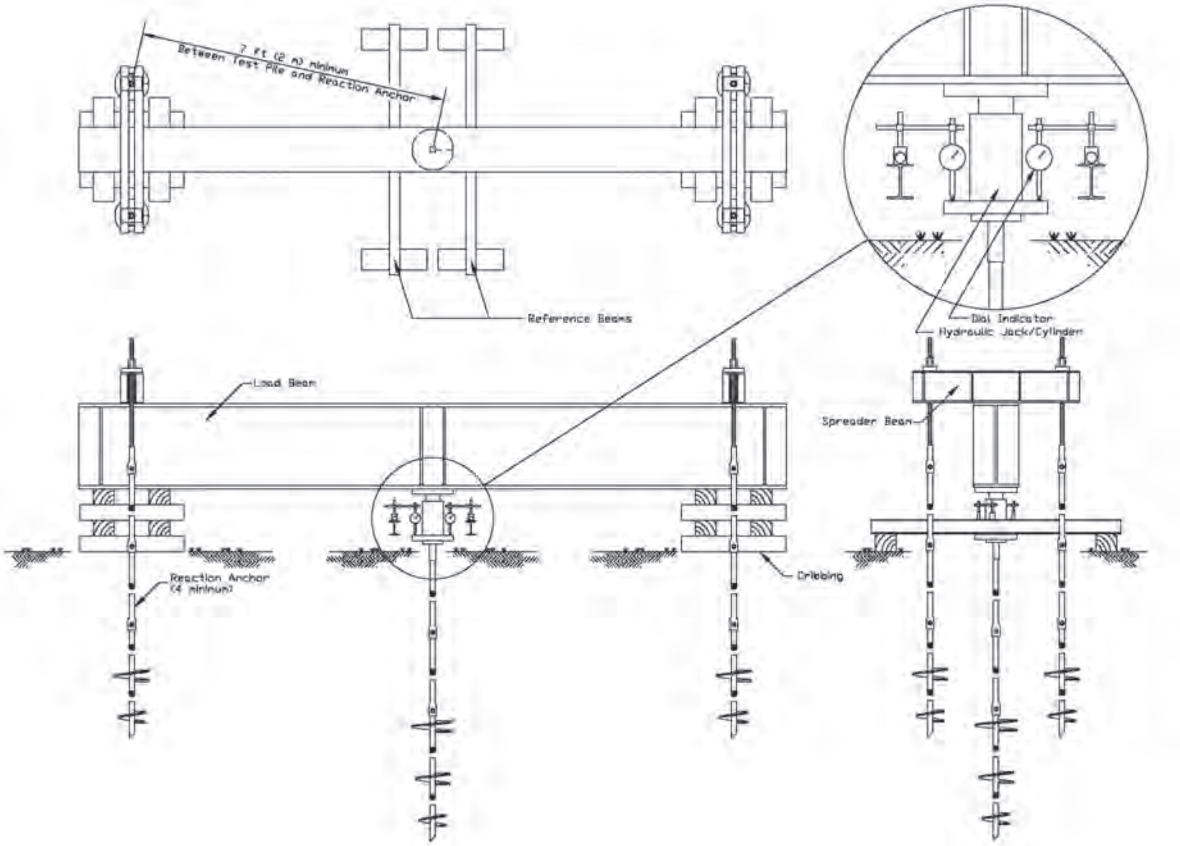
“The slow-testing methods . . . (outlined by the ASTM D1143-07. . . are very time-consuming. When the objective of the test is to determine the bearing capacity of the pile, these methods can actually make the data difficult to evaluate and disguise the pile true load movement behavior, thereby counteracting 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



Basic Compression Field Test Set-up
Figure B-3

Indoor Compression Test
Figure B-4

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 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			

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.

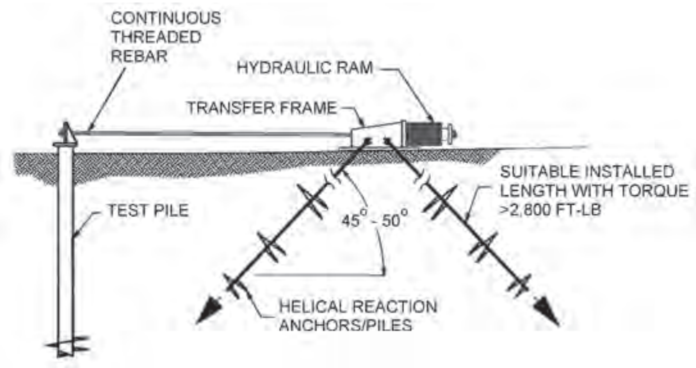
STATIC LOAD TESTS (LATERAL)

Helical pile/anchor offer maximum benefits structurally when loaded axially (concentrically) 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.

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



Lateral Load Test Equipment Configuration
Figure B-5

Lateral Load Test Apparatus
Figure B-6

Test Procedure

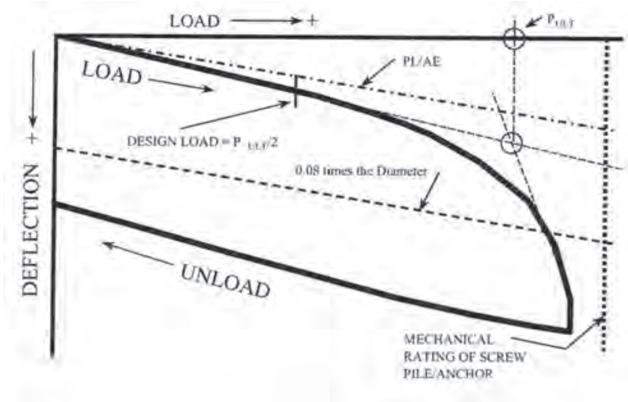
1. In order to conduct a lateral load test on an installed pile/anchor, it is necessary to install a reaction anchor system. The reaction anchor system consists of helical pile/anchor installed at a battered angle, and using a test apparatus setup such as shown in Figure B-5. Once the reaction anchor 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.

STATIC AXIAL LOAD TESTS (COMPRESSION/TENSION)

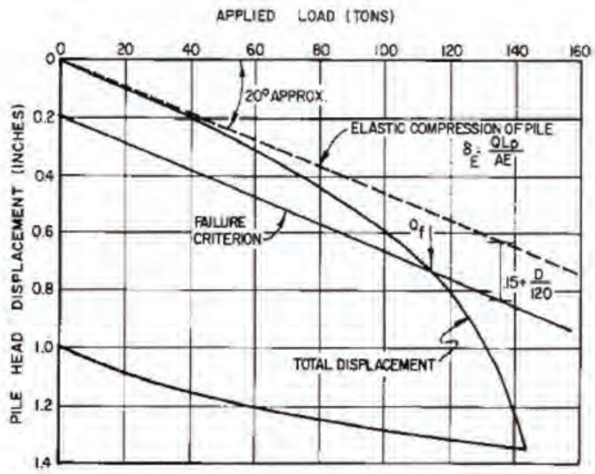
Pre-Production Load Tests

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



Sample Compression Test Load-Deflection Curve
Figure B-7



Davisson Method for Determining Net Displacement
Figure B-8

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:

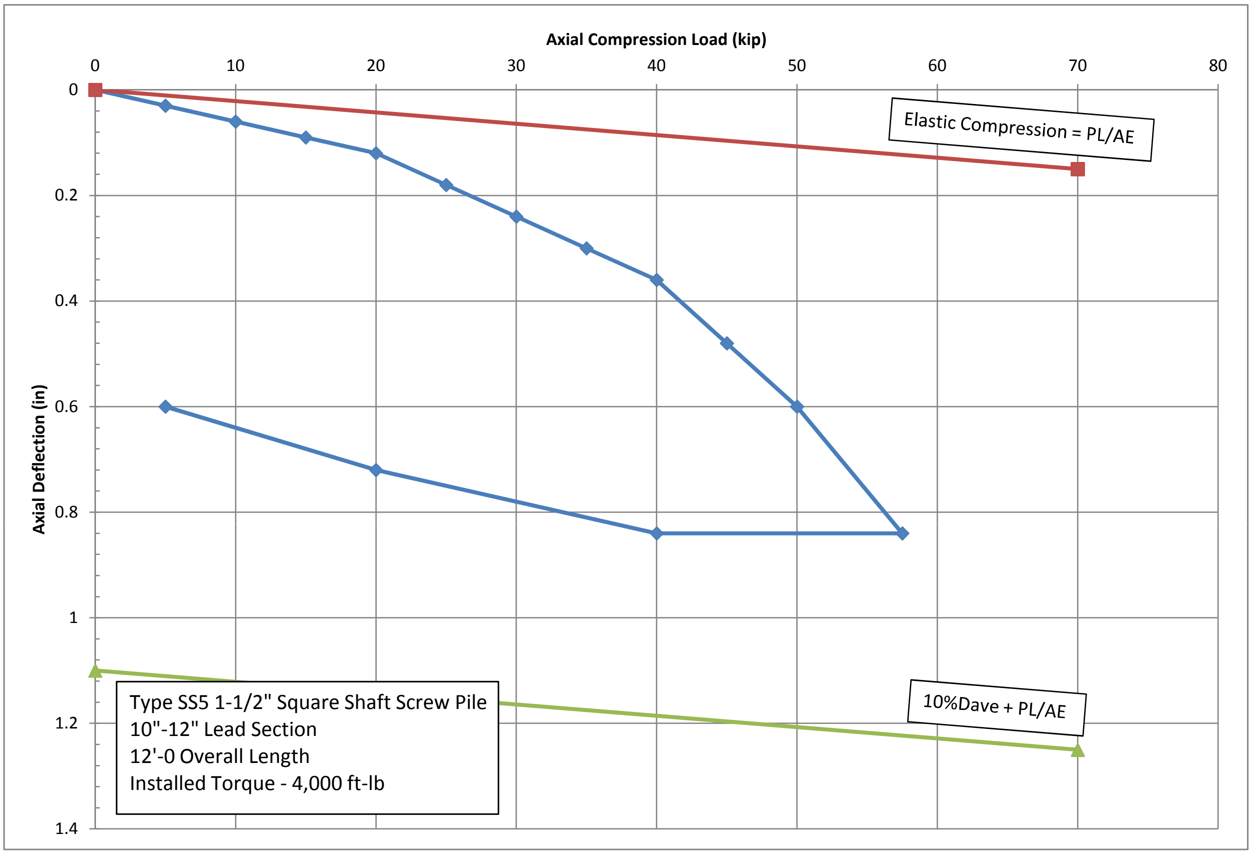
1. 50% of the applied load causing a net displacement (total displacement less rebound) of the pile of 0.01" per ton of applied load, or
2. 50% of the applied load causing a net displacement of the pile of 1/2". Net displacement is defined as the gross displacement at the test load less the elastic compression.

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

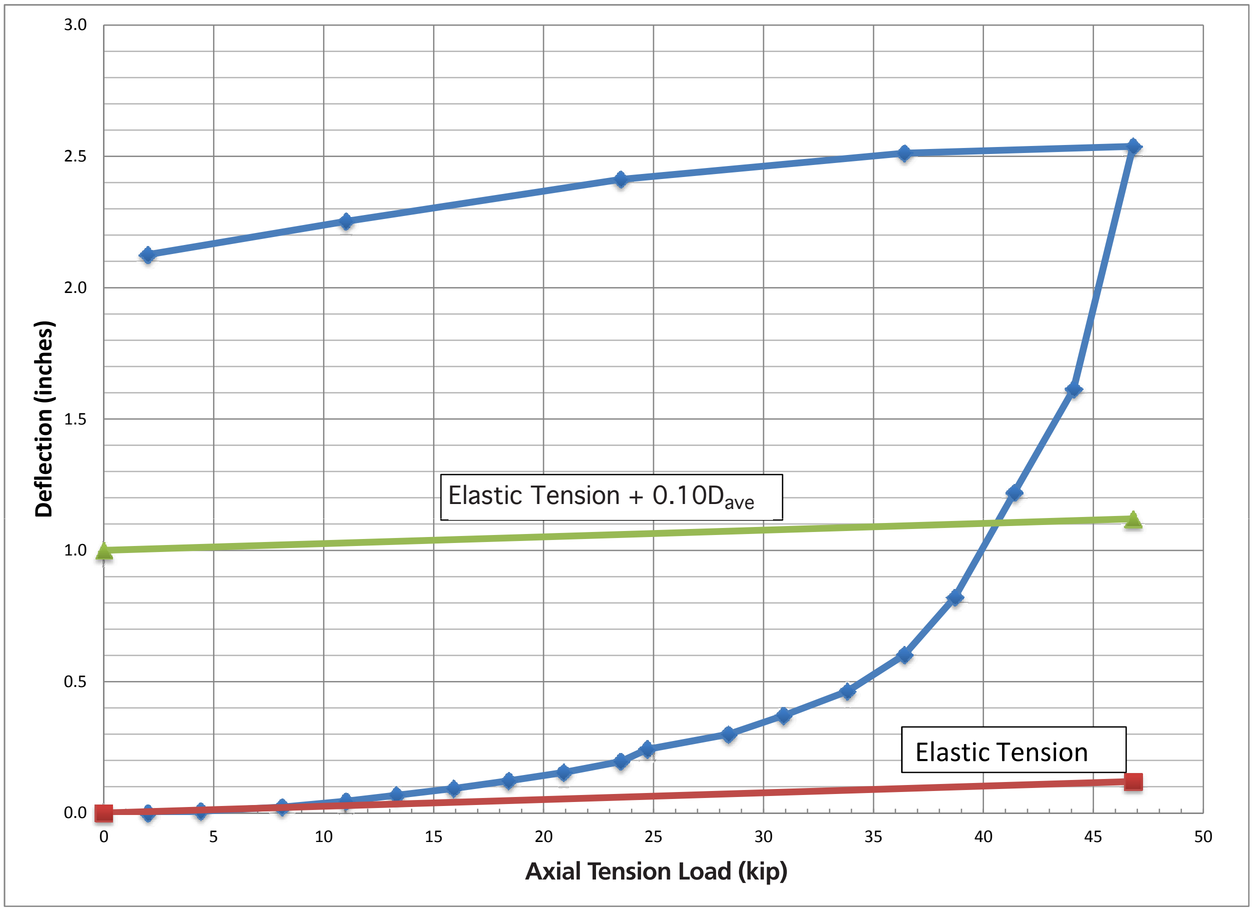


ASTM D1143 “Quick Test” Compression Plot
Figure B-9

“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 + $0.10D_{ave}$, 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 + $0.10D_{ave}$ 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 x 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 @ 12.



ASTM D3689 "Quick Test" Tension Plot
Figure B-10

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).

CHANCE® HELICAL PILE/ANCHOR AXIAL TEST

Project:	Date:	Sheet of
Anchor/Pile Number:	Anchor/Pile: ☐ SS5 ☐ SS150 ☐ SS175 ☐ SS200 ☐ SS225 ☐ RS	
Helix Configuration:	Total Depth:	
Time: Start Finish	Recorded by:	

PRESS (psi)	LOAD (kip)	TIME (min)	DISPLACEMENT		
			GAUGE A (in)	GAUGE B (in)	GAUGE C (in)

References

1. AC358 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.

HOW TO USE THIS MANUAL - DESIGN OF HELICAL PILES & ANCHORS A BASIC GUIDELINE FOR DESIGNERS
APPENDIX C

CONTENTS

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.

How to Use this Manual – Design of Helical Piles & Anchors:

A Basic Guideline for Designers

Contributors:
Cary Hannon, PE – Vice President of Engineering Foundation Technologies, Inc.
Gary L. Seider, PE – Engineering Manager, Hubbell Power Systems, Inc.

I. INTRODUCTION

This Technical Design Manual (TDM) is a comprehensive collection of information for the express purpose to educate the practicing engineer in the art of helical pile design. The amount of information is extensive, and we recognize the need to provide a short length "primer" for the busy professional who does not have the time to read and learn all the comprehensive methods used to design helical piles. The goal of this "How To" is to bring the design and selection of helical piles and anchors into a short easy-to-follow Guideline. This Guideline will provide the design method used every day by the Application Engineering Staffs at Hubbell Power Systems, Inc. and its authorized Civil Construction Distributors. Citations throughout will direct the designer where to find the required information in the Technical Design Manual. The result is a simple step-by-step process culminating in a helical pile design that can then be correctly written into a project specification.

II. HELICAL PILE CAPACITY

The design method for helical pile capacity is simple. It consists of two limit states criteria; namely the Ultimate Resistance and the Serviceability Limit. Serviceability is the behavior of a helical pile at a particular load that is less than the ultimate resistance. For helical pile design, the Serviceability Limit primarily deals with limiting the deflection or displacement of the pile at a specified service load. Ultimate Resistance is the limit state based on the structural strength or the geotechnical capacity of the helical pile, defined as the point at which no additional load can be applied without failure. For helical pile design, ultimate resistance typically consists of two elements – the **geotechnical capacity** and the **structural capacity, or strength.** It is more descriptive to refer to structural "strength" of the helical pile components, which is the approach taken in the TDM.

A. According to the International Building Code (IBC) Section 1810.3.3.1.9, there are four ways to determine the ultimate resistance of helical piles.

- **Method 1:** Base resistance plus shaft resistance of the helical pile, where the base resistance is equal to the sum of the areas of the helical bearing plates times the ultimate bearing resistance of the soil or rock comprising the bearing stratum, and shaft resistance is equal to the frictional resistance of the soil times the shaft area above the helix bearing plates. This is commonly referred to as the theoretical geotechnical limit state method. It is described in great detail in Section 5 of the TDM.
- **Method 2:** Ultimate capacity determined from **well documented** correlations with installation torque. This is commonly referred to as the empirical geotechnical limit state method. The key words are "well documented" which will be discussed later. Torque correlation is described in Section 6 of the TDM.
- **Method 3:** Ultimate capacity determined from load tests. This is the most direct method to determine the geotechnical capacity of any pile, not just helical piles. Load testing of helical anchors and pile is described in Appendix B of the TDM.
- **Method 4:** Resistance of the pile's structural elements (shaft, helix, couplings, connection to structure). Structural strength is described in Sections 5 & 7 of the TDM.

Of the four methods above, the only one that is unique to helical piles is Method 2, commonly referred to as **torque correlation.**

B. According to IBC Section 1810.3.3.1.9, the geotechnical capacity (Methods 1, 2, or 3 above) shall not exceed the strength of the pile's structural elements (Method 4); including the pile connection to structure, pile shaft, pile shaft couplings, and the helix bearing plates. The structural strength of CHANCE brand helical piles is described in Section 7 of the TDM.

C. Therefore, both the geotechnical capacity and the structural strength of the helical pile must be determined; and whichever limit state is the **lesser,** will control the capacity. This is the ultimate resistance of the helical pile. In most cases, the geotechnical capacity will be the limit state, but the structural strength can sometimes control.

D. *Allowable Strength Design (ASD) or Limits States Design (LRFD).* ASD has been used for many years for the geotechnical capacity of deep foundations. It is sometimes referred to as *deterministic* design since the factor of safety is determined based on standard practice. LRFD is sometimes referred to as *probabilistic* design. It uses load factors and resistance factors based on statistically based probabilities of uncertainty. In the United States, most geotechnical design is deterministic based (global factor of safety); whereas in Canada most geotechnical design is probabilistic (limit states – ULS, SLS). The TDM includes both LRFD design and ASD allowable strength values, so the design can use either design method.

E. The Serviceability Limit may also control. Serviceability is the load/deflection response of a helical pile at a particular load of interest, i.e. a factored load well below the ultimate resistance limit state. There may be strict deflection limits required based on the application; the structure may be sensitive to overall settlement or differential settlement, which may require the helical pile ultimate resistance to be increased. For example, a deflection limit may be specified at the working/design load. Cherry and Perko (2012) reviewed hundreds of tension and compression load tests. They suggested that for end-bearing helical anchors/piles, the net displacement of the helix plates at the working loads averaged about 0.25 in (6.4mm). The working load is based on the geotechnical capacity divided by a factor of safety of 2 (deterministic design). CHANCE application engineers have either conducted or reviewed the results of several hundred load tests, which support the findings of Cherry and Perko. Serviceability limits should also take into account the elastic response of the helical pile material, which can be significant for deep piles with slender shafts.

III.DESIGN PROCESS

The designer has a specific task to perform, or problem to solve to which helical piles can offer a solution. At the beginning of the design process, it is best to keep all options on the table until circumstances dictate one foundation option(s) as being the better choice for the client. The designer should always keep in mind the client is best served with a good solution at a reasonable price, both of which are not always intuitively obvious. As with any deep foundation, helical pile design has several steps. The steps can be summarized as:

A. Data Gathering:

- The loads applied to the foundation. Section 4 of the TDM is a brief review of structural loads and provides several tables that can be used to estimate dead and live loads for various residential & commercial structures. If applicable, lateral loads must be included.
- The description and strength characteristics of the project soils. See Section 2 of the TDM for a brief review of soil mechanics and the procedures used for site investigations, which are typically summarized in the geotechnical report. Information needed in the geotechnical report includes: soil profile, Nspt values per ASTM D-1586, depth to ground water, the presence of fill, debris, or cobbles, and bedrock.
- The designer must determine load resistance requirements and serviceability based on the application. This includes choosing either ASD with a deterministic factor of safety, or LRFD with probabilistic load and resistance factors. Section 5 for the TDM provides guidelines to evaluate soil properties for foundation design, and also gives estimates of helical pile displacement at working loads. Section 5 also provides the design methodology used with HeliCAP®, which is the design software most often used to determine the axial capacity of helical piles.
- The applicability of local, regional, or national building codes. The designer must comply with code requirements depending on the jurisdiction. For example, some codes require helical piles to be tested for every project. Others only require load tests if the pile capacity is above a certain limit. Codes often dictate acceptance criteria in terms of allowable displacement for deep foundations, such as the City of Chicago and New York building codes.
- Location tolerances. The helical pile designer must understand the location tolerances for the piles. For example, most CHANCE helical piles can be installed to a location tolerance of 1 inch or less, and an elevation tolerance of 1/8 inch. Angular tolerances are typically less than 2°.

B. Feasibility:

- Helical piles are designed to transfer load to soil or bedrock with a reasonable displacement. However, they are not designed to drill into solid rock. Table 7-4 on page 7-12 is a quick reference guide for feasibility. It lists helical pile type based on the upper limit Nspt range of soils that pile type can be installed into, along with the typical upper limit of ultimate resistance. It's a good place to start for helical pile feasibility. For example, Type RS2875.276 2-7/8" OD pipe shaft helical piles can be installed into soils with Nspt blow counts up to 35 bpf.
- The size (diameter) of the helical pile shaft should be closely tied to its application. CHANCE offers small displacement (up to 4 in.), medium displacement (4 in, to 8 in.), and large displacement (> 8 in) helical piles. The pile shaft should be large enough to transfer the axial and lateral loads to the soil. However, it is detrimental to oversize the helical pile shaft. This is because of torque correlation – the relationship between the amount of torque energy required to install a helical pile and its load capacity. Smaller diameter helical piles more easily advance like a screw, which minimizes soil disturbance and increases capacity efficiency. More information about shaft type and size will be presented later.

- Project site factors such as equipment access, overhead clearance, right-of-way restrictions, spoils disposal, noise restrictions, etc. must be considered. This is often where helical piles turn out to be the most cost effective deep foundation. Small equipment results in low mobilization cost and easy access.
- Manageable schedule must be considered as well. Helical piles and anchors can be loaded immediately after installation, which can save time compared to waiting for concrete or grout to cure.

C. It is convenient to break down the geotechnical capacity and the structural strength into subcategories or groups. For helical piles and anchors the groups are:

- P1 – bracket or connection to structure
- P2 – shaft, including couplings
- P3 – Helix(s)
- P4 – Soil (geotechnical) capacity, including resistance to both axial and lateral loads

We recommend the design sequence be inverted – start with P4 – soil (geotechnical) capacity because it usually will control the ultimate resistance.

IV.P4 – GEOTECHNICAL CAPACITY:

The axial and lateral capacity is determined per the methods detailed in Section 2 and Section 5 of the TDM. Installation torque requirements can be estimated at this point. If a geotechnical report is available, use HeliCAP® v2.0 Helical Capacity Design Software to determine the axial capacity (tension, compression, or both) via bearing capacity on the helix plates and side resistance on the shaft **[Method 1]**. HeliCAP® will help determine the shaft type (square shaft, pipe shaft, Combo Pile, or grouted PULLDOWN Pile), shaft size (diameter), pile depth, helix configuration (number and size of helix plates), and estimate the torque required to install the pile.

If a geotechnical report is not available, then axial capacity must be determined by other methods. Helical piles have the advantage of being installed (screwed) into the ground and then removed (unscrewed) quickly. A “probe” helical pile can be installed to assess the relative shear strength of the soil profile using torque correlation relationships per TDM Section 6. Well documented correlations with torque are used to estimate helical pile capacity based on the torque measured with the probe pile **[Method 2]**. The shaft type, shaft size (diameter), pile depth, helix configuration can be determined based on the probe pile.

The axial capacity can also be determined from full-scale load tests per Appendix B of the TDM **[Method 3]**. Full-scale tests are often used to verify Method 1 capacity and Method 2 torque correlation.

If a geotechnical report is available, the lateral capacity of a vertical shaft can be determined with various methods including the Finite Difference method (LPILE & GROUP by Ensoft®) and the Broms’ Method (1964a) and (1964b) as detailed in Section 5 of the TDM **[Method 1]**. Each of these methods may be applied to Round Shaft helical piles or PULLDOWN® Micropiles. 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 piles can be used to resist lateral loads by components of the axial capacity on the battered pile. The induced shear and moment in battered piles often dictates the shaft size and batter angle.

If a geotechnical report is not available, the lateral capacity of a vertical shaft must be determined from load tests per Appendix B of the TDM **[Method 3]**.

P4 SHAFT Type and Size:
The shaft type/size is critical to both the axial and lateral capacity – especially for compression in soft/loose overburden soils where lateral stability of the shaft must be considered. The following is a brief summary of the 4 different shaft types for helical piles.

- **Type 1 - Square Shaft:** Square shaft piles are foundation elements that range in size from 1-1/2" solid round-cornered-square (RCS) to 2-1/4" solid RCS. They are compact sections, meaning they have relatively low section properties, but relatively large cross-sectional area since they are solid bars. They are more efficient than pipe shaft helical piles in regards to axial 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. Therefore, square shaft helical piles are better at penetrating dense material than pipe shaft helical piles.

  Square shaft piles have slender cross sections. Therefore, they do not have a large cross section to resist much lateral load via passive earth pressure along the side of the shaft. In addition, they do not have much section modulus/ stiffness to resist buckling under compressive loads without support from the surrounding soil. As long as there is sufficient soil confinement around the pile to prevent buckling, square shaft piles are suitable for compressive loads. As a general rule, if the soil profile has ASTM D-1586 SPT $_N60$ value of 5 or greater, there is sufficient lateral support to prevent the square shafts from buckling at the compressive loads that they are rated for. If SPT $_N60$ values are 4 or less, then square shaft buckling may be a practical concern. A rigorous analysis can be done if enough reliable soil data is available, but the problem is best solved by selecting either a pipe shaft or Helical PULL-DOWN Micropile as described in the following sections.

  The designer is encouraged to use square shaft helical piles as much as possible due to their advantages with torque correlation efficiency and better penetration in dense soil.

- T**ype 2 – Pipe Shaft:** Pipe shaft piles are foundation elements that range in size from 2-7/8" OD pipe shaft to 10-3/4" OD pipe shaft with various wall thicknesses and material strengths. Pipe shaft piles have larger section properties compared to square shaft, so they are used to resist lateral load, or to provide stability when columnar buckling or potential unsupported length is a concern. The designer may ask why not use pipe shaft helical piles exclusively? The answer is square shaft helical piles offer greater axial capacity for a given amount of installation energy due to their greater efficiency (see the torque correlation table C-1 below). In addition, pipe shaft helical piles do not penetrate dense material as effectively as square shaft. Therefore, the designer must size the helical pile shaft large enough to transfer/resist all loads, but no larger than necessary. Helical piles evaluated per ICC-ES AC358 comply with the requirement of International Building Code (IBC) Section 1810.3.3.1.9 for the use of "well documented" correlations with installation torque.

  Helical piles, whether they are square shaft or pipe shaft, are generally considered to be slender members. The lateral capacity is dependent on the effective projected area of the pile shaft, the flexural stiffness of the pile, and the resistance of the soil as the pile deflects laterally under load. Due to their slender size, helical pile shafts have relatively small effective projected area for the soil to bear against. Therefore, helical piles with shaft diameter ≤ 4" have about 4 kip lateral resistance; shaft diameters ≤ 8" have about 10 kip lateral resistance; and shaft diameters ≤ 10" have about 20 kip lateral resistance at typical allowable lateral displacements of 1" or less. As mentioned previously, square shaft helical piles don't have any significant lateral capacity.

Table C-1

PRODUCT SERIES	DESCRIPTION	EVALUATED PER AC358	K_t
SS125	1.25" ROUND CORNERED SQUARE BAR		10
SS5	1.50" ROUND CORNERED SQUARE BAR	YES	10
SS150	1.50" ROUND CORNERED SQUARE BAR		10
SS175	1.75" ROUND CORNERED SQUARE BAR	YES	10
SS200	2.00" ROUND CORNERED SQUARE BAR		10
SS225	2.25" ROUND CORNERED SQUARE BAR		10
RS2875.203	2.875" OD, 0.203 WALL PIPE	YES	9
RS2875.276	2.875" OD, 0.276 WALL PIPE	YES	9

- **Type 3 - Combo Pile:** A combo pile (Combination Pile) is a compression helical pile that has the advantages of both square shaft and pipe shaft. A combo pile has a square shaft lead section that is better at penetrating dense material and generating bearing capacity; and is then transitioned to a pipe shaft for the plain extensions where over- burden soils are softer/less dense and a larger section modulus is desired for lateral stability and/or buckling resistance, or when lateral load resistance is required. Another advantage provided by combo piles is the torque correlation factor (Kt) is increased compared to the straight pipe shaft pile per the table below. Note as the overall shaft length increases, the Kt factor decreases.

Table C-2 - Combo Pile Length Less than 30'-0

COMBO PILE TYPE	SAND	CLAY	COMBINED
SS5/150/RS2875	10	9.5	10
SS175/RS3500	9.5	9	9
SS200/RS3500	9.5	9	9

Table C-3 - Combo Pile Length Greater than 30'-0

COMBO PILE TYPE	SAND	CLAY	COMBINED
SS5/150/RS2875	9.5	9.5	9.5
SS175/RS3500	9	8.5	8.5
SS200/RS3500	8.5	8	8

- **Type 4 - A Helical PULLDOWN Micropile** is a helical pile that has the shaft section encased in a small diameter grout column, typically 5" – 7" in diameter. Both square shaft and pipe shaft helical piles can be encased in a grout column, but square shaft is much more common. It has the advantage of the square shaft lead section to penetrate dense material for end-bearing. The added grout column provides greater section properties for shaft stability and lateral resistance in soft soils. Lateral load resistance with grouted shafts requires a steel case – typically extending 5'-0 to 10'-0 from the pile head. The grout in contact with the soil will develop side resistance via a bond zone in suitable soil stratum. This can greatly increase the total axial capacity of the pile (end-bearing and side resistance) as well as stiffen the axial load response of the pile. The grout column also provides additional corrosion protection to the steel shaft.

  Grouted shaft Helical PULLDOWN Micropiles are recommended for square shaft piles in soft soils, when additional capacity via side resistance is needed, or when working loads exceed about 60 kip. To-date, Helical PULLDOWN Micropiles have achieved 450 kip ultimate resistance.

P4 Other Considerations:

There are several 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.

1. 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. Refer to Table 7-4 of the TDM as a good place to start. It lists torque correlated capacities for shaft diameters up to 4.5" OD **[Method 2]. Large diameter pipe shaft (≥ 6") and PULLDOWN Piles can achieve higher capacities than those listed in Table 7-4.** Allowable load upper limit for CHANCE helical piles up to 10" nominal diameter is 100 ton. Tension capacity is controlled by the structural strength of the couplings as detailed in P2 below.

2. The helix plates must generate the downward thrust required to advance the shaft through the soil. 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 diameter of the helical plates (higher aspect ratio), 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 (lower aspect ratio). Displacing more soil will require more installation energy, i.e. additional installation torque and down pressure. The greater the installation energy, the larger the required equipment to install the pile. For example, a 25 ton allowable load square shaft helical pile can be installed with a mini-excavator or skid-steer. However, an 8" diameter pipe shaft helical pile requires a 20 to 25 ton track-hoe excavator.

3. If a soil stratum is too dense, or the shaft too large relative to the size of the helix 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 of the TDM for a complete explanation of torque correlation for helical anchors and piles). A spun-out pile 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 torque correlation as is normally done for a normally installed helical pile. The pile's capacity will depend on the type of material the helical plate(s) 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.

4. Lateral resistance requires either pipe shaft or Helical PULLDOWN Micropiles. A 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, 10 kip for 6" to 8" diameter helical piles, and up to 20 kip for 10" diameter piles at allowable lateral displacements of 1" or less. The use of battered (inclined) piles can be utilized to resist lateral loads if needed and are discussed in Section 5 of the TDM.

5. For tension only foundation elements, square shaft is always the logical choice. As noted above, square shaft helical anchors 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. The size and strength of the square shaft section is governed by the required installation torque, not the tension capacity. 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 tension strength is governed by the shear strength of the coupling bolt – see Section 7 of the TDM.

6. For piles required to resist compression and tension loads, the designer must recognize that helical piles are a pre-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. The tolerance is required to ensure the connections 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 Helical PULLDOWN Micropiles fills the connections, thereby removing the bolt tolerance as well as stiffening the axial load response. That is why grouted shafts are often utilized for piles with reversing load conditions. Grouting the ID of pipe shaft helical piles will also stiffen the coupling for reversing load conditions. Pipe shaft piles with couplings above grade should be grout filled to stiffen the connection.

V. P1, P2 AND P3 – STRUCTURAL STRENGTH:

The axial and lateral strength of the helical pile components (shaft, helix and connection to structure) is determined per the methods detailed in AISC 360-10 Steel Construction Manual and Chapter 18 of the International Building Code (IBC). The structural strength of CHANCE helical piles is detailed in Section 7 of the TDM **[Method 4]**. The factors required for structural design are soil strength (firm, soft, fluid), the strength of the concrete, end condition (pinned, fixed, free), Application (new construction, remedial repair, tiebacks), coupling strength, and load direction (tension, compression, or both).

Soil strength is an important factor because it affects buckling & bracing of helical piles. It is important to categorize the project soils as either "fluid" (N=0), "soft" (0<N<5) or "firm" (N≥5) as detailed in Section 5 of the TDM. If the soil is "fluid", then buckling is possible and the shaft size is determined based on the critical buckling load. Examples are provided in Section 8 of the TDM (Examples 16, 17 & 18). If the soil is "soft" or "firm" buckling is not the concern, but depth to fixity and lateral support is. The term "fully braced" is used by some in the industry to describe a pile shaft with complete soil confinement all the way from the pile head to the tip. However, Hubbell Power Systems Inc. application engineers believe the term "fully braced" is unachievable from a practical standpoint. A "fully braced" condition is not listed as an option in Section 7 of the TDM since it is considered unrealistic and ensures the capacity of the helical pile will better match long term performance. Therefore, Section 7 details the nominal, LRFD design and ASD allowable compression strength of helical piles in terms of "firm soil" [5'-0 depth to fixity] and "soft soil" [10'-0 depth to fixity].

Once the soil strength is determined, the designer must now consider the end condition (K) at the pile head and how it affects the effective length of the pile shaft. The connection to the structure (and the effective length) greatly affects the structural capacity of the pile. A pinned condition means the pile head is restricted against lateral translation (side to side movement) but is free to rotate as shown in Table C-C2.2 (b) below from AISC 360-05. A pinned condition uses a K of 0.7. A fixed condition mean the pile head is restricted against both lateral translation and rotation as shown in Table C-C2.2 (a) below. A fixed condition uses a K of 0.5. To achieve a fixed end condition, the pile head has to be embedded at least 7.5" from the bottom of a concrete pile cap/footing/grade beam. Anything less than that is typically considered pinned. A pile with a fixed end condition has a shorter effective length, thereby having a greater stability and higher axial compressive strength. The compressive strength of a "free" headed helical pile (Table C-C2.2 (e) is not provided in the TDM. It can be provided as needed using a K factor of 2.0.

Table C-C-2.2 - from AISC 360-05

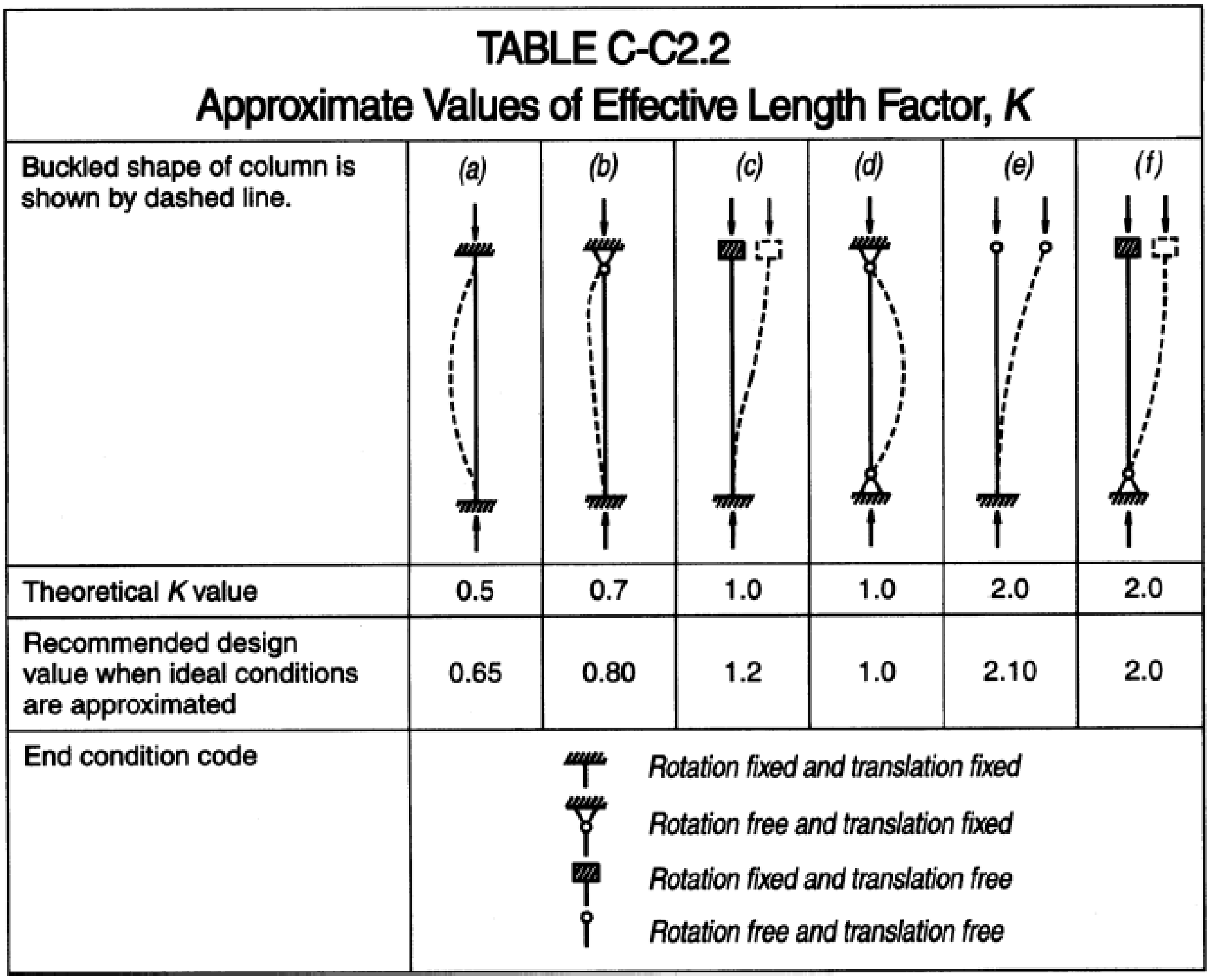


TABLE C-C2.2
Approximate Values of Effective Length Factor, K

Buckled shape of column is shown by dashed line.	(a)	(b)	(c)	(d)	(e)	(f)
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design value when ideal conditions are approximated	0.65	0.80	1.2	1.0	2.10	2.0
End condition code	*Rotation fixed and translation fixed* *Rotation free and translation fixed* *Rotation fixed and translation free* *Rotation free and translation free*					

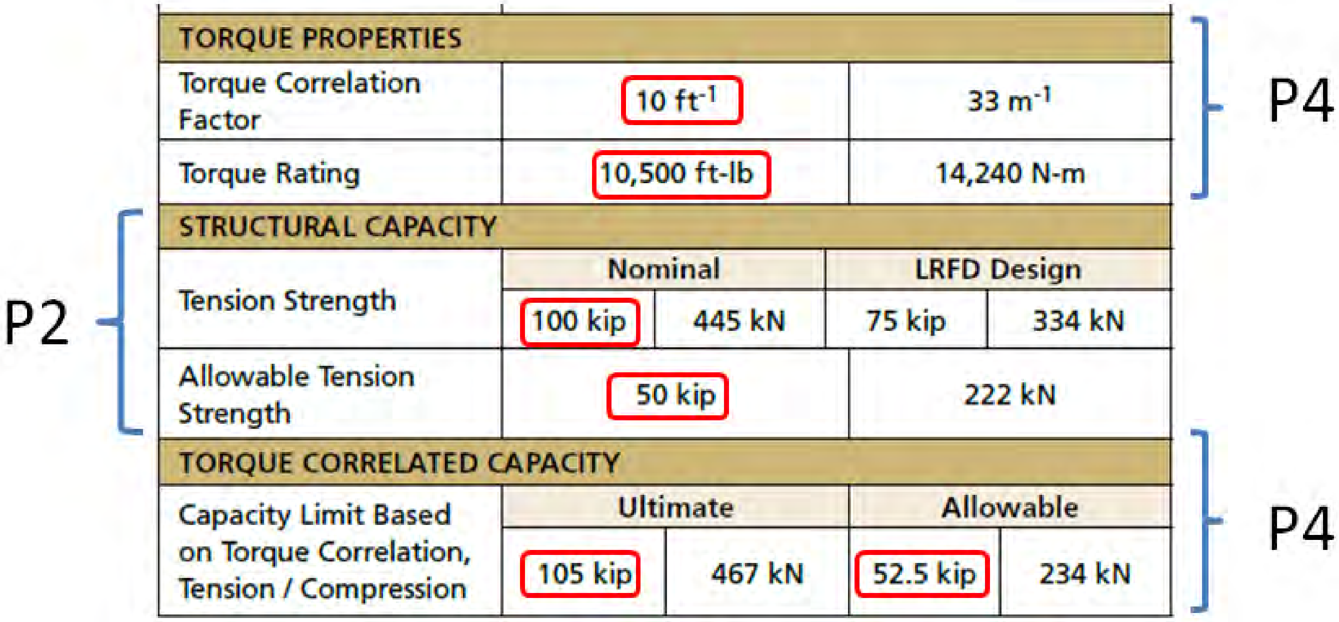
The strength of the concrete will also factor into the axial compressive strength of helical piles. Higher strength concrete results in higher bearing pressure with both embedded new construction pile caps (P1) and foundation repair brackets (P1).

Helical piles can be one-piece foundation elements, but are more commonly produced in sections that are coupled together during installation. Therefore, the strength of the coupling must be considered in the design as part of the shaft (P2). CHANCE helical pile couplings are designed to meet or exceed the torque correlated geotechnical capacity **[Method 2]**. They are also designed to meet or exceed the bending strength of the shaft itself. Structurally, the couplings limit both the tension and compression strength. For CHANCE Type SS helical piles, the coupling bolt is the limiting factor for tension strength.

Load direction is an important consideration and strongly affects the shaft type and size required. This was discussed previously under P4. The Application (new construction, foundation repair, earth retention, etc.) also affects the shaft type and size required. For example, it is not practical to use large diameter shaft helical piles for underpinning existing building structures.

Section 7 is broken down by specific helical pile product families. Each family sub-section lists the tension and compression strengths in various tables, in addition to specifications and available configurations. For example, the P2 (shaft) strength and P4 (geotechnical) tension capacity for Type SS175 helical piles are shown below.

Table C-3 - SS175 - P2 Tension Strength and P4 Torque Correlated Capacity

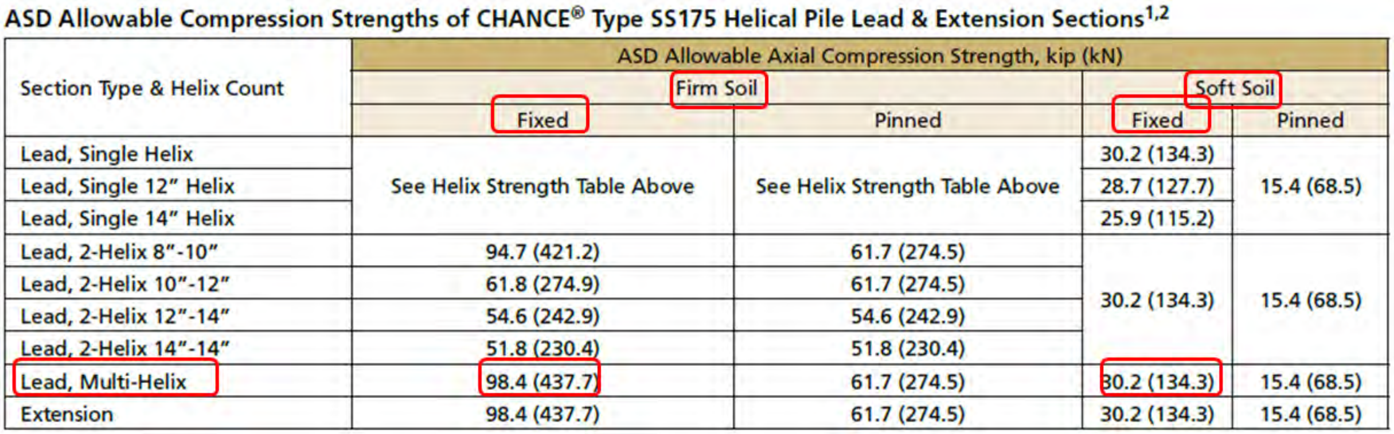


TORQUE PROPERTIES				
Torque Correlation Factor	10 ft^{-1}		33 m^{-1}	
Torque Rating	10,500 ft-lb		14,240 N-m	
STRUCTURAL CAPACITY				
Tension Strength	Nominal		LRFD Design	
	100 kip	445 kN	75 kip	334 kN
Allowable Tension Strength	50 kip		222 kN	
TORQUE CORRELATED CAPACITY				
Capacity Limit Based on Torque Correlation, Tension / Compression	Ultimate		Allowable	
	105 kip	467 kN	52.5 kip	234 kN

The pre-qualified and verified torque correlation factor (Kt) is 10 for Type SS175. The torque rating for SS175 is 10,500 ft-lb. Therefore, per P4 **[Method 2]**, the torque correlated capacity limit for SS175 is 105 kip (see Section 6 TDM). The nominal strength of Type SS175 shaft (P2) is limited to 100 kip by the shear strength of the coupling bolt. Comparing the two, 105 kip > 100 kip, therefore P2 tension strength controls at max torque. If the installation torque is less than 10,000 ft-lb, then P4 **[Method 2]** will control. The allowable geotechnical capacity of 52.5 kip is based on a deterministic factor of safety of 2.

It is convenient to tabulate axial compression strength in terms of either P2 (shaft) & P3 (helix), or P1 (bracket) & P2 (shaft). The table below from Section 7 of the TDM lists the P2 (shaft) and P3 (helix) ASD allowable strengths for Type SS175 square shaft helical piles. It is used to easily determine P2 and P3, which can then be compared to P4 to see which will control the design. The table is broken down by soil type, end condition, and number/diameter of the helix plates.

Table C-4 - SS175 - P2 Shaft Compression Strength and P3 Helix Strength in Firm or Soft Soil



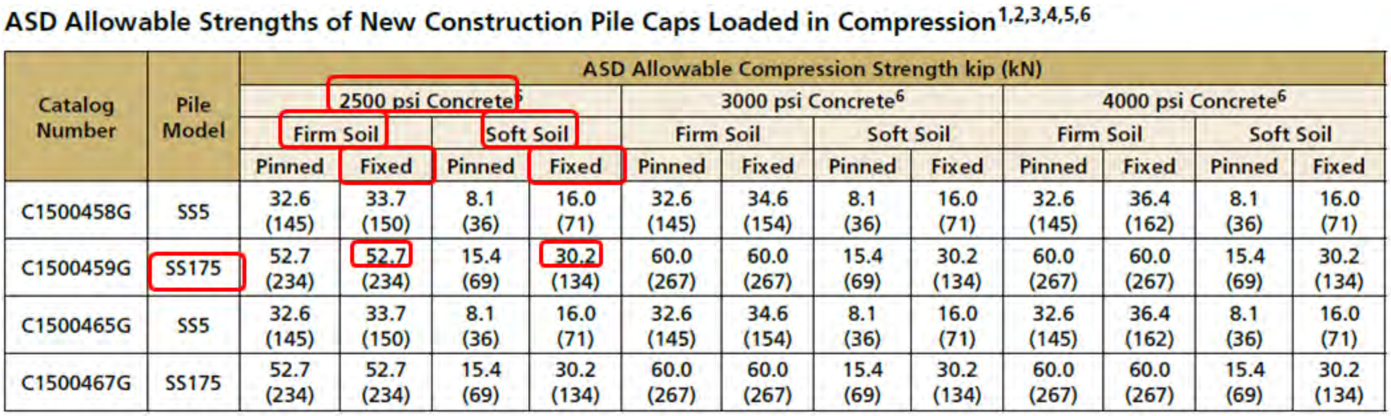
ASD Allowable Compression Strengths of CHANCE® Type SS175 Helical Pile Lead & Extension Sections^{1,2}

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 example, a Type SS175 helical pile in firm soil & fixed end condition with multi-helix plates (3 or more plates) has ASD allowable compression strength of 98.3 kip. However, that exceeds the P4 geotechnical allowable capacity of 52.5 kip. But if the soil is soft with the same fixed end condition, the ASD allowable compression strength is 30.2 kip; which is less than the P4 geotechnical allowable capacity of 52.5 kip. The difference is the depth to fixity, which is 5'-0 in firm soils and 10'-0 in soft soils.

The table below from Section 7 of the TDM lists the P1 (new construction bracket) and P2 (shaft) ASD allowable strengths for Type SS175 helical piles. It is used to easily determine P1 and P2, which can then be compared to P4 to see which will control the design. The table is broken down by concrete strength, soil type and end condition.

Table C-5 - SS175 – P1 Pile Cap Compression Strength and P2 Shaft Compression Strength in Firm and Soft Soils



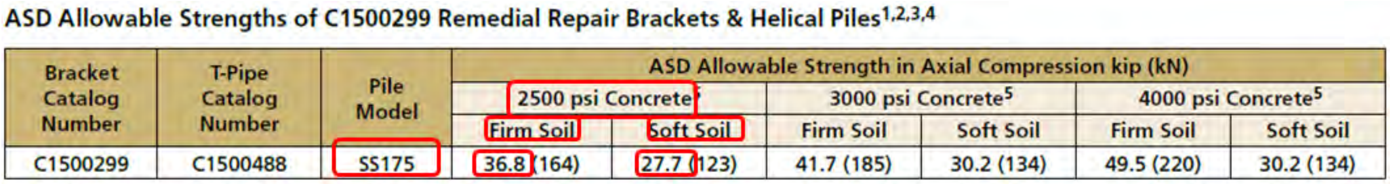
ASD Allowable Strengths of New Construction Pile Caps Loaded in Compression[1,2,3,4,5,6]

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 example, a Type SS175 helical pile in firm soil & fixed end condition with a new construction cap embedded in 2500 psi concrete has an ASD allowable compression strength of 52.7 kip based on the strength of the cap (P1). The P4 geotechnical allowable capacity of 52.5 kip is basically the same. But if the soil is soft with the same fixed end condition, the ASD allowable compression strength is 30.2 kip based on the shaft strength; which is less than the P4 geotechnical allowable capacity of 52.5 kip. Again, the difference is the depth to fixity, which is 5'-0 in firm soils and 10'-0 in soft soils.

The table below from Section 7 of the TDM lists the P1 (remedial repair bracket) and P2 (shaft) ASD allowable strengths for Type SS175 helical piles. It is used to easily determine P1 and P2, which can then be compared to P4 to see which will control the design. The table is broken down by concrete strength and soil type. CHANCE Remedial Repair Brackets provide fixed end condition at the bracket-shaft connection.

Table C-6 - SS175 – P1 Repair Bracket Compression Strength and P2 Shaft Compression Strength in Firm and Soft Soils



ASD Allowable Strengths of C1500299 Remedial Repair Brackets & Helical Piles[1,2,3,4]

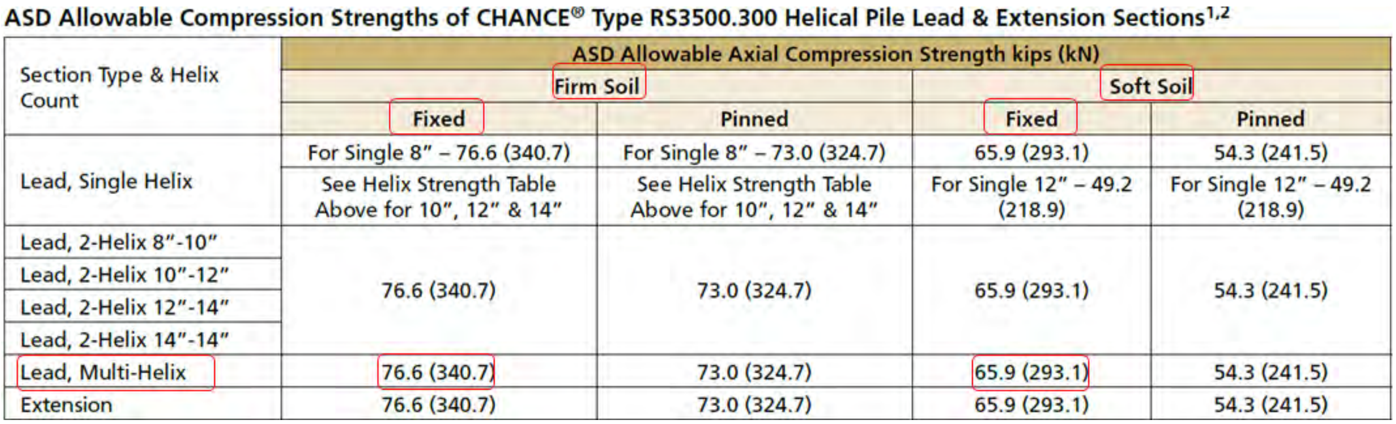
Bracket Catalog Number	T-Pipe Catalog Number	Pile Model	ASD Allowable Strength in Axial Compression kip (kN)					
			2500 psi Concrete[5]		3000 psi Concrete[5]		4000 psi Concrete[5]	
			Firm Soil	Soft Soil	Firm Soil	Soft Soil	Firm Soil	Soft Soil
C1500299	C1500488	SS175	36.8 (164)	27.7 (123)	41.7 (185)	30.2 (134)	49.5 (220)	30.2 (134)

For example, a Type SS175 helical pile in firm soil with a remedial repair bracket connected to an existing 2500 psi concrete footing has an ASD allowable compression strength of 36.8 kip based on the strength of the repair bracket (P1). The P4 geotechnical allowable capacity of 52.5 kip is greater, which means the bracket strength controls the design. This is also true if the soil is soft; the ASD allowable compression strength is 27.7 kip based on the bracket strength. The allowable load for remedial repair brackets is less because of the eccentric compressive load. Note from the table above the allowable strength can increase with stronger concrete.

Note from Table C-4 above that the allowable shaft (P2) compressive strength for SS175 in soft soils is significantly less than the torque correlated (P4) capacity. That is one reason why pipe shaft or grouted shaft helical piles are used.

The table below from Section 7 of the TDM lists the P2 (shaft) and P3 (helix) ASD allowable strengths for Type RS3500 3-1/2" OD pipe shaft helical piles. It is used to easily determine P2 and P3, which can then be compared to P4 to see which will control the design. The table is broken down by soil type, end condition, and number/diameter of the helix plates.

Table C-7 – RS3500 - P2 Shaft Compression Strength and P3 Helix Strength in Firm or Soft Soil



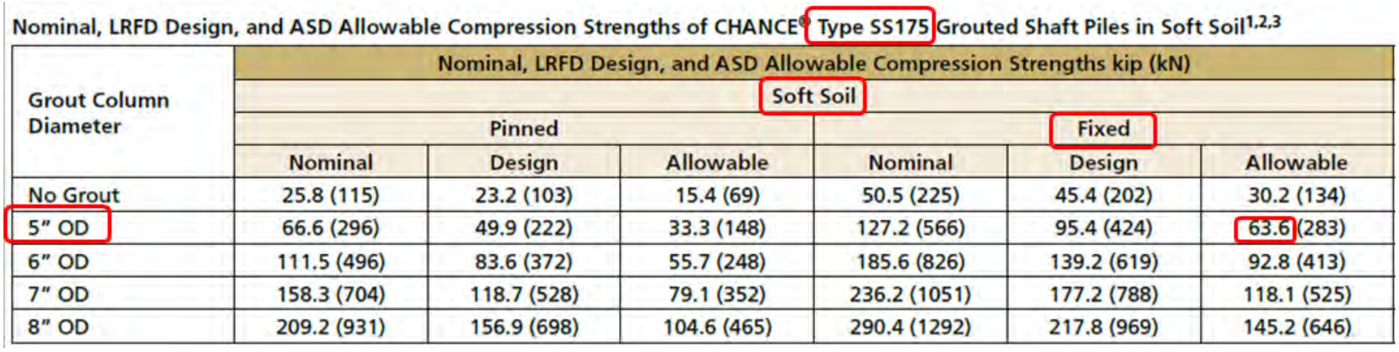
ASD Allowable Compression Strengths of CHANCE® Type RS3500.300 Helical Pile Lead & Extension Sections[1,2]

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) See Helix Strength Table Above for 10", 12" & 14"	For Single 8" – 73.0 (324.7) See Helix Strength Table Above for 10", 12" & 14"	65.9 (293.1) For Single 12" – 49.2 (218.9)	54.3 (241.5) 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 example, a Type RS3500 helical pile in firm soil & fixed end condition with multi-helix plates (3 or more plates) has ASD allowable compression strength of 76.6 kip. But the ASD allowable compression strength in soft soil is either 65.9 kip with a fixed end condition, or 54.3 with a pinned end condition. These ASD allowable strengths are much higher than for SS175 in soft soil, which are 30.2 kip and 15.4 kip with fixed and pinned end conditions respectively. The P4 torque based geotechnical allowable capacity for RS3500 is 45.5 kip, which is less than the structural strength of RS3500 for any combination of soil type and end condition and thus controls the design. This is why SS/RS Combo piles are a good choice in soft overburden soil conditions.

Another way to increase structural strength is with grouted shaft Helical PULLDOWN Micropiles per Table C-7 below. The grout column increases the section modulus, which in turn increases the axial compression strength. Another benefit of the grout column is increased axial capacity (P4) base and shaft resistance, due to the soil-grout bond **[Method 1]**.

Table C-8 – SS175 Grouted Shaft in Soft Soils P2 Shaft Compression Strength



Nominal, LRFD Design, and ASD Allowable Compression Strengths of CHANCE® Type SS175 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	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)

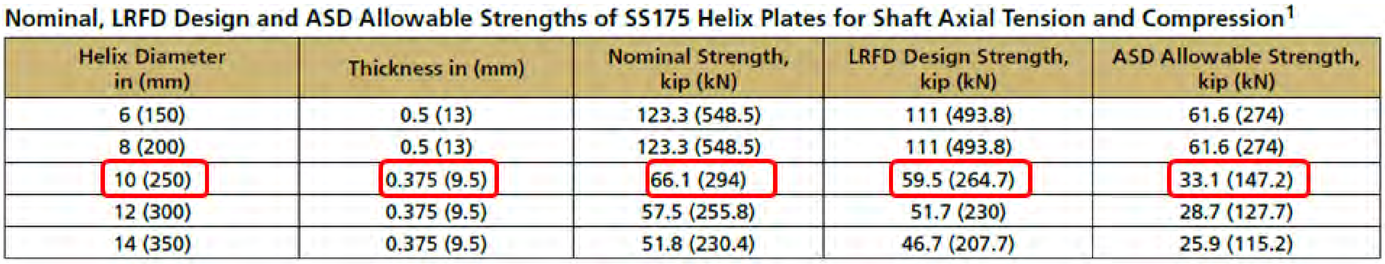
For example, an SS175 helical pile with a 5" diameter grout column more than doubles the ASD allowable compression strength of the P2 shaft. Larger grout columns increase the structural strength even higher. This is an example where torque correlation **[Method 2]** does not limit the (P4) geotechnical capacity. Base and side resistance **[Method 1]** calculated with HeliCAP® v2.0 Helical Capacity Design Software is often greater than strictly torque relationships.

The helix strength (P3) is best determined directly by testing. The photos below (courtesy of CTL | Thompson) show how the helix strength can be determined. The load is applied through the shaft and resisted by the helix shaped fixture. The line of bearing is located at the average helix radius. The load is applied until the helix plate closes or the welds fail due to bending and shear. The test is stopped when the applied load begins to drop off. The maximum test load is considered the ultimate strength of the helix.

Fig. C-1 – P3 Helix Strength Set-Up

Fig. C-2 – RS2875 14" Dia. Helix – Test Results

Table C-9 – SS175 P3 Helix Strength



Nominal, LRFD Design and ASD Allowable Strengths of SS175 Helix Plates for Shaft Axial Tension and Compression[1]

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)

The allowable helix strength (P3) must equal or exceed the end-bearing capacity (P4) of the of the helix plates. It is possible for the bearing capacity of a helix plate to exceed the structural strength of the helix plate For example, an SS175 10" diameter helix plate has an allowable strength of 33.1 kip per Table C-9 above. If the maximum allowable torque based capacity of an SS175 helical pile (52.5 kip) is needed, then more than one 10" helix is required to meet structural strength requirements since 33.1 kip is less than 52.5 kip. A twin-helix or triple-helix configuration will work. This is an example where the designer may want to specify a minimum number of helix plates in the project plans.

As helix plate diameter increases, the helix strength (P3) generally decreases. This is because the line of bearing (average radius) increases with increasing diameter, which in turn increases the moment arm distance. The increased distance increases the bending forces at the helix/shaft welded connection.

Load tests **[Method 3]** are used to verify the feasibility and capacity of helical piles/anchors and are described in detail in Appendix B of the TDM. They can be part of a pre-production test program where at least one helical pile is installed and tested to determine the ultimate resistance and the load/deflection response. Project requirements may also require production tests on a specified number of helical piles/anchors to ensure capacity and performance requirements are being met. It is **VERY IMPORTANT** that the performance requirements be clearly specified **BEFORE** the start of work. It should be part of the data gathering process and feasibility assessment for helical piles. Helical piles are primarily end-bearing foundation elements, meaning they derive most of their resistance with the helix plates transferring load to the soil at the pile tip. Therefore, the load/deflection response of a helical pile at a particular load (serviceability) must take into account the section modulus and length of the shaft. The designer must understand that long end-bearing piles will displace more than short end-bearing piles because of the pile length.

The recommended acceptance criteria for the allowable capacity of helical piles/anchors is 50% of the applied test load causing a net displacement equal to 10% of the average helix diameter. This means that total displacement of the pile/anchor may exceed 1 inch in order to fully mobilize the bearing capacity of the helix plates. This is the acceptance criteria used in ICC-ES Acceptance Criteria AC358 for Helical Systems and Devices, per Section 4.4.1.2. It can be expressed mathematically as PL/AE + 0.10Dave, where "PL/AE" is the elastic shortening or lengthening of the pile shaft under load. As mentioned previously, the net displacement of the helix plates at allowable loads will average 0.25 in (6.4mm) ± 0.12 in when using a geotechnical factor of safety of two.

VI. SUMMARY:

In **summary,** helical pile design determines the geotechnical resistance (P4) and structural capacity (P1, P2, & P3), typically in that order. Probe helical piles and load tests are often done before start of work when a geotechnical report is not available or when verification of capacity is required. The geotechnical and structural resistance are separate limit states and whichever one is the **lesser** will control the design. In most cases, the geotechnical resistance (P4) will be the controlling factor. The designer is encouraged to design helical piles so that the geotechnical resistance (P4) controls to make the most efficient use of the soil's ability to bear load. This often means choosing the right shaft type/size, end condition, and helix configuration to maximize capacity.

VII. RELIABILITY:

Reliability is an important aspect of helical pile design. Reliability is defined as the probability of long-term satisfactory performance. The better the capacity prediction method(s) used, the greater the reliability. Hubbell Power Systems, Inc. recommends using base plus shaft resistance **[Method 1]** and torque correlation **[Method 2]** to determine capacity whenever possible. Perko 2009 did a statistical analysis of helical pile capacity in order to check the reliability of this approach. He used a database of several hundred load tests in the analysis and used a factor of safety of 2 to determine a safe allowable load (deterministic approach). Using bearing capacity theory, the load test data suggests that 1 out of 10 helical piles will exhibit unsatisfactory performance. That is a 90% success rate, but still means 10% will have unacceptable performance. Using torque correlation, load test data suggests that 0.3 out of 10 will exhibit unsatisfactory performance. That's a 97% success rate which is much better, but still means that 3% will have unacceptable performance. Methods 1 and 2 are independent methods used to determine helical pile capacity. When two independent methods are statistically combined, the result of poor helical pile performance drops to only 3 piles out of 1000, or 0.3%. That is a 99.7% success rate, which most engineers agree is acceptable reliability. Loads tests **[Method 3]** is another independent method of capacity prediction which can be used when soil data is lacking or uncertain, or when soil conditions change.

VIII. OTHER TOPICS RELATED TO DESIGN:

Corrosion Potential: Underground corrosion is discussed in detail in Appendix A of the TDM. In most ground conditions, corrosion is not a practical concern for deep foundations, including helical piles. There is typically little to no oxygen in undisturbed soils, especially below the ground 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 driven steel H-piles. If the geotechnical report declares the corrosion potential is moderate to severe for a given project, then a square shaft helical pile is a good choice because of its solid cross section and low perimeter surface area compared to a pipe shaft; which is hollow and has more perimeter surface area relative to the cross-sectional area of steel. Hot-dip galvanization adds a thick coating of zinc to the steel pile. It provides a durable coating that increases service life. Service life calculations based on metal loss rates can be done when corrosion potential data is available. Appendix A of the TDM contains 4 design examples for corrosion design.

A Helical PULLDOWN® Micropile with its solid square shaft encased in a very dense grout mixture provides the most resistance to corrosion since the grout acts as an additional layer of protection. Cathodic protection, or adding a corrosion allowance (additional thickness of sacrificial steel) are also options in aggressive environments.

Helix strength: The structural strength of an individual helix is dependent on the plate thickness, grade of steel, diameter, and strength of the weld that connects it to the pile/anchor shaft. There must be enough helix plates so that the sum of their individual strengths can share the load that is required of the pile/anchor. The product family sub-sections in Section 7 of the TDM provide the P3 helix strengths. A performance-based specification requires a minimum number of helix plates required to share the load. The size of each helix plate is left up to the installation contractor as long as the minimum number plates is provided, and that other requirements are met, such as minimum depth and installation torque. For example, if 60 kip capacity is required, and the individual helix strength is 40 kip, then a minimum of two helix plates are required to share the 60 kip load. A prescriptive-based specification would be explicit on the exact number and size of the helix plates.

Helix Size and Configuration: The size (diameter) of helix plates have a significant influence on the installation and performance of a helical pile/anchor. The helical configuration (number and size of helix plates) can change from pile to pile. The designer can choose between a **performance** based design and a **prescriptive** based design. A performance based design means the helical pile contractor is responsible for some design and construction procedures. A prescriptive based design means the owner or designer has the sole responsibility for all aspects of helical pile design and installation. Hubbell Power Systems, Inc. recommends using a performance based design in most situations.

An example of a performance based design for helical piles is minimum number of helix plates, minimum installation torque, and minimum depth. The contractor can then decide the actual number and size of helix plates, depths and torque required to achieve the required resistance; so long as the specified minimums are met. A prescriptive based design is the actual number and size of helix plates, actual installation torque, and actual depth. A prescriptive design may 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 helix plates must be smaller. Alternately, the softer or less dense the bearing soil strata, the helix plates must be larger to generate the required torque/capacity.

It is important that the smallest helix plate be the bottom-most helix. A multi-helix pile 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” or 10”/12”/14”. The larger the shaft size, the larger the smallest helix diameter. For example, the smallest helix plate on pipe shaft is typically 10 in or larger.

Helical piles with multiple helix 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”. 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 required depth. Helical extensions can be removed by unscrewing the pile/anchor, taking them off and reinstalling the pile/anchor. If helix plates on the lead section need to be removed, it will require the installation contractor to supply a different configuration lead section 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 having to remove helical plates regardless of the method.

Minimum Length (depth): The minimum length (depth) for helical piles to behave as a deep foundation is controlled by the depth to the top-most helix plate. The plate closest to the ground surface should be a minimum vertical depth of 5 diameters (5D) where D is the diameter of the largest helix. If the helix plate is not installed to this depth, the failure mode will be similar to a shallow foundation, i.e. 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 increasing 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.

Helical piles are required to be a minimum length to ensure that the pile is deep enough to provide reliable, long term capacity. Minimum depth ensures the helix plate(s) are located in a soil stratum that will bear load over the long term with reasonable settlement. Geotechnical reasons can override the 5D requirement. Geotechnical reasons that affect minimum length are frost depth, seasonal change in moisture content, depth of fill, organic soils, volume change (shrink-swell) soils, expansive soils, liquefiable soils, and ground water fluctuations. For example, if it is known that a compressible peat layer exists between 15' and 20' depth, then it is important for the pile to bear in soil stratum below the peat layer. Therefore, a minimum depth should be required that locates the helix plates in a bearing soil below the peat layer, thereby ensuring the pile will not settle over time as the peat consolidates.

Tension Piles/Anchors – The 5D requirement over the uppermost helix for tension elements is very 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. ICC-ES Acceptance Criteria AC358 has specified a minimum depth for helical tension anchors. AC358 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.

For helical tieback anchors, the 5D requirement is 5D beyond the active failure plane, which is dependent on the friction 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.

Cost: The total installed length has a direct impact on the cost of the helical 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 helical 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 helical piles, which is one of their advantages. A thorough discussion of bidding and construction documents and strategies is discussed in **Section X** of this Guide, titled "Construction Documents".

IX. HOW TO SPECIFY HELICAL PILES:

A. *Minimum Capacity or Installation Torque*: Whether using a performance or prescriptive specification, the helical pile/anchor capacity (ultimate resistance) should be specified in order to ensure that the required pile/anchor resistance is achieved. This can be done by specifying the minimum capacity directly or indirectly by specifying the required installation torque. The designer can choose either way.

A.1: Minimum Capacity: Regardless of the design method used, the ultimate resistance is the same. Ultimate resistance is the limit state based on the structural strength or the geotechnical capacity of the helical pile, defined as the point at which no additional load can be applied without failure.

A factor of safety (or a resistance factor) is applied to the ultimate resistance to provide a reserve capacity greater than expected loads. This “normal use” load is commonly referred to as service, design, working, SLS or un-factored load. The safety or resistance factor may be prescribed by building code, but is often left up to the designer. A proper factor of safety/resistance 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/resistance applied. Conversely, the less uncertainty, the lower the factor of safety/resistance applied. For ASD design, the industry standard for helical piles is a factor of safety of 2 for permanent applications. For LRFD design, the resistance factor (Ø) recommended for helical piles used in compression range from 0.65 to 0.75. The resistance factor (Ø) recommended for helical piles used in tension range from 0.55 to 0.65.

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).

One problem with construction documents regarding helical piles/anchors is clearly identifying the capacity required. The best method is to clearly define the ultimate resistance required. If the designer chooses to specify the un-factored load, then the loads should be clearly identified as (service/design/working/SLS/un-factored loads) and clearly state what the required factor of safety/resistance is.

A.2: Installation Torque: 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.** Installation torque should not be used to specify minimum capacity for helical tieback anchors when 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 the anchorage does not fail the proof test.

If the installation torque approach is utilized, the designer should be aware that torque capacity correlations only apply to helical piles with advancement rate that equals or exceeds 85% of the helix pitch per revolution at the time of final torque measurement. Refer to Section 6 of the TDM for a full discussion of torque correlation (Kt) relationships. On-site testing can be used to obtain a site specific Kt, otherwise use the default values listed in Table C-1 above.

Also, tension and multi-helix compression capacity should be determined based on the average torque measured over the last three helix diameters of installed length. Most specifications simplify this to 3 feet. The reason this is done is to better predict the bearing capacity of the helix plates as they distribute load to the soil in a passive pressure bulb either below (compression) or above (tension) the helix plate(s). Depending on how fast the torque increases over the last 3 feet of penetration will have a significant impact on the capacity of the helical pile/anchor. Note that it is virtually impossible to average a helical anchor/pile’s maximum torque rating over the last three average helix diameters, which means a shaft with higher torque strength may be needed in very dense soils.

X. CONSTRUCTION DOCUMENTS:

A. *Construction Plans*: The previous sections presented the various design elements that should be considered when using helical piles/anchors. Each one of the following design elements should be defined in the construction plans on a well-engineered project.

- Shaft Type
- Shaft Size
- Helix Configuration
- Pile/Anchor Length
- Minimum Capacity or Install 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 author'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:

Table C-10 - Helical Pile Data Summary

Pile Type	Square Shaft Helical Pile
Shaft Material:	CHANCE Type SS175 1-3/4" Solid Square Shaft
Helix Configuration	8"/10"/12" Helix Plates
Bid Length	28'-0
Ultimate Resistance, or	80 kip Minimum
Installation Torque	8,000 ft-lb Min Average

Other design parameters can also be added such as grout column diameter for grouted Helical PULL-DOWN® Micropiles, minimum length (if different from bid length), termination type, angle of installation, or required casing diameter & length. Soil conditions may also require the pile head end condition (fixed or pinned) be specified if shaft capacity controls the design.

The above summary provides enough information for bidders to aggressively bid on the same items as other bidders. It reduces the 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 helical 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 designer, 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 bidder's, 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 helical piles prior to bidding. Helical piles/anchors are well suited to exploratory installations because of 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 the pricing will be.

Generally, a pricing structure that allows for per/pile price to a specified bid depth with unit pricing for additional/deductible length works best. For example, if the geotechnical information available indicates 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 based on increments of helical pile section lengths (5'-0 & 7'-0) rather than 1' increments, since 7'-0 is the most common section length. This is because the same amount of material is likely to be used once the contractor has to add an additional section. 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. Many helical tieback projects have benefited by utilizing this approach.

Another unit pricing strategy 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 5000 lineal feet (LF) of piling. Payment would be made by the unit price for the quantity of piling installed, whether it is 4500 LF or 5500 LF.

C. *Technical Specifications*: Technical Specifications are an important part of well-crafted construction documents and should further define the details regarding 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

FORMS
APPENDIX D

CONTENTS

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: ____________________

Address: ____________________

____

____

Type: ☐ Foundation ☐ Underpinning/Shoring ☐ New Construction ☐ Rock ☐ Tower Foundation ☐ Other:

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.

HeliCAP® Helical Capacity Design Software
Buyer Qualification and Order Form

Qty	Description	Price Each	Hard Drive Serial # (see instructions on next page)
1	HeliCAP® Helical Capacity Design Software	________	______________________________

☐ 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 ______________

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® Hare. 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.

CHANCE® Helical Pile/Anchor Axial Test

Project:	Date:	Sheet of
Anchor/Pile Number:	Product Series: ☐ SS ☐ RS	
Helix Configuration:	Total Depth:	
Time: Start Finish	Recorded by:	

PRESS (psi)	LOAD (kip)	TIME (min)	DISPLACEMENT		
			GAUGE A (in)	GAUGE B (in)	GAUGE C (in)

CHANCE® Helical Pile/Anchor Installation Log

Project:

Date:

Sheet of

Anchor/Pile Number:

Product Series: ☐ SS ☐ RS

Helix Configuration:

Installation Angle:

Time: Start Finish

Recorded by:

DEPTH (ft)	PRESSURE (psi)	TORQUE (ft-lb)	COMMENTS

CHANCE HELICAL PULLDOWN® Micropile Installation Log

Project:	Date:	Sheet of
Anchor/Pile Number:	Product Series: ☐ SS ☐ RS	
Helix Configuration:	Installation Angle:	
Grout Column Diameter:	Sleeve Depth: From to	
Time: Start Finish	Recorded by:	

DEPTH (ft)	PRESSURE (psi)	TORQUE (ft-lb)	GROUT FLOW (Volume/Shaft/Length)

GLOSSARY of TERMS

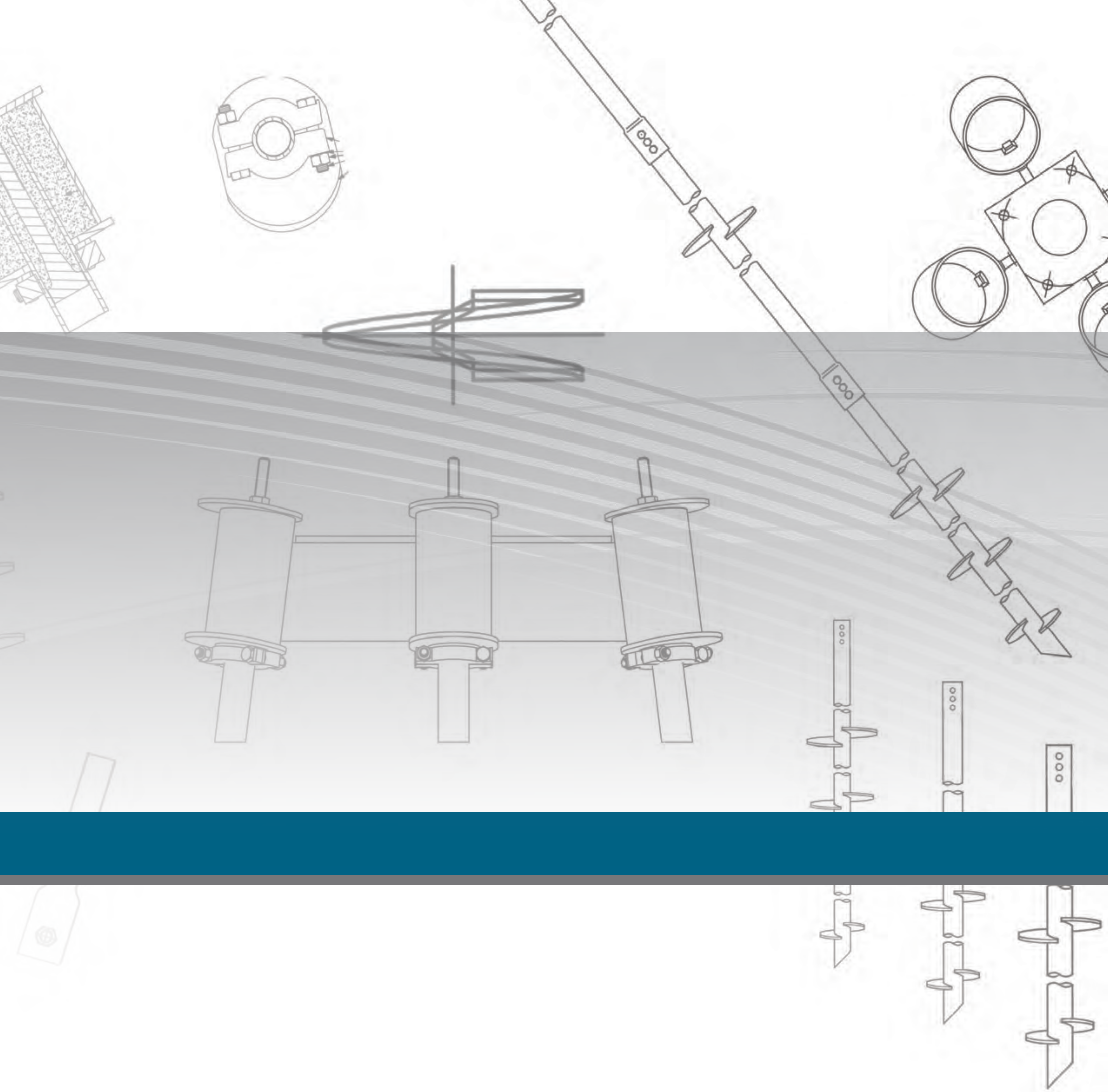
Alignment Load (AL)	A low magnitude load applied to a pile/anchor at the start of the load test to keep the testing equipment correctly positioned and to remove any slack in the reaction system.
Allowable Capacity	The geotechnical capacity of a pile/anchor or pier as determined by a reduction of the 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.
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.
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.
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.
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.
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.
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."
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.

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.
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.
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.
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.
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 Section	With reference to a CHANCE® Helical Pile, a lead section
Test Load	The maximum load applied to a pile or pier during testing.
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
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.
Working Load	Another term for Design Load.



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