DESIGN, INSTALLATION AND TESTING OF HELICAL PILES & ANCHORS

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CHANCE® Civil Construction
Centralia, MO USA

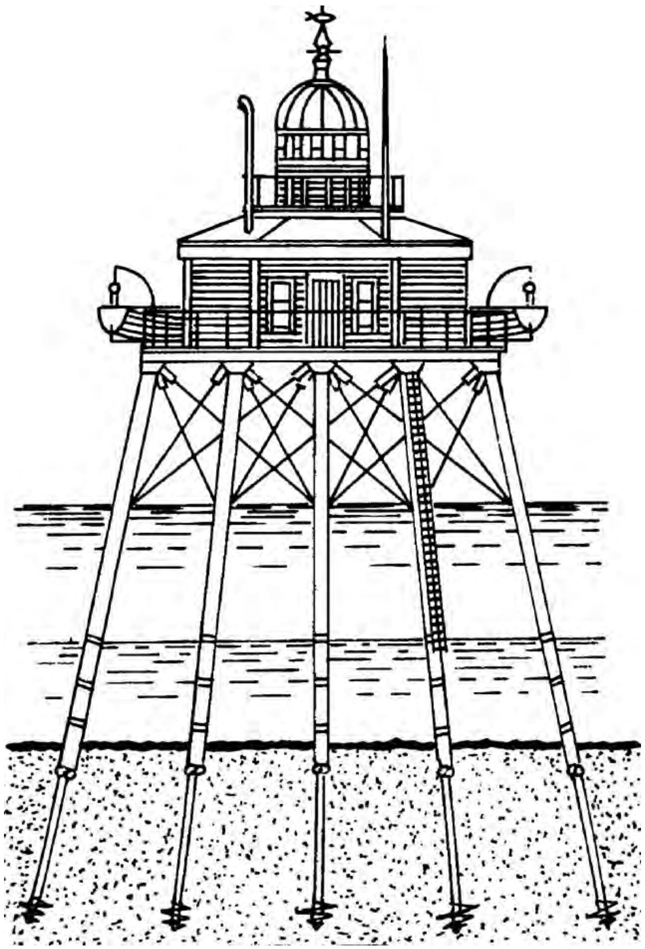
HUBBELL® POWER SYSTEMS

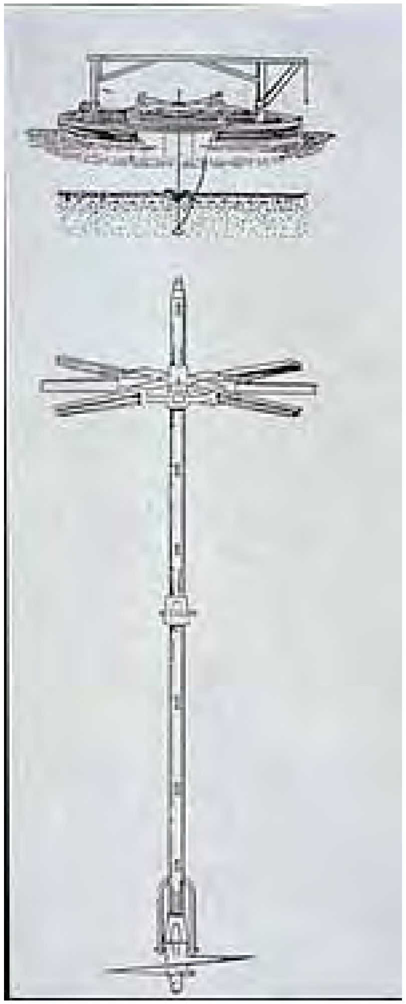
CHANCE Civil Construction

Historical Perspective

- 1st Recorded Screw Pile was by Alexander Mitchell in 1836 for Moorings and then applied by Mitchell to Maplin Sands Lighthouse in England in 1838.
- In 1851, a Screw Pile Light House was established as the Bridgeport Harbor Light, Connecticut on the west side of the harbor.
- In the 1850's, More Than 100 Light Houses were Constructed Along the East Coast, the Florida Coast and the Gulf of Mexico using Screw Pile Foundations.

Mitchell’s Screw Pile - 1836

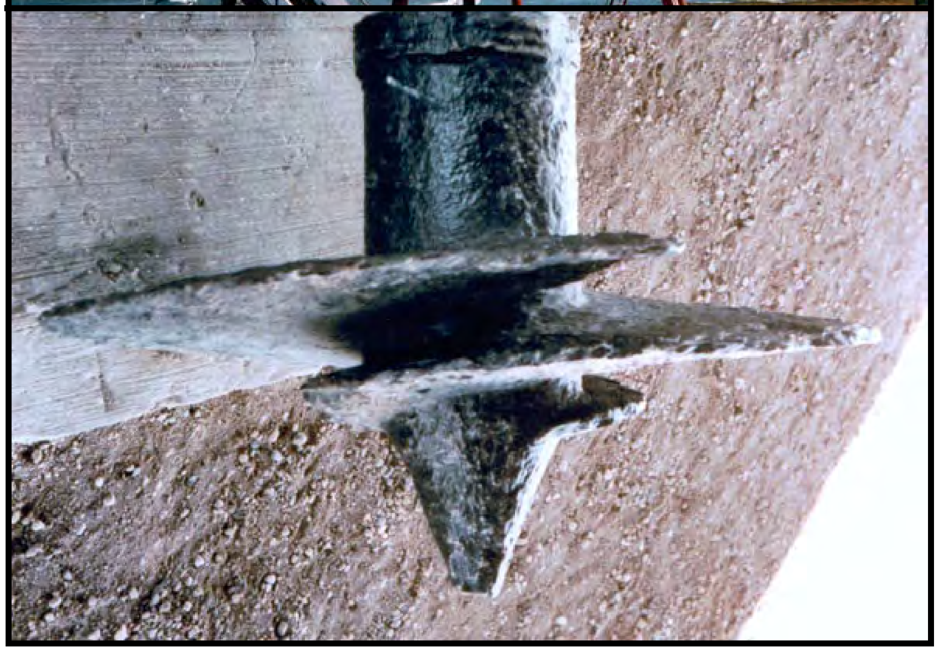




“on Submarine Foundations; particularly Screw-Pile and Moorings”, by Alexander Mitchell, Civil Engineer and Architects Journal, Vol. 12, 1848.

“ whether this broad spiral flange, or “Ground Screw,” as it may be termed, be applied … to support a superincumbent weight, or be employed … to resist an upward strain, its holding power entirely depends upon the area of its disc, the nature of the ground into which it is inserted, and the depth to which it is forced beneath the surface.”

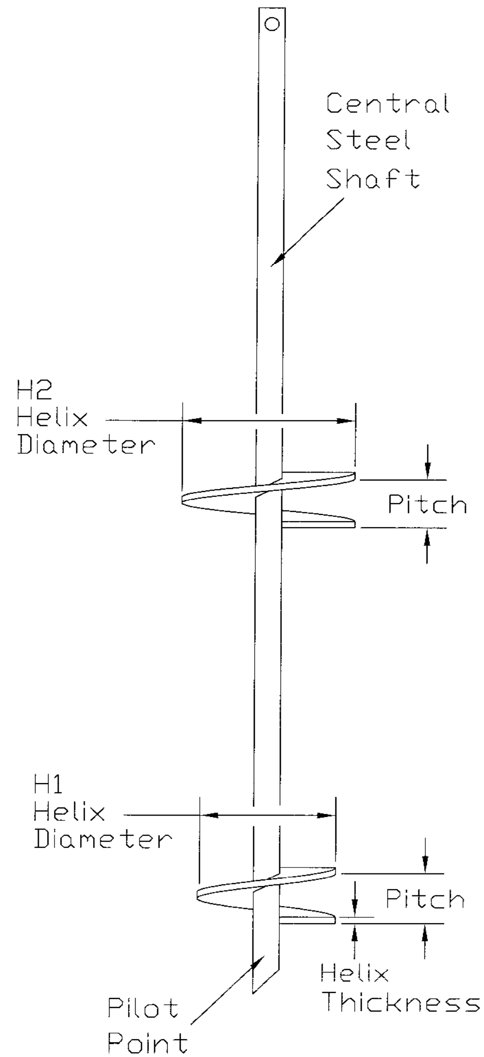
Mitchell Lighthouse at
Hooper’s Strait, Maryland
Installed 1870’s
Removed 1960’s
Museum at St. Michael, MD



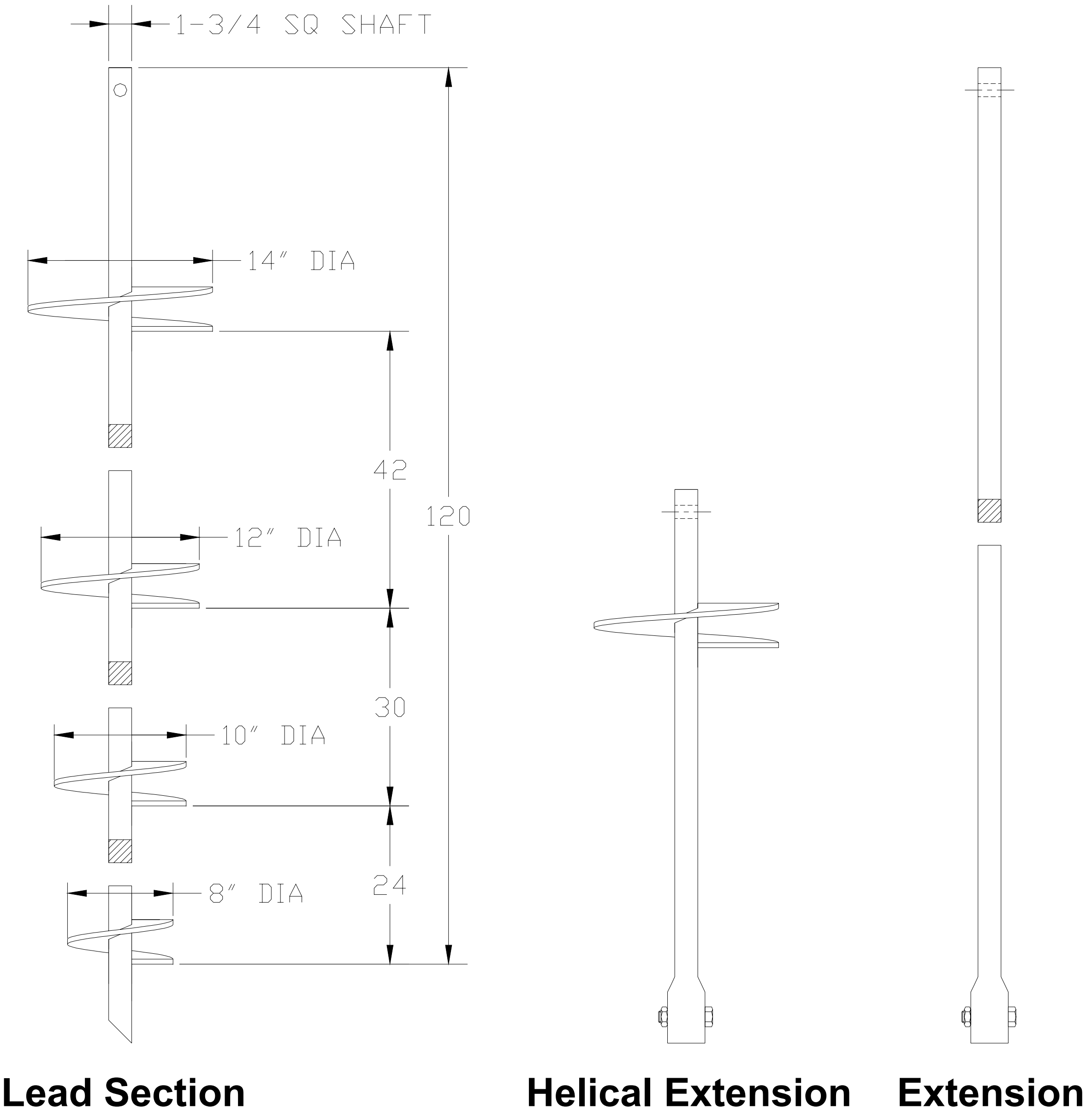
Extracted Cast Iron Screw Pile,
≈ 30” Diameter

What is a Helical Anchor/Pile?

- A helical anchor/pile consists of one or more helix-shaped bearing plates attached to a central shaft, which is installed by rotating or "torqueing" into the ground. Each helix is attached near the tip, is generally circular in plan, and formed into a helix with a defined pitch. Helical anchors/piles derive their load-carrying capacity through both end bearing on the helix plates and skin friction on the shaft.

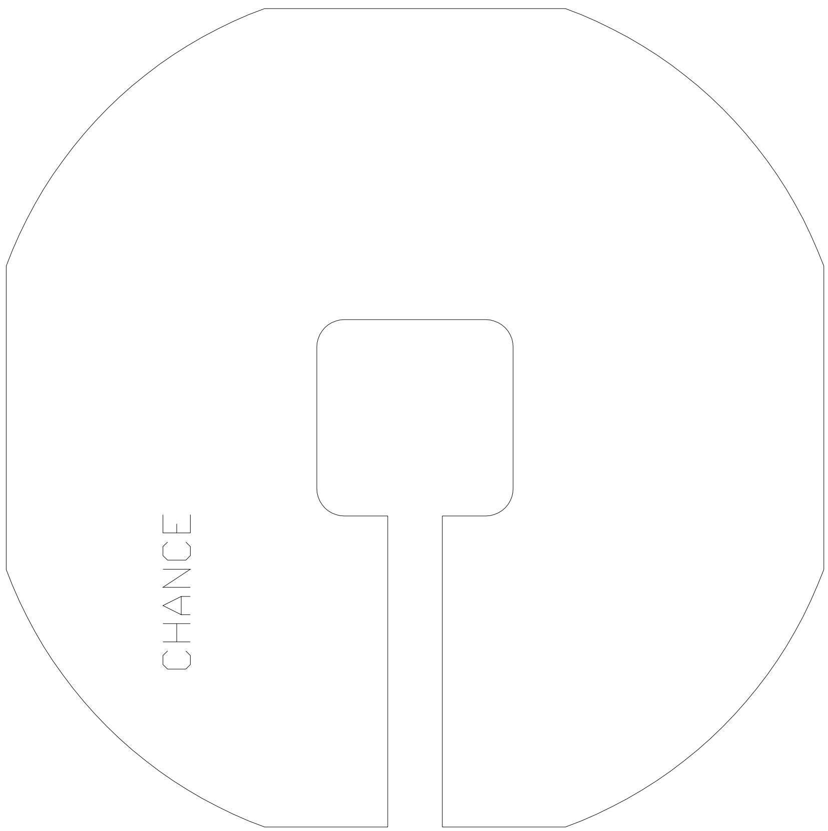


Extendable Helical Piles – Either Square or Round Shaft



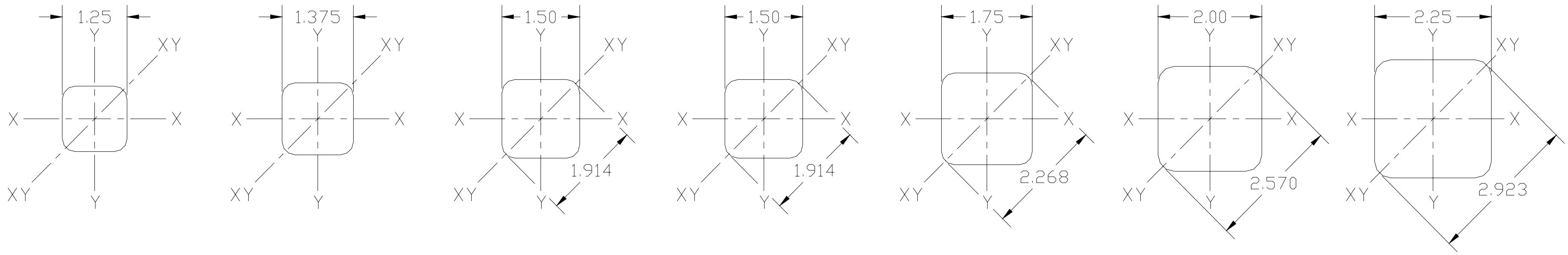
NO MORE THAN 6 HELICES PER ANCHOR

Standard Helix Diameters



Standard Helix Sizes and Projected Areas	
DIAMETER in (cm)	AREA ft^2 (m^2)
6 (15)	0.185 (0.0172)
8 (20)	0.336 (0.0312)
10 (25)	0.531 (0.0493)
12 (30)	0.771 (0.0716)
14 (35)	1.049 (0.0974)
16 (40)	1.385 (0.1286)

Type SS Series - Shaft Mechanical Properties



SS125 Square Shaft	SS1375 Square Shaft	SS5 Square Shaft	SS150 Square Shaft	SS175 Square Shaft	SS200 Square Shaft	SS225 Square Shaft
Torque Rating (ft-lb)						
4,000	5,500	5,500	7,000	11,000	16,000	23,000
Ultimate Tension Strength Based on Bolt Strength * (kip)						
60	75	70	70	100	150	200
Allowable Load Tension Load Based on Bolt Strength † (kip)						
30	37.5	35	35	50	75	100
Tension/Compression Capacity Limit Based on Shaft Torque Rating ** (kip)						
40	55	55	70	110	150*	200*
Allowable Tension/Compression Load Limit Based on Shaft Torque Rating † (kip)						
20	27.5	27.5	35	55	75*	100*

Highlighted Product Series are most common

* Based on Mechanical Strength of Coupling.

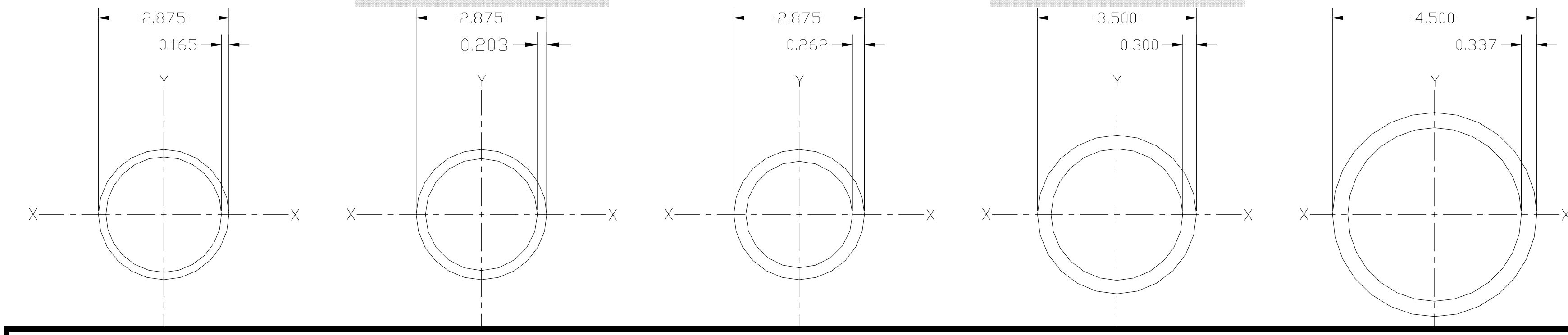
** Based on Shaft Torque Rating – Tension/Compression = Shaft Torque Rating x K_t

"Default " K_t for the SS Series = 10 ft^{-1}

† Allowable Loads are based on a Factor of Safety of two (2).

Type RS Series - Shaft Mechanical Properties

RS2875.165 Round Shaft	RS2875.203 Round Shaft	RS2875.262 Round Shaft	RS3500.300 Round Shaft	RS4500.337 Round Shaft



Torque Rating (ft-lb)				
4,500	5,500	7,500	13,000	23,000
Ultimate Tension Strength Based on Bolt Strength * (kip)				
50	60	100	120	140
Allowable Load Tension Load Based on Bolt Strength † (kip)				
25	30	50	60	70
Tension/Compression Capacity Limit Based on Shaft Torque Rating ** (kip)				
36	44	60	91	138
Allowable Tension/Compression Load Limit Based on Shaft Torque Rating † (kip)				
18	22	30	45.5	69

Highlighted Product Series are most common.

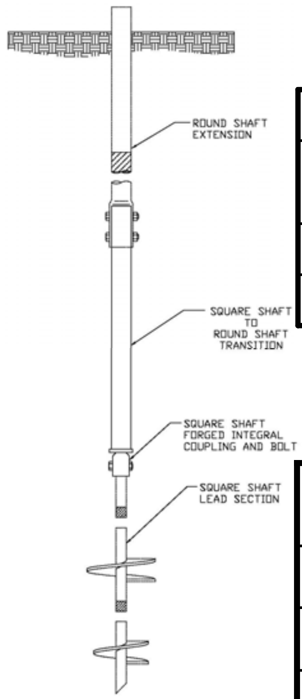
* Based on Mechanical Strength of Coupling.
** Based on Shaft Torque Rating – Tension/Compression = Shaft Torque Rating x K_t
"Default " K_t for the RS2875.XXX Series = 8 ft^{-1}; for the RS3500.300 Series = 7 ft^{-1}; for the RS4500.337 Series = 6 ft^{-1}.
† Allowable Loads are based on a Factor of Safety of two (2).

RS2875.276 and RS8625 Series Now available

TYPE "SS/RS" COMBINATION SERIES

Type SS5/SS150 to RS2875.203 Combination Series
and
Type SS175/SS200 to RS3500.300 Combination Series

Pile Assembly with RS Transition Coupler



Transition Couplings - Torque Ratings

CATALOG NUMBER	DESCRIPTION	TORQUE RATINGS
C278-0150	SS5/SS150 square shaft to a RS2875.203 round shaft	5,500 ft-lbs
T107-0808	SS175 square shaft to a RS3500.300 round shaft	11,000 ft-lbs
T107-0809	SS200 square shaft to a RS3500.300 round shaft	13,000 ft-lbs

Mechanical Ratings of Combination Series

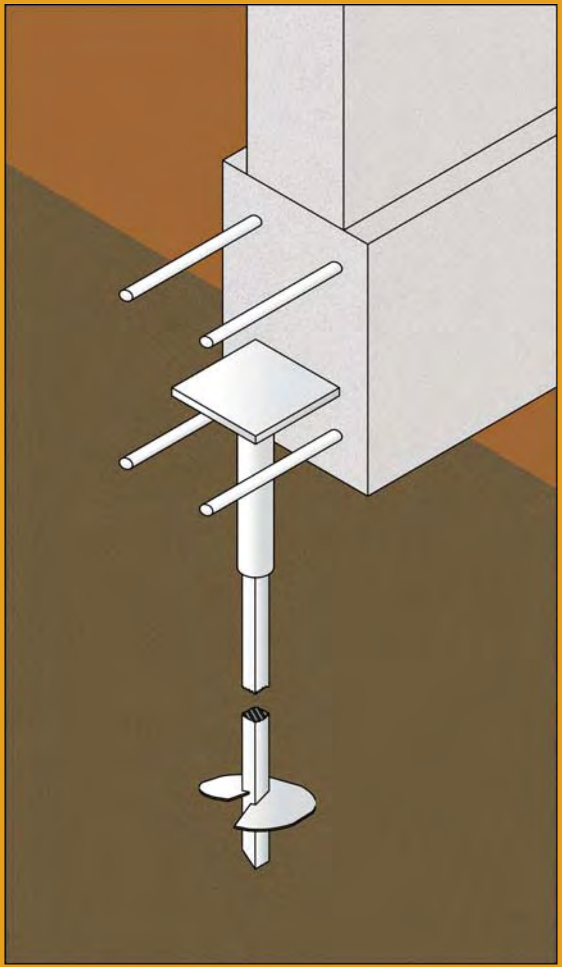
DESCRIPTION	ULTIMATE TENSION STRENGTH* lbs (kn)	TENSION/COMPRESSION LIMIT** lbs (kn)
SS5/RS2875.203	60,000. (267)	44,000. (196)
SS150/RS2875.203	60,000. (267)	44,000. (196)
SS175/RS3500.300	100,000. (445)	91,000. (405)
SS200/RS3500.300	120,000. (534)	91,000. (405)

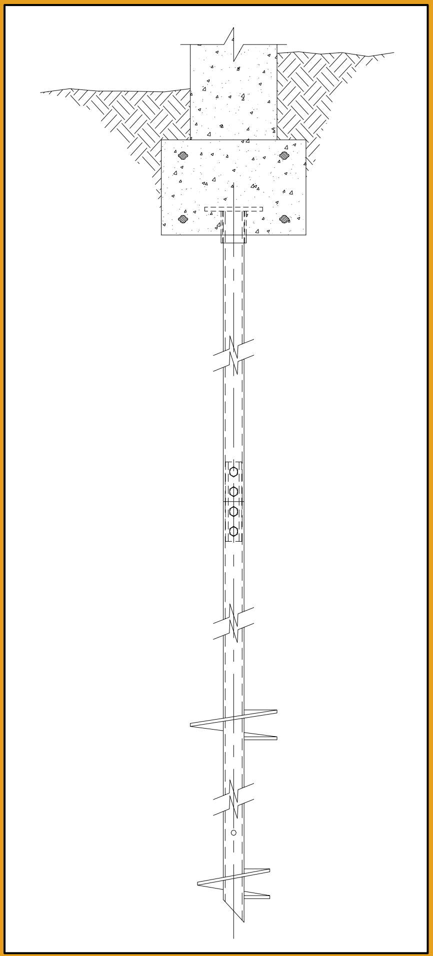
* Based on Mechanical Strength of Coupling.
** Based on Shaft Torque Rating – Tension/Compression = Shaft Torque Rating x K_t
"Default " K_t for the SS Series = 10 ft^{-1}, for the RS2875 Series = 8 ft^{-1}, for the RS3500 Series = 7 ft^{-1}.

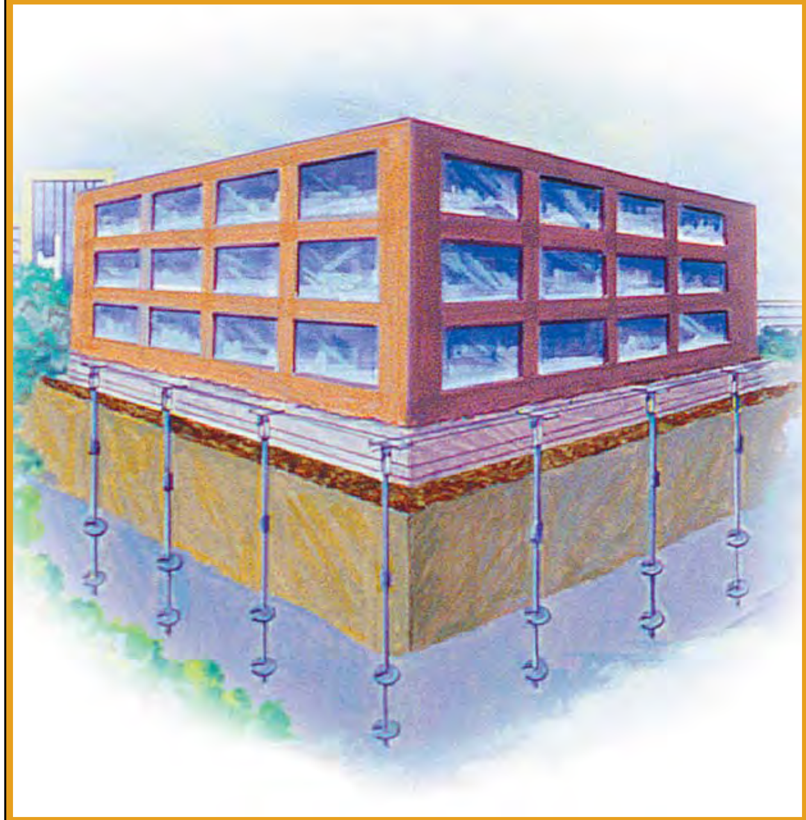
ADVANTAGES – HELICAL PILES & ANCHORS

- Quick, Easy Turnkey Installation
- Immediate Loading
- Small Installation Equipment
- Pre-Engineered System
- Easily Field Modified
- Torque-to Capacity Correlation
- Install in Any Weather
- Solution for:
  - Restricted Access Sites
  - High Water Table
  - Weak Surface Soils
- Environmentally Friendly
- No Vibration
- No Spoils to Remove
- No Concrete

Helical Screw Piles for New Construction


Square Shaft Helical Pile


Round Pipe Shaft Helical Pile



Ft. Sill, OK Troop Housing and Headquarters Facilities

- Three manufactured housing companies
- Four different floor plans
- Three different sites
- Three different pile types (RS2875, RS3500, RS4500 and SS5)
- Tension, Compression and Lateral Loads

Ft. Sill Troop Housing

New Construction - Slabs and Foundations

Screw Piles Supporting Structural Slab

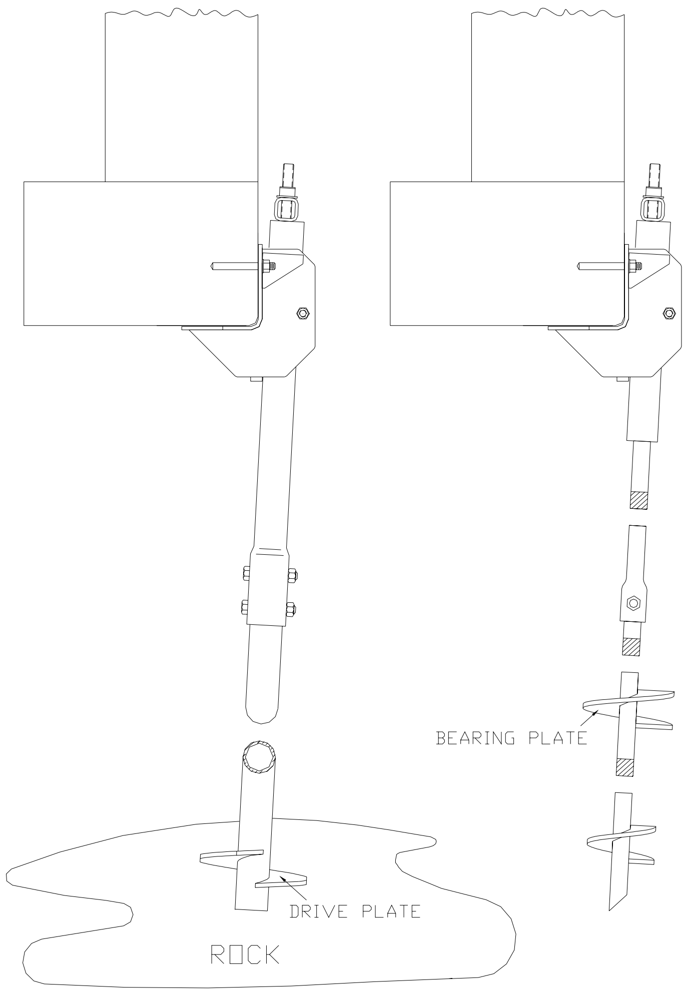
Access Limitations


DEERE

Foundation Underpinning

Remedial Repair Bracket – C150-0121

SS5, SS150 (1-1/2 Square Shaft) & RS2875.203 Round Shaft Pile



Foundation Underpinning with Helical Piles

Screw Foundation Installation with Portable Installer

Foundation Underpinning with Helical Piles

Repair Brackets

Raising Building with Repair Brackets

Foundation Underpinning Brackets

STANDARD-DUTY
FOUNDATION REPAIR BRACKET

<u>FOR 1 ½" SHAFT</u>
RATED CAPACITIES:
20,000 LB. WITH SS5 Helical Piles
25,000LB. WITH SS150 Helical Piles
<u>FOR 1 ¾" SHAFT</u>
RATED CAPACITY: 30,000LB.

HEAVY-DUTY
FOUNDATION REPAIR BRACKET

<u>FOR 1 ¾" SHAFT</u>
RATED CAPACITY: 40,000LB.

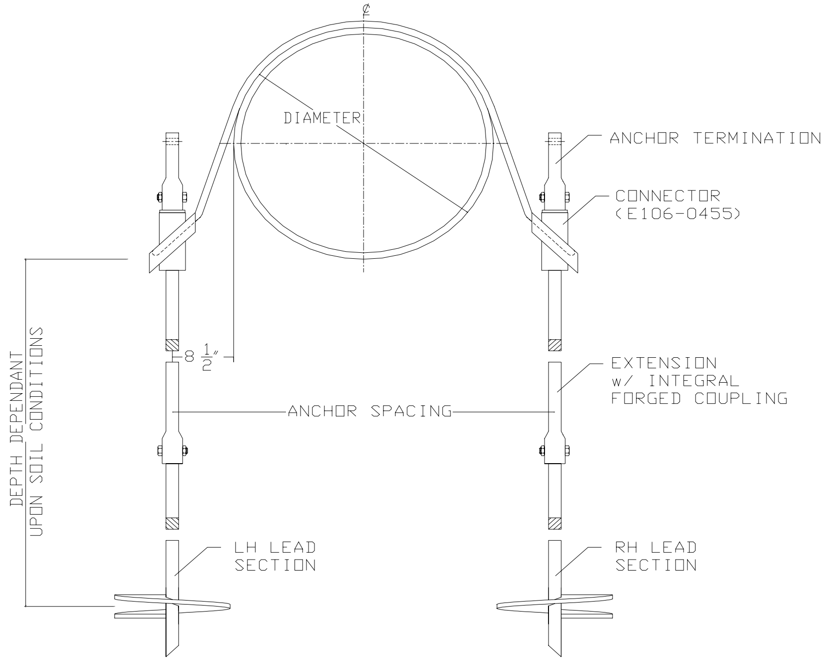
Baptist Church
Burlington, Ontario

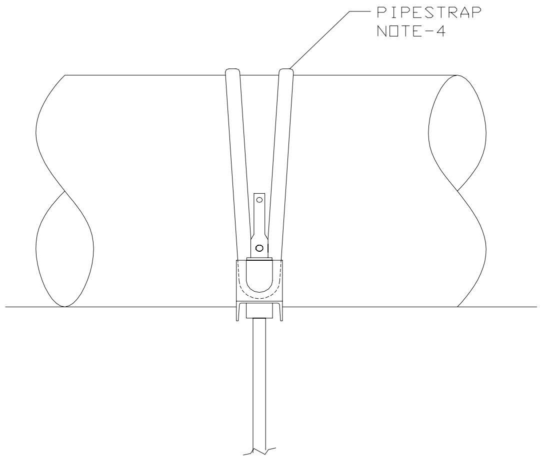
Walkways for Wetlands

Tie Down & Buoyancy Control

Band Shell at the Capitol

Pipeline Buoyancy Control





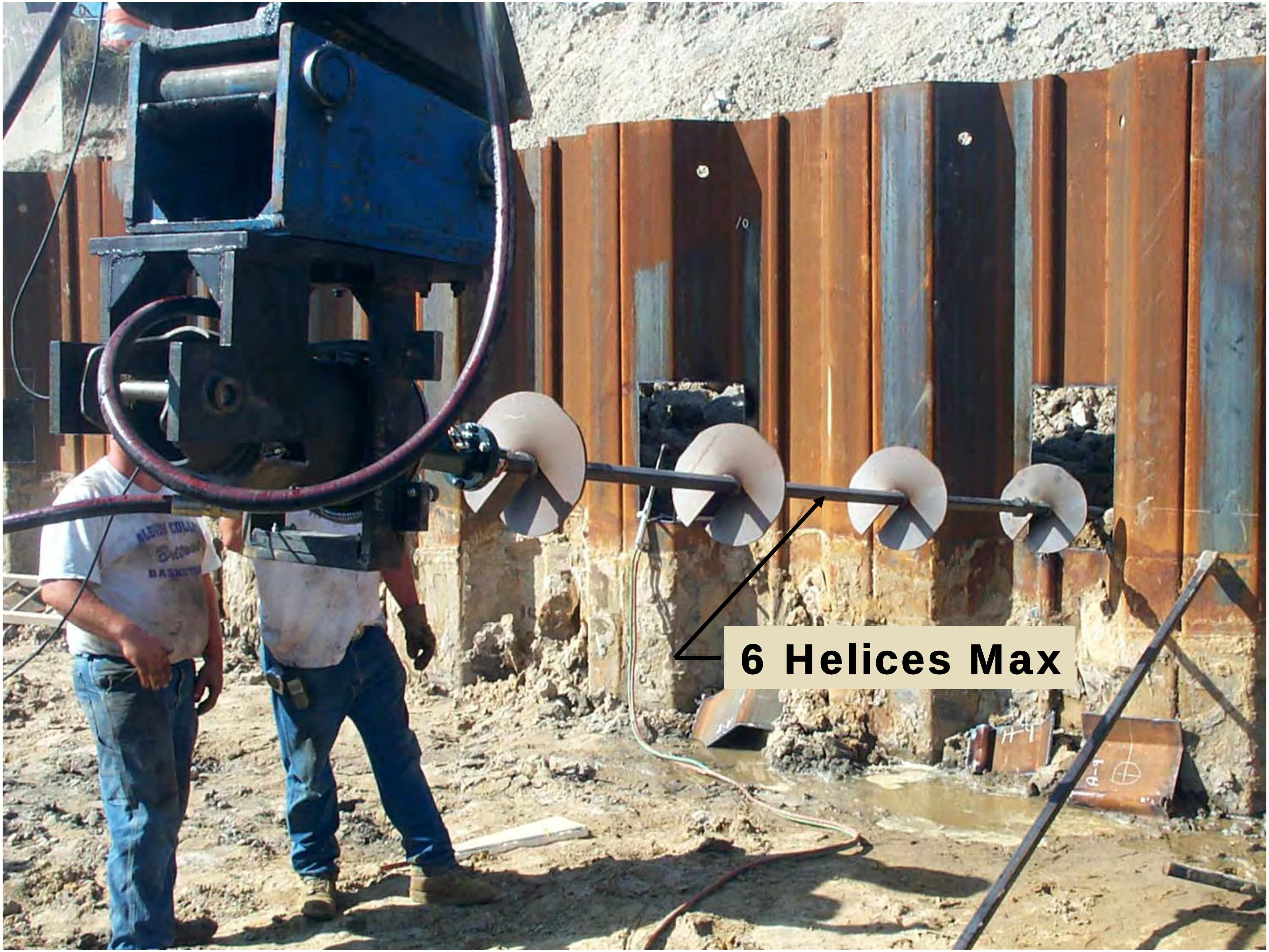
Pipeline Buoyancy Control

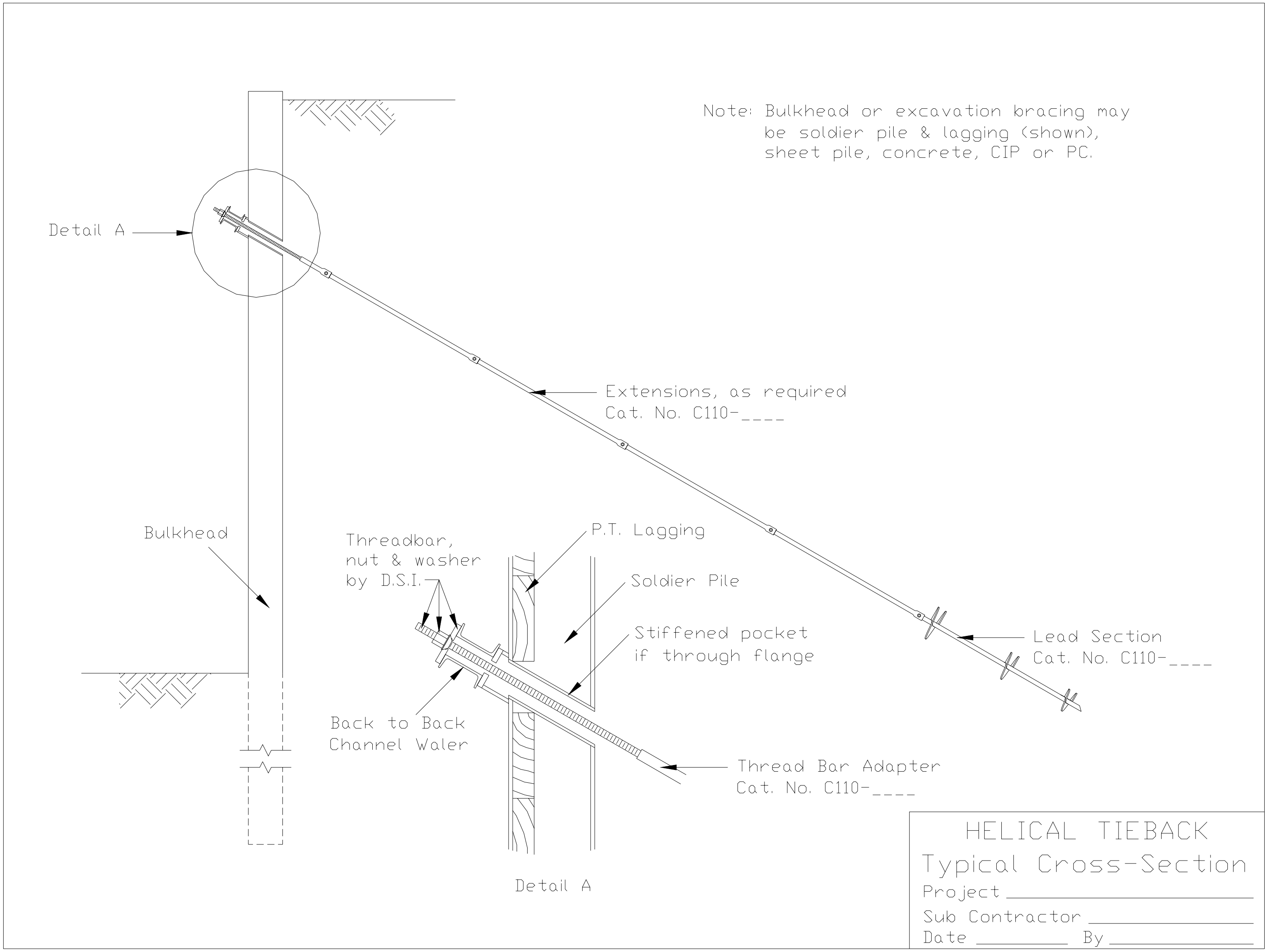
THE QUINCY MA SEWER PIPELINE

- Over 1000 HS Helical Pulldown® Micropiles used
- Soils consisted of mixed soils-organic silt, peat and clay.

CHANCE® Helical Products
(Tension & Compression)

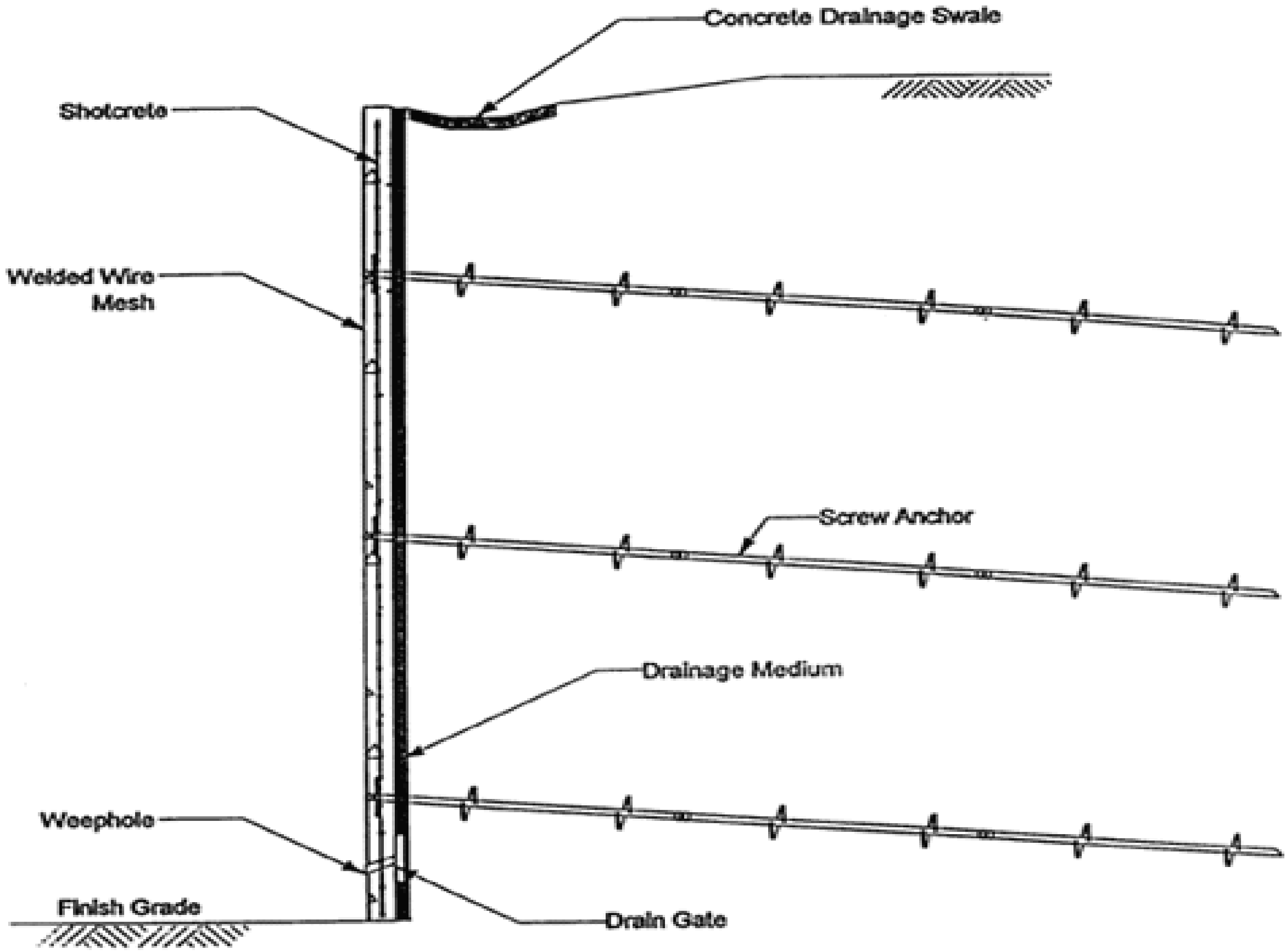
**5 Guys Contemplate
An Anchor Rod**


6 Helices Max



Note: Bulkhead or excavation bracing may be soldier pile & lagging (shown), sheet pile, concrete, CIP or PC.
Detail A
Extensions, as required
Cat. No. C110-____
Bulkhead
Threadbar, nut & washer by D.S.I.
P.T. Lagging
Soldier Pile
Stiffened pocket if through flange
Lead Section
Cat. No. C110-____
Back to Back Channel Waler
Thread Bar Adapter
Cat. No. C110-____
Detail A
HELICAL TIEBACK
Typical Cross-Section
Project ____
Sub Contractor ____
Date ____ By ____

Soil Screws - Section Detail



Soil Screws for Soil Nail Walls


Increasing Size of Building Lot
Alpharetta, GA

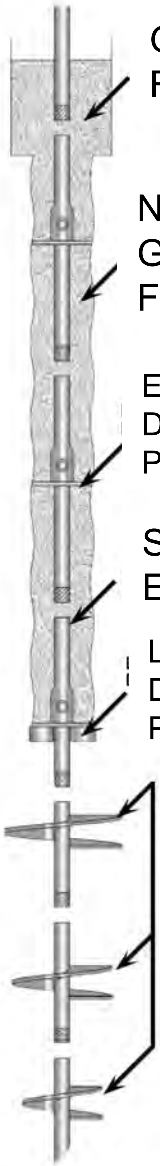
HELICAL PULLDOWN® MICROPILES

HUBBELL®
POWER SYSTEMS

CHANCE
Civil Construction

HELICAL PULLDOWN® MICROPILES

- Screw Pile Foundation Installation Method Used to Increase the Section Modulus of a Standard SS or Pipe Shaft.
- Patent Protected
  - U.S. 5,707,180; Methods and Apparatus
  - Other U.S. and Foreign Patents Pending
- Method of Displacing Soil Around the Anchor Shaft and Replacing with Grout Column.
  - Soil is Displaced by "Lead Displacement Plate".
  - "Extension Displacement Plates" Serve as Centralizers and Provide the Means for Which the Grout is "Pulled-Down".



GROUT RESEVOIR

Installing Lead Case

Installing Top Case
(Grout Reservoir)

Adding Centralizer

Pouring Grout

Joint Packing

Installing Shaft Extension

Grout “Pulled Down”

SOIL CAPACITY - INDIVIDUAL BEARING METHOD

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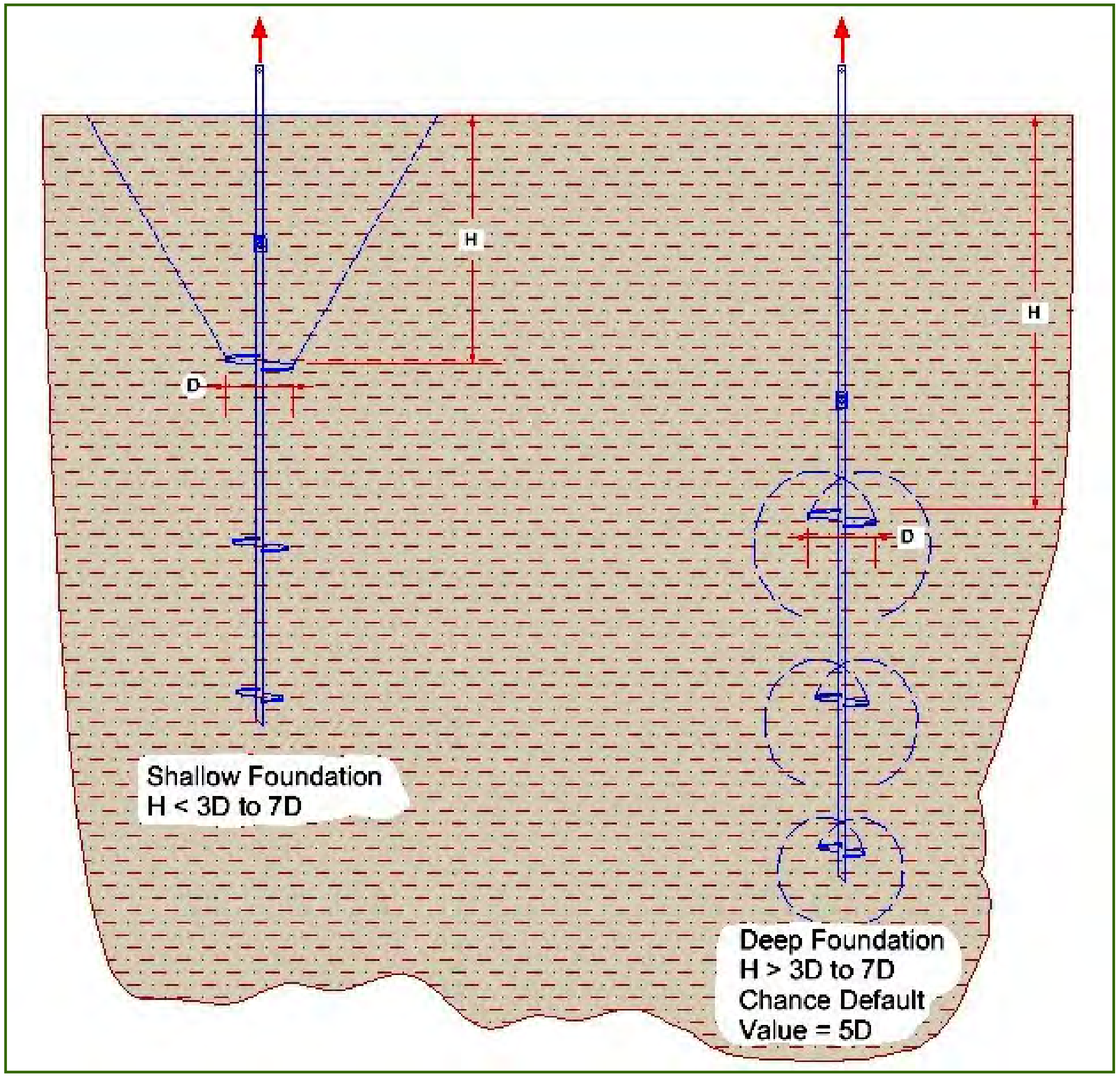
Shallow vs. Deep Helical Anchors/Piles



Soil Stress Distribution

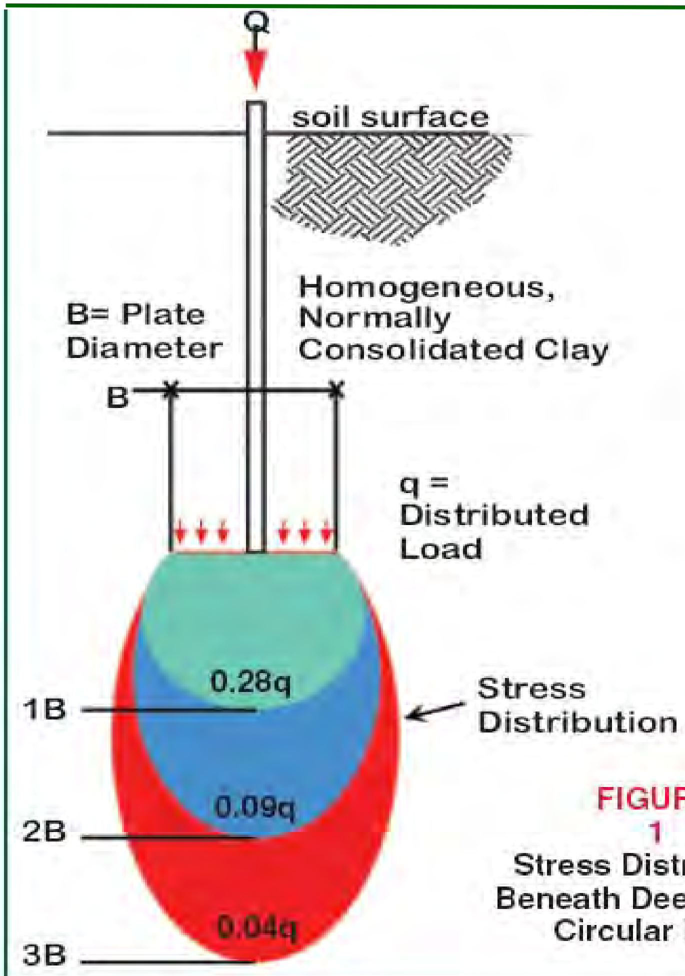
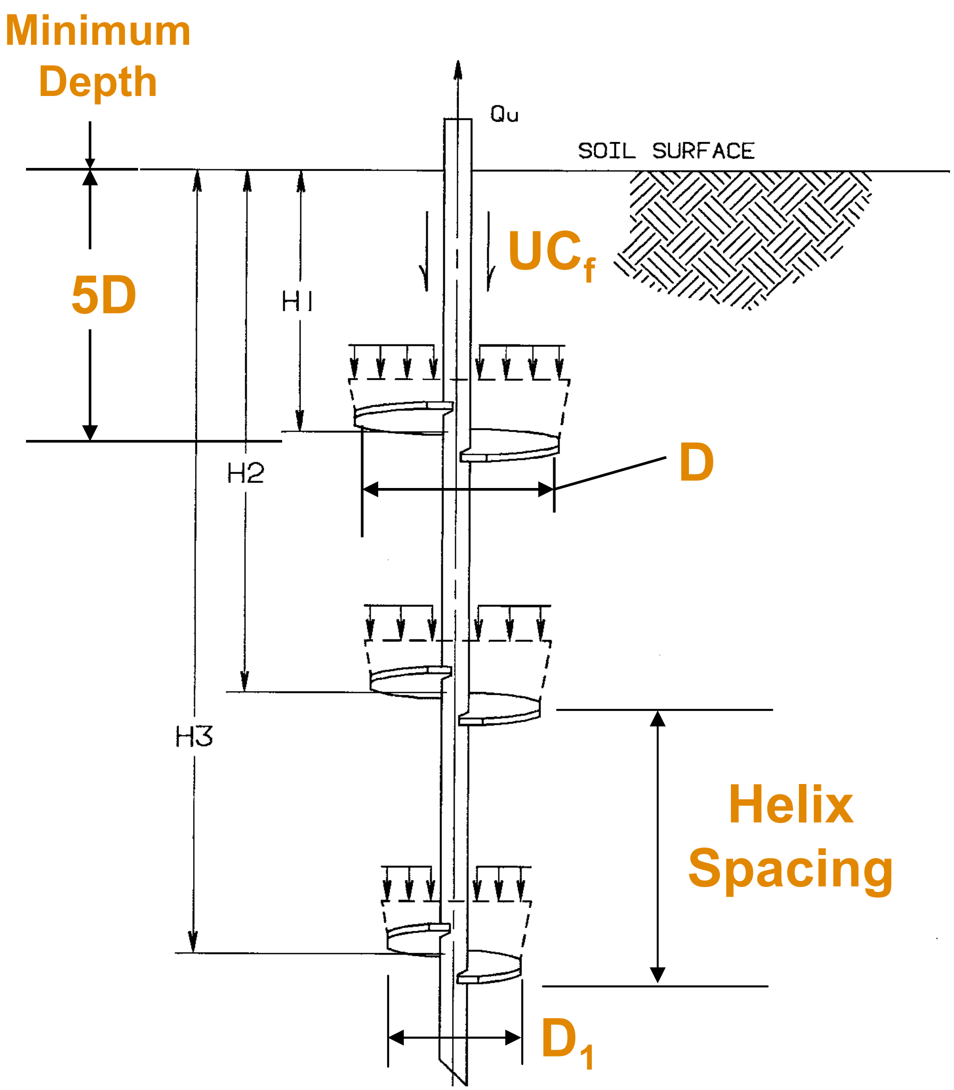


FIGURE 1
Stress Distribution
Beneath Deep Buried
Circular Plate

Plate Bearing Capacity Model



- Total Capacity Equal to Sum of Individual Helix Bearing Capacities
- Model valid for both tension and compression
- Helix Spacing $\geq 3D_1$
- Min. Depth $\geq$ 5D (also need to be deeper than zone of seasonal moisture fluxuation)
- Capacity (UC_f) Due to Friction Along Shaft = Zero.

Individual Bearing (Chance) Method

Determine End Bearing Capacity of Helical Configuration

General Bearing Capacity Equation:

$$Q_{ult} = A\,(CN_c + qN_q + (½)\gamma BN_\gamma)$$

where:

- A = Area of footing
- C = Cohesion
- q = Overburden Pressure = (γD)
  (D = Depth of footing below groundline)
- γ = Unit Weight of Soil
- B = Width of Footing
- N_c, N_q, & N_γ = Bearing Capacity Factors
  (Nc = 9 for ratio of top helix depth to helix diameter > 5)

Individual Bearing (Chance) Method

"Individual Bearing Plate" Method

$$Q_{ult} = \sum Q_h$$

where:

- Q_{ult} = Total Multi-helix Anchor/Pile Ultimate Capacity
- Q_h = Individual Helix Ultimate Capacity

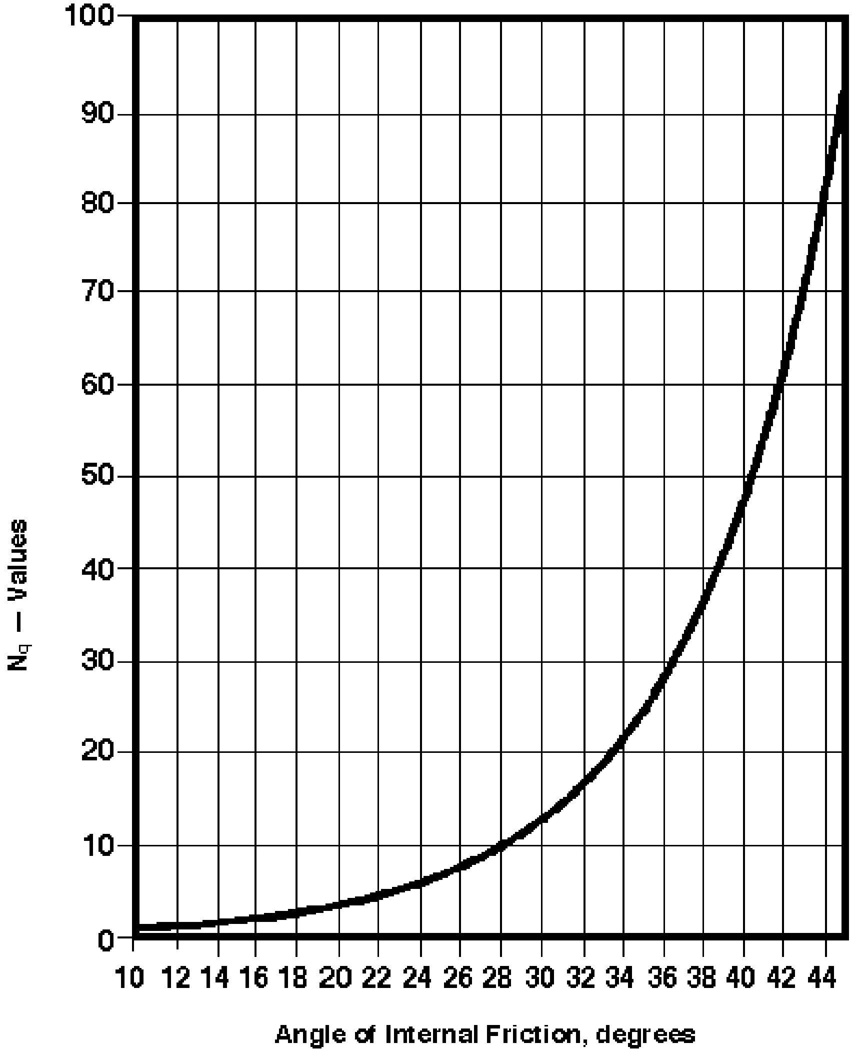
$$Q_h = A_h\ (N_c C + \gamma D N_q) \ \leq\ Q_s$$

$$Q_h = A_h\ (9C + \gamma D N_q) \ \leq\ Q_s$$

where:

- A_h = Projected Area of Helix
- N_c = 9 for ratio of top helix depth to helix dia. > 5
- D = Depth of Helix Plate below Groundline
- N_q = Bearing Capacity Factor for Sand
- Q_s = Upper Mechanical Limit determined by Helix Strength

Bearing Capacity Factor Curve



- N_q vs. Angle of Internal Friction
- Cohesionless Soils
- Adapted from G. G. Meyerhof Factors for Driven Piles in his paper ***Bearing Capacity and Settlement of Pile Foundations***, 1976
- Equation:

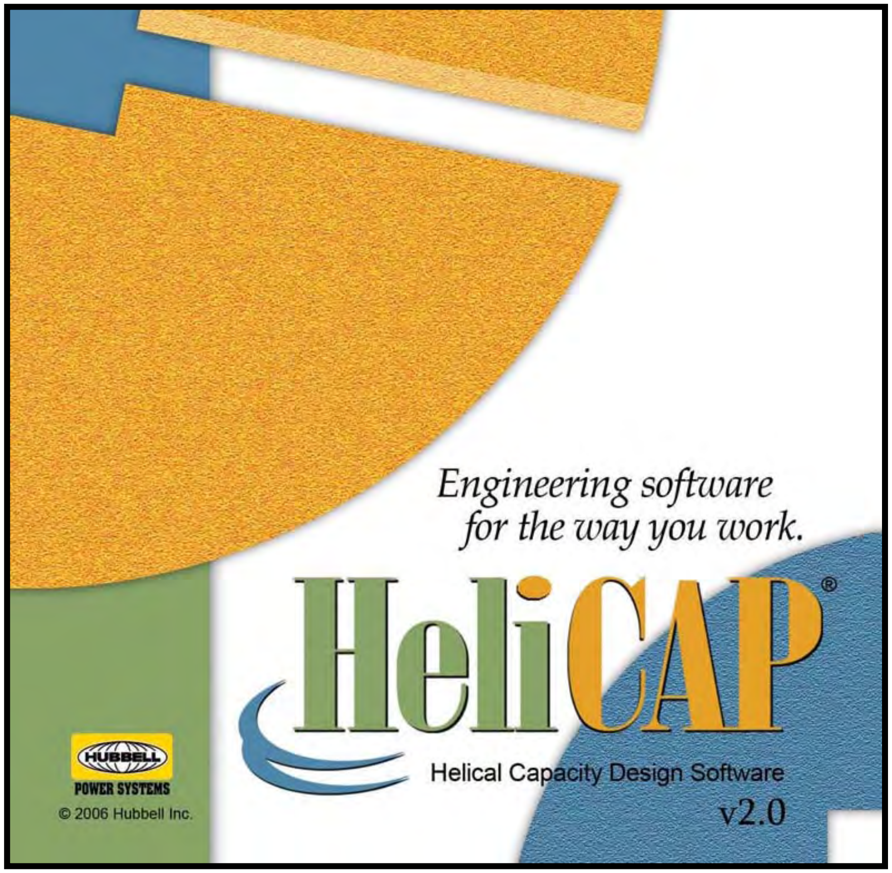
$$Nq=0.5\ (12^*\phi)^{\phi/54}$$

FACTOR OF SAFETY

- Select an Appropriate Factor of Safety (FS) to Apply to the Ultimate Capacity of the Helical Anchor/Pile to Develop the required Design, or Working Capacity per Anchor/Foundation.

- In general, Chance Civil Construction recommends a minimum FS of 2 for permanent construction and 1.5 for temporary construction.

HeliCAP® v2.0 Helical Capacity Design Software



- Microsoft Windows Based Bearing, Uplift, and Friction Capacity Software
- 4 Types of Helical Applications- Compression, Tension, Tiebacks, and Soil Screws
- Within those applications can also calculate friction capacity of a grout column or steel pipe shaft. New
- Based on soil and anchor/pile inputs the program returns theoretical capacities and installation torque.

INSTALLATION TORQUE CORRELATION TO CAPACITY

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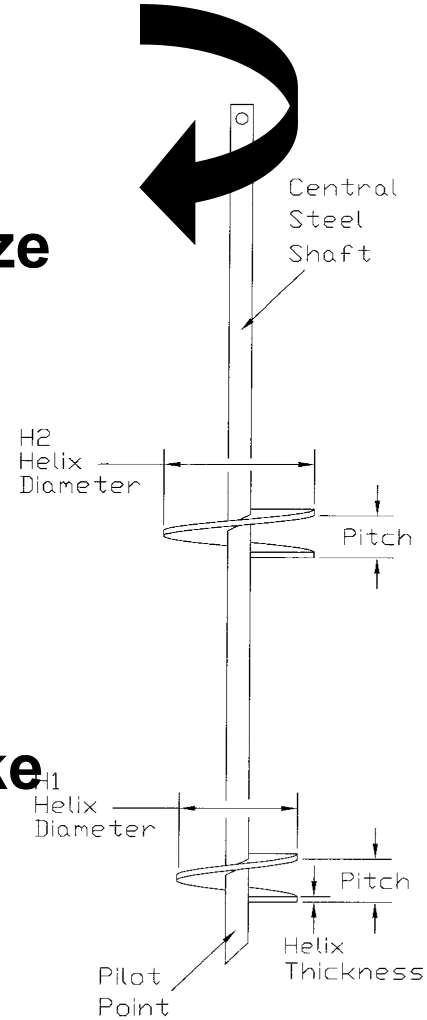
Helical Piles & Anchors - HOW THEY WORK

- **Low Soil Displacement Foundation Element Specifically Designed to Minimize Disturbance During Installation**

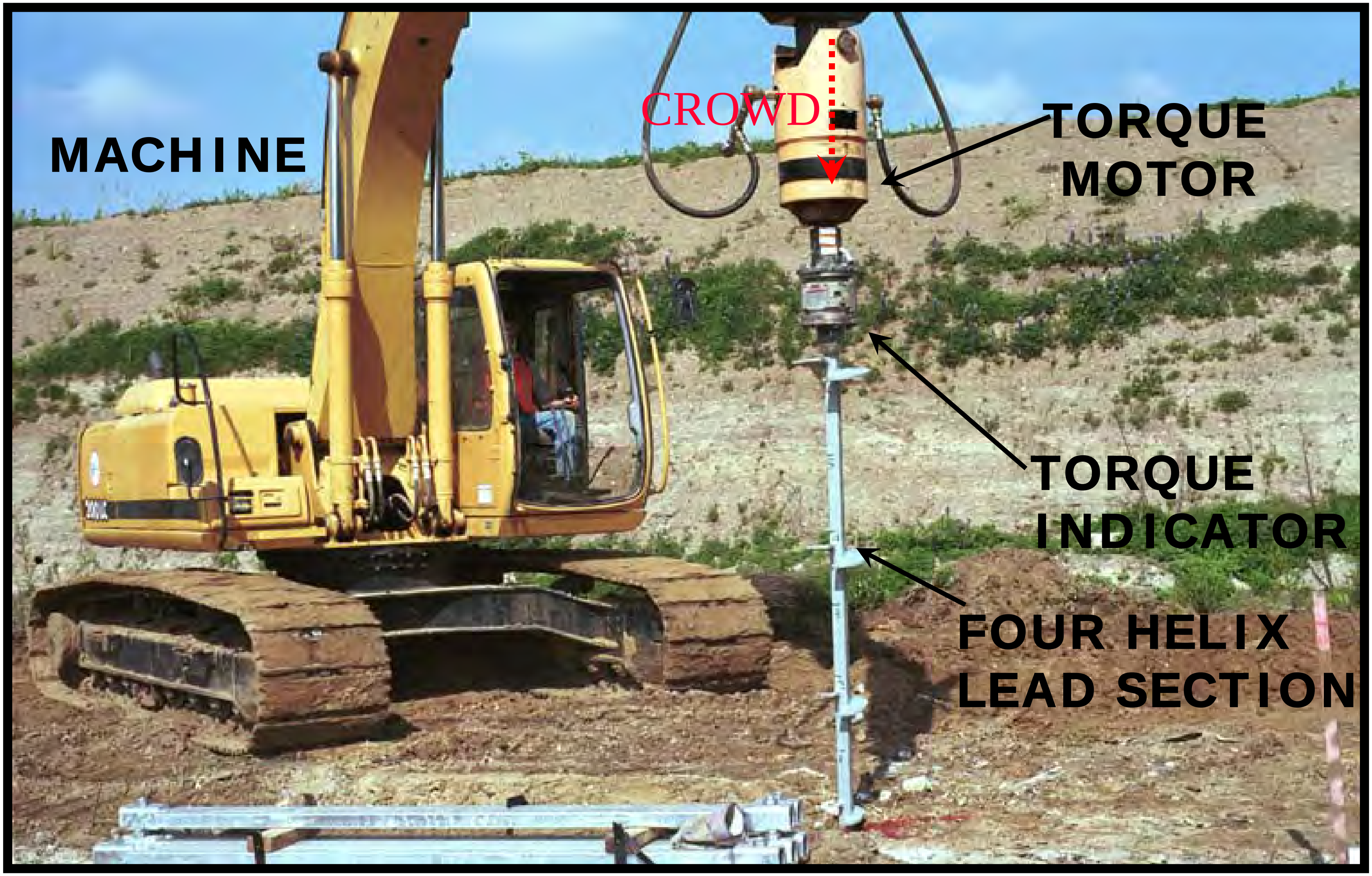
- **Consists of One or More Helix Plates Attached to a Central Steel Shaft**

- **Rotated, or "Screwed" into Soil Much Like a Wood Screw Driven into a Piece of Wood**



INSTALLATION ENERGY

- **Must Equal the Energy Required to Penetrate the Soil, plus the Energy Loss Due to Friction**
- **Provided by the Machine – Consists of Two Parts:**
  - **Rotation Energy** – Supplied by the Torque Motor
    - Rotation and Inclined Plane of Helix Provides Downward Thrust
    - A.k.a. *INSTALLATION TORQUE*
  - **Downward Force, or *Crowd*** – Supplied by the Machine


MACHINE
CROWD
TORQUE MOTOR
TORQUE INDICATOR
FOUR HELIX LEAD SECTION

INSTALLATION TORQUE VS. ULTIMATE CAPACITY

The Torque Required to Install a Helical Pile or Anchor is Empirically Related to Its Ultimate Capacity.

- $Q_{ult} = K_t T$
  - Where:
    - Qult = Ultimate Capacity [lb (kN)]
    - K_t = Empirical Torque Factor [ft-1 (m-1)]
      - “Default” Value = 10 (33) for Type “SS”
      - “Default” Value = 8 (26) for 2-7/8” Pipe Shaft
      - “Default” Value = 7 (23) for 3-1/2” Pipe Shaft
      - “Default” Value = 6-7 (20-23) for 4-1/2” Pipe Shaft
    - T = Installation Torque, [ft-lb (kN-m)]

INSTALLATION TORQUE VS. ULTIMATE CAPACITY

- The Value of K_t is not a Constant - May Range from 3 to 20 ft^{-1} (10 to 66 m^{-1}). Depends on:
  - **Soil Conditions**
    - **Type SS**
      - Normally Consolidated Clay – K_t = 10
      - Overconsolidated Clay – K_t = 12-14
      - Sensitive Clay – K_t < 10
      - Sands – K_t = 12+
  - **Central Steel Shaft/Helix Size**
    - K_t Inversely Related to Shaft and Helix Size
  - **Helix Thickness**
    - K_t Inversely Related to Helix Thickness
  - **Application (Tension or Compression)**
    - Compression Capacity is Generally Higher Than Tension Capacity

TORQUE - ADVANTAGES

- Provides Excellent Field Control Method of Installation

- Monitors Soil Conditions

- **Torque is a Direct Measure of Soil Shear Strength**

- Predicts Holding Capacity of the Soil

- Helical Piles/Anchors Can be Installed to Specified Torque

TORQUE - REQUIREMENTS

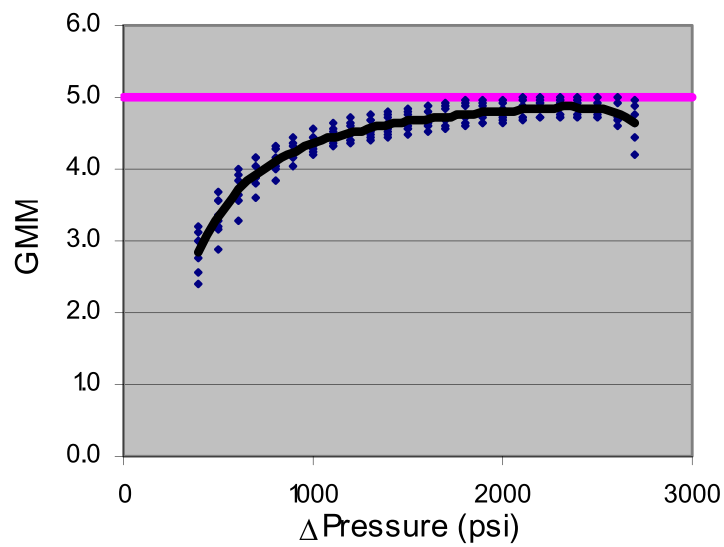
- Requires Competent, Well-Trained Installers
  - CHANCE® Certification Program
- Requires Installation in the Field to Determine Capacity
- Requires Torque Monitoring Equipment

RELIABILITY OF TORQUE/CAPACITY MODEL

- ***Uplift Capacity of Helical Anchors in Soil* [Hoyt & Clemence 1989]**
  - Analyzed 91 Load Tests
  - 24 Different Test Sites
  - Sand, Silt, and Clay Soils Represented
  - Calculated Capacity Ratio (Q_{act}/Q_{calc})
  - Three Different Load Capacity Models
    - Cylindrical Shear
    - Individual Bearing
    - Torque Correlation
- **Torque Correlation Method Yields More Consistent Results than Either of the Other Two Methods**
- **Best Suited for On-Site Production Control and Termination Criteria**

Torque Monitoring Methods/Devices

- **Shaft Twist**
  - Visible Indication of Torque (Square Shaft)
- **Shear Pin Torque Limiter**
  - Point-Wise Indicator
  - Simple Design, Easy to Use
  - Requires Occasional Maintenance
- **Mechanical Dial Indicator**
  - Continuous Reading Indicator
  - Comes with Laboratory Calibration Sheet
  - Fairly Durable
- **Differential Pressure Correlations**
  - Level 1 – Manufacturers Gear Motor Multiplier
  - Level 2 - Certified Gear Motor Test Results (most accurate)

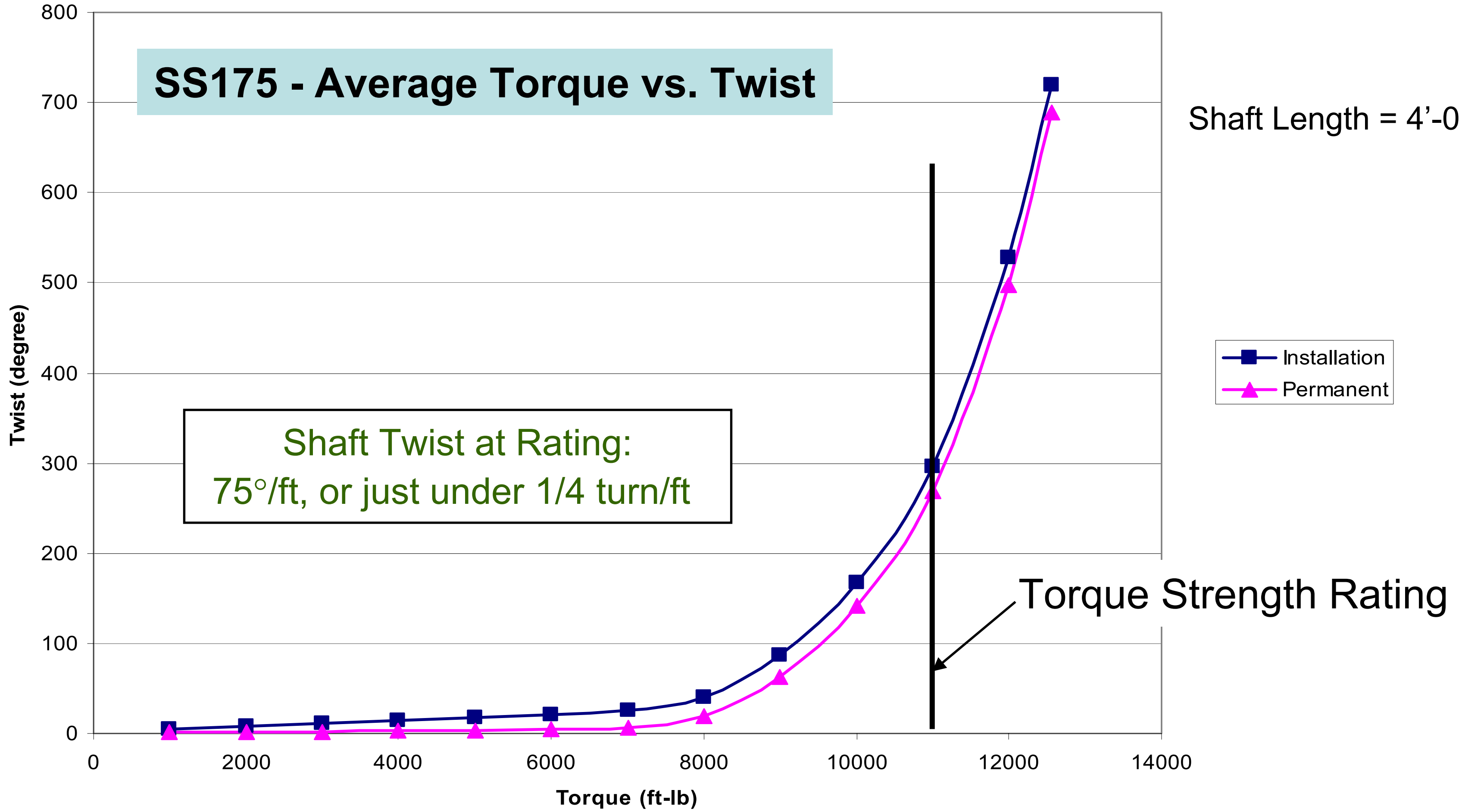


Shaft Twist Approach

Shaft Twist – SS175 Helical Pulldown® Micropile

≈ ½ Twist/ft.
≈ 12,000. ft-lbs

Shaft Twist Approach

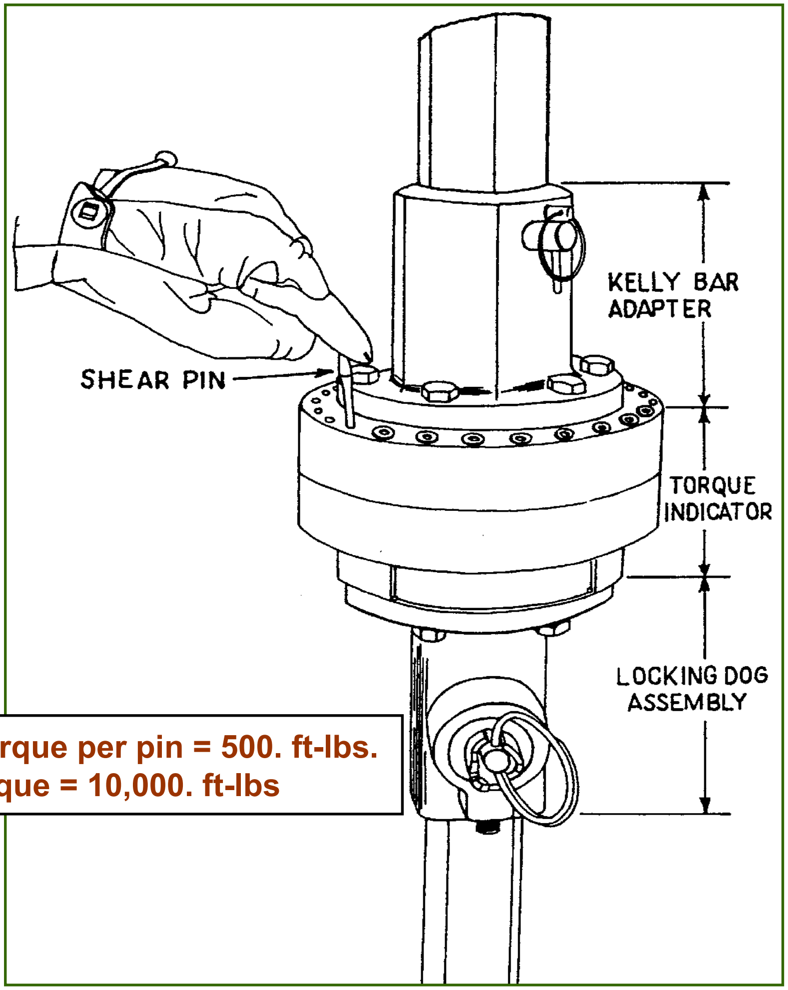


Torque Rating based on Shaft Twist only applies to the Type SS Series. It does not apply to the Type RS Series.

Type RS Series Do Not Exhibit Much Shaft Twist Prior to Failure.
Torque Must Be Closely Monitored to Avoid Over-Torque.

PIPE SHAFT ELONGATION OF HOLES

Shear Pin Torque (Limiter) Indicator



Shear Torque per pin = 500. ft-lbs.
Max. Torque = 10,000. ft-lbs

Shear halves turn freely when pins shear.

Mechanical Dial Torque Indicator

Mechanical Dial Torque Indicator

- **Indicates Installation Torque Directly by Measuring the Twist of a Torsion Bar.**
- **Indicates Installation Torque Directly in ft.-lbs.**
- **Max. Torque = 20,000 ft lbs**

DIFFERENTIAL PRESSURE TORQUE INDICATOR

DP-1 (I) - Differential Pressure Torque Indicator

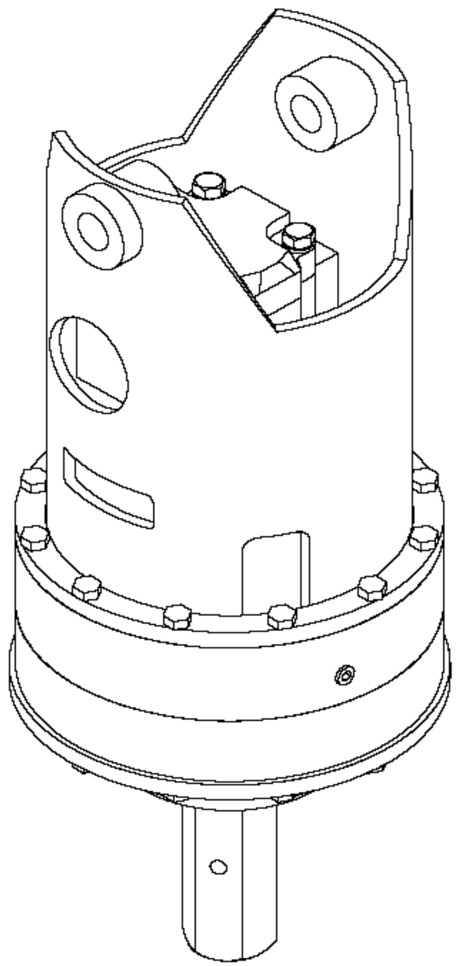
- **Measures "Pressure Drop" across a Hydraulic Torque Motor.**
- **Pressure Drop is Directly Related to the Installation Torque Applied.**

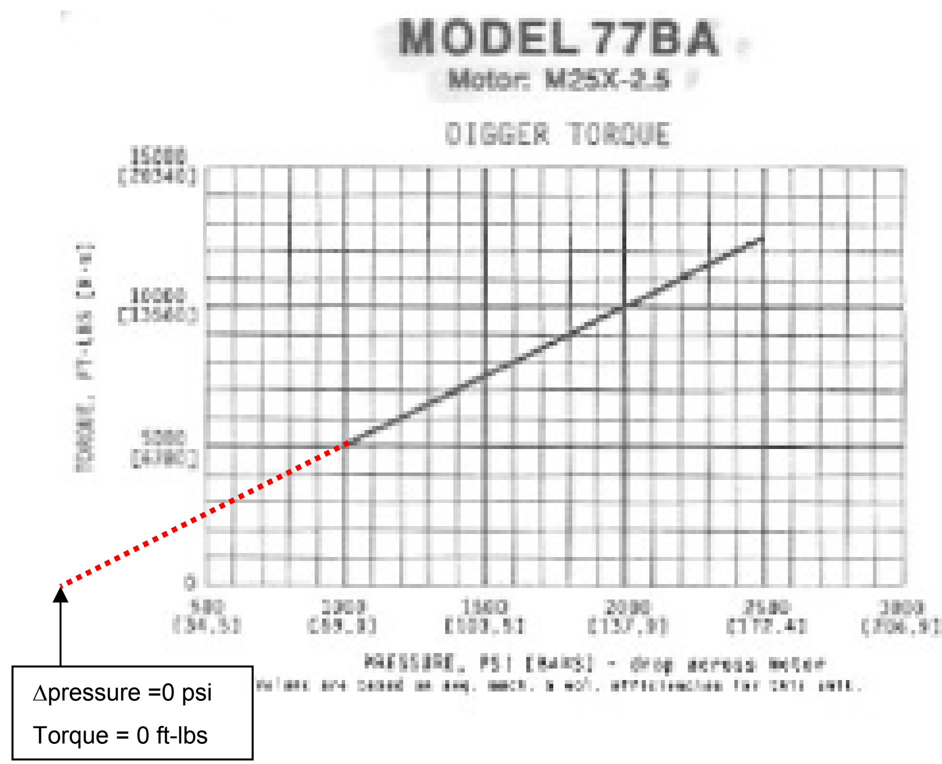
Torque to Pressure Correlation based on
Cubic Inch Displacement and Gear Ratio of Drive Head Motor

Gear Motor Testing

Control Station and Data Acquisition

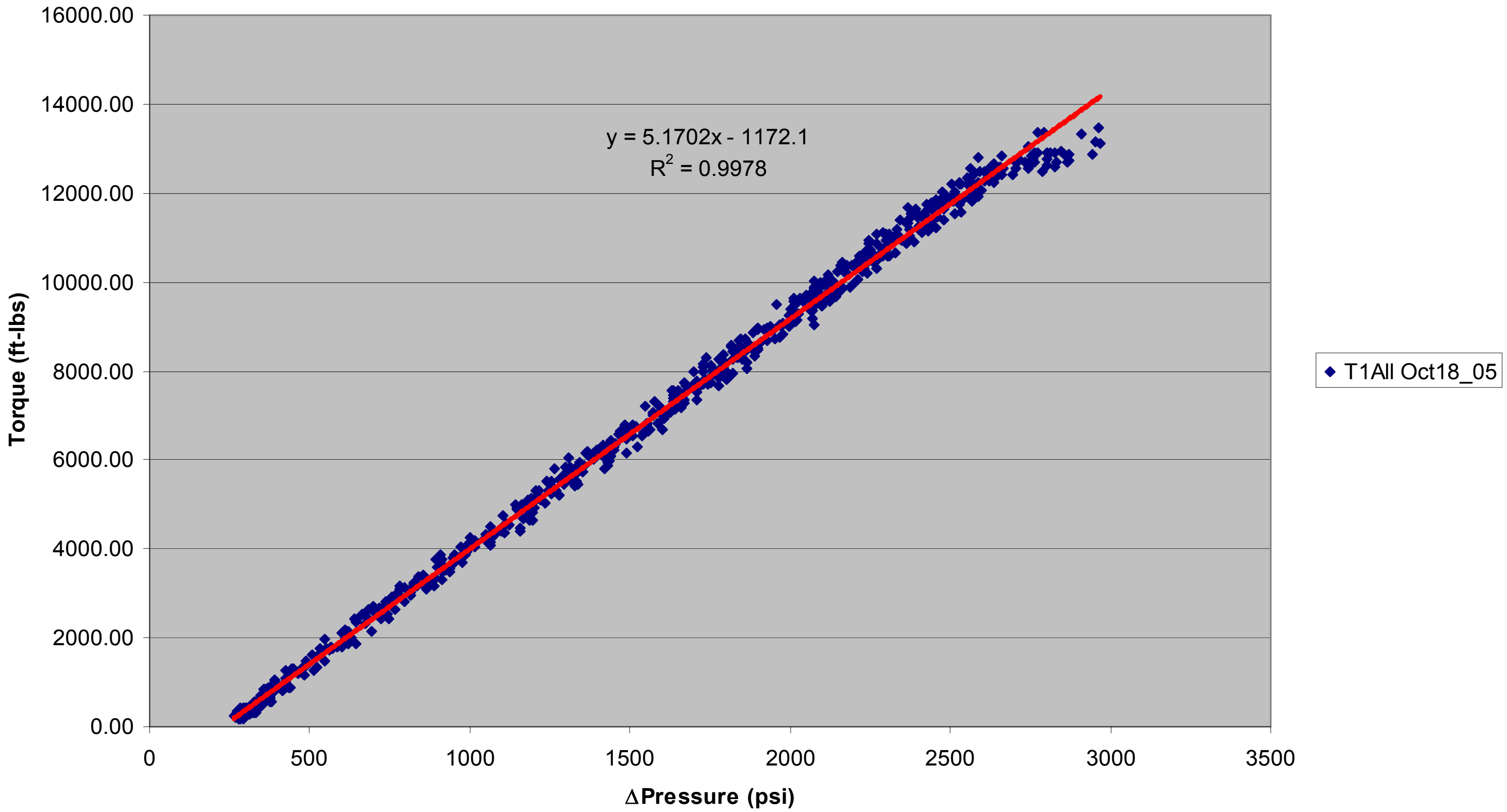
Eskridge 77BA – 12,000 ft-lb



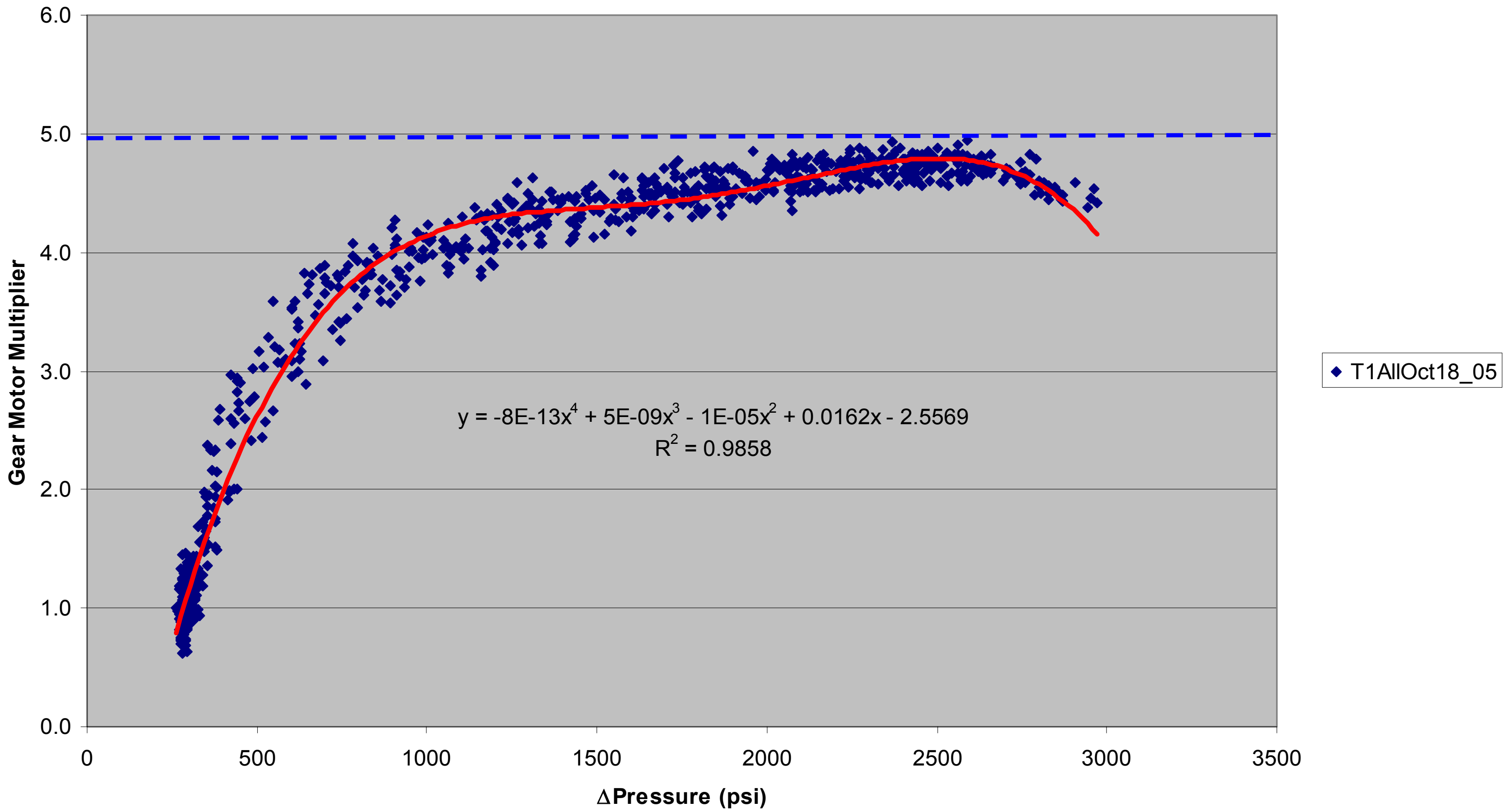


Gear Motor D – 12,000 ft-lbs

Corrected Torque-ΔPressure Relationship
Eskridge B28-4,500 ft-lb
Gear Motor D
Test 1All October 18, 2005

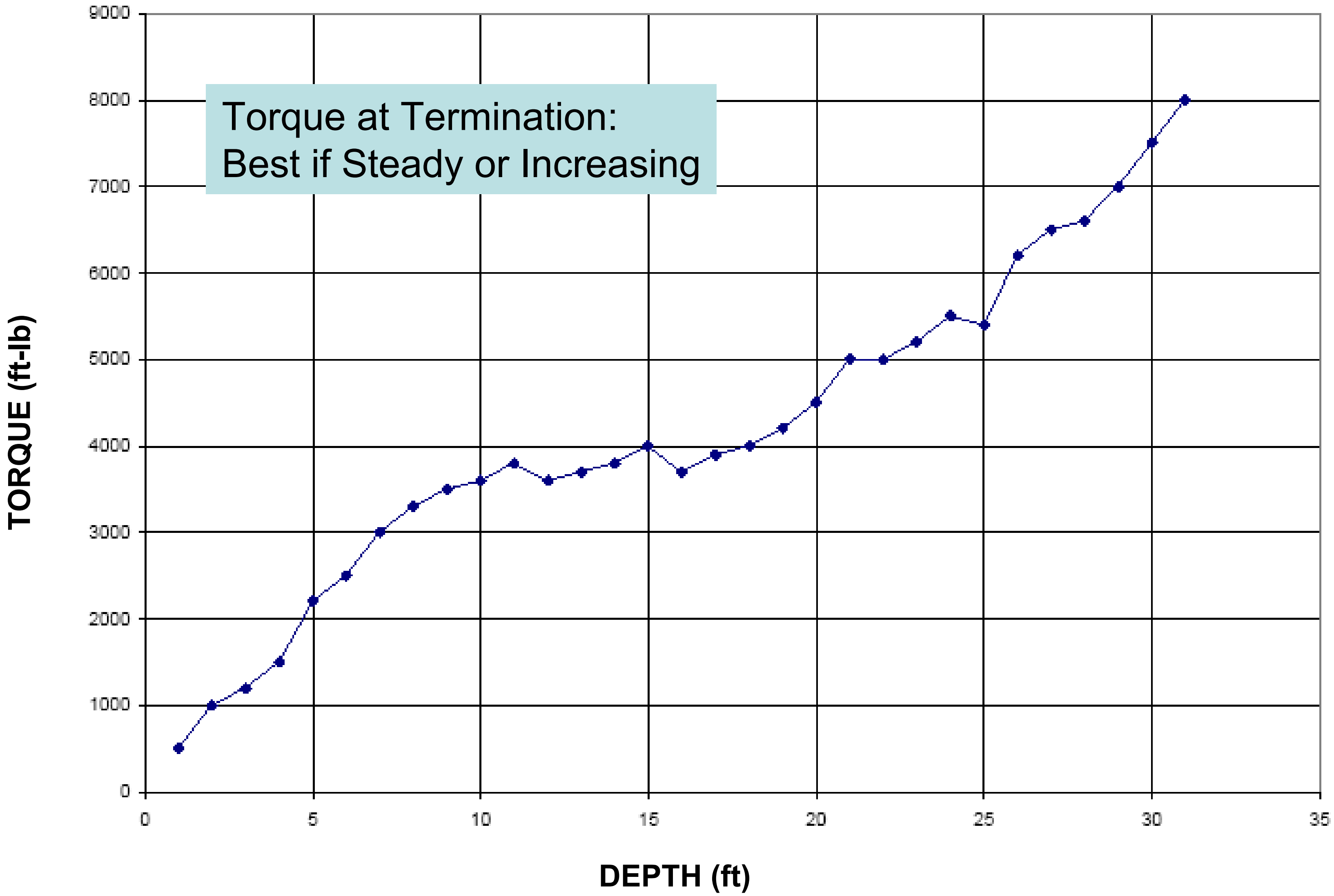


Corrected ΔPressure-Gear Motor Multiplier Relationship
Eskridge 77BA - 12,000 ft-lb
Gear Motor D
Test 1All October 18, 2005



INSTALLATION LOG – TORQUE VS. DEPTH

SSI75 w/ 8, 10, 12 & 14 in HELICES, LENGTH 31 FT
VERTICAL INSTALLATION – CLAY SOIL



Installation Torque vs. Ultimate Capacity

Telecom Tower Site
Guy Anchor Installation Log
SS5 Series w / 8”,10”,12” Lead

Depth (ft)	Torque (ft-lbs)
1	1480
2	2220
3	2220
4	2220
5	2220
6	2220
7	2220
8	2220
9	2220
10	2590
11	2590
12	2590
13	2440
14	2700
15	3340
16	3340
17	3170
18	3700
19	3700

Design Load per 7/16” EHS Guywire = 17,000. lbs.
Working Capacity per Anchor = 17,000. lbs.
Minimum Factor of Safety = 2.0
Required Ultimate Capacity (UC) = 17,000. x 2.0
= 34,000. lbs.

Ave. Installation Torque (Ta) = (3,170. + 3,700. + 3,700.) / 3
Ta = 3,523.0 ft-lbs.
Ultimate Capacity based on Ta = Kt x Ta
Ultimate Capacity based on Ta = 10 x 3,523.0
= 35,230. lbs > 34,000. lbs.

Application Guidelines

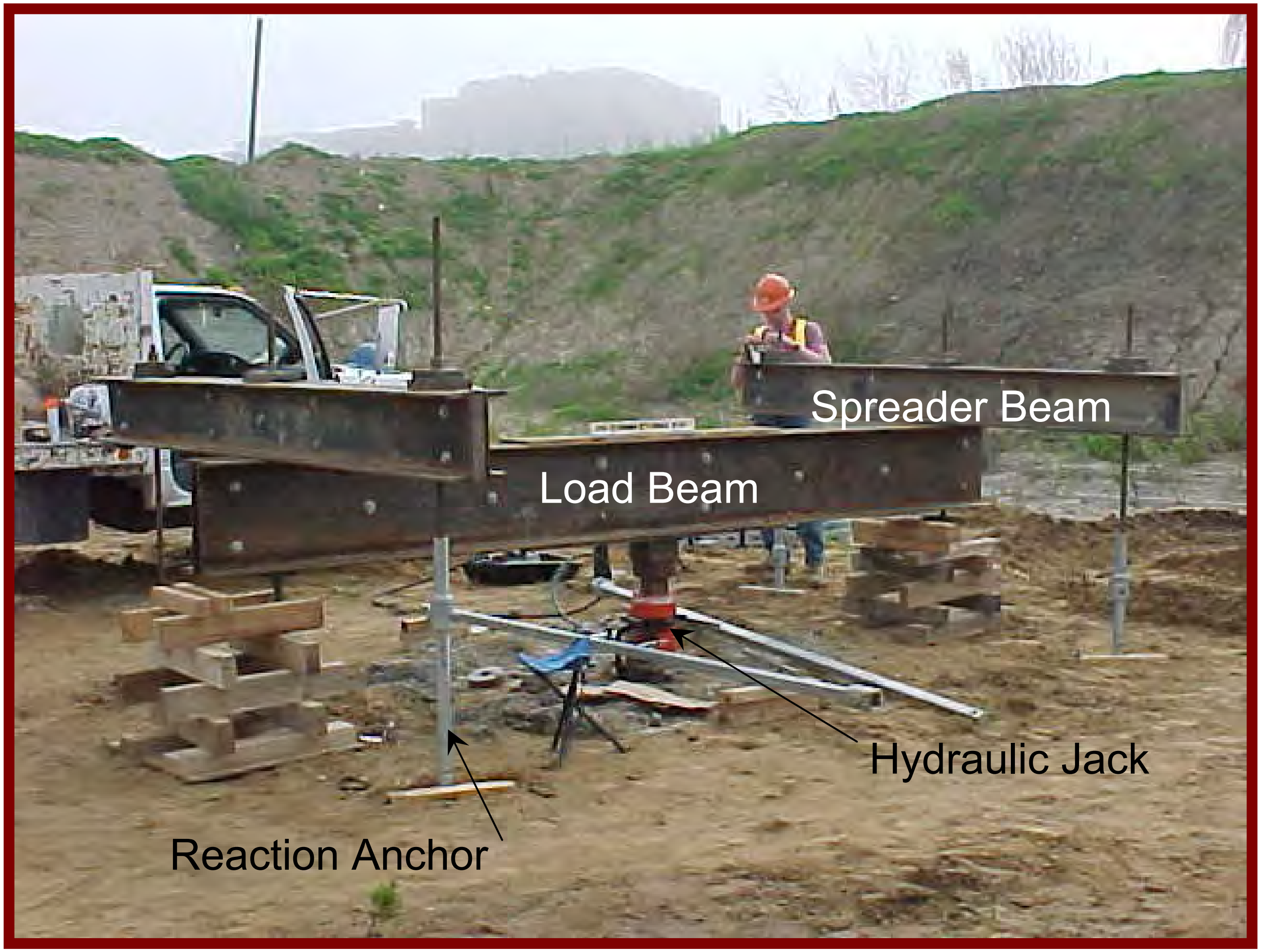
- Installation torque should be averaged over the last three diameters of embedment of the largest helix. This provides an indication of capacity based on average soil properties throughout the zone stressed by the helix plates.
- If stronger, denser, etc. stratum overlies the bearing stratum, check installation torque in the stratum to ensure screw anchor/foundation can be installed to final intended depth without torsional overstressing.
- For a given shaft length, use fewer longer extensions rather than many shorter extensions. This will result in fewer connections.

LOAD TESTING HELICAL PILE SYSTEMS

HUBBELL®
POWER SYSTEMS

CHANCE
Civil Construction

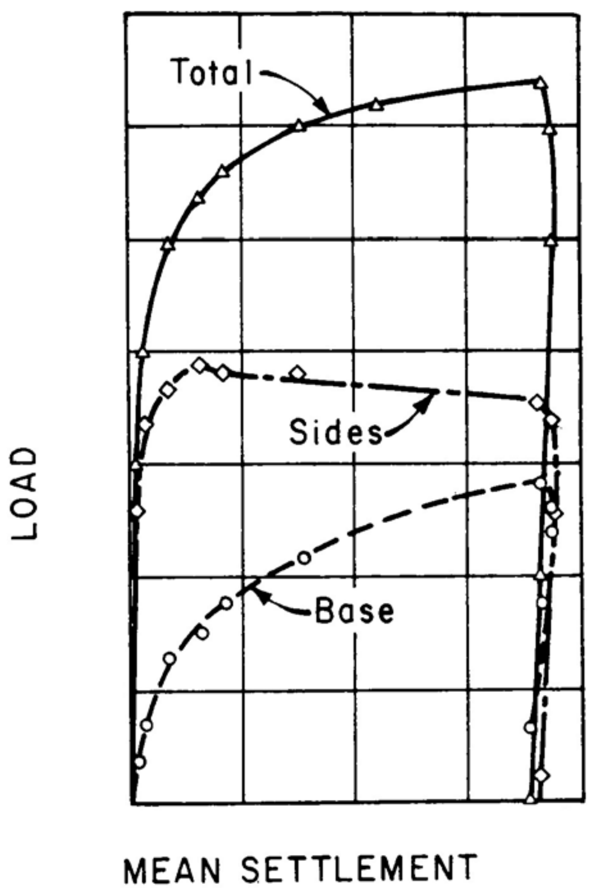
Compression Load Test




PERI GT24 01-092 180
PERI

Load-Settlement Response

Relative Development of Side and Base Resistance



<u>Maximum side resistance</u> (friction) is mobilized after downward displacement of from 0.5 to greater than 3 percent of the shaft (grout column) diameter, with a mean of approximately 2 percent [Reese, Wright (1977)].

This side resistance or friction continues almost equal to the ultimate value during further settlement. No significant difference is found between cohesive and cohesionless soil except that further strain in clay sometimes results in a decrease in shaft resistance to a residual value. In contrast, the point <u>(end bearing) resistance</u> develops slowly with increasing load and does not reach a maximum until settlements have reached on the order of 10 percent of the diameter of the base (largest helix) [Terzaghi, Peck (1948)].

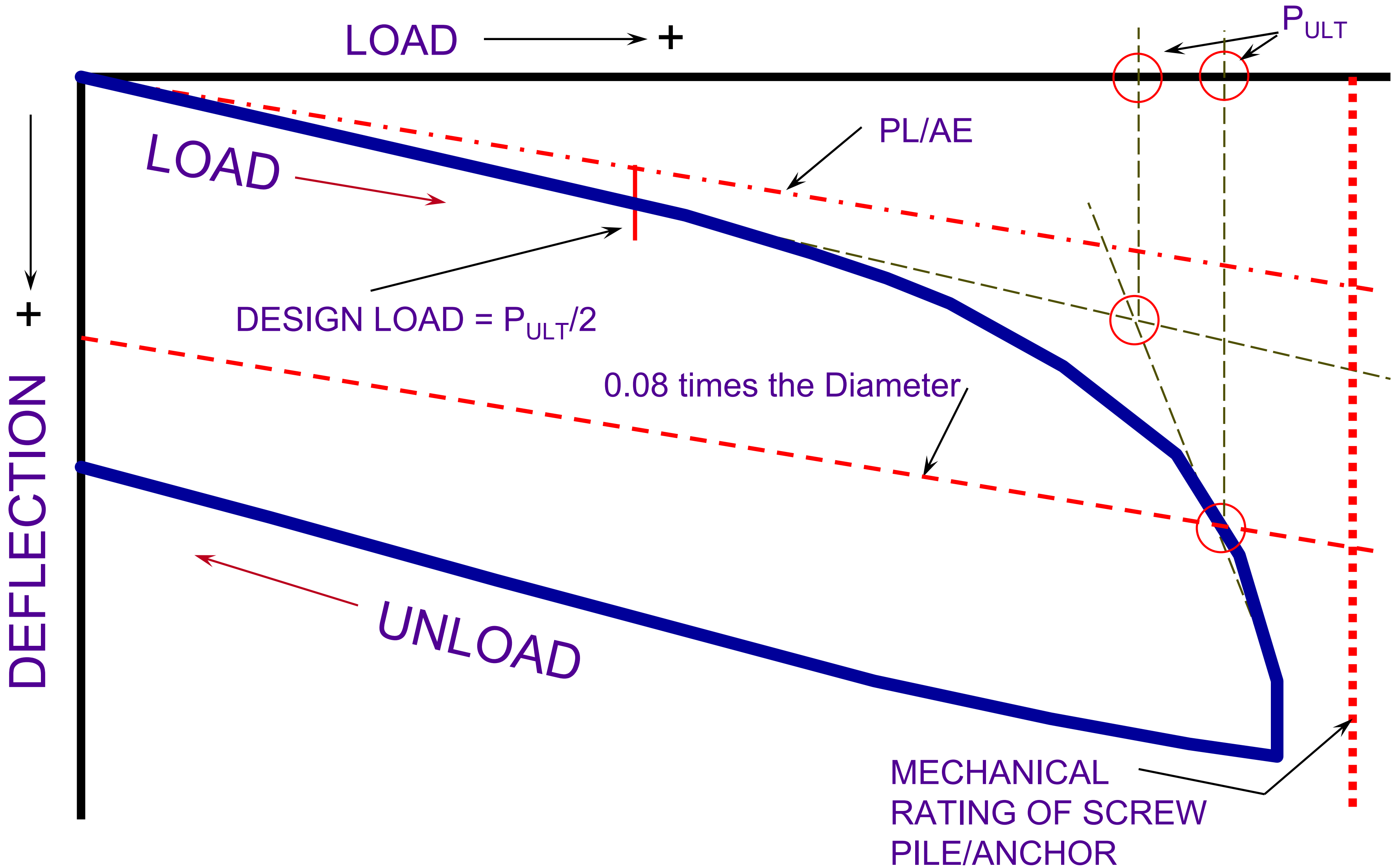
Load Test Acceptance Criteria

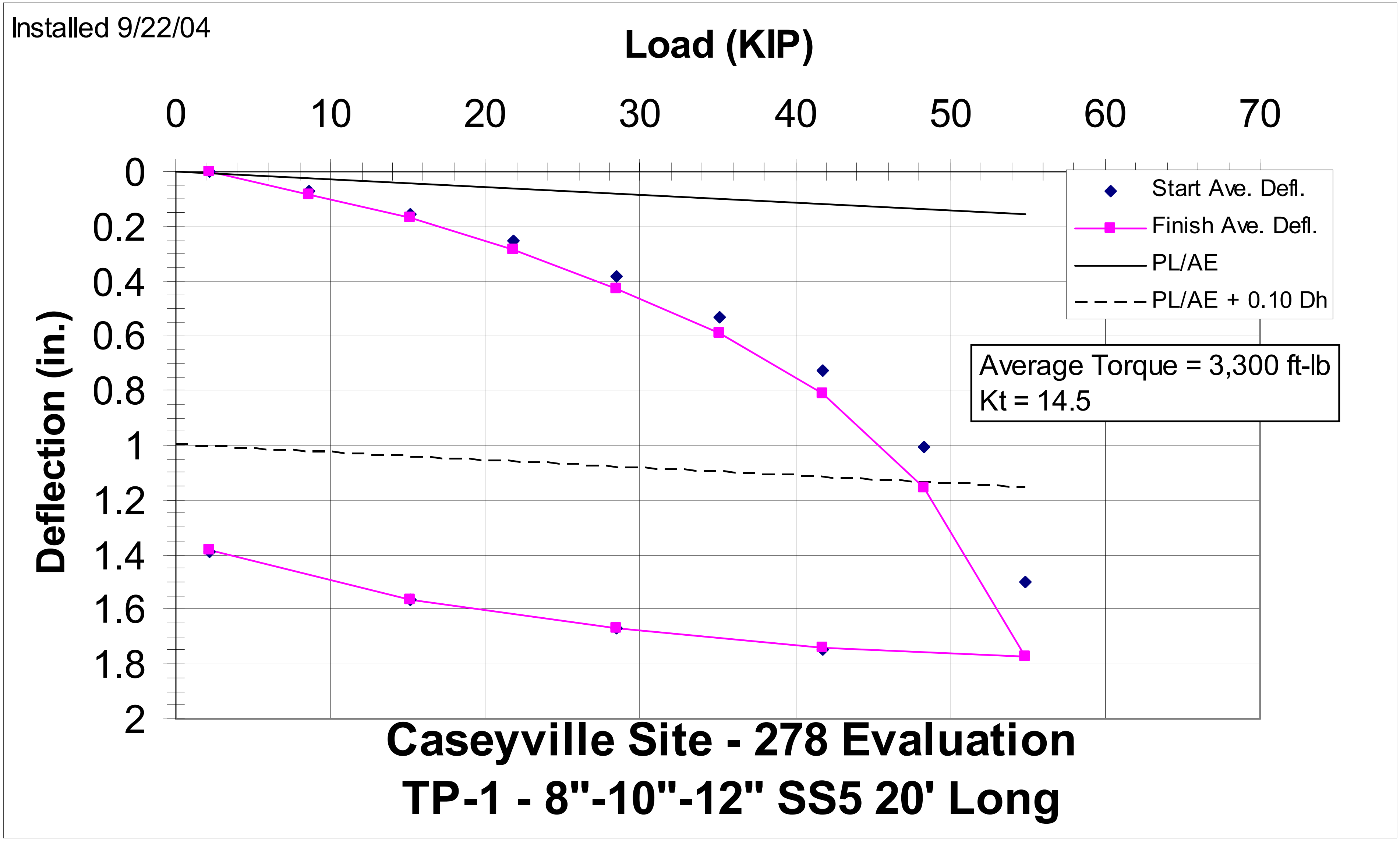
- **Intersection of Tangents**
  - Intersection of Lines Tangent to Linear and Non-Linear Portion of Curve
  - Quick Method in Field

- **Davisson Failure Load (DFL)**
  - Offset Parallel to Elastic Compression Line
  - PL/AE + (0.15 + D/120)
  - Typically Used for Friction Only Piles

- **8% to 10% of Pile Diameter (Diameter Method)**
  - Offset Parallel to Elastic Compression Line
  - PL/AE + 0.08Dh
  - Dh = Largest Helix Diameter
  - Recommended for End-Bearing Screw Piles

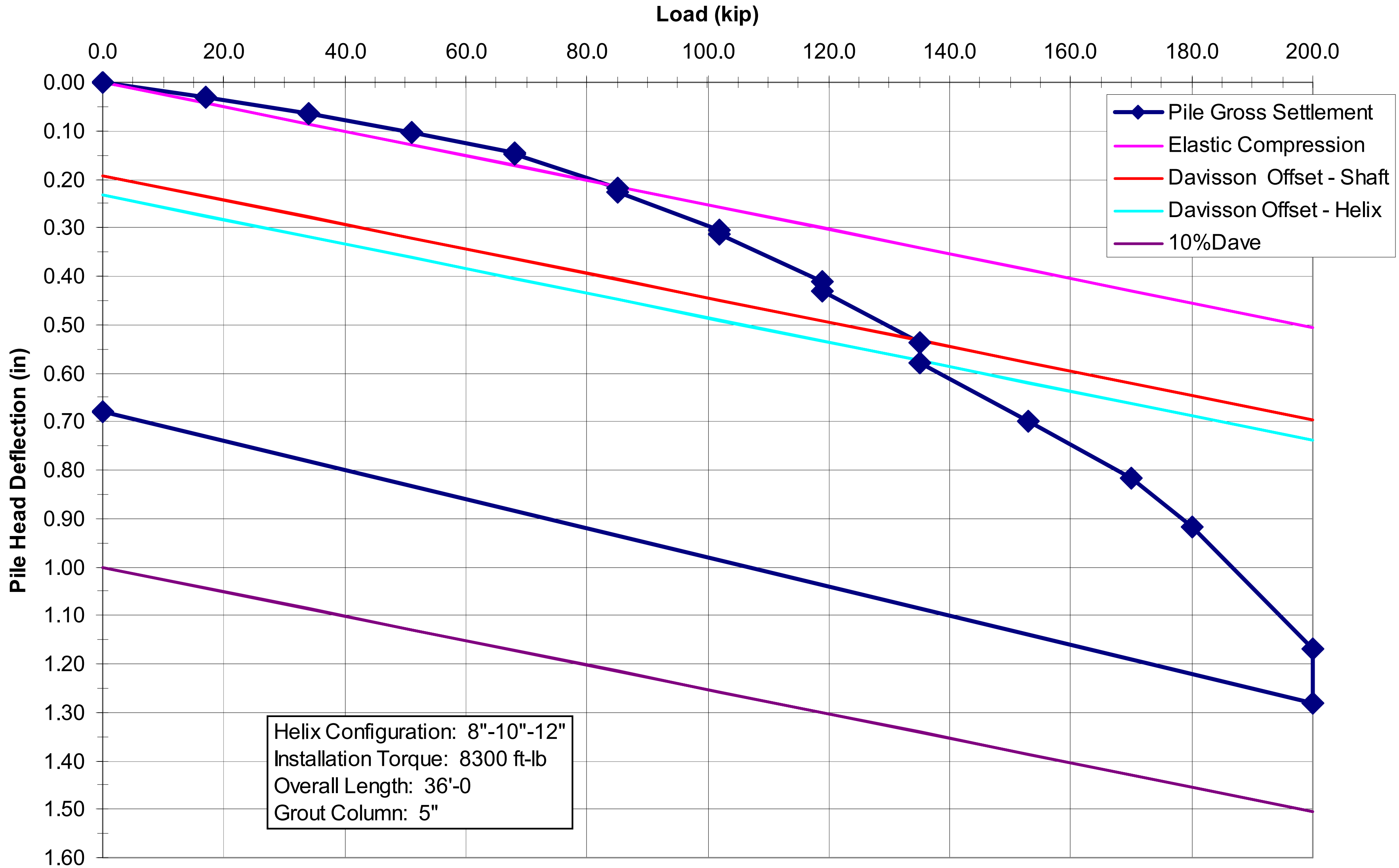
Sample Load-Deflection Curve of Compression Test





Installed 9/22/04
Load (KIP)
0
10
20
30
40
50
60
70
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Deflection (in.)
Start Ave. Defl.
Finish Ave. Defl.
PL/AE
PL/AE + 0.10 Dh
Average Torque = 3,300 ft-lb
Kt = 14.5
Caseyville Site - 278 Evaluation
TP-1 - 8"-10"-12" SS5 20' Long

Waterhouse Project - WFP Grouted Helical Pile
CHANCE SS175 - Load vs. Pile Head Displacement




THANK YOU