Maximum allowable moment at midspan (Step 9) is 566 lb-ft/ft., therefore:

FS_{MC} = (566 / 327) = 1.73 OK **Equation 8-53**

Check shear force at cantilever (Sc) using Equation 8-54.

$= K_a [\gamma (H_1^2 / 2) + qH_1]$ **Equation 8-54**

$S_c = 0.33 [120 (3^2 / 2) + 100 (3)]$

$= 277$ lb/ft

Determine allowable shear using Equation 8-55

$V_N = 0.125 \sqrt{f'_c}\ h_c$ **Equation 8-55**

$= 0.125 \sqrt{4}\ (4) = 1000$ lb/lf

FS_{shear} = (1000 / 277) = 3.6 OK **Equation 8-56**

DESIGN EXAMPLE 11
HELICAL PILES/ANCHORS for TELECOMMUNICATION TOWERS

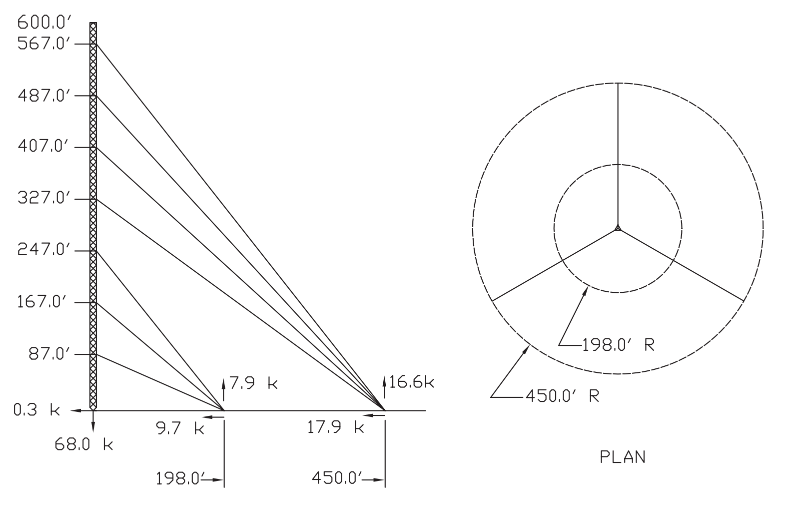
SYMBOLS USED IN THIS DESIGN EXAMPLE

Purpose

This Design Example provides an aid in the selection of appropriate helical guywire anchors and center mast helical piles for telecommunication towers.

The guywire loads are to be resisted by a helical tension anchor. When the vertical and horizontal components are provided the resultant must be determined as well as the angle between the resultant load and the horizontal, (this is the angle the helical anchor should be installed at to properly resist the guywire load(s)). There may be one or more guywires that come to the ground to be restrained by one or more helical anchors depending on the magnitude of the load and/or the soil strength. Helical piles can be used to resist the loads from the structure mast. These loads will generally be composed of a vertical load and a lateral load at the base of the mast or pole.

If the structure is a self supporting tower (SST), the loads from each leg of the tower must be resisted. These generally consist of vertical uplift and compression loads and a horizontal shear load at the ground line. These three loads can be dealt with in a number of ways. Typically one or more helical piles are used for each leg of the tower and may be installed at a batter to better resist the horizontal shear loads. Steel grillages and reinforced concrete caps have been used to facilitate load transfer from the structure to the helical piles. This type design will not be covered in this design example since the intent is to focus on the guyed mast tower structure.



Tower Guy Anchor and Foundation
Figure 8-18

Figure 8-18 shows the tower that will be used for these sample calculations. It will be noted that the four upper guywires come to the ground at a single guywire point and that the three lower guywires come to ground at a different guywire point. There must be at least a single helical anchor installed at each of these points to provide restraint for the guywires which in turn stabilize the tower by resisting lateral loads on the structure.

For this tower, the vertical and horizontal components of the guywire loads are given and must be resolved into the tension load the helical guywire anchor is to resist.

Upper Guywire Loads

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

Lower Guywire Loads

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

Mast Foundation Loads

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

Selecting Helical Guywire Anchors

Hubbell Power Systems, Inc. HeliCAP® Engineering Software will be utilized to determine the appropriate helical anchor/pile sizes for this tower. Soil conditions are shown in the Sample Boring Log in Figure 8-19. The soil data and guywire anchor data was input into the HeliCAP® Engineering Software to get an appropriate output. The minimum acceptable Factor of Safety (FS) = 2.

Upper Guywire Helical Anchor

The HeliCAP® Summary Report for the upper guywire helical anchor is shown in Figure 8-20. This report provides the following information:

- Helical Anchor: SS5 (1.5” square shaft, 5500 ft-lbs torque rating, 70 kips ultimate tension rating)
- Lead Section: 4 helix (8”-10”-12”-14”)
- Installation Angle: 43°
- Datum Depth (depth below grade where installation starts): 0 ft
- Length: 45 (ft along the shaft at the 43° installation angle)
- Recommended Ultimate Capacity (R_{uc}): 50.2t (kips tension)

The Factor of Safety for this tension anchor is $R_{uc} / T_{lg} = 50.2 / 24.4 = 2.05 > 2$ (OK). Use this helical anchor at each of three upper guywire anchor locations per tower.

The required average minimum installation torque (T) is:

$$T = (T_{ug} \times FS) / K_t \qquad \textbf{Equation 8-57}$$

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

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

where: K_t = Empirical torque factor = 10 (default value for Type SS5 series)

T = 4,900 ft-lbs is less than the rated torque (5,500 ft-lbs) of the Type SS5 series. (OK).

Lower Guywire Helical Anchor

The HeliCAP® Summary Report for the lower guywire helical anchor is shown in Figure 8-21. This report provides the following information:

- Helical Anchor: SS5 (1.5” square shaft, 5500 ft-lbs torque rating, 70 kips ultimate tension rating)
- Lead Section: 4 helix (8”-10”-12”-14”)
- Installation Angle: 39°
- Datum Depth (depth below grade where installation starts): 0 ft
- Length: 25 ft (along the shaft at the 39° installation angle)
- Recommended Ultimate Capacity (R_{uc}): 26.6t (kips tension)

The Factor of Safety for this tension anchor is R_{uc} / T_{ug} = 26.6 / 12.5 = 2.12 > 2 (OK) Use this helical anchor at each of three lower guywire anchor locations per tower.

$$T = (T_{lg} \times FS) / K_t \quad \textbf{Equation 8-58}$$

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

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

where: K_t = Empirical torque factor = 10 (default value for Type SS5 series)

T = 2,500 ft-lbs is less than the rated torque (5,500 ft-lbs) of the Type SS5 series. (OK).

Helical Pile

Given:

- Compression Load = 68.0 k
- Shear Load = 0.3 k

Assume three helical piles installed at 120° intervals in plan view with each pile battered away from vertical at a 10° angle:

68/3 piles = 22.67k ultimate/pile element.

Assume entire shear (0.3 k) is taken by one battered pile. Therefore, the resultant axial load (DL) to a battered pile is:

$DL = (22.67^2 + 0.3^2)^{0.5} = 22.7k$

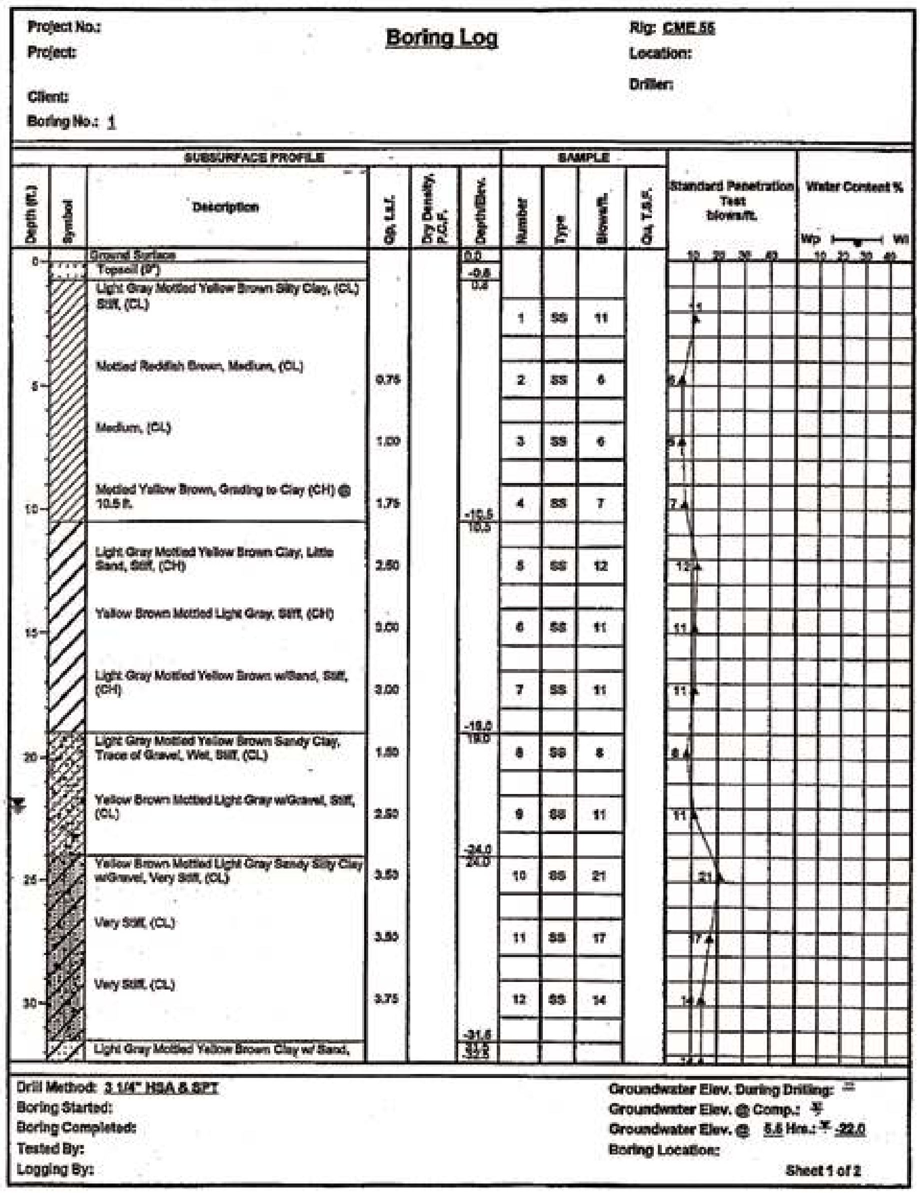
The HeliCAP® Summary Report for the helical piles is shown in Figure 8-22. This report provides the following information:

- Helical Pile: SS175 (1.75” square shaft, 10,500 ft-lbs torque rating, 100 kips ultimate tension rating)
- Lead Section: 4 helix (8”-10”-12”-14”)
- Installation Angle: 80° below horizontal (10° away from vertical)
- Datum Depth: (depth below grade where installation starts): 0 ft
- Length: 34 ft (along the shaft at the 80° installation angle)
- Recommended Ultimate Capacity (R_{uc}): 50.7c (kips compression)

The Factor of Safety for this compression pile is R_{uc} / DL = 50.7 / 22.7 = 2.23 > 2 (OK) Use three SS175 helical piles per tower base. The three helical piles must be captured in a "pile cap." This may be a reinforced concrete cap, the design of which is beyond the scope of this design example. The design of this concrete pile cap is left to the structural engineer.

	T	=	$(DL \times FS) / K_t$	**Equation 8-59**
		=	(22,700 x 2.0) / 10	
		=	4,500 ft-lbs	
where:	K_t	=	Empirical torque factor = 10 (default value for Type SS175 series)	

T = 4,500 ft-lbs is less than the rated torque (10,500 ft-lbs) of the Type SS175 series. (OK).



Sample Boring Log
Figure 8-19

HeliCAP SUMMARY REPORT

b Name: Tower Guy Calculations

b Number: Upper Guy

ring No: 1

chor Use: Tension

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Water Table Depth: 22 ft

Capacity Summary

Anchor Number	Anchor Family	Helix Depth (ft)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 43 Datum Depth: 0 Length: 45					
14" helix	SS 5	25.2	16.9t 24.8c			
12" helix	SS 5	27.2	17t 14.7c			
10" helix	SS 5	28.9	10.1t 9.5c	50.2t	50.2t	5502
8" helix	SS 5	30.3	6.1t 5.3c	54.4c	54.4c	

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (lb/ft2)	N	Angle of Internal Friction (Degrees)	Unit Weight (lb/ft3)
0	Clay	1375	11	0	102
5	Clay	750	6	0	92
7	Clay	750	6	0	92
10	Clay	875	7	0	94
12	Clay	1500	12	0	104
15	Clay	1375	11	0	102
17	Clay	1375	11	0	102
20	Clay	1000	8	0	96
22	Clay	1375	11	0	102
25	Clay	2625	21	0	120
27	Clay	2125	17	0	114
30	Clay	1750	14	0	108
32	Clay	1750	14	0	108
35	Clay	1500	12	0	104
37	Clay	1625	13	0	106
40	Clay	1500	12	0	104
42	Clay	1375	11	0	102
45	Clay	2125	17	0	114
47	Clay	2500	20	0	120
50	Clay	6125	49	0	138

HeliCAP® Summary Report for Upper Guywires
Figure 8-20

DESIGN EXAMPLES

DESIGN EXAMPLES

HeliCAP SUMMARY REPORT

Job Name: Tower Guy Calculations

Job Number: Lower Guy

Boring No: 1

Anchor Use: Tension

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Water Table Depth: 22 ft

Capacity Summary

Anchor Number	Anchor Family	Helix Depth (ft)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 39 Datum Depth: 0 Length: 25					
14" helix	SS 5	10.6	7.4t 10.2c			
12" helix	SS 5	12.5	7.5t 10.3c			
10" helix	SS 5	14.1	7.1t 6.9c	26.6t	26.6t	3002
8" helix	SS 5	15.4	4.4t 4.2c	31.7c	31.7c	

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (lb/ft2)	N	Angle of Internal Friction (Degrees)	Unit Weight (lb/ft3)
0	Clay	1375	11	0	102
5	Clay	750	6	0	92
7	Clay	750	6	0	92
10	Clay	875	7	0	94
12	Clay	1500	12	0	104
15	Clay	1375	11	0	102
17	Clay	1375	11	0	102
20	Clay	1000	8	0	96
22	Clay	1375	11	0	102
25	Clay	2625	21	0	120
27	Clay	2125	17	0	114
30	Clay	1750	14	0	108
32	Clay	1750	14	0	108
35	Clay	1500	12	0	104
37	Clay	1625	13	0	106
40	Clay	1500	12	0	104
42	Clay	1375	11	0	102
45	Clay	2125	17	0	114
47	Clay	2500	20	0	120
50	Clay	6125	49	0	138

HeliCAP® Summary Report for Lower Guywires
Figure 8-21

HeliCAP SUMMARY REPORT

Job Name: Tower Foundation Calculations

Job Number: Three Foundations per Tower Base

Boring No: 1

Anchor Use: Compression

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Water Table Depth: 22 ft

Capacity Summary

Anchor Number	Anchor Family	Helix Depth (ft)	Helix Capacity (kips)	Total Anchor Capacity (kips)	Recommended Ultimate Capacity (kips)	Torque (ft-lbs)
Anchor 1	Angle: 80 Datum Depth: 0 Length: 34					
14" helix	SS 175	25.6	16.9t 23.2c			
12" helix	SS 175	28.5	15.8t 13.8c			
10" helix	SS 175	31	8.9t 8.3c	47.1t	47.1t	5323
8" helix	SS 175	32.9	5.3t 5.3c	50.7c	50.7c	

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (lb/ft2)	N	Angle of Internal Friction (Degrees)	Unit Weight (lb/ft3)
0	Clay	1375	11	0	102
5	Clay	750	6	0	92
7	Clay	750	6	0	92
10	Clay	875	7	0	94
12	Clay	1500	12	0	104
15	Clay	1375	11	0	102
17	Clay	1375	11	0	102
20	Clay	1000	8	0	96
22	Clay	1375	11	0	102
25	Clay	2625	21	0	120
27	Clay	2125	17	0	114
30	Clay	1750	14	0	108
32	Clay	1750	14	0	108
35	Clay	1500	12	0	104
37	Clay	1625	13	0	106
40	Clay	1500	12	0	104
42	Clay	1375	11	0	102
45	Clay	2125	17	0	114
47	Clay	2500	20	0	120
50	Clay	6125	49	0	138

HeliCAP® Summary Report for Foundations
Figure 8-22

DESIGN EXAMPLE 12
HELICAL ANCHORS for PIPELINE BUOYANCY CONTROL
SYMBOLS USED IN THIS DESIGN EXAMPLE

OD	Outside Diameter	8-53
T_w	Pipe Wall Thickness	8-53
F_y	Minimum Yield Strength of Pipe	8-53
P_d	Pipe Design Pressure	8-53
P_m	Pipe Maximum Operating Pressure	8-53
T_m	Pipe Maximum Operating Temperature	8-53
F	Construction Type Design Factor	8-53
E	Longitudinal Joint Factor	8-53
T	Temperature Factor	8-53
D_c	Density of Coating	8-53
T_c	Thickness of Coating	8-53
D_b	Density of Backfill	8-53
FS	Factor of Safety	8-53
W_p	Weight of Pipe per Linear Foot	8-54
I	Moment of Inertia	8-54
S	Section Modulus	8-54
W_c	Weight of Coating per Linear Foot	8-55
W_g	Gross Buoyancy	8-55
W_n	Net Buoyancy	8-55
L_b	Allowable Span Length Based on Bending Stress	8-55
P	Maximum Design Pressure	8-55
F_h	Hoop Stress	8-55
F_l	Longitudinal Stress	8-55
F_b	Allowable Longitudinal Bending Stress	8-55
M_{max}	Maximum Moment at Mid-Span Between Pipeline Anchor Sets	8-56
L_d	Mid-Span Vertical Displacement Based on Mid-Span Deflection	8-56
Y	Mid-Span Vertical Displacement	8-56
L_p	Allowable Span Length Based on Mechanical Strength of Pipeline Bracket	8-56
UC_p	Ultimate Mechanical Strength of Pipeline Bracket	8-56
WC_p	Working Capacity of Pipeline Bracket	8-56
L_a	Allowable Span Length Based on Uplift Capacity of Anchors in Boring	8-56

PURPOSE

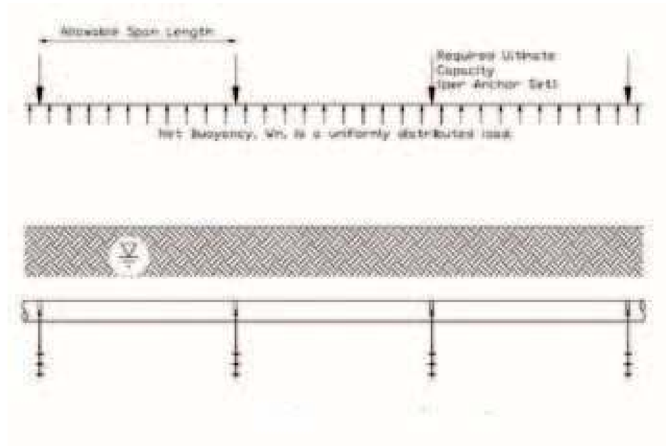
This Design Example provides an aid in the selection of appropriate helical anchors for pipeline buoyancy control.

ASSUMPTIONS

- Pipe contents: Natural gas
- Pipe Outside Diameter (OD): 42”
- Pipe Wall Thickness (T_W): 0.938”
- Grade of Pipe: API 5L, Grade X65
- Minimum Yield Strength Of Pipe (F_y): 65,000 psi
- Pipe design pressure (P_d): 1,440 psi
- Maximum Operating Pressure (P_m): 1,440 psi
- Maximum Operating Temperature (T_m): 85° F
- Construction type design factor (F): 0.50
- Longitudinal joint factor (E): 1.0
- Temperature Factor (T): $T_m < 250°F$
- Coating: Fusion Bonded Epoxy
- Density of coating (D_c): 70.0 pcf
- Coating thickness (T_c): 16 mils
- Pipeline placement: Land Based in Trench with 4’-0 of Cover above Top of Pipe
- Backfill material: Loose, Poorly Graded Silty Sand
- Specific Gravity of Backfill Material: 1.44
- Density of backfill material (D_b) = 1.44 x 62.4 pcf = 89.9 pcf (use 90.0 pcf)
- Span between anchor sets: Simple Span with Pin-Pin Ends
- Maximum vertical displacement at Mid-Span between Anchor Sets = $L_g/360$
- Minimum Factor of Safety (FS) for Mechanical Strength Of Hardware/Anchors = 2.0
- Minimum Factor of Safety (FS) for Anchor Soil Capacity = 2.0
- Soil data: As shown in Figure 8-23

Sample Problem - Natural Gas Pipeline			
Borehole BH-1			
HeliCAP® Software Input Values			
Depth (ft)	Clay Cohesion (psf)	Sand N-Value (SPT)	Soil
0		7	sand
3		7	sand
5		28	sand
7		21	sand
10		30	sand
12		21	sand
13	60		clay
15	60		clay
20	380		clay
25	500		clay
30	250		clay
35	460		clay
40	1250		clay
45	2000		clay
50	1560		clay
55	1250		clay
60	2250		clay
65	1320		clay
70	750		clay
75	750		clay

Borehole BH-1 Sample Data
Figure 8-23



Schematic Diagram
Figure 8-24

SOLUTION

Net Buoyancy (W_n)

Properties of pipe:

- Weight per linear foot (W_p):

$$W_p = [D_s \times \pi \times (42.0^2 - 40.124^2)] / (4 \times 144)$$ **Equation 8-60**

$$= [490.0 \times \pi \times (1764.0 - 1609.935)] / (576)$$

$$= 411.74 \text{ plf}$$

- Moment of inertia (I) = 25515.8 in^4
- Section modulus (S) = 0.7032 ft^3

Properties of coating:

- Weight per linear foot (W_c):

W_c = $[D_c \times \pi \times (42.032^2 - 42.0^2)] / (4 \times 144)$ **Equation 8-61**

= $[70.0 \times \pi \times (42.032^2 - 42.0^2)] / (4 \times 144)$

= 1.03 plf

Buoyancy:

- Gross buoyancy (W_g):

W_g = $[D_b \times \pi \times (42.032^2/12^2)] / 4$ **Equation 8-62**

= $[90.0 \times \pi \times (42.032^2/12^2 / 4$

= 865.8 plf

- Net buoyancy (W_n):

W_n = $W_g - W_p - W_c$ **Equation 8-63**

= 865.8 - 411.74 - 1.03

= 453.03 plf (use 453.0 plf)

Allowable Span Length (L_b) Based on Bending Stress

- Maximum design pressure (P):

P = $[(2 \times f_y \times T_w)/OD] \times F \times E \times T$ **Equation 8-64**

= $[(2 \times 65{,}000 \times 0.938)/42.0] \times 0.5 \times 1.0 \times 1.0$

= 1451.7 psi (use given P_d of 1440.0 psi)

- Hoop stress (F_h):

F_h = $(P_d \times OD)/(2 \times T_w)$ **Equation 8-65**

= $(1440.0 \times 42.0)/(2 \times 0.938)$

= 32,238.8 psi

- Longitudinal stress (F_l):

F_l = $(0.25 \times P_d \times OD)/T_w$ **Equation 8-66**

= $(0.25 \times 1440.0 \times 42.0)/0.938$

= 16,119.4 psi

- Allowable longitudinal bending stress (F_b):

$F_b + F_l$ = $0.75 \times (F \times E \times T) \times F_y$ **Equation 8-67**

F_b = $[0.75 \times (0.5 \times 1.0 \times 1.0) \times 65{,}000] - 16{,}119.4$

= 8,255.6 psi

DESIGN EXAMPLES

HUBBELL

where:

$F_b = M_{max}/S$ **Equation 8-68**

M_{max} = Maximum moment at mid-span between pipeline anchor sets

$= (W_n \times L_b^2)/8$

$L_b = [(8 \times S \times Fb)/W_n]^{1/2}$

$= [(8 \times 0.7032 \times 8255.6 \times 144)/453.0]^{1/2}$

$= 121.5$ ft

Allowable Span Length (L_d) Based on Mid-Span Deflection

- Mid-span vertical displacement (Y) at center of span:

$Y = L_d/360$ **Equation 8-69**

$L_d/360 = (5 \times W_n \times L_d^4) / (384 \times E \times I)$

$L_d = [(384 \times E \times I) / (360 \times 5 \times W_n)]^{1/3}$

$L_d = [(384 \times 29{,}000{,}000 \times 25525.8/144) / (360 \times 5 \times 453.0)]^{1/3}$

$L_d = 134.2$ ft

$Y = (134.2/360) \times 12 = 4.5$ in

Allowable Span Length (L_p) Based on the Mechanical Strength of Pipeline Bracket

- Rated ultimate mechanical strength (UC_p) of pipeline bracket = 80,000 lbs
- Rated mechanical working capacity (WC_p) of pipeline bracket (using FSm of 2.0):

$WC_p = UC_p/FS_m$ **Equation 8-70**

$= 80{,}000/2$

$= 40{,}000$ lbs

$WC_p = (W_n \times L_p/2) \times 2$ **Equation 8-71**

$L_p = WC_p/W_n$

$= 40{,}000/453.0$

$= 88.3$ ft

Allowable Span Length (L_a) Based on the Uplift Capacity of Anchors in Soil (Boring B-1)

- Ultimate uplift capacity (UC_a) ranges from 45,900 to 41,700 lbs with overall anchor depths below ground line of 51'-0 to 60'-0. See Figure 8-25. Use UC_a = 40,000 lbs.
- Working uplift capacity (WC_a) (using FS_s of 2.0):

$WCa = UC_a/FS_s$ **Equation 8-72**

$= 40{,}000/2$

$= 20{,}000$ lbs

- There are two anchors located at each anchor support location along the pipeline, therefore, the total working uplift capacity (WC_s) per anchor set = WC_a x 2 anchors = 20,000 x 2 = 40,000 lbs.

$L_a = WC_s/W_n$ **Equation 8-73**

$= 40{,}000/453.0$

$= 88.3$ ft

SUMMARY

The uplift capacity plot data was obtained from the soil strength parameters shown in Figure 8-23 and capacities generated by HeliCAP® Engineering Software. The maximum span length between anchor sets is limited to 88 ft based on the ultimate mechanical strength of the pipeline brackets and the ultimate uplift capacity of the anchors in the soil boring shown in Figure 8-25.

Only one soil boring was provided along this proposed section of pipeline. If the soil conditions vary at the anchor set locations and the required average installation torque of 4,000 ft-lbs for a span length of 88 ft cannot be achieved at reasonable anchor depths, the span lengths should be reduced as shown in Table 8-8.

Hubbell Power Systems, Inc. manufactures two band types for use with pipeline buoyancy control systems. See Figure 8-26. Each system has advantages depending on the application and local acceptance. Both systems will provide adequate buoyancy control with industry accepted Factors of Safety.

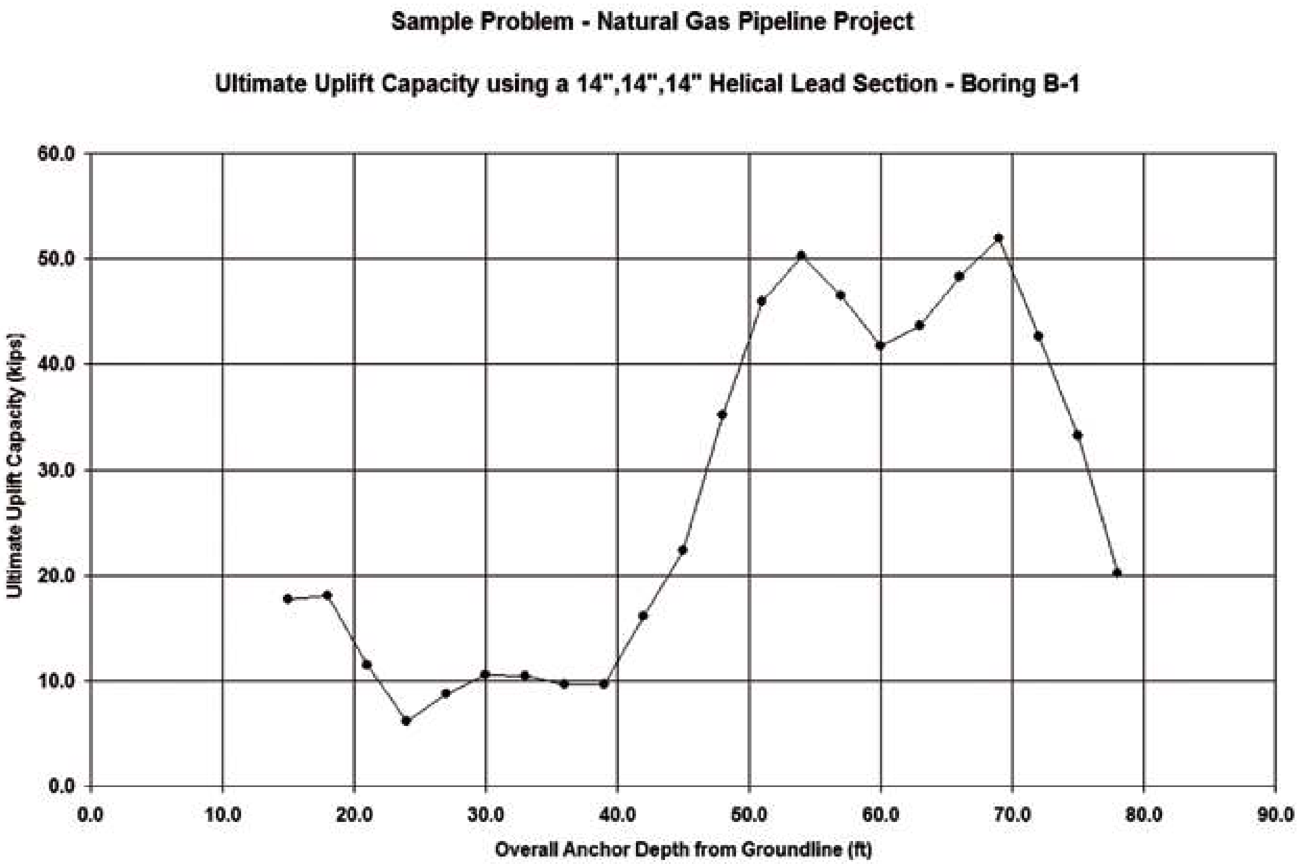
Summary of Design Criteria, Table 8-7

	MAXIMUM ALLOWABLE SPAN LENGTH (ft)	REQUIRED UC_s PER ANCHOR SET (lbs)[2]	REQUIRED UC_a PER ANCHOR SET (lbs)[2]	MINIMUM INSTALLATION TORQUE (ft-lbs)[1,2]
Longitudinal Bending	121.5	110,080	55,040	5,500
Mid-Span Deflection	134.2	121,585	60,793	6,100
Mechanical Strength of Bracket	88.3	80,000	40,000	4,000
Anchor Capacity	88.3	80,000	40,000	4,000

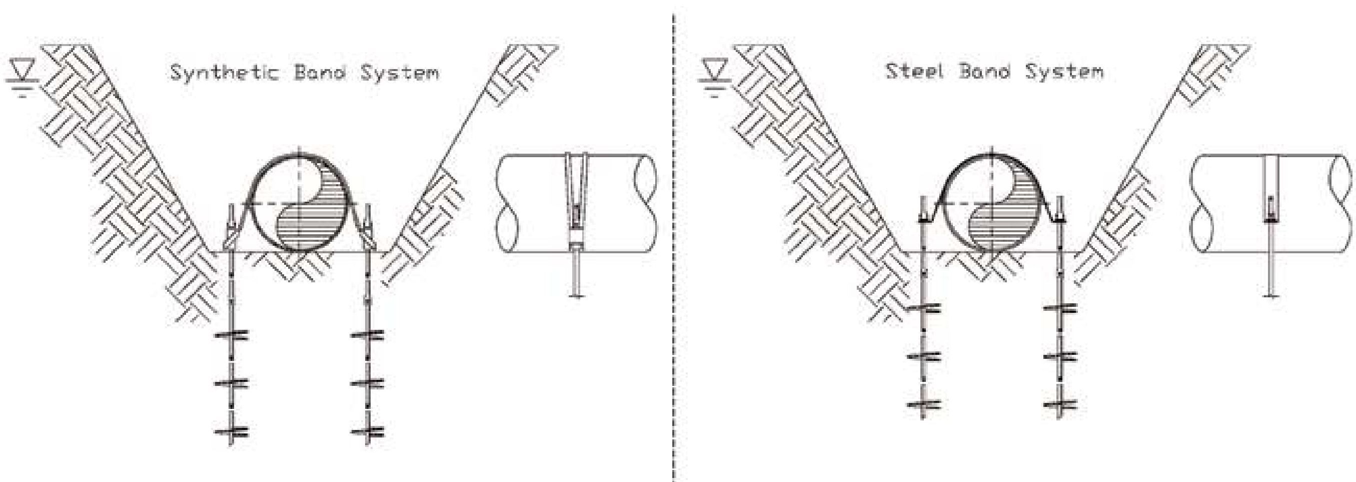
Notes:
1. The required average minimum installation torque is based on using the published installation torque to ultimate capacity ratio (K_t) of 10:1 for the Type SS series anchor material. Torque = UC_a/K_t.
2. These values include a minimum acceptable industry standard Factor of Safety of 2 for helical anchors/piles when used in permanent applications. These pipeline anchors are considered by Hubbell Power Systems, Inc. to be a permanent application. If the client or their representative opts to use a lower Factor of Safety these values will have to be reduced accordingly. For example, at a span length of 88.3 ft, the working capacity per anchor set is 453.0 plf x 88.3 ft = 40,000 lbs. Applying an FS of only 1.5, the required UC_s is 1.5 x 40,000 = 60,000 lbs. The required UC_a is 60,000 lbs/2 anchors = 30,000 lbs. The required minimum installation torque is 30,000/10 = 3,000 ft-lbs.

Span Reduction Schedule, Table 8-8

SPAN LENGTH (ft)	REQUIRED UC_s PER ANCHOR SET (lbs)	REQUIRED UC_a PER ANCHOR (lbs)	MINIMUM INSTALLATION TORQUE (ft-lbs)
88	80,000	40,000	4,000
77	70,000	35,000	3,500
66	60,000	30,000	3,000
55	50,000	25,000	2,500
44	40,000	20,000	2,000



Ultimate Uplift Capacity
Figure 8-25



Band Systems
Figure 8-26

DESIGN EXAMPLE 13
TYPE RS HELICAL PILES for LATERAL SUPPORT
SYMBOLS USED IN THIS DESIGN EXAMPLE

PROBLEM

A CHANCE® Helical Type SS175 1-3/4" square shaft helical anchor/pile is proposed for a pedestrian bridge abutment. The top section of the shaft is to be encased in a 6" nominal steel pipe and grout to provide lateral resistance. The top ten feet of the soil profile is medium-stiff clay with a cohesion factor (c) of 1000 psf. Determine what length of 6" diameter steel case is required to resist 4400 lbs of lateral load using the Broms' Method.

Assumptions

- The 1-3/4" square shaft below the 6" cased section provides no lateral resistance.
- The solution method used is shown in Figure 8-27.
- Eccentricity is assumed to be 1 ft.

Solution

P	=	Applied horizontal shear load: Use 4400 lbs. Include a Factor of Safety of 2 in the calculations, thus doubling the horizontal shear load; P = 2 x 4400 = 8800 lbs.
C_u	=	Cohesion of clay: Use C_u = 1000 psf
D	=	Diameter of foundation: Use D = 6.625" (6" nominal pipe size)
e	=	Eccentricity; distance above grade to resolved load: Use e = 1 ft
L	=	Minimum length of foundation based on above criteria.

f = P/9 (C_u) D **Equation 8-74**

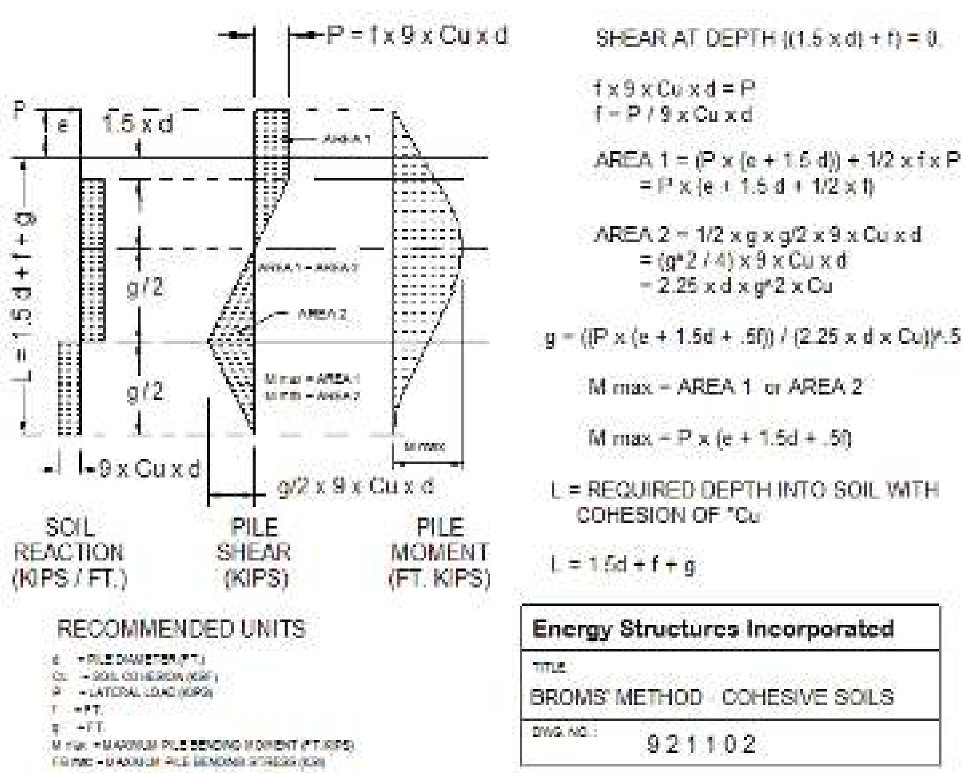
= 8800 lbs/9 (1000 psf) (6.625 in/12)

= 1.771 ft

$M^{POS}{}_{MAX}$	=	P [e + 1.5(d) + 0.5(f)]	**Equation 8-75**
	=	8800 lbs [1 ft + 1.5 (6.625 in/12) + 0.5 (1.771 ft)]	
	=	23,880 ft-lbs	
$M^{POS}{}_{MAX}$	=	2.25 (d) g^2 (Cu)	**Equation 8-76**
23,880 ft-lbs	=	2.25 (6.625 in/12) g^2 (1000 psf)	
g^2	=	19.22 ft^2	
g	=	$\sqrt{19.22}$	
	=	4.38 ft	
L	=	1.5D + f + g	**Equation 8-77**
	=	1.5 (6.625 in/12) + 1.771 ft + 4.38 ft	
	=	6.98 ft	

Summary

The 6" nominal steel case should be at least 7'-0 long to resist the 4400 lb lateral load.



Broms' Method for Laterally Loaded Short Piles
Figure 8-27

DESIGN EXAMPLE 14
INSTANT FOUNDATIONS® for STREET LIGHT SUPPORTS
SYMBOLS USED IN THIS DESIGN EXAMPLE

SLF	Street Light Foundation	8-61
DL	Dead or Down Load	8-61
V	Horizontal or Lateral Shear Load	8-61
M	Moment Loads	8-61
AASHTO	American Association of State Highway and Transportation Officials	8-61
L	Required Length	8-63
c	Cohesion of Soil	8-63
FS	Factor of Safety	8-63
V_F	Applied Shear at Groundline including Factor of Safety	8-63
V_M	Applied Moment at Groundline including Factor of Safety	8-63
D	Diameter of Foundation	8-63
q	Broms' Coefficient	8-63
M_{MAX}	Maximum Moment Applied to Foundation	8-63
φ	Internal Angle of Friction	8-64
γ	Unit Weight of Soil	8-64
K_p	Passive Earth Pressure Coefficient	8-64

PURPOSE

This Design Example provides example solutions to aid in the selection of appropriate CHANCE® Helical Instant Foundation® products for different job parameters.

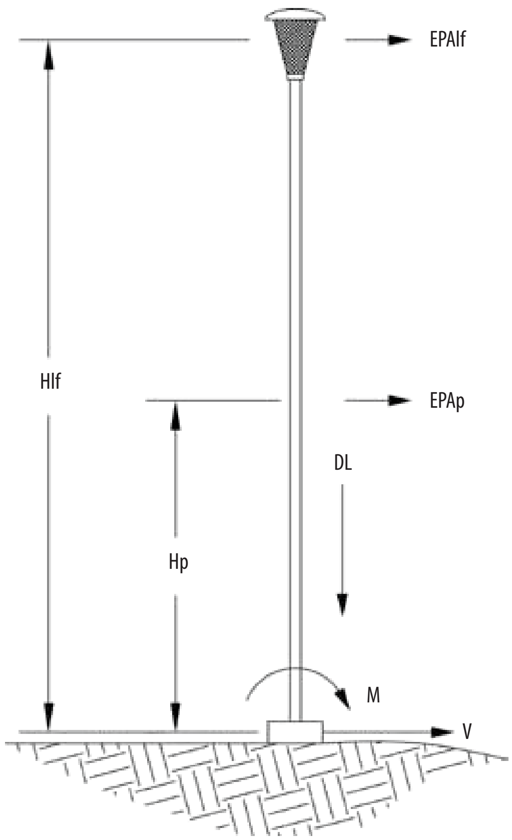
SLF LOADS

The resulting pole loads to be resisted by a street light foundation (SLF) are dead or vertical down loads (DL), horizontal, lateral or shear loads (V) due to wind on the pole and luminaire (light fixture), and overturning moment loads (M) resulting from the tendency to bend at or near the ground line as the wind causes the pole to displace and the foundation restrains the pole base at one location (see Figure 8-28).

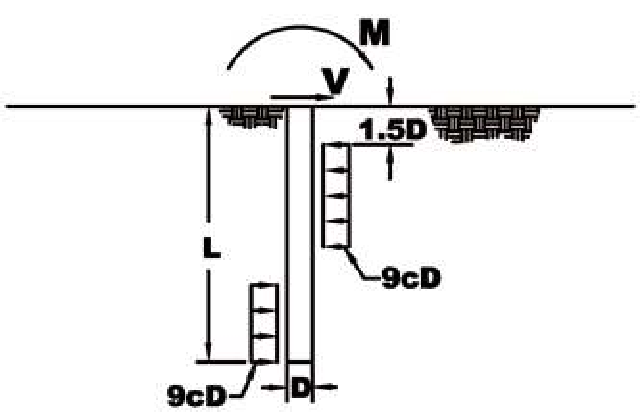
The DL for an SLF application is so small that a foundation sized to resist V and M will typically be much more than adequate to resist DL. Therefore, DL will not control the SLF design and will not be considered here. If DL is large enough to be of concern for an application where an SLF will be used, it may be evaluated based on bearing capacity equations applied to the soil around the helical bearing plate and friction along the shaft. These evaluations are beyond the scope of this design example, which will only deal with SLF applications.

Since SLF products are used as lighting foundations along public highways, it is appropriate to mention the American Association of State Highway and Transportation Officials (AASHTO) publication *Standard Specifications for Structural Support for Highway Signs, Luminaires and Traffic Signals*. This document is often taken as the controlling specification for jobs using SLF's and will be referenced throughout this discussion.

wp = Wind Pressure	SLF REACTIONS
EPAlf = Effective Projected Area of a Light Fixture	Vlf = [EPAlf x wp]
EPAp = Effective Projected Area of a Light Pole	Vp = [EPAp x wp]
Hlf = Moment Arm to EPAlf Centroid	V = Vlf +Vp
Hp= Moment Arm to EPAp Centroid	M = [Vlf x Hlf] + [Vp x Hp]



Pole Load Diagram
Figure 8-28



Foundation in Cohesive Soil
Figure 8-29

SLF SELECTION

The SLF selection process is a trial and error procedure that may require more than one iteration. First, select an SLF diameter based on the applied bending moment (M) that must be resisted. That is, ensure that the applied moment is less that the allowable moment on the shaft. Determining the allowable moment requires a structural analysis of the pipe shaft section capacities (often based on a reduced cross section through cable ways, bolt slots, base plate size, welds, etc). This effort should be familiar to engineers engaged in design work, so a sample of this process will not be given here.

The foundation shaft diameter will often be as large as or larger than the base diameter of the pole to be supported. Allowable moment capacities for CHANCE® Helical Instant Foundation® products are provided in Table 10-2 in Section 10 of this Technical Design Manual. These capacities, when compared to the ground line reactions of the pole, can be used to choose a starting diameter to resist the applied loads. In this regard, shear is usually not the controlling factor for SLF shaft size but rather the moment load. (Note: The starting size may change as the given soil conditions for a job may dictate the final SLF size required.)

The design or selection of a foundation size to resist light pole loads in a given soil may be determined by various methods. Numerical methods using finite element and finite difference techniques may be used but have proven to be somewhat sophisticated for the rather simple SLF application. The Fourth Edition of the AASHTO specification lists a number of preliminary design methods that can be employed in the design process. Among those listed and discussed are the methods developed by Bengt B. Broms for embedment lengths in cohesive and cohesionless soils and a graphical method dealing with the embedment of lightly loaded poles and posts. The Broms method will be used for this design example as experience has shown these methods to both useable and appropriate. Calculations are provided for both cohesive soil (clay) and cohesionless soil (sand).

COHESIVE SOIL (see Figure 8-29)

Assumed values:

- Applied shear load at the groundline (V) = 460 lbs.
- Applied moment at the groundline (M) = 8600 ft-lbs.
- Foundation diameter is 6” nominal Schedule 40. Use 6.625” as the actual pipe size in calculations. Cableway openings are 2.5” wide by 12” high. The allowable moment capacity of this foundation shaft size and cableway opening is 10,860 ft-lbs.
- The required length (L) will be determined using the Broms method.
- Cohesion (c) = 1000 psf.
- Factor of Safety = 2.

V_F = V (FS) **Equation 8-78**

= 460 (2)

= 920 lbs

V_M = M (FS) **Equation 8-79**

= 8600 (2)

= 17,200 ft-lbs

L = 1.5D+q [1+{ 2 + (4H+6D)/q} $^{0.5}$] **Equation 8-80**

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

= 4.82 ft

where:

	D	=	Diameter of foundation = 6.625 inches
where:	q	=	V_F/9cD = 920 / (9 x 1000 x 6.625/12) = 0.185157ft
	c	=	Shear strength of cohesive soil = 1000 psf
	H	=	Moment / Shear = M/V = V_M / V_F = 17200 ft-lbs / 920 lbs = 18.69565 ft
	L	=	Calculated Foundation Length to Provide a SF of 2 Against Soil Failure.

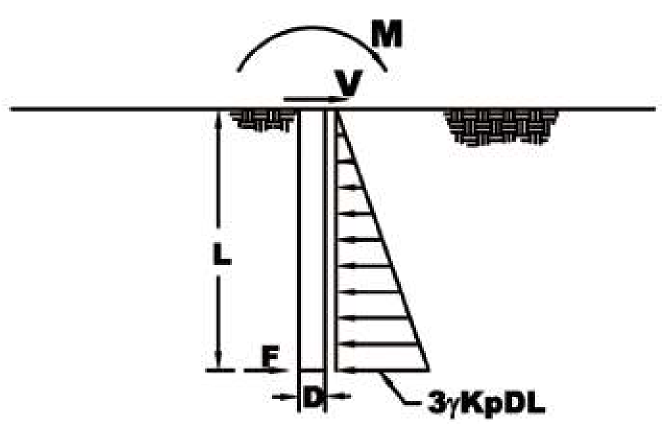
The length required to provide a Factor of Safety of 2 against soil failure is 4.82 ft. Since SLF lengths are provided in even foot lengths, use L = 5 ft. For the required embedment length, the maximum moment in the shaft is:

M_{MAX} = V (H + 1.5D + 0.5q) **Equation 8-81**

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

= 9023.5 ft-lbs

Maximum moment can be compared with the allowable moment capacity of the foundation shaft to determine adequacy. For this example the allowable moment in the 6” pipe shaft is given as 10,860 ft-lbs, which is greater than the applied moment. Therefore, the 6” diameter by 5’ long SLF is adequate for the applied loads in the clay soil.



Foundation in Cohesionless Soil
Figure 8-30

COHESIONLESS SOIL (See Figure 8-30)

Assumed values:

- Applied shear load at the groundline (V) = 460 lbs.
- Applied moment at the groundline (M) = 8600 ft-lbs.
- Foundation diameter is 6" nominal Schedule 40. Use 6.625" as the actual pipe size in calculations. Cableway openings are 2.5" wide by 12" high. The allowable moment capacity of this foundation shaft size and cableway opening is 10,860 ft-lbs.
- The required length (L) will be determined using the Broms method.
- $\varphi = 30°$
- $\gamma = 100$ lbs/ft3
- Factor of Safety = 2.

$$V_F = V\,(FS) = 460\,(2) = 920 \text{ lbs}$$ **Equation 8-78**

$$V_M = M\,(FS) = 8600\,(2) = 17{,}200 \text{ ft-lbs}$$ **Equation 8-79**

Broms equation for cohesionless soil requires a trial and error solution. For the trial and error solution, start by assuming the foundation diameter (D) is 6.625" and the length (L) is 6 feet:

$$0 \leq L^3 - (\,2V_FL / K_{P\gamma}D\,) - (\,2VM / K_{P\gamma}D\,)$$ **Equation 8-82**

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

$$= -58.35$$

$$0 > -58.35$$

where:

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

γ = Effective unit weight of soil = 100 lbs/ft^3

The 6 foot length is too short so we will try a 7 foot length and repeat the calculation:

$$0 = 7^3 - [2 \times 920 \times 7) / (3 \times 100\,\{6.625/12\})] - [(2 \times 17200) / (3 \times 100 \times \{6.625/12\})]$$

$$= 57.53$$

$$0 < 57.53$$

A 7 foot long SLF will be adequate. The maximum moment in the foundation shaft can be determined with the following equation:

$$M_{MAX} = V\,(\,H + 0.54 \times (\,V / \gamma DK_P\,)^{0.5}\,)$$ **Equation 8-83**

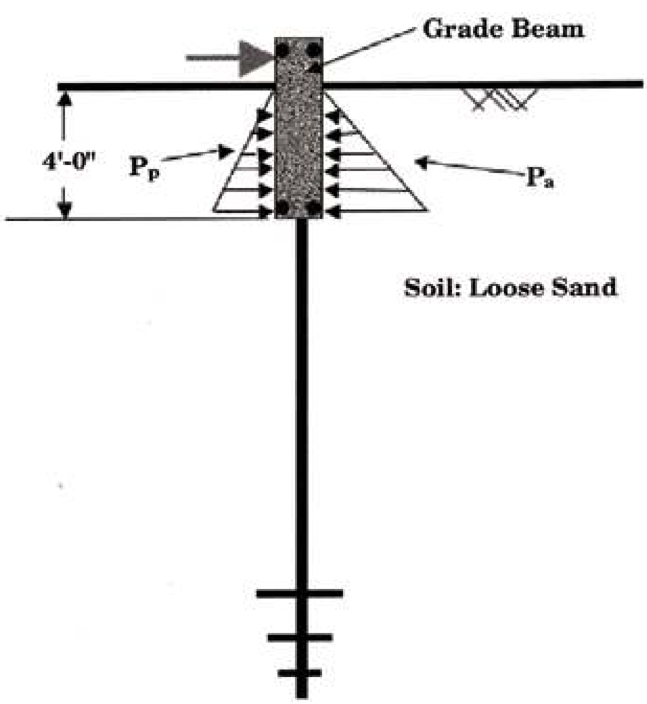
$$= 460\,(18.69565 + 0.54 \times (\,460/100 \times (6.625/12) \times 3)^{0.5})$$

$$= 9013.968 \text{ ft-lbs}$$

This is less than the allowable moment capacity of 10,860 ft-lbs, therefore a 6" diameter by 7' long SLF is adequate for the applied load in the sandy soil.

DESIGN EXAMPLE 15
FOUNDATION EARTH PRESSURE RESISTANCE
SYMBOLS USED IN THIS DESIGN EXAMPLE

pcf	Pounds per Cubic Foot	8-65
K_a	Active Earth Pressure Coefficient	8-65
K_p	Passive Earth Pressure Coefficient	8-65
P_a	Active Load	8-66
P_p	Passive Load	8-66



Earth Pressure on a Grade Beam
Figure 8-31

PROJECT

A CHANCE® Helical Type SS5 1-1/2” square shaft helical anchor is proposed as part of a pier and beam foundation for a residential structure (see Figure 8-31). The top of the helical anchor is fixed in a concrete grade beam that extends 4’-0 below grade. The surface soils are loose sands. Determine the lateral capacity of the grade beam using the Rankine earth pressure method.

ASSUMPTIONS

- The lateral capacity of the 1-1/2” square shaft helical anchor is limited based on shaft size. It is generally not assigned any contribution to the lateral capacity of a foundation
- The effective length of the grade beam for lateral resistance is 25’-0
- Assume a unit weight of 95 pcf
- The water table is well below the bottom of the grade beam
- There are no surcharge loads
- From Table 8-9, $K_a = 0.2$, $K_p = 3$

SOLUTION

P_a	=	$0.5K_a\gamma H^2$	**Equation 8-84**
	=	0.5 x 0.2 x 95 x 42	
	=	152 lb/ft	
P_p	=	$0.5K_p\gamma H^2$	
	=	0.5 x 3 x 95 x 42	
	=	2280 lb/ft	
P_p - P_a	=	2280 - 152	
	=	2128 lb/ft	
Total lateral resistance	=	2128 x 25'-0 = 53,200 lbs	

NOTE: In this example, more than 1" of movement will probably be required to fully mobilize the total lateral resistance. Partial mobilization requires less deflection.

Coefficients of Earth Pressure (Das, 1987), Table 8-9

SOIL	K_0' DRAINED	K_0' TOTAL	K_a' TOTAL	K_p' TOTAL
Clay, soft [1]	0.6	1	1	1
Clay, hard [1]	0.5	0.8	1	1
Sand, loose	0.6	0.53	0.2	3
Sand, dense	0.4	0.35	0.3	4.6

Note:
[1] Assume saturated clays.

DESIGN EXAMPLE 16
BUCKLING EXAMPLE USING the DAVISSON METHOD

SYMBOLS USED IN THIS DESIGN EXAMPLE

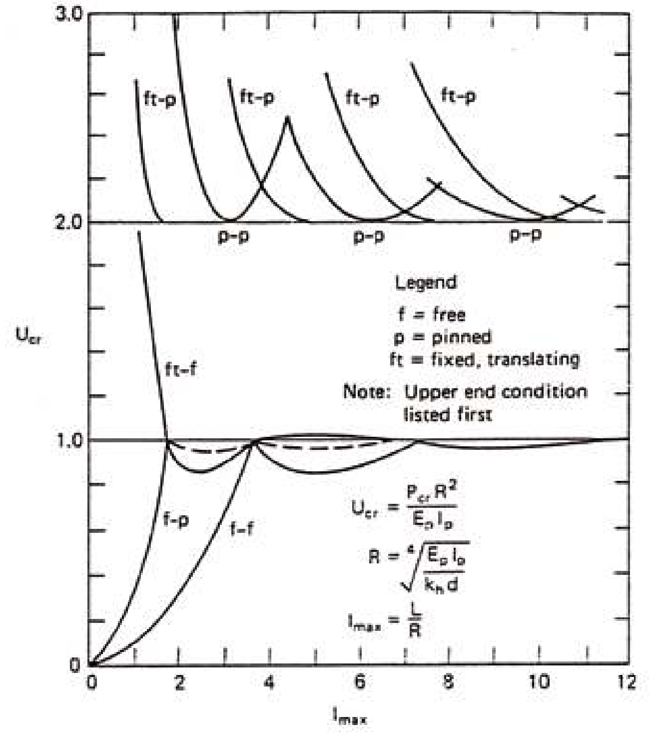
k_h .... Empirical Torque Factor for Helix 8-67
U_{cr} .... Critical Capacity 8-67
R .... Resistance 8-68
I_{max} .... Maximum Moment of Inertia 8-68
P_{cr} .... Critical Pressure 8-68
E_p .... Modulus of Elasticity 8-68
I_p .... Moment of Inertia 8-68
D .... Shaft Diameter 8-68
kip .... Kilopound 8-68

PROJECT

A three-helix CHANCE® Helical Type SS150 1-1/2” square shaft helical pile is to be installed into the soil profile as shown in Figure 8-33. The top three feet is uncontrolled fill and is assumed to be soft clay. The majority of the shaft length (12 feet) is confined by soft clay with a k_h = 15 pci. The helix plates will be located in stiff clay below 15 feet. The buckling model assumes a pinned-pinned end condition for the helical pile head and tip. Determine the critical buckling load using the Davisson method.

ASSUMPTIONS

- k_h is constant, i.e., it does not vary with depth. This is a conservative assumption because k_h usually varies with depth, and in most cases increases with depth.
- Pinned-pinned end conditions are assumed. In reality, end conditions are more nearly fixed than pinned, thus the results are generally conservative.
- From Figure 8-32, $U_{cr} \approx 2$



Poulos and Davis (1980)
Figure 8-32

$R = \sqrt[4]{(30 \times 10^6 \times 0.396) / (15 \times 1.5)} = 26.96$ **Equation 8-85**

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

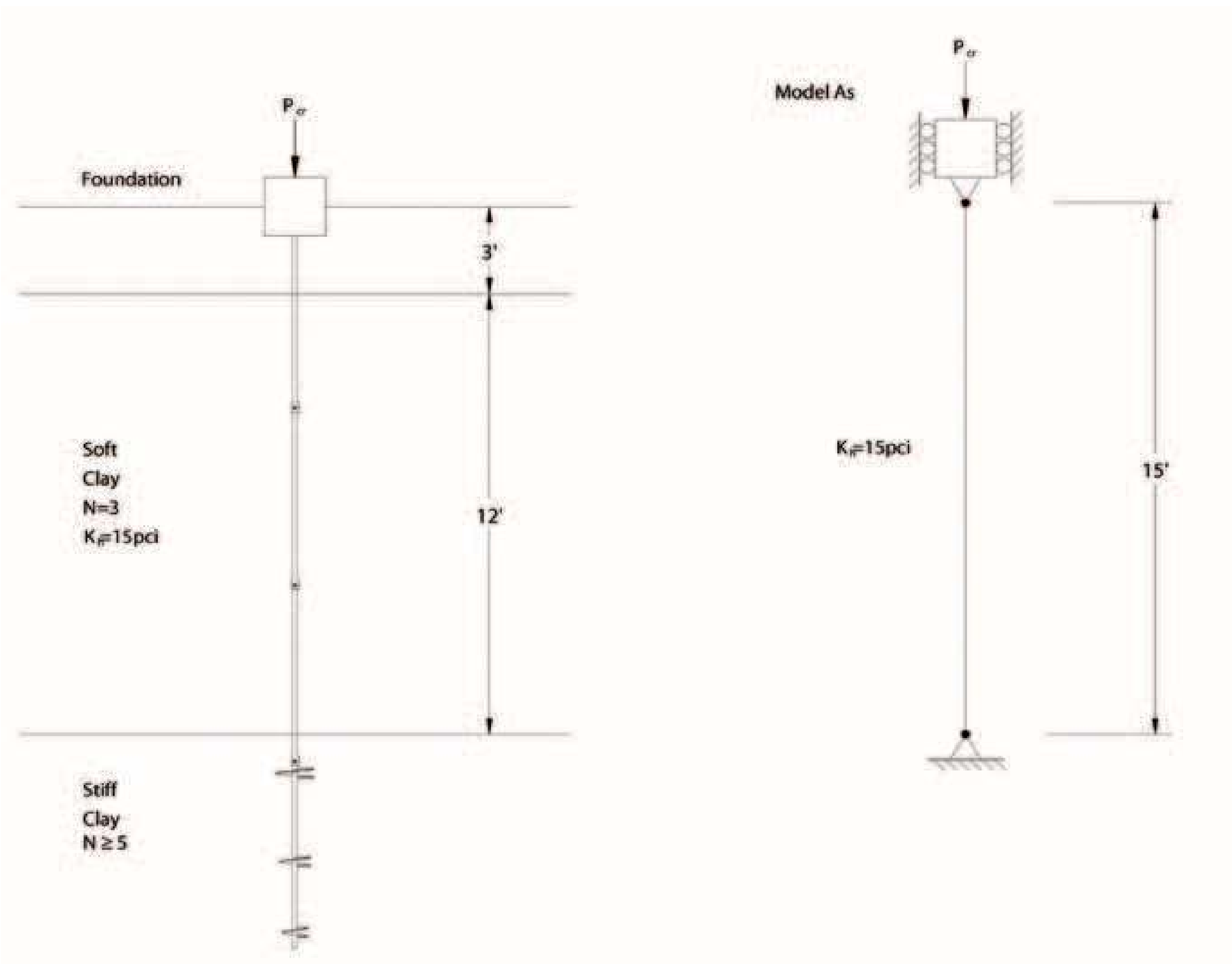
$= 6.7$

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

$= 32.69$ kips

CHANCE® Helical Type SS150 Square Shaft Foundations Physical Properties, Table 8-10

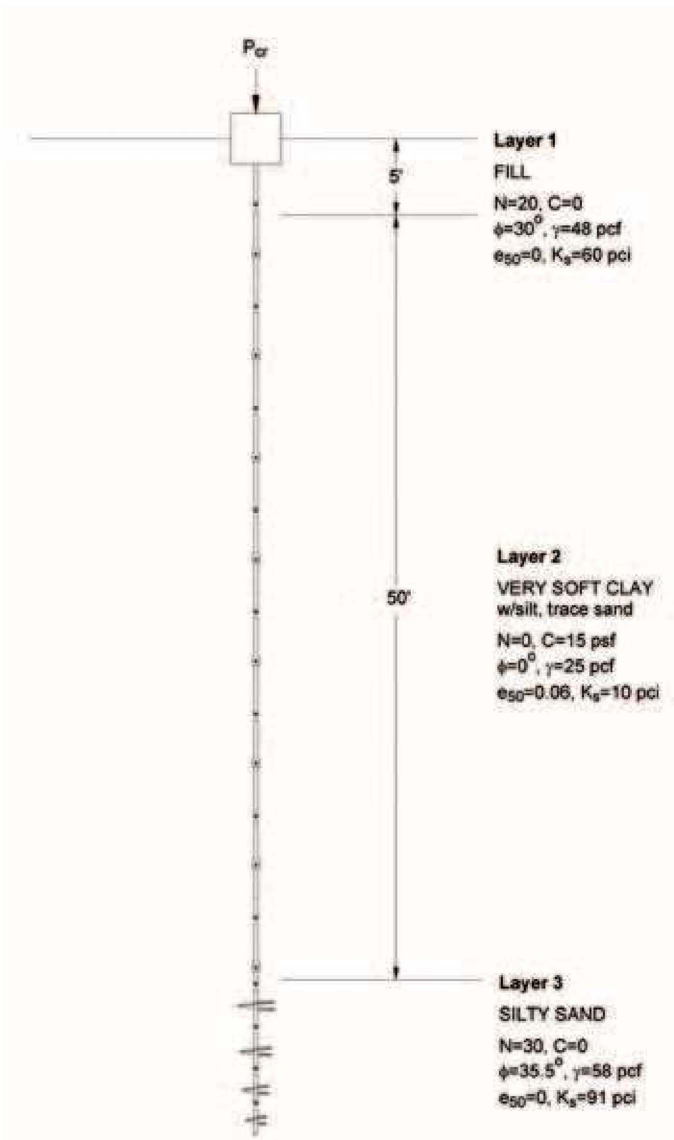
MODULUS of ELASTICITY (E_p)	MOMENT of INERTIA (I_p)	SHAFT DIAMETER (D)
30×10^6 psi	0.396 in^4	1.5 in



Foundation Details
Figure 8-33

DESIGN EXAMPLE 17
BUCKLING EXAMPLE USING the FINITE DIFFERENCE METHOD
SYMBOLS USED IN THIS DESIGN EXAMPLE

WOH	Weight of Hammer	8-69
WOR	Weight of Rod	8-69
psf	Pounds per Square Foot	8-69
ID	Inside Diameter	8-70
HPM	CHANCE HELICAL PULLDOWN® Micropile	8-70



Foundation Details
Figure 8-34

A four-helix CHANCE® Helical Pile is to be installed into the soil profile as shown in Figure 8-34. The top five feet is compacted granular fill and is considered adequate to support lightly loaded slabs and shallow foundations. The majority of the shaft length (50 feet) is confined by very soft clay described by the borings as "weight of hammer" (WOH) or "weight of rod" (WOR) material. WOH or WOR material means the weight of the 130-lb drop hammer or the weight of the drill rod used to extend the sampler down the borehole during the standard penetration test is enough to push the sampler down 18+ inches. As a result, a low cohesion value (15 psf) is assumed. The helix plates will be located in dense sand below 55 feet. Determine the critical buckling load of a Type SS175 1-3/4" square shaft and Type RS3500.300 round shaft piles using LPILEPLUS 3.0 for Windows® (ENSOFT, Austin, TX).

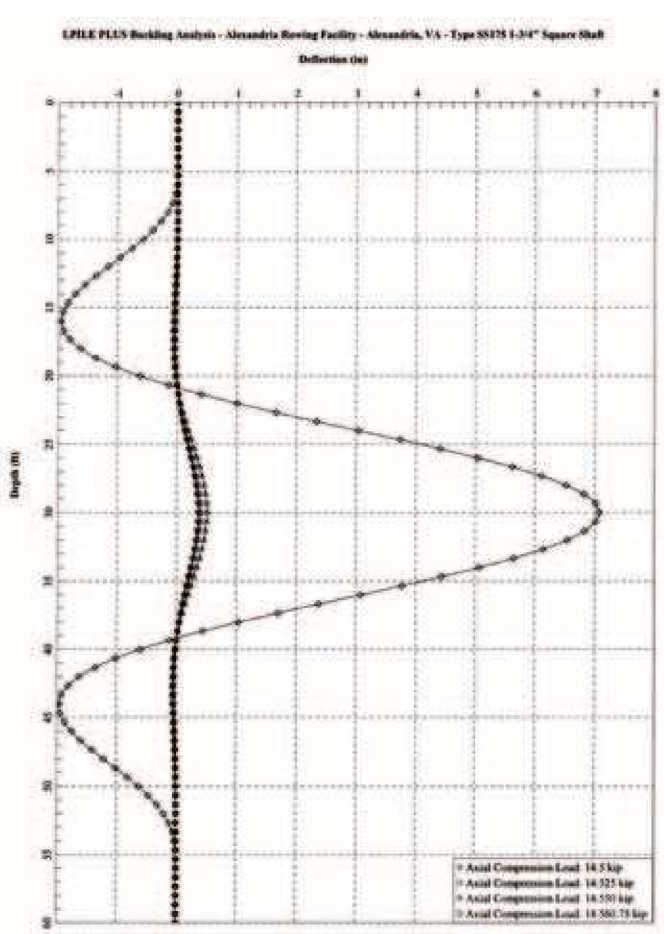
When the computer model is completed, the solution becomes an iterative process of applying successively increasing loads until a physically logical solution converges. At or near the critical buckling load, very small increasing increments of axial load will result in significant changes in lateral deflection – which is a good indication of elastic buckling. Figure 8-35 is an LPILEPLUS output plot of lateral shaft deflection vs depth. As can be seen by the plot, an axial load of 14,561 lb is the critical buckling load for a Type SS175 1-3/4" square shaft because of the dramatic increase in lateral deflection at that load compared to previous lesser loads. Figure 8-36 indicates a critical buckling load of 69,492 lb for Type RS3500.300 round shaft.

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

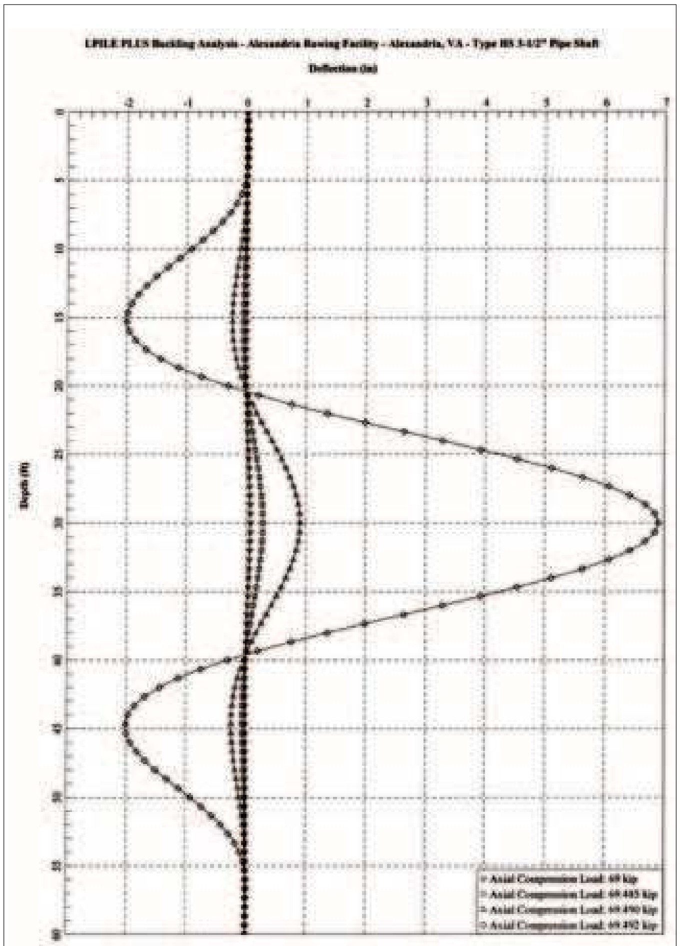
Type RS3500.300 is 3,200 lb for pinned-pinned and 12,800 lb for fixed-fixed. This is a good indication that shaft confinement provided by the soil will significantly increase the buckling load of helical piles. This also indicates that even the softest materials will provide significant resistance to buckling.

All extendable helical piles have couplings or joints used to connect succeeding sections together in order to install the helix plates in bearing soil. One inherent disadvantage of using the finite difference method is its inability to model the effects of bolted couplings or joints that have zero joint stiffness until the coupling rotates enough to bring the shaft sides into contact with the coupling walls. This is analogous to saying the coupling or joint acts as a pin connection until it has rotated a specific amount, after which it acts as a rigid element with some flexural stiffness. All bolted couplings or joints, including square shaft and round shaft piles, have a certain amount of rotational tolerance. This means the joint initially has no stiffness until it has rotated enough to act as a rigid element. In these cases, it is probably better to conduct buckling analysis using other means, such as finite element analysis, or other methods based on empirical experience as mentioned earlier.

If couplings are completely rigid, i.e., exhibit some flexural stiffness even at zero joint rotation, axial load is transferred without the effects of a pin connection, and the finite difference method can be used. An easy way to accomplish rigid couplings with round shaft piles is to pour concrete or grout down the ID of the pipe after installation. Another method is to install a grout column around the square or round shaft of the foundation using the CHANCE HELICAL PULLDOWN® Micropile (HPM) method. The HPM is a patented (U.S. Patent 5,707,180) installation method initially developed to install helical anchor foundations in very weak soils where buckling may be anticipated.



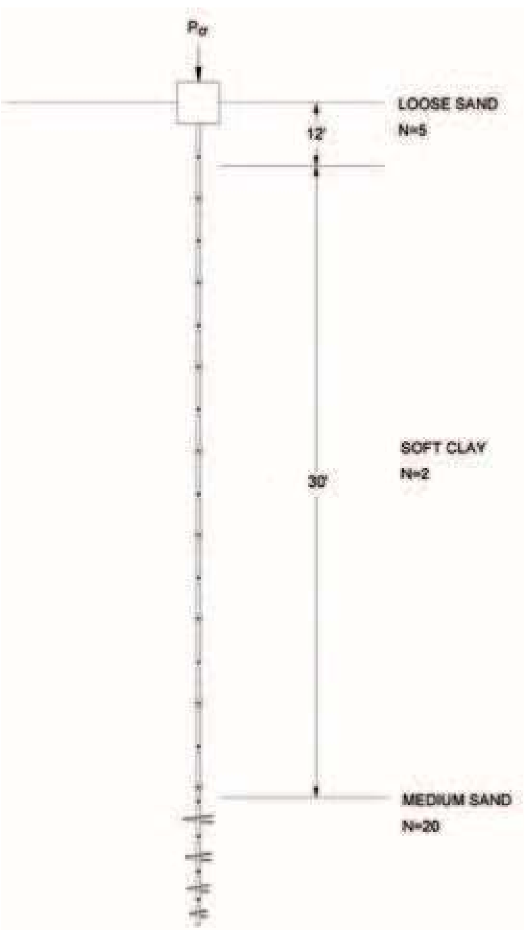
LPILE^PLUS Output Plot of Deflection vs Depth
Figure 8-35



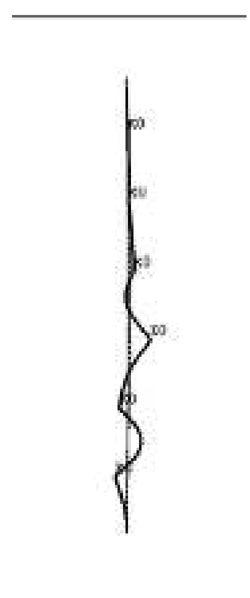
LPILE^PLUS Output Plot of Deflection vs Depth
Figure 8-36

DESIGN EXAMPLE 18
BUCKLING EXAMPLE USING the FINITE DIFFERENCE METHOD
SYMBOLS USED IN THIS DESIGN EXAMPLE

SPT	Standard Penetration Test	8-71
N	SPT Blow Count	8-71
psf	Pounds per Square Foot	8-71
kip	Kilopound	8-71
HPM	CHANCE HELICAL PULLDOWN® Micropile	8-71



Foundation Details
Figure 8-37


Displaced Shape of Shaft ANSYS® Output
Figure 8-38

A three-helix CHANCE® Helical Type SS5 1-1/2" square shaft helical pile is to be used to underpin an existing townhouse structure that has experienced settlement (see Figure 8-37 for soil profile details). The top 12 feet is loose sand fill, which probably contributed to the settlement problem. The majority of the shaft length (30 feet) is confined by very soft clay with an SPT blow count "N" of 2. As a result, a cohesion value (250 psf) is assumed. The helix plates will be located in medium-dense sand below 42 feet. Determine the critical buckling load using the ANSYS integrated file element model.

Output indicates the Type SS5 1-1/2" square shaft buckled at around 28 kip. Figure 8-38 shows the displaced shape of the shaft (exaggerated for clarity). The "K0" in Figure 8-38 are the locations of the shaft couplings. Note that the deflection response is controlled by the couplings, as would be expected. Also note that the shaft deflection occurs in the very soft clay above the medium-dense bearing stratum. Since the 28 kip buckling load is considerably less than the bearing capacity (55+ kip) it is recommended to install a grout column around the 1-1/2" square shaft using the CHANCE HELICAL PULLDOWN® Micropile (HPM) method.

SOIL SCREW® RETENTION WALL SYSTEM
SECTION 9

CONTENTS

SYMBOLS USED IN THIS SECTION

Symbol	Description	Page
FS	Factor of Safety	9-5
AWS	American Welding Society	9-7
SPT	Standard Penetration Test	9-8
N	SPT Blow Count	9-8
LI	Liquidity Index	9-8
K_t	Empirical Torque Factor	9-11
c	Cohesion of Soil	9-15
φ	Angle of Internal Friction	9-15
θ	Failure Plane Angle	9-16
RF	Resisting Force	9-17
DF	Driving Force	9-17
SSCF	SOIL SCREW® Anchor Component Force	9-17
WWF	Welded Wire Fabric	9-17
GWT	Ground Water Table	9-19
P_{des}	Design Load per Pier	9-15
DS	Design Load	9-15
T	Indicated Force	9-20

INTRODUCTION

Hubbell Power Systems, Inc. provides the SOIL SCREW® Retention Wall System as an efficient and economical system to retain soil during excavation and construction of structures below grade. The following are some of the advantages of this system over other soil retention methods:

- Fast installation without specialized equipment;
- Immediate support without curing time;
- Reduced installation time - post-tensioning not required;
- No need for H-piles, walers and heavy reinforced walls;
- Immediate on-site capacity verification; and
- Excavations adjacent to existing structures are possible when used with ATLAS RESISTANCE® Piers or CHANCE® Helical Piles;

The CHANCE® Underpinning/Shoring system provides for underpinning existing shallow footings, permitting excavation adjacent to the existing structure to a depth that would otherwise undermine the existing footing. The system allows excavation to proceed directly adjacent to an existing building without fear of vibration or structural damage to the building.

Commercial property owners often want to construct buildings with maximum possible footprints and a basement to maximize the potential of the site. If there is an existing building with a shallow footing adjacent to the proposed construction site, that building will need to be protected against damage from settlement due to removal of the soil that is laterally supporting the existing footing. Similar protection is required when a sloping excavation is cut next to an existing shallow footing in order to construct a building, parking lot, or roadway adjacent and down-slope of this footing.

The SOIL SCREW® Retention Wall System is designed to provide protection to the existing structure by using a combination of foundation support products. ATLAS RESISTANCE® Piers or CHANCE® Helical Piles are used to underpin the foundation of the existing structure. The structural load from the shallow footing is transferred down to a suitable bearing stratum below the depth of the intended excavation. The SOIL SCREW® Retention Wall System, combined with a reinforced shotcrete retaining wall is then used to maintain stability of the cut slope and the underpinning system as the excavation proceeds. For some conditions CHANCE® Helical Tieback Anchors can be used at the underpinning bracket to further ensure against lateral footing movement of existing buildings.

Other methods require the use of impact driven "soldier" piles. The major disadvantages to this system are the equipment size, noise and vibrations caused by the installation of the piles. This can be bothersome, annoying and stressful to the occupants of surrounding buildings, could damage sensitive electronics and/or could cause settlement of the building being protected. Because the CHANCE® Foundation Stabilization System and support uses hydraulic power for driving the underpinning, helical tieback anchors, and Helical SOIL SCREW® Anchors, it is extremely quiet and practically vibration free, thus allowing full use of neighboring buildings during the construction process.

PRODUCT BENEFITS

CHANCE SOIL SCREW® Retention Wall Systems offer the following benefits:

- Low installed cost
- No vibration
- Shorter installation lengths
- Ease of installation in limited access areas
- Minimum disturbance to site
- Immediate loading
- On-site load test capability
- Reusable in temporary stabilization applications

SYSTEM DESCRIPTION

The CHANCE SOIL SCREW® Retention Wall System creates an internally reinforced soil mass when closely spaced in a regular geometric pattern and protected by a reinforced facing of shotcrete. It differs from helical tieback anchors even though the appearance of the products is similar.

A tieback restrained wall is generally constructed by installing a structural wall facing system that is anchored to the earth by means of high strength helical anchors that are installed to a stratum of soil of sufficient strength to resist the forces placed upon the wall by the retained earth. The helical tieback anchor experiences a tension load equal to the retained earth forces. The structural retaining wall must be designed with sufficient strength to be able to support the soil load between tiebacks without excessive deformation.

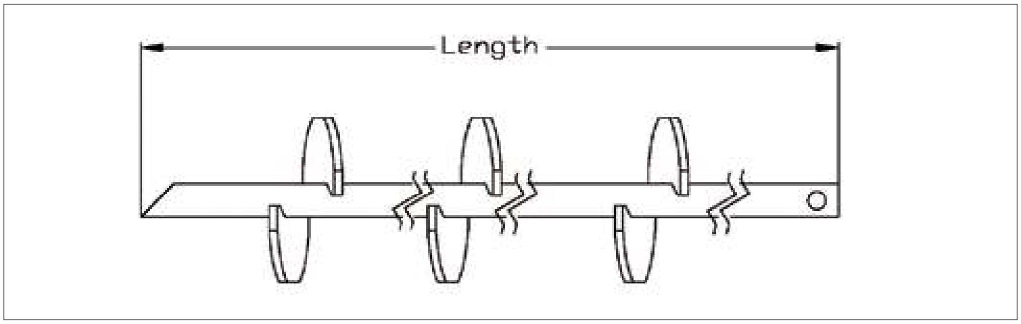
CHANCE® Helical SOIL SCREW® Anchors are designed and installed differently than helical tieback anchors. They are generally seated at a shallower depth than helical tieback anchors when installed to retain similar soil masses. Most importantly, the Helical SOIL SCREW® Anchors are not tensioned after installation; they are passive elements. When the SOIL SCREW® Retention Wall System is installed it holds the soil as a single mass of sufficient internal stability to provide a suitable Factor of Safety (FS) against failure. The load on the Helical SOIL SCREW® Anchors is created across the movement plane as the soil mass moves slightly downward due to gravity.

Many projects require that excavations be extremely close to existing structures. By combining ATLAS RESISTANCE® Modified Piers, or CHANCE® Helical Piles, CHANCE® Helical Tieback Anchors, and the CHANCE SOIL SCREW® Retention Wall System together, the designer is able to safely support an existing structure and the underlying soil mass during adjacent excavations. ATLAS RESISTANCE® Piers or CHANCE® Helical Piles support the structural load of the perimeter of the building, thus dramatically reducing the surcharge on the soil mass that must be retained. CHANCE® Helical Tieback Anchors are used for lateral support of the building's footing in projects where deep, adjacent excavations are required and/or for buildings with perimeter weights exceeding 4,000 pounds per linear foot. With the surcharge loads properly transferred away from the soil mass under the building, the design for soil retention using CHANCE® Helical SOIL SCREW® Anchors is greatly simplified and requires fewer Helical SOIL SCREW® Anchors. In many instances, this method is the only economical way to accomplish this task. This method of structure/soil mass support prevents structure distress that may manifest itself during potential settlement as the soil mass loads the CHANCE SOIL SCREW® Retention Wall System.

SOIL SCREW® RETENTION WALL SYSTEM SELECTION GUIDELINES

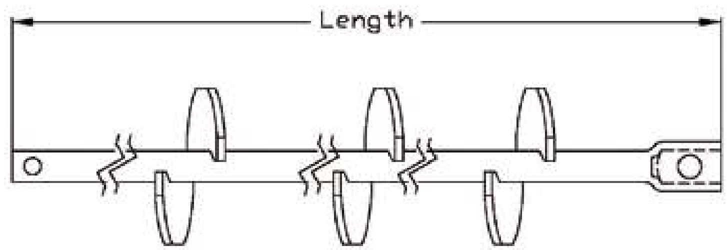
The CHANCE SOIL SCREW® Retention Wall System is available in two shaft sizes and two helix diameters. A variety of shaft lengths are offered to provide a designer an adequate selection for any application and load requirements. Design and installation requires input and supervision by a professional engineer and adequate site specific soil information.

CHANCE SOIL SCREW® Retention Wall System (Type SS5 and SS175 Series) Lead Sections



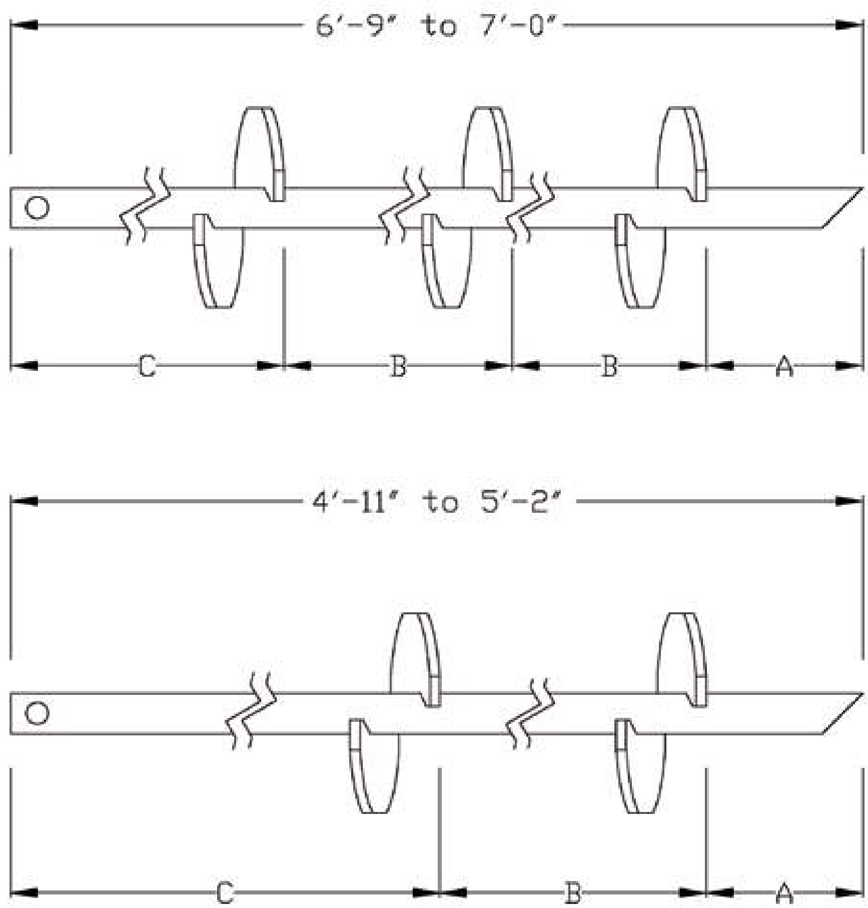
Product Designation	Product Series	Length	No. Plates	Plate Size	Weight lb.
C1100692	SS5	4'-11	2	8" Dia.	49
C1100691	SS5	7'-0	3	8" Dia.	69
C11002350301	SS175	5'-2	2	8" Dia.	62
T11006740302	SS175	6'-9	3	6" Dia.	75

CHANCE SOIL SCREW® Retention Wall System (Type SS5 and SS175 Series) Extension Sections



Product Designation	Product Series	Length	No. Plates	Plate Size	Weight lb.
C1100690	SS5	4'-9	2	8" Dia.	42
C1100689	SS5	6'-9	3	8" Dia.	50
C11004500301	SS175	6'-11	2	6" Dia.	70
C11004500302	SS175	6'-10	3	8" Dia.	75

CONFIGURATIONS - SQUARE SHAFT LEAD SECTIONS



TYPE SS5 and SS175 SERIES

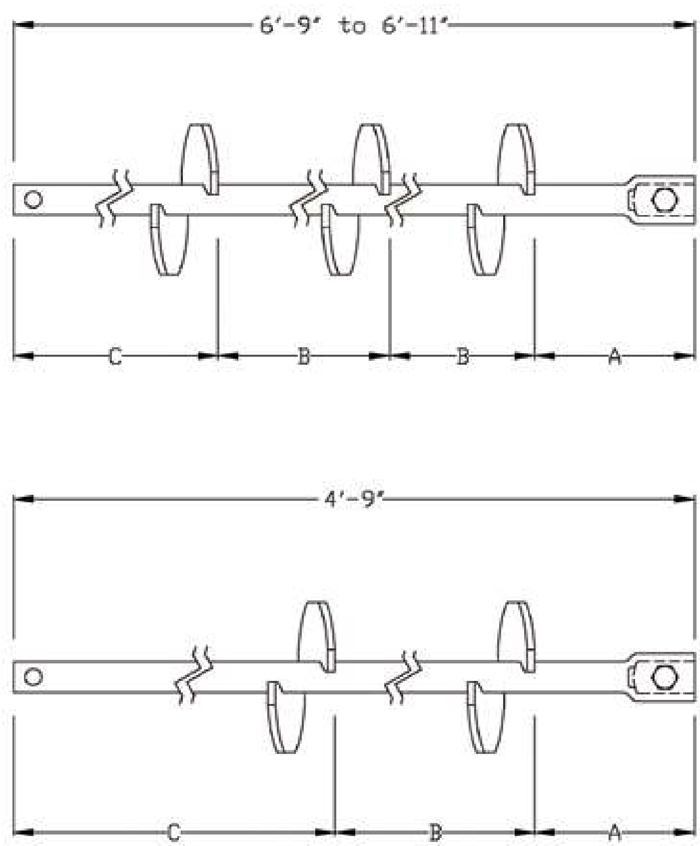
CHANCE SOIL SCREW® Retention Wall System (Type SS5 and SS175 Series) Lead Sections

CONFIGURATION TABLE (Leads and Extensions)						
Bar Size	Plate Size	Length	Dim A	Dim B	Dim C	No. Plates
1-1/2" Square Soil Screw® Lead Section	8" Dia.	4'-11	6"	29"	24"	2
		7'-0	6"	29"	20"	3
1-1/2" Square Soil Screw® Extension	8" Dia.	4'-9	5"	29"	23"	2
		6'-9	6"	29"	17"	3
1-3/4" Square Soil Screw® Lead Section	6" Dia.	5'-2	8"	30"	24"	2
	8" Dia.	6'-9	6"	30"	15"	3
1-3/4" Square Soil Screw® Extension	6" Dia.	6'-11	6"	30"	17"	3
	8" Dia.	6'-10	9"	29"	15"	3

NOTES – SOIL SCREW® ANCHOR PRODUCTS (Type SS5 and SS175 Series):

- Refer to the schematic drawings at the bottom of page 9-6 and below for Dimensions A, B and C.
- All extensions include integrally forged couplings, machine bolts and hex nuts
- All helical plates are welded to the shaft in conformance to the American Welding Society (AWS) Structural Welding Code AWS D1.1" and applicable revisions.
- Available Finish: Hot Dip Galvanized (HDG)

CONFIGURATIONS - SQUARE SHAFT EXTENSION SECTIONS



TYPE SS5 and SS175 SERIES

PRELIMINARY DESIGN CONSIDERATIONS

The following requirements must be considered:

1. An evaluation of: (a) the foundation soil strata (below the reinforced soil mass), (b) the soil stratum into which the helix plates will be located, and (c) the soil behind the reinforced soil mass to be retained by the SOIL SCREW® Retention Wall System.
2. A selection of the appropriate Helical SOIL SCREW® Anchor including shaft size, helix plate diameter and length of embedment.
3. A determination of the ultimate tension capacity of the Helical SOIL SCREW® Anchors with a suitable Factor of Safety.

The following preliminary design guide for Helical SOIL SCREW® Anchors is intended to provide a basic understanding of SOIL SCREW® Retaining Wall theory.

SOIL SCREW® Anchor wall design requires professional geotechnical and engineering input. Specific information involving the structures, soil characteristics and foundation conditions must be used for the final design.

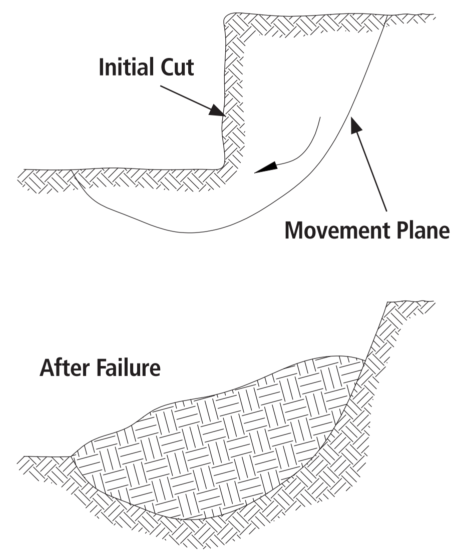
PRELIMINARY DESIGN RECOMMENDATIONS

- The top of the Helical SOIL SCREW® Anchor wall typically moves in the range of 0.1% to 0.3% of the wall height. Vertical and lateral movements are expected to be approximately 1/4" for a ten-foot cut and 1/2" for a 20-foot cut. This lateral movement is of concern when there is a structure located at the top of the proposed cut. It is therefore required that either ATLAS RESISTANCE® Piers or CHANCE® Helical Piles underpin the existing structure. It is recommended to use CHANCE® Helical Tieback Anchors at each underpinning placement location whenever the cut exceeds 12 feet and/or the existing structural line load is greater than 4,000 lb/ft.
- Surcharge loads due to slabs, column footings, overburden soils, vehicular traffic, or other structures behind the wall must be considered when calculating the soil loads to be retained by the Helical SOIL SCREW® Anchors.
- The CHANCE® SOIL SCREW® Retention Wall System is best suited to cemented or medium-dense to dense sand and to low plasticity clay soils with Standard Penetration Test (SPT) N values ≥ 8. Use caution in highly plastic clays and silts.
- The CHANCE® SOIL SCREW® Retention Wall System is poorly suited for jointed weathered rock material that dips into the excavation, loose sand with SPT N values ≤ 7 and in those cohesive soils with SPT N values of ≤ 6 (clays with cohesion < 850 psf or an allowable bearing stress < 2,000 psf) anywhere in the depth profile of soil that is to be excavated.
- Clean to relatively clean cohesionless soils with poor stand-up time typically require a 1" (±) flash shotcrete coating to be placed simultaneously with the excavation. The maximum recommended incremental face cut height is four feet or less. Use CHANCE® Helical Tieback Anchors when underpinning/shoring next to an existing structure.
- Use of the underpinning/shoring system is permissible for excavations of up to 20 feet and under extremely favorable conditions shall not exceed 25 feet.
- The underpinning/shoring system is a temporary support system. Creep is generally not a problem, however, the system is not recommended when the Liquidity Index (LI) is >0.2.
- SOIL SCREW® Anchors must have helix plates of the same diameter continuously along the installed length.
- SOIL SCREW® Anchors must be installed at a minimum downward angle of 5° from horizontal and typically do not exceed 15° downward angle.
- Engineering design shall include verification of several levels of design analysis:

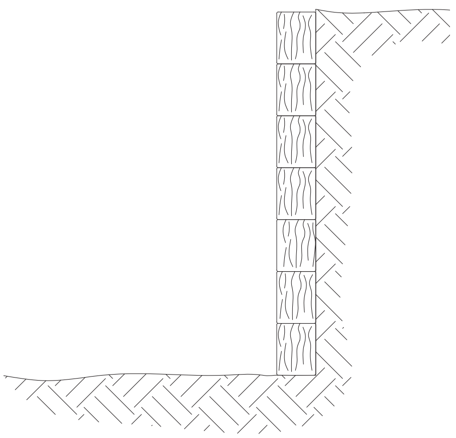
  Internal stability: The soil mass acts as a coherent mass

  External stability: The ability to resist lateral sliding

  Global stability: The ability to resist massive rotational failure outside the "internally stabilized soil" mass



Typical Failure Mode of an Unstable Excavation
Figure 9-1



Cut Slope with Timber Wall
Figure 9-2

IMPORTANT NOTICE

A Registered Professional Engineer shall design the CHANCE SOIL SCREW® Retention Wall System. The installation shall be performed by trained and certified installing contractors/dealers.

GEOTECHNICAL and STRUCTURAL ENGINEERING

For an introduction and guidance on how to design retention walls using the CHANCE SOIL SCREW® Retention Wall System, refer to the SOIL SCREW® Retention Wall System Design Manual. For a copy of this manual, please contact your area CHANCE® Distributor or visit the Hubbell Power Systems, Inc. website at www.abchance.com.

Design Example 10 in Section 8 provides a detailed wall design using the CHANCE SOIL SCREW® Retention Wall System.

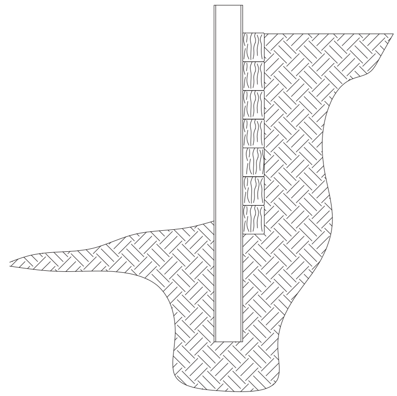
CHANCE Helical SOIL SCREW® Anchors look similar to helical tieback anchors, but they are different and they act differently to stabilize a slope. To understand how Helical SOIL SCREW® Anchors act and the differences between the two products, we must examine a cut slope that is unable to stand for an extended time on its own (see Figure 9-1).

A simple method to improve stability of the slope would be to stack railroad ties against the cut face so that the soil would have to push the ties over in the process of failing (see Figure 9-2). If this proves insufficient, driving "soldier" piles in front of the railroad ties (now termed "lagging") enhances the stability. Now the soil must push the lagging and the soldier piles over before failure can occur (see Figure 9-3).

If this is still insufficient to stabilize the soil, a beam can be installed along the wall connecting the soldier piles. This beam is called a "waler" and it is anchored by helical tieback anchors to a stable portion of the soil mass behind the failure plane (see Figure 9-4). Now as the slope attempts to fail, the sliding soil pushes against the lagging, the lagging pushes against the soldier piles, the soldier piles push against the waler, and the waler pulls on the tiebacks. If the helical tieback anchors provide enough resistance, the whole system is stable. The design of the wall system (the lagging, soldier piles and the waler) brings the distributed soil force against the lagging toward, and concentrates the load at, the helical tieback anchors. After the tiebacks are installed, they are usually post-tensioned. When helical tiebacks are used for this type of application, they are typically concentrated in a few tiers, and are designed so that all tension resistance is attained within the stable soil mass behind the potential movement plane.

Helical SOIL SCREW® Anchors differ from helical tieback anchors because they are designed to attain pullout resistance within the sliding soil mass as well as the stable mass behind the movement plane. For Helical SOIL SCREW® Anchors to be effective, they must have helices along the whole length of the shaft. When the unstable soil mass begins to slide, it moves against the helices buried within this unstable mass (see Figure 9-5). The resistance generated on the helices within the unstable mass secures the soil directly and reduces the resulting soil pressure against the wall. The net effect is that Helical SOIL SCREW® Anchors reduce the structural requirements for the wall system. In most cases the Helical SOIL SCREW® Anchors are connected directly to the wall without the use of soldier piles or walers. The retaining wall is therefore thinner than a wall required when using tieback anchors.

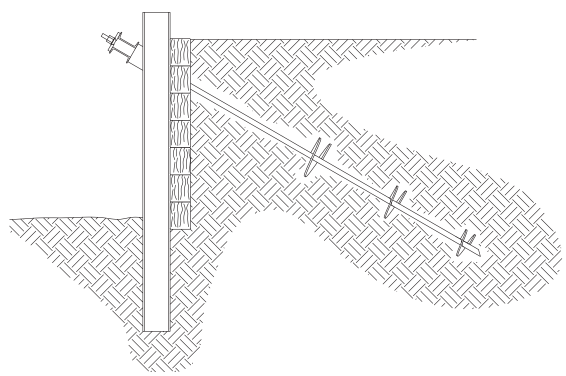
Helical SOIL SCREW® Anchors are more evenly distributed on the wall and therefore carry lighter loads than helical tieback anchors. Helical SOIL SCREW® Anchors should not be post-tensioned as post-tensioning puts bearing stresses on the wrong side of the helices that are embedded in the unstable soil mass. Some engineers require that a small load (1000 pounds or less) be applied to newly installed Helical SOIL SCREW® Anchors to remove any slack in the connections.



Cut Slope with Solder Pile and Lagging
Figure 9-3

Because Helical SOIL SCREW® Anchors are not post-tensioned, the unstable soil mass has to slump slightly before the SOIL SCREW® System can develop resistance. SOIL SCREW® Retaining Walls deflect both vertically downward and laterally outward during this slumping process. The magnitudes of both deflections typically vary from 0.1% to 0.3% of the wall height (see Figure 9-6). For example, the top of a 12-foot high wall will typically deflect from 1/8” to 3/8” downward and outward. Because 3/8” settlement approaches the level that can cause damage in some structures, the Hubbell Power Systems, Inc. Underpinning/Shoring System includes helical tieback anchors at the underpinning bracket whenever excavation depths exceed 12 feet or structural footing loads exceed 4,000 lb/ft. Post-tensioning these tieback anchors prior to excavation allows the deflections at the footing to be controlled to an acceptable level.

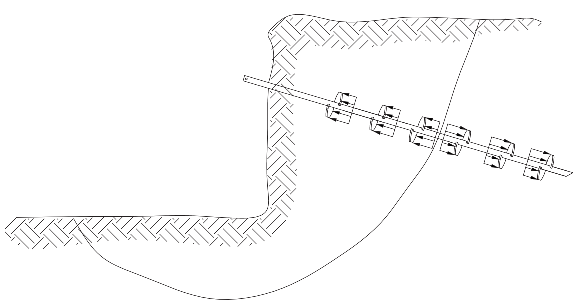
Because of the potential severity of a structural failure involving one of these systems, Hubbell Power Systems, Inc. recommends that a staff application engineer, or an engineer from an authorized CHANCE® Distributor perform a preliminary design and make a final wall design review. The preliminary design will give recommendations for the Helical SOIL SCREW® Anchors and, if the project requires, specific underpinning piers/piles and/or helical tieback anchors to be used on the specific project. Details for the placement of the products, the required embedment depths and minimum installation resistances and torques will be recommended. These preliminary recommendations, estimates of installation depths and wall thickness will aid in preparing cost estimates. Both the installing contractor/dealer and the Engineer of Record shall review these recommendations. The CHANCE® Distributor or Hubbell Power Systems, Inc. Engineer will work with the Engineer of Record as required to resolve any issues regarding the preliminary design. The Engineer of Record must accept and approve the final design before construction can begin.



Cut Slope with Tieback Wall
Figure 9-4

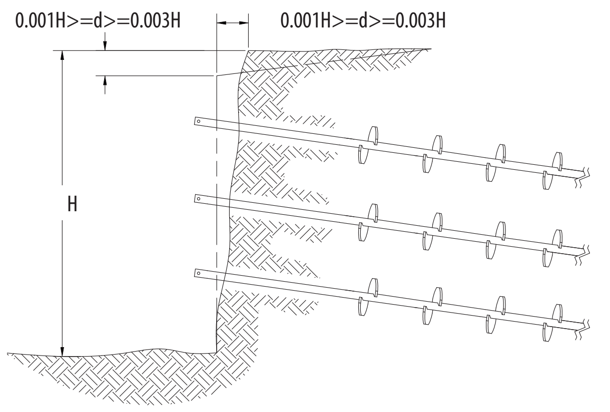
Shotcrete

Shotcrete is portland cement concrete or mortar propelled at high velocity (typically by air pressure) onto a surface. With wet process shotcrete, the dry materials are mixed with water and pumped to a nozzle, where air is added to project the material onto the surface. Dry process shotcrete, also known as “gunite”, delivers the dry material to the nozzle by air pressure where water is added at the point of discharge. The water and dry materials mix during deposition. Each process has its own advantages and disadvantages, but either, or both, may be used to construct the wall facing for the CHANCE SOIL SCREW® Retention Wall System.



Cut Slope Stabilized with
Helical SOIL SCREW® Anchors
Figure 9-5

The wet process allows for high deposition rates up to three times the rate attainable with gunite with less rebound (5% vs. 15% for gunite). In addition, the nozzleman need not be as highly skilled for this process. The major disadvantages to the shotcrete wet process are the extensive cleanup required and the difficulty scheduling ready-mix deliveries. The gunite (dry) process has the advantage of easy clean up and the ability to mix materials on site. Gunite has more disadvantages than shotcrete. Gunite has a relatively low deposition rate (slower application), has more rebound and requires highly skilled operators.



Typical Horizontal and Vertical Deflections
of a SOIL SCREW® Wall
Figure 9-6

The functions of shotcrete in the CHANCE SOIL SCREW® Retention Wall System are:

- To prevent sloughing and spalling of the excavated soil face.
- To prevent buckling of the underpinning pier/pile, if required on the project.
- To transfer the earth pressures to the Helical SOIL SCREW® Anchors instead of the inner wall face.

In some instances, the system is exposed only temporarily. The excavation is usually filled in after the basement wall is constructed or permanent facing is built in front of the system's wall. In some cases, however, the system wall will be permanently exposed and must also perform cosmetic functions.

Flexural strength, shear strength and ductility are the important characteristics of the wall in this application. The wall must resist the movement of the retained soil and restrain the underpinning pier/pile (if used on the project) from buckling, both of which require flexural strength. The wall must also transfer load to the SOIL SCREW® Anchor head, which requires both shear and flexural strength. Because deformation is necessary to generate the resistance that makes the system stable, the wall must tolerate some deformation without losing its strength. The properties of the shotcrete that contribute to these wall characteristics are compressive strength and bond strength.

A structural engineer employed by the owner will typically prepare the final shotcrete wall design. Hubbell Power Systems, Inc. suggests that the wall design be reviewed by one of their staff application engineers or authorized Distributors.

LIMITING LOAD CAPACITIES

Ultimate Tension Strength

The ultimate tension strengths indicated in Table 9-1 represent the net tension strengths of the Helical SOIL SCREW® Anchor shaft/coupling systems. The designer must use an adequate Factor of Safety in the design to preclude Helical SOIL SCREW® Anchor failure in tension. A Factor of Safety of 2:1 is often used.

Torque Strength Rating

The torque ratings indicated in Table 9-1 represent the maximum torque that should be applied to the Helical SOIL SCREW® Anchor during installation in homogeneous soils. The risk of torsional fracture increases significantly as the applied torque increases beyond these limits. In obstruction-laden soils, the maximum torques that should be applied during installation are 80% of the table limits due to the increased risk of torsional fracture posed by impact loading. The designer must consider these torque ratings in evaluating whether the Helical SOIL SCREW® Anchors can be installed to the required depths. In addition, these torque ratings pose practical limits to the ultimate tension capacities that can be developed by limiting the strengths of soils into which the Helical SOIL SCREW® Anchors can be installed. The practical limit to the ultimate tension capacities that can be achieved (in lbs) is about ten times the installation torques (in ft-lbs) that may be applied during installation using a torque factor (K_t) of 10. See Section 6 for a detailed discussion of the correlation of installation torque of a helical anchor to its ultimate tension capacity.

Ultimate Tension Strengths and Torque Ratings for CHANCE® Helical SOIL SCREW® Anchors, Table 9-1

CHANCE® SOIL SCREW® PRODUCT	ULTIMATE TENSION STRENGTH	TORQUE RATING
SS5 Series 1-1/2" (38 mm) Round Corner Sq	70,000 lbs	5,700 ft-lbs*
SS175 Series 1-3/4" (45 mm) Round Corner Sq	100,000 lbs	10,500 ft-lbs*
*Refer to Ultimate Tension Strength and Torque Rating in the text. Practical load limits in the field may be limited due to the factors discussed in the above paragraph.		

GENERAL CONSTRUCTION CONSIDERATIONS of UNDERPINNING/SHORING SYSTEMS

The CHANCE SOIL SCREW® Retention Wall System for underpinning/shoring next to an existing structure is a specialized construction process and must be installed by Certified CHANCE® Installer. Listed below are some general items regarding the construction procedures:

WARNING! DURING THE COURSE OF CONSTRUCTION, THE FOOTING AND FACE OF THE SHORING SHOULD BE CONTINUOUSLY MONITORED FOR ANY MOVEMENTS. IF MOVEMENTS ARE NOTED, THE CONSTRUCTION PROCESS SHOULD BE STOPPED, TEMPORARY BRACING INSTALLED AND THE ENGINEER AND/OR GEOTECHNICAL ENGINEER SHOULD BE IMMEDIATELY NOTIFIED FOR FURTHER DIRECTION.

1. As is the case in conventional underpinning of buildings using ATLAS RESISTANCE® Modified Piers or CHANCE® Helical Piles, the footing must be properly prepared so that the pier/pile bracket can be positioned under the footing with a minimum of eccentricity with the wall load. This process may involve chipping the concrete to provide a proper bearing surface and creating a notch in the spread footing to reduce pier/pile eccentricity.
2. For those projects requiring underpinning and CHANCE® Helical Tieback Anchors at the pier/pile bracket, the tieback must be installed to the required length and torque prior to installing the underpinning system.
3. If ATLAS RESISTANCE® Modified Piers are used as the underpinning system, the process requires the use of pier sleeving to prevent buckling at the joints of the pier pipe. Every sleeve joint must be at least 18” away from a pier pipe joint. In some cases grouting of the pier pipe along with the insertion of a steel reinforcement bar may be specified.
4. The pier sleeving must be installed to a minimum of 2 feet below the deepest excavation (cut).
5. If using ATLAS RESISTANCE® Modified Piers, the piers shall be driven to the required depth and load tested to 150% of the design load. Then each pier shall be preloaded to at least 95% of the design load and locked off. If using CHANCE® Helical Piles as the underpinning system, the helical piles shall be installed to the required minimum depths and minimum average installation torques.
6. When the ATLAS RESISTANCE® Pier or CHANCE® Helical Pile underpinning system installation is complete, the helical tieback anchor shall be attached to the pier/pile bracket and preloaded. Normally the tieback is preloaded to the design load.
7. Upon completion of all of the underpinning and tieback operations, the wall face excavation can commence. If the soils are generally cohesionless (sands, etc.) or there is any danger of the soil face sloughing off, a 1” thick flash coat of shotcrete shall be immediately placed against the face of the cut as the excavation proceeds. If the cut soil is capable of standing by itself, then the first layer of shotcrete can be applied after the initial cut is complete. The same procedure shall be followed for subsequent incremental excavations. Under no circumstances should a cut of any height be left open at the face for more than two hours.
8. The depth of cut on the first excavation, as well as on subsequent incremental excavations shall be at least one foot deeper than the depth of the row of Helical SOIL SCREW® Anchors. See Figure 9-13, which shows a 6-foot cut and 5-foot deep row of Helical SOIL SCREW® Anchors.
9. When the first excavation is complete (with or without shotcrete flash coating), the first row of CHANCE® Helical SOIL SCREW® Anchors is installed to the requirements indicated in the design specifications (length of installation, minimum torque, installation angle, etc.). A Helical SOIL SCREW® Anchor shall be positioned immediately adjacent to each underpinning pier/pile. Shotcrete is placed onto the cut face to 1/2 of the total specified shotcrete thickness.
10. The welded wire mesh reinforcement is set against the face of the wet shotcrete along the cut face of the wall with excess reinforcement turned outward at the bottom of the cut to allow for overlap of reinforcement on successive stages.
11. Welded rebar assemblies with bearing plates are positioned over each Helical SOIL SCREW® Anchor and secured against the welded wire mesh reinforcement and (still) wet shotcrete face.
12. The remaining shotcrete is installed to provide the total thickness specified.
13. Steps 7 through 12 above are repeated after each incremental excavation. Stabilization continues until all of the Helical SOIL SCREW® Anchors are installed and the reinforced shotcrete wall is completed to the design depth.

CONCEPTS and APPLICATIONS of UNDERPINNING/SHORING SYSTEMS

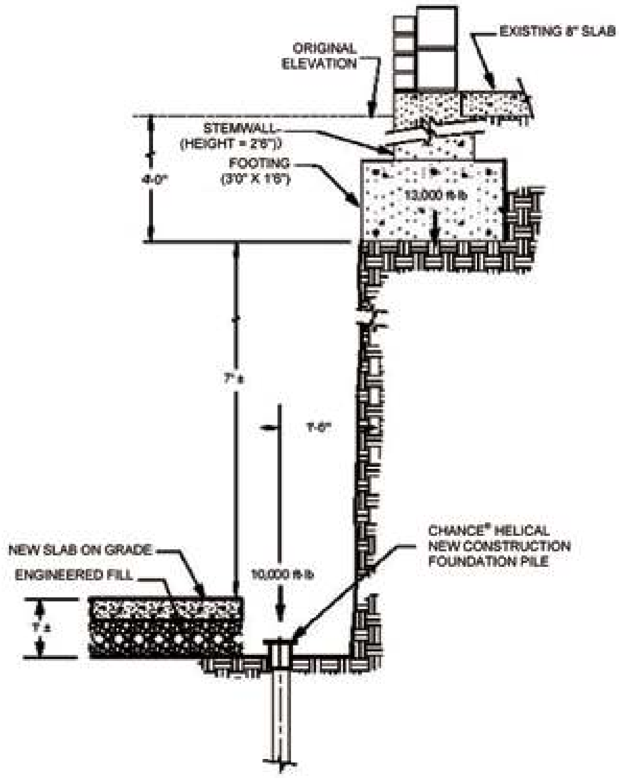
BACKGROUND

The construction of additions to office and commercial buildings or new construction adjacent to existing buildings requires earth excavation much deeper than the footing elevation of the immediately adjacent building(s). The use of sheet pile and/or H-piles with wood lagging to prevent adjacent footing subsidence requires the use of dynamic pile driving equipment with the attendant vibrations and noise levels. There are decided disadvantages to these traditional approaches since the vibrations may cause movement of the existing building foundation and subsequent structural damage. Additionally, the vibration levels can often lead to a shutdown of business operations if conducted during normal working hours.

Hubbell Power Systems, Inc. offers an underpinning/shoring system that not only avoids the vibrations and noise level issues, but also permits the shoring and excavation to proceed at a more rapid pace. In many cases this results in an overall cost savings to the prime contractor and owner. The examples covered below are intended to illustrate some of the design concepts and applications of this system.

In conducting preliminary designs for projects using the underpinning/shoring system and in the development of the case studies that follow, Hubbell Power Systems, Inc. uses certain guidelines. These guidelines are briefly summarized below:

1. Hubbell Power Systems, Inc. does not currently recommend using the underpinning/shoring system for excavations exceeding 25 feet.
2. Although ATLAS RESISTANCE® Piers or CHANCE® Helical Foundation Piles can be used for the underpinning stage; it is preferred to use the ATLAS RESISTANCE® Pier if "hard stratum" is within a reasonable depth at the proposed construction site.
3. The ATLAS RESISTANCE® Piers used for underpinning the existing building foundation must be sleeved with the joints of the sleeves offset from the joints of the underpinning pier pipe.
4. It is recommended in cases where the line load equals or exceeds 4,000 pounds per lineal foot and/or the depth of cut exceeds 12 feet to use a CHANCE® Helical Tieback integrated at the pier bracket level. This requirement uses the pier and tieback combination as illustrated in Figure 9-11. This helical product is used as a tieback anchor and not a SOIL SCREW® Anchor.
5. Helical SOIL SCREW® Anchors must be installed at a minimum downward angle of 5° and generally not to exceed 15°.
6. All Helical SOIL SCREW® Anchors have the same size helix plates continuously along the installed length of the shaft.
7. The bottom cantilever of shotcrete wall should be limited to 2/3 of the typical spacing for the Helical SOIL SCREW® Anchor row, but should not exceed 3 feet.
8. If the foundation soils to be excavated contain cohesionless soils (sands, sands and gravels and gravel and silty sands) a "flash coat" of shotcrete should be applied immediately as the cut is made.
9. CHANCE® Installers must receive formal training in the "concept" and "field installation technique" prior to using the underpinning/shoring system on an actual project.



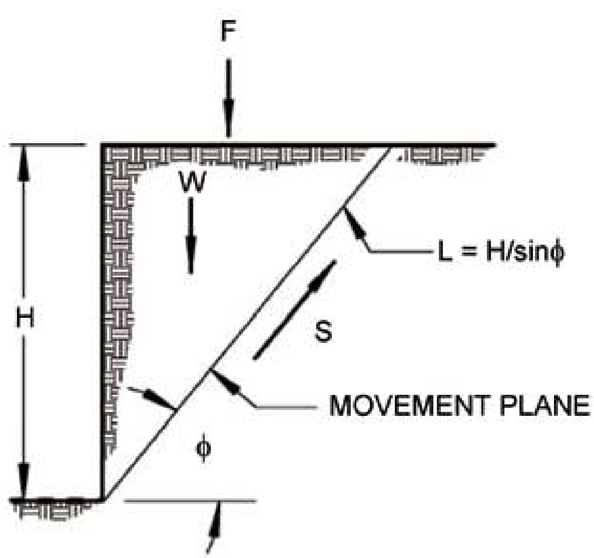
Cross Section of Existing Footing and Planned Excavation
Figure 9-7

NOTE: The designs and data shown in the following examples are not intended for use in actual design situations. Each project and application is different as to soils, structure and related factors.

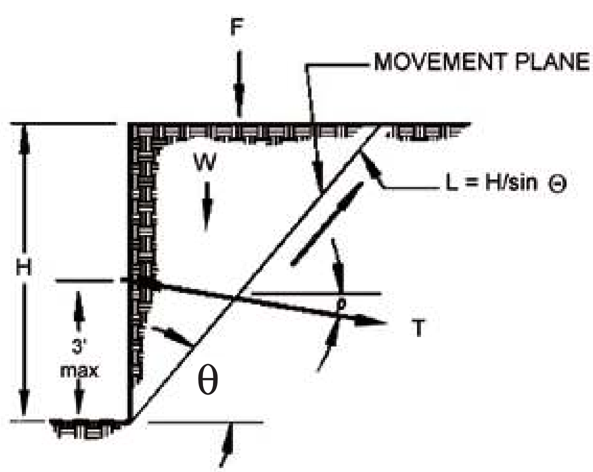
CASE STUDY 1 - HIGH FOUNDATION LINE LOAD with SHALLOW CUT

Northern Excellence University is planning to construct an addition to the existing Book Science Building. The existing building has a continuous perimeter footing as shown in Figure 9-7. The building is a 3-story structure and has a foundation line load of 13,000 pounds per lineal foot. This reinforced concrete footing is seated about 4 feet below the existing ground line as noted in Figure 9-7. There are no column footings at the exterior wall of the existing building immediately adjacent to the proposed addition.

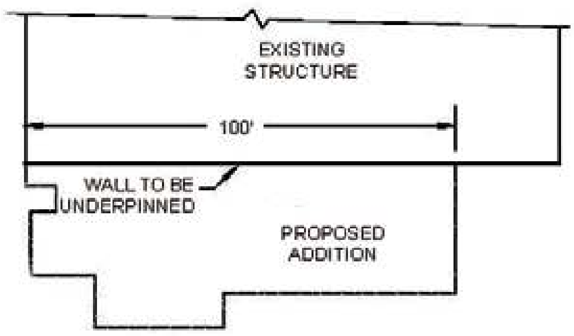
The proposed building addition will be placed immediately adjacent to a 100-foot section of one wall of the existing building as shown in Figure 9-10. The foundation for the new building will also be a reinforced concrete continuous footing, but it will be set eight feet below the bottom of the existing building footing as shown in Figure 9-7. The estimated footing load for the new addition is 10,000 pounds per lineal foot. As noted in Figure 9-7, a surcharge load will exist arising from the Live Load on the floor slab (100 lb/ft^2), the weight of the concrete slab and the overburden pressure from approximately 3-1/2 feet of soil cover over the top of the existing footing.



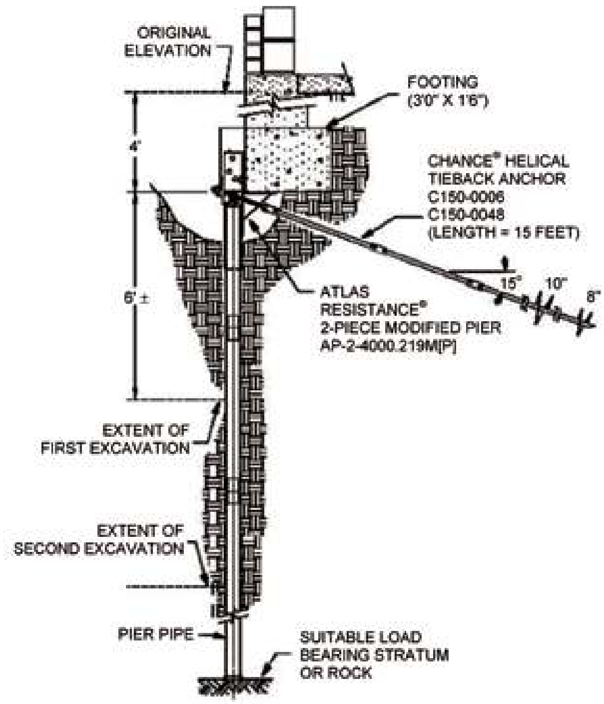
Analysis of Soil Mass Forces
Figure 9-8



Analysis of Stabilized Mass Forces
Figure 9-9



Plan View of Job Site
Figure 9-10



Existing Structure Underpinning with Integral Tieback Anchor
Figure 9-11

A geotechnical investigation was conducted at the site and the results showed that below the first foot of topsoil, a stratum of silty to sandy clay existed to a depth of 18 feet. The Standard Penetration Test (SPT) blow count, "N" for this soil was consistently in the 9 to 10 range through the 18 feet. Both by correlation with the "N" values and from the results of hand held penetrometer tests on the soil, this silty to sandy clay was determined to have a cohesion, "c" of 1,000 pounds per square foot and a friction angle, "φ" of 10°. Below the 18 feet of silty to sandy clay a stratum of weathered sandstone was encountered to the bottom of the borings at 20 feet at which the driller experienced auger refusal. No ground water was encountered during the soil borings.

Underpinning System - ATLAS RESISTANCE® Modified Piers

As noted above, a stratum of sandstone exists at the site beginning at a depth of 18 feet. Auger refusal was experienced at a depth of 20 feet. Allowing for four feet from the ground elevation of the boring log to the bottom of the footing to be underpinned indicates that the length of the underpinning pier pipe will be 16 feet. The existing footing line load is:

$$p = 13{,}000 \text{ lb/ft}$$ **Equation 9-1**

If we assume a pier spacing of 4 ft, center to center, the load per pier becomes:

$$p_{des} = 13{,}000 \text{ lb } (4 \text{ ft}) = 52{,}000 \text{ lbs}$$ **Equation 9-2**

Based on a requirement of installing an ATLAS RESISTANCE® Pier to a tested load resistance of at least 50% higher than the design load leads to:

$$DS = 52{,}000\ (1.5) = 78{,}000 \text{ lbs}$$ **Equation 9-3**

An ATLAS RESISTANCE® 2-Piece Modified Pier part number AP-2-4000.219[M] is selected. This pier is designed with a 4" diameter pier pipe and has an ultimate capacity of 98,000 lbs. The "M" indicates the use of 4-1/2" diameter sleeving over the pier pipe. The sleeved portion of the pier shall extend down to a depth of 10'-6" (three lengths of sleeve pipe). Since this is temporary construction, corrosion protection is unnecessary. Details of the underpinning and tieback anchorage are shown in Figure 9-11.

INTEGRATED TIEBACK SYSTEM - CHANCE® Helical Tieback Anchors

Following the recommendation of using an integrated tieback whenever the line load exceeds 4,000 lbs/ft, a CHANCE® Helical Tieback Anchor must be selected for used with each ATLAS RESISTANCE® 2-Piece Modified Pier placement. For this situation, the C1500006 Tieback Anchor Lead Section and C1500048 Tieback Extension with coupling and hardware is recommended.

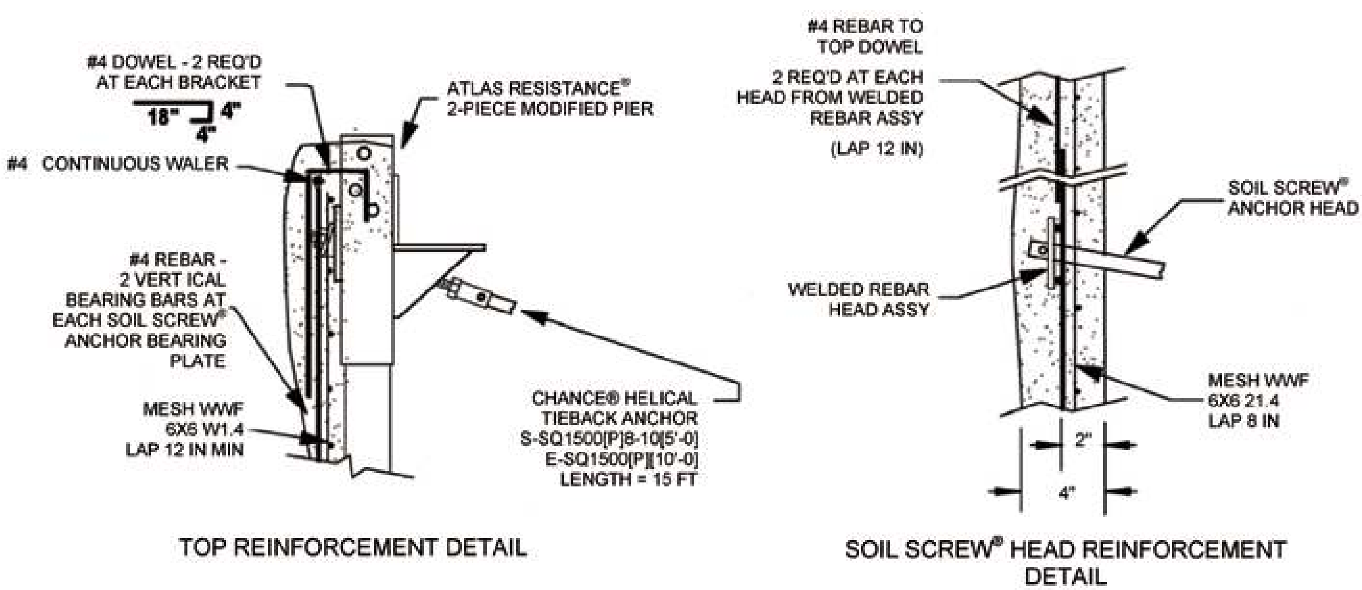
The installed length is estimated to be 15 feet. The installed angle is 15° down from horizontal. The lead section consists of one 8-inch and one 10-inch diameter plate welded to a 1-1/2" square solid steel shaft. Installed torque is estimated to be 2,000 ft-lbs, minimum. No corrosion protection is required because the construction is temporary.

SOIL SCREW® RETENTION WALL SYSTEM

The body mass of soil that would slide along the movement plane if failure were to occur as excavation takes place is illustrated in Figure 9-8. If one uses the soil properties previously listed with an assumed failure plane angle (θ) of 51°, the driving force and resisting force may be calculated. In order to provide a Factor of Safety against failure of the body mass, a single line of CHANCE® Helical SOIL SCREW® Anchors will be used. A minimum Factor of Safety of 2.0 is required against such a failure. (Note that the typical design Factor of Safety for Helical SOIL SCREW® Anchors ranges from 1.3 to 2.0.) A Factor of Safety of 2.0 was selected because of the very high foundation line load of the existing footing above the excavation. In conducting the SOIL SCREW® Anchor analysis, it assumed that the CHANCE® Helical tieback anchors did not contribute to the holding capacity of the body mass of soil even though the tieback prevents cantilever at the top of the wall.

Also shown in Figure 9-8 is the resistance to movements that occur along the movement plane arising from the shear strength of the soil. This shear strength is made up of both the cohesion and friction acting along that plane.

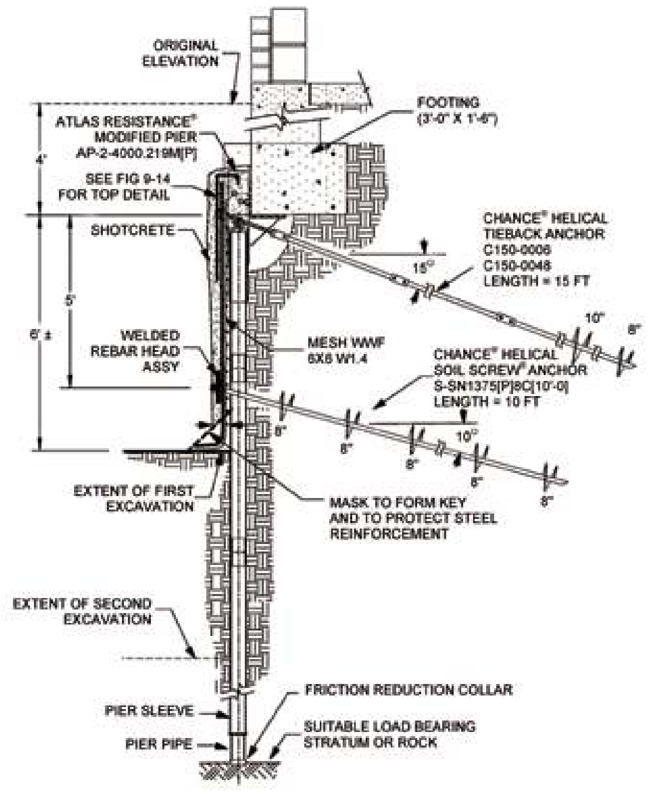
In Figure 9-9 the same body mass of soil is shown, but now the single Helical SOIL SCREW® Anchor shown provides additional resistance to sliding that develops along the movement plane. If the installation angle of the Helical SOIL SCREW® Anchor is 10°, the new driving force and new resisting force may be calculated.



Reinforcement Details for Case Study #1
Figure 9-12

Generally, the Factor of Safety is illustrated by the following equation:

	FS	=	RF / (DF - SSCF)	**Equation 9-4**
where	FS	=	Factor of Safety	
	RF	=	Resisting force	
	DF	=	Driving force	
	SSCF	=	SOIL SCREW® Anchor component force	



SOIL SCREW® Anchor Configuration for Case Study #1
Figure 9-13

Resisting Force (RF) arises from the shear strength of the soil (c and φ) along the movement plane and the Helical SOIL SCREW® Anchor component parallel to the movement plane. Driving Force (DF) is the component of the soil body mass (weight) in the direction of the movement plane. Helical SOIL SCREW® Anchor Component Force (SSCF) is the component of the total Helical SOIL SCREW® Anchor holding capacity (ultimate capacity) in the direction of the movement plane. Internal stability analysis as described herein is typically done with commercially available software such as SNAILZ (Caltrans) or Gold Nail (Golder Associates); see the CHANCE® Soil Screw® Retention Wall System Design Manual for an example. Helical SOIL SCREW® Anchor tension capacity is calculated with HeliCAP® Helical Capacity Design Software and input into the stability analysis software.

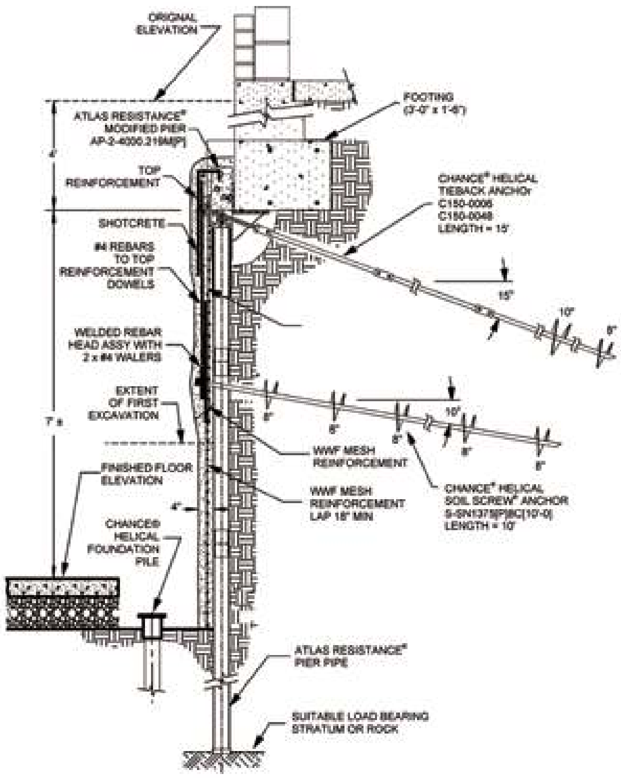
For the specific conditions defined above, the CHANCE® Helical SOIL SCREW® Anchor Lead Section C1100692 and C1100690 Extension is selected. The Helical SOIL SCREW® Anchor lead section consists of 8" diameter plates welded along the entire length of a 1-1/2" square shaft. Minimum installed length is 10 feet. Installed angle is 10° down from horizontal. Installed torque is estimated to be 1,500 ft-lb minimum. The single row of Helical SOIL SCREW® Anchors is set immediately adjacent to each underpinning pier pipe at a depth of 5 feet below the integrated tieback anchor (this will maintain the 3 foot maximum allowable bottom cantilever). No corrosion protection is required.

SHOTCRETE WALL

The shotcrete wall is a temporary facing for the excavation. Since there is a CHANCE® Helical Tieback Anchor at the top, the wall will be laterally anchored at the pier brackets to allow longer spacing for the single row of Helical SOIL SCREW® Anchors. The bottom cantilever should be 3 feet.

The vertical bearing bars are extended from the welded rebar head assembly to the dowels and waler at the top of the wall in order to augment the welded wire fabric reinforcing (see Figures 9-13 and 9-14).

The top wall segment is checked for flexure and shear using the distributed SOIL SCREW® Anchor head forces and one-way beam action. Two #4 reinforcing bar walers shall be placed continuously along the SOIL SCREW® Anchor row. The selected wall thickness is 4". Reinforcing is a welded wire fabric (WWF 6x6 W.14 or equivalent) spaced midway in the shotcrete wall at a 2" nominal depth.



Excavation to the Final Elevation
Figure 9-14

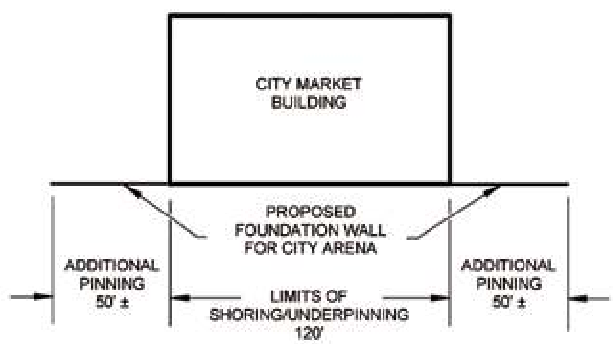
SOIL SCREW® ANCHOR HEAD DESIGN

The shotcrete wall design is critical to the punching shear of the SOIL SCREW® Anchor heads and flexural strength of the all face between the SOIL SCREW® Anchor heads. The SOIL SCREW® Anchor head forces are expected to be approximately 1/2 of the total SOIL SCREW® Anchor tension load. The shotcrete facing is checked for flexure and punching shear using two-way slab action. This information is used in the internal stability analysis. A welded rebar head assembly can be used at each placement to provide local reinforcement. It is spliced to the horizontal walers and the vertical bearing bars previously described. To accomplish the proper positioning of the welded rebar head assembly and rebar, the welded wire fabric must be pushed into the initial 2” face coat of shotcrete approximately 1/2” at each SOIL SCREW® Anchor head. The 4” wall thickness and reinforcement selected above are adequate.

The first 6 feet of soil is excavated and the soil body mass is stabilized. Figure 9-13 shows the installation of a CHANCE® Helical SOIL SCREW® Anchor, welded wire reinforcement, welded rebar head assembly and shotcrete. Note that the shotcrete stops short of the bottom of the excavation to allow for splicing the welded wire mesh reinforcement and a suitable shotcrete joint. Figure 9-14 show excavation to the final elevation along with continued stabilization of the soil mass. Construction of the new foundation begins with the installation of CHANCE® New Construction Helical Piles.

CASE STUDY 2 - LOW FOUNDATION LINE WITH DEEP CUT

The City of High Hope is planning to build a new multi-purpose arena that will seat 8,000 people. The arena will be located within the downtown district. A 20-foot deep cut will be required for the new construction to provide sufficient elevation for the arena seating yet maintain a low ground level building profile. A portion of the arena wall will be immediately adjacent to the existing historic city market building (see Figure 9-15). The city market building is a single story warehouse that measures 60 by 120 feet. The back wall of the market building will abut the new arena wall. The market building was constructed in the early 1900s and has an unreinforced concrete grade beam foundation that measures three feet wide by two feet deep. The grade beam, seated three feet below the existing grade, has a line load of 3,000 lbs per lineal foot. The general configuration of the footing along with installed underpinning and tieback is shown in Figure 9-16.



Plan View of Job Site
Figure 9-15

A geotechnical investigation conducted at the site found a 30-foot thick stratum of silty sand below approximately two feet of topsoil and fill material that consisted of silt, sand and cinders. The Standard Penetration Test (SPT) blow count "N" in this silty sand increased with depth from N=13 to N=18. Sufficient silt is present in the sand to hold a shallow vertical cut for a short period of time. Below the silty sand stratum at a depth of 32 feet the borings encountered a hard glacial till of clayey sand and gravel. The SPT value recorded were N=50+. By correlating the N values, the friction angle of the silty sand (ϕ) was estimated to be 30°. The ground water table (GWT) was located at 15 feet which means dewatering will be required prior to excavation.

Based on discussion with the designer and contractor, a decision was made to use the CHANCE® Helical underpinning/shoring technique in the immediate vicinity of the city market building. The Helical SOIL SCREW® Anchors will continue for an additional 50 feet on each side of the market building as the slope is cut in a benched pattern. Beyond this zone, adequate clear distance exists to back-slope the cut side without providing any wall retaining system.

Underpinning System - ATLAS RESISTANCE® Modified Piers

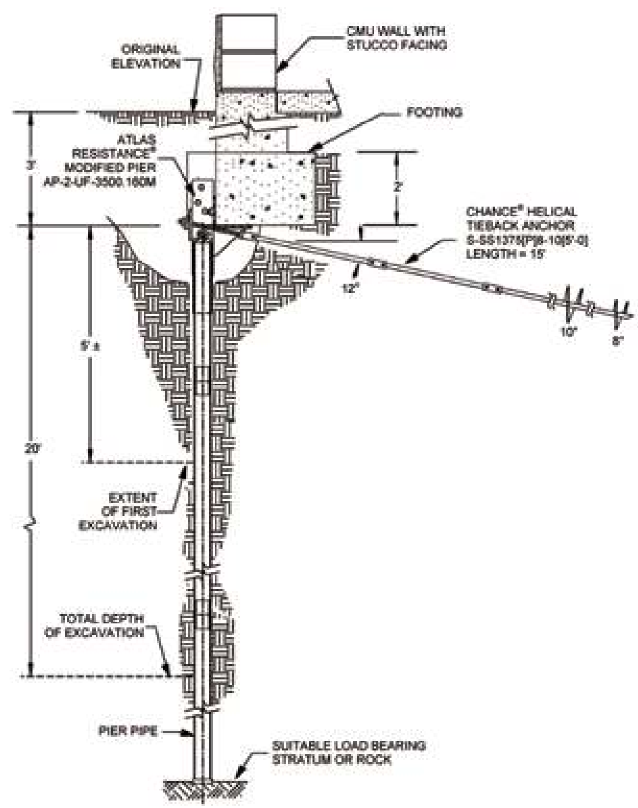
As noted above, a hard glacial till exists at a depth of 29 feet below the bottom of the market building footing. The estimated length of the underpinning pier pipe is 32 feet. The existing line load is 3,000 lb/ft. Although the footing line load is relatively light, the fact that the 24" thick footing is not reinforced will limit the spacing of the piers to five feet on center. Based on this spacing, the design load per pier becomes:

$$P_{des} = 3{,}000 \text{ lb } (5 \text{ ft}) = 15{,}000 \text{ lbs} \qquad \textbf{Equation 9-5}$$

Based on the requirement of installing ATLAS RESISTANCE® Modified Piers to a tested load resistance of at least 50% higher than the design load leads to:

$$DS = 15{,}000\ (1.5) = 22{,}500 \text{ lbs} \qquad \textbf{Equation 9-6}$$

For this requirement, the ATLAS RESISTANCE® AP-2-3500.165[PA] M 2-Piece Modified Pier is selected. The modified pier has a 3-1/2" diameter pier pipe and has an ultimate capacity of 91,000 lbs. "M" indicates the use of 4" diameter sleeving over the pier pipe. The sleeved portion of the pier shall extend down to a depth of 21 feet (six lengths of sleeve pipe). "PA" indicates the product is manufactured of mill finish steel (plain) with flow coated corrosion protection of the pier pipe. Since this is temporary construction, the corrosion protection is unnecessary; however this product is supplied with corrosion protected pipe as standard. Details of the underpinning and tieback anchorage are shown in Figure 9-16.



SOIL SCREW Configuration for Case Study #2
Figure 9-16

Integrated Tieback System - CHANCE® Helical Tieback Anchors

Although the footing line load is less than the 4,000 lb/ft criteria, the depth of the cut to be shored is 20 feet. This exceeds the recommended 12 foot limitation and as such a CHANCE® Helical Tieback Anchor must be selected for use with each modified pier placement. For this situation Type SS5 1-1/2" square shaft Lead Section and Extension are the recommended components.

The lead section consists of one 8" and one 10" diameter plate welded to a 1-1/2" square shaft. Minimum installed length is estimated to be 15 feet. Installed angle is 12° down from horizontal. Installed torque is estimated to be 1,800 ft-lb minimum. No corrosion protection is required since the construction is temporary.

SOIL SCREW® Shoring System - CHANCE® Helical SOIL SCREW® Anchors

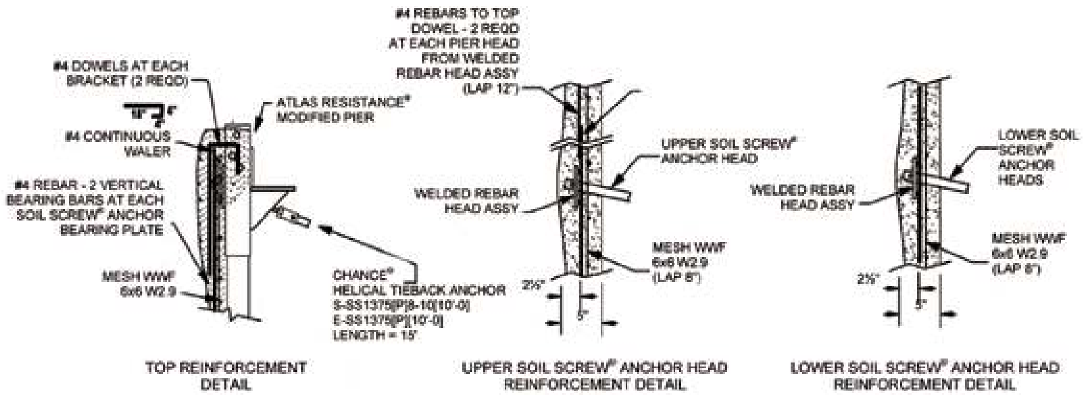
Because the depth of cut is 20 feet from grade (17 feet below the bottom of the footing of the market building), three Helical SOIL SCREW® Anchors are required. In this case a Factor of Safety of 1.5 was used because the existing market building is relatively light. In conducting the soil analysis, it was assumed that the CHANCE® Helical Tieback Anchor does not contribute to the holding capacity of the body mass of soil. As in Case Study 1, internal stability analysis is typically done with commercially available software such as SNAILZ (Caltrans) or GoldNail (Golder Associates), and SOIL SCREW® Anchor tension capacity is calculated with HeliCAP® Helical Capacity Design Software and input into the stability analysis software. In this project, the shear strength is from the frictional nature of the cohesionless soil (silty sand) and its magnitude is related to the friction angle ($\varphi = 30°$ in this case).

As described in the CHANCE® SOIL SCREW® Retention Wall System Design Manual, SOIL SCREW® Anchors add to the resisting force along the movement plane. In this case, however, the indicated force (T) is the resultant of all three rows of Helical SOIL SCREW® Anchors. Placement of the three rows of Helical SOIL SCREW® Anchors is shown in Figure 9-18. The value for the ultimate holding capacity required (including the Factor of Safety) is:

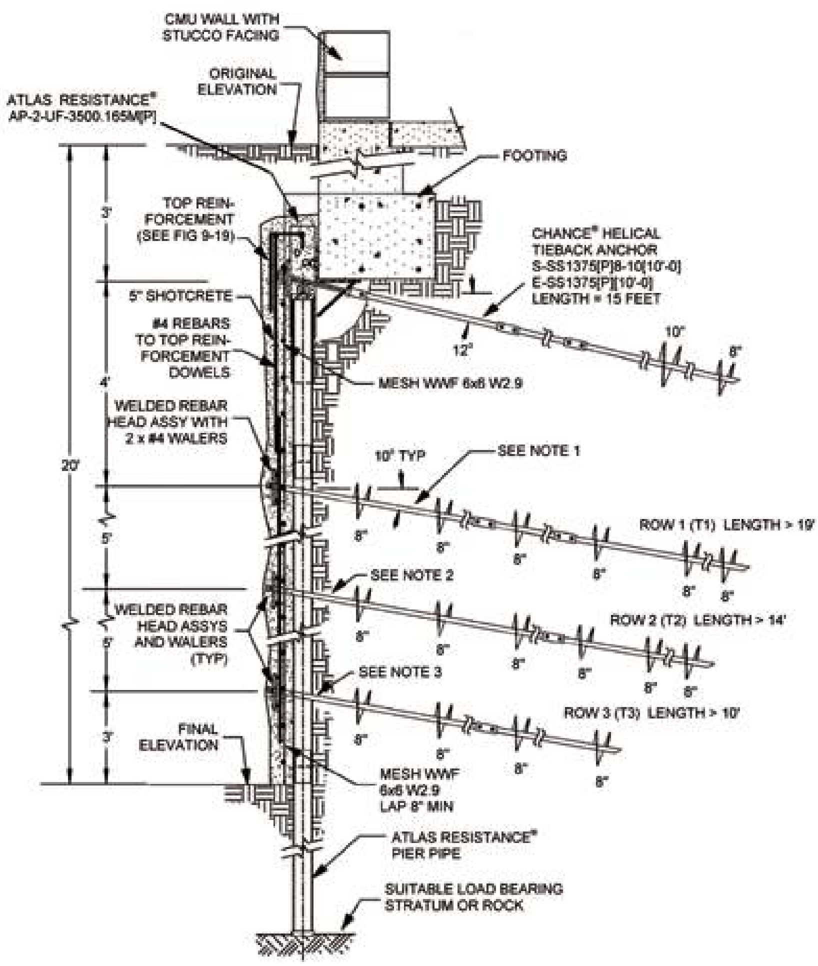
$$T = T_1 + T_2 + T_3 \qquad \textbf{Equation 9-7}$$

The results of extensive testing of soil nail walls indicate that the top row of soil nails or screws is most heavily loaded with the successively lower rows having lesser holding capacity requirements. The following are the recommended CHANCE® Helical SOIL SCREW® Systems for this project:

- SOIL SCREW® Anchor Row #1 (T_1): C2200691 Lead and two C1100689 Extensions. The SOIL SCREW® Anchor has continuously spaced 8" diameter plates along the entire length of a 1-1/2" solid square steel shaft. The SOIL SCREW® Anchor will be installed to a minimum length of 19 feet, 10° down from horizontal and to an estimated torque of 2,500 ft-lbs.
- SOIL SCREW® Anchor Row #2 (T_2): C2200691 Lead and one C1100689 Extension. The SOIL SCREW® Anchor has continuously spaced 8" diameter plates along the entire length of a 1-1/2" solid square steel shaft. The SOIL SCREW® Anchor will be installed to a minimum length of 14 feet, 10° down from horizontal and to an estimated torque of 1,800 ft-lbs.
- SOIL SCREW® Anchor Row #3 (T_3): C1100692 Lead and C1100690 Extension. The SOIL SCREW® Anchor has continuously spaced 8" diameter plates along the entire length of a 1-1/2" solid square steel shaft. The SOIL SCREW® Anchor will be installed to a minimum length of 10 feet, 10° down from horizontal and to an estimated torque of 1,000 ft-lbs.



Reinforcement Details for Case Study #2
Figure 9-17



NOTE 1: CHANCE® HELICAL SOIL SCREW® - S-SN1375[P]8C[10'-0] - E-SN1375[P][10'-0] - LENGTH = 20'

NOTE 2: CHANCE® HELICAL SOIL SCREW® - S-SN1375[P]8C[10'-0] - E-SN1375[P][6'-8] - LENGTH = 16'-8"

NOTE 3: CHANCE® HELICAL SOIL SCREW® - S-SN1375[P]8C[10'-0] - E-SN1375[P][6'-8] - LENGTH = 13'-4"

Excavation and Stabilization
Figure 9-18

Shotcrete Wall

The shotcrete wall is a temporary facing for the excavation. Since the soil analysis assumed that the CHANCE® Helical Tieback Anchors do not contribute to the holding capacity of the body mass of soil (see Figure 9-8), the CHANCE® Helical SOIL SCREW® Anchors were designed to hold the total body mass. The bottom cantilever should be limited to 2/3 of the typical spacing for the SOIL SCREW® Anchor row, but should not exceed 3 feet. In this case the cantilever is 3 feet.

Vertical bearing bars are extended from the welded rebar head assemblies at the upper row of SOIL SCREW® Anchors to the dowels and waler at the top of the wall in order to augment the selected shotcrete wall thickness (5”). Welded wire fabric reinforcing (WWF 6x6 W2.9 or equivalent) is spaced midway within the shotcrete wall at a 2-1/2” nominal depth. The top wall segment is checked for flexure and shear using the distributed SOIL SCREW® Anchor head forces and one-way beam action. Two #4 reinforcing bar walers are placed continuously along each SOIL SCREW® Anchor row (see Figures 9-17 and 9-18).

SOIL SCREW® Anchor Head Design

The SOIL SCREW® Anchor head forces are expected to be approximately 1/2 of the SOIL SCREW® Anchor tension load. The shotcrete facing is checked for flexure and punching shear using two-way slab action. This information is used in the internal stability analysis. A wall plate could have been placed at the wall face to maximize punching shear resistance, but in this example a welded rebar head assembly that includes a wall plate is placed on each Helical SOIL SCREW® Anchor at the middle of the shotcrete wall as shown in Figure 9-18 (refer to SOIL SCREW® Anchor Wall Accessories for details of the welded rebar head assembly). The welded rebar head assembly shall be spliced to the horizontal walers at each row of Helical SOIL SCREW® Anchors and to the vertical bearing bars between the upper row of Helical SOIL SCREW® Anchors and the dowels at the pier brackets. To properly position and embed the welded rebar head assembly and rebar, the welded wire fabric must be pushed into the initial 2-1/2” face coat of shotcrete approximately 1/2” at each SOIL SCREW® Anchor head. The 5” wall thickness and reinforcement described above are adequate.

References:

1. AASHTO Highway Subcommittee on Bridges and Structures, Manual on Foundation Investigations, American Association of State Highway and Transportation Officials, 1978.
2. Federal Highway Administration Publication No. FHWA-SA93-026, Recommendations Clouterre, English Translation, 1993.
3. Federal Highway Administration Publication No. FHWA-SA-96-069, Manual for Design and Construction Monitoring of Soil Nail Walls, 1996.
4. Federal Highway Administration Publication No. FHWA-SA-96-071, Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines, 1996.
5. Federal Highway Administration Publication No. FHWA-SA-96-072, Corrosion/Degradation of Soil Reinforcement for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, 1996.

FOUNDATION LIGHTING AND SIGNS SYSTEM
SECTION 10

CONTENTS

SYMBOLS USED IN THIS SECTION

FS	Factor of Safety	10-5
AASHTO	American Association of State Highway and Transportation Officials	10-7
EPA	Effective Projected Area	10-7

DISCLAIMER

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

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

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

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

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

INTRODUCTION

Hubbell Power Systems, Inc. manufactures the Foundation Lighting and Signs System to provide resistance to lateral loads and moment loads due to wind and other load conditions. The versatility and ease of construction of the CHANCE® Foundation Lighting and Signs System permits great flexibility in a number of applications. Typical uses for these products are foundations for equipment pads, foundation supports for signs, supports for light standards and decorative poles, and other eccentric load applications.

PRODUCT BENEFITS

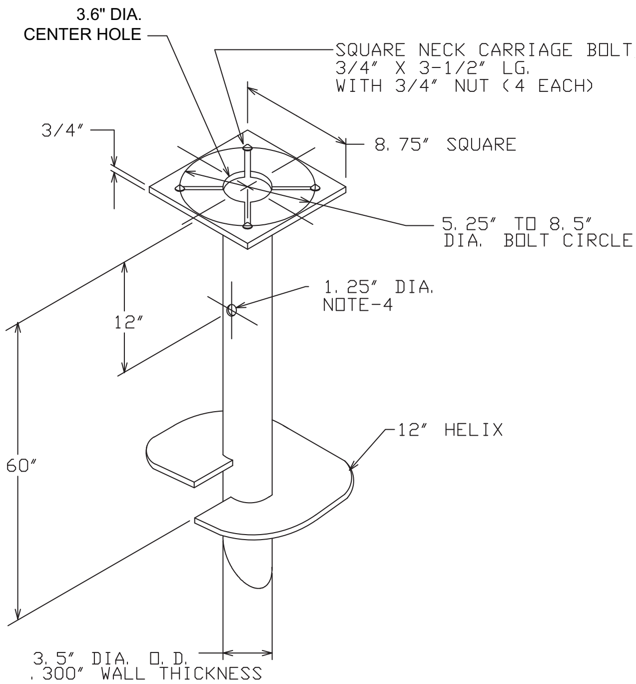
The Foundation Lighting and Signs System offers the following benefits:

- Fast installation.
- No vibration.
- Ease of installation in limited access areas.
- Minimum disturbance to site.
- No excavation required.
- All steel foundation.
- Immediate structure installation.
- Ready for immediate wiring.
- All weather installation.
- On-site load test capability.

This section describes the CHANCE® Foundation Lighting and Signs System products for overturning moment loads and lateral support that are typically maintained in stock to provide quick delivery to the project site. Table 10-1 and Figure 10-1 illustrate just a few of the Foundation Lighting and Signs products that are available in each of the product series. Our manufacturing facility is capable of rapidly fabricating products to suit the application.

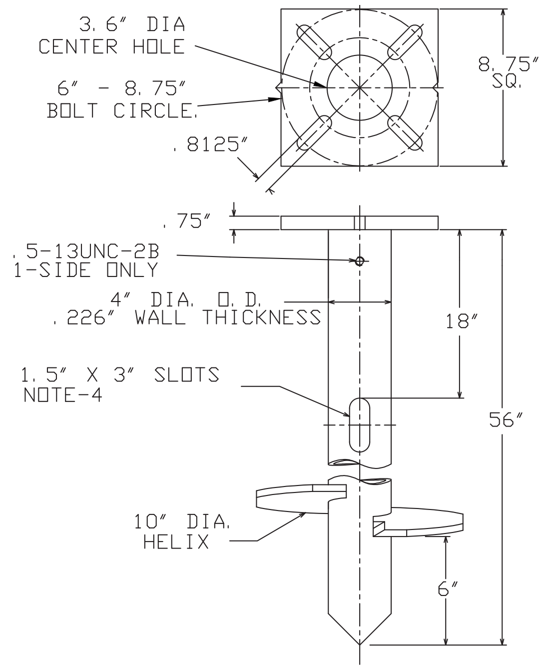
FOUNDATION LIGHTING AND SIGNS System Product Selection, Table 10-1

DETAIL	CATALOG NO	PILE DIA	LENGTH	NOTES
A	T1120143	3-1/2"	5' - 0"	1. Manufacturer to have in effect industry recognized written quality control for all materials and manufacturing processes. 2. All material to be new, unused and mill traceable meeting specifications found on product drawing. 3. Additional lengths and configurations are available as standard catalog numbers.
B	T1120338	4"	4' - 8"	
C	C11232JG4VL	6-5/8"	5' - 0"	
D	C11242NG4VP	8-5/8"	5' - 0"	
E	T1120592	10-3/4"	5' - 0"	



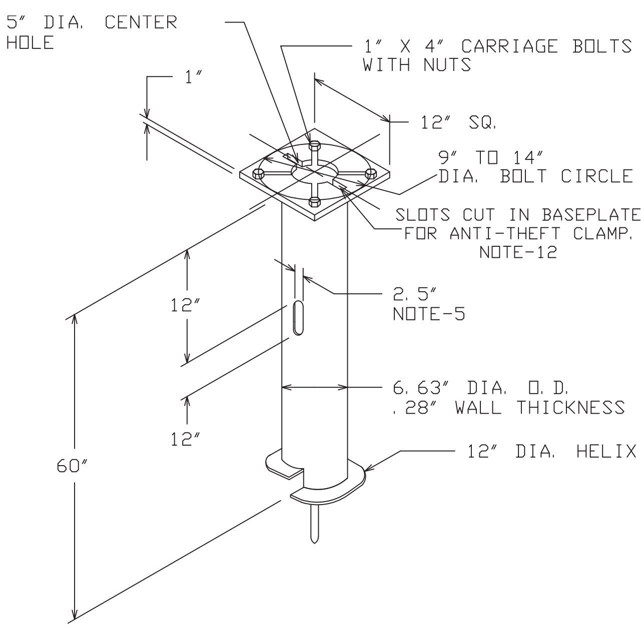
A

LIGHTING FOUNDATION
CAT. NO. T1120143
Figure 10-1A



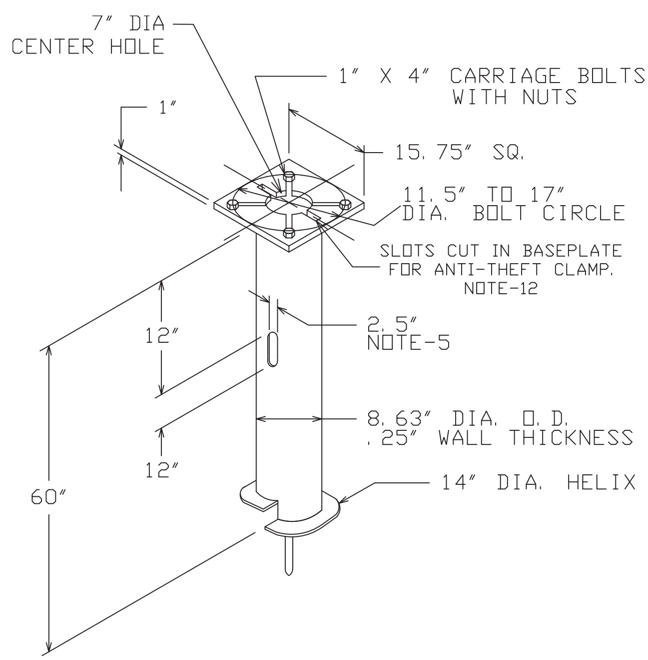
B

DECORATIVE LIGHTING FOUNDATION
CAT NO T112-0338
MOUNTING HARDWARE ORDER T1120393
Figure 10-1B



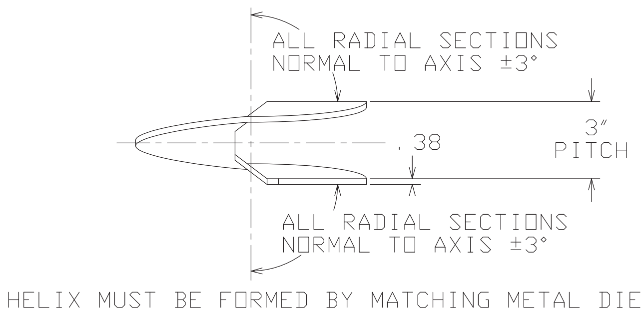
C

LIGHTING FOUNDATION
CAT NO C11232JG4VL
Figure 10-1C

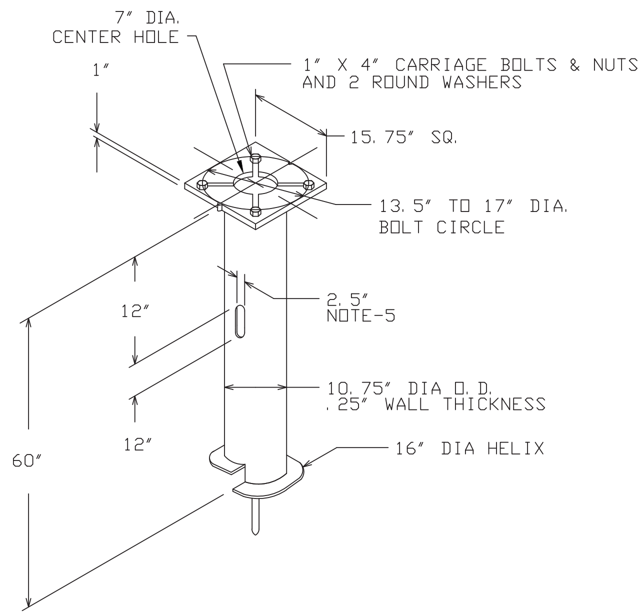


D

LIGHTING FOUNDATION
CAT NO C11242NG4VP
Figure 10-1D



SIDE VIEW OF TRUE HELICAL SHAPE



E

LIGHTING FOUNDATION CAT NO T112-0592

Figure 10-1E

RECOMMENDED FACTORS of SAFETY for DESIGN

The variability of soil conditions that may exist at a project site, plus the varied nature of loading on structures and how these loads are transferred through foundation elements, requires the consulting engineer and/or dealer/installing contractor to use an appropriate Factor of Safety (FS) in design for use with the Chance® Foundation Lighting and Signs System. Generally this Factor of Safety is a minimum of 2:1 on all permanent loading conditions and a minimum of 1.5:1 for any temporary load situation. National and local building code regulations may require more stringent Factors of Safety on certain projects.

DESIGN GUIDELINES

The Foundation Lighting and Signs System provides manufactured single helix fixed length products for use as foundations for varied applications such as light poles, signs and equipment supports. There are many applications for these tubular helical specialty products. Each application will require:

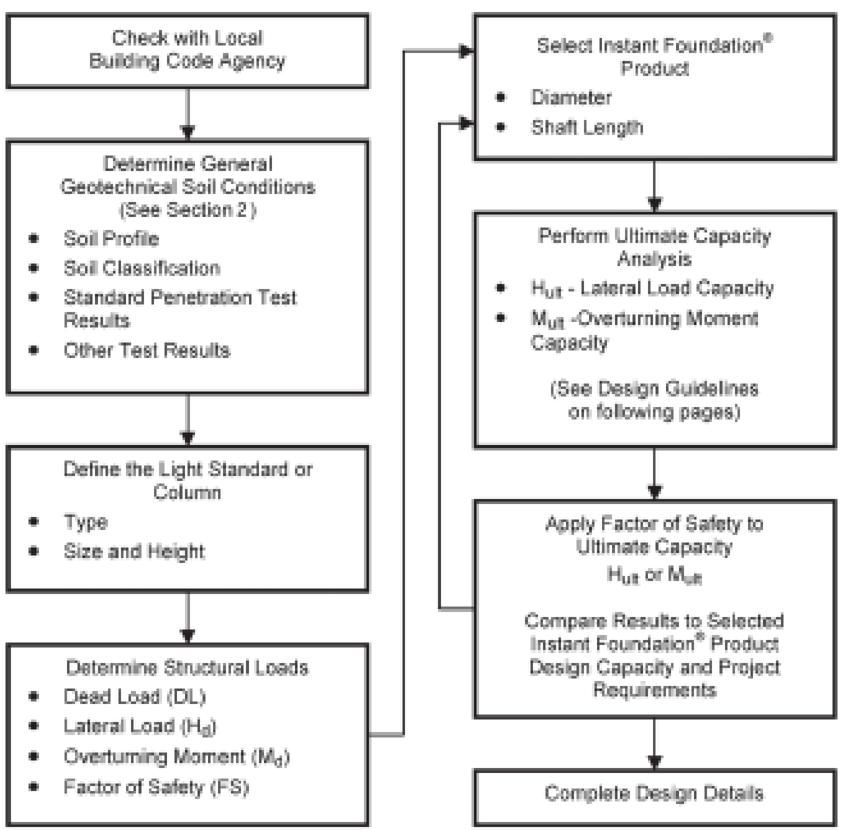
1. An evaluation of the soil strata and soil characteristics of that stratum in which the product will be installed.
2. A selection of the appropriate Foundation Lighting and Signs Product shaft diameter, shaft length, base plate size, bolt diameter and bolt circle diameter.
3. A determination of the ultimate bearing capacity and suitable Factor of Safety.

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

The following preliminary design guide information is intended to assist dealers, installing contractors, and consulting engineers to select the appropriate CHANCE® Foundation Lighting and Signs Product to resist overturning moment and lateral load.

The Hubbell Power Systems, Inc. Pole Load Determination Data Sheet is provided on page 10-9. This can be used to gather and record the information required to determine the loads to be applied to a light pole foundation. The loads and given soil conditions are then used to determine the appropriate Foundation Lighting and Signs Product size required for the job. The SELECT-A BASE™ Lighting Base Program is an on-line program used for preliminary foundation selection. The program incorporates a database of CHANCE® Lighting Bases. The program inputs include loading conditions (wind, moment, and/or lateral), pole/pole arm details and soil data. The software is free and easy to use on-line at www.abchance.com.

INSTANT FOUNDATION® SYSTEM DESIGN STEPS



LIGHT POLE STANDARDS PRODUCTS

CHANCE® Foundation Lighting and Signs® Products for light pole standards are designed to resist both the lateral forces and overturning moments from wind loads. Controlling design standards for wind loads can be determined either by consulting local or national building codes or conformance to standards set by the American Association of State Highway and Transportation Officials (AASHTO). These standards will provide the required design wind load based on geographic region and the factors associated with the shape and type of structure in order to determine the resulting wind pressure. This wind pressure is then applied to the effective projected area (EPA) of the light pole, arm and fixture. These lateral forces can be used to determine the resultant lateral force and overturning moment applied to the foundation as shown in Figure 10-4. The luminaire or fixture supplier may be consulted to determine the actual effective projected area for the specific light assembly.

Table 10-2 provides the suggested shaft diameter and installation requirements for various lateral load-overturning moment ranges. Table 10-3 provides the minimum recommended design life based on the structure type. This has been reproduced from AASHTO Specification, 4th Edition, 2001. The designer can make a site-specific analysis, or an analysis can be obtained by completing the Pole Load Determination Data Sheet on page 10-9 and submitting it to Hubbell Power Systems, Inc. to determine the most appropriate Instant Foundation® Product.

Installed Light Standard
Figure 10-2

Foundation Lighting and Signs® Products are Easily Installed Using Common Construction Equipment.
Figure 10-3

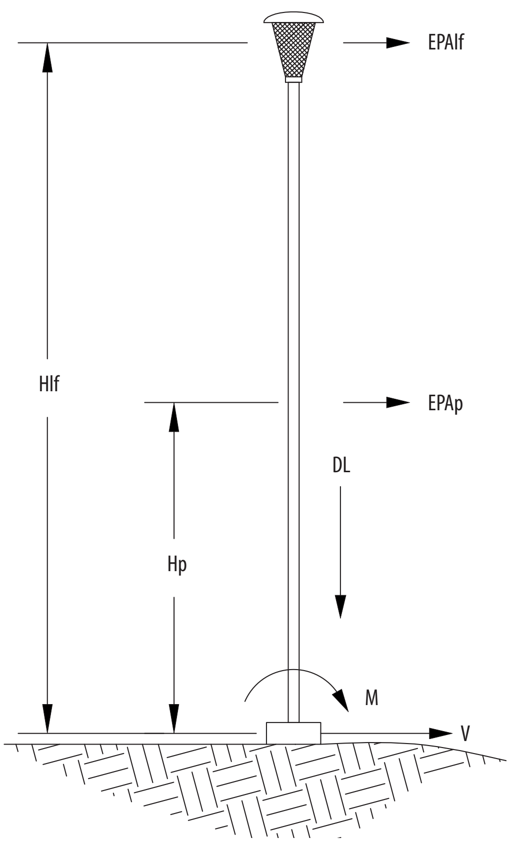
CHANCE® Foundation Lighting and Signs® System for Light Standards, Table 10-2

DESIGN LATERAL LOAD[2]	DESIGN OVERTURNING MOMENT[2]	RECOMMENDED HELICAL FOUNDATION[2]	PRODUCT PART NUMBER
150 – 500 lb.	≤ 2,800 ft-lb.	3.5″ Dia x 5′ Long	T1120143
150 – 500 lb.	≤ 3,500 ft-lb.	4″ Dia x 4′-8″ Long	T1120338
500 – 1,000 lb.	≤ 10,500 ft-lb.	6-5/8″ Dia x 5′ Long	C11232JG4VL
1,000 – 1,200 lb.	≤ 21,000 ft-lb.	8-5/8″ Dia x 5′ Long	C11242NG4VP
1,200 – 1,500 lb.	≤ 37,000 ft-lb.	10-3/4″ Dia x 5′ Long	T1120592

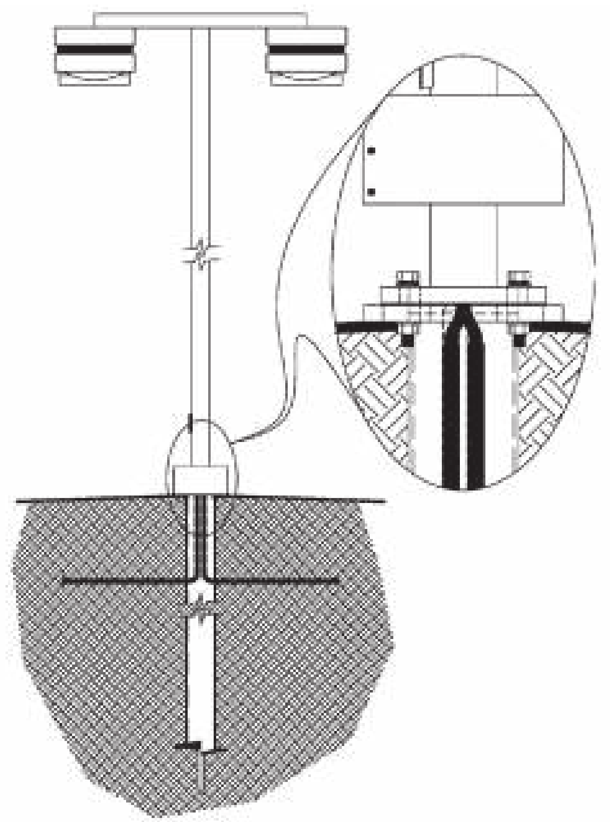
Notes:
1. The above lateral loads and overturning moments are mechanical ratings of the indicated foundation. Project soil conditions must be evaluated during preliminary design.
2. These design loads are based on allowable bending in the pipe shaft with cableway widths of 1.25″ in 3.5″ dia, 1.5″ in 4″ dia and 2.5″ in all other foundations.

wp = Wind Pressure
EPAlf = Effective Projected Area of a Light Fixture
EPAp = Effective Projected Area of a Light Pole
Hlf = Moment Arm to EPAlf Centroid
Hp= Moment Arm to EPAp Centroid

SLF REACTIONS
Vlf = [EPAlf x wp]
Vp = [EPAp x wp]
V = Vlf +Vp
M = [Vlf x Hlf] + [Vp x Hp]



Resultant Pile Foundation Loads
Figure 10-4



Light Standard Connection Details
Figure 10-5

 | Hubbell Power Systems, Inc. |

Recommended Minimum Design Life, Table 10-3

DESIGN LIFE	STRUCTURE TYPE
50 Years	• Luminaire support structures exceeding 15m (49.2 ft) in height. • Overhead sign structures.
25 Years	• Luminaire support structures less than 15m (49.2 ft) in height. • Traffic signal structures.
10 Years	• Roadside sign structures.

(Reproduced from AASHTO Specification, 4th Edition, 2001)

LATERALLY LOADED FOUNDATIONS

Certain projects require a rapidly installed foundation that must resist lateral loads. Examples of these projects include:

- Equipment platforms for communication towers or mechanical systems.
- Seaside structures subjected to wave action.
- Temporary classroom/mobile building foundations.
- Solar Panels

Each project must be evaluated and designed and should include geotechnical and professional engineering input. Hubbell Power Systems, Inc. offers a "Preliminary Design Service" for evaluating the feasibility of using Foundation Lighting and Signs® Products on such specific projects.

FOUNDATION LIGHTING AND SIGNS® SYSTEM SPECIFICATIONS

The Specification at the end of this section provides a typical specification for the CHANCE® Foundation Lighting and Signs® System.

1. American Association of State Highway and Transportation Officials (AASHTO) Specification, 4th Edition, 2001.
2. Uniform Building Code, Volume 2 - Division 3, 1997.

POLE LOAD DETERMINATION DATA SHEET			
Luminaire mounting height:		☐ m	☐ ft
Height of pole:		☐ m	☐ ft
Outside diameter of pole top:		☐ cm	☐ in
Outside diameter of pole bottom:		☐ cm	☐ in
Arm length:		☐ m	☐ ft
Arm tip outside diameter:		☐ cm	☐ in
Arm bottom outside diameter:		☐ cm	☐ in
Luminaire weight:		☐ kg	☐ lb
Luminaire EPA (projected area x C_d):		☐ m^2	☐ ft^2
Basic wind speed:		☐ kph	☐ mph
Minimum design life (Default design life is 25 yrs. See Table 10-3):		☐ 10 ☐ 25	☐ 50 yrs
Number of arms:			
Number of luminaires:			
Pole shape:	☐ Cylinder ☐ Flat ☐ Hexdecagonal (16 sides) ☐ Dodecagonal (12 sides) ☐ Octogonal (8 sides) ☐ Square (4 sides) ☐ Diamond		
Arm shape:	☐ Cylinder ☐ Flat ☐ Hexdecagonal (16 sides) ☐ Dodecagonal (12 sides) ☐ Octogonal (8 sides) ☐ Square (4 sides) ☐ Diamond		
Is this pole/foundation in Alaska?		☐ Yes	☐ No
Required foundation bolt diameter:		☐ cm	☐ in
Required foundation bolt circle diameter:		☐ cm	☐ in
Site Soil Data (if available):			

SPECIFICATION

CHANCE® Foundation Lighting and Signs® System

- 3-1/2" Dia x 0.300" Wall
- 4" Dia x 0.226" Wall
- 6-5/8" Dia x 0.280 Wall
- 8-5/8" Dia x 0.250" Wall
- 10-3/4" Dia x 0.250" Wall

The usual application for this foundation is where loads are moderate and the project requires greater column stiffness than is possible with the typical square shaft helical pile. Examples of applications are: Light Standards, Curbside Business Sign Support, Electrical/Mechanical Equipment Pad Support, Cantilevered Loads, etc.

PART 1 – GENERAL

1.1 SCOPE OF WORK

This work consists of furnishing labor, tools, equipment and materials associated with the preparation and installation of the CHANCE® Foundation Lighting and Signs® System for structural foundation support according to the specifications contained herein. The work includes, but is not limited to, the following:

1. Diligent investigation of the possible existence and location of underground utilities situated at or near the area of work;
2. Excavation and preparation of foundation soil to grade for foundation installation;
3. Mounting of the hydraulic gear motor on a backhoe unit or similar auxiliary powered equipment, and the installation of the Foundation Lighting and Signs® Product to the required torque resistance at the required depth (if torque resistance measurement is required).
4. Removal of the hydraulic gear motor.
5. Conducting an optional Field Load Test on one or more Foundation Lighting and Signs® Products.
6. Clean Up.

1.2 REFERENCES

1. Building Officials and Code Administrators International, Inc. (BOCA) Basic National Building Code.
2. American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals.

1.3 DELIVERY, STORAGE AND HANDLING

All foundation products shall be handled and transported carefully to prevent any deformation or damage. Care should be taken to prevent the accumulation of dirt, mud or other foreign matter on the steel materials. Such accumulation shall be completely removed prior to installation.

PART 2 - MATERIAL

2.1 HYDRAULIC GEAR MOTOR

The torque rating of the hydraulic gear motor used to install the Foundation Lighting and Signs® Product shall be adequate to install the required foundation. It is suggested that the torque rating be 25 percent higher than the planned installation torque. Depending upon the soil conditions and pile configuration, different hydraulic gear motors may be required.

2.2 3-1/2" and 4" DIAMETER HELICAL FOUNDATION LIGHTING AND SIGNS® SERIES

2.2.1 Foundation Shaft Section

The shaft section consists of a tubular hot rolled steel pile section 3-1/2" in diameter with a 0.300" wall thickness, or 4" diameter with a wall thickness of 0.226" conforming to ASTM A-53, A-252 and A-500. The length of the foundation shall be as specified: 4', 4'-8", 5', etc. The lead end of the 3.5" and 4" foundations shall have a single or double bevel cut to aid in starting the foundation installation. Welded to the shaft shall be one ASTM A-635 steel helical plate with a thickness of 3/8" and a 3" pitch.

2.2.2 Foundation System Base Mounting Plates

Foundation base plates may be round or square, of various sizes in plan view and may vary in thickness from 1/2" to 1-1/2" depending on job requirements.

2.3 6-5/8", 8-5/8" and 10-3/4" DIAMETER HELICAL FOUNDATION LIGHTING AND SIGNS® SERIES

2.3.1 Foundation Shaft Section

The shaft section consists of 6" diameter (6-5/8" outside diameter with 0.280" wall), 8" diameter (8-5/8" outside diameter with 0.250" wall) or 10" (10-3/4" outside diameter with 0.250" wall) steel pipe conforming to ASTM A-53, A-252 or A-500. The length of the foundation may be 4', 5', 7', 8' or 10' long as required by the application. The pile section shall have two wire access slots located 1800 from each other. The integral foundation cap plate shall have an alignment notch located directly above one of the wire access slots. Welded to the lead end of the foundation shaft shall be a steel helical plate with a 3" pitch. To aid in starting the pile, a 1-1/4" diameter steel rod shall extend beyond the center of the helix to provide a pilot.

2.3.2 Foundation System Base Mounting Plates

Foundation base plates may be round or square, of various sizes in plan view and may vary in thickness from 3/4" to 1-1/2" depending on job requirements.

2.4 WELDMENTS

All welded connections shall conform to the requirements of the American Welding Society Structural Welding Code, AWS D1.1 and applicable revisions.

PART 3 - EXECUTION

The following is intended to provide the controlling specification for the major steps undertaken in the installation of the CHANCE® FOUNDATION LIGHTING AND SIGNS® Systems. Variations in the installation procedure may occur depending on the application and the structural support required.

WARNING! THOROUGHLY INVESTIGATE THE POSSIBLE EXISTENCE AND LOCATION OF ALL UNDERGROUND UTILITIES SITUATED AT OR NEAR THE AREA OF WORK BEFORE PROCEEDING. SERIOUS INJURY MAY RESULT FROM FAILURE TO LOCATE ALL UNDERGROUND UTILITIES.

3.1 PREPARATION

The soil shall be excavated to the proper grade for placement of the CHANCE® Foundation Lighting and Signs® Product. Stakes should be set at each foundation location prior to commencement of work. The foundation layout and staking should be under the supervision of the responsible structural engineer and be accomplished using fully qualified and trained technicians familiar with foundation layout.

3.2 INSTALLATION OF THE FOUNDATION LIGHTING AND SIGNS® PRODUCT

The hydraulic gear motor shall be installed on a backhoe or other suitable pile installation unit. Mount the Foundation Lighting and Signs® Product to the hydraulic gear motor via the appropriate kelly bar adapter and installing tool using two structural grade bolts and nuts. The foundation is positioned vertically over a marked pile location and driven into the soil by means of the hydraulic gear motor. Rotary installation continues until the required design torque is achieved at or below the predetermined depth. The baseplate is typically installed to grade or slightly above to allow clearance for bolt mounting of the pole base. It is important that the installation torque remain at or above the predetermined value during this process. Details of the installation shall be provided to the supervising engineer for review.

3.3 DOCUMENTATION

When required, the dealer/installing contractor shall monitor the torque applied to the foundation during installation. It is recommended that the installation torque be recorded at one-foot intervals throughout the installation. The installation torque may be measured with a calibrated torque indicator. At the conclusion of the installation, a copy of the foundation installation record shall be provided to the engineer for review.

3.4 LOAD TEST (Optional)

A detailed description on the requirements and procedures for conducting a Load Test may be found in Appendix B (LOAD TESTS). The results of the Field Load Test provide guidance for determining the ultimate and allowable foundation loads.

Load testing should be conducted under the supervision of the responsible engineer.

Depending on the project specifications, a Working Load Test may be required. Normally, the first installed foundation is selected for this test; however, some specifications require ultimate loading of the foundation. If an Ultimate Load Test is required, a test foundation must be installed in an alternate location on the site in addition to the pile locations marked. After the Ultimate Load Test is completed, the test foundation may be removed from the soil and used on the project, provided it is not damaged.

3.5 CLEAN UP

Upon completion of the installation of the CHANCE® Foundation Lighting and Signs® Product, all equipment shall be removed from the site. Any disturbed soils in the area of the foundation shall be restored to the dimensions and condition specified by the engineer.

END OF SPECIFICATION

CORROSION

CORROSION - AN OVERVIEW
APPENDIX A

CONTENTS

SYMBOLS USED IN THIS SECTION

pH	Acidity or Alkalinity of a Solution	A-7
ASTM	American Society for Testing and Materials	A-7
V	Voltage	A-7
I	Electrical Current	A-25
R	Resistance or Resistivity	A-8
L	Pin spacing	A-8
NBS	National Bureau of Standards	A-8
FHWA	Federal Highway Administration	A-9
AASHTO	American Association of State Highway and Transportation Officials	A-9
R_{meter}	Resistivity Indication from Nillson Resistivity Meter	A-13
WSF	Wenner Spacing Factor	A-13
CL	Corrosion Weight Loss	A-17
GWT	Ground Water Table	A-19
ppm	Parts per Million	A-9
ASL	Allowable Steel Loss	A-21
SL	Service Life	A-22
G	Amount of Galvanized Coating	A-23
W_s	Weight of Steel Pile	A-24
K_2	Weight Loss by Corrosion	A-24

CORROSION

DISCLAIMER

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

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

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

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

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

INTRODUCTION

Corrosion is defined as the degradation of a material or its properties due to a reaction with the environment. Corrosion exists in virtually all materials, but is most often associated with metals. Metallic corrosion is a naturally occurring process in which the surface of a metallic structure is oxidized or reduced to a corrosion product such as rust by chemical or electrochemical reaction with the environment. The surface of metallic structures is attacked through the migration of ions away from the surface, resulting in material loss over time. Given enough time, the material loss can result in significant reduction of area, which in turn leads to a reduction in the structural capacity of a given metallic element. When corrosion eventually destroys a sufficient amount of the structure's strength, a failure will occur.

The corrosion mechanisms involved with buried metallic structures are generally understood, but accurate prediction of metal loss rates in soil is not always easily determined. This appendix provides an introduction to the concepts of underground corrosion and the factors that influence this corrosion in disturbed and undisturbed soils. A few design examples are provided to give the reader a better understanding as to whether corrosion is a critical factor in a CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Pier application. This section is not intended to be a rigorous design guide, but rather a "first check" to see if corrosion is a practical concern given the specific project site conditions. A qualified corrosion engineer should be consulted for a site specific recommendation if steel foundation products are to be used in a known corrosive soil.

Experience over the past 50 years has shown the vast majority of square shaft and round shaft helical anchors/piles have a calculated service life well in excess of the design life of the structure (typically 50 to 75 years in the United States). In highly corrosive soils and areas of stray currents (e.g., underground transmission pipelines, DC railroads) additional measures must be taken to protect steel foundation products. In these cases, active protective measures such as sacrificial anodes are employed.

CORROSION THEORY

To understand why metallic corrosion occurs, it is necessary to understand how a metal, such as carbon steel, is formed. During the steel making process, natural low energy iron ore is refined into metal. This process adds a great deal of energy to the metal. When the steel is placed into a corrosive environment, it will, by natural processes, return to its low energy state over time. To make the return trip, the steel must give up the energy gained at the mill. This is the essence of the reduction process that we call corrosion.

Mechanical strength, physical size and shape, and chemical composition of the steel are all properties that must be considered when designing CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Piers. Mechanical and physical properties are well defined and controlled during the manufacturing process. This is also true of the chemical composition, primarily due to the superior process controls used by the steel mills. Of the three properties, chemical composition is the primary factor with respect to corrosion.

Corrosion of steel is an electrochemical process. Romanoff (1957) stated:

> "For electrochemical corrosion to occur there must be a potential difference between two points that are electrically connected and immersed in an electrolyte. Whenever these conditions are fulfilled, a small current flows from the anode area through the electrolyte to the cathode area and then through the metal to complete the circuit, and the anode area is the one that has the most negative potential, and is the area that becomes corroded through loss of metal ions to the electrolyte. The cathode area, to which the current flows through the electrolyte, is protected from corrosion because of the deposition of hydrogen or other ions that carry the current.
>
> "The electrochemical theory of corrosion is simple, i.e., corrosion occurs through the loss of metal ions at anode points or areas. However, correlation of this theory with actual or potential corrosion of metals underground is complicated and difficult because of the many factors that singly or in combination affect the course of the electrochemical reaction. These factors not only determine the amount or rate at which corrosion occurs but also the kind of corrosion."

Depending on the many factors that affect the electrochemical reaction, corrosion can affect a metal in several different ways. Some of these types are listed below:

Corrosion Types, Table A-1

TYPE	CHARACTERISTICS
Uniform or Near Uniform	Corrosion takes place at all area of the metal at the same or a similar rate.
Localized	Some areas of the metal corrode at different rates than other areas due to heterogeneities in the metal or environment. This type of attack can approach pitting.
Pitting	Very highly localized attack at specific areas resulting in small pits that may penetrate to perforation.

Considerations need to be applied as to the types and rates of corrosion anticipated. Current theory does not permit accurate prediction of the extent of expected corrosion unless complete information is available regarding all factors. Therefore, uniform corrosion will be the corrosion type discussed herein.

Romanoff states there are several conditions that must be met before the corrosion mechanism takes place. These are:

Electrical Factors

Two points (anode and cathode) on a metallic structure must differ in electrical potential. The anode is defined as the electrode of an electrochemical cell at which oxidation occurs, i.e., the negative terminal of a galvanic cell. The cathode is defined as the electrode of an electrochemical cell at which reduction occurs, i.e., the positive terminal of a galvanic cell. An electrical potential can be caused by differences in grain orientation within the steel structure, i.e., different orientations of the steel grain structure can cause some grains to act as anodes while others act as cathodes, while the rest of the steel material exhibits excellent electrical conductivity. In addition, chemical anisotropy, non-metallic inclusions, strained and unstrained areas, and other imperfections on the surface of a metal can create potential differences that drive the corrosion process.

Metallic Path

The anode and the cathode must be electrically bonded or connected to complete the circuit.

Electrolyte

The principle function of soil moisture is to furnish the electrolyte for carrying current. The ions in the electrolyte may be hydrogen and hydroxyl ions from the water itself and a variety of cations and anions, which depend upon the number and amount of soluble salts dissolved in the water. The presence of these ions determines the electrical conductivity, expressed as resistivity (measured in ohms/cm), of the electrolyte, as well as chemical properties such as acidity or alkalinity, and the development of chemical reactions between the primary products of corrosion and the electrolyte. For example, ferrous material is corroded by electrolytes that contain sulfates or chlorides from the soil because the corrosion products formed at the anode and the cathode are both soluble.

Aeration

Aeration affects the access of oxygen and moisture to the metal. Oxygen, either from atmospheric sources or from oxidizing salts or compounds, stimulates corrosion by combining with metal ions to form oxides, hydroxides, or metal salts. If corrosion products are soluble or are otherwise removed from the anodic areas, corrosion proceeds, but if the products accumulate, they may reduce corrosion by providing a barrier that is more noble (cathodic) than the bare metal. The aeration characteristics of a soil are dependent upon physical characteristics such as the particle size, particle size distribution, and unit weight. In volume change soils such as clay, a reduction in moisture content results in cracks that provide effective channels for the oxygen of the air to reach buried metal. Disturbed soils such as fill result in oxygen being more readily available. In some instances, atmospheric oxygen can become trapped in isolated pockets or cells creating the potential for localized anodic regions.

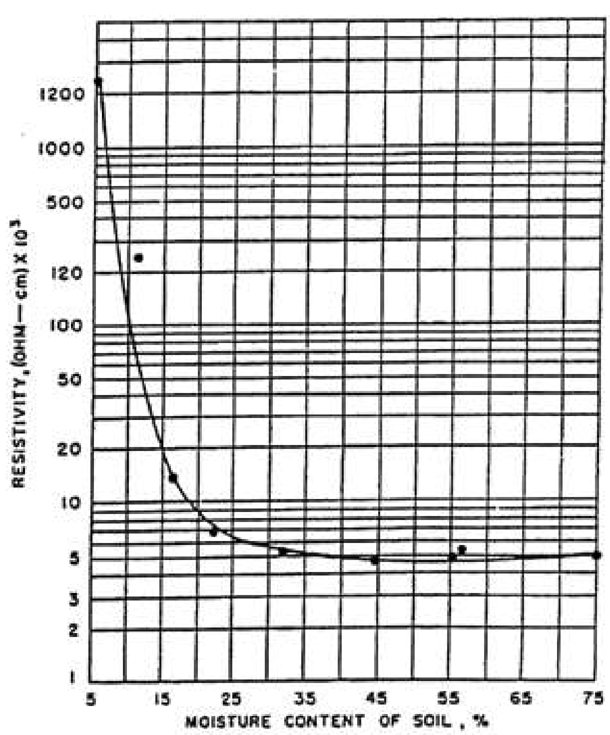
SOIL ENVIRONMENTS

SOIL TYPE

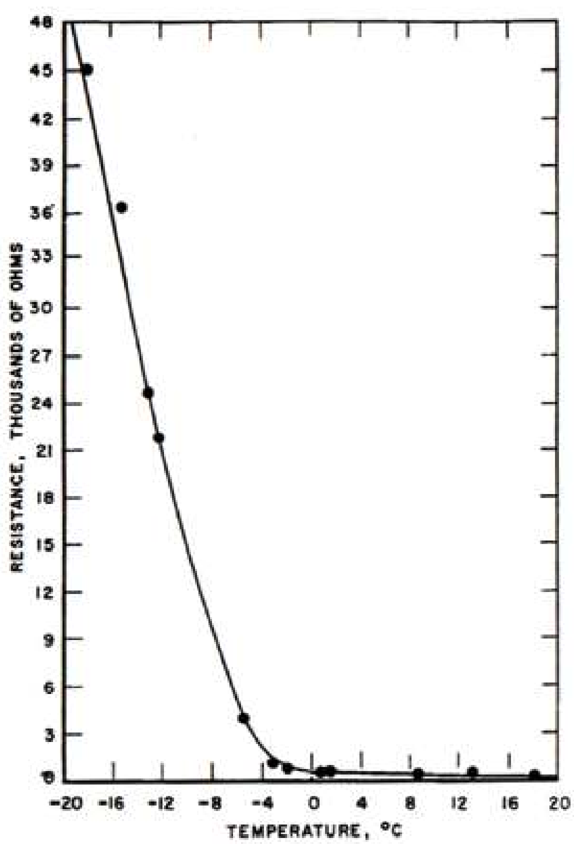
Soils constitute the most complex environment known to metallic corrosion. Corrosion of metals in soil can vary from relatively rapid material loss to negligible effects. Obviously, some soil types are more corrosive than others. The origin of soils, along with climate, geologic location, plant and animal life, and the effects of man all influence the corrosive potential of a given soil. Chemical analysis of soils is usually limited to determinations of the constituents that are soluble in water under standardized conditions. The elements that are usually determined are the base-forming elements, such as sodium, potassium, calcium, and magnesium; and the acid-forming elements, such as carbonate, bicarbonate, chloride, nitrate, and sulfate. The nature and amount of soluble salts, together with the moisture content of the soil, largely determine the ability of the soil to conduct an electric current. Therefore, fine-grained soils such as clays and some silts are considered to have a greater corrosion potential because they typically have lower hydraulic conductivity resulting in the accumulation of acid and base forming materials, which cannot be leached out very quickly. However, granular soils such as sands and gravels are considered to have a reduced corrosion potential because they typically have increased hydraulic conductivity, resulting in the leaching of accumulated salts.

GROUND WATER

Moisture content in soil will probably have the most profound effect when considering corrosion potential than any other variable. No corrosion will occur in environments that are completely dry. The effect of moisture content on the resistivity of a clay soil is shown in Figure A-1. When the soil is nearly dry, its resistivity is very high (i.e., no corrosion potential). However, the resistivity decreases rapidly with increases in moisture content until the saturation point is reached, after which further additions of moisture have little or no effect on the resistivity. Figure A-2 shows the effect of temperature on the resistivity of a soil. As the temperature decreases down to the freezing point (32°F or 0°C), the resistivity increases gradually. At temperatures below the freezing point, the soil resistivity increases very rapidly.



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

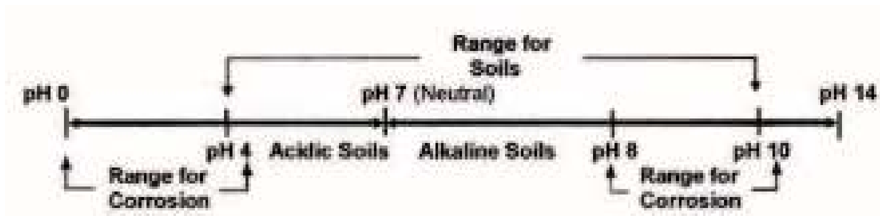


Effect of Temperature on Earth Resistance
(Romanoff, 1957)
Figure A-2

SOIL pH

Soil pH can be used as an indicator of corrosion loss potential for metals in soil. The term "pH" is defined as the acidity or alkalinity of a solution that is assigned a number on a scale from 0 to 14. A value of 7 represents neutrality, lower numbers indicate increasing acidity and higher numbers increasing alkalinity. Each unit of change represents a ten-fold change in acidity or alkalinity which is the negative logarithm of the effective hydrogen-ion concentration or hydrogen-ion activity in gram equivalents per liter of solution. The development of acidity in soils is a result of the natural processes of weathering under humid conditions. Acidic soils are those that have had soluble salts and other materials removed, usually by moderate to high rainfall. In general, the soils of the Midwest and Eastern United States are acid to a considerable depth, whereas the soils whose development has been retarded by poor drainage or other conditions are alkaline. Most soils fall within a pH range that is strongly acid to mildly alkaline.

Extremely acid soils (below pH 4.5) and very strongly alkaline soils (above pH 9.1) have significantly high corrosion loss rates when compared to other soils (see Figure A-3). Soil pH is best measured in the field using a pH meter and following the methods defined in ASTM G 51 – 77.

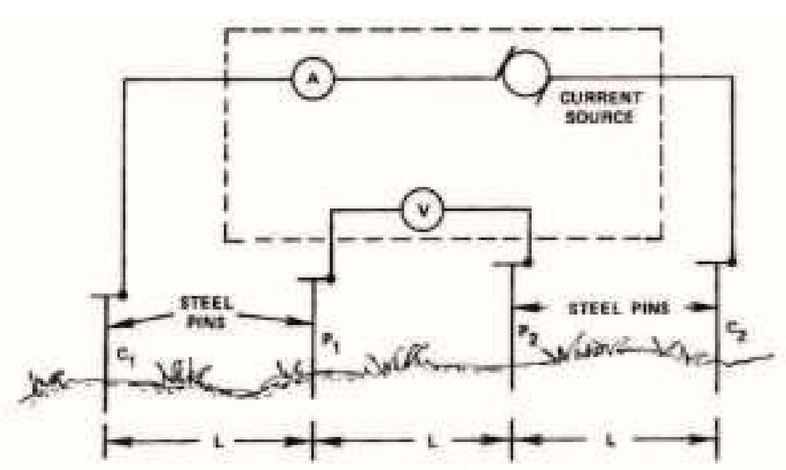


Corrosion of Metal in Soil vs pH
Figure A-3

SOIL RESISTIVITY

Soil resistivity (the reciprocal of conductivity) is the one variable that has the greatest influence on corrosion rate. However, other factors such as hydrogen-ion concentration, soluble salts and total acidity are interrelated, and it is difficult to control conditions so that there is only one variable. In general, the lower the resistivity, the higher the corrosion rate. Metals buried in low resistivity soils will generally be anodic, whereas metals buried in adjacent high resistivity soils will generally be cathodic.

As shown in Figure A-1, moisture content has a profound effect on resistivity. Soil that is completely free of water has extremely high resistivity. For example, sandy soils that easily drain water away are typically non-corrosive; clayey soils that hold water have low resistivity and are typically corrosive. Backfill material will generally be more corrosive than native earth because the backfill soil has a higher moisture content. In addition, backfill material typically never reconsolidates back to the same degree as native soil, allowing more penetration and retention of water.



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

Soil resistivity is typically measured using one or both of two methods: (1) testing onsite with the Wenner four-pin method, and/or (2) taking a soil sample to a laboratory for a soil box resistivity test. The recommended practice is the onsite Wenner four-pin method per ASTM G57-78. The four-pin method is recommended because it measures the average resistivity of a large volume of earth with relative ease. As Figure A-4 shows, this method places four pins at equal distances from each other. A current is then sent through the two outer pins. By measuring the voltage across the two inner pins, the soil resistance can be calculated using Ohm's Law (V= IR). Soil resistivity can be determined using Equation A-1.

	Resistivity	=	191.5 (R) (L) (ohms/cm)	**Equation A-1**
where	R	=	Resistance measured with a soil resistivity meter	
	L	=	Pin spacing (ft)	

The soil box resistivity test is not recommended because it requires taking large number of samples for an accurate map of soil resistivities in a given area. The soil box test is also much more time-consuming than the four-pin method. Table A-2 is offered as a guide in predicting the corrosion potential of a soil with respect to resistivity alone.

Soil Resistivity and Potential Corrosion Rate, Table A-2

RESISTANCE CLASSIFICATION	SOIL RESISTIVITY (ohms/cm)	CORROSION POTENTIAL
Low	0 - 2000	Severe
Medium	2000 - 10,000	Moderate
High	10,000 - 30,000	Mild
Very High	Above 30,000	Unlikely

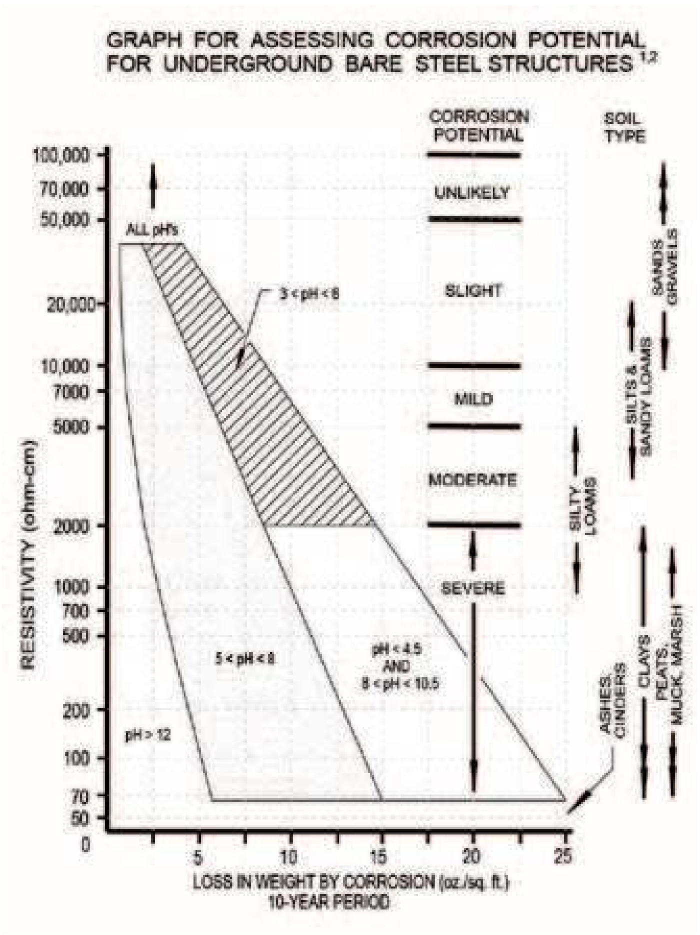
PREDICTING CORROSION LOSS

BARE STEEL

The National Bureau of Standards (NBS) performed extensive studies of underground corrosion between 1910 and 1955. More than 36,500 metal samples were exposed at 128 test locations throughout the United States. In 1957, Romanoff presented the results of these investigations in Underground Corrosion (1957). The studies showed that most underground corrosion was a complex electrochemical process dependent on the various properties discussed previously. The NBS studies were primarily concerned with buried pipeline corrosion. Since pipes are installed in backfilled trenches, the NBS work was performed on specimens placed in trenches ranging from 18 in (0.46 m) to 6 ft (1.8 m) deep. The following conclusions can be drawn from these studies:

- The metal loss rates reported were from samples placed in backfilled, i.e., disturbed soils.
- Atmospheric oxygen or oxidizing salts stimulate corrosion by combining with metal ions to form oxides, hydroxides, or metallic salts. This is particularly true in disturbed soils at or near the soil surface.
- The least corrosive soils had resistivities above 3,000 ohms/cm and low soluble salt concentrations.
- Metal loss rates in disturbed soils can be determined by assuming they will be similar to the loss rates found at test sites with similar pH and resistivity levels as provided in NBS Circular 579, Tables 6, 8 and 13.

Hubbell Power System, Inc. bulletin 01-9204, Anchor Corrosion Reference and Examples, contains extensive metal loss rate data derived from Romanoff's work. It is recommended that this information be used to determine the service life of non-galvanized steel in disturbed soil. The service life for most structures in the United States is 50 to 75 years. Assuming a corrosion allowance for steel piles/piers, Romanoff's metal loss rate data for specific soil types and locations can be used to determine if the required service life can be achieved.



Steel Loss Due to Corrosion
Figure A-5

Romanoff's data can also be arranged in easy-to-use graphs or tables. Figure A-5 provides a preliminary estimate for metal corrosion loss of bare steel if specific information is available on the soil (soil type, pH and resistivity). Figure A-5 provides a technique for quickly assessing those situations for which concern and design consideration for corrosion must be taken into account when metallic structures are placed below ground. For example, a clay soil with resistivity of 2000 ohms/cm and a pH of 6 will have an average metal loss rate of approximately 5 oz/ft^2/10yrs, or 0.5 oz/ft^2/yr. This figure was developed from the results of the NBS studies in addition to similar field experimentation results as presented in the Proceedings, Eighth International Ash Utilization Symposium, Volume 2, American Coal Ash Association, Washington, DC, 1987.

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

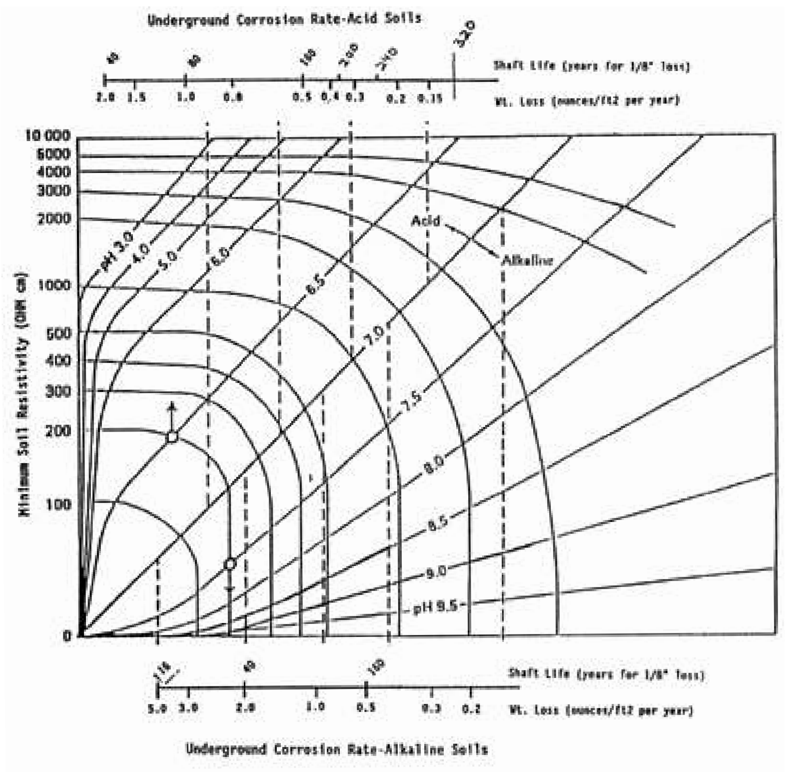
Electromechanical Properties of Mildly Corrosive Soils, Table A-3

PROPERTY	TEST DESIGNATION	CRITERIA
Resistivity	AASHTO T-288-91	> 3000 ohm/cm
pH	AASHTO T-289-91	>5 < 10
Sulfates	AASHTO T-290-91	200 ppm
Chlorides	AASHTO T-291-91	100 ppm
Organic Content	AASHTO T-267-86	1% maximum

The design corrosion rates, per FHWA-SA-96-072, suitable for use in mildly corrosive soils having the electrochemical properties listed in Table A-3 are:

For zinc: 15 μm/year (0.385oz/ft^2/yr) for the first two years
4 μm/year (0.103 oz/ft^2/yr) thereafter

For carbon steel: 12 μm/year (0.308 oz/ft^2/yr)



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

Examples:

- For pH of 6.5 and resistivity of 200 ohms/cm weight loss is approximately 1.3 oz/ft^2/yr and expected life (for 1/8" shaft loss) is approximately 65 years.
- For pH of 7.5 and resistivity of 200 ohms/cm weight loss is approximately 2.3 oz/ft^2/yr and expected life (for 1/8" shaft loss) is approximately 38 years.

Other methods are available to predict corrosion loss rates. Figure A-6 is a nomograph for estimating the corrosion rate of helical anchor/pile/pier shafts. It is a corrosion nomograph adapted from the British Corrosion Journal (King, 1977). Its appeal is its ease of use. If the resistivity and soil pH are known, an estimate of the service life (defined as 1/8" material loss, for example) of a CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Pier shaft can be obtained for either an acidic or alkaline soil.

CORROSION LOSS RATES

WATER/MARINE ENVIRONMENT

Factors other than resistivity and pH can have a strong influence on corrosion loss rates. It is well known that marine environments can be severely corrosive to unprotected steel, particularly in tidal and splash zones. Corrosion loss rates in these environments can be quite high, averaging 6.9 oz/ft.2 (Uhlig, Corrosion Handbook, 2000). Salt spray, sea breezes, topography, and proximity all affect corrosion rate. Studies have shown that the corrosion rate for zinc exposed 80 ft (24.4 m) from shore was three times that for zinc exposed 800 ft (244 m) from shore.

Seawater immersion is less corrosive than tidal or splash zones. This is because seawater deposits protective scales on zinc and is less corrosive than soft water. Hard water is usually less corrosive than soft water toward zinc because it also deposits protective scales on the metallic surface. Table A-4 provides corrosion loss rates of zinc in various waters. In most situations, zinc coatings would not be used alone when applied to steel immersed in seawater, but would form the first layer of a more elaborate protective system, such as active protection using sacrificial anodes.

Corrosion of Zinc in Various Waters (Corrosion Handbook, Volume 13 Corrosion, ASM International), Table A-4

WATER TYPE	μ m/yr	mils/yr	oz/ft^2
Seawater			
Global oceans, average	15 - 25	0.6 - 1.0	0.385 - 0.642
North Sea	12	0.5	0.308
Baltic Sea and Gulf of Bothnia	10	0.4	0.257
Freshwater			
Hard	2.5 - 5	0.1 - 0.2	
Soft river water	20	0.8	0.513
Soft tap water	5 - 10	0.2 - 0.4	0.128 - 0.257
Distilled water	50 - 200	2.0 - 8.0	1.284 - 5.130

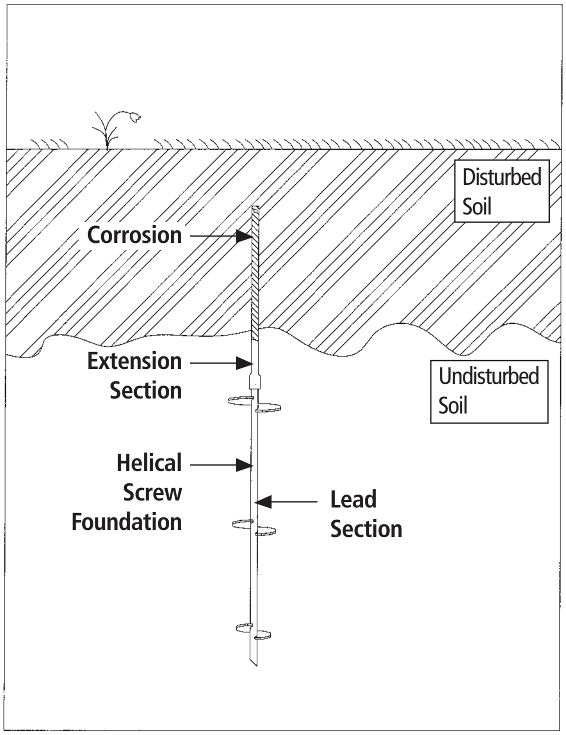
CORROSION in UNDISTURBED SOIL

In NBS Monograph 127, *(Underground Corrosion of Steel Pilings)* (Romanoff, 1972), it was reported that driven steel piles did not experience appreciable corrosion when driven into undisturbed soils. These findings were obtained during NBS studies of steel pile corrosion. Romanoff also stated that the NBS corrosion data for steel exposed in disturbed soils was not applicable to steel piles driven in undisturbed soil. He concluded:

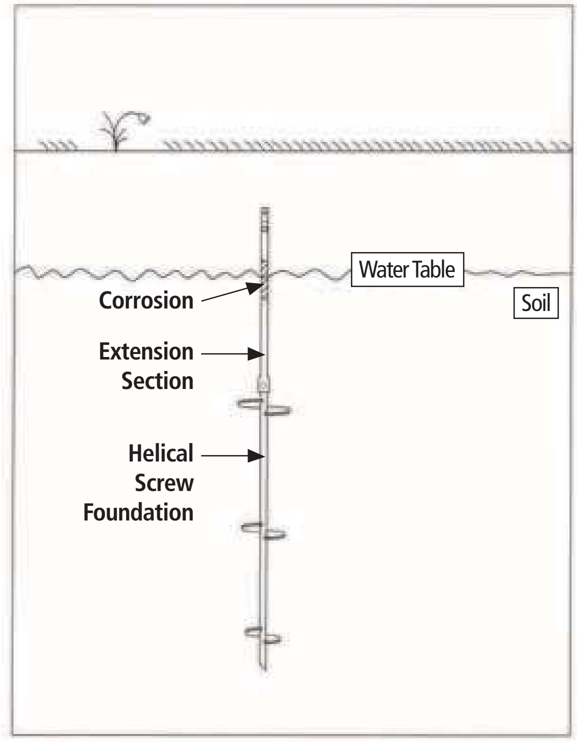
> ". . . that soil environments which are severely corrosive to iron and steel buried under disturbed conditions in excavated trenches were not corrosive to steel piling driven in the undisturbed soil. The difference in corrosion is attributed to the differences in oxygen concentration. The data indicates that undisturbed soils are so deficient in oxygen at levels a few feet below the ground line or below the water table zone that steel pilings are not appreciably affected by corrosion, regardless of the soil types or the soil properties. Properties of soils such as type, drainage, resistivity, pH, or chemical composition are of no practical value in determining the corrosiveness of soils toward steel pilings driven underground."

The following conclusions can be drawn from these studies:

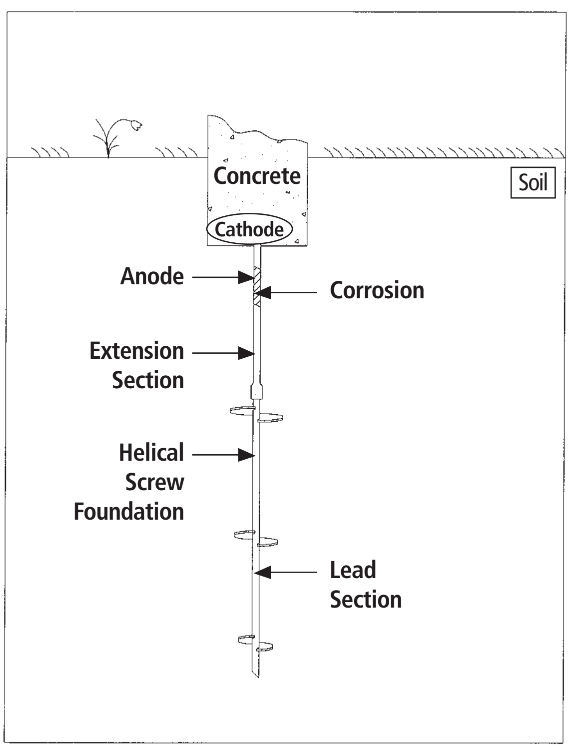
- Oxygen is required at cathodic sites to support underground corrosion of a steel foundation product.
- Disturbed soils (fill) contain an adequate supply of oxygen to support underground corrosion, at least at shallow depths. Thus, the top-most extension(s) of the CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Pier central steel shaft merits corrosion protection, either using passive protection like zinc, epoxy or teflon coatings or active protection like sacrificial anodes.
- The aggressiveness of disturbed soils can be measured, and they can be classified as aggressive and non-aggressive (see Table A-2).
- Undisturbed soils were deficient in oxygen a few feet below the ground surface, or below the water table. It is recommended to install the helical bearing plates of a helical pile/anchor into de-aerated soil.



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



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



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

The role of oxygen in an undisturbed soil overrides the effects of soil resistivity, pH, etc. In those situations where a steel foundation product is installed into a soil profile where a disturbed soil layer overlies undisturbed soil, the section of the central shaft in the disturbed soil is cathodic to the rest of the foundation in the undisturbed region as illustrated in Figure A-7. As a result, the most severe corrosion occurs on the section of the central shaft just below the disturbed layer.

Similarly, a steel foundation product located in undisturbed soil with a high water table can suffer some corrosion attack at the waterline as illustrated in Figure A-8. This combination does not result in serious attack, but it is believed that the situation is aggravated by a continuously changing water table, which would draw in oxygen as the waterline dropped. The section of the central shaft above the waterline acts as a weak cathode to the anode below the waterline.

Helical piles are commonly terminated in concrete cap or grade beams. The area of steel in the concrete forms a passive oxide film generated by the action of the highly alkaline environment, and this area is cathodic to the rest of the helical pile in the soil. However, the high resistivity of the concrete limits the effectiveness of the cathode, thereby limiting the small amount of corrosion attack to the region of the helical pile immediately outside the concrete as illustrated in Figure A-9.

FIELD MEASUREMENT of SOIL RESISTIVITY

Field measurement of soil resistivity is not a difficult or time consuming process and results in the most accurate assessment of corrosion potential for the site. Hubbell Power Systems, Inc. recommends the use of the Nillson Model 400 Soil Resistance Meter System. The depth of the soil resistivity measurement is directly related to the pin spacing on the surface. The most accurate assessment is obtained by performing the test using a pin spacing of 5-20 foot intervals. In addition, the test should be repeated at a right angle to the original test to ensure that stray currents are not influencing the readings.

A. Equipment Set-Up

1. Insert the four sensor pins into the soil in a straight line leading away from the Resistivity Meter at a center-to-center distance of five feet (see Figure A-10).
2. Connect one wire to each pin and to the appropriate terminal on the Nillson meter.

B. Resistivity Measurement

1. Adjust the OHMS resistivity dial and the MULTIPLIER dial to the maximum setting (turned fully to the right) (see Figure A-11).
2. Place the SENSITIVITY switch in the LOW position and rotate the MULTIPLIER dial to the left until the meter needle goes past the NEUTRAL point, then rotate the MULTIPLIER one position to the right. Note the MULTIPLIER (M) amount on the field notes.
3. Move the OHMS dial to the left until the meter needle is at NEUTRAL.
4. Adjust the SENSITIVITY switch to HIGH position and adjust the OHMS dial to refine the reading.
5. Record the reading (R_{meter})
6. Return the OHMS and MULTIPLIER to the maximum settings and repeat the test.
7. Repeat the test with the pins spaced at 10-feet on center, then at 15-feet and 20-feet on center. Record the readings

C. Calculation of Soil Resistivity

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

where:

R_{meter} = Meter resistance reading (ohms)

M = Meter MULTIPLIER reading

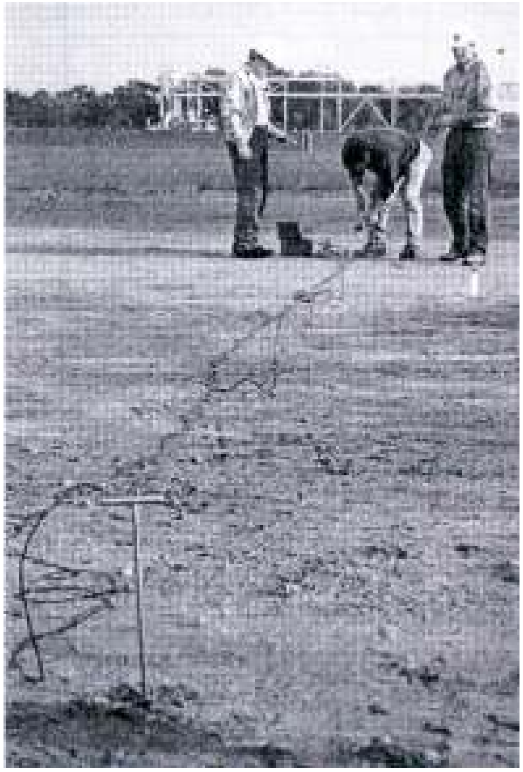
WSF = Wenner spacing factor = 191.5L (ft) = 628L (m)

L = Pin spacing

R = Soil resistivity (ohms/cm)

D. Additional Resistivity Measurements

1. The soil resistivity (R) is the average value over the depth of soil equal to the spacing of the pins. Therefore, to get a profile of the soil resistivity one must repeat the procedures in paragraph B above with the pins spaced at 10, 15 and 20 feet on center.
2. Repeat the entire test at right angles to the original alignment.



Sensor Pin Installation
Figure A-10

Nillson Resistivity Meter
Figure A-11

E. Documentation

Record the field data and the calculations onto the Soil Resistivity Log. A sample log is presented below (See Figure A-12).

F. Evaluate Results

When the Soil Resistivity (R) has been determined, refer to Figure A-5 to determine an estimate of the loss of weight by corrosion over a 10-year period for underground bare steel structures.

COMBINED WENNER 4-PIN SOIL RESISTIVITY LOG				
Location:			Job No.	
Date:	Weather Conditions:		Orientation of Pins:	
WENNER METHOD OF SOIL RESISTIVITY				
PIN SPACING (Depth in Feet)	METER RESISTANCE (R_{Meter}) (ohms)	METER MULTIPLIER (M)	WENNER SPACING FACTOR (WSF) (191.5* x Pin Spacing)	SOIL RESISTIVITY R = (R_{Meter}) x M x WSF

* If pin spacing is measured in meters, use WENNER SPACING FACTOR (WSF) of 628 instead of 191.5

Sample Resistivity Log
Figure A-12

CORROSION CONTROL TECHNIQUES

The amount and type of corrosion control is a function of structure type, service life, and the overall aggressiveness of the project soils. The following requirements are typical. The specifier should review and edit as appropriate for the project.

- **Structure Type:** Temporary structures generally do not require corrosion protection. A temporary structure is defined within a specified time frame (i.e., months rather than years). In general, permanent structures have a service life greater than 24 months.
- **Service Life:** A typical service life of 50 to 75 years should be used unless otherwise specified. If the service life of a temporary CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Pier is likely to be extended due to construction delays, it should be considered permanent. For a service life of less than 20 years in non-aggressive soil, corrosion protection is not recommended.
- **Soil:** Soil can be classified as aggressive or non-aggressive. See Guide to Model Specification -Helical Piles for Structural Support and Model Specification - Helical Tieback Anchors for Earth Retention in Appendix C of this Technical Design Manual for examples of aggressiveness classifications. It is recommended that steel foundation elements installed into soils classified as aggressive be provided with some type of corrosion protection.

Several alternatives are available to protect steel foundation products against corrosion and can be roughly categorized in terms of cost. Because of the added cost, the need for corrosion protection must be carefully determined and specified as necessary. Depending upon the classification as to the corrosion potential for a soil environment, several alternatives are available to deter the corrosion cycle and extend the performance life of the underground steel element. These control measures can be split into categories:

- **Passive Control:** For use in soils classified as mild to moderate corrosion potential. It typically consists of a metal loss allowance (i.e., 1/8") and/or coatings – such as galvanization or epoxy. Passive control is relatively inexpensive.
- **Active Control:** For use in soils classified as moderate to severe corrosion potential. It typically consists of cathodic protection via the use of sacrificial anodes. Active control is relatively expensive and is used in permanent applications.

PASSIVE CONTROL

Allowable Metal Loss Rate

As mentioned previously, Hubbell Power Systems, Inc. bulletin 01-9204, Anchor Corrosion Reference and Examples, contains extensive metal loss rate data derived from Romanoff's work. Other metal loss rate data is presented on pages A-8 through A-12. The design examples at the end of this section demonstrate passive control calculations that estimate the service life of helical pile shafts in soil using these metal loss rates. Design Example 1 uses the metal loss rates from Romanoff (Bulletin 01-9204). The service life is defined as the estimated length of time required for 1/8" of material loss to occur on the helical pile/anchor shaft. Design Example 2 uses the metal loss rates from Figure A-5 in conjunction with Equation A-2. The service life in this example is defined as the estimated length of time required for a 10% material loss to occur on the helical pile shaft. Design Example 3 uses the design corrosion rates per FHWA-SA-96-072 (as quoted here on page A-8) and an assumed service life of 85 years.

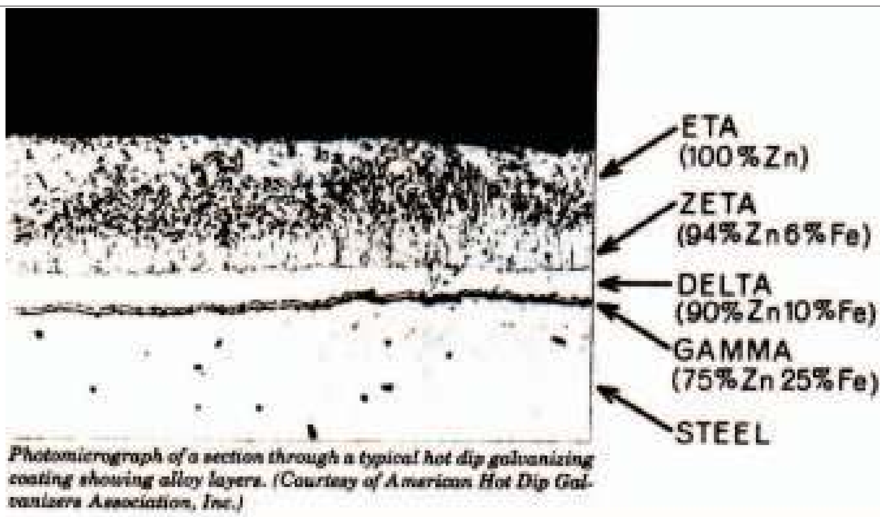
The amount of loss in these design examples is strictly arbitrary, but the assumed material loss of 1/8" in Design Example 1 is common for pile evaluation.

Galvanization (Passive Control)

Aggressive soils, and the conditions illustrated in Figures A-7, A-8, and A-9 demonstrate the need to coat the section of the steel foundation product above the waterline in the disturbed soil and, in particular, the area of the central shaft in the concrete cap or grade beam. Thus, by removing the cathode, the anode/cathode system is disrupted resulting in reduced corrosion. If it were possible to apply a coating capable of guaranteed isolation of the steel surface from the electrolyte (soil), all corrosion concerns would be solved. However, a coating capable of 100% guaranteed isolation has yet to be developed. Epoxy coatings provide excellent electrical isolation, but will chip and abrade easily during handling and installation. The same holds true for porcelain, teflon, and polyurethane coatings. A small chip or crack in the protective coating can cause corrosion activity to be highly localized, possibly leading to severe damage. ***The single best coating for steel foundation products is hot dip galvanizing.***

The first step in the galvanizing process is pickling the steel in dilute acid. This removes any rust, scale, oil or other surface contaminants. The clean steel is then dipped in a vat of molten zinc for time periods ranging up to several minutes for the more massive steel foundations. After the hold period, the zinc-coated steel is withdrawn from the vat at a controlled rate, which allows the coating to quickly cool and harden. The result is a tough, combined zinc and zinc-iron coating which metallurgically bonds to the steel. Other galvanization processes, such as mechanical galvanizing and electroplating, do not form a coating that is metallurgically bonded to the steel.

Hubbell Power System, Inc. galvanizes to the latest ASTM standards – either ASTM A153 class B or ASTM A123. ASTM A153 Class B requires an average weight of zinc coating to be 2.0 oz./ft^2 (3.4 mils) and any individual specimen to be no less than 1.8 oz./ft^2 (3.1 mils). ASTM A123 can be used to specify thicker zinc coatings – up to 2.3 oz./ft^2 (3.9 mils) depending on the coating thickness grade used. Regardless of which ASTM galvanizing specification is used, typical zinc coating thickness for hot-dip galvanized CHANCE® Helical Pile/Anchor or ATLAS RESISTANCE® Piers ranges between 4 and 6 mils.



Photomicrograph of Zinc Layer Section
Figure A-13

Figure A-13 illustrates how zinc and steel react to form zinc-iron alloy layers. The bottom of the picture shows the base steel, then a series of alloy layers and, on the outside, the relatively pure outer zinc layer. The underlying zinc-iron alloy layers are actually harder than the base steel. Therefore, below the relatively soft pure zinc layer, the zinc-alloy layers provide protection in abrasive conditions such as dense sands and gravels.

Hot dip galvanized coatings protect the carbon steel shaft in two ways. First, the zinc coating provides a protective layer between the foundation's central shaft and the environment. Second, if the zinc coating is scratched and the steel surface exposed, the zinc, not the steel, will corrode. This is because zinc is a dissimilar metal in electrical contact with the steel, thus the difference in potential between the two metals and their relative chemical performance (anode or cathode) can be judged by examining a galvanic series as shown in Table A-5. The materials at the top of the list are most active (anodic) compared to the noble (cathodic) materials at the bottom of the list. Steel is more noble than zinc, thus the more active zinc coating will act as an anode and corrode while the more noble steel will be the cathode and be protected.

Service Life Increase Through Galvanization

Hubbell Power Systems, Inc. bulletin 01-9204, Anchor Corrosion Reference and Examples, contains extensive metal loss rate data on galvanized steel derived from Romanoff's work. It is recommended that this information be used to determine the service life of the hot dipped galvanized coating in disturbed soil. When hot-dip galvanized steel is used, the total service life should be increased by the time it takes the zinc coating to be lost due to corrosion. Another method for estimating service life increase is presented in the following paragraphs.

The results of the studies conducted by the National Bureau of Standards and by Porter indicated that a galvanized coating (zinc) was effective in delaying the onset of corrosion in the buried steel structures. Typical conclusions drawn from this study for 5 mil (3 oz/ft^2) galvanized coatings include:

- It is adequate for more than 10 years corrosion protection for inorganic oxidizing soils.
- It is adequate for more than 10 years corrosion protection for inorganic reducing soils.
- It is insufficient for corrosion protection in highly reducing organic soils (pH<4), inorganic reducing alkaline soils and cinders, typically offering 3 to 5 years of protection in such cases.

It was also noted, however, that the use of a galvanized coating significantly reduces the rate of corrosion of the underlying steel structure once the zinc coating was destroyed.

The observed rates of corrosion for the galvanized coating were different (less) than that for bare steel in the NBS study. For galvanized coatings (zinc) of 5 mils, Equation A-3 can be used to estimate the corrosion (weight loss) rate.

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

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

R = Soil resistivity (ohms/cm)

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

Manufactured Metallic Coating (Passive Control)

Hubbell Power Systems, Inc. provides triple coat corrosion protection as a standard feature on the 3-1/2" diameter by 0.165" wall (3500.165 series) ATLAS RESISTANCE® Pier pipe and as an optional feature on the 2-7/8" diameter 0.165 wall (2875.165 series) ATLAS RESISTANCE® Pier pipe. The triple coating consists of:

- Hot-dipped uniform zinc galvanizing
- Chromate conversion coating
- Clear organic polymer coating

The triple coating can significantly reduce the corrosion process by mechanically preventing access of oxygen to the steel surface of the pipe. Data from the manufacturer indicates that this corrosion protection is equivalent to 3 mil (1.8 oz/ft^2) of hot dip galvanizing. Because of the thinness of this film and possible scratching of the coating, this corrosion protection technique should not be used in soils classified as severe.

Galvanic Series in Seawater, Table A-5

ACTIVE ↑	Magnesium
	Zinc
	Beryllium
	Aluminum Alloys
	Cadmium
	Mild Steel, Cast Iron
	300 Series Stainless Steel (Active)
	Aluminum Bronze
	Naval Brass
	Tin
	Copper
	Lead-Tin Solder (50/50)
	90-10 Copper Nickel
	Lead
	Silver
	300 Series Stainless Steel (Passive)
	Titanium
	Platinum
PASSIVE ↓	Graphite

Bituminous and Other Coatings (Passive Control)

Bituminous as well as other materials have been used as coatings on buried steel elements for years as a corrosion protection technique. The primary requirements of a bituminous coating are good adherence (permanence), continuous coating and resistance to water absorption. The bituminous coating can either be heat baked onto the shaft or field applied just prior to installation. As is the case for the manufactured coatings, this coating technique prevents oxygen and water from contacting the metal surface, thus preventing or retarding the corrosion process.

Bituminous or asphaltic coatings or paints only provide physical protection from the environment. They will wear off quickly due to the abrasive action during installation of CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Piers. Extension sections are typically hot-dip galvanized, but other coatings can be specified. Practical application of asphaltic coatings is generally limited to the extension sections located at or near the surface where the coating will provide the greatest benefit. Bituminous and other coatings are best applied in severely corrosive conditions where part of the helical anchor/pile is exposed above grade. Examples are steel foundations used in tidal marshes, coastal regions, and contaminated soils.

A limited amount of available data indicates that bituminous coatings can extend the performance life of underground steel piles and piers by 5 to 15 years, depending on the soil environment and the thickness of the coating. For the vast majority of CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Pier applications, the use of coating techniques (galvanized and/or bituminous) will provide a sufficiently long-term solution for corrosion protection.

Cathodic Protection (Active Control)

As indicated previously, corrosion is an electrochemical process that involves a flow of direct electrical current from the corroding (anodic) areas of the underground metallic structure into the electrolyte and back onto the metallic structure at the non-corroding (cathodic) areas. In situations where metallic structures such as Hubbell Power Systems, Inc. foundation products are to be placed in a severe corrosive soil environment, an active corrosion control technique should be used. This active control technique is termed cathodic protection. Cathodic protection is a method of eliminating corrosion damage to buried steel structures by the application of DC current. The effect of the DC current is to force the metallic surface to become cathodic (i.e., collecting current). If the current is of sufficient magnitude, all metallic surfaces will become cathodic to the external anode.

Both sacrificial anode and impressed current (rectifier and ground bed) cathodic protection systems are used to provide the required current. If the current source is derived from a sacrificial metal (magnesium and zinc are the two most common galvanic anodes used in soils), the effectiveness will depend on the soil properties in which it is placed. More available current is generated from a sacrificial anode in low resistance soils than high resistance soils. It is also best to place impressed current anode beds in lower resistant soils. However, since the available driving potential is greater (rectifier control), the soil resistivity is less significant.

Current requirements needed to protect a steel structure from corrosion will vary due to physical and environmental factors. These requirements could range from 0.01ma/ft^2 of metal surface for a well-applied, high-dielectric-strength plastic coating to 150 ma/ft^2 for bare steel immersed in a turbulent, high velocity, salt-water environment. In soil, 1 to 3 ma/ft^2 is typically used as the required current to protect carbon steel.

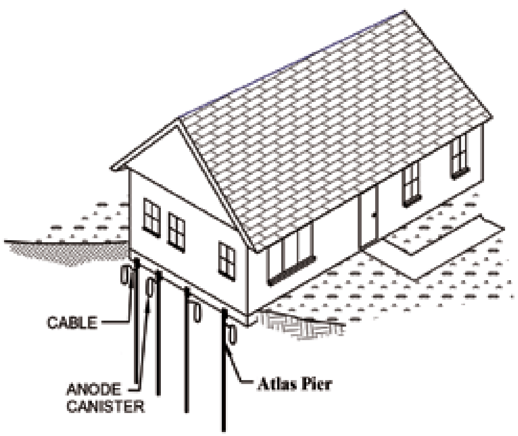
The basic principle in cathodic protection is to apply a direct current of higher electromotive potential than that generated by the corroding metallic structure, thus effectively eliminating the corrosion process.

Sacrificial Anodes (Active Control)

In the case of CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Piers, sacrificial anodes are the most common method of cathodic protection used. This is done by electrically connecting the steel to a properly selected anode of a less noble metal such as zinc or magnesium. The dissimilar metals buried in a common electrolyte (soil) form a galvanic cell. The cell works much like the battery in the family car; the less noble anode corrodes or sacrifices itself while the more noble cathode is protected. For steel to be cathodically protected, it is generally recognized that at least one of the following conditions must be met:

- The potential of the steel must be at -0.85 volts or more negative with respect to a saturated copper-copper sulfate half-cell in contact with the electrolyte, or
- A potential shift of -0.3 volts or more negative upon connection of the cathodic protection.

Magnesium, zinc and aluminum are the most commonly used galvanic sacrificial anodes. The sacrificial anode (galvanic) is attached to each underground metallic structure by a metallic conductor (cable) and placed within the common electrolyte (soil medium). The sacrificial anode works best when a small amount of current is needed and/or when the soil resistivities are low. Anodes are installed normally 3 feet below the surface and 3 to 7 feet from the CHANCE® Helical Piles/Anchors and ATLAS RESISTANCE® Pier.



Sacrificial Anode Protection System
Figure A-14

In designing and using sacrificial anode systems, the soil profile conditions as to the type of soil, resistivities, soil pH and location of the ground water table (GWT), if present, must be determined. Among the design considerations for the system:

- Use of wire type or canister type anode
- Selection of the appropriate anode material (magnesium, titanium, etc.)
- Designing the ground bed (location, dimensions, horizontal vs. vertical, depth of placement, type of backfill, etc.)
- Determining the number of piles/piers per anode
- Type, size and connections between pile(s) and the sacrificial anode.

The application of cathodic protection using galvanic sacrificial anode bags to underground metallic structures offers the following advantages:

- No external power supply required
- Low system cost (bags and installation)
- Minimum maintenance costs

CATHODIC PROTECTION PRODUCTS

Hubbell Power Systems, Inc. recommends a selection of magnesium anodes (9, 17, 32, and 48-pound bag sizes) for cathodic protection of foundation support systems. Cathodic protection is generally used to extend the life of a steel product in corrosive soil beyond the added life available by hot dip galvanizing the components. While it is possible to protect mill finish steel, the engineer usually calls for the cathodic protection in addition to zinc galvanizing.

FACTORS INFLUENCING ANODE OUTPUT:

- Soil Resistivity: Current output from the magnesium anode increases as the soil resistivity decreases. Therefore, magnesium anodes are usually specified in applications where the soil resistivity is 5,000 ohms/cm or less. The effectiveness of this type of cathodic protection decreases as the resistivity increases above 5,000 ohms/cm. Above 10,000 ohms/cm resistivity, magnesium anodes are not effective.

- Anode Surface Area: The amount of current output generated by an anode is directly proportional to the surface area of the anode. Different manufacturers of cathodic protection produce anodes with different surface areas. Just because magnesium anodes from different manufacturers weigh the same is not to be assumed that the current output will be the same. The data presented here is representative for the products identified here.
- Alloy Potential: H-1 magnesium alloy has an open circuit potential of -1.53 to -1.55 volts, which works well with vertically installed foundation support systems. High potential anodes are available from other sources. These high cost, high potential anodes are generally used along horizontal pipelines where the higher potential produced by the anode translates to fewer anodes being required. Table A-5 provides estimates of current output from a single, standard potential H-1 magnesium alloy anode as related to soil resistivity.

Magnesium Anodes, Table A-5

MAGNESIUM ANODES TYPE H-1 STANDARD POTENTIAL MAGNESIUM			
Item No	Magnesium Weight	Package Size	Unit Weight
PSA4438	9 lb.	6” Dia. x 17” Tall	27
PSA4439	17 lb.	6-1/2” Dia. x 24” Tall	45
PSA5106	32 lb.	8” Dia. x 28” Tall	72
PSA4440	48 lb.	8” Dia. x 38” Tall	100

MAGNESIUM ANODE CURRENT OUTPUT – mA					
Resistivity – ohm-cm	1,000	2,000	3,000	4,000	5,000
9# Anode	106.5	53.3	35.5	26.6	21.3
17# Anode	150	75	50	37.5	30
32# Anode	159	79.5	53	39.8	31.8
48# Anode	163.5	81.8	54.5	40.9	32.7

Design Example 4 at the end of this section provides a method for estimating the service life of a sacrificial magnesium anode. For additional information on anode selection, refer to Hubbell Power Systems, Inc. bulletin 2-8307, Cathodic Protection of Anchors – A Basic Guide to Anode Selection and Hubbell Power Systems, Inc. bulletin 01-9204, Anchor Corrosion Reference and Examples.

Impressed Current (Active Control)

In areas of the most severe corrosion potential, where a larger current is required and/or in high resistance electrolytes, an impressed current system is generally recommended which requires a power source, rectifier and a ground bed of impressed current anodes. These systems require a continuous external power source.

The majority of applications where Hubbell Power Systems, Inc. foundation products may be specified will not require an active corrosion protection system. In those cases where the combination of soil and electrolyte conditions requires an active system, the sacrificial anode protection system will likely be the most economical approach.

Active cathodic protection systems must be individually designed to the specific application. The major variables are soil moisture content, resistivity of soil and pH. Each of these items influences the final selection of the cathodic protection system. Typical design life for the cathodic protection is 10 to 20 years, depending upon the size and length of the anode canister.

DESIGN EXAMPLES

Design Example 1:

- Project: Santa Rosa, CA Residence

  The purpose of the calculations is to estimate the service life of Type SS Helical Pile Shafts on the subject project. Service life is defined as the estimated length of time required for 1/8" of material loss to occur on the helical pile shaft. This amount of loss is strictly arbitrary, but is common for pile evaluation.

- Given:

  Helical piles galvanized to ASTM A153 (Minimum Zinc Coating = 1.8 oz/ft^2)

  Soil resistivity is 760 ohms/cm minimum

  Soil pH - 7.70

  Water soluble chloride – 11 ppm

  Water soluble sulfate – 417 ppm

- Assumptions:

  It is assumed that the material loss rates will be similar to the loss rates found at test sites with similar pH and resistivity levels as given in Romanoff's Underground Corrosion, NBS Circular #579 (1957), Tables 6, 8 and 13.

  In Circular #579, Site #5 is indicated as having a resistivity of 1,315 ohms/cm and a pH of 7.0. This soil is Dublin Clay Adobe and is located around Oakland, California. In addition, Site #2 is indicated as having a resistivity of 684 ohms/cm and a pH of 7.3. This soil is Bell Clay and is located around Dallas, Texas. The corrosion rates for these two sites will be used to estimate the life of the Type SS helical pile shaft material.

- Allowable Steel Loss:

  Based on the loss of 1/8" thickness of the helical pile shaft, calculate the allowable steel loss (ASL) in terms of weight per unit area:

$$\begin{aligned} ASL &= (0.125\ in)\ (0.283\ lb/in^3)\ (16) \\ &= (0.566\ oz/in^2)\ (144\ in^2/ft^2) \\ &= 81.5\ oz/ft^2 \end{aligned}$$

- Average Metal Loss per Year:

  From Site #5: (Dublin Clay Adobe)

EXPOSURE DURATION (years)	WEIGHT LOSS (oz/ft^2)	LOSS PER YEAR (oz/ft^2)
1.9	1.4	0.737
4.1	2.2	0.585
6.2	4.8	0.774
8.1	5.2	0.642
12.1	5.4	0.446
17.5	8.3	0.474

The average metal loss per year is 0.61 oz/ft^2. Note that as the duration of exposure increases, the material loss per year generally decreases.

CORROSION

- Pile Shaft Life:

  To determine the pile shaft service life (SL), the allowable steel loss is divided by the average loss per year:

  SL = (81.5 oz/ft^2) / (0.61 oz/ft^2)

  = 133.6 years

- Total Zinc Coating Loss:

  CHANCE® Helical Piles/Anchors are typically provided already hot dip galvanized per ASTM A153. The coating thickness for ASTM A153 class B = 1.8 oz/ft^2. From Romanoff, NBS Circular #579, Page 110, Table 65 gives the following average loss rates for Site #5 soils:

EXPOSURE DURATION (years)	WEIGHT LOSS (oz/ft^2)	LOSS PER YEAR (oz/ft^2)
10.17	2.66	0.262

- Estimated Life of Zinc: 1.8 oz/ft^2 / 0.262 oz/ft^2 = 6.9 years
- Total Estimated Service Life of Helical Pile Shaft: 133.6 + 6.9 = 140.5 years
- From Romanoff Site #2 (Bell Clay):

EXPOSURE DURATION (years)	WEIGHT LOSS (oz/ft^2)	LOSS PER YEAR (oz/ft^2)
2.1	2.4	1.143
4.0	3.0	0.750
5.9	3.4	0.576
7.9	3.6	0.456
12.0	5.9	0.492
17.6	8.1	0.460

The average loss per year is 0.65 oz/ft^2. Note that as the duration of exposure increases, the material loss per year generally decreases.

- Helical Pile Shaft Life:

  To determine the helical pile shaft's service life (SL), the allowable steel loss is divided by the average loss per year.

  SL = (81.5 oz/ft^2) / (0.65 oz/ft^2)

  = 125.4 years

- Total Zinc Coating Loss:

  CHANCE® Civil Construction helical anchors/piles are already provided hot dip galvanized per ASTM A153. The coating thickness for ASTM A153 class B = 1.8 oz/ft^2. From Romanoff, NBS Circular #579, Page 110, Table 65 gives the following average loss rates for site #2 soils.

EXPOSURE DURATION (years)	WEIGHT LOSS (oz/ft^2)	LOSS PER YEAR (oz/ft^2)
9.92	0.44	0.044

- Estimated Life of Zinc: 1.8 oz/ft^2 / 0.044 oz/ft^2 = 40.9 years
- Total Estimated Service Life of Helical Pile Shaft: 125.4 + 40.9 = 166.3 years

- Summary:

  Total estimated service life of helical pile shaft in Site #5 soils = 140.5 years

  Total estimated service life of helical pile shaft in Site #2 soils = 166.3 years

  These calculations are an estimate of the service life only (1/8" material loss from shaft) and are based upon loss rates obtained from Romanoff's disturbed soil sites. It is generally accepted that the majority of any corrosion will occur at or near the surface. Therefore, it is very likely that helical pile shaft metal loss will control the design. In the event the estimated service life does not meet the design requirements, one option is to use a larger sized helical pile shaft.

Design Example 2:

- Project: An access bridge designed to cross a wetland area.

  The purpose of the calculations is to estimate the service life of Type RS3500.300 Helical Piles on this project. The service life is defined as the estimated length of time required for a 10% metal loss to occur to the helical pile shaft.
- Given:
  1. Helical Piles will receive a hot dipped galvanized coating (G) of 5-mil thick (3-oz/ft^2)
  2. Soil Resistivity (R) – 1,000 ohms/cm
  3. Soil pH – 6.0
  4. Soil type – organic silt in top 10' with SPT blow counts of 2 to 4 blows per foot.
- Assumptions:
  1. The metal loss rates will be based on the values given in Figure A-5 with a pH of 6.0 and a resistivity of 1,000 ohms/cm. These values place the organic silt in the severe corrosion environment region.
  2. The galvanized coating loss rates will be based on Equation A-3 as shown on page A-17.
- Estimated Life of Galvanized Coating:

  To estimate average life for galvanized coating in a location with a soil resistivity of 1000 ohms/cm, Equation A-3 is used:

$$\begin{aligned} CL_1 &= 0.25 - 0.12 \log_{10} (R/150) \\ &= 0.25 - 0.12 \log_{10} (1000/150) \\ &= 0.25 - 0.12\ (0.824) \\ &= 0.15 \text{ oz/ft}^2\text{/yr} \end{aligned}$$

where: CL_1 = Weight loss per year

The estimated life of the galvanized coat is:

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

Equation A-4

where: G = Amount of galvanized coating = 3.0 oz/ft^2 for typical hot dipped galvanized coating (5 mil)

L_1 = Life expectancy (yrs)

CORROSION

- Estimated Life of of Steel:

  The formula for estimating average life for loss in steel wall thickness is given in Equation A-5 below:

$$L_2 = W_s/K_2 \qquad \textbf{Equation A-5}$$

where:

L_2 = Life expectancy (yrs)

W_s = Weight of steel pile (oz/ft^2)

K_2 = Loss in weight by corrosion ($oz/ft^2/yr$) as determined from Figure A-5

Reference to Figure A-5 indicates a corrosion weight loss range for bare steel of approximately 3 to 10 oz/ft^2 for a 10-year period. In this case (also checking the NBS data) an estimate was used of 8 oz/ft^2 for 10 years. Therefore K_2 = 8.0 oz/ft^2 per 10 years or 0.8 oz/ft^2/year.

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

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

The estimated additional life becomes:

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

- Life Estimate Summary (Galvanized Steel Round Shaft):

  Based upon the assumptions, the results of this analysis indicate that the CHANCE® Type RS3500.300 helical pile as specified for the bridge foundation will experience an average 40 to 45 year estimated life.

Design Example 3:

Extendable helical piles/anchors consist of segmented elements that are coupled together with structural bolts. It is possible for coupling bolts to be located near the surface in disturbed soils. Therefore, it is recommended that the coupling bolt service life be calculated based on corrosion loss rates. This can be accomplished using methods similar to those shown in Design Example 1.

- Determine the diameter reduction of Type SS5/150 coupling bolts using corrosion loss rates per FHWA-SA-96-072. Type SS5/150 Helical Piles/Anchors use 3/4” diameter bolts per ASTM A325. Assume a service life of 85 years.
- Total Zinc Coat Loss:

  Hubbell Power Systems, Inc. provided fasteners are hot dip galvanized per ASTM A153. The coating thickness for ASTM A153 class B = 1.8 oz/ft^2.

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

  Estimated life of zinc coating = [1.8 oz/ft^2 - 0.77 oz/ft^2 = 1.03 oz/ft^2/0.103 oz/ft^2 = 10 years] + 2 years = 12 years
- Total Steel Loss:

  Coupling bolt steel loss will occur after the zinc coating is lost. The exposure time to corrosion for the bolt steel is: 85 years – 12 years = 73 years.

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

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

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

- Determine the tensile load capacity reduction of Type SS5/150 Coupling Bolts: The minimum ultimate tensile strength for CHANCE® Type SS5/150 Helical Piles/Anchors is 70 kip. The failure mechanism is double shear of the coupling bolt. Assuming a linear relationship between diameter and shear capacity, the bolt diameter reduction from an 85-year exposure per FHWA-SA-96-072 corrosion loss rates suitable for use in mildly corrosive soils will result in a reduced tension load capacity, i.e., 0.68 x 70/0.75 = 63.5 kips.

Design Example 4:

1. Estimated Average Life of Sacrificial Magnesium Type Anode:

The formula for estimating average life for sacrificial magnesium anode life is given in Equation A-6 below:

$$L_3 = [57.08 (K_3) (W_a)] / I$$ **Equation A-6**

where:

L_3 = Life expectancy of magnesium or zinc anode (yrs)

K_3 = Efficiency of anode bag (60%-70%)

W_a = Weight of anode (lbs)

I = Current output of anode (mA). Available from Table A-5 for CHANCE® Civil Construction supplied anodes or from the vendor when using other anodes.

NOTE: Equation A-6 is not unit consistent.

Assume that in the previous Design Example 2, the pile performance life is to be further extended (beyond 40 to 45 years) by use of a 48-pound magnesium sacrificial anode for each pile. For this size bar and soil resistivity condition (R = 1000 ohms/cm), the vendor indicates I = 163.5 mA and K = 65%. Therefore, Equation A-12 becomes:

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

$$= 11 \text{ yrs}$$

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16. Uhlig's Corrosion Handbook, Second Edition, Edited by R. Winston Revie, Electrochemical Society Series, 2000.
17. West, Edward L., Cathodic Protection of Anchors - A Basic Guide to Anode Selection, A.B. Chance Bulletin 2-8307, A.B. Chance Company, Centralia, MO, 1983.
18. Winterkorn, Hans F., and Hsai-Yang Fang, Foundation Engineering Handbook, Van Nostrand Reinhold Company, New York, NY, 1962.
19. Various Cathodic Protection System Vendors.

LOAD TESTS

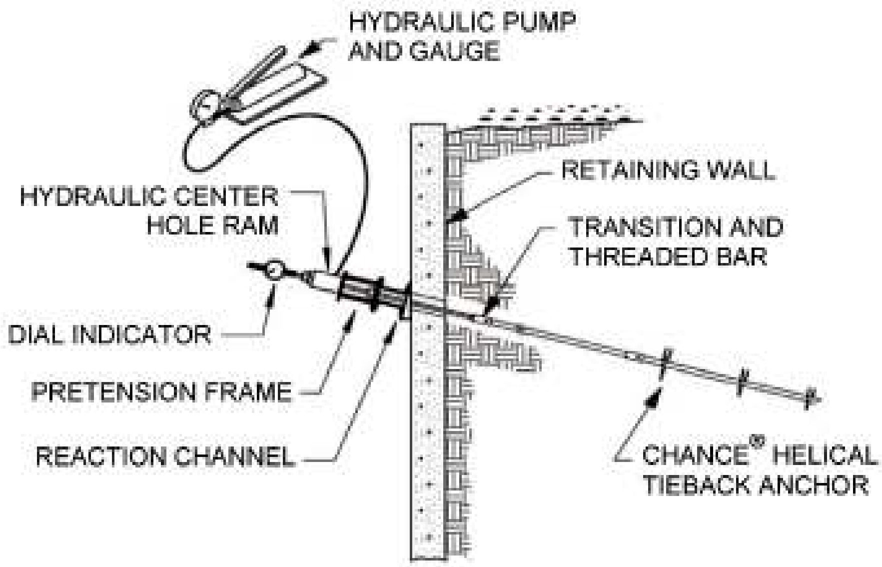
LOAD TESTS
APPENDIX B

CONTENTS

LOAD TESTS

SYMBOLS USED IN THIS SECTION

STATIC LOAD TESTS (TIEBACKS)



It is recommended that the Field Load Tieback Test be conducted under the supervision of a Registered Professional Engineer. The engineer will specify the test and measurement procedure, load increments, time intervals and acceptable ultimate deflection consistent with specific project and load conditions. If the required ultimate load and test ultimate load results are close, the engineer may choose to adjust the tieback spacing, the length of installation to achieve greater installation torques, and/or the helical plate configuration on each tieback to achieve the desired Factor of Safety (FS).

Hardware Configuration for Performing a Load Test on a Retaining Wall or to Pretension a Wall with Soil Overburden.
Figure B-1

TEST PROCEDURE

WARNING! DO NOT ALLOW ANYONE TO STAND BEHIND OR IN LINE WITH THE THREADED BAR AND JACK DURING THIS TEST. SERIOUS INJURY MAY OCCUR IF A COMPONENT FAILS DURING TESTING.

1. Determine the required length of the helical tieback anchor to locate the helix plates into the target soil stratum as determined from the project boring logs. Use this data to select the tieback design and ultimate tension capacity and the estimated installation torque. Install the helical tieback anchor to the determined length and torque requirements.
2. If the soil overburden has not been excavated from behind the wall, connect the thread bar adapter/transition to the helical tieback by reaching through the hole in the wall. Install the continuously threaded bar, reaction channel, hydraulic ram (loading device), pretension frame (if required), dial indicator (or other measuring device such as Total Station Unit), hydraulic pump and gauge (see Figure B-1). The magnitude of the test pressure is determined as follows:

$$P_T \text{ (test pressure) psi} = \frac{\text{DL (design load) lbs x FS (Factor of Safety = 1.25 to 2.5)}}{\text{A (effective cylinder area) in}^2}$$

NOTE: The effective cylinder areas (A) are available from the manufacturers of center hole rams (i.e., Enerpac, Power Team, Simplex, etc).

The load application system, i.e., center hole ram and pump, shall be calibrated by an independent testing agency prior to the load testing of any tiebacks. For additional details, refer to the Model Specification - Helical Tieback Anchors for Earth Retention at http://www.abchance.com/resources/specifications.

An Alignment Load (AL), usually 5% to 10% of the Design (Working) Load (DL), should be applied to the helical tieback anchor prior to the start of field load tests. The initial alignment load helps to remove any looseness in the tieback shaft couplings and thread bar transition system.

3. Pre-Production Tests (Optional):

   Load tests shall be performed to verify the suitability and capacity of the proposed helical tieback anchor, and the proposed installation procedures prior to the installation of production tiebacks. The owner shall determine the number of pre-production tests, their location and acceptable load, and movement criteria. Such tests shall be based, as a minimum, on the principles of the performance test as described below. If pre-production tiebacks are to be tested to their ultimate capacity, then an additional purpose of the pre-production tests is to empirically verify the ultimate capacity to average installing torque relationship of the helical tiebacks for the project site. Testing above the performance test maximum applied load of 125% x DL should follow the loading procedures and increments as given in the Static Axial Load Tests (Compression/ Tension) section to follow.

Anchor Tension Load Test in Minneapolis, MN
Figure B-2

4. Performance Tests:

   The number of tiebacks that require performance testing shall be defined in the project specifications. The minimum number of tiebacks for performance testing shall be two (2). Helical tieback anchors shall be performance tested by incrementally loading and unloading the tieback in accordance with the Performance Test Schedule (see Table B-1). The applied load shall be increased from one increment to the next immediately after recording the anchor movement. The load shall be held long enough to obtain and record the movement reading at all load increments other than the maximum test load. The maximum test load (1.25 x DL) shall be held for a minimum of 10 minutes. Anchor movements shall be recorded at 0.5, 1, 2, 3, 4, 5, 6, and 10 minutes. Refer to Acceptance Criteria on page B-12 for additional hold periods, if required, and acceptable movement criteria.

5. Proof Testing:

   All anchors which are not performance tested shall be proof tested. The proof test shall be performed by incrementally loading the helical anchor in accordance with the Proof Test Schedule (see Table B-2). The load shall be raised from one increment to another after an observation period. At load increments other than the maximum test load, the load shall be held for a period not to exceed two (2) minutes. The two minute observation period shall begin when the pump begins to load the anchor to the next load increment. Movement readings shall be taken at the end of the two minute observation period.

   The dealer/installing contractor or engineer shall plot the helical anchor displacement vs. load for each load increment in the proof test. The 1.25DL test load shall be maintained for five (5) minutes. This five minute observation period shall commence as soon as 1.25DL is applied to the anchor. Displacement readings shall be recorded at 0.5, 1, 2, 3, 4, and 5 minutes. Refer to Acceptance Criteria on page B-12 for additional hold periods, if required, and acceptable displacement criteria.

Performance Test Schedule, Table B-1

PERFORMANCE TEST SCHEDULE				
CYCLICAL LOAD INCREMENTS (%DL/100)				
AL	AL	AL	AL	AL
0.25DL*	0.25DL	0.25DL	0.25DL	0.25DL
	0.25DL	0.50DL	0.50DL	0.50DL
		0.75DL*	0.75DL	0.75DL
			1.00DL*	1.00DL
				1.25DL*
				Reduce to lock-off load#

AL = Alignment Load, usually 10 to 15% of DL.
DL = Design (Working) Load
* The dealer/installing contractor shall plot the helical anchor movement for each load increment marked with an asterisk (*) in the performance schedule and plot the residual displacement at each alignment load versus the highest previously applied load.
# Helical tieback anchors which are performance tested may be completely unloaded prior to the lock-off load procedure. Final adjusting to the lock-off load does not require further movement readings.
See the Performance Testing Procedures in the Model Specification - Helical Tieback Anchors for Earth Retention at http://www.abchance.com/resources/specifications for further information regarding load test equipment, load test set-up, dial gauges for monitoring anchor displacement, etc.

Proof Test Schedule, Table B-2

PROOF TEST SCHEDULE	
LOAD TEST SCHEDULE (%DL/100)	OBSERVATION PERIOD (MIN.)
AL	AL
0.25DL	2.0
0.50DL	2.0
0.75DL	2.0
1.00DL	2.0
1.25DL	5.0
Reduce to lock-off load#	

AL = Alignment Load, usually 10 to 15% of DL.
DL = Design (Working) Load
# Helical tieback anchors which are proof tested may be completely unloaded prior to the lock-off load procedure. Final adjusting to the lock-off load does not require further displacement readings.
See the Proof Testing Procedures in the Model Specification - Helical Tieback Anchors for Earth Retention at http://www.abchance.com/resources/specifications for further information regarding load test equipment, load test set-up, dial gauges for monitoring anchor displacement, etc.

STATIC AXIAL LOAD TESTS (COMPRESSION/TENSION)

PRE-PRODUCTION LOAD TESTS

Load tests shall be performed to verify the suitability and capacity of the proposed helical anchor/pile, and the proposed installation procedures prior to installation of production helical anchors/piles. These load tests shall be performed prior to the installation of the production helical anchors/piles. The Owner shall determine the number of pre-production load tests, their location, acceptable load and displacement criteria, and the type(s) of load direction (i.e., tension, compression, or both). An additional purpose of pre-production tests is to empirically verify the ultimate capacity to the average installing torque relationship of the helical pile/anchor for the project site with the torque measurement equipment used for the project. Pre-production helical pile/anchor installation methods, procedures, equipment, and overall length shall be identical to the production helical anchors/piles to the extent practical except where approved otherwise by the Owner.

It is recommended that any field load test for compression or tension be conducted under the supervision of a Registered Professional Engineer. The engineer will specify the test and measurement procedure, load increments, time intervals, and acceptable ultimate displacement consistent with specific project and load conditions. Test procedures shall conform to ASTM D-1143-07, Standard Test Method for Pile under Static Axial Compressive Load and/or ASTM D3689-07, Standard Test Method for Pile under Static Axial Tension Load unless otherwise specified by the engineer. These ASTM specifications do not specify a particular method to be used, but rather provide several slow-testing and quick-testing optional methods.

Citing the Canadian Foundation Engineering Manual, 2007:

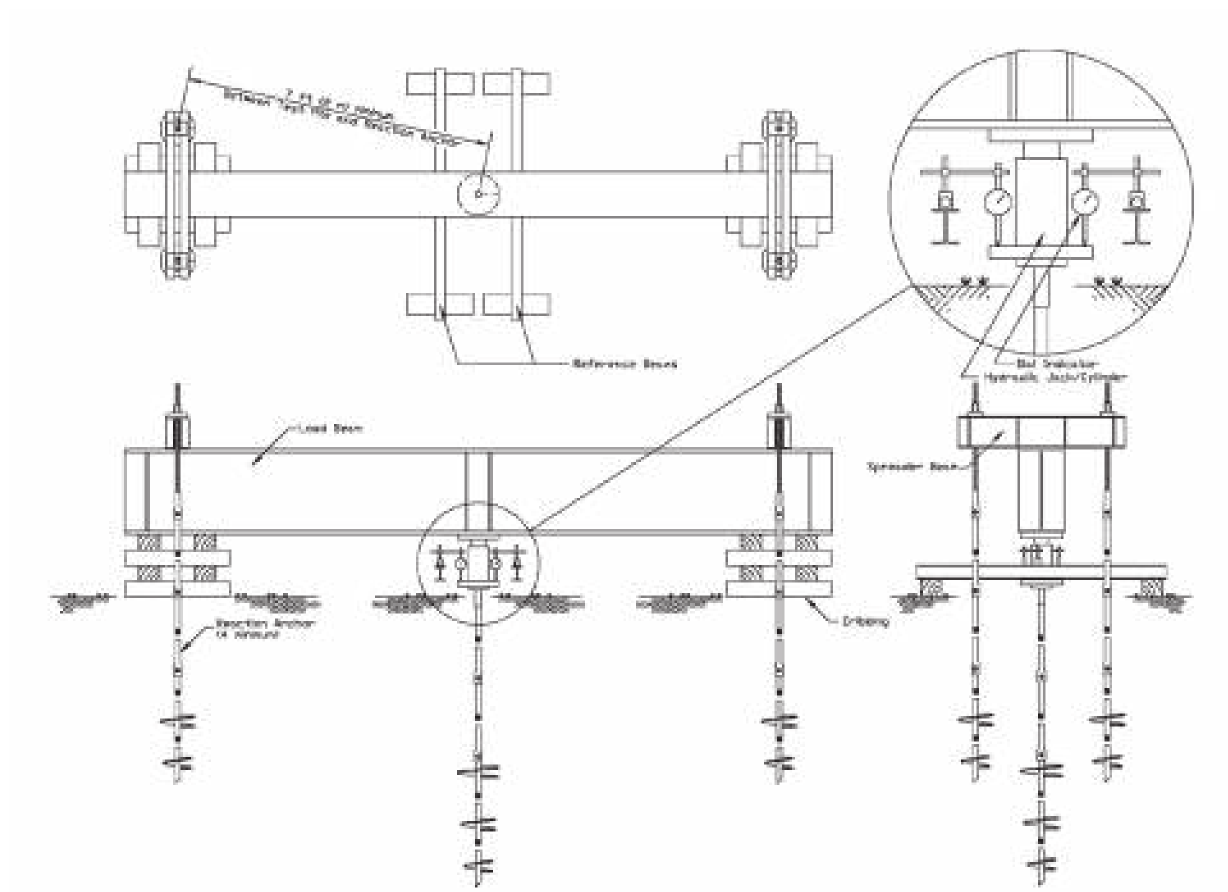
"The slow-testing methods . . . (outlined by the ASTM D1143-07. . . are very time-consuming. When the objective of the test is to determine the bearing capacity of the pile, these methods can actually make the data difficult to evaluate and disguise the pile true load movement behavior, thereby counteracting the objective of the test. The benefit of the (slow) test methods lies in the additional soil-pile behavior information, occasionally obtained, which the interpreting engineer can use, when required, in an overall evaluation of the piles.

". . . For routine testing and proof testing purposes, the quick methods . . . are sufficient. Where the objective is to determine the bearing capacity of the pile . . . the quick test is technically preferable to the slow methods."

Therefore, the following test procedure is based on the "Quick Load Test Method for Individual Piles". This test procedure shall be considered to meet the minimum requirements for load testing. It is not intended to preclude local building codes, which may require the use of other testing methods as described in the ASTM specifications..

PRE-PRODUCTION LOAD TESTS

1. Determine the depth to the target stratum of soil from the geotechnical site investigation report that includes boring logs. Use these data to select an pile/anchor design capacity, ultimate capacity and estimate the installation torque at the target stratum and depth.
2. Set the spacing and install the four reaction anchors at the test site (see Figure B-3). The recommended spacing between the test pile and the reaction anchors is at least 5D, where D = diameter of the largest helical plate. For tension only tests, the reaction anchors are not required.
3. Install the test helical pile at the centroid of the reaction anchors to the target depth and torque resistance. For tension tests, install the test anchor at the desired location to the target depth and torque resistance.
4. Mount the two anchor beams on the four reaction anchors/piles and the reaction beam between the anchor beams (see Figure B-3). For tension tests, center the reaction beam over the anchor and support each end of the beam on cribbing or dunnage. The helical reaction piles are not required if the surface soils have sufficient bearing strength to support the cribbing/dunnage under the applied loading without excessive deflections.
5. Install a load cell, hydraulic load jack, actuator and pressure gauge. The center hole load jack will be mounted below the reaction beam for a bearing (compression) test (see Figure B-3) and above the reaction beam for an anchor (tension) test. A solid core hydraulic jack can be used for compression tests.
6. Set the displacement measuring devices. Deflection measuring devices can include analog dial or electronic digital



Basic Compression Field Test Set-up
Figure B-3

Indoor Compression Test
Figure B-4

gauges (must be accurate to .001") mounted on an independent reference beam, a transit level surveying system, or other types of devices as may be specified by the engineer.

7. Apply and record a small alignment or seating load, usually 5% to 10% of the design load. Unless otherwise defined, the ultimate test load shall be assumed equal to 200% of the design load. Hold the seating load constant for 10 minutes or until no further displacement is measured.

8. Set the displacement measuring device(s) to zero.

9. Axial compression or tension load tests shall be conducted by loading the helical anchor/pile in step-wise fashion as shown in Table B-3 to the extent practical. Pile/anchor head displacement shall be recorded at the beginning of each step and after the end of the hold time. The beginning of the hold time shall be defined as the moment when the load equipment achieves the required load step. There is a generalized form for

recording the applied load, hold periods, and pile/anchor head deflections provided at the end of this Section.

10. Test loads shall be applied until continuous jacking is required to maintain the load step or until the test load increment equals 200% of the design load (i.e., 2.0 x DL), whichever occurs first. The observation period for this last load increment shall be 10 minutes or as otherwise specified. Displacement readings shall be recorded at 1, 2, 3, 4, 5 and 10 minutes (load increment maxima only).

11. The applied test load shall be removed in four approximately equal decrements per the schedule in Table B-3. The hold time for these load decrements shall be 1 minute, except for the last decrement, which shall be held for 5 minutes. Refer to Acceptance Criteria on page B-13 for acceptable movement criteria.

NOTE: Refer to Helical Pile Load Tests in the Model Specification - Helical Piles for Structural Support at http://www.abchance.com/resources/specifications for further information regarding load test equipment, load test setup, dial gauges for monitoring anchor displacement, etc..

PRODUCTION LOAD TEST PROCEDURES (OPTIONAL - AS SPECIFIED)

1. Follow the test setup procedures listed under Pre-Production Load Test Procedures (Items 1 through 7), **except** the maximum test load to be applied to the pile/anchor is the Design Load (DL). (This may be the only type of load test conducted depending on the conditions.)
2. The Contractor shall perform axial load tests on the number and location of helical piles as specified by the Owner. At the Contractor's suggestion, but with the Owner's permission, tension tests may be performed in lieu of compression tests up to 1.00 DL for helical piles with sufficient structural tension capacity. The requirements of Table B-4 may be regarded as a minimum, however, it is not recommended to test production helical piles to values of up to 2.0 DL unless the helical pile's failure load is significantly higher than 2.0 DL. The maximum production helical pile test load shall be determined by the Owner. For example, ASTM D1143 stipulates testing to 2.0 DL.

Pre-Production Test Schedule, Table B-3

PRE-PRODUCTION TEST SCHEDULE			
CYCLICAL LOAD INCREMENTS (%DL/100)			
Load Increment	Hold Period (Min.)	Load Increment	Hold Period (Min.)
AL	1.0	AL	1.0
0.20DL	4.0	0.50DL	4.0
0.40DL	4.0	1.00DL	4.0
0.60DL	4.0	1.20DL	4.0
0.80DL	4.0	1.40DL	4.0
1.00DL	4.0	1.60DL	4.0
0.75DL	4.0	1.80DL	4.0
0.50DL	4.0	2.00DL	10.0
0.25DL	4.0	1.50DL	4.0
		1.00DL	4.0
		0.50DL	4.0
		AL	5.0
AL = Alignment Load, usually 10% of DL; DL = Design (Working) Load			

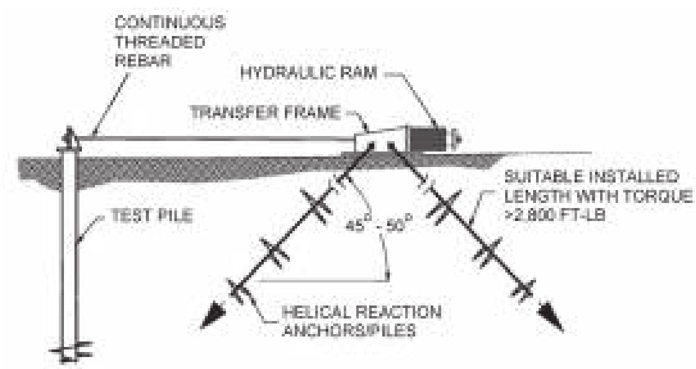
3. Axial compression or tension load tests shall be conducted by loading the helical pile/anchor in the load sequence as shown in Table B-4. Anchor/pile head displacement shall be recorded at the beginning of each step and after the end of the hold time. The beginning of the hold time shall be defined as the moment when the load equipment achieves the required load step. The observation period for this last load increment shall be 5 minutes or as otherwise specified. Displacement readings shall be recorded at 0.5, 1, 2, 3, 4, and 5 minutes (load increment maxima only).
4. The applied test load shall be removed in four approximately equal decrements per the schedule in Table B-4. The hold time for these load decrements shall be 1 minute, except for the last decrement, which shall be held for 5 minutes. Refer to Acceptance Criteria on page B-13 for acceptable displacement criteria.

STATIC LOAD TESTS (LATERAL)

Helical pile/anchor offer maximum benefits structurally when loaded axially (concentrically) either in tension or compression. In certain design situations, the anchors/piles may be subjected to lateral loads and it is important to establish their lateral load capacity. Such applications may include support for communication equipment platforms, foundations for light poles, and sign standards or use as foundation systems for modular homes. It is recommended that the Field Lateral Load Test on pile/anchor be conducted under the supervision of a Registered Professional Engineer. The engineer will specify the test and measurement procedure, load increments, time intervals, and acceptable ultimate deflection consistent with specific project and load conditions. If the desired ultimate lateral load capacity and test lateral load capacity results are close, the engineer may choose to increase the diameter of the anchor/pile shaft and/or use a concrete collar on the anchor/pile head in order to achieve the desired Factor of Safety. Lateral load tests shall be conducted in accordance with ASTM D-3966-07, Standard Test Method for Piles under Lateral Load.

Production Test Schedule (Optional - as Specified), Table B-4

PRODUCTION TEST SCHEDULE	
LOAD INCREMENT	HOLD PERIOD (MIN.)
AL	0
0.20 DL	4.0
0.40 DL	4.0
0.60 DL	4.0
0.80 DL	4.0
1.00 DL	5.0
0.60 DL	1.0
0.40 DL	1.0
0.20 DL	1.0
AL	5.0
AL = Alignment Load, usually 10 of DL. DL = Design (Working) Load	



Lateral Load Test Equipment Configuration
Figure B-5

Lateral Load Test Apparatus
Figure B-6

TEST PROCEDURE

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

2. Threaded steel bar or cable shall be used to connect the test pile to the reaction anchor frame. A hydraulic ram and pressure gauge is installed to apply the test load(s) and to measure the applied force.

3. Set the displacement measuring devices. Displacement measuring devices can include analog dial or electronic digital gauges (must be accurate to 0.001”) mounted on a reference beam, a transit surveying system, or other type of device as specified by the engineer.

4. For the Load Capacity Tests, follow steps 7 through 11 in the Static Axial Load Tests on page B-6 & B-7.

5. A failure criterion is often established by the project engineer and will reflect project specific conditions. The load versus lateral deflection is plotted. Interpretation of these results to determine the ultimate and working lateral load capacities often requires engineering judgment. Refer to Acceptance Criteria on page B-14 for acceptable displacement criteria.

CAPACITY VERIFICATION FOR ATLAS® RESISTANCE PIERS

On occasion, a building owner or engineer may want confirmation that existing ATLAS RESISTANCE® Pier underpinning is supporting the load as initially designed. Many times this request comes as a result of a client seeing tension cracks in the drywall or masonry. Many such requests are generated as a result of the owner failing to improve a poor drainage situation, from a failure to maintain the soil moisture around the perimeter of the structure or from leaks in the plumbing system. It is possible that the stratum upon which the pier is founded is receding. Changes can also occur that increase subsurface water near the structure such as a drainage system becoming clogged or an inoperative sump pump. In partial underpinning situations, additional loads may be imposed from adjacent areas experiencing further settlement resulting in a much greater load from the time of the previous installation. In these conditions, additional piers will be required along with adjustment of affected earlier installed piers.

The following gives the dealer/installing contractor and engineer guidance for answering these concerns and the engineer assistance with specifications for pier bearing verification.

TEST AND ADJUSTMENT PROCEDURE

1. Excavate and expose the top half of the pier bracket at each location to be tested and adjusted.
2. Check the pier pins to see if they are tight by tapping the heads of the pier pins with a hammer and then attempting to remove the pins using pliers.
   a. If the pier pins are loose:
      - The pier may be bearing on a stratum that is receding or that has deteriorated. Load test the pier.
      - The pier pipe or pier bracket component may have failed. If inspection of the components reveals a failure, replace the failed component and return it to Hubbell Power Systems, Inc. for evaluation. Load test the pier.
      - The footing may have heaved from expansion of the underlying soil if the floor slopes toward the interior. If evaluation of the structural elements, elevation measurements, drainage, and soil moisture content reveals heaving, then correcting the drainage or plumbing may allow the pier to return to the desired elevation. Schedule another inspection after the remedial work is complete and the soil has stabilized.

   b. If the pier pins are tight but the floor slopes toward the perimeter:
      - The interior floor may be heaving. If an evaluation of the structural elements and elevations reveal interior heaving, a plumbing test, an evaluation of the surface drainage, and subsurface soil conditions should be performed and the deficiencies must be corrected before any attempt to adjust the perimeter is performed.
      - The bearing stratum may be receding or compressing under the pier load as the structure continues to settle. Load test the pier.
3. Load testing procedure for ATLAS RESISTANCE® Piers:
   a. Install a lift head onto the pier bracket and place a 25 ton hydraulic ram with hose, gauge, and hand pump on the top pier platform.
   b. Slowly advance the ram while monitoring the top pier platform for creep.
   c. If little or no movement is observed, then the end of the pier is probably still founded upon competent material. Continue to increase the force on the ram until the structure begins to lift. (If the pier advances into the soil more than the stroke of the ram, skip to step f below.)
   d. Record the load test force that was required to begin to lift the structure. The formula for this force is: Gauge Pressure x 5.15 = Verification or Test Force (verify effective area of ram).
   e. Compare this force to the force indicated on the original pier log. (Variation of ±15% is acceptable.) (Skip to step i below.)
   f. Remove lift head assembly and top pier platform and install the pier driving equipment, drive stand, hydraulic drive cylinder, gauge, and gasoline or electric pump. Drive the pier pipe as if this was a new installation until suitable bearing is obtained. Record the driving force. The formula for this force is: Gauge Pressure x 8.29 = Driving Force (verify effective area of drive cylinder).
   g. Cut the added pier pipe to proper length and record the added length required at this pier.
   h. Install the top pier platform and lift head.
   i. Repeat steps a through e for **each pier that requires load bearing verification**.
4. Procedure for Adjusting Piers:
   a. Prepare a system of hydraulic rams and manifold(s) that are connected to all of the piers that need to be adjusted. Follow the normal elevation recovery procedure as described in the Typical Specification for the ATLAS RESISTANCE® Pier system being tested. Typical Specifications are available on the Hubbell Power Systems, Inc. website, www.abchance.com.

b. Carefully apply pressure using the hand pump to restore the lost elevation. Valve off each ram as the foundation elevation reaches the target. Record the lifting force and the amount of lift at each placement. The formula is: Gauge Pressure x 5.15 = Lifting Force.

c. Once the structure has reached the target elevation, install pier shims and pier pins as described in the Typical Specification for the ATLAS RESISTANCE® Pier system being tested. The Typical Specifications are available on the Hubbell Power Systems, Inc. website, www.abchance.com.

d. Carefully reduce the hydraulic pressure at each ram, remove the rams and lift heads

e. Replace and compact the excavated soil and leave the area clean and neat.

5. Report the results:

a. A Pier Installation Report shall be prepared that includes:
- A pier layout of the area of work with each pier location indicated,
- The verification or test force,
- The amount of downward movement required before reaching this force,
- The lifting force, and
- The amount of lift that was required to restore the foundation to the target elevation.

b. Report to the engineer or owner any surface or subsurface drainage conditions observed and any suspected plumbing problems (such as water seeping into all or only several excavations). It is important that the Owner understand that any plumbing leaks or drainage deficiencies that are observed at the time of the adjustment be corrected immediately, otherwise stability issues may continue.

ACCEPTANCE CRITERIA

Static Load Tests (Tiebacks)

PRE-PRODUCTION AND PERFORMANCE TESTS

The net displacement shall not exceed 0.05” during the first log cycle of time, i.e., 1 min to 10 min. If the anchor movement between the one (1) minute and ten (10) minute readings exceeds 0.05”, then the 1.25 DL test load shall be maintained for an additional 20 minutes. Displacements shall be recorded at 15, 20, 25, and 30 minutes. Net displacement is the difference between the movement recorded at the initial time increment and the final time increment of the log cycle of time. The initial time increment is 1 min and the final time increment is 10 min for the first log cycle of time for Pre-Production and Performance Tests.

The net displacement shall not exceed 0.10” during the final log cycle of time (examples, 3 min to 30 min, 6 min to 60 min, etc). If the acceptance criteria is not satisfied, then the anchor test shall be continued for an additional 30 minutes. Displacements shall be recorded at 45 and 60 minutes. If the acceptance criteria is not satisfied after this extended observation period, then the contractor shall exercise one of the options as provided in Section 6.5, Acceptance Criteria, in the Model Specification - Helical Tieback Anchors for Earth Retention found on www.abchance.com.

PROOF TESTS

The net movement shall not exceed 0.05” during the first log cycle of time, i.e., 0.5 min to 5 min. If the anchor movement between the one-half (1/2) minute and five (5) minute readings exceeds 0.05”, then the 1.25 DL test load shall be maintained for an additional 5 minutes. Displacements shall be recorded at 6 and 10 minutes.

The net displacement shall not exceed 0.10” during the final log cycle of time (examples, 1 min to 10 min, 3 min to 30 min, etc). If the acceptance criteria is not satisfied, then the anchor test shall be continued for an additional 20 minutes. Displacements shall be recorded at 15, 20, 25, and 30 minutes. If the acceptance criteria is not satisfied after this extended observation period, then the contractor shall exercise one of the options as provided in Section 6.5, Acceptance Criteria, in the Model Specification - Helical Tieback Anchors for Earth Retention found on www.abchance.com.

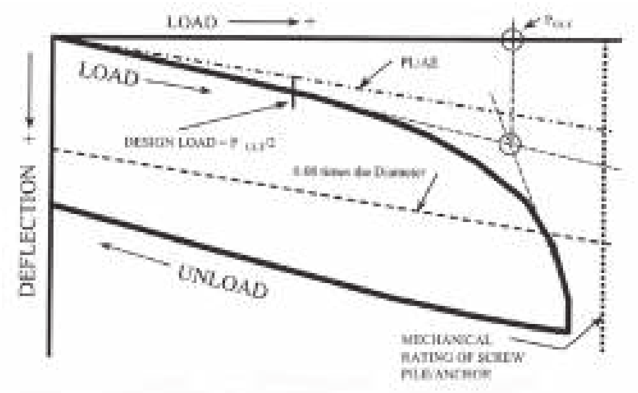
Static Axial Load Tests (Compression/Tension)

PRE-PRODUCTION LOAD TESTS

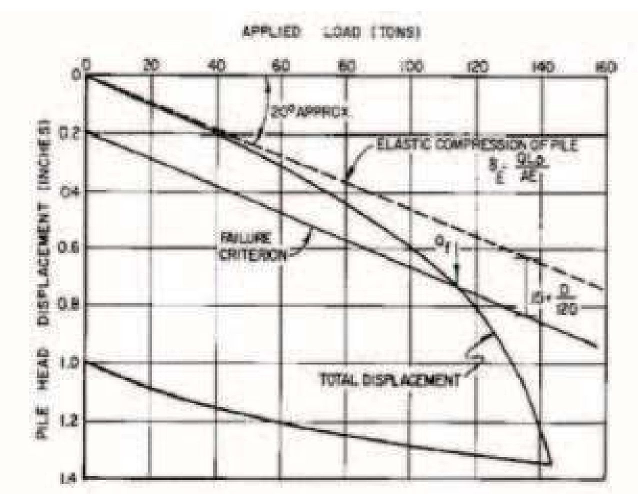
Acceptance of the load test results is generally governed by the building code for that jurisdiction and is subject to review by the structural designer. The structural designer determines the maximum displacement the structure can withstand without undue loss of function or distress. The acceptance criteria must be defined prior to conducting the load test.

The load displacement data may be plotted for a quick overview of the results. Figure B-7 shows a sample test plot. Various building codes have their own acceptance criteria, which is generally a limit on deflection at the factored load. A fast way to determine the ultimate geotechnical capacity is by use of a technique called the "intersection of tangents." This is accomplished by graphically constructing two tangent lines. One line is drawn tangent to the second "straight line" portion of the load curve, which is beyond the curved or non-linear portion of the load deflection curve. The other line is drawn tangent to the initial "straight line" portion of the load deflection curve. The point where the two tangents intersect identifies an estimate of the ultimate capacity.

An example of a Code-based acceptance criteria for the allowable capacity is the Chicago and New York City Code, which calls for the design load to be the lesser of:



Sample Compression Test Load-Deflection Curve
Figure B-7



Davisson Method for Determining Net Displacement
Figure B-8

1. 50% of the applied load causing a net displacement (total displacement less rebound) of the pile of 0.01" per ton of applied load, or

2. 50% of the applied load causing a net displacement of the pile of 1/2". Net displacement is defined as the gross displacement at the test load less the elastic compression.

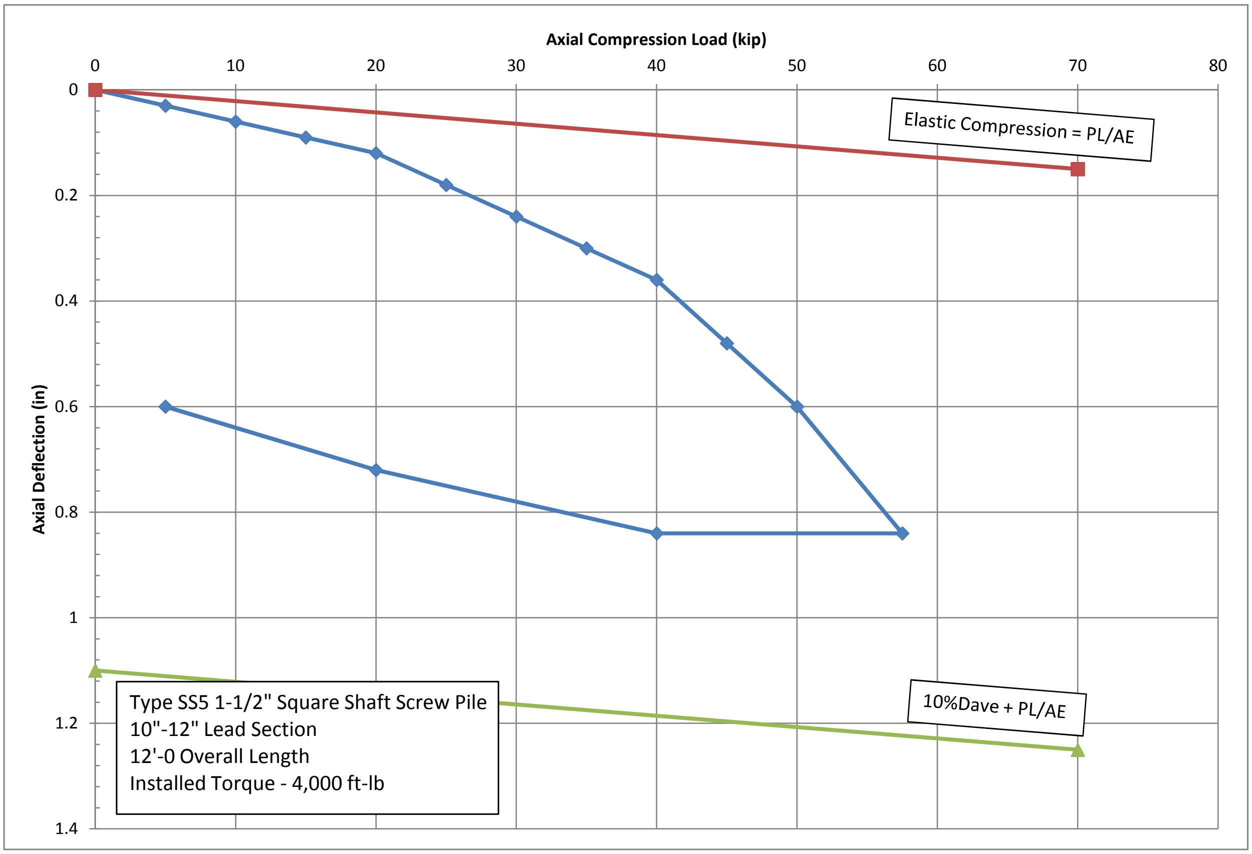
Other allowable capacity acceptance criteria include:

- Maximum total displacement under a specified load.
- Maximum net displacement after the test load.
- Maximum displacement under the design load, or various techniques such as that defined by the Davisson Method (1973) and shown in Figure B-8.

The recommended acceptance criteria for the allowable geotechnical capacity for helical piles/anchors is 1/2 of the applied test load causing a net displacement (gross displacement less the elastic compression/tension) not to exceed 0.10 times the average diameter of the helix plate(s). This is the acceptance criteria used in ICC-ES Acceptance Criteria AC358 for Helical Systems and Devices, per Section 4.4.1.2.

When relatively low foundation capacities are required, the allowable capacity for helical piles/anchors might be based on minimum depth and minimum torque criteria. This is similar to what the New York City code for driven piles up to 30 tons requires, which is to define capacity by the minimum "blows per foot of set." The subject of load tests and acceptance criteria are discussed by Crowther (1988) and may be referred to for a more complete treatment of the subject.

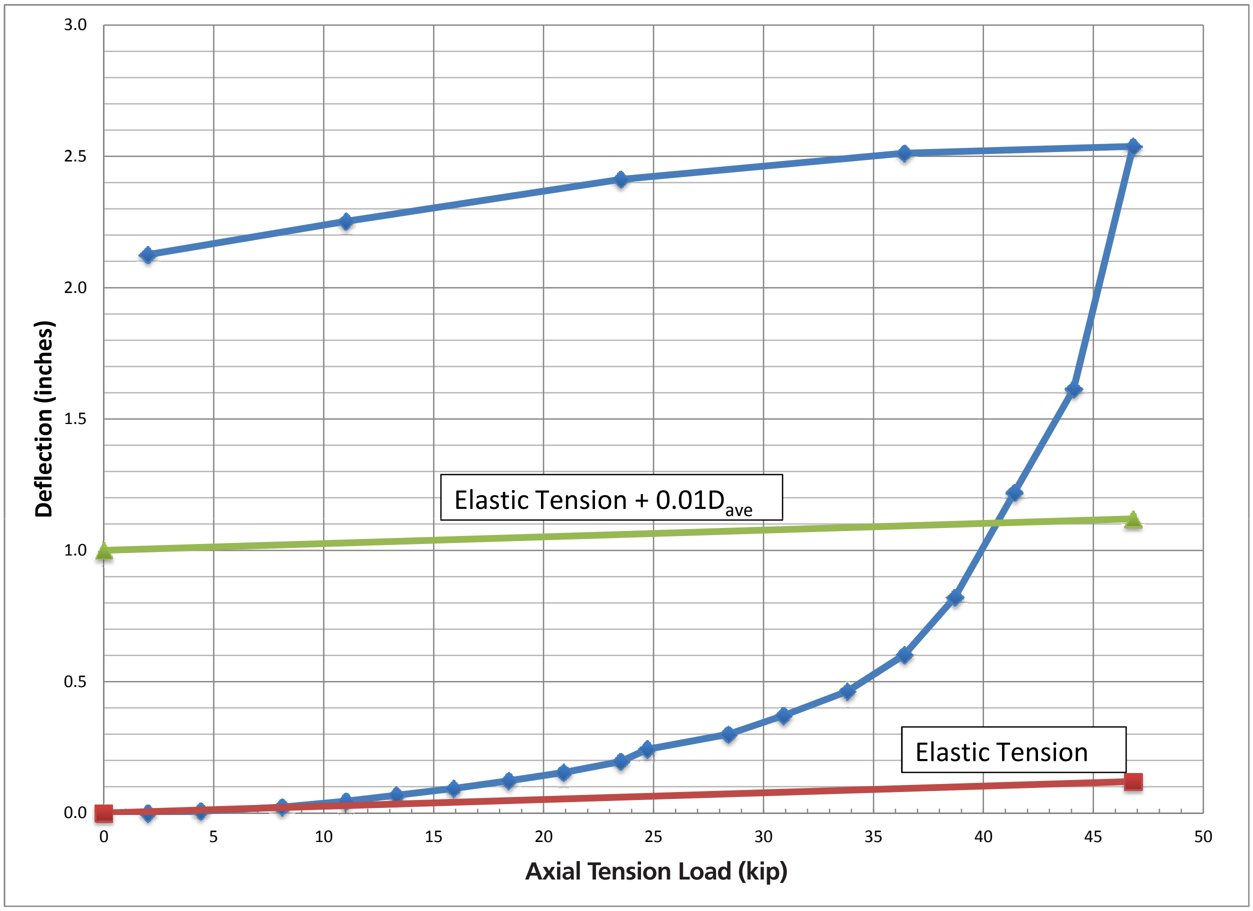
Figure B-9 is a plot of results from a compression "quick test" per ASTM D1143-07 of a 12 ft long, 1-1/2" square shaft helical pile having 10" and 12" helix plates. It was installed in the residual fine grained soils of Roanoke,



ASTM D1143 "Quick Test" Compression Plot
Figure B-9

Virginia and tested immediately after installation. The load-displacement curve is completely below the elastic compression line, indicating no skin friction was acting on the shaft during the test. The load-displacement curve does not cross the PL/AE + $0.01D_{ave}$, which indicates the maximum test load is less than the ultimate geotechnical capacity of the helical pile.

Figure B-10 is a plot of results from a tension "quick test" per ASTM D3689-07 of a 16 foot long, 1-1/2" square shaft helical anchor having 8", 10" and 12" helix plates. It was installed in the residual fine grained soils of Centralia, MO and tested immediately after installation. The load-displacement curve is completely above the elastic tension line (red line), indicating no skin friction was acting on the shaft during the test. The load-displacement curve crosses the PL/AE + $0.01D_{ave}$ line at approximately 41 kip. The average installation torque over the last three readings was 3,450 ft-lb. The torque correlation method (K_t) of capacity prediction says the ultimate geotechnical capacity is 3,450 x 10 = 34,500 lb (34.5 kip), using a K_t of 10 ft^{-1} as outlined in Section 6. The tested ultimate geotechnical capacity based on 10% average helix diameter net displacement is 41 kip. Therefore, the K_t based on the load test is 41,000/3450 = 11.9 ≅ 12.



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

PRODUCTION LOAD TESTS (OPTIONAL)

Some projects are large enough in size to justify the expense of several production tests. Production tests are useful to verify helical anchor/pile capacity at multiple locations across the project site, especially with varying soil conditions. The net displacement of helical anchor/piles at the allowable load (1/2 the geotechnical capacity) typically ranges between 0.25 inches (25 mm) and 0.5 inches (51 mm) total vertical movement as measured relative to the top of the helical anchor/pile prior to the start of testing. The Owner or structural engineer usually determines what the allowable displacement is, and it must be defined prior to conducting the Production Load Test. Limiting axial net deflections of 1" to 1-1/2" at the ultimate geotechnical capacity are typical.

STATIC LOAD TESTS (LATERAL)

Acceptance Criteria for Helical Systems and Devices AC358 states the allowable load capacity shall be equal to half the load required to cause 1 inch (25 mm) of lateral deflection as measured from the ground surface. The acceptance criteria must be defined prior to conducting the Lateral Load Test. The acceptance criteria must be realistic in its magnitude so as not to potentially damage the structure. Limiting lateral deflections of 1"+ at the ultimate load capacity have been used on some projects. It is suggested that large lateral loads be resisted through some other means (such as helical anchors, battered helical piles, or enlarged concrete pile caps/grade beams).

CHANCE® HELICAL PILE/ANCHOR AXIAL TEST

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

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

References

1. AC358 Acceptance Criteria for Helical Systems and Devices, ICC-Evaluation Services, June 2013 Revision.
2. ASTM D1143-07, Static Load Test Method for Piles under Static Axial Compressive Load, American Society for Testing and Materials, Philadelphia, PA.
3. ASTM D3689-07, Standard Test Method for Pile under Static Axial Tension Load, American Society for Testing and Materials, Philadelphia, PA.
4. ASTM D-3966-07, Standard Test Method for Piles under Lateral Load, American Society for Testing and Materials, Philadelphia, PA.
5. Canadian Foundation Engineering Manual, Canadian Geotechnical Society, 1985.
6. Crowther, Carroll L., Load Testing of Deep Foundations, John Wiley and Sons, 1988.
7. Davisson, M.T., High Capacity Piles, Department of Civil Engineering, Illinois Institute of Technology, Chicago, IL, 1973.

HELICAL PILES & ANCHORS
A BASIC GUIDELINE FOR DESIGNERS
APPENDIX C

CONTENTS

DISCLAIMER

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

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

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

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Helical Piles & Anchors:

A Basic Guideline for Designers

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Edited by Hubbell Power Systems, Inc.

I. INTRODUCTION

Helical piles and anchors have made tremendous gains in popularity and acceptance in the first part of the 21st century. They are used increasing more in varied applications such as underpinning settling foundations, new construction piles, tiebacks, guy anchors, pipe supports, solar panel foundations, thrust restraints, and street light foundations. They are gaining acceptance and are used in residential, commercial, industrial and heavy civil markets.

Many consulting engineers will not use helical products in their everyday design and application jobs. They may have gone through training or become familiar with design for a specific project but have lost that ability through infrequent use and choose to either not relearn and/or not use the helical products or to "leave it to the specialty contractor." This Guideline is to help shorten and refresh the process so engineers can efficiently design with helical piles and anchors to be profitable and add value for their clients.

The goal of this Guideline is to bring the design, selection, and procurement of helical piles and anchors into a practical perspective. This Guideline will not focus on academic theory, but will present practical solutions to problems involving helical piles and anchors. The intent is to provide this information to engineers to help them solve problems on projects that they are involved with in an effective manner.

II. DESIGN REQUIREMENTS

A. Shaft Type of Helical Pile/Anchor

There are 4 basic types of helical piles available. The following is a brief summary of the 4 different types of helicals.

- **Type 1 - Square Shaft**

Square shaft piles are more efficient than pipe shaft helical piles in regards to capacity derived from installation energy. A square shaft helical pile will have more axial capacity than a pipe shaft helical pile installed with the same amount of torsional energy into the same soil profile.

Square shaft helical piles are better at penetrating dense material than pipe shaft helical piles.

The square shaft piles have slender cross sections. Therefore, they do not have a large section modulus/stiffness to resist buckling under compressive loads without support from the surrounding soil. As long as there is sufficient passive soil pressure around the pile to prevent buckling, square shaft piles are suitable for compressive loads. As a general rule, if the soil profile has ASTM D1586 SPT N_{60} value of 5 or greater, there is sufficient passive soil pressure to prevent the square shafts from buckling at the compressive loads that they are rated for. If SPT N_{60} values are 4 or less, then buckling may be a concern and is a complex problem dependent on a number of variables. A rigorous analysis can be done if enough reliable soil data is available, but the problem can normally be more efficiently solved by selecting another shaft type with a larger section modulus.

- **Type 2 - Pipe Shaft**

Pipe shaft helical piles are not as efficient in regard to load capacity derived from installation energy, but have a larger section modulus when buckling of the square shafts or potential unsupported length is a concern.

Pipe shaft helical lead sections do not penetrate dense material as effectively as square shaft lead sections.

- **Type 3 - Combo Pile**

A combo pile (Combination Pile) is a helical pile that has both the advantages of square shaft and pipe shaft helicals. A combo pile has a square shaft lead section that is better at penetrating dense material and generating load capacity, and is then transitioned to a pipe shaft for the plain extensions where overburden soils are softer and a larger section modulus is desired for buckling resistance, or when lateral load resistance is required.

- **Type 4 – HELICAL PULLDOWN® Micropile**

A HELICAL PULLDOWN® Micropile is a square shaft helical foundation or anchor that has the plain extension sections encased in a small diameter grout column, typically 5” – 7” in diameter. Pipe shaft helical piles can also be encased in a grout column, but that is less common. Similar to the combo pile, it has the advantage of the square shaft lead section to penetrate dense material. The added grout column provides a larger section modulus for buckling resistance and lateral resistance in softer soils. Lateral load resistance with grouted shafts requires a steel case. The grout in contact with the soil will develop friction capacity via a bond zone in suitable soil stratum. This can greatly increase the total axial capacity of the pile (end-bearing and skin friction) as well as stiffen the load response of the pile. The grout column also provides additional corrosion protection to the steel shaft. The HELICAL PULLDOWN® Micropile is a patented technology exclusive to Hubbell Power Systems, Inc. installing contractors.

There are a minimum of 6 design considerations that should be taken into account when choosing the required shaft type. This is often the most important aspect of specifying a helical pile and too often receives the least amount of attention prior to installation.

A.1. Axial Capacity of Shaft **Reference: Section 5**
Section 7

Is the shaft section sufficient to carry the intended axial load? This will have a great deal to do with the selection of the shaft type. There are four basic types of helical piles. See above for brief description.

Type 1 - Square Shaft
Type 2 - Pipe Shaft
Type 3 - Combo Pile (Square shaft lead with pipe shaft extensions)
Type 4 - Grouted HELICAL PULLDOWN® Micropiles.

If SPT N_{60} values are 4 or less, the section modulus should be increased by choosing a pipe shaft or encasing the square shaft within a grout column, i.e. HELICAL PULLDOWN® Micropile. Another benefit of choosing a grouted shaft pulldown pile is that it is a composite pile rather than an end bearing only pile. It can generate capacity from both end bearing of the helical plates as well as friction capacity from the grout. Often the torque correlated axial capacities listed in Section 7 of the square shaft product family can be exceeded for compressive loads because of the enlargement of the section modulus and the addition of the friction capacity resulting from the addition of the grout column. Tension loads are controlled by the mechanical limits of the couplings. The increase in compression capacity can be verified with a load test. A further benefit of grouted shaft piles is they will have a stiffer load/deflection response than an end bearing only pile.

A.2. Penetration into Desired Geologic Strata **Reference: p. 5-52**

The helical plates must generate the thrust required to advance the shaft through the soil profile. The helical plate or screw thread is an inclined plane. Helical piles (i.e. screw piles) are displacement piles that have the advantage of no spoils. The soil that is displaced by the shaft during installation is displaced to the side. The smaller the shaft size relative to the size of the helical plates (low displacement pile), the more efficient the pile will be in regards to capacity derived from the same installation energy. A helical pile that has a smaller shaft size relative to the size of the helical plates will be better at penetrating dense soil than one with a larger shaft size relative to the size of the helical plates (high displacement pile). Displacing more soil will require more installation energy, i.e. additional installation torque. The greater the installation energy, the larger the required equipment to install the pile.

Square shaft helicals are better at penetrating dense material than pipe shaft helical piles. Where penetration into dense material is required, and a larger section is needed in the upper portions of the pile for buckling reasons, a Combo Pile or a HELICAL PULLDOWN® Micropile are good choices as the square shaft lead sections will penetrate into the dense material better than a pile with a pipe shaft lead. If a soil strata is too dense or the shaft too large relative to the size of the helical plates, the pile could "spin-out". "Spin-out" means that the pile is still being rotated but is not advancing, and installation torque drops dramatically. This is similar to "stripping" a screw. **The capacity-to-torque correlation is no longer valid for spun-out piles.** (Note: see Section 6 – Installation Methodology for a complete explanation of torque correlation for helical anchors and piles) Now, rather than having a helical pile where torque is used as an indicator of the pile capacity, it is just an end bearing pile that was advanced to depth via a screw mechanism. This does not mean that the pile has no capacity, but rather that the capacity cannot be estimated by the installation energy as is normally done for a low-displacement helical pile. The pile's capacity will depend on the type of material the helical plates are in, how much the soil was disturbed, and whether or not the shaft tip, or pilot point, contributes to the capacity in end bearing. High capacities can be possible if the shaft tip is sitting on rock.

A.3. Lateral Loading Reference: p. 5-42 thru 5-47

Helical piles, whether they be square shaft, pipe shaft or HELICAL PULLDOWN® Micropiles, are generally slender members (low displacement pile). Lateral capacity of piles is dependent on the flexural stiffness of the pile, and the resistance of the soil the pile shaft will be bearing against as it deflects. Due to their slender size, helical pile shafts have a small effective projected area for the soil to bear against. Therefore, low displacement helical piles do not have much lateral capacity at typical tolerances for allowable lateral displacement. Square shaft piles don't have any significant lateral capacity. Pipe shaft and HELICAL PULLDOWN® Micropiles have a limited amount. A grouted shaft HELICAL PULLDOWN® Micropile with a steel casing at the top of the pile will offer the stiffest pile section and the most resistance to lateral loads. Lateral capacity ranges from 2 to 4 kip for 3" to 4" diameter piles to 10 kip for 6" to 10" diameter helical piles at typical lateral displacement tolerances. The use of battered (inclined) piles can be utilized to resist lateral loads if needed and are discussed in Section 5 of this Manual.

A.4. Corrosion Potential Reference: App. A

There is extensive information on corrosion of steel piling in soils. In most conditions, corrosion is not a practical concern of either square shaft or pipe shaft helical piles. Corrosion is the oxidation of the steel members of a helical pile/anchor. There is typically little to no oxygen in undisturbed soils, especially below the water table. Driven steel piles have been installed with pile hammers for more than a century and are still commonly used today. The vast majority of interstate highway bridges in the Piedmont regions of the southeast United States are bearing on steel H-piles. If corrosion is a concern for a given project, then a square shaft helical pile is a solid cross section and has much less perimeter surface area for corrosion to occur compared to a pipe shaft; which is hollow and has much more perimeter surface area (inside and out) compared to the cross-sectional area of steel. A HELICAL PULLDOWN® Micropile, where the solid square shaft is encased in a very dense grout mixture, provides the most resistance to corrosion. Cathodic protection, or corrosion allowance (sacrificial steel) are also options in aggressive environments or applications.

A.5. Tension Only Loads.

For tension only members, square shaft (Type SS) is always the logical choice. As noted above, square shaft helicals are more efficient in regards to load capacity versus installation energy (torque correlation), are better at penetrating dense soils, and have less surface area for corrosion potential. There is more sacrificial steel (relative to total cross-sectional area) available when considering corrosion in square shafts. The size and strength of the shaft is governed by the required installation torque; there is more steel section available than is required to carry the rated axial tension load. The reason for this is because the steel in the shaft is subjected to more stress during installation than it will ever see while in service. Once the helical anchor is installed, the ultimate mechanical tension strength is governed by the shear strength of the coupling bolt. The square shaft has more available steel cross-section (compared to pipe shaft) that can be sacrificed before the tensile strength is reduced.

A.6. Reversing Loads.

For piles that are required to resist compression and tension loads, the designer must recognize that helical piles are a manufactured product with bolted connections. There is manufacturing tolerance in each connection. For example, most helical piles have up to 1/8" axial tolerance in each connection. If the manufacturer did not allow for that tolerance, connections would often not fit together in the field. If the load reverses, the top of the pile will displace (up or down) a distance equaling the sum of the bolt tolerance in all of the bolted connections before it can resist the reversed load. This may or may not be of concern to the designer and is dependent on the type of structure that is being supported with the piles. The grout column of a HELICAL PULLDOWN® Micropile fills those connections, thereby removing the bolt tolerance as well as stiffening the load response. That is why grouted shafts are often utilized for piles with reversing load conditions. Grouting the inside of pipe shaft helicals will also stiffen the coupling movements for reversing load conditions.

B. Shaft Size

There are a minimum of 2 design considerations that must be accounted for when choosing the required shaft size.

1. **Torsional Capacity of Shaft** **Reference: Section 7**

Basic helical design methodology states that installation energy has a direct relationship to pile capacity. The shaft selected must be able to withstand the expected installation torque required for the pile to reach the intended capacity and the required depth or specific soil strata. If a dense layer must be penetrated prior to reaching the required termination depths, the shaft must have enough torsional capacity to pass through the dense layer. Otherwise pre-drilling through the dense layer may be required.

2. **Axial Capacity of Shaft** **Reference: Section 7**
Section 5

The shaft section must be capable of withstanding the required axial load. This will have a great deal to do with the selection of the shaft type and size. If the torsional strength is sufficient to reach the required depth and torque-correlated capacity, the shaft section will be sufficient to carry the axial load. The load capacities listed in the Specifications Table for each Product Family in Section 7 of this Manual are limited by torque for compressive loads and by the coupling strength for tension. The exception to this are when there are soft or very loose soils that do not provide sufficient passive soil pressure via confinement to prevent buckling under compression loads, (SPT N_{60} values of 4 or less). A square shaft can be up-sized to a pipe shaft to prevent buckling for lighter loads, or a grout column may be added with a HELICAL PULLDOWN® Micropile to provide increased section modulus that would allow the axial capacities in the Product Family Specifications Table in Section 7 to be exceeded. See the increased compression load capacity tables for HELICAL PULLDOWN® Micropiles with various diameter grout columns in Section 7.

C. Helical Configuration

There is a minimum of 1 design element that must be considered when choosing the suggested/required helical configuration for a performance-based specification or 2 design elements if using a prescriptive-based specification.

1. **Mechanical Capacity of Individual Helical Plates** **Reference: Section 7**

The mechanical capacity or strength of an individual helical plate is dependent on the thickness, grade of steel, and diameter; and strength of the weld that connects it to the pile/anchor shaft. In most cases, the mechanical capacity of a given diameter helix plate will increase with increasing shaft diameter. As a minimum, there must be enough helical plates so that the sum of their individual capacities can share the load that is required of the pile/anchor. A performance-based specification would only require that the minimum number of helical plates be provided that is necessary to share the load. The size of each plate would be left up to the installation contractor as long as the minimum number is provided and that other requirements are met, such as minimum depth and torque. For example, if 60 kips capacity is required, and the individual helix capacity is 40 kips, then a minimum of two helices would be required to share the 60 kip load. A prescriptive-based specification would be explicit on the exact number and size of the helix plates.

2. <u>Size of Helical Plates</u> **Reference: Section 7**

The size of helical plates can have a significant influence on the installation and performance of a helical pile/anchor. The helical configuration (smaller or larger diameter helix plates) required can change from pile to pile. If the specifier is not comfortable with a performance-based specification, (minimum number of helical plates, minimum torque capacity, minimum depth), then a more prescriptive approach can be given. This may also be required for comparative bid reasons and is fine as long as a payment mechanism for adjustment is provided. Typically, the denser the soil, the smaller the helical plates must be. Alternately, the softer or less dense the terminating soil strata, the larger the helical plates will need to be to generate the required torque/capacity.

Typical helical sizes range from 8" to 14" diameter. 16" diameter helix plates are available, but are not as common. It is important that the smallest helix be the first or penetrating helix. A multi-helix lead will then have subsequent helices increasing in size. Generally, the same size helix is not repeated until the largest size available is reached. For example, a typical three-helix configuration would be an 8"/10"/12" on all square shaft sizes (1.5" and larger), or a 10"/12"/14" helical configuration on smaller square shaft sizes (1.25" and 1.5") or pipe shaft. Generally, larger square shaft sizes would only be used to generate larger load capacities; hence are generally not used unless being installed into dense material. Therefore, a smaller 8" helix is needed to better penetrate the dense material. A pipe shaft has a larger section/cross sectional area, which results in small remaining area of an 8" helix plate. Therefore, the smallest helix plate typically used on pipe shaft is generally a 10" diameter.

Helical plates are inclined planes and provide the driving mechanism for the rotational advancement of the pile/anchor. Helical configurations with multiple helical plates will drive straighter, and are more likely to advance properly than single helix configurations, and perform better. If too few helical plates are used, the most likely installation problem is "spinning out" (See above: Shaft Type, Penetration into desired geologic strata). This can be solved by adding more helix plates, larger helix plates, and/or more crowd pressure (downward force from installing equipment). Increasing crowd pressure may require a larger piece of equipment (excavator, backhoe etc.). Generally, adding more helical plates is more economical compared to upsizing to larger equipment. If too many helical plates are used, the likely installation problem is that the torque capacity of the shaft is reached prior to reaching the desired depth. Helical extensions can be removed by unscrewing the pile/anchor, taking them off and reinstalling the pile/anchor. If helical plates on the lead section need to be removed, it will require the installation contractor to supply a different helical lead or remove helical plates in the field with a torch or saw. Removal of helix plates in the field is done quite often, but for cost/time reasons the installing contractor would prefer not have to remove helical plates regardless of the method.

If there is limited risk in exceeding the torque capacity of the shaft prior to the required/desired depth, and that depth exceeds approximately 30', it is more economical to have enough helical plates - either to generate the required capacity (in the case of soft to medium bearing strata) or to penetrate the bearing strata (in the case of dense bearing strata) in the beginning rather than run the risk of either not getting the capacity at a reasonable length or "spinning out" trying to penetrate something dense. Extracting a pile/anchor and then reinstalling it at those lengths, while very do-able, generally have time costs that far exceed the cost of providing a helical extension on the first attempt.

D. Pile/Anchor Length

There are a minimum of 2 design elements that should be considered when requiring/estimating a pile/anchor length, whether using a performance or prescriptive based specification.

1. **Minimum Length** **Reference: Section 5**

Compression Only Piles – For helicals used as compression piles, often there is a geotechnical reason that the piles be a minimum length to ensure that the pile is deep enough to achieve required capacity needed for the long term. For example, if it is known that a compressible peat layer exists between 15’ and 20’ depths, then it is important for the piles to have bearing capacity in soil strata below the peat layer. Therefore, a minimum depth should be required to ensure that the piles are bearing below the peat layer and will not settle over time as the peat consolidates.

If there is no geotechnical reason to require a deeper minimum length, the minimum length for the pile to behave as a deep foundation is that the upper-most helix (the plate closest to the ground surface) is a minimum depth of 5 diameters (5D) of the helix plate below grade or subgrade. If the helical plate is not installed to this depth, the failure mode will be similar to a shallow foundation. This could cause a rupture of soil at the surface if there is not enough confining pressure. For example, if a site has loose overburden sand that trends to medium-dense sand with varying depth, with little risk of the sand getting looser with depth, the minimum length requirement may be “the uppermost helix must be 5D below sub-grade”. Most specifications simplify this to 5 feet below subgrade.

Tension Piles/Anchors – The 5D requirement over the uppermost helix for tension elements is extremely important. If this requirement is not met, there is not enough confining pressure and a wedge or plug of soil can erupt to the surface as the anchor fails. For helical tieback anchors, the 5D requirement is 5D beyond the active failure plane, which is dependent on the friction (φ) angle of the soil and the wall height. It is important that the helical plates are not stressing soil in the active failure wedge. If this happens, the wall could experience a global type failure. Again, most specifications simplify this dimension to 5 feet beyond the active failure plane. Therefore, the minimum length requirement for helical tiebacks should be “the uppermost helix must be 5 feet beyond the active failure plane”. There should be a schedule, table, or formula for determining this in the field to ensure that the minimum length is achieved.

2. **Cost**

The total installed length has a direct impact on the cost of the pile/anchor in both material cost and installation time. The designer must always keep this in mind. The length defined (or undefined) by the bidding documents has enormous ramifications on the cost. Well written bidding documents should define the piles well enough to obtain the pile/anchor performance that the owner requires, as well as obtain competitive pricing from the installing contractor. If the piles are not well defined, the installation contractor that leaves the most out of his bid will likely get the job. This is not good for the owner as it increases the likelihood that the owner is not going to get the performance from the piles that is needed; or be presented with an expensive change order after construction has begun. Bidding should be based upon a minimum estimated bid length with some method for adjustment for differing lengths. This approach better utilizes the flexibility of helicals, which is one of their advantages. A thorough discussion of bidding and construction documents and strategies is discussed in Section III of this Appendix, titled “Construction Documents”.

E. **Pile/Anchor Minimum Capacity or Installation Torque**

Whether using a performance or prescriptive specification, the pile/anchor capacity should be specified in order to ensure that the desired pile/anchor capacity is achieved and that one of the primary advantages of helicals is utilized, which is measuring installation energy (torque).

1. **Minimum Capacity**

All structural members, regardless of the method of determining the load capacity or strength that the member is designed to resist, are designed with a factor of safety to provide for possible overload conditions; or for the possibility that the member is understrength for some unknown or unforeseen reason. This normal use load is commonly referred to by names such as service, design, working, or un-factored load.

A factor of safety is applied to this load to provide a reserve load capacity beyond that which it is expected see under normal use. This safety factor may be prescribed by building code, but is often left up to the engineer-of-record. A proper factor of safety is a combination of economics and statistics. It is not typically economically feasible to design for zero probability of failure. Generally the more uncertainty, the higher the factor of safety applied. Conversely, the less uncertainty, the lower the factor of safety applied. The industry standard for helical piles is a factor of safety of 2 for permanent applications. Generally, for tieback anchors that are going to be individually post-tensioned and tested, a factor of safety of 1.5 is used. A lower factor of safety is justified since there is less uncertainty (the tieback is tested). This load that contains the safety factor is usually referred to as either the ultimate or factored load.

One of the biggest problems with construction documents regarding helical piles/anchors is clearly identifying the load required. The best method is to clearly define the loads as ultimate/factored loads on the construction documents. If not, then the loads should be clearly identified as (service/design/working/un-factored loads) and clearly state what the required factor of safety is.

OR

2. **Installation Torque** **Reference: Section 6, Section 7**

Installation torque can also be specified as the minimum requirement as it relates to the pile/anchor capacity required. This should only be done for piles/anchors that will not receive a proof test. This should not be done for tieback anchors where each anchor will be post tensioned and proof tested. In that case, passing the proof test is the only criteria that matters and obtaining a minimum torque is really a convenience for the contractor to ensure that he does not fail the proof test.

If the minimum torque approach is utilized, the specifier should be aware that torque capacity correlations differ depending on the type and size of shaft used. Please refer to Section 6 for a full discussion of Torque/Capacity (K_t) relationships. Empirical Torque Factors are soil dependent. Unless on-site testing is performed to obtain a site specific Emperical Torque Factor, statically conservative default values are typically used. A table of recommended default values for K_t is provided for your convenience.

Shaft Type	Shaft Size	Kt
Square	1.25”	10 ft^{-1}
Square	1.5”	10 ft^{-1}
Square	1.75”	10 ft^{-1}
Square	2.0”	10 ft^{-1}
Square	2.25”	10 ft^{-1}
Pipe	2-7/8” OD	9 ft^{-1}
Pipe	3.5” OD	7 ft^{-1}
Pipe	4.5” OD	6 ft^{-1}

Also, tension capacities should correspond to the average torque measured over the last three average helix diameters of installed length. Most specifications simplify this to 3 feet. This is because in tension, the helical plates are bearing against the soil that they have already passed through. So depending on how fast the torque increased, this could have a significant impact on the capacity of the anchor. Obviously, it is virtually impossible to average a helical anchor/pile's maximum torque rating over the last three average helix diameters.

III. CONSTRUCTION DOCUMENTS

A. Construction Plans

The previous section defined the design elements that should be considered when electing to use helical piles/anchors. Each one of these should be defined in the construction plans on a well-engineered project.

- Shaft Type
- Shaft Size
- Helical Configuration
- Pile/Anchor Length
- Minimum Capacity or Torque

By defining the parameters that will be acceptable for each of these design elements, more favorable results will be obtained from both a pricing and performance perspective. It is the writer's experience that summarizing the pile/anchor parameters in a format similar as listed above works well.

For example; consider using the following format or similar plans:

Helical Pile Data Summary

Pile Type:	Square Shaft Helical Pile
Shaft Material:	SS175 (1.75"x1.75" solid square shaft)
Helical Configuration:	8"/10"/12" helices
Bid Length:	28'-0
Minimum Capacity:	80 kips ultimate capacity

Other parameters can also be added such as grout column diameter for grouted HELICAL PULLDOWN® Micropiles, minimum length (if different from bid length), termination type, angle of installation, or required casing.

The above summary provides enough information for bidders to aggressively bid on the same items as other bidders. It reduces their risk of being undercut by a contractor bidding with either lesser material or a lesser estimated length. This also gives the owner and the engineer a comparative basis for their bid analysis. A method for payment should also be established for deviations from the bid length and should be considered in the bid analysis.

B. Bidding Documents

Well-crafted construction documents will allow installation contractors to accurately bid and properly install piles to serve their intended purpose. It is in the owner's and engineer's best interest for contractors to have the proper information to be able to accurately bid and properly install the piles/anchors. Poorly-crafted construction documents with lack of definition will result either in high pricing because the contractor has to assume an inordinate amount of risk, less than desired performance from the piles/anchors, installation problems, or change orders from the contractor. None of these things make the engineer-of-record, or helical piles attractive to the owner for future projects.

Bid processes can be handled in several different ways, and are dependent on the particular aspects and needs of each project. No two projects are exactly the same. Therefore, different aspects of the project may be the driving force behind the bid process or bid structure. These could be price, speed, or function. Helical piles/anchors are used in design/build projects, lump sum bids and projects with a unit pricing structure. It is the writers experience that unless there is a wealth of geotechnical information that is available to the bidders, lump sum pricing is generally not in the owner's best interest. A pricing structure that shares some of the risk with the owner and the contractor tends to result in better overall pricing. One exception to this would be if the bidders are allowed access to the site to install probe or exploratory piles prior to bidding. Helical piles/anchors are well suited to exploratory installations because of the torque to capacity relationships, the pile/anchor material can be recovered, and there is minimal disruption to the site. The less risk the contractor assumes, the better pricing will be.

Generally, a pricing structure that allows for a per/pile price to a specified bid depth with unit pricing for additional/deductible length works best. For example, if the geotechnical information available indicated that the average pile/anchor depth to be between 25'-0 and 30'-0 then a bid length of 28'-0 might be established with unit pricing by the foot for piles that exceed or are short of that length. Unit pricing would likely be even better if it is in established in increments of 7'-0 rather than 1' increments since 7'-0 is the length of most common material plain extensions. This is because the same amount of material is likely to be used once the contractor has to add an additional piece. In other words, if the pile depth exceeds 28'-0, there is an additional unit cost per unit additional 7'-0 extension. Some situations may lend themselves to providing a unit price for helical extensions also. Many tieback projects have benefited by utilizing this approach.

Another unit pricing strategy that is used effectively is to have the bidders provide a unit price per foot for the entire length of piling or anchorage on the project and not have a price per pile/anchor. In other words, the construction plans might show 100 piles at an average 50' depth and the bid quantity would be set up for unit pricing by the foot, (or 7' increments) for 500 lineal feet (LF) of piling. Payment would be made by the unit price for the quantity of piling installed, whether it is 450 LF or 550 LF.

C. Technical Specifications

Technical Specifications are an important part of well-crafted construction documents and should further define the details regarding the helical piles or anchors. Technical Specifications should define anything that affects the pricing or performance of the piles or anchors. At a minimum, the following should be defined:

- Pile materials
- Installation tools and equipment
- Quality control methods
- Installation records required
- Installation tolerances and techniques
- Load testing requirements, procedures, and acceptance criteria (if any)

Model specifications for helical piles, anchors, and tiebacks that can be used as templates and edited for your specific project needs are included on www.abchance.com.

FORMS

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APPENDIX D

CONTENTS

FORMS

DISCLAIMER

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

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

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

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

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

CHANCE™ ATLAS™

PRELIMINARY DESIGN REQUEST FORM

Contact at Hubbell Power Systems, Inc.:

Installing Contractor

Firm: ______________________ Contact ______________________

Phone: ______________ Fax: ______________ Cell: ______________

Project

Name: ______________________

Address: ______________________

____

____

Type: ☐ Foundation ☐ Underpinning/Shoring ☐ New Construction ☐ Rock ☐ Tieback Retaining ☐ Other: ☐ Soil Nail Retaining

Project Engineer ? ☐ Yes ☐ No

Firm: ______________________ Contact: ______________________

Address: ______________________ Phone: ______________________

______________________ Fax: ______________________

______________________ Email: ______________________

Geotechnical Engineer ? ☐ Yes ☐ No

Firm: ______________________ Contact: ______________________

Address: ______________________ Phone: ______________________

______________________ Fax: ______________________

______________________ Email: ______________________

Loads

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

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

____

____

____

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

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

____

Date: ______________ Requested Response: ______________________

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

FORMS

HUBBELL

HeliCAP® Helical Capacity Design Software
Buyer Qualification and Order Form

Qty	Description	Price Each	Hard Drive Serial # (see instructions on next page)
1	HeliCAP® Helical Capacity Design Software	________	______________________________

☐ Please send me a copy of HeliCAP® on CD.

Three additional licenses are available per copy. Go to www.abchance.com or contact Hubbell Power Systems, Inc. for more information.

BACKGROUND INFORMATION

Engineer

- ☐ Structural
- ☐ Geotechnical
- ☐ Civil
- ☐ Mechanical
- ☐ Electrical
- ☐ Registered professional
- ☐ Previous helical experience
- ☐ Other ____________

Contractor

- ☐ General
- ☐ Sub
- ☐ Design-Build
- ☐ Other ____________

- ☐ **Architect**
- ☐ **Distributor**
- ☐ **Government Agency**
- ☐ **Educational Institute**
- ☐ **Student**
- ☐ **Power Utility**
- ☐ **End User**
- ☐ **Other** ____________

APPLICATION REFERENCE

UTILITY

- ☐ Guy Anchors (Transmission Line)
- ☐ Telecommunication Towers
- ☐ DOT/FFA
- ☐ Registered Professional
- ☐ Other ____________

RESIDENTIAL

- ☐ Underpinning (Foundation Repairs)
- ☐ Basement Wall Anchors
- ☐ Other ____________

COMMERCIAL

- ☐ Underpinning (Foundation Repairs)
- ☐ Deep Foundations
- ☐ Pipeline Anchors (Buoyancy
- ☐ Earth Retention (Tiebacks and Soil Nails)
- ☐ Tiedowns (Uplift Restraint)
- ☐ Boardwalks - Walkways
- ☐ Other ____________

System Requirements

- Windows® XP/7/8
- Pentium® 100 MHz processor
- 32 Mb RAM
- 35 Mb free hard disk space
- 2X CD-ROM drive
- MAC users must have Virtual PC installed.

How to Find Your Hard Drive Serial Number

Your hard drive serial number is required in order to issue a license key for the HeliCAP® Helical Capacity Design Software. To find your hard drive serial number:

- Click the Start button at the lower left corner of the desktop.
- In the search prompt, type “cmd”.
- A dialog box will pop up that should have “CMD”. It should be near the top of the box and it should be highlighted. Press Enter.
- A DOS window should appear and display a DOS prompt. The DOS prompt will normally start with “C:”, which is the default drive. If you want to install HeliCAP® on a different drive, type the drive letter followed by a colon (e.g., “d:”) at the prompt and press Enter.
- Type “vol” at the DOS prompt and press Enter. The hard drive serial number (or Volume Serial Number) will be displayed. The Volume Serial Number is 8 digits, with a dash in between. The characters are alpha numeric.
- Record the serial number and close the DOS prompt window.

CHANCE® Helical Pile/Anchor Axial Test		
Project:	Date:	Sheet of
Anchor/Pile Number:	Product Series: ☐ SS ☐ RS	
Helix Configuration:	Total Depth:	
Time: Start Finish	Recorded by:	

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

ATLAS RESISTANCE® Piers Installation Log

Project:				Sheet of
Pier Number:				
Pier Designator:				Installation Date:
Maximum Work Capacity:				Installation Technician:
Installation Cylinder Effective Area:				
DEPTH (ft)	PIER SECTION	PRESSURE (psi)	LOAD (lbs)	NOTES
3'-6	1			
7'-0	2			
10'-6	3			
14'-0	4			
17'-6	5			
21'-0	6			
24'-6	7			
28'-0	8			
31'-6	9			
35'-0	10			
38'-6	11			
42'-0	12			
45'-6	13			
49'-0	14			
52'-6	15			
56'-0	16			
59'-6	17			
63'-0	18			
66'-6	19			
70'-0	20			
73'-6	21			
77'-0	22			
80'-6	23			
84'-0	24			
87'-6	25			
Total Full Section Length:				Length of Cut-Off Section:
Depth to Pier:				Total Depth from Grade:

LIFTING LOG

Lift Ram Effective Area:				Date of Lift:
Final Lift	Lift Amount (in)	Pressure (psi)	Load (lbs)	Comments:

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CHANCE® Helical Pile/Anchor Installation Log

Project:	Date:	Sheet of
Anchor/Pile Number:	Product Series: ☐ SS ☐ RS	
Helix Configuration:	Installation Angle:	
Time: Start Finish	Recorded by:	

DEPTH (ft)	PRESSURE (psi)	TORQUE (ft-lb)	COMMENTS

CHANCE HELICAL PULLDOWN® Micropile Installation Log

Project:	Date:	Sheet of
Anchor/Pile Number:	Product Series: ☐ SS ☐ RS	
Helix Configuration:	Installation Angle:	
Grout Column Diameter:	Sleeve Depth: From to	
Time: Start Finish	Recorded by:	

DEPTH (ft)	PRESSURE (psi)	TORQUE (ft-lb)	GROUT FLOW (Volume/Shaft/Length)

ATLAS RESISTANCE® Piers - Project Summary Log									
Project:					Project Completion Date:				
					Sheet of				
Pier Number	Date	Total Depth	Install Pressure	Install Load	Stage	Final Lift Pressure	Final Lift Load	Final Lift Amount	FS Drive vs Lift
1									
2									
3									
4									
5					⇦				
6									
7									
8									
9									
10					DRIVE				
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GLOSSARY of TERMS

Alignment Load (AL)	A low magnitude load applied to a pile/anchor at the start of the load test to keep the testing equipment correctly positioned and to remove any slack in the reaction system.
Allowable Capacity	The geotechnical capacity of a pile/anchor or pier as determined by a reduction of the ultimate capacity with an appropriate factor of safety or resistance factor.
Anchor or Anchorage	A combination of anchor and the soil or deeply weathered rock into which it is installed that together resist tension loads applied to the anchor.
ATLAS RESISTANCE® Pier	An assembly of structural steel components that includes a foundation bracket assembly attached to the concrete foundation, which is then mounted to a steel pier that is installed to bedrock or dense bearing stratum via hydraulic jacking of the pipe shaft segments.
Axial Load (P)	An axially oriented compression or uplift (tension) load supported by an pile/anchor or pier resulting from dead, live and seismic loads.
Bearing Load	A load generally regarded as an axial compressive load on a pile or pier.
Bearing Stratum	Soil layers of sufficient strength to be capable of resisting the applied axial load transferred by a pile or pier.
Contractor	The person or firm responsible for performing the required construction, i.e., installation of CHANCE® Helical Piles/Anchors or ATLAS RESISTANCE® Piers.
Coupling	A central steel shaft connection for CHANCE® Type SS and RS helical piles. Couplings may be either separable sleeve couplings or integral forged sockets.
Coupling Bolts	High strength structural steel fasteners used to connect helical anchor/pile segments together. For CHANCE® Type SS segments the coupling bolt transfers axial loads. For CHANCE® Type RS segments the coupling bolt transfers both axial and torsional loads.
Coupling, Pier Sleeve	A steel tubing of suitable outside diameter to fit into a pier starter and extension section to provide a means for attaching the various pier sections together for ATLAS RESISTANCE® Piers. It allows for extending the pier to the required depth.
Creep	The movement that occurs during the Creep Test of a pile/anchor or pier under a constant load.
Dead Load (DL)	Generally, vertical loads comprised of the weight of the structure plus various fixed assets, such as equipment, machinery, walls and other permanent items.

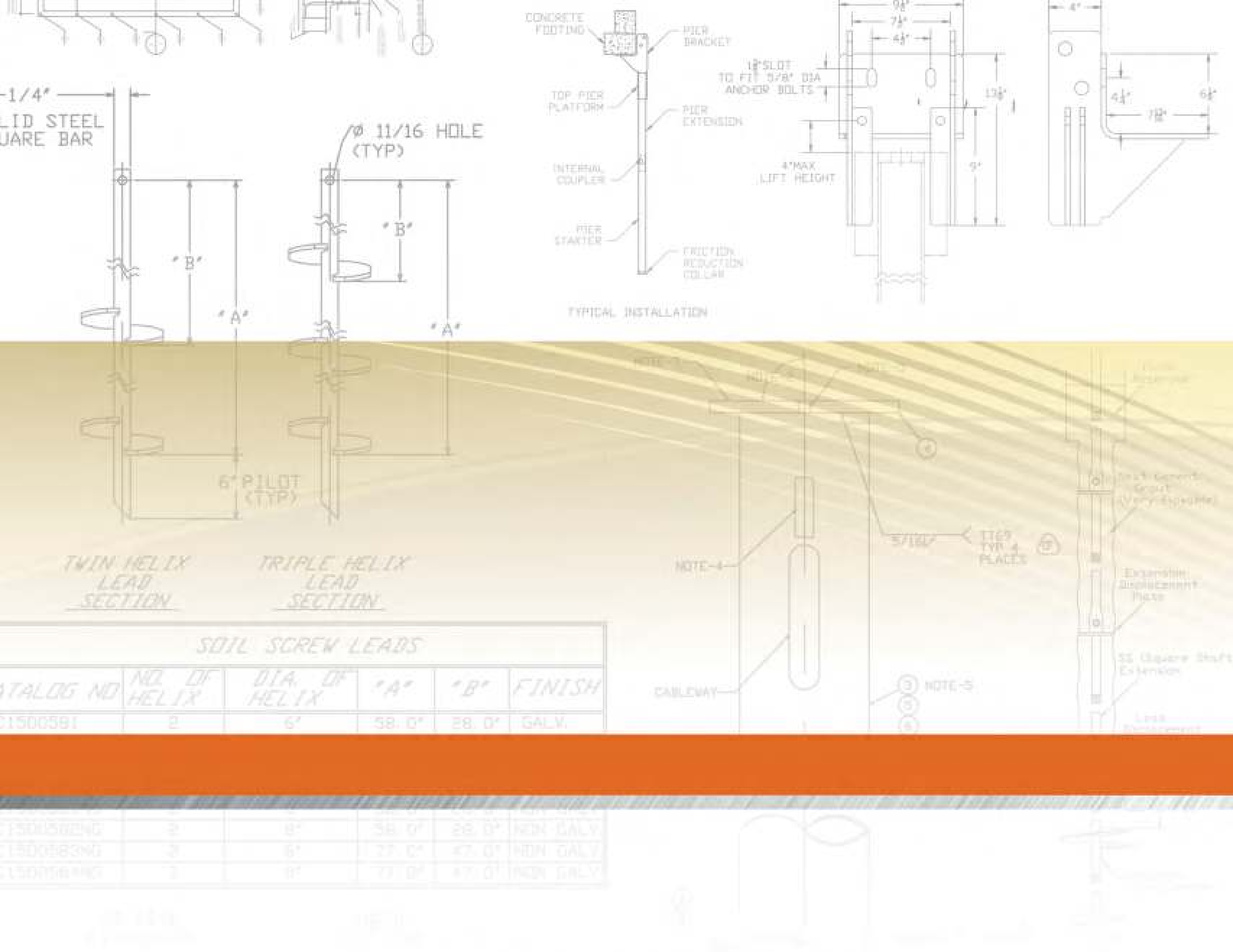
Design Load (Pd)	The maximum anticipated service load applied to a pile or pier, comprised of calculated dead and live loads. Also known as Working Load.
Effective Stress	The total force on a cross section of a soil mass that is transmitted from grain to grain of the soil, divided by the area of the cross section. Also known as Intergranular Stress.
Elastic Movement	The recoverable movement measured during a pile/pier load test resulting from the elastic shortening or lengthening of the pile/pier shaft material.
End Bearing	The transfer of axial loads to the soil at the tip of a helical pile via helix plates or at the tip of a pier.
Evaluation Services Report (ESR)	The evaluation of a manufactured product or building component by the evaluation services of the various model code agencies (ICC). The report outlines the requirements that must be met to satisfy the intent of the Building Code.
Extension Pier Section	With reference to an ATLAS RESISTANCE® Pier, the pipe sections following the starter pier section that extend the starter section to the load bearing stratum. The extension pier sections are equipped with a pier sleeve that allows for coupling the extensions to the starter section or other extensions.
Failure Criteria	A method used to determine the ultimate capacity of a pile/anchor based on a load test. A typical failure criteria for helical piles is the load where the pile head displacement is equal to 10% of the average helix diameter plus the elastic movement.
Foundation Soil Load	The load from soil overburden on the outstanding toe of a footing. This soil load is in addition to the existing structure weight supported by the footing. It increases the dead load used as a reaction to install a push pier and therefore aids the installation. However, it may work to defeat attempts to lift a structure and may require reduction or removal if a lift is required.
Friction Reduction Collar	The enlarged section at the bottom of the pipe starter section of an ATLAS RESISTANCE® Pier. The collar diameter is larger than the following pipe shaft, thus forcing the displaced soil away from the pipe shaft.
Gunite	A dry concrete mixture that is carried to a nozzle in moving air where it is mixed with water. The operator controls the water-cement ratio.
Helical Extension	A helical pile/anchor component installed immediately following the lead section (if required) to increase the bearing area of the foundation. This component consists of one or more helical plates welded to a central steel shaft.
Helical Pile	A bearing type foundation consisting of a lead section, helical extension (if required by site conditions), plain extension section(s) and a pile cap. Also known as a screw pile or helical screw foundation.

HELICAL PULLDOWN® Micropile	A small diameter, soil displacement, cast-in-place helical pile in which the applied load is resisted by both end bearing and friction. The design is protected under United States Patent 5,707,180, Method and Apparatus for Forming Piles In-Situ.
Helix Plate	A round steel plate formed into a ramped spiral. The helical shape provides the downward force used to install a helical pile/anchor, plus the plate transfers the load to the soil in end bearing. Helical plates are available in various diameters and thicknesses.
Impact Driven	A pile driven with a pile hammer.
In-Situ	In the natural or original position. Used in soil mechanics to describe the original state of soil condition prior to disturbance from field testing or sampling methods.
Installation Torque	The resistance generated by a helical pile/anchor when installed into soil. The installation resistance is a function of the soil plus the size and shape of the various components of the helical pile/anchor. The installation energy must equal the resistance to penetrate the soil (penetration energy) plus the energy loss due to friction (friction energy).
Kip	One thousand pounds of force, or a "kilopound."
Lagging	Horizontal members, usually of timber or concrete, spanning between soldier piles to retain the soil between pile locations. They transfer the load directly from the soil to the soldier piles.
Lateral Load (V)	A load applied perpendicular to the longitudinal axis of a pile or pier resulting from live and seismic loads. Also called a shear load.
Lead Section	The first helical pile/anchor component installed into the soil, consisting of single or multiple helix plates welded to a central steel shaft. The helical plates transfer the axial load to bearing stratum.
Live Load (LL)	A load comprised of roof, wind, floor, and in some cases, seismic loads. Floor loads include people, temporary or non-fixed equipment, furniture and machinery. Roof loads include ice and snow.
Load Bearing Stratum	See Bearing Stratum.
Net Settlement	The non-elastic (non-recoverable) movement or displacement of a pile/pier measured during load testing.
Open Specification	An arrangement in which the contractor is given the responsibility for the scope and design of the pile or pier installation. The construction, capacity and performance of the pile or pier are the sole responsibility of the contractor. This specification is most common for securing bids on temporary projects, and is not recommended for permanent applications. See also Performance Specification and Prescriptive Specification.
Overburden	Natural or placed material that overlies the load bearing stratum.

Performance Specification	An arrangement in which the contractor is given the responsibility for certain design and/or construction procedures, but must demonstrate to the owner through testing and/or mutually agreed upon acceptance criteria that the production piles/piers meet or exceed the specified performance parameters. The contractor and owner share responsibility for the work. See also Open Specification and Prescriptive Specification.
Pier Head Assembly	An ATLAS RESISTANCE® Pier bracket or other termination device that allows attachment to an existing footing or floor slab.
Pile Cap	A means of connection through which structural loads are transferred to a pile or pier. The type of connection varies depending on the requirements of the project and the type of pile/pier material used. NOTE: Care must be used in the design of pile caps to ensure adequate structural load transfer. Design constraints such as expansive soils, compressible soils and seismic loads must be accounted for in pile cap design.
Pipe Shaft	A central shaft element made from hollow, steel, round pipe, ranging in diameter from 2" to 10". Also known as Hollow Shaft, Round Shaft (Type RS), Type T/C and Type PIF for CHANCE® Helical Piles.
PISA® System	The acronym for Power Installed Screw Anchor. The PISA® System was originally developed for the power utility industry in the late 1950's.
Plain Extension	A central steel shaft segment without helical plates. It is installed following the installation of the lead section or helical extension (if used). The units are connected with separable sleeve couplings or integral forged couplings and bolts. Plain extensions are used to extend the helical plates beyond the specified minimum depth into competent load bearing stratum.
Pore Pressure	Unit stress carried by the water in the soil pores in a cross section.
Post Tensioning	The stressing of a structure after all structural elements are in place (e.g., loading a tieback anchor to post tension a retaining wall).
Preloading	A load applied to a pile prior to connection to a structure to minimize structural movement in service. Also known as Prestressing.
Prescriptive Specification	An arrangement in which the owner has the sole responsibility for the scope and design of the pile or pier installation and specifies the procedures that must be followed. Prescriptive specifications mandate the owner to be responsible for the proper performance of the production piles/piers. The contractor is responsible for fulfilling the obligations/details as specified in the construction documents.

Pretensioning	The prestressing of an anchor or foundation prior to the service load being applied.
Proof Test	The incremental loading of a pile or pier, where the load is held for a period of time and the total movement is recorded at each load increment. The maximum applied load is generally 1.0 to 1.25 times the design load.
Rebound	Waste created by sprayed concrete falling to the floor or ground below the intended target location. Rebound is usually half for shotcrete compared to gunite.
Reinforced Earth	A soil mass whose overall shear strength has been increased via some reinforcing technique (e.g., SOIL SCREW® Anchor, soil nail, geofabric, etc.).
Round Shaft	Hollow steel, round pipe, central shaft elements ranging in diameter from 2" to 10". Also known as Hollow Shaft, Round Shaft (Type RS), Type T/C and Type PIF for CHANCE® Helical Piles.
Safety Factor (SF)	The ratio of the ultimate capacity to the working or design load used for the design of any structural element. Also referred to as a factor of safety.
Seismic Load	A load induced on a structure caused by ground motions resulting from a seismic event (earthquake). Usually included as part of the live load.
Shaft	A steel or composite steel/grout shaft or rod used to transfer load from the surface to the bearing plates.
Shotcrete	A wet concrete mixture that is pumped to a nozzle where air is added to carry the concrete mix to the application. Often used to quickly provide a facing on soil nail or SOIL SCREW® Anchor reinforced retaining walls.
Soil Nail	A steel rod driven or drilled and grouted into the ground to reinforce, stabilize, or strengthen soil such as the soil mass behind a retaining wall.
SOIL SCREW® Anchor	A CHANCE® Helical Anchor with helices welded along the entire length of the shaft. A SOIL SCREW® Anchor is used to engage the soil and serves the same function as a soil nail, i.e., soil reinforcement.
Soldier Pile	An H or WF section normally driven (or placed in a drilled hole and backfilled with weak grout or concrete) vertically at intervals of several feet to resist the load on the lagging of a retaining wall. It is the main structural element of a retaining wall. Also known as an h-pile.
Square Shaft (SS)	A solid steel, round-cornered-Square central Shaft element ranging in size from 1-1/4" to 2-1/4". Also known as Type SS for CHANCE® Helical Anchors.
Starter Pier Section	With reference to an ATLAS RESISTANCE® Pier, the first pipe section to be placed in the ground. It is usually equipped with a friction reduction collar.
Starter Section	With reference to a CHANCE® Helical Pile, a lead section, but usually used in reference to a SOIL SCREW® Anchor.
Test Load	The maximum load applied to a pile or pier during testing.

Thread Bar Adapter	A section of central steel shaft that can be used to connect a tiedown or ground anchor to a new or existing concrete foundation/pile cap via a high tensile strength pre-stressing thread bar.
Tieback	A tension anchor used to resist the loads on a retaining wall due to the earth pressure and other loads at or near the top of a wall.
Tiedown	A device used to transfer tensile loads to soil. Tiedowns are used for seismic retrofit. They consist of a central steel shaft, helix bearing plates, coatings, corrosion protection, a means of connection, etc. Also known as a ground anchor.
Top Pier Platform	The top section of an ATLAS RESISTANCE® Pier equipped with vertical stabilizers that facilitate attachment to the pier bracket.
Torque Rating	The maximum torque energy that can be applied to a helical anchor/pile during installation in soil. Also known as allowable torque or safe torque.
Ultimate Capacity (Qu)	The limit state based on the structural and/or geotechnical capacity of a pile or pier, defined as the point at which no additional capacity can be justified.
Ultimate Load (Pu)	The load determined by applying a safety factor to the working load. The ultimate load applied to a structural element must be less than the ultimate capacity of that same element or a failure limit state may occur.
Underpinning Bracket	A bracket used to connect an existing strip or spread foundation or footing to a CHANCE® Helical Pile or ATLAS RESISTANCE® Pier.
Uplift Load	Generally, an axial tensile load on an anchor.
Verification Test	Similar to the Proof Test except a cyclic loading method is used to analyze total, elastic and net movement of the pile. Used for pre-contract or pre-production pile load tests.
Vertical Stabilizer	A steel plate element, welded to the side of the top pier platform, which prevents lateral movement within the pier bracket. Vertical stabilizers will allow the pier bracket to move vertically up from the top pier platform but prevent the bracket from moving below a previously set elevation.
Waler	A horizontal structural member placed along soldier piles to accept the load from the piles and transmit it to struts, shoring or tieback anchors.
Working Load	Another term for Design Load.



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