<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>GLOSSARY OF TERMS</td>
<td>2</td>
</tr>
<tr>
<td>PRODUCT DESIGN AND SELECTION</td>
<td>3</td>
</tr>
<tr>
<td>PRELIMINARY CONSIDERATIONS</td>
<td>4</td>
</tr>
<tr>
<td>LOADS - FACTOR OR SAFETY</td>
<td>5</td>
</tr>
<tr>
<td>SOIL MECHANICS</td>
<td>6</td>
</tr>
<tr>
<td>SOIL TESTING – Torque vs. Bearing Capacity Method</td>
<td>7</td>
</tr>
<tr>
<td>ULTIMATE GEOTEchnICAL AXIAL PILE CAPACITY</td>
<td>8</td>
</tr>
<tr>
<td>• HELIX BEARING CAPACITY</td>
<td></td>
</tr>
<tr>
<td>• SKIN FRICTION AND ADHESION</td>
<td></td>
</tr>
<tr>
<td>COLUMN BUCKLING</td>
<td>9</td>
</tr>
<tr>
<td>LATERAL CAPACITY</td>
<td>10</td>
</tr>
<tr>
<td>CORROSION</td>
<td>11</td>
</tr>
<tr>
<td>PRODUCT SELECTION GUIDE</td>
<td>12</td>
</tr>
<tr>
<td>• RATED ULTIMATE MECHANICAL CAPACITY</td>
<td></td>
</tr>
<tr>
<td>• ALLOWABLE LOADS</td>
<td></td>
</tr>
<tr>
<td>PRODUCT SPECIFICATIONS</td>
<td>13</td>
</tr>
<tr>
<td>FIELD QUALITY CONTROL</td>
<td>14</td>
</tr>
<tr>
<td>LOAD TESTING</td>
<td>15</td>
</tr>
<tr>
<td>PRODUCT DRAWINGS</td>
<td>16</td>
</tr>
<tr>
<td>ER REPORT - DRAFT</td>
<td>17</td>
</tr>
</tbody>
</table>
SECTION 1

INTRODUCTION

WHAT IS A HELICAL FOUNDATION 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 Foundation Pile”. The DFI (Deep Foundation Institute) defines “pile” as the generic term for foundations.

A helical foundation pile provides the same function as other foundations such as drive pile, auger cast pile and micro-pile to support or resist loads transferred into the pile by any type of structure. This load can be tension, compression, lateral or combination. See Section 8 for a detailed discussion concerning loads.

A helical foundation 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 foundation piles are installed into the ground by 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 4 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. This is one of the major advantages of foundation piles. See Section 12.

A helical pile includes three components:

1. Shaft:

   Shaft sizes typically range from 1.25” to 2.00” Round Cornered Square (RCS) high strength steel bar and from 2-7/8” to 8.625” diameter hollow steel pipe. Soil conditions and expected loads that will result from installation and application 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 at least four functions –
   
   a. To sustain sufficient torque capacity to install the pile
   b. To sustain loads transferred from the helices – during and after installation
   c. To sustain loads transferred from the structure – after installation
   d. To provide the proper connection (interface) to the structure

2. Helices:

   Helical foundation 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 diameter helices 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 Screw Pile Foundation. This method utilizes the Terzaghi’s general bearing equation:

   \[ q_{ult(g)} = A_h \times ((c \times N_c) + (q \times N_q)) \]
The above equation and its application for Helical Foundation Pile Systems will be discussed in detail in Section 5.

Helices have at least four functions –

a. To pull the pile into the soil to the required depth - during installation  
b. To provide the required torque and bearing capacity - during and after installation  
c. To transfer load into the soil by means of exerting bearing pressure - after installation  
d. To provide the required strength (welded connection) between the helix and shaft

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 brackets to slip fit bracket 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 foundation 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 foundation piles than with other types of foundation systems.
- In addition to significant cost savings, the smaller (less specialized) installation equipment, used with helical foundation, allows for quick responses to situations requiring immediate action.  
- The relatively small size of the installation equipment allows for MacLean-Dixie piles to be installed in confined areas (such as inside buildings or areas with low head room clearance) where other conventional means of foundations would be neither feasible nor practical. In some cases the installation equipment can be hand held. 
- The installation of a helical foundation pile is virtually vibration free, thus allowing installation near existing foundations or footings.
- Onsite Quality Control: By applying the torque vs. capacity relationship, the ultimate capacity of the pile can be determined at the time of its installation.  
- The installation of screw pile foundations does not create spoils. This eliminates the time and cost associated with spoil removal and disposal.

Environmental:

- Installation is virtually vibration free and a benefit where vibration can be detrimental to existing structures. 
- Noise level is relatively low.
- Due to the low vibration and noise level, MacLean-Dixie 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.
- Contributes to “GREEN” environment

Seismic Loads – New Construction and Seismic Retrofit:

- During seismic events, the flexibility of the steel shafts used with MacLean-Dixie helical foundation piles will better accommodate movement than conventional shallow foundation systems. The advantages of helical pile foundations to resist seismic loads are now recognized in areas prone to seismic activity.
HISTORY

1800’s

Alexander Mitchell developed power-installed helical foundations in England in the early 1800’s. These power-installed foundations were used in conjunction with the construction of several lighthouses in the English tidal basin.

1920’s

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

1950’s

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

1960’s

The use of the helical screw 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 helical screw anchors including foundation. 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, DOT and Tiebacks for earth retaining walls.

Present:

The use of helical piles now include, temporary and permanent earth retaining systems (tieback anchors), underpinning system for structures subjected to settlement, pipeline supports, buoyancy control for underground or underwater pipelines, equipment mounts, street light foundations and new construction. Geotechnical engineers have become increasingly aware of helical screw pile foundations and their applications.

In addition to providing foundation solutions to residential foundations, MacLean-Dixie helical piles have been used to entirely support a 9-story commercial structure.

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 screw anchor industry.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable Load – Mechanical (ALm)</td>
<td>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.</td>
</tr>
<tr>
<td>Allowable Load – Geotechnical (ALg)</td>
<td>The maximum allowable load that may be transferred into a helical foundation 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.</td>
</tr>
<tr>
<td>Creep</td>
<td>The continuous deflection (movement) of a pile while subjected to a constant load.</td>
</tr>
<tr>
<td>Crowd</td>
<td>Axial compressive force applied to the helical foundation pile as needed to ensure that the helical foundation pile advances into the ground a distance equal to the helix pitch for each revolution.</td>
</tr>
<tr>
<td>Dead Load</td>
<td>Loads resulting from the weight of the structure plus all material (equipment) permanently fastened thereto or supported thereby.</td>
</tr>
<tr>
<td>Design Load (DL)</td>
<td>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 and Working Load.</td>
</tr>
<tr>
<td>Effective Torsional Resistance</td>
<td>Effective Torsional Resistance is used to estimate Ultimate Geotechnical Capacity of a pile during construction. Helical foundation piles are typically installed to a predetermined Specified Installation Torque.</td>
</tr>
<tr>
<td>Extension With Helix</td>
<td>Same as a Plain Extension, but with one or more helices welded to it. Typically used where headroom limitations requires a shorter lead and extension with helix are used to install all the required helices. Also used when additional helices are required as an onsite modification when unexpected weak soils are encountered and additional helices are required. The Extension With Helix is attached directly above the Helical Lead section or sometimes above other helical extensions.</td>
</tr>
</tbody>
</table>
**Factor of Safety**
See Safety Factor.

**Failure – Geotechnical**
Unless otherwise noted, geotechnical failure is achieved 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 Compression, Tension, Lateral or Dynamic.

**Geotechnical Capacity**
The maximum load that can be resisted via the bearing of helical plates on the soil and skin friction or adhesion between the soil and shaft 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 Screw Pile Foundation 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 rotated in the ground, the helical shape provides thrust along its longitudinal axis thus aiding in the helical foundation pile installation, plus the plate transfers axial load to the soil through bearing after installation.

**Live Load**
Loads resulting from vehicles, people, snow, ice, wind, and impact. Other forces resulting from earthquakes and other extraordinary conditions.

**Load Test**
Determining capacity and relation of load to movement by applying incremental loads to the helical screw 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 Foundation 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 Foundation 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 Foundation 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
<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft</td>
<td>The central shaft of a Helical Foundation Pile Anchor used to transfer load from the structure to the bearing plate/s (helices). Shafts may be solid square steel bar or hollow steel pipe sections. Shaft sizes typically range from 1.25” to 2.00” Round Cornered Square, and from 2.875” to 8.625” diameter hollow round.</td>
</tr>
<tr>
<td>Specified Installation Torque</td>
<td>The Effective Torsional Resistance to be achieved - as specified by the engineer.</td>
</tr>
<tr>
<td>Ultimate Pile Capacity - Geotechnical</td>
<td>The maximum load that can be applied to a Helical Foundation Pile prior to geotechnical failure. At this point no additional capacity can be justified.</td>
</tr>
<tr>
<td>(UCg)</td>
<td></td>
</tr>
<tr>
<td>Ultimate or Rated Pile Capacity -</td>
<td>The manufacturers' Rated Ultimate Mechanical Capacity of the Helical Foundation Pile.</td>
</tr>
<tr>
<td>Mechanical</td>
<td></td>
</tr>
<tr>
<td>(UCm)</td>
<td></td>
</tr>
<tr>
<td>Ultimate Pullout Resistance</td>
<td>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.</td>
</tr>
<tr>
<td>Working Load</td>
<td>See Design Load.</td>
</tr>
</tbody>
</table>
PRODUCT DESIGN AND SELECTION FLOW CHART

The following includes some of the basic items to be considered before recommending a particular Helical Foundation Pile configuration. A flow chart outlining the basic steps is shown on Page 3.3.

1. A DEEP FOUNDATION IS REQUIRED

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

2. PROJECT PARAMETERS

The owner (or his consultant) submits the pertinent project information to the MACLEAN-DIXIE dealer, 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:
  - Head Room clearance.
  - Proximity to existing structures.
  - Access to jobsite
  - Underground Obstructions
  - Expected depth of water during and after construction

3. PRELIMINARY REVIEW

The MACLEAN-DIXIE dealer, distributor or consultant reviews the project information regarding the application of Helical Foundation piles for the project.

Are MACLEAN-DIXIE Helical Foundation 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 Foundation 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. MACLEAN-DIXIE typically recommends a minimum Safety Factor (SF) 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 (>= 4.5” dia. shaft size) skin friction between the pile 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 MACLEAN-DIXIE 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

An experienced MACLEAN-DIXIE dealer, distributor or consultant will make product recommendations based on the following items. Depending upon specific project parameters, additional items, not listed below, may also require consideration.

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

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 <= 4?

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

Scope:

The purpose of a Helical Foundation 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 COMPRESSION. 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 = 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 Foundation Pile that passes through this active zone is often reduced in size so as to minimize skin friction. When 1.25” 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 Foundation Pile > = (Design Load) x (Safety Factor)  [Equation 5.2]

Where:

Ultimate Capacity of a Helical Foundation 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 Foundation Pile to its Design Load.

A Safety Factor of 2 is often applied for Helical Foundation 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: Soil mechanics is the science of understanding and predicting how soil will respond to externally applied forces or pressures. 3

What is Soil? Soil is produced from rock by a process of weathering, i.e. the breaking down of rock into smaller and smaller pieces through mechanical and chemical processes.

Two 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. The manner in which these soils are transported can be applied to further categorize this type of soil. See Table 6.1.

<table>
<thead>
<tr>
<th>Types</th>
<th>Manner of Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial or Fluvial</td>
<td>running water</td>
</tr>
<tr>
<td>Glacial</td>
<td>glacier action</td>
</tr>
<tr>
<td>Aeolian</td>
<td>wind action</td>
</tr>
</tbody>
</table>

Soil Characterization: Most soil classification systems used in construction classify soils based upon two experimental characterizations of soil. These two measurements are (1) grain-size distribution curve (or graduation curve), and (2) soil consistency (Atterberg limits). 3 These two methods of soil classification are discussed in the following paragraphs.

Grain-Size Distribution Curve: Grain-size analyses can be either mechanical or performed with a hydrometer. The mechanical method (Sieve Analysis) will be discussed here.

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 6.1 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).

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>Weight Retained (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot; (9.5)</td>
<td>43</td>
</tr>
<tr>
<td>No. 4 (4.75)</td>
<td>195</td>
</tr>
<tr>
<td>No. 10 (2.00)</td>
<td>281</td>
</tr>
<tr>
<td>No. 40 (.425)</td>
<td>127</td>
</tr>
<tr>
<td>No. 100 (.150)</td>
<td>44</td>
</tr>
<tr>
<td>No. 200 (.075)</td>
<td>25</td>
</tr>
<tr>
<td>Pan (&lt;.075)</td>
<td>135</td>
</tr>
</tbody>
</table>

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
### Solution to Problem 6.1

<table>
<thead>
<tr>
<th>SIEVE NO.</th>
<th>SIEVE DIA mm</th>
<th>PERCENT PASSING OF TOTAL %</th>
<th>MASS OF SOIL THRU EACH SIEVE</th>
<th>MASS AMOUNT PASSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3/8</td>
<td>9.500</td>
<td>850.000</td>
<td>807.000</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4.750</td>
<td>612.000</td>
<td>607.000</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>2.000</td>
<td>331.000</td>
<td>321.000</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>0.425</td>
<td>204.000</td>
<td>200.000</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>0.150</td>
<td>160.000</td>
<td>151.000</td>
</tr>
<tr>
<td>6</td>
<td>200</td>
<td>0.075</td>
<td>135.000</td>
<td>131.000</td>
</tr>
<tr>
<td>7</td>
<td>pan</td>
<td>0.010</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

**TOTAL** 850

### Figure 6.1

**Grain Size Distribution Curve - Semi Log**

D (50) = The average sieve opening that allows 50% by weight to pass through
D (60) = The average sieve opening that allows 60% by weight to pass through
D (30) = The average sieve opening that allows 30% by weight to pass through
D (10) = The average sieve opening that allows 10% by weight to pass through

D (50) = 2.800 approx.
D (60) = 3.400 approx.
D (30) = 1.200 approx.
D (10) = 0.030 approx.

Cu = Uniformity Coefficient = \( \frac{D(60)}{D(10)} = 113.3333 \)
$Cc = \text{Coefficient of Curvature (Graduation)}$

$Cc = \frac{D(30)^2}{D(60) \times D(10)} = 14.118$

According to the Unified Soil Classification System:

- Gravel ($>4.75 \text{ mm}$) = 28%
- Sand ($<4.75 \text{ mm} > .075 \text{ mm}$) = 56%
- Clay / Silt ($< .075 \text{ mm}$) = 16%

100%

**Table 6.2**

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

1 mm = .03937 inch
Figure 6.3 Typical Grain Size Distribution (Graduation Curve)
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](image)

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 volume of soil.

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. (i.e. 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 ($S_i$) 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 ($S_i$) for the vast majority of clays range between 2 and 4 and are considered Insensitive. For sensitive clays, ($S_i$) can range from 4 to 8. For extra sensitivity clays, ($S_i$) can range between 8 and 16. Clays with ($S_i$) greater than 16 are described as quick clays. Highly sensitive soils should be avoided when installing any type of pile. When installing Helical Foundation 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 6.5.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Classification</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW</td>
<td>Substantial amounts of all grain particle sizes</td>
<td>Predominantly one size or range of sizes with some intermediate sizes missing</td>
</tr>
<tr>
<td>GP</td>
<td>Predominantly one size or range of sizes with some intermediate sizes missing</td>
<td>Substantial amounts of all grain particle sizes</td>
</tr>
<tr>
<td>GM</td>
<td>Wide range in grain size and substantial amounts of all grain particle sizes</td>
<td>Plastic fines (to identify, see ML below)</td>
</tr>
<tr>
<td>GC</td>
<td>Plastic fines (to identify, see CL below)</td>
<td>Predominantly one size or range of sizes with some intermediate sizes missing</td>
</tr>
<tr>
<td>SW</td>
<td>Predominantly one size or range of sizes with some intermediate sizes missing</td>
<td>Plastic fines (to identify, see CL below)</td>
</tr>
<tr>
<td>SP</td>
<td>Plastic fines (to identify, see CL below)</td>
<td>Predominantly one size or range of sizes with some intermediate sizes missing</td>
</tr>
<tr>
<td>SM</td>
<td>Predominantly one size or range of sizes with some intermediate sizes missing</td>
<td>Plastic fines (to identify, see CL below)</td>
</tr>
<tr>
<td>SC</td>
<td>Plastic fines (to identify, see CL below)</td>
<td>Predominantly one size or range of sizes with some intermediate sizes missing</td>
</tr>
<tr>
<td>ML</td>
<td>Will not leave a stain on a wet palm.</td>
<td>Will leave a stain on a wet palm.</td>
</tr>
<tr>
<td>CL</td>
<td>Will leave a stain on a wet palm.</td>
<td>Will leave a stain on a wet palm.</td>
</tr>
<tr>
<td>MH</td>
<td>Will leave a stain on a wet palm.</td>
<td>Will leave a stain on a wet palm.</td>
</tr>
<tr>
<td>CH</td>
<td>Will leave a stain on a wet palm.</td>
<td>Will leave a stain on a wet palm.</td>
</tr>
<tr>
<td>OL</td>
<td>Will leave a stain on a wet palm.</td>
<td>Will leave a stain on a wet palm.</td>
</tr>
<tr>
<td>OH</td>
<td>Will leave a stain on a wet palm.</td>
<td>Will leave a stain on a wet palm.</td>
</tr>
<tr>
<td>Pt</td>
<td>Will leave a stain on a wet palm.</td>
<td>Will leave a stain on a wet palm.</td>
</tr>
</tbody>
</table>

Table 6.5 Soil Identification: Unified Soil Classification System
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 SiO$_2$. 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.

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. The capacity of a Helical Foundation 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 firm usually performs the types of tests 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 (FA) based on SPT “N” values**: Should be used with caution and only when other information is not made available. Soil-boring logs often do not include tested values for the angle of internal friction (FA), but usually include SPT "N" values of the soil.

For foundation design, the SPT or Standard Penetration Test is the most widely used method in the U.S. for soil exploration and testing. The SPT method will be discussed in detail later in this section.
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.

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 firm usually performs the types of tests shown below during or immediately after their sub-surface exploration. The results of the tests are included in their geotechnical report and sub-surface exploration report.

1. **Unconfined Compression Test**: Widely used method. 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* (q_u) of the soil. 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 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.

3. **Pocket Penetrometer**: Generally not considered as accurate as the above methods. 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 and assumes saturated clay of medium plasticity. See Note 1 at the end of this Section.

\[
\text{Cohesion (ksf)} = \frac{\text{SPT “N” value}}{8} \quad [\text{Equation 6.1}]
\]

The design method discussed in 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 method discussed in 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 or shrinkage] is expected to develop.\(^5\)

Loads transferred into the pile from either soil expansion or 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 MACLEAN-DIXIE Helical Foundation Piles. The small surface area of these piles minimizes skin friction. When using 1.25” sq. to 2.00 sq. helical anchors, skin friction forces can be disregarded with little error.

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

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

2. A 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 Foundation 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. The sum of the last 12 inches of penetration is referred to as the “SPT “N” value” at the sounding depth.
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. Always ask questions. 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
### Figure 6.6 Typical Soil Boring Log

**SAMPLE**

<table>
<thead>
<tr>
<th>Depth Below Surface (ft)</th>
<th>Casing per ft</th>
<th>Sampler per 6 Inches</th>
<th>ID</th>
<th>Depth (ft)</th>
<th>Identification of Soils/Remarks</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>A</td>
<td>0-2</td>
<td>S-1 Orange-Yellow cmf SAND, trace Silt, trace mf Gravel, (moist)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td></td>
<td>B</td>
<td>2-4</td>
<td>S-2 Yellow-Brown cmf SAND, trace Silt, trace mf Gravel. (moist)</td>
<td>F</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td></td>
<td>C</td>
<td>4-6</td>
<td>S-3 Dk. Brown cmf Sand, and Silt</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
<td>D</td>
<td>6-8</td>
<td>S-4 Dk. Brown-Reddish m’l SAND, little” Silt. (moist)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td></td>
<td>E</td>
<td>8-10</td>
<td>S-5 Dk. Brown-Reddish m’l SAND, little Silt, trace” decayed vegetation. (wet)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td></td>
<td>F</td>
<td>10-12</td>
<td>S-6 Top: Brown-Reddish m’l SAND, trace” Silt. (wet)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td></td>
<td>G</td>
<td></td>
<td>Bot: “Yellow-Gray cmf SAND, trace Silt, trace’ mf Gravel, trace’ decayed wood,</td>
<td>13.0’</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td></td>
<td>H</td>
<td></td>
<td>S-7 Gray Organic SILT, little” Peat, trace’ mf Sand. (med soft to firm) (wet)</td>
<td>MO1</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td></td>
<td>I</td>
<td></td>
<td>Recovery = 13” P.P.=0.25, TV=2.0-1.0 tsf</td>
<td>18.5’</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>J</td>
<td></td>
<td>UD-1 Gray Organic SILT, little” Peat. Found</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td>K</td>
<td></td>
<td>m” SAND, little” Silt @ bottom of tube. Rec = 23 3/4”</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td>L</td>
<td></td>
<td>S-8 Gray m”l SAND, trace” Silt. (organic odor)</td>
<td>SB2</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td>M</td>
<td></td>
<td>S-9 Gray Organic SILT, trace’ mf Sand. (wet)</td>
<td>MO3</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td>N</td>
<td></td>
<td>Recovery=24” P.P.=0.25 tsf, TV=3.75-1.0 tsf</td>
<td>28.0’</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td>O</td>
<td></td>
<td>UD-2 Gray mf SAND, little” Organic Silt. Recovery 10”</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td>P</td>
<td></td>
<td>S-10 Gray mf Sand, and” Silt. (organic odor)</td>
<td>MO3</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td>Q</td>
<td></td>
<td>S-11 Gray mf SAND, little” Silt. (organic odor)</td>
<td>MO3</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td>R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td>T</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td>U</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td>V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td>W</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
<td>Z</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td>AA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td>AB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
<td>AC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td>AD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td></td>
<td></td>
<td>AE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td></td>
<td></td>
<td>AF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
<td></td>
<td>AG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td></td>
<td></td>
<td>AH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td>AI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td></td>
<td></td>
<td>AJ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td></td>
<td></td>
<td>AK</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td></td>
<td></td>
<td>AL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td></td>
<td></td>
<td>AM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td>AN</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Relative Density (Dr) Of Granular Soils**

<table>
<thead>
<tr>
<th>Clayey Soils</th>
<th>Relative Density (Dr) Of Granular Soils</th>
<th>Consistency of Clayey Soils</th>
<th>Proportions Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clayey Silt</td>
<td>0-15%</td>
<td>soft (S)</td>
<td>trace 1-10%</td>
</tr>
<tr>
<td>Silt &amp; Clay</td>
<td>15-35%</td>
<td>firm (F)</td>
<td>little 10-20%</td>
</tr>
<tr>
<td>Clay &amp; Silt</td>
<td>35-65%</td>
<td>med hard (MH)</td>
<td>some 20-35%</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>65-85%</td>
<td>hard (H)</td>
<td>and 35-50%</td>
</tr>
<tr>
<td>Clay</td>
<td>85-100%</td>
<td>very hard (VH)</td>
<td></td>
</tr>
</tbody>
</table>

**VISUAL IDENTIFICATION TERMS USED**

- **Plain Text Representation**
NOTES:
1. The determination of the values 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.

References:
3. Arnold Verruijt, Soil Mechanics, 2001, Delft University of Technology, Netherlands
6. University of Florida – IFAS Extension, Fact Sheet SL-29, Soil Texture

* * * * *
SECTION 7

SOIL TESTING - TORQUE vs. BEARING CAPACITY
Helical Foundation Piles

Scope:

Because of the abundance of empirical data (gathered over the last 20 yrs) regarding installation torque vs. tension capacity, the following test provides information that can be used, in conjunction with existing geotechnical reports and bore 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.

Procedure:

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 (ft²) multiplied by the Bearing Stress Capacity (psf) of the soil.

- The Ultimate Bearing Capacity (lbs) of the helix can also be equated to F₁ (ft⁻¹) x Torque (ft-lbs).

So, equating the two relationships shown above:

[Helix Area (ft²)] x [Ultimate Bearing Stress Capacity of the soil (psf)] = F₁ (ft⁻¹) x Torque (ft-lbs)

So:

Ultimate Bearing Stress Capacity of the Soil (psf) = \[
\frac{F_1 \times \text{Torque (ft-lbs)}}{\text{Helix Area (ft²)}}
\] [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 quick pull test cannot be performed, we recommend that a Torque Factor (F₁) of 10 ft⁻¹ be applied for square shaft anchors as discussed in this manual.

Applying a value of 10 for F₁ 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 Foundation Piles

Solution:

1. A test Helical Foundation 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 $F_t = 10$.

   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 50,868 lbs. Based on a safety factor of 2, the allowable design load for this pile would be 25,434 lbs. ($25 \text{ kips} > 20 \text{ kips} = \text{OK}$) 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 $50,868 \text{ lbs} / 10 \text{ ft} = 5,087 \text{ ft-lbs}$. 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 -
  $9 \times c = \text{Soil bearing stress capacity (ksf)}$ – Equation 8.3
  $N / 8 = c \text{ (ksf)}$ – Equation 8.4
  So: $Nc \times (N/8) = \text{Soil bearing stress capacity (ksf)}$, $Nc = 9$ – See Equation 8.3
  Let $N = 4$ (SPT N-values of 4 or less indicate that bucking may occur.)
  So: $9 \times (4/8) = \text{Soil bearing stress capacity (ksf)} = 4.5 \text{ ksf} = 4,500 \text{ psf}$
  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.
  $6,024 \text{ psf} > 4,500 = \text{OK}$ – 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).
SECTION 7

Example Problem No. 7.1

TEST ANCHOR:

<table>
<thead>
<tr>
<th>Qty of Helixes</th>
<th>1 ea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Helix Dia.</td>
<td>14 in</td>
</tr>
<tr>
<td>Gross Helix Area</td>
<td>1.017 sq ft</td>
</tr>
<tr>
<td>Shaft Size</td>
<td>1.75 in Sq.</td>
</tr>
<tr>
<td>Net Helix Area</td>
<td>0.9960 sq ft</td>
</tr>
<tr>
<td>Torque Factor</td>
<td>10</td>
</tr>
</tbody>
</table>

LOG SHEET NO. 7.1

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Torque (ft-lbs)</th>
<th>Soil Bearing Capacity (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>600</td>
<td>6.024</td>
</tr>
<tr>
<td>2</td>
<td>600</td>
<td>6.024</td>
</tr>
<tr>
<td>3</td>
<td>600</td>
<td>6.024</td>
</tr>
<tr>
<td>4</td>
<td>600</td>
<td>6.024</td>
</tr>
<tr>
<td>5</td>
<td>600</td>
<td>6.024</td>
</tr>
<tr>
<td>6</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>7</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>8</td>
<td>1,250</td>
<td>12.550</td>
</tr>
<tr>
<td>9</td>
<td>1,250</td>
<td>12.550</td>
</tr>
<tr>
<td>10</td>
<td>1,250</td>
<td>12.550</td>
</tr>
<tr>
<td>11</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>12</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>13</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>14</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>15</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>16</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>17</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>18</td>
<td>750</td>
<td>7.530</td>
</tr>
<tr>
<td>19</td>
<td>1,750</td>
<td>17.570</td>
</tr>
<tr>
<td>20</td>
<td>1,750</td>
<td>17.570</td>
</tr>
<tr>
<td>21</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>22</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>23</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>24</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>25</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>26</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>27</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>28</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>29</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>30</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>31</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>32</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>33</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>34</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>35</td>
<td>2,275</td>
<td>22.841</td>
</tr>
<tr>
<td>36</td>
<td>3,750</td>
<td>37.651</td>
</tr>
<tr>
<td>37</td>
<td>3,750</td>
<td>37.651</td>
</tr>
<tr>
<td>38</td>
<td>3,750</td>
<td>37.651</td>
</tr>
<tr>
<td>39</td>
<td>3,750</td>
<td>37.651</td>
</tr>
<tr>
<td>40</td>
<td>3,750</td>
<td>37.651</td>
</tr>
</tbody>
</table>

Estimated Soil Bearing Capacity

In this case, the Ultimate Pile Capacity would be 50,868 lbs. (50 kips) for compression and tension.

Based on a safety factor of 2, the allowable Design Load for this pile would be 25,434 lbs. (25 kips) for compression and tension.
ULTIMATE GEOTECHNICAL AXIAL PILE CAPACITY

Part 1 - Individual Plate Capacity (IPC) Method


Parameters:

1. This method addresses the theoretical ultimate helix / soil bearing capacity of a helical foundation 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 Foundation 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

\[ q_{ult(g)} = A_h \times ((c \times N_c) + (q \times N_q) + (.5 \times U_W \times B \times N_b)) \]

\( A_h = \) 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 \( (\phi) \) 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

\( U_W = \) Effective Unit Weight of the soil.

\( B = \) Base Width

For Helical Foundation Piles, the base width term \( (.5 \times U_W \times B \times N_b) \) 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).
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 ($\phi$). 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. $N_q$ is a function of the angle of internal friction ($\phi$) of the cohesionless soil and is referred to as the friction term. Chart 8.1 is based on Terzaghi’s equation for $N_q$ - 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 up to 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 capacity 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 $\phi = 0.00$ DEG)**

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.

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

Most boring logs include blow counts $N$ (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.

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

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

$$c = 1/2 \times q_u \quad [\text{Equation 8.4a}]$$

Where: $q_u =$ Unconfined Compressive Strength
COHESIONLESS SOILS  (c = 0.00)

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

\[ q_{ult(g)} = A_h \times (q \times N_q) \]  

[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.

\( N_q = \) 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 \( N_q \) modified for Helical Foundation Piles by applying a reduction factor of .60. See Example Problems 8.1 and 8.2.

\[ N_q = 0.60 \times \frac{a^2}{2 \times \cos^2 \left(0.7854 + \frac{\phi}{2}\right)} \]  

[Equation 8.5a]

\( a = e^{(0.75\pi - \phi/2)} \times \tan \phi \)

\( \phi = \) Angle of internal friction (radians)

Chart 8.1

![Chart 8.1: Estimated Bearing Capacity Factor (Nq) - Granular Cohesionless Soils](chart.png)
### Table 8.1
#### Angle of Internal Friction ($\phi$) vs. Nq
##### For Helical Foundation Piles

Granular Cohesionless Soils

<table>
<thead>
<tr>
<th>$\phi$</th>
<th>Nq</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>4.463</td>
</tr>
<tr>
<td>21</td>
<td>4.959</td>
</tr>
<tr>
<td>22</td>
<td>5.514</td>
</tr>
<tr>
<td>23</td>
<td>6.138</td>
</tr>
<tr>
<td>24</td>
<td>6.841</td>
</tr>
<tr>
<td>25</td>
<td>7.632</td>
</tr>
<tr>
<td>26</td>
<td>8.526</td>
</tr>
<tr>
<td>27</td>
<td>9.538</td>
</tr>
<tr>
<td>28</td>
<td>10.685</td>
</tr>
<tr>
<td>29</td>
<td>11.989</td>
</tr>
<tr>
<td>30</td>
<td>13.473</td>
</tr>
<tr>
<td>31</td>
<td>15.169</td>
</tr>
<tr>
<td>32</td>
<td>17.110</td>
</tr>
<tr>
<td>33</td>
<td>19.338</td>
</tr>
<tr>
<td>34</td>
<td>21.903</td>
</tr>
<tr>
<td>35</td>
<td>24.864</td>
</tr>
<tr>
<td>36</td>
<td>28.294</td>
</tr>
<tr>
<td>37</td>
<td>32.279</td>
</tr>
<tr>
<td>38</td>
<td>36.928</td>
</tr>
<tr>
<td>39</td>
<td>42.369</td>
</tr>
<tr>
<td>40</td>
<td>48.762</td>
</tr>
<tr>
<td>41</td>
<td>56.308</td>
</tr>
<tr>
<td>42</td>
<td>65.250</td>
</tr>
<tr>
<td>43</td>
<td>75.899</td>
</tr>
<tr>
<td>44</td>
<td>88.642</td>
</tr>
<tr>
<td>45</td>
<td>103.971</td>
</tr>
</tbody>
</table>
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 Chart 8.2 shows an approximate relationship between SPT N blow count and angle of internal friction. Chart 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:

\[
\text{Friction Angle (} \phi \text{) } = 27 + .31 \times \text{N}(70)
\]  

[Equation 8.6]

MIXED OR c - \( \phi \) 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 - \( \phi \) 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 - \( \phi \) 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), he 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 Foundation 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.
ULTIMATE GEOTECHNICAL AXIAL PILE CAPACITY

Part 2 – A Method of Determining Friction (Adhesion) Between Soil and Pile Surface


Skin friction between the soil and pile surface of Helical Foundation Piles with shaft sizes of 3.5” OD or less is 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 Naval Design Manual 7.02 and is discussed below.

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

\[ Q_T = Q_H + Q_F \]  

[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**

\[ Q_F = \sum (C_A \times (\pi \times D) \times dL) \]  

[Equation 8.6b]

Where:

\( C_A \) = Adhesion based on the soil’s cohesion as shown on the table (shown below) in the Navy Design 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**

<table>
<thead>
<tr>
<th>Consistency of Soil</th>
<th>Cohesion, C (psf)</th>
<th>Adhesion, C_A (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Soft</td>
<td>0 - 250</td>
<td>0 - 250</td>
</tr>
<tr>
<td>Soft</td>
<td>250 - 500</td>
<td>250 - 460</td>
</tr>
<tr>
<td>Med. Stiff</td>
<td>500 - 1000</td>
<td>460 - 700</td>
</tr>
<tr>
<td>Stiff</td>
<td>1000 - 2000</td>
<td>700 - 720</td>
</tr>
<tr>
<td>Very Stiff</td>
<td>2000 - 4000</td>
<td>720 - 750</td>
</tr>
</tbody>
</table>
COHESIONLESS (GRANULAR) SOILS

\[ Q_F = \sum (q \times K \times \tan (\phi')) \times \pi \times D \times dL \]  
[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.

- \( \phi' \) = 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 the 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.

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:


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 (feel) 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 ($\phi$) should be entered directly as degrees (not radians).

$$N_q = \frac{0.60 \times e^{(0.75 \times \pi() - \phi \times \pi() / 360) \times \tan(\phi \times \pi() / 180))^2}}{(2 \times \cos(0.7854 + \phi \times \pi() / 360))^2}$$

Where:
- $e = 2.7182818$
- $\phi = \text{Angle of Internal Friction - degrees}$
- $\pi() = \pi$

Example 8.1 shows the results of applying an Excel spreadsheet to determine the capacity of a 1.75" square shaft anchor with a helix configuration of 8", 10" and 12". In this example, a portion of the pile passes through very soft clay and a check for column buckling (Section 9) is required.

An example of a "hand calculation" for this problem is also shown in Example Problem 8.2.
## Example 8.1
### Helix Bearing Capacity

**PARAMETERS:**
- Ultimate Compressive Load: 40 kips
- Ultimate Tension Load: 38 kips
- Estimated Number of Piles (ea): 60

**PRELIMINARY CALCULATION:**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>SPT N (Blows/ft)</th>
<th>Shear Strength (Calculated) (in)</th>
<th>Number of Piles</th>
<th>Pressure (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C L A Y</td>
<td>6</td>
<td>0.750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C L A Y</td>
<td>6</td>
<td>0.750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C L A Y</td>
<td>6</td>
<td>0.750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C L A Y</td>
<td>6</td>
<td>0.750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C L A Y</td>
<td>6</td>
<td>0.750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C L A Y</td>
<td>6</td>
<td>0.750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C L A Y</td>
<td>6</td>
<td>0.750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C L A Y</td>
<td>6</td>
<td>0.750</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PILE SURFACE FRICTION FACTOR:** 0.064 (no skin friction)

At a minimum depth of 41 ft., the ultimate geotechnical compressive capacity of this pile is 40 kips and the ultimate tension (split) capacity is 38 kips.

Applying a torque factor (Kt) of 10 for RC shaft piles, the recommended average torque for the last 3 ft. of installation shall be \( k = 4,000 \) ft. lbs. of constant or increasing torque.

Note that the upper portion of the pile passes through a very soft area of clay with SPT "N" values of \( < 8 \). This requires that the buckling strength of the pile be considered. Using the Davison (1963) method and applying a value of 12 pcf for the Modulus of Subgrade Reaction (KH) shows the critical buckling load for this pile to be 43.36 kips.

\[ 43.36 \text{ kips} > 40 \text{ kips} \Rightarrow \text{OK} \]

The Working Load or Allowable Load for this pile shall be determined by applying an appropriate safety factor to the pile's Ultimate Capacity.

### ULT. THEORETICAL GEOTECHNICAL BEARING CAPACITY OF HELIXES

#### Pile #1:

- **VERTICAL DEPTH OF BOTTOM HELIX:** 41.00 ft. from T.O.G.
- **MAXIMUM TENSION CAPACITY:** 39.92 kips
- **MAXIMUM COMPRESSION CAPACITY:** 41.63 kips

### HELIX LOADS

<table>
<thead>
<tr>
<th>Helix No.</th>
<th>Nom Dia in (in)</th>
<th>Ultimate Tension (kips)</th>
<th>Ultimate Comp. (kips)</th>
<th>Nominal Vertical Depth of Helix (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>18.29</td>
<td>18.29</td>
<td>35.600</td>
</tr>
<tr>
<td>2</td>
<td>13.24</td>
<td>39.00</td>
<td></td>
<td>43.000</td>
</tr>
<tr>
<td>SUM</td>
<td></td>
<td></td>
<td></td>
<td>82.600</td>
</tr>
</tbody>
</table>

### THEORETICAL ULTIMATE AXIAL GEOTECHNICAL PILE CAPACITY

- **TENSION:** 39.92 kips
- **COMPRESSION:** 41.63 kips

1. THE ABOVE INCLUDES HELIX CAPACITY ONLY - NO PILE / SOIL FRICTION
2. WEIGHT OF PILE IS NOT CONSIDERED IN THE ABOVE CALCULATION
3. SEE ATTACHED NOTES AND RECOMMENDATIONS.
4. REQUIRED DEPTHS MAY VARY
5. THE CAPACITIES SHOWN ABOVE ARE ULTIMATE APPROPRIATE SAFETY FACTORS SHOULD BE APPLIED.
6. LOAD TESTS ARE RECOMMENDED.
7. ULTIMATE LOADS SHALL NOT EXCEED THE MECHANICAL STRENGTH OF THE PILE

**RECOMMENDED SHAFT:**
- **HELICAL SHAFT:** 1.375 RCS
- **MINIMUM TENSION CAPACITY:** 10,000 ft-lbs

---

©Copyright 2010 MacLean Power Systems
Issued: April 1, 2010
Supersedes: June 1, 2006
Example 8.1

Helix Bearing Capacity vs. Depth Charts

**SECTION 8**

**CHART A**

**Estimated Theoretical Geotechnical Ultimate Pile Capacity**

- **TENSION**
- **COMPRESSION**

**VERTICAL DEPTH OF BOTTOM HELIX (FT)**

**CHART B**

**Estimated Installation Torque**

- **INSTALLATION TORQUE**
- **TORQUE LIMIT**

**VERTICAL DEPTH OF BOTTOM HELIX (FT)**

**TOTAL EFFECTIVE AREA OF HELIXES:** 1.515 sq ft
Example 8.2 – “Hand Calculated”

As discussed above, 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 applied.

\[ q_{ult(g)} = A_h \times (q \times N_q) = \text{Helix Ultimate Geotechnical Bearing Capacity} \]

\( q \) = Effective overburden pressure is defined as the average unit weight of the soil times its depth.

\( N_q \) = Bearing Capacity Factor for Cohesionless Soil – \( N_q \) 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 |
| Water Depth | 17 ft |

<table>
<thead>
<tr>
<th>HELIX DEPTH (ft)</th>
<th>Over-burden Pressure (Depth x Avg Unit Weight) (psf)</th>
<th>Below Helix Pressure Capacity (psf)</th>
<th>Bearing Capacity (Nq)</th>
<th>Net Helix Area (ft²)</th>
<th>Ultimate Helix Capacity (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36.0</td>
<td>2,096</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36.5</td>
<td>2,115</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37.0</td>
<td>2,134</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37.5</td>
<td>2,153</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38.0</td>
<td>2,172</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38.5</td>
<td>2,190</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39.0</td>
<td>2,209</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39.5</td>
<td>2,228</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40.0</td>
<td>2,247</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40.5</td>
<td>2,266</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41.0</td>
<td>2,284</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41.5</td>
<td>2,303</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42.0</td>
<td>2,322</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42.5</td>
<td>2,341</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43.0</td>
<td>2,360</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43.5</td>
<td>2,378</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44.0</td>
<td>2,397</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44.5</td>
<td>2,416</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45.0</td>
<td>2,435</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Helix Bearing Capacity =** 41,631 (lbs)

**Recommended Design Load =** 20,815 (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 Foundation 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 9.0 shows a typical screw 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 9.1.

**Figure 9.0 Helical Foundation Piles**

<table>
<thead>
<tr>
<th>Air</th>
<th>Water</th>
<th>Extremely Disturbed Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>La</td>
</tr>
</tbody>
</table>

**Figure 9.1 (k = 1)**

**Equation 9.2 Davisson (1963)**

\[ P_{cr} = \frac{\pi^2 \times E \times I}{(k \times L_a)^2} \]

• \( P_{cr} \) = 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 9.1, \( k = 1 \). See Reference 4 for additional end restraint conditions and values of \( k \).
• \( L_a = L \) = Unbraced length \((in.)\) – receiving no lateral support. \((kL = \text{Effective unbraced length})\)
For steel columns, the Euler Equation applies to long slender columns with slenderness ratios \((kL/r)\) equal to or greater than: 

\[ ((2 \times \pi(\pi^2 \times E)) / (Fy))^{.5} \]

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 \((2 \times \pi(\pi^2 \times E)) / (Fy))^{.5}\), 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's interesting to note that, for Equation 9.1 (Euler), the critical buckling load \((P_{cr})\), for a long slender column, can not be increased by using a steel with higher strength properties. For this type of column, \(P_{cr}\) 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 9.0). 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 \((P_{cr})\) and the allowable design load with a Safety Factor 4.

\[ I = .396 \text{ in}^4 \]
\[ A = 2.19 \text{ in}^2 \]
\[ r = (.396 / 2.19)^{.5} = .42523 \text{ in} \]
\[ k = 1 \]

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

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

   Minimum slenderness ratio for Euler = \( ((2 \times \pi(\pi^2 \times E)) / (Fy))^{.5} = 97.67 \)

   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. \(P_{cr} [\text{Euler}] = (\pi^4 \times E \times I) / (k \times L)^2 \)

\[ P_{cr} = (3.1416^2 \times 29,000,000 \times .396) / (1.0 \times 48)^2 = 49,194 \text{ lbs.} \]

   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 \((P_{cr})\) 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 \((P_{cr})\) 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 Foundation Piles

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

**EXAMPLE:**

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

\[
kL/r = 112.88 \quad \text{for an unsupported length (kL) of 48.00 inches}
\]

Note:

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

The Euler formula can be used when \( kL/r \) equals or exceeds: \( ((2 \times \pi(\gamma^2 x E) / (Fy))^4.5 \)

Let: \( ((2 \times \pi(\gamma^2 x E) / (Fy))^4.5 = \Theta \)

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

\[
Pcr \ [\text{Euler}] = (pi(\gamma^2 x E x I)) / ((kL)^2) \quad \text{[Equation 9.1]}
\]

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

\[
Pcr \ [\text{CRC}] = (1 - ((kL/r)^2 / (2 x \Theta^2))) x Fy x Area \quad \text{[Equation 9.1a]}
\]

The column length with a slenderness ratio \( kL/r \) equal to \( \Theta \) 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 appropriate 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 bucking 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 Foundation 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 form 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 Fig. 9.2.

\[
Pcr = Ucr \times \frac{E \times I}{R^2}
\]  

[Equation 9.2]

Where:

- \( Ucr \) = A dimensionless factor governed by the end connections (restraints) of the pile. See Figure 9.2.
- \( E \) = Modulus of Elasticity of the pile material (Steel = 29,000,000 psi).
- \( I \) = Minimum cross sectional Moment of Inertia of the pile (in\(^4\)).
- \( R = ((E \times I) / (Kh \times d))^{0.25} \)
- \( R^2 = ((E \times I) / (Kh \times d))^{0.50} \)
- \( Kh \) = Modulus of Subgrade Reaction (lbs/cu in) See Table 9.1.
- \( d \) = Pile diameter (in.)
As shown above, for p-p conditions (both ends pinned – no translation), the minimum value for Ucr is 2.0 for all Imax (L/R) values. Setting Ucr to 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. It is recommended that a geotechnical engineer, experienced in the area, provide the final design values of Kh.

<table>
<thead>
<tr>
<th>Soil</th>
<th>Modulus of Subgrade Reaction, Kh (lbs / cu in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose Sand</td>
<td>15 - 20</td>
</tr>
<tr>
<td>Soft Clay</td>
<td>20 - 70</td>
</tr>
<tr>
<td>Very Soft Clay</td>
<td>10 - 20</td>
</tr>
</tbody>
</table>
Example 9.2 – Below Ground

A twin helix foundation pile anchor (Figure 9.0) 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.

Applying the Davisson Method, determine the critical buckling load $P_{cr}$ and allowable working load based on a safety factor of 2.

$$P_{cr} = \text{Ucr} \times \frac{E \times I}{R^2}$$

(See Fig. 9.2)

Where:

$\text{Ucr} = 2$ = A dimensionless factor governed by the end connections (restraints) of the pile. See Figure 9.2.

$E$ = Modulus of Elasticity of the pile material (Steel = 29,000,000 psi)

$I$ = Minimum cross sectional Moment of Inertia of pile. (in$^4$).

$R = \left(\frac{E \times I}{(Kh \times d)}\right)^{0.25}$

$R^2 = \left(\frac{E \times I}{(Kh \times d)}\right)^{0.50}$

$Kh$ = Modulus of Subgrade Reaction (lbs/cu in). See Table 9.1.

$d$ = Pile diameter (in.)

$U_{cr} = 2$ - Assume a p-p connection for the ends. (Figure 9.2).

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

$I_{max} = L / R$

$L = L_s = 25 \times 12 = 300$ inches

$E = 29,000,000$ for steel

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

$d = 1.50$ in.

$R = \left(\frac{29,000,000 \times .396}{(12 \times 1.5)}\right)^{0.25} = 28.26$

$R^2 = 798.75$

$I_{max} = L / R = 300 / 28.26 = 10.62, U_{cr} = 2$

As discussed above, assuming a p-p connection for the ends, $U_{cr}$ 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 $Kh$.

$$P_{cr} = 2 \times \left(\frac{29,000,000 \times .396}{798.75}\right) = 28,755$ \text{ lbs} \quad \text{(Also See Figure 9.3)}$$

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 $P_{cr}$ 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 $P_{cr}$ 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, $P_{cr}$. If a hollow round shaft (i.e. P28 to P8 Piles) were used in place of a solid square shaft, the increase of $P_{cr}$ would be significantly larger.
If $U_{cr}$ 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 $P_{cr}$ for a range of values of $K_h$. Applying a constant value for $U_{cr}$ greatly simplifies the use of the Davisson equation. With $U_{cr}$ held constant - only $K_h$, not pile length, governs the critical buckling load $P_{cr}$. As discussed above, $U_{cr} = 2$ seems to be a relatively conservative approach for analyzing Helical Foundation Pile. $P_{cr}$ vs. $K_h$ curves for a 1.50” round cornered square shaft and a 1.75” sq round cornered square shaft are shown below in Figures 9.3 and 9.4.

References:
LATERAL CAPACITY

UNRESTRAINED OR FREE-HEAD SHORT RIGID HELICAL FOUNDATION 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 Foundation 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 helical foundation 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 to 10 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 Foundation Piles. We recommend that the engineer familiarize himself 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 here.

- Figure 10.1 Cohesive Soils
- Figure 10.2 Cohesionless Soils

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 program. 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

\[ H_u = f \times 9 \times Cu \times d \]

Shear at depth \((1.5 \times d) + f\) = 0

\[ f = \frac{H_u}{9 \times Cu \times d} \]

\[ M_{max} = \text{AREA 1 or AREA 2} \]

\[ M_{max} = H_u \times (e + 1.5d + .5f) \]

\[ L = \text{REQUIRED DEPTH INTO SOIL WITH COHESION OF "Cu".} \]

\[ L = 1.5d + f + g \]

Recommended units:
- \(d\) = pile diameter (ft.)
- \(Cu\) = soil cohesion (ksf)
- \(H_u\) = lateral load (kips)
- \(f\) = ft.
- \(g\) = ft.
- \(M_{max}\) = maximum pile bending moment (ft. kips)
- \(FB_{max}\) = maximum pile bending stress (ksi)

Energy Structures Inc.

Broms Method of Analyzing Laterally Loaded Short Piles

File: BROMS.DWG

Dwg. No. 921102
SUM OF REACTION VECTORS = \[ \sum R = 3 \times uw \times d \times Kp \times \text{L}^2 \]

SUM OF REACTION VECTORS AT ANY DEPTH "y"
\[ \sum f = 3/2 \times uw \times d \times Kp \times y^2 \]

DEPTH OF MAXIMUM BENDING MOMENT = \( f \)
\[ Hu = 3/2 \times uw \times d \times Kp \times f^2 \]
\[ f = 0.8165 \times \sqrt{\frac{Hu}{uw \times d \times Kp}} \]

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: \( 3 \times uw \times d \times Kp \times y \) ... in which \( uw \) 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 and \( y \) 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:
\[ Kp = \frac{(1 + \sin [\phi])}{(1 - \sin [\phi])} \quad \text{or} \quad Kp = \tan^2 (45 + [\phi / 2]) \]

A graph plotting \( Kp \) vs. \( \phi \) (angle of internal friction - degs) is shown on the following page.

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.
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

<table>
<thead>
<tr>
<th>COHESIVE SOILS</th>
<th>COHESIONLESS SOILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>See Figure 10.1</td>
<td>See Figure 10.2</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
  f & = \frac{Hu}{(9 \times Cu \times d)} \\
  M_{\text{max}} & = Hu \times (e + 1.5d + .5f) \\
  g & = \left(\frac{(Hu \times (e + 1.5d + .5f))}{(2.25 \times d \times Cu)}\right)^{.5} \\
  L & = (1.5 \times d) + f + g \\
  M_{\text{max}} & = Hu \times (e + (.66666 \times f)) \\
  H_{\text{max}} & = \frac{.5 \times uw \times d \times Kp \times L^3}{(e + L)} \\
  Kp & = \tan^2 \left(45 + \left[\frac{\phi}{2}\right]\right)
\end{align*}
\]

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.
- \(M_{\text{max}}\) = 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
- \(\phi\) = Soil’s angle of internal friction – degs

References:


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
   $\phi = 30$ degs
   Cohesion = 0

   Location 2 – Cohesive Soil
   Clay
   Water Depth = 7.5 ft
   Cohesion = 1 ksf
   $\phi = 0$ 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 MacLean Dixie’s Standard P8 Series Helical Pile with a wall thickness of .188”. So the standard P8 Series Helical Foundation 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  

PROJECT NAME:  
FOUNDATION PILES

Date: December 27, 2009  
Time: 9:53:22 PM

ESI DWG NO 940331-T  
BROMS EQUATIONS - COHESIONLESS SOIL - SAND

\[ H_u = \frac{0.5 \times u_w \times d \times K_p \times L^3}{e + L} \]

\[ f = 0.8165 \times (H_u / u_w \times d \times K_p)^{0.5} \]

\[ M_{max} = H_u \times (e + (0.6667 \times f)) \text{ ft-lbs} \]

\[ K_p = \tan^2(45 + (f_a / 2)) \]

COHESIONLESS SOIL - SAND  
Water Table Depth = 10.5 ft

\[ e = 1.00 \text{ ft} \]  
\[ u_w = 100.0 \text{ pcf} \]  
\[ d = 8.625 \text{ inches} \]  
\[ f_a = 30.0 \text{ degs} \]

\[ 45 + (f_a / 2) = 60.0 \text{ degs} \]

\[ K_p = 3,000 \text{ Coefficient of Passive Earth Pressure} \]

\[ L = 8.52 \text{ ft} \]  
Minimum depth of pile into firm soil.

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

\[ H_u = 7,0041 \text{ kips} \]  
Ultimate Lateral Capacity*

\[ f = 4,654 \text{ ft} \]  
depth of maximum pile bending moment

\[ M_{max} = 28,733 \text{ ft-kips} \]  
344,798 in-lbs

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

\[ I = 44.36 \text{ in}^4 \]  
based on gross section area

\[ F_b \text{ max} = \frac{M_c}{I} = 33,519 \text{ psi} \]  
at a depth of: 4.65 ft

---

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.

---

Pile Bending Moment (ft-kips)  
Cohesionless Soils

©Copyright 2010 MacLean Power Systems  
Issued: April 1, 2010  
Supercedes: June 1, 2006
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

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)

\[ L = (1.5 \times d) + 1 + g \]

\[ f = H_u / (9 \times Cu \times d) \]

\[ g = (Hu \times (e + 1.5 \times d + .5 \times f)) / (2.25 \times d \times Cu) \times 5 \]

\[ M_{max} = H_u \times (e + 1.5 \times d + .5 \times f) \]

COHESIVE SOIL - CLAY

<table>
<thead>
<tr>
<th>Hu</th>
<th>7.00</th>
<th>kips</th>
<th>Ultimate Lateral Pile Capacity *</th>
</tr>
</thead>
<tbody>
<tr>
<td>e</td>
<td>1.00</td>
<td>ft</td>
<td>Eccentricity of Load</td>
</tr>
<tr>
<td>d</td>
<td>8.625</td>
<td>inches</td>
<td>0.719 ft</td>
</tr>
<tr>
<td>Cu</td>
<td>1.000</td>
<td>ksf</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>1.082</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g*2</td>
<td>11.337</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>3.367</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| L   | 5.53 | ft | Minimum Depth of Pile into firm soil |

| M_{max} | 18,334 | ft-kips | 229,012 | 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.

***

MacLean Power Systems
Issued: April 1, 2010
Supercedes: June 1, 2006

©Copyright 2010 MacLean Power Systems
SECTION 11

CORROSION

SCOPE:

This section is intended to provide general criteria for evaluating the affect of underground corrosion on Helical Foundation Piles. Acceptance criteria for Helical Foundation 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, shall 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

<table>
<thead>
<tr>
<th>Soil Resistivity (ohm-cm)</th>
<th>Classification of Soil Corrosiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 900</td>
<td>Very severe</td>
</tr>
<tr>
<td>900 to 2,300</td>
<td>Severe</td>
</tr>
<tr>
<td>2,300 to 5,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>5,000 to 10,000</td>
<td>Mild</td>
</tr>
<tr>
<td>10,000 to 30,000</td>
<td>Very mild</td>
</tr>
<tr>
<td>&gt;30,000</td>
<td>Unlikely</td>
</tr>
</tbody>
</table>

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 FOUNDATION PILES IN SOIL

Our experience has shown that corrosion problems associated with helical foundation 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 foundation 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 foundation 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.  

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**

**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 foundation piles.** Galvanizing specifications for MACLEAN-DIXIE 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/ft² (3 mils) with a minimum thickness of 1.8 oz/ft² (2.8 mils). ASTM A123 can also be applied to provide a thicker zinc coating up to 2.3 oz/ft² (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 foundation piles, Bituminous or other types of specialized coatings are often used to provide protection from the environment.

**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:**

\[
\text{Qty. of Anodes Required} = \frac{\text{Current Demand} \times \text{Life of Anode}}{\text{Anode Capacity}}
\]

- **Current Requirement** = To protect bare metal in the ground a current of 11 to 22 mA / m² 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/m² or in the US, 1 mA/ft² or .001 A/ft² 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)

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

- Soil Resistivity = 1000 ohm-cm
- Exposed Area – not coated = .718 m² (7.729 ft²)
- 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.

\[
\text{Current Demand} = .718 \text{ m}^2 \times 11 \text{ mA/m}^2 = 7.90 \text{ mA or .0079 A}
\]

\[
\text{Anode Capacity} = 3.6 \text{ kg x 1200 Ah/kg} = 4320 \text{ Ah}
\]

\[
\text{Qty of Anodes} = \frac{(0.0079) \times (40 \times 365 \times 24)}{3.6 \times 1200} \text{ Ah} = 0.6408 \text{ anodes required}
\]

This anode would supply a service life of 40/.6408 yrs or 62.42 yrs.

Or shown in another way:

\[
\text{The Life of an Anode (yrs)} = \frac{\text{The Rated Capacity (Ah)}}{\text{Current Demand (Ah/yr)}}
\]

\[
\text{Rated anode capacity} = 3.6 \times 1200 = \text{Ah} = 4320 \text{ Ah}
\]

\[
\text{Current Demand for one year} = 0.0079 \times 365 \times 24 = 69.204 \text{ Ah}
\]

\[
\text{Expected Anode Life} = 4320 / 69.204 = 62.42 \text{ yrs.}
\]

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

\[
\text{L (yrs)} = \frac{\text{[Total Capacity of the Anode]}}{\text{[Amps Consumed in 1 yr]}}
\]

\[
\text{L (yrs)} = \frac{\text{CC x W}}{365 \times 24 \times \text{CD}}
\]

[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^2)

From example problem:

\[
L \ (\text{yrs}) = \frac{544 \ \text{Ah/lb} \times (3.6 \times 2.205) \ \text{lb} / (365 \times 24) \ \text{hrs} \times 7.729 \ \text{ft}^2 \times .001 \ \text{Amp/ft}^2}{67.706} = 63.8 \ \text{yrs} = \text{years to consume 100\% of anode.}
\]

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.

\[
L \ (\text{yrs}) = 34.25 \times \frac{\text{Anode Weight (lbs) / Area to be protected (ft}^2)}{\
\text{Equation 11.3}
\]

Figure 11.1 shows a magnesium anode used to provide corrosion protection to a buried helical foundation pile assembly in East Texas USA. In the case of helical foundation piles, electrical conductivity is required throughout all components requiring protection.
WHEN SHOULD CORROSION CONTROL MEASURES BE CONSIDERED? – Allowable Material Loss

Experience has shown that corrosion control measures beyond the standard galvanized coating for helical foundation 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 40 to 50 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.

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, MACLEAN-DIXIE helical foundation piles are hot dip galvanized to ASTM A153 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**  

\[ \text{Estimated Service Life (yrs)} = \text{M (yrs)} + \text{Z (yrs)} = \text{Lt} \quad \text{[Equation 11.4]} \]

- \( M \) (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.
Figure 11.2

Service Life as a Function of Resistivity
(Bare Carbon Steel)
abstracted from FHWA-NHI-0044 Fig. 2 page 11

Figure 11.3

Service Life (yrs) - Carbon Steel
(1/8" Metal Loss)
abstracted from NBS Cir. 579
Figure 11.4

Life of Zinc Coat (yrs)

Resistivity (ohm-cm)

Figure 11.5

Life of Zinc vs. Resistivity
Zinc Loss = 1.8 oz / ft²
abstracted from FHWA-NHI-0044 figure 1, page 10
As discussed above, corrosion control measures are most often required only to the uppermost region of helical foundation 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 foundation piles generally do not experience significant corrosion.

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

Example Problem

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 Foundation 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.

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

MACLEAN-DIXIE helical foundation piles are hot dip galvanized to ASTM A153 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.
Sacrificial Anodes: (Example Problem)

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:

\[ L \text{ (yrs)} = \frac{CC \times W}{365 \times 24 \times CD} \]

**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:

\[
CC = 500\text{ Ah/ lb} \\
W = .6 \times 32\text{ lbs} \\
CD = 29.6\text{ ft}^2 \times .001\text{ A/ft}^2 = .0296\text{ Amps Demanded}
\]

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

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 = \((365 \times 24) / 500 = 17.52\) lbs per Amp demanded.

So: To consume 60% of the anode:

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

Also, Equation 11.3 = \(L \text{ (yrs)} = 34.25 \times \frac{\text{Anode Weight (lbs)}}{\text{Area to be protected (ft}^2\text{)}}\)

\(34.25 \times \frac{32}{29.6} = 37.02\text{ yrs to consume 60\% of the anode}\)

**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”


* * * * *
1. Shaft

Helical foundation pile includes 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 1.25” 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, except the 2” RCS. A cast steel coupler is used for the 2” extension.

**Pipe Pile (2.875” OD to 8.625” OD):** Structural steel pipe, welded or seamless as per ASTM A500 grade C or equal welded with “Strength Square” couplings. The coupling shall be made of cast steel with matching square shapes.

**Coupling for 2” RCS and Pipe Piles:** Cast steel as per ASTM A958 grade SC1045 or equal with minimum of 40 ksi yield and 80 ksi ultimate strength.

### Table 12.1 Material Specifications

<table>
<thead>
<tr>
<th>Shaft Size for Leads and Extensions</th>
<th>Designation</th>
<th>ASTM Specification or Equal</th>
<th>Minimum Yield Strength (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25” Square Shaft</td>
<td>D3</td>
<td>A576-Gr. 1045</td>
<td>60</td>
</tr>
<tr>
<td>1.50” Square Shaft</td>
<td>D6</td>
<td>A576-Gr. 10V45M</td>
<td>70</td>
</tr>
<tr>
<td>1.50” Square Shaft – High Strength</td>
<td>D7</td>
<td>A576-Gr. 1530M</td>
<td>90</td>
</tr>
<tr>
<td>1.75” Square Shaft</td>
<td>D10</td>
<td>A576-Gr. 1530M</td>
<td>90</td>
</tr>
<tr>
<td>2.00” Square Shaft</td>
<td>D15</td>
<td>A576-Gr. 1530M</td>
<td>90</td>
</tr>
<tr>
<td>2.875” O.D. (0.203” wall, Sch40 Pipe)</td>
<td>P28</td>
<td>A500-Gr. C</td>
<td>50</td>
</tr>
<tr>
<td>2.875” O.D. (0.276”wall, Sch80 Pipe)</td>
<td>P28H</td>
<td>A500-Gr. C</td>
<td>50</td>
</tr>
<tr>
<td>3.500” O.D. (0.216” wall, Sch40 Pipe)</td>
<td>P35</td>
<td>A500-Gr. C</td>
<td>50</td>
</tr>
<tr>
<td>3.500” O.D. (0.300”wall, Sch80 Pipe)</td>
<td>P35H</td>
<td>A500-Gr. C</td>
<td>50</td>
</tr>
<tr>
<td>4.500” O.D. (0.237” wall, Sch40 Pipe)</td>
<td>P45</td>
<td>A500-Gr. C</td>
<td>50</td>
</tr>
<tr>
<td>4.500” O.D. (0.337” wall, Sch80 Pipe)</td>
<td>P45H</td>
<td>A500-Gr. C</td>
<td>50</td>
</tr>
<tr>
<td>8.625” O.D. X 0.1875” wall</td>
<td>P8</td>
<td>A500-Gr. C</td>
<td>50</td>
</tr>
</tbody>
</table>

### A. Torque vs. Ultimate Load Capacity

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. $K_t \times$ Torque (ft-lbs) = Ultimate Capacity (lbs) The values of $K_t$ shown in Table 12.2 are empirically based on experience 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 12.2, 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 his 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 12.2
RATED MAXIMUM DESIGN LOADS (ALLOWABLE LOADS) – BASED ON INSTALLATION TORQUE *

<table>
<thead>
<tr>
<th>Shaft Size</th>
<th>Designation</th>
<th>$K_t$</th>
<th>Rated Torsional Capacity (ft-lbs)</th>
<th>Ultimate Capacity</th>
<th>Maximum Design Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25” Square Shaft</td>
<td>D3</td>
<td>10</td>
<td>3,400</td>
<td>34,000</td>
<td>17,000</td>
</tr>
<tr>
<td>1.50” Square Shaft</td>
<td>D6</td>
<td>10</td>
<td>5,500</td>
<td>60,000</td>
<td>30,000</td>
</tr>
<tr>
<td>1.50” Square Shaft (high str.)</td>
<td>D7</td>
<td>10</td>
<td>7,000</td>
<td>70,000</td>
<td>35,000</td>
</tr>
<tr>
<td>1.75” Square Shaft</td>
<td>D10</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
</tr>
<tr>
<td>2.00” Square Shaft</td>
<td>D15</td>
<td>10</td>
<td>15,000</td>
<td>150,000</td>
<td>75,000</td>
</tr>
<tr>
<td>2.875” O.D. (0.203” wall)</td>
<td>P28</td>
<td>8</td>
<td>7,500</td>
<td>80,000</td>
<td>40,000</td>
</tr>
<tr>
<td>2.875” O.D. (0.276” wall)</td>
<td>P28H</td>
<td>8</td>
<td>9,000</td>
<td>100,000</td>
<td>50,000</td>
</tr>
<tr>
<td>3.500” O.D. (0.216” wall)</td>
<td>P35</td>
<td>7</td>
<td>11,400</td>
<td>100,000</td>
<td>50,000</td>
</tr>
<tr>
<td>3.500” O.D. (0.300” wall)</td>
<td>P35H</td>
<td>7</td>
<td>15,000</td>
<td>140,000</td>
<td>70,000</td>
</tr>
<tr>
<td>4.500” O.D. (0.237” wall)</td>
<td>P45</td>
<td>6</td>
<td>20,000</td>
<td>140,000</td>
<td>70,000</td>
</tr>
<tr>
<td>4.500” O.D. (0.337” wall)</td>
<td>P45H</td>
<td>6</td>
<td>26,000</td>
<td>200,000</td>
<td>100,000</td>
</tr>
<tr>
<td>8.625” O.D. X 0.1875” wall</td>
<td>P8</td>
<td>4.5</td>
<td>44,500</td>
<td>240,000</td>
<td>120,000</td>
</tr>
</tbody>
</table>

* Maximum Design Loads (Allowable Loads) are based on a Factor of Safety of 2 (See Section 5). Column buckling considerations are not addressed (See Section 9).  
* Loads are axial.  
* Ultimate tension is based on mechanical strength of pipe and coupling.  
* Ultimate Compression Capacity (lbs) = ultimate helix/soil bearing capacity (lbs) = $K_t$ x Torque (ft-lbs), (See Sec.13).  
* Rated maximum design loads assume that the torsional capacity of the pile has been achieved.  
* If the soil's bearing capacity beneath the helices is greater than that above the helices, the geotechnical compression capacity of the pile will be greater, 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.  
** Depending on pile depth and type of soil, skin friction (after soil remolds around the pipe) will increase the total capacity of the P45 and P8 Pipe Piles.  
** A concrete or grout filled P8 Pipe Pile may significantly increase its capacity. P8 Pipe Piles have been successfully load tested to 180,000 lbs. Unless otherwise noted, the P8 Pipe Pile should be filled with suitably reinforced concrete or grout of sufficient strength after installation.

### B. 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. This is especially true in dense sands and gravel.

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 confining strengths (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 LPILE can be applied to perform buckling analysis. The Davisson (1963) method is discussed in detail in Section 9.

C. Pipe piles with Square coupling – 2.875” OD to 8.625” OD pipes

MacLean-Dixie “Strength Squared” couplings (patent pending) allow for the full torsional capacity of the pile to be transferred through the coupling 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 other types of couplings.

The MacLean-Dixie square male coupling 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.

D. 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.

2. Helix

**Helix Material:** High Strength, Low Carbon Alloy 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 range from 3/8” for standard helices to 1/2” for high strength helices.

Helical foundation 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 P8. The P8 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 that 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.

3. 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 or (2) Helix loads exceeding the values shown in Table 12.3.

4. Center-to-Center Spacing Between Helical Screw Pile Foundations

The recommended spacing between adjacent helix of Helical Screw Pile Foundations is five times the diameter of the largest helix. The minimum spacing is three times the diameter of the largest helix, 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 screw piles can provide a convenient method of maintaining the minimum spacing.

### Table 12.3

<table>
<thead>
<tr>
<th>Mechanical rated capacities &amp; units</th>
<th>1.25&quot; Round Corner Square Shaft</th>
<th>1.50&quot; Round Corner Square Shaft</th>
<th>1.75&quot; Round Corner Square Shaft</th>
<th>2.00&quot; Round Corner Square Shaft</th>
<th>2.875&quot; O.D. Pipe Shaft</th>
<th>3.50&quot; O.D. Pipe Shaft</th>
<th>4.50&quot; O.D. Pipe Shaft</th>
<th>8.625&quot; O.D. Pipe Shaft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helix grade; ksi</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>3/8&quot; ultimate Capacity; kips</td>
<td>22</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>NA</td>
<td>40</td>
<td>40</td>
<td>NA</td>
</tr>
<tr>
<td>1/2&quot; ultimate Capacity; kips</td>
<td>NA</td>
<td>50</td>
<td>50</td>
<td>60</td>
<td>60</td>
<td>NA</td>
<td>60</td>
<td>70</td>
</tr>
</tbody>
</table>

### Allowable

| 3/8" allowable Capacity; kips      | 11                               | 15                               | 15                               | 20                               | NA                    | 20                    | 20                    | 25                    |
| 1/2" allowable Capacity; kips      | NA                               | 25                               | 25                               | 30                               | 30                    | NA                    | 30                    | 35                    |

Notes:
1. Ultimate Helix Capacities and Allowable Helix Loads are based on a 12" diameter helix, except for P8 Pipe Pile. For other helix sizes, see the Material and Quality Specifications section in the MacLean Engineering Manual.
2. All loads are axial.
<table>
<thead>
<tr>
<th>Shafts</th>
<th>1.25” Round Corner Square Shaft D3</th>
<th>1.50” Round Corner Square Shaft D6</th>
<th>1.50” Round Corner Square Shaft D7</th>
<th>1.75” Round Corner Square Shaft D10</th>
<th>2.00” Round Corner Square Shaft D15</th>
<th>2.875” O.D. Pipe Shaft 0.203” wall P28</th>
<th>2.275” wall P28H</th>
<th>0.216” wall P35</th>
<th>0.300” Wall P35H</th>
<th>0.237” wall P45</th>
<th>0.337” wall P45H</th>
<th>8.625” O.D. Pipe Shaft 0.1875” Wall P8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Str. ksi</td>
<td>60</td>
<td>70</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Moment of inertia, in^4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sxx=Syy; lxx=lly=lx</td>
<td>0.194</td>
<td>0.396</td>
<td>0.396</td>
<td>0.746</td>
<td>1.260</td>
<td>1.530</td>
<td>1.924</td>
<td>3.017</td>
<td>3.894</td>
<td>7.233</td>
<td>9.611</td>
<td>44.250</td>
</tr>
<tr>
<td>Section mod.</td>
<td>0.310</td>
<td>0.528</td>
<td>0.528</td>
<td>0.853</td>
<td>1.260</td>
<td>1.064</td>
<td>1.339</td>
<td>1.724</td>
<td>2.225</td>
<td>3.214</td>
<td>4.271</td>
<td>10.261</td>
</tr>
<tr>
<td>Section mod. - Sxy; in^3</td>
<td>0.240</td>
<td>0.414</td>
<td>0.414</td>
<td>0.657</td>
<td>0.980</td>
<td>1.064</td>
<td>1.339</td>
<td>1.724</td>
<td>2.225</td>
<td>3.214</td>
<td>4.271</td>
<td>10.261</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coupling</th>
<th>AS Forged</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast steel SC 1045; ksi</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>40/80</td>
<td>40/80</td>
<td>40/80</td>
<td>40/80</td>
<td>40/80</td>
<td>40/80</td>
<td>40/80</td>
<td></td>
</tr>
<tr>
<td>Bolt(s) Dia.* SAE J429</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1 1/8</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1 1/8</td>
<td>3/4</td>
</tr>
<tr>
<td>Bolt qty. (ea)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

| Transition | Pipe to RCS** | NA | NA | NA | NA | NA | 1 1/2 | 1 1/2 | 1 3/4 | 1 3/4 | 2 | 2 | 1 3/4 | 2 |

| Table 12.5 HELIX NET BEARING AREAS * |
| Nominal diameter (in) | units | 1.25” Round Corner Square Shaft D3 | 1.50” Round Corner Square Shaft D6 | 1.50” Round Corner Square Shaft D7 | 1.75” Round Corner Square Shaft D10 | 2.00” Round Corner Square Shaft D15 | 2.875” O.D. Pipe Shaft 0.203” wall P28 | 2.275” wall P28H | 0.216” wall P35 | 0.300” Wall P35H | 0.237” wall P45 | 0.337” wall P45H | 8.625” O.D. Pipe Shaft 0.1875” Wall P8 |
|----------------------|-------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| 6 ft² | .166 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 8 ft² | .313 | .308 | .308 | .303 | .296 | .300 | .300 | .278 | .278 | .236 | .236 | NA |
| 10 ft² | .505 | .501 | .501 | .495 | .489 | .494 | .494 | .473 | .473 | .430 | .430 | NA |
| 12 ft² | .729 | .724 | .724 | .719 | .712 | .732 | .732 | .711 | .711 | .668 | .668 | NA |
| 14 ft² | 1.007 | 1.002 | 1.002 | .996 | .990 | 1.014 | 1.014 | .993 | .993 | .950 | .950 | 0.659 |
| 16 ft² | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.984 |
| 20 ft² | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 1.766 | |
| 24 ft² | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 2.719 | |

*S  Bolt diameter in inches.  
** Use same coupling bolt shown for RCS

* Shaft areas have been deducted

©Copyright 2010 MacLean Power Systems  
Issued: April 1, 2010  
Supersedes: June 1, 2006
QUALITY AT MACLEAN - DIXIE

MacLean-Dixie's 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.

MacLean-Dixie offers Round Cornered Square (RCS) shaft from 1-1/4" to 2", inclusive and "Strength Square" Pipe piles from 2-7/8" to 8-5/8" outside diameter. Four sizes have been tested per ICC-ES AC358, Acceptance Criteria for Helical Foundation Systems and Devices to insure the integrity of the MacLean-Dixie products. The four sizes are 1-1/2" RCS D6, 1-3/4" RCS D10, 2-7/8" O.D. (sch 40, P28) and 3-1/2" O.D. (sch 40, P35) pipe piles.

Product Design
- Product is designed to meet or exceed the published MacLean-Dixie performance ratings.
- All designs are tested at MacLean-Dixie's 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 supervisor, the quality assurance personnel, and employees monitor the processes to insure that all aspects of the design and its quality are met.
- Documented audits are available for review.
- Calibrated gages are readily available to verify the size, check threads, and to evaluate hole locations.
- Five or six pins load tests on the helix and/or torque tests are performed periodically to insure the quality of the product.
- Certified welders are used for the foundation piles (helical and non-helical) and tension guy anchors and associated products.

Hot-Dip Galvanizing
- All hot-dip galvanizing products meet ASTM A153 or A123 specification for coating thickness and finishing.

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

Final inspection audits verify proper assembly
Helical Anchor Lead and Extension Sections
Helical Foundation 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 the Fig. 1. The lead and extension material conforms to ASTM A576, Grade 1045 with 60ksi minimum yield strength.

- **Lead** - the lead has a through hole at the upper end and pointed edge 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 offered with or without the helices.

Helix - Helical Bearing Plate
Helix, 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 A1011/1018 with 55ksi min. yield strength. The outer diameters of available helix sizes range from 6” to 14”. Helices are welded to the RCS solid steel shaft.

Connection Bolts
Each Extension Section is provided with one 5/8” diameter x 3” long Hex Head Bolt per ASTM A325 and one 5/8” Hex Jam Nut per ASTM A563.

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

Installation Torque Rating
The Ultimate Mechanical Strength Torque rating of DIXIE HFS™ 1 ¼” D3 RCS shaft Multi-Helix Lead Sections and Extensions is 3,400 [ft-lb] based upon empirical test data.

**Anchor Mechanical Strength Rating**
The maximum design load for DIXIE HFS™ 1 ¼” D3 RCS Multi-Helix anchor is 17,000 lb for tension and compression with safety factor of 2.

**Axial Load Single Helix Mechanical Strength Ratings**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8”</td>
<td>6”</td>
<td>0.166</td>
<td>32</td>
</tr>
<tr>
<td>3/8”</td>
<td>8”</td>
<td>0.313</td>
<td>30</td>
</tr>
<tr>
<td>3/8”</td>
<td>10”</td>
<td>0.505</td>
<td>28</td>
</tr>
<tr>
<td>3/8”</td>
<td>12”</td>
<td>0.729</td>
<td>26</td>
</tr>
<tr>
<td>3/8”</td>
<td>14”</td>
<td>1.007</td>
<td>20</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

Note: The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
Helical Anchor Lead and Extensions
Helical Foundation 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 the Fig. 2. 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
Helix, 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 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 Foundation 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 Mechanical Strength Torque rating of DIXIE HFS™ 1 ½” D6 RCS shaft Multi-Helix Lead Sections and Extensions is 5.500 [ft-lb] based upon empirical test data.

Anchor Mechanical Strength Rating
The maximum design load for DIXIE HFS™ 1 ½” D6 RCS Multi-Helix foundation pile/anchor is 30,000 lb for tension and 27,500 lb for compression with safety factor of 2. (Section 12, Table 12.2)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8”</td>
<td>8”</td>
<td>0.308</td>
<td>34</td>
</tr>
<tr>
<td>3/8”</td>
<td>10”</td>
<td>0.501</td>
<td>32</td>
</tr>
<tr>
<td>3/8”</td>
<td>12”</td>
<td>0.724</td>
<td>30</td>
</tr>
<tr>
<td>3/8”</td>
<td>14”</td>
<td>1.002</td>
<td>24</td>
</tr>
<tr>
<td>1/2”</td>
<td>8”</td>
<td>0.308</td>
<td>58</td>
</tr>
<tr>
<td>1/2”</td>
<td>10”</td>
<td>0.501</td>
<td>54</td>
</tr>
<tr>
<td>1/2”</td>
<td>12”</td>
<td>0.724</td>
<td>50</td>
</tr>
<tr>
<td>1/2”</td>
<td>14”</td>
<td>1.002</td>
<td>40</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

Note: The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
Helical Anchor Lead and Extensions
Helical Foundation 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 the Fig. 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 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
Helix, 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 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 Foundation 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 Mechanical Strength Torque rating of DIXIE HFS™ 1 1/2” D7 RCS shaft Multi-Helix Lead Sections and Extensions is 7,000 [ft-lb.] based upon empirical test data.

Anchor Mechanical Strength Rating
The maximum design load for DIXIE HFS™ 1 1/2” D7 RCS Multi-Helion foundation pile/anchor is 35,000 lb for tension and compression with safety factor of 2. (Section 12, Table12.2).

Axial Load Single Helix Mechanical Strength Ratings

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8”</td>
<td>8”</td>
<td>0.308</td>
<td>34</td>
</tr>
<tr>
<td>3/8”</td>
<td>10”</td>
<td>0.501</td>
<td>32</td>
</tr>
<tr>
<td>3/8”</td>
<td>12”</td>
<td>0.724</td>
<td>30</td>
</tr>
<tr>
<td>3/8”</td>
<td>14”</td>
<td>1.002</td>
<td>24</td>
</tr>
<tr>
<td>1/2”</td>
<td>8”</td>
<td>0.308</td>
<td>58</td>
</tr>
<tr>
<td>1/2”</td>
<td>10”</td>
<td>0.501</td>
<td>54</td>
</tr>
<tr>
<td>1/2”</td>
<td>12”</td>
<td>0.724</td>
<td>50</td>
</tr>
<tr>
<td>1/2”</td>
<td>14”</td>
<td>1.002</td>
<td>40</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

Note: The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
Helical Anchor Lead and Extension Sections
Helical Foundation 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 the Fig. 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 Plate
Helix, 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 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 Foundation 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 Mechanical Strength Torque rating of DIXIE HFS™ 1 ¾” D10 RCS shaft Multi-Helix Lead Sections and Extensions is 10,000 [ft-lb.] based upon empirical test data.

Anchor Mechanical Strength Rating
The maximum design load for DIXIE HFS™ 1 ¾” D10 RCS Multi-Helix foundation pile/anchor is 50,000 lb for tension and compression with safety factor of 2. (Section 12, Table12.2)

Axial Load Single Helix Mechanical Strength Ratings

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
<td>8&quot;</td>
<td>0.303</td>
<td>40</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>10&quot;</td>
<td>0.495</td>
<td>38</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>12&quot;</td>
<td>0.719</td>
<td>36</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>14&quot;</td>
<td>0.996</td>
<td>28</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>8&quot;</td>
<td>0.303</td>
<td>64</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>10&quot;</td>
<td>0.495</td>
<td>60</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>12&quot;</td>
<td>0.719</td>
<td>56</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>14&quot;</td>
<td>0.996</td>
<td>44</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

Note: The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
DIXIE HFS™ 2” RCS, D15 MULTI-HELIX FOUNDATION PILE & TENSION ANCHORS

Helical Anchor Lead and Extensions
Helical Foundation 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 the Fig. 5. 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 on both ends with cast steel square coupler or an integral forged upset socket square coupler and matches the ends of lead and extension. It is available with or without the helices. Cast steel is per ASTM A958, SC1045 or equal with a minimum of 40ksi yield and 80ksi ultimate strength.

Helix - Helical Bearing Plates
Helix, 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 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 two 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 Foundation Pile Anchor Lead Sections, Extension Sections, connection bolts and nuts are hot dip galvanized per ASTM A153 or ASTM A123.

Installation Torque Rating
The Ultimate Mechanical Strength Torque rating of DIXIE HFS™ 2” D15 RCS shaft Multi-Helix Lead Sections and Extensions is 15,000 [ft-lb.] based upon empirical test data.

Anchor Mechanical Strength Rating
The maximum design load for DIXIE HFS™ 2” D15 RCS Multi-Helix foundation pile/anchor is 75,000 lb for tension and compression with safety factor of 2. (Section 12, Table12.2)

Axial Load Single Helix Mechanical Strength Ratings

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2”</td>
<td>8”</td>
<td>0.303</td>
<td>68</td>
</tr>
<tr>
<td>1/2”</td>
<td>10”</td>
<td>0.495</td>
<td>64</td>
</tr>
<tr>
<td>1/2”</td>
<td>12”</td>
<td>0.719</td>
<td>60</td>
</tr>
<tr>
<td>1/2”</td>
<td>14”</td>
<td>0.996</td>
<td>48</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

Note: The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
SECTION 13

DIXIE HFS™ 2.875" O.D - P28, SCH40 MULTI-HELIX FOUNDATION PIPE PILES

Helical Pipe Pile Lead and Extension with “Strength Square” coupling
Helical Foundation Pipe Pile Lead and Extensions consist of a central 2.875" O.D. (sch40) pipe with “Strength Square” couplings and/or helices welded as shown in Fig. 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 1-1/2" RCS D6 or D7 can be used for special soil conditions.
- **Extension** - the extension pipe has male/female cast steel couplings welded on both end. 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.
- **“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
Helix, 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 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 Mechanical Strength Torque rating of DIXIE HFS™ Pipe Pile 2.875” OD, P28, sch40 Multi-Helix Lead Section and Extensions is 7.500 [ft-lb.] based upon empirical test data.

Anchor Mechanical Strength Rating
The maximum design load for DIXIE HFS™ 2.875” O.D., P28, sch40 Multi-Helix pipe pile is 40,000 lb for tension and 30,000 lb for compression with safety factor of 2. (Section 12, Table 12.2)

Axial Load Mechanical Strength Ratings

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8”</td>
<td>8”</td>
<td>0.278</td>
<td>44</td>
</tr>
<tr>
<td>3/8”</td>
<td>10”</td>
<td>0.473</td>
<td>42</td>
</tr>
<tr>
<td>3/8”</td>
<td>12”</td>
<td>0.711</td>
<td>40</td>
</tr>
<tr>
<td>3/8”</td>
<td>14”</td>
<td>0.993</td>
<td>32</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

Note: The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
Helical Pipe Pile Lead and Extension with “Strength Square” coupling

Helical Foundation Pipe Pile Lead and Extensions consist of a central 2.875” O.D. (sch80) pipe with “Strength Square” couplings and/or helices welded as shown in Fig. 7.

- **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 1-1/2” RCS D6 or D7 can be used for special soil conditions.
- **Extension** - the extension pipe has male/female cast steel couplings welded on both end. 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.
- **“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

Helix, 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 P28H Pipe Pile.

Connection Bolts

Each Extension pipe is provided with two 3/4” diameter x 3 3/4” 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 Mechanical Strength Torque rating of DIXIE HFS™ Pipe Pile 2.875” O.D, P28H, sch80 Multi-Helix Lead Section and Extensions is 9.000 [ft-lb.] based upon empirical test data.

Anchor Mechanical Strength Rating

The maximum design load for DIXIE HFS™ 2.875” O.D., P28H, sch80 Multi-Helix pipe pile is 50,000 lb for tension and 36,000 lb for compression with safety factor of 2. (Section 12, Table 12.2)

Axial Load Mechanical Strength Ratings

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8”</td>
<td>8”</td>
<td>0.278</td>
<td>44</td>
</tr>
<tr>
<td>3/8”</td>
<td>10”</td>
<td>0.473</td>
<td>42</td>
</tr>
<tr>
<td>3/8”</td>
<td>12”</td>
<td>0.711</td>
<td>40</td>
</tr>
<tr>
<td>3/8”</td>
<td>14”</td>
<td>0.993</td>
<td>32</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

Note: The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
Helical Pipe Pile Lead and Extensions with “Strength Square” coupling

Helical Foundation Pipe Pile Lead and Extension consist of a central 3.5” O.D. (sch40) pipe with “Strength Square” couplings and/or helices welded as shown in Fig. 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 1-3/4” RCS D10 can be used for special conditions.
- **Extension** - the extension pipe has male/female cast steel couplings welded on both end. 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.
- **“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**

Helix, 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 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 Mechanical Strength Torque rating of DIXIE HFS™ Pipe Pile 3.50” O.D., P35, sch40 Multi-Helix Lead Sections and Extensions is 11.400 [ft-lb.] based upon empirical test data.

**Anchor Mechanical Strength Rating**

The maximum design load for DIXIE HFS™ 3.50” O.D., P35, sch40 Multi-Helix pipe pile is 50,000 lb for tension and 40,000 lb for compression with safety factor of 2. (Section 12, Table 12.2)

**Axial Load Single Helix Mechanical Strength Ratings**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8”</td>
<td>8”</td>
<td>0.278</td>
<td>68</td>
</tr>
<tr>
<td>3/8”</td>
<td>10”</td>
<td>0.473</td>
<td>64</td>
</tr>
<tr>
<td>3/8”</td>
<td>12”</td>
<td>0.711</td>
<td>60</td>
</tr>
<tr>
<td>3/8”</td>
<td>14”</td>
<td>0.993</td>
<td>48</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

**Note:** The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
Helical Foundation Pipe Pile Lead and Extensions with “Strength Square” coupling

Helical Foundation Pipe Pile Lead and Extension consist of a central 3.5” O.D. (sch80) pipe with “Strength Square” couplings and/or helices welded as shown in Fig. 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 1-3/4” RCS D10 can be used for special conditions.
- **Extension** - the extension pipe has male/female cast steel couplings welded on both end. 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.
- **“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**

Helix, 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 Mechanical Strength Torque rating of DIXIE HFS™ Pipe Pile 3.50” O.D., P35H, sch80 Multi-Helix Lead Sections and Extensions is 15,000 [ft-lb.] based upon empirical test data.

**Anchor Mechanical Strength Rating**

The maximum design load for DIXIE HFS™ 3.50” O.D., P35H, sch80 Multi-Helix pipe pile is 70,000 lb for tension and 52,500 lb for compression with safety factor of 2. (Section 12, Table 12.2)

**Axial Load Single Helix Mechanical Strength Ratings**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2”</td>
<td>8”</td>
<td>0.278</td>
<td>78</td>
</tr>
<tr>
<td>1/2”</td>
<td>10”</td>
<td>0.473</td>
<td>74</td>
</tr>
<tr>
<td>1/2”</td>
<td>12”</td>
<td>0.711</td>
<td>70</td>
</tr>
<tr>
<td>1/2”</td>
<td>14”</td>
<td>0.993</td>
<td>56</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

**Note:** The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
Helical Pipe Pile Lead and Extension with “Strength Square” coupling

Helical Foundation Pipe Pile Lead and Extensions consist of a central 4.5” O.D. (sch 40) pipe with “Strength Square” couplings and/or helices welded as shown in Fig. 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’ RCS D15 can be used for special soil conditions.
- **Extension** - the extension pipe has male/female cast steel couplings welded on both end. 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.
- **‘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**

Helix, 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 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 Mechanical Strength Torque rating of DIXIE HFS™ 4.5” O.D., P45 sch40 Multi-Helix Lead Section and Extensions is 20,000 [ft-lb.] based upon empirical test data.

**Anchor Mechanical Strength Rating**

The maximum design load for DIXIE HFS™ 4.5” O.D., P45, sch40 Multi-Helix pipe pile is 70,000 lb for tension and 60,000 lb for compression with safety factor of 2. (Section 12, Table12.2)

**Axial Load Single Helix Mechanical Strength Ratings**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2”</td>
<td>8”</td>
<td>0.236</td>
<td>88</td>
</tr>
<tr>
<td>1/2”</td>
<td>10”</td>
<td>0.430</td>
<td>84</td>
</tr>
<tr>
<td>1/2”</td>
<td>12”</td>
<td>0.668</td>
<td>80</td>
</tr>
<tr>
<td>1/2”</td>
<td>14”</td>
<td>0.950</td>
<td>64</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

**Note:** The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
Helical Pipe Pile Lead and Extension with “Strength Square” coupling
Helical Foundation Pipe Pile Lead and Extensions consist of a central 4.5” O.D. (sch80) pipe with “Strength Square” couplings and/or helices welded as shown in Fig. 11.

- **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’ RCS D15 can be used for special soil conditions.
- **Extension**: The extension pipe has male/female cast steel couplings welded on both end. 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.
- **“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**
Helix, 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 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 Mechanical Strength Torque rating of DIXIE HFS™ 4.5” O.D., P45H, sch80 Multi-Helix Lead Section and Extensions is 26,000 [ft-lb.] based upon empirical test data.

**Anchor Mechanical Strength Rating**
The maximum design load for DIXIE HFS™ 4.5” O.D., P45H, sch80 Multi-Helix pipe pile is 100,000 lb for tension and 78,000 lb for compression with safety factor of 2. (Section 12, Table12.2)

**Axial Load Single Helix Mechanical Strength Ratings**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2”</td>
<td>8”</td>
<td>0.236</td>
<td>88</td>
</tr>
<tr>
<td>1/2”</td>
<td>10”</td>
<td>0.430</td>
<td>84</td>
</tr>
<tr>
<td>1/2”</td>
<td>12”</td>
<td>0.668</td>
<td>80</td>
</tr>
<tr>
<td>1/2”</td>
<td>14”</td>
<td>0.950</td>
<td>64</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

**Note**: The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
SECTION 13

DIXIE HFS™ 8.625” O.D - P8, MULTI-HELIX FOUNDATION PIPE PILES

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

Helical Foundation 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 Fig. 12

- **Lead** - the lead pipe has the “Strength Square” female coupling and reducer hub welded to accept the 1-3/4” or 2” RCS. It is available with or without the helices.
- **RCS Lead** - the appropriate 1-3/4” RCS D10 or 2” RCS D15 is used based for soil conditions.
- **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 50ksi minimum yield strength.
- **“Strength Square”** Male/female couplings and reducer hub are cast steel per ASTM A958, SC1045 or equal with 40ksi yield and 80ksi ultimate strength minimum.

Helix - Helical Bearing Plates

Helix, 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 with 55ksi min. yield strength. The available helix sizes range from 8” to 14” for the RCS shaft and 16” to 24” for the P8 pipe pile.

Connection Bolts

(4) 3/4” diameter bolts x 1-1/2” long per ASTM A325 for the “Strength Square” couplings and (1) 7/8” diameter bolt per ASTM A325 for 1-3/4” RCS or (1) 1-1/8” diameter bolt per SAE J429 for 2” RCS. Associated jam nut is 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 Mechanical Strength Torque rating of DIXIE HFS™ 8.625” O.D., P8, pipe pile with Multi-Helix Lead Section and Extensions is 44.500 [ft-lb.] based upon empirical test data.

Anchor Mechanical Strength Rating

The maximum design load for DIXIE HFS™ 8.625” O.D., P8, pipe pile with Multi-Helix is 120,000 lb for tension and 100,000 lb for compression with safety factor of 2. (Section 12, Table12.2)

Axial Load Single Helix Mechanical Strength Ratings

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2”</td>
<td>14”</td>
<td>0.659</td>
<td>85</td>
</tr>
<tr>
<td>1/2”</td>
<td>16”</td>
<td>0.984</td>
<td>80</td>
</tr>
<tr>
<td>1/2”</td>
<td>20”</td>
<td>1.766</td>
<td>60</td>
</tr>
<tr>
<td>1/2”</td>
<td>24”</td>
<td>2.719</td>
<td>50</td>
</tr>
</tbody>
</table>

(1) The Axial Load Mechanical Ratings are derived from empirical test data based upon the test method per ICCES-AC358.

Note: The in-situ axial load capacity of any helical foundation pile or anchor is dependent upon an analysis of the interaction between the helical bearing plates and the site-specific soil conditions. The installed ultimate load capacity may therefore be less than the Ultimate Mechanical Strength Rating of the helical pile or anchor system components. In addition, the ultimate load capacity of an installed helical pile or anchor may be governed by installation torque limitations.
DIXIE HFS™ Dixie350™ - New Construction Bracket for 1-½”, 1-¾” and 2” RCS (Round Corner Square) and 2-7/8”, 3-½” and 4-½” pipe piles

Table 1- New Construction Bracket for RCS Foundation & Pipe Piles - Mechanical Rating

<table>
<thead>
<tr>
<th>Cat. Prefix</th>
<th>Shaft</th>
<th>NEW CONSTRUCTION BRACKETS</th>
<th>W in.</th>
<th>L in.</th>
<th>T in.</th>
<th>Fig.</th>
<th>Bolt in.</th>
<th>qty</th>
<th>Gr.</th>
<th>Maximum Compression Load (Kips)</th>
<th>Allowable Compression Load (Kips)</th>
<th>Plate Material Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6</td>
<td>1-1/2” RCS</td>
<td>NCB060604P28</td>
<td>6</td>
<td>6</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>1</td>
<td>8</td>
<td>55</td>
<td>27.5</td>
<td>ASTM A36</td>
</tr>
<tr>
<td>D6</td>
<td>1-1/2” RCS</td>
<td>NCB080804P28</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>1</td>
<td>8</td>
<td>55</td>
<td>27.5</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>1-1/2” RCS</td>
<td>NCB060604P28</td>
<td>6</td>
<td>6</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>1</td>
<td>8</td>
<td>70</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>1-1/2” RCS</td>
<td>NCB080804P28</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>1</td>
<td>8</td>
<td>70</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>D10</td>
<td>1-3/4” RCS</td>
<td>NCB060604P35</td>
<td>6</td>
<td>6</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>1</td>
<td>8</td>
<td>70</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>D10</td>
<td>1-3/4” RCS</td>
<td>NCB080804P35</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>1</td>
<td>8</td>
<td>100</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>D15</td>
<td>2” RCS</td>
<td>NCB060604P45</td>
<td>6</td>
<td>6</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>60</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>P28</td>
<td>2-7/8Odx.203”</td>
<td>NCB060604P28</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>60</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>P28H</td>
<td>2-7/8Odx.276”</td>
<td>NCB060604P28</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>72</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>P28H</td>
<td>2-7/8Odx.276”</td>
<td>NCB080804P28</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>72</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>P35</td>
<td>3-1/2 OD x .216”</td>
<td>NCB080804P35</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>80</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>P35</td>
<td>3-1/2 OD x .216”</td>
<td>NCB101006P35</td>
<td>10</td>
<td>10</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>80</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>P35H</td>
<td>3-1/2OD x .300”</td>
<td>NCB060604P28</td>
<td>10</td>
<td>10</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>105</td>
<td>52.5</td>
<td></td>
</tr>
<tr>
<td>P35H</td>
<td>3-1/2OD x .300”</td>
<td>NCB080804P28</td>
<td>10</td>
<td>10</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>105</td>
<td>52.5</td>
<td></td>
</tr>
<tr>
<td>P45</td>
<td>4-1/2 OD x .237”</td>
<td>NCB060604P45</td>
<td>10</td>
<td>10</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>120</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>P45H</td>
<td>4-1/2 OD x .337”</td>
<td>NCB080804P45</td>
<td>10</td>
<td>10</td>
<td>½</td>
<td>15</td>
<td>¾</td>
<td>2</td>
<td>5</td>
<td>156</td>
<td>78</td>
<td></td>
</tr>
</tbody>
</table>

Note: For 1-½” RCS, the allowable capacity is limited to 26,900 lb by bolt shear, if grade 5 bolt is used.
For 1-⅜” RCS, the allowable capacity is limited to 36,750 lb by bolt shear, if grade 5 bolt is used.

General

The New Construction Brackets are placed at the end of the Helical Foundation Piles or Anchors to support the new or repair construction for axial loading as shown in Fig 13&14. 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.
**General**

The Dixie Helical Foundation System (DixieHFS™) is used to provide deep foundation support for surface foundation elements as well as to address foundation settlement issues as shown in Fig. 16. Dixie350 Bracket provides means for connection between installed helical foundation RCS/Pipe Piles and structural building components, typically foundation grade beams, footings, or slabs. Dixie350 is a unique, patent pending one-piece cast iron design permitting up to 50 kips application with additional supporting surface capability if required.

**Lifting Bar Assemblies**

Lifting Bar Assemblies are consists of a cross bar member at top and a various size pipe at bottom to fit snug over RCS or P28/P28H or fit inside of P35 shafts. It uses 1-3/4" RCS, 1530M material for the cross bar and a 40" long pipe, ASTM A500 material welded together as shown in Fig. 15 & 16. For P35H, a 2" RCS, 1530M material is used for the cross and a 24" long bar welded at the bottom as shown in Fig. 17.

**Connection Bolts**

Each lifting assembly is provided with two 7/8” diameter x 12” all threaded studs per ASTM A325 with four 7/8” Hex 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 Working Load rating for MacLean DixieHFS™ Dixie350, Foundation cast iron bracket is 52,500 lb. The Minimum Ultimate Failure Load rating for DixieHFS™ Dixie350 Foundation cast iron bracket is 105,000 lb.
Helical Foundation Piles and anchors consist of a central shaft with one or more helices.

Helices have three 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
3. To provide the required torsional and bearing capacity for proper installation and end use.

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 provide the required torsional capacity for proper installation
2. To sustain loads transferred from the helices – during and after installation
3. To sustain compressive, tension and shear loads – transferred from other structures – 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.

The installation of a helical foundation pile can be compared to the installation of a self-tapping wood screw. (i.e. The torque achieved during installation 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 screw 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 installation. If $Q_{ult}$ 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.

\[
Q_{ult} = K_t \times T
\]  

[Equation 14.1]

Where:

$Q_{ult} = \text{The expected geotechnical ultimate tension capacity. [lbs]}$  
\( \text{(Includes helix-bearing capacity only. Does not include skin friction.)} \)

$K_t = \text{Torque Factor [ft}^{-1}] \text{ See Table 14.1}$

$T = \text{Average Installation Torque [lb-ft] – defined below}$
The ultimate tension capacity determined by Equation 14.1 \( Q_{ult} \) 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 3 or 4 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 torque 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 MACLEAN-DIXIE helical products, the recommended Torque Factor values \( (K_t) \) are shown in Table 14.1. As discussed below, torque factors can vary. The following recommendations should be used with caution.

<table>
<thead>
<tr>
<th>Shaft Size</th>
<th>( K_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square Shaft piles/Anchors</td>
<td>10</td>
</tr>
<tr>
<td>2.875” Diameter Helical Pipe Piles</td>
<td>8</td>
</tr>
<tr>
<td>3.50” Diameter Helical Pipe Piles</td>
<td>7</td>
</tr>
<tr>
<td>4.50” Diameter Helical Pipe Piles</td>
<td>6</td>
</tr>
<tr>
<td>8.625” Diameter Helical Pipe Piles</td>
<td>4.5</td>
</tr>
</tbody>
</table>

For shaft diameters greater than 3.5”, MACLEAN-DIXIE recommends a full-scale load test at the jobsite to determine \( K_t \).

The above values for \( K_t \) are based on experience and field-testing in various locations and soil types, with various helix and shaft configurations. It should be noted that \( K_t \) 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 \( K_t \).

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 \( K_t \) 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 \( K_t \) for the project.

The value of \( Q_{ult} \) 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 \( Q_{ult} \).

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. \( Q_{ult} \) 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 digger head 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. \( \geq .75" \)).

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 \( Q_{ult} \).

5. All helical products manufactured by MACLEAN-DIXIE shall be installed by MACLEAN-DIXIE 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 FOUNDATION PILES UNDER STATIC AXIAL LOAD

Scope:

The following is intended to provide a general description of load testing a Helical Screw Pile Foundation. 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.

A. The procedures in this document have been adapted from:

1. ASTM D 1143 Standard Test Method for Piles Under Static Axial Compressive Load

Re: Quick Load Test Method for Individual Piles

B. Purpose of Load Test

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

C. Installation of Test Pile

1. The following safety procedures shall be followed:
   a. All safety procedures of the pile manufacturer and the owner’s representative
   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.
D. 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 owner’s satisfaction. All calibration and certification reports shall 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

E. 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. See Section A

A secondary (backup) measuring system is highly recommended.
F. 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 min 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.

G. 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 shall be forwarded to the owner's representative.

H. Reduction of Data

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

I. Approval Criteria

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

References


MacLean DixieHFS™ "STRENGTH SQUARE" Multi-Helix Foundation Pipe piles Catalog Numbering System

**Extension Section Catalog Numbering System**

**Example:**

**P35 E 84 S 14 2 U**

<table>
<thead>
<tr>
<th>Material Size</th>
<th>Helix Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>P28-2.875&quot; O.D. PIPE, 208&quot; WALL</td>
<td>S = 3/8&quot;, T=1/2&quot;</td>
</tr>
<tr>
<td>P38H-2.875&quot; O.D. PIPE, 276&quot; WALL</td>
<td></td>
</tr>
<tr>
<td>P38H-3.50&quot; O.D. PIPE, 300&quot; WALL</td>
<td></td>
</tr>
<tr>
<td>P45-4.50&quot; O.D. PIPE, 237&quot; WALL</td>
<td></td>
</tr>
<tr>
<td>P45H-4.50&quot; O.D. PIPE, 337&quot; WALL</td>
<td></td>
</tr>
<tr>
<td>P8-6.25&quot; O.D. PIPE, 188&quot; WALL</td>
<td></td>
</tr>
</tbody>
</table>

**Lead Section Catalog Numbering System**

**Example:**

**P35 A 84 S 10 12 14 2 U**

<table>
<thead>
<tr>
<th>Material Size</th>
<th>Helix Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>P28-2.875&quot; O.D. PIPE, 208&quot; WALL</td>
<td>S = 3/8&quot;, T=1/2&quot;</td>
</tr>
<tr>
<td>P38H-2.875&quot; O.D. PIPE, 276&quot; WALL</td>
<td></td>
</tr>
<tr>
<td>P38H-3.50&quot; O.D. PIPE, 300&quot; WALL</td>
<td></td>
</tr>
<tr>
<td>P45-4.50&quot; O.D. PIPE, 237&quot; WALL</td>
<td></td>
</tr>
<tr>
<td>P45H-4.50&quot; O.D. PIPE, 337&quot; WALL</td>
<td></td>
</tr>
<tr>
<td>P8-6.25&quot; O.D. PIPE, 188&quot; WALL</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**

* P8 pipe pile lead section is a transition pile either uses a 1 3/4" RCS or 2" RCS lead section as listed on the right.

---

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

**DIXIE HFS™ CATALOG NUMBERING SYSTEM**

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC. and its unauthorized use or publication without the express written consent of MacLean Dixie, LLC. is strictly prohibited.

**DATE:** 12/28/08
**SCALE:** FULL
**NO.:** P3500
**ENG. REF.:** R 3 of 1
MacLean DixieHFS™ 1-1/4" D3 Helical Foundation Piles & Tension Anchors

TORQUE STRENGTH RATING OF 3,400 FT-LB
ULTIMATE COMPRESSION CAPACITY = 34 KIPS WITH A
TORQUE FACTOR k_t = 10
SINGLE 12" HELIX ULTIMATE STRENGTH = 26 KIPS; 3/8" THICK
ULTIMATE TENSION STRENGTH = 34 KIPS WITH COUPLING BOLT

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

NOTES:
1. FINISH - HOT DIP GALV. PER ASTM A153 OR BLACK BY
ADDITION OF SUFFIX “U” AFTER CAT. NO.
2. SHAFT MATERIAL - ROUND CORNERED SQUARE (RCS)
STEEL BARS PER ASTM A29 AND ASTM A576 GRADE 10V45M,
WITH MILL CERT. AT 70 KSI MIN. YIELD STRENGTH.
3. HELIX MATERIAL - HOT ROLLED LOW CARBON STEEL SHEET,
STRIP, OR PLATE PER ASTM A1018 HSLAS55, WITH MIN YIELD
STRENGTH = 55 KSI FOR 3/8" THICK MATERIAL.
4. COUPLING BOLTS: 5/8" DIAMETER X 3" LONG HEX HEAD PER
ASTM A325 AND 5/8" HEX JAM NUTS PER ASTM A563.
5. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.
6. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER
AWS CODE D1.1.
7. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10
ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS.

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS™ 1-1/4" D3 Helical foundation
Piles & Tension Anchors

All information contained in this disclosure whether patentable or
otherwise comprises proprietary information of MacLean Dixie, LLC.
and its unauthorized use or publication without the express written
consent of MacLean Dixie, LLC is strictly prohibited.
MacLean Dixie HFS™ 1-1/2" D6 Helical Foundation Piles & Tension Anchors

TORQUE STRENGTH RATING OF 5,500 FT-LB
ULTIMATE COMPRESSION CAPACITY - 55 KIPS WITH A
TORQUE FACTOR (Kt) = 10
SINGLE 12" HELIX ULTIMATE STRENGTH - 38 KIPS, 3/8" & 50 KIPS, 1/2"
ULTIMATE TENSION STRENGTH - 60 KIPS WITH COUPLING BOLT

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

NOTES:
1. FINISH - HOT DIP GALV. PER ASTM A153 DR BLACK BY
ADDING SUFFIX "O" AFTER CAT. NO.
2. SHAFT MATERIAL - ROUND CORNERED SQUARE (RCS)
STEEL BARS PER ASTM A29 AND ASTM A616 GRADE 10V45M,
WITH MILL CERT. AT 70 KSI MIN. YIELD STRENGTH.
3. HELIX MATERIAL - HOT ROLLED LOW CARBON STEEL PER ASTM A1018
OR EQUAL WITH 55 KSI MINIMUM YIELD STRENGTH.
4. COUPLING BOLTS: 3/4" DIAMETER X 3" LONG HEX HEAD PER
ASTM A325 AND 3/4" HEX JAM NUTS PER ASTM A563.
5. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.
6. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER AWS CODE D1.1
7. SEE TEST REPORT FOR ALLOWABLE AXIAL AND LATERNAL LOAD
PER ICC-ES ACCEPTANCE CRITERIA, AC350 BY CTL/THOMSON, AN
ACREDITED TEST LABORATORY.
8. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10
ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS
MacLean Dixie HFS® 1-1/2" D7 Helical Foundation Piles & Tension Anchors

TORQUE STRENGTH RATING OF 7,000 FT-LB
ULTIMATE COMPRESSION CAPACITY - 70 KIPS WITH A
 TORQUE FACTOR (Kt) = 10
SINGLE 12" HELIX ULTIMATE STRENGTH - 30 KIPS, 3/8" & 50 KIPS, 1/2"
ULTIMATE TENSION STRENGTH - 70 KIPS WITH COUPLING BOLT

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

EXTENSION
EX. D7E84

TWO HELIX EXTENSION
EX. D7E84S12I4S11

SINGLE HELIX LEAD
EX. D784S12

TWO HELIX LEAD
EX. D784S12I4

THREE HELIX LEAD
EX. D784S10I214

TYPICAL PILE/ANCHOR ASSEMBLY
EX. D7120SB101214 LEAD AND EXTENSIONS

NOTES:

1. FINISH - HOT DIP GALV. PER ASTM A153 OR BLACK BY
   ADDING SUFFIX "B" AFTER CAT. ND.

2. SHAFT MATERIAL - ROUND CORNERED SQUARE (RCS)
   STEEL BARS PER ASTM A29 AND ASTM A576 GRADE 1530M
   WITH MILL CERT. AT 90 KSI MIN. YIELD STRENGTH.

3. HELIX MATERIAL - HOT ROLLED LOW CARBON STEEL PER ASTM A1018
   OR EQUAL WITH 55 KSI MINIMUM YIELD STRENGTH.

4. COUPLING BOLTS: 3/4" DIAMETER X 3" LONG HEX HEAD PER
   ASTM A325 AND 3/4" HEX JAM NUTS PER ASTM A563.

5. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.

6. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER
   AWS CODE D11.

7. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10
   ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS.

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS™ 1-1/2" D7 Helical Foundation Piles & Tension Anchors

All information contained in this disclosure whether patentable or
otherwise comprises proprietary information of MacLean Dixie, LLC.
and its unauthorized use or publication without the express written
consent of MacLean Dixie, LLC. is strictly prohibited.
MacLean Dixie HFS™ 1-3/4" D10 Helical Foundation Piles & Tension Anchors

Torque strength rating of 10,000 ft-lb
Ultimate compression capacity - 100 kips with a
torque factor (Kt) = 10
Single 12" helix ultimate strength - 36 kips, 3/8" & 56 kips, 1/2"
Ultimate tension strength - 100 kips with coupling bolt

For catalog numbering system see drawing No. P3500

Notes:
1. Finish - Hot dip galv. per ASTM A153 or black by adding suffix "U" after cat. no.
2. Shaft material - round cornered square (RCS) steel bars per ASTM A69 and ASTM A576 grade 1530M with mill cert. at 90 ksi min. yield strength.
3. Helix material - hot rolled low carbon steel per ASTM A1018 or equal with 55 ksi minimum yield strength.
4. Coupling bolts: 7/8" diameter X 3-1/2" long hex head per ASTM A325 and 7/8" hex jam nuts per ASTM A563.
5. Nominal spacing between helical plates is 3X the lower dia.
6. All welding to be done by welders certified per AWS D1.1.

7. See test report for allowable axial and lateral load per ICC-ES Acceptance Criteria, AC358 by CTL/Thomson, an accredited IAS 17025 testing laboratory.
8. All material is manufactured as per ICC-ES, AC10 acceptance criteria for quality control documents.

ICC-ES APPLICATION FILE # 09-10-09

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS™ 1-3/4" D10 Helical Foundation Piles & Tension Anchors

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC. and its unauthorized use or publication without the express written consent of MacLean Dixie, LLC. is strictly prohibited.
MacLean DixieHFS™ 2" D15 Helical Foundation Piles & Tension Anchors

TORQUE STRENGTH RATING OF 15,000 FT-LBS
ULTIMATE COMPRESSION CAPACITY - 150 KIPS WITH A
TORQUE FACTOR (Kt) = 10
SINGLE 12" HELIX ULTIMATE STRENGTH - 60 KIPS; 1/2" THICK
ULTIMATE TENSION STRENGTH - 150 KIP WITH COUPLING BOLT

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

NOTES:
1. FINISH - HDG DIP GALV. PER ASTM A153 OR BLACK BY
   ADDING SUFFIX "B" AFTER CAT. NO.
2. SHAFT MATERIAL - ROUND CORNERED SQUARE (RCS)
   STEEL BARS PER ASTM A29 AND ASTM A576 GRADE 1530M
   WITH MILL CERT. AT 90 KSI MIN. YIELD STRENGTH.
3. HELIX MATERIAL - HDG ROLLED LOW CARBON STEEL PER ASTM A501B
   OR EQUAL WITH 55 KSI MINIMUM YIELD STRENGTH.
4. COUPLING BOLTS: 1-1/8" DIAMETER X 4-1/4" LONG HEX HEAD PER
   SAE J429 AND 1-1/8" HEX JAM NUTS PER ASTM A563.
5. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.
6. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER
   AWS CODE D1.1
7. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10
   ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS

All information contained in this disclosure whether patentable or
otherwise comprises proprietary information of MacLean Dixie, LLC.
and its unauthorized use or publication without the express written
consent of MacLean Dixie, LLC. is strictly prohibited.
MacLean DixieHFS™ 2.875" OD - P28, sch40  "STRENGTH SQUARE" HELICAL FOUNDATION PIPE PILES

TORQUE STRENGTH RATING OF 7,500 FT-LB
ULTIMATE COMPRESSION CAPACITY - 60 KIPS WITH A
TORQUE FACTOR (Kt) = 8
SINGLE 12" HELIX ULTIMATE STRENGTH - 40 KIPS; 3/8" THICK
ULTIMATE TENSION STRENGTH - 80 KIPS

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

"STRENGTH SQUARE" PIPE EXTENSION EX. P28EB84
"STRENGTH SQUARE" PIPE EXTENSION W/HELIX EX. P28EB84S14
"STRENGTH SQUARE" SINGLE HELIX LEAD EX. P28B4S14
"STRENGTH SQUARE" DOUBLE HELICES LEAD EX. P28B4S1012
"STRENGTH SQUARE" TRIPLE HELICES LEAD EX. P28B4S10124

NOTES:
1. FINISH - HOT DIP GALV. PER ASTM A153. FOR BLACK, ADD SUFFIX "U" AFTER CAT. NO.
2. PIPE MATERIAL - 2.875" O.D. X 0.203" WALL, SCHEDULE 40 PER ASTM A500 OR EQUAL WITH MINIMUM 50KSI YIELD STRENGTH.
3. "STRENGTH SQUARE" COUPLING - CAST STEEL PER ASTM A958, SCl045 OR EQUAL WITH 40KSI YIELD AND 60KSI ULTIMATE STRENGTH MINIMUM.
4. HELIX MATERIAL - HOT ROLLED LOW CARBON STEEL PER ASTM A1018 OR EQUAL WITH 55 KSI MINIMUM YIELD STRENGTH, STRENGTH FOR 3/8" THICK MATERIAL.
6. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.
7. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER AWS CODE D1.1
8. SEE TEST REPORT FOR ALLOWABLE AXIAL AND LATERNAL LADD PER ICC-ES ACCEPTANCE CRITERIA AC358 BY CTI/THOMSON, AN ACREDITED IAS 17025 TESTING LABORATORY.
9. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10 ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS

PATENT PENDING

ICC-ES APPLICATION FILE # 09-10-09

DIXIE HFS™ 2.875" OD - P28, sch40
Helical Foundation Pipe Piles

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC. and its unauthorized use or publication without the express written consent of MacLean Dixie, LLC. is strictly prohibited.
MacLean Dixie HFS™ 2.875" O.D. - P28H, sch80 HEAVY "STRENGTH SQUARE" HELICAL FOUNDATION PIPE PILES

TORQUE STRENGTH RATING OF 9,000 FT-LB
ULTIMATE COMPRESSION CAPACITY - 72 KIPS WITH A
TORQUE FACTOR (K_t) = 8
SINGLE 12" HELIX ULTIMATE STRENGTH - 40 KIPS; 3/8" THICK
ULTIMATE TENSION STRENGTH - 100 KIPS

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

NOTES:
1. FINISH - HOT DIP GALV. PER ASTM A153. FOR BLACK, ADD SUFFIX "B" AFTER CAT. NO.
2. PIPE MATERIAL - 2.875" O.D. X 0.276" WALL, SCHEDULE 80 PER ASTM A500 OR EQUAL WITH MINIMUM 50KSI YIELD STRENGTH.
3. "STRENGTH SQUARE" COUPLING - CAST STEEL PER ASTM A958, S0145 OR EQUAL WITH 40KSI YIELD AND 60KSI ULTIMATE STRENGTH MINIMUM.
4. HELIX MATERIAL - HOT ROLLED LOW CARBON STEEL PER ASTM A1018 OR EQUAL WITH 55 KSI MINIMUM YIELD STRENGTH.
6. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.
7. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER AWS DI1.
8. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10 ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS

PATENT PENDING
MacLean Dixie HFS™ 3.5" O.D. - P35, sch40 "STRENGTH SQUARE" HELICAL FOUNDATION PIPE PILES

TORQUE STRENGTH RATING OF 11,400 FT-LB
ULTIMATE COMPRESSION CAPACITY - 80 KIPS WITH A
TORQUE FACTOR (Kg) = 7
SINGLE 12" HELIX ULTIMATE STRENGTH - 60 KIPS; 3/8" THICK
ULTIMATE TENSION STRENGTH - 100 KIPS

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

![Diagram of helical piles with various configurations]

NOTES:
1. FINISH - HOT DIP GALV. PER ASTM A153. FOR BLACK, ADD SUFFIX "U" AFTER CAT. NO.
2. PIPE MATERIAL - 3.500" O.D. X 0.216" WALL, SCHEDULE 40 PER ASTM A500 OR EQUAL WITH MINIMUM 50KSI YIELD STRENGTH.
3. "STRENGTH SQUARE" COUPLING - CAST STEEL PER ASTM A958, SC1045 OR EQUAL WITH 40KSI YIELD AND 80KSI ULTIMATE STRENGTH MINIMUM.
4. HELIX MATERIAL - HOT ROLLED LOW CARBON STEEL PER ASTM A101B OR EQUAL WITH 55 KSI MINIMUM YIELD STRENGTH.
5. COUPLING BOLTS 7/8" DIAMETER X 4-1/2" LONG HEX HEAD PER ASTM A325 AND 7/8" HEX JAM NUTS PER ASTM A563.
6. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.
7. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER AWS D1.1.

PATENT PENDING

ICC-ES APPLICATION FILE # 09-10-09

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS™ 3.5" O.D. - P35, sch40
Helical Foundation Pipe Piles

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC. and its unauthorized use or publication without the express written consent of MacLean Dixie, LLC. is strictly prohibited.
MacLean Dixie HFS™ 3.5" O.D. - P35H, sch80 HEAVY "STRENGTH SQUARE" HELICAL FOUNDATION PIPE PILES

TORQUE STRENGTH RATING OF 15,000 FT-LB
ULTIMATE COMPRESSION CAPACITY - 105 KIPS WITH A
TORQUE FACTOR (Kt) = 7
SINGLE 12" HELIX ULTIMATE STRENGTH - 70 KIPS; 1/2" THICK
ULTIMATE TENSION STRENGTH - 140 KIPS

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

NOTES:
1. FINISH - HOT DIP GALV. PER ASTM A153. FOR BLACK, ADD SUFFIX "U" AFTER CAT. NO.
2. PIPE MATERIAL - 3.500" O.D. X 0.300" WALL, SCHEDULE 80 PER ASTM A500 DR EQUAL WITH MINIMUM 50KSI YIELD STRENGTH.
3. "STRENGTH SQUARE" COUPLING - CAST STEEL PER ASTM A958. SC1045 DR EQUAL WITH 40KSI YIELD AND 80KSI ULTIMATE STRENGTH MINIMUM.
4. HELIX MATERIAL - HOT ROLLED LOW CARBON STEEL PER ASTM A1018 DR EQUAL WITH 55 KSI MINIMUM YIELD STRENGTH.
5. COUPLING BOLTS: 7/8" DIAMETER X 4-1/2" LONG HEX HEAD PER ASTM A325 AND 7/8" HEX JAM NUTS PER ASTM A563.
6. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.

7. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER AWS D1.1.
8. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10 ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS

PATENT PENDING

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS™ 3.5" O.D. - P35H, sch80
Heavy Helical Foundation Pipe Piles

DATE: 03/10/09 DRAWN: FULL
ENG. REF. P3509 R/3
MacLean DixieHFS™ 4.5" O.D. - P45, sch40 "STRENGTH SQUARE" HELICAL FOUNDATION PIPE PILES

TORQUE STRENGTH RATING OF 20,000 FT-LB
ULTIMATE COMPRESSION CAPACITY - 120 KIPS WITH A
TORQUE FACTOR (K) = 6
SINGLE 12" HELIX ULTIMATE STRENGTH - 80 KIPS; 1/2" THICK
ULTIMATE TENSION STRENGTH - 140 KIPS

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

NOTES:
1. FINISH - HOT DIP GALV. PER ASTM A153. FOR BLACK, ADD
   SUFFIX "U" AFTER CAT. NO.
2. PIPE MATERIAL - 4,500' O.D. X 0.237" WALL SCHEDULE 40 PER
   ASTM A500 OR EQUAL WITH MINIMUM 50KSI YIELD STRENGTH.
3. "STRENGTH SQUARE" COUPLING - CAST STEEL PER ASTM A958, SC1045
   OR EQUAL WITH 40KSI YIELD AND 80KSI ULTIMATE STRENGTH.
4. HELIX MATERIAL - HOT ROLLED LOW CARBON STEEL PER ASTM A1018
   OR EQUAL WITH 55 KSI MINIMUM YIELD STRENGTH.
5. COUPLING BOLTS: 1" DIAMETER X 5" LONG HEX HEAD PER ASTM
   A325 AND 1" HEX JAM NUTS PER ASTM A563.
6. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.
7. ALL WELDING TO BE DONE BY WELDERS CERTIFIED UNDER
   SECTION 5 OF THE AWS CODE D1.1.
8. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10
   ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS.

PATENT PENDING

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS™ 4.5" O.D. - P45, sch40
Helical Foundation Pipe Piles

All information contained in this disclosure whether patentable
or otherwise comprises proprietary information of MacLean Dixie, LLC.
and its unauthorized use or publication without the express written
consent of Maclean Dixie, LLC, is strictly prohibited.
MacLean Dixie HFS™ 4.5" O.D. - P45H, sch80 HEAVY "STRENGTH SQUARE" HELICAL FOUNDATION PIPE PILES

TORQUE STRENGTH RATING OF 25,000 FT-LB
ULTIMATE COMPRESSION CAPACITY - 156 KIPS WITH A
TORQUE FACTOR (K) = 6
SINGLE 12" HELIX ULTIMATE STRENGTH - 80 KIPS; 1/2" THICK
ULTIMATE TENSION STRENGTH - 200 KIPS

FOR CATALOG NUMBERING SYSTEM SEE DRAWING NO. P3500

NOTES:
1. FINISH - HOT DIP GALV. PER ASTM A53. FOR BLACK, ADD SUFFIX "U" AFTER CAT. NO.
2. PIPE MATERIAL - 4.500" ID X 0.337" WALL, SCHEDULE 80 PER
ASTM A500 OR EQUAL WITH MINIMUM 30KSI YIELD STRENGTH
3. "STRENGTH SQUARE" COUPLING - CAST STEEL PER ASTM A959. SC1045
OR EQUAL WITH 40KSI YIELD AND 80KSI ULTIMATE STRENGTH MINIMUM.
4. HELIX MATERIAL - HOT ROLLED LDW CARBON STEEL PER ASTM A1018
OR EQUAL WITH 55 KSI MINIMUM YIELD STRENGTH.
5. COUPLING BOLTS: 1" DIAMETER X 5" LUG HEX HEAD PER ASTM
A325 AND 1" HEX JAM NUTS PER ASTM A563.
6. NOMINAL SPACING BETWEEN HELICAL PLATES IS 3X THE LOWER DIA.

7. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER AWS D1.1.
8. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10
ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS

PATENT PENDING

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS™ 4.5" O.D. - P45H, sch80
Heavy Helical Foundation Pipe Piles

DATE 03/10/09 SCALE FULL NO. P3511
ENG. REF. 3 1
MacLean DixieHFS™ "Strength Square" Extension/Transition Helical Foundation Pipe Piles for RCS shaft

D6 PILES

P28E84X
TORQUE: 7,500 FT-LBS
P28HE84X
TORQUE: 10,000 FT-LBS

2 1/8" HDG. HEX HEAD BOLT & NUT

1 1/2" TWIN HELIX ANCHOR (ORDERED SEPARATELY)

CAST STEEL COUPLING

D10 PILES

P35E84X
TORQUE: 11,400 FT-LBS
P35HE84X
TORQUE: 14,300 FT-LBS

7/8" HDG. HEX HEAD BOLT & NUT

1 3/4" TWIN HELIX ANCHOR (ORDERED SEPARATELY)

CAST STEEL COUPLING

D15 PILES

P45E84X
TORQUE: 17,000 FT-LBS
P45HE84X
TORQUE: 25,000 FT-LBS

1 1/8" HDG. HEX HEAD BOLT & NUT

2" TWIN HELIX ANCHOR (ORDERED SEPARATELY)

CAST STEEL COUPLING

NOTES:
1. HOT DIP GALV. PER ASTM A153, AFTER FABRICATION.
2. PIPE MATERIAL - SCHEDULE 40 OR 80 PER ASTM A500 OR EQUAL.
3. COUPLER - CAST STEEL PER ASTM A958, SCI045 OR EQUAL WITH 40ksi YIELD AND 60ksi ULTIMATE STRENGTH MINIMUM.
4. COUPLING BOLTS: P28E84X - 3/4" DIA. X 2" GR. 8 BOLT
   P28HE84X - 3/4" DIA. X 2" GR. 8 BOLT
   P35E84X - 7/8" DIA. X 3 1/2" GR. 8 BOLT
   P35HE84X - 7/8" DIA. X 3 1/2" GR. 8 BOLT
   P45E84X - 1 1/8" DIA. X 4 1/4" GR. 8 BOLT
   P45HE84X - 1 1/8" DIA. X 4 1/4" GR. 8 BOLT
5. ALL WELDING TO BE DONE BY WELDERS CERTIFIED PER AWS DII.
6. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10
   ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTS

PATENT PENDING

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS® Extension/Transition
Helical Foundation Pipe Piles for RCS

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC.
and its unauthorized use or publication without the express written
consent of MacLean Dixie, LLC. is strictly prohibited.
Extension
W/ 3/4" Hex Bolts

Transition
W/ Lead
DIXIE350H-BK

DIXIE350-TP4A

NOTES:
1. MATERIAL: BRACKET - DUCTILE IRON, GRADE 654512 PER ASTM A536; RCS SHAFT - PER ASTM A29 OR A576
2. HOT DIP GALV PER ASTM A153, AFTER FABRICATION.
3. DO NOT EXCEED 165 FT-LBS OF TORQUE ON 7/8" DIAMETER THREAD RODS DURING STABILIZING OR LOAD LOCK-OFF.
4. RECOMMENDED ANCHOR SHAFT CUTOFF LEVEL ABOVE THE BOTTOM OF THE FOOTING IS 10" TO 11" MAXIMUM LIFT DISTANCE.
5. THE DIXIE350H BRACKET HAS AN WORKING / ULTIMATE LOAD OF 525/305 KIPS. (2 TO 1 SAFETY FACTOR)
6. FOR D6 ANCHORS, 1-1/2" RCS IS RATED 95/75 KIPS AND FOR D7 ANCHORS, 1-1/2" RCS IS RATED 70/55 KIPS.

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE350-B4, FOUNDATION BRACKET
FOR D6 & D7, 1-1/2" RCS

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC and its unauthorized use or publication without the express written consent of MacLean Dixie, LLC. is strictly prohibited.
DDXIE3500-B2 LIST OF COMPONENTS

<table>
<thead>
<tr>
<th>ITEMS</th>
<th>CATALOG #</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DIXIE350H-BK</td>
<td>BRACKET ASSEMBLY</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>DDXIE350-TP5A</td>
<td>T-PIPE ASSEMBLY</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTES:
1. MATERIAL: BRACKET - DUCTILE IRON, GRADE 654512 PER ASTM A536; RCS SHAFT - PER ASTM A29 OR A576
2. HOT DIP GALV PER ASTM A153, AFTER FABRICATION.
3. DO NOT EXCEED 165 FT-LBS OF TORQUE ON 7/8" DIA. LIFTING THREAD RODS DURING STABILIZING OR LOAD LOCK-OFF.
4. RECOMMENDED ANCHOR SHAFT CUTOFF LEVEL ABOVE THE BOTTOM OF THE FOOTING IS 10'-1" MAXIMUM LIFT DISTANCE.
5. THE DIXIE350H BRACKET HAS AN WORKING / ULTIMATE LOAD OF 92.5/105KIPS. (2 TO 1 SAFETY FACTOR)
6. FOR D10 ANCHORS, 1-3/4" RCS IS RATED 50/100 KIPS.
   FOR P35 PIPE PILES, 3-1/2" OD. IS RATED 40/80KIPS.

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE350-B5, FOUNDATION BRACKET
FOR D10 RCS & P35 PIPE PILES

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC and its unauthorized use or publication without the express written consent of MacLean Dixie, LLC is strictly prohibited.
All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC and its unauthorised use or publication without the express written consent of MacLean Dixie, LLC is strictly prohibited.

DIXIE350-B6, FOUNDATION BRACKET
FOR P28 & P28H PIPE PILES

1. MATERIAL: BRACKET - DUCTILE IRON, GRADE 654512 PER ASTM A536; RCS SHAFT - PER ASTM A29 OR A576
2. HOT DIPP GALV PER ASTM A153, AFTER FABRICATION.
3. DO NOT EXCEED 165 FT-LBS OF TORQUE ON 7/8" DIA. LIFTING THREAD RODS DURING STABILIZING OR LOAD LOCK-OFF.
4. RECOMMENDED ANCHOR SHAFT CUTOFF LEVEL ABOVE THE BOTTOM OF THE FOOTING IS 10" TO 11" MAXIMUM LIFT DISTANCE.
5. THE DIXIE350H BRACKET HAS AN WORKING / ULTIMATE LOAD OF 52.5/105KIPs. (2 TO 1 SAFETY FACTOR)
6. FOR P28 PIPE PILE; 2.875" O.D. SCH40 IS RATED 30/60KIPs.
   FOR P28H PIPE PILE; 2.875" O.D. SCH80 IS RATED 36/72KIPs.
DIXIE350-B7, FOUNDATION BRACKET
FOR D15, 2" RCS

NOTES:
1. MATERIAL: BRACKET - DUCTILE IRON, GRADE 654512 PER ASTM A536; RCS SHAFT - PER ASTM A29 OR A576
2. HOT DIP GALV PER ASTM A153, AFTER FABRICATION
3. DO NOT EXCEED 165 FT-LBS OF TORQUE ON 7/8" DIA. LIFTING THREAD RODS DURING STABILIZING OR LOAD LOCK-OFF.
4. RECOMMENDED ANCHOR SHAFT CUTOFF LEVEL ABOVE THE BOTTOM OF THE FOOTING IS 10" TO 12" MAXIMUM LIFT DISTANCE.
5. THE DIXIE350H BRACKET HAS AN WORKING / ULTIMATE LOAD OF 50/100 KIPS. (2 TO 1 SAFETY FACTOR)
6. FOR D15 ANCHORS, 2" RCS IS RATED 52.5/105KIPS

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC. and its unauthorized use or publication without the express written consent of MacLean Dixie, LLC. is strictly prohibited.
DIXIE350H-BK

DIXIE350-TB8A

NOTES:
1. MATERIAL: BRACKET - DUCTILE IRON, GRADE 654512 PER ASTM A536; RCS SHAFT - PER ASTM A29 OR A576
2. HOT DIP GALV PER ASTM A153, AFTER FABRICATION
3. DO NOT EXCEED 200 FT-LBS OF TORQUE ON 1" DIA. LIFTING THREAD RODS DURING STABILIZING OR LOAD LOCK-OFF.
4. RECOMMENDED ANCHOR SHAFT CUTOFF LEVEL ABOVE THE BOTTOM OF THE FOOTING IS 10" TO 11" MAXIMUM LIFT DISTANCE.
5. THE DIXIE350H BRACKET HAS AN WORKING / ULTIMATE LOAD OF 52.5/105KIPS. (2 TO 1 SAFETY FACTOR)
6. FOR DI5 ANCHORS, 2" RCS IS RATED 60/120 KIPS.

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE350-B8, FOUNDATION BRACKET FOR P35H PIPE PILES

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC. and its unauthorized use or publication without the express written consent of MacLean Dixie, LLC. is strictly prohibited.
NOTES:

1. FINISH:
   BLACK. FOR GALVANIZED MATERIAL PER ASTM A153 OR A123 BY ADDING SUFFIX "G" AFTER THE CAT. NO.

2. MATERIAL SPECIFICATION
   TOP PLATE - PER ASTM A-36
   CASTING - STEEL, PER ASTM A958, SC1045 GRADE 40/80.

3. RATING:
   COMPRESSION WORKING/DESIGN LOAD RATING AS NOTED.
   THIS RATING IS VALID ONLY IF THE PIER CAP DETAIL HAS BEEN DESIGNED TO ENSURE ADEQUATE LOAD TRANSFER FROM REINFORCED CONCRETE FOUNDATION TO SCREW PIER, AND IN ACCORDANCE WITH EXISTING LOCAL CODE REQUIREMENTS AND / OR ESTABLISHED LOCAL PRACTICES.

4. HARDWARE:
   HEX HEAD BOLT AS SHOWN IN THE TABLE W/JAM NUT.

For 1-1/2" RCS, the allowable capacity is limited to 26,900 lbs by bolt shear, if a grade 5 bolt is used.
For 1-3/4" RCS, the allowable capacity is limited to 36,750 lbs by bolt shear, if a grade 5 bolt is used.
MacLean DixieHFS™ Concrete Slab Bracket

TYPICAL INSTALLATION OF SLAB REPAIR BRACKET

NOTES:
1. FINISH: HOT DIP GALV. PER ASTM A153, AFTER FABRICATION.
2. TUBE MATERIAL - ASTM 500 STRUCTURAL STEEL TUBING
   CHANNEL - PER ASTM A36
   BOLT - HEX HEAD BOLT PER J429 GRADE 5

MECHANICAL RATING ON BRACKET
WORKING LOAD: 5,000 LB.
MAXIMUM RATING LIFTING LOAD: 7,500 LB.
ULTIMATE STRENGTH: 10,000 LB

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS™ CONCRETE SLAB BRACKET
MacLean Dixie™ WALKWAY SUPPORT BRACKETS

N-6401-0050
HDW: 5/8" X 5 1/2" BOLTS W/NUTS - 2 EA.
FOR 1 3/4" R.C.S.Q. HELICAL PIER

N-6401-0066
HDW: 1/2" X 10" BOLTS W/NUTS - 2 EA.
FOR 1 3/4" R.C.S.Q. HELICAL PIER

N-6401-0070
HDW: 1/2" X 5 1/2" BOLTS W/NUTS - 2 EA.
FOR 1 3/4" R.C.S.Q. HELICAL PIER

N-6401-0103
HDW: 3/4" X 5 1/2" BOLTS W/NUTS - 2 EA.
FOR 1 3/4" R.C.S.Q. HELICAL PIER

N-6401-0085
HDW: NONE
FOR 1 1/2" R.C.S.Q. HELICAL PIER

NOTES:
1. HOT DIP GALV. PER ASTM A153, AFTER FABRICATION.
2. PIPE MATERIAL - 2" SCH 40 (2.875" O.D. X 0.15" WALL) OR
   2 1/2" SCH 40 (3.575" O.D. X 0.23" WALL) PER ASTM A500
   GRADE B OR EQUAL.
3. SADDLE MATERIAL - HOT ROLLED STEEL PER ASTM A36.
4. BOLTS PER ASTM A325 AND HEX NUTS PER ASTM A563.
   BOLT SIZES AS NOTED.
5. ALL WELDING TO BE DONE BY WELDERS CERTIFIED UNDER
   SECTION 5 OF THE AWS CODE 11.
6. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, AC10
   ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTATION.

MacLean Dixie HFS
A MACLEAN POWER SYSTEMS COMPANY
11411 ADDISON STREET
FRANKLIN PARK, IL 60131-1130

DIXIE HFS WALK WAY SUPPORT
BRACKETS

All information contained in this disclosure whether patentable or
otherwise comprises proprietary information of MacLean Dixie, LLC,
and its unauthorized use or publication without the express written
consent of MacLean Dixie, LLC, is strictly prohibited.
**MacLean Dixie HFS Wall Anchor with components**

- **WALL ANCHOR EXTENSION**
- **WALL PLATE ASSEMBLY**
- **WALL PLATE**
  - 1 1/4" HEAVY HEX NUT
  - 1 1/4" - 7 UNC THREAD
  - SQUARE WASHER (4" X 4" X 1/4" THK.)

**WALL ANCHORS**

<table>
<thead>
<tr>
<th>RCSQ SHAFT SIZE</th>
<th>DESCRIPTION</th>
<th>CATALOG NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/4&quot;</td>
<td>6&quot; HELIX</td>
<td>I39.5S6</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>8&quot; HELIX</td>
<td>I39.5S8</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>10&quot; HELIX</td>
<td>I39.5S10</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>12&quot; HELIX</td>
<td>I39.5S12</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>14&quot; HELIX</td>
<td>I39.5S14</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>6&quot; HELIX</td>
<td>I69.5S6</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>8&quot; HELIX</td>
<td>I69.5S8</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>10&quot; HELIX</td>
<td>I69.5S10</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>12&quot; HELIX</td>
<td>I69.5S12</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>14&quot; HELIX</td>
<td>I69.5S14</td>
</tr>
</tbody>
</table>

**PLAIN EXTENSION BARS**
1 1/4" PLAIN EXT. BARS (3,400 FT. LBS. TORQUE)
1 1/2" PLAIN EXT. BARS (6,000 FT. LBS. TORQUE)

**THREADS WALL ANCHOR PLATE KITS**
FOR 1 1/4" AND 1 1/2" SHAFT

<table>
<thead>
<tr>
<th>RCSQ SHAFT SIZE</th>
<th>CATALOG NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/4&quot;</td>
<td>N-6401-0023</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>N-6401-0002</td>
</tr>
</tbody>
</table>

**NOTES:**

1. FINISH: HOT DIP GALV. PER ASTM A153, AFTER FABRICATION.
2. SHAFT MATERIAL - ROUND CORNERED SQUARE (RCS) STEEL PER ASTM A29 AND ASTM A576 GRADE C1045 FOR 1 1/4" AND C1045 FOR 1 1/2" WITH 60 KSI AND 75 KSI MIN. YIELD STRENGTH.
3. HELIX MATERIAL - HIGH STRENGTH, LOW ALLOY STEEL PER ASTM A1011/1018 WITH 55 KSI MIN. YIELD STRENGTH FOR 3/8" THICK MATERIAL.
4. COUPLING BOLTS: 5/8" X 3" HEX HEAD FOR 1-1/4" RCSQ SHAFT & 3/4" X 3" HEX HEAD FOR 1-1/2" RCSQ SHAFT. HEX BOLTS PER ASTM A325. JAM NUTS PER ASTM A563.
5. SEE ICC-ES LEGACY REPORT PFC-5551 FOR ALLOWABLE AXIAL LOAD AND SPECIFICATIONS.
6. ALL MATERIAL IS MANUFACTURED AS PER ICC-ES, ACI ACCEPTANCE CRITERIA FOR QUALITY CONTROL DOCUMENTATION.

**Typical Installation of Wall Anchor Kit**

All information contained in this disclosure whether patentable or otherwise comprises proprietary information of MacLean Dixie, LLC. and its unauthorized use or publication without the express written consent of MacLean Dixie, LLC. is strictly prohibited.
1.0 EVALUATION SCOPE

Compliance with the 2007 ICCES AC358 Acceptance Criteria for Helical Foundation Systems and Devices

2.0 DESCRIPTION

2.1 General:
The MacLean Dixie Helical Foundation System is used to underpin foundations of existing structures, to form deep foundations for new structures, to retrofit or remediate deficient foundations of existing structures, and to provide bearing for new foundations. The foundation piles are used with foundation attachment brackets, designed and manufactured by MacLean Dixie, to connect the foundation of the existing or new structures to the installed helical foundation pile.

2.2 Helical Foundation System:

2.2.1 General:
A helical foundation system is designed to resist axial compression, axial tension, and/or lateral load from the structure. It consists of a lead section, extension-with-helix (optional), extension section(s), and a bracket.

2.2.2 Leads and Extensions:
The foundation pipe lead section consists of a central steel shaft with one or more welded helical-shaped circular steel plate(s). The central steel shaft is either 1-1/2 or 1-3/4 inch (38.1 or 44.5mm) Round Cornered Square (RCS) bar or 2-7/8 or 3-1/2 inch (73.0 or 88.9mm) outside diameter round steel pipe. The lead end is cut at a 45° ±/−5° angle. [See figures 9, 12, 15, and 18.]

The helix is a helical-shaped circular steel plate made from either 3/8 or 1/2 inch (9.5 or 12.7mm) thick steel plate with 8, 10, 12 or 14 inch diameters (203, 254, 305 or 356mm). The helix is split from the center to the outside edge and formed with all radial sections normal to the central longitudinal axis, +/−3° and with a 3 inch (76mm) pitch. The pitch is the distance between the leading and trailing edge. The helix is then welded to the steel shaft with the smallest helix in the lead and each succeeding helix spaced three times the diameter of the previous helix. After fabrication, the helical steel pile is hot-dipped galvanized per ASTM A123 or A153 latest revision.

Each lead section of a helical foundation pile has provisions at the top for a connection to an extension and has an earth-penetrating pilot at the bottom. Each extension has provisions for a coupling at one end and a connection at the other.

The coupling for the RCS extension and extension-with-helix piles is an integrally forged socket that slips over a RCS shaft of the same size. Each socket has a transverse hole to join lead or extension sections with a bolt and nut. [See figures 10, 11, 13 and 14.]
The lead section of the pipe pile has a female steel coupling welded to the upper end. The extension has a matching male and female steel coupling welded at each end of the pipe. Each coupling has two transverse holes $90^\circ$ apart and each can be connected with two bolts and nuts. [See figures 16, 17, 19, and 20.]

2.2.3 Foundation Attachments (Brackets):

2.2.3.1 Repair Bracket:
A foundation repair bracket is used to apply load to the structure to stabilize or lift the foundation. It is mounted to the helical pipe pile then the shelf of the bracket is placed underneath the foundation while the face of the bracket is bolted to the side of the foundation. A lifting T-pipe or T-bar and two 7/8 inch ASTM A325 studs are used to lift the foundation via a lifting cylinder. [See figure 5.] The bracket is a one-piece ductile iron casting per ASTM A536 and is hot-dipped galvanized as per ASTM A123 or A153.

2.2.3.2 New Construction Bracket:
A new construction bracket is placed atop the helical RCS or pipe pile. [See figures 1 and 2.] The cap plate is a steel plate 1/2 inch (12.7 mm) or 3/4 inch (19.1 mm) thick that meets or exceeds the requirement of ASTM A36. The bracket is black (no coating) or hot-dipped galvanized as per ASTM A123 or A153.

2.3 Material Specifications:

2.3.1 Helical Plates:
The helices are high strength low alloy steel per ASTM A1018 with a minimum 55 ksi (379 MPa) yield strength and 65 ksi (450 MPa) tensile strength or equal.

2.3.2 Pile Shafts (Lead Sections and Extensions):
The 1-1/2 inch (38 mm) RCS shafts are hot-wrought carbon steel conforming to ASTM A576, Grade C1045 or equal with a minimum 70 ksi (482 MPa) yield strength and 100 ksi (689 MPa) tensile strength. For the 1-3/4 inch (44.5mm), the shaft is steel conforming to ASTM A576, Grade 1530 or equal with a minimum 95 ksi (655 MPa) yield strength and 120 ksi (827 MPa) tensile strength.

The 2-7/8 and 3-1/2 inches (73 and 88.9mm) pipe shafts conform to ASTM A500, Grade B or equal with minimum yield strengths of 50 ksi (345 MPa). The coupling are made from cast steel conforming to ASTM A958, Grade SC1045 or equal with a minimum 40 ksi (276 MPa) yield strength and 80 ksi (551 MPa) tensile strength.

2.3.3 Bolts:

2.3.3.1 Coupling Bolts:
The coupling bolts for lead and extension are 3/4 inch (19.1mm) or 7/8 inch (22.2mm) in diameter conforming to ASTM A325, Type 1 and have a Class C hot-dipped zinc coating to ASTM A153. Nuts conform to ASTM A563 and have a Class C hot-dipped zinc coating to ASTM A153.

2.3.3.2 Repair Bracket Lifting Studs:
The repair bracket lifting studs are two 7/8 inch (22.2 mm) diameter fully threaded rods conforming to ASTM A325 material. The studs have a Class C hot-dipped zinc coating to ASTM A153.

2.3.3.3 Repair Bracket Securing Bolts:
The bolts used to secure the lead or extension to the repair bracket are 1/2 inch (12.7 mm) diameter conforming to ASTM A325. The bolts have a Class C hot-dipped zinc coating to ASTM A153.
2.3.3.4 Concrete Anchor Bolts:
Anchor bolts used to secure the repair bracket to the foundation are 5/8 inch (15.9 mm) in diameter for all foundation brackets. The concrete anchor bolts have a Class C hot-dipped zinc coating to ASTM A153.

2.4 Design:

2.4.1 General:
Structural calculations must be submitted to the building official for each project, and must be based on accepted engineering principles. The design of the steel components must be in accordance with the Load and Resistance Factor Design (LRFD) Specification in Chapter 22, Division III of the code. The LRFD design strengths of the steel components are described in Tables 3 through 10. The overall capacity of the MacLean Dixie Helical Foundation Systems depend on the analysis of the interaction of the helical plates, bracket and the soil, and may be less than the LRFD design strengths noted in this report. Combined flexural and compressive stresses and column buckling of the foundation piles due to compression loads must be included in the analysis. Construction in Seismic Zones 3 and 4 requires compliance with Section 1809.5.1 of the code. A soil investigation report is necessary and must include the following:
1. Soil properties, including those affecting design;
2. Allowable soil bearing pressure;
3. Suitability for use in seismically active areas;
4. Information on ground-water table, frost depth, and corrosion.

2.4.2 Connection to Structure:

2.4.2.1 Repair:
Connection of the building structure to the helical steel piles must be designed by a licensed Professional Engineer. Bolted connections shall be designed to resist applicable loads in accordance with the code or appropriate evaluation report. The effects of reduced lateral sliding resistance due to uplift from wind or seismic loads shall be considered for each project. In addition, the condition of the foundation where the helical pile bracket is placed must be considered. Additional plates may be added to the bracket shelf to further distribute the load.

2.4.2.2 New Construction:
Connection of the building structure to the helical steel piles must be designed by a licensed Professional Engineer. The cap bracket for concrete foundation slab or foundation must be designed and justified to the satisfaction of the building official for concentrated loads to the bracket. Rebar may be added to the cap plate to better secure the cap plate to the foundation.

2.5 Installation:

2.5.1 General:
The MacLean Dixie Helical Foundation System is installed by factory trained and certified installers.

2.5.1.1 Helical RCS and Pipe Piles:
The foundation piles are typically installed using hydraulic rotary motors having forward and reverse capabilities. The torque rating (torsional force) for each of the included four steel pile shaft sizes are 5.5 kip-feet (8.13 kN-m) for 1-1/2 inch (38mm) RCS shafts, 10.0 kip-feet (13.56 kN-m) for 1-3/4 inch (45mm) RCS shafts, 7.5 kip-feet (10.17 kN-m) for 2-7/8 inch (73mm) pipe shafts, and 11.4 kip-feet (14.46 kN-m) for 3-1/2 inch (89mm) pipe shafts. The foundation piles must be positioned and angled as specified in the approved plans. Foundation piles attached to structures are installed either under vertically plumb or at a slight inward slope projecting under the foundations. The foundation piles must be installed in a continuous manner with the lead advancing at the helix pitch. The pile rotation rate is typically in the range of 5 to 20 revolutions per minute. Extensions (number and length) are selected based on the approval plans as specified per the site conditions by licensed Professional Engineer. The extensions and the foundation pile lead section are connected with the coupling bolts. Coupling bolts must be tightened firmly with a wrench. The foundation piles are installed to the
minimum depth shown on plans but with the top helix not less than 5 feet (1525 mm) below the bottom of the foundation.

2.5.1.2 Foundation Attachments:
The foundation repair bracket, as specified in the approved plans, is installed by a certified MacLean Dixie installer. The foundation must be excavated to create an “L” shaped cavity with nominal 30 inch (762mm) opening and a nominal depth of 18 inches (457mm) below the foundation bottom surface to access the foundation for the bracket. The exposed foundation surfaces must be prepared and smoothly dressed to receive the foundation bracket (“lifting bracket”) without obstruction on the bearing or facing surfaces. The bracket must be pinned firmly to the foundation by driven or threaded fasteners. This connection may occur during or after helical foundation pile installation. The foundation pile lead and shaft extensions must be installed into soil as set forth in Section 2.5.1.1. When the pile is installed to the required depth, if the top of the extension is not within the required elevation, excess shaft extension above the foundation may be cut, nominally about 8 to 10 inches (203 to 254mm) above the footing. Attachment of the foundation repair bracket to the foundation pile shall be in accordance with the approved plans.

New foundation brackets are placed on top of the helical pile. The top of the lead or extension may be cut off to level as required.

2.6 Special Inspection:
Special inspection in accordance with Section 1701.5.11 of the UBC or 1704.9 of the IBC shall be provided for the installation of the foundation piles and foundation brackets. Where on-site welding is required, inspection in accordance of Section 1704.3 of the IBC or Section 1701.5.5 of the UBC is required. Items to be confirmed by the special inspector shall include, but not be limited to, the manufacturer’s certification of installers, verification of the manufacturer, helical pile and bracket configuration, the installation torque and depth of the foundation piles and compliance of the installation with the approved construction documents and this evaluation report. In lieu of continuous special inspection, periodic special inspection in accordance with Section 1701.6.2 of the UBC is permitted provided that installers are certified by the manufacturer, a periodic inspection schedule and structural observations in accordance with Section 1702 are provided.

Periodic inspections shall be performed in accordance with the following schedule, subject to the building official’s approval:

1. Before the start of work: Verify manufacturer, verify installer’s certification by the manufacturer, and confirm foundation pile and bracket configuration compliance with construction documents and this evaluation report.
2. Installation of first helical foundation pile: Verify that location, installation torque, and depth of helical foundation piles comply with construction documents; verify that installer and keep an installation log.
3. First connection to building structure: Verify that installation of foundation repair brackets or new construction brackets complies with construction documents and this evaluation report.
4. End of work: Verify that installation log complies with requirements specified in the construction documents; verify that installation of all structural connections complies with construction documents and this evaluation report.

2.7 Identification:
Foundation piles have “D” stamped on the RCS shaft and have “MPS” marking on the coupling for pipe piles. The foundation piles are also identified by a tag or label bearing the MacLean Dixie name and address, the catalog number, the product description, the evaluation report number, and the name of the inspection agency.

3.0 EVIDENCE SUBMITTED
Material specifications, shaft calculations, new construction bracket calculations, field test of helical piles, lab test of helical piles, repair bracket tests, basics of helical installation, and a quality control manual.
4.0 FINDINGS
The MacLean Dixie Helical Foundation System described in this report complies with the 2007 ICCES AC358 Acceptance Criteria for Helical Foundation Systems and Devices and is subject to the following conditions:

4.1 The helical foundation piles are manufactured, identified, and installed in accordance with this report.
4.2 Special inspection is provided in accordance with Section 2.6 of this report.
4.3 Engineering calculations and drawings, in accordance with recognized engineering principles and design parameters, are provided to the building official.
4.4 A soil investigation for each project site must be provided to the building official for approval in accordance with Section 2.4.1 of this report.
4.5 The helical foundation piles are designed to the satisfaction of the building official.
4.6 The helical foundation piles are manufactured at the MacLean Dixie, LLC facility located in Birmingham, Alabama, under a quality control program per AC10 with inspections by an IAS accredited inspection agency per AC98.

This report is subject to re-examination in two years.
NEW CONSTRUCTION & FOUNDATION REPAIR BRACKETS

Table 1 - New Construction Bracket for RCS Foundation & Pipe Piles - Mechanical Rating

<table>
<thead>
<tr>
<th>Cat. Prefix</th>
<th>Shaft</th>
<th>NEW CONSTRUCTION BRACKETS</th>
<th>W in.</th>
<th>L in.</th>
<th>T in.</th>
<th>Fig.</th>
<th>Bolt in.</th>
<th>qty</th>
<th>Gr.</th>
<th>Maximum Compression Load (Kips)</th>
<th>Allowable Compression Load (Kips)</th>
<th>Plate Material Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6</td>
<td>1-1/2” RCS</td>
<td>NCB060604P28-1</td>
<td>6</td>
<td>6</td>
<td>½</td>
<td>3</td>
<td>%</td>
<td>1</td>
<td>8</td>
<td>55</td>
<td>27.5</td>
<td>ASTM A36</td>
</tr>
<tr>
<td>D6</td>
<td>1-1/2” RCS</td>
<td>NCB080804P28-1</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>3</td>
<td>%</td>
<td>1</td>
<td>8</td>
<td>55</td>
<td>27.5</td>
<td></td>
</tr>
<tr>
<td>D10</td>
<td>1-3/4” RCS</td>
<td>NCB080804P35-1</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>3</td>
<td>7/8</td>
<td>1</td>
<td>8</td>
<td>100</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>D10</td>
<td>1-3/4” RCS</td>
<td>NCB101006P35-1</td>
<td>10</td>
<td>10</td>
<td>¾</td>
<td>3</td>
<td>7/8</td>
<td>1</td>
<td>8</td>
<td>100</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>P28</td>
<td>2-7/8 OD x 203”</td>
<td>NCB060604P28</td>
<td>6</td>
<td>6</td>
<td>½</td>
<td>3</td>
<td>%</td>
<td>2</td>
<td>5</td>
<td>60</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>P28</td>
<td>2-7/8 OD x 203”</td>
<td>NCB080804P28</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>3</td>
<td>%</td>
<td>2</td>
<td>5</td>
<td>80</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>P35</td>
<td>3-1/2 OD x 216”</td>
<td>NCB080804P35</td>
<td>8</td>
<td>8</td>
<td>½</td>
<td>3</td>
<td>7/8</td>
<td>2</td>
<td>5</td>
<td>25</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>P35</td>
<td>3-1/2 OD x 216”</td>
<td>NCB101006P35</td>
<td>10</td>
<td>10</td>
<td>¾</td>
<td>3</td>
<td>7/8</td>
<td>2</td>
<td>5</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

Note: For 1-1/2” RCS, the allowable capacity is limited to 26,000 lb by bolt shear, if grade 5 bolt is used. For 1-3/4” RCS, the allowable capacity is limited to 36,750 lb by bolt shear, if grade 5 bolt is used.

The allowable load shown in table 2 is the maximum test load of the entire system on 2,500 psi concrete per AC358 section 3.10.1.13 and as shown in AC358, figure 6.
1-1/2" RCS FOUNDATION PILE SYSTEM

Table 3 – 1 1/2" RCS Foundation Pile Mechanical Rating – Lead Section With Single or Multiple Helices

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D660S8</td>
<td>5'</td>
<td>1-1/2</td>
<td>8&quot;</td>
<td>NA</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D660S10</td>
<td>5'</td>
<td>1-1/2</td>
<td>10&quot;</td>
<td>NA</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D660S12</td>
<td>5'</td>
<td>1-1/2</td>
<td>12&quot;</td>
<td>NA</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D660S10</td>
<td>5'</td>
<td>1-1/2</td>
<td>8&quot;</td>
<td>10&quot;</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D660S12</td>
<td>5'</td>
<td>1-1/2</td>
<td>12&quot;</td>
<td>10&quot;</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D684S8</td>
<td>7'</td>
<td>1-1/2</td>
<td>8&quot;</td>
<td>NA</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D684S10</td>
<td>7'</td>
<td>1-1/2</td>
<td>10&quot;</td>
<td>NA</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D684S12</td>
<td>7'</td>
<td>1-1/2</td>
<td>12&quot;</td>
<td>NA</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D684S810</td>
<td>7'</td>
<td>1-1/2</td>
<td>8&quot;</td>
<td>10&quot;</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D684S10</td>
<td>7'</td>
<td>1-1/2</td>
<td>10&quot;</td>
<td>12&quot;</td>
<td>NA</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D684S10</td>
<td>7'</td>
<td>1-1/2</td>
<td>8&quot;</td>
<td>10&quot;</td>
<td>12&quot;</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D684S1012</td>
<td>7'</td>
<td>1-1/2</td>
<td>10&quot;</td>
<td>12&quot;</td>
<td>14&quot;</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
<td>ASTM A29 &amp; ASTM A576 Grade 10V45M F_y=100ksi min. F_t=70ksi min.</td>
</tr>
<tr>
<td>D684S1012</td>
<td>7'</td>
<td>1-1/2</td>
<td>8&quot;</td>
<td>10&quot;</td>
<td>12&quot;</td>
<td>14&quot;</td>
<td>10 5,500</td>
<td>55,000</td>
<td>27,500</td>
<td></td>
<td></td>
<td>HSLA</td>
</tr>
</tbody>
</table>

For SI units: 1 inch = 25.4 mm; 1 pound = 0.00448 KN; 1 ksi = 6.985 Mpa

1. The in-situ axial load capacity of any pile is dependent upon an analysis between the bearing plate and the site-specific soil conditions. The maximum load is determined by the maximum installation torque multiplying the torque factor Kt, as shown in Table 1 & 2.
2. The torque factor Kt is established through empirical data and it might be significantly reduced in highly sensitive clays and very soft soil. It should be determined by the registered design professional responsible for the preparation of the construction document.
3. For bevel leading edge on the helix, add suffix "V" to the catalogue #. Ex. D684S1012V.
4. For repair bracket, the allowable load is 23kips for 2500 psi concrete unless it is fully braced without rotation applied to the bracket.
5. Other lead or extension lengths are permissible for special requirements. All requirements, other than length, must comply with all the specifications delineated in this report.

Table 4 – 1 1/2" RCS Helical Foundation Pile Mechanical Rating – Extension Sections With or Without Single or Multiple Helices

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>QTY</th>
<th>SIZE</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6E42</td>
<td>3.5'</td>
<td>1-1/2</td>
<td>NA</td>
<td>10</td>
<td>5,500</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>D6E60</td>
<td>5'</td>
<td>1-1/2</td>
<td>NA</td>
<td>10</td>
<td>5,500</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>D6E84</td>
<td>7'</td>
<td>1-1/2</td>
<td>NA</td>
<td>10</td>
<td>5,500</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>D6E120</td>
<td>10'</td>
<td>1-1/2</td>
<td>NA</td>
<td>10</td>
<td>5,500</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>D6E42S14</td>
<td>3.5'</td>
<td>1-1/2</td>
<td>14&quot;</td>
<td>10</td>
<td>5,500</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>D6E60S12</td>
<td>5'</td>
<td>1-1/2</td>
<td>12&quot;</td>
<td>10</td>
<td>5,500</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>D6E60S14</td>
<td>5'</td>
<td>1-1/2</td>
<td>14&quot;</td>
<td>10</td>
<td>5,500</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>D6E84S14</td>
<td>7'</td>
<td>1-1/2</td>
<td>14&quot;</td>
<td>10</td>
<td>5,500</td>
<td>1/4&quot;</td>
</tr>
</tbody>
</table>

1. To specify required helix spacing for helical extensions, add suffix "S" and the distance from the connection point. Ex. D6E60S12S14 – helix spacing is 14" from the leading edge of the helix to the connection point.
2. For bevel leading edge on the helix, add suffix "V" to the catalogue #. Ex. D6E84S12V.
For SI units: 1 inch = 25.4 mm; 1 pound = 0.00448 KN; 1 ksi = 6.985 Mpa

1. The in-situ axial load capacity of any pile is dependent upon an analysis between the bearing plate and the site-specific soil conditions. The maximum load is determined by the maximum installation torque multiplying the torque factor \( K_t \) as shown in Table 1.

2. The torque factor \( K_t \) is established through empirical data and it might be significantly reduced in highly sensitive clays and very soft soil. It should be determined by the registered design professional responsible for the preparation of the construction document.

3. For bevel leading edge on the helix, add suffix "V" to the catalogue #. Ex. D1084S1012V.

4. For repair bracket, the allowable load is 35kips for 2500 psi concrete unless it is fully braced without rotation applied to the bracket.

5. Other lead or extension lengths are permissible for special requirements. All requirements, other than length, must comply with all the specifications delineated in this report.

### Table 5 – 1 ¾” RCS Foundation Pile Mechanical Rating – Lead Section With Single or Multiple Helices

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D1060S8</td>
<td>5'</td>
<td>1- ¾”</td>
<td>8”</td>
<td>NA</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
<td>HSLA ASTM A1018 Grade 55 F_y =95ksi min. F_t =65ksi min.</td>
</tr>
<tr>
<td>D1060S10</td>
<td>5'</td>
<td>1- ¾”</td>
<td>10”</td>
<td>NA</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
<td>ASTM A29 &amp; ASTM A576 Grade 1530M F_y =120ksi min.</td>
</tr>
<tr>
<td>D1060S12</td>
<td>5'</td>
<td>1- ¾”</td>
<td>12”</td>
<td>NA</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
<td>F_t =65ksi min.</td>
</tr>
<tr>
<td>D1060S1012</td>
<td>5'</td>
<td>1- ¾”</td>
<td>8”</td>
<td>10”</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
<td>F_t =65ksi min.</td>
</tr>
<tr>
<td>D1084S8</td>
<td>7”</td>
<td>1- ¾”</td>
<td>8”</td>
<td>NA</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
<td>F_t =65ksi min.</td>
</tr>
<tr>
<td>D1084S10</td>
<td>7”</td>
<td>1- ¾”</td>
<td>10”</td>
<td>NA</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
<td>F_t =65ksi min.</td>
</tr>
<tr>
<td>D1084S12</td>
<td>7”</td>
<td>1- ¾”</td>
<td>12”</td>
<td>NA</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
<td>F_t =65ksi min.</td>
</tr>
<tr>
<td>D1084S81012</td>
<td>7”</td>
<td>1- ¾”</td>
<td>8”</td>
<td>10”</td>
<td>12”</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
<td>F_t =65ksi min.</td>
</tr>
<tr>
<td>D1084S1012</td>
<td>7”</td>
<td>1- ¾”</td>
<td>10”</td>
<td>12”</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>100,000</td>
<td>50,000</td>
<td>F_t =65ksi min.</td>
</tr>
</tbody>
</table>

1. To specify required helix spacing for helical extensions, add suffix “S” and the distance from the connection point. Ex. D10E60S1012S14 – helix spacing is 14” from the leading edge of the helix to the connection point.

2. For bevel leading edge on the helix, add suffix "V" to the catalogue #. Ex. D1084S1012V.

### Table 6 – 1 ¾” RCS Helical Foundation Pile Mechanical Rating – Extension Sections With or Without Single or Multiple Helices

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D10E42</td>
<td>3.5’</td>
<td>1- ¾”</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>1/8”</td>
<td>ASTM A325 Grade 5 F_y=92ksi min.</td>
<td>ASTM A29 &amp; ASTM A576 Grade 1530M F_y =95ksi min.</td>
</tr>
<tr>
<td>D10E60</td>
<td>5’</td>
<td>1- ¾”</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>1/8”</td>
<td>ASTM A1018 Grade 55 F_y=55ksi min. F_t =65ksi min.</td>
<td></td>
</tr>
<tr>
<td>D10E84</td>
<td>7”</td>
<td>1- ¾”</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>1/8”</td>
<td>F_t =65ksi min.</td>
<td>F_t =120ksi min.</td>
</tr>
<tr>
<td>D10E120</td>
<td>10”</td>
<td>1- ¾”</td>
<td>NA</td>
<td>10</td>
<td>10,000</td>
<td>1/8”</td>
<td>F_t =65ksi min.</td>
<td>F_t =120ksi min.</td>
</tr>
<tr>
<td>D10E42S14</td>
<td>3.5’</td>
<td>1- ¾”</td>
<td>14”</td>
<td>10</td>
<td>10,000</td>
<td>1/8”</td>
<td>F_t =65ksi min.</td>
<td>F_t =120ksi min.</td>
</tr>
<tr>
<td>D10E60S12</td>
<td>5’</td>
<td>1- ¾”</td>
<td>12”</td>
<td>10</td>
<td>10,000</td>
<td>1/8”</td>
<td>F_t =65ksi min.</td>
<td>F_t =120ksi min.</td>
</tr>
<tr>
<td>D10E60S14</td>
<td>5’</td>
<td>1- ¾”</td>
<td>14”</td>
<td>10</td>
<td>10,000</td>
<td>1/8”</td>
<td>F_t =65ksi min.</td>
<td>F_t =120ksi min.</td>
</tr>
<tr>
<td>D10E84S14</td>
<td>7”</td>
<td>1- ¾”</td>
<td>14”</td>
<td>10</td>
<td>10,000</td>
<td>1/8”</td>
<td>F_t =65ksi min.</td>
<td>F_t =120ksi min.</td>
</tr>
</tbody>
</table>
### TABLE 7 – 2.875" O.D. Foundation Pipe Pile Mechanical Rating – Lead Section With Single or Multiple Helices

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P2864S8</td>
<td>5'</td>
<td>2-7/8&quot;</td>
<td>8&quot;</td>
<td>NA</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td>HSLA</td>
<td>ASTM A1018</td>
</tr>
<tr>
<td>P2864S10</td>
<td>5'</td>
<td>2-7/8&quot;</td>
<td>10&quot;</td>
<td>NA</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td>Grade 55</td>
<td>F_y = 55ksi min.</td>
</tr>
<tr>
<td>P2864S12</td>
<td>5'</td>
<td>2-7/8&quot;</td>
<td>12&quot;</td>
<td>NA</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td>Grade 55</td>
<td>F_y = 65ksi min.</td>
</tr>
<tr>
<td>P2864S1012</td>
<td>5'</td>
<td>2-7/8&quot;</td>
<td>10&quot;</td>
<td>12&quot;</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2884S5</td>
<td>7'</td>
<td>2-7/8&quot;</td>
<td>8&quot;</td>
<td>NA</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td>HSLA</td>
<td>ASTM A1018</td>
</tr>
<tr>
<td>P2884S10</td>
<td>7'</td>
<td>2-7/8&quot;</td>
<td>10&quot;</td>
<td>NA</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td>Grade 55</td>
<td>F_y = 55ksi min.</td>
</tr>
<tr>
<td>P2884S12</td>
<td>7'</td>
<td>2-7/8&quot;</td>
<td>12&quot;</td>
<td>NA</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td>Grade 55</td>
<td>F_y = 65ksi min.</td>
</tr>
<tr>
<td>P2884S1012</td>
<td>7'</td>
<td>2-7/8&quot;</td>
<td>10&quot;</td>
<td>12&quot;</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2884S1012</td>
<td>7'</td>
<td>2-7/8&quot;</td>
<td>10&quot;</td>
<td>12&quot;</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2884S1012</td>
<td>7'</td>
<td>2-7/8&quot;</td>
<td>10&quot;</td>
<td>12&quot;</td>
<td>NA</td>
<td>8</td>
<td>7,500</td>
<td>60,000</td>
<td>30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For SI units: 1 inch = 25.4 mm; 1 pound = 0.00448 KN; 1 ksi = 6.985 Mpa

1. The in-situ axial load capacity of any pile is dependent upon an analysis between the bearing plate and the site-specific soil conditions. The maximum load is determined by the maximum installation torque multiplying the torque factor Kt as shown in Table 1 & 2.
2. The torque factor Kt is established through empirical data and it might be significantly reduced in highly sensitive clays and very soft soil. It should be determined by the registered design professional responsible for the preparation of the construction document.
3. For bevel leading edge on the helix, add suffix "V" to the catalogue #. Ex. P2884S1012V.
4. For repair bracket, the allowable load is 30kips for 2500 psi concrete.
5. Other lead or extension lengths are permissible for special requirements. All requirements, other than length, must comply with all the specifications delineated in this report.

### TABLE 8 – 2.875" O.D. Helical Foundation Pipe Pile Mechanical Rating – Extension Sections With or Without Single or Multiple Helices

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat. No.</td>
<td></td>
<td>QTY</td>
<td>SIZE</td>
<td>TYPE</td>
<td></td>
</tr>
<tr>
<td>P28E42</td>
<td>3.5'</td>
<td>1</td>
<td>2-7/8&quot;</td>
<td>NA</td>
<td>8</td>
</tr>
<tr>
<td>P28E64</td>
<td>5.3'</td>
<td>1</td>
<td>2-7/8&quot;</td>
<td>NA</td>
<td>8</td>
</tr>
<tr>
<td>P28E84</td>
<td>7'</td>
<td>1</td>
<td>2-7/8&quot;</td>
<td>NA</td>
<td>8</td>
</tr>
<tr>
<td>P28E124</td>
<td>10.3'</td>
<td>1</td>
<td>2-7/8&quot;</td>
<td>NA</td>
<td>8</td>
</tr>
<tr>
<td>P28E42S14</td>
<td>3.5'</td>
<td>1</td>
<td>2-7/8&quot;</td>
<td>14&quot;</td>
<td>8</td>
</tr>
<tr>
<td>P28E64S12</td>
<td>5.3'</td>
<td>1</td>
<td>2-7/8&quot;</td>
<td>12&quot;</td>
<td>8</td>
</tr>
<tr>
<td>P28E64S14</td>
<td>5.3'</td>
<td>1</td>
<td>2-7/8&quot;</td>
<td>14&quot;</td>
<td>8</td>
</tr>
<tr>
<td>P28E84S14</td>
<td>7'</td>
<td>1</td>
<td>2-7/8&quot;</td>
<td>14&quot;</td>
<td>8</td>
</tr>
</tbody>
</table>

1. To specify required helix spacing for helical extensions, add suffix "S" and the distance from the connection point. Ex. P28E64S12S14 – helix spacing is 14” from the leading edge of the helix to the connection point.
2. For bevel leading edge on the helix, add suffix "V" to the catalogue #. Ex. P28E84S10V.
### TABLE 9 – 3.5” O.D. Foundation Pipe Pile Mechanical Rating – Lead Section With Single or Multiple Helices

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P3564S8</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td>HSLA</td>
<td>ASTM A1018 Grade 55 F_y=55ksi min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F_y=65ksi min.</td>
</tr>
<tr>
<td>P3564S10</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3564S12</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3564S810</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3584S8</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3584S10</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3584S12</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3584S810</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3584S1012</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3584S81012</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3584S8101214</td>
<td>7</td>
<td>11,400</td>
<td>80,000</td>
<td>40,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For SI units: 1 inch = 25.4 mm; 1 pound = 0.00448 KN; 1 ksi = 6.985 Mpa

1. The in-situ axial load capacity of any pile is dependent upon an analysis between the bearing plate and the site-specific soil conditions. The maximum load is determined by the maximum installation torque multiplying the torque factor Kt as shown in Table 1 & 2.
2. The torque factor Kt is established through empirical data and it might be significantly reduced in highly sensitive clays and very soft soil. It should be determined by the registered design professional responsible for the preparation of the construction document.
3. For bevel leading edge on the helix, add suffix "V" to the catalogue #. Ex. P3584S1012V.
4. For repair bracket, the allowable load is 35kips for 2500 psi concrete and 40kips for 4000 psi concrete.
5. Other lead or extension lengths are permissible for special requirements. All requirements, other than length, must comply with all the specifications delineated in this report.

### TABLE 10 – 3.5” O.D. Helical Foundation Pipe Pile Mechanical Rating – Extension Sections With or Without Single or Multiple Helices

<table>
<thead>
<tr>
<th>Lead Sections</th>
<th>Kt</th>
<th>Max. Installation Torque Capacity (ft-lbs)</th>
<th>Bolts</th>
<th>Helical Material Specification</th>
<th>Round cornered square shaft Material Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>QTY</td>
<td>SIZE</td>
<td></td>
</tr>
<tr>
<td>P35E42</td>
<td>10</td>
<td>11,400</td>
<td>2</td>
<td>7/8”</td>
<td></td>
</tr>
<tr>
<td>P35E64</td>
<td>10</td>
<td>11,400</td>
<td>2</td>
<td>7/8”</td>
<td></td>
</tr>
<tr>
<td>P35E84</td>
<td>14</td>
<td>11,400</td>
<td>2</td>
<td>7/8”</td>
<td></td>
</tr>
<tr>
<td>P35E64S10</td>
<td>10</td>
<td>11,400</td>
<td>2</td>
<td>7/8”</td>
<td></td>
</tr>
<tr>
<td>P35E84S10</td>
<td>10</td>
<td>11,400</td>
<td>2</td>
<td>7/8”</td>
<td></td>
</tr>
<tr>
<td>P35E64S10</td>
<td>14</td>
<td>11,400</td>
<td>2</td>
<td>7/8”</td>
<td></td>
</tr>
<tr>
<td>P35E84S10</td>
<td>14</td>
<td>11,400</td>
<td>2</td>
<td>7/8”</td>
<td></td>
</tr>
</tbody>
</table>

1. To specify required helix spacing for helical extensions, add suffix “S” and the distance from the connection point. Ex. P35E60S12S14 – helix spacing is 14” from the leading edge of the helix to the connection point.
2. For bevel leading edge on the helix, add suffix “V” to the catalogue #. Ex. P3584S12V.
For more information:
MacLean-Dixie HFS
11411 Addison Avenue
Franklin Park, Illinois 60131
(847) 455-0014
(847) 455-0029
www.macleanpower.com

Helical Foundation Systems
Engineering Reference Manual
Building Solid Foundations