MacLean™
CIVIL PRODUCTS

BUILDING SOLID FOUNDATIONS

HELICAL FOUNDATION SYSTEMS ENGINEERING REFERENCE MANUAL

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INTRODUCTION

WHAT IS A HELICAL PILE?

Terms such as Helical Foundation Pile, Helical Screw Pile Foundation, Screw Piles, Helical Anchors, Screw Anchors, and Helical Piers are often used interchangeably throughout the industry. The preferred description is “Helical Pile”. The DFI (Deep Foundations Institute) defines “pile” as the generic term for foundations. MacLean Civil Products (MCP) a division of MacLean Power Systems supports and produces several brands of helical piles including our patented Strength Squared coupling system, Dixie350 foundation repair brackets, MVP grouted pile displacement plates, and high capacity product lines.

A helical pile serves the same function as other deep foundations such as driven piles, auger cast piles and micro-piles to support or resist loads transferred into the pile by any type of structure. These loads can be tensile, compressive, lateral or a combination of the three. See Section 8 for a detailed discussion concerning loads.

A helical pile is simply a steel shaft with one or more helices (formed plates) welded to it. Installation of this type of pile can be compared to that of a self-tapping wood screw. Helical piles are installed into the ground by turning the pile into the ground with the application of rotational torque, usually provided by a hydraulic powered drive head. The axial capacity of the pile is directly related to the torque achieved throughout the last 3 to 5 ft. of installation (i.e. three times the diameter of the largest helix). This *torque vs. capacity* relationship for low displacement piles (i.e. <= 3.50” shaft dia.) provides for an excellent on-site quality control method, as discussed in Section 12.

A helical pile includes three components:

1. Shaft

Shaft sizes typically range from 1.50” to 2.00” Round Cornered Square (RCS) high strength steel bar and from 2-7/8” to 8-5/8” diameter hollow steel pipe. Soil conditions, the expected foundation loads and the anticipated installation torque normally govern the required size and shape of the shaft. Other factors, such as the method of connecting the pile to the structure, may also influence the required shaft size and shape.

The shaft has four primary functions:

a. To sustain sufficient torque capacity to install the pile
b. To resist loads transferred to the helices during installation
c. To provide the proper connection (interface) to the structure
d. To sustain loads transferred from the structure after installation

2. Helices

Helical piles usually include one to six helices. In the case of multi-helix lead sections, the smaller diameter helix always enters the ground first, followed by a larger diameter helix or helices of the same size. This minimizes installing torque. The distance between any two helices should be at least three times the diameter of the smaller (or lower) helix. To minimize soil disturbance, helices must be formed to a true helical shape with uniform pitch by matching metal dies.

The maximum load that each helix can exert against the soil is equal to the effective bearing capacity of the soil times the projected area of the helix.

The total pile capacity provided by the helices is simply the sum of the individual helix bearing capacities. For low displacement piles (i.e. < = 3.5” dia), skin friction is usually considered negligible and 100% of the pile capacity is assumed to be provided by the helix / soil reaction.

The Individual Plate Capacity (IPC) method is now recognized throughout the industry as an effective method of predicting the Geotechnical Ultimate Capacity of a Helical Pile Foundation. This method utilizes Terzaghi's general bearing equation:

$$q_{ult(g)} = A_h \times ((c \times N_c) + (q \times N_q)) \quad \text{[Equation 6.1]}$$

The above equation and its application for Helical Piles will be discussed in detail in Section 5.

Helices have two primary functions:

a. To pull the pile into the soil to the required depth during installation
b. To transfer load into the soil by means of exerting bearing pressure after installation

3. Pile / Structure Interface Connection

Methods of connecting the pile to the structure depend on the type of structure to be supported. Connections can range from complex welded/cast brackets to slip fit brackets onto the top of the pile. The major consideration for this connection is to assure that there is adequate load transfer from the structure to the pile.

ADVANTAGES AND BENEFITS

Construction

- The installation equipment for a helical pile is generally smaller, lighter, and less specialized than that required for other types of foundations such as drilled piers, driven piles, and auger cast piles. The cost of mobilizing equipment (move in – move out) is generally much less with helical piles than with other types of foundation systems.
- In addition to significant cost savings, the smaller (less specialized) installation equipment used with helical foundations allows for quick responses to situations requiring immediate action.
- The relatively small size of the installation equipment allows for MCP piles to be installed in confined areas (such as inside buildings or areas with low head room clearance) where conventional foundations would be unfeasible or impractical. In some cases the installation equipment can be hand held.
- The installation of a helical pile is virtually vibration free, thus allowing installation near existing foundations or footings.
- Onsite quality control can be accomplished by applying the torque vs. capacity relationship, thus verifying the ultimate capacity of the pile at the time of its installation.
- The installation of helical pile foundations does not create spoils. This eliminates the time and cost associated with spoil removal and disposal.

Environmental

- Installation is virtually vibration free; a benefit where vibration can be detrimental to existing structures.
- Noise level is relatively low.
- Due to the low vibration and noise level, MCP piles can be installed in close proximity to existing structures and populated areas.
- The relatively light (low ground pressure) equipment minimizes surface damage to the area. In some cases the installation equipment can be hand held.
- Since the installation of helical piles does not create spoils, significant savings can be realized on contaminated sites.
- Contributes to "GREEN" environment by using recycled steel and providing opportunity to recycle or reuse existing structures.

Seismic Loads – New Construction and Seismic Retrofit

- During seismic events, the flexibility of the steel shafts used with MCP helical piles will better accommodate movement than concrete foundation systems. The advantages of a helical pile foundation to resist seismic loads are now recognized in areas prone to seismic activity.

HISTORY

1800's

Alexander Mitchell developed cast iron helical piles in England in the early 1800's. These pile were used in conjunction with the construction of several lighthouses in the English tidal basin and large railway bridges throughout the world. The first patent for helical piles was awarded to Mitchell in 1833.

1920's

Light load capacity manually installed helical anchors began to be used by the electric power industry for guy anchorage of utility poles.

1950's

Power driven helical anchors began to be used by the electric power industry for tension loads of up to 36,000 pounds for towers and utility poles worldwide. The primary use of these anchors was to resist tension loads of guy wires.

1960's

The use of helical anchors was extended by the electric power industry for guy anchorage of transmission towers with tension loads exceeding 100,000 pounds. Engineers were beginning to explore other applications for helical anchors including building foundations. It became apparent that screw anchors could resist compression loads as well as tension loads.

1970's

Helical screw anchors became the preferred method of guying electrical transmission towers and utility poles. The Torque vs. Load Capacity relationship is recognized as a major advantage of Helical Piles.

1990's

Helical Piles became an accepted method of providing deep foundations. Applications include (but are not limited to) Foundation Retrofits, New Construction, Marine Moorings, Boardwalks, Department of Transportation applications and Tiebacks for earth retaining walls.

Present

In today's construction, Owners, Architects, Designers and Geotechnical engineers have become increasingly aware of helical pile foundations and products, their applications and advantages of the system. Several applications for helical piles and helical products include:

- Temporary and permanent earth retaining systems (tieback anchors)
- Underpinning or repair systems for structures subjected to settlement
- Pipeline supports and buoyancy control for underground or underwater pipelines
- Instant street light foundations
- New construction ranging from residential to large commercial developments

MCP helical piles and products are used throughout all types of construction across the globe ranging from residential foundation repair to heavy commercial and industrial foundations to retaining wall tiebacks. In select soil conditions and special project requirements, a grouted pile such as the MacLean Vortex Pile (MVP) is utilized to address site specific foundation issues. The MCP high capacity line (4.5"+ diameter pipe shaft) is recommended for projects with large axial (>150 kip) and lateral (>5 kip) loading requirements and/or sites with extensive low consistency soils (SPT N < 5).

Terzaghi's general bearing equation is now recognized as an effective method of predicting pile capacity. The accepted industry use of Terzaghi's general bearing equation coupled with Torque vs. Load Capacity relationships have proven to be two of the most important developments in the helical pile industry.

GLOSSARY OF TERMS

Allowable Load – Mechanical (ALm)	The maximum allowable load on a structural element as specified by the manufacturer. ALm is usually limited to 50% of the Rated Ultimate Mechanical Capacity.
Allowable Load – Geotechnical (ALg)	The maximum allowable load that may be transferred into a helical pile as determined by the geotechnical properties of the soil. Usually determined by load test behavior or engineering analysis. ALg is typically limited to 50% of the Ultimate Geotechnical Capacity of the pile, but this may vary, depending on project parameters and other factors.
Creep	The continuous deflection (movement) of a pile while subjected to a constant load.
Crowd	Axial compressive force applied to the helical pile as needed to ensure that the helical pile advances into the ground a distance equal to the helix pitch for each revolution.
Dead Load	Loads resulting from the weight of the structure plus all material (equipment) permanently placed within the structure.
Design Load (DL)	The maximum load that will be transferred to the pile. The Design Load is expressed in terms of magnitude and direction. Design Loads can be Tensile, Compressive or Lateral. Also known as Service Load, Working Load, or Nominal Load.
Effective Torsional Resistance	Effective Torsional Resistance is used to estimate Ultimate Geotechnical Capacity of a pile during construction. Helical piles are typically installed to a predetermined *Specified Installation Torque*.
Extension With Helix	Same as a Plain Extension, but with one or more helices welded to it. Typically used where headroom limitations require a shorter lead section. Also used when additional helices are required as an onsite modification when unexpectedly weak soils are encountered. The Extension With Helix is attached directly above the Helical Lead section or sometimes above another extension with helix section.
Factor of Safety	See Safety Factor.
Failure – Geotechnical	Unless otherwise noted, geotechnical failure occurs when continuous deflection (movement) of a pile occurs while subjected to a constant load, i.e. when creep occurs.

Foundation	An element that connects a structure to the earth. Loads are transferred from the structure, to the foundation, to the earth. These loads can be Compressive, Tensile, Lateral or Dynamic.
Geotechnical Capacity	The maximum load that can be resisted via the bearing of helical plates on the soil and the skin friction between the shaft and soil in which the pile is embedded.
Helical Extension	See Extension with Helix.
Helical Lead Section	A central Shaft with one or more Helices welded to it. The first component of a Helical Pile that enters the soil. Extensions are used in conjunction with the Helical Lead Section to achieve the specified depth and to enter competent soil.
Helix	Generally a rounded steel plate formed into a helical flight. When turned in the ground, the helical shape provides thrust along its longitudinal axis thus aiding in the helical pile installation. After installation the plate transfers axial load to the soil through bearing.
Live Load	Loads resulting from vehicles, people, snow, ice, wind, impact, earthquakes and other forces resulting from extraordinary conditions.
Load Test	Determining capacity and relation of load to deflection by applying incremental loads to the helical pile. Engineers, to determine Allowable Load, often apply the results of load tests. See Proof Test.
Mechanical Strength	See Rated or Ultimate Mechanical Capacity.
Nominal Load	See Design Load.
Plain Extension	A central shaft (with no helices) that is attached directly above the helical lead section. Extensions are coupled together and are used to extend the helical lead section to a required depth and into a soil stratum of suitable strength.
Proof Test	Load testing a Helical Pile by applying loads in predetermined increments, maintaining each load for a period of time and recording deflection at the beginning and end of each increment. Engineers, to determine Allowable Load, often apply the results of proof tests.

Rated or Ultimate Mechanical Capacity	The Ultimate Mechanical Capacity of a structural element as specified by its manufacturer. Determined by load tests and/or engineering analysis. Also referred to as Mechanical Strength.
Rated or Ultimate Torsional Strength	The maximum torque that can be safely applied to a Helical Pile during installation.
Reveal	The distance from the ground surface to the upper end of the last installed extension of an anchor, measured along the anchor's longitudinal axis.
Safety Factor (SFg) - Geotechnical	The ratio of the Ultimate Geotechnical Capacity (UCg) of a Helical Pile to the Design Load.
Safety Factor (SFm) - Mechanical	The ratio of the Rated Ultimate Mechanical Capacity of a structural element to the Design Load.
Service Load	See Design Load.
Shaft	The central shaft of a Helical Pile used to transfer load from the structure to the helices. Shafts may be solid square steel bar or hollow steel pipe sections. Shaft sizes typically range from 1.50" to 2.00" Round Cornered Square, and from 2.875" to 8.625" diameter pipe.
Specified Installation Torque	The Effective Torsional Resistance to be achieved - as specified by the engineer.
Ultimate Pile Capacity - Geotechnical (UCg)	The maximum load that can be applied to a Helical Pile prior to geotechnical failure. At this point no additional capacity can be justified.
Ultimate or Rated Pile Capacity - Mechanical (UCm)	The manufacturers' Rated Ultimate Mechanical Capacity of the Helical Pile.
Ultimate Pullout Resistance	Limit state based on the lesser of mechanical strength or geotechnical capacity of the helical anchor - defined as the point at which no additional axial tension load can be justified.
Working Load	See Design Load.

PRODUCT DESIGN AND SELECTION FLOW CHART

The following includes some of the basic items to be considered before recommending a particular Helical pile configuration. A flow chart outlining the basic steps is shown on Page 3 - 3.

1. A DEEP FOUNDATION IS REQUIRED

The owner (or their consultant) has decided that a deep foundation system is required for an existing or proposed structure.

2. PROJECT PARAMETERS

The owner (or their consultant) submits the pertinent project information to the MCP certified installer, distributor or consultant. This information typically includes (but is not limited) to the following items.

- Construction Schedule
- Geotechnical Report – Soil Boring Logs
- Applicable Codes and Specifications
- Design Loads and the required Factor of Safety
- Pile Testing Specifications (if applicable)
- Jobsite Conditions that may affect construction methods or types of equipment or personnel required
    - Headroom clearance
    - Proximity to existing structures
    - Underground obstructions
    - Access to jobsite
    - Expected depth of water during and after construction
    - Safety regulations

3. PRELIMINARY REVIEW

The MCP certified installer, distributor or consultant reviews the project information regarding the application of helical piles for the project.

Are MCP Helical piles recommended for this project?

If NO: Explanation of reason/s to be provided to the owner (or his consultant)
If YES: Proceed with PRODUCT RECOMMENDATIONS

Items to be addressed when evaluating the feasibility of helical piles for a specific project:

Site Access

The proximity to other structures, right-of-way and jobsite obstructions are some of the earliest considerations one must consider in any construction or improvement project. Access for the equipment may also be restricted due to overhead limits and safety issues.

Working Loads (Design Loads)

The Working Load (Design Load) represents the maximum load that will be transferred to the pile. MCP typically recommends a minimum Safety Factor of 2 for permanent structures, thus the required Ultimate Capacity of the pile will be at least twice its Working Load. The designer needs to select the proper shaft size and helix configuration to provide the required Ultimate Mechanical Strength of the pile as well as the required Ultimate Geotechnical Capacity. As noted above, a Safety Factor of 2 for permanent structures is usually applied, but this may vary depending upon the project parameters. See Section 5 for further discussion of loads and Safety Factors.

Soils

Helical compression piles, by definition, are generally considered end-bearing piles and as such rely on the strength of the soil beneath the helices. In the case of tension loads, the piles rely on the soil strength above the helices. For pipe piles (>= 3.5" dia. shaft size) skin friction between the shaft surface and the soil also contributes to the total pile capacity. Information and data required for estimating soil strength and pile/soil friction is typically extracted from the geotechnical reports and sub-surface explorations. See Section 8 for the methods of calculating the theoretical ultimate pile capacity. The sub-surface exploration is most often performed in accordance to ASTM D 1586 (The Standard Penetration Test). This method is discussed in detail in Section 6. Another method, The Cone Penetration Test, may also be applied. The sub-surface exploration report is usually an attachment to the geotechnical report. The geotechnical report, along with the sub-surface exploration report, should contain the information that is required by the methods discussed in Section 8 for determining the theoretical ultimate pile capacity. The quality of this information and its interpretation is critical in selecting an optimum pile configuration. See Section 6 for additional information regarding soils.

In the absence of site-specific soil information, it may be advisable to install and load test one or more test piles to determine the optimum pile design or to apply the method discussed in Section 7.

Equipment

A wide variety of equipment can be utilized for projects. Selection of equipment is based on several factors including job location (inside or outside buildings), headroom clearance, access to jobsite and torsional requirements. Equipment typically ranges from large excavators to mini-excavators (Bob-Cats) to portable hand held equipment.

Qualified Installers

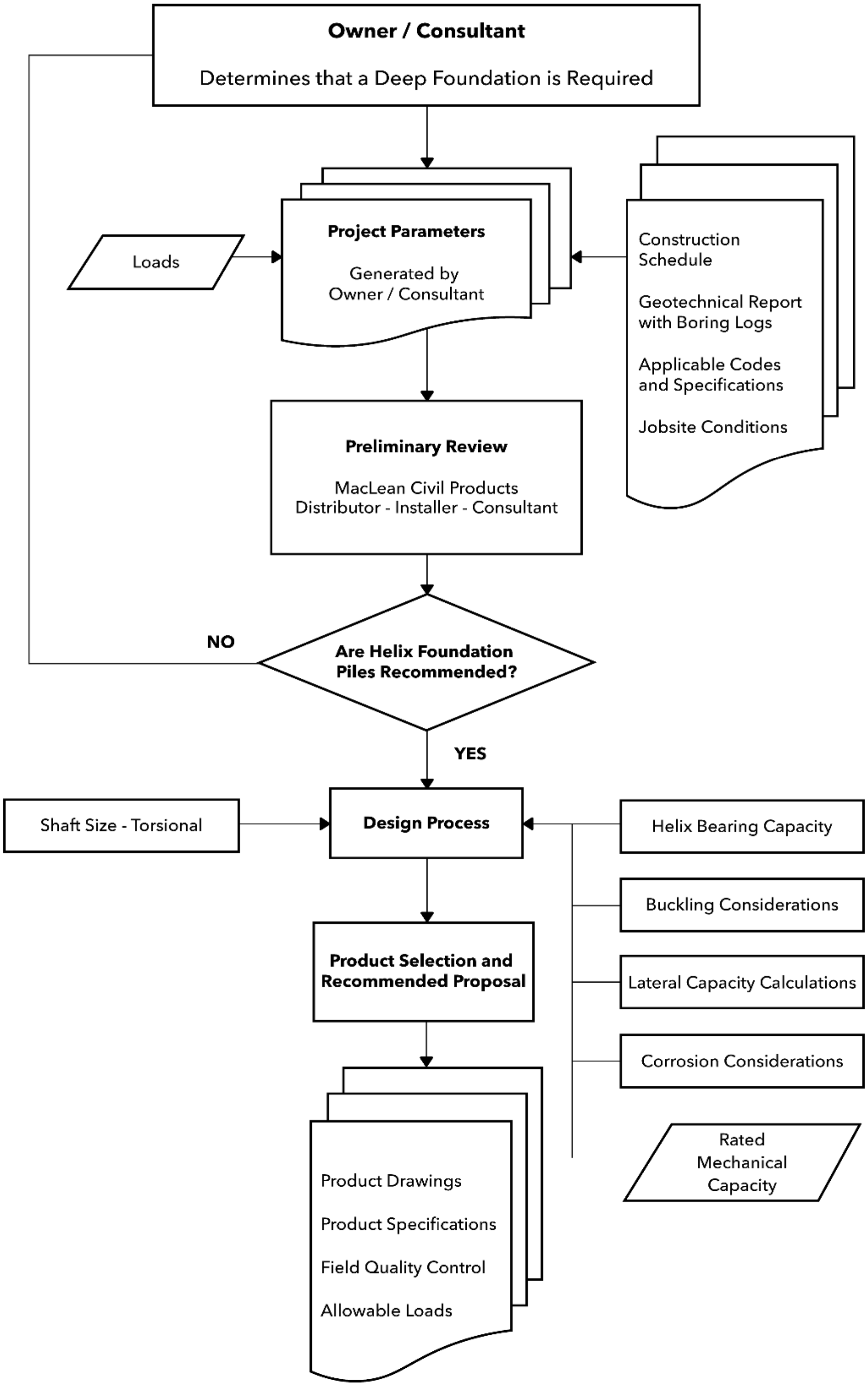
The MCP distributor can supply a list of qualified installers for a particular project. Qualified installers are available in nearly all areas in the US and many areas in Canada.

4. PRODUCT RECOMMENDATION

The RTD online software package provided on the MCP website (www.maclean.kbmax.com/products) is an excellent resource for product recommendations. An experienced MCP certified installer, distributor or consultant can make product recommendations. Depending upon specific project parameters, additional items, not listed below, may also require consideration. The following should be considered to make the best and most economic product recommendations:

- Required Ultimate Geotechnical Pile Capacity
    - Helix Bearing Capacities
    - Skin Friction – If applicable
    - Lateral and Buckling Considerations
    - Factor of Safety
    - Corrosion Considerations
- Shaft Size – Maximum Expected Installation Torque – Structural Loads
- Helical Pile Installation
    - Specified Installation Torque
    - Field Quality Control
    - Load Testing Recommendations
    - Safety Procedures
- Applicable Codes and Specifications
- Pile Termination – Structure / Pile Interface Connection
- Product Drawings and Specifications
- Rated Mechanical Capacity of the Pile

Figure 3.1: PRODUCT DESIGN AND SELECTION FLOWCHART



PRELIMINARY DESIGN CONSIDERATIONS – CHECK LIST

Before making final product recommendations, items that may affect the intended performance of the pile (or your recommendations) should be checked. Using a checklist similar to that shown below is recommended.

SOILS

- ☐ **Quality of Available Geotechnical information?**
- ☐ **Recommendations and/or Cautionary Notes in the Geotechnical Report?**
- ☐ **Expansive Soils?**
- ☐ **Negative Skin Friction?**
- ☐ **Seasonal Variations in Water Depth?**
- ☐ **Abrupt Changes in Soil Properties**
- ☐ **Rock?**
- ☐ **Corrosion?**
- ☐ **SPT N-values greater than 60?**
- ☐ **SPT N-values less than 5?**

PRODUCT APPLICATION

- ☐ **Design Load?**
- ☐ **Temporary or Permanent?**
- ☐ **Helix Bearing Capacity Calculations?**
- ☐ **Helix Loads?**
- ☐ **Manufacturers' Rated (Ultimate) Mechanical Capacity?**
- ☐ **Maximum Installation Torque?**
- ☐ **Applicable Codes and Specifications?**
- ☐ **Safety Factor?**
- ☐ **Center to Center Spacing between Piles?**
- ☐ **Buckling Considerations?**
- ☐ **Lateral Loading Considerations?**
- ☐ **Delivery Time?**

CONSTRUCTION

- ☐ **Construction Schedule?**
- ☐ **Head Room Clearance?**
- ☐ **Proximity to Existing Structures?**
- ☐ **Underground Obstructions?**
- ☐ **Access to Jobsite?**
- ☐ **Safety Regulations?**

LOADS – FACTOR OF SAFETY

The purpose of a Helical Pile is to resist externally applied forces. These forces are usually referred to as "loads". Loads are transferred from the structure to the foundation pile. Loads may also result from negative or positive skin friction (i.e. soil shrinkage, settlement [drag], or expansion).

Loads are generally classified as, TENSILE (uplift) and/or COMPRESSIVE. In some cases, loads may reverse direction. This can be the result of wind direction change or extraordinary events such as earthquakes, etc. REVERSING loads are rare but, if they occur, additional engineering consideration may be required. The pile may also be subjected to a MOMENT and/or LATERAL load which will require additional engineering consideration. The following applies to axially loaded piles only.

The maximum expected force that will be applied to a pile is usually referred to as its Design Load (DL). Design Load is defined here as the sum of the maximum values of the axial Dead Load, Live Load and Soil Shrinkage / Expansion Load. Design Loads, also referred to as Working Load or Service Load, should include both magnitude and direction.

Design Load (DL) = (Dead Load) + (Live Load) + (Soil Shrinkage / Expansion Load) [Equation 5.1]

Where:

Design Load = the maximum axial load that the pile will be subjected to under any circumstance.

Dead Load = the maximum axial load resulting from the weight of the structure plus all material (equipment) permanently fastened thereto or supported thereby.

Live Load = all loads that are not included in the Dead Load, such as loads resulting from vehicles, people, snow, ice, wind and impact. Also includes other forces resulting from earthquakes and other extraordinary conditions. Live loads are often specified in the project specifications and/or the applicable building codes.

Soil Shrinkage / Expansion Loads = skin friction loads that result from the movement of the soil relative to the pile's surface. These loads are sometimes considered as part of the Live Load. The stratum of soil that may shrink, expand or move relative to the pile is often referred to as the active zone. The portion of the Helical Pile that passes through this active zone is often reduced in size so as to minimize skin friction. When 1.50" to 2.00" round cornered square shafts are used through this area, skin friction force can usually be disregarded with little error.

Ultimate Capacity of a Helical pile > = (Design Load) x (Safety Factor) [Equation 5.2]

Where:

Ultimate Capacity of a Helical pile = the lesser of the theoretical Geotechnical or the Mechanical Ultimate Capacity of the pile.

Safety Factor (Factor of Safety) = the ratio of the Ultimate Capacity of the Helical pile to its Design Load.

A Safety Factor of 2 is often applied for Helical Piles, but this can vary, depending on project specifications, the quality of the geotechnical information made available, whether or not load testing was performed, applicable building codes, and the degree to which onsite quality control was applied.

SOIL MECHANICS

Soil mechanics is the understanding and predicting of how soil will respond to externally applied forces or pressures. This includes the study and classification of soils in order to assign soil strength properties to predict the soil's behavior. Soil studies often include field drilling to obtain soil samples, physical review to classify and laboratory analysis to assign soil properties.[3]

What is Soil? *Soil* is a matrix of particle, air and water. The particles of soil are generally produced from parent rock by a numerous physical processes. Weathering is a method of producing soils particles that involves the breaking down of rock into smaller pieces through mechanical and/or chemical processes which can occur at or below the ground surface or subgrade.

Types of Soil: When soil remains over the rock from which it was produced; it is referred to as *Residual Soils*. This type of soil tends to have better properties for supporting foundation loads than *Transported Soils,* which is discussed below.

When soils are transported and deposited in other areas (away from the original rock), they are referred to as *Transported Soils*. Transported soils will generally have differing soil strength properties from residual soils due to the disturbance of transportation. These soils may be less dense and have a lower consistency than their parent soil. The manner in which these soils are transported can be applied to further categorize this type of soil. See Table 6.1.

Table 6.1: Transported Soils

Types	Manner of Transport
Alluvial or Fluvial	Running water
Glacial	Glacier action
Aeolian	Wind action
Fill	Man-made efforts

Soil Characterization: Most soil classification systems used in construction classify soils based on two laboratory analyses. (1) grain-size distribution curve (or gradation curve), and (2) soil consistency (Atterberg limits) are discussed in the following paragraphs.

Grain-Size Distribution Curve: Grain-size (sieve) analysis is commonly utilized to assess the particle size distribution (or gradation) of a soil sample. A sieve analysis is a mechanical laboratory analysis conducted to derive the gradation of soils that will not pass through a number 200 (0.075 mm) sieve. Soils passing the number 40 sieve can be classified with a hydrometer analysis to provide gradation for extremely fine soil particles.

The soil is passed through a series of screens - sieves (largest opening on top). The sieve openings are progressively smaller from top to bottom. See Table 6.2 for U.S. Standard Sieve Sizes. The mass (weight) of soil retained by each screen is carefully measured as well as the mass remaining in the bottom pan. This allows for the determination of the percent of the total weight of soil that passes through each of the different sieves. This information is then plotted on a semi-log chart. This chart is usually referred to as "The Grain Size Distribution Curve" or "Particle-Size Distribution Curve". This chart shows not only the range of particle sizes present in the soil but also the distribution of various size particles. Soils in which the particle sizes are distributed over a wide range (Figure 6.1) are termed *well graded*. Soils in which most of the grains are the same size are termed as *poorly graded*. Figure 6.1 shows a typical Grain-Size Distribution Curve for a cohesionless granular material.

Example Problem No. 6.1

The following measurements were obtained from a mechanical grain size analysis (Sieve Analysis).

Sieve Size (mm)	Weight Retained (g)
3/8” (9.5)	43
No. 4 (4.75)	195
No. 10 (2.00)	281
No. 40 (.425)	127
No. 100 (.150)	44
No. 200 (.075)	25
Pan (<.075)	135

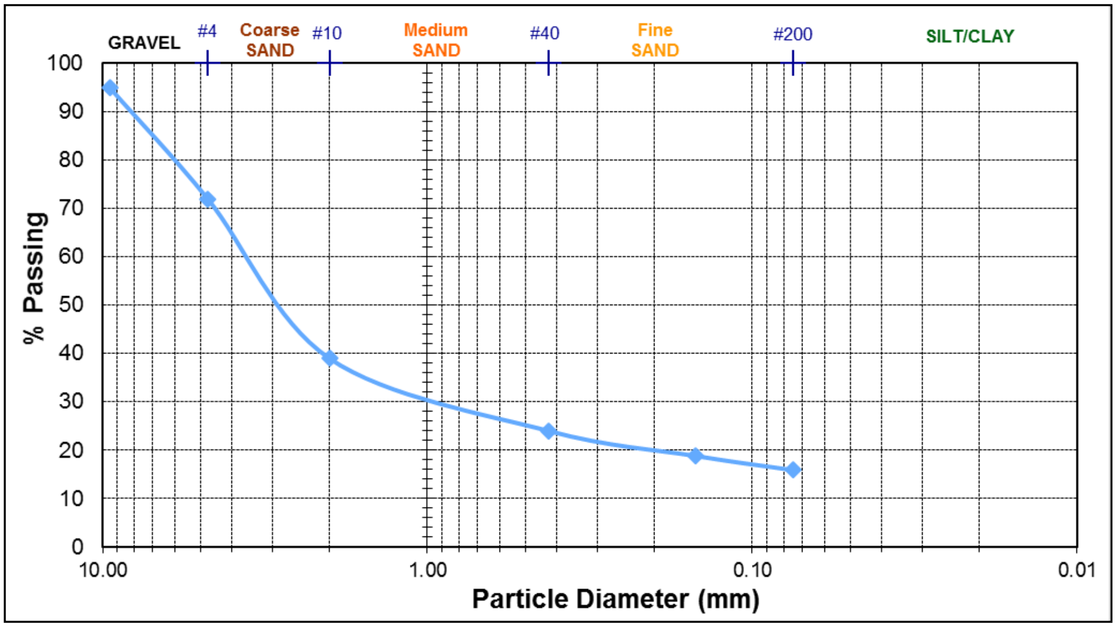
Determine:

1. The average opening that allowed 50% of the total weight of the soil to pass through, D (50)
2. Coefficient of Uniformity (Cu)
3. Coefficient of Curvature (Cc)
4. The percent of total weight of the sample that is gravel, sand and clay

1 mm = .03937 inch   g = grams = .002205 lbs.

	Sieve No.	Sieve Dia (mm)	% Passing	% Retained	Mass retained (g)	Mass passing (g)	
						850	Initial Mass
1	3/8	9.5	94.94	5.06	43	807	
2	4	4.75	72.00	22.94	195	612	
3	10	2	38.94	33.06	281	331	
4	40	0.425	24.00	14.94	127	204	
5	100	0.15	18.82	5.18	44	160	
6	200	0.075	15.88	2.94	25	135	
7	Pan	0.01	0.00	15.88	135	0	
				Total Mass	850		

Figure 6.1: Grain Size Distribution Curve



D (50) = The average sieve opening that allows 50% by weight to pass through =2.8 approx.
D (60) = The average sieve opening that allows 60% by weight to pass through =3.4 approx.
D (30) = The average sieve opening that allows 30% by weight to pass through =1.2 approx.
D (10) = The average sieve opening that allows 10% by weight to pass through =0.03 approx.
Cu=Uniformity Coefficient =D(60/ D(10)= 113.333   **Cc**=Coefficient of Curvature (Graduation)=D(30)^2/(D(60)*D(10))=14.118

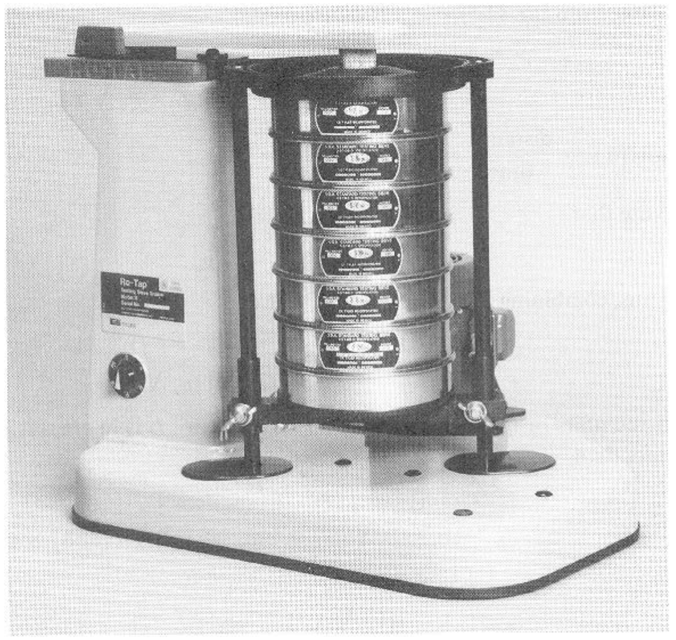
According to the Unified Soil Classification System:			Percent
Gravel (>4.75 mm) =	100.000	72.000	28%
Sand (<4.75 mm > .075 mm) =	72.000	16.000	56%
Clay / Silt (< .075 mm) =			16%
			100%

Table 6.2:
U.S Standard Sieve Sizes

Sieve No.	Opening (mm)
4	4.750
6	3.350
8	2.360
10	2.000
16	1.180
20	.850
30	.600
40	.425
50	.300
60	.250
80	.180
100	.150
140	.106
170	.088
200	.075
270	.053

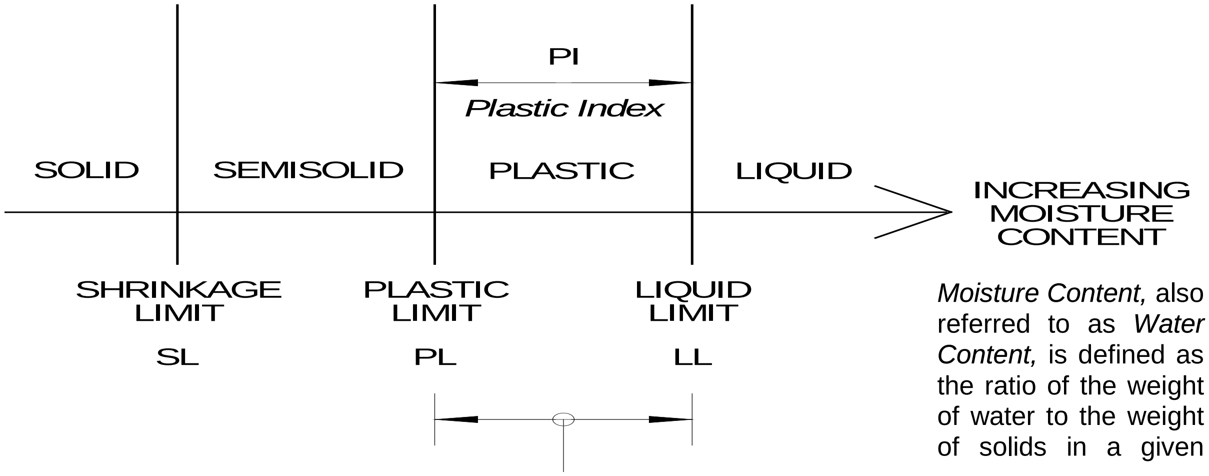
1 mm = .03937 inch

Figure 6.2
Laboratory Sieve Set-up



Soil Consistency (Atterberg Limits): When clay is present in fine-grained soils, it can be remolded in the presence of some moisture without crumbling. This cohesive nature is because of the adsorbed water surrounding the clay particles. In the early 1900’s, Albert Atterberg, a Swedish scientist, developed a method to describe the consistence of fine-grained soils with varying moisture contents. At very low moisture content, soil behaves more like a brittle solid. When the moisture is very high, the soil may flow like a liquid with the properties of a heavy fluid. Based on water content, Atterberg defined four basic states characterizing the behavior of cohesive soils and the three limits (Atterberg Limits) separating the basic states.[1] See Figure 6.4.

Figure 6.4: Atterberg Limits



Moisture Content, also referred to as *Water Content,* is defined as the ratio of the weight of water to the weight of solids in a given

Generally predictable behavior for Helical Piles

Liquidity Index = (Moisture Content – PL) / (LL – PL) = (Moisture Content – PL) / Plastic Index

Shrinkage Limit (SL): When moisture is gradually removed from clay, shrinkage occurs until the moisture content has been reduced sufficiently. Inversely, as moisture content is increased, soils may expand. The moisture content that coincides with no further shrinkage is defined as its *Shrinkage Limit*. (If additional moisture is removed beyond the SL, further shrinkage will not continue.)

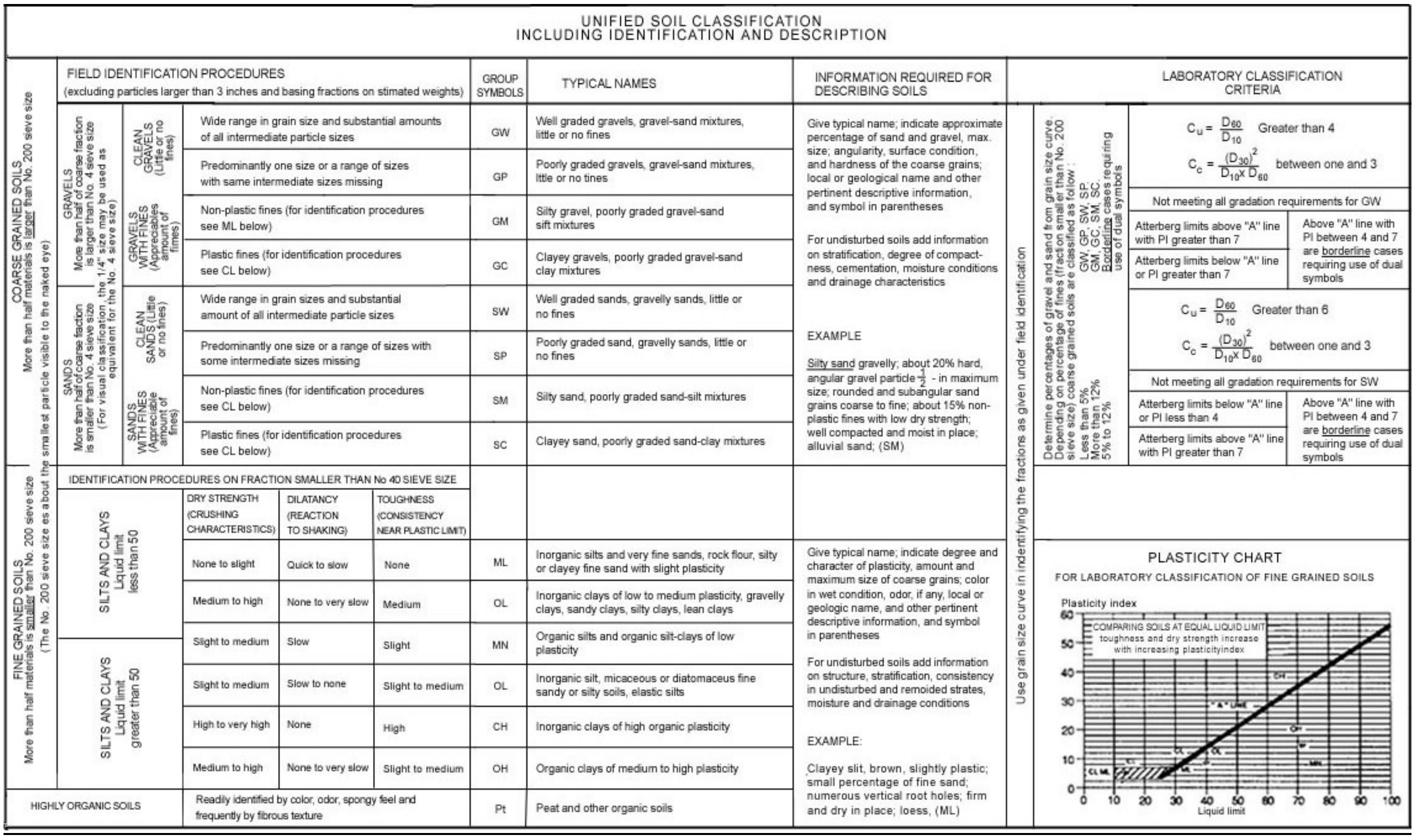
Plastic Limit (PL): The Plastic Limit is the lower limit of the Plastic Stage. When the soil is rolled into threads of 3.2 mm (1/8”), crumbling will not occur if the moisture content is greater than PL. In this case, the moisture content coinciding with crumbling would be defined as the soils Plastic Limit (PL). If the natural water content is less than the plastic limit (liquidity index negative), the soil cannot be remolded.[2]

Liquid Limit (LL): If the water content of a natural soil stratum is greater than the liquid limit (liquidity index greater than 1.0), remolding transforms the soil into a thick viscous slurry.[2]

Sensitivity: The strength of some types of soils may be significantly reduced when disturbed. These types of soils are referred to as *Sensitive*. Sensitivity (S_t) of a soil can be defined as the ratio of the unconfined compressive strength of an undisturbed specimen to the unconfined compressive strength of the specimen at the same water content but in a remolded state. The values of (S_t) for the vast majority of clays range between 2 and 4 and are considered *Insensitive*. For *sensitive clays*, (S_t) can range from 4 to 8. For *extra sensitivity clays*, (S_t) can range between 8 and 16. Clays with (S_t) greater than 16 are described as *quick clays*. Highly sensitive soils should be avoided when installing any type of pile. When installing Helical Piles, this can be accomplished by increasing the depth of the pile beyond the sensitive stratum as indicated by the geotechnical report and boring log. If this cannot be accomplished, full scale load testing will be required to establish the proper torque factor (Kt) for the pile. Marine and lake clays and organic silts with high water content can be highly sensitive. In the U.S., highly sensitive clays are seldom encountered, but the possibility of their occurrence should not be overlooked.

Soil Classification: The most widely used system for classifying soils in the U.S. is the Unified Classification System. This method of classification categorizes soils into 15 groups and is shown here in Table 6.3.

Table 6.3: Soil Identification: Unified Soil Classification System



UNIFIED SOIL CLASSIFICATION
INCLUDING IDENTIFICATION AND DESCRIPTION

			FIELD IDENTIFICATION PROCEDURES (excluding particles larger than 3 inches and basing fractions on stimated weights)			GROUP SYMBOLS	TYPICAL NAMES	INFORMATION REQUIRED FOR DESCRIBING SOILS			LABORATORY CLASSIFICATION CRITERIA	
COARSE GRAINED SOILS More than half materials is larger than No. 200 sieve size (The No. 200 sieve size es about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fracton is larger than No. 4 sieve size (For visual classification, the 1/4" size may be used as equivalent for the No. 4 sieve size)	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes			GW	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentage of sand and gravel, max. size; angularity, surface condition, and hardness of the coarse grains; local or geological name and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics EXAMPLE Silty sand gravelly; about 20% hard, angular gravel particle $\frac{1}{2}$ - in maximum size; rounded and subangular sand grains coarse to fine; about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM)	Use grain size curve in indentifying the fractions as given under field identification	Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follow: Less than 5% GW, GP, SW, SP. More than 12% GM, GC, SM, SC. 5% to 12% Borderline cases requiring use of dual symbols	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} x D_{60}}$ between one and 3	
			Predominantly one size or a range of sizes with same intermediate sizes missing			GP	Poorly graded gravels, gravel-sand mixtures, lttle or no tines				Not meeting all gradation requirements for GW	
		GRAVELS WITH FINES (Appreciables amount of fimes)	Non-plastic fines (for identification procedures see ML below)			GM	Silty gravel, poorly graded gravel-sand sift mixtures				Atterberg limits above "A" line with PI greater than 7	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures see CL below)			GC	Clayey gravels, poorly graded gravel-sand clay mixtures				Atterberg limits below "A" line or PI greater than 7	
	SANDS More than half of coarse fraction is smaller than No. 4 sieve size	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amount of all intermediate particle sizes			SW	Well graded sands, gravelly sands, little or no fines				$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} x D_{60}}$ between one and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing			SP	Poorly graded sand, gravelly sands, little or no fines				Not meeting all gradation requirements for SW	
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see CL below)			SM	Silty sand, poorly graded sand-silt mixtures				Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures see CL below)			SC	Clayey sand, poorly graded sand-clay mixtures				Atterberg limits above "A" line with PI greater than 7	
FINE GRAINED SOILS More than half materials is smaller than No. 200 sieve size	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No 40 SIEVE SIZE		DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)							
	SILTS AND CLAYS Liquid limit less than 50		None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sand with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; color in wet condition, odor, if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoided strates, moisture and drainage conditions EXAMPLE: Clayey slit, brown, slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess, (ML)		PLASTICITY CHART FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS		
			Medium to high	None to very slow	Medium	OL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays					
			Slight to medium	Slow	Slight	MN	Organic silts and organic silt-clays of low plasticity					
	SILTS AND CLAYS Liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	OL	Inorganic silt, micaceous or diatomaceus fine sandy or silty soils, elastic silts					
			High to very high	None	High	CH	Inorganic clays of high organic plasticity					
			Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity					
HIGHLY ORGANIC SOILS			Readily identified by color, odor, spongy feel and frequently by fibrous texture			Pt	Peat and other organic soils					

Chemical Composition: Besides the difference in grain size, the chemical composition of soil can also be helpful in distinguishing between various types of soils. Sand and gravel usually consist of the same minerals as the original rock from which they were created by the erosion process. This can be quartz, feldspar or glimmer. Sand mostly consists of quartz. The chemical formula of this mineral is $SiO2$. Fine-grained soils may contain the same minerals, but they also contain the so-called clay minerals, which have been created by chemical erosion. The main clay minerals are kaolinite, montmorillonite and illite. These minerals consist of compounds of aluminum with hydrogen, oxygen and silicates. They differ from each other in chemical composition, but also in geometrical structure, at the microscopic level. The microstructure of clay usually resembles thin plates. On the microscale there are forces between these very small elements, and ions of water may be bonded. Because of the small magnitude of the elements and their distances, these forces include electrical forces and the Van der Waals forces. Although the interaction of clay particles is of a different nature than the interaction between the much larger grains of sand or gravel, there are many similarities in the global behavior of these soils. There are some essential differences, however. The deformations of clay are time dependent, for instance. When a sandy soil is loaded it will deform immediately, and then remain at rest if the load remains constant. Under such conditions a clay soil will continue to deform, however. This is called creep. It is very much dependent upon the actual chemical and mineralogical constitution of the clay. Also, some clays, especially clays containing large amounts of montmorillonite, may show a considerable swelling when they are getting wetter. Peat contains the remains of decayed trees and plants. Chemically it therefore consists partly of carbon compounds. It may even be combustible, or it may produce gas. As a foundation material peat and other organic soils (organic clay) are usually not very suitable, because they tend to be very compressible.[3]

Soil Shear Strength: The structural strength of soil is primarily a function of its shear strength, where shear strength refers to the soil's ability or resist sliding along internal, 3-dimensional surfaces within a mass of soil.[3] The load resistance capacity of a Helical Pile is dependent upon the effective bearing capacity of the soils surrounding its helices. Soil bearing capacity is directly related to the soil's shear strength and because of this; shearing strength is one of the most important engineering properties of soil to consider when designing foundations. The shearing strength of a material is the maximum shear stress that it can withstand prior to shear failure. As discussed below, soil shear stress can be categorized as either occurring in cohesionless, cohesive or mixed soils. This manual addresses cohesionless and cohesive soils.

Soil Shear Strength – Cohesionless (Granular) Soils: Cohesionless soils, such as sands and gravels, derive their shear strength from the mechanical sliding friction and interlocking forces developed between the individual grains. As in the case for all friction calculations, normal force (i.e. over-burden pressure) acting on these grains will increase the soil's shear strength capacity accordingly. For a granular soil, the angle of internal friction (FA) includes both the soil's sliding friction and the interlocking forces. The internal friction angle (FA) is governed by properties such as unit weight, grain size and shape. As discussed in Section 8, the bearing capacity of a cohesionless soil is equal to the over-burden pressure times the Bearing Capacity Factor (Nq). Nq is determined solely by the angle of internal friction (FA) of the cohesionless soil.

Before designing foundations, in cohesionless soils, the soil's angle of internal friction (FA) has to be determined.

Several methods may be applied to determine the angle of internal friction (FA). A geotechnical engineering laboratory usually performs the types of analysis shown below during or immediately after their sub-surface exploration. The results of these tests should be included in their geotechnical report and/or sub-surface exploration report.

1. Shear Box Method: Straightforward and relatively portable - results may not be as accurate as those obtained with a Triaxial Shear Test.

2. Triaxial Shear Test: Most accurate method.

3. Determine the approximate angle of internal friction (friction angle) based on SPT "N" values: Soil-boring logs often do not include tested values for the friction angle but often include SPT "N" values of the soil. The N-value can be used to derive the friction angle, as discussed in Section 8. It should be noted this derivation is an estimation and should be used with caution as a design assumption.

Soil Shear Strength – Cohesive Soils (Fine Grained Soils): Clay is the finest textured of all the soil classes. Clay usually forms extremely hard clods or lumps when dry but is extremely sticky and plastic when wet. When containing the proper amount of moisture (Figure 6.4, Plastic Index region), it can be "ribboned out" to a remarkable degree by squeezing between thumb and forefinger, and may be rolled into a long, very thin wire.[6]

In its natural state, except in areas near the surface, clay is usually saturated (i.e. all the voids between solids are filled with water). The following assumes saturated clay of medium plasticity.

Cohesion: Due to the extremely small grain size (< .074 mm or < .003"), the friction and interlocking forces that occur between the fine-grained soils (clay) are a great deal less than that with granular soils (sand). But clay does have shear strength. When moist, clay soils have particles that because of molecular and mechanical bonding "stick together". This "*bonding together of the particles*" is not well understood, but appears to be influenced by moisture content, grain structure, and unit weight. The shear strength that is provided to the soil by this "*bonding or attraction between particles"* is referred to as "Cohesion".

Several methods are often used to determine Cohesion (**c**). A geotechnical engineering laboratory usually performs the types of analysis shown below during or immediately after their sub-surface exploration. The results of the analysis are included in their geotechnical report and sub-surface exploration report.

1. Unconfined Compression Test: The most direct quantitative measure of consistency is the load per unit area at which unconfined prismatic or cylindrical samples of the soil fail in a simple compression test. This quantity is known as the *unconfined compressive strength* ($\mathbf{q_u}$) of the soil.[2] An axial load is placed onto a sample (with no lateral support), the load is increased until the soil fails. The compressive stress that causes failure is defined as the *unconfined compressive strength* (q_u) of the soil. The height of the sample will be twice its width or diameter. Assuming (FA = 0.00), Cohesion (**c**) is equal to approximately $\mathbf{q_u / 2}$ (based on saturated clay of medium plasticity).

2. Shear (or Torvane): A small hand held device with vanes extending in a radial direction from the center of the end surface of a cylinder (1" diameter across vanes). The vanes are pressed into the clay to their full depth whereupon a torque is applied through a calibrated spring until the clay fails along the cylindrical surface circumscribing the vanes. Cohesion (c) is read directly from the indicator on the calibrated spring. This is often part of the procedure when conducting Standard Penetration Test or soil sampling.

3. Pocket Penetrometer: The Pocket Penetrometer measures the unconfined compressive strength (q_u) [$c = q_u / 2$]. This is often part of the procedure when conducting Standard Penetration Tests. The plunger is pushed into a split spoon sample to a depth of 1/4". The compressive strength of the soil is read directly from a calibrated spring. This reading is approximately equal to the *unconfined compressive strength* q_u of the soil. The results of this test should be used with caution. Depending on the type of clay, engineers often discount the values of a Pocket Penetrometer by as much as 30% to 50%. This test is not recommended for sandy or silty clays.

4. Determine the approximate cohesion of the soil by the results of the Standard Penetration Test: Not as accurate as items 1 and 2 above. Equation 6.1 should be used with caution and only if no other information is made available. The following equation is based on data from Terzaghi and Peck[2] and assumes saturated clay of medium plasticity. See Note 1 at the end of this Section.

   Cohesion (ksf) = SPT "N" value / 8 [Equation 6.1]

The design method for cohesive soils or clays (Section 8) is based on the assumption that the angle of internal friction (FA) of clay is 0.00. In this case, cohesion will equal the shear strength of the clay. Likewise, the design method for cohesionless soils or sands (Section 8) is based on the assumption that the cohesion of granular soils such as sand is 0.00. These assumptions may not truly reflect the properties of all soils, but do seem to provide adequate estimates of pile capacities.

Expansion and Shrinkage: Most clay will experience volume changes coinciding with changes in moisture content. Soil that is particularly susceptible to significant volume changes is said to be in the soil's *active zone*. Both Expansion and Shrinkage can cause serious damage to structures and foundations. The helical section of a pile should always be installed well below the active zone. The shaft passing through the active zone should be as small as possible so as to minimize skin friction between the soil (active zone) and pile. Battered piles should be avoided.

Negative Skin Friction: Deep foundation elements installed through compressible material can experience "down drag" forces or negative skin friction along the shaft that results from downward movement of adjacent soil relative to the pile. This Negative skin friction results primarily from consolidation of a soft deposit caused by dewatering (moisture removal) or the placement of fill. Negative skin friction is particularly severe on batter pile installations because the force of subsiding soil is large on the outer side of the batter pile and soil settles away from the inner side of the pile. This can result in bending of the pile. Batter pile installations should be avoided where negative skin friction (and soil expansion/shrinkage) is expected to develop.[5]

Loads transferred into the pile from either soil *expansion/shrinkage* or *negative skin friction* can be significant, especially with large diameter wood or steel piles. The large surface area of these types of piles can result in very large friction forces (skin friction). This can adversely affect the performance of the pile, and cause the pile to fail. In these types of soils, it is recommended to use MCP Helical piles. The small surface area of these piles minimizes skin friction. When using 1.5" to 2.00" RCS helical anchors, skin friction forces can be disregarded with little error.

Sub-surface Investigation: Prior to designing a Helical Pile, or any type of foundation, the following information will be required.

1. Maximum Allowable (Design) Load that can be expected.

2. Geotechnical Report: This report is prepared by geotechnical engineers and provides pertinent information concerning the project. The Geotechnical Report should include any information that could affect the present or future behavior of the foundation. This would include, seasonal water tables, sub-surface conditions, and any type of natural occurrence, which could affect the future integrity of the foundation. The geotechnical report should address the corrosion potential of the soil. A major part of the geotechnical report will be the attached "soil boring logs". Boring Logs show the results of sub-surface investigations. These are usually performed by a Standard Penetration Test (SPT) or a Cone Penetration Test (CPT). The Standard Penetration Test, developed in 1927, is currently the most popular and economical means to obtain subsurface information. Virtually all of the information required to design a Helical Pile can be extracted from a well prepared Geotechnical Report and the attached Boring Logs. The Cone Penetration Test has certain advantages and although not as popular as the SPT is now more widely used. The Standard Penetration Test method will be discussed here.

The Standard Penetration Test (SPT) ASTM D 1586:

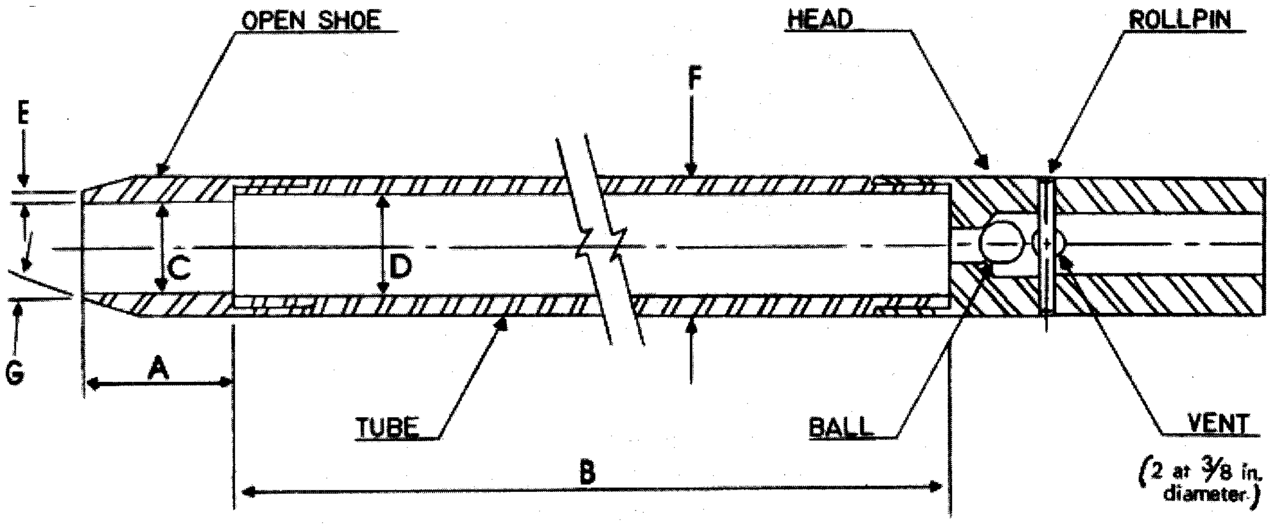
The number of blows required to drive a split spoon sampler a distance of 12 inches after an initial penetration of 6 inches is referred to as an "N" value or SPT "N" value. This SPT test is covered under ASTM Standard D1586 (latest revision), which requires the use of a standard 2" (O.D.) split barrel sampler (Figure 6.5), driven by a 140-pound hammer dropping 30 inches in free fall. This procedure is generalized as follows [5]:

a. Clean the boring of all loose material and material disturbed by drilling.
b. Insert sampler, verifying the sampler reaches the same depth that was drilled.
c. Obtain a consistent 30-inch free-fall drop of the hammer.
d. Using the standard hammer and drop, drive the sampler 18 inches, or until refusal is reached. Refusal is defined as a penetration of less than 6 inches for 100 hammer blows.
e. Count and record the number of blows required to drive the split spoon for each 6 inches of penetration. Disregard the blow counts for the first 6 inches as this is a seating load. The sum of the last 12 inches of penetration is referred to as the SPT "N" value.

Along with additional information, the number of blows (from 6" to 18") will be recorded onto the Boring Logs. The boring logs should show the true adjusted ASTM D 1586 SPT N-values. Throughout this test, the split spoon will be opened and its contents examined and tested as discussed above. The results of these tests will be recorded onto the bore logs and/or the geotechnical report. *Unfortunately, there is not a standard format for either the Geotechnical Report or the Boring Log.* It is highly recommended that the engineer carefully review and understand the Geotechnical Report before designing any type of foundation. See Figure 6.6 for an example of a typical boring log.

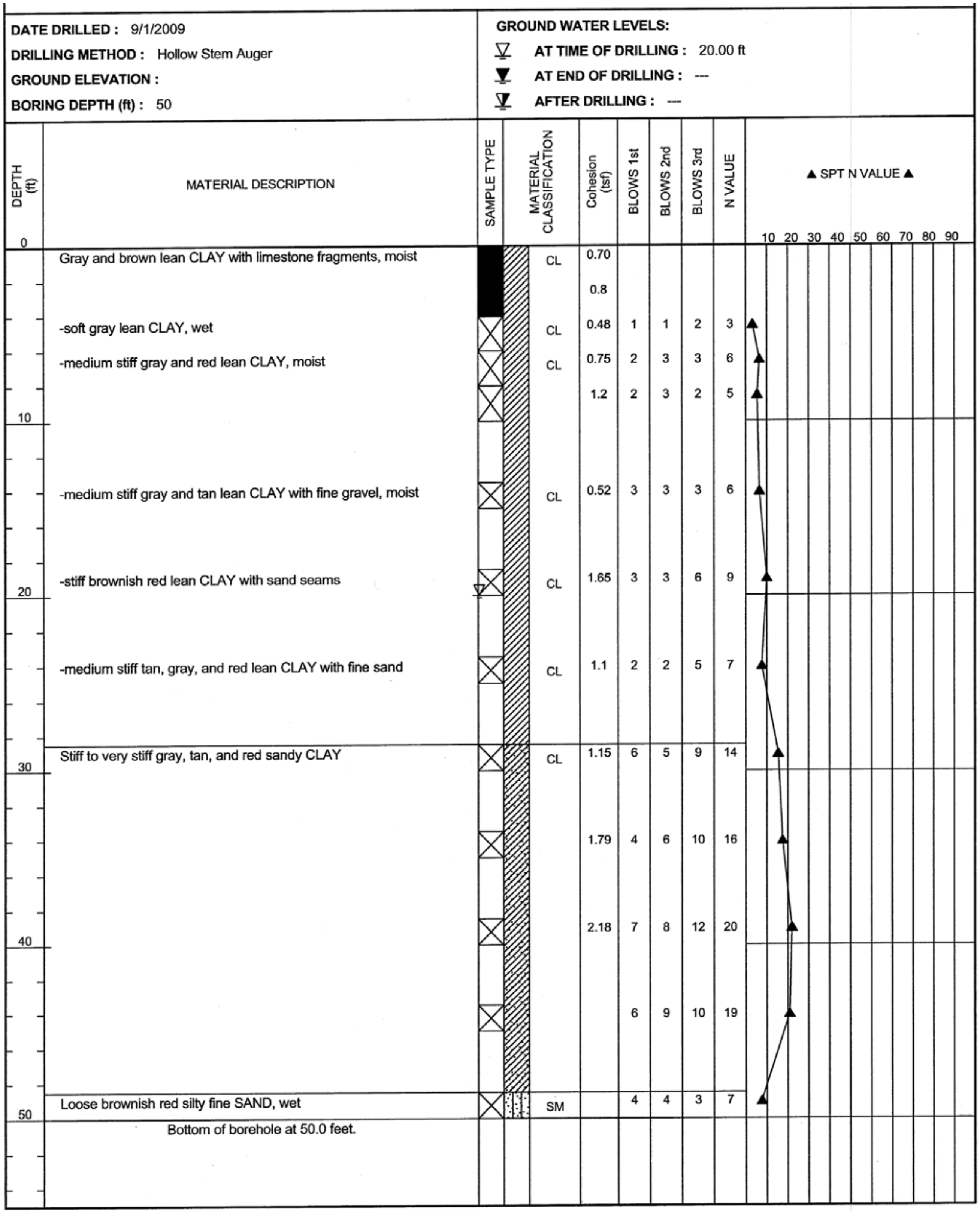
In gravel deposits (with particles 1" and greater), the SPT values may be artificially large. This can be the result of gravel particles being lodged in the open end of the Split Spoon Sampler. The boring log often includes "recovery (inches)". A small recovery in gravelly soils often indicates a plugged sampler. SPT "N"-values in these soils should be adjusted or discounted.

Figure 6.5: Split-Barrel Sampler – ASTM D 1586



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°

Figure 6.6: Typical Soil Boring Log



DATE DRILLED : 9/1/2009
DRILLING METHOD : Hollow Stem Auger
GROUND ELEVATION :
BORING DEPTH (ft) : 50

GROUND WATER LEVELS:
∇ **AT TIME OF DRILLING :** 20.00 ft
▼ **AT END OF DRILLING :** ---
∇ **AFTER DRILLING :** ---

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE	MATERIAL CLASSIFICATION	Cohesion (tsf)	BLOWS 1st	BLOWS 2nd	BLOWS 3rd	N VALUE
0	Gray and brown lean CLAY with limestone fragments, moist	■	CL	0.70				
		■		0.8				
	-soft gray lean CLAY, wet	☒	CL	0.48	1	1	2	3
	-medium stiff gray and red lean CLAY, moist	☒	CL	0.75	2	3	3	6
10		☒		1.2	2	3	2	5
	-medium stiff gray and tan lean CLAY with fine gravel, moist	☒	CL	0.52	3	3	3	6
20	-stiff brownish red lean CLAY with sand seams	∇ ☒	CL	1.65	3	3	6	9
	-medium stiff tan, gray, and red lean CLAY with fine sand	☒	CL	1.1	2	2	5	7
30	Stiff to very stiff gray, tan, and red sandy CLAY	☒	CL	1.15	6	5	9	14
		☒		1.79	4	6	10	16
40		☒		2.18	7	8	12	20
		☒			6	9	10	19
50	Loose brownish red silty fine SAND, wet	☒	SM		4	4	3	7
	Bottom of borehole at 50.0 feet.							

References:

1. Braja M. Das, California State University, Fundamentals of Geotechnical Engineering, Second Edition, Thompson Publishing
2. Karl Terzaghi and Ralph B. Peck, Soil Mechanics in Engineering Practice, Second Edition, John Wiley & Sons
3. Arnold Verruijt, Soil Mechanics, 2001, Delft University of Technology, Netherlands
4. Joseph E. Bowles, Foundation Analysis and Design, Fourth Edition, McGraw-Hill, Inc.
5. Naval Facilities Engineering Command, Foundations and Earth Structures, Design Manual 7.02 – September 1986
6. University of Florida – IFAS Extension, Fact Sheet SL-29, Soil Texture

* * * * *

SOIL TESTING

TORQUE vs. BEARING CAPACITY METHOD

Because of the abundance of empirical data collected over the past 25 years regarding installation torque vs. tension capacity, the following test provides information that can be used, in conjunction with existing geotechnical reports and boring logs or when soil information is unavailable.

The following procedure may be applied for estimating the in-situ bearing capacity of soil. This test is straightforward, economical and quick. Depending upon depth, as many as 20 to 30 tests can be conducted in one day. Since soil properties can vary significantly (even across small areas), this test can provide the pile designer with valuable information.

1. Install a square shaft helical anchor (< = 2.00” sq.) to a predetermined depth. A single 14” helix is generally recommended, but helix size may vary depending on soil properties. The fewer helices, the more accurate the results.

2. During installation, monitor and record the torque at 1 ft. increments.

The torque achieved during installation is directly related to the effective bearing capacity of the soil.

- The Ultimate Bearing Capacity (lbs) of the helix can be equated to its projected area (ft^2) multiplied by the Bearing Stress Capacity (psf) of the soil.

- The Ultimate Bearing Capacity (lbs) of the helix can also be equated to the Torque Factor K_t (ft^{-1}) x Torque (ft-lbs).

So, equating the two relationships shown above:

[Helix Area (ft^2)] x [Ultimate Bearing Stress Capacity of the soil (psf)] = K_t (ft^{-1}) x Torque (ft-lbs)

So:

$$\textbf{Ultimate Bearing Stress Capacity of the Soil (psf)} = \frac{\mathbf{K_t\ (ft^{-1})\ x\ Torque\ (ft\text{-}lbs)}}{\mathbf{Helix\ Area\ (ft^2)}} \quad \text{[Equation 7.1]}$$

- By applying Equation 7.1, a stress capacity profile (i.e. Bearing Stress Capacity vs. Depth) of the soil can be prepared. See Example Problem 7.1 below.

- By using the methods discussed in Section 8, an optimum pile configuration can be determined.

If possible, a quick pull test of the test anchor at several depths and locations is recommended. This will allow a more accurate relationship between torque and capacity to be determined. If a quick pull test cannot be performed, we recommend that a Torque Factor (K_t) of 10 ft^{-1} be applied for square shaft anchors as discussed in this manual.

Applying a value of 10 for K_t generally provides good results in cohesive soils (clay) and may be somewhat conservative (i.e. under predicts) in granular cohesionless soils (sand).

The above test provides the following information:

1. Estimated Soil Bearing Capacity Profile
2. Whether or not underground obstructions may inhibit the installation of anchors.
3. The over-all suitability of the soil for the installation of helical anchors.
4. Provides for an opportunity to evaluate the available geotechnical reports and boring logs.

Example Problem 7.1

- A pile is required to support a maximum load of 20 kips compression - design / working load
- Minimum required Safety Factor (Theoretical Ultimate Capacity / Design Load) > = 2
- Soil information is unavailable.
- It is assumed that the soil is clay (cohesive) of medium plasticity

Determine: The required helix configuration, shaft size and depth of the Helical Piles

Solution:

1. A test Helical Pile anchor (1.75 RCS with one 14” helix) is installed to a depth of 40 ft. Torque is monitored at 1 ft. increments and recorded on Log Sheet 7.1 shown on the following page.

2. Applying Equation 7.1, the estimated soil bearing stress capacity is determined for each foot of depth. This is recorded on Log Sheet 7.1 on the following page. Pull testing was not performed, so K_t = 10.

   From a depth of 21 ft. to 35 ft., the torque achieved by the test anchor remained constant.

   Product Recommendation for a Design Load of 20 kips:

   Helix Configuration - See calculation sheet on the following page:

   > A pile with a 10”– 12”–14” helix configuration installed to a depth of 30 ft. will provide a theoretical ultimate capacity of 50,479 lbs. Based on a safety factor of 2, the allowable design load for this pile would be 25,239 lbs. (25 kips > 20 kips = OK) Since, in this case, the soil bearing stress capacity is the same above and beneath the helices, the ultimate compression capacity will be the same as the ultimate tension capacity.

   Shaft Size:

   > Assuming a RCS shaft, the estimated installation torque for this pile would be 50,868 lbs / 10 ft^{-1} = 5,087 ft-lbs. If this soil were typical for the other areas of the jobsite, then a standard D6 (1.50” RCS) anchor (5,500 ft-lbs) could be recommended. (Also see note below.)

   Column buckling may also be checked:

   > Assuming the soil is clay -
   >
   > 9 x c = Soil bearing stress capacity (ksf) – Equation 8.3
   >
   > N / 8 = c (ksf) – Equation 8.4
   >
   > So: Nc x (N/8) = Soil bearing stress capacity (ksf), Nc = 9 – See Equation 8.3
   >
   > Let N = 4 (SPT N-values of 4 or less indicate that bucking may occur.)
   >
   > So: 9 x (4/8) = Soil bearing stress capacity (ksf) = 4.5 ksf = 4,500 psf
   >
   > > A soil bearing stress capacity of 4,500 psf or less indicates that column bucking can occur. The minimum soil bearing capacity in this case is 6,024 psf.
   > >
   > > 6,024 psf > 4,500 = OK – Column buckling should not occur.

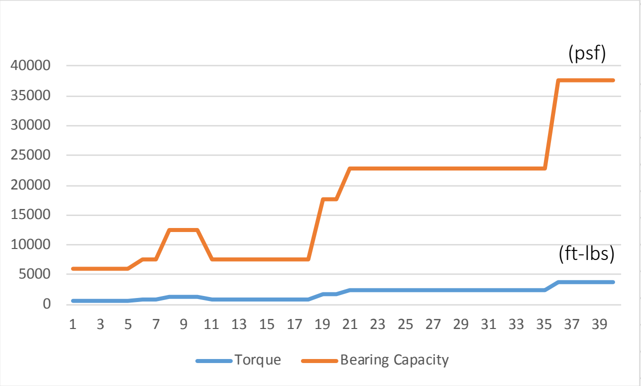
   Note: Based on a Design Load of 20 kips, two shaft sizes could be proposed for the above pile. The 1.50” sq. shaft (discussed above) or a 2.50” Sch 40 pipe (2.875” OD).

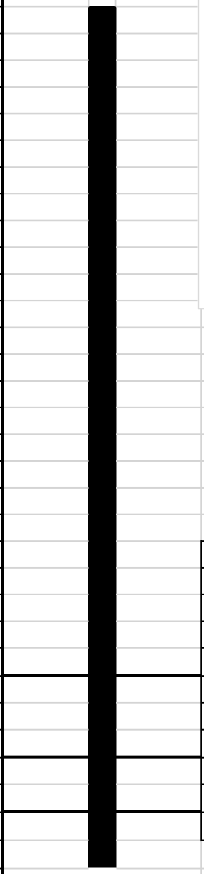
Helical Test Anchor Analysis

Number of Helix	1	each
Helix Diamter	14	inch
Helix area	0.996	sq ft
Shaft size	1.75	in sq
Torque factor (Kt)	10	1/ft

Torque Log

Depth (ft)	Torque (ft-lbs)		Estimated soil bearing capacity (psf)
1	600		6024
2	600		6024
3	600		6024
4	600		6024
5	600		6024
6	750		7530
7	750		7530
8	1250		12550
9	1250		12550
10	1250		12550
11	750		7530
12	750		7530
13	750		7530
14	750		7530
15	750		7530
16	750		7530
17	750		7530
18	750		7530
19	1750		17570
20	1750		17570
21	2275		22841
22	2275		22841
23	2275		22841
24	2275		22841
25	2275		22841
26	2275		22841
27	2275		22841
28	2275		22841
29	2275		22841
30	2275		22841
31	2275		22841
32	2275		22841
33	2275		22841
34	2275		22841
35	2275		22841
36	3750		37651
37	3750		37651
38	3750		37651
39	3750		37651
40	3750		37651





Prelimenary Pile Design			
Helix			
Diameter	Net Area	Soil Bearing Capacity	Est. Capacity
inch	sq.ft.	psf	lbs
14	0.996	22,841	22,750
12	0.719	22,841	16,423
10	0.495	22,841	11,306
		Total Est. Pile Load	50,479

ULTIMATE GEOTECHNICAL AXIAL PILE CAPACITY

PART I – INDIVIDUAL PLATE CAPACITY (IPC) METHOD

A Method for Estimating the Theoretical Ultimate Helix Capacity of a Helical Pile, Adapting Terzaghi's General Bearing Equation

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Parameters:

1. This method addresses the theoretical ultimate helix / soil bearing capacity of a helical pile. Friction (adhesion) between the pile's surface and the soil is discussed in Part 2 of this section.

2. The spacing between any two helices shall be a minimum of 3 times the diameter of the smaller (or lower) helix. If the distances between helices are significantly less than 3 diameters, the ultimate theoretical capacity of the pile may be reduced. In these cases, the pile manufacturer shall provide the appropriate de-rating factors. See Section 12 regarding helix selection.

3. The IPC method assumes that the mechanical capacity of the helix and the pile assembly exceeds the design load by an appropriate safety factor.

4. The IPC method assumes that the pile will behave as a deep foundation, i.e. the top helix will be installed to a minimum depth of at least 5 times its diameter.

5. The ultimate capacity of an individual helix is equal to the product of the effective bearing stress capacity of the soil times the projected net area of the helix. *The ultimate theoretical pile capacity is simply the sum of the individual helix capacities*.

6. After initial disturbance, the remolded strength of some types of soils may be significantly reduced. These soils are referred to as *sensitive*. The equations shown below assume soils of medium plasticity and do not apply to highly sensitive soils. Highly sensitive soils should always be avoided with any type of pile. For Helical piles, this can often be accomplished by increasing the depth of the pile beyond the sensitive strata as indicated by the boring logs. If this cannot be accomplished, load testing will be required to determine the *theoretical ultimate pile capacity* and the *specified installation torque* for the pile. Sensitive soils are discussed in more detail in Section 6.

Terzaghi's General Bearing Equation [Equation 8.1]

$$\mathbf{q_{ult(g)} = A_h \times ((c \times N_c) + (q \times N_q) + (0.5 \times UW \times B \times N_b))}$$

A_h = Projected Net Area of the Helix
$q_{ult(g)}$ = Ultimate geotechnical bearing capacity of an individual helix. The upper limit of this term is the minimum ultimate mechanical capacity of the helix as rated by the pile manufacturer.
c = Cohesion (Undrained Shear Strength) of the soil.
c = approximately 1/2 of the Unconfined Compressive Strength (q_u) of an undisturbed soil sample.
N_c, N_q, N_b = Bearing Capacity Factors
N_c = 9 for clay soils of medium plasticity - with an angle of internal friction (ϕ) of 0.0 degrees.
N_q = Bearing Capacity Factor for granular cohesionless soils. See chart 8.1 and equation 8.5a.
q = Effective overburden pressure
UW = Effective Unit Weight of the soil.
B = Base Width

For Helical piles, the base width term **($0.5 \times UW \times B \times N_b$)** is relatively small and can be neglected with little error. Eliminating the Base Width Factor from Equation 8.1 results in the following general equation (See Equation 8.2).

$$q_{ult(g)} = \underset{(1)}{A_h} \times ((\underset{(2)}{c \times N_c}) + (\underset{(3)}{q \times N_q}))$$ [Equation 8.2]

The *ultimate theoretical pile capacity* (excluding pile/soil friction) is the sum of the individual helix capacities as determined from Equation 8.2. This equation includes the following three terms:

Term (1) – the projected net area of the helix (A_h)

Term (2) – (*Cohesion Term* – Clay) the ultimate soil bearing stress capacity that will be provided by the soil's cohesion. This equation, term (2), assumes saturated clay of medium plasticity.

Term (3) – (*Depth/Friction Term* – Granular Soils, Sand) The ultimate soil bearing stress capacity that will be provided by a combination of the effective overburden pressure (q) and the angle of internal friction of the soil (ϕ). Overburden pressure (q) is the product of the average effective unit weight of the soil times its depth and is referred to as the *depth term*. Nq is a function of the angle of internal friction (ϕ) of the cohesionless soil and is referred to as the *friction term*. Chart 8.1 is based on Terzaghi's equation for Nq - modified for helical screw pile applications.

The effective bearing stress capacities of the soil (i.e. the sum of terms 2 and 3 of Equation 8.2) are usually determined from data extracted from geotechnical reports and boring logs. The IPC method averages the soil's strength parameters for an axial distance of 3 helix diameters from each helix in the direction of load. See note 2. Using this method, and applying a standard computer spreadsheet such as Excel, the theoretical ultimate capacity of each helix, for each foot of penetration, can readily be determined. The results are then summed and the *theoretical ultimate pile capacit*y is determined for each foot of penetration for both tension and compression loading. Results are often shown on a chart that plots Ultimate Compressive and Tension Capacities against Depth for the selected helix configuration. See Example Problems 8.1 and 8.2 at the end of this section. In soils with abrupt changes in properties and strength, occurring within the stress zones of helices, the IPC method requires additional consideration by the engineer. In these types of soils, simply averaging the soil strength for 3 diameters may give incorrect values of the helix capacity.

COHESIVE SOILS (ANGLE OF INTERNAL FRICTION ϕ = 0.00 DEGS)

Eliminating Term 3 (Depth/Friction Term) from Equation 8.2 yields the following equation:

$$q_{ult(g)} = A_h \times (c \times N_c)$$

Where: **$N_c = 9$** for clay soils of medium plasticity and with an angle of internal friction of 0.0 degrees.

$$q_{ult(g)} = A_h \times (c \times 9)$$ [Equation 8.3]

Most boring logs include blow counts, SPT N-value (ASTM D 1586) but often do not include cohesion or unconfined values. In this case, the following equation may be used for clays of medium plasticity to estimate their cohesion. Equation 8.4 is based on empirical studies and should be used with caution. See Note 6. We recommend using tested values of cohesion (such as **$c = q_u / 2$**) when at all possible.

$$c\ (\text{ksf}) = N/8$$ [Equation 8.4]

Where: **N** = Blow Count Value per ASTM D1586 Standard Penetration Test

$$c = 1/2 \times q_u$$ [Equation 8.4a]

Where: **q_u** = *Unconfined Compressive Strength*

COHESIONLESS SOILS (c = 0.00)

Eliminating Term 2 (Cohesion Term) from Equation 8.2 yields the following equation:

$$q_{ult(g)} = A_h \times (q \times N_q) \qquad \text{[Equation 8.5]}$$

Where:

q = Effective overburden pressure. Which is defined as the average unit weight of the soil times its depth. The effective unit weight of soil at or below the water table will equal its saturated unit weight minus the unit weight of water.
Nq = Bearing Capacity Factor for Cohesionless Soil is a function of the *angle of internal friction* of the soil. Equation 8.5a, Chart 8.1 and Table 8.1 shows this relationship based on Terzaghi's values for Nq[1] modified for Helical Piles by applying a reduction factor of .60. See Example Problems 8.1 and 8.2.

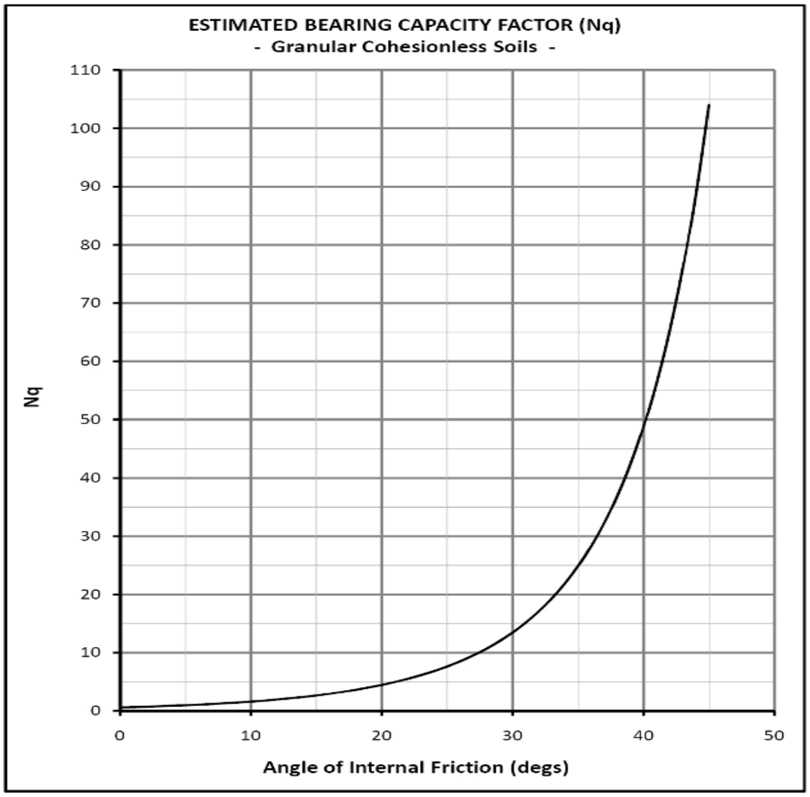
$$Nq = .60 \times \frac{a^2}{2 \times \cos^2(.7854 + \phi/2)} \qquad \text{[Equation 8.5a]}$$

$a = e$ ^ $(.75\,\pi - \phi/2) \times \tan\phi$
ϕ = Angle of internal friction (radians)

Table 8.1: (ϕ) vs. Nq – For Helical Piles
Granular Cohesionless Soils

ϕ	Nq
20	4.463
21	4.959
22	5.514
23	6.138
24	6.841
25	7.632
26	8.526
27	9.538
28	10.685
29	11.989
30	13.473
31	15.169
32	17.110
33	19.338
34	21.903
35	24.864
36	28.294
37	32.279
38	36.928
39	42.369
40	48.762
41	56.308
42	65.250
43	75.899
44	88.642
45	103.971

Chart 8.1: Estimated Bearing Capacity Factor

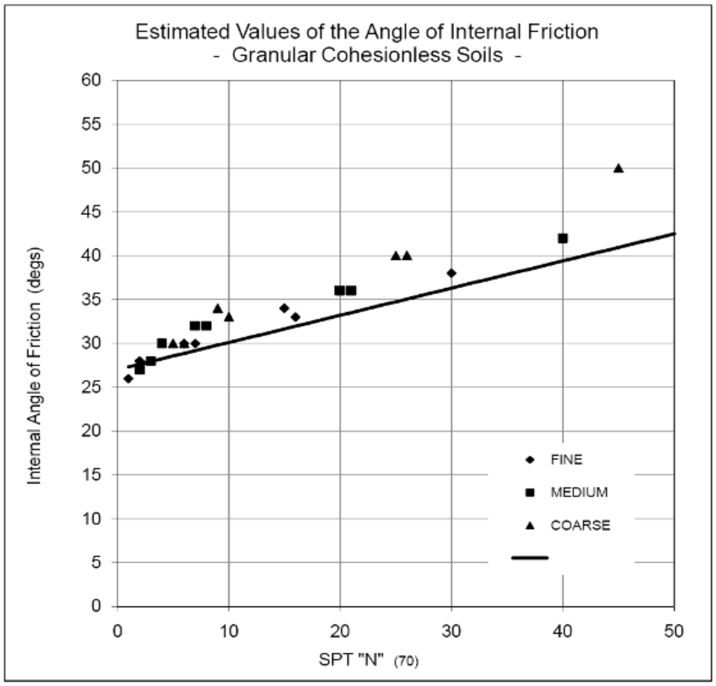


COHESIONLESS SOILS - continued

Soil boring reports and bore logs often do not provide the soil's angle of internal friction, but usually will provide the SPT N blow counts. In this case Table 8.2 shows an approximate relationship between SPT N blow count and angle of internal friction. Table 8.2 is based on empirical data (Bowles – Forth Edition)[1] and should be used with caution. We recommend using the actual tested angle of internal friction whenever possible. The line on the chart shows a relationship that can be expressed as:

Friction Angle (ϕ) = 27 + .31 x $N_{(70)}$ [Equation 8.6]

Table 8.2: Estimated Values of ϕ



MIXED OR c - ϕ SOILS

Typically the IPC method assumes that the soil stratum at a particular depth is either cohesive (angle of internal friction = 0.00 degs) or cohesionless (cohesion = 0.00). If the soil stratum includes both cohesive properties and friction properties it is referred to as a mixed or **c - ϕ** soil. The bearing stress capacity of this type soil can easily be determined from Equation 8.2, but accurate values of **c, Nc** and **Nq** are necessary. Mixed or **c - ϕ** soils should be approached with caution. We recommend that the engineer be familiar with this type of soil and the jobsite soil conditions.

An alternate approach:

If the engineer cannot determine the expected soil behavior (i.e. cohesive or cohesionless), they should perform the calculations for both types of soils and choose the lesser capacity. An appropriate safety factor should then be applied.

Notes:

1. The reliability of these methods or other theoretical methods to predict ultimate pile capacities is dependent upon the quality of the soil data and their interpretation by the engineer.

2. An experienced engineer should apply these methods. Typically a stress zone region of 3 helix diameters in the direction of load is usually applied, but this (and the method of averaging soil stress capacity) may vary, depending upon a number of factors, including soil type and condition. If possible, all of the helices should be in a single stratum of either cohesive or cohesionless soil.

3. Theoretical ultimate pile capacities (as determined by this or any other method) are based on empirical equations. Load testing is recommended.

4. All piles shall be installed to a *specified installation torque* recommended by the design engineer. Ultimate torque values shall not exceed mechanical torque ratings set by the manufacturer's guidelines and/or specifications.

5. *Theoretical ultimate pile capacity* is defined here (Parts 1 and 2) as the minimum load which will cause continuous deflection (creep) without a further increase in load.

6. Clay Soils: The determination of the value of q_u by means of unconfined compression tests or of c by means of a portable torsion vane is so expedient that the ultimate bearing capacity should not be estimated on the basis of the results of the Standard Penetration Test [2] [i.e. "N" / 8 ksf] . If possible, we recommend that q_u be determined by unconfined compression tests. The average value of the *undrained shear strength* c may then be estimated by the relationship of $c = q_u / 2$. Other methods of estimating the values of c, should be used with caution. Applying the results of tests conducted with a *hand or pocket penetrometer* to determine the ultimate bearing capacity of clay is not recommended.

7. Designing Helical piles for Cohesionless Soils

As shown in Equation 8.5, the theoretical ultimate helix capacity is directly proportional to the effective overburden pressure (q). The effective unit weight of soil at or beneath the water table is equal to its in-situ unit weight minus the unit weight of water. For this reason a rise in water table can significantly reduce pile capacity. If a rise in water table can occur after construction is completed, the engineer should take the following steps.

- Preliminary Design - Assuming the highest possible water table and using the IPC method described above, design the pile.

- Check Preliminary Design at the lowest possible water table depth - Assuming the lowest possible water table depth that can be expected during construction, determine the *theoretical ultimate pile capacities* (and the expected installation torques) for each foot of installation. The pile capacities (and installation torques) at the lower water table will be greater. This increase can be significant and may require a pile with greater torsional capacity and/or different helix configuration than originally proposed. Modify the preliminary pile design if/as required.

- Final Design and Check – Assume the highest water table and determine if the *theoretical ultimate capacity* of the final pile configuration is acceptable.

PART II – A METHOD OF DETERMINING FRICTION (ADHESION) BETWEEN SOIL AND PILE INTERFACE

Naval Facilities Engineering Command, "Foundations & Earth Structures", Design Manual 7.02, September 1986 (NAVFAC)

Skin friction between the soil and pile surface of Helical Piles with shaft sizes of 3.5" OD or less are relatively small when compared to the total helix capacity, and for this reason can be neglected with little error.

But for deep piles with larger diameters (i.e. 4.5" or larger), friction becomes more significant. A convenient method of estimating this friction (or adhesion) is shown in the NAVFAC Manual 7.02 and is discussed below.

The estimated ultimate axial capacity of a helical screw pile can be shown by the following equation:

$$\mathbf{Q_T = Q_H + Q_F} \qquad \text{[Equation 8.6a]}$$

Where:

Q_T = Total *theoretical ultimate pile capacity* (Note 2)
Q_H = Sum of individual helix capacities as discussed above.
Q_F = Total friction (adhesion) between the soil and pile surface as discussed below.

COHESIVE SOILS

$$\mathbf{Q_F = \Sigma\ (C_A \times (\pi \times D) \times dL)} \qquad \text{[Equation 8.6b]}$$

Where:

C_A = Adhesion based on the soil's cohesion as shown on the table (shown below) in the NAVFAC Manual Figure 2 – p. 7.2-196.
D = Pile diameter
dL = Element length of Pile subjected to adhesion or friction (Note 1).

RECOMMENDED VALUES OF ADHESION – For Steel Piles

Consistency of Soil	Cohesion, C (psf)	Adhesion, C_A (psf)
Very Soft	0 - 250	0 - 250
Soft	250 - 500	250 - 460
Med. Stiff	500 - 1000	460 - 700
Stiff	1000 - 2000	700 - 720
Very Stiff	2000 - 4000	720 - 750

COHESIONLESS (GRANULAR) SOILS

$$Q_F = \Sigma\ (q \times K \times TAN\ (fa') \times \pi \times D \times dL)$$ [Equation 8.6c]

Where:

q = Effective overburden stress (i.e. vertical stress) at each increment of depth (dL) from ground surface to the bottom of the pile. The Naval Manual limits overburden stress (q) to its value at a depth of 20 x B. *It should be noted on the calculation sheets if greater values of q are applied.*
K = Coefficient of Lateral Earth Pressure – Ratio of horizontal to vertical effective stress. Unless other information is provided, a value of K = 1.0 may be applied for preliminary calculations.
fa' = Friction Angle between the soil and pile surface. (*Not to be mistaken as the angle of internal friction of the soil.*)
D = Pile Diameter
dL = Element length of Pile subjected to friction (Note 1).

Notes:

1. Usually the top portion of a pile will be in disturbed soil and will not contribute significantly to friction. For this reason, the top section of the pile (at least 5 x D) is often disregarded when determining friction.
2. Stiff soils, such as dense sand and stiff clay, underlying very compressible soils such as soft silts and clays may require additional engineering consideration. An example of this would be a pile passing through very soft silt with the helices firmly imbedded into dense sand. In this case, the skin friction will usually be neglected, and the helix bearing capacity (point load) will determine the ultimate pile capacity.[2]
3. Forces resulting from soil expansion, shrinkage or negative skin friction (down drag) are not addressed here. If any of these loads can occur, additional engineering consideration will be required. See Section 5 and 6 for information regarding these types of loads.

References:

1. Joseph E. Bowles, Foundation Analysis and Design – Forth Edition, McGraw-Hill, Inc.
2. Karl Terzaghi and Ralph B. Peck, Soil Mechanics in Engineering Practice – Second Edition, John Wiley and Sons.

Example 8.1

Determining helix / soil bearing capacities can be accomplished by hand calculations, but this would often be extremely time consuming. Since the calculations are numerous, but not complex, a basic spreadsheet, such as Excel, has proven to be a very convenient method of performing the calculations. Spreadsheets can also generate capacity vs. depth charts, thus giving the engineer more control for the various options. In addition, various reports can be easily generated directly from the spreadsheets.

Values for Nq can be entered from Table 8.1 or from Eq. 8.1 or from Eq. 8.7 shown below.

Equation 8.7 is in the format that can be entered directly into Excel. For Equation 8.7, the angle of internal friction (ϕ) should be entered directly as degrees (not radians).

[Equation 8.7]

$$\text{Nq} = \ .60 \text{ x } \left(\frac{\text{(}e\text{ \textasciicircum((.75 x pi() – }\phi\text{ x pi() / 360) x TAN (}\phi\text{ x pi() / 180)))\textasciicircum 2}}{\text{(2 x (COS (.7854 + }\phi\text{ x pi() / 360))\textasciicircum 2)}} \right)$$

Where:

e = 2.7182818

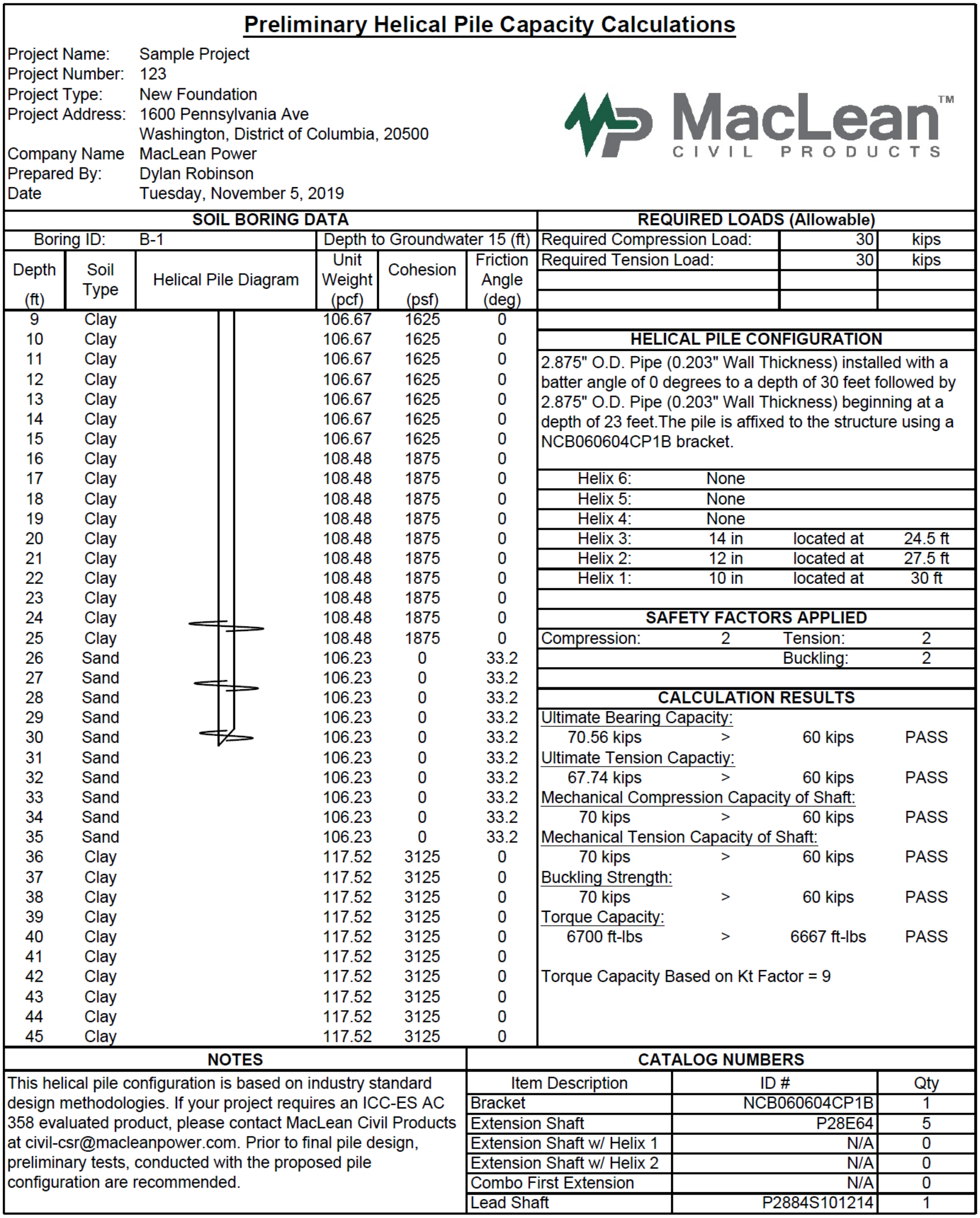
ϕ = Angle of Internal Friction - degrees

pi() = π

Example 8.1 shows an illustration of the Real Time Design (RTD) summary for a sample project using a 2 7/8" pipe pile. In this example, a portion of the pile passes through very soft clay and a check for column buckling (Section 9) is required. The RTD system automatically performs buckling calculations in soils with less than 5 blow counts.

An example of a "hand calculation" for this problem is also shown in Example Problem 8.2.

Example 8.1 – RTD summary report results detailing the helix configuration, geotechnical and mechanical capacities of the pile, depth, and the required installation torque.



Preliminary Helical Pile Capacity Calculations

Project Name:	Sample Project
Project Number:	123
Project Type:	New Foundation
Project Address:	1600 Pennsylvania Ave Washington, District of Columbia, 20500
Company Name	MacLean Power
Prepared By:	Dylan Robinson
Date	Tuesday, November 5, 2019

SOIL BORING DATA

Boring ID: B-1 Depth to Groundwater 15 (ft)

Depth (ft)	Soil Type	Helical Pile Diagram	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg)
9	Clay		106.67	1625	0
10	Clay		106.67	1625	0
11	Clay		106.67	1625	0
12	Clay		106.67	1625	0
13	Clay		106.67	1625	0
14	Clay		106.67	1625	0
15	Clay		106.67	1625	0
16	Clay		108.48	1875	0
17	Clay		108.48	1875	0
18	Clay		108.48	1875	0
19	Clay		108.48	1875	0
20	Clay		108.48	1875	0
21	Clay		108.48	1875	0
22	Clay		108.48	1875	0
23	Clay		108.48	1875	0
24	Clay		108.48	1875	0
25	Clay		108.48	1875	0
26	Sand		106.23	0	33.2
27	Sand		106.23	0	33.2
28	Sand		106.23	0	33.2
29	Sand		106.23	0	33.2
30	Sand		106.23	0	33.2
31	Sand		106.23	0	33.2
32	Sand		106.23	0	33.2
33	Sand		106.23	0	33.2
34	Sand		106.23	0	33.2
35	Sand		106.23	0	33.2
36	Clay		117.52	3125	0
37	Clay		117.52	3125	0
38	Clay		117.52	3125	0
39	Clay		117.52	3125	0
40	Clay		117.52	3125	0
41	Clay		117.52	3125	0
42	Clay		117.52	3125	0
43	Clay		117.52	3125	0
44	Clay		117.52	3125	0
45	Clay		117.52	3125	0

REQUIRED LOADS (Allowable)

Required Compression Load:	30	kips
Required Tension Load:	30	kips

HELICAL PILE CONFIGURATION

2.875" O.D. Pipe (0.203" Wall Thickness) installed with a batter angle of 0 degrees to a depth of 30 feet followed by 2.875" O.D. Pipe (0.203" Wall Thickness) beginning at a depth of 23 feet.The pile is affixed to the structure using a NCB060604CP1B bracket.

Helix 6:	None		
Helix 5:	None		
Helix 4:	None		
Helix 3:	14 in	located at	24.5 ft
Helix 2:	12 in	located at	27.5 ft
Helix 1:	10 in	located at	30 ft

SAFETY FACTORS APPLIED

Compression:	2	Tension:	2
		Buckling:	2

CALCULATION RESULTS

Ultimate Bearing Capacity:			
70.56 kips	>	60 kips	PASS
Ultimate Tension Capactiy:			
67.74 kips	>	60 kips	PASS
Mechanical Compression Capacity of Shaft:			
70 kips	>	60 kips	PASS
Mechanical Tension Capacity of Shaft:			
70 kips	>	60 kips	PASS
Buckling Strength:			
70 kips	>	60 kips	PASS
Torque Capacity:			
6700 ft-lbs	>	6667 ft-lbs	PASS

Torque Capacity Based on Kt Factor = 9

NOTES

This helical pile configuration is based on industry standard design methodologies. If your project requires an ICC-ES AC 358 evaluated product, please contact MacLean Civil Products at civil-csr@macleanpower.com. Prior to final pile design, preliminary tests, conducted with the proposed pile configuration are recommended.

CATALOG NUMBERS

Item Description	ID #	Qty
Bracket	NCB060604CP1B	1
Extension Shaft	P28E64	5
Extension Shaft w/ Helix 1	N/A	0
Extension Shaft w/ Helix 2	N/A	0
Combo First Extension	N/A	0
Lead Shaft	P2884S101214	1

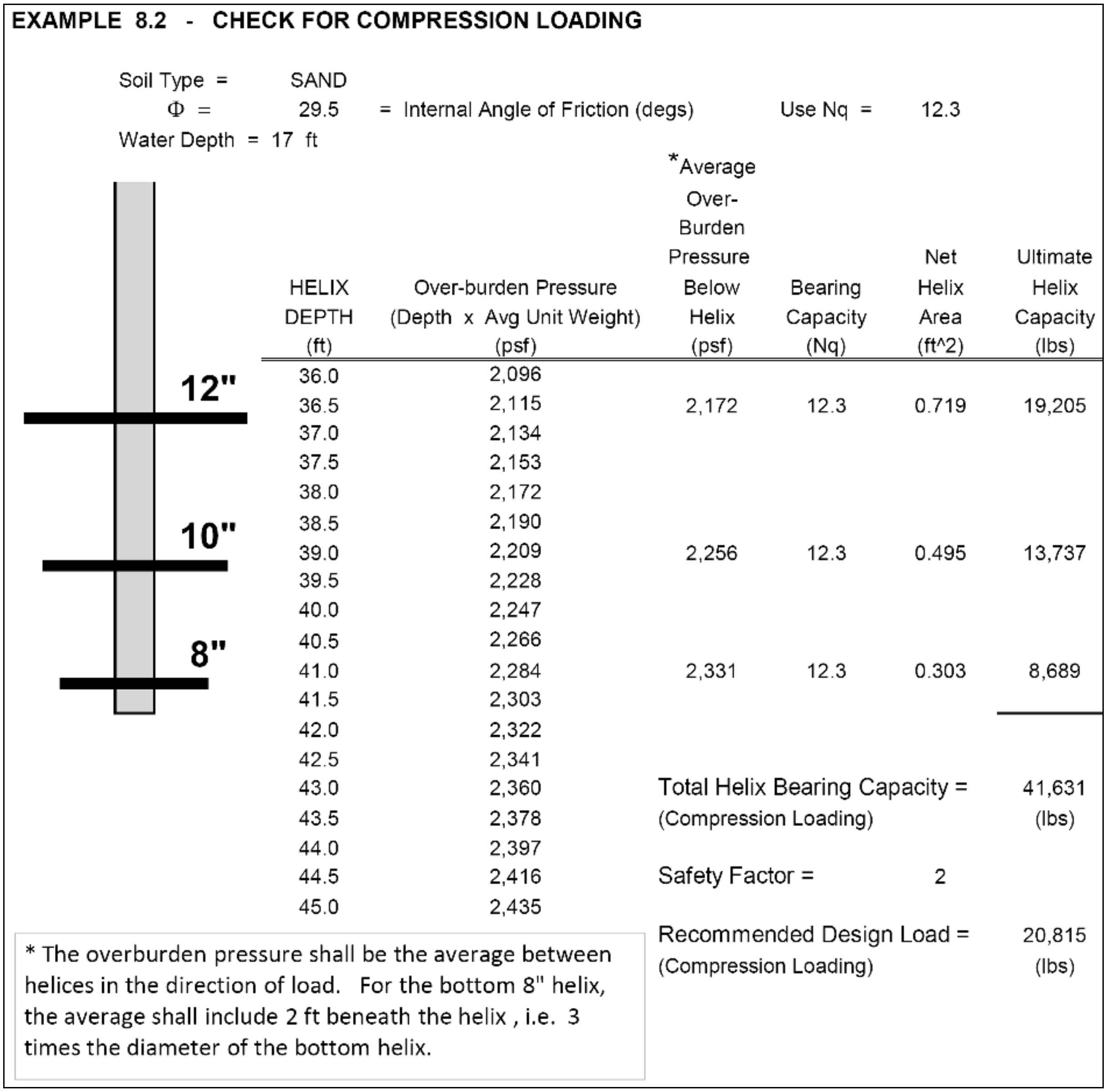
Example 8.2 – Hand Calculation

As discussed previously, the Terzaghi General Bearing Equation is best solved with standard computer spreadsheets such as Excel. The following example is a simplified condition, intended to show the basic calculations that would be required for problem 8.1. In this case, the helices are installed into granular – cohesionless soil so Equation 8.5 will be applied.

$q_{ult(g)} = A_h \times (q \times N_q)$ = Helix Ultimate Geotechnical Bearing Capacity
q = Effective overburden pressure is defined as the average unit weight of the soil times its depth.
Nq = Bearing Capacity Factor for Cohesionless Soil – Nq is a function of the *angle of internal friction* of the soil as previously discussed.

A 1.75” square shaft anchor with 8”, 10” and 12” helices is installed into granular cohesionless soil (sand) at a depth of 41 ft.

Determine: The Ultimate Pile Compressive Capacity and Recommended Design Load (assuming a Safety Factor of 2).



EXAMPLE 8.2 - CHECK FOR COMPRESSION LOADING

Soil Type = SAND
Φ = 29.5 = Internal Angle of Friction (degs) Use Nq = 12.3
Water Depth = 17 ft

HELIX DEPTH (ft)	Over-burden Pressure (Depth x Avg Unit Weight) (psf)	*Average Over-Burden Pressure Below Helix (psf)	Bearing Capacity (Nq)	Net Helix Area (ft^2)	Ultimate Helix Capacity (lbs)
36.0	2,096				
36.5	2,115	2,172	12.3	0.719	19,205
37.0	2,134				
37.5	2,153				
38.0	2,172				
38.5	2,190				
39.0	2,209	2,256	12.3	0.495	13,737
39.5	2,228				
40.0	2,247				
40.5	2,266				
41.0	2,284	2,331	12.3	0.303	8,689
41.5	2,303				
42.0	2,322				
42.5	2,341				
43.0	2,360				
43.5	2,378				
44.0	2,397				
44.5	2,416				
45.0	2,435				

Total Helix Bearing Capacity = 41,631
(Compression Loading) (lbs)

Safety Factor = 2

Recommended Design Load = 20,815
(Compression Loading) (lbs)

* The overburden pressure shall be the average between helices in the direction of load. For the bottom 8" helix, the average shall include 2 ft beneath the helix , i.e. 3 times the diameter of the bottom helix.

COLUMN BUCKLING

Buckling considerations of Helical Piles can be divided into two areas, *above ground line* and *below ground line*. An entirely different engineering approach is required for each of these conditions. *Above ground*, the pile shaft is surrounded by air, water or highly disturbed soils – providing no effective lateral support. *Below ground*, the pile shaft is surrounded by soil – thus receiving some degree of lateral support. Figure 9.1 shows a typical helical pile foundation subjected to an axial compression load.

The following discussion assumes that the pile is axially loaded with no lateral loads or bending moments occurring anywhere on the pile and the end conditions (restraints) are p-p (pin – pin) i.e. column ends are pinned, and free to rotate with translation fixed. See Figure 9.2.

Figure 9.1: Helical Piles

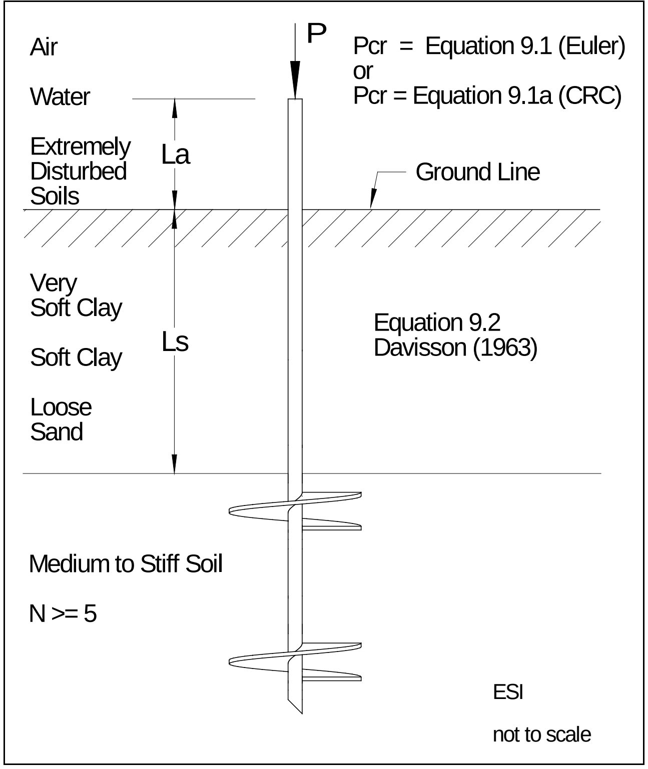
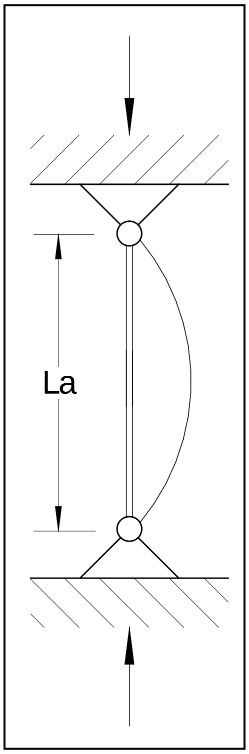


Figure 9.2: (k = 1)



ABOVE GROUND LINE

The portion of the pile that is above the ground line can be addressed by applying the classic Euler Equation or the CRC Equation. The classic Euler Equation 9.1 addresses long slender columns while the CRC Equation 9.1a addresses shorter columns. These equations and some examples of their applications are discussed below. *Above ground line* buckling considerations for Helical Piles are generally not required, but some piles may have a considerable portion of their shaft in areas that do not provide effective lateral support. These cases deserve special attention.

$$\mathbf{Pcr = (\pi^2 \times E \times I) / (k \times La)^2} \qquad \text{[Equation 9.1 Euler Equation]}$$

Pcr = Critical buckling load of the column. At this load, buckling may occur
E = Modulus of Elasticity of the pile material. (For Steel, E = 29,000,000 psi)
I = Minimum Moment of Inertia of the pile (in^4) – net section property
k = a constant - determined by the methods used to restrain the ends of the column. For the end conditions discussed above and shown in Figure 9.2, k = 1. See Reference 4 for additional end restraint conditions and values of k.
La = L = Unbraced length (in.) – receiving no lateral support. (kL = Effective unbraced length.)

For steel columns, the Euler Equation applies to long slender columns with slenderness ratios (kL/r) equal to or greater than: ((2 x Pi()^2 x E) / (Fy))^.5

Where: **r** = (I / Area)^.5 = minimum radius of gyration of the section
Fy = Yield Strength (proportional limit) of the material

For shorter columns with slenderness ratios less than ((2 x Pi()^2 x E) / (Fy))^.5, Euler Equation does not apply. For these types of columns the Column Research Council (CRC) proposes Equation 9.1a. This equation and its applications are discussed in detail on the following page.

Note: As stated above, when applying either equation 9.1 or 9.1a, we recommend that **k** = 1. End conditions for foundations are generally more fixed than pinned and in these cases **k** would be less than one. Our recommendation of setting the value of **k** to 1 is generally a conservative approach. See Reference 4 for additional information regarding the values of **k** for additional types of end restraints.

*It is interesting to note that, for Equation 9.1 (Euler), the critical buckling load (**Pcr**), for a long slender column, cannot be increased by using a steel with higher strength properties. For this type of column, **Pcr** is totally governed by its modulus of elasticity, its cross sectional shape properties, unbraced length and method of end connections (restraint). This is not the case for short piles when applying the CRC equation.*

Example 9.1 – Above Ground

The above ground portion (laterally unsupported) of a pile is 4 ft. (See Figure 9.1). The pile shaft is 1.50" RCS solid steel square bar (Fy = 70 ksi). Adequate lateral support is provided at the ground line. Determine the critical buckling load (**Pcr**) and the allowable design load with a Safety Factor 4.

Where: **I** = .396 in^4

A = 2.19 in^2

r = (.396 / 2.19)^.5 = .42523 in

k = 1

1. Check to determine which equation to use. (Euler or CRC)

Slenderness Ratio = kL/r = (1 x 48) / .42523 = 112.88

Minimum slenderness ratio for Euler = ((2 x Pi()^2 x E) / (Fy))^.5 = 97.67

112.8 > 97.67 so Euler Equation applies.

2. Determine the maximum load (lbs) that the above ground portion of the column can be expected to support - without buckling. **Pcr** [Euler] = (Pi^2 x E x I) / (k x La)^2

Pcr = (3.1416^2 x 29,000,000 x .396) / (1.0 x 48)^2 = 49,194 lbs.

Assuming a Safety Factor of 4, the allowable load would be 49,194 / 4 = 12,300 lbs.

The above problem is an example of applying Euler Equation to determine the critical buckling load (**Pcr**) for a long slender steel column.

As discussed above, for short columns with lesser slenderness ratios, the Euler Equation may not apply. For these piles, the loads given by Euler's equation may be too large. For these types of columns, the Column Research Council (CRC) proposes the formula (Equation 9.1a) shown on the following page. A graph (Figure 9.1a) that plots the critical buckling load (**Pcr**) vs. length for the 1.50" square shaft discussed in the previous example problem shows the relationship between the Euler and CRC Equations.

Euler and CRC Equations for Above Ground Sections of Helical Piles

PROPERTIES OF COLUMN

1.50" D6 SOLID RCS STEEL BAR

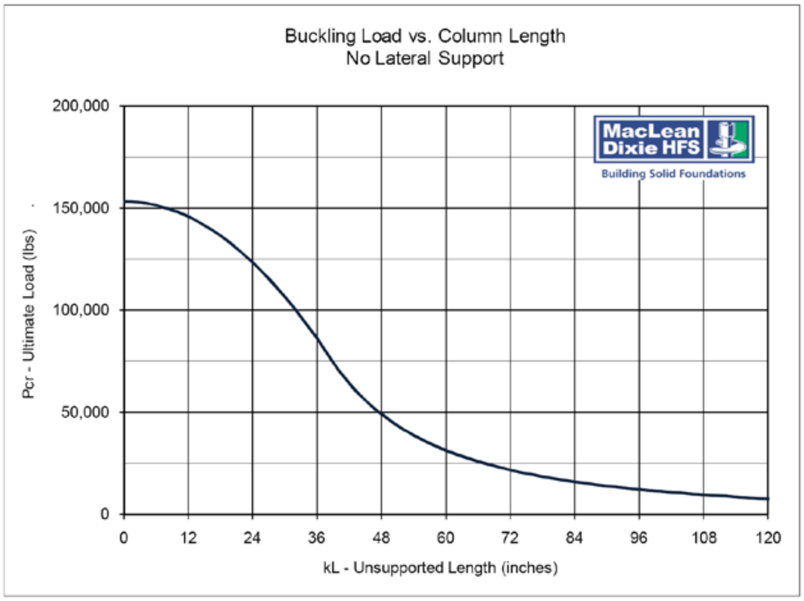
@ =	90.430	See notes
E =	29,000,000	psi
Fy =	70,000	psi
k =	1	-
O.D. =	1.5000	in.
r =	0.4252	in.
Area =	2.190	in.^2
I =	0.396	in.^4

The chart shows the theoretical load (Pcr) that will cause column bucking. The allowable load (Design Load) will be determined by dividing the critical load (Pcr) by an appropriate safety factor.

LATERALY UNSUPPORTED UN-BRACED COLUMN

1.50" D6 SOLID RCS STEEL BAR

Figure 9.1a



EXAMPLE:

Pcr at an unsupported length (kL) of 48.00 inches = 49,194 lbs LONG COLUMN - EULER FORMULA CAN BE USED

kL/r = 112.88 for an unsupported length (kL) of 48.00 inches

Note:

Slenderness Ratio of a column is defined as kL / r.

The Euler formula can be used when kL/r equals or exceeds: ((2 x PI()^2 x E) / (Fy))^.5

Let: ((2 x PI()^2 x E) / (Fy))^.5 = @

For these types of steel columns (where kL/r >= @) Equation 9.1 may be used.

Pcr [Euler] = (pi()^2 x E x I) / ((kL)^2) `[Equation 9.1]`

For steel columns with slenderness ratios less than @, the loads given by Euler's equation will be too large. For these columns (where kL/r < @), the Column Research Council (CRC) proposes Equation 9.1a.

Pcr [CRC] = (1 - ((kL/r)^2 / (2 x @^2))) x Fy x Area `[Equation 9.1a]`

The column length with a slenderness ratio (kL/r) equal to @ is indicated by a reversal of direction of the change of the slope of the curve shown above.

At a length of 0.00 inches, the resulting compression stress will equal the material's yield stress.

The above buckling equations are in accordance to the Manual of Steel Construction - Allowable Stress Design - ninth edition, American Institute of Steel Construction, Inc.

The engineer should determine the approprioate safety factor and the maximum permissible slenderness ratio (kL/r) for the particular column. These properties can vary, depending on section size and shape, method of loading, and other parameters.

BELOW GROUND LINE

Early investigations of the buckling of piles (Granholm, 1929) showed that for piles of normal dimensions driven through soft soil, buckling should not take place except in extremely soft soil. However, with the increasing use of very slender piles (including Helical Piles), the possibility of buckling has had to be reconsidered. In recent years, considerable research has been carried out in this area in an attempt to obtain better methods for estimating pile-buckling loads. So far, the majority of analytical methods have employed *subgrade-reaction* theory.[1] Several programs such as LPILE, which apply finite difference techniques are available. Other approaches such as the Davisson (1963) Method are generally regarded as "hand calculation methods" but are best-applied using computer spread sheet programs. The Davisson (1963) Method and some examples of its application are discussed below.

As a general rule, buckling should not occur when the soil along the total length of the pile has an ASTM D 1586 SPT N-value > 4. This assumes axial loading, with no shear or bending moment acting at the top of the pile.

The Davisson Method is based on the following assumptions:

1. The pile is initially (and remains) perfectly straight and plumbed.

2. The axial load is constant in the pile, i.e. no load is transferred from the pile through skin friction.

3. The piles are axially loaded with no lateral loads or bending moments.

4. The Modulus of Subgrade Reaction (**Kh**) is constant throughout the length of the pile.

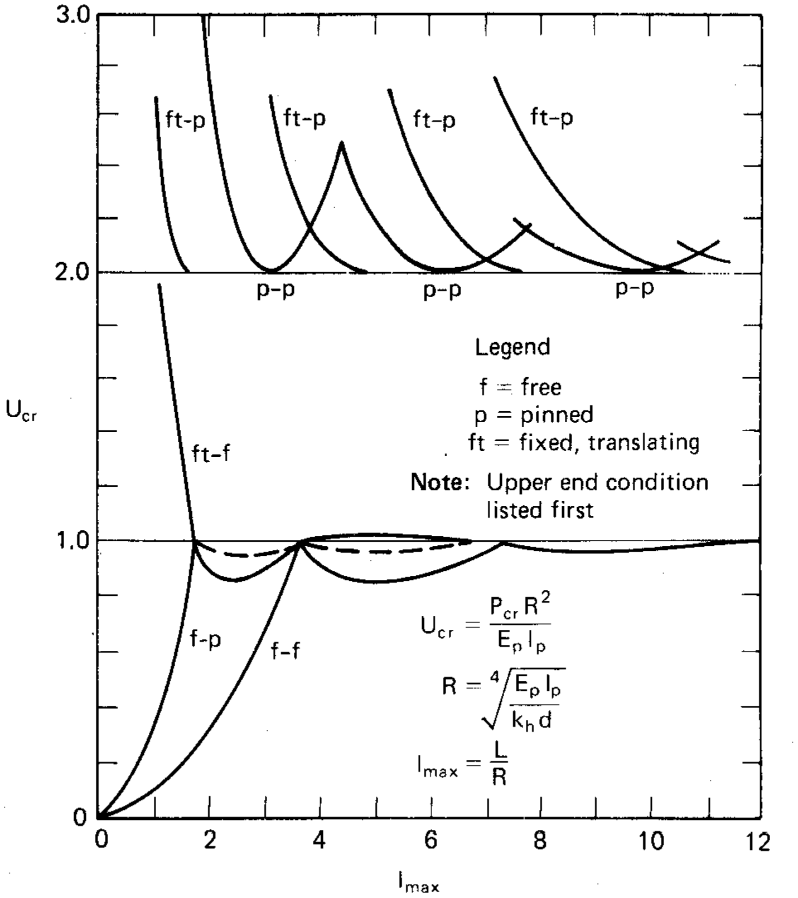
Davisson's equation for buckling load (**Pcr**) can be expressed as Equation 9.2 shown below. See Figure 9.3.

$$\mathbf{Pcr = Ucr \quad x \left(\frac{E \text{ x } I}{R^2} \right)} \qquad \text{[Equation 9.2]}$$

Where:

Ucr = A dimensionless factor governed by the end connections (restraints) of the pile. See Figure 9.3.
E = Modulus of Elasticity of the pile material (Steel = 29,000,000 psi).
I = Minimum cross sectional Moment of Inertia of the pile (in^4).
R = ((E x I) / (Kh x d))^ $^{.25}$
R^2 = ((E x I) / (Kh x d))^ $^{.50}$
Kh = Modulus of Subgrade Reaction (lbs/cu in) See Table 9.1.
d = Pile diameter (in.)

Figure 9.3: Buckling Load vs. Length for Kh = Constant (Davisson, 1963) [1]



As shown above, for p-p conditions (both ends pinned – no translation), the minimum value for **Ucr** is 2.0 for all **I_{max} (L/R)** values. Setting **Ucr** = 2.0 (for initial estimates) is probably a reasonably conservative approach - since the pile will more than likely be fixed at the top (interconnected to the structure). Assuming a pile with fixed section and material properties and **Ucr** =2, the only remaining variable here would be the value of Kh.

Table 9.1 is intended to be used only as a representative guide for values of **Kh**. Additionally, if very thick layers (15+ feet) of less than 5 blow per foot soil is present the Davisson Method may not accurately predict the below ground buckling behavior of the pile. In this case, it is recommended that a geotechnical engineer, experienced in the area, evaluate the buckling potential of the pile and provide the final design values of Kh.

Table 9.1: Range of Values of Modulus of Subgrade Reaction, Kh

Soil	**Modulus of Subgrade Reaction, Kh (lbs / cu in.)**
Loose Sand	15 - 20
Soft Clay	20 - 70
Very Soft Clay	10 - 20

Example 9.2 – Below Ground

A twin helix foundation pile anchor (Figure 9.1) has been installed so that the helical lead section is in a stratum of medium to stiff clay. 25 ft. (Ls) of the shaft passes through very soft clay with a SPT N-value of 2 to 3.

The anchor shaft is 1.50” square solid steel bar – RCS.

Apply the Davisson Method, to determine the critical buckling load **Pcr** and allowable working load based on a safety factor of 2.

$$Pcr = Ucr \times \left(\frac{E \times I}{R^2} \right)$$

(See Fig. 9.2)

Where:

Ucr = 2 = A dimensionless factor governed by the end connections (restraints) of the pile. See Figure 9.3.
E = Modulus of Elasticity of the pile material (Steel = 29,000,000 psi)
I = Minimum cross sectional Moment of Inertia of pile. (in^4).
R = ((E x I) / (Kh x d))^ $^{.25}$
R^2 = ((E x I) / (Kh x d))^ $^{.50}$
Kh = Modulus of Subgrade Reaction (lbs/cu in). See Table 9.1.
d = Pile diameter (in.)

Where:

Ucr = 2 - Assume a p-p connection for the ends. (Figure 9.3).

Kh = 12 lbs / cu in. (Table 9.1, very soft clay).

I_{max} = L / R

L = Ls = 25 x 12 = 300 inches

E = 29,000,000 for steel

I = .396 in.^4 (Table 12.3)

d = 1.50 in.

R = ((29,000,000 x .396) / (12 x 1.5))^ $^{.25}$ = 28.26

R^2 = 798.75

I_{max} = L / R = 300 / 28.26 = 10.62, Ucr = 2

As discussed above, assuming a p-p connection for the ends, Ucr can be set to 2.0 for all values of **I_{max}**. In this case, the above calculation would be redundant with the only variable being Kh.

***Pcr** = 2 x ((29,000,000 x .396) / 798.75) = 28,755 lbs* (Also See Figure 9.4)

Based on a safety factor of 2, the allowable load would be 28,755 / 2 = 14,377 lbs.

SUMMARY

In this case the allowable working load for the section of the pile above ground will govern. (See Example 9.1) The maximum allowable working load for this pile would be 12,300 lbs.

* * *

*It is interesting to note that a significant increase in **Pcr** can be realized if a 1.75” square shaft is used in place of the 1.50” square shaft. In this case, the value of **Pcr** would be increased to 43,358 lbs. Regardless of the **Kh** value, the increase from a 1.50” sq shaft to a 1.75” sq shaft would yield an approximate 48% increase in the critical buckling load, **Pcr**. If a hollow round shaft (i.e. P28 to R86 Piles) were used in place of a solid square shaft, the increase of **Pcr** would be significantly larger.*

If **Ucr** is set at a constant value of 2 (i.e. lowest possible value for a pin-pin connection), the following curves can be used to determine the Davisson value of **Pcr** for a range of values of **Kh**. *Applying a constant value for* **Ucr** *greatly simplifies the use of the Davisson equation*. With **Ucr** held constant - only **Kh**, not pile length, governs the critical buckling load **Pcr**. As discussed above, **Ucr** = 2 seems to be a relatively conservative approach for analyzing Helical Pile. **Pcr** vs. **Kh** curves for a 1.50" round cornered square shaft and a 1.75" sq round cornered square shaft are shown below in Figures 9.4 and 9.5.

Figure 9.3: 1.5" Round Cornered Square Shaft

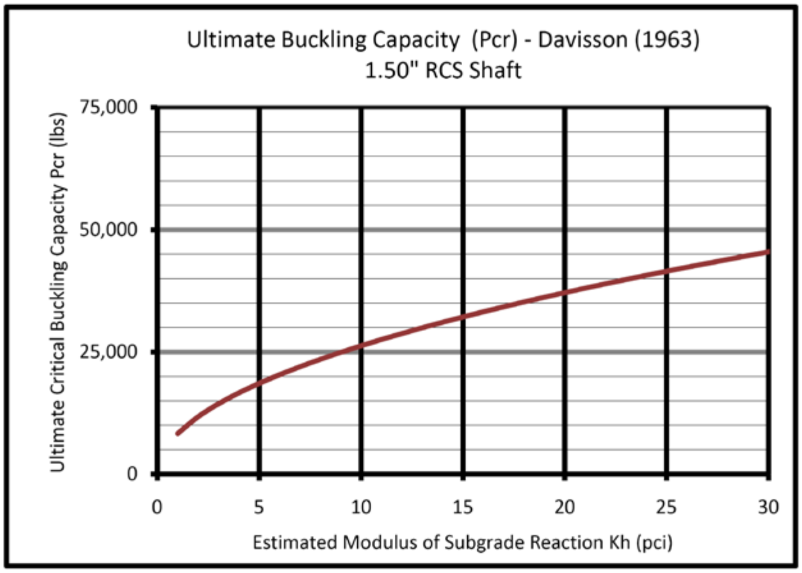
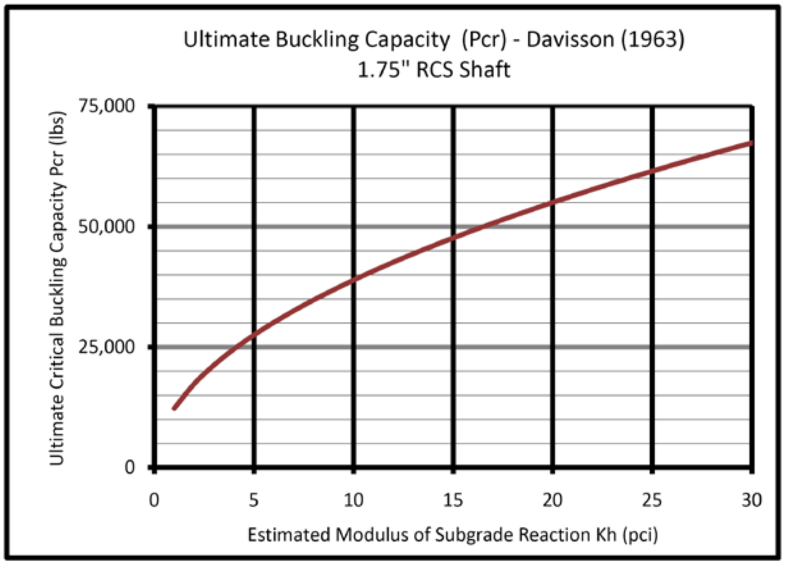


Figure 9.4: 1.75" Round Cornered Square Shaft



References:

1. H. G. Poulos, E. H. Davis, The University of Sydney, "Pile Foundation Analysis and Design" 1980 Pages 143 - 150, John Wiley and Sons
2. F. E. Miller, H. A. Doeringsfeld, The University of Minnesota, "Mechanics of Material", Second Edition, International Textbook Company
3. Steve Timoshenko, James M. Gere, Stanford University, "Mechanics of Materials", 1972, D. Van Nostrand Company.
4. Manual of STEEL CONSTRUCTION – Allowable Stress Design, ninth edition, American Institute of Steel Construction, Inc.

LATERAL CAPACITY

UNRESTRAINED OR FREE-HEAD SHORT RIGID HELICAL PILES

The piles discussed below can be either a single length of pipe, or a pipe top section assembled to a standard square shaft helical lead.

Helical Piles generally use hollow round shafts in lieu of solid square shafts for two reasons:

1. **Column Buckling**: In the case of a stiff or dense soil stratum underlying very soft clay or silt (SPT N value < 5), the use of hollow round shafts in lieu of solid square shafts can significantly increase the axial compression capacity of the pile. For column loading (i.e. column buckling considerations), a hollow round shaft is much more efficient than a solid square shaft. This is discussed in detail in Section 9.

2. **Lateral Capacity**: To achieve greater lateral capacity, the top section of the Helical Pile will often be of a greater diameter than the bottom section. A typical configuration would be a round cornered square (RCS) helical lead topped with a 2-7/8" to 8-5/8" pipe (used in place of the standard RCS extension). The pipe section is usually embedded to a depth of at least 5 to10 ft. below the surface. The RCS helical lead facilitates penetration into underlying very stiff or dense soils while providing the required axial capacity. The pipe section provides the required lateral capacity.

Also, skin friction between the soil and the pile is much greater when using a round shaft in lieu of a square shaft. In some cases this can significantly increase the axial capacity of the pile. See Section 8.

This section addresses the lateral capacity of Unrestrained or Free-Head Short Rigid Helical Piles. We recommend that the engineer familiarize themself with the articles shown in items 1, 2 and 3 of the references listed here.

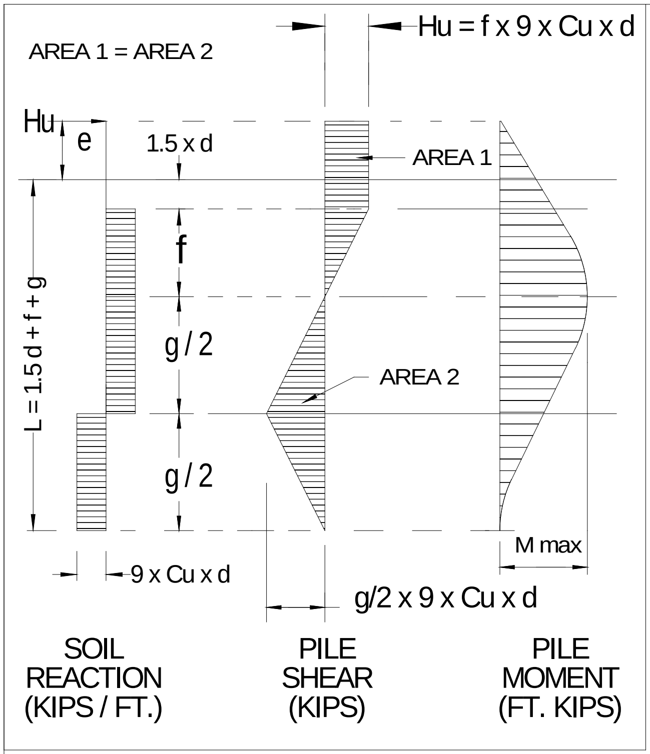
H. G. Poulos, E. H. Davis, The University of Sydney, "Pile Foundation Analysis and Design" 1980, John Wiley and Sons (Ref. 3) is highly recommended as a particularly valuable and concise source of information on laterally loaded short rigid piles as well as buckling consideration of slender piles which are discussed in Section 9.

A shear/moment diagram for either "cohesive" or "cohesionless" soils can easily demonstrate Broms' theory and its equations. A simple static solution of these diagrams will yield the equations that determine the required pile embedment depth and pile size to resist the specified lateral load. The following reaction/shear/moment diagrams for homogeneous soils are enclosed in Figure 10.1 and 10.2.

Broms' method determines the ultimate soil resistance to a lateral load as well as the maximum moment induced into the pile. Broms' methods may be used to evaluate lateral capacity for both fixed and free pile head conditions in either cohesive or cohesionless soils. This section addresses the Free-Head Short Rigid Pile condition only.

Equations for free pile head conditions in either cohesive (clay) or cohesionless (granular, sand) soils are shown on Table 10.1. Broms' method is typically an iterative process - best solved with a computer spreadsheet. Broms' method is considered a "hand calculation method" which generally agrees with field results for short piles. More elaborate approaches (not included in this section), utilizing finite element techniques (computer programs) may also be applied. As for all theoretical solutions, pile testing is recommended.

Figure 10.1: Broms' Method for Short Free-Headed Piles – Cohesive Soils - Clay



SHEAR AT DEPTH $((1.5 \times d) + f) = 0$

so:

$f \times 9 \times Cu \times d = Hu$

$f = Hu / 9 \times Cu \times d$

$\text{AREA 1} = (Hu \times (e + 1.5\,d)) + 1/2 \times f \times Hu$
$= Hu \times (e + 1.5\,d + 1/2 \times f)$

$\text{AREA 2} = 1/2 \times g \times g/2 \times 9 \times Cu \times d$
$= (g\text{^}2 / 4) \times 9 \times Cu \times d$
$= 2.25 \times d \times g\text{^}2 \times Cu$

$g = ((Hu \times (e + 1.5d + .5f)) / (2.25 \times d \times Cu))\text{^}.5$

M max = AREA 1 or AREA 2

M max $= Hu \times (e + 1.5d + .5f)$

L = REQUIRED DEPTH INTO SOIL WITH COHESION OF "Cu".

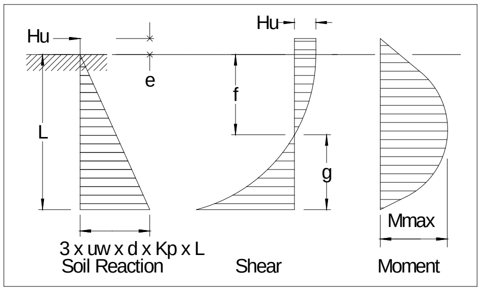
$L = 1.5d + f + g$

FOR COHESIVE SOILS ONLY

RECOMMENDED UNITS

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

Figure 10.2: Broms' Method for Short Free-Headed Piles – Cohesionless (granular) Soils



SUM MOMENTS ABOUT TOE OF REACTION POLYGON.

$$Hu \times (e + L) = (3/2 \times uw \times d \times Kp \times L^2) \times L/3$$

$$\boxed{Hu = \frac{.5 \times uw \times d \times Kp \times L^3}{e + L}}$$

BENDING MOMENT = AREA UNDER SHEAR CURVE

MAX. MOMENT = AREA UNDER SHEAR CURVE AT DEPTH "f".

SUM OF REACTION VECTORS = $\sum R$

$$\sum R = 3 \times uw \times d \times Kp \times \int_0^L y \,.\, dy$$

$$\boxed{\sum R = 3/2 \times uw \times d \times Kp \times L^2}$$

SUM OF REACTION VECTORS AT ANY DEPTH "y"

$$\boxed{\sum r = 3/2 \times uw \times d \times Kp \times y^2}$$

DEPTH OF MAXIMUM BENDING MOMENT = f

$$Hu = 3/2 \times uw \times d \times Kp \times f^2$$

$$\boxed{f = .8165 \times \sqrt{\frac{Hu}{uw \times d \times Kp}}}$$

$$Mmax = \int_0^e Hu \,.\, dy + \int_0^f Hu - 3/2 \times uw \times d \times Kp \times y^2 \,.\, dy$$

$$= Hu \times y \Big]_0^e + Hu \times y - 3/2 \times uw \times d \times Kp \times (y^3)/3 \Big]_0^f$$

$$= Hu \times e + Hu \times f - [\,3/2 \times uw \times d \times Kp \times f^2\,] \times f/3$$

$$[\,3/2 \times uw \times d \times Kp \times f^2\,] = Hu$$

$$= Hu \times e + Hu \times f - Hu \times f/3$$

$$= Hu \times e + Hu \times (f - f/3)$$

$$= Hu \times e + Hu \times (2/3\, f)$$

$$Mmax = Hu \times (e + 2/3\, f)$$

MOMENT AT ANY POINT DOWN PILE ...

$$M = (Hu \times e) + (Hu \times y - .5 \times uw \times d \times Kp \times y^3)$$

UNRESTRAINED (FREE-HEAD) SHORT PIL
IN COHESIONLESS SOILS

In the above analysis, it is assumed that the lateral earth pressure which develops at failure is equal to three (3) times the passive Rankine earth pressure which can be shown by the equation:
3 x uw x d x Kp x y

Where: **uw** is the unit weight of the soil
d is the pile diameter
Kp is the coefficient of passive earth pressure as calculated by the Rankine earth pressure theory
y is the depth below the ground surface

The unit weight, **uw**, is equal to submerged unit weight if the ground water table is located at or above the section to be considered. We recommend that the soil from ground surface to pile depth be entered as either "dry" or "wet". i.e. The water table will be either at the surface or beneath the bottom of the pile.

For cohesionless soils, the coefficient **Kp** can be calculated from:

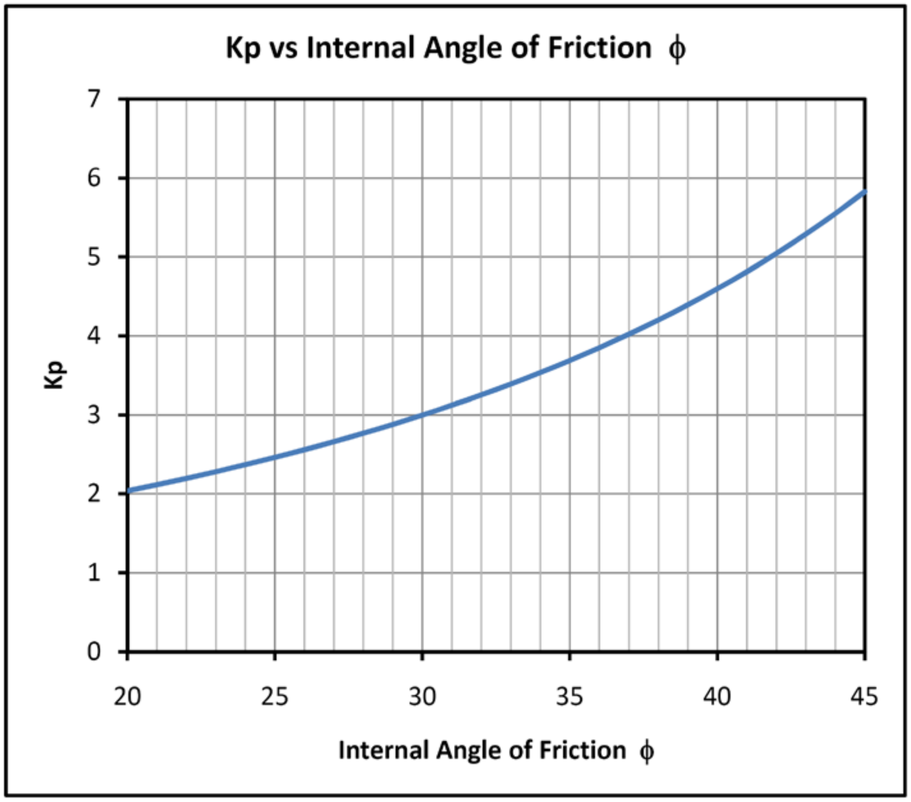
$$Kp = (1 + \sin[\phi]) \;/\; (1 - \sin[\phi]) \qquad \text{or} \qquad Kp = \tan^2(45 + [\phi / 2])$$

A graph plotting **Kp** vs. ϕ (angle of internal friction - degs) is shown in Figure 10.3.

Broms' (1964) makes the following assumptions for piles in cohesionless soils:

1. The lateral deflections are sufficiently large, at failure, as to develop the full passive resistance equal to three times the passive Rankine earth pressure from the ground surface down to the location of the center of rotation. [The diagram shown above, assumes this condition at the bottom of the pile.]
2. The active earth-pressure acting on the back of the pile is neglected.
3. The shape of the pile section has no influence on the distribution of ultimate soil pressure or the ultimate resistance.
4. The full lateral resistance is mobilized at the movement considered.

Figure 10.3: Coefficient of Passive Earth Pressure vs. Angle of Internal Friction ϕ



* * *

Notes – Broms' Equations

The Broms' equations discussed here apply to either cohesive or cohesionless homogeneous soils. Ground water is assumed to be at the surface or below the bottom of the pile.

Solving the equations generally require an iterative process.

- Select a standard pile size and desired depth.
- For cohesive soils (clay), the required ultimate lateral load is entered to determine the required pile depth and resulting moment.
- For cohesionless soils (sand), depth is entered to determine the resulting ultimate lateral capacity and moment. Depth will be increased until the resulting ultimate lateral capacity is equal to the required capacity.
- Check depth and moment capacity of the selected pile. Change pile size and depth if/as required.

Table 10.1: BROMS' EQUATIONS – SHORT FREE-HEADED PILES

COHESIVE SOILS See Figure 10.1	COHESIONLESS SOILS See Figure 10.2
f = Hu / (9 x Cu x d)	f = .8165 x ((Hu / (uw x d x Kp))^.5)
M_{max} = Hu x (e + 1.5 d + .5f)	M_{max} = Hu x (e + (.66666 * f))
g = ((Hu x (e + 1.5d + .5f)) / (2.25 x d x Cu))^.5	Hu_{max} = (.5 x uw x d x Kp x L^3) / (e + L)
L = (1.5 x d) + f + g	Kp = $\tan^2$ (45 + [ϕ / 2])

Where:

Hu = Ultimate Lateral Load (Design Lateral Load x Safety Factor) - kips
Cu = Soil Cohesion – ksf
d = Pile Diameter – ft.
e = Eccentricity of Load (Hu) – ft.
M_{max} = Maximum moment induced in the pile as a result of the lateral load – ft-kips
g = ft.
f = ft.
L = Length (depth) of pile – ft.
uw = effective unit weigh of soil - kcf
Kp = Coefficient of Passive Earth Pressure
ϕ = Soil's angle of internal friction – degs

References:

1. Bengt B. Broms, "Lateral Resistance of Piles in Cohesionless Soils", Proceedings of the American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, May 1964.

2. Bengt B. Broms, "Lateral Resistance of Piles in Cohesive Soils", Proceedings of the American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, March 1964.

3. H. G. Poulos, E. H. Davis, The University of Sydney, "Pile Foundation Analysis and Design" 1980 Pages 143 - 150, John Wiley and Sons

Example 10.1 - Broms' Method – Cohesionless and Cohesive Soils

Given:

1. 8" steel pipe piles (8.625" OD) are specified for a proposed building project.
2. The specified ultimate lateral load for the piles is 7 kips, applied 1 ft above ground surface.
3. The piles will be installed at two separate locations. Soil properties are as follows:

Location 1 – Cohesionless Soil

Sand
Water Depth = 10.5 ft
Unit Weight = 100 pcf
ϕ = 30 degs
Cohesion = 0

Location 2 – Cohesive Soil

Clay
Water Depth = 7.5 ft
Cohesion = 1 ksf
ϕ = 0 degs

Determine:

1. The required pile depth at each location
2. The maximum moment induced into the pile at each location
3. The recommended pile at each location

Method:

Applying the equations in Table 10.1, the required depth and maximum moment can be determined at each location. The maximum moment can then be used to determine the required yield strength and wall thickness of the pile.

Solution:

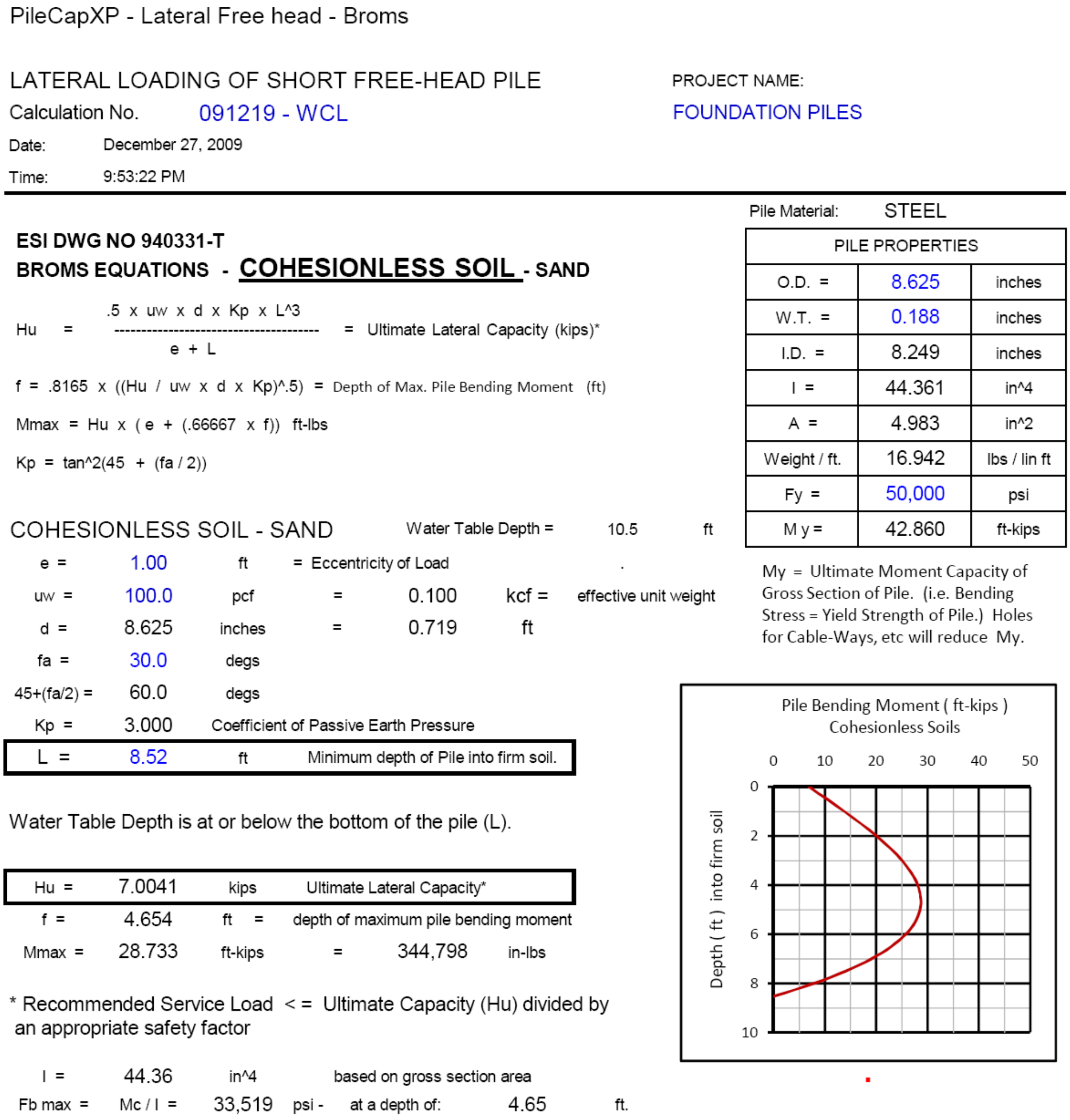
Applying these equations is often an iterative process and for this reason an Excel type spreadsheet solution is recommended. A spread sheet solution (yielding the results shown below) is shown on the following pages.

- Recommended pile length (tip depth) at Location 1 (Sand) = 9 ft.
- Recommended pile length (tip depth) at Location 2 (Clay) = 6 ft.
- Pile Section Size: Maximum ultimate bending stress occurs at Location 1 (Sand). This is less than the rated yield strength of MCP 8" Helical Pile with a wall thickness of 0.188". So the standard R86 Series Helical Pile can be recommended at both locations.

* * *

Example 10.1 – continued

Location 1 – Sand



PileCapXP - Lateral Free head - Broms

LATERAL LOADING OF SHORT FREE-HEAD PILE

Calculation No. 091219 - WCL

Date: December 27, 2009

Time: 9:53:22 PM

PROJECT NAME:

FOUNDATION PILES

Pile Material: STEEL

PILE PROPERTIES		
O.D. =	8.625	inches
W.T. =	0.188	inches
I.D. =	8.249	inches
I =	44.361	in^4
A =	4.983	in^2
Weight / ft.	16.942	lbs / lin ft
Fy =	50,000	psi
M y =	42.860	ft-kips

My = Ultimate Moment Capacity of Gross Section of Pile. (i.e. Bending Stress = Yield Strength of Pile.) Holes for Cable-Ways, etc will reduce My.

ESI DWG NO 940331-T

BROMS EQUATIONS - COHESIONLESS SOIL - SAND

$$Hu = \frac{.5 \times uw \times d \times Kp \times L^3}{e + L} = \text{Ultimate Lateral Capacity (kips)*}$$

f = .8165 x ((Hu / uw x d x Kp)^.5) = Depth of Max. Pile Bending Moment (ft)

Mmax = Hu x (e + (.66667 x f)) ft-lbs

Kp = tan^2(45 + (fa / 2))

COHESIONLESS SOIL - SAND

Water Table Depth = 10.5 ft

e =	1.00	ft	= Eccentricity of Load			
uw =	100.0	pcf	=	0.100	kcf =	effective unit weight
d =	8.625	inches	=	0.719	ft	
fa =	30.0	degs				
45+(fa/2) =	60.0	degs				
Kp =	3.000	Coefficient of Passive Earth Pressure				
L =	8.52	ft	Minimum depth of Pile into firm soil.			

Water Table Depth is at or below the bottom of the pile (L).

Hu =	7.0041	kips	Ultimate Lateral Capacity*		
f =	4.654	ft =	depth of maximum pile bending moment		
Mmax =	28.733	ft-kips	=	344,798	in-lbs

* Recommended Service Load < = Ultimate Capacity (Hu) divided by an appropriate safety factor

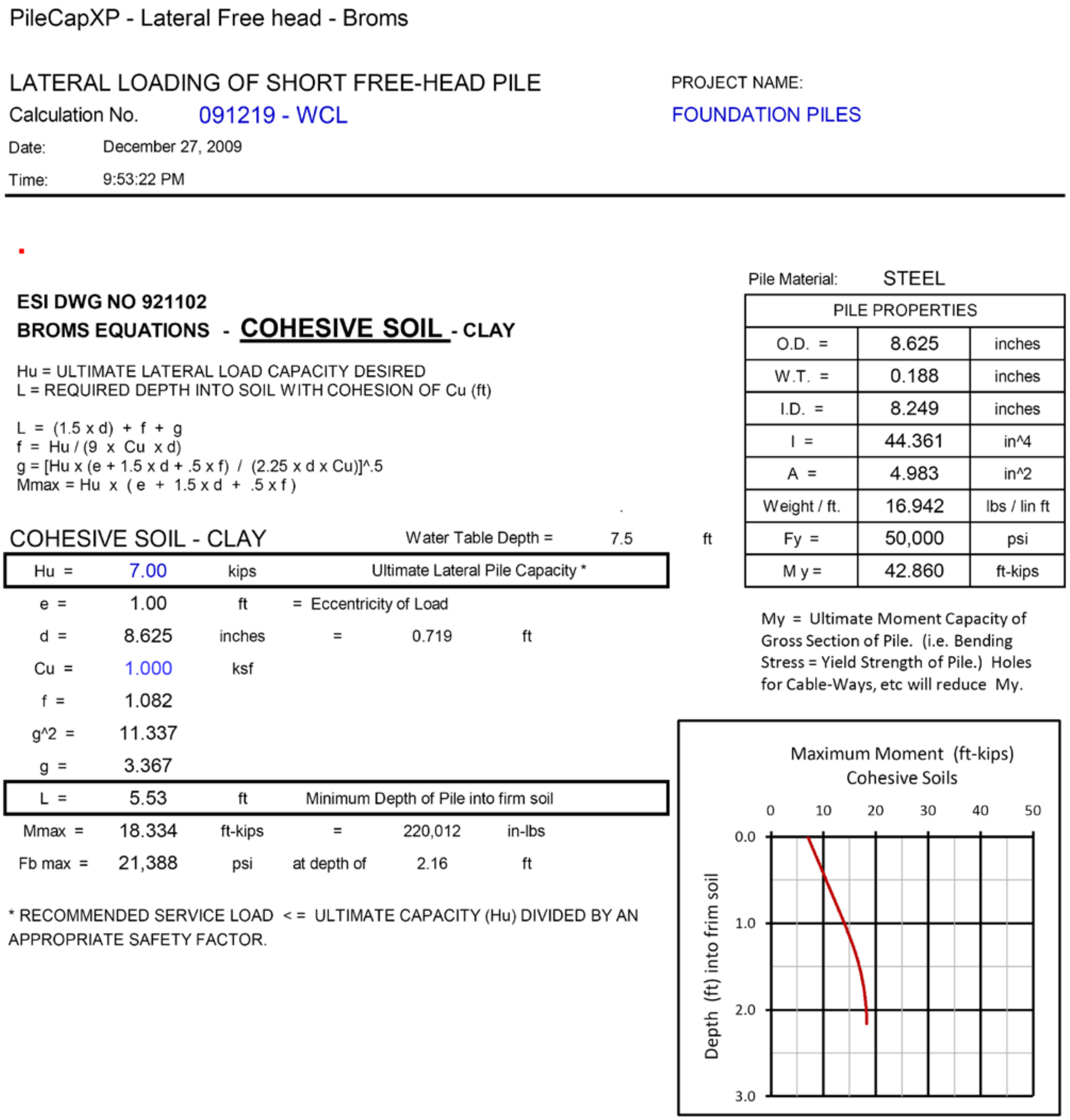
I = 44.36 in^4 based on gross section area

Fb max = Mc / I = 33,519 psi - at a depth of: 4.65 ft.

* * *

Example 10.1 – continued

Location 2 – Clay



PileCapXP - Lateral Free head - Broms

LATERAL LOADING OF SHORT FREE-HEAD PILE

Calculation No. 091219 - WCL

Date: December 27, 2009

Time: 9:53:22 PM

PROJECT NAME:

FOUNDATION PILES

ESI DWG NO 921102

BROMS EQUATIONS - COHESIVE SOIL - CLAY

Hu = ULTIMATE LATERAL LOAD CAPACITY DESIRED
L = REQUIRED DEPTH INTO SOIL WITH COHESION OF Cu (ft)

L = (1.5 x d) + f + g
f = Hu / (9 x Cu x d)
g = [Hu x (e + 1.5 x d + .5 x f) / (2.25 x d x Cu)]^.5
Mmax = Hu x (e + 1.5 x d + .5 x f)

Pile Material: STEEL

PILE PROPERTIES		
O.D. =	8.625	inches
W.T. =	0.188	inches
I.D. =	8.249	inches
I =	44.361	in^4
A =	4.983	in^2
Weight / ft.	16.942	lbs / lin ft
Fy =	50,000	psi
M y =	42.860	ft-kips

My = Ultimate Moment Capacity of Gross Section of Pile. (i.e. Bending Stress = Yield Strength of Pile.) Holes for Cable-Ways, etc will reduce My.

COHESIVE SOIL - CLAY Water Table Depth = 7.5 ft

Hu =	7.00	kips	Ultimate Lateral Pile Capacity *		
e =	1.00	ft	= Eccentricity of Load		
d =	8.625	inches	=	0.719	ft
Cu =	1.000	ksf			
f =	1.082				
g^2 =	11.337				
g =	3.367				
L =	5.53	ft	Minimum Depth of Pile into firm soil		
Mmax =	18.334	ft-kips	=	220,012	in-lbs
Fb max =	21,388	psi	at depth of	2.16	ft

* RECOMMENDED SERVICE LOAD < = ULTIMATE CAPACITY (Hu) DIVIDED BY AN APPROPRIATE SAFETY FACTOR.

Note: Regarding Cohesive Clay Soils - Unless cohesion is changed, water depth does not affect the lateral load capacity, required depth or moment of a pile. This is not the case with cohesionless soils.

* * *

CORROSION

This section is intended to provide general criteria for evaluating the effect of underground corrosion on Helical Piles. Acceptance criteria for Helical Piles shall be in accordance, but not limited, to ICC-ES-AC358 – latest revision. A Professional Engineer, familiar with the jobsite area and the corrosive behavior of the soil, can provide all applicable recommendations concerning corrosion control.

FUNDAMENTALS OF CORROSION OF METALS IN SOIL

Corrosion is the deterioration or dissolution of metal or its properties by chemical or electrochemical reaction with the environment. When a large surface is affected it can be viewed as general corrosion and approximated by an average fictitious uniform rate of corrosion per year. If confined to small points so that definite indentations form in the metal surface, it is referred to as pitting corrosion and generally reported as maximum pit depth per year. Corrosion is fundamentally a return of metals to their native state as oxides and salts. Only the more noble metals and copper exist in nature in their metallic state. In areas of high rainfall, the passage of time has resulted in the leaching of soluble salts and other compounds, rendering these soils generally acidic. In arid locations, soluble salts are brought to the upper soil layers through capillary and evaporative processes, causing the soils to be generally alkaline. Current flows because of a voltage difference between two metal surfaces or two points on the same surface in the presence of an electrolyte. Two pieces of metal or two portions of the same metal in an electrolyte seldom have the same potential. The amount of potential difference depends on the nature of the metal, the condition of the surface, the nature of the electrolyte, and the presence of different materials at the interface of the metal and electrolyte. The authoritative reference work to date on underground corrosion is National Bureau of Standards (NBS) Circular 579. It is recommend that the reader obtain a copy of this paper.

The corrosion mechanism of ferrous and other metals in soils is essentially electrochemical. For corrosion to occur, there must be a potential difference between two points that are electrically connected in the presence of an electrolyte. Under these conditions, a current will flow from the anodic area through the electrolyte or soil to the cathodic area and then through the metal to complete the circuit. The anodic area becomes corroded by the loss of metal ions to the electrolyte. In general, the most corrosive soils contain large concentrations of soluble salts, especially in the form of sulfates, chlorides, and bicarbonates and may be characterized as very acidic (low pH) or highly alkaline (high pH). Clayey and silty soils are characterized by fine texture, high water-holding capacity, and consequently, by poor aeration and poor drainage. They are also prone to be potentially more corrosive than soils of coarse nature such as sand and gravel where there is greater circulation of air. Buried metals corrode significantly by the process of differential aeration and sometimes by bacterial action. Corrosion by differential aeration may result from substantial local differences in type and compaction of the soil or variations in the oxygen or moisture content resulting thereof. Such a phenomenon is generally associated with fine-grained soils. Bacterial corrosion is associated with the presence of anaerobic sulfate-reducing bacteria that reduce any soluble sulfates present in the soil to sulfides. The corrosion process can be slowed or mitigated by the use of zinc or other types of coatings discussed below.

To summarize the above paragraphs (edited from FHWA-NHI-00-044), underground corrosion is an electrochemical process that requires oxygen availability plus the existence of three of the following conditions. Remove any of these three conditions and corrosion stops.

1. An anode/cathode system
2. An electrically conducting path between the anode and cathode
3. An electrolyte in contact with the anode/cathode system

When underground corrosion occurs, the soil serves as an electrolyte. The rate of corrosion will be directly related to the soil's ability to conduct an electrical current i.e. to provide an electrolyte connecting the anode and cathode of the system. The quality of the electrolyte can be expressed as conductivity or as the inverse to conductivity - “resistivity”. Soil resistivity is a measure of how easily a soil will allow an electric current to flow through it. Soils with high resistivities are poor electrolytes. Soils with very low resistivities are excellent electrolytes. A soil with low resistivity will generally promote more corrosion than a soil with greater resistivity. In disturbed soils, resistivity is one of the most important properties of a soil when predicting underground corrosion. Soil resistivity can be measured using the method described in the ASTM

Standard G57-84 - Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method. Table 11.1 shows a typical relationship between soil resistivity and soil corrosiveness. Resistivity – Corrosiveness tables such as Table 11.1 are subjective and will vary between publications.

Table 11.1: Soil Resistivity – Soil Corrosiveness

Soil Resistivity (ohm-cm)	Classification of Soil Corrosiveness
0 to 900	Very severe
900 to 2,300	Severe
2,300 to 5,000	Moderate
5,000 to 10,000	Mild
10,000 to 30,000	Very mild
>30,000	Unlikely

Edward Escalante states in his paper titled Concepts of Underground Corrosion ….. "The results [of the tests conducted] reveal that soil composition is less important than soil resistivity, but both are subordinate in importance to oxygen availability. Thus, corrosion is negligible in undisturbed soils where oxygen concentration is low."

CORROSION OF HELICAL PILES IN SOIL

Our experience has shown that corrosion problems associated with Helical Piles (both square shaft and pipe sections) are extremely rare, but in areas with a history of corrosion problems and/or areas subjected to stay currents, corrosion control measures should be considered. If warranted, protective measures such as coatings or sacrificial anodes may be specified. A Professional Engineer shall provide all recommendations concerning corrosion control measures and specifications.

The corrosion behavior of Helical Piles in soil can be divided into two categories.

1. Corrosion In Disturbed Soil

A disturbed soil is a soil in which digging, backfilling, or other upheaval has occurred.

Edward Escalante states in his paper referenced above … [Regarding corrosion in disturbed soils] "… a poor relationship was found to exist between soil pH and corrosion. … The only measurement that did show any relationship to soil aggressiveness was the resistivity of the soil. In general, disturbed soils with low resistivities (500 ohm-cm or below) are indicative of highly corrosive conditions. However, as the resistivities increase above 2,000 ohm-cm, the soil corrosion-resistivity relationship becomes less reliable."

The soil's resistivity along with the availability of oxygen in disturbed soils facilitates the corrosion process. For this reason only the top portion of the Helical Pile (the top most extension/s) usually warrants corrosion consideration.

2. Corrosion in Undisturbed Soil

An undisturbed soil has not been disturbed by digging, backfilling, or other upheavals.

Early studies on steel piles driven underground indicated that the corrosion observed over a period of several years was much less than expected on the basis of the disturbed soil data. It was also noted that this corrosion was independent of the soil conditions. The diffusion of oxygen in undisturbed soil, and particularly below the water line is sufficiently low that the corrosion process is effectively stifled. The section of the pile in the disturbed soil is cathodic to the rest of the pile in the undisturbed region. As a result, the most severe corrosion occurs on the section of the pile just below the disturbed layer. A pile located in undisturbed soil with a high water table can suffer some corrosion attack at the waterline. Generally, this does not result in serious attack at the waterline and is believed to be caused by a continuously changing water table which would draw in oxygen as the waterline dropped. In this case, as in the one before, the section of the pile above the waterline acts as a weak cathode to the anode below the waterline. [2]

Steel piles are often concrete capped when used to support structures. The area of the steel in the concrete forms a passive oxide film generated by the action of the highly alkaline concrete environment. This area is cathodic to the rest of the pile in the soil. Fortunately, the high resistivity of the concrete limits the effectiveness of the cathode, and the small amount of corrosion attack that results is concentrated in the region of the pile immediately outside of the concrete. This corrosion has been shown to be relatively minor.

METHODS OF CORROSION PROTECTION

1. Coatings

Galvanized Coatings

A common method to protect carbon steel from corrosion is hot dip galvanizing. This consists of depositing the bare steel into a bath of molten zinc. Coatings of this type initially protect the underlying metal mechanically. Hot dip galvanizing is also extremely durable. When scratched or subjected to abrasion during construction, the galvanized coating will continue to supply protection (unlike other types of coatings). When the continuity of the coating is destroyed by potential difference on the surface, the underlying metal may be protected either galvanically or mechanically by the formation of a protective film of zinc oxides. The protection process is of a sacrificial nature in which zinc acts as the sacrificial anode to the bare portions of the steel until it is all consumed.

Hot dip galvanizing has long been recognized as the most effective and durable type of coating for Helical Piles. Galvanizing specifications for MCP products include the latest ASTM Standards A153 Class B or A123. ASTM A153 Class B requires an average weight of zinc coating to be 2.0 oz/ft^2 (3 mils) with a minimum thickness of 1.8 oz/ft^2 (2.8 mils). ASTM A123 can also be applied to provide a thicker zinc coating up to 2.3 oz/ft^2 (3.9 mils) if required.

Other Coatings

Effective coatings are dielectric. They cannot conduct current and therefore deprive the corrosion mechanism of a path for galvanic currents to flow, essentially terminating the corrosion process. Coatings need to be durable to withstand abrasion under normal construction conditions and should have strong bonding properties to the base metal to ensure long-term integrity.

To be effective, coatings must be impermeable to gases and moisture and free of even microscopically thin gaps at the interface between the metal and the coating. Their ability to withstand construction-induced abrasions is a major concern.

In highly corrosive soils, coatings are generally recommended only for the upper part of the anchor, beginning at ground line and continuing down to a depth just below the *disturbed soil*. Often this will be the top most extension/s. As discussed above, damage to the coating during installation is a prime concern.

Exposed (above ground) sections of an anchor can experience very severe corrosion when subjected to swamp and marsh conditions in which water depth is continuously changing (i.e. the splash zone). In this type of environment, protection measures are highly recommended. For exposed sections of Helical Piles, Bituminous or other types of specialized coatings are often used to provide protection from the environment.

2. Sacrificial Anodes

In areas of extremely aggressive soils, the galvanized coating and the allowable metal loss (as discussed below) may not provide the required service life. In this case, cathodic protection can be used to minimize the rate of corrosion to an acceptable level. The use of anodes for corrosion control protects the buried steel by forcing the steel to become cathodic in relation to the anode. The anode accomplishes this by providing for a small current between it and the steel, thus the steel becomes cathodic. Typically, anodes will be made from alloys of either Magnesium or Zinc. Magnesium alloy anodes, because of their large driving voltage, are principally used to protect buried steel in soils. Because of the risk of overprotection and high consumption rates, Magnesium anodes are generally not suited (nor required) for high conductivity environments such as seawater. Zinc anodes are suitable for the protection of carbon steel in high conductivity electrolytes, such as seawater. Zinc anodes are also used in applications where spark and fire hazards need to be avoided as in storage tanks containing flammable products. In addition to sacrificial anodes, other systems (not discussed here) can be used to supply the required currents. Most often these systems deliver impressed currents produced from AC to DC rectifiers. (i.e. Rectifier and Ground Bed systems)

Magnesium Anode Selection: [Equation 11.1]

Qty. of Anodes Required = Current Demand x Life of Anode / Anode Capacity

Current Requirement = to protect bare metal in the ground a current of 11 to 22 mA / m^2 has been found to be generally adequate, except for extreme or unusual conditions. This value must be modified to suit particular conditions, but for preliminary calculations a value of 11 mA/m^2 or in the US, 1 mA/ft^2 or .001 A/ft^2 is often used as the required current to protect buried carbon steel.

Anode Capacity = Ampere-Hour (Ah) Rating = Current capacity of the anode. The ampere rating varies with different conditions. For magnesium anodes this value is in the range of 1200 Ah/Kg or (544 Ah/lb). In the US, 500 Ah/lb is often used for estimates.

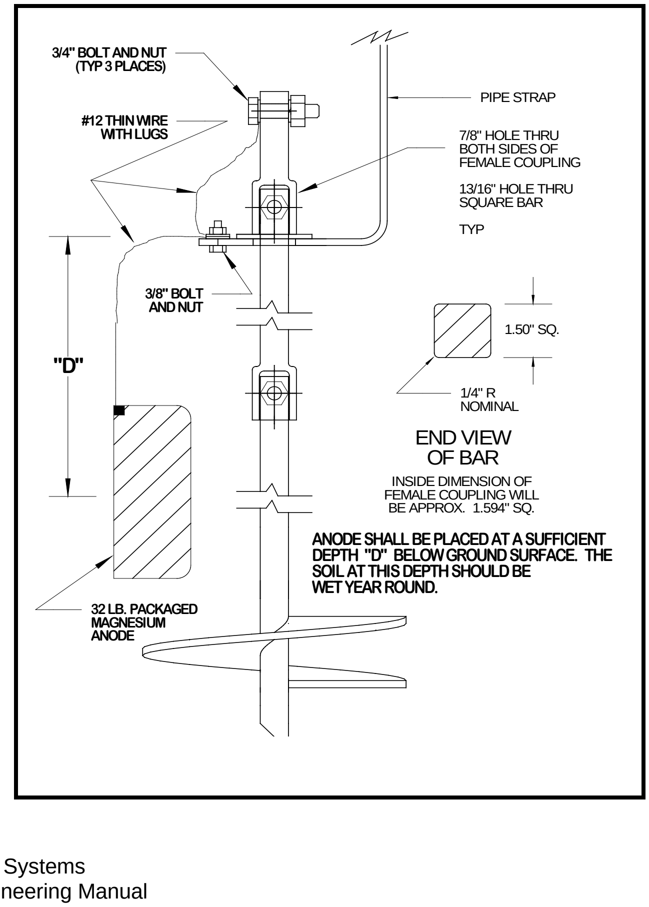
Current Demand (mA or A) **= (Surface Area to be Protected) x (Current Requirement)**. Always check anode performance charts to confirm that the anode/s can deliver the required current.

Surface Area = (Total Area) x (Fraction of Surface Exposed)

Fraction of Surface Exposed = that portion of the surface not effectively coated (% / 100)

Figure 11.1 shows a magnesium anode used to provide corrosion protection to a buried Helical Pile assembly. In the case of Helical Piles, electrical conductivity is required throughout all components requiring protection.

Figure 11.1: Cathodic Protection of Helical Pile



Example Problem 11.1: (Also see example problem on page 11.11)

Soil Resistivity = 1000 ohm-cm
Exposed Area – not coated = .718 m^2 (7.729 ft^2)
Desired Service Live = 40 yrs
Use a 3.6 kg (7.93 lbs) magnesium anode that is available at the jobsite.

Solution: Determine number of years required to consume 100% of the anode applying Eq. 11.1.

Current Demand = .718 m^2 x 11 mA/m^2 = 7.90 mA or .0079 A
Anode Capacity = 3.6 kg x 1200 Ah/kg = 4320 Ah

Qty of Anodes = ((.0079) x (40 x 365 x 24)) Ah / (3.6 x 1200) Ah = .6408 anodes required
This anode would supply a service life of 40/.6408 yrs or 62.42 yrs.

Or shown in another way:

The Life of an Anode (yrs) = The Rated Capacity (Ah) / Current Demand (Ah/yr)

Rated anode capacity = 3.6 x 1200 = Ah = 4320 Ah
Current Demand for one year = .0079 x 365 x 24 = 69.204 Ah
Expected Anode Life = 4320 / 69.204 = 62.42 yrs.

The following equation can be used as a guide to estimate the life in years of a magnesium anode.

L (yrs) = [Total Capacity of the Anode] / [Amps Consumed in 1 yr]

L (yrs) = CC x W / 365 x 24 x CD [Equation 11.2]

CC = Ampere-Hour Rating = Actual current capacity of the anode. For magnesium anodes this value is in the range of 1200 Ah/Kg or 544 Ah/lb. 500 Ah/lb is often used in the US for approximations. Caution: Values of anode capacity may vary in different soils.
W = Weight of Anode (lbs) - Typically, 60% of the anode weight is used to determine the useful effective life of an anode.
CD = Current Demand = Surface Area to be Protected (ft^2) x Current Requirement (Amps/ft^)

From example problem:

L (yrs) = 544 Ah/lb x (3.6 x 2.205) lb / (365 x 24) hrs x 7.729 ft^2 x .001 Amp/ft^2 =

= 4318.272 / 67.706 = 63.8 yrs = years to consume 100% of anode.

Using Current Capacity of the anode (CC) = 500 Ah/lb and Current Requirement = .001 A/ft^2 yields a convenient method of estimating the life of a magnesium anode. Equation 11.3 (shown below) can be applied to estimate the time required to consume 60% of the anode weight. This equation assumes that the anode meets or exceeds the current demand.

L (yrs) = 34.25 x [Anode Weight (lbs) **/ Area to be protected** (ft^2)] [Equation 11.3]

WHEN SHOULD CORROSION CONTROL MEASURES BE CONSIDERED?

Experience has shown that corrosion control measures beyond the standard galvanized coating for Helical Piles and anchors are seldom required.

Type of Structure (or Load) to be supported – Temporary or Permanent

Temporary: Service Life less than 3 yrs. Anchors used on a temporary basis generally will not require any type of corrosion consideration. An example of this would be tieback anchors for a temporary earth retaining wall, which generally do not require galvanizing.

Permanent: Projects often specify a service life of 30 to 40 yrs. In this case, the design engineer should consider the risk of corrosion along with the other aspects of his design. Data regarding the soil's corrosive properties is often included with the "request for bid package" attached with the geotechnical report. This will include information such as, Resistivity, pH, Soil Type, Ground Water Depth, and Moisture Content. If applicable, additional information such as the likelihood of stray currents, standing water, and any history of previous corrosion problems in the area should also be included. The design engineer can then review the information and consider whether or not additional corrosion protection is required. As discussed below, metal loss calculations should be performed as a first step. If metal loss is significant, corrosion control measures should be addressed.

ALLOWABLE MATERIAL LOSS

Determining Metal Loss (carbon steel):

The length of time required to experience 1/16" to 1/8" metal loss is often defined as the service life for piles. Depending on loading requirements and size, the allowable metal loss for bolts may be less. Information in M. Romanoff's, Underground Corrosion," *NBS Circular 579*, U.S. Dept. of Commerce, 1957 lists results of tests performed in 54 areas of the US. This includes pH, years of exposure, and wt. loss of buried steel. The scatter chart shown in Figure 11.3 has been adapted from this data to show service life for 1/8" metal loss.

The charts, tables and information in this manual should be used only as general guidelines.

Another source to obtain metal loss data is The Federal Highway Administration's *Publication No. FHWA-NHI-00-044* Figure *2; page 11*. Figure 11.2 has been extracted from the FHWA's scatter chart to show service life for 1/8" and 1/16" metal loss.

For projects occurring at the locations listed in Romanoff's paper and with similar soils, we recommend applying the data in M. Romanoff's paper referenced above. An example is shown below.

Determining Zinc Loss:

The **total life** of the pile will equal the time required to experience the allowable metal loss plus the time required to lose the zinc galvanized coating. See Equation 11.4. As discussed above, MCP Helical Piles are hot dip galvanized to ASTM A123 standards. This standard requires an average weight of zinc coating to be 2.0 oz/ft^2 with a minimum weight of 1.8 oz/ft^2. Romanoff's paper referenced above includes a listing of different types of soils, their resistivity and the expected loss of weight from buried zinc plates. Unfortunately, as shown in Figure 11.4, the relationship between zinc loss and soil resistivity is inconsistent. Soil resistivity often is a poor indicator for predicting zinc loss. If a project occurs at or near one of the locations referenced in Romanoff's paper, then this data may be of some use. Otherwise charts such as Figure 11.5 may be used to provide an approximate estimate of zinc loss. See example problem below.

Estimated Service Life (yrs) = M (yrs) + Z (yrs) = Lt [Equation 11.4]

M (yrs) = the length of time required for the pile to experience allowable metal loss.
Z (yrs) = the length of time required to experience 1.8 oz/ft^2 of zinc loss.

As discussed previously, corrosion control measures are most often required only to the uppermost region of

Helical Piles, which includes that portion of the pile passing through *disturbed soil*, and to a depth directly below the disturbed soil. Often this includes only the topmost extension/s. The helical section of the pile is usually installed sufficiently deep into undisturbed soils where low oxygen concentration and availability minimizes corrosion. Our experience has shown that the helical portions of Helical Piles generally do not experience significant corrosion.

The purpose of this document is to provide general information only. A Professional Engineer should provide all final specifications and recommendations concerning corrosion.

Figure 11.2: Service Life – Bare Carbon Steel

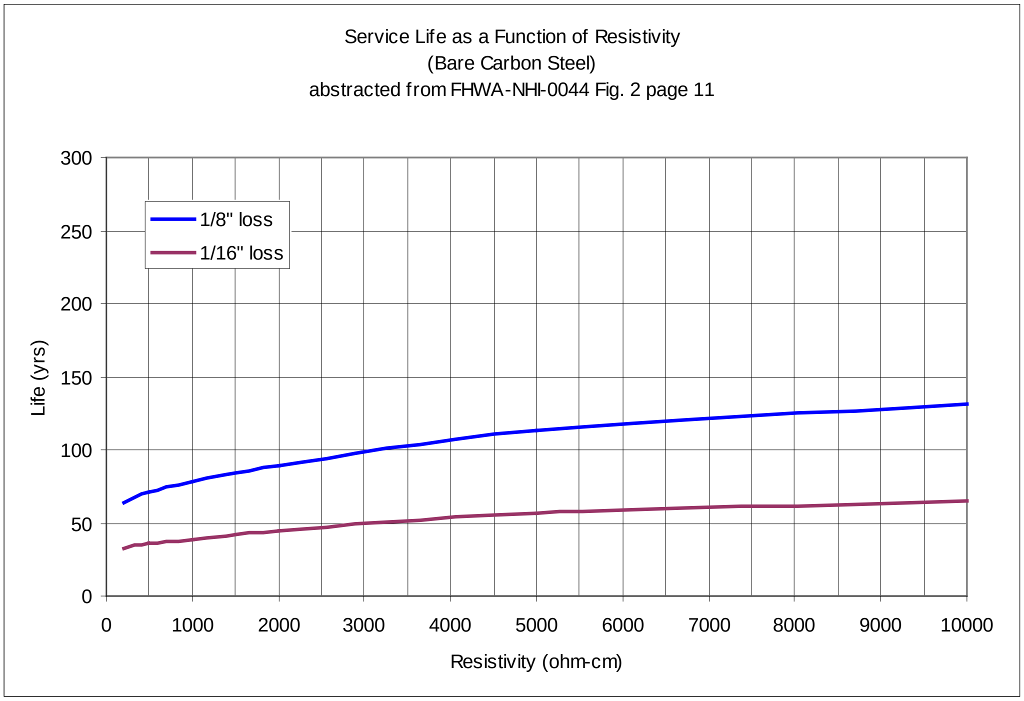


Figure 11.3: Service Life – Carbon Steel

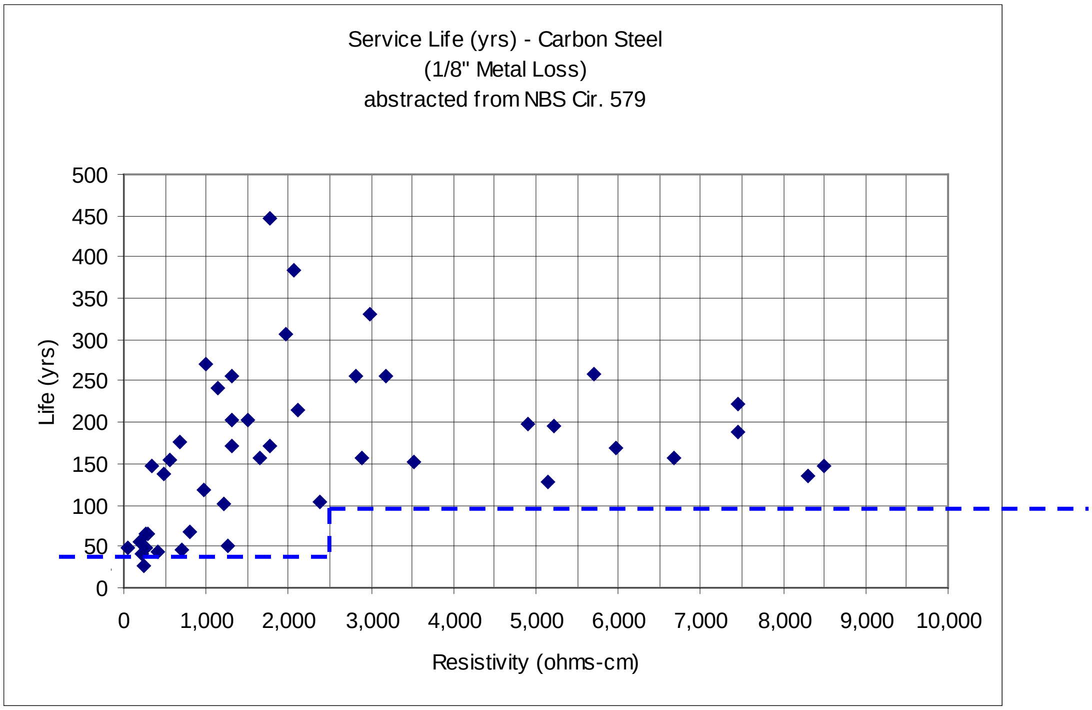


Figure 11.4: Life of Zinc Coat

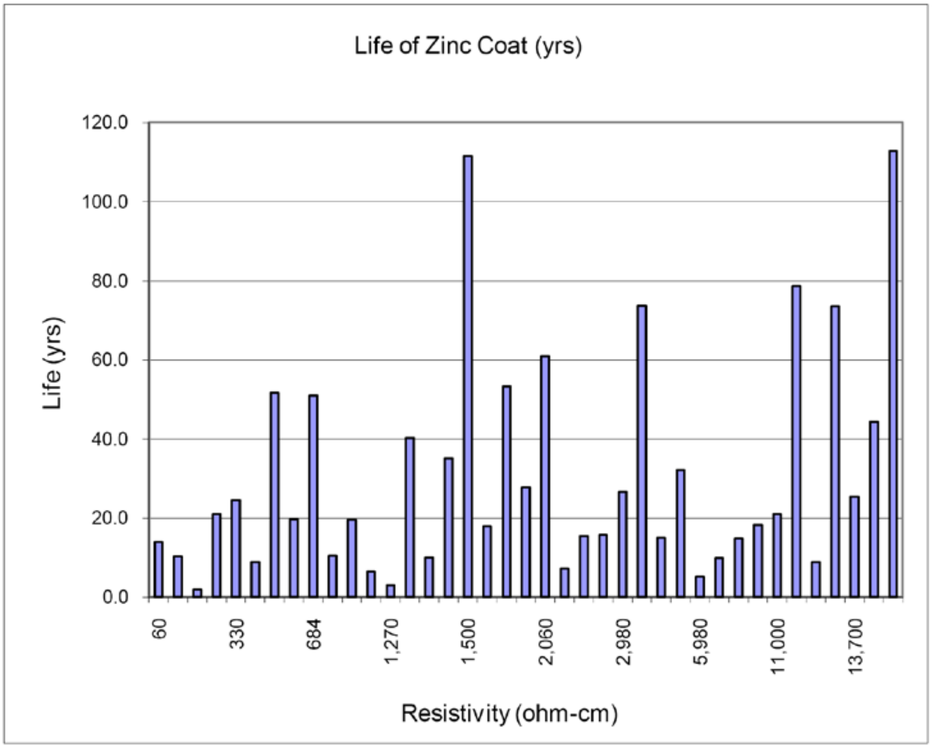
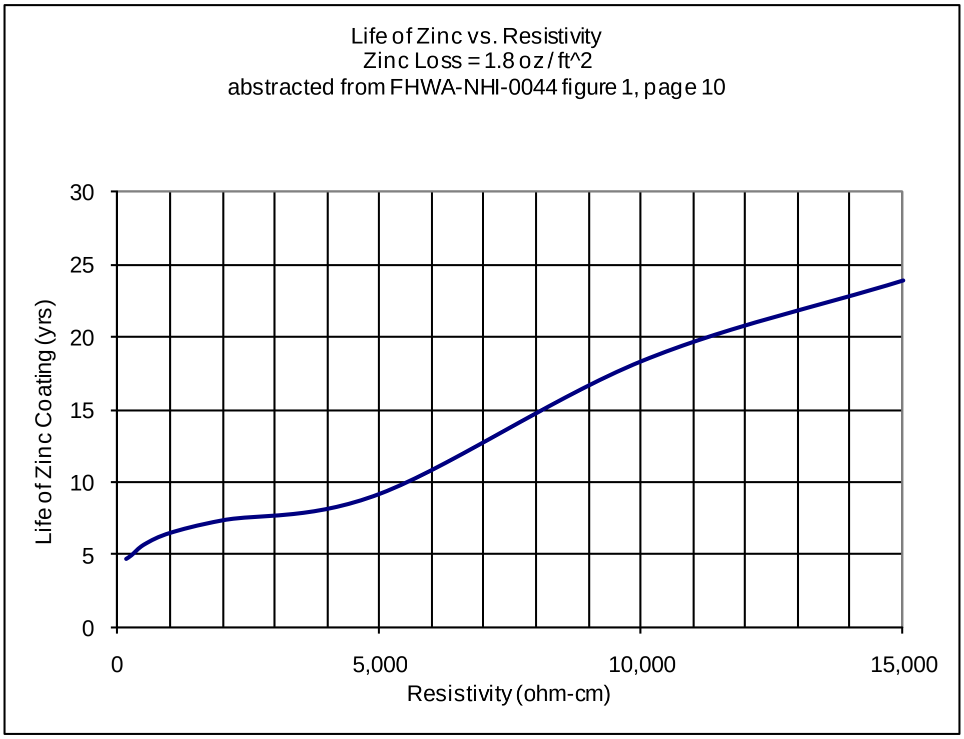


Figure 11.5: Life of Zinc vs. Resistivity



Example Problem 11.2:

Assuming an acceptable metal loss of 1/8”, determine the approximate service life for the anchor shown below.

Given:

Pile Parameters:

- Qty of (2) Helical Piles installed 6 ft. apart. Each Pile is installed to a depth of 42 ft.
- Shaft Size = 1.75” round corner square bar
- Helix Configuration = 10”, 12”, and 14” diameter – each helix is .375” thick
- Coating = Hot Dip Galvanized as per ASTM A153 (minimum zinc coating = 1.8 oz/ft^2)
- Jobsite Location: San Antonio, TX
- General Soil Description: Houston Black Clay

Solution:

Estimated Service Life = Metal Loss (yrs) + Zinc Loss (yrs) (See Equation 11.4)

Assume Service Life for this anchor will be the length of time required for 1/8” metal loss.

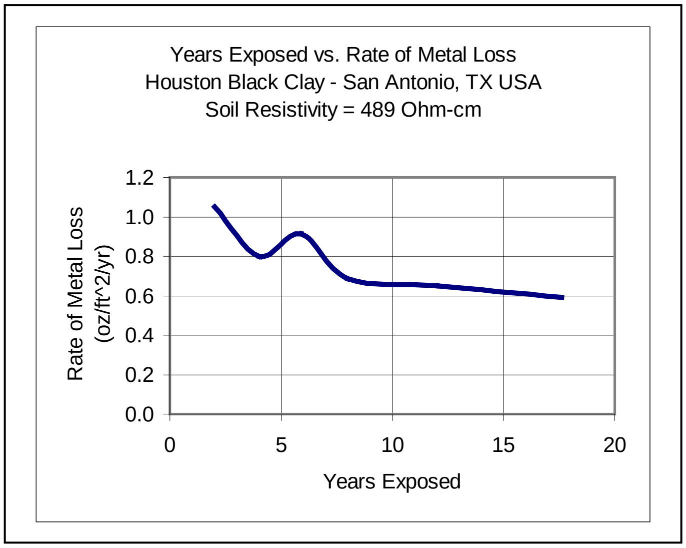
Fortunately, this project occurs in an area referenced in the NBS cir 579 Tables 6,8,13 by Melvin Romanoff. The properties reported in the NBS paper for this site are shown below.

NBS Test Site	*Location*	*Resistivity Ohm-cm*	*PH*	*Drainage*	*Duration of Exposure (yrs)*	*Loss in Weight Oz/ft^2*
15 Houston Black Clay	*San Antonio, TX*	*489*	*7.5*	*Poor*	*2*	*2.1*
					4	*3.2*
					5.9	*5.4*
					8	*5.5*
					12	*7.8*
					17.6	*10.4*

Metal Loss:

Yrs Exposed	Metal Loss oz/ft^2	Loss per Yr oz/ft^2	
2.0	2.1	1.1	
4.0	3.2	0.8	
5.9	5.4	0.9	
8.0	5.5	0.7	
12.0	7.8	0.7	
17.6	10.4	0.6	
Avg Metal Loss		0.8	oz/ft^2/yr

Figure 11.6



Average metal loss per year = .8 oz/ft^2
Note: As Figure 11.6 shows, the rate of material loss generally decreases with time.
Unit Weight of Steel = 490 lbs/ft^3
The weight of 1 sq ft of 1/8" metal loss = (.125 x 12 x 12) x (490/1728) x 16 = 81.67 oz
Metal Loss: Estimated Service Life (1/8" metal loss) = 81.67 / .8 = 102 yrs

Zinc Loss:

Standard MCP Helical Piles are hot dip galvanized to ASTM A123 standards. This standard requires an average weight of zinc coating to be 2.0 oz/ft^2 with a minimum weight of 1.8 oz/ft^2.

Data from the NBS cir 579 Table 65 by Melvin Romanoff shows the loss of zinc coating for a pipe buried at site 15 (referenced above). For duration of 10.06 yrs, the average loss of zinc coating was .35 oz/ft^2 or the average zinc loss per year would be: .35 oz/ft^2/10.06 yr = .0348 oz/ft^2/yr

Service life of zinc coat = 1.8 oz/ft^2 / .0348 oz/ft^2/yr = 52 yrs

Total Life: (Equation 11.4)

Years required to experience 1/8" metal loss and 1.8 oz/ft^2 zinc loss = Lt

Lt = 102 + 52 = 154 yrs.

Conclusion: (Expected Life of Anchor)

This project occurs in an area referenced in the NBS cir 579 by Melvin Romanoff. Data from this document can be used with relative confidence to predict corrosion behavior in the area shown.

If the project occurred in an area not referenced in the NBS cir 579, charts such as those shown above may be used to make general predictions. Applying these charts, the total life of the anchor would be approximately 50 yrs. Values from these types of charts should be used with caution. **We recommend that every effort be made to obtain corrosion data (history) of the area in question.**

As shown in Figure 11.4, zinc loss can vary greatly. Estimating zinc loss in areas not included in papers such as those in the NBS cir. 579 should be approached with caution.

Example 11.3: Sacrificial Anodes

If sacrificial anodes were specified for additional corrosion protection, the approximate size and qty of anodes could be estimated by the following procedure.

Given:

Anchor Description:
Shaft Size = 1.75” round corner square bar x 42 ft long
Helix Configuration = 10”, 12”, and 14” diameter – each helix is .375” thick
Required Anode Life: 20 yrs
Assume useful life of anode at 60% consumption.
Select a 32 lb Magnesium Anode.

Step 1: Determine total area to be protected:

Area of Shaft:

Area of each shaft = ((4 x 1.75 x 12) / 144) x 42 = 24.5 sq ft per shaft

Area of Helices:

Top and Bottom Surfaces of helices – each anchor:

= ((pi/4) x (10^2 + 12^2 + 14^2) x 2) / 144
= ((.7854) x (100 + 144 + 196) x 2) / 144
= (.7854 x 440 x 2) / 144
= 4.8 sq ft

Edges - each anchor: = (pi x (10 + 12 + 14) x .375) / 144 = .295 sq ft
Total Area of Helices = 4.8 + .295 = 5.1 sq ft

Total Area to be protected – each anchor = 24.5 + 5.1 = 29.6 sq ft.

Step 2: Determine **Current Demand (CD)**, i.e. the required current to protect the steel.

= .001 A/ft^2 x 29.6 sq ft. = .0296 A

Check Manufacturer’s Anode Performance Charts to verify that the anode can supply this current. If selected anode cannot deliver the required Amps, then use additional anodes.

Step 3: Determine **Current Consumed In 1 Yr**.

.0296 x 365 x 24 = 259.3 Ah/yr

Step 4: Determine the **Total Capacity Of The Anode**.

= 500 Ah / lb x 32 lb = 16,000 Ah

Step 5: Determine the **life of the anode** at 100% consumption =
(Total Anode Capacity) / (Annual Consumption).

= 16,000 Ah / 259.3 Ah/yr = 61.7 yrs

Step 6: Determine the **life of the anode** at 60% consumption.

= .6 x 61.7 = 37 yrs

Also applying Equation 11.2 :

L (yrs) = CC x W / 365 x 24 x CD

CC = Ampere-Hour Rating = Actual current capacity of the anode. For magnesium anodes this value is in the range of 1200 Ah/Kg or 544 Ah/lb. 500 Ah/lb is often used in the US for approximations.
W = Weight of Anode (lbs) - Typically, 60% of the anode weight is used to determine the useful effective life of an anode.
CD = Current Demand = Surface Area to be Protected (ft^2) x Current Requirement (Amps/ft^2). Check Anode performance charts to confirm that the anode can deliver the required current.

Where:

CC = 500 Ah/ lb
W = .6 x 32 lbs
CD = 29.6 ft^2 x .001 A/ft^2 = .0296 Amps Demanded

$$\mathbf{L\ (yrs)} = \frac{\textbf{ANODE CAPACITY}}{\textbf{ANNUAL CONSUMPTION}}$$

$$\mathbf{L\ (yrs)} = \frac{500 \times .6 \times 32}{365 \times 24 \times .0296} = 37.02 \text{ yrs}$$

Also: Equation 11.2 may be reduced to yield the annual lost (lbs) of a Magnesium anode …
The loss (lbs) per year for a Magnesium anode = (365 x 24) / 500 = **17.52** lbs per Amp demanded.

So: To consume 60% of the anode:

$$\mathbf{L\ (yrs)} = \frac{\textbf{TOTAL WEIGHT OF ANODE TO BE CONSUMED (lbs)}}{\textbf{AMOUNT CONSUMED ANNUALLY (lbs/yr)}}$$

$$L\ (60\%)\ \text{yrs} = \frac{.6 \times 32\ (\text{lbs})}{17.52 \times .0296\ (\text{lbs/yr})} = 37.02\ (\text{yrs})$$

Also, Equation 11.3 = **L (yrs) = 34.25 x [Anode Weight (lbs) / Area to be protected (ft^2)]**

34.25 x (32 / 29.6) = 37.02 yrs to consume 60% of the anode

References:

1. Publication No. FHWA-NHI-00-044, “Mechanically Stabilized Earth Walls And Reinforced Soil Slopes, Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes”

2. Edward Escalante “Concepts of Underground Corrosion”, Effects of Soil Characteristics on Corrosion, ASTM STP 1013, V. Chaker and J.D. Palmer, Eds., American Society for Testing and Materials, Philadelphia, 1989.

3. M. Romanoff, "Underground Corrosion," *NBS Circular 579*, U.S. Dept. of Commerce, 1957. This document can now be obtained from National Association of Corrosion Engineers – Houston, Texas USA.

4. Publication ICC-ES-AC658, “Acceptance Criteria for Helical Foundation Systems and Devices”

* * * * *

PRODUCT SELECTION GUIDE – HELICAL PILES

Shaft

Helical Piles include a lead and extension(s). The lead section is made of a central steel shaft with single or multiple helices. The extension can be plain or with single or multiple helices.

Round Cornered Square Shaft (RCS from 1.5" to 2.00"): Hot Rolled, Low Carbon, High Strength Alloy, solid steel bar conforming to ASTM A29 and ASTM A576 - Grade 1045, 10V45M, 1530M, or equal. Coupling shall be an integral part of the shaft, with an upset hot forged socket.

Pipe Pile (2.875" OD to 4.5" OD): Structural steel pipe, welded or seamless as per ASTM A500 grade C or equal welded with "Strength Square" couplings.

Coupling for Pipe Piles: The patented (US 8,777,520 B2) MCP cast steel pipe coupler is cast from ASTM A958 grade SC1045 steel or equal with minimum of 40 ksi yield and 80 ksi ultimate strength.

Table 12.1
MATERIAL SPECIFICATIONS

Shaft Size for Leads and Extensions	**Designation**	**ASTM Specification or Equal**	**Minimum Yield Strength (ksi)**
1.50" Square Shaft	D6	A576-Gr. 10V45M	70
1.50" Square Shaft – High Strength	D7	A576-Gr. 1530M	90
1.75" Square Shaft	D10	A576-Gr. 1530M	90
2.00" Square Shaft	D15	A576-Gr. 1530M	90
2.875" O.D. (0.203" wall, Sch40 Pipe)	P28	A500-Gr. C	50
2.875" O.D. (0.276"wall, Sch80 Pipe)	P28H	A500-Gr. C	50
3.500" O.D. (0.216" wall, Sch40 Pipe)	P35	A500-Gr. C	50
3.500" O.D. (0.300" wall, Sch80 Pipe)	P35H	A500-Gr. C	50
4.500" O.D. (0.237" wall, Sch40 Pipe)	P45	A500-Gr. C	50
4.500" O.D. (0.337" wall, Sch80 Pipe)	P45H	A500-Gr. C	50
8.625" O.D. (0.1875" wall)	R86L	A500-Gr. C	50

Pile Capacity

Helical Piles may have two load capacities per pile shaft type, mechanical and geotechnical. The ultimate mechanical pile capacity (the pile capacity based strictly on the strength of materials) is used by design professionals to develop helical pile designs based on project building codes. The ultimate mechanical capacity and ultimate torsional capacity of the indicated pile shaft can be found in Table 12.2a.

The ultimate geotechnical capacity is based on the assigned torque correlation factor and the shaft's rated torsional capacity. These values can be found in Table 12.2b. The required Rated Torsional Strength of the shaft will typically equal the pile's desired Geotechnical Ultimate Helix Bearing Capacity divided by the Torque Factor (K_t) of the shaft, i.e. **K_t x Torque** (ft-lbs) = Ultimate Capacity (lbs) The values of **K_t** shown in Table 12.2b. are based on industry standards and/or field-testing in various locations and soil types. In some cases **K_t** can vary. See Section 7 for a more detailed discussion of K_t.

Using Table 12.2b. the shaft size or sizes with the required Rated Torsional Capacity can be selected. We recommend limiting the estimated required torque to a value somewhat less than the Rated Torsional Capacity. This will facilitate installation when unexpected hard layers are encountered.

The values of K_t shown below are intended to assist the designer in selecting the proper shaft size for the particular application. Larger values of K_t can provide greater geotechnical pile capacities, but Design Loads should not induce: (1) stresses into the shaft which exceed one-half of the Yield Strength shown in Table 12.1 or (2) Helix loads exceeding the values shown in Table 12.3.

Table 12.2a.
HELICAL PRODUCT MECHANICAL CAPACITIES

Shaft Size	Pile Shaft Designation	Rated Torsional Capacity (ft-lbs)[1]	Ultimate Mechanical Shaft Capacities for Axial Loading (lbs)[2]
1.50” Square Shaft	D6	5,500	68,000
1.50” Square Shaft (high str.)	D7	7,000	70,000
1.75” Square Shaft	D10	10,400	100,000
2.00” Square Shaft	D15	15,000	150,000
2.875” O.D. (0.203” wall)	P28	7,500	70,000
2.875” O.D. (0.276” wall)	P28H	8,000	90,000
3.500” O.D. (0.216” wall)	P35	11,400	100,000
3.500” O.D. (0.300” wall)	P35H	15,000	120,000
4.500” O.D. (0.237” wall)	P45	20,000	130,000
4.500” O.D. (0.337” wall)	P45H	26,000	180,000
8.625” O.D. (0.1875” wall)	R86L	40,000	200,000 compression[3] / 120,000 tension

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[1] Rated torsional capacity is based on strength of materials resisting torsional forces.

[2] Mechanical capacity for axial loads are based on strength of materials of the pile to resist axial (compression and tension) loading. Actual in place loads may not reach the ultimate mechanical capacities due to soil types, helix configuration or design methodology.

[3] Higher axial resistance may require filling the pile shaft with grout and possibly rebar following installation.

Table 12.2b.
ULTIMATE GEOTECHNICAL CAPACITIES

Shaft Size	Pile Shaft Designation	Kt[4]	Rated Torsional Capacity (ft-lbs)[5]	Estimated Geotechnical capacities per torque correlation[6]			
				Ultimate Capacity[7]		Maximum Design Load[8]	
				Tension (lbs)	Compression (lbs)	Tension (lbs)	Compression (lbs)
1.50” Square Shaft	D6	10	5,500	55,000	55,000	27,500	27,500
1.50” Square Shaft (high str.)	D7	10	7,000	70,000	70,000	35,000	35,000
1.75” Square Shaft	D10	10	10,400	100,000	100,000	50,000	50,000
2.00” Square Shaft	D15	10	15,000	150,000	150,000	75,000	75,000
2.875” O.D. (0.203” wall)	P28	9	7,500	67,500	67,500	30,000	30,000
2.875” O.D. (0.276” wall)	P28H	9	8,000	72,000	72,000	36,000	36,000
3.500” O.D. (0.216” wall)	P35	7	11,400	80,000	80,000	40,000	40,000
3.500” O.D. (0.300” wall)	P35H	7	15,000	105,000	105,000	52,500	52,500
4.500” O.D. (0.237” wall)	P45	6	20,000	120,000	120,000	60,000	60,000
4.500” O.D. (0.337” wall)	P45H	6	26,000	156,000	156,000	78,000	78,000
8.625” O.D. (0.1875” wall)[9]	R86L	5	40,000	120,000[10]	200,000	60,000	100,000

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[4] Torque correlation factor or Kt value is based on empirical data collected from loading test studies in numerous soil types and industry standards. Actual Kt factors may be lower or higher based on soil condition. If a higher Kt factor is utilized, it is recommended to verify the modified Kt factor with a documented ASTM load test program.

[5] Rated torsional capacity is based on strength of materials resisting torsional forces.

[6] Geotechnical pile capacity per torque correlation is based on maximum torsional capacity multiplied by referenced torque correlation factor to estimate maximum axial capacities when the torque correlation method is employed for design or verification. See section 13 for further explanation.

[7] Ultimate capacity derived from the torque correlation method.

[8] Design load reflects 0.5 of ultimate capacity or a safety factor of 2.

[9] Wall thickness of 0.25” are available upon request as a custom design for required higher load resistance.

[10] Tension load is controlled by connecting bolt capacity in tension.

Square Shaft or Round Pipe Shaft

Square shafts are more efficient than round pipe. When installed to the same torque, the capacity of a square shaft anchor will be greater than that of a round shaft anchor. (This is discussed in Section 13.) In addition, because of the small cross sectional area, square shafts can penetrate into denser soils (higher Standard Penetration Test N-values) than round pipe sections.

Square shafts are generally the best choice for new and existing construction unless:

1. Significant lateral (shear) loads are expected. (i.e. bending stresses which exceed the shaft's allowable yield stress or lateral loads, which exceed the pile/soil capacity.) See Section 10.

2. Large compressive loads, coupled with soft soils of very low consistency (with SPT blow counts less than 5) are expected (i.e. column buckling considerations). See Section 9.

As a general rule, buckling should not occur when the soil along the total length of the pile has an SPT blow count of 5 or greater. This assumes axial loading, with no shear or bending moment acting at the top of the pile.

When very weak soils are encountered (i.e. SPT blow counts of less than 5), hand calculations using the Davisson (1963) method or computer programs such as RTD or LPILE can be applied to perform buckling analysis. The Davisson (1963) method is discussed in detail in Section 9.

Pipe piles with Square coupling – 2.875" OD to 8.625" OD pipes

MCP patented "Strength Squared" couplings (patent US 8,777,520 B2) allow for the full torsional capacity of the pile to be transferred through the coupler to its adjacent member while maintaining full axial and torsional capacity during and after installation. This design eliminates the problems caused by elongated holes and deformation of the bolts, which often occurs with round to round interfaces. This system totally eliminates the possibility of a "rip out" failure from the pipe being overstressed due to reduction of surface area caused by coupling holes in the pipe wall.

The MCP square male couplings also accommodates RCS helical leads. This combination of pipe with a RCS helical lead allows for a more efficient penetration into hard soils such as dense sand and gravel. The upper pipe section provides for an increase in buckling strength of the pile. When using a combination pile the strength values of the RCS lead should be used for installation torque capacity and load estimations.

Mechanical Properties

Design Loads (i.e. axial, shear and bending moments) transferred to the shaft (via the structure or the pile interface connection) shall not result in stresses or loads that exceed the properties shown in tables 12.1 through 12.4.

Helix

Helix Material: High Strength, Low Carbon Steel plate conforming to ASTM A1018 grade 55 with 55 ksi minimum yield strength. Helices are formed using matching dies to assure a true consistent helical shape and a uniform pitch. Thicknesses are offered from 3/8" for standard helices and 1/2" for high strength helices.

Helical Piles usually include one to six helices. In the case of multi-helical lead sections, the smaller diameter helix always enters the ground first – followed by larger or equal diameter helix or helices. The difference between diameters of adjacent helices should not exceed 2" except the R86. The R86 should not exceed 4" in diameter for the adjacent helices. The distance between any two helices should be at least three times the diameter of the lower helix.

Loads are transferred from the structure to the shaft. The shaft transfers its load to the helices, which in turn transfers their load to the soil. Section 8 discusses the Terzaghi General Bearing Equation, which can be applied through an iterative process to determine the required helix configuration. Data from geotechnical reports and soil boring logs are generally required when using this method. If geotechnical information is unavailable, assumptions will have to be made or an anchor test should be conducted. Also, see Section 7 for an alternate method of estimating soil properties.

The Ultimate Geotechnical Capacity of the pile will be the sum of the individual helix capacities as determined from the Terzaghi General Bearing Equation method (Section 8) or from other methods such as those discussed in Section 7.

The resulting load on any individual helix shall not exceed the values shown in Table 12.3.

The number of helices for clay (cohesive) soils should be limited to 4 or 5. The number of helices for granular or sandy soils (cohesionless) should be limited to 6. If more helices are used than recommended above, load testing is advisable.

Structure / Pile Interface Connection

The ultimate capacity of the structure/pile interface connection (or bracket) shall be at least two times the maximum Design Load.

Design Loads (i.e. axial, shear and bending moments) transferred to the shaft (via the structure or the pile interface connection) shall not induce:

1. Stresses into the shaft which exceed one-half of the Yield Strength shown in Table 12.1
2. Helix loads exceeding the values shown in Table 12.3.

Center-to-Center Horizontal Spacing Between Helical Piles

The recommended spacing between adjacent helices of Helical Piles is five times the diameter of the largest helix. The minimum spacing is four times the diameter of the largest helix measured center of pile to center of pile, but this usually requires additional attention by the construction crew to assure that the helical lead sections do not drift towards each other during installation. Since spacing requirements apply only to the helices, a slight batter during the installation of the helical piles can provide a convenient method of maintaining the minimum spacing.

Table 12.3
HELICES - MECHANICAL RATED CAPACITIES - ALLOWABLE LOADS (DESIGN LOADS)

Mechanical rated capacities & units	1.50” Round Corner Square Shaft	1.50” Round Corner Square Shaft	1.75” Round Corner Square Shaft	2.00” Round Corner Square Shaft	2.875” O.D. Pipe Shaft		3.50” O.D. Pipe Shaft		4.50” O.D. Pipe Shaft		8.625” O.D. Pipe Shaft
					0.203” wall	0.276” wall	0.216” wall	0.300” Wall	0.237” wall	0.337” wall	0.1875” Wall
3/8” ultimate Capacity; kips	30	30	40	NA	40	40	50	50	NA	NA	NA
1/2" ultimate Capacity; kips	50	50	60	60	NA	NA	60	60	70	70	80

Notes:

1. Ultimate Helix Capacities are based on a 12” diameter helix, except for 8.625” Pipe Pile. For other helix sizes, see the Material and Quality Specifications section in the MacLean Engineering Manual.
2. All loads are axial.

Table 12.4
PROPERTIES FOR SHAFTS AND COUPLINGS

Shafts	1.50” Round Corner Square Shaft	1.50” Round Corner Square Shaft	1.75” Round Corner Square Shaft	2.00” Round Corner Square Shaft	2.875” O.D. Pipe Shaft		3.50” O.D. Pipe Shaft		4.50” O.D. Pipe Shaft		8.625” O.D. Pipe Shaft
					0.203” wall	0.276” wall	0.216” wall	0.300” Wall	0.237” wall	0.337” wall	0.188” Wall
Yield strength; ksi	70	90	90	90	50	50	50	50	50	50	50
Section area; in^2	2.190	2.190	3.010	3.940	1.704	2.253	2.228	3.016	3.174	4.407	4.970
Perimeter; in	5.571	5.571	6.571	7.571	9.032	9.032	10.996	10.996	14.137	14.137	27.096
Moment of inertia, Ixx=Iyy=Ixy; in^4	0.396	0.396	0.746	1.260	1.530	1.924	3.017	3.894	7.233	9.611	44.250
Section modulus, Sxx=Syy; in^3	0.528	0.528	0.853	1.260	1.064	1.339	1.724	2.225	3.214	4.271	10.261
Section modulus, Sxy; in^3	0.414	0.414	0.657	0.980	1.064	1.339	1.724	2.225	3.214	4.271	10.261
Coupling											
Forged	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No
Cast steel SC 1045; ksi (yield/tensile)	NA	NA	NA	NA	40/80	40/80	40/80	40/80	40/80	40/80	NA
Bolt(s) Dia.* ASTM A325	0.750	0.750	0.875	NA	0.750	0.750	0.875	0.875	1	1	1
Bolt(s) Dia.* SAE J429	NA	NA	NA	1.125	NA	NA	NA	NA	NA	NA	NA
Bolt qty. (ea)	1	1	1	1	2	2	2	2	2	2	4
Transition**											
*Pipe to RCS****	NA	NA	NA	NA	1.5	1.5	1.75	1.75	2	2	NA

* Bolt diameter in inches.
** To specify transition pile, add the suffix “X” on catalog number.
*** Use same coupling bolt shown for RCS.

Table 12.5
HELIX NET BEARING AREAS (ft^2) *

Nominal diameter (in)	1.50” Round Corner Square Shaft	1.50” Round Corner Square Shaft	1.75” Round Corner Square Shaft	2.00” Round Corner Square Shaft	2.875” O.D. Pipe Shaft		3.50” O.D. Pipe Shaft		4.50” O.D. Pipe Shaft		8.625” O.D. Pipe Shaft
					0.203” wall	0.276” wall	0.216” wall	0.300” wall	0.237” wall	0.337” wall	0.188” Wall
8	0.308	0.308	0.303	0.296	0.300	0.300	0.278	0.278	0.236	0.236	NA
10	0.501	0.501	0.495	0.489	0.494	0.494	0.473	0.473	0.430	0.430	NA
12	0.724	0.724	0.719	0.712	0.732	0.732	0.711	0.711	0.668	0.668	NA
14	1.002	1.002	0.996	0.990	1.014	1.014	0.993	0.993	0.950	0.950	0.659
16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.984
20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.766
24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.719

* Shaft areas have been deducted.

PRODUCT SPECIFICATIONS

QUALITY AT MACLEAN CIVIL PRODUCTS

MCP is ISO 9001:2015 Registered Company, QSR-938. Its quality system addresses all areas of the business. The quality assurance manual, which is fully compliant with ICC-ES AC10, is available on request. The manual details the complete quality procedure.

MCP product line offers Round Cornered Square (RCS) shaft from 1.50” to 2.00”, inclusive and “Strength Square” Pipe piles from 2.875” to 8.625” outside diameter. Five MCP product lines (D6, D10, P28, P35, and P35H) have been evaluated and approved by the International Code Council (ICC) Evaluation Service (ES). The results of this evaluation can be reviewed in the ICC-ES Evaluation Service Report ESR-3032. The scope of the ICC-ES report includes evaluation of the submitted MCP products according to the most current release of the ICC-ES Acceptance Criteria for Helical Foundation Systems and Devices (AC358) and ICC International Building Code. ESR-3032 includes 1.50” and 1.75” RCS, 2.875” O.D. and 3.50” O.D. pipe piles, repair and new construction brackets.

Product Design

- Products are designed to meet or exceed the published MCP performance ratings.
- All designs are evaluated at our MCP laboratory and/or by independent laboratories contracted based on their extensive industry knowledge.

Materials

- Certified steel is used in the manufacturing process.
- Mill certification on every receipt is reviewed to assure it meets the requirement and periodically is verified throughout the year by outside laboratories.
- Non-conforming material is segregated to prevent inadvertent use.

Manufacturing

- The plant supervisor, quality assurance personnel and manufacturing employees monitor the processes to ensure that all aspects of the design are met.
- Documented audits are available for review.
- Calibrated gauges are readily available to verify the size, check threads, and to evaluate hole locations.
- Compression load tests on the helix and/or torque tests are performed periodically to ensure the quality of the product welds.
- All welders are certified by AWS Code D1.1.

Hot-Dip Galvanizing

- All hot dip galvanizing products meet ASTM A153 or A123 specifications for coating thickness and finishing.

Assembly

- Product is assembled only after all its hardware and components are inspected and accepted according to the drawing specification.

Final inspection audits verify proper assembly according to the drawing requirements.

MCP 1.50" RCS D6 MULTI-HELIX FOUNDATION PILE & TENSION ANCHORS

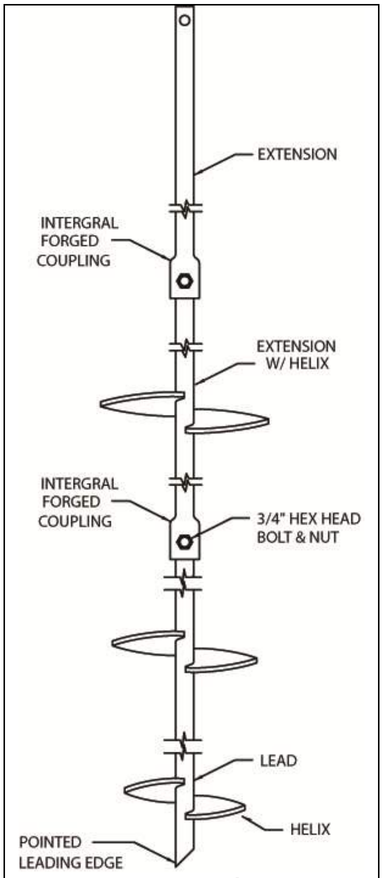


Figure 1
Typical Helical Pile or Anchor Assembly

Helical Anchor Lead and Extensions

Helical Pile or Anchor Lead and Extension Sections consist of a central solid square shaft (lead) manufactured from round cornered square (RCS) solid steel bar as shown in Figure 1. The lead and extension material conforms to ASTM A576, Grade 10V45M or equal with 70ksi minimum yield strength.

- Lead - the lead has a through hole at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Extension - the extension has a through hole at the upper end and an integral forged upset socket square coupler at the lower end to accept the mating lead or extension. It is available with or without helices.

Helix - Helical Bearing Plate

The helical bearing plate is formed to a 3" pitch from 3/8" or 1/2" thick steel plate that conforms to high strength low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the RCS solid steel shaft

Connection Bolts

Each Extension Section is provided with one 3/4" diameter x 3" long Hex Head Bolt per ASTM A325 and one 3/4" Hex Jam Nut per ASTM A563.

Corrosion Protection

Helical Pile or Anchor Lead Sections, Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 1.50" RCS shaft Multi-Helix Lead Sections and Extensions is 5,500 [ft-lb] with a torque correlation factor or Kt of 10.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 1.50" RCS Multi-Helix foundation pile/anchor is 68 kips with safety factor of 2. (Section 12, Table 12.2a).

Axial Load Single Helix Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
3/8"	8"	0.308	30
3/8"	10"	0.501	30
3/8"	12"	0.724	30
3/8"	14"	1.002	30
1/2"	8"	0.308	50
1/2"	10"	0.501	50
1/2"	12"	0.724	50
1/2"	14"	1.002	50

MCP 1.50" RCS D7 MULTI-HELIX FOUNDATION PILE & TENSION ANCHORS

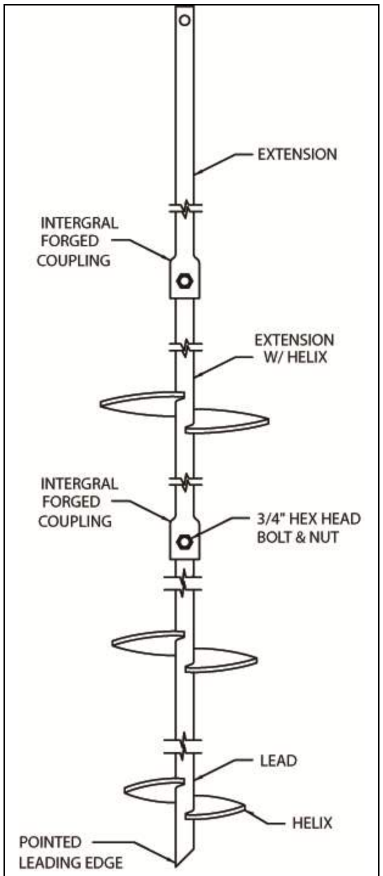


Figure 2
Typical Helical Pile or Anchor Assembly

Helical Anchor Lead and Extensions

Helical Pile or Anchor Lead and Extension Sections consist of a central solid square shaft (lead) manufactured from round cornered square (RCS) solid steel bar as shown in Figure 2. The lead and extension material conforms to ASTM A576, Grade 1530M or equal with 90ksi minimum yield strength.

- Lead - the lead has a through hole at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Extension - the extension has a through hole at the upper end and a forged square coupler at the lower end to accept the mating lead or extension. It is available with or without the helices.

Helix - Helical Bearing Plates

The helical bearing plate is formed to a 3" pitch from 3/8" or 1/2" thick steel plate that conforms to high strength low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the RCS solid steel shaft.

Connection Bolts

Each Extension Section is provided with one 3/4" diameter x 3" long Hex Head bolt per ASTM A325 and one 3/4" Hex Jam Nut per ASTM A563.

Corrosion Protection

Helical Pile or Anchor Lead Sections, Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 1.50" RCS shaft Multi-Helix Lead Sections and Extensions is 7,000 [ft-lb.] with a torque correlation factor or Kt of 10.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 1.50" RCS Multi-Helix foundation pile/anchor is 70 kips with safety factor of 2. (Section 12, Table12.2a).

Axial Load Single Helix Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
3/8"	8"	0.308	30
3/8"	10"	0.501	30
3/8"	12"	0.724	30
3/8"	14"	1.002	30
1/2"	8"	0.308	50
1/2"	10"	0.501	50
1/2"	12"	0.724	50
1/2"	14"	1.002	50

MCP 1.75” RCS D10 MULTI-HELIX FOUNDATION PILE & TENSION ANCHORS

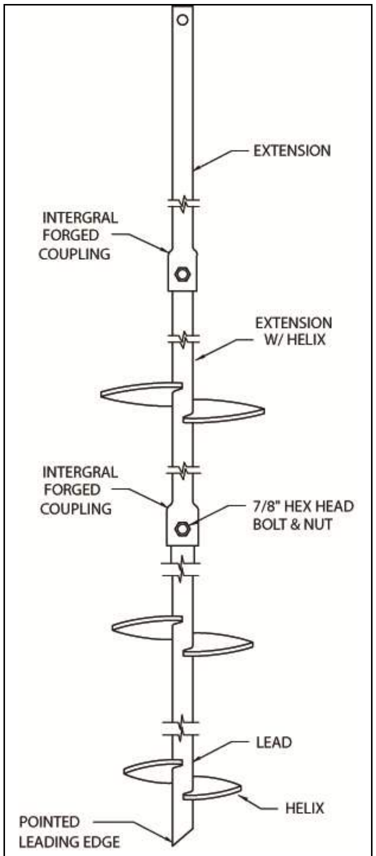


Figure 3

Typical Helical Pile or Anchor Assembly

Helical Anchor Lead and Extension Sections

Helical Pile or Anchor Lead and Extension Sections consist of a central solid square shaft (lead) manufactured from round cornered square (RCS) solid steel bar as shown in Figure 3. The lead and extension material conforms to ASTM A576, Grade 1530M or equal with 90ksi minimum yield strength.

- Lead - the lead has a through hole at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Extension - the extension has a through hole at the upper end and an integral forged upset socket square coupler at the lower end to accept the mating lead or extension. It is available with or without the helices.

Helix - Helical Bearing Plate

The helical bearing plate is formed to a 3" pitch from 3/8” or 1/2” thick steel plate that conforms to high strength, low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the RCS solid steel shaft.

Connection Bolts

Each Extension Section is provided with one 7/8" diameter x 3½" long Hex Head bolt per ASTM A325 and one 7/8" Hex Jam Nut per ASTM A563.

Corrosion Protection

Helical Pile or Anchor Lead Sections, Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 1.75” RCS shaft Multi-Helix Lead Sections and Extensions is 10,400 [ft-lb.] with a torque correlation factor or Kt of 10.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 1.75” RCS Multi-Helix foundation pile/anchor is 100 kips with safety factor of 2. (Section 12, Table12.2a)

Axial Load Single Helix Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
3/8”	8”	0.303	40
3/8”	10”	0.495	40
3/8”	12”	0.719	40
3/8”	14”	0.996	40
1/2”	8”	0.303	60
1/2”	10”	0.495	60
1/2”	12”	0.719	60
1/2”	14”	0.996	60

MCP 2.0” RCS D15 MULTI-HELIX FOUNDATION PILE & TENSION ANCHORS

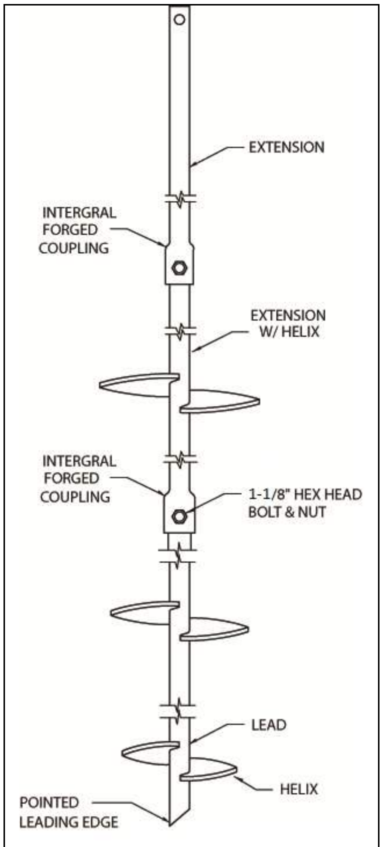


Figure 4
Typical Helical Pile or Anchor Assembly

Helical Anchor Lead and Extensions

Helical Pile or Anchor Lead and Extension Sections consist of a central solid square shaft (lead) manufactured from round cornered square (RCS) solid steel bar as shown in Figure 4. The lead and extension material conforms to ASTM A576, Grade 1530M or equal with 90ksi minimum yield strength.

- Lead - the lead has a through hole at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Extension - the extension has a through hole at the upper end and an integral forged upset socket square coupler at the lower end to accept the mating lead or extension. It is available with or without the helices.

Helix - Helical Bearing Plates

The helical bearing plate is formed to a 3" pitch from 1/2” thick steel plate that conforms to high strength, low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the RCS solid steel shaft.

Connection Bolts

Each Extension Section is provided with one 1-1/8” diameters x 4-¼” long Hex Head bolts per SAE J429 and one 1-1/8” Hex Jam Nuts per ASTM A563.

Corrosion Protection

Helical Pile Anchor Lead Sections, Extension Sections and nuts are hot dip galvanized per ASTM A153 or ASTM A123. Bolts are coated with yellow zinc dichromate.

Installation Torque Rating

The Ultimate Torque rating of MCP 2.0” RCS shaft Multi-Helix Lead Sections and Extensions is 15,000 [ft-lb.] with a torque correlation factor or Kt of 10.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 2.00” RCS Multi-Helix foundation pile/anchor is 150 kips with safety factor of 2. (Section 12, Table12.2a).

Axial Load Single Helix Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
1/2”	8”	0.296	60
1/2”	10”	0.489	60
1/2”	12”	0.712	60
1/2”	14”	0.990	60

MCP 2.875” O.D. SCH40 P28 MULTI-HELIX FOUNDATION PIPE PILES

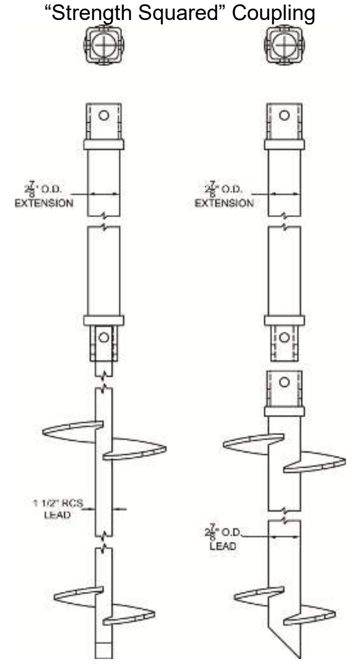


Figure 5

Typical Helical Pile or Anchor Assembly

Helical Pipe Pile Lead and Extension with “Strength Square” coupling

Helical Pipe Pile Lead and Extensions consist of a central 2.875” O.D. (0.203” wall) pipe with “Strength Square” couplings and/or helices welded as shown in Figure 5.

- Lead - the lead pipe has female cast steel coupling welded at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Lead Alternate - a 1.50” RCS D6 or D7 can be used for special soil conditions.
- Extension - the extension pipe has male/female cast steel couplings welded on both ends. It is available with or without the helices.
- Pipe Material - Cold formed, welded or seamless steel conforms to ASTM A500 Grade C or equal material with 50ski minimum yield strength.
- Couplers- “Strength Square” male/female couplings are cast steel per ASTM A958, SC1045 or equal with 40ksi yield and 80ksi ultimate strength minimum.

Helix - Helical Bearing Plates

The helical bearing plate is formed to a 3" pitch from 3/8” thick steel plate that conforms to high strength, low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the P28 Pipe Pile.

Connection Bolts

Each Extension pipe is provided with two 3/4” diameter x 3 ¾” long Hex Head bolts per ASTM A325 and one 3/4” Hex Jam Nuts per ASTM A563.

Corrosion Protection

Helical Foundation Pipe Pile Anchor Lead and Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 2.875” O.D. (0.203” wall) Pipe Pile Multi-Helix Lead Section and Extensions is 7,500 [ft-lb.] with a torque correlation factor or Kt of 9.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 2.875” O.D. (0.203” wall) Pipe Pile Multi-Helix is 70 kips with safety factor of 2. (Section 12, Table 12.2a).

Axial Load Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
3/8”	8”	0.300	40
3/8”	10”	0.494	40
3/8”	12”	0.732	40
3/8”	14”	1.014	40
½”	8”	0.300	50
½”	10”	0.494	50
½”	12”	0.732	50
½”	14”	1.014	50

MCP 2 .875” O.D SCH80 P28H MULTI-HELIX FOUNDATION PIPE PILES

“Strength Squared” Coupling

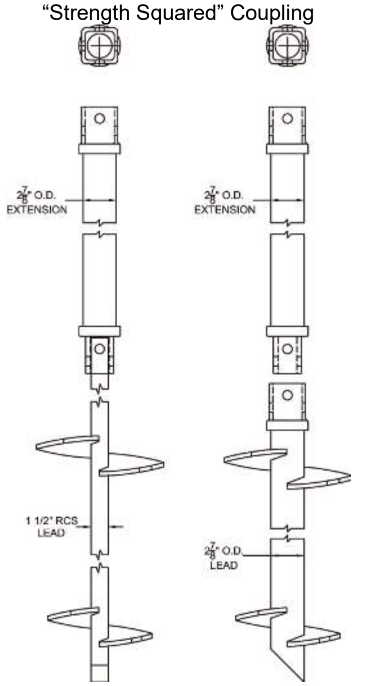


Figure 6

Typical Helical Pile or Anchor Assembly

Helical Pipe Pile Lead and Extension with “Strength Square” coupling

Helical Pipe Pile Lead and Extensions consist of a central 2.875” O.D. (0.275” wall) pipe with “Strength Square” couplings and/or helices welded as shown in Figure 6.

- Lead - the lead pipe has female cast steel coupling welded at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Lead Alternate - a 1.50” RCS D6 or D7 can be used for special soil conditions.
- Extension - the extension pipe has male/female cast steel couplings welded on both ends. It is available with or without the helices.
- Pipe Material – Cold formed, welded or seamless steel confirms to ASTM A500 Grade C or equal material with 50ski minimum yield strength.
- Couplers- “Strength Square” male/female couplings are cast steel per ASTM A958, SC1045 or equal with 40ksi yield and 80ksi ultimate strength minimum.

Helix - Helical Bearing Plates

The helical bearing plate is formed to a 3" pitch from 3/8” thick steel plate that conforms to high strength, low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the P28H Pipe Pile.

Connection Bolts

Each Extension pipe is provided with two 3/4” diameter x 3 ¾” long Hex Head bolts per ASTM A325 and one 3/4” Hex Jam Nuts per ASTM A563.

Corrosion Protection

Helical Foundation Pipe Pile Anchor Lead and Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 2.875” O.D (0.276” wall) Pipe Pile Multi-Helix Lead Section and Extensions is 8,000 [ft-lb.] with a torque correlation factor or Kt of 9.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 2.875” O.D. (0.276” wall) Pipe Pile Multi-Helix is 90 kips with safety factor of 2. (Section 12, Table 12.2a).

Axial Load Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
3/8”	8”	0.300	40
3/8”	10”	0.494	40
3/8”	12”	0.732	40
3/8”	14”	1.014	40
½”	8”	0.300	50
½”	10”	0.494	50
½”	12”	0.732	50
½”	14”	1.014	50

MCP 3.50” O.D. SCH40 P35 MULTI-HELIX FOUNDATION PIPE PILES

“Strength Squared” Coupling

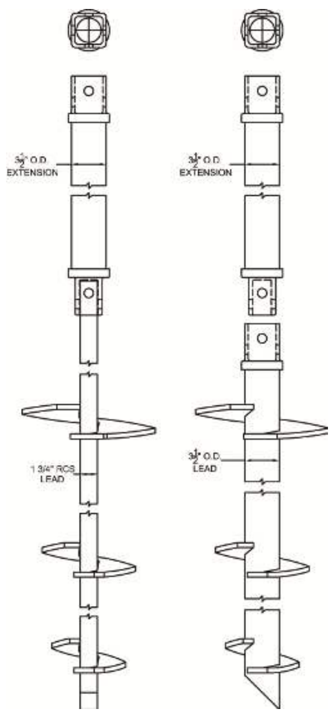


Figure 7
Typical Helical Pile or Anchor Assembly

Helical Pipe Pile Lead and Extensions with “Strength Square” coupling

Helical Pipe Pile Lead and Extension consist of a central 3.50” O.D. (0.216” wall) pipe with “Strength Square” couplings and/or helices welded as shown in Figure 8.

- Lead - the lead pipe has female cast steel coupling welded at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Lead Alternate - a 1.75” RCS D10 can be used for special conditions.
- Extension - the extension pipe has male/female cast steel couplings welded on both ends. It is available with or without the helices.
- Pipe Material - Cold formed, welded or seamless steel confirms to ASTM A500 Grade C or equal material with 50ksi minimum yield strength.
- Couplers- “Strength Square” male /female couplings are cast steel per ASTM A958, SC1045 or equal with 40ksi yield and 80ksi ultimate strength minimum.

Helix - Helical Bearing Plates

The helical bearing plate is formed to a 3" pitch from 3/8” thick steel plate that conforms to high strength, low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the P35 Pipe Pile.

Connection Bolts

Each Extension pipe is provided with two 7/8” diameter x 4 ½” long Hex Head bolts per ASTM A325 and one 7/8” Hex Jam Nuts per ASTM A563.

Corrosion Protection

Helical Foundation Pipe Pile Anchor Lead and Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 3.50” O.D. (0.216” wall) Pipe Pile Multi-Helix Lead Sections and Extensions is 11,400 [ft-lb.] with a torque correlation factor or Kt of 7.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 3.50” O.D. (0.216” wall) Pipe Pile Multi-Helix is 100 kips with safety factor of 2. (Section 12, Table 12.2a).

Axial Load Single Helix Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
3/8”	8”	0.278	50
3/8”	10”	0.473	50
3/8”	12”	0.711	50
3/8”	14”	0.993	50

MCP 3.50” O.D. SCH80 P35H MULTI-HELIX FOUNDATION PIPE PILES

“Strength Squared” Coupling

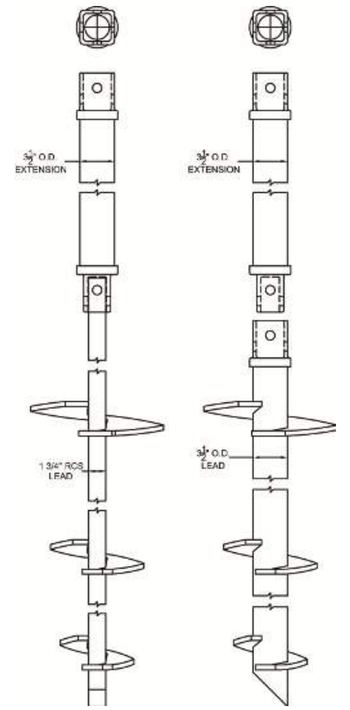


Figure 8

Typical Helical Pile or Anchor Assembly

Helical Pipe Pile Lead and Extensions with “Strength Square” coupling

Helical Pipe Pile Lead and Extension consist of a central 3.50” O.D. (0.300” wall) pipe with “Strength Square” couplings and/or helices welded as shown in Figure 8.

- Lead - the lead pipe has female cast steel coupling welded at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Lead Alternate - a 1.75” RCS D10 can be used for special conditions.
- Extension - the extension pipe has male/female cast steel couplings welded on both ends. It is available with or without the helices.
- Pipe Material - Cold formed, welded or seamless steel confirms to ASTM A500 Grade C or equal material with 50ksi minimum yield strength.
- Coupler- “Strength Square” male /female couplings are cast steel per ASTM A958, SC1045 or equal with 40ksi yield and 80ksi ultimate strength minimum.

Helix - Helical Bearing Plates

The helical bearing plate is formed to a 3" pitch from 3/8” thick steel plate that conforms to high strength, low alloy steel per ASTM A1018 with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the P35H Pipe Pile.

Connection Bolts

Each Extension pipe is provided with two 7/8” diameter x 4 ½” long Hex Head bolts per ASTM A325 and one 7/8” Hex Jam Nuts per ASTM A563.

Corrosion Protection

Helical Foundation Pipe Pile Anchor Lead and Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 3.50” O.D. (0.300” wall) Pipe Pile Multi-Helix Lead Sections and Extensions is 15,000 [ft-lb.] with a torque correlation factor or Kt of 7.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 3.50” O.D. (0.300” wall) Pipe Pile Multi-Helix is 120 kips with safety factor of 2. (Section 12, Table 12.2a).

Axial Load Single Helix Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
1/2”	8”	0.278	60
1/2”	10”	0.473	60
1/2’	12”	0.711	60
1/2’	14”	0.993	60

MCP 4.50” O.D SCH40 P45 MULTI-HELIX FOUNDATION PIPE PILES

“Strength Squared” Coupling

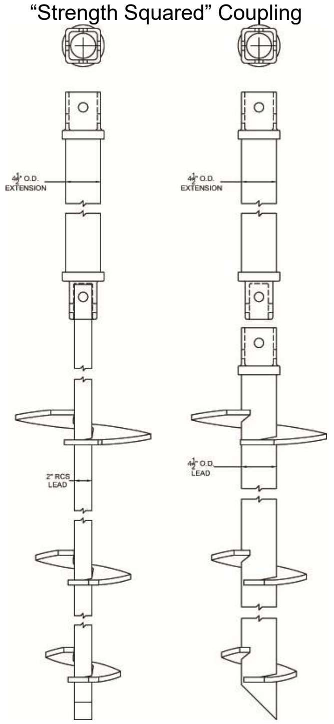


Figure 9
Typical Helical Pile or Anchor Assembly

Helical Pipe Pile Lead and Extension with “Strength Square” coupling

Helical Pipe Pile Lead and Extensions consist of a central 4.50” O.D. (0.237” wall) pipe with “Strength Square” couplings and/or helices welded as shown in Figure 9.

- Lead - the lead pipe has female cast steel coupling welded at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Lead Alternate -a 2.00’ RCS D15 can be used for special soil conditions.
- Extension - the extension pipe has male/female cast steel couplings welded on both ends. It is available with or without the helices.
- Pipe Material – Cold formed, welded or seamless steel confirms to ASTM A500 Grade C or equal material with 50ksi minimum yield strength.
- Coupler- “Strength Square” Male/female couplings are cast steel per ASTM A958 SC1045 or equal with 40ksi yield and 80ksi ultimate strength minimum.

Helix - Helical Bearing Plates

The helical bearing plate is formed to a 3" pitch from 1/2” thick steel plate that conforms to high strength, low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the P45 pipe pile.

Connection Bolts

Each Extension pipe is provided with two 1” diameter x 5” long Hex Head bolts per ASTM A325 and two 1” Hex Jam Nuts per ASTM A563.

Corrosion Protection

Helical Foundation Pipe Pile Anchor Lead and Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 4.50” O.D. (0.237” wall) Pipe Pile Multi-Helix Lead Section and Extensions is 20,000 [ft-lb.] with a torque correlation factor or Kt of 6.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 4.50” O.D. (0.237” wall) Pipe Pile is 130 kips with safety factor of 2. (Section 12, Table12.2a).

Axial Load Single Helix Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
1/2"	8”	0.236	70
1/2”	10”	0.430	70
1/2”	12”	0.668	70
1/2”	14”	0.950	70

MCP 4.50” O.D SCH80 P45H MULTI-HELIX FOUNDATION PIPE PILES

“Strength Squared” Coupling

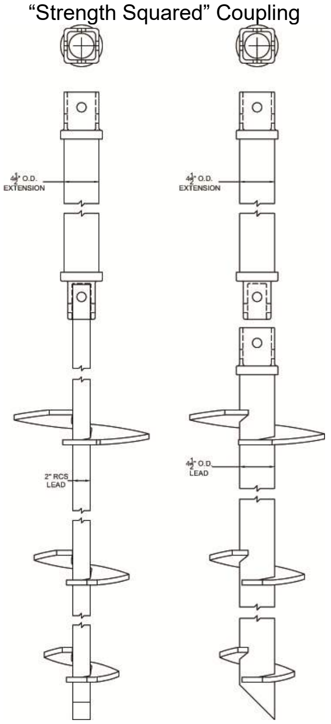


Figure 10

Typical Helical Pile or Anchor Assembly

Helical Pipe Pile Lead and Extension with “Strength Square” coupling

Helical Pipe Pile Lead and Extensions consist of a central 4.5” O.D. (0.337” wall) pipe with “Strength Square” couplings and/or helices welded as shown in Figure 10.

- Lead - the lead pipe has female cast steel coupling welded at the upper end and pointed end at the lower end. It is welded with one or more circular helical-shaped steel plates (Helix).
- Lead Alternate - a 2.00’ RCS D15 can be used for special soil conditions.
- Extension - the extension pipe has male/female cast steel couplings welded on both ends. It is available with or without the helices.
- Pipe Material – Cold formed, welded or seamless steel confirms to ASTM A500 Grade C or equal material with 50ksi minimum yield strength.
- Coupler- “Strength Square” Male/female couplings are cast steel per ASTM A958 SC1045 or equal with 40ksi yield and 80ksi ultimate strength minimum.

Helix - Helical Bearing Plates

The helical bearing plate is formed to a 3" pitch from 1/2’ thick steel plate that conforms to high strength, low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The outer diameters of available helix sizes range from 8" to 14". Helices are welded to the P45H pipe pile.

Connection Bolts

Each Extension pipe is provided with two 1” diameter x 5” long Hex Head bolts per ASTM A325 and two 1” Hex Jam Nuts per ASTM A563.

Corrosion Protection

Helical Foundation Pipe Pile Anchor Lead and Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 4.50” O.D. (0.337” wall) Pipe Pile Multi-Helix Lead Section and Extensions is 26,000 [ft-lb.] with a torque correlation factor or Kt of 6.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 4.50” O.D. (0.337” wall) Pipe Pile Multi-Helix is 180kips with safety factor of 2. (Section 12, Table12.2a).

Axial Load Single Helix Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
1/2"	8”	0.236	70
1/2”	10”	0.430	70
1/2”	12”	0.668	70
1/2”	14”	0.950	70

MCP 8.625” O.D (0.188” wall) R86 MULTI-HELIX FOUNDATION PIPE PILES

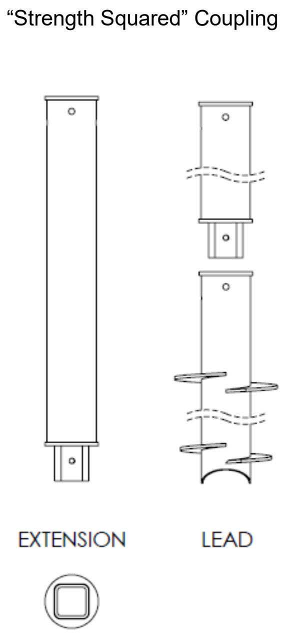


Figure 11

Helical Pipe Pile Lead and Extensions with “Strength Square” coupling

Helical Pipe Pile Lead and Extensions consist of a central 8.625” O.D pipe with 0.188” wall with “Strength Square” couplings and /or helices welded as shown in Figure 11.

- Lead - the lead pipe has the “Strength Square” female coupling plate and open “fish tail” nose to cut thru soil.
- Extension - the extension pipe has the “Strength Square” male/female coupling welded on both ends. It is available with or without the helices.
- Pipe Material - Cold formed, welded or seamless steel confirms to ASTM A500 Grade C or equal material with 50ski minimum yield strength.
- Coupler- “Strength Square” Male/female couplings are fabricated from steel per ASTM A500 & A572.

Helix - Helical Bearing Plates

The helical bearing plate is formed to a 3" pitch from 3/8” or 1/2” thick steel plate that conforms to high strength, low alloy steel per ASTM A1018 or approved equivalent with 55ksi min. yield strength. The available helix sizes range from 14” to 24” for the R86 pipe pile.

Connection Bolts

Four 1” diameter bolts x 2-1/2” long per ASTM A325 for the “Strength Square” couplings.

Corrosion Protection

Helical Foundation Pipe Pile Anchor Lead and Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating

The Ultimate Torque rating of MCP 8.625” O.D. (0.188” wall) Pipe Pile Multi-Helix Lead Section and Extensions is 40,000 [ft-lb.] with a torque correlation factor or Kt of 5.

Anchor Mechanical Strength Rating

The Ultimate axial load resistance for MCP 8.625” O.D. (0.188” wall) Pipe Pile Multi-Helix is 200 kips in compression and 120 kips in tension with safety factor of 2. (Section 12, Table12.2a).

Axial Load Single Helix Mechanical Strength Ratings

Helix Thickness (inches)	Helix Diameter (inches)	Helix Bearing Area (ft^2)	Single-Helix Axial Load Strength Rating (kips)
1/2"	14”	0.659	80
1/2”	16”	0.984	80
1/2”	20”	1.766	80
1/2”	24”	2.719	80

MCP - New Construction Bracket for 1.50”, 1.75” and 2.00” RCS and 2.875”, 3.50”and 4.50” Pipe Piles

Typical Installation of New Construction Brackets

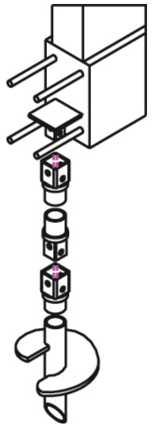


Figure 12

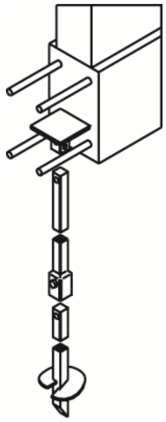


Figure 13

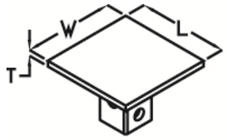
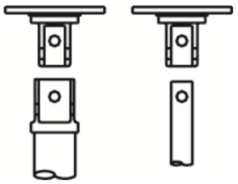


Figure 14



Pile Designation	Shaft Dimensions (in)	New Construction Bracket	W (in)	L (in)	T (in)	Bolts			Ultimate Mechanical Compression Capacity (kips)	Ultimate Mechanical Tension Capacity (kips)*	Plate Material Spec.
						Dia. (in)	Qty.	Gr.			
D6/D7	1.50” RCS	NCB060604P28-1	6	6	1/2	3/4	1	5	70	70	ASTM A36 **F_y**=36ksi min. **F_t**=58ksi min.
D10	1.75” RCS	NCB080806P35-1	8	8	3/4	7/8	1	5	100	100	
D15	2.00” RCS	NCB101006P45-1	10	10	3/4	1-1/8	1	8	150	150	
P28/P28H	2.875” OD	NCB060604P28	6	6	1/2	3/4	2	5	90	72	
P35/P35H	3.50” OD	NCB080806P35	8	8	3/4	7/8	2	5	120	105	
P45/P45H	4.50” OD	NCB101006P45	10	10	3/4	1	2	5	180	156	
R86L	8.625” OD x .188”	NCB121204R86	12	12	1/2	1	4	5	200	120	

* Additional tension load, up to the value of the ultimate compression load, may be achieved by welding the bracket to the pile. Any postproduction weld should be designed and observed by the project engineer of record. R86 coupling material is made from A500 tubing.

General

The New Construction Brackets are placed at the end of the Helical Piles or Anchors to support the axial loads of the overlying construction as shown in Figure 12 and 13. The top plate is made of ASTM A36 steel and the bottom is the cast steel male cap, the same casting used on Pipe piles and is made from ASTM SC1045 steel with 40ksi minimum yield strength and 80ksi minimum ultimate strength.

MCP - Foundation Repair Bracket for 1.50”, 1.75” and 2.00” RCS and 2.875”, 3.50” and 4.50” Pipe Piles

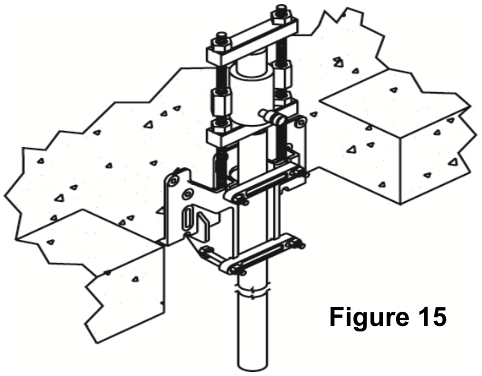


Figure 15

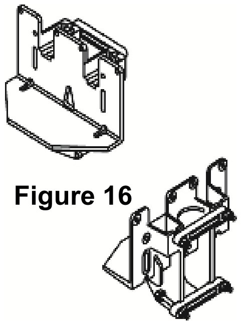


Figure 16

Back View

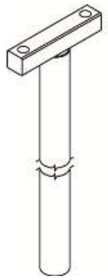


Figure 17

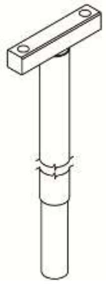


Figure 18

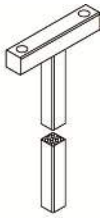


Figure 19

Pile Designation	Shaft Dimensions (in)	Repair Bracket	T-Pipe	Figure	Ultimate Compression Load (kips)*	Bracket Material (Ductile Iron) Specification
D6/D7	1.50” RCS	Dixie350**	B1	16 & 18	50	ASTM A536 / Grade 654512
D15, P45/P45H	2.00” RCS & 4.50” OD	Dixie450		16 & 17	120	
P28/P28H, P35/P35H	2.875” & 3.50” OD	Dixie350**	B3	16 & 19	100	
D6	1.50” RCS	Dixie350**	B4**	16 & 18	48	
D10	1.75” RCS	Dixie350**	B5**	16 & 17	77	
P28	2.875” OD x .203”	Dixie350**	B6**	16 & 17	60	
P35	3.50” OD x .216”	Dixie350**	B7**	16 & 17	74	
P35H	3.50” OD x .300”	Dixie350**	B08**	16 & 19	77	

* Values reflect ultimate mechanical rating for the bracket and hardware. Actual field capacity may be less due to condition and strength of existing footing concrete. Actual capacity may be adversely affected by inadequate connection of bracket to footing’s concrete face.

** Product approved per AC358 by a third party as reported in the ICC-ES ESR-3032.

General

The patented MCP repair bracket product line (Dixie350™) is designed for use as a helical pile termination to facilitate underpinning of existing foundation elements as shown in Figure 15. Dixie350™ connects the deep foundation element of the helical pile (RCS/Pipe Piles) to the existing structure typically through connections with the foundation grade beams, footings, or slabs. Dixie350™ is a patented (US 8,777,520 B2) one-piece cast iron bracket with hardware for connection of the bracket to the helical pile. The Dixie350™ is recommended only for resisting compression loads.

Lifting Bar Assemblies

Lifting Bar Assemblies consist of a 1-3/4” round corner square steel bar of appropriate length welded to a steel pipe or RCS. These are sized to accommodate the appropriate pile shaft as shown in Figure 17, 18 and 19.

Connection Bolts

Each lifting assembly is provided with two 7/8” diameter x 12” all threaded studs per ASTM A325 with four 7/8” Square Nuts per ASTM A563.

Corrosion Protection

Foundation bracket, Dixie350™, the lifting assembly and associated hardware are hot dip galvanized per ASTM A153 or ASTM123.

Load Rating

The Maximum Design Load rating for MCP Dixie350™ cast iron bracket is 55,000 lb. The Ultimate Load rating for Dixie350™ cast iron bracket is 110,000 lb.

FIELD QUALITY CONTROL

INSTALLATION TORQUE vs. ULTIMATE PILE CAPACITY

Helical Foundation Piles and anchors consist of a central shaft with one or more helices.

Helices have two functions:

1. To pull the pile into the soil to a required depth during installation
2. To transfer load to the soil by means of exerting bearing pressure against the soil after installation

The maximum load that each helix can exert against the soil is equal to the effective bearing capacity of the soil times the projected area of the helix. This is referred to as the *theoretical ultimate helix capacity*. The total *theoretical ultimate pile capacity* is simply the sum of the individual helix capacities. See Section 8. Helices must be formed to a true helical shape with uniform pitch by matching metal dies to minimize soil disturbance and to assure that the rate of penetration will be one pitch (helix opening) per revolution.

The shaft has three functions:

1. To sustain sufficient torque capacity to install the pile
2. To resist loads transferred to the helices during installation
3. To provide the proper connection (interface) to the structure
4. To sustain loads transferred from the structure after installation

Helical Foundation Piles with shaft sizes of 3.5” O.D. or less can be regarded as low displacement piles. For low displacement piles, 100% of *theoretical ultimate pile capacity* is provided by the helix / soil bearing capacity. Soil-to-shaft friction will be considered negligible.

Helical piles are turned into the subgrade with varying downward force applied to facilitate the pile’s advancement. The turning force (torque) along with the downward force (crowd) will advance the pile to the installation depth. It is easy to see why helical pile placement is often compared to the installation of a self-tapping wood screw. The torque achieved during installation of the wood screw is proportional to both the pullout capacity of the screw and the strength of the material it’s being screwed into. This correlation between torque and pullout capacity can also be extended to helical piles, thus providing an excellent method of *onsite quality control*. By applying Equation 14.1, the expected ultimate tension capacity can be estimated at the time of installation. If $\mathbf{Q^t_{ult}}$ is determined to be less than that required then the anchor length can be extended or other modifications may be incorporated. If the capacity is significantly greater than that required, then the length of the anchor may be reduced or other modifications may be incorporated. In both cases modifications can be accomplished at the time of installation.

Besides full-scale load testing, the application of Equation 14.1 is considered the most accurate method of predicting the *theoretical ultimate capacity* of a helical screw pile.

$$\mathbf{Q^t_{ult} = K_t \times T} \qquad \text{[Equation 14.1]}$$

Where:

$\mathbf{Q^t_{ult}}$ = the expected geotechnical ultimate tension capacity. [lbs] (Includes helix-bearing capacity only. Does not include skin friction.)
$\mathbf{K_t}$ = Torque Factor [ft^{-1}] See Table 14.1
T = Average Installation Torque [lb-ft] – defined below

The *ultimate tension capacity* determined by Equation 14.1 ($\mathbf{Q^t_{ult}}$) is defined as the minimum tension load that will cause continuous deflection (creep).

The *average installation torque* (**T**) can be defined as the average torque achieved for the last 4 or 5 ft. of installation or for a minimum distance of three diameters of the largest helix. When averaging the installation torque, the torque should be constant or gradually increasing – not decreasing. Project specifications and installation procedures often refer to *specified installation torqu*e when discussing pile installation requirements. *Specified installation torque* is usually synonymous to *average installation torque* or *effective torsional resistance* but this should be clarified with the engineer. Abrupt changes in torque readings shall be reported to the engineer for additional consideration.

For MCP helical products, the recommended *Torque Factor* values ($\mathbf{K_t}$) are shown in Table 14.1. As discussed below, torque factors can vary. The following recommendations should be used with caution.

Table 14.1: Shaft Size

Shaft Size	$\mathbf{K_t}$
RCS Square Shaft Piles	10
2.875" Diameter Helical Pipe Piles	9
3.500" Diameter Helical Pipe Piles	7
4.500" Diameter Helical Pipe Piles	6
8.625" Diameter Helical Pipe Piles	5

For shaft diameters greater than 3.5", MCP recommends a full-scale load test at the jobsite to determine $\mathbf{K_t}$.

The above values for $\mathbf{K_t}$ are based on experience and field-testing in various locations and soil types, with various helix and shaft configurations. It should be noted that $\mathbf{K_t}$ might be significantly reduced in highly sensitive clays and very soft soils. The strength of *sensitive soils* may be significantly reduced when disturbed. See Section 6. In these areas, the values in Table 14.1 will not apply. It is highly recommended to avoid sensitive soils with any type of pile, including helical products. This can often be accomplished by increasing the depth of the pile beyond the sensitive strata as indicated by the soil-boring log. If this cannot be accomplished, full-scale load testing will be required to determine the pile capacity and the value of $\mathbf{K_t}$.

We believe the values in Table 14.1 to be generally conservative, but recommend conducting a full-scale load test at the beginning of each project when practical. The value of $\mathbf{K_t}$ determined by this test can then be applied with a higher degree of accuracy than the recommended values shown in Table 14.1. This also provides for an opportunity to confirm the *theoretical ultimate pile capacity* as determined by applying the classic bearing equations shown in this manual. For large projects, a pre-production load test should be performed prior to final design. This will determine both the optimum pile design and the value of $\mathbf{K_t}$ for the project.

The value of $\mathbf{Q^t_{ult}}$ determined from Equation 14.1 represents the *theoretical ultimate tension or uplift capacity*. In most cases the compression capacity will be equal to or slightly larger than the tension capacity. If the soil is cohesionless, the overburden pressure beneath the helix will generally be greater than that above the helix. Also the bottom helix will be resting on undisturbed soil. Assuming the soil remains the same beneath the pile, either of these cases will provide a compressive capacity slightly larger than $\mathbf{Q^t_{ult}}$.

In some cases the *theoretical ultimate compression capacity* may be significantly greater than the *theoretical ultimate tension capacity.* This will result when a soil stratum of significantly greater bearing capacity is located directly beneath the pile. (i.e. a hard layer) In this case, the *theoretical ultimate compression capacity* can be determined by applying the classical bearing equations discussed in this manual. A geotechnical report with boring logs will be required when applying the classical bearing equations, or the method discussed in Section 7 may be applied.

When applying Equation 14.1 for compressive loaded piles, a test anchor should be installed to assure that the installation torque (i.e. bearing capacity) of the soil remains constant or increases in the areas beneath the pile. $\mathbf{Q^t_{ult}}$ may then be used to represent both *theoretical ultimate tension capacity* and *theoretical ultimate compression capacity*.

Note:

1. Always allow the helices to “track” down with minimum down pressure (crowd). Excessive down pressure during installation can affect the amount of torque achieved.

2. The path of the helical screw pile should be straight. The torque drive unit should follow straight behind the pile with no side loading and minimum crowd. Side loading at the top of the pile will unrealistically increase the torque.

3. Table 14.1 does not apply for helices with thick leading edges (i.e. >= 0.75”).

4. The rotational speed of helical foundation piles should be 10 – 12 rpm when torque is monitored. Excessive rpm’s during torque monitoring will increase the torque. This can result in an unrealistic value of $\mathbf{Q^t_{ult}}$.

5. All helical products manufactured by MCP shall be installed by MCP approved installers.

Torque shall be “continuously” monitored and recorded during the installation of Helical Foundation Piles. Break-a-way or other torque relief devices such as pressure relief systems (without continuous readout) are not recommended.

PROCEDURE FOR LOAD TESTING HELICAL PILES UNDER STATIC AXIAL LOAD

The following is intended to provide a general description of load testing to evaluate the load resistance of a helical pile. For a particular project, the owner, his consultant, or the applicable building code authority will specify the type of test to be conducted and the acceptance criteria.

The procedures in this document have been adapted from:

1. ASTM D 1143 Standard Test Method for Piles Under Static Axial Compressive Load
2. ASTM D 3689 Standard Test Method for Individual Piles Under Static Axial Tensile Load

Re: Quick Load Test Method for Individual Piles

Purpose of Load Test

1. To determine the response of the pile under a static axial load
2. To determine the ultimate axial capacity of the pile

Installation of Test Pile

1. While MCP cannot take any responsibility for project site safety, the following safety procedures are recommended:
    a. All safety procedures of the pile manufacturer and the owner's representative
    b. American Nation Standards Institute Standard B30.1 Safety Code for Jacks
    c. All safety precautions and requirements listed in ASTM D 1143 and ASTM D 3698
    d. All safety procedures of the company conducting the test
2. Unless otherwise noted, test piles shall be of the identical configuration and quality as that proposed for the project.
3. The test shall be conducted within an area approved by the owner's representative.
4. Test piles shall be installed using the same methods and procedures as that proposed for the production piles.
5. Installation torque shall be continually monitored and recorded in one ft. increments throughout the installation of the test pile.
6. The test pile shall be installed to the minimum *specified installation torque* value based on the anticipated ultimate capacity.
7. Piles that are tested to ultimate capacity shall not be used as production piles.

Apparatus for Applying Loads

1. All equipment shall be in accordance to the applicable ASTM standards referenced above.
2. The loading apparatus shall be independently calibrated and certified to the project specifications. All calibration and certification reports should be forwarded to the owner's representative.
3. The equipment shall have the capacity of producing, maintaining and reversing the test loads in the required increments.
4. If, during the test, the readings are suspected of being erratic or incorrect, the equipment should immediately be inspected, recalibrated and recertified.
5. The load reaction frame shall comply with applicable ASTM Standards. Figure 15.1 shows a typical load reaction frame.

Figure 15.1: Full Scale Compression Load Test

Apparatus for Measuring Pile Displacement

Pile displacement may be measured with dial gages, scales or a combination of both. Other methods may also be incorporated, but the method used to measure pile displacement must be in accordance with applicable ASTM standards as previously referenced in Section 15. One or more secondary (backup) measuring system is highly recommended.

Quick Load Method for Individual Piles – Compression and Tension

1. Apply a small alignment (preload) to the pile (5% of the ultimate load). After this load is applied, all displacement measuring devices shall be set to zero or to a datum reference position.
2. Apply the load in increments of 10 to 15% of the proposed design load with a constant time interval between increments of 2.5 minutes or as otherwise specified. Add load increments until continuous jacking is required to maintain the test load or until the specified capacity of the loading apparatus is reached, whichever occurs first, at which time stop the jacking.
3. After a 5 minute interval or as otherwise specified, remove the full load from the pile in four approximately equal decrements with 5 minutes between decrements so that the shape of the rebound curve may be determined.

Monitoring and Recording Readings for the Quick Load Test Method

Record readings of time, load, and deflection immediately before and after the application of each load increment or decrement and at intermediate time intervals as specified. When the maximum load has been applied, take readings and record when the jacking is stopped. Repeat after 2.5 minutes and again at 5 minutes.

All deflection devices (primary and back up) should be read simultaneously.

A data plot of load vs. displacement shall be maintained during the load test. This allows for erratic data to be recognized immediately and corrective action taken. This will also allow for a preliminary estimate of the pile’s ultimate capacity to be determined. A quick method for this is the “Intersection of Tangents” method.

All test data and procedures should be forwarded to the owner’s representative.

Reduction of Data

The load and deflection readings discussed above should be recorded in a format approved by the owner’s representative prior to testing.

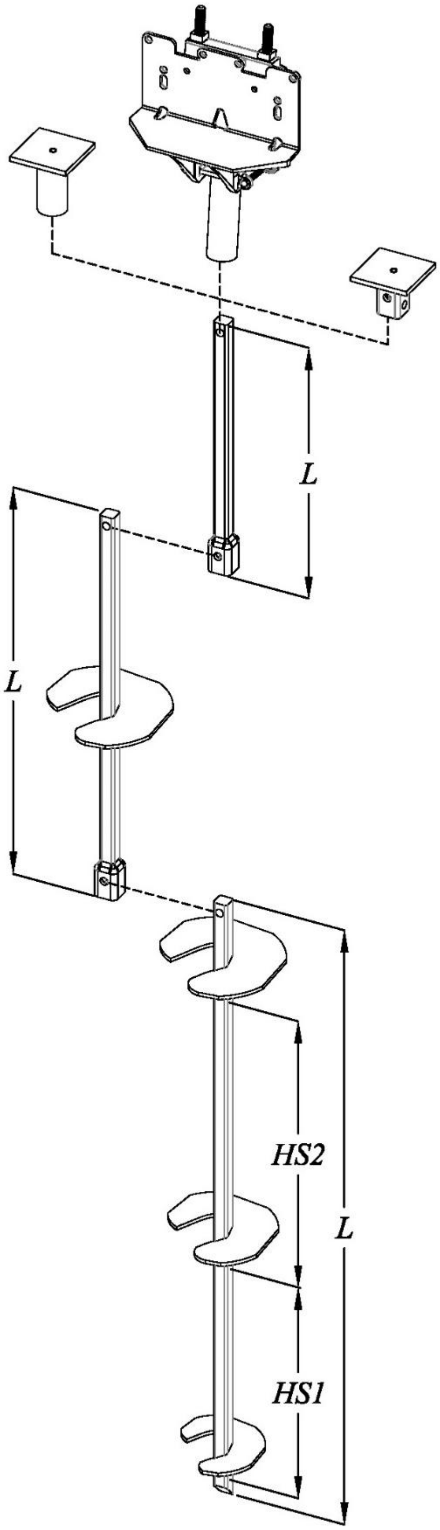
Approval Criteria

The owner’s representative or applicable building code authority should accept or reject the pile’s performance - based on the results of the test method specified for the project.

References

1. ASTM D 1143 “Standard Test Method for Piles Under Static Axial Compressive Load”, American Society for Testing and Materials, Philadelphia, PA
2. ASTM D 3689 “Standard Test Method for Individual Piles Under Static Axial Tensile Load”, American Society for Testing and Materials, Philadelphia, PA

1-1/2” RCS PILE (TORQUE RATING - 5,500 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB06042040HU	6"x6"x1/2"
SB08042040H	8"x8"x1/2"

REPAIR BRACKET
Catalog Number
DIXIE350**
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB060604CP1G**	6"x6"x1/2"

REPAIR BRACKET T-PIPES
Catalog Number
B4**
B1

EXTENSIONS	
Catalog No.	L
D6616U**	42
D6620U**	60
D6625U**	84
D6630U**	120

EXTENSIONS W/ HELIX^{++}		
Catalog No.	Helix Dia.	L
D6E42S12**	12	42
D6E60S14**	14	60
D6E84S142**	14, 14	84

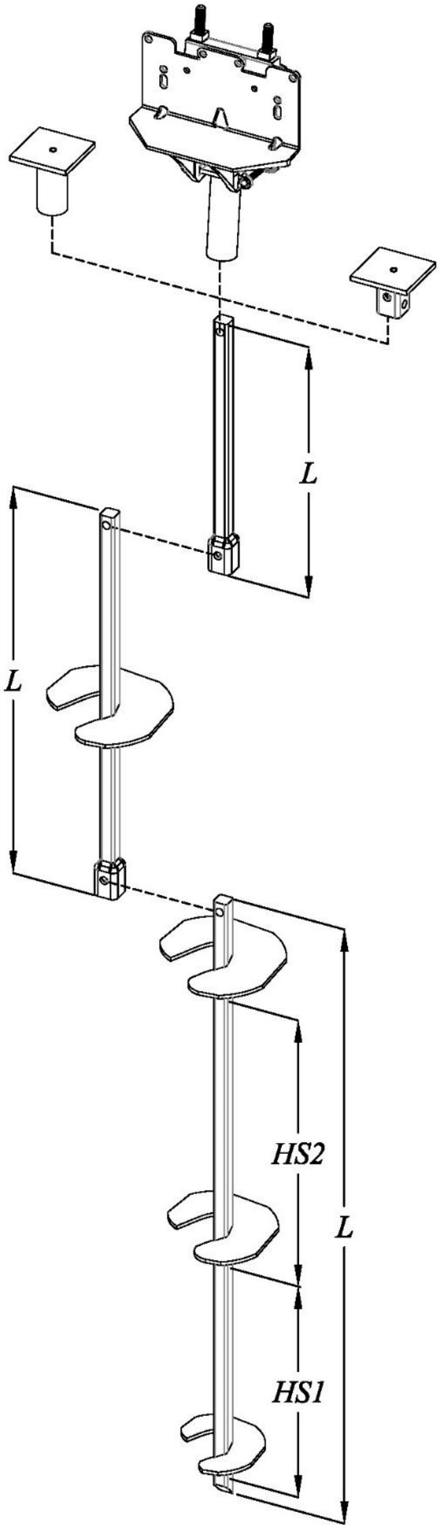
LEADS^{++}				
Catalog No.	Helix Dia.	HS1	HS2	L
D660S810**	8, 10	24	-	60
D684S81012**	8, 10, 12	24	30	84
D6637**	10, 12, 14	30	36	84

Notes

- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 70 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Connection Hardware – (3/4” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 68 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 5,500 ft-lb is 55 kips.
- **Product approved per AC358 by a third party as reported in the ICC-ES ESR-3032.
- $^{++}$This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.
-

It is recommended that a licensed design professional review this document to ensure that this product meets or exceeds the required dimensional and loading requirements. MPS is not liable for the misuse of this document/product.

1-1/2” RCS HIGH STRENGTH ANCHOR (TORQUE RATING – 7,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB06042040HU	6"x6"x1/2"
SB08042040H	8"x8"x1/2"

REPAIR BRACKET
Catalog Number
DIXIE350
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB060604P281	6"x6"x1/2"

REPAIR BRACKET T-PIPES
Catalog Number
B1

EXTENSIONS	
Catalog No.	L
D6616U7	42
D6620U7	60
D6625U7	84
D6630U7	120

EXTENSIONS W/ HELIX++		
Catalog No.	Helix Dia.	L
D7E42S12	12	42
D7E60S14	14	60
D7E84S142	14, 14	84

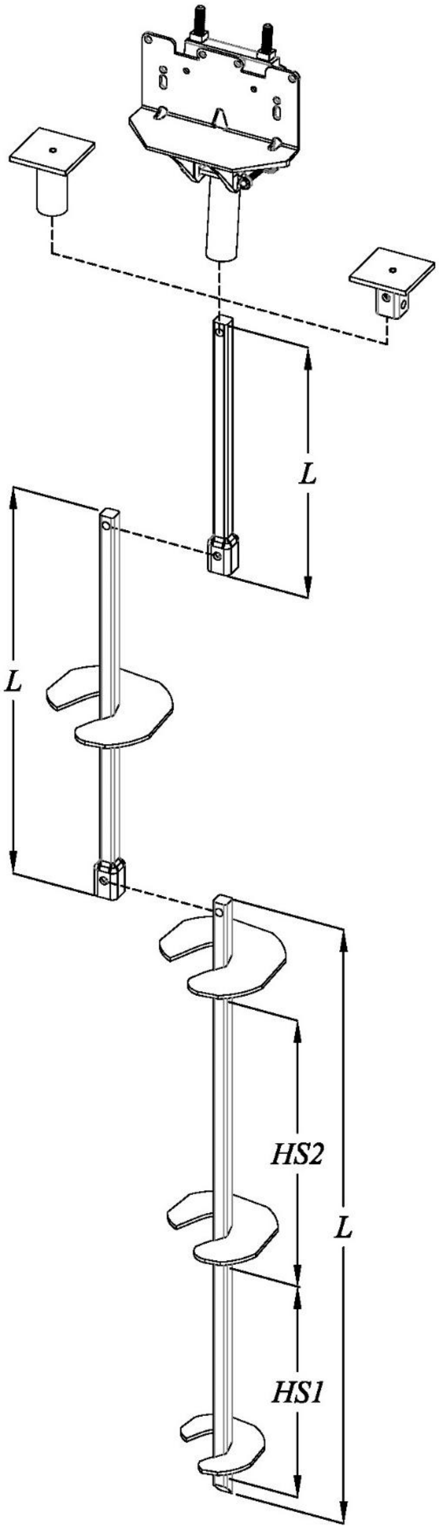
LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
D66327	8, 10	24	-	60
D66367	8, 10, 12	24	30	84
D66377	10, 12, 14	30	36	84

Notes

- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 90 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Connection Hardware – (3/4” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 70 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 7,000 ft-lb is 70 kips.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

It is recommended that a licensed design professional review this document to ensure that this product meets or exceeds the required dimensional and loading requirements. MPS is not liable for the misuse of this document/product.

1-3/4” RCS PILE (TORQUE RATING – 10,400 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB06042540HU	6"x6"x1/2"
SB08042540H	8"x8"x1/2"

REPAIR BRACKET
Catalog Number
DIXIE350**
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB080806CP2**	8"x8"x3/4"
NCB080804P351	8"x8"x3/4"

REPAIR BRACKET T-PIPES
Catalog Number
B5**

EXTENSIONS	
Catalog No.	L
D17516**	42
D17520**	60
D17525**	84
D17530**	120

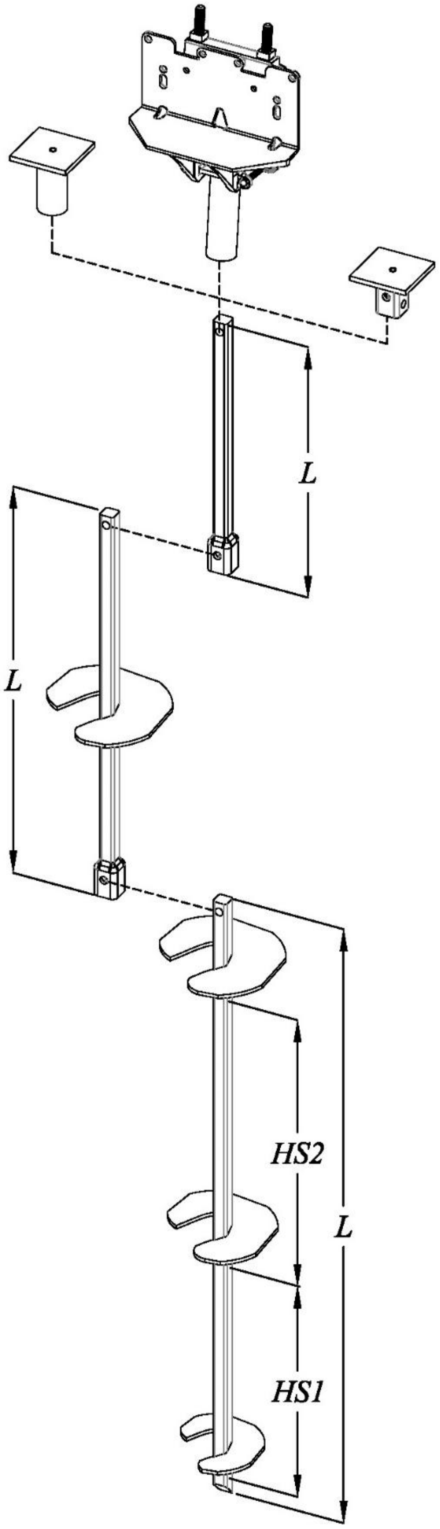
EXTENSIONS W/ HELIX^{++}		
Catalog No.	Helix Dia.	L
D10E42S12**	12	42
D10E60S14**	14	60
D10E84S142**	14, 14	84

LEADS^{++}				
Catalog No.	Helix Dia.	HS1	HS2	L
D17532**	8, 10	24	-	60
D17536**	8, 10, 12	24	30	84
D17537**	10, 12, 14	30	36	84

Notes

- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 90 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Connection Hardware – (7/8” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 100 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 10,400 ft-lb is 100 kips.
- **Product approved per AC358 by a third party as reported in the ICC-ES ESR-3032.
- $^{++}$This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

2” RCS PILE (TORQUE RATING – 15,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB10063040	10”x10”x3/4”
SB12063040	12”x12”x3/4”

REPAIR BRACKET
Catalog Number
DIXIE350
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB101006P451	10"x10"x3/4"
NCB121206P451	12"x12"x3/4"

REPAIR BRACKET T-PIPES
Catalog Number
B9

EXTENSIONS	
Catalog No.	L
D15E42	42
D15E60	60
D15E84	84
D15E120	120

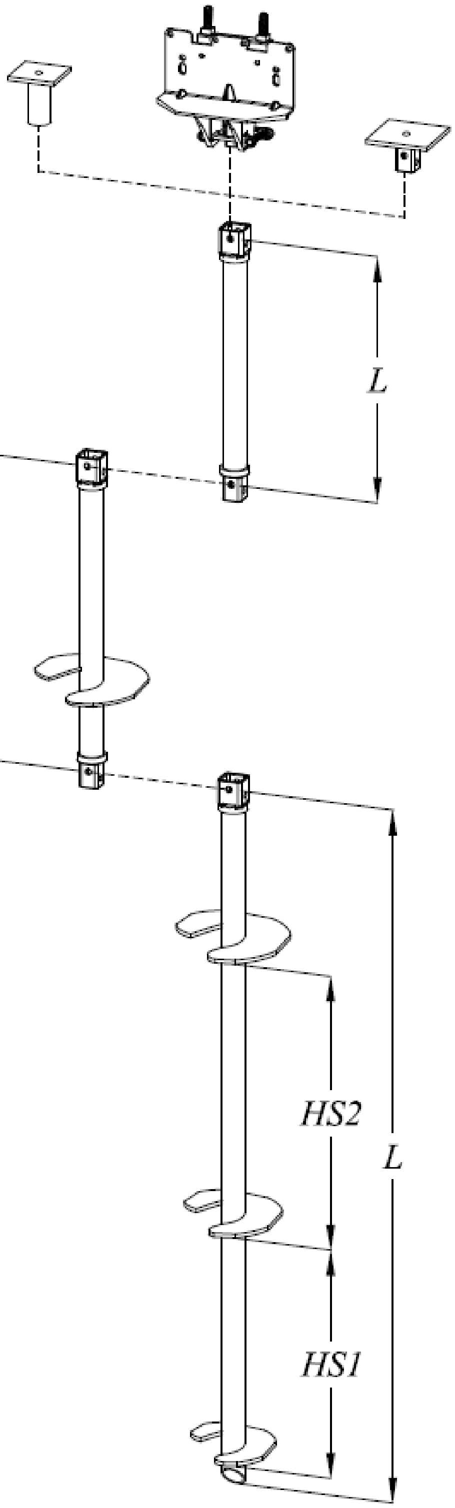
EXTENSIONS W/ HELIX++		
Catalog No.	Helix Dia.	L
D15E42S12	12	42
D15E60S14	14	60
D15E84S142	14, 14	84

LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
D1560S810	8, 10	24	-	60
D1584S81012	8, 10, 12	24	30	84
D1584S101214	10, 12, 14	30	36	84

Notes

- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 90 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 1/2” thickness.
- Connection Hardware – (1-1/8” diameter) Bolts per SAE J429 with yellow zinc dichromate coating. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 150 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 15,000 ft-lb is 150 kips.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

2-7/8” (0.203” WALL) PIPE PILE (TORQUE RATING – 7,500 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB06043040H	6"x6"x1/2"
SB10043040H	10”x10”x1/2”

REPAIR BRACKET
Catalog Number
DIXIE350**
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB060604CP1B**	6"x6"x1/2"
NCB080804P28	8"x8"x1/2"

REPAIR BRACKET T-PIPES
Catalog Number
B6**
B3

EXTENSIONS	
Catalog No.	L
P28E42**	42
P28E64**	60
P28E84**	84
P28E124**	120

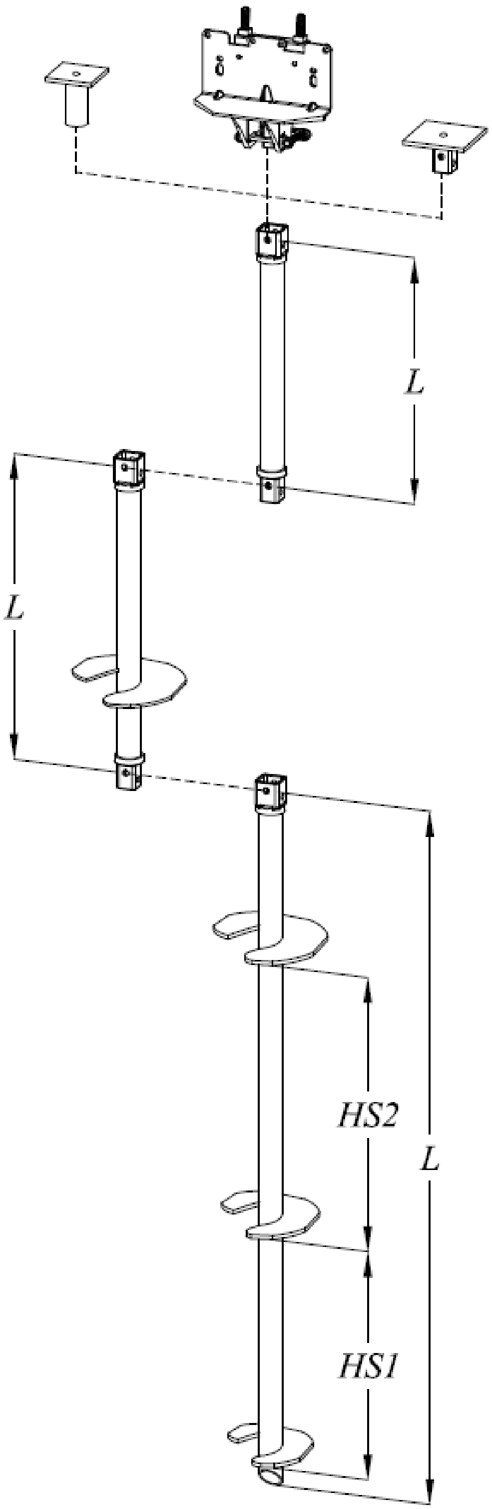
EXTENSIONS W/ HELIX++		
Catalog No.	Helix Dia.	L
P28E42S12**	12	42
P28E64S14**	14	60
P28E84S142**	14, 14	84

LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
P2864S810**	8, 10	24	-	60
P2884S81012**	8, 10, 12	24	30	84
P2884S101214**	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material – Pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Connection Hardware – (3/4” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 70 kips.
- Ultimate geotechnical rating with recommended Kt factor of 9 at the rated torque capacity of 7,500 ft-lb is 67.5 kips.
- **Product approved per AC358 by a third party as reported in the ICC-ES ESR-3032.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

2-7/8” (0.276” WALL) PIPE PILE (TORQUE RATING – 8,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB06043040H	6"x6"x1/2"
SB10043040H	10”x10”x1/2”

REPAIR BRACKET
Catalog Number
DIXIE350
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB060604P28	6"x6"x1/2"
NCB080804P28	8"x8"x1/2"

REPAIR BRACKET T-PIPES
Catalog Number
B3

EXTENSIONS	
Catalog No.	L
P28HE42	42
P28HE64	60
P28HE84	84
P28HE124	120

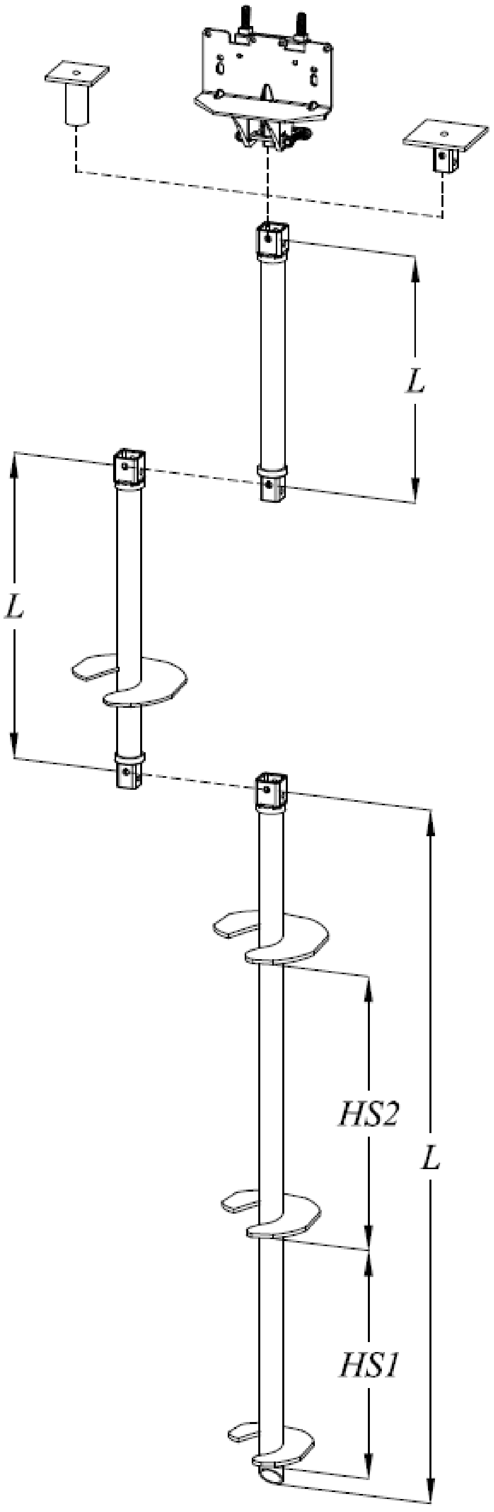
EXTENSIONS W/ HELIX++		
Catalog No.	Helix Dia.	L
P28HE42S12	12	42
P28HE64S14	14	60
P28HE84S142	14, 14	84

LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
P28H64S810	8, 10	24	-	60
P28H84S81012	8, 10, 12	24	30	84
P28H84S101214	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material – Pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Connection Hardware – (3/4” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 90 kips.
- Ultimate geotechnical rating with recommended Kt factor of 9 at the rated torque capacity of 8,000 ft-lb is 72 kips.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

3 1/2” (0.216” WALL) PIPE PILE (TORQUE RATING – 11,400 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB08085040H	8"x8"x1/2"
SB10105040H	10”x10”x1/2”

REPAIR BRACKET
Catalog Number
DIXIE350**
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB080806CP2B**	8"x8"x1/2"
NCB101006P35	10"x10"x3/4"

REPAIR BRACKET T-PIPES
Catalog Number
B7**
B3

EXTENSIONS	
Catalog No.	L
P35E42**	42
P35E64**	60
P35E84**	84
P35E124**	120

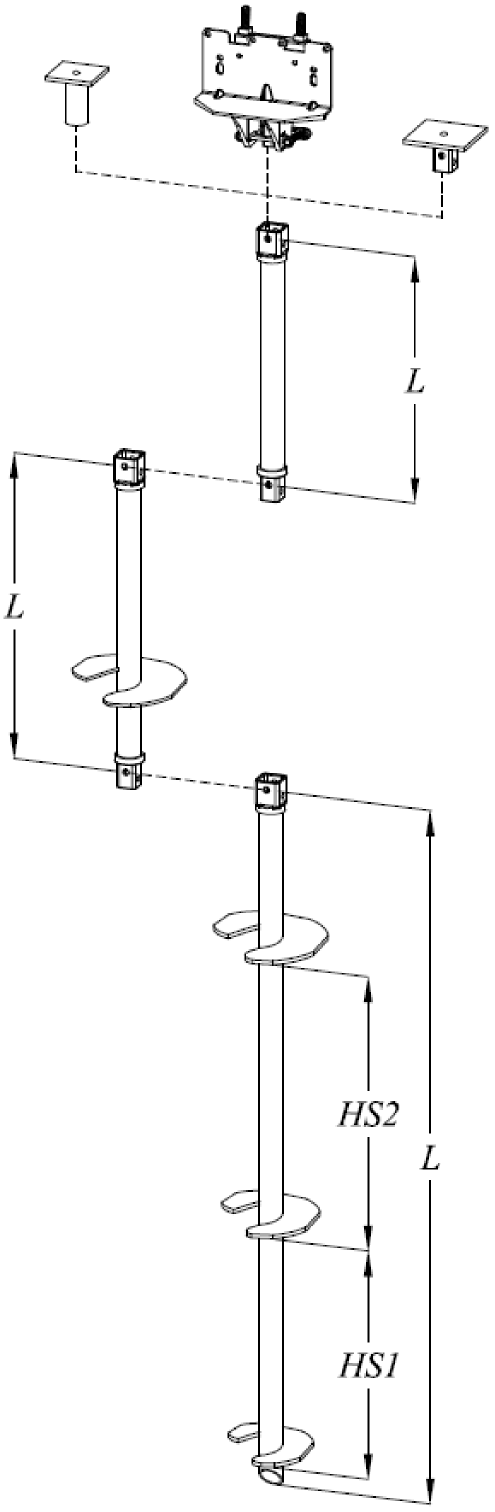
EXTENSIONS W/ HELIX^{++}		
Catalog No.	Helix Dia.	L
P35E42S12**	12	42
P35E64S14**	14	60
P35E84S142**	14, 14	84

LEADS^{++}				
Catalog No.	Helix Dia.	HS1	HS2	L
P3564S810**	8, 10	24	-	60
P3584S81012**	8, 10, 12	24	30	84
P3584S101214**	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material – Pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Connection Hardware – (7/8” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 100 kips.
- Ultimate geotechnical rating with recommended Kt factor of 7 at the rated torque capacity of 11,400 ft-lb is 80 kips.
- **Product approved per AC358 by a third party as reported in the ICC-ES ESR-3032.
- $^{++}$This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

3 1/2” (0.300” WALL) PIPE PILE (TORQUE RATING – 15,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB08085040H	8"x8"x1/2"
SB10105040H	10”x10”x1/2”

REPAIR BRACKET
Catalog Number
DIXIE350**
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB080806CP2B**	8"x8"x1/2"
NCB101006P35	10"x10"x3/4"

REPAIR BRACKET T-PIPES
Catalog Number
B08**
B3

EXTENSIONS	
Catalog No.	L
P35HE42**	42
P35HE64**	60
P35HE84**	84
P35HE124**	120

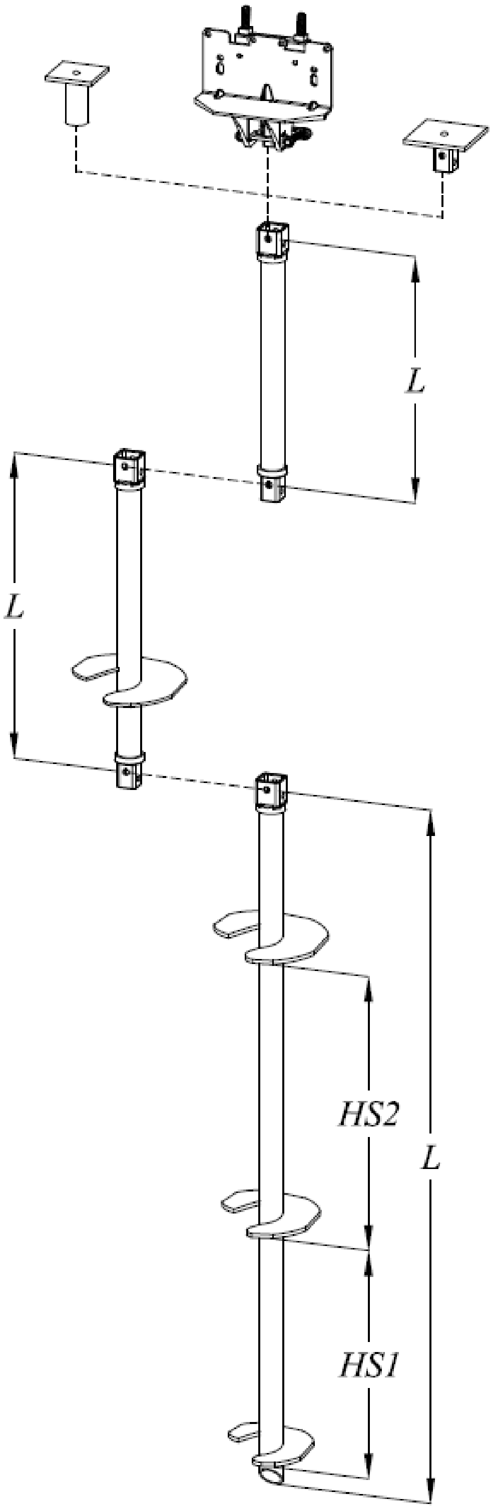
EXTENSIONS W/ HELIX^{++}		
Catalog No.	Helix Dia.	L
P35HE42S12**	12	42
P35EH64S14**	14	60
P35HE84S142**	14, 14	84

LEADS^{++}				
Catalog No.	Helix Dia.	HS1	HS2	L
P35H64S810**	8, 10	24	-	60
P35H84S81012**	8, 10, 12	24	30	84
P35H84S101214**	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material – Pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Connection Hardware – (7/8” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 120 kips.
- Ultimate geotechnical rating with recommended Kt factor of 7 at the rated torque capacity of 15,000 ft-lb is 105 kips.
- **Product approved per AC358 by a third party as reported in the ICC-ES ESR-3032.
- $^{++}$This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

4 1/2” (0.237” WALL) PIPE PILE (TORQUE RATING – 20,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB08065040H	8"x8"x3/4"
SB10065040H	10”x10”x3/4”

REPAIR BRACKET & T-PIPE
Catalog Number
DIXIE450

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB101006P45	10"x10"x3/4"

EXTENSIONS	
Catalog No.	L
P45E64	60
P45E84	84
P45E124	120

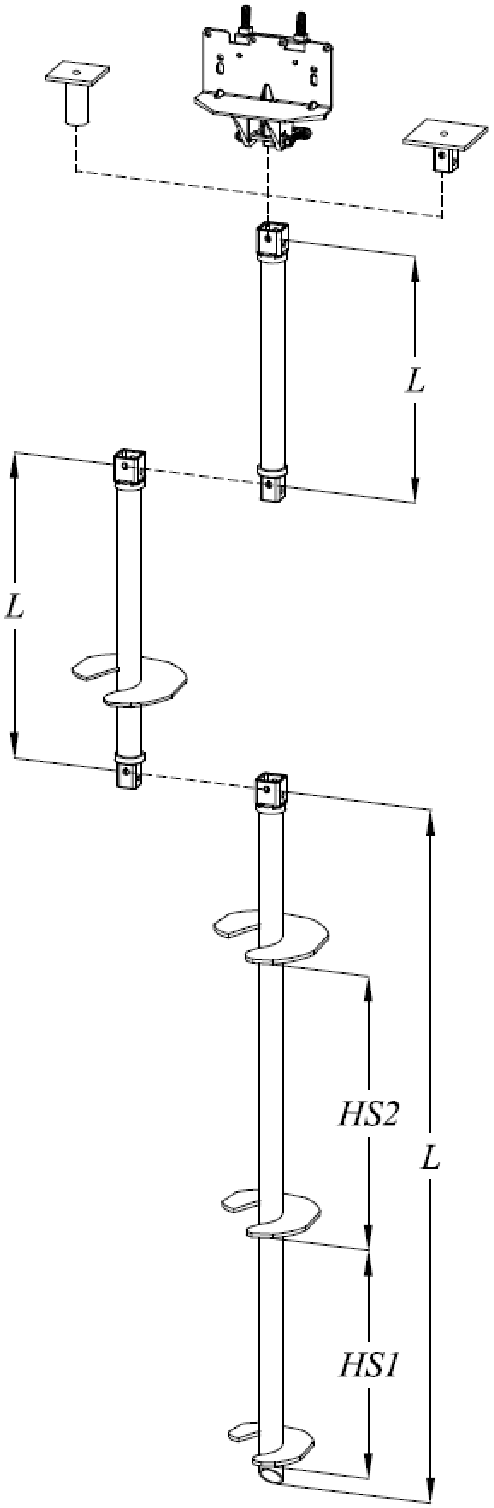
EXTENSIONS W/ HELIX++		
Catalog No.	Helix Dia.	L
P45E42T12	12	42
P45E64T14	14	60
P45E84T142	14, 14	84

LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
P4564T810	8, 10	24	-	60
P4584T81012	8, 10, 12	24	30	84
P4584T101214	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material – Pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 1/2” thickness.
- Connection Hardware – (1” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 130 kips.
- Ultimate geotechnical rating with recommended Kt factor of 6 at the rated torque capacity of 20,000 ft-lb is 120 kips.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

4 1/2” (0.337” WALL) PIPE PILE (TORQUE RATING – 26,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB08065040H	8"x8"x3/4"
SB10065040H	10”x10”x3/4”

REPAIR BRACKET & T-PIPE
Catalog Number
DIXIE450

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB101006P45	10"x10"x3/4"

EXTENSIONS	
Catalog No.	L
P45HE64	60
P45HE84	84
P45HE124	120

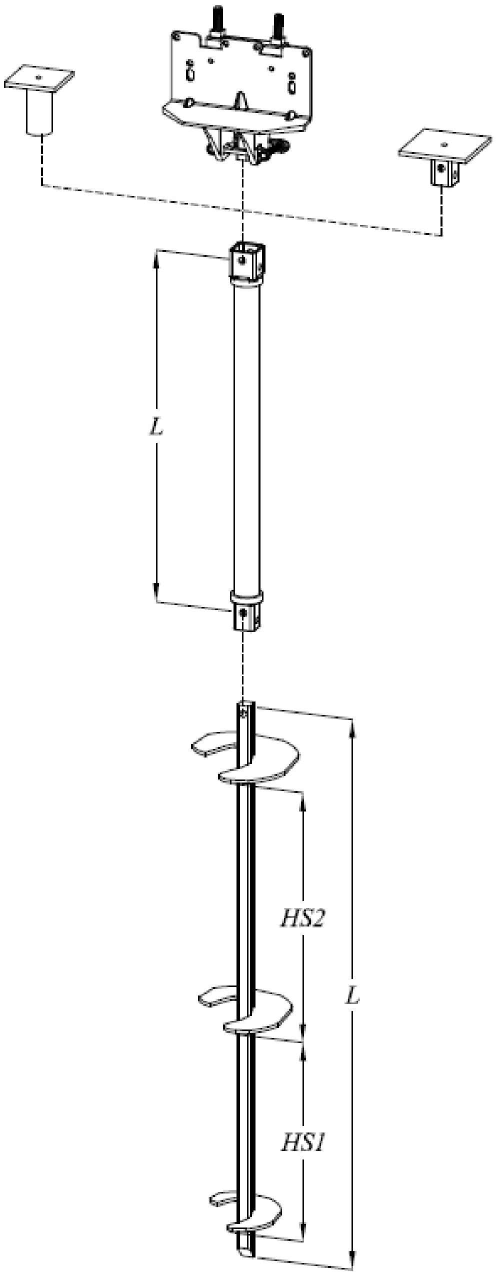
EXTENSIONS W/ HELIX++		
Catalog No.	Helix Dia.	L
P45HE42T12	12	42
P45HE64T14	14	60
P45EH84T142	14, 14	84

LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
P45H64T810	8, 10	24	-	60
P45H84T81012	8, 10, 12	24	30	84
P45H84T101214	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material – Pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 1/2” thickness.
- Connection Hardware – (1” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 180 kips.
- Ultimate geotechnical rating with recommended Kt factor of 6 at the rated torque capacity of 26,000 ft-lb is 156 kips.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

1-1/2” RCS / 2-7/8” (0.203” WALL) PIPE COMBO PILE (TORQUE RATING – 5,500 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB06043040H	6"x6"x1/2"
SB10043040H	10”x10”x1/2”

REPAIR BRACKET
Catalog Number
DIXIE350**
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB060604CP1B**	6"x6"x1/2"
NCB080804P28	8"x8"x1/2"

REPAIR BRACKET T-PIPES
Catalog Number
B6**
B3

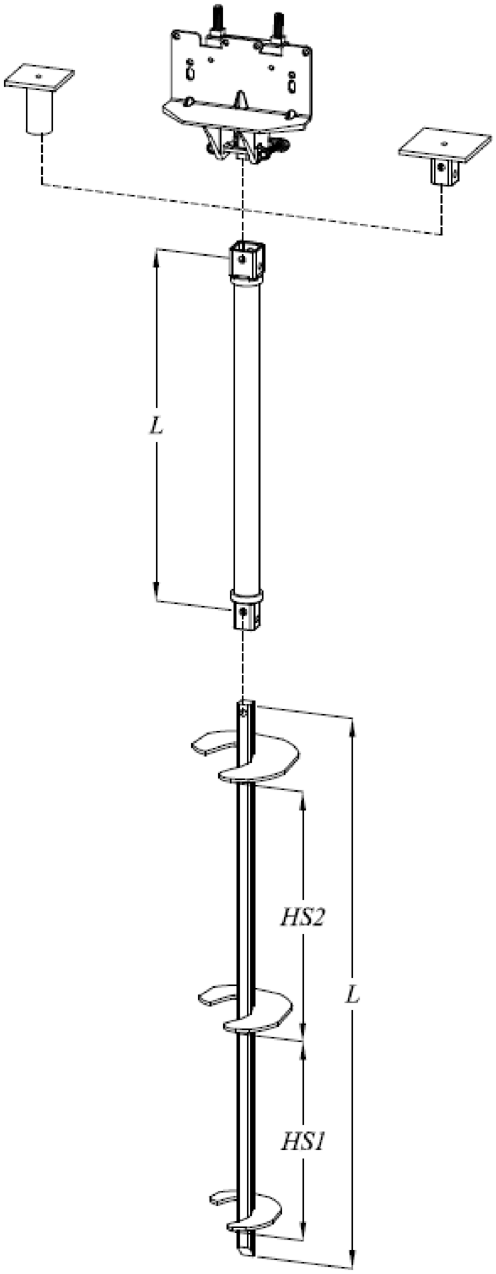
EXTENSIONS	
Catalog No.	L
P28E42**	42
P28E64**	60
P28E84**	84
P28E124**	120

LEADS^{++}				
Catalog No.	Helix Dia.	HS1	HS2	L
D660S810**	8, 10	24	-	60
D684S81012**	8, 10, 12	24	30	84
D6637**	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast with steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 70 ksi yield strength & pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Connection Hardware – (3/4” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 68 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 5,500 ft-lb is 55 kips.
- **Product approved per AC358 by a third party as reported in the ICC-ES ESR-3032.
- $^{++}$This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

1-1/2" RCS / 2-7/8" (0.203" WALL) PIPE COMBO PILE (TORQUE RATING – 7,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB06043040H	6"x6"x1/2"
SB10043040H	10"x10"x1/2"

REPAIR BRACKET
Catalog Number
DIXIE350
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB060604P28	6"x6"x1/2"
NCB080804P28	8"x8"x1/2"

REPAIR BRACKET T-PIPES
Catalog Number
B3

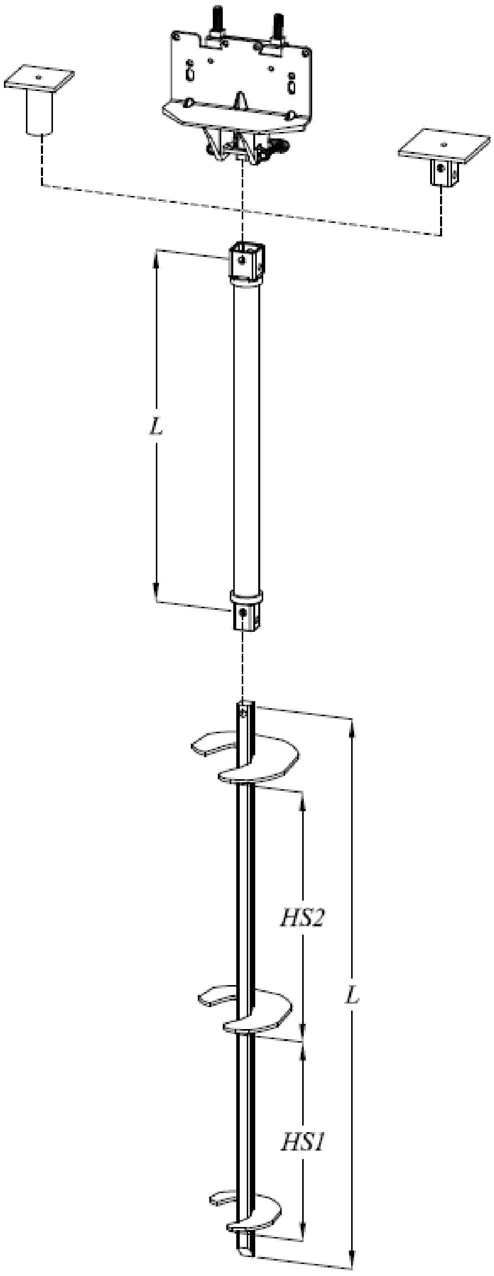
EXTENSIONS	
Catalog No.	L
P28HE42	42
P28HE64	60
P28HE84	84
P28HE124	120

LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
D66327	8, 10	24	-	60
D66367	8, 10, 12	24	30	84
D66377	10, 12, 14	30	36	84

Notes

- "Strength Square" couplers male and female are cast with steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 90 ksi yield strength & pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8" or 1/2" thickness.
- Connection Hardware – (3/4" diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3" pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as "HS1" and "HS2" below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a "U" catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 70 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 7,000 ft-lb is 70 kips.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

1-3/4” RCS / 3 1/2” (0.216” WALL) PIPE COMBO PILE (TORQUE RATING – 10,000 FT-LB



SLIP BRACKETS	
Catalog Number	Plate Size
SB08085040H	8"x8"x1/2"
SB10105040H	10”x10”x1/2”

REPAIR BRACKET
Catalog Number
DIXIE350**
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB080806CP2B**	8"x8"x1/2"
NCB101006P35	10"x10"x3/4"

REPAIR BRACKET T-PIPES
Catalog Number
B7**
B3

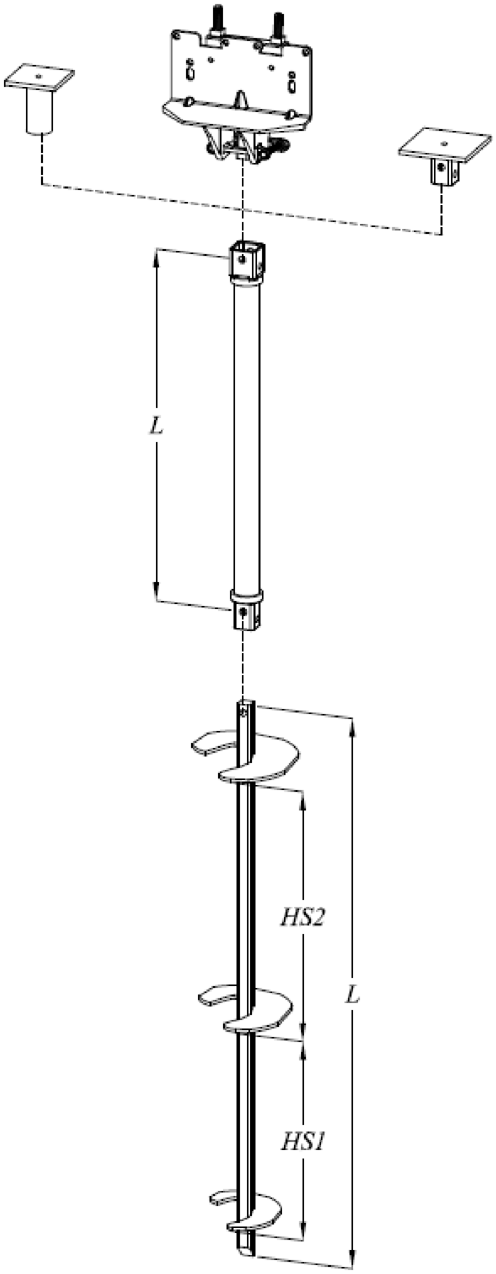
EXTENSIONS	
Catalog No.	L
P35E42**	42
P35E64**	60
P35E84**	84
P35E124**	120

LEADS^{++}				
Catalog No.	Helix Dia.	HS1	HS2	L
D17532**	8, 10	24	-	60
D17536**	8, 10, 12	24	30	84
D17537**	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast with steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 90 ksi yield strength & pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or ½” thickness.
- Connection Hardware – (7/8” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 100 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 10,000 ft-lb is 100 kips.
- **Product approved per AC358 by a third party as reported in the ICC-ES ESR-3032.
- $^{++}$This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

1-3/4” RCS / 3 1/2” (0.300” WALL) PIPE COMBO PILE (TORQUE RATING – 10,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB08085040H	8"x8"x1/2"
SB10105040H	10”x10”x1/2”

REPAIR BRACKET
Catalog Number
DIXIE350**
DIXIE350F

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB080806CP2B**	8"x8"x1/2"
NCB101006P35	10"x10"x3/4"

REPAIR BRACKET T-PIPES
Catalog Number
B08**
B3

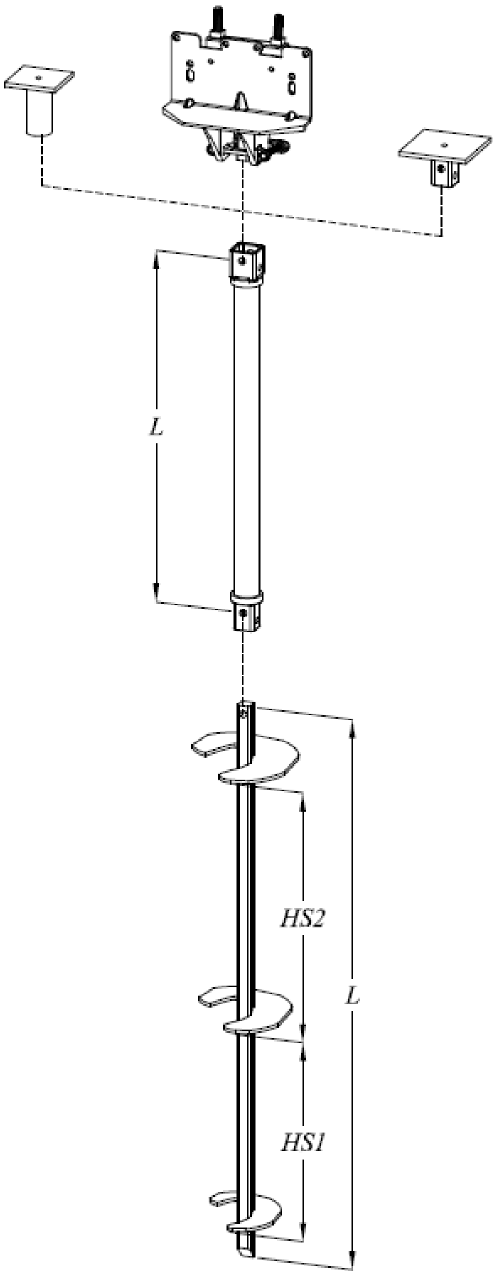
EXTENSIONS	
Catalog No.	L
P35HE42**	42
P35HE64**	60
P35HE84**	84
P35HE124**	120

LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
D17532**	8, 10	24	-	60
D17536**	8, 10, 12	24	30	84
D17537**	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast with steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 90 ksi yield strength & pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or ½” thickness.
- Connection Hardware – (7/8” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 100 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 10,000 ft-lb is 100 kips.
- **Product approved per AC358 by a third party as reported in the ICC-ES ESR-3032.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

2” RCS / 4 1/2” (0.237” WALL) PIPE COMBO PILE (TORQUE RATING – 15,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB08065040H	8"x8"x3/4"
SB10065040H	10”x10”x3/4”

REPAIR BRACKET
Catalog Number
DIXIE450

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB101006P45	10"x10"x3/4"

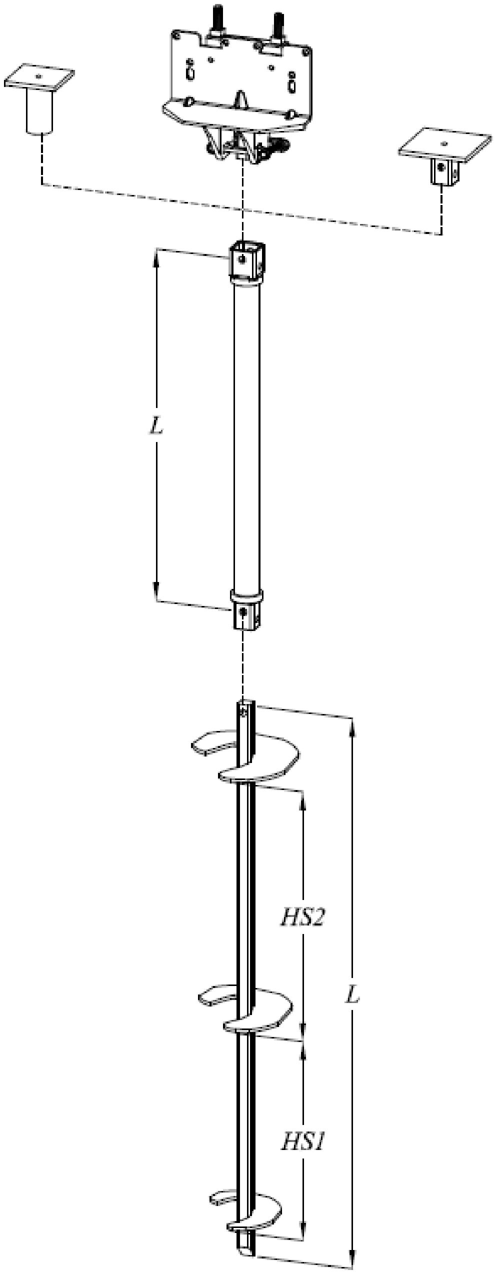
EXTENSIONS	
Catalog No.	L
P45E64	60
P45E84	84
P45E124	120

LEADS^{++}				
Catalog No.	Helix Dia.	HS1	HS2	L
D1560S810	8, 10	24	-	60
D1584S81012	8, 10, 12	24	30	84
D1584S101214	10, 12, 14	30	36	84

Notes

- “Strength Square” couplers male and female are cast with steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 90 ksi yield strength & pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 1/2” thickness.
- Connection Hardware – (RCS/pipe, 1-1/8” diameter) Bolts per SAE J429 with yellow zinc dichromate coating. (Pipe/pipe, 1” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 130 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 15,000 ft-lb is 130 kips – limited by the mechanical rating.
- $^{++}$This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

2” RCS / 4 1/2” (0.337” WALL) PIPE COMBO PILE (TORQUE RATING – 15,000 FT-LB)



SLIP BRACKETS	
Catalog Number	Plate Size
SB08065040H	8"x8"x3/4"
SB10065040H	10”x10”x3/4”

REPAIR BRACKET
Catalog Number
DIXIE450

NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB101006P45	10"x10"x3/4"

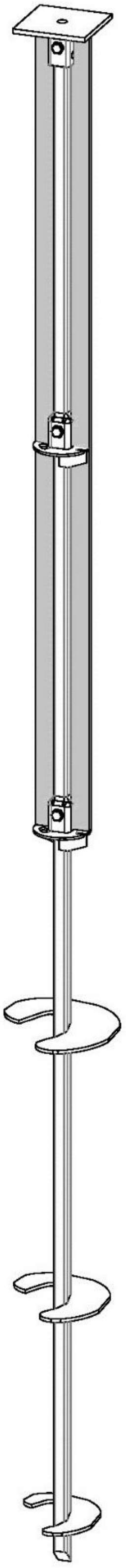
EXTENSIONS	
Catalog No.	L
P45HE64	60
P45HE84	84
P45HE124	120

LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
D1560S810	8, 10	24	-	60
D1584S81012	8, 10, 12	24	30	84
D1584S101214	10, 12, 14	30	36	84

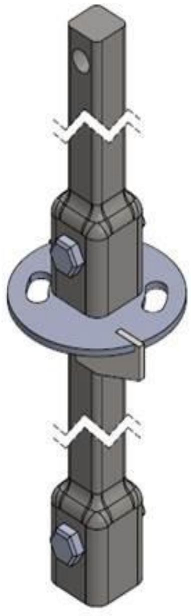
Notes

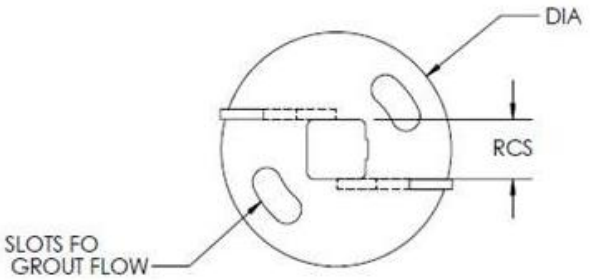
- “Strength Square” couplers male and female are cast with steel per ASTM A958, SC1045 or equal with 40 ksi yield strength.
- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 90 ksi yield strength & pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 1/2” thickness.
- Connection Hardware – (RCS/pipe, 1-1/8” diameter) Bolts per SAE J429 with yellow zinc dichromate coating. (Pipe/pipe, 1” diameter) Bolts per ASTM A325. Jam nuts per A563. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial (compression and tension) loading is 150 kips.
- Ultimate geotechnical rating with recommended Kt factor of 10 at the rated torque capacity of 15,000 ft-lb is 150 kips.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

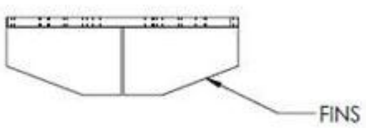
"MVP" GROUTED PILE – (1.5", 1.75", 2") RCS



SOIL DISPLACEMENT PLATES		
Catalog No.	Grout Diameter	RCS Shaft
MVP56	5	1.5"
MVP66	6	1.5"
MVP610	6	1.75"
MVP810	8	1.75"
MVP1010	10	1.75"
MVP815	8	2"
MVP1015	10	2"



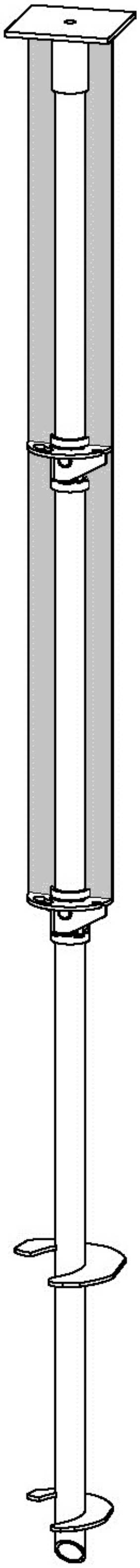




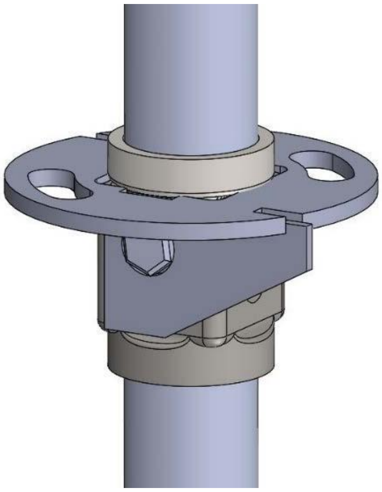
Notes

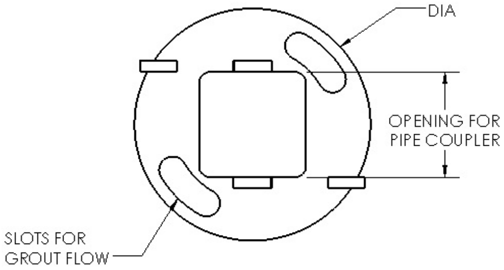
- Shaft Material - Round Corner Square (RCS) steel bar per ASTM A576 with minimum 70 ksi (S6) or 90 ksi (S7, S10 & S15) yield strength based on shaft profile.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8" or 1/2" thickness.
- Connection Hardware – Material and finish as required per shaft size.
- All welds performed by welders certified by AWS code D1.1.
- Products supplied non-galvanized.
- Ultimate mechanical rating for axial (compression & tension) loading to be calculated based on soil condition, grout column strength, and quality of installation.
- Cement based grout shall be Portland cement conforming to ASTM C150 Type I, II, III or IV.
- Concrete compressive strength, f'c, at 28 days should be at least 3,000 psi.
- Pre-packaged grout mixes should be flowable, uniform consistency and must adhere to manufacturer's instructions.

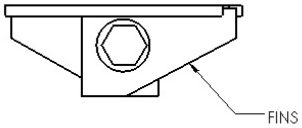
“MVP” GROUTED PILE – (2.875”, 3.50”, 4.50”) PIPE PILE



SOIL DISPLACEMENT PLATES		
Catalog No.	Grout Diameter	RCS Shaft
MVP6P28	6	2.875”
MVP8P28	8	2.875”
MVP8P35	6	3.5”
MVP10P35	10	3.5”
MVP12P35	12	3.5”
MVP10P35	10	4.5”
MVP12P45	12	4.5”



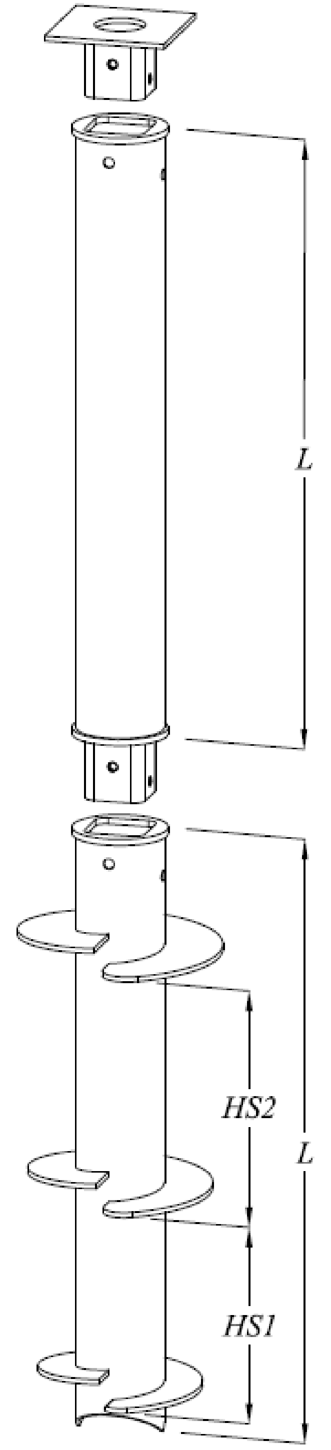




Notes

- Shaft Material – Pipe pipe per ASTM A500 Grade C with minimum 50 ksi yield strength based on shaft profile.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Cutter Plate Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength.
- Connection Hardware – Material and finish as required per shaft size.
- All welds performed by welders certified by AWS code D1.1.
- Products supplied non-galvanized.
- Ultimate mechanical rating for axial (compression & tension) loading to be calculated based on soil condition, grout column strength, and quality of installation.
- Cement based grout shall be Portland cement conforming to ASTM C150 Type I, II, III or IV.
- Concrete compressive strength, f’c, at 28 days should be at least 3,000 psi.
- Pre-packaged grout mixes should be flowable, uniform consistency and must adhere to manufacturer’s instructions.

8 5/8” (.188” WALL) PIPE PILE (TORQUE RATING – 40,000 FT-LB)



NEW CON. BRACKETS	
Catalog Number	Plate Size
NCB121204R86	12"x12"x1/2"

EXTENSIONS	
Catalog No.	L
R86LE60	60
R86LE84	84
R86LE120	120

LEADS++				
Catalog No.	Helix Dia.	HS1	HS2	L
R86L60T16	16	-	-	60
R86L84T1416	14,16	42	-	84
R86L120T141620	14,16,20	42	48	120

Notes

- Shaft Material – Pipe per ASTM A500 Grade C with a minimum 50 ksi yield strength.
- Helix Material – Hot rolled low carbon steel per ASTM A1018 Grade 55 or approved equivalent with minimum 55 ksi yield strength in 3/8” or 1/2” thickness.
- Connection Hardware – (1” diameter) Bolts per ASTM A325. Hot dipped galvanized per ASTM A153.
- All welds performed by welders certified by AWS code D1.1.
- All helices formed with nominal 3” pitch.
- Nominal spacing between helices is 3 times the diameter of the lower helix as designated as “HS1” and “HS2” below.
- Products Hot Dipped Galvanized per ASTM A123 following fabrication. Non-galvanized products are designated with a “U” catalog number suffix.
- Ultimate mechanical rating for axial loading is 200 kips (compression) and 120 kips (tension).
- Ultimate geotechnical rating with recommended Kt factor of 5 at the rated torque capacity of 40,000 ft-lb is 200 kips.
- ++This list is intended for general reference only and does not represent a complete catalog of all available helix configurations.

CONTACT US

Additional product drawings and information is available at www.macleancivilproducts.com or contact your local distributor www.macleancivilproducts.com/distributor-locations

MacLean Civil Products ICC-ES ESR-3032 report available at www.icc-es.org/reports/pdf_files/ICC-ES/ESR-3032.pdf

Real Time Design (RTD) helical pile design tool available at www.maclean.kbmax.com/products

Contact MacLean Civil Products customer service at 800-325-5360 or by filling out the Get in Touch form at www.macleancivilproducts.com/contact-us