Foundation Repair Products
and
Helical Torque Anchors™

ECP®

DESIGN and TECHNICAL SERVICE MANUAL

— Tenth Edition —

"Designed and Engineered to Perform"

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EARTH CONTACT PRODUCTS

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ECP Design and Technical Service Manual

-- Tenth Edition --

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EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

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Tenth Printing – 01/2021

Earth Contact Products, LLC reserves the right to change design features, specifications and products without notice, consistent with our efforts toward continuous product improvement. We also make changes and corrections to the technical design text consistent with the state of the art. Please check with Engineering Department, Earth Contact Products to verify that you are using the most recent design information and product specifications.

From the author:

This manual was written and configured with many different readers in mind. The goal was to present the technical theories and equations in a simple, understandable way. This manual is not intended to be a rigorous text on soil mechanics and engineering theory. The intent was to produce a manual that distills the theory down to make it easy to understand and to be able reach the answer, or arrive at a technical solution in a timely manner. The technical information provided herein can help the engineer with a basic understanding of soils and foundation support designs. Unlike some other technical manuals, there is nothing left out of this *ECP Design and Technical Service Manual* that prevents the reader from performing a design analysis and arriving at a workable solution without calling to a manufacturer or a professional engineer for assistance. This does not mean that one should not consult a registered engineer to clarify something or to review your analysis and solution.

Engineers: The theoretical explanations, the assumptions, and equations to arrive at solution were written with engineers mind. It is the goal here to provide sufficient technical data and guidance necessary to design typical foundation support or tieback systems. This book is not intended to be a thorough analysis of all aspects of the subject, but rather a handbook for determining solutions to typically encountered design situations in the field.

The dry, technical theory is there if the reader is interested in learning the subject matter more thoroughly, but the reader can find extensive use of tables and graphs in this edition which were designed to reduce the need to master the engineering theory or the need to perform difficult mathematical equations to arrive at a solution.

Non-Engineers: This book is also written with non-engineers in mind; such as project managers, estimators, contractors; and foundation repair company owners, office supervisors and field superintendents who are in the business of installing foundation support systems.

Our unique methods for rapidly obtaining estimates are presented throughout the book. *Quick*-Solve™ design estimating allows non-engineers to arrive at a viable solution to a foundation support problem in a minimum amount of time without a lot of mathematics. The reader will find that the **Design Examples** presented in this manual are solved two ways. First, engineering theory and equations are used to design a support system, and secondly by demonstrating how a non-engineer can use our *Quick*-Solve™ design estimating to arrive at a budgetary solution. These side-by-side comparisons demonstrate that the *Quick*-Solve™ methods shown in this manual produce comparable solutions.

The product lines are divided into relevant chapters. While some topics overlap, an attempt to make each section stand alone so that the reader can concentrate on only the subject of interest at the time.

1. ***ECP Torque Anchor™ Helical Screw Products*** (including a chapter devoted to **Earth Plate Anchors**),
2. **ECP Steel Piers™ - Resistance Steel Pier Products,**
3. **Introduction to Steel Corrosion in soil**.

Many ECP Torque Anchor™ products presented such as TA-150, TA175, TA-288 and TA-350 configurations have been evaluated by ICC and are identified in this manual with the ICC-ES ESR-3559 designation.

Likewise ECP Steel Piers™ Models PPB-300 and PPB-350 with standard under footing brackets along with the patented ECP Inertia Sleeve™ have also been evaluated by ICC and are identified in this manual with the ICC-ES ESR-4771 designation.

Thank you for placing your trust and confidence in ECP products.

DJC, PE/December 2020

Earth Contact Products

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This manual not intended to replace professional engineering input and judgment. It is highly recommend that you seek professional engineering input on any critical projects. It is also considered good practice to incorporate a minimum factor of safety of 2.0 or more into each and every design. It is highly recommended to perform field load tests on heavily loaded foundation elements and on any critical projects. It is vital to always seek professional engineering input when in doubt or when available information is incomplete or confusing.

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-- Tenth Edition --

ECP Torque Anchors™

ECP Steel Piers™

Introduction to Steel Corrosion

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Technical Design Assistance

Earth Contact Products, LLC. has a knowledgeable staff that stands ready to help you with understanding how to prepare preliminary designs, installation procedures, load testing, and documentation of each placement when using ECP Torque Anchors™. If you have questions or require engineering assistance in evaluating, designing, and/or specifying Earth Contact Products, please call us at 913 393-0007, Fax at 913 393-0008.

ECP Helical Torque Anchors™

Technical Design Manual

- **Square Bar Helical Torque Anchors™**
- **Tubular Helical Torque Anchors™**
- **Torque Anchor™ Pile Caps, Utility Brackets and Shaft Terminations**

EARTH CONTACT PRODUCTS
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Chapter 1 - ECP Torque Anchors™ Technical Design Manual

Screw piles have been in use for more than 160 years. In 1838 a lighthouse was built upon screw piles designed by an Irish engineer, Alexander Mitchell. In 1863, Eugenius Birch designed the Brighton West Pier in Brighton, England. These piers are still in use 150 years later. The original screw piles were installed at 10 feet per hour using eight 20-foot long torque bars and the strength of 32 to 40 men.

In the United States, the Thomas Point Shoal Lighthouse on Chesapeake Bay, Maryland near Annapolis, Maryland is the only remaining lighthouse built upon helical screw piles that is still at its original location. This lighthouse has a hexagonal shape measuring 35 feet across, and it is still being supported by seven original helical screw piles. The Thomas Point Shoal Lighthouse was constructed and put into operation on November 20, 1875. The helical

Thomas Point Shoal Lighthouse

screw piles that support the structure consist of ten inch diameter wrought iron shafts with cast iron helical screw flanges at the end of each shaft. At Thomas Point Shoal the screw piles were advanced to a depth of 11-1/2 feet into to sandy bottom of Chesapeake Bay. The signal light is mounted 43 feet above the surface of the water.

Cast iron coupling at Thomas Point Lighthouse

Sporadic use of screw piles has been documented throughout the 19th and early 20th centuries mainly for supporting structures and bridges over weak or wet soil.

Hydraulic torque motors became available in the 1960's, which allowed for easy and fast installation of screw piles. Screw piles then became the favored product for resisting tensile forces. Electric utility companies began to use screw piles for tie down anchors on transmission towers and for guy wires on utility poles.

Screw piles are ideal for applications where there is a need to resist both axial tension and compression forces. Some examples of structures requiring resistance to both compressive and tensile forces are metal buildings, canopies and monopole telecommunication tower foundations. Current uses for screw pile foundations include foundations for commercial and residential structures, light poles, retaining wall tieback anchors, restorations of failed foundations, pipeline and pumping equipment supports, elevated walkways, bridge abutments, and numerous uses in the electric utility industry.

ECP Torque Anchors™

ECP Torque Anchors™ are a part of the complete product line of screw piles, steel piers and foundation support products manufactured by Earth Contact Products, LLC, a family owned company based in Olathe, Kansas. The company was built upon the ECP Steel Pier™, a fourth generation end bearing steel mini-pile designed and patented for ECP.

Our 100,000 square foot state of the art manufacturing facility produces all components and steel assemblies. The only processes not done in our facility are galvanization and hot forge upsetting of shaft couplings. We are able to custom design and configure products to your engineered specific applications. Earth Contact Products uses only certified welders and robotics for quality fabrication.

ICC-ES Evaluation Report ER-3559 covers most Torque Anchor™ products presented here.

Torque Anchor™ Components

The ECP Torque Anchor™ consists of a shaft fabricated from either solid square steel bar or tubular steel. Welded to the shaft are one or more helical plates. The plates can vary from 6 inches to 16 inches diameter and are 3/8 or 1/2 inch thick depending upon the application. Typically plate diameters increase from the bottom of the shaft upward. Helical plates are spaced a distance of three times the diameter of the plate directly below unless specified otherwise by the engineer. The standard thickness for all helical plate diameters is 3/8 inch, except for the 16 inch diameter helical plate which is manufactured only in 1/2 inch thickness. In high capacity applications or in obstruction laden soils, a helical plate thickness of 1/2 inch may be ordered for all plate sizes. The standard pitch of all helical plates is three inches, which means that the anchor advances into the soil a distance of three inches during one revolution of the shaft.

The standard lead shaft lengths of most products are 10 inches, 5 feet, 7 feet and 10 feet, however, other lengths may be specially fabricated for large quantity specialized applications. Because Torque Anchors™ are considered deep foundation elements; they are usually installed into the soil to a depth greater than just the length of the typical lead section.

Extensions of various lengths are available and are supplied with couplings and hardware for attachment to the lead or other extensions allowing the Torque Anchor™ assembly to reach the desired depth. Helical plates may also be installed on the extensions where the length of the lead is not sufficiently long enough to allow for the proper interval between helical plates. The number of the plates per Torque Anchor™ is limited only by the shaft capacity to transmit the torque needed to advance the Torque Anchor™ into the soil.

Torque Anchors™ may terminate with a pile cap that embeds into a new concrete foundation. In other applications such as tieback anchors, a transition is made from the anchor shaft to a continuously threaded rod for attachment to the wall or other object. Various beams, wall plates, etc. can be attached to the threaded bar for wall support, for restorations, or to simply stabilize walls or other structure from overturning forces. When the application requires existing foundation restoration or stabilization, foundation brackets are available that attach between the Torque Anchor™ and the foundation beam, footing or slab. The purpose of the foundation bracket is to transfer the load from the foundation element to the Torque Anchor™.

Product Benefits

- **Quickly Installed**
- **Low Installed Cost**
- **Installs With Little Or No Vibration**
- **Installs In Areas With Limited Access**
- **Little Or No Disturbance To The Site**
- **Soil Removal From Site Unnecessary**
- **Installed Torque Correlates To Capacity**
- **Easily Load Tested To Verify Capacity**
- **Can Be Loaded Immediately After Installation**
- **Installs Below The Unstable And Sinking Soil To Firm Bearing**
- **Small Shaft Size Limits "Down Drag" From Shallow Consolidating Soils**
- **All Weather Installation**
- **ICC-ES Evaluation ESR 3559 applies to many TA-150, TA-175, TA-288 and TA-350 products identified in this chapter**

Product Limitations

Torque Anchors™ **are not suitable** in locations where subsurface material may damage the shaft or the helices. Soils containing cobbles, large amounts of gravel, boulders, construction debris, and/or landfill materials are usually unsuitable for helical product installations.

Because these products have slender shafts, buckling may occur when passing through extremely weak soil. The soft soil may not exert sufficient lateral force on the narrow shaft to prevent the shaft from buckling. When extremely soft soils are present, generally having a Standard Penetration Test – "N" < 5 blows per foot, one must take into consideration the axial stiffness of the anchor shaft in the design.

The slender shafts also render the typical Torque Anchor™ ineffective against large lateral loads or overturning moments.

Table 1. ECP Torque Anchor™ Product Designations		
Product	**Prefix**	**Product Description**
Helical Lead Sections	TAH	Lead Section With One 3/8" Thick Helical Plate
	HTAH	Lead Section With One 1/2" Thick Helical Plate
	TAF	Lead Section with Multiple 3/8" Thick Helical Plates
	HTAF	Lead Section with Multiple 1/2" Thick Helical Plates
Shaft Extensions	TAE	Extension Section with Coupling & Hardware
Transitions	TAT	Transition Coupling – Helical Tieback Anchor Shaft to Threaded Bar
New Construction Pile Caps	TAB–NC	New Construction Compression Pile Cap
	TAB–T	New Construction Tension Pile Cap (Compression and uplift support)
Brackets for Foundation Repair	TAB-150-SUB + TAB-150 TT TAB-288L-MUB + TAB-288-TTM	Foundation Bracket – Fits 1-1/2" Sq. Shaft Helical Pile Shaft Foundation Bracket – Fits 2-7/8" x 0.203" Wall Tubular Helical Pile Shaft
	TAB - LUB TAB- 175-TT 288-TT 350-TT	Large Foundation Bracket – Fits Under Footing and Connects to Pile Shaft: T-Tube for use with 1-3/4" Square Shaft T-Tube for use with 2-7/8" Diameter Tubular Shaft T-Tube for use with 3-1/2" Diameter Tubular Shaft
Brackets for Slab Repair	TAB-150-LP TAB-288-LP	Porch Bracket – Fits 1-1/2" Square or 2-7/8" Dia. Helical Pile Shaft
	TAB-150-SSB	Screw Lift Slab Bracket – Fits 1-1/2" Square Helical Pile Shaft
	PPB-166-HSB	Hydraulic Lift Slab Bracket – Fits 1-1/2" Square Helical Pile Shaft & PPB-300-EPS
	TAB-288-LHSB TAB-288-HSB	Hydraulic Lift Slab Bracket – Fits 2-7/8" Diameter Tubular Shaft Also Fits: 1-1/2" Square Shaft 1-3/4" Square Shaft
Timber Bracket	TAB-XXX-TB	Bracket to timber beams – Helical Pile Shaft
Wall Plate	PA	Stamped Wall Plate – Fastens Wall To Threaded Shaft From Tieback

Table 2. Capacities of ECP Helical Torque Anchors					
Shaft Size	**Installation Torque Factor (k)**	**Axial Compression Load Limit**	**Ultimate- Limit Tension Strength**	**Useable Torsional Strength**	**Practical Load Limit Based on Torsional Strength**
1-1/2" Square Bar	10	70,000 lb.	70,000 lb.	7,000-lb	Load limited to the rated capacity of the attachments and the lateral soil strength against the shaft
1-3/4" Square Bar	10	100,000 lb.	100,000 lb.	10,000 ft-lb	
2" Square Bar	8.5 (Compression 10 (Tension)	127,500 lb.	150,000 lb.	15,000 ft-lb	
2-7/8" Tubular – 0.203" Wall LW	9	60,000 lb.	60,000 lb.	5,500 ft-lb	50,000 lb
2-7/8" Tubular – 0.276" Wall	9	100,000 lb.	100,000 lb.	9,000 ft-lb	81,000 lb
3-1/2" Tubular – 0.300" Wall	8	115,000 lb.	120,000 lb.	13,000 ft-lb	104,000 lb
4-1/2" Tubular – 0.337" Wall	7	160,000 lb.	160,000 lb.	22,000 ft-lb	154,000 lb

Most of ECP TA-150, TA-175, TA-288 and TA-350 Torque Anchor™ product lines have an ICC evaluation and ICC-ES 3559 has been issued.

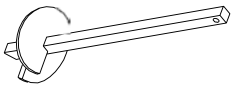
The designer should select a product that provides adequate additional torsional capacity for the specific project and soil conditions.

IMPORTANT NOTES:

The capacities listed for "Axial Compression Load Limit", "Ultimate Limit Tension Strength" and "Useable Torsion Strength" in Table 2 are mechanical ratings. One must understand that the actual installed load capacities for the product are dependent upon the soil conditions at a specific job site. The "Useable Torsional Strengths" given here are the **maximum** values that one should apply to the product. Furthermore, these torsional ratings assume homogeneous soil conditions and proper alignment of the drive motor to the shaft. In homogeneous soils up to 95% or more of the "Useable Torsional Strength" shown in Table 2 can be applied. In obstruction-laden soils, torsion spikes may cause impact fractures of the shaft, couplings or other components. Where impact loading is expected, Actual Applied Shaft Torsion should be reduced by 30% or more from that shown in Table 2. When dealing with poor soil conditions on site, select a larger shaft to reduce chance of fracture or damage during installation.

Another advantage of selecting a higher "Useable Torsion Strength" value from Table 2 is that one may be able to drive the pile slightly deeper after the torsional requirements have been met, thus eliminating the need to cut the pile shaft in the field.

The load transfer attachment capacity must be verified for the design. Standard attachments and ratings are shown following the Torque Anchor™ product listings. Special configurations to fit your project can be fabricated to your specifications upon request.



1-1/2" Round Corner Square Bar Torque Anchors™

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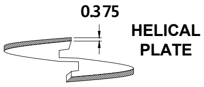
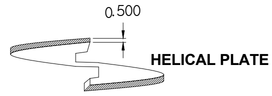


1-1/2" Round Corner Square Torque Anchor™ Lead Configurations - 3/8" Plate – 7,000 ft-lb*

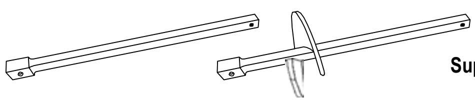


1-1/2" Round Corner Square Torque Anchor™ Lead Configurations – 1/2" Plate – 7,000 ft-lb*

Shipping & Design Information

Part No.	Description	Wt	Part No.	Description	Wt	Bdl Qty	Plate Area
TAH-150-10-8	10" lead w/ 3/8" x 8" helical	11 lbs	N/A	N/A	N/A	25 Pcs	0.33 sq. ft
TAH-150-10-10	10" lead w/ 3/8" x 10" helical	14 lbs					0.53 sq. ft
TAH-150-10-12	10" lead w/ 3/8" x 12" helical	17 lbs					0.77 sq. ft
TAH-150-10-14	10" lead w/ 3/8" x 14" helical	21 lbs					1.05 sq. ft
TAH-150-60-8	60" lead w/ 3/8" x 8" helical	43 lbs	HTAH-150-60-8	60" lead w / 1/2" x 8" helical	44 lbs	25 Pcs	0.33 sq. ft
TAH-150-60-10	60" lead w/ 3/8" x 10" helical	46 lbs	HTAH-150-60-10	60" lead w / 1/2" x 10" helical	48 lbs		0.53 sq. ft
TAH-150-60-12	60" lead w/ 3/8" x 12" helical	49 lbs	HTAH-150-60-12	60" lead w / 1/2" x 12" helical	52 lbs		0.77 sq. ft
TAH-150-60-14	60" lead w/ 3/8" x 14" helical	53 lbs	HTAH-150-60-14	60" lead w / 1/2" x 14" helical	57 lbs		1.05 sq. ft
TAF-150-60-8-10	60" lead w/ 3/8" x 8" & 10" helical	50 lbs	HTAF-150-60-8-10	60" lead w / 1/2" x 8" & 10" helical	54 lbs		0.86 sq. ft
TAF-150-60-10-12	60" lead w/ 3/8" x 10" & 12" helical	56 lbs	HTAF-150-60-10-12	60" lead w / 1/2" x 10" & 12" helical	62 lbs		1.30 sq. ft
TAF-150-60-12-14	60" lead w/ 3/8" x 12" & 14" helical	63 lbs	HTAF-150-60-12-14	60" lead w / 1/2" x 12" & 14" helical	72 lbs		1.82 sq. ft
TAH-150-84-8	84" lead w/ 3/8" x 8" helical	58 lbs	HTAH-288-84-8	84" lead w / 1/2" x 8" helical	60 lbs	25 Pcs	0.33 sq. ft
TAH-150-84-10	84" lead w/ 3/8" x 10" helical	61 lbs	HTAH-288-84-10	84" lead w / 1/2" x 10" helical	64 lbs		0.53 sq. ft
TAH-150-84-12	84" lead w/ 3/8" x 12" helical	64 lbs	HTAH-288-84-12	84" lead w / 1/2" x 12" helical	68 lbs		0.77 sq. ft
TAH-150-84-14	84" lead w/ 3/8" x 14" helical	68 lbs	HTAH-288-84-14	84" lead w / 1/2" x 14" helical	73 lbs		1.05 sq. ft
TAF-150-84-8-10	84" lead w/ 3/8" x 8" & 10" helical	66 lbs	HTAF-288-84-8-10	84" lead w / 1/2" x 8" & 10" helical	70 lbs		0.86 sq. ft
TAF-150-84-10-12	84" lead w/ 3/8" x 10" & 12" helical	72 lbs	HTAF-288-84-10-12	84" lead w / 1/2" x 10" & 12" helical	78 lbs		1.30 sq. ft
TAF-150-84-12-14	84" lead w/ 3/8" x 12" & 14" helical	79 lbs	HTAF-288-84-12-14	84" lead w / 1/2" x 12" & 14" helical	87 lbs		1.82 sq. ft
TAF-150-84-8-10-12	84" lead w/ 3/8" x 8", 10" & 12" helical	77 lbs	HTAF-288-84-8-10-12	84" lead w / 1/2" x 8", 10" & 12" helical	84 lbs		1.63 sq. ft
TAF-150-84-10-12-14	84" lead w/ 3/8" x 10", 12" & 14" helical	86 lbs	HTAF-288-84-10-12-14	84" lead w / 1/2" x 10", 12" & 14" helical	97 lbs		2.35 sq. ft
TAH-150-120-8	120" lead w/ 3/8" x 8" helical	81 lbs	HTAH-150-120-8	120" lead w/ 1/2" x 8" helical	83 lbs	25 Pcs	0.30 sq. ft.
TAH-150-120-10	120" lead w/ 3/8" x 10" helical	84 lbs	HTAH-150-120-10	120" lead w/ 1/2" x 10" helical	87 lbs		0.50 sq. ft.
TAH-150-120-12	120" lead w/ 3/8" x 12" helical	87 lbs	HTAH-150-120-12	120" lead w/ 1/2" x 12" helical	91 lbs		0.74 sq. ft.
TAH-150-120-14	120" lead w/ 3/8" x 14" helical	91 lbs	HTAH-150-120-14	120" lead w/ 1/2" x 14" helical	96 lbs		1.02 sq. ft
TAF-150-120-8-10	120" lead w/ 3/8" x 8" & 10" helical	89 lbs	HTAF-150-120-8-10	120" lead w/ 1/2" x 8" & 10" helical	93 lbs		0.80 sq. ft
TAF-150-120-10-12	120" lead w/ 3/8" x 10" & 12" helical	95 lbs	HTAF-150-120-10-12	120" lead w/ 1/2" x 10" & 12" helical	101 lbs		1.24 sq. ft
TAF-150-120-12-14	120" lead w/ 3/8" x 12" & 14" helical	102 lbs	HTAF-150-120-12-14	120" lead w/ 1/2" x 12" & 14" helical	110 lbs		1.76 sq. ft
TAF-150-120-8-10-12	120" lead w/ 3/8" x 8", 10" & 12" helical	100 lbs	HTAF-150-120-8-10-12	120" lead w/ 1/2" x 8", 10" & 12" helical	107 lbs		1.54 sq. ft
TAF-150-120-10-12-14	120" lead w/ 3/8" x 10", 12" & 14" helical	109 lbs	HTAF-150-120-10-12-14	120" lead w/ 1/2" x 10", 12" & 14" helical	120 lbs		2.26 sq. ft

1-1/2" Round Corner Square Bar Torque Anchor™ Extensions



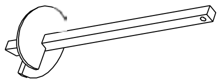
Supplied with Hardware

ESR-3559

Part No.	Description	Bdl Qty	Wt	Plate Area
TAE-150-36	36" Extension	50 Pcs	26 lbs	N/A
TAE-150-42	42" Extension		28 lbs	
TAE-150-60	60" Extension		41 lbs	
TAE-150-84	84" Extension		56 lbs	
TAE-150-120	120" Extension		79 lbs	
TAE-150-42-14	42" Extension w/ 3/8" x 14" Flight	25 Pcs	43 lbs	1.05 sq. ft

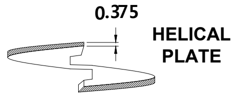
Note: Products Listed Above Are Standard Items And Are Usually Available From Stock.
Other Specialized Configurations Are Available As Special Order – Allow Extra Time For Processing.
All Helical Plates Are Spaced At Three Times The Diameter Of The Preceding Plate
Effective Length Of Extension Is 3" Less Than Overall Dimension Due to Coupling Overlap
All Product Hot Dip Galvanized Per ASTM A123 Grade 75
ECP TA-150 products have an ICC evaluation and ICC-ES 3559 has been issued.

Please see "IMPORTANT NOTES" on Table 2

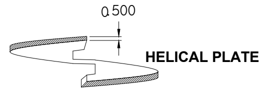


1-3/4” Round Corner Square Bar Torque Anchors™

ESR-3559



1-3/4” Round Corner Square Torque Anchor™ Lead Configurations – 3/8” Plate – 11,000 ft-lb*

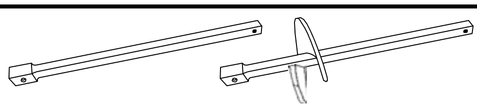


1-3/4” Round Corner Square Torque Anchor™ Lead Configurations – 1/2” Plate – 11,000 ft-lb*

Shipping & Design Information

Part No.	Description	Wt	Part No.	Description	Wt	Bdl Qty	Plate Area
TAH-175-60-8	60" lead w/ 3/8" x 8" helical	56 lbs	HTAH-175-60-8	60" lead w/ 1/2" x 8" helical	58 lbs		0.33 sq. ft
TAH-175-60-10	60" lead w/ 3/8" x 10" helical	59 lbs	HTAH-175-60-10	60" lead w/ 1/2" x 10" helical	61 lbs		0.52 sq. ft
TAH-175-60-12	60" lead w/ 3/8" x 12" helical	62 lbs	HTAH-175-60-12	60" lead w/ 1/2" x 12" helical	66 lbs		0.76 sq. ft
TAH-175-60-14	60" lead w/ 3/8" x 14" helical	66 lbs	HTAH-175-60-14	60" lead w/ 1/2" x 14" helical	71 lbs	25 Pcs	1.05 sq. ft
TAH-175-60-8-10	60" lead w/ 3/8" x 8" & 10" helical	64 lbs	HTAF-175-60-8-10	60" lead w/ 1/2" x 8" & 10" helical	68 lbs		0.85 sq. ft
TAH-175-60-10-12	60" lead w/ 3/8" x 10" & 12" helical	70 lbs	HTAF-175-60-10-12	60" lead w/ 1/2" x 10" & 12" helical	76 lbs		1.28 sq. ft
TAH-175-60-12-14	60" lead w/ 3/8" x 12" & 14" helical	75 lbs	HTAF-175-60-12-14	60" lead w/ 1/2" x 12" & 14" helical	85 lbs		1.81 sq. ft
TAH-175-84-8	84" lead w/ 3/8" x 8" helical	78 lbs	HTAH-175-84-8	84" lead w/ 1/2" x 8" helical	78 lbs		0.33 sq. ft
TAH-175-84-10	84" lead w/ 3/8" x 10" helical	79 lbs	HTAH-175-84-10	84" lead w/ 1/2" x 10" helical	82 lbs		0.52 sq. ft
TAH-175-84-12	84" lead w/ 3/8" x 12" helical	83 lbs	HTAH-175-84-12	84" lead w/ 1/2" x 12" helical	86 lbs		0.76 sq. ft
TAH-175-84-14	84" lead w/ 3/8" x 14" helical	86 lbs	HTAH-175-84-14	84" lead w/ 1/2" x 14" helical	91 lbs		1.05 sq. ft
TAH-175-84-8-10	84" lead w/ 3/8" x 8" & 10" helical	84 lbs	HTAF-175-84-8-10	84" lead w/ 1/2" x 8" & 10" helical	88 lbs	25 Pcs	0.85 sq. ft
TAH-175-84-10-12	84" lead w/ 3/8" x 10" & 12" helical	96 lbs	HTAF-175-84-10-12	84" lead w/ 1/2" x 10" & 12" helical	96 lbs		1.28 sq. ft
TAH-175-84-12-14	84" lead w/ 3/8" x 12" & 14" helical	95 lbs	HTAF-175-84-12-14	84" lead w/ 1/2" x 12" & 14" helical	105 lbs		1.81 sq. ft
TAH-175-84-8-10-12	84" lead w/ 3/8" x 8", 10" & 12" helical	95 lbs	HTAF-175-84-10-12	84" lead w/ 1/2" x 8", 10" & 12" helical	102 lbs		1.61 sq. ft
TAH-175-84-10-12-14	84" lead w/ 3/8" x 10", 12" & 14" helical	103 lbs	HTAF-175-84-10-12-14	84" lead w/ 1/2" x 10", 12" & 14" helical	115 lbs		2.33 sq. ft
TAH-175-120-8	120" lead w/ 3/8" x 8" helical	107 lbs	HTAH-175-120-8	120" lead w/ 1/2" x 8" helical	109 lbs		0.33 sq. ft
TAH-175-120-10	120" lead w/ 3/8" x 10" helical	110 lbs	HTAH-175-120-10	120" lead w/ 1/2" x 10" helical	113 lbs		0.52 sq. ft
TAH-175-120-12	120" lead w/ 3/8" x 12" helical	113 lbs	HTAH-175-120-12	120" lead w/ 1/2" x 12" helical	117 lbs		0.76 sq. ft
TAH-175-120-14	120" lead w/ 3/8" x 14" helical	117 lbs	HTAH-175-120-14	120" lead w/ 1/2" x 14" helical	122 lbs		1.05 sq. ft
TAH-175-120-8-10	120" lead w/ 3/8" x 8" & 10" helical	115 lbs	HTAF-175-120-8-10	120" lead w/ 1/2" x 8" & 10" helical	119 lbs	25 Pcs	0.85 sq. ft
TAH-175-120-10-12	120" lead w/ 3/8" x 10" & 12" helical	121 lbs	HTAF-175-120-10-12	120" lead w/ 1/2" x 10" & 12" helical	127 lbs		1.28 sq. ft
TAH-175-120-12-14	120" lead w/ 3/8" x 12" & 14" helical	125 lbs	HTAF-175-120-12-14	120" lead w/ 1/2" x 12" & 14" helical	136 lbs		1.81 sq. ft
TAH-175-120-8-10-14	120" lead w/ 3/8" x 8", 10" & 12" helical	126 lbs	HTAF-175-120-8-10-12	120" lead w/ 1/2" x 8", 10" & 12" helical	133 lbs		1.61 sq. ft
TAH-175-120-10-12-14	120" lead w/ 3/8" x 10", 12" & 14" helical	133 lbs	HTAF-175-120-10-12-14	120" lead w/ 1/2" x 10", 12" & 14" helical	146 lbs		2.33 sq. ft

1-3/4” Round Corner Square Bar Torque Anchor™ Extensions



Supplied with Hardware

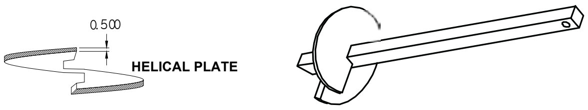
ESR-3559

Part No.	Description	Bdl Qty	Wt	Plate Area
TAE-150-36	36" Extension		34 lbs	
TAE-150-42	42" Extension		39 lbs	
TAE-150-60	60" Extension	50 Pcs	55 lbs	N/A
TAE-150-84	84" Extension		75 lbs	
TAE-150-120	120" Extension		106 lbs	
TAE-150-42-14	42" Extension w/ 3/8" x 14" Flight	25 Pcs	54 lbs	1.05 sq. ft

Note: Products Listed Above Are Standard Items And Are U
Other Specialized Configurations Are Available As Special Order – Allow Extra Time For Processing.
All Helical Plates Are Spaced At Three Times The Diameter Of The Preceding Plate
Effective Length Of Extension Is 3” Less Than Overall Dimension Due to Coupling Overlap
All Product Hot Dip Galvanized Per ASTM A123 Grade 75 usually Available From Stock.
ECP TA-175 products have an ICC evaluation and ICC-ES 3559 has been issued.

Please see “IMPORTANT NOTES” on Table 2

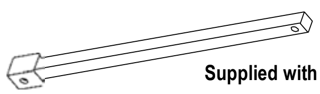
2” Round Corner Square Bar Torque Anchors™



2” Round Corner Square Torque Anchor™ Lead Configurations – 1/2” Plate – 15,000 ft-lb*

Part No.	Description	Wt	Plate Area
HTAF-200-60-8-10	60" lead w/ 1/2" x 8" & 10" helical	83 lbs	0.84 sq. ft
HTAF-200-60-10-12	60" lead w/ 1/2" x 10" & 12" helical	91 lbs	1.28 sq. ft
HTAF-200-60-12-14	60" lead w/ 3/8" x 12" & 14" helical	100 lbs	1.80 sq. ft
HTAF-200-60-12-16	60" lead w/ 1/2" x 14" & 16" helical	111 lbs	2.44 sq. ft
Lead Bundle Quantity – 20 Pieces			
HTAF-200-84-8-10	84" lead w/ 1/2" x 8" & 10" helical	109 lbs	0.84 sq. ft
HTAF-200-84-10-12	84" lead w/ 1/2" x 10" & 12" helical	117 lbs	1.28 sq. ft
HTAF-200-84-12-14	84" lead w/ 1/2" x 12" & 14" helical	127 lbs	1.80 sq. ft
HTAF-200-84-14-16	84" lead w/ 1/2" x 14" & 16" helical	138 lbs	2.44 sq. ft
HTAF-200-84-10-12	84" lead w/ 1/2" x 8", 10" & 12" helical	123 lbs	1.60 sq. ft
HTAF-200-84-10-12-14	84" lead w/ 1/2" x 10", 12" & 14" helical	136 lbs	2.32 sq. ft
Lead Bundle Quantity – 20 Pieces			
HTAF-200-120-8-10	120" lead w/ 1/2" x 8" & 10" helical	149 lbs	0.33 sq. ft
HTAF-200-120-10-12	120" lead w/ 1/2" x 10" & 12" helical	157 lbs	0.52 sq. ft
HTAF-200-120-12-14	120" lead w/ 1/2" x 12" & 14" helical	166 lbs	0.76 sq. ft
HTAF-200-120-14-16	120" lead w/ 1/2" x 14" & 16" helical	177 lbs	1.05 sq. ft
HTAF-200-120-10-12	120" lead w/ 1/2" x 8", 10" & 12" helical	163 lbs	0.85 sq. ft
HTAF-200-120-10-12-14	120" lead w/ 1/2" x 10", 12" & 14" helical	176 lbs	1.28 sq. ft
HTAF-200-120-12-14-16	120" lead w/ 1/2" x 12", 14" & 16" helical	192 lbs	1.81 sq. ft
Lead Bundle Quantity – 20 Pieces			

2” Round Corner Square Bar Torque Anchor™ Extensions



Supplied with Hardware

2” Round Corner Square Torque Anchor™ Lead Configurations – 1/2” Plate – 15,000 ft-lb*

Part No.	Description	Wt	Bdl Qty
TAE-200-60	60" Extension	72 lbs	20 Pcs
TAE-200-84	84" Extension	99 lbs	
TAE-200-120	120" Extension	142 lbs	

Notes:

Products Listed Above Are Standard Items And Are Usually Available From Stock.

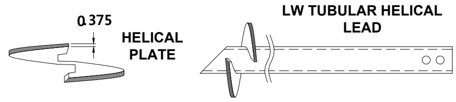
Other Specialized Configurations Are Available As Special Order – Allow Extra Time For Processing.

All Helical Plates Are Spaced At Three Times The Diameter Of The Preceding Plate

Effective Length Of Extension Is 3” Less Than Overall Dimension Due to Coupling Overlap

All Product Hot Dip Galvanized Per ASTM A123 Grade 75

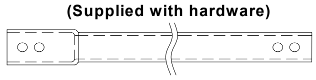
2-7/8” O.D. x 0.203” Wall Tubular Shaft Light Duty Torque Anchors™



1-3/4” Round Corner Square Torque Anchor™ Lead Configurations – 3/8” Plate – 5,500 ft-lb*

Part No.	Description	Wt	Plate Area
TAH-288L-60-8	60" lead w / 3/8" x 8" helical	34 lbs	0.30 sq. ft.
TAH-288L-60-10	60" lead w / 3/8" x 10" helical	37 lbs	0.50 sq. ft.
TAH-288L-60-12	60" lead w / 3/8" x 12" helical	40 lbs	0.74 sq. ft.
TAH-288L-60-14	60" lead w / 3/8" x 14" helical	44 lbs	1.02 sq. ft
TAF-288L-60-8-10	60" lead w / 3/8" x 8" & 10" helical	41 lbs	0.80 sq. ft
TAF-288L-60-10-12	60" lead w / 3/8" x 10" & 12" helical	47 lbs	1.24 sq. ft
TAF-2854-60-12-14	60" lead w / 3/8" x 12" & 14" helical	54 lbs	1.76 sq. ft
TAH-288L-84-8	84" lead w / 3/8" x 8" helical	45 lbs	0.30 sq. ft.
TAH-288L-84-10	84" lead w / 3/8" x 10" helical	48 lbs	0.50 sq. ft.
TAH-288L-84-12	84" lead w / 3/8" x 12" helical	51 lbs	0.74 sq. ft.
TAH-288L-84-14	84" lead w / 3/8" x 14" helical	55 lbs	1.02 sq. ft
TAF-288L-84-8-10	84" lead w / 3/8" x 8" & 10" helical	53 lbs	0.80 sq. ft
TAF-288L-84-10-12	84" lead w / 3/8" x 10" & 12" helical	59 lbs	1.24 sq. ft
TAF-288L-84-12-14	84" lead w / 3/8" x 12" & 14" helical	66 lbs	1.76 sq. ft
TAF-288L-84-8-10-12	84" lead w / 3/8" x 8", 10" & 12" helical	64 lbs	1.54 sq. ft
TAF-288L-84-10-12-14	84" lead w / 3/8" x 10", 12" & 14" helical	74 lbs	2.26 sq. ft
TAH-288L-120-8	120" lead w / 3/8" x 8" helical	63 lbs	0.30 sq. ft.
TAH-288L-120-10	120" lead w / 3/8" x 10" helical	65 lbs	0.50 sq. ft.
TAH-288L-120-12	120" lead w / 3/8" x 12" helical	69 lbs	0.74 sq. ft.
TAH-288-120-14	120" lead w / 3/8" x 14" helical	91 lbs	1.02 sq. ft
TAF-288-120-8-10	120" lead w / 3/8" x 8" & 10" helical	89 lbs	0.80 sq. ft
TAF-288-120-10-12	120" lead w / 3/8" x 10" & 12" helical	95 lbs	1.24 sq. ft
TAF-288-120-12-14	120" lead w / 3/8" x 12" & 14" helical	102 lbs	1.76 sq. ft
TAF-288-120-8-10-12	120" lead w / 3/8" x 8", 10" & 12" helical	100 lbs	1.54 sq. ft
TAF-288-120-10-12-14	120" lead w / 3/8" x 10", 12" & 14" helical	109 lbs	2.26 sq. ft
Lead Bundle Quantity – 25 Pieces			

2-7/8” O.D. x 0.203” Wall Tubular Shaft Light Duty Torque Anchor™ Extensions



1-3/4” Round Corner Square Torque Anchor™ Lead Configurations – 1/2” Plate – 11,000 ft-lb*

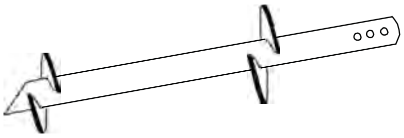
Part No.	Description	Wt	Bdl Qty
TAE-288L-36	36" Extension	21 lbs	50 Pcs
TAE-288L-60	60" Extension	32 lbs	
TAE-288L-84	84" Extension	44 lbs	
TAE-288L-120	120" Extension	61 lbs	

Notes:

Extension is supplied with ASTM A325 bolts & nuts.

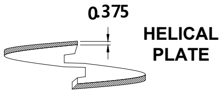
All Product Hot Dip Galvanized Per ASTM A123 Grade 75

Please see “IMPORTANT NOTES” on Table 2

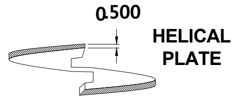


2-7/8” O.D. x 0.276” Wall Tubular Torque Anchors™

ESR-3559



Standard Duty Torque Anchor™ Lead Configurations
<u>3/8” Plate</u> – 9,000 ft-lb*

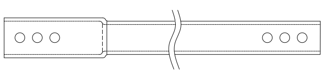


Standard Duty Torque Anchor™ Lead Configurations
<u>1/2” Plate</u> – 9,000 ft-lb*

Shipping & Design Information

Part No.	Description	Wt	Part No.	Description	Wt	Bdl Qty	Plate Area
TAH-288-60-8	60" lead w / 3/8" x 8" helical	43 lbs	HTAH-288-60-8	60" lead w / 1/2" x 8" helical	44 lbs	25 Pcs	0.30 sq. ft.
TAH-288-60-10	60" lead w / 3/8" x 10" helical	46 lbs	HTAH-288-60-10	60" lead w / 1/2" x 10" helical	48 lbs		0.50 sq. ft.
TAH-288-60-12	60" lead w / 3/8" x 12" helical	49 lbs	HTAH-288-60-12	60" lead w / 1/2" x 12" helical	52 lbs		0.74 sq. ft.
TAH-288-60-14	60" lead w / 3/8" x 14" helical	53 lbs	HTAH-288-60-14	60" lead w / 1/2" x 14" helical	57 lbs		1.02 sq. ft
TAF-288-60-8-10	60" lead w / 3/8" x 8" & 10" helical	50 lbs	HTAF-288-60-8-10	60" lead w / 1/2" x 8" & 10" helical	54 lbs		0.80 sq. ft
TAF-288-60-10-12	60" lead w / 3/8" x 10" & 12" helical	56 lbs	HTAF-288-60-10-12	60" lead w / 1/2" x 10" & 12" helical	62 lbs		1.24 sq. ft
TAF-288-60-12-14	60" lead w / 3/8" x 12" & 14" helical	63 lbs	HTAF-288-60-12-14	60" lead w / 1/2" x 12" & 14" helical	72 lbs		1.76 sq. ft
TAH-288-84-8	84" lead w / 3/8" x 8" helical	58 lbs	HTAH-288-84-8	84" lead w / 1/2" x 8" helical	60 lbs	25 Pcs	0.30 sq. ft.
TAH-288-84-10	84" lead w / 3/8" x 10" helical	61 lbs	HTAH-288-84-10	84" lead w / 1/2" x 10" helical	64 lbs		0.50 sq. ft.
TAH-288-84-12	84" lead w / 3/8" x 12" helical	64 lbs	HTAH-288-84-12	84" lead w / 1/2" x 12" helical	68 lbs		0.74 sq. ft.
TAH-288-84-14	84" lead w / 3/8" x 14" helical	68 lbs	HTAH-288-84-14	84" lead w / 1/2" x 14" helical	73 lbs		1.02 sq. ft
TAF-288-84-8-10	84" lead w / 3/8" x 8" & 10" helical	66 lbs	HTAF-288-84-8-10	84" lead w / 1/2" x 8" & 10" helical	70 lbs		0.80 sq. ft
TAF-288-84-10-12	84" lead w / 3/8" x 10" & 12" helical	72 lbs	HTAF-288-84-10-12	84" lead w / 1/2" x 10" & 12" helical	78 lbs		1.24 sq. ft
TAF-288-84-12-14	84" lead w / 3/8" x 12" & 14" helical	79 lbs	HTAF-288-84-12-14	84" lead w / 1/2" x 12" & 14" helical	87 lbs		1.76 sq. ft
TAF-288-84-8-10-12	84" lead w / 3/8" x 8", 10" & 12" helical	77 lbs	HTAF-288-84-8-10-12	84" lead w / 1/2" x 8", 10" & 12" helical	84 lbs		1.54 sq. ft
TAF-288-84-10-12-14	84" lead w / 3/8" x 10", 12" & 14" helical	86 lbs	HTAF-288-84-10-12-14	84" lead w / 1/2" x 10", 12" & 14" helical	97 lbs		2.26 sq. ft
TAH-288-120-8	120" lead w / 3/8" x 8" helical	81 lbs	HTAH-288-120-8	84" lead w / 1/2" x 8" helical	83 lbs	25 Pcs	0.30 sq. ft.
TAH-288-120-10	120" lead w / 3/8" x 10" helical	84 lbs	HTAH-288-120-10	84" lead w / 1/2" x 10" helical	87 lbs		0.50 sq. ft.
TAH-288-120-12	120" lead w / 3/8" x 12" helical	87 lbs	HTAH-288-120-12	84" lead w / 1/2" x 12" helical	91 lbs		0.74 sq. ft.
TAH-288-120-14	120" lead w / 3/8" x 14" helical	91 lbs	HTAH-288-120-14	84" lead w / 1/2" x 14" helical	96 lbs		1.02 sq. ft
TAF-288-120-8-10	120" lead w / 3/8" x 8" & 10" helical	89 lbs	HTAF-288-120-8-10	84" lead w / 1/2" x 8" & 10" helical	93 lbs		0.80 sq. ft
TAF-288-120-10-12	120" lead w / 3/8" x 10" & 12" helical	95 lbs	HTAF-288-120-10-12	84" lead w / 1/2" x 10" & 12" helical	101 lbs		1.24 sq. ft
TAF-288-120-12-14	120" lead w / 3/8" x 12" & 14" helical	102 lbs	HTAF-288-120-12-14	84" lead w / 1/2" x 12" & 14" helical	110 lbs		1.76 sq. ft
TAF-288-120-8-10-12	120" lead w / 3/8" x 8", 10" & 12" helical	100 lbs	HTAF-288-120-8-10-12	84" lead w / 1/2" x 8", 10" & 12" helical	107 lbs		1.54 sq. ft
TAF-288-120-10-12-14	120" lead w / 3/8" x 10", 12" & 14" helical	109 lbs	HTAF-288-120-10-12-14	84" lead w / 1/2" x 10", 12" & 14" helical	120 lbs		2.26 sq. ft

Tubular Torque Anchor™ Extensions



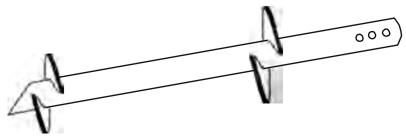
Supplied with Hardware

ESR-3559

Part No.	Description	Bdl Qty	Wt	Plate Area
TAE-288-36	36" Extension	50 Pcs	26 lbs	N/A
TAE-288-60	60" Extension		41 lbs	
TAE-288-84	84" Extension		56 lbs	
TAE-288-120	120" Extension		79 lbs	

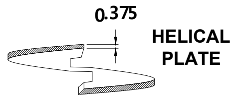
Note: Products Listed Above Are Standard Items And Are Usually Available From Stock.
Other Specialized Configurations Are Available As Special Order – Allow Extra Time For Processing.
All Helical Plates Are Spaced At Three Times The Diameter Of The Preceding Plate
All Product Hot Dip Galvanized Per ASTM A123 Grade 75.
The nominal wall thickness of the tubing is 0.276” wall with a minimum allowable thickness of 0.262” wall.
ECP TA-288 products have an ICC evaluation and ICC-ES 3559 has been issued.

Please see “IMPORTANT NOTES” on Table 2

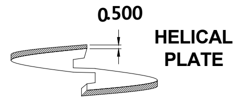


3-1/2” O.D. x 0.300” Wall Tubular Shaft Torque Anchors™

ESR-3559



Torque Anchor™ Lead Configurations
3/8” Plate – 13,000 ft-lb*

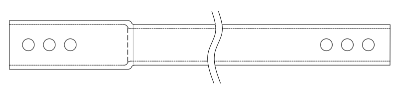


Torque Anchor™ Lead Configurations
1/2” Plate – 13,000 ft-lb*

Shipping & Design Information

Part No.	Description	Wt	Part No.	Description	Wt	Bdl Qty	Plate Area
TAH-350-60-10	60" lead w / 3/8" x 10" helical	59 lbs	HTAH-350-60-10	60" lead w / 1/2" x 10" helical	61 lbs		0.48 sq. ft
TAH-350-60-12	60" lead w / 3/8" x 12" helical	62 lbs	HTAH-350-60-12	60" lead w / 1/2" x 12" helical	66 lbs		0.72 sq. ft
TAH-350-60-14	60" lead w / 3/8" x 14" helical	66 lbs	HTAH-350-60-14	60" lead w / 1/2" x 14" helical	71 lbs	25 Pcs	1.00 sq. ft
TAF-288H-60-8-10	60" lead w / 3/8" x 8" & 10" helical	64 lbs	HTAF-350-60-8-10	60" lead w / 1/2" x 8" & 10" helical	68 lbs		0.76 sq. ft
TAF-288H-60-10-12	60" lead w / 3/8" x 10" & 12" helical	70 lbs	HTAF-350-60-10-12	60" lead w / 1/2" x 10" & 12" helical	76 lbs		1.20 sq. ft
TAF-288H-60-12-14	60" lead w / 3/8" x 12" & 14" helical	75 lbs	HTAF-350-60-12-14	60" lead w / 1/2" x 12" & 14” helical	85 lbs		1.72 sq. ft
TAH-350-84-10	60" lead w / 3/8" x 10" helical	79 lbs	HTAH-350-84-10	84" lead w / 1/2" x 10" helical	82 lbs		0.48 sq. ft
TAH-350-84-12	60" lead w / 3/8" x 12" helical	83 lbs	HTAH-350-84-12	84" lead w / 1/2" x 12" helical	86 lbs		0.72 sq. ft
TAH-350-84-14	60" lead w / 3/8" x 14" helical	66 lbs	HTAH-350-84-14	84" lead w / 1/2" x 14" helical	91 lbs		1.00 sq. ft
TAF-288H-84-8-10	84" lead w / 3/8" x 8" & 10" helical	84 lbs	HTAF-350-84-8-10	84" lead w / 1/2" x 8" & 10" helical	91 lbs		0.76 sq. ft
TAF-288H-84-10-12	84" lead w / 3/8" x 10" & 12" helical	90 lbs	HTAF-350-84-10-12	84" lead w / 1/2" x 10" & 12" helical	96 lbs		1.20 sq. ft
TAF-288H-84-12-14	84" lead w / 3/8" x 12" & 14" helical	95 lbs	HTAF-288H-84-12-14	84" lead w / 1/2" x 12" & 14" helical	105 lbs	25 Pcs	1.72 sq. ft
TAF-288H-84-8-10-12	84" lead w / 3/8" x 8", 10" & 12" helical	95 lbs	HTAF-288H-84-8-10-12	84" lead w / 1/2" x 8", 10" & 12" helical	102 lbs		1.48 sq. ft
TAF-288H-84-10-12-14	84" lead w / 3/8" x 10", 12" & 14" helical	108 lbs	HTAF-288H-84-10-12-14	84" lead w / 1/2" x 10", 12" & 14" helical	115 lbs		2.20 sq. ft
TAH-350-120-10	120" lead w / 3/8" x 10" helical	110 lbs	HTAH-350-120-10	120" lead w / 1/2" x 10" helical	113 lbs		0.48 sq. ft
TAH-350-120-12	120" lead w / 3/8" x 12" helical	113 lbs	HTAH-350-120-12	120" lead w / 1/2" x 12" helical	117 lbs		0.72 sq. ft
TAH-350-120-14	120" lead w / 3/8" x 14" helical	117 lbs	HTAH-350-120-14	120" lead w / 1/2" x 14" helical	122 lbs		1.00 sq. ft
TAF-350-120-8-10	120" lead w / 3/8" x 8" & 10" helical	115 lbs	HTAF-350-120-8-10	120" lead w / 1/2" x 8" & 10" helical	122 lbs		0.76 sq. ft
TAF-350-120-10-12	120" lead w / 3/8" x 10" & 12" helical	121 lbs	HTAF-350-120-10-12	120" lead w / 1/2" x 10" & 12" helical	127 lbs	25 Pcs	1.20 sq. ft
TAF-350-120-12-14	120" lead w / 3/8" x 12" & 14" helical	126 lbs	HTAF-350-120-12-14	120" lead w / 1/2" x 12" & 14" helical	136 lbs		1.72 sq. ft
TAF-350-120-8-10-12	120" lead w / 3/8" x 8", 10" & 12" helical	125 lbs	HTAF-350-120-8-10-12	120" lead w / 1/2" x 8", 10" & 12" helical	133 lbs		1.48 sq. ft
TAF-288H-120-10-12-14	120" lead w / 3/8" x 10", 12" & 14" helical	133 lbs	HTAF-288H-120-10-12-14	120" lead w / 1/2" x 10", 12" & 14" helical	146 lbs		2.20 sq. ft

Tubular Torque Anchor™ Extensions



Supplied with Hardware

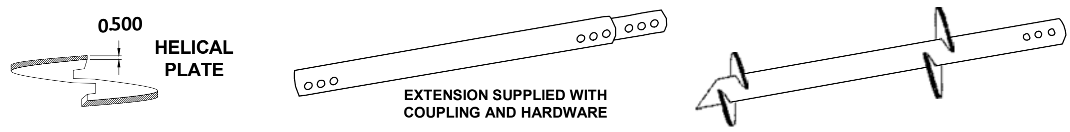
ESR-3559

Part No.	Description	Bdl Qty	Wt	Plate Area
TAE-350-36	36" Extension		36 lbs	
TAE-350-60	60" Extension	40 Pcs	57 lbs	N/A
TAE-350-84	84" Extension		77 lbs	
TAE-350-120	120" Extension		108 lbs	

Note: Products Listed Above Are Standard Items And Are Usually Available From Stock.
Other Specialized Configurations Are Available As Special Order – Allow Extra Time For Processing.
All Helical Plates Are Spaced At Three Times The Diameter Of The Preceding Plate
All Product Hot Dip Galvanized Per ASTM A123 Grade 75
ECP TA-350 products have an ICC evaluation and ICC-ES 3559 has been issued.

Please see “IMPORTANT NOTES” on Table 2

4-1/2” O.D. x 0.337” Wall Tubular Shaft – Torque Anchors™ With 1/2” Plate



Standard Duty Torque Anchor™ Lead Configurations – 22,000 ft-lb*

Part No.	Description	Bdl Qty	Wt	Plate Area
HTAH-450-60-10	60" lead w / 1/2" x 10" helical	16 Pcs	85 lbs	0.24 sq. ft
HTAH-450-60-12	60" lead w / 1/2" x 12" helical		89 lbs	0.44 sq. ft
HTAH-450-60-14	60" lead w / 1/2" x 14" helical		94 lbs	0.68 sq. ft
HTAF-450-60-10-12	60" lead w / 1/2" x 10" & 12" helical		99 lbs	1.11 sq. ft
HTAF-450-60-12-14	60" lead w / 1/2" x 12" & 14" helical		109 lbs	1.63 sq. ft
HTAH-450-84-10	84" lead w / 1/2" x 10" helical	16 Pcs	115 lbs	0.24 sq. ft
HTAH-450-84-12	84" lead w / 1/2" x 12" helical		119 lbs	0.44 sq. ft
HTAH-450-84-14	84" lead w / 1/2" x 14" helical		124 lbs	0.68 sq. ft
HTAF-450-84-10-12	84" lead w / 1/2" x 10" & 12" helical		129 lbs	1.11 sq. ft
HTAF-450-84-12-14	84" lead w / 1/2" x 12" & 14" helical		139 lbs	1.63 sq. ft
HTAF-450-84-10-12-14	84" lead w / 1/2" x 10", 12" & 14" helical		149 lbs	2.07 sq. ft
HTAH-450-120-10	120" lead w / 1/2" x 10" helical	16 Pcs	160 lbs	0.24 sq. ft
HTAH-450-120-12	120" lead w / 1/2" x 12" helical		164 lbs	0.44 sq. ft
HTAH-450-120-14	120" lead w / 1/2" x 14" helical		169 lbs	0.68 sq. ft
HTAF-450-120-10-12	120" lead w / 1/2" x 10" & 12" helical		174 lbs	1.11 sq. ft
HTAF-450-120-12-14	120" lead w / 1/2" x 12" & 14" helical		184 lbs	1.63 sq. ft
HTAF-450-120-10-12-14	120" lead w / 1/2" x 10", 12" & 14" helical		194 lbs	2.07 sq. ft

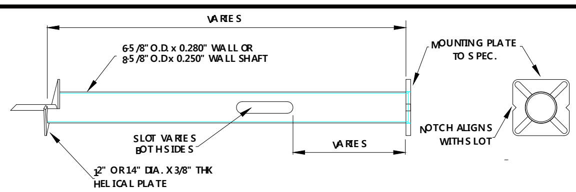
High Strength Torque Anchor™ Extensions

Part No.	Description	Bdl Qty	Wt	Plate Area
TAE-450-36	36" Extension	20 Pcs	73 lbs	N/A
TAE-450-60	60" Extension		102 lbs	
TAE-450-84	84" Extension		132 lbs	
TAE-450-120	120" Extension		177 lbs	

Note: Products Listed Above Are Standard Items And Are Usually Available From Stock.
Other Specialized Configurations Are Available As Special Order – Allow Extra Time For Processing.
All Helical Plates Are Spaced At Three Times The Diameter Of The Preceding Plate
All Product Hot Dip Galvanized Per ASTM A123 Grade 75

Please see “IMPORTANT NOTES” on Table 2

Light Pole Anchor Configurations



Part Number With Stinger End	Description	Helix Diameter	Length	Ultimate-Limit Capacity (SPT ≥ 5 bpf)		Weight
				Overturning Moment	Lateral Load	
LPS-400-60 12	4” x 0.226” Wall – 5’-0” Long	12”	5’-0”	< 5,000 ft-lb	< 500 lb	88 lbs
LPS-663-60 12	6-5/8” x 0.280” Wall – 5’-0” Long	12”	5’-0”	< 12,000 ft-lb	< 1,000 lb	156 lbs
LPS-663-84 14	6-5/8” x 0.280” Wall – 7’-0” Long	14"	7’-0”	< 12,000 ft-lb	< 1,000 lb	209 lbs
LPS-863-60 14	8-5/8” x 0.250” Wall – 5’-0” Long	14”	5’-0”	< 17,500 ft-lb	< 1,200 lb	177 lbs
LPS-863-84 14	8-5/8” x 0.250” Wall – 7-0” Long	14”	7’-0”	< 17,500 ft-lb	< 1,200 lb	222 lbs
HDW-LPS-100	Hardware Kit	Kit Includes - 1" x 4" Carriage Bolt, Washers, & Nuts Sufficient for one Light Pole Installation				4 lbs

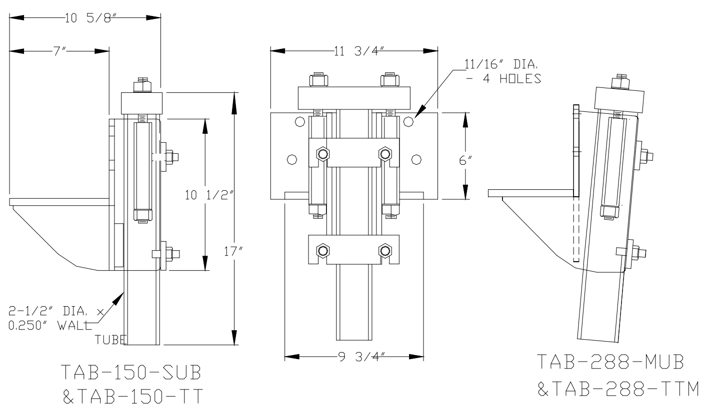
Note: Standard Products are shown in table Include: Standard Integral Pile Cap - 1” thick x 15-3/4” square plate welded to shaft – Mounting plate includes four 1-1/8” slots designed to accept 1” diameter mounting bolts - Cable access slot provided on opposite sides of shaft – (2” x 10” Standard) - Stinger end shaft design has single chamfer on bottom of shaft with an protruding “stinger” for easy alignment.
Dip Galvanized Per ASTM A123 Grade 75.

Special Product Designs Are Available: We fabricate custom light pole supports to your shaft length and mounting design specifications.
Please allow extra time for fabrication.

Torque Anchor™ Utility Brackets

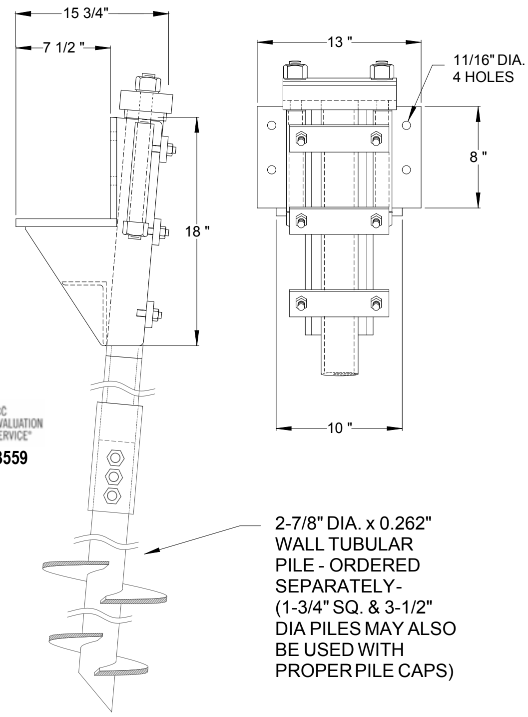
TAB-150-SUB Standard Duty & TAB-288-MUB Light Weight Utility Bracket

Shaft Size:	1-1/2" Sq.	2-7/8" Dia.
Bracket Part Number:	TAB-150-SUB	TAB-288-MUB
Pier Cap:	TAB-150-TT T-Tube	TAB-288-TTM T-Tube
Ultimate-Limit Capacity:	40,000 lb.[1]	
Bearing Area:	68-1/4 sq. inches	
Standard Lift Capacity:	4 inches	



TAB-LUB Large Utility Bracket

Shaft Size:	1-3/4" Sq.	2-7/8" Dia.	3-1/2" Dia.
Bracket Part Number:	TAB-LUB	TAB-LUB	TAB-LUB
Pier Cap: [2]	TAB-175-TT T-Tube	TAB-288-TT T-Tube	TAB-350-TT T-Tube
Ultimate-Limit Capacity:	98,000 lb.[1]		
Bearing Area:	75 square inches		
Standard Lift Capacity:	5-1/2 inches		



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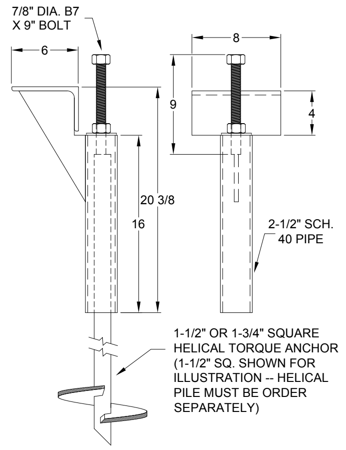
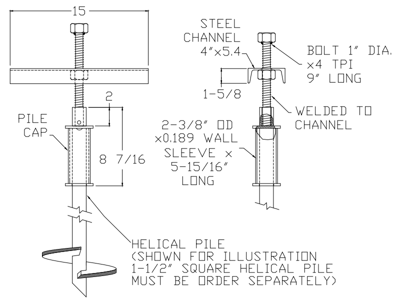
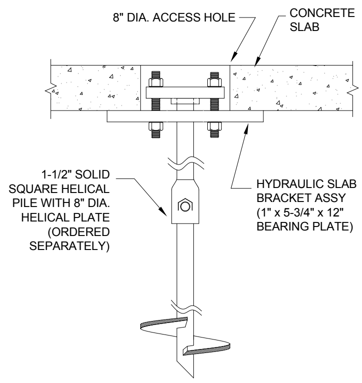
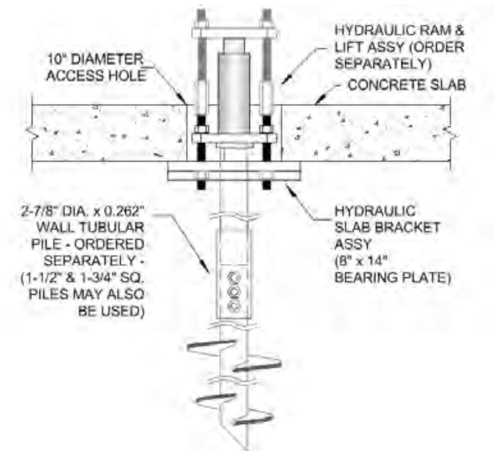
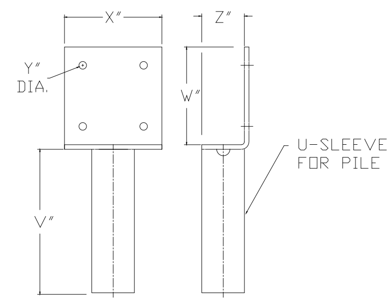
NOTES:

1. These are mechanical capacity ratings. Foundation strength and soil capacity will dictate actual capacity.
2. The TAB-LUB Bracket is the same component for three different shaft sizes; the Pile Cap configuration varies to accommodate the appropriate shaft for the application.
3. ICC-ES ESR-3559 evaluation reports available for the Large Utility Brackets.

Part No.	Description	Ultimate Limit Capacity	Pallet Quantity	Weight
TAB-150-SUB	HELICAL BRACKET STANDARD w/ 150 T-TUBE	40,000 lbs	25	58 lbs
TAB-288-MUB	LIGHT WEIGHT UTILITY BRACKET 288	40,000 lbs	25	56 lbs
TAB-175-LUB	HELICAL BRACKET LARGE W/ 175 T-TUBE (Fits 1-3/4" Square Shaft)	98,000 lbs	25	122 lbs
TAB-288-LUB	HELICAL BRACKET LARGE W/ 288 T-TUBE (Fits 2-7/8" dia Tubular)	98,000 lbs	25	117 lbs
TAB-350-LUB	HELICAL BRACKET LARGE W/ 350 T-TUBE (Fits 3-1/2" dia Tubular)	98,000 lbs	25	123 lbs

Torque Anchor™ Porch & Slab Brackets

TAB–150-LP Porch Bracket TAB–288-LP (not shown)	TAB-150 SSB Slab Bracket	PPB–166 Hydraulic Lift Slab Bracket
		

TAB-288-HSB Hydraulic Lift Slab Bracket[1]	ZTAB–XXX-TB Timber Bracket[5]
	 Please contact ECP with design specifications

Part Number		Fits Torque Anchor	Ultimate Limit Capacity[2 3]	Maximum Lift[4]	Weight	Notes
TAB -150 -LP		1-1/2" Sq	9,000 lbs	4-1/2"	25 lbs	1. Load transfer and elevation recovery is accomplished using ECP Steel Pier™ Bracket Lift Assemblies. (Purchased Separately) The TAB-288-HSB Bracket requires an ECP Model requires an ECP Model 350 Lift Assembly. 2. The capacities listed for foundation brackets are mechanical ratings, and the actual installed load capacities are dependent upon the strength and condition of the concrete, and the specific soil conditions on the job site. Concrete strength for the above ratings was assumed to be 3,000 psi. 3. Capacities based upon "soft" soil values "N" > 5 blows per foot 4. Bracket lift height may be increased by ordering longer continuously threaded bracket rods. 5. Special Order Product – Configuration to fit your design and load. Allow extra time for processing. Please contact ECP for assistance and pricing.
TAB -288 -LP		2-7/8" Tubular	16,000 lbs	4-1/2"	28 lbs	
TAB -150 -SSB		1-1/2" Sq	8,000 lbs	4"	16 lbs	
PPB -166 (8" Dia Hole)		1-1/2" Sq	22,000 lbs	4"	37 lbs	
		1-3/4" Sq				
		2 - 7/8" Tubular				
PPB -166 -G (8" Dia Hole)		1-1/2" Sq	22,000 lbs	4"	37 lbs	
		1-3/4" Sq				
		2 - 7/8" Tubular				
TAB -288 –HSB	Requires 10" dia. access hole thru slab	2 - 7/8" Tubular	40,000 lbs	4"	65 lbs	
TAB -288 -HSBG		2 - 7/8" Tubular		4"	65 lbs	
ZTAB -150 –TB[5]		1-1/2" Sq	Capacity dependent upon design and specifications	Price determined from design specifications	15 lbs	
ZTAB -288 -- TB[5]		2 - 7/8" Tubular			23 lbs	

Torque Anchor™ Utility Brackets

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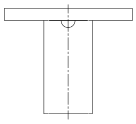
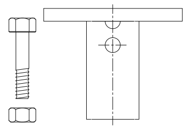
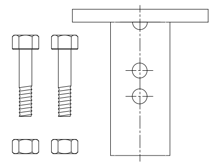


Compression (No Bolts)
Illustration “A”



Tension Illustration “B” (One Bolt)



Tension Illustration “C” (Two Bolts)

Part Number	Illustration	Pile Size	Bearing Plate	Pile Sleeve	Ultimate Limit Capacity Compressive	Ultimate Limit Capacity Tension	Weight
TAB -150 -NC [6]	A	1-1/2" Sq Bar	1/2" x 6" x 6"	2-1/2” x 2-1/2” x 1/4” 5-3/4” Long	70,000 lbs	N/A	7
TAB -150 -NCG [6]	A				70,000 lbs		7
TAB -150 –T [6]	B				70,000 lbs	63,000 lbs	8
TAB -150 -TG [6]	B				70,000 lbs	63,000 lbs	8
TAB -175 -NC [6]	A	1-3/4" Sq Bar	3/4" x 8" x 8"	2-1/2” x 2-1/2” x 1/4” 7-3/4” Long	100,000 lbs	N/A	17
TAB -175 -NCG [6]	A				100,000 lbs		17
TAB -175 -T [6]	B				100,000 lbs	80,000 lbs	18
TAB -175 -TG [6]	B				100,000 lbs	80,000 lbs	18
TAB -200 -NC	A	2" Sq Bar	1" x 8" x 8"	3” x 3” x 3/8” 7-3/4 Long	127,500 lbs	N/A	34
TAB -200 -NCG	A				127,500 lbs		34
TAB -200 -T	B				127,500 lbs	120,000 lbs	36
TAB -200 -TG	B				127,500 lbs	120,000 lbs	36
TAB -288L -NC	A	2-7/8" Dia Tubular	1/2" x 6" x 6"	3-1/2" Dia x 0.216” 5-3/4" Long	60,000 lbs	N/A	9
TAB -288L -NCG	A				60,000 lbs		9
TAB -288L -T	B				60,000 lbs	44,000 lbs	10
TAB -288L -TG	B				60,000 lbs	44,000 lbs	10
TAB -288 -NC	A	2-7/8" Dia. Tubular	3/4" x 8" x 8"	3-1/2" Dia x 0.216” 7-3/4" Long	100,000 lbs	N/A	19
TAB -288 -NCG	A				100,000 lbs		19
TAB -288 -T	C				100,000 lbs	80,000 lbs	21
TAB -288 -TG	C				100,000 lbs	80,000 lbs	21
TAB -350 –NC [6]	A	3-1/2" Dia. Tubular	3/4" x 8" x 8"	4"-1/2” Dia x 0.337 “ 7-3/4" Long	115,000 lbs	N/A	24
TAB -350 -NCG [6]	A				115,000 lbs		24
TAB -350 -T [6]	C				115,000 lbs	97,000 lbs	26
TAB -350 -TG [6]	C				115,000 lbs	97,000 lbs	26
TAB -450 -NC	A	4-1/2" Dia. Tubular	1" x 10" x 10"	5-9/16" Dia x 0.375” 7-3/4" Long	160,000 lbs	N/A	45
TAB -450 -NCG	A				160,000 lbs		45
TAB -450 -T	C				160,000 lbs	143,000 lbs	49
TAB -450 -TG	C				160,000 lbs	143,000 lbs	49

Pile Cap Notes:

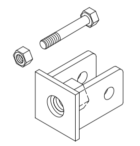
1. Capacities based upon 3,000 psi concrete. Reduce loading or increase plate area appropriately for lower strength concrete.
2. Pile caps shown are standard items and are usually available from stock. Note: TAB-288L-T and TAB-288-T are not interchangeable because bolt hole spacing varies.
3. Part numbers for tension include attachment holes and SAE J429 Grade 8 hardware as shown; compression pile caps do not include hardware or mounting holes.
4. Compressive capacity ratings of some pile caps are limited by compressive pile shaft capacity.
5. Pile caps are supplied plain steel -- hot dip galvanized per ASTM A123 Grade 75 is available.
6. New construction pile caps evaluated by ICC. Report ICC-ES ESR-3559.

Custom fabricated pile caps are available for all shaft sizes by special order – allow extra time for processing.

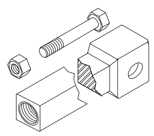
Earth Contact Products

Torque Anchor™ Transitions & Wall Plates

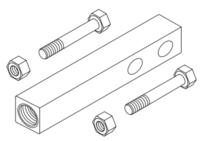
Transition Assemblies



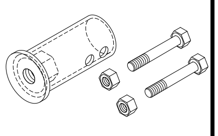
TAT-150



TAT-150-HD
TAT-175-HD



TAT-200



TAT-288L - TAT 288–
TAT-350 – TAT-450

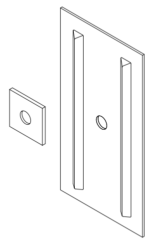
TAT-150	TAT-150-HD	TAT-175-HD	TAT-200
Output Thd. Major Dia. 1” (B-12 Coil Rod)	Output Thd. Major Dia. 1-1/8” (WF-8)	Output Thd. Major Dia. 1-3/8” (WF-10)	Output Thd. Major Dia. 1-7/16” (R71-10)
Plate Washer 3/8” x 5” x 5”	Plate Washer 3/8” x 5” x 5”	Plate Washer 3/8” x 6” x 6”	Plate Washer Not Supplied
Ultimate-Limit Capacity 38,000 lb.	Ultimate-Limit Capacity 70,000 lb.	Ultimate-Limit Capacity 99,000 lb.	Ultimate-Limit Capacity 155,000 lb.

TAT-288L	TAT-288	TAT-350	TAT-450
Output Thd. Major Dia. 1-3/8” (WF-10)	Output Thd. Major Dia. 1-3/8” (WF-10)	Output Thd. Major Dia. 1-3/8” (WF-10)	Output Thd. Major Dia. 1-1/2” (WF-11)
Plate Washer Not Supplied. Order Separately to the Engineer’s Specifications			
Ultimate-Limit Capacity 60,000 lb.	Ultimate-Limit Capacity 100,000 lb.	Ultimate-Limit Capacity 120,000 lb.	Ultimate-Limit Capacity 140,000 lb.

Stamped Wall Plates

PA-LWP

12” x 26” - 2.2 ft^2 Bearing



Wall Plates include:
Flat Washer 3/16”x4”x6”
Clamping Cap: 8,250 lb.
Hot Dip Galvanize.

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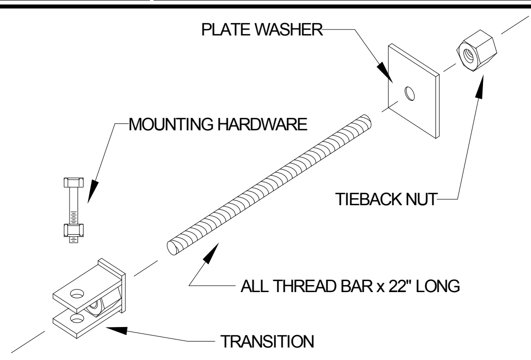
Transition Notes:

1. Transitions listed are standard items; usually available from stock.
2. Hot dip galvanized per ASTM A123 Grade 75
3. The capacities listed are mechanical ratings.
4. All Transitions are supplied with 48” All Thread Rod. (All thread coil rod supplied on TAT-150 assembly is 22” long.),
5. All Transitions are supplied with Nut and Mounting Hardware. Square shaft transitions have a flat washer included. (No flat washer supplied with the TAT-200 Transition Kit.)

(TAT-150 Sketch Below – Other Transition Assemblies are Similar)

The sketch to the right shows the components that are shipped with solid bar transition assemblies. The transition and the hardware required to attach the transition to the tieback will vary depending upon the product ordered. Please refer to the table above for additional details. Tubular transitions and TAT-200 do not include a flat wall plate. As the angle of installation usually varies generally from 15º to 30º, bevel washers should be ordered separately.



Part No.	Description	Ultimate Limit Capacity Tension	Package Quantity	Weight
TAT-150	TRANSITION KIT 150 W/ 22" 1" COIL ROD	38,000 lbs	5 Sets	16 lbs
TAT-150-HD	TRANSITION KIT HD 150 W/ 48" WF8	70,000 lbs		26 lbs
TAT-175-HD	TRANSITION KIT 175 W/ 48" WF10	99,000 lbs		41 lbs
TAT-200	TRANSITION KIT 200 W/ 48" R71-10	150,000 lbs		41 lbs
TAT-288L	TRANSITION KIT 288 L W/ 48" WF8	60,000 lbs		18 lbs
TAT-288	TRANSITION KIT 288 W/ 48" WF10	100,000 lbs		31 lbs
TAT-350	TRANSITION KIT 350 W/ 48" WF10	120,000 lbs		33 lbs
TAT-450	TRANSITION KIT 450 W/ 48" WF11	140,000 lbs		45 lbs

Table 3.	Symbols Used In This Chapter
α	Tieback installation angle from horizontal
A	Projected area of helical plate – ft^2
c	Undrained shear strength of the soil – lb/ft^2
d_x	Helical plate diameter -- ft
$d_{largest}$	Diameter of Largest Helical Plate
D_{cr}	Critical Depth – The distance from ground surface to the shallowest helical tieback plate. ($D_{cr} = 6 \times d_{largest}$)
γ	Dry Density Of The Soil – lb/ft^3
ϕ	Internal Friction Angle of Soil
FS	Factor Of Safety (Generally FS = 2)
H	Height of soil against wall or basement - ft
h	Vertical depth from surface to helical plate
h_{mid}	Vertical depth from the ground surface to a point midway between the lowest and highest helical plates – ft
k	Empirical factor relating ultimate capacity of a pile or tieback to the installation torque – ft^{-1} ($k = P_u$ or T_u / T)
K	Torque conversion factor that is used to determine torque motor output from pressure differential across motor
L	Total product length required by the design
L_0	Minimum required horizontal embedment
L_{15}	Distance to achieve the minimum required embedment length, "L_0" at 15^0 Installation Angle
N	Standard Penetration Test (SPT) Results. N = Number of blows with a 140 lb hammer to penetrate the soil a distance of one foot. (Note: "N" may be given directly or in 3 segments. Always add the last two segment counts to get "N" – 4/5/7 is N = 12.)
N_c	Bearing capacity factor for clay soil
N_q	Bearing capacity factor for granular soil
pH	Measure of acidity or alkalinity
P	Foundation or Wall Load – lb/Lineal ft
P_u	Ultimate pile or anchor capacity* – lb.
P_w	Working or design load – lb.
Δp	Pressure differential measured across a torque motor $\Delta p = p_{in} - p_{out}$ - psi
q	Soil overburden pressure (lb/ft^2)
S	Helical Plate Embedment for Tension - ft
T	Installation or Output Torque – ft-lb
T_u	Ultimate Tension Capacity – lb
T_w	Working Tension Load – lb
w	Distributed load along foundation – lb/lin.ft.
X	Product Spacing - ft

* Unfactored Limit, use as nominal, "P_u" value per design codes

Design Criteria

The Bearing Capacity of a Torque Anchor™ (P_w) can be defined as the load which can be sustained by the Torque Anchor™ without producing objectionable settlement, either initially or progressively, which results in damage to the structure or interferes with the use of the structure.

Bearing Capacity is dependant upon many factors:

- Kind Of Soil,
- Soil Properties,
- Surface and/or Ground Water Conditions,
- Torque Anchor™ Configuration (Shaft Size & Type, Helix Diameter(s), and Number Of Helices),
- Depth to Bearing,
- Installation Angle,
- Torque Anchor™ Spacing,
- Installation Torque,
- Type of Loading - Tension, Compression, Alternating Loads, etc.

The design of Helical Torque Anchors™ uses classical geotechnical theory and analysis along with empirical relationships that have been developed from extensive field load testing. In order to prepare an engineering design, geotechnical information is required from the site along with structural load requirements including a factor of safety - "FS".

The most accurate design requires knowledge from soil testing using the Standard Penetration Test (SPT) standardized to ASTM D1586 plus laboratory evaluations of the soil strength, which is usually given as soil cohesion – "c", soil density – "γ", and granular friction angle – "ϕ"

Soils will vary from site to site and may vary from point to point on some sites. Each analysis must use data relevant to the project at hand as each project has different parameters.

Each design requires specific information involving the structure and soil characteristics at the site. Each design should involve geotechnical and engineering input.

The following preliminary design information is intended to assist with the selection of an appropriate ECP Torque Anchor™ system for a given project.

Deep Foundations

Torque Anchor™ systems must be considered as deep foundation elements.

As a rule of thumb, helical piles must be installed deeper than the <u>Critical Depth of six times the diameter of the largest helix.</u> The depth is measured from the intended final surface elevation to the uppermost helical plate of the Torque Anchor™.

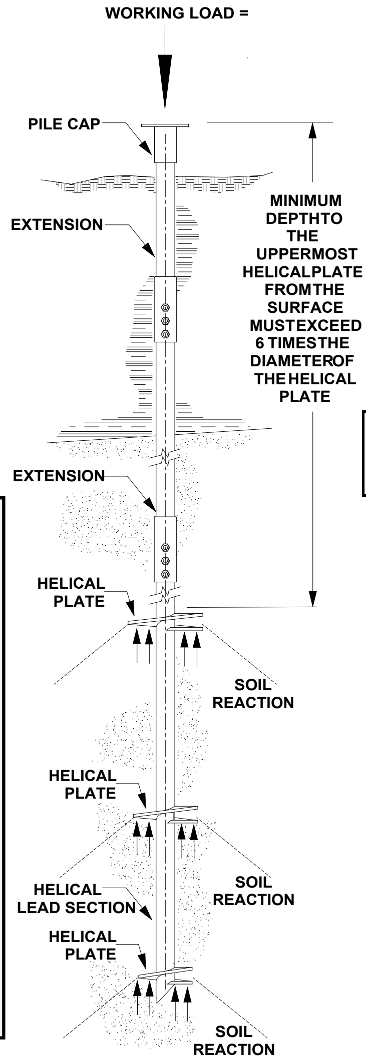


Figure 1. Helical Pile Load and Reaction Diagram

The capacity of a multi-helix deep foundation system assumes that the ultimate bearing capacity is the sum of the bearing support from each plate of the system. Testing has shown that when the helical plates are spaced at three times the diameter away from the adjacent lower helical plate, each plate will develop full efficiency and soil capacity. Spacing the helical plates at less than three diameters is possible, however, each plate will not be able to develop full capacity and the designer will have to include a plate efficiency factor in the analysis when conducting the design.

Pile or anchor shaft spacing should be no closer than five times the diameter of the largest plate at the bearing depth. Pile shaft spacing as close as three diameters has been successfully installed, but this work requires special installation equipment that can maintain accurate installation angles. The spacing requirement of five times the diameter of the largest plate <u>is measured at the target depth</u>. It is normal practice to cluster several shafts at the same surface location with each shaft having a suitable outward batter to accomplish the required shaft to shaft spacing at the final installed depth.

Using guidelines described above, the ultimate capacity of an ECP Torque Anchor™ system can be calculated from the following equation:

Equation 1: Ultimate Theoretical Capacity:

$$P_u \text{ or } T_u = \Sigma A_H (c\, N_c + q\, N_q)$$

Where:

P_u or T_u = Ult. Capacity of Torque Anchor™ - (lb)
ΣA_H = Sum of Projected Helical Plate Areas (ft^2)
c = Cohesion of Soil - (lb/ft^2)
N_c = Bearing Capacity Factor for Cohesion
q = Soil Overburden Pressure to h_{mid} depth – (lb/ft^2)
N_q = Bearing Capacity Factor for Granular Soil.

The ultimate capacity is defined as the load that results in a deformation of one inch. In general ultimate capacity is the working or service load with a factor of safety of 2.0 applied.

If one has access to a soil report in which "c", "γ", and "ϕ" are given, then Equation 1 can be solved directly. Unfortunately, many soil reports often do not contain these values and the designer must decide which soil type is more likely to control the ultimate capacity.

When one is unsure of the soil type or the soil behavior cannot be determined, we recommend that one calculate loads using cohesive soil behavior because the result will be conservative.

In all cases, we highly recommend field testing to verify the accuracy of the preliminary design load capacities.

Soil Behavior

The following information is provided to introduce the reader to the field of soil mechanics. Explained are the terms and theories used to determine soil behavior and how this behavior relates to Torque Anchor™ performance. This is not meant to substitute for actual geotechnical soil evaluations. A thorough study of this subject is beyond the scope of this manual. The values presented here are typical of those found in geotechnical reports.

Cohesive Soil (Clays & Silts)

Cohesive soil is soil that is generally classified as a fine grained clay soil and/or silt. By comparison, granular soils like sands and gravels are sometimes referred to as non-cohesive or cohesionless soil.

- Clays or cohesive soils are defined as soils where the internal friction between particles is approximately zero. This internal friction angle is usually referred to as "ϕ" or "phi".
- Cohesive soils have a rigid behavior when exposed to stress. Stiff clays act almost like rock. They remain solid and inelastic until they fail. Soft clays act more like putty. The soft clay bends and molds around the anchor when under stress.

Table 5. Properties of Cohesive Soil			
Soil Density Description	SPT Blow Count - "N"	Undrained Shear Strength "c" -- lb/ft^2	Unconfined Compressive Strength lb/ft^2
Very Soft	0 – 2	< 250	< 500
Soft	2 – 4	250–500	500—1,000
Firm	4 – 8	500–1,000	1,000—2,000
Stiff	8 – 15	1,000–2,000	2,000—4,000
Very Stiff	15 – 32	2,000–4,000	4,000—8,000
Hard	32 – 48	4,000–6,000	8,000—12,000
Very Hard	> 48	> 6,000	> 12,000

Undrained Shear Strength – "c": The undrained shear strength of a soil is the maximum amount of shear stress that may be placed on the soil before the soil yields or fails. This value of "c" only occurs in cohesive soils where the internal friction angle, "ϕ", of the fine grain particles is zero or nearly zero. The value of "c" generally increases with soil density; therefore, one can expect that stiff clays have greater undrained shear strength than soft clay soil. It is easy to understand that when dealing with cohesive soils; that the greater the shear strength "c" of the soil, the greater the bearing capacity. It also follows that the capacity of the soil tends to increase with depth.

Table 4. Cohesive Soil Classification			
Soil Description	USCS Symbol	Density Description	Density "γ" lb/ft^3
Inorganic silt, rock flour, silty or clayey fine sand or silt with low plasticity	ML	Soft	90
		Stiff	110
		Hard	130
Inorganic clay of low to medium plasticity, sandy clay, gravelly clay, lean clay	CL	Soft	90
		Stiff	110
		Hard	130
Organic silts and organic silty clays, low plasticity	OL	Soft	75
		Stiff	90
		Hard	105
Inorganic silt, fine sandy or silty soils, elastic silts - high plasticity	MH	Soft	80
		Stiff	93
		Hard	105
Inorganic clays of high plasticity, fat clay, silty clay	CH	Soft	90
		Stiff	103
		Hard	115
Organic silts and organic clays of medium to high plasticity	OH	Soft	75
		Stiff	95
		Hard	110
Peat and other highly organic soils	PT	--	--

Cohesive Bearing Capacity Factor - "N_c": The bearing capacity factor for cohesion is an empirical value proposed by Meyerhof in the Journal of the Geotechnical Engineering Division, Proceedings of ASCE, 1976. For small shaft helical piles or tieback anchors with plate diameters under 18 inches, the value of the Cohesive Bearing Capacity Factor, "N_c" was found to a value of approximately 9, therefore "N_c" = 9 is a generally accepted value to use when determining capacities of helical piles and anchors embedded in cohesive soils.

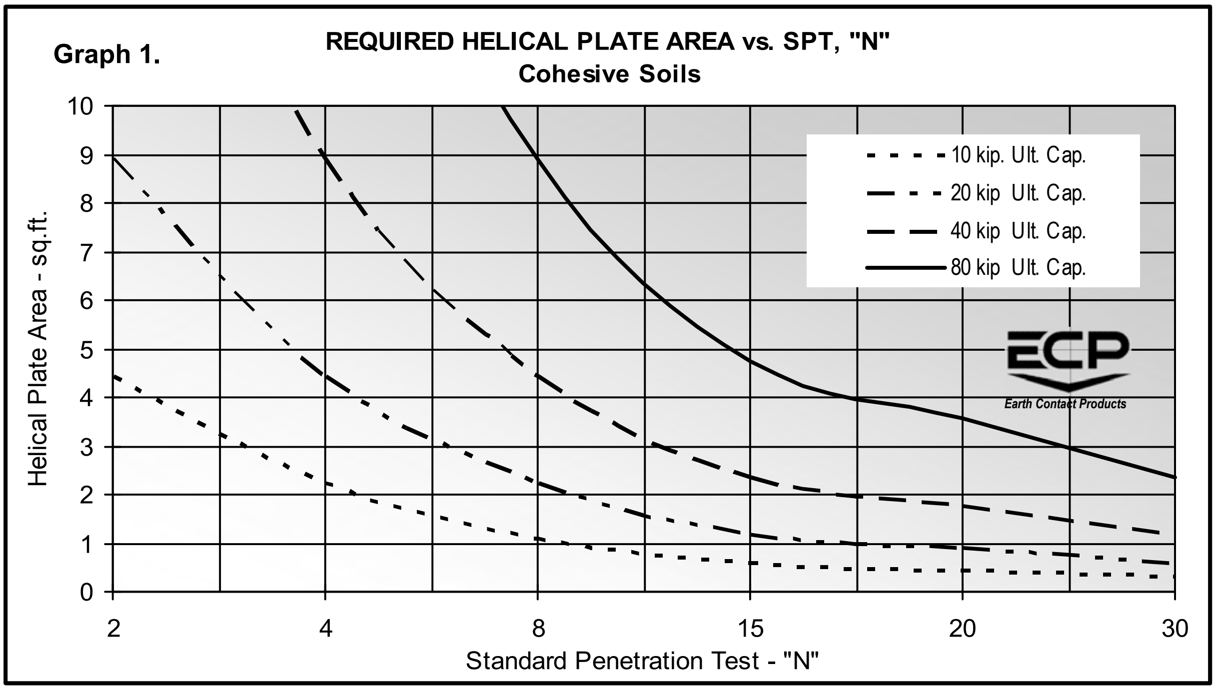
When determining the ultimate capacity for a Torque Anchor™ situated in cohesive soil, Equation 1 may be simplified because the internal friction, "ϕ", of the soil particles can be assumed to be zero and the "N_c" = 9 is assumed. Equation 1 can be modified when dealing with cohesive soil as shown below:

Equation 1a

Ultimate Capacity - Cohesive Soil

$$P_u \text{ or } T_u = \Sigma A_H\ (9c) \text{ or } \Sigma A_H = P_u \text{ or } T_u / (9c)$$

Where:
P_u or T_u = Ultimate Cap. of Torque Anchor™ - (lb)
ΣA_H = Sum of Projected Helical Plate Areas (ft^2)
c = Cohesion of Soil - (lb/ft^2)



Graph 1 above may be used to quickly get a rough estimate of the plate area requirements in cohesive (clay & silty) soils based upon Standard Penetration Test, "N", values at the termination depth of the pile or anchor. One may also use Graph 1 to compare results obtained from Equation 1a.

Cohesionless Soil (Sands & Gravels)

In cohesionless soil, particles of sand act independently of each other. This type of soil has fluid-like characteristics. When cohesionless soils are placed under stress they tend to reorganize into a more compact configuration as the load increases.

Cohesionless soils achieve their strength and capacity in several ways.

- The soil density
- The overburden pressure (The unit weight of the soil above the Torque Anchor™)
- The internal friction angle "ϕ"

Soil Overburden Pressure – "q": The soil overburden pressure at a given depth is the summation of density "γ" (lb/ft^3) of each soil layer multiplied by its thickness, "h". The moist density of the soil is used when calculating the value of "q" for soils above the water table. **Below the water table the buoyancy effect of the water must be taken into consideration.** The submerged density of the soil where all voids in the soil have been filled with water is determined by subtracting the buoyant force of the water (62.4 lb/ft^3) from the moist density of the soil.

Table 6. Cohesionless Soil Classification

Soil Description	USCS Symbol
Well Graded Gravel Or Gravel-Sand	GW
Poorly Graded Gravel Or Gravel-Sand	GP
Silty Gravel Or Gravel-Sand-Silt Mixtures	GM
Clayey Gravel Or Gravel-Sand-Clay Mixtures	GC
Well Graded Sand Or Gravelly-Sands	SW
Poorly Graded Sand Or Gravelly-Sands	SP
Silty Sand Or Sand Silt Mixtures	SM
Clayey Sands Or Sand-Clay Mixtures	SC

To arrive at value for soil overburden pressure on a single helical plate of a Torque Anchor™, the value of "q_{plate}" for each stratum of soil must be determined from the intended final surface elevation to the helical plate elevation, "h_{plate}". By using Equation 1b, the ultimate bearing capacity of the helical plate is determined. The ultimate capacity of a multi-plate helical pile may be determined by summing the capacities of all helical plates. A simpler method often used to estimate the ultimate capacity of a multi-plate pile configuration is to determine the soil overburden, "q", at a depth midway between the upper helical plate and the lowest helical plate, "h_{mid}". This value of "q" is used to estimate the ultimate capacity of the pile configuration.

Table 7.	Properties of Cohesionless Soil				
Soil Density Description	SPT Blow Count "N"	Friction Angle "ϕ"	Bearing Capacity Factor "N_q"	Density "γ" lb/ft³	
				Moist Soil	Submerged
Very Loose	≤ 2	28⁰	12	70 – 100	45 - 62
	3 – 4	28⁰	13		
Loose	5 – 7	29⁰	14 – 15	90 – 115	52 - 65
	8 – 10	30⁰	15 – 16		
Medium Dense	11 – 15	30⁰ - 32⁰	17 - 19	110 –130	68 - 90
	16 – 19	32⁰ - 33⁰	20 – 22		
	20 – 23	33⁰ - 34⁰	23 – 25		
	24 – 27	34⁰ - 35⁰	26 – 29		
	28 – 30	35⁰ - 36⁰	30 – 32		
Dense	31 – 34	36⁰ - 37⁰	34 - 37	110 – 140	80 - 97
	35 – 38	37⁰ - 38⁰	39 – 43		
	39 – 41	38⁰ - 39⁰	45 – 48		
	42 – 45	39⁰ - 40⁰	50 – 56		
	46 – 50	40⁰ - 41⁰	59 – 68		
Very Dense	> 50	> 42⁰	End Bearing	140+	> 85

Cohesionless Bearing Capacity Factor - "N_q": Zhang proposed the ultimate compression capacity of the helical screw pile in a thesis for the University of Alberta in 1999. From this work the dimensionless empirical value "N_q" was introduced. "N_q" is related to the friction angle of the soil - "ϕ", as estimated in Table 7.

When determining the ultimate capacity for a Torque Anchor™ in cohesionless soils, Equation 1 may be simplified because granular soils have no soil cohesion. Therefore "c" may be assumed to be zero. Equation 1 when used for cohesionless soils can be modified as follows:

Equation 1b:

Ultimate Capacity - Cohesionless Soil

$$P_u \text{ or } T_u = \Sigma A_H (q\, N_q) \text{ or}$$

$$\Sigma A_H = P_u \text{ or } T_u/(q\, N_q)$$

Where:

P_u or T_u = Ult. Capacity of Torque Anchor™ - (lb)

ΣA_H = Projected Helical Plate Area(s) (ft^2)

q = Soil Overburden Pressure from the surface to plate depth "h" – (lb/ft^2)

N_q = Bearing Capacity Factor for Granular Soil.

Effect of Water Table on Pile Capacity:

It cannot be emphasized enough that the buoyant force of water on the soil overburden can dramatically change the load capacity of the helical pile or anchor. Calculating soil overburden for a specific site usually entails determining the density of each stratum of soil between the surface and the termination depth of the helical support product.

To illustrate the effect of the water table on the pile capacity the following example assumes that site contains 25 feet of cohesionless soil that is homogeneous, has a constant density of 100 lb/ft^3 and a constant SPT - "N" = 10 bpf that extends beyond 25 feet. Such uniform soil as this is seldom found. In the second example all assumptions remain except the water table is assumed to be located ten feet below grade.

Using Equation 1b and Table 7 the ultimate capacity of a TAF-288 8-10-12 pile when no ground water is present is: **$\underline{\Sigma A_H = 1.54\ ft^2}$**

$\mathbf{P_u = \Sigma A_H (q\, N_q)}$ = 1.54 [(100 x 25 ft) x 16]

$\underline{P_u = 61{,}600\ lb}$ (Damp soil - no water Present)

When the water table is present at 10 feet below grade, **notice the reduction in pile capacity** that is caused by the buoyant force of the water.

$\mathbf{P_u = \Sigma A_H (q\, N_q)}$

$\mathbf{P_u}$ = 1.54 [(100 x 10 ft) + (60 x 15)] x 16

$\underline{P_u = 46{,}816\ lb}$ (Water Table at 10 feet)

The reduction in capacity of the same pile configuration in the same soil when water is present at 10 feet below grade is approximately 76%. **This demonstrates that knowing the level of the water table is necessary for safe design.**

Using Equation 1b must be used again to determine a new helical plate area requirement and a new pile configuration that will have sufficient plate area to support 61,600 pounds in the soil with the higher water table.

$\mathbf{\Sigma A_H = P_u/(q\ N_q)}$

$\Sigma A_H = 61{,}600/[(100 \times 10\ \text{ft}) + (60 \times 15)] \times 16$

$\underline{\mathbf{\Sigma A_H = 2.03\ ft^2}}$

The closest standard product that will provide this helical plate area is a TAF-288 (10-12-14), which offers 2.26 ft^2 of plate area.

This example clearly illustrates that if subsurface water is not considered during the designing process, it is highly likely that the pile or anchor will be under designed and could fail.

Mixed Soils – Cohesive and Cohesionless Soils

When reviewing soil boring logs one often sees descriptions that combine the two soil types. One often sees such terms as “clayey sand” or “sandy clay” in the soil descriptions on the soil boring log.

The soils engineers use terms to describe soils that contain both cohesive soil and granular soil in the samples. When one encounters such descriptions in the soil report, the design analysis requires that both soil types be considered. Equation 1 must be used to determine the ultimate capacity or projected helical area requirement. The designer must assign a percentage of each type of soil present when placing data into Equation 1.

Table 8 Mixed Soil Descriptions

Soil Description	Estimated Percentage Present
“trace”	1% to 5%
“slightly”	6% to 15%
“little”	10% to 20%
“with”	15% to 25%
“silty” or clayey”	20% to 49%
“some”	20% to 34%
“very”	35% to 49%

Note: There is no national standard for soil description percentages reported by soil engineers. Listed above are the descriptors and most commonly encountered percentages. For increased accuracy, or when working on a critical project, verify the descriptive percentages with the project soil engineer.

Table 8 provides guidance for relative percentages of each type of soil. Experience has shown that there is no national standard for these soil descriptions. Because of this, Table 8 provides the most typical percentages. It is always a good idea to check with the soil engineer to verify his or her soil type percentages on a specific soil boring log when working on a critical project.

When preparing a load capacity design when mixed soils are present, adjust for the percentages of cohesive and cohesionless soils present in Equation 1. For example, assume that the soils engineer described the soil on the site as being **“clayey sand”**. Referring to Table 8 there is a range from **20% to 49%** for the cohesive clay component in the sample. For this illustration it is assumed that no additional data is available from the soil engineer regarding the percentages present. A value for the cohesive clay component of the soil is estimated to be about 30% and the remaining 70% of the soil is assumed to be sand:

Equation 1 is modified as shown to adjust to the reported soil composition:

P_u = Helical Plate Area x (30% strength of clay + 70% strength of sand)

$\mathbf{P_u = \Sigma A_H\ (0.30\ c\ N_c + 0.70\ q\ N_q)}$

The result of the analysis will be a helical pile capacity that is lower than if it was embedded in only sand, but greater than if embedded only in clay.

Keep in mind that when dealing with incomplete data, it is wise to add a greater factor of safety or to choose the percentage used for the cohesionless soil component at the lower end of the range shown in Table 8.

Effects of Water Table Fluctuations and Freeze Thaw Cycle

When designing helical anchors, the amount of water present in the soil at the time of installation, and possible moisture changes in the future, must be considered. If the anchor is installed near the water table, the capacity of the anchor can dramatically change with the changing level of the water table.

Cohesionless soil is buoyed by the water when the soil around the helical pile or anchor becomes saturated. This buoyancy of the soil particles in the soil reduces the load capacity of the anchor. A different situation exists if the anchor is just below the water table and dry conditions cause the water table to drop. As the water drains from between the soil particles, the soil around the helical plates could begin to consolidate. This soil consolidation may cause the anchor to creep and require adjustment.

It is also important to know the maximum frost depth along with the range of depth for the water table at the job site to insure a solid and stable installation. Anchors should always be installed below the lowest recorded frost depth plus a minimum depth of three diameters of the uppermost plate. In most cases this is usually means installing the helical plates three to four feet below the lowest expected frost depth. The reasoning here is that when the soil thaws and the ice changes to water, the soil can become saturated. From the discussion above about installations made near the water table, a similar situation exists with thawing frost. Load capacity could reduce because saturated soil cannot support as much load as damp to dry soil. Clay soil is especially vulnerable and can become plastic when saturated. A saturated cohesive soil might simply flow around the helical plates causing anchor creep or failure. In addition, when the plates are terminated within the freeze-thaw zone, freezing water within the pores of the soil can lead to upward pressure on the helical plates resulting in movement and/or loss of strength.

Monitoring the installation torsion on the shaft can predict the performance of the anchor at the time of installation, but changes in the soil moisture can affect the product's long term holding ability.

Budgetary Capacity Estimates by *Quick*-Solve™ Design Method

Many installers and engineers are familiar with the *Soil Classification Table* that other manufacturers use for budgetary helical anchor designs. This table "classifies" soil into eight soil groups ranging from solid rock down to very soft clays, organics and peats. These Soil Classifications are used for reference to estimate expected pile capacities indicated by graphs or tables.

Table 9 below reproduces the *Soil Classification Table* showing the classification levels offered by other manufacturers along with anticipated values for Standard Penetration Tests, "N", likely to be found within each classification. The *Holding Capacity Graphs* 2 through 5 that follow were developed to provide rough estimates of holding capacities for various sizes and combinations of helical plates attached to Torque Anchor™ shafts when installed into these soil classifications.

It must be clearly understood that Graphs 2 through 5 are provided to offer general estimated load capacities for piles or anchor configuration installed into a soil that fits within a certain soil classification. The graphs are not intended to be a substitute for engineering judgement and design calculations detailed earlier that rely upon specific soil data relative to the project. Table 9 and Graphs 2 through 5 represent general trends of capacity through different *homogeneous* soil classifications. The graphs are based upon conservative estimates.

Graphs 2 through 5 represent the ultimate capacity of the helical plate configuration in the soil, and one must always apply a suitable factor of safety to the service load before using these tables to insure reliability of any tieback or pile installation.

In very dense soil or rock stratum when rotation of the helical anchor shaft does not advance the product into the soil, the helical plates are not able to fully embed and cannot achieve the capacity level predicted by Terzaghi's bearing capacity formula (Equation 1). The soil classification graphs disregard Class 0 through Class 2 because these soils are usually too dense for the Torque Anchors™ to advance without pre-drilling,

Likewise, soil Class 8 was not represented in the graphs because Class 8 soils usually contain significant amounts of organics or fill materials. The organics may continue to decay and/or soil with organics and/or fill may not be properly consolidated and are therefore not considered suitable for long term support.

Graphs 2 through 5 presented here also show a shaded area for Class 7 soils and part of Class 6 soils. This is to alert the user that, in some cases, soils that fall within these shaded areas of the graphs may not be robust enough to support heavy loads. If the soil in the shaded areas contain fill; the fill could contain rocks, cobbles, trash, and/or construction debris. In addition, these soils may not be fully consolidated and/or could contain organic components. Any of these could allow for creep of a foundation element embedded within the stratum. This could cause a serious problem for permanent or critical installations. When such weak soils are encountered, it is strongly recommended that the anchor or pile be driven deeper so that the Torque Anchor™ will penetrate beyond all weak and possibly unstable soil into a more robust and stable soil stratum underlying these undesirable strata.

It is also important to understand that the Graphs 2 through 5 below do not take into consideration the size of the shaft or type of shaft being used in conjunction with the helical plate configurations. As a result, these graphs could suggest holding capacities well above the "Useable Torsional Capacity" of the helical shafts shown in Table 2.

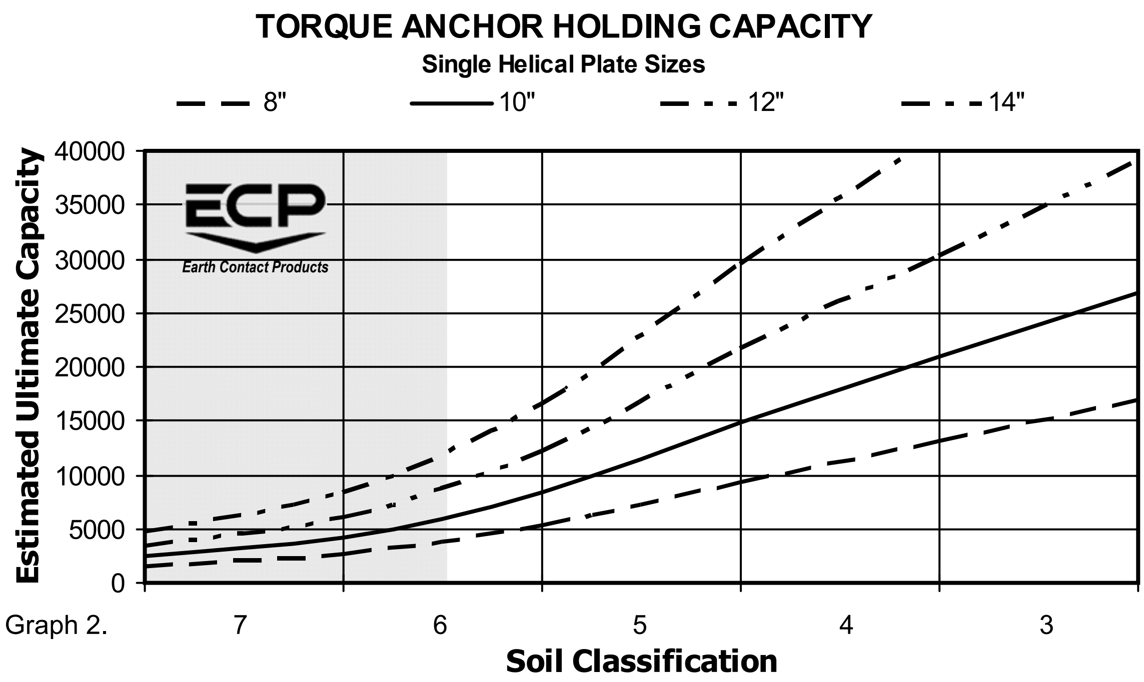
Where the graph line is truncated at the top of the graph for a particular helical plate configuration, one should not try to extrapolate a higher capacity than indicated by the top line because these plate configurations have reached the ultimate mechanical capacity for that particular configuration being represented. It might be possible to achieve higher capacities with a given configuration presented in the graphs if one orders the Torque Anchor™ with one-half inch thick helical plates instead of the standard three-eighths inch thickness. Please check with ECP or your engineer to determine if using thicker helical plates could achieve a higher ultimate capacity requirement on a particular project.

Table 9. SOIL CLASSIFICATIONS

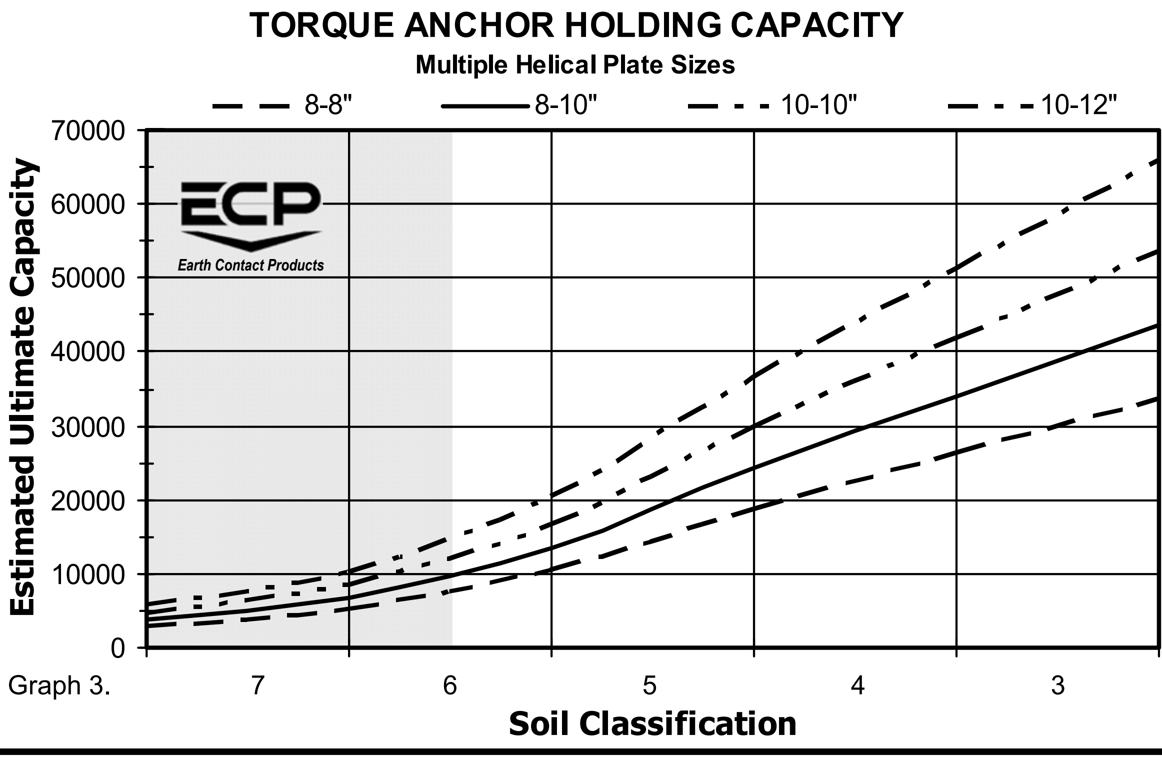
Class	Soil Description	Geological Classification	Standard Penetration Test Range - "N" (Blows per foot)
0	Solid Hard Rock (Unweathered)	Granite; Basalt; Massive Sedimentary	No penetration
1	Very dense/cemented sands; Coarse gravel and cobbles	Caliche	60 to 100+
2	Dense fine sands; very hard silts and/or clays	Basal till; Boulder clay; Caliche; Weathered laminated rock	45 to 60
3	Dense sands/gravel, hard silt and clay	Glacial till; Weathered shale; Schist, Gneiss; Siltstone	35 to 50
4	Medium dense sand/sandy gravels; very stiff /hard silt/clay	Glacial till; Hardpan; Marl	24 to 40
5	Medium dense coarse sand and sandy gravel; Stiff/very stiff silt and clay	Saprolites; Residual soil	14 to 25
6	Loose/medium dense fine/coarse sand; Stiff clay and silt	Dense hydraulic fill; Compacted fill; Residual soil	7 to 15
7	Loose fine sand; soft/medium clay; Fill	Flood plain soil; Lake clay; Adobe; Clay gumbo; Fill	4 to 8
8	Peat, Organic silts, Fly ash, Very loose sand; Very soft/soft clay	Unconsolidated fill; Swamp deposits; Marsh soil	WOH to 5 (WOH = Weight of Hammer)

Notes:

1. Soils in class "0", class "1" and a portion of class "2" are generally not suitable for tieback anchorage because the helical plates are unable to advance into the very dense/hard soil or rock sufficiently for anchorage.
2. When installing anchors into soils classified from "7" and "8", it is advisable to continue the installation deeper into more dense soil classified between "3" and "5" to prevent creep and enhanced anchor capacity.
3. Shaft buckling must be considered when designing compressive anchors that pass through Class 8 soils.



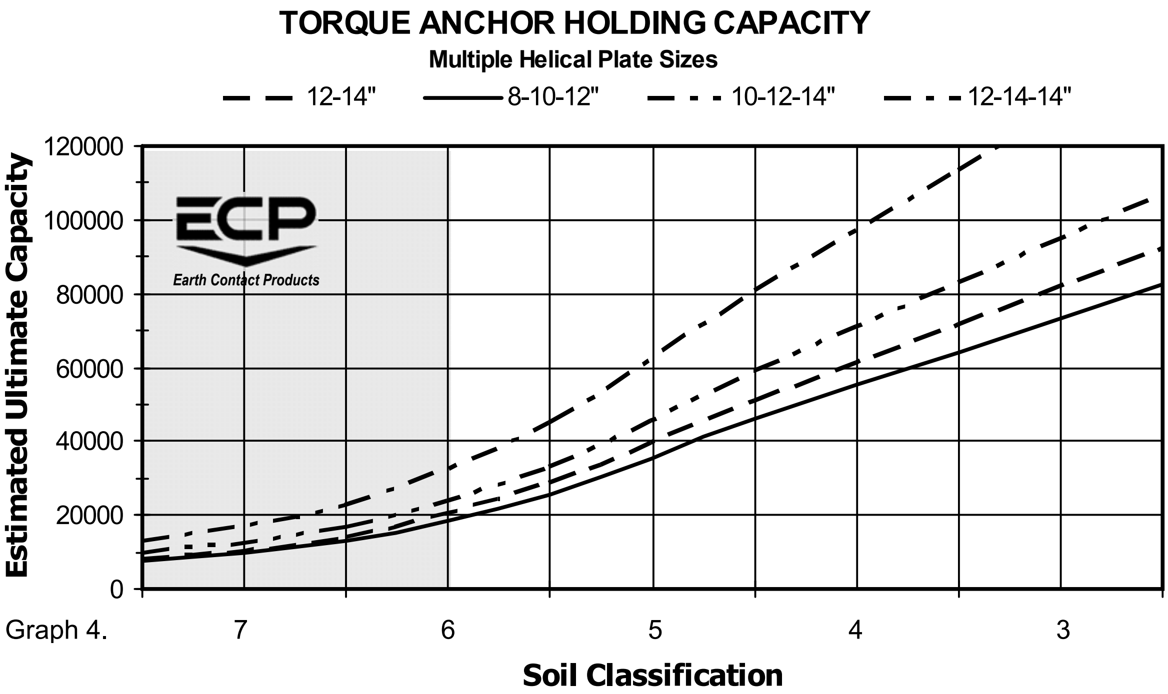
Graph 2.



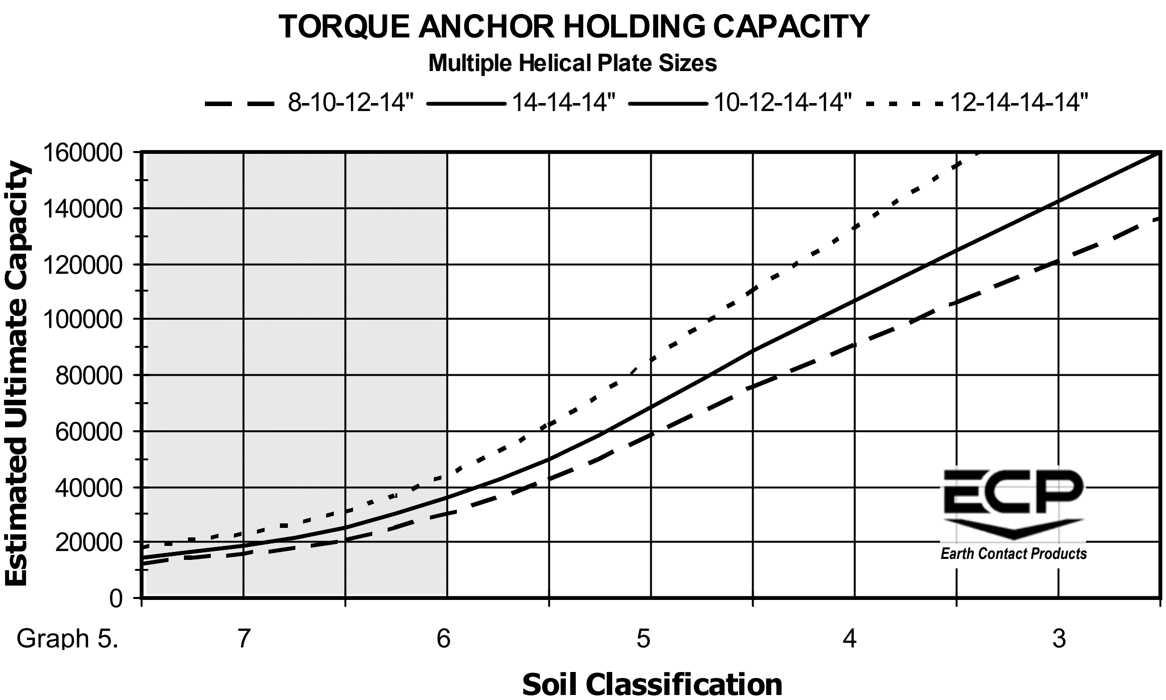
Graph 3.

The following graphs present holding capacity estimates for standard ECP Torque Anchor™ configurations and for other common plate configuration designs dictated by a particular application.

Note: It is advisable not to install Torque Anchors™ into Soil Classes in the shaded area for better stability and performance. In situations where this is not possible, we recommend increasing the factor of safety for a safer design. Installing the Torque Anchors™ to an underlying stratum that has a higher bearing capacity and a more stable soil classification is recommended.



Graph 4.



Graph 5.

Note: It is advisable not to install Torque Anchors™ into Soil Classes in the shaded area for better stability and performance. In situations where this is not possible, we recommend increasing the factor of safety for a safer design. Installing the Torque Anchors™ to an underlying stratum that has a higher bearing capacity and a more stable soil classification is recommended.

The capacity of a helical product can be estimated by accurately measuring the installation shaft torsion. Several methods are commonly used. Transducers attached to the hydraulic lines, strain gauge monitors, shear pins and monitoring pressure differential across the installation motor are all common ways to determine installation torque being applied to the anchor shaft. The average recorded shaft torsion must be at or above the torque requirement during the final three feet of installation to confirm meeting the installation torque requirement. By continuing to install the helical product beyond first reaching the shaft torsion requirement insures that all anchor plates are sufficiently embedded into the target soil and this reduces the chance of creep, settlement or pullout in the future.

Field load testing is required to verify the actual load capacity. During a field test, the helical product is loaded in the direction of the intended compressive or tensile load and at the intended installation angle. ASTM D1143 and ASTM 3689 field load tests measure the ultimate capacity of the helical product when fully loaded. There is normally a small shaft movement when a helical product is initially loaded due to "seating" the plates into the soil. This movement is normally not considered in the test measurement. Before beginning the field load test, a small initial "seating" load of 1,500 to 2,000 pounds is usually applied to the pile or anchor prior to commencing test procedures. During testing, the load on the helical shaft is incrementally increased and after applying each load increment the movement at the top of the shaft is measured against a fixed point. If creep occurs only during the application of the incremental load, the test can continue immediately after measuring the initial creep increment. As the load increases and nears ultimate capacity, the pile or anchor may continue to slowly move for a period of time after the incremental load was applied. During this time the incremental load on the helical product must be maintained as the shaft continues to creep. The total deflection shall not be determined until the movement ceases and the pile or anchor becomes stable. If after 15 to 20 minutes, the movement is continuing or the total measured creep exceeds the established limit for acceptance, the useful capacity of the pile or anchor has been exceeded. The load increment prior to this final load increment shall be recorded as the ultimate capacity of the product. Load capacity is discussed in greater detail in Chapter 2 of this technical manual.

Soil type will affect the performance of the helical product during field testing. For example, piles or anchors installed in clay will show minimal creep with increasing load and then suddenly and continuously start moving. Cohesionless soils, on the other hand, usually will produce a more predictable load to creep curve.

Installation Torque

Shaft torsion during installation can provide a reasonably accurate estimate of the expected ultimate capacity of the helical product. The relationship between the shaft torsion during installation and the ultimate capacity of the pier or anchor is empirical and was developed from results from thousands of tests. When one applies rotational torsion to a shaft at grade, some of the torque energy is lost before it reaches the helical plates at the bottom end of the shaft. This is due to friction between the shaft and the soil.

Figure 2, below, illustrates that not all of the torque applied to the shaft by the motor reaches the helical plates. The actual torque applied to the helical plates is $T_{Plates} = T_{Motor} - T_{Shaft}$. The friction generated between the circumference of the shaft and the soil is directly related to the shaft configuration and size along with the properties of the soil. Because of this loss of efficiency in transmitting the motor torque down to the plates, an empirical *Soil Efficiency Factor* ("k") must be employed to arrive at a reasonable estimate of pile or anchor ultimate capacity.

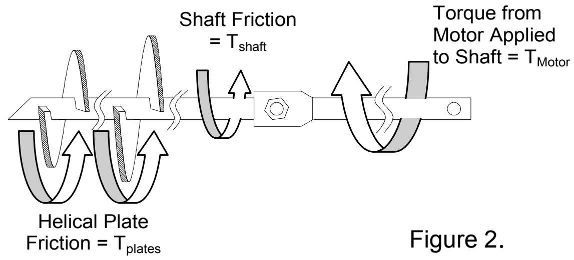


Figure 2.

Shaft torsion should always be monitored during the installation of helical screw piles and anchors. Generally, the ultimate holding capacity of the typical *solid square shaft helical product* within a given soil stratum is ten times the average shaft torsion measured over the final three feet of installation.

When estimating the anchor's capacity, one must not consider any torque readings on an anchor when it is stalled or encountering obstructions; instead average the readings three feet before the stall. Likewise the shaft torsion readings on an anchor that spins upon encountering very dense soil cannot be used. When a tension anchor spins, it must be removed and repositioned. The torsion measurements on the new placement shall be averaged over three feet, but the anchor shall not be installed to the spin depth.

Due to larger friction between the soil and tubular shaft configurations, one cannot use the ten to one relationship mentioned above to estimate ultimate capacity of tubular shafts.

A more detailed discussion of the relationship between torque on the shaft and anchor capacity is presented in the next section.

Helical Torque Anchor™ Design Considerations

Projected Areas of Helical Plates: When determining the capacity of a screw pile in a given soil, knowledge of the projected total area of the helical plates is required. This projected area is the summation of the areas of the helical plates in contact with the soil less the cross sectional area of the shaft. Table 10 provides projected areas in square feet of bearing area for various plate diameters on different shaft configurations.

Allowable Helical Plate Capacity: When conducting a preliminary design, one must also be aware of the mechanical capacity of the helical plate and the shaft weld strength. Average capacities of plates are given in Table 11. Actual capacities are generally higher than shown for smaller diameter helical plates. Capacities are also slightly higher when the helices are mounted to larger diameter tubular shafts.

Designs using 12" to 14" diameter plates on square bar shafts will have ultimate mechanical capacities that are slightly lower than shown in Table 11. This variance is usually not a concern except when a small shaft is highly loaded with only a single or double helix configuration.

Relationships between Installation Torque and Torque Anchor™ Capacity: Estimating the capacity of a given screw pile based upon the installation torque has been used for many years.

Unless a load test is performed on site to determine a specific value for the relationship between installation shaft torsion and ultimate product capacity, commonly referred to as *Soil*

Table 10. Projected Areas* of Helical Torque Anchor™ Plates

Helical Plate	6" Dia.	8" Dia.	10" Dia.	12" Dia.	14" Dia.	16" Dia.
Shaft	**Projected Area – ft^2**					
1-1/2" Sq.	0.181	0.333	0.530	0.770	1.053	1.381
1-3/4" Sq.	0.175	0.328	0.524	0.764	1.048	1.375
2" Sq.	0.168	0.321	0.518	0.758	1.041	1.396
2-7/8" Dia	0.151	0.304	0.500	0.740	1.024	1.351
3-1/2" Dia	0.130	0.282	0.478	0.719	1.002	1.329
4-1/2" Dia	0.086	0.239	0.435	0.675	0.959	1.286

* Projected area is the face area of the helical plate less the cross sectional area of the shaft.

Important: When a 90^0 spiral cut leading edge is specified, the projected areas listed in Table 10 will be reduced by approximately 20%.

Table 11. Average Ultimate Mechanical Helical Plate Capacities

Helical Plate Thickness	Average Ultimate Load	Average Service Load
6" through 14" Diameter Plates		
3/8"	40,000 lb	20,000 lb
1/2"	50,000 lb	25,000 lb
16" Diameter Plate		
1/2"	40,000 lb	20,000 lb

Efficiency Factor, "k", a conservative value should be selected when designing. While values for "k" have been reported from 2 to 20, most projects will produce a value of "k" in the 6 to 14 range. Earth Contact Products suggests using the values for "k" as shown in Table 12 when estimating Torque Anchor™ ultimate capacities.

Table 12. Soil Efficiency Factor "k"

Torque Anchor™ Type	Typically Encountered Range "k"	Suggested Average Value, "k"
1-1/2" Sq. Bar	9 - 11	10
1-3/4" Sq. Bar	9 - 11	10
2" Sq. Bar	8.5 (Compression)	8.5
	10 (Tension)	10
2-7/8" Diameter	8 - 9	9
3-1/2" Diameter	7 - 8	8
4-1/2" Diameter	6 - 7	7

It is important to understand that the value of "k" is a measure of friction during installation as illustrated in Figure 2 on page 25 above. This friction has a direct relationship between the soil properties and anchor design. For example, "k" for clay soil would usually be greater than for dry sand. The "k" for a square bar is generally higher than for a tubular pile. Keep in mind that the suggested values in Table 12 are only guidelines. Graph 6 illustrates how the *Soil Efficiency Factor*, "k" affects the ultimate capacity of a pile or anchor. It can be seen that the ultimate capacity varies significantly when the same torque is applied to each different shaft configuration.

It is also important to refer to Table 2 for the *Useable Torque Strength* values to avoid shaft fractures during installation.

Equation 2: Helical Installation Torque

$$T = (P_u \text{ or } T_u) / k, \text{ or } (P_u \text{ or } T_u) = k \times T$$

Where,

T = Final Installation Torque - (ft-lb) (Averaged Over the Final 3 to 5 Feet)
P_u or T_u = Ult. Capacity of Torque Anchor™ - (lb)
k = Empirical Torque Factor - (ft^{-1})

An appropriate factor of safety of 2.0, minimum, must always be applied when using design or working loads with Equation 3.

To determine *Soil Efficiency Factor*, "k" from field load testing, Equation 2 can be rewritten as:

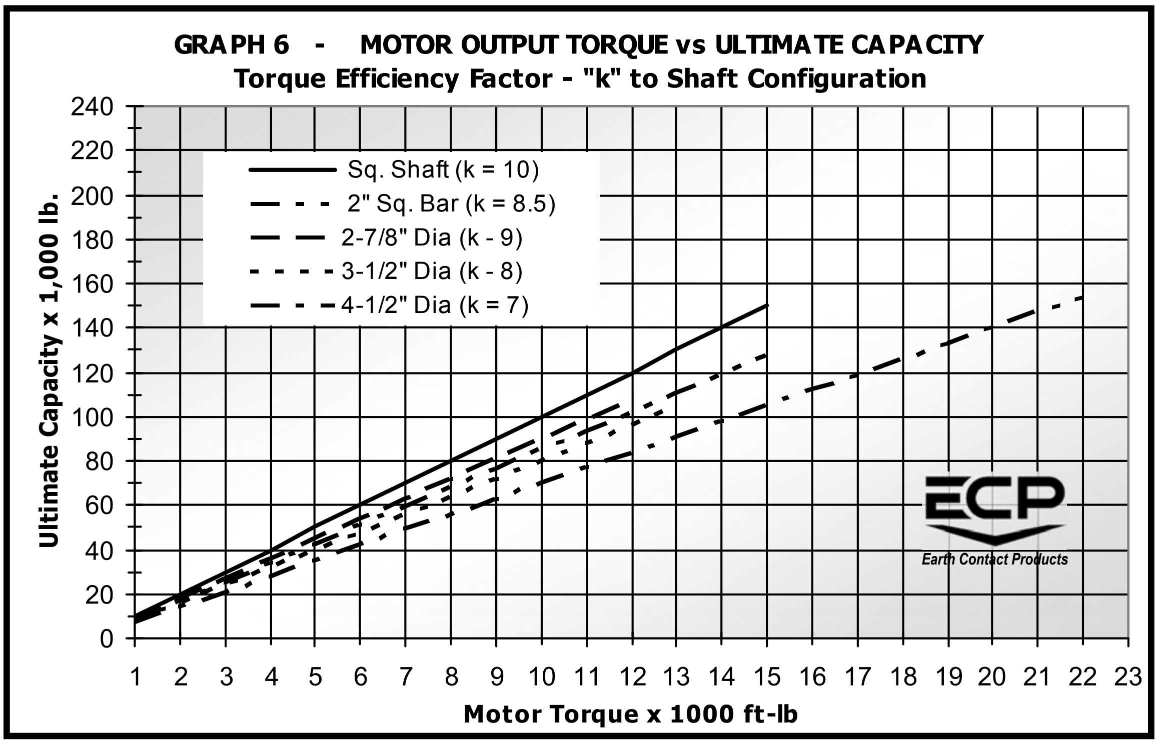
Equation 2a: Soil Efficiency Factor

$$k = (P_u \text{ or } T_u) / T$$

Where,

k = Empirical Torque Factor - (ft^{-1})
P_u or T_u = Ult. Capacity of Torque Anchor™ - (lb)
T = Final Installation Torque - (ft-lb)

Always verify capacity on any critical project by performing a field load test.



Torque Anchor™ Spacing – "X": Equation 3 is used to determine the center-to-center spacing of Torque Anchors™.

Equation 3: Torque Anchor™ Spacing
"X" = P_u/(w) x (FS), or **P_u = ("X") x (w) x (FS)**

Where,
- "X" = Product Spacing - (ft)
- P_u = Ultimate Capacity - (lb)
- w = Distributed Load on Foundation or Wall (lb/ft)
- FS = Factor of Safety (Typically 2.0 – Foundations or Permanent Walls and 1.5 for Temporary Walls)

Plate Embedment in Tension Applications: When a pile must resist uplift or tension loads, the pile must be adequately embedded into the bearing stratum to offer resistance to pull out.

<u>The pile must first qualify as a deep foundation</u>, defined as being installed to a depth from intended surface elevation of no less than six times the diameter of the largest and shallowest helical plate (**6 x $d_{Largest}$**). In addition, to insure that the pile is fully embedded, the required terminal torsion applied to the shaft must have been an average of the torsion developed <u>over a distance of no less than three times the diameter of the uppermost (largest) plate.</u> $L_t = 3 \times d_{Largest}$

Preventing "Punch Through": A soil boring on occasion may report a layer of competent soil overlaying a weak and softer stratum of soil. , One must consider the possibility that the Torque Anchor™ could "punch through" to the weaker soil when fully loaded to achieve axial compressive bearing. Use caution in situations when designing the Torque Anchor™ in any competent soil situated directly above a weaker soil stratum.

When designing a pile in such situations, it is recommended that a distance greater than five times the diameter of the lowest (smallest) helical plate (5 x d_{Lowest}) must exist below the tip of the Torque Anchor™ to prevent "punching through" into the stratum of weaker soil and possibly failing.

Tieback Design Considerations

One of the most common applications for helical tieback anchors is for supplemental basement wall support. Many basement walls show signs of inwardly bulging, have horizontal tension fractures and/or have rotated inwardly. Consolidation of the fill soil, inoperative drain tiles, plumbing leaks, ponding water on the surface near the basement wall, or other environmental factors are largely the cause of the distress seen in many basement wall failures.

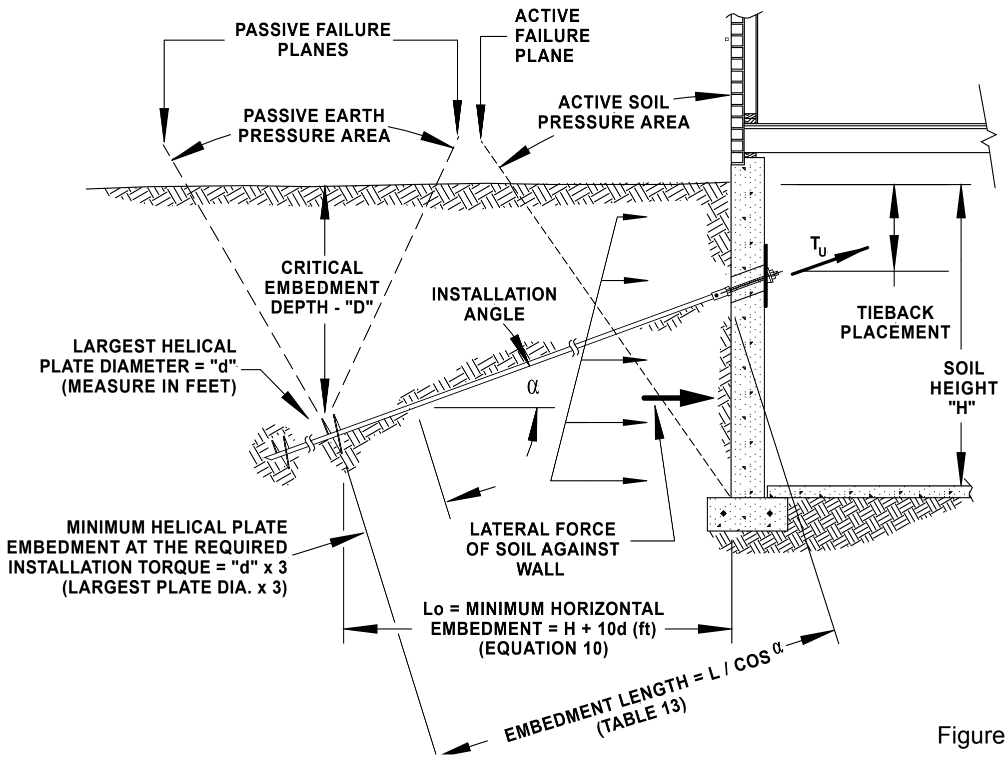


Figure 3.

When ECP Helical Torque Anchor™ tiebacks are installed and anchored into the soil; two repair options are available:

1. The tieback is designed and loaded to support or supplement the wall structure. Soil is not removed from behind the wall; therefore, the wall can be only supported and not restored.

2. The soil behind the wall is removed and the tieback anchor is used to restore the wall to near its original position. Proper granular material must be used as backfill against the wall after restoration along with a proper ground water drainage system for stability.

The wall will always be exposed to active pressure from the soil and possible hydraulic force from water. For the Torque Anchor™ to properly develop resistance against this active pressure, the anchor must be installed beyond this active soil area. Once beyond this area, the tieback can develop passive earth pressure against the helical plate(s). Figure 3, above, shows the general layout for a tieback project and design elements for the embedment of the helical plates for proper support.

It is most important that any basement wall repair include an investigation, and any remedial work required to prevent any future conditions where the soil behind the wall can become saturated. If the drainage work is not accomplished immediately following tieback installation, the design must assume that there will be hydraulic pressure against the wall. An engineer can determine if the wall has sufficient structural integrity to support these combined loads if drainage corrections are not implemented.

Design of retaining walls is very complicated and requires engineering input. This manual has greatly simplified the equations so that the reader can quickly and relatively easily obtain an estimate of the reaction force required to stabilize and support a failing retaining wall. This material should be used with caution for new construction retaining walls or basement wall designs.

Placement of Tiebacks: The vertical placement of the tieback is dictated by the height of the soil against the wall. It is recommended that the tieback be installed close to the point of maximum bulging of the wall and/or close to the most severe horizontal crack in the wall. When the wall is constructed of blocks, or where a concrete wall is severely distressed, vertical steel supports and/or horizontal waler beams must be used to provide even distribution of the reaction force of the anchor across the face of the wall.

The typical vertical mounting location for tieback anchors is 20% to 50% of the distance down from the elevation where the soil touches down to the wall to the bottom of the wall. Seek engineering assistance for walls taller than 12 feet and/or more complicated projects.

Hydrostatic Pressure: If water is present or suspected behind a basement or retaining wall, the additional force of the hydrostatic pressure must be added to the load requirements of the tieback anchor.

When soil and/or subsurface conditions are unknown, it MUST be assumed in the design that water pressure is present.

Basement Tieback Applications: If a basement wall fails because of insufficient structural integrity, improper fill against the wall and/or improper compaction of the fill, then Equation 4 may be used for approximating the load per lineal foot against the basement wall. This equation assumes that no hydrostatic pressure is present. Please refer to Figures 3 & 4.

Equation 4: Basement Wall Load

$$P_{HM} = 18 \times (H^2) \quad \text{(Moist - No Water Pressure)}$$

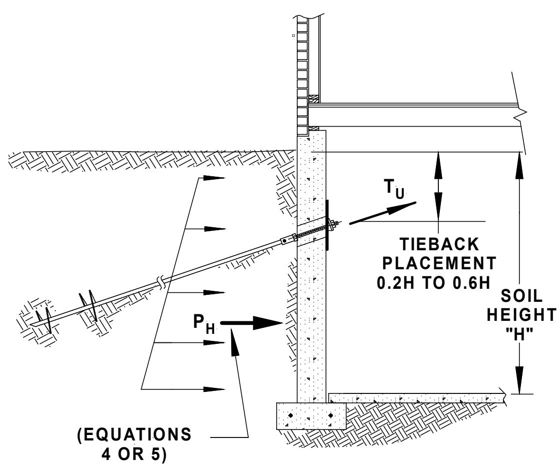


Figure 4. Basement Tieback Application

When water pressure is present behind the basement wall or if it is not known if hydrostatic pressure exists, **Equation 5 should always be used to estimate the load.**

Equation 5: Basement Wall Load
$$P_{HS} = 45 \times (H^2)$$ (Saturated - Water is Present)

Where:
P_{HS} = Saturated Soil Load on Wall - (lb/lineal foot)
H = Height of Backfill - (ft)

Simple Retaining Wall Tieback Applications: Similarly, if a retaining wall fails because of insufficient structural capacity, improper fill against the wall and/or consolidation of the fill, then Equation 6 may be used to approximate the load per lineal foot of retaining wall. If the soil at the top of the wall is level as shown in Figure 5, then the value of "S" in Equations 6 & 7 becomes zero. **This equation assumes that no hydrostatic pressure present**. (Refer to Figures 3 and 5.)

Equation 6: Simple Retaining Wall Load
$$P_{HM} = 24 \times (H + S)^2$$ (Moist - No Water Pressure)

Equation 7: Simple Retaining Wall Load
$$P_{HS} = 50 \times (H + S)^2$$ (Saturated - Water is Present)

Where:
P_{HS} = Saturated Soil Load on Wall - (lb/lineal foot)
P_{HM} = Moist Soil Load on Wall - (lb/lineal foot)
H = Height of Backfill - (ft)
S = Height of Soil Surcharge - (ft)

Simple Retaining Wall Tieback Applications with Soil Surcharge: A load on a retaining wall with a simple soil surcharge load such as shown in Figure 6 may also be approximated using Equations 6 & 7. One must first estimate the surcharge height, "S" as shown.

When water pressure is present behind the retaining wall or it is unknown if hydrostatic pressure exists, **Equation 7 must be used to estimate the load on the retaining wall.**

Ultimate Tieback Capacity Selection: To determine the ultimate tieback capacity requirement, multiply the soil force against the wall by the selected center to center tieback spacing appropriate for the existing or planned wall construction and loading.

Equation 8: Ultimate Tieback Capacity
$$T_U = (P_H) \times (\text{"X"}) \times FS$$

Where:
T_U = Ultimate Tieback Capacity Tension – (lb)
P_H = Foundation Load or Force on Wall – (lb/lin.ft)
FS = Factor of Safety (Typically 2.0 - Permanent Walls and 1.5 for Temporary Walls)
"X" = Center to Center Spacing of Tiebacks – (ft)

It is highly recommended to consult a registered professional engineer when more complex surcharge loads such as a structure, parking lot, road, etc. is located on the surface near the top of the retaining wall.

Horizontal Embedment Length – "L_0": The Torque Anchor™ must be installed into soil a sufficient distance away from the wall so that the helical plate(s) can fully develop anchoring beyond any failure planes. (See Figure 3.)

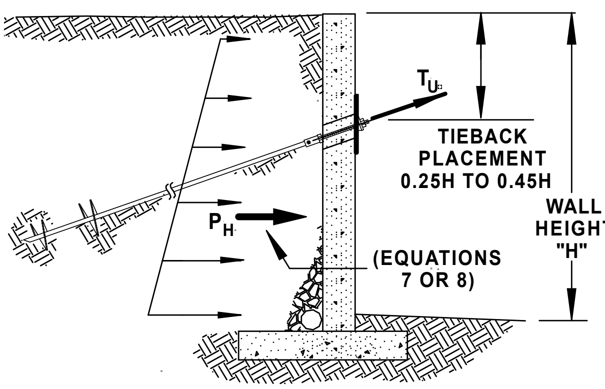


Figure 5. Simple Retaining Wall Tieback Application

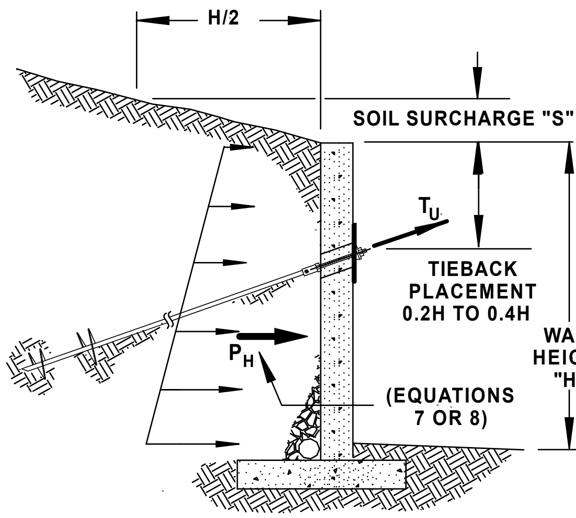


Figure 6. Simple Retaining Wall with Soil Surcharge

Equation 9: Horizontal Embedment

$$L_0 = H + 10d_{largest}$$

Where:

L_0 = Minimum Horizontal Embedment Length from Wall to the Shallowest Plate – (ft)

H = Height of Soil Against Wall - (ft)

$d_{largest}$ = Diameter Of Largest Plate - (ft)

Installation Angle – "α": Typically in tieback applications, Torque Anchors™ are installed at downward angles of 5^0 to 30^0 measured from horizontal. Most often the designer calls for installed angles between 10^0 and 20^0. The larger the angle, the less shaft material is required to reach the Critical Embedment Depth - **"D_{cr}".** One also must be aware that the shaft must also have suitable length to provide the required horizontal embedment length. (See Figure 3.)

Table 13 provides equations to obtain the shaft length – **"L"** at selected downward angles and gives a Horizontal Embedment and the Depth to the largest plate. Use the longest length - **"L"** determined from the cells to the right of the installation angle **"α".**

Critical Embedment Depth – "D": In tension applications there is a shallow failure mechanism for screw piles. The anchor fails when the soil suddenly erupts from insufficient soil overburden on the anchor. To prevent such failures, Torque Anchors™ must be installed to a sufficient embedment depth to be considered a deep foundation. This is illustrated in Figure 3 on Page 28.

As a general rule of thumb, many designers use six times the diameter of the largest helical plate from the surface elevation to the top of largest helical anchor plate - **(d)** as **Critical Embedment Depth - "D"**.

Table 13. Angular Embedment Length

Installation Angle, "α", Declination From Horizontal	**IMPORTANT:** Use the cell with the longer **"L"** for the design.	
	Multiply the additional depth required from wall penetration to obtain **Critical Depth** to obtain Tieback Length **"L".**	Length "L" required to reach the **Minimum Horizontal Embedment** at the specified downward angle "α"
10^0	6 x add'l depth	$L_{10} = [H + (10\ d_{lg})] \times 1.015$
15^0	4 x add'l depth	$L_{15} = [H + (10\ d_{lg})] \times 1.035$
20^0	3 x add'l depth	$L_{20} = [H + (10\ d_{lg})] \times 1.064$
25^0	2.5 x add'l depth	$L_{25} = [H + (10\ d_{lg})] \times 1.104$

H = Height of Backfill (ft) d_{lg} = Largest Plate Dia. (ft)

Torque Anchor™ Installation Limits

Shaft Strength: The data in Table 2 gives the strength ratings for various shaft configurations in axial tension, compression and shaft torsion. **The values are from mechanical testing and not from tests in the soil.** Because Torque Anchor™ products are installed by rotating them into the soil; the installation torsion can limit the ultimate strength of the product.

The *Useable Torsional Strength* column in Table 2 indicates the maximum installation torque that should be intentionally applied to the Torque Anchor™ shaft during installation in homogeneous soil. The risk of product failure dramatically increases when one exceeds these limits.

When choosing a product for a project, the designer should select a product that has an adequate margin of torsional strength above the torque required for embedment. This margin will allow for increases in torque during the final embedment length after the initial torsional resistance criterion has been met. In addition, fractures from unexpected impact loading can and often occur during installation, especially in obstruction laden soils.

It is recommended that a margin of at least 30% above the required installation torque be allowed to insure proper embedment and to prevent shaft impact fractures.

It is important to also understand that the empirical torsional factor "k" reduces the practical limit on the ultimate capacity that can be developed in the soil. This is especially important when designing with larger tubular products because large tubular shafts pass through the soil less efficiently than smaller tubular shafts and solid square bars.

Shaft Stiffness: When the tubular Torque Anchor™ is installed through soft soils that display a Standard Penetration Test value "N" ≤ 4 blows per foot ("N" ≤ 5 for square shafts), the possibility of shaft buckling must be considered in assessing the axial compressive capacity of the pile.

It is important to remember that tubular shafts provide superior resistance to buckling than solid square bars when used in axial compression applications.

This is because tubular shafts have greater flexural stiffness. (They have a larger moment of inertia.) In general tubular pile configurations the larger shaft diameter will provide greater resistance to lateral deflection or buckling within the soil.

Table 14 Torque Anchor™ Shaft Stiffness Comparisons

Torque Anchor™ Shaft Configuration	Cross Section Area - in^2	Moment of Inertia - in^4 (Stiffness)	Pier Stiffness Relative to TA-288
TA-150 (1-1/2" Square)	2.21	0.40	21%
TA-175 (1-3/4" Square)	3.00	0.74	39%
TA-200 (2" Square)	4.00	1.33	69%
TA-288L (2-7/8" Dia x 0.203")	1.70	1.53	80%
TA-288 (2-7/8" Dia x 0.276")	**2.25**	**1.92**	**100%**
TA-350 (3-1/2" Dia x 0.300")	3.02	3.89	203%
TA-450 (4-1/2" Dia x 0.337")	4.41	9.61	501%

Table 14 illustrates how tubular piles have superior shaft stiffness when compared to solid square bars. It is interesting to note that the 2-7/8" diameter tubular Torque Anchor™ with a wall thickness of 0.276 inches costs approximately the same as a Torque Anchor™ fabricated from 1-3/4" solid square bar stock. Please notice in Table 14 that the 1-3/4" solid square bar is only 40% as stiff as the 2-7/8" diameter tubular product. It is clear that the 2-7/8" tubular product is the better choice when designing foundation piles that are to be loaded in axial compression.

Another situation where shaft buckling should be considered is where there are both axial compression and lateral forces acting upon the pile. Normally when the pile terminates within a footing, this is not a problem. When the pile is not fixed at the surface, there may be factors present that affect buckling. These factors include shaft diameter, length, soil density and strength, and pile cap attachment.

Buckling Loads In Weak Soil: Whenever a slender shaft does not have adequate lateral soil support, the load carrying capacity of the shaft is reduced as shaft buckling becomes an issue. In the case of tubular Torque Anchors™, the full ultimate capacity is available provided the soil through which the pile penetrates maintains a value for "N" $\geq$ 4 blows per foot or greater as reported on a Standard Penetration Test for the entire length of the pile embedment. The pile must also be secured to a suitable footing at grade level to prevent lateral forces transmitting to the top of the pile.

Whenever one encounters weak soils such as peat or other organic soils, improperly consolidated soil, or where the pile may become fully exposed from the soil due to erosion; the pile will not be able to support the full rated capacity listed in Table 2.

In addition to the amount of lateral soil support on the shaft, both the length of the pile pipe that is exposed to insufficient lateral support and the stiffness of the slender shaft will affect the reduction in allowable capacity.

It should be noted that solid square shafts are only recommended to be installed through soils having SPT, "N" values greater or equal to five blows per foot.

The reason for this is the shaft offers very little strength against buckling when subjected soils with SPT blow less than five. When designing piles in axial compression that must penetrate weak soils, it is good practice to consider tubular products for the application.

The most accurate way to determine the buckling load of a helical pile shaft in weak soil is by performing a buckling analysis by finite differences. There are several specialized computer programs that can perform this analysis and allow the introduction of shaft properties and soil conditions that can vary with depth. Another, less accurate method of estimating critical buckling is by Davisson Method, "*Estimating Buckling Loads for Piles"* (1963). In this method, Davisson assumes various combinations of pile head and tip boundary conditions with a constant modulus of sub-grade reaction, "k_H" with depth. Load transfer to the soil due to skin friction is assumed to not occur and the pile is straight. Davisson's formula is shown as Equation 10 below.

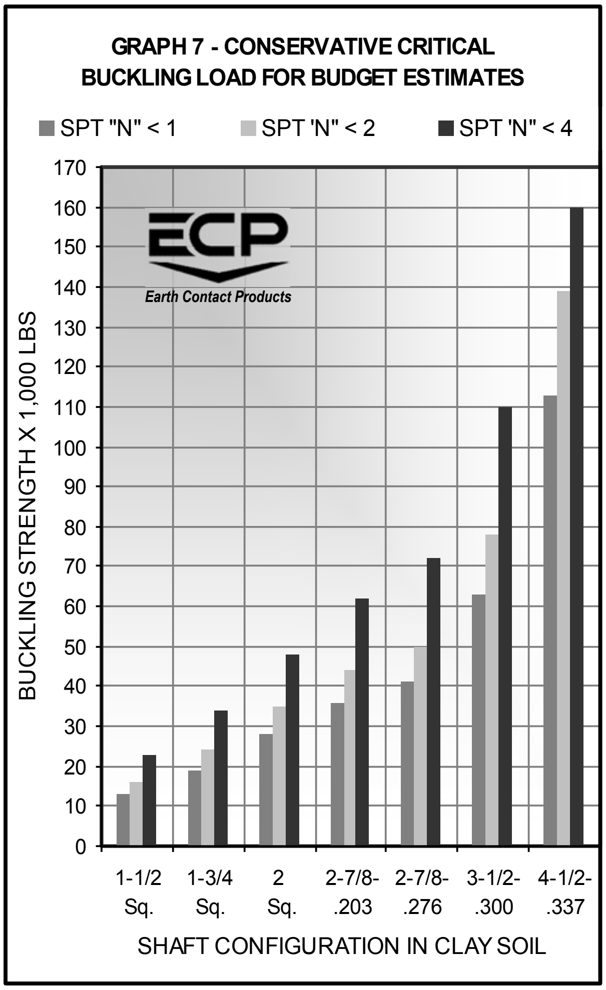
Equation 10: Critical Buckling

$$P_{cr} = U_{cr} E_p I_p / R^2$$

Where:

P_{cr} = Critical Buckling Load – lb
U_{cr} = Dimensionless ratio (Assume = 1)
E_p = Shaft Mod. of Elasticity = 30 x 10^6 psi
I_p = Shaft Moment of Inertia = in^4
$R = \sqrt[4]{E_p I_p / k_H d}$
d = Shaft Diameter – in

Computer analysis of shaft buckling is the recommended method to achieve the most accurate results. Many times, however, one must have general information to prepare a preliminary design or budget proposal. Table 15 below provides Conservative Critical Buckling Load Estimates for various shaft sizes penetrating through different types of weak homogeneous soils. Graph 7 presents a visual representation of critical buckling loads that will quickly identify shaft configurations with Insufficient Buckling Strength when passing through soft soils that do not adequately support the shaft.

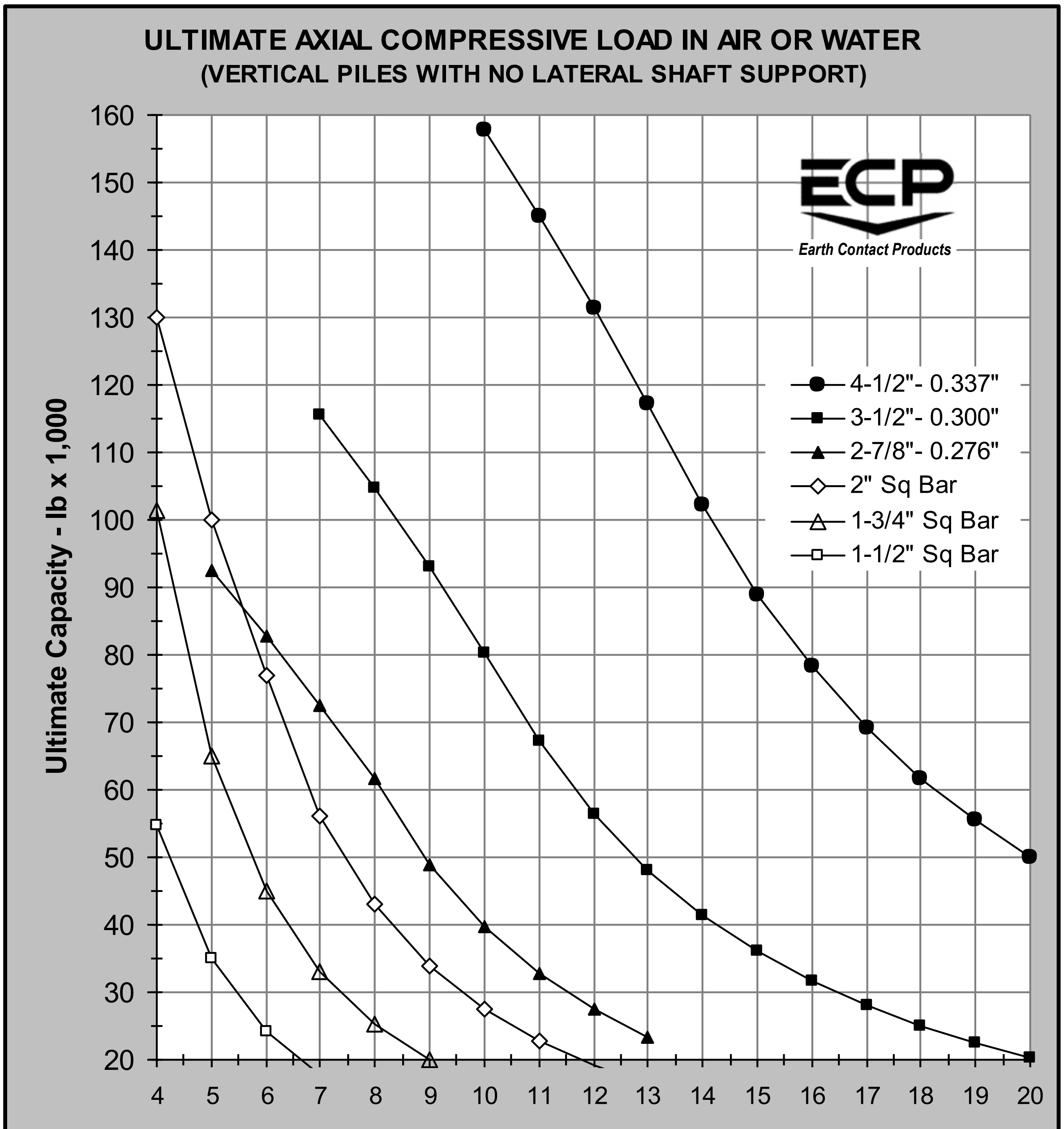


Allowable Compressive Loads - Pile in Air: Graph 8 shows the reduction in allowable axial compressive loading relative to the length of the pier shaft that is <u>without</u> lateral support. Table 14 illustrates that the 4-1/2" diameter tubular Torque Anchor™ provides an axial stiffness of more than five times that of a 2-7/8" diameter shaft. In addition, Graph 8 demonstrates that the 4-1/2" diameter pile has an ultimate capacity of more than four times that of the 2-7/8" diameter shaft when each shaft has ten feet of exposed column height without any lateral support. When one compares the buckling capacity of the 4-1/2" and diameter shaft to the 1-3/4" solid square shaft, the 4-1/2" diameter tubular shaft has more than three times the capacity. The same comparison between the 3-1/2" diameter shaft and the 1-3/4" solid square shaft, the 3-1/2 shaft has 1.6 times greater buckling capacity.

Table 15 — Working Loads Under Buckling Load Conditions For Budgetary Estimating – (Factor of Safety = 2.0)

Shaft Size	Uniform Soil Condition			
	Organics N ≤ 1	Very Soft Clay N = 1 - 2	Soft Clay N = 2 - 4	Loose Sand N = 2 - 4
1-1/2" Sq	14,000 lb	16,000 lb	23,000 lb	18,000 lb
1-3/4" Sq.	20,000 lb	24,000 lb	34,000 lb	27,000 lb
2" Sq.	28,000 lb	35,000 lb	48,000 lb	43,000 lb
2-7/8" Dia x 0.203"	19,000 lb	22,000 lb	31,000 lb	25,000 lb
2-7/8" Dia x 0.276"	20,000 lb	24,000 lb	34,000 lb	28,000 lb
3-1/2" Dia x 0.300"	33,000 lb	39,000 lb	55,000 lb	45,000 lb
4-1/2" Dia x 0.337"	59,000 lb	69,000 lb	98,000 lb	80,000 lb

Each design where shaft buckling is possible requires specific information involving the structure and soil characteristics at the site. We strongly recommend that the final structural design be prepared or reviewed and approved by a geotechnical and structural engineer.



Graph 8

Technical Design Assistance

Earth Contact Products, LLC. has a knowledgeable staff that stands ready to help you with understanding how to prepare preliminary designs, installation procedures, load testing, and documentation of each placement when using ECP Torque Anchors™. If you have questions or require engineering assistance in evaluating, designing, and/or specifying Earth Contact Products, please call us at 913 393-0007, Fax at 913 393-0008.

NOTES:

Earth Contact Products, LLC reserves the right to change design features, specifications and products without notice, consistent with our efforts toward continuous product improvement. We also make changes and corrections to the technical design text consistent with the state of the art. Please check with Engineering Department, Earth Contact Products to verify that you are using the most recent design information and product specifications.

Earth Contact Products

Chapter 2

ECP Earth Plate Anchors™

Technical Design Manual

- **PAL Plate Anchor Kit – Large 2.96 ft^2**
- **PAM Plate Anchor Kit – Medium 2.31 ft^2**
- **PAS Plate Anchor Kit – Small 1.65 ft^2**

EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

Table of Contents

Chapter 2 - ECP Earth Plate Anchors Technical Design Manual

ECP Earth Plate Anchors: ECP Earth Plate Anchors are a part of the complete product line of screw piles, steel piers and foundation support products manufactured by Earth Contact Products, LLC, a family owned company based in Olathe, Kansas. The company was built upon the ECP Steel Pier™, a fourth generation end bearing steel mini-pile designed and patented for ECP.

ECP Earth Plate Anchors are quickly installed and are an inexpensive way to provide supplemental lateral support to distressed basement and retaining walls.

Poor Drainage Problems: Basement wall distress is usually the result of having saturated soil situated against the basement wall. It is quite common for a builder to prepare a level lot before construction. Many times after construction is complete the builder does not grade the soil to provide positive drainage away from the new structure. As a result pooling water can lead to soil saturation at the basement wall. Saturated soil conditions can also be caused by gutter downspouts that discharge adjacent to the perimeter of the structure. Another common practice involves improperly constructed landscape improvements that promote soil saturation at the basement wall. Landscapers sometimes excavate the soil at the perimeter of the structure and fill it with planting soil. The plant-friendly landscape soil usually drains very well, but a serious soil moisture problem can occur in the soil underlying these planters as the water that is trapped below the planter migrates downward and saturates the underlying soil. In other instances a planter adjacent to the foundation is often created below the elevation of the lawn. This is done to prevent the plant-friendly soil from migrating to the lawn. All of these bad drainage conditions can saturate the soil at the basement wall, which then increases the horizontal force against the basement wall. This hydraulic force is the most common causes of basement and retaining wall distress, cracks, seeps and bowing.

One should remediate all causes of excessive water pressure as a part of any repair work that includes earth anchors for supplemental horizontal wall support.

Ignoring these drainage issues will result in a “band-aid” basement wall repair that does not remedy the underlying cause of the wall distress. Continued wall movement and possible failure are possible.

Plate Anchor Components: Earth Plate Anchors looks deceptively simple, but one needs to have an understanding of how these products work, and how to determine the proper Earth Plate Anchor Kit to install to obtain satisfactory results.

The ECP Earth Plate Anchor Kit contains:

1. An Earth Anchor Plate that is constructed from two 10 gauge stamped steel plates with hot dip galvanizing. Each plate has two stiffening ribs that run parallel with the long dimension of the plate, and each plate has earth cleats formed at the narrow ends of plate. Earth Plate Anchor Kits are available in three sizes:
   - PAL – Large 2.96 ft^2
   - PAM – Medium 2.31 ft^2
   - PAS – Small 1.65 ft^2

2. The 10 gauge galvanized steel Wall Plate measures 12 by 26 inches. This plate also has two stiffening ribs that run parallel with the long dimension.

3. An Anchor Rod Assembly consists of one or two 3/4”-10 B-7 all thread rods and couplings that can adjust distances of 9 to 14 feet from the wall. Two 3/4”-10 square nuts and a 4 by 6 inch plate washer are included to attach the Earth Soil Plate and the interior Wall Plate to the Anchor Rod Assembly.

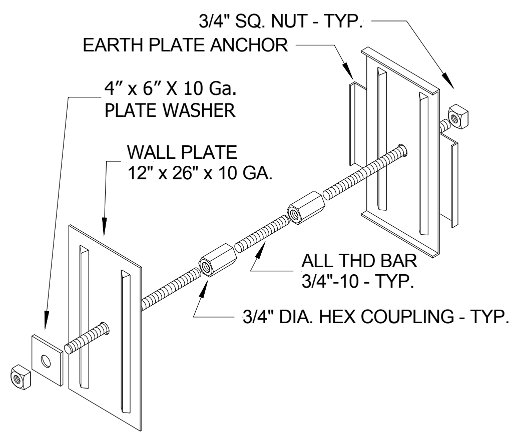


Figure 1. Earth Plate Anchor Kit Components

Table 1. Plate Anchor Kits and Parts

Large Plate Anchor Kits			
Part No.	**PAL Plates**	**Anchor Rods**	**Kit Weight**
PAL – 108	12" x 26" interior wall plate 24"x 24" exterior plate anchor 4"x 6" washer 2-3/4" square nuts 3/4" x 3" coupler* 3/4" dia. B-7 all thd rod	Qty 1 – 108" rod	57 lbs
PAL - 8484		Qty 2 - 84" rods	64 lbs
PAL - 8454		Qty 1 - 84" & Qty 1 - 54" rod	61 lbs
PAL - 5454		Qty 2 - 54" rods	57 lbs

Medium Plate Anchor Kits			
Part No.	**PAL Plates**	**Anchor Rods**	**Kit Weight**
PAM - 108	12" x 26" interior wall plate 24"x 16" exterior plate anchor 4"x 6" washer 2-3/4" square nuts 3/4" x 3" coupler* 3/4" dia. B-7 all thd rod	Qty 1 - 108" rod	53 lbs
PAM- 8484		Qty 2 - 84" rods	61 lbs
PAM - 8454		Qty 1 - 84" & Qty 1 - 54" rod	57 lbs
PAM - 5454		Qty 2 - 54" rods	54 lbs

Small Plate Anchor Kits			
Part No.	**PAL Plates**	**Anchor Rods**	**Kit Weight**
PAS - 108	12" x 26" interior wall plate 16"x 16" exterior plate anchor 4"x 6" washer 2-3/4" square nuts 3/4" x 3" coupler* 3/4" dia. B-7 all thd rod	Qty 1 - 108" rod	49 lbs
PAS - 8484		Qty 2 - 84" rods	57 lbs
PAS - 8454		Qty 1 - 84" & Qty 1 - 54" rod	53 lbs
PAS - 5454		Qty 2 - 54" rods	56 lbs

*** 3" coupler is not included on PAL-108, PAM-108 or PAS-108 kits**

Table 2. Plate Anchor Parts

Part No.	Description	Weight
PA - LWP	Large Interior Wall Plate 12"x26" Galvanized	16 lbs
PA - LC	Large Exterior Cleat 24" x 24" Galvanized	25 lbs
PA - MC	Medium Exterior Cleat 24" x 16" Galvanized	22 lbs
PA - SC	Small Exterior Cleat 16" x 16" Galvanized	17 lbs
PAR - 108	108" x 3/4" B7 All-Thread Rod Galvanized	13 lbs
PAR - 84	84" x 3/4" B7 All-Thread Rod Galvanized	11 lbs
PAR - 54	54" x 3/4" B7 All-Thread Rod Galvanized	7 lbs
PAN	3/4"-10 Square Nut Galvanized	0.5 lbs
PA - C	Coupler 3/4"-10 x 3"	0.32 lbs
PA - Wax	Bowl Wax	17 lbs
PA - PSC	Safety Cap for Anchor Rods	0.01 lbs
PA - RPT	Rod Point for Anchor Rods	1.25 lbs
PAS	Plate anchor Socket	2 lbs
PA - TW	Plate Anchor Torque Wrench	4 lbs
PAD - SDS	SDS Anchor Driver Tool	5 lbs
PAD - SP	Spline Anchor Driver Tool	5 lbs
PA - RP	Rod Puller	17 lbs
PAW - 46	4" x 6" Plate Anchor Washer Galvanized	2 lbs

Wall Plates, Exterior Cleats and Anchor Washers are galvanized to ASTM A123 – Grade 75

Product Benefits

- **Quickly Installed**
- **Low Installed Cost**
- **Installs With Little Or No Vibration**
- **Installs In Areas With Limited Access**
- **Little Or No Disturbance To The Site**
- **Soil Removal From Site Unnecessary**
- **Easily Load Tested To Verify Capacity**
- **Can Be Loaded Immediately After Installation**
- **Easily adjusted if needed**
- **Installs without heavy equipment**
- **All Weather Installation**

Product Limitations: Earth Plate Anchors are not suitable in locations where the soil contains cobbles, large amounts of gravel, boulders, construction debris, and/or landfill materials. The anchors may not be suitable if highly organic soils and/or saturated soil are encountered at the installation depth for Earth Anchor Plate.

When extremely soft soils are present, generally soil with Standard Penetration Test – "N" < 2 blows per foot, the Earth Anchor Plate might not be able to develop sufficient earth resistance in such weak soil and/or there could be anchor creep in the future that results in customer complaints.

Design Criteria: The Bearing Capacity of an Earth Plate Anchor (T_{SL}) can be defined as the load which can be sustained by the anchor plate without producing objectionable movement, either initially, or progressively, which results in continued damage to the wall or interferes with the use of the structure.

Bearing Capacity is dependant upon many factors:

- **Kind Of Soil,**
- **Soil Properties,**
- **Surface Drainage**
- **Ground Water Conditions,**
- **Size of Earth Anchor Plate**
- **Vertical Embedment,**
- **Horizontal Embedment,**
- **Earth Anchor Spacing,**

The design of Earth Plate Anchors uses classical geotechnical theory and analysis along with empirical relationships that have been developed from field load testing. The most accurate design requires knowledge from field soil testing using the Standard Penetration Test (SPT) standardized to ASTM D1586 plus laboratory evaluations of the soil shear strength, which is usually given as soil cohesion – "c", soil density – "γ", and granular friction angle – "ϕ"

Using classical geotechnical theory, the maximum capacity of an ECP Earth Plate Anchor can be calculated from the following equation:

Equation 1 Maximum Theoretical Capacity:

$$T_{MAX} = A\,(c\,N_c + q\,N_q)$$

This equation determines the Maximum Tensile Capacity of an anchor by multiplying the projected area of the Earth Plate Anchor by the sum of the strength of the clay component and strength of the granular component in the soil.

Because Earth Plate Anchor products are usually selected for their economy, engineering advice and geotechnical information are usually in the budget. Typically the installing contractor must perform the analysis, design and product selection on these projects.

In order to assist with design and selection of ECP Earth Plate Anchors, we offer a simplified process that is based upon classical theory along with known empirical data. In addition, general assumptions about the soil composition from a site examination and estimated soil strength must be determined by the installer before attempting to complete a design.

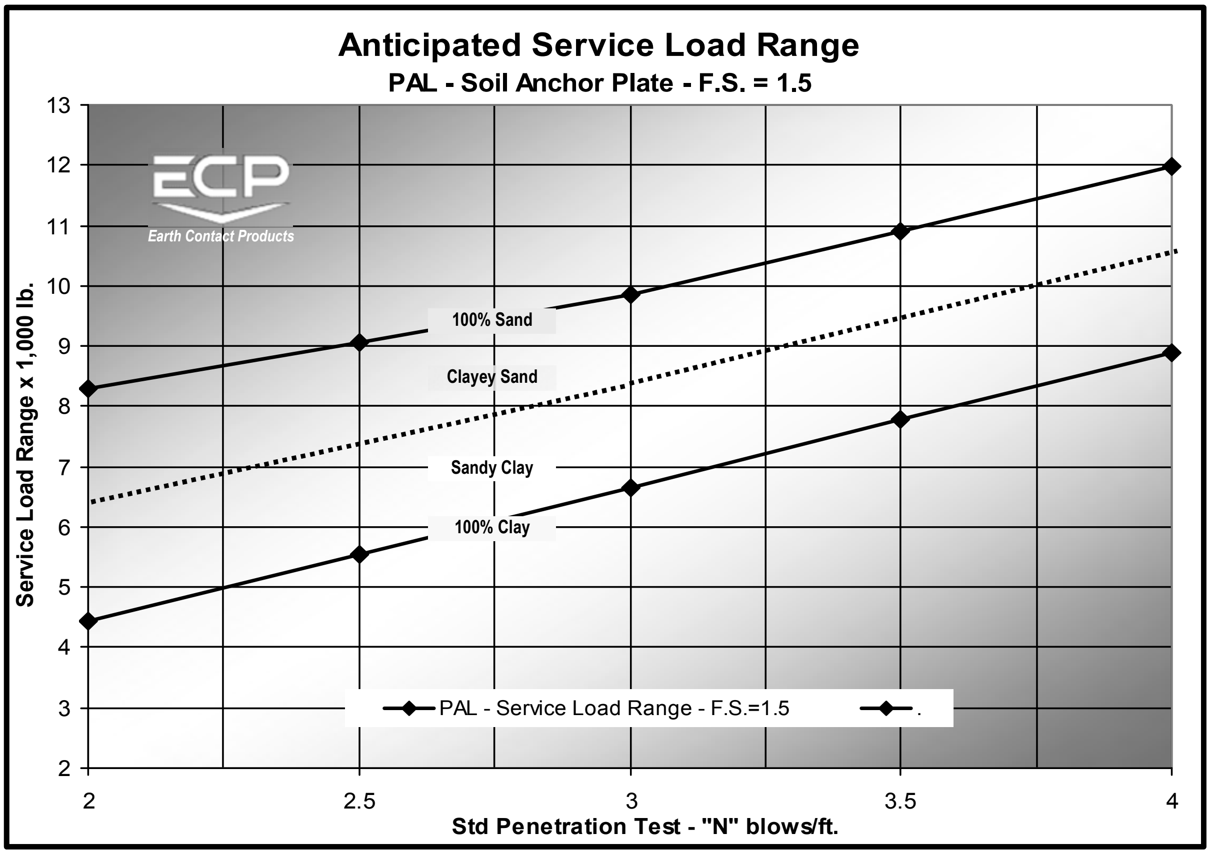
In the graphs presented next page we have calculated the **Estimated Factored Service Load Capacity (T_{SL}) x (F.S. = 1.5)** for ECP Earth Plate Anchors when embedded five feet into either 100% clay soil or 100% sand. Midway between the clay and sand lines is a dashed line that represents a soil that consists of equal parts sand and clay.

Table 3.	Symbols Used In This Chapter
A	Projected area of Earth Anchor Plate – ft^2
c	Undrained shear strength of the soil – lb/ft^2
D_W	Soil depth to basement wall penetration -- ft
D_{min}	Depth to Earth Plate – The distance from ground surface to the top of the soil plate. $D_{min} = d_w + 1$ ft (Minimum)
F.S.	Factor Of Safety (Minimum FS = 1.5)
H	Height of soil against wall of basement - ft
L_{MIN}	Horizontal embedment length - L_{min} = H x 1.5
N_c	Bearing capacity factor for clay soil
N_q	Bearing capacity factor for granular soil
P_{HM}	Horizontal force on wall from moist soil
P_{HS}	Horizontal force on wall from saturated soil
q	Weight of soil at Earth Anchor depth – lb/ft^2
S	Height of Soil Surcharge Above Retaining Wall- (ft)
T_{MAX}	Maximum Tension Capacity – lb (No FS)
T_{SL}	Tension Service (Working) Load – lb
X	Anchor spacing along the wall - ft
N	Standard Penetration Test (SPT) – "N" = Number of blows with a 140 lb hammer to penetrate the soil a distance of one foot.

The graphs report Factored Service Load (T_{SL}) capacities within any clay/sand mixture over a range of soil strengths between SPT – "N" = 2 and 4 blows per foot.

How to use the graphs: A proper and accurate design requires soil data and engineering analysis. Because this anchoring product is normally used to make quick and inexpensive repairs, soil and engineering input are normally not below to help the installer arrive at a <u>reasonable estimate</u> of the expected Factored Service Load (T_{SL}) available for a given ECP Earth Anchor Plate.

Before the graphs can be used, the installer must estimate the composition of the soil and soil strength from data collected from a test hole dug near the proposed Earth Anchor Plate installations at the site. A field estimate of the ratio between clay and sand is needed along with an estimate of the soil strength at the anticipated installation depth of the Earth Anchor Plate.


Anticipated Service Load Range
PAL - Soil Anchor Plate - F.S. = 1.5
Service Load Range x 1,000 lb.
Std Penetration Test - "N" blows/ft.
100% Sand
Clayey Sand
Sandy Clay
100% Clay
PAL - Service Load Range - F.S.=1.5
Earth Contact Products
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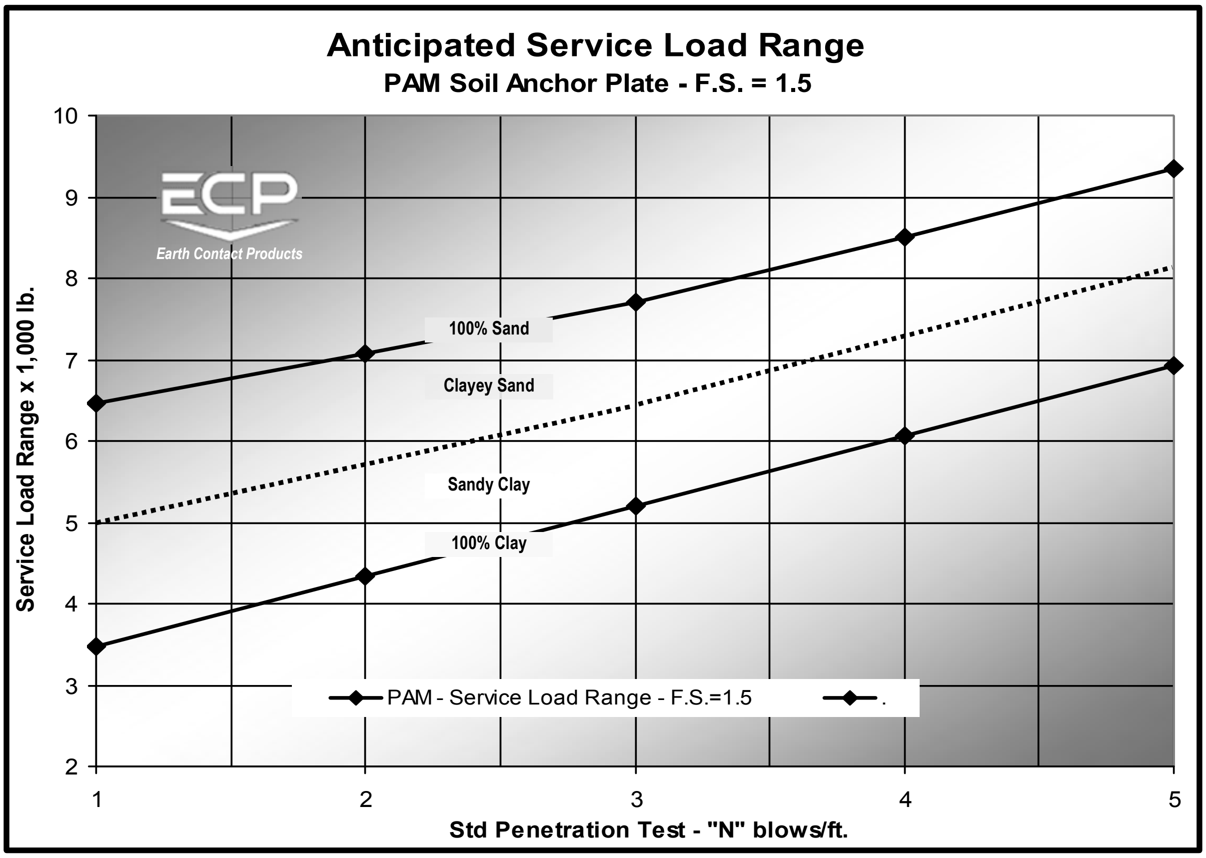
Anticipated Service Load Range
PAM Soil Anchor Plate - F.S. = 1.5
Service Load Range x 1,000 lb.
Std Penetration Test - "N" blows/ft.
100% Sand
Clayey Sand
Sandy Clay
100% Clay
PAM - Service Load Range - F.S.=1.5
Earth Contact Products
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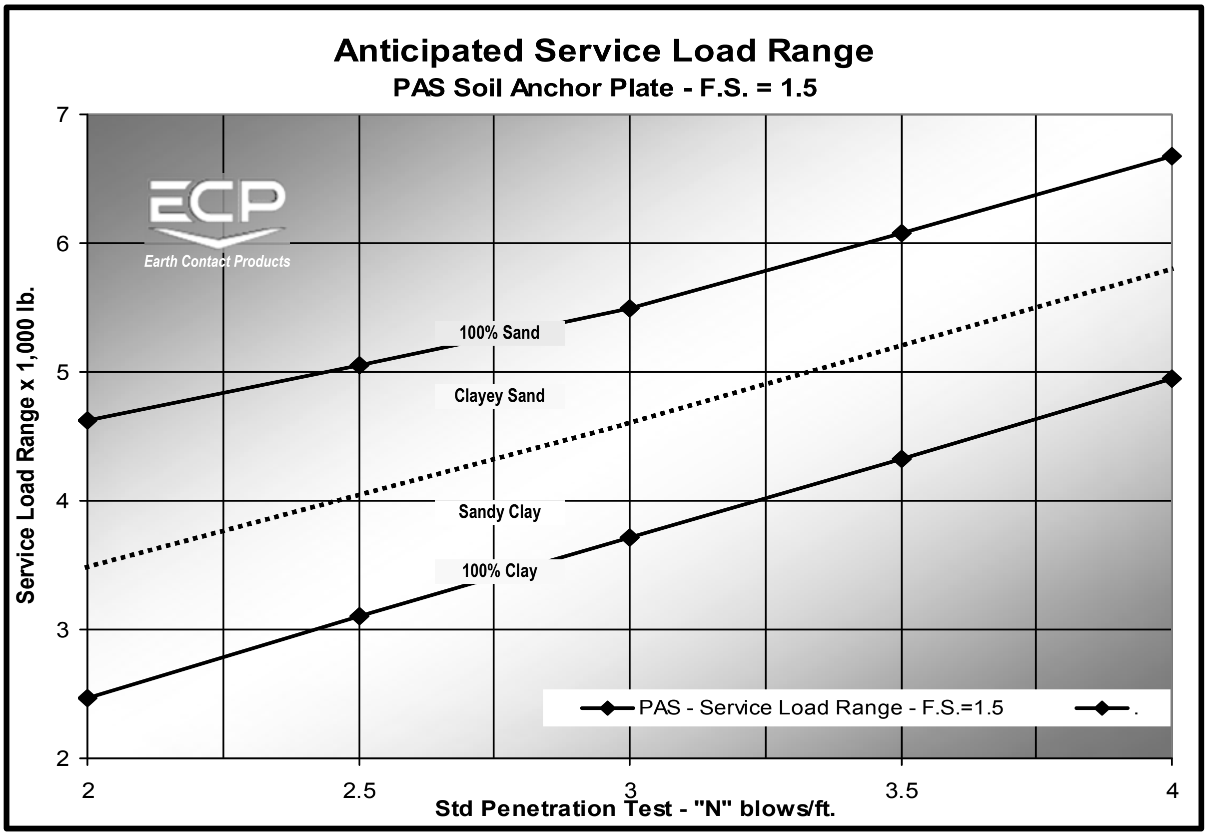


Graph reading example

The soil at the site was observed and estimated to be soft slightly sandy clay at a depth of six feet below grade where the Earth Anchor Plates will be installed. An approximate value for Standard Penetration Test was estimated at **"N" = 2.5 bpf**.

Looking at the sample graph next page, the top graph line is soil consisting of 100% sand and the lower graph line 100% clay soil. The graph also incorporates a minimum Factor of Safety (FS) of 1.5 in the calculations to arrive at an estimated Service (working) Load (T_{SL}) for the Earth Plate Anchor.

The dashed line represents soil that consists of equal parts sand and clay. Moving upward from the dashed line means that the observed soil at the site contains more sand than clay, similarly moving downward means that the soil contains more clay and less sand. This is why it is very important to inspect and accurately estimate the soil composition at the job site.

If available, soil borings from nearby jobs could be referenced to assist the installer to determine soil data at the proposed job site.

When in doubt, the most conservative result can be obtained from assuming that the soil composition is mostly clay.

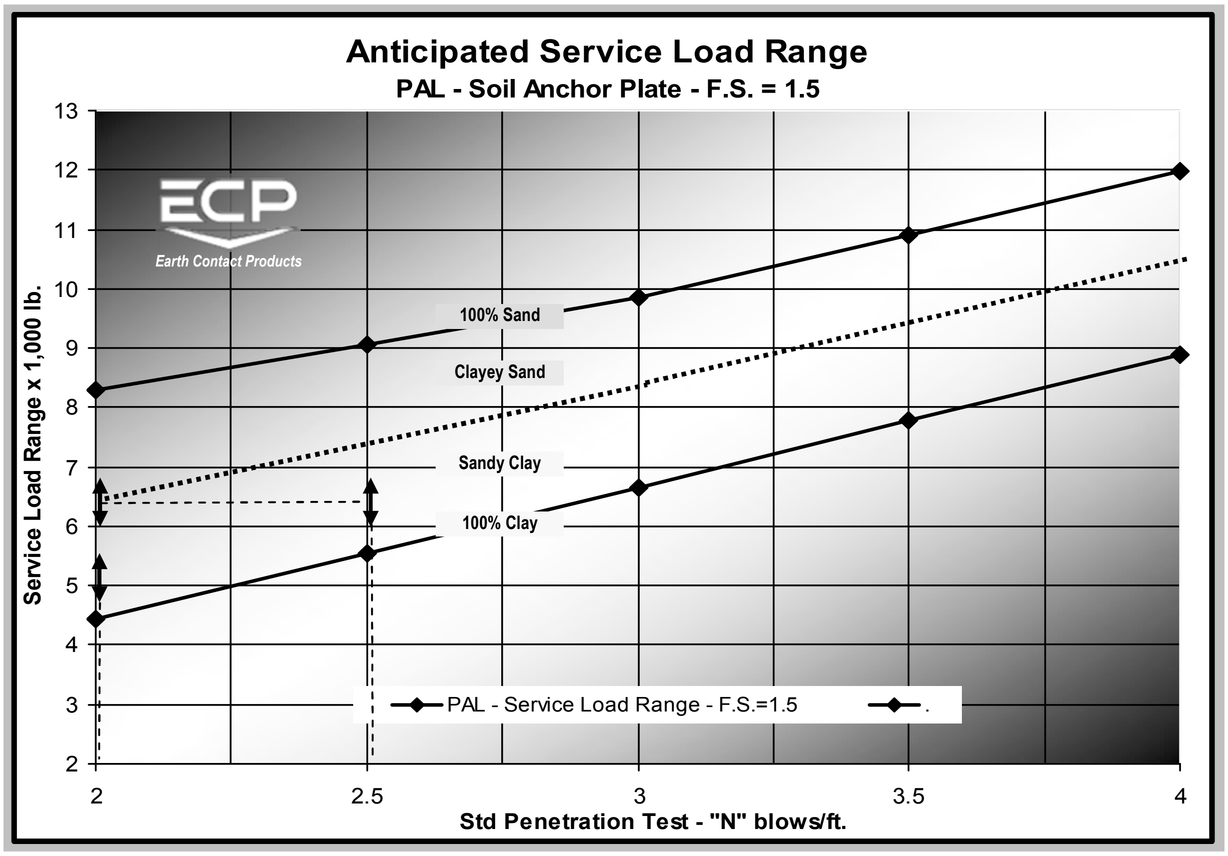
The information for this example has been entered on the graph on next page. One can see that the graph predicts a range of Service Load capacities based upon the field soil data estimates.

In this example, the estimated Service Load (T_{SL}) that might be expected is between 6,000 and 6,800 pounds when installing the ECP Earth Plate Anchor "PAL" Kit. Notice that the example used SPT, "N" = 2.5 bpf.

One should also consider checking capacities within softer soil. If the soil at the site was actually "N" = 2 bpf, the estimated Service Load is 4,700 to 5,500 pounds as shown at the left edge of the graph.

This example also illustrates the fact that the load estimates are very dependent upon accurate soil information from the job site.

If one is unsure of the soil, a very conservative option would be to consider using a lower value for SPT, "N", and read horizontally from closer to the 100% clay line on the graph.



In this case a very conservative service load value of 5,000 pounds is suggested.

Determining horizontal force on wall: The horizontal force of the soil against a basement wall could be determined by calculations.

Below are the generalized equations for calculating horizontal saturated soil loads on the failing basement wall.

Equation 2: Basement Wall Load
$\mathbf{P_{HS} = 45 \times (H^2)}$ (Saturated - Water is Present)

Where: P_{HS} = Soil Load on wall - (lb/lineal foot)
H = Height of backfill against wall - (ft)

Equation 3: Simple Retaining Wall Load
$\mathbf{P_{HS} = 50 \times (H + S)^2}$ (Saturated - Water is Present)

Where: P_{HS} = Soil Load on Wall - (lb/lineal foot)
H = Height of Backfill - (ft)
S = Height of Soil Surcharge - (ft)

Keep in mind that most basement wall failures are the result of increased horizontal force caused by saturated soil. We suggest as "Safe Use" design that you always assume saturated soil conditions.

It is extremely important to determine if excessive water is present and to eliminate the cause of soil saturation as part of any project to add supplemental wall support. When soil and/or subsurface conditions are unknown, it MUST be assumed in the design that water pressure is present.

It is to know that when the excessive hydrostatic pressure is removed from behind the basement wall, the horizontal soil load is reduced by 60%.

Horizontal basement wall load graph: ECP has developed a graph to assist with determining the horizontal basement wall load (P_{HS}), which allows the installer to quickly determine the horizontal force without making calculations.

Looking at the graph on next page the upper line represents the horizontal force against the wall caused by saturated soil conditions (P_{HS}) at the wall.

The dashed lower line indicates the reduction in horizontal force possible if all the sources of the excessive water are mitigated and after sufficient time for the soil to revert to moist condition - (P_{HM}).

When one is investigating a bowing or failing basement wall, the deteriorating condition is almost always caused by excessive horizontal force as a result of hydrostatic (water) pressure being present.

It is recommended to use the upper line on the graph (P_{HS}), which represents that saturated soil conditions exist and are creating large horizontal basement wall pressures.

Horizontal force example: Assume 7-1/2 feet of soil is against a cracked and bowing basement wall. The horizontal wall load is quickly determined using the graph, ***"Horizontal Force Against Basement Wall"*** below. Follow a vertical line up from the mark on the "X" axis indicating soil height of 7-1/2 feet. After reaching the upper line (saturated soil) on the graph, read horizontally to the "Y" axis to see the horizontal force (P_{HS}) against the wall.

In this example the estimated force on the basement wall from the saturated soil, P_{HS} = 2,600 pounds per lineal foot.

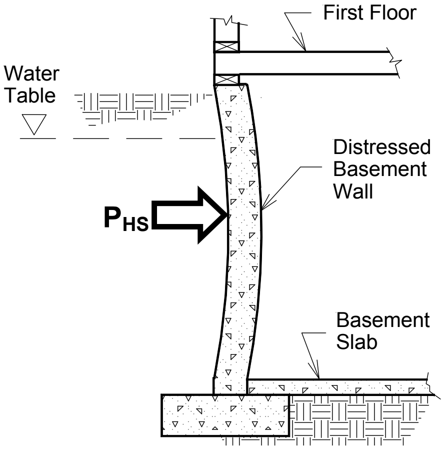
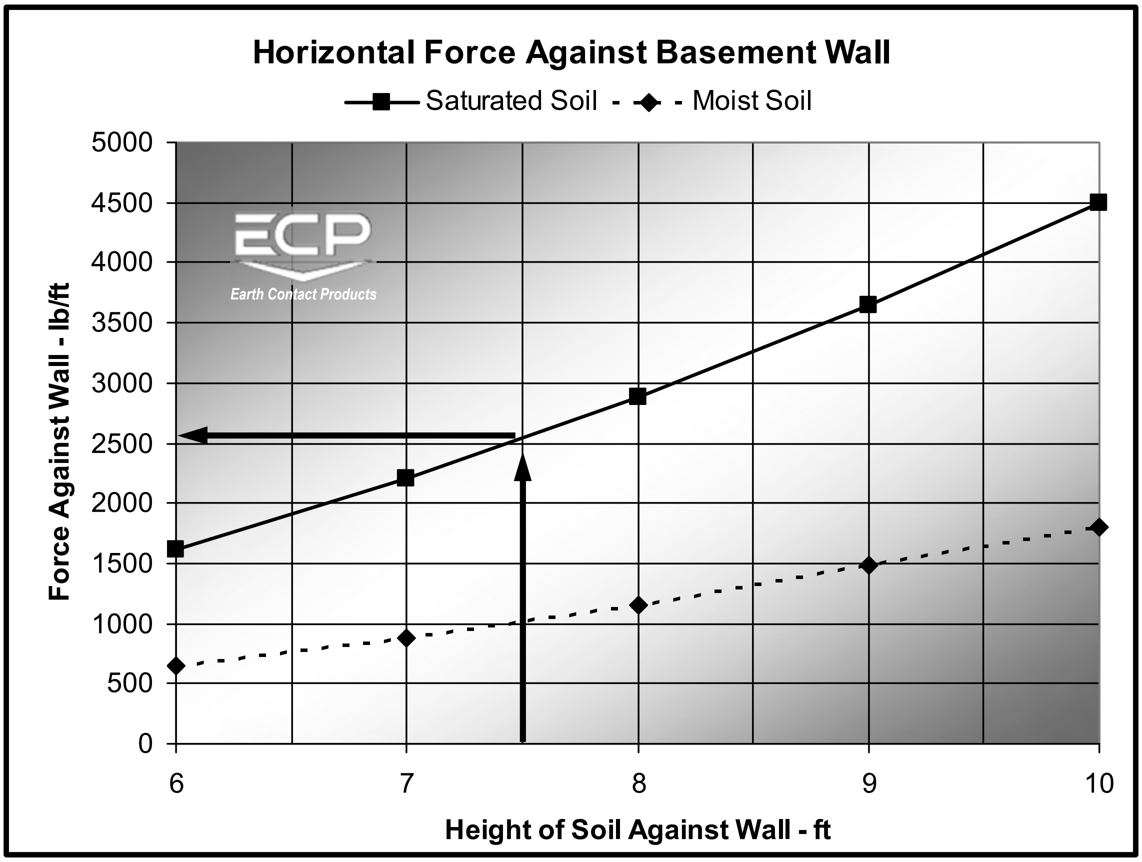


Figure 2. Force (P_{HS}) on wall from saturated soil.



Earth Anchor Plate Embedment: The basement wall is always exposed to active pressure from the soil and possible hydraulic force from water within the soil. For the ECP Earth Plate Anchor to properly develop resistance against these active pressures, the anchor plate must be installed beyond the area of active soil. Once beyond the active area, the Earth Anchor Plate can develop passive earth pressure against the face of the plate. Figure 3, below, shows the general layout for a plate anchor project along with the minimum horizontal and vertical embedment distances for the ECP Earth Plate Anchor kit installation to insure proper support.

It is most important that any basement wall repair include an investigation and remedial work required to prevent any future condition where the soil behind the wall becomes saturated.

If the drainage work is not accomplished immediately following ECP Earth Plate Anchor installations, excessive hydraulic pressure against the wall will remain. Most basement walls are not designed to resist the increased horizontal force created by saturated soil at the wall. While one could install anchors to supplement the lateral strength of the wall and not address the underlying cause of the failure, doing such a repair cannot be considered a permanent solution.

Vertical Placement of Wall Plates – "d_w": The vertical placement of the interior wall plate is dictated by the height of the soil against the basement wall. It is recommended that the interior wall plate be installed close to the point of maximum bulging of the wall and/or close to the most severe horizontal crack in the wall.

The typical vertical mounting locations for typical basement wall plates are 20% to 50% of the distance from where the grade is located to the to the floor slab.

When the wall is constructed of blocks, or where a concrete wall is severely distressed, vertical steel supports and/or horizontal whaler beams are used to provide even distribution of the reaction force from the anchor across the face of the damaged wall.

Seek engineering assistance for very tall walls and/or when badly bowing and fractured walls are encountered. The engineer can inspect and determine if the distressed wall has sufficient structural integrity for continued support against the significantly greater wall load that exists if drainage corrections are not implemented.

Horizontal Embedment Length – "L_{min}": The Earth Plate Anchor must be installed into the soil a sufficient distance away from the wall and beyond any failure planes so that the Earth Anchor Plate can fully develop anchoring capacity. (Figure 3)

Equation 4: Minimum Horizontal Embedment

$$L_{min} = H \times 1.5$$

Where:

L_{min} = Minimum Horizontal Embedment Length from basement wall to Earth Anchor Plate – (ft)

H = Height of soil against wall - (ft)

Minimum Embedment Depth – "D_{min}": In tension applications there is the possibility of a shallow failure. The anchor can fail when the soil suddenly erupts due to insufficient soil embedment of the Earth Anchor Plate. To prevent such failures, anchor plates must be installed to a proper depth to prevent this kind of failure. The depth is illustrated in Figure 3.

Equation 5: Minimum Vertical Embedment

$$D_{min} = d_w + 1\ ft$$ (to top of earth plate)

Where:

D_{min} = Minimum Vertical Embedment From grade to top of Earth Anchor Plate or Frost depth – ft, (Whichever is greater)

d_w = Placement depth of interior wall plate – (Feet down from grade at the wall)

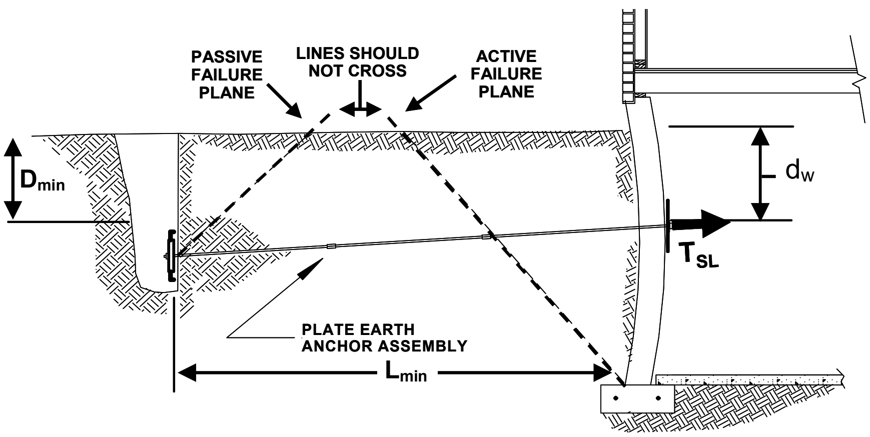


Figure 3. Minimum vertical and minimum horizontal embedment

Lateral spacing of anchors – "X": The lateral distance spacing between the Earth Plate Anchors is dependent upon the following:

1. The estimated Service Load Capacity (**T_{SL}**) of the Earth Anchor Plate,
2. The type of wall construction,
3. The amount of distress to the wall caused by the horizontal force of the saturated soil.

Equation 6: Wall Plate Placement – "X"

$$X = T_{SL}/P_{HS} \times FS$$

Where: X = Wall Plate Spacing – feet
T_{SL} = Tension Service Load – lb.
P_{HS} = Horizontal Force on Wall – lb/ft
FS = Factor of Safety

When a badly distressed wall is constructed with concrete blocks, or where a non-reinforced concrete wall is severely distressed, vertical steel supports and/or horizontal whaler beams must be used to provide even distribution of the reaction force from the anchor across the face of the wall.

One must verify that the typical spacing for a given project is viable; the **Factored Service Load Capacity** (**FT_{SL}**) of the Earth Plate must be confirmed by using the ***"Anticipated Service Load Range"*** graph.

Typically used spacing is provided in Table 3.

Table 3. Lateral Anchor Spacing

Type of Wall	Typical Spacing
Concrete Block	4 to 5 feet
Reinforced Concrete	5 to 6 feet
Rock Wall	Consult Engineer

Example: Confirming viable anchor spacing

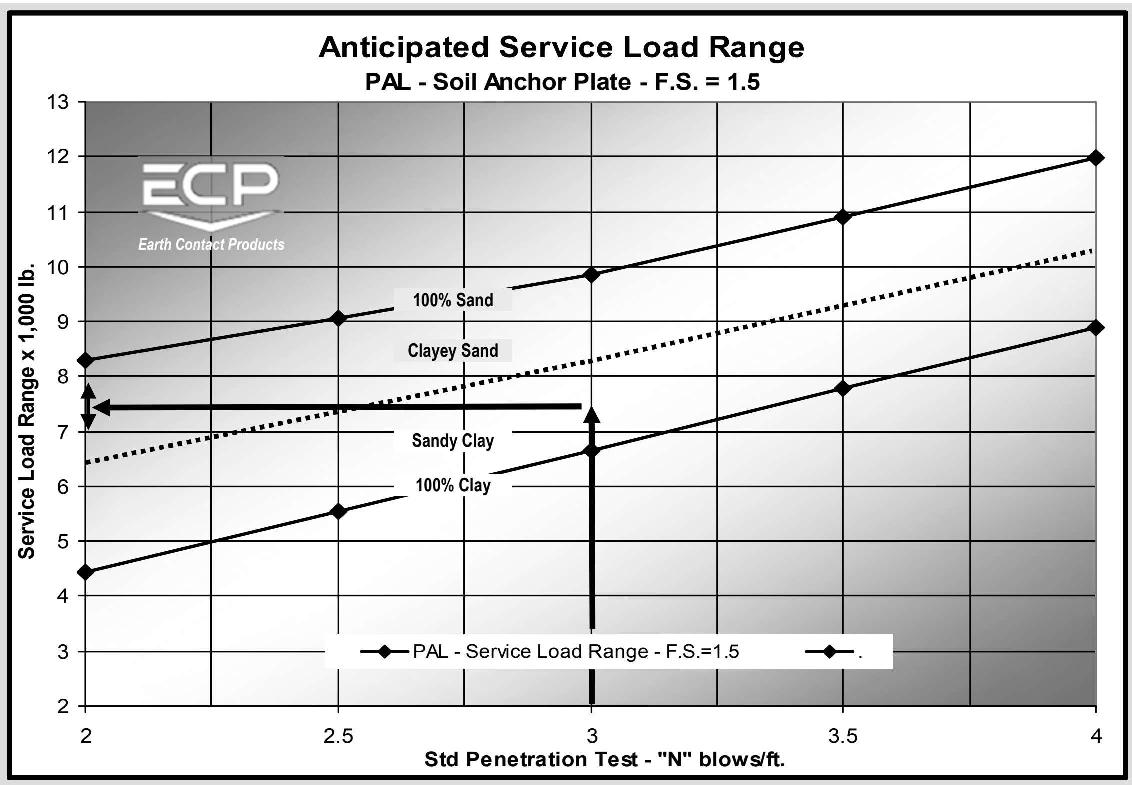
- Basement wall: 8 ft concrete block
- Overburden height of soil – 6 ft
- Wall is bowing at 3 feet above the floor
- Assume anchor spacing – 4 ft O.C. (Table 3)
- Field Estimated Soil Properties:
  Soft, Sandy Clay – "N"= 3 bpf

$P_{HS} = 45 \times (H^2)$ (Equation 2) **$= 45 \times (6\ ft^2) = 1{,}620$ lb/ft**

Anchor spacing is verified by multiplying the Factored Tensile Service Load - **T_{SL}** by the selected anchor spacing that we selected - 4 ft.

T_{SL} = **P_{HS} x "X"** = 1,620 lb/ft x 4 ft = 6,750 lb

A check of *"Anticipated Service Load Range"* graph below confirms that the spacing is satisfactory for Sandy Clay, "N" = 3 bpf. The graph suggests a capacity between 6,900 and 7,800 lbs with a Factor of Safety of 1.5.



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EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

ECP Torque Anchors™
Introduction to ECP Helical Soil Nails

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Chapter 3 – Introduction to ECP Soil Nails

Before one can begin a discussion of soil nailing, a clear understanding of the difference between **soil nails** and **tieback anchors** is required. Many times one hears the term “Soil Nail” and “Tiebacks” used interchangeably and this demonstrates a lack of understanding of the products.

Suppose that a construction project requires an excavation where the side of a soil cut cannot be provided with a stable slope. Figure 1 illustrates the soil cut and excavation for this project.

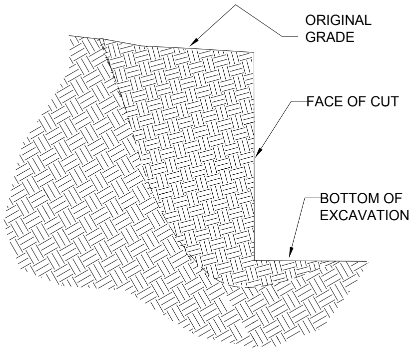


Figure 1

One can easily understand that without some kind of containment of the soil at the face of the cut, a collapse of the soil along a failure plane is likely to occur. This failure can happen very quickly and without warning. The failure might look something like Figure 2. The unstable soil moves to the bottom of the excavation leaving a natural and stable slope for the remaining soil. This interface between the stable and unstable soil is called a slip plane.

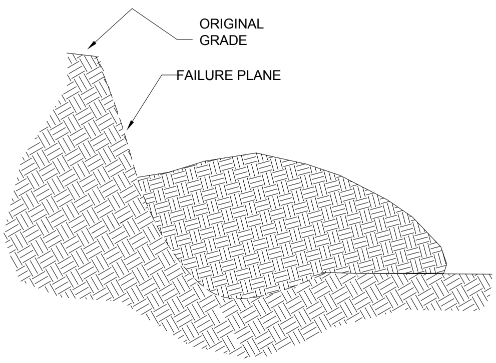


Figure 2

The most common way to prevent this kind of soil failure is to provide lateral support to the unstable soil situated in front of the slip plane. One common way to do this is with a retaining wall and tieback anchors. The tiebacks work together with the structural retaining wall to provide sufficient lateral support to retain the unstable soil mass. The retaining wall must be designed and constructed to provide rigid support for the soil mass over the distance between the tieback anchor placements. One often sees tieback anchors spaced eight to twelve feet apart along the length of the retaining wall. The spacing and number of anchors depends upon the wall height, surcharge loads and properties of the retained soil. Tieback anchors must be driven into the soil to a depth that is sufficient to provide tension resistance in the anchor shaft that is equal to the soil forces pushing against the retaining wall. A typical soil cut with a retaining wall is illustrated in Figure 3.

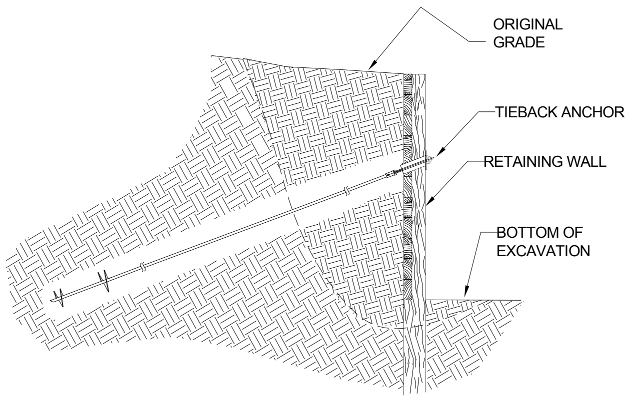


Figure 3

In many construction projects soil nails can be used to retain the unstable soil mass.

Soil Nails must be installed in a close evenly spaced, geometric pattern. Excavation depths must be small increments, typically measuring 4 to 6 feet deep until the final depth of cut is reached. No massive retaining wall structure is required.

Usually only one depth increment can be completed per day. Immediately following the incremental excavation of the soil and the installation of the soil nails, the vertical face of the soil cut is covered with steel mesh reinforcement and a coating of shotcrete.

Soil nails are passive structural elements and are <u>not tensioned after installation</u>. The soil nail achieves pullout resistance from within the sliding soil mass in front of the slip plane and the stable soil mass located behind the slip plane. The geometric system of soil nail placements creates an internally reinforced soil mass that is stable. Figure 4 shows a sketch of a typical soil nail installation.

Notice that each soil nail shaft has great number

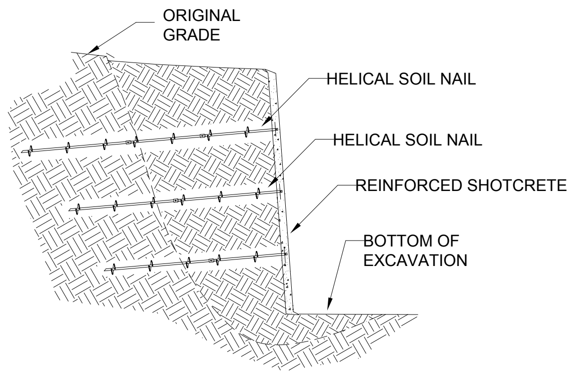


Figure 4

helical plates along the shaft all with the same diameter. These helical plates are evenly spaced along the length of the shaft. By comparison, a tieback anchor has one or more helical plates situated at the tip of the tieback. Helical plates on tieback anchors generally have plates increasing diameter moving upward from the tip of the anchor. Once a tieback anchor lead section is installed, extensions without helical plates are used to extend the helical plates at the tip of the anchor to the target depth. This characteristic of tieback anchors is clearly shown in Figure 3. When comparing these two products, soil nails always have identical small diameter helical plates evenly spaced along the entire length of the Soil Nail shaft.

Soil nails may be the product of choice in applications where the vibrations from installing sheet piling or "H" piles may cause structural distress to nearby structures. Soil nails are generally installed to a shallower depth than tiebacks, which might be an advantage if deeply installed tiebacks have to cross property lines and/or terminate under structures owned by other parties; or where otherwise obstructed.

Soil nails work very efficiently in medium dense to dense sand with Standard Penetration Test values, "N" > 7 blows per foot. They also are suited for low plasticity cohesive soil (clays) with SPT values, "N" ≥ 8 blows per foot, which also have soil cohesion values exceeding 1,000 psf through the entire depth of soil to be stabilized.

ECP Soil Nail Components

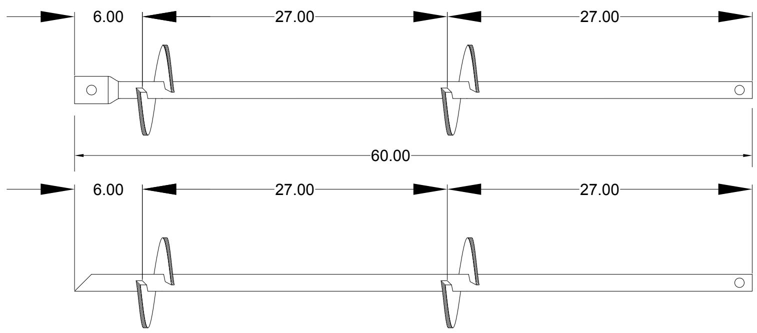
ECP Soil Nail products consist of a shaft fabricated from either 1-1/2 inch or 1-3/4 inch solid square steel bar. Welded along the entire length of the soil nail shaft are identically sized helical plates measuring six or eight inches diameter with a plate thickness of 3/8 inch. The available lead shaft lengths for ECP Soil Nails are nominally five or seven feet long; however, other lengths may be specially fabricated. Soil nail extensions are also available in nominal lengths of five and seven feet. The extensions also contain evenly spaced helical plates of the same diameter as the lead section. Soil nail extensions are supplied with integral couplings and hardware for attachment to an already installed lead or other extensions allowing the soil nail assembly to reach the designed embedment length requirement.

Soil nails may be terminated with a large flat wall plate or an assembly of reinforcing bars welded to a small wall plate. The wall plates will eventually be embedded into a reinforced shotcrete wall covering.

Product Benefits

- **Quickly Installed Using Rotary Hydraulic Torque Motor**
- **Installs With Little Or No Vibration**
- **Installs In Areas With Limited Access**
- **No Post-Tensioning – Immediate Support**
- **No Need for "H" Piles, Sheet Piling, or Walers**
- **In Temporary Applications, Soil Nail Removal and Reuse is Possible**

Table 1. ECP Square Shaft Soil Nails



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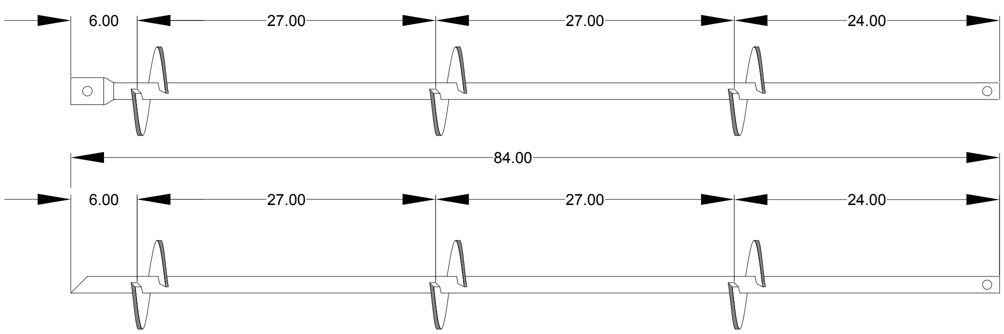
ECP Soil Nail Product Configurations

Part Number	Shaft Size	Torque Limit*	Plate Size	No. Plates	Shaft Length	Bundle Quantity	Weight
TAS-150-60 06-06 Lead	1-1/2" Square	7,000 ft-lb	6" Dia.	2	5'- 0"	25	43 lbs
TAS-175-60 06-06 Lead	1-3/4" Square	10,000 ft-lb					59 lbs
TAS-150-60 08-08 Lead	1-1/2" Square	7,000 ft-lb	8" Dia.	2	5'- 0"	25	48 lbs
TAS-175-60 08-08 Lead	1-3/4" Square	10,000 ft-lb					63 lbs
TASE-150-60 06-06 Extension	1-1/2" Square	7,000 ft-lb	6" Dia.	2	5'- 0"	25	46 lbs
TASE-175-60 06-06 Extension	1-3/4" Square	10,000 ft-lb					57 lbs
TASE-150-60 08-08 Extension	1-1/2" Square	7,000 ft-lb	8" Dia.	2	5- 0"	25	50 lbs
TASE-175-60 08-08 Extension	1-3/4" Square	10,000 ft-lb					61 lbs



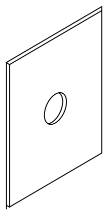
Part Number	Shaft Size	Torque Limit*	Plate Size	No. Plates	Shaft Length	Bundle Quantity	Weight
TAS-150-84 06-06-06 Lead	1-1/2" Square	7,000 ft-lb	6" Dia.	3	7'- 0"	25	62 lbs
TAS-175-84 06-06-06 Lead	1-3/4" Square	10,000 ft-lb					80 lbs.
TAS-150-84 08-08-08 Lead	1-1/2" Square	7,000 ft-lb	8" Dia.	3	7'- 0"	25	68 lbs.
TAS-175-84 08-08-08 Lead	1-3/4" Square	10,000 ft-lb					86 lbs.
TASE-150-84 06-06-06 Extension	1-1/2" Square	7,000 ft-lb	6" Dia.	3	7'- 0"	25	64 lbs
TASE-175-84 06-06-06 Extension	1-3/4" Square	10,000 ft-lb					83 lbs.
TASE-150-84 08-08-08 Extension	1-1/2" Square	7,000 ft-lb	8" Dia.	3	7'- 0"	25	70 lbs
TASE-175-84 08-08-08 Extension	1-3/4" Square	10,000 ft-lb					90 lbs.

Note: All helical plates are 3/8" thick and spaced as shown above.
Extensions supplied with integral coupling and SAE J429 grade 8 bolts and nuts.
Product is hot dip galvanized per ASTM A123 Grade 75.
Soil Nail products available as special order – Inquire for pricing and delivery.– Allow extra time for processing.

Please see "IMPORTANT NOTE" below on Table 2.

ECP Soil Nail Terminations

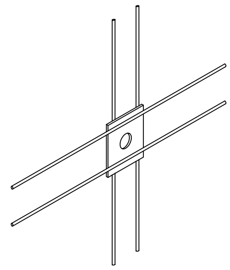
Wall Plate



Part No. TAS-150 WP 12-12 – Wall Plate for 1-1/2” square Soil Nail shaft. 1/2” x 12” x 12” with 2-1/8” dia. hole

Part No. TAS-175 WP 12-12 – Wall Plate for 1-3/4” square Soil Nail shaft. 1/2” x 12” x 12” with 2-3/8” dia. hole

Wall Plate with Rebar



Part No. TAS-150 WPR – Wall Plate for 1-1/2” square Soil Nail shaft. 3/8” x 6” x 6” with 2-1/8” dia. hole, and four #4 rebar by 36” long

Part No. TAS-175 WPR 3/8 – Wall Plate for 1-3/4” square Soil Nail shaft. 3/8” x 6” x 6” with 2-3/8” dia. hole, and four #4 rebar by 36” long.

Product Limitations

Soil nails are designed to attain pullout resistance from within the sliding soil mass along with the resistance from the stable soil behind the movement plane. As a result of this natural tensioning, one must anticipate small soil movements horizontally and vertically at the top of the excavation on the order of 1/8 inch movement for each five feet of excavation. These movements are normally not of concern unless a building is situated close to the proposed soil cut. Creep of the soil mass after the initial soil movement is usually not a problem; however when the soil liquidity index is > 0.2, a soil nail matrix is not recommended.

Soil nails may not be suitable in situations where the soil report indicates the presence of weathered rock anywhere within the area to be stabilized. Soil nails are also not recommended in loose sand with SPT value of “N” < 7 blows per foot. The use of soil nails must be approached with caution where highly plastic clays and silts are present within the soil mass. Soil nails are not recommended for low plasticity clay soil having SPT value of “N” ≤ 6 blows per foot.

The practical limit for excavations using the soil nail stabilization technique is approximately 20 feet; although under ideal soil conditions, excavations as deep as 25 feet deep have been reported.

When designing soil stabilization with surcharge loads near the top of the excavation such as buildings, roads, soil overburden, etc, the surcharge loads must be included with the weight of the soil mass being retained. With an expected slump of 1/8 inch for each five feet of excavation, one should consider stabilizing the perimeter footings of nearby structures whenever the excavation exceeds 10 to 12 feet because lateral and vertical movements on the order of 1/4 to 3/8 inch could cause structural damage to the existing structures nearby.

Table 2. Capacities Of ECP Soil Nails

Shaft Size	Shaft Configuration	Ultimate-Limit Tension Strength	Useable Torsion
1-1/2” Square	Solid Bar	70,000 lb.	7,000 ft-lb
1-3/4” Square	Solid Bar	100,000 lb.	10,000 ft-lb

IMPORTANT NOTE:
The capacities listed are mechanical ratings. One must understand that the actual installed load capacities are dependent upon the actual soil conditions on a specific job site and the strength of the termination connection. The *Useable Shaft Torsional Strengths* given here are the maximum values that should be applied to the product. Furthermore, these torsional ratings assume homogeneous soil conditions and proper alignment of the drive motor. In homogeneous soils it might be possible to achieve 90% to 95% of the ultimate torsional strength shown in the table.

The designer should select a product that provides adequate additional torsional capacity for the specific project and soil conditions.

Each soil nail design requires very specific and detailed information involving the soil characteristics at the site and surcharge loads, if any. Each design is complicated and highly technical. The design and specifications should only be prepared by a Registered Professional Engineer trained in soil nail design and familiar with the specific job site.

Soil nails not only look different from Torque Anchor™ Tiebacks they are designed differently. It is important to understand the dramatic differences in these products before working with soil nails.

For soil nails to be effective, they must have equal diameter helical plates spaced evenly along the entire length of shaft.

Remember that soil nails are not tensioned to gain strength; they gain pullout resistance from within the sliding soil mass that is located in front of the slip plane. The concept is rather simple to understand. As the unstable soil mass begins to slip downward and outward, the sliding soil creates a force against the back side of the helical plates embedded within this moving soil mass. The force generated by the sliding soil against these helical plates is resisted on the front side of the remaining helical plates that are embedded within the stable soil behind the slip plane. Figure 5 illustrates the way that the equal and opposite forces are developed along the Soil Nail shaft.

The forces developed within the soil nail system remove the structural need for an exterior retaining wall. In most cases the soil nails wall plates are embedded directly into the shotcrete coating. There is no need for sheet piles, "H" piles or whales. The soil mass is stabilized by the matrix of soil nails, therefore only a thin shotcrete wall is necessary.

Soil nails are installed in a geometrical matrix to distribute the load evenly; and as such, soil nails are more lightly loaded than tieback anchors.

Some engineers might specify a small "seating" load be applied to the soil nail after installation to remove slack in the couplings; but in general practice, soil nails are usually not tensioned after installation because tensioning can change the balance of stresses on the helices.

Soil nailing is a passive restraint system, meaning that the soil nails are not post-tensioned, the unstable soil mass has to slump slightly before the soil nail system can develop internal forces to resist the soil movements.

Soil nailed walls can be expected to deflect both downward and outward during the slumping of the soil mass. Expected movements of approximately 1/8" of vertical and horizontal move-ment of the top of the wall for each five feet of excavation are common.

These movements are normally not a concern except when an existing structure is situated near the top of the excavation. The soil overburden load from a nearby structure can be reduced by

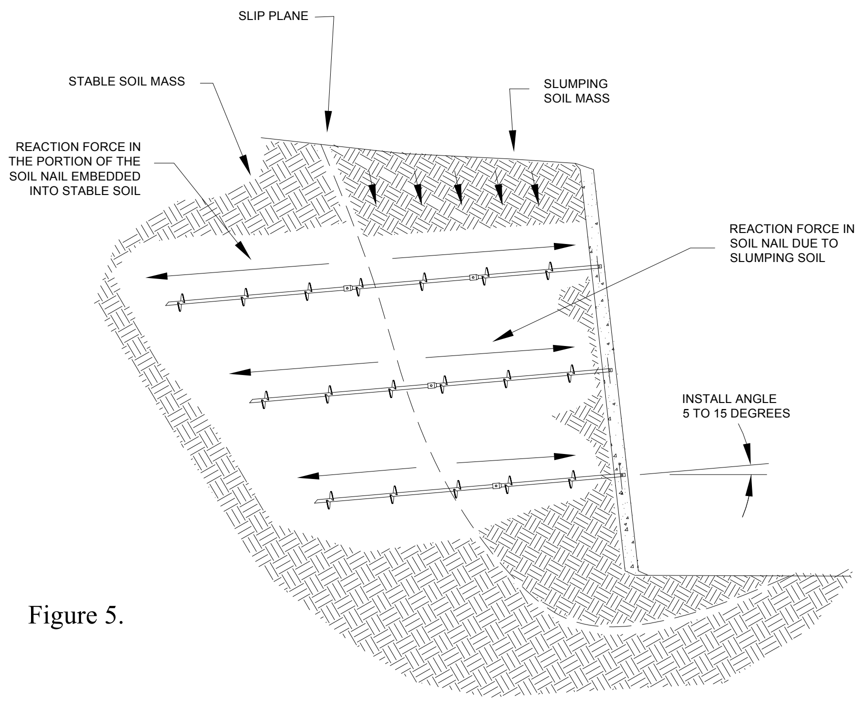


Figure 5.

providing supplemental foundation support to the perimeter beam and/or column footings of the existing structure. ECP Steel Piers™ are recommended to transfer the structural load of the existing building foundation to the deep support provided by ECP Steel Piers™. The ECP Steel Piers™ not only reduce the surcharge on the soil mass, they prevent vertical settlement of the existing footing as the slight movement of the soil mass occurs during the tensioning of the soil nail matrix. If there are concerns with regard to lateral movements of the building's footings, the designer has the ability to prevent lateral footing movements of the existing structure by using Torque Anchor™ tieback anchors along with ECP Steel Piers™ to provide both lateral and vertical stability to the building's footing.

Figure 6 shows details of a typical soil nail installation. Usually four to five feet of soil is excavated and immediately followed by the installation of the first row of soil nails. Notice that the first row has the longest shaft length because the distance to the slip plane is the greatest. The soil nail is not installed to a specified torsion requirement like tieback anchors; rather the length of embedment, the installation angle and center to center spacing is the important elements in soil nail installations.

Once all of the soil nails situated within the first excavation increment are installed, one-half of the required thickness of shotcrete is placed on the wall followed immediately by the installation of the wall plates and reinforcing steel mesh. The reinforcing mesh is cut long enough to provide suitable splice overlap at the next increment of soil excavation. A surface coating of shotcrete is installed over the steel reinforcement to provide the final thickness of concrete specified by the engineer. All work is then left to cure prior to the next depth increment excavation.

Prior to the beginning the next excavation increment (usually the next day), the amount of slump at the top of the excavation must be measured to insure that the recently installed soil nails are performing as intended. When approved, the next depth increment can be excavated followed by the installation of the next row of soil nails followed by the immediate installation of the first layer of shotcrete. The

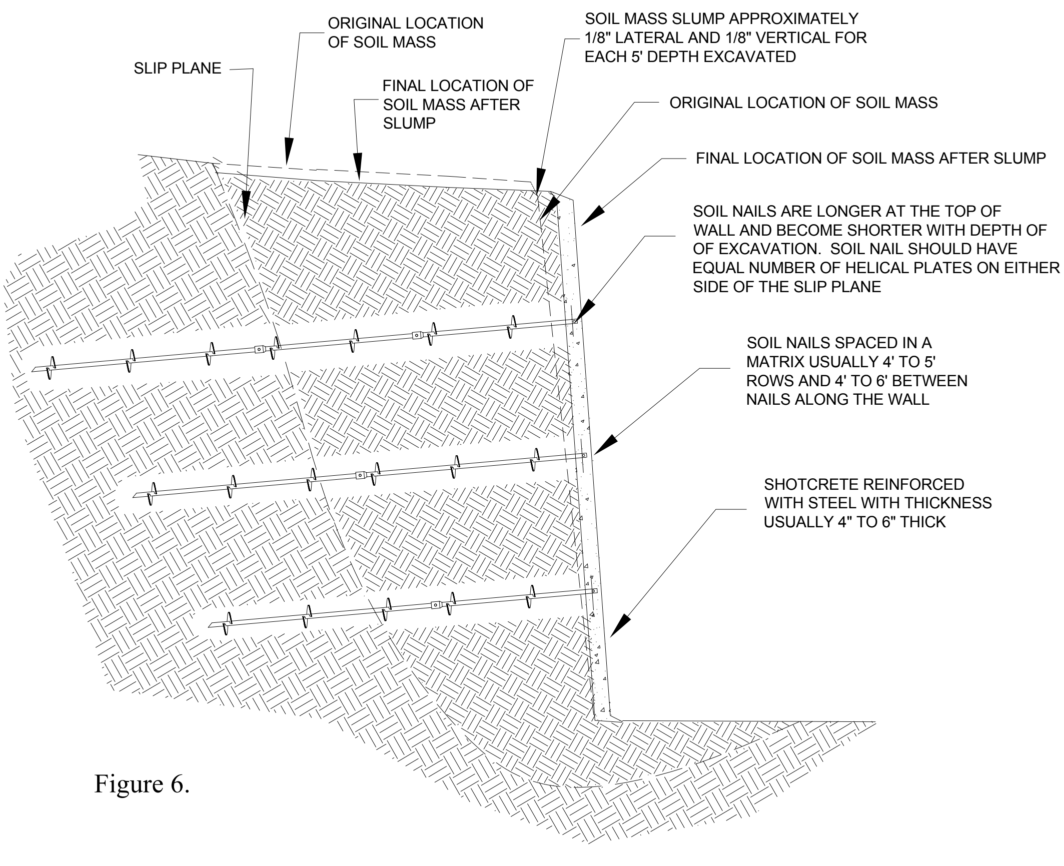
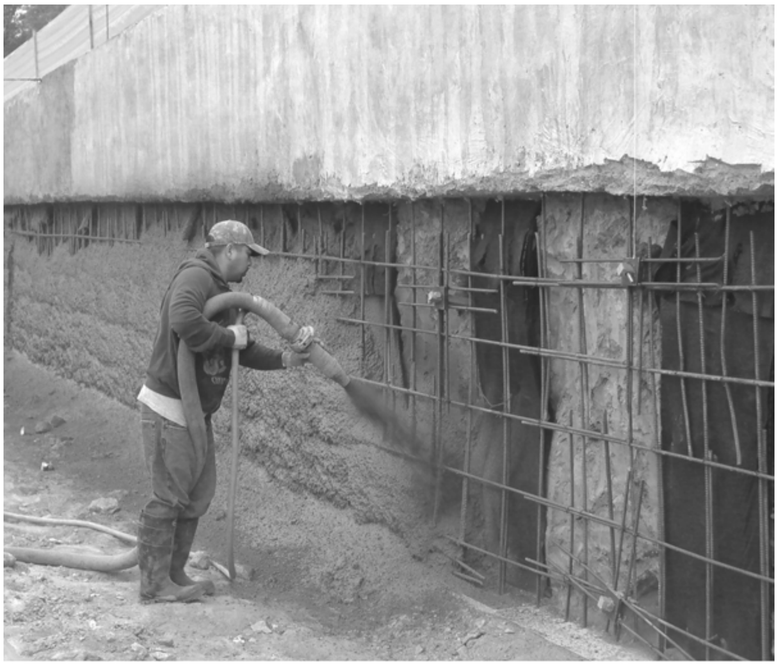


Figure 6.

only difference between the initial and subsequent incremental excavations is that the new layers of shotcrete and steel must be interlocked to the previous work to provide continuity to the wall.

Shotcrete

Shotcrete is a process where Portland cement concrete, or mortar, is propelled under air pressure onto a surface. ECP recommends the wet process where the dry ingredients are mixed with water and then sent to the spray nozzle as opposed to "Gunite" where the materials are mixed as they leave the nozzle. Shotcrete deposits more concrete with less rebound upon impact than "Gunite".



The photographs show ECP Soil Nail installation and Shotcrete application.

Field Documentation

It is very important for the installer to be aware that soil nailing projects involve risk; and as such, close communications with the engineer and attention to detail is extremely important. The data collected on site will assist the engineer to determine if the project is progressing according to plan. Field data should be recorded on each soil nail product installed. Usually, the field superintendent is the person responsible for recording field data. This raw field data is normally compiled at the end of the day into a *Daily Installation Report*. This report should be assembled in a form that is easy to read and understand. At the start of each day the *Daily Installation Report* from the previous day should be provided to the engineer prior to his field measurements and before beginning the next excavation increment. ECP suggests reporting the following data on each installed soil nail to the engineer each day:

Engineering Design and Supervision

Design should involve professional geotechnical and engineering input. Each soil nail design requires very specific and detailed information involving the soil characteristics at the site and surcharge loads, if any. Each design is complicated and highly technical. The final design and specifications should only be prepared by a Registered Professional Engineer trained in soil nail design and familiar with the specific job and job site.

1. A diagram with the numbered locations of the installed ECP Soil Nail for reference
2. ECP Soil Nail product part numbers of the items that were installed
3. The elevation from the surface to the soil nail entry point
4. The soil nail installation angle
5. The installed length of the soil nail
6. The installation torque required to advance the soil nail into the soil recorded at one foot intervals
7. Notes should be made on the torsion log for each soil nail placement to report the presence of non-uniform soil or if the soil nail encounters an obstruction during installation

Two skid steer machines are shown above installing a second row of ECP Soil Nails.

A view of a finished ECP Soil Nail retaining wall.

NOTE: Technical Design Assistance Is Not Offered For Soil Nail Projects

Soil Nail design should only be performed after a thorough site and soil investigation by a registered professional engineer because soil nail projects carry the risk of severe failure. All field installation procedures should be performed under the direct supervision of the on site design engineer of record. As these types of projects require on site inspections and evaluations, extremely detailed soil reports, extensive engineering calculations, and intimate knowledge of the job site, ECP is unable offer complementary preliminary designs for soil nail projects.

ECP Helical Torque Anchors™

Installation Guidelines and Testing Procedures

- Hydraulic Torque Motors
- Installation Procedures
- Field Testing of Torque Anchors™

EARTH CONTACT PRODUCTS
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Table of Contents

Chapter 4 - ECP Torque Anchors™ - Installation and Testing Guidelines

ECP Torque Anchors™ are usually installed with a hydraulic motor and reduction gear box assembly. Some motors offer a two speed gear box, which allows the installer to increase the advancement the Torque Anchor™ through the upper strata of the soil. When approximately 75% of the design installation torque has been reached, the rotational speed is reduced to between 5 and 10 rpm until the final torque is achieved for the required embedment length.

Symbols Used In This Chapter	
d	Deflection of pile under test loading – in.
k	Empirical efficiency factor relating ultimate capacity of a pile or tieback to the installation torque – ft^{-1} ($k = P_u$ or T_u / T)
K	Torque conversion factor that is used to determine torque motor output from pressure differential across motor
P_u	Ultimate pile or anchor capacity* – lb.
Δp	Pressure differential measured across a torque motor $\Delta p = p_{in} - p_{out}$ - psi
T	Installation or Motor Output Torque – ft-lb
T_u or P_u	Ultimate Helical Product Capacity – lb

Installation Torque

Installation torque on the shaft, the *Soil Efficiency Factor* (“k”) and Table 1 were introduced and discussed in Chapter 1. These items are reproduced for reference below.

Shaft torsion during installation can provide a reasonably accurate estimate of the ultimate capacity of the installed helical screw product. The relationship between the shaft torsion during installation and the ultimate helical product capacity is empirical and was developed from results from thousands of tests. When one applies rotational torsion to the end of the shaft at grade level, some of the torque energy is lost before it reaches the helical plates at the bottom end of the shaft. This loss of torque is due to friction between the shaft and the soil.

In Figure 1 below, notice that not all of the torque applied to the shaft by the motor reaches the helical plates. The actual torque applied to the helical plates is $T_{Plates} = T_{Motor} - T_{Shaft}$. The friction generated between the surface area of the shaft and the soil is directly related to the type and size of the shaft along with properties of the soil at the installation site. Because of this transmission torque loss in transmitting the motor torque to the plates, an empirical *Soil Efficiency Factor* (“k”) must be employed to arrive at a reasonable estimate of ultimate capacity expected from the pile or anchor.

Soil Efficiency Factor – “k”: Is the relationship between installation motor torque and ultimate capacity of the installed Torque Anchor™. Estimating the ultimate capacity of helical foundation product based upon the installation torque has been used for many years.

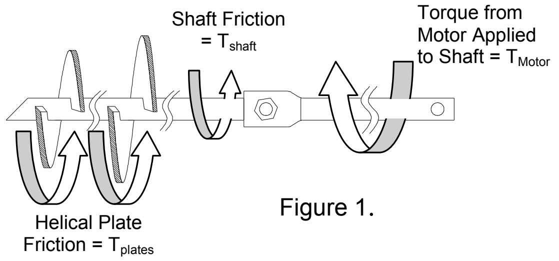

Figure 1.

Unless a load test is performed to create a site specific value for the *Soil Efficiency Factor* (“k”), a value must be estimated when designing. While values for “k” have been reported from 2 to 20, most projects will produce a value of “k” in the 6 to 14 range. Earth Contact Products offers a range of values for *Soil Efficiency Factors* (“k”) in Table 1. Graph 1 on Page 7 also illustrates this. These “k” values may be used for estimating empirical ultimate capacities of installed Torque Anchors™. These values may be used until a field load test can provide a more accurate site specific value for “k”. Table 1 lists typical values of “k” for general estimations of ultimate capacity of Torque Anchors™ based upon the output torque at the installation motor shaft.

Table 12. Soil Efficiency Factor “k”

Torque Anchor™ Type	Typically Encountered Range “k”	Suggested Average Value, “k”
1-1/2” Sq. Bar	9 - 11	10
1-3/4” Sq. Bar	9 - 11	10
2” Sq. Bar	8.5 (Compression)	8.5
	10 (Tension)	10
2-7/8” Diameter	8 - 9	9
3-1/2” Diameter	7 - 8	8
4-1/2” Diameter	6 - 7	7

Understand that the value of the *Soil Efficiency Factor* (“k”) is an estimation of friction loss during installation. The amount of friction loss has a direct relationship to soil properties and the anchor shaft.

Table 2.	Capacities of ECP Helical Torque Anchors				
Shaft Size	**Installation Torque Factor (k)**	**Axial Compression Load Limit**	**Ultimate- Limit Tension Strength**	**Useable Torsional Strength**	**Practical Load Limit Based on Torsional Strength**
1-1/2" Square Bar	**10**	**70,000 lb.**	**70,000 lb.**	**7,000-lb**	**Load limited to the rated capacity of the attachments and the lateral soil strength against the shaft**
1-3/4" Square Bar	**10**	**100,000 lb.**	**100,000 lb.**	**10,000 ft-lb**	
2" Square Bar	**8.5** (Compression **10** (Tension)	**127,500 lb.**	**150,000 lb.**	**15,000 ft-lb**	
2-7/8" Tubular – 0.203" Wall LW	**9**	**60,000 lb.**	**60,000 lb.**	**5,500 ft-lb**	**50,000 lb**
2-7/8" Tubular – 0.276" Wall	**9**	**100,000 lb.**	**100,000 lb.**	**9,000 ft-lb**	**81,000 lb**
3-1/2" Tubular – 0.300" Wall	**8**	**115,000 lb.**	**120,000 lb.**	**13,000 ft-lb**	**104,000 lb**
4-1/2" Tubular – 0.337" Wall	**7**	**160,000 lb.**	**160,000 lb.**	**22,000 ft-lb**	**154,000 lb**

Most of ECP TA-150, TA-175, TA-288 and TA-350 Torque Anchor™ product lines have an ICC evaluation and ICC-ES 3559 has been issued.

The designer should select a product that provides adequate additional torsional capacity for the specific project and soil conditions,

IMPORTANT NOTES:

The capacities listed for "Axial Compression Load Limit", "Ultimate Limit Tension Strength" and "Useable Torsion Strength" in Table 2 are mechanical ratings. One must understand that the actual installed load capacities for the product are dependent upon the soil conditions at a specific job site. The "Useable Torsional Strengths" given here are the **maximum** values that one should apply to the product. Furthermore, these torsional ratings assume homogeneous soil conditions and proper alignment of the drive motor to the shaft. In homogeneous soils up to 95% or more of the "Useable Torsional Strength" shown in Table 2 can be applied. In obstruction-laden soils, torsion spikes may cause impact fractures of the shaft, couplings or other components. Where impact loading is expected, Actual Applied Shaft Torsion should be reduced by 30% or more from that shown in Table 2. When dealing with poor soil conditions on site, select a larger shaft to reduce chance of fracture or damage during installation.

Another advantage of selecting a higher "Useable Torsion Strength" value from Table 2 is that one may be able to drive the pile slightly deeper after the

The "k" value for square bars is generally higher than for tubular shafts. Keep in mind that the suggested values in Table 1 are only guidelines.

It is also important to refer to Table 2 at the beginning of Chapter 1 for the *Useable Torsional Strength* that can be applied to a specific anchor shaft. Being mindful of the torsional strength rating of the shaft will help to avoid shaft fractures during installation.

Failure to verify that the chosen shaft configuration has sufficient reserve torsional capacity could result in an unexpected shaft fracture during installation especially in soils containing debris, rocks and cobbles.

Equation 1: Installation Torque

$$T = (T_u \text{ or } P_u) / k \text{ or } (T_u \text{ or } P_u) = k \times T$$

Where,
T = Final Installation Torque - (ft-lb)
(Averaged Over the Final 3 to 5 Feet)
T_u or P_u = Ultimate Capacity - (lb)
(Measured from field load tests)
k = Soil Efficiency Factor - (ft^{-1})

To determine the site specific *Soil Efficiency Factor,* ("k") from field load testing, Equation 1 is rewritten as:

Equation 2: Site Specific Soil Efficiency Factor

$$k = (T_u \text{ or } P_u) / T$$

Where: k = Soil Efficiency Factor - (ft^{-1})
$T_u = P_u$ = Ultimate Capacity - (lb)
(Calculated or measured from field load tests)
T = Final Installation Torque - (ft-lb)

An appropriate factor of safety must always be applied to the design or working loads when using Equation 1 and 2.

Determining Installation Torque

- **Twisting of the Solid Square Bar** – This method of torque control is the least accurate method to determine the torsion that is being applied to the shaft. The reason this method is inaccurate, and not recommended, is because the point at which twisting occurs will vary with fluctuations in the steel chemistry used to make the bar, the differences in torsional strength from bar to bar within a mill run of bars, and the tolerances in the steel compositions between mill runs of similar bars. The length of shaft can also affect the number of twists for a given shaft torque. ECP does not recommend using this method to determine installation torque.

- **Shear Pin Hub** – This device uses a hub that attaches between the motor and the anchor shaft. Maximum shaft torsion is determined by inserting a number of shear pins between the flanges of the hub. Each pin usually represents 500 ft-lbs. Based upon the total number of pins used, one can restrict the maximum torsion that can be applied to the shaft. When the desired torsion is reached, the pins shear and the hub no longer transmits torsion to the helical anchor shaft. For this device to accurately predict ultimate capacity, the soil into which the screw anchor is installed must be homogeneous and with no obstructions. The shear pin hub, by nature, tends to overestimate the shaft torsion. If, during installation, the helical plates encounter an obstruction or something that causes a spike in the shaft torque, the shear pins become deformed and weakened. In addition, if the target stratum rapidly becomes very dense, the shear pins may break before all plates have been properly embedded. This is especially important in tension applications where the desired shaft torsion should be averaged over a distance of at least three feet before terminating the installation. Earth Contact Products does not endorse the shear pin hub and considers it a less accurate way to measure shaft torsion.
- **Single Pressure Gauge** – Many operators install a single pressure gauge at the inlet to the hydraulic gear motor. This is a dangerous practice and <u>not</u> recommended because in nearly every hydraulic system there is back pressure. This back pressure represents energy that enters the gear motor, but is not used by the motor. The back pressure simply causes the oil to flow back into the system and to the reservoir. Typically, back pressures can range from 200 to 500 psi, and in some cases higher.

The danger in using a single gauge to estimate shaft torsion is that the back pressure is unknown. As a result, <u>the shaft torsion on the shaft is overestimated</u>, which results in an anchor capacity prediction that is overstated.

Anchors installed with a single gauge system, in general, will not produce the actual capacity as expected and could fail.

- **Dual Pressure Gauges** -- One of the most common ways to determine motor output torque is to measure the difference between the input pressure and output pressure across the motor. When using two gauges installed one on each port of the gear motor, the actual pressure drop across the motor is monitored. This is a theoretical representation of the amount of hydraulic energy that was used by the motor. Once the pressure differential is determined, the output shaft torque can be estimated from motor performance data provided by each motor manufacturer.

It is especially important to have the gauges calibrated regularly. Gauges can become damaged and rendered inaccurate in the field.

- **Strain Gauge Monitor** (Torque Transducer) This device provides a direct display of installation torque being applied to the shaft; it also provides a recorded history of the shaft torsion through the entire depth of installation. This system consists of three parts; a Torque Analyzer Rotor installed on the flanged coupling between the motor and anchor shaft, a Torque Analyzer PDA indicator and a battery charger.

  The unit is extremely rugged and ideal for field based applications. The strain gauge monitor measures the torque applied between two flanges located between the motor output shaft and the helical anchor shaft. This data is transmitted to a PDA readout device for display and logging. This method of measuring the torque applied is highly accurate (+/- 0.25%). The torque sensor is built into the housing of the flanges and the data is transferred by a wireless transmitter fitted into the housing.

  The torque data captured by the PDA is recorded as a text file that can be viewed or downloaded to any computer software for further analysis, such as Microsoft Excel.

  This unit is the most accurate and rapid way to monitor and record installation torque. It is highly recommended.

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Converting Motor Pressure To Shaft Torsion

When differential pressure is measured across the motor ports, it can then be converted to motor output torsion. This can be accomplished by using Torque Motor Output Curves for the specific motor being used, or one can use the motor specific *Torque Motor Conversion Factor,* ("K"). Both are available from motor manufacturers.

Torque Motor Conversion Factor – "K": Each motor has a unique *Torque Motor Conversion Factor*, ("K") which is the relationship between the differential pressure measured across the hydraulic ports of the motor and the shaft output torque of the motor. This factor, which is referred to as "K", may be used to calculate the output torque of a motor. In Table 2 on the following page we have provided hydraulic gear motor manufacturers' data for several commonly used hydraulic torque motors. The important column in this table is the *Torque Motor Conversion Factor* ("K").

Important: Do not confuse the *Torque Motor Conversion Factor*, "K", with the *Soil Efficiency Factor,* "k", which is the measure of the soil friction on the shaft.

Equation 3 below is used to convert pressure differential into motor shaft output torque.

Equation 3: Motor Output Torque

$$T = K \times \Delta P$$

Where,

T = Hydraulic Motor Output Torque - ft-lb

K = Torque Motor Conversion Factor – (Table 16)

$\Delta P = p_{in} - p_{out}$ = Motor Pressure Differential

When determining the installation torque from hydraulic pressure differentials, it is imperative that the motor outlet pressure be subtracted from the motor inlet pressure <u>BEFORE</u> referring to any tables or charts that convert differential motor pressure to output shaft torque.

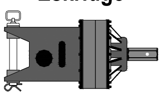
Table 2 presents the *Torque Motor Conversion Factor,* ("K") for some commonly used hydraulic torque motors, which will assist in determining the motor output torque when pressure differential is known.

Important: Determining output shaft torsion <u>when operating at very low motor output torque</u> should be approached with caution. Hydraulic torque motor curves are not exactly linear. Errors are possible at the low end of the motor output curve when using a fixed value of "K".

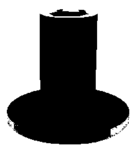
Caution: It is very important to capture the pressure differential <u>directly across the motor ports</u>.

If the pressure measurement connections are made at other locations, the differential pressure reading may be inaccurate and could result in incorrect estimates of motor shaft torsions.

Finally, the accuracy of the data is only as accurate as the gauges. Calibrate the pressure gauges regularly to insure accurate results.

Table 2.	Hydraulic Torque Motor Specifications								
Illustration	**Model Number**	**Graph No.**	**Torque Output** ft-lb	**Motor Torque Conversion Factor – “K”**	**Maximum Pressure** psi	**Max. Flow** gpm	**Output Speed** rpm	**Hex Output Shaft**	**Weight** lb.
PRO-DIG 	**L6K5**	10	6,335	**2.53**	2,500	16	13.8	2”	132
	L7K5	9	7,644	**2.55**	3,000	35	32.8	2-1/2	363
	X9K5	9	9,663	**3.22**	3,000	35	26	2-1/2	365
	X12K5	9	12,612	**4.20**	3,000	40	23.5	2-1/2”	366
	T12K	10	5,597/ 12,128	**2.24/4.85**	2,500	65	70/32	2-1/2” or 2-3/4	382
	X16K5	11	16,563	**5.52**	3,000	40	17.9	3”	565
	X20K	11	20,670	**6.89**	3,000	40	14.3	3”	571
Eskridge 	**B26 16:1**	12	4,500	**1.5**	3,000	10	10	2” Dia Keyed	68
	B5016-21F54	12	5,000	**1.71**	3,000	20	24	2”	150
	77BA	13	12,000	**5.0**	2,400	40	19	2-1/2”	250

IMPORTANT: Torque Motor Conversion Factor, “K”, tends to become lower than shown in this table when pressure differentials are below 1,000 psi. As a safety guideline, use only 90% of the “K” shown when pressure differentials are between 750 and 900 psi; use 80% of “K” shown for pressure differentials between 500 and 750 psi.

Torque Motor Accessories			
DT-150-5 1.50 inch Sq. Shaft Drive Tool	**DT-175-5** 1.75 inch Sq. Shaft Drive Tool	**DT-200-5** 2 inch Hex Drive Tool	**DT-250-5** 2.50 inch Hex Drive Tool
			
DT-288-L-5 2.88 inch Drive Tool (Two Hole)	**DT-288-5** 2.88 inch Drive Tool (Three Hole)	**DT-350-5 and DT-350-7*** 3-1/2 inch Dia. Drive Tool	**Link Arm**
			
Pipe Install Tool	**Hydraulic Motor Pressure Monitor**	**Shear Pin Torque Indicator**	**Smart Anchor Monitor**
			

*** DT-350-7 Drive Tool. Similar to DT-350-5 but with 7-5/8” flange (Not Shown)**

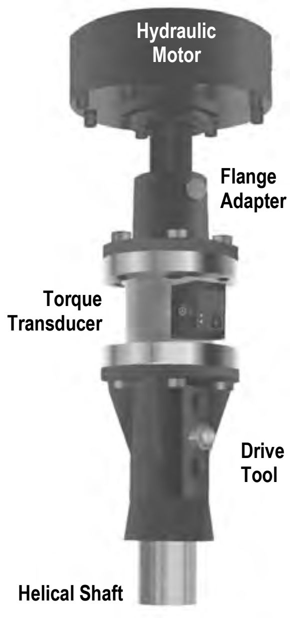
ECP Smart Anchor Monitor (SAM) and Assembly Configuration

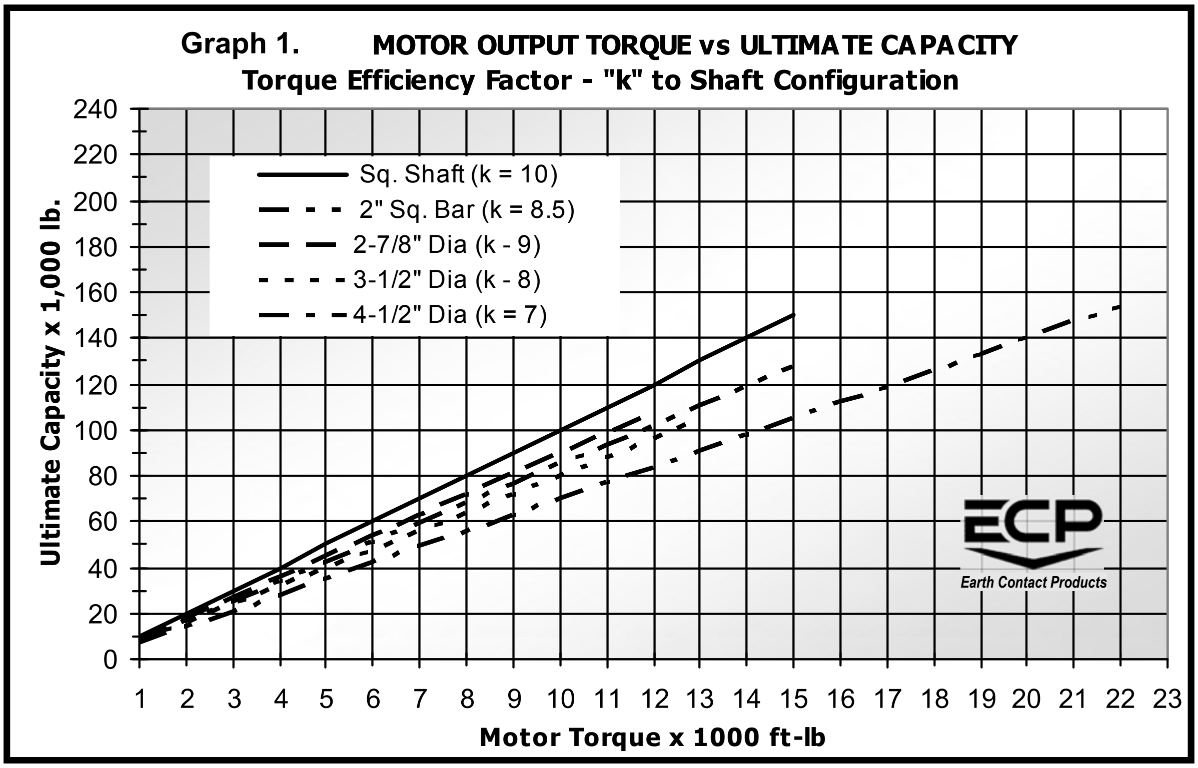
The torque transducer is attached between the hydraulic gear motor and the Torque Anchor™ shaft to be monitored during installation. This state of the art tool provides the highest quality helical anchor installation monitoring and recording.

- Highly accurate (+/-0.25%) torque monitoring capabilities
- Angle and depth monitoring
- GPS data recorder for exact location of the anchor
- Multiple wireless PDA's can be used to view one drive
- Data can be exported to third party software
- Shaft RPM Indicator
- Calibrated to NIST (National Institute of Standards & Technology Certification)
- Extremely rugged design
- No mechanical parts

This quick reference can be used to estimate the ultimate capacity of a Torque Anchor™ when the motor output torque and the shaft configuration are known.

Caution: When using the Solid Square Shaft curve, do not exceed the *"Useable Torsional Strength"* of the shaft.

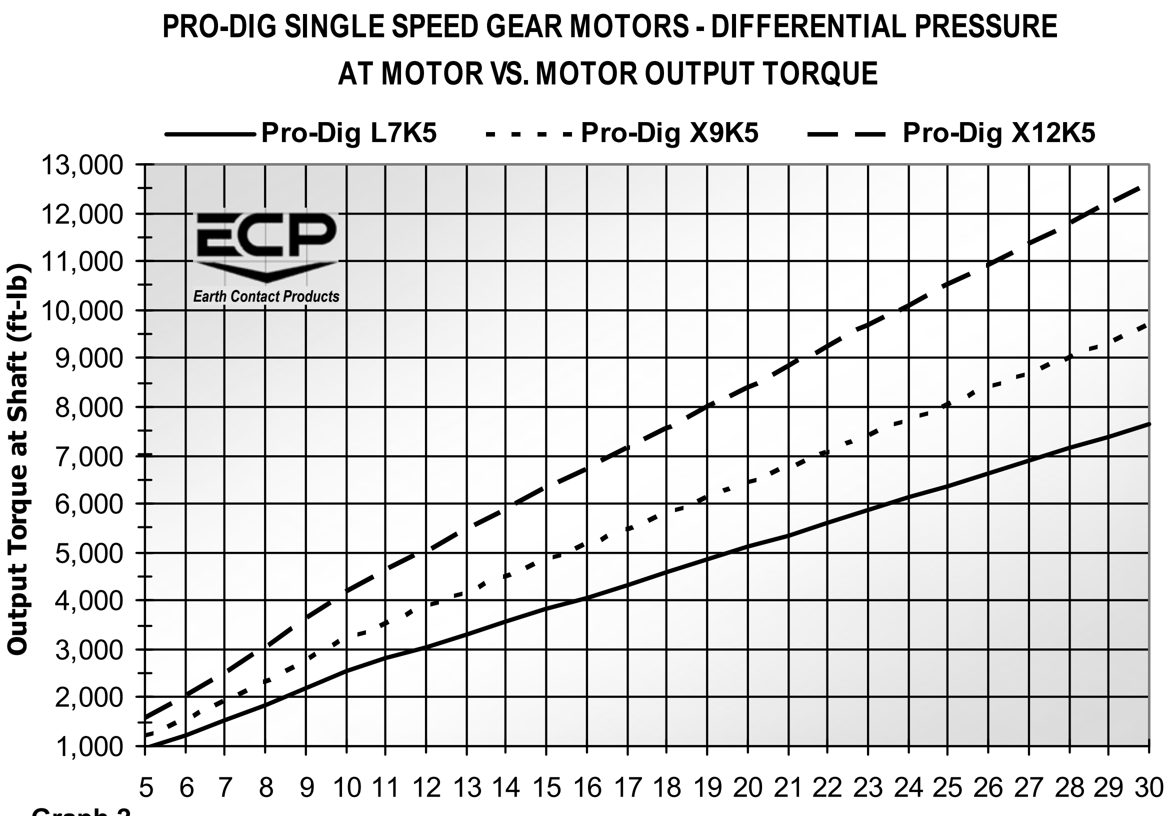




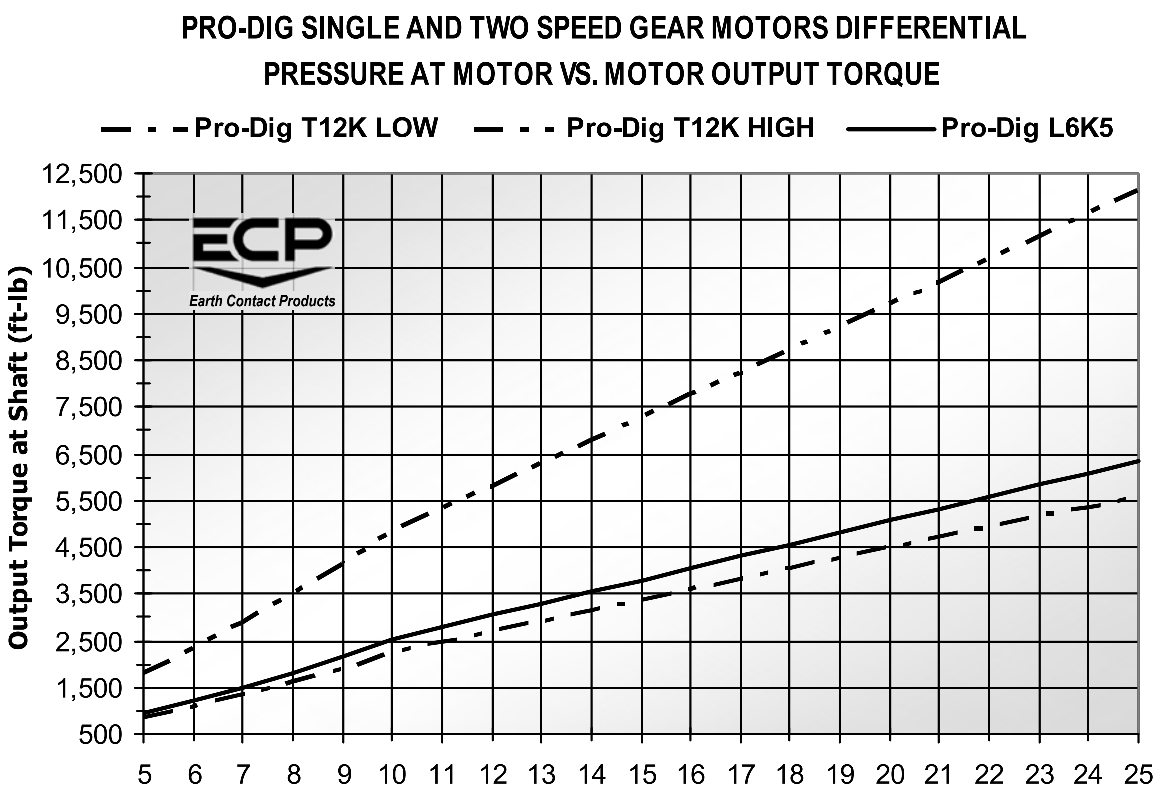
ECP Hydraulic Torque Motor Performance Curves

Motor performance curves provide a quick source for motor torque output based upon the actual pressure differential across the motor ports.

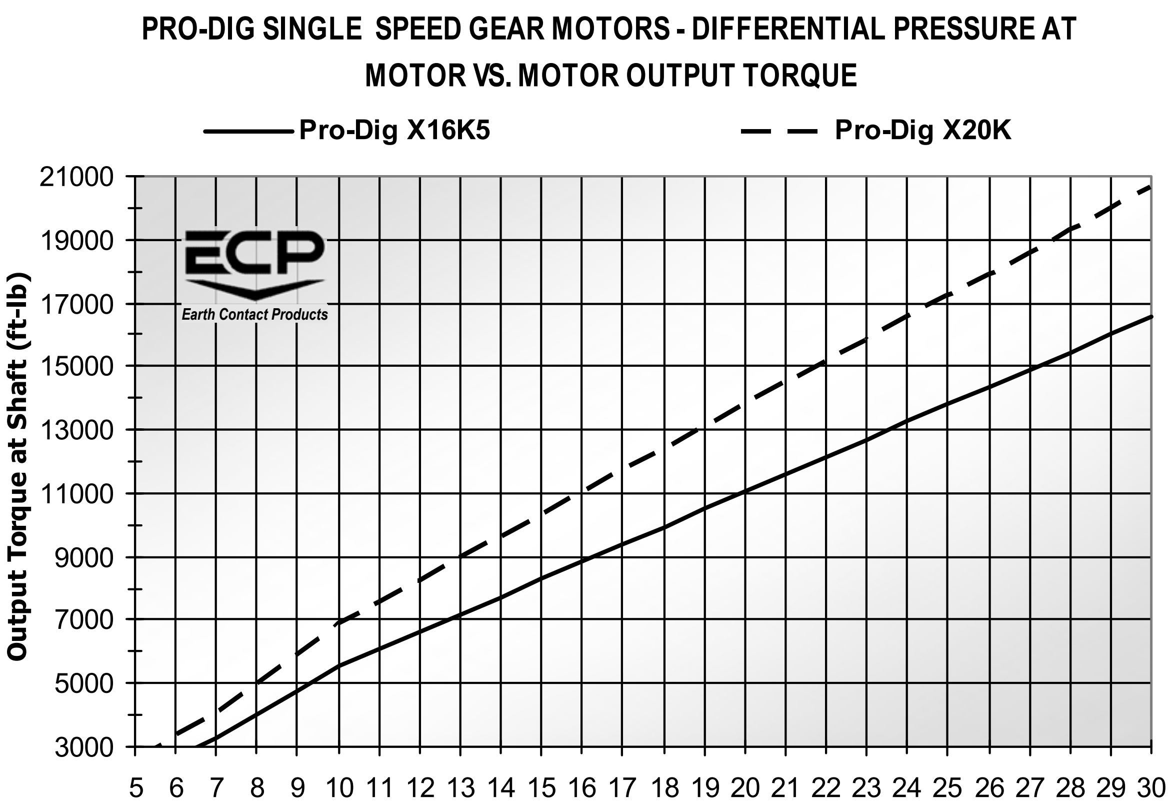
The graphs on the following pages are hydraulic motor performance curves for Pro-Dig and Eskridge gear motors that are normally in stock and ready for immediate delivery.



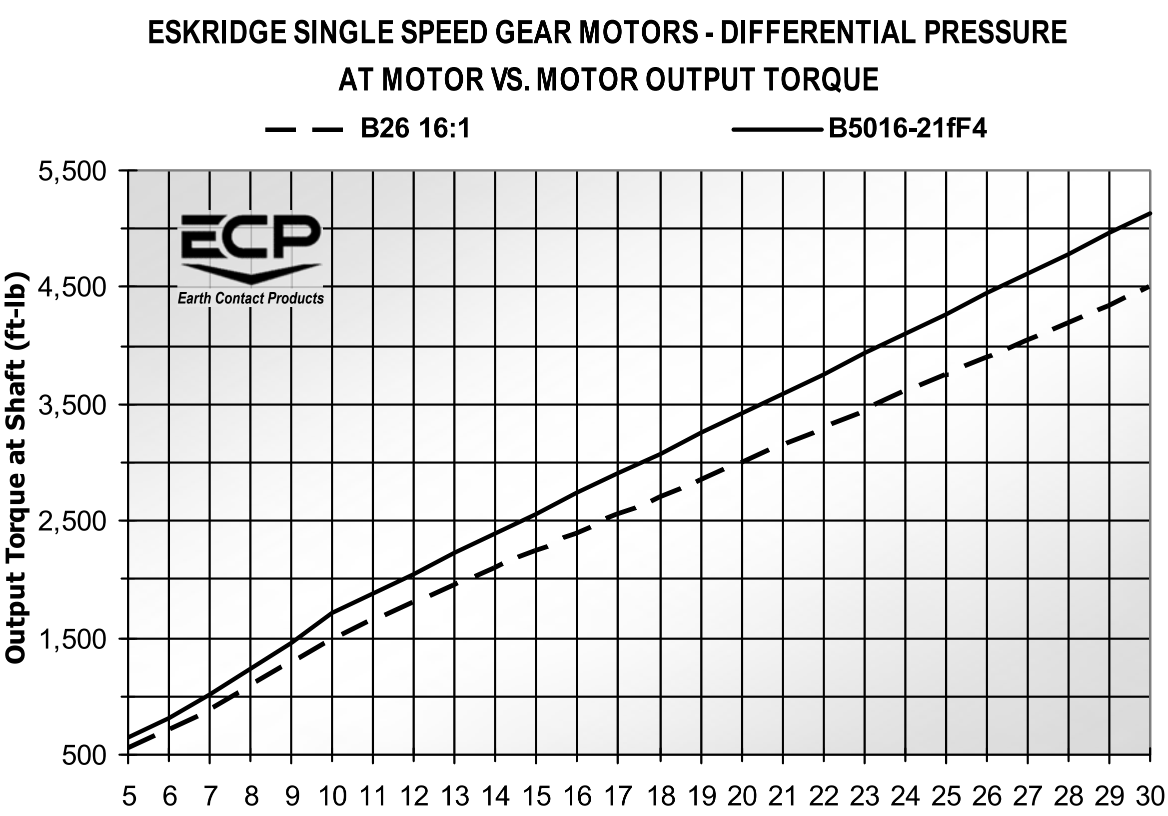
Graph 2.



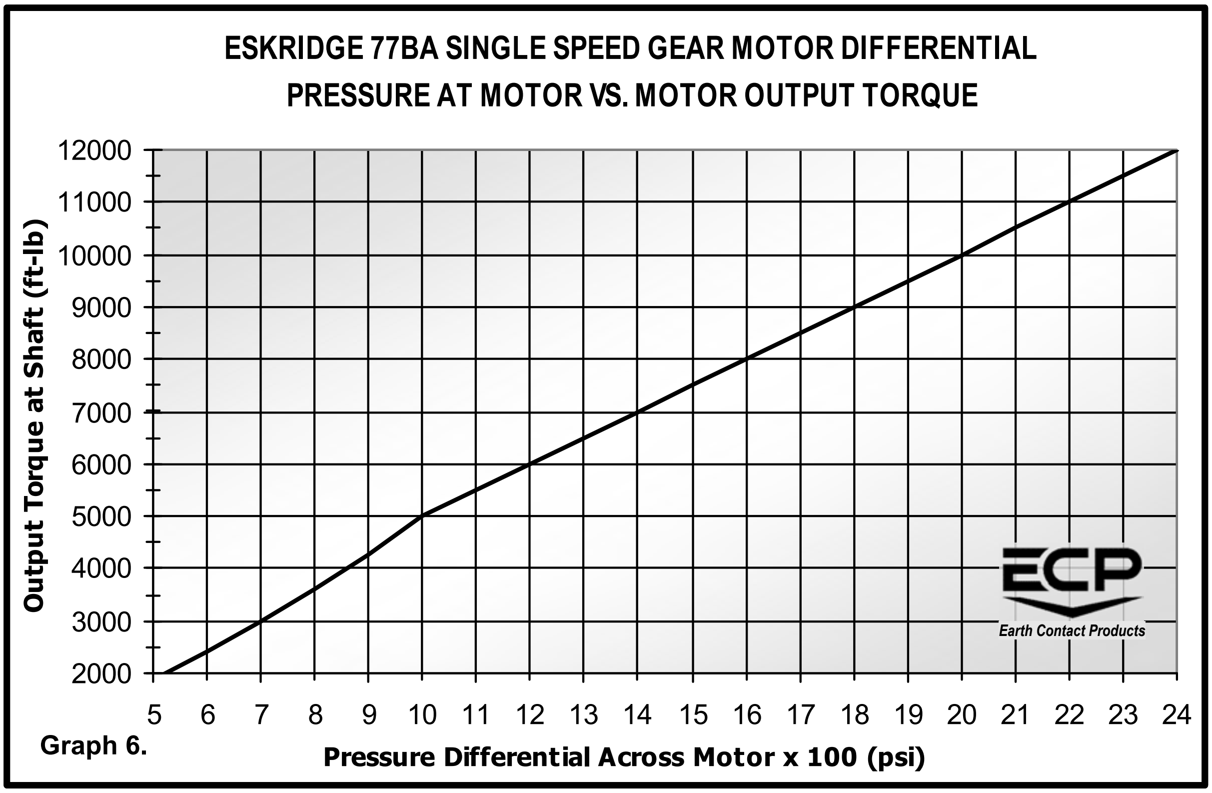
Graph 3.



Graph 4.



Graph 5.



Graph 6.

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Structural Compressive Pile and/or Tensile Helical Anchor Installation Procedure

General Considerations:

- Prepare site for safe working conditions.
- Thoroughly investigate the site for any and all underground utilities before excavating.
- Excavate as required for installation of the product.
- Install ECP Helical Torque Anchor™ to depth and torque specifications
- Cut shaft to length and install a pile cap or wall support assembly as specified
- Load test to verify design and capacity of the product and installation
- Remove equipment from work area and clean work area

Installation Plan:

The torque anchors shall be installed as shown on the written new construction or repair plan that was prepared by the engineer or the installer, and submitted to the owner or their representative. The plan shall include, but not be limited to:

- Size and number of placements
- Helical plate configuration
- Spacing between helical torque anchors™
- Minimum depth of embedment
- Minimum target torque requirement
- Load testing requirements

STEP 1 – Installation Requirements:

- The minimum average installation torque and the minimum length shown on the plans shall be satisfied prior to termination the installation. The installation torque shall be an average of the installation torque recorded during a minimum of the last three feet of installation.
- The torsional strength rating of the torque anchor™ shall not be exceeded during installation. If the torsional strength limit for the torque anchor™ has been reached, but the anchor has not reached the target depth, the following modifications are acceptable:
    - A. If the torsional strength limit is achieved prior to reaching the target depth, the installation may be acceptable if reviewed and approved by the engineer and/or owner.
    - B. The installer may remove the torque anchor™ and install a new one with fewer and/or smaller diameter helical plates with review and approval by the engineer and/or owner
- If the target depth/length is achieved, but the torsional requirement has not been met; the installer may do one of the following subject to the review and approval of the engineer and/or owner:
    - A. Install the torque anchor™ farther into the soil to obtain the required installation torsion.
    - B. The installer may remove the torque anchor™ and install a new one with an additional helical plate and/or larger diameter helical plates.
    - C. Reduce the load capacity of the placement and provide additional helical torque anchors™ at closer spacing to achieve the required total support for the project.
- If the torque anchor™ hits an obstruction or is deflected from its intended path, the installation shall be terminated and the anchor removed. Either the obstruction must be removed or the torque anchor™ relocated as directed by the engineer and/or owner and the installation resumed.
- In no case shall a torque anchor™ be backed out and reinstalled to the same depth. If an anchor must be removed for any reason, it must be installed to a deeper embedment of at least three feet.
- After meeting the installation requirements, the installer may remove the final plain extension section and replace it with a shorter one to obtain the design elevation, or he may cut the extension to length. The cut shall be smooth and at 90 degrees to the axis of the shaft. <u>It is not permissible to reverse the installation to obtain the desired coupling elevation</u>.

STEP 2 – Torque Anchor™ Installation:

The hydraulic installation motor shall be installed on a suitable machine capable providing the proper installation angle, reaction against installation torque, and downward force (crowd). The lead section shall be positioned with the shaft at the proper installation angle(s) at the designated location(s). The opposite end shall be attached to the hydraulic installation motor with a pin(s) and retaining clip(s).

If using portable equipment, the torque reaction bar MUST be properly secured against movements in all directions. Torque Anchor™ lead sections shall be placed at the locations indicated on the plans. The lead section shall be advanced into the soil in a smooth and continuous manner using sufficient force for uniform advancement. The installer shall have knowledge of the desired pressure differential that will produce the desired terminal installation torque approved by the engineer before beginning the installation.

Once the lead is installed, the motor shall be unpinned from the lead. One or more extensions shall be installed and securely bolted in place with the hardware supplied by the manufacturer.

The torque anchor™ shall be continued to be driven to the average design torque until the bottom end of the torque anchor™ is at the design depth. Once the design torque at the design depth has been achieved, the installation motor shall be removed from the torque anchor™.

STEP 3 – Documentation:

The installer shall carefully monitor the torque applied to the anchor as it is installed. It is recommended that the installation torque be recorded at one foot intervals, but should never exceed every two feet. The data may be collected from electronic torsion monitoring equipment that has been calibrated to the installation motor being used. Installation torque may also be monitored by noting the differential pressure across the installation motor and determining the torque from the manufacturer's published torque curves.

At the conclusion of the installation, the raw field data shall be converted into an installation report that includes the location of each placement, the installation depth, installation torque readings at intervals and the averaged installation torque over the final three feet.

STEP 4 – Torque Anchor™ Termination:

- **Pile Cap or Bracket** – The pile cap, slab pier bracket, utility bracket, or porch bracket shall be installed by placing the appropriate sleeve over the torque anchor™ shaft. If the foundation will be subjected to uplift, the pile cap shall be bolted to the torque anchor shaft using bolt(s) and nut(s) supplied by the manufacturer having the same diameter and strength rating as used to couple the pile sections.
- **Transition** – The transition is sometimes used for equipment anchorage. The transition shall be bolted to the end of the torque anchor™ using the hardware supplied by the manufacturer. All-thread bar shall be attached between the transition and the equipment base. If required, the installer may place a center-hole ram over the continuously threaded bar to preload pile in tension as specified. The mounting nuts shall then be tightened securely to maintain the preload. In less critical applications the wall plate nuts may be tightened to a torque specified by the engineer or owner.

STEP 5 – Clean up:

Remove all scrap and other construction debris from the site. Remove all tools and equipment, clean them and store them. Any disturbed soils in the area of work shall be restored to the dimensions and condition specified by the engineer and/or owner. Dispose of all construction debris in a safe and legal manner.

End Procedure

TORQUE ANCHOR™ INSTALLATION RECORD			
Job Name:		Date:	
Job Address:		Placement Number: (Show On Sketch)	
Installing Crew:			
Torque Motor Make:	Model No:	Torque Conversion: "K" =	Maximum Motor Output: ft-lb
Press. Gauge Make: Max psi =		Strain Ga. Make: Max. Torque =	
Motor Back Pressure = psi	Machine Motor is Mounted to:		
ECP Torque Anchor™ Lead Designation:		Plate Sizes: 1. 2. 3. 4. 5. Shaft Size: ☐ Sq. ☐ Tubular	

Depth From Grade To Tip (ft)	Δ Pressure (psi)	Torque (ft-lb)	Depth From Grade To Tip (ft)	Δ Pressure (psi)	Torque (ft-lb)
1			21		
2			22		
3			23		
4			24		
5			25		
6			26		
7			27		
8			28		
9			29		
10			30		
11			31		
12			32		
13			33		
14			34		
15			35		
16			36		
17			37		
18			38		
19			39		
20			40		

NOTES:

Field Test Procedures for Static Axial Compression and Tensile Loads

Many projects require field testing to verify capacity, in other cases a field test can provide valuable information. Not only will the load test verify that the anchor or pile has achieved the capacity requirement, a field load test on the job site can provide a precise *Soil Efficiency Factor*, "k", for the particular shaft configuration being installed at this specific site.

In the utility industry, guy anchors do not have to meet such stringent requirements as permanent structural supports. In general, the amount of creep allowed in guy wire applications is typically four to six inches. When testing support for permanent structures, a factor of safety of 2.0 is most commonly accepted by engineers for building foundations, structural supports and other permanent anchorages such as retaining walls. The testing procedures are the same, whether the maximum movement of the anchor of four inches is allowed for guy applications or the ECP recommended allowable maximum of one inch of movement for permanent structural support applications.

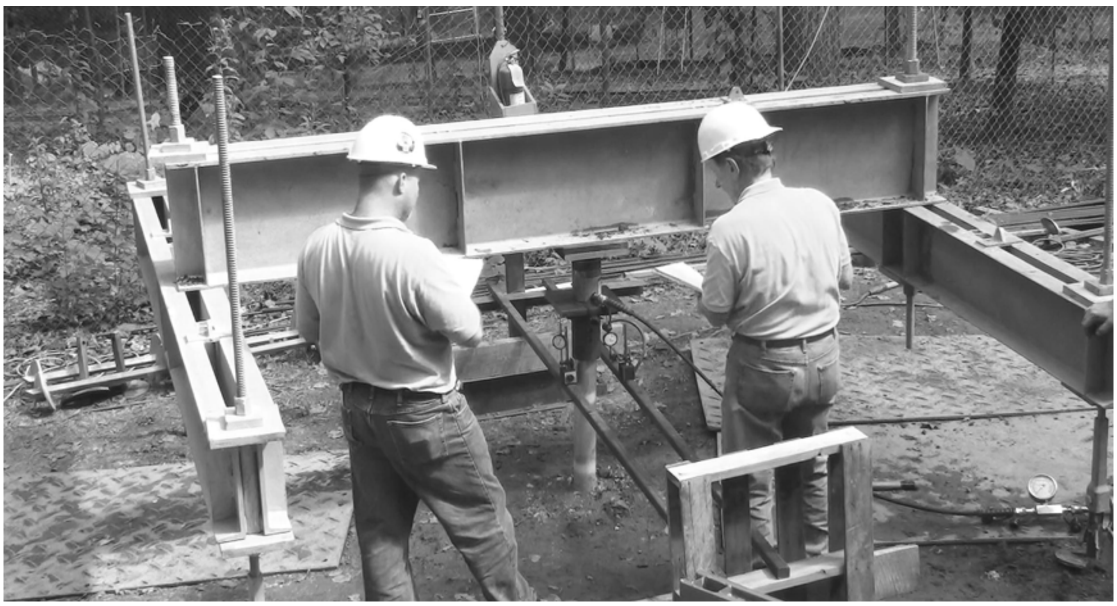
In this section the test procedures closely conform to ASTM D1143 and D3689 specifications.

It is recommended that any field load test for compressive bearing or tension anchor resistance be conducted under the supervision of a Registered Professional Engineer.

The increments and failure criteria provided below in our *"Basic Procedure for Quick Tests"* outlines are conservative and designed for tests on supports for permanent buildings and retaining walls.

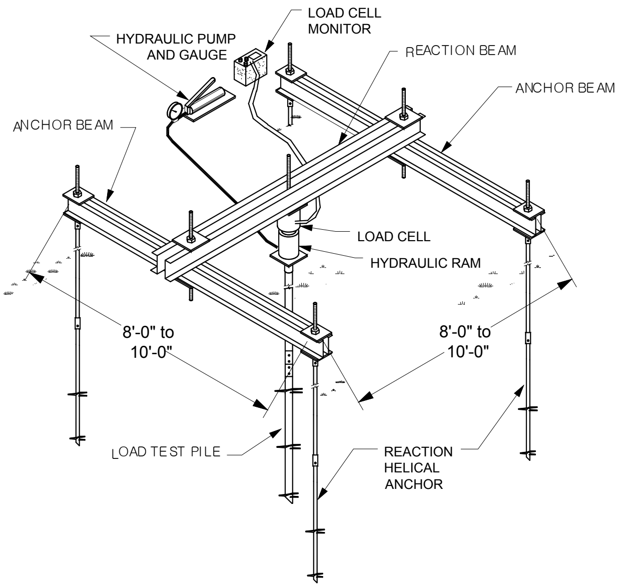
When determining acceptable criteria for guy wire anchorage or for other temporary anchorages, the failure criterion could differ from the test procedures presented here because significantly more creep is usually acceptable in guy anchor applications. For this reason, the engineer in charge should be consulted to modify the test procedure, the load increments, time intervals, measurement procedures, and the acceptable ultimate deflection that is consistent with the specific project and load conditions. If the result of load testing suggests less than the ultimate load requirement has been achieved, the responsible engineer may choose to adjust the product spacing and/or increase the depth of anchor installation and/or modify the projected helical plate area on the shaft in order to achieve a higher capacity and/or the desired factor of safety and acceptable shaft deflection.

The first procedural outline is based closely on the ASTM D1143 and D3689 testing procedures. The "Quick Test" procedure outlined below will more quickly produce an estimate of actual anchor performance on the job site. This load test will provide a more accurate ultimate load capacity than by relying only upon the *Soil Efficiency Factor*, "k" of the shaft as it penetrates the soil.



Basic Procedure for Quick Tension or Compression Tests

1. Determine the depth to the target stratum of soil from the geotechnical site investigation report that includes boring logs. Use this data to select a pile design capacity, ultimate capacity and estimate the installation torque at the target stratum and depth.
2. Set the spacing and install the four reaction piles at the test site. The recommended spacing between the test pile and the reaction piles is 5D where D = diameter of the largest helical plate.
3. Install the test helical product pile at the center between the reaction piles to the target depth and torque resistance.
4. Mount the two anchor beams on the four reaction piles and the reaction beam between the anchor beams and level.
5. Install a load cell (or certified pressure gauge) and hydraulic ram. The center-hole load ram must be mounted below the reaction beam for a bearing (compression) test and above the reaction beam for an anchor (tension) test.
6. Set the deflection measuring devices. Deflection measuring devices can include dial gauges (accuracy to 0.001") with minimum travel of one inch greater than the acceptable deflection mounted on a reference beam, a transit level surveying system, or other types of devices as may be specified by the Engineer.
7. Apply a small seating/alignment load, usually 5% of the ultimate load. Hold the seating load constant for a minimum of four minutes or until no further displacement is measured.



8. Set the deflection measuring device(s) to zero in preparation to starting the test.
9. Apply the first load increment of 5% of the ultimate load and hold that load constant for a minimum of four minutes to a maximum of 15 minutes. Monitor the incremental deflection (Δd) at intervals of 30 sec., 1, 2, and 4 minutes (per the "quick" test procedure of ASTM) and at longer intervals of 8 and 15 minutes when permitted. The monitoring may be stopped after 4 or 15 minutes as long as the rate of deflection is less than 0.002" per minute. If Δd (at 15 minutes) < 0.330", proceed to the next 5% load increment and repeat Step 9 until the ultimate load is reached or failure occurs by excessive deflection (vertical deformation).
10. Once the maximum loading condition is reached, unloading commences with two to five unloading decrements that are approximately equal. Hold each decrement for a minimum of four minutes to a maximum of 15 minutes recording the movement at each decrement. A frequently used failure criteria for permanent support of physical structures is "d" > 1.0" to define the ultimate acceptable load with a permanent deflection of "d" < 0.5" after unloading.

A failure criterion is often different than outlined in this typical procedure. The failure criteria should be reviewed and established by the project engineer prior to testing. He can provide project specific test acceptance conditions for the installation. Acceptance criteria are sometimes quite different for applications such as guy wire anchorage and for temporary tension anchors. Discuss test procedures with the Engineer of Record on the project.

A plot of load versus pile deflection "d" is often prepared after testing to determine the acceptable ultimate and working load capacities of the anchor, and for review of the actual performance of the helical pile or anchor in the soil under changing load conditions.

End Test Procedure

FIELD LOAD TEST REPORT

PROJECT DATA	Load Test Log No. of	Date:	Zip Code:
	Project No.	Address:	
	Project Name:		
	Load Type: (Compression, Tension or Lateral)		
	Project Ultimate Load:	Project Working Load:	
PRODUCT TESTED	Helical Product No:	Shaft Size:	
	Part No.	Part No.	
	Part No.	Part No.	
LOAD TEST EQUIPMENT INFORMATION	Load Test Cylinder Capacity:	Effective Cylinder Area:	
	Manufacturer:	Cylinder Part Number:	

Test Load Increment Number	Load Force (lbs)	Hydr. Press. (psi)	Load Cell Reading	Initial Dial Reading	Instrument Reading or Dial Gauge Reading (.001 in.)					
					30 sec.	1 min.	2 min.	4 min.	8 min.	15 min.
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

FAILURE LOAD lbs.	**MODE OF FAILURE:**
COMMENTS:	

NOTES:

ECP Helical Torque Anchors™

Design Examples

- Heavy Weight New Construction
- Light Weight New Construction
- Basement Wall Tieback Anchors
- Retaining Wall Tieback Anchors
- Foundation Restoration
- Motor Output Torque
- Ultimate Capacity from Field Data

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Table of Contents

Chapter 5 - ECP Torque Anchors™ Design Examples

Design Example 1 – Heavy Weight New Construction – Cohesionless Soil

Structural Details:

- New Building – 2 story house with basement
- Estimated weight 3,700 lb/ft
- Working load on foundation piles – 30,000 lb
- Top of pile to be 12" above the soil surface
- Soil data:
  6 feet of sandy clay fill (CL), stiff
  Density = 110 pcf
  30 feet of medium grained, well graded sand (SW), medium dense, SPT "N" = 22
  Density = 120 pcf $\Phi = 32^0$
  Water table = 14 ft
  Recommended target depth = 18 ft.

Torque Anchor™ Design:

1. Select the proper capacity equation and collect the known information.

The target soil on the site is cohesionless so Equation 1b from Chapter 1 is used:

$\mathbf{P_u = \Sigma A_H (q\, N_q)}$ Where:

P_w = 30,000 lb
FS = Factor of Safety = 2.0

$\mathbf{P_u}$ = P_w x FS = 30,000 lb x 2.0 = **60,000 lb**.

$\mathbf{h_{mid}}$ **= 18 ft**.
(Use the designer's target depth of 18 ft. This is the measurement from the surface to midway between the helical plates.)

q = 1,852 lb/ft^2
= (110 lb/ft^3 x 6 ft) + (120 lb/ft^3 x 8 ft) + (120 – 62) lb/ft^3 x 4 ft) = 1,852 lb/ft^2

$\mathbf{N_q}$ **= 24** (Use "N" = 22 - Chapter 1 - Table 7)

Rearrange Equation 1b to solve for the required helical plate area.

$\mathbf{\Sigma A_H = P_u / (q\, N_q)}$

ΣA_H = 60,000 lb / 1,852 lb/ft^2 x 24

$\mathbf{\Sigma A_H = 1.35\ ft^2}$

2. Select the ECP Helical Torque Anchor™ suitable to support the load.

Referring to Chapter 1, Table 2 the 2-7/8" diameter x 0.276 wall thickness standard tubular pile shaft is selected as most economical for this application. Our project requires ultimate capacity of 60,000 pounds of compressive strength. The selected pile shaft has a *Compressive Load Limit* of 100,000 pounds and a *Useable Torsional Strength* of 9,000 ft-lbs.

Referring to Chapter 1, Table 10 the combination of helical plates is selected from the row opposite the 2-7/8" shaft size. At least 1.35 ft^2 of bearing area is needed to support an ultimate capacity of 60,000 pounds. Viewing the product data table on Chapter 1 – Page 9, one can see that the **TAF-288-84 8-10-12** is a good fit.

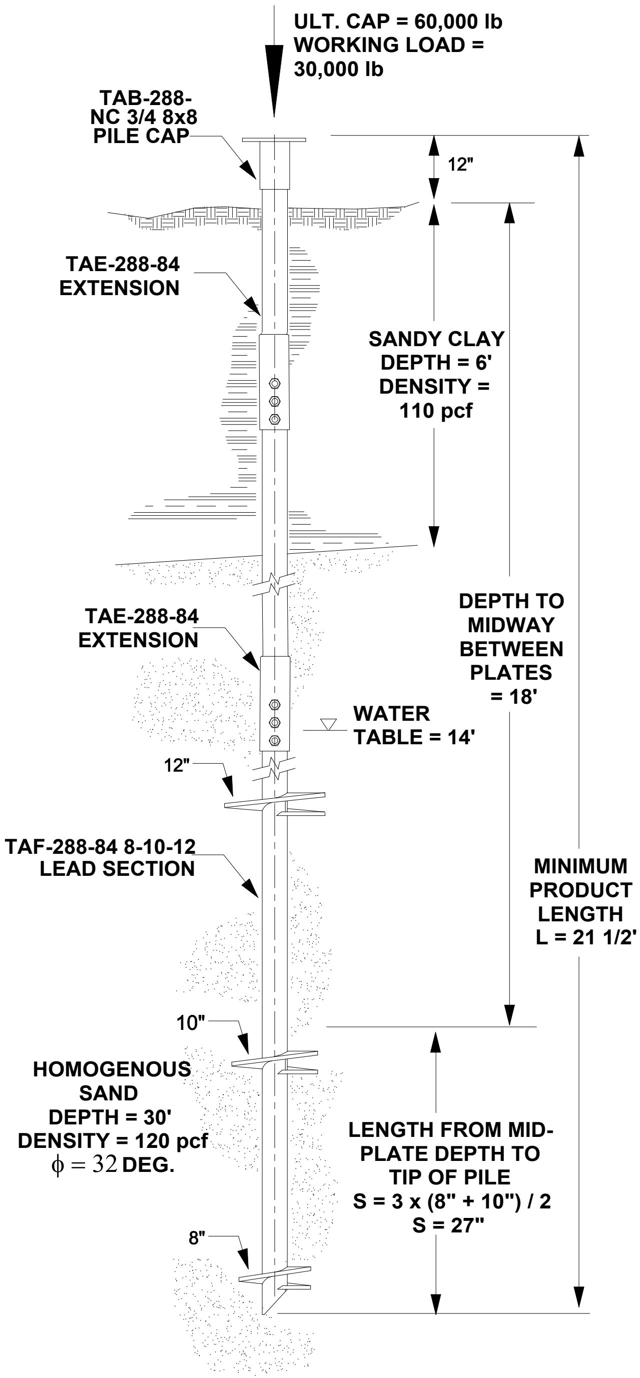


Figure 1. Design Example 1 & 2

An alternate way to select the product most suitable is to use Table 10 in Chapter 1.

Table 10.	Projected Areas* of Helical Torque Anchor™ Plates					
Helical Plate	**6" Dia.**	**8" Dia.**	**10" Dia.**	**12" Dia.**	**14" Dia.**	**16" Dia.**
Shaft	**Projected Area – ft²**					
1-1/2" Sq.	0.181	0.333	0.530	0.770	1.053	1.381
1-3/4" Sq.	0.175	0.328	0.524	0.764	1.048	1.375
2" Sq.	0.168	0.321	0.518	0.758	1.041	1.396
2-7/8" Dia	0.15[illegible]	**0.304**	**0.500**	**0.740**	1.024	1.351
3-1/2" Dia	0.130	0.282	0.478	0.719	1.002	1.329
4-1/2" Dia	0.086	0.239	0.435	0.675	0.959	1.286

Select the combination of 8", 10", and 12" diameter plates on the 2-7/8" diameter tubular shaft.

ΣA_H = 0.304 + 0.500 + 0.740 = **1.544 ft²**

ΣA_H = **1.54 ft²** > 1.35 ft²

This plate combination provides a total area of 1.54 ft², which exceeds the required plate area of 1.35 ft², arrived at from Equation 2b.

Designation for the selected Torque Anchor™ configuration is found on Chapter 1 – Page 7.

TAF-288-84 08-10-12

3. Installation Torque: Equation 2 in Chapter 1 calculates the estimated installation torque.

T = P_u / k, Where,

P_u = 60,000 lb. (30,000 Working Load x 2.0)

K = 9 (Chapter 1 - Table 12)

T = 60,000 lb / 9 ft^{-1}

T = 6,700 ft-lb

4. Torque Anchor™ Capacity Verification: A review of Table 2 in Chapter 1 indicates that the 2-7/8" diameter Torque Anchor™ has a *Useable Torsional Strength* of 9,000 ft-lb. The torque requirement of 6,700 ft-lb is 26% below the torsional limit of the shaft. The selection will work for this application based upon the soil report stating that the soil is sandy clay fill and homogenous sand with no mention of rocks, debris or other obstructions. A review of Table 11 in Chapter 1 shows that three 3/8" thick helical plates have a mechanical ultimate capacity of 120,000 pounds (40,000 lb x 3), which is double our requirement for this installation, so the mechanical capacity of the pile assembly exceeds the project requirements.

5. Installed Product Length. The installed length required to accomplish this design is a summation of all the lengths given and to be determined here.

A. The pile cap is placed **1 ft.** above grade

B. h_{mid} = **18 ft.** (Specified by engineer)

C. Calculate length from h_{mid} (mid-plate) to pile tip (Recall that the helical plates are spaced at three times the diameter of the nearest lower plate.)

h_{tip} = [(3 x 8" dia)+(3 x 10" dia)] / 2 = 27"

h_{tip} = 2-1/2 ft (Round up to 30".)

L = 1 ft. (Above grade) + 18 ft. + 2-1/2 ft =

L = 21-1/2 feet (Total shaft length)

6. Torque Anchor™ Specifications:

The specified Torque Anchor™ assembly will consist of the following:

- **TAF-288-84 08-10-12** This is a 2-7/8" diameter standard tubular lead, having a length of 7 feet long, with an 8", a 10", and a 12" diameter 3/8" thick plate on the shaft.
- **TAE-288-84** Extension, which is nominal 7 feet long and includes coupling hardware.
- **TAE-288-120** Extension, which is nominal 10 feet long with coupling hardware.
- **TAB-288 NC** Pile Cap for use with the 2-7/8" diameter tubular shaft in compression loading. Pile Cap has a 3/4"x8"x8" bearing plate.
- The total length of the assembled products from above is 24 feet long. The Torque Anchors™ shall be installed to minimum depth of 21-1/2 feet at the locations designated on the plan and must develop a sufficient compressive strength as determined by the **minimum average** installation torque of 7,100 ft-lb at this specified target depth of 21-1/2 feet or lower.
- If 7,100 ft-lb is not achieved before reaching 24 feet, then additional extensions may be required.

End Design Example 1

Design Example 1A – Heavy Weight New Construction – *Quick*-Solve™ Design Method

Design Details:

- Compressive Service Load = 30,000 lbs at each pile. (See Figure 1 in Example 1 above.)
- The soil information about the site indicated 6 feet of stiff sandy clay fill (CL) followed by 30 feet medium dense sand (SP)

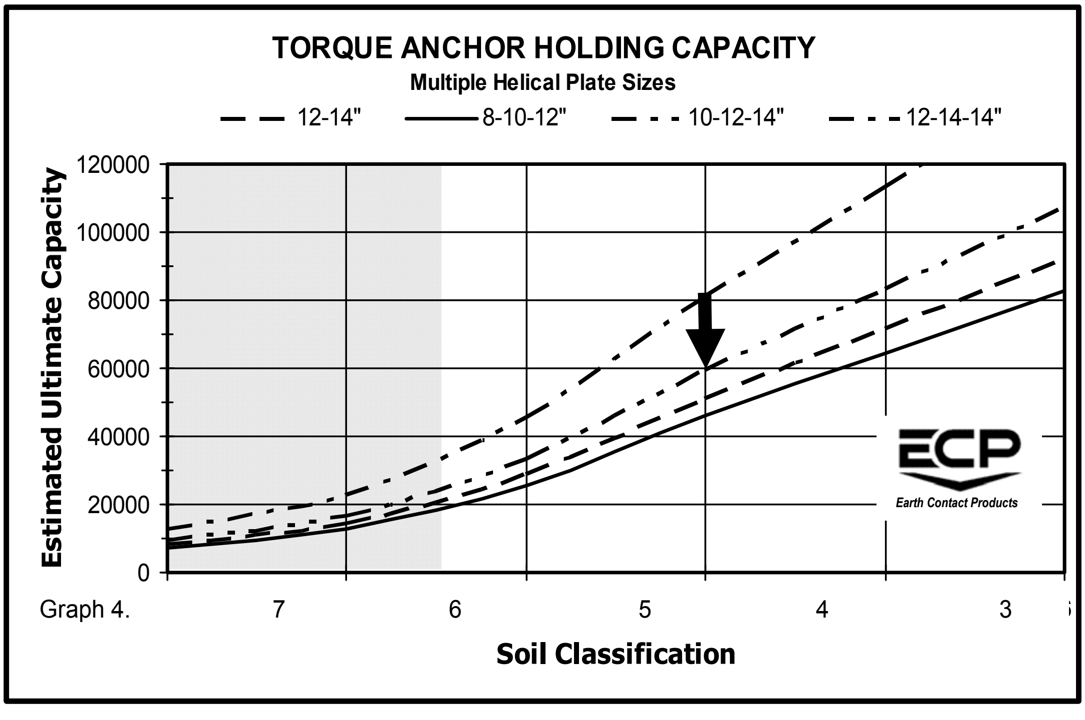
ECP Torque Anchor™ Design: The soil data provides only a rough description of the soil on the site with no SPT, "N", values or any indication of water table. The quick estimating method for designing the compression piles to support the structure is used. The thorough analysis for this project using the bearing capacity equations was demonstrated in Design Example 1 – Page 2. **Comparisons between the results of the two methods will be discussed.**

1. Determine the Soil Class. Referring to the *Soil Classification Table* (Chapter 1 - Table 9) a Soil Class between 4 and 5 is selected based upon the description of the soil.

2. Ultimate Helical Pile Capacity. The engineer provided the Service Load (or working load) on this project based upon his knowledge of the calculated structural weight. Because the pile must have the capability to support more than just the service capacity, a Factor of Safety must be added to the Service Load to determine the Ultimate Capacity of the pile design. In this case, a factor of safety of 2.0 is used to arrive at 60,000 pounds per pile ultimate capacity.

3. Select the proper compression pile from the estimated capacity graphs. Referring to Graph 4 from Chapter 1 (reproduced below), notice that the capacity line for a Torque Anchor™ with 10", 12" and 14" diameter helical plates attached crosses between Soil Class 4 & 5 at 60,000 pounds. The 10", 12" and 14" diameter plate configuration is selected for the quick design.

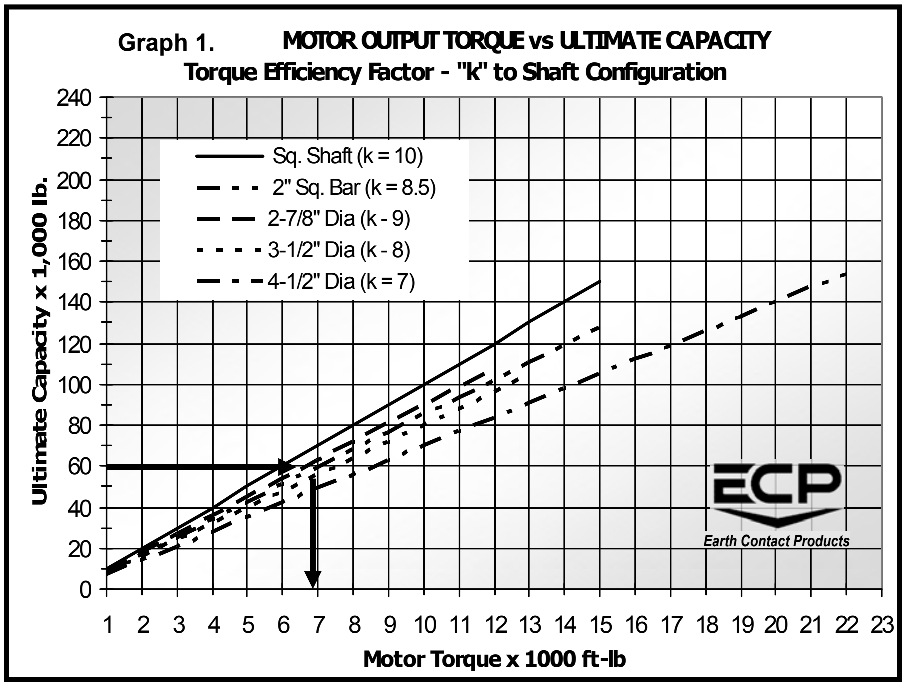
4. Check the Shaft Strength and Torsional Strength to see which shaft is suitable. Refer to Table 2 in Chapter 1 and select the 2-7/8 inch diameter standard tubular shaft, which has sufficient capacity to support the load, and has sufficient torsional shaft strength for installation. The required ultimate capacity for each pile is 60,000 lbs. The 2-7/8 inch standard tubular product, with 0.276 inch wall thickness, has an *Axial Compressive Load Limit* rating of 100,000 pounds and a *Practical Load Limit based on Torsional Strength* of 81,000 pounds assuming a *Useable Torsional Strength* of 9,000 ft-lbs. The 2-7/8 inch diameter, 0.276 inch wall standard helical pile provides suitable torsional capacity and a sufficient practical load limit to exceed the ultimate load requirement of 60,000 pounds.



Graph 4.

The choice is verified.

5. Installation Torque. Use Graph 1 from Chapter 4 or Equation 2 **from Chapter 1 to** determine the installation torque requirement for the selected piles.



Find a capacity of 60,000 pounds on the left side of Graph 1 and move horizontally to where the graph line for 2-7/8 inch diameter shafts intersects with 60,000 pounds. Read down to determine that the motor torque requirement is 6,900 ft-lb.

T = 6,900 ft-lb, min.

Calculating from Equation 2 shows a comparison of results between the formula and the graph.

T = P_u / k, Where,

P_u = 60,000 lb   k = 9 (Table 12)

T = 60,000 lb / 9 ft^{-1} = 6,700 ft-lb

T = 6,700 ft-lb (Not a significant difference)

6. <u>Minimum</u> Embedment Depth. The minimum depth requirement from the surface to the shallowest plate on the pile must be at least six times the diameter of the 14" dia. top helical plate. (Chapter 1, Equation 9)

D = 6 x (14 in /12 in/ft) = ~~7 feet~~ < 18' (specified)

D_{mid} = 18' mid-plate (Specified by engineer)

7. <u>Minimum</u> Required Shaft Length. Helical plates are spaced at three times the diameter of the next lower plate. The selected configuration was 10-12-14. The additional shaft length from h_{mid} (mid-plate) depth of 18 ft. to the pile tip must be determined and added to h_{mid} = 18 feet.

h_{tip} = [(3 x 10" dia)+(3 x 12" dia)] / 2 = 33"

h_{tip} = 2-3/4 ft (Round up to 3 ft)

L_{min} = 18'+ 3' + 1 ft (specified above grade)

L_{min} = 22 feet - Minimum Shaft Length

The least amount of shaft needed for this design is a 7 foot lead, one 7 foot and one 10 foot extension section (Extensions have a coupled length of 6 inches less than nominal length.) This is a combined length of 24 feet.

8. Torque Anchor™ Specifications. The minimum pile assembly shall consist of:

- **TAF-288-84 10-12-14** – 2-7/8" diameter standard tubular shaft with 0.276" wall thickness with a 10", a 12" and a 14" diameter plate on a 7'-0" long shaft,
- **TAE-288-84** & **TAE-288-120** extension sections – 7' & 10' long.

If 7,000 ft-lb is not achieved before reaching 24 feet, then additional extensions may be required.

End of Example 1A

Review of Results of Example 1 & 1A

One can see that the result obtained by the *Quick*-Solve™ analysis clearly suggested a larger pile configuration than predicted by the calculations.

The *Quick*-Solve™ system was designed to be conservative and this example demonstrates this. It is likely that the 10-12-14 pile design of Example 1A will reach the required shaft torque at a shallower depth than the 8-10-12 pile. In this case, the engineer may require the pile terminate at least 22 feet below grade to meet specifications. It is possible that the 10-12-14 may over torque the shaft. If this is the case, with the engineer's permission, you could cut off the 10 inch plate.

This type of problem may appear when using incomplete soil data and using the *Torque Anchor™ Capacity Graphs,* but the ability to rapidly obtain a preliminary design is a valuable tool.

Design Example 1B – Heavy Weight New Construction – <u>Weak Soil</u>

In this variation, the same construction load and soil conditions prevail as stated in Design Example 1 with the exception **that five feet of extremely weak soil now exists directly below the surface**.

Additional Design Details:

- The soil data revealed a least five feet of very loose sand fill and very soft clay organic soil near the surface.
- Standard Penetration Test values for this weak layer were reported to be "N" = 1 to 3 blows per foot - Soil Class = 8
- Below 5 feet the soil profile is the same as shown in Design Example 1.

ECP Torque Anchor™ Design: The soil data here suggests that below the initial five feet of very weak soil, the soil profile is similar to the soil in Design Example 1. Referring to Example 1, it can be recalled that the pile configuration required supporting the 60,000 pound ultimate load on pile using an 8-10-12 inch diameter plate configuration. The 2-7/8 inch diameter tubular shaft, with 0.276 inch wall thickness, had a sufficient *Axial Compressive Load Limit* to support the design load and sufficient *Useable Torsional Strength* to install the pile under the soil conditions represented in Design Example 1.

> Knowing that there exists a layer of extremely weak soil near the surface on this site is important information because helical piles have slender shafts and require sufficient lateral soil support against the shaft to prevent shaft buckling under full load. (See Table 9, Chapter 1 - Class 8 soil)

1. Determine the Buckling Strength. Please note that Chapter 1 – Table 2 provides *Axial Compression Load Limits* for helical pile shafts **<u>when the shafts are installed into soil that provides sufficient lateral support along the pile shaft</u>**.

> Testing has suggested that shaft buckling is not an issue when the soil has a SPT value, "N" ≥ 4 blows per foot for <u>tubular shafts</u> and "N" ≥ 5 blows per foot for <u>solid square shafts</u>.

In this design example there exists just under the surface a five foot layer of very weak Class 8 soil consisting of loose sand and soft organic clay. These very weak soils overlay inorganic clay that is able to provide sufficient lateral shaft support for the required load.

> The *Axial Compressive Load Limit* of 100,000 pounds (Table 2 - Chapter 1) **is not valid** when this 2-7/8 inch diameter tubular shaft passes through Class 8 soil with reported SPT values, "N" = 1 to 3 bpf.

Instead of using Table 2 for the compressive load limit on the shaft, <u>one must understand that the weak upper layer of soil is not able to provide sufficient lateral support to the shaft to prevent bucking.</u>

In Chapter 1 - Table 15, ***Conservative Critical Buckling Load Estimates*** (reproduced below) demonstrates this shaft weakness quite clearly for various soil strengths and types. Referring to Table 15 below, it can be seen that the estimated buckling strength for the 2-7/8 inch diameter, 0.276 inch wall standard helical Torque Anchor™ shaft when it passes through soil consisting of very loose sand fill and soft organic clay having SPT values that range from "N" = 1 to 3 blows per foot is only **48,000 pounds**.

This layer of weak soil is not capable of lateral shaft support when a 60,000 pound compressive load is applied. Shaft buckling within the weak upper level soil must be considered.

2. Select a Pile Shaft with Suitable Buckling Strength. The axial ultimate compressive capacity requirement for this project is 60,000 pounds on the pile shaft.

Table 15 Conservative Critical Buckling Load Estimates

Shaft Size	Uniform Soil Condition			
	Organics N ≤ 1	**Very Soft Clay N = 1 - 2**	Soft Clay N = 2 - 4	Loose Sand N = 2 - 4
1-1/2" Sq	13,000 lb	16,000 lb	23,000 lb	19,000 lb
1-3/4" Sq.	19,000 lb	24,000 lb	48,000 lb	28,000 lb
2" Sq.	28,000 lb	35,000 lb	96,000 lb	43,000 lb
2-7/8" Dia x 0.203"	36,000 lb	44,000 lb	62,000 lb	51,000 lb
~~2-7/8" Dia x 0.276"~~	39,000 lb	**~~48,000 lb~~**	69,000 lb	56,000 lb
3-1/2" Dia x 0.300"	~~63,000 lb~~	**78,000 lb**	110,000 lb	90,000 lb
4-1/2" Dia x 0.337"	113,000 lb	139,000 lb	160,000 lb	160,000 lb

The 2-7/8" diameter shaft size selected in Design Example 1 must be changed to a stiffer shaft to be able to successfully pass through the very week upper soil strata without buckling.

A 3-1/2 inch diameter tubular shaft is able to offer more shaft stiffness (also called Moment of Inertia) or resistance to buckling. Referring to Table 15 (previous page); notice the row labeled "3-1/2 inch dia. x 0.300" presents a conservative estimated buckling load capacity of 78,000 pounds for this larger diameter shaft. Because very weak soil exists near the surface in this example, the specified pile shaft diameter must be increased to prevent buckling of the pile shaft as the pile passes through these weak soils.

3. Torque Anchor™ Specifications. The Torque Anchor™ plate configuration remains as originally determined to support the structural load, but the shaft diameter must be increased to the 3-1/2 inch diameter, 0.300 inch wall tubular shaft for increased buckling strength:

- **TAF-350-84 08-10-12** Lead Section
- **TAE-350-84** Extension Section
- **TAE-350-120** Extension Section
- **TAB-350 NC** Pile Cap that fits over the 3-1/2" tubular shaft and has a 3/4" x 8" x 8" bearing plate.

4. Installation Torque. Please remember that a larger diameter tubular shaft will pass through the soil less efficiently due to friction with the soil. This effect of soil friction on different tubular shaft diameters was fully discussed at the beginning of Chapter 4.

As a result, when the design requires a change in shaft size, the installation torque requirement must be recalculated. The shaft friction is higher for a larger diameter shaft; therefore, the Soil Efficiency Factor ("k") will be lower.

A check of Table 1 in Chapter 4 shows that the 3-1/2 inch diameter shaft has a recommended efficiency factor, "k" = 8 as compared to "k" of 9 for a 2-7/8 inch diameter shaft used for the earlier design.

Equation 2 in Chapter 1 is used to calculate a new installation torque requirement for the larger 3-1/2 inch diameter pile shaft.

$\mathbf{T = P_u / k}$, Where,

P_u = 60,000 lb

k = 8 (Table 12 – Chapter 1)

$T = 60{,}000 \text{ lb} / 8 \text{ ft}^{-1} = 7{,}500 \text{ ft-lb}$

T = 7,500 ft-lb, minimum

End of Example 1B

Earth Contact Products recommends that a Registered Professional Engineer conduct the evaluation and design of Helical Torque Anchors™ where shaft buckling may occur due to the shaft being installed through weak soil or in cases where the shaft is fully exposed without lateral shaft support.

Review of Results of Example 1 & 1B

It is important to remember that buckling is an issue when pile shafts pass through weak soils anywhere along the length of the shaft. The key is to watch SPT - "N" values at all soil depths.

Soil strata that are weaker than "N" < 5 blows per foot for solid square shaft installations and weaker than "N" < 4 blows per foot for tubular shafts could allow shaft buckling. When such weak soils are reported, please check the critical buckling load in Table 15 to select a shaft diameter suitable for support through the weak soil stratum. This could require a larger shaft diameter be used.

Exposed Pile Shafts: When a pile shaft extends above the ground, (in the air or in water), this portion of the pile shaft has <u>no lateral support</u>; please refer to Graph 8 - Chapter 1. Here you can estimate the critical buckling load for various shaft configurations relative to the amount of exposed shaft in the air or water. (Unsupported column height)

Technical Design Assistance

Earth Contact Products, LLC. has a knowledgeable staff that stands ready to help you with understanding how to prepare preliminary designs, installation procedures, load testing, and documentation of each placement when using ECP Torque Anchors™. If you have questions or require engineering assistance in evaluating, designing, and/or specifying Earth Contact Products, please call us at 913 393-0007, Fax at 913 393-0008.

Design Example 2 – Light Weight New Construction – Cohesive Soil

Structural Details:

- New building – single story brick veneer house on monolithic concrete slab on grade
- The estimated weight is 1,269 lb/lineal ft on the 18” tall steel reinforced perimeter beam
- The client wants Torque Anchors™ on the perimeter of the structure because of lot fill.
- Top of shaft to be one foot below soil surface
- Soil data:
  4 feet of poorly compacted fill – “N” = 5
  6 feet of silty clay (CH) – “N” = 5 to 7
  15 feet of very stiff clay (CL) “N”= 25 to 30 bpf

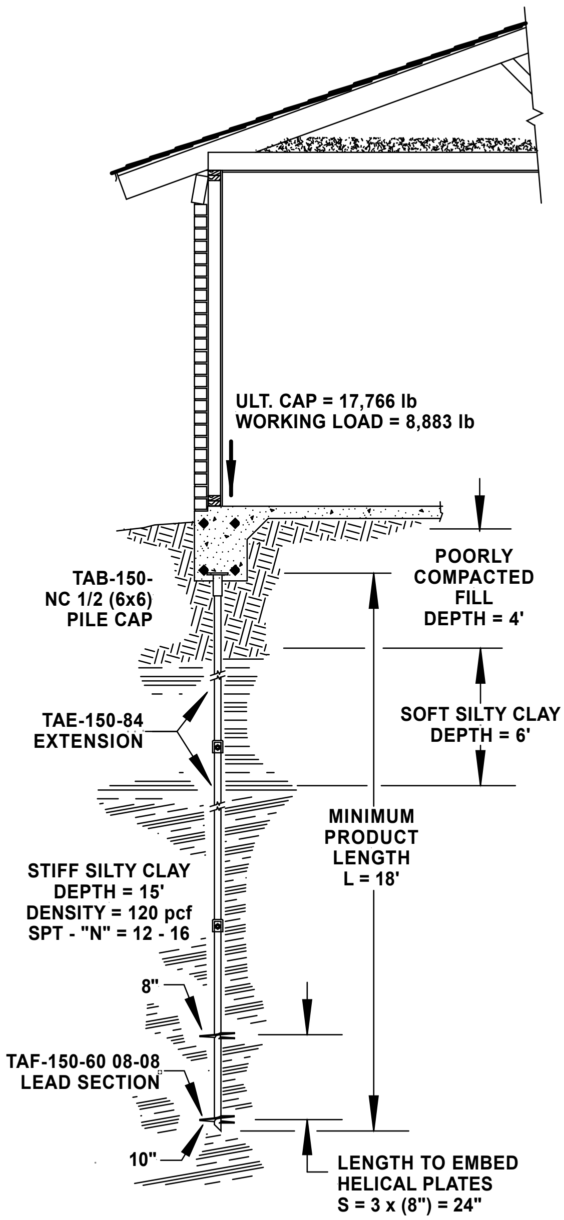


Figure 8. Design Example 2

Torque Anchor™ Design:

1. Select suitable pile spacing and working load from the description of the foundation beam. Use Equation 3 from Chapter 1 to determine the working load on the helical pile. First refer to Graph 2 - Chapter 6 to determine recommended spacing for an 18” beam. Choose **“X” = 7 ft**

$\mathbf{P_u = (“X”) \times (w) \times (FS)}$:

Where,
P_u = Ultimate Capacity of Torque Anchor™ (lb)
w = Foundation Load (lb/ft)
= 1,269 lb/lineal foot
FS = 2.0
“X” = Suggested Product Spacing = 7 ft

$\mathbf{P_u} =$ 1,269 lb/ft x 7 ft x 2.0

$\mathbf{P_u} =$ 17,766 lb (Use 18,000 lb.)

$\mathbf{P_u = 18{,}000\ lb}$

2. Select the proper ultimate capacity equation and collect the known information. Because the soil on the site is cohesive (clay soil), Equation 1a from Chapter 1 is used:

$\mathbf{\Sigma A_H = P_u / (9c)}$ Where:
P_u = 18,000 lb
c = 3,400 lb/ft^2 (Assume “N” = 27 bpf)

$\mathbf{\Sigma A_H} = P_u / (9 \times 3{,}400)$

$\mathbf{\Sigma A_H} =$ 18,000 lb / 30,600 lb/ft^2

$\mathbf{\Sigma A_H = 0.59\ ft^2}$

3. Select the ECP Helical Torque Anchor™ suitable to support the load. The requirement states an ultimate compressive capacity of 18,000 lb. Referring to Table 2 in Chapter 1, the 1-1/2” solid square pile shaft is an economical choice because it has an *Axial Compressive Load Limit* rating of 70,000 pounds and a *Useable Torsional Strength* of 7,000 ft-lbs.

Looking at the product tables following Table 2 one can easily see on Chapter 1 – Page 6 that an 8” and a 10” diameter helical plate on a 1-1/2 inch solid square shaft has a plate area of 0.87 ft^2. The designation is TAF-150-60 08-10.

Referring to Table 10 from Chapter 1 (next page), we can manually select a combination of plates along the row to the right of the 1-1/2” square shaft size. At least 0.59 ft^2 of bearing area is required according to Step 2.

The combination of 8 & 10 inch diameter plates on the 1-1/2” solid square shaft is selected.

$\mathbf{\Sigma A_H} = 0.333 + 0.533 = \mathbf{0.87\ ft^2} > 0.59\ ft^2$ **- O.K.**

This plate combination provides a total area of 0.87 ft^2, which exceeds the required 0.59 ft^2.

Table 10.	Projected Areas* of Helical Torque Anchor™ Plates					
Helical Plate	**6" Dia.**	**8" Dia.**	**10" Dia.**	**12" Dia.**	**14" Dia.**	**16" Dia.**
Shaft	**Projected Area – ft^2**					
1-1/2" Sq.	0.181	0.333	0.530	0.770	1.053	1.381
1-3/4" Sq.	0.175	0.328	0.524	0.764	1.048	1.375
2" Sq.	0.168	0.321	0.518	0.758	1.041	1.396
2-7/8" Dia	0.151	0.304	0.500	0.740	1.024	1.351
3-1/2" Dia	0.130	0.282	0.478	0.719	1.002	1.329
4-1/2" Dia	0.086	0.239	0.435	0.675	0.959	1.286

The designation for the standard length Torque Anchor™ product that was selected by either method is: **TAF-150-60 08-10**

As an alternate, a single 12" diameter plate could be selected with a projected area of 0.77 ft^2. (Two 8" diameter plates also have sufficient area of 0.67 ft^2, but this configuration is a special order product.)

4. Installation Torque: Equation 2 in Chapter 1 gives an estimation of the required installation shaft torsion. It is determined as follows:

$\mathbf{T = P_u / k}$ (Equation 2)

Where, P_u = 18,000 lb

k = 10 (Table 12 – Chapter 1)

T = 18,000 lb / 10 ft^{-1}

T = 1,800 ft-lb

5. Torque Anchor™ Capacity Verification: A review of Table 2 in Chapter 1 indicates that the 1-1/2" solid square bar Torque Anchor™ has a *Useable Torsional Strength* of 7,000 ft-lb, which is nearly four times the installation torque required for this project. There was no mention of rocks, debris or other obstructions in the project information. Therefore this is excellent product for this project. Table 11 in Chapter 1 shows the *Ultimate Mechanical Helical Plate Capacity* of 80,000 pounds (40,000 lb x 2) for the two 3/8" thick helical plates. The mechanical capacity of the selected pile configuration is more than adequate.

6. Installed Product Length. The stiff silty clay has been targeted as the soil stratum where the helical plates will be founded. A depth of 18 feet was specified in order to locate the plates below the weaker soil layers. This depth places the plates midway into the very stiff clay stratum. The installed length required to accomplish this design depth is specified = 18 ft

L = 18 ft

7. Torque Anchor™ Specifications: The Torque Anchor™ assembly is specified from the standard products listed near the beginning of Chapter 1:

- **TAF-150-60 08-10**, which is a 1-1/2" solid square bar product on a standard 5 foot long shaft, with 8" & 10" diameter, 3/8" thick helical plates
- **TAE-150-84** Extension, which is nominally 7 feet long, but the coupling overlaps 3 inches providing an effective length of 6'-9" The extension includes coupling hardware. <u>Two extensions are required</u> and equal 13-1/2 feet.
- **TAB-150 NC** Pile Cap that fits over the 1-1/2" square bar and has a 1/2" x 6" x 6" bearing plate.

The total length of the assembled products from above is 18-1/2 feet long.

Placements shall be 7 feet on center along the perimeter grade beam

An average installation torque of 1,800 ft-lb or more must occur at the target depth of 18 feet.

<u>It is recommended that additional extension be on hand in case the shaft torque requirement is not achieved at 18 1/2 feet</u>.

End Design Example 2

"Designed and Engineered To Perform"

Technical Design Assistance

Earth Contact Products, LLC. has a knowledgeable staff that stands ready to help you with understanding how to prepare preliminary designs, installation procedures, load testing, and documentation of each placement when using ECP Torque Anchors™. If you have questions or require engineering assistance in evaluating, designing, and/or specifying Earth Contact Products, please call us at 913 393-0007, Fax at 913 393-0008.

Design Example 2A – Light Weight New Construction – *Quick*-Solve™ Design Method

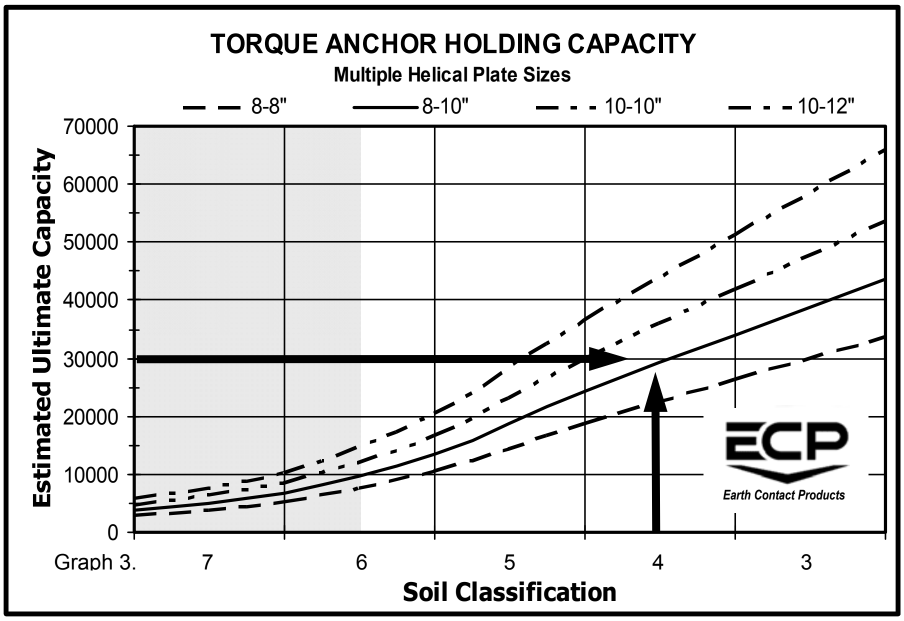
Design Details from Design Example 2:

- The ultimate capacity on each pile spaced at 7 feet on center is 18,000 pounds
- Top of shaft to be one foot below soil surface
- Soil data:
  4 feet of poorly compacted fill followed by 6 feet of silty clay (CH) over 15 feet of very stiff clay (CL)

ECP Torque Anchor™ Design: Because this is a compressive load application and there exists some poorly compacted fill, the Soil Class selection of must be conservative.

1. Determine the Soil Class: Referring to the Soil Classification Table (Table 9 – Chapter 1) and recalling that the soil on the site is very stiff clay, Soil Class 4 is selected. The poorly compacted fill should not be a problem at this light loading as long as the helical plates are installed into the underlying very stiff clay.

2. Select the proper compression pile configuration from the estimated capacity graphs: Referring to Graph 3 from Chapter 1 (reproduced right), notice that the capacity line for an anchor with an 8 & 10 diameter helical plates attached crosses the midpoint of Soil Class 4 at 30,000 lb. The 8–10 inch diameter plate configuration is selected for the design.
(Two 8" diameter plates also have sufficient capacity of 22,500 lb, but the configuration is a special order product.)



Graph 3.

3. Check the Shaft Strength and Torsional Strength to select a suitable shaft. Refer to Table 2 in Chapter 1 to locate a shaft with a higher than 18,000 lb. *Axial Compression Load Limit* and a sufficient *Useable Torsional Strength.* Select the 1-1/2 inch solid square shaft with an *Axial Compression Load Limit* rating of 70,000 pounds based upon an installation torsional limit of 7,000 ft-lbs. The selected pile shaft provides suitable *Useable Torsional Strength* and a sufficient practical load limit to exceed all of the design requirements. Table 9 in Chapter 1 shows an *Ultimate Mechanical Helical Plate Capacity* of 80,000 pounds (40,000 lb x 2) for two 3/8" thick helical plates on the shaft. The pile configuration is TAF-150-60 08-10.

4. Installation Torque: Use Graph 1 from Chapter 4; (Please see on next page) or can be determined from Equation 2 from Chapter 1 to determine the installation torque requirement for these piles. Find 18,000 lb ultimate capacity value on the left side of Graph 1 and locate the intersection with the graph line for a solid square shaft. Then read down to determine the motor torque requirement of 1,800 ft-lb. **T = 1,800 ft-lb, minimum**

To calculate the installation torque, use Equation 2. (Shown here for comparison)

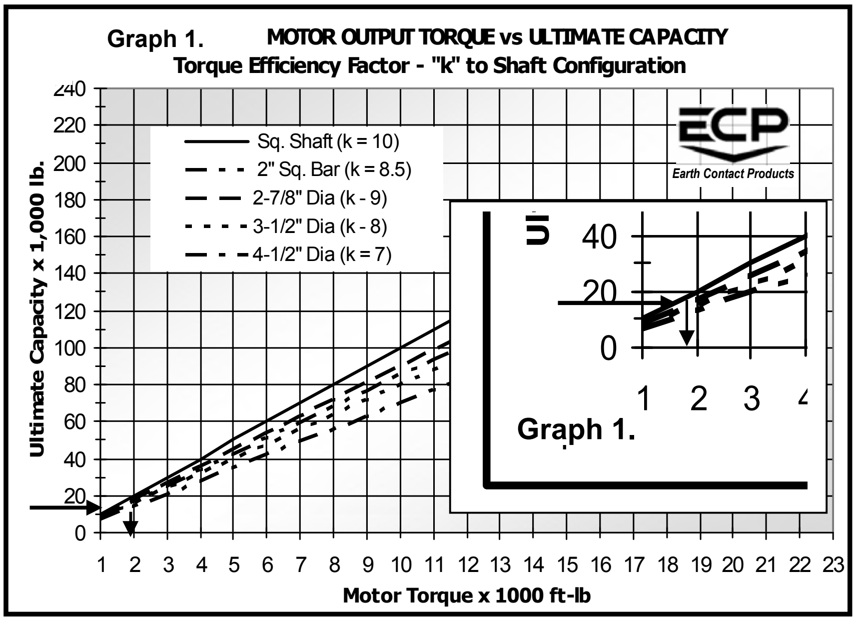
$T = P_u / k$, Where,

P_u = 18,000 lb k = 10 (Table 12)

T = 18,000 lb / 10 ft^{-1} = 1,800 ft-lb

T = 1,800 ft-lb, minimum – O.K.

5. Minimum Embedment Depth. In Chapter 1 of the manual, there is a discussion about helical products being deep foundation elements. The formulas presented herein are based upon "deep foundation theory". For the results of the calculations, tables and graphs to be accurate, there must be sufficient soil burden over the anchor or pile. Deep foundation theory dictates that the minimum depth from the surface to the shallowest plate must exceed six times the largest plate diameter.



Minimum Embedment Depth:

$D = 6 \times d_{largest\ plate}$

(* The minimum depth equation cannot be used here.)

> ***Notice:** The soil information provided on this project stated soft soil existed directly below the surface before reaching the targeted stiff to very stiff clay below 10 feet. **The calculated "Minimum Vertical Depth" for this design would be 5 ft. This is invalid. The pile must be at 18 feet as specified by the engineer.**

$D_{(Engr\ Reqd)}$ = Minimum Vertical Depth = 18 ft

6. Minimum Required Shaft Length - The least amount of shaft required to meet the design requirement is a 5 foot lead section, a 5 foot extension and a 10 foot extension.

Additional extensions could be required if the torsion requirement of 1,800 ft-lb is not achieved at the 18 ft depth.

7. Torque Anchor™ Selection:

- **TAF-150-60 08-10** – 1-1/2 inch solid square shaft that has 8" & 10" diameter plates on a 5'-0" long shaft,
- **TAE-150-60 & TAE-150-120** extension – 5 foot extension section & hardware, (4'-9" effective length) and 10 foot extension (9'-9" effective length).
- **TAB-150 NC** Pile Cap that fits over the 1-1/2" square bar and has a 1/2" x 6" x 6" bearing plate.

Total pile length is 19-1/2 feet.

Final Shaft Torque = 1,800 ft-lb, minimum

It recommended having additional extensions on hand should the target shaft torsion of 1,800 ft-lbs not be achieved at 19-1/2 feet shaft depth.

End of Example 2A

Review of Results of Example 2 & 2A

One can see that the result obtained by the *Quick*-Solve™ analysis clearly suggested the same pile design as determined by the calculated analysis. Therefore the TAF-150 08-10 is a valid design and should work well on this project. Recall that the specified depth was 18 feet of shaft that terminated one foot below grade.

*** NOTE:** The *Quick*-Solve™ method for Example 2A is not able to compensate for the fill soil near the surface. Recall that the graphs are based upon capacities of helical piles installed into ***homogeneous soil***, which means that the soil is consistent at all depths. Clearly this is not the case in this example because of the weak upper strata of fill soils. A pile installation deeper than 19 feet might be required to support the load.

Design Example 3 – Basement Wall Tieback Anchor -- Cohesive Soil

Structural Details:

- Cast concrete basement wall is 8 feet tall and 10 inches thick.
- Unknown soil backfill against the wall is 7 feet high
- The only soil information about the site is that there exists inorganic clay (CL), stiff to very stiff – 115 pcf

Torque Anchor™ Design: Because there is so little information about the soil on this project, the designer will have to make judgments about the conditions on the site.

1. Estimate the lateral soil force against the wall: Equation 5 - Chapter 1 is selected because hydrostatic pressure <u>must</u> be assumed to be part of the reason for the damage to the wall.

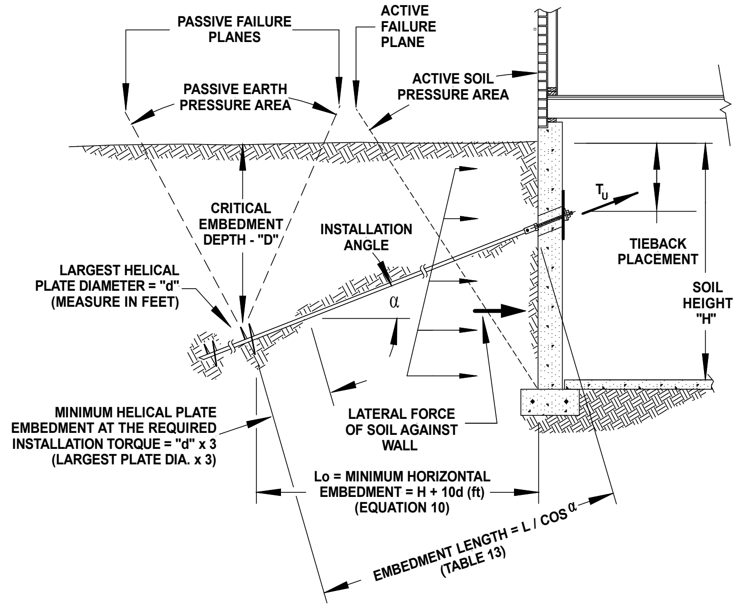


Figure 9. Design Example 3

$\mathbf{P_H = 45 \times (H^2)}$

Where, H = 7 ft

$P_H = 45 \times (49) = 2{,}205$

$\mathbf{P_H = 2{,}205}$ **lb/lineal foot**

2. Ultimate Tieback Capacity: Choose Torque Anchor™ spacing at 5 ft on center as typical for a damaged basement wall of unknown quality of construction. Use Equation 8 - Chapter 1 to determine the Ultimate Capacity on the Torque Anchor™.

$\mathbf{T_u = (P_H) \times (\text{“X”}) \times FS}$, Where:

T_u = Ultimate Tieback Capacity – lb

P_H = Horizontal Soil Force on Wall – lb/lin.ft

FS = Factor of Safety (Typically 2:1 permanent support and 1.5:1 for temporary support)

"X" = Center to Center Spacing of Tiebacks - ft

In this example, the ultimate capacity becomes:

$\mathbf{T_u} = 2{,}205$ lb x 5 ft x 2

$\mathbf{T_u = 22{,}050}$ **lb**

3. Select the proper bearing capacity equation and collect the known information: Because the soil on the site is cohesive, Equation 1a – Chapter 1 is used:

$\mathbf{\Sigma A_H = T_u / (9c)}$,

Where: $\mathbf{T_u = 22{,}050}$ **lb**

$\mathbf{c = 2{,}000}$ **lb/ft²**

(Table 5 - Chapter 1 Stiff to Very Stiff Clay)

$\mathbf{\Sigma A_H} = T_u / (9 \times 2000\ \text{lb/ft}^2)$

$\mathbf{\Sigma A_H} = 22{,}050\ \text{lb} / 18{,}000\ \text{lb/ft}^2$

$\mathbf{\Sigma A_H = 1.23\ ft^2}$

4. Select the ECP Helical Torque Anchor™ configuration suitable for the load: Referring to Table 2 – Chapter 1 choose the 1-1/2" solid square pile shaft. This shaft has an ultimate tensile strength for this job is 22,050 lb and the 1-1/2 inch solid square shaft an *Ultimate Limit Tension Strength* rating of 70,000 pounds and a *Useable Torsional Strength* of 7,000 ft-lbs.

Looking at the product tables following Table 2 one can easily see on Chapter 1 – Page 6 that a 10" and a 12" diameter helical plate on a 1-1/2 inch solid square shaft offer a plate area of 1.30 ft^2. The lead designation is TAF-150-60 10-12.

As an alternate, refer to Table 10 – Chapter 1 (See below) and select a combination of plates in the row opposite the 1-1/2" solid square shaft size that add to at least 1.23 ft^2 of bearing area. The combination of a 10" and a 12" diameter plate on the 1-1/2" solid square shaft provides a total area of 1.30 ft^2, which exceeds our calculated area requirement of 1.23 ft^2.

The Torque Anchor™ tieback product designation **TAF-150-60 10-12** is selected from the Standard Product Tables for the 1-1/2 inch solid square shaft products on Page 6. This anchor configuration will provide ultimate capacity required for tension support of the wall when spaced along the wall at 5 feet center to center.

Table 10. Projected Areas* of Helical Torque Anchor™ Plates						
Helical Plate	6" Dia.	8" Dia.	10" Dia.	12" Dia.	14" Dia.	16" Dia.
Shaft	Projected Area – ft^2					
1-1/2" Sq.	0.181	0.33[illegible]	**0.530**	**0.770**	1.053	1.381
1-3/4" Sq.	0.175	0.328	0.524	0.764	1.048	1.375
2" Sq.	0.168	0.321	0.518	0.758	1.041	1.396
2-7/8" Dia	0.151	0.304	0.500	0.740	1.024	1.351
3-1/2" Dia	0.130	0.282	0.478	0.719	1.002	1.329
4-1/2" Dia	0.086	0.239	0.435	0.675	0.959	1.286

5. Installation Torque: Use Equation 2 - Chapter 1, or use Graph 6 from Chapter 1 shown in the example above to calculate the installation torque requirement for this anchor.

$T = T_u / k$, Where,

T_u = 22,050 lb

k = 10 (Table 12, below from Chapter 1)

T = 22,050 lb / 10 ft^{-1}

T = 2,200 ft-lb

The torque must be developed for a distance that is long enough to insure that the helical plates are properly embedded and develop the required tension capacity. <u>The torque requirement must be averaged over a distance of at least three times the diameter of the largest plate</u>. The 2,200 ft-lbs must be measured continuously for a <u>minimum</u> distance of 3 feet before terminating the installation. (12" diameter plate x 3)

Table 12. Soil Efficiency Factor "k"		
Torque Anchor™ Type	Typically Encountered Range "k"	Suggested Average Value, "k"
1-1/2" Sq. Bar	9 - 11	**10**
1-3/4" Sq. Bar	9 - 11	10
2" Sq. Bar	8.5 (Compression)	8.5
	10 (Tension)	10
2-7/8" Diameter	8 - 9	9
3-1/2" Diameter	7 - 8	8
4-1/2" Diameter	6 - 7	7

6. Minimum Horizontal Embedment: Determine the *Minimum Embedment Length* from Equation 9 in Chapter 1 or Figure 3 in Chapter 1.

$L_0 = H + (10 \times d_{Largest})$ Where,

H = Height of Soil - (7 ft)

$d_{Largest}$ = Largest Plate Dia. (12 in = 1 ft)

L_0 = 7 ft + (10 x 1 ft) **= 17 feet**

L_0= <u>17 feet</u> Min. Horiz. Embedment

7. Calculate the Critical Depth – D_{cr}:

Use 6 x $d_{Largest\ plate.}$ (Discussed Page 34)

(See *Results for Tieback Design*, next page.)

D_{cr} = 6x1 (ft) = **6 feet.**

8. Select Installation Angle and Determine Product Length: Position the anchors to penetrate the wall at two feet below the soil surface. **(Note: This location is three feet down from top of basement wall.)** In Step 7 above, it was determined that the required Critical Depth, (D_{cr}), is 6 feet, which means that the 12" diameter plate must terminate at an elevation least 4 feet lower than where the anchor shaft penetrated the wall. Select an installation angle of 15^0 and determine the minimum installed product length that will provide the needed extra soil depth requirement of 4 feet above the 12" plate that will insure the needed critical depth. his can be determined as follows:

$L_{15\ deg}$ = 4 ft / sine 15^0 (Table 13, Chapter 1)

$L_{15\ deg}$ = 4 ft / 0.259 = **15-1/2 ft**

The minimum distance from the wall to the 12" plate when installed at a 15^0 downward angle is **15-1/2 feet** to insure meeting the D_{cr} = 6 feet.

Comparing the minimum horizontal embedment length of **17 feet** from Step 6 to the 15-1/2 foot length required for obtaining Critical Depth at 15^0 installation angle; **<u>it is clear that 17 feet of horizontal length of embedment from the wall is the controlling distance</u>**.

There will be an additional length of shaft required to get to the 12 inch diameter plate to the required distance of 17 feet due to the 15^0 downward installation angle of the shaft needed to achieve Critical Depth, (D_{cr}). Here is how to calculate the additional shaft length needed due to the 15^0 downward installation angle.

Use the equation shown on Chapter 1 - Table 13 for a 15^0 downward angle to determine the shaft length to the 12 inch diameter plate.

$L_{15\ deg}$ = [H + (10 $d_{largest}$)] x 1.035

$L_{15\ deg}$ = [7 ft + (10 x 1 ft] x 1.035 = **17.6 feet**

Total Shaft Length Needed: $L_{Total} = L_{15} + L_{Tip}$

Where, $L_{Tip} = 3D_{10"\ dia.}$

L_{Total} = 17.6 ft + (3 x 10")/12"

L_{Total} = 17.6 ft + 2.5 ft = **20.1 ft**

Use: L_{Total} = 20 ft at $\alpha = 15^0$ (Minimum)

Specify required product length by selecting standard product assembled lengths exceeding 20’ long.

8. Torque Anchor™ Specifications: The Torque Anchor™ assembly will consist of products selected from the Standard Product Selection near the beginning of Chapter 1.

- **TAF-150-84 10-12** -- 1-1/2” solid square bar lead section with a 10” and a 12” diameter plate attached to a standard 7’-0” long shaft length.
- **TAE-150-60** extension – 5’ extension bar & hardware are specified for ease of installation in the basement. (4’-9” effective length). Minimum of three 5 foot extensions are required.

The assembled length the Torque Anchor™ tieback assembly is **21-1/4 feet**.

- **TAT-150** – Light Duty Transition that connects from 1-1/2” square anchor bar to a 22” length of continuous threaded rod and includes hardware.
- **PA-LWP** – Stamped steel wall plate that measures 12” x 26”

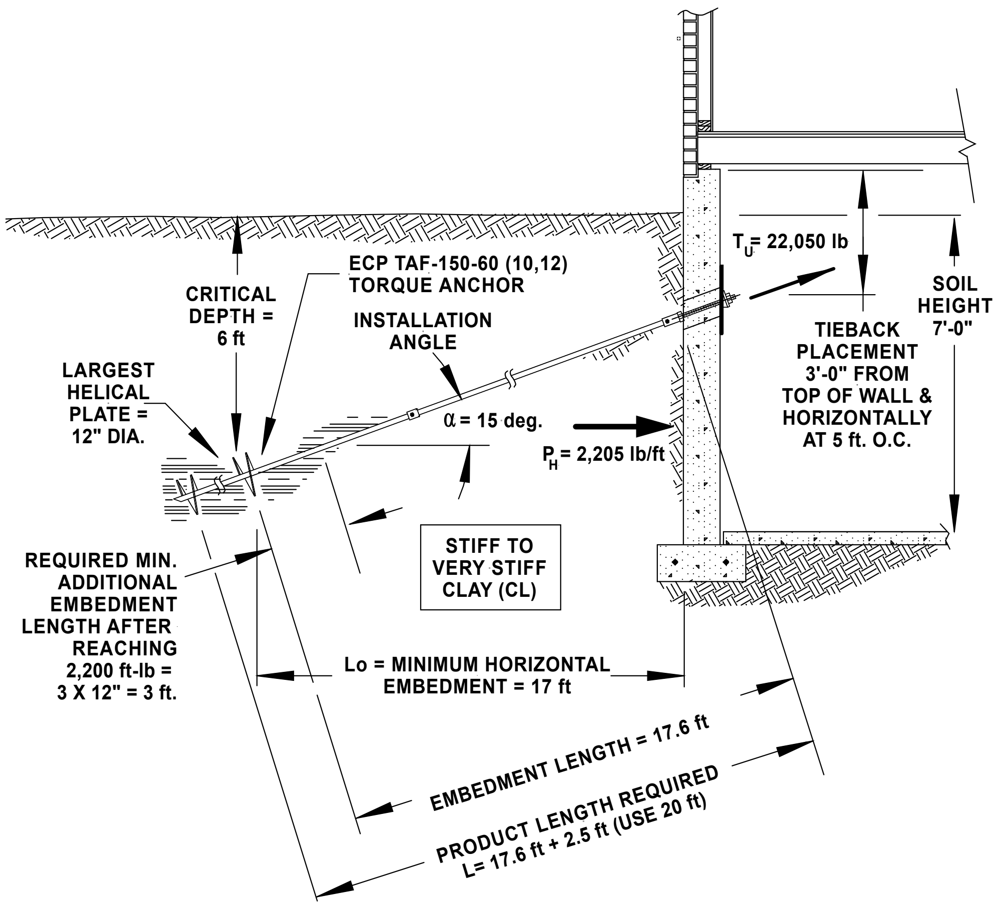
The anchors shall be mounted along the wall on 5 feet on center at a distance of 3 feet from the top of the basement wall. (Two feet below soil level)

The anchors shall be angled down at 15^0. The tieback must be installed to a minimum shaft length of 20 feet

Average installation torque of 2,200 ft-lb or greater is required for a minimum distance of at least 3 feet embedding 17 feet of length of shaft. Otherwise the anchor must be driven deeper using additional extension sections until the torque requirement is satisfied.

The design specifications are shown on the sketch below.

End of Example 3



Results for Tieback Design Example 3.

Design Example 3A – Basement Wall Tieback Anchor – *Quick*-Solve™ Design Method

Mandatory Installation Requirements

Before beginning a complicated basement tieback anchor design like Design Example 3A using the *Quick*-Solve™ design method with only general data from graphs and tables; the following **MANDATORY INSTALLATION REQUIREMENTS MUST ALWAYS BE DEFINED** in the final design before the *Quick*-Solve™ design method will be successful.

Before performing a *Quick*-Solve™ Design for a basement tieback system, the following items MUST be defined and specified to insure a "Safe Use" design:

1. **The anchor must penetrate the wall at between 3 and 5 feet from the floor** of an 8 foot tall basement wall. (This is also valid for a 9 foot basement wall with no more than eight feet of soil overburden.

2. There must be at least two feet of soil above the penetration point for the tiebacks.

3. Ground water must be assumed present behind the wall.

4. The working soil load on the wall shall be assumed to be 2,900 lb/lineal ft, unless otherwise given**.** To obtain the ultimate load on each tieback, multiply 2,900 lb/lineal ft. by a Factor of Safety = 2 and by the anchor spacing on the wall (feet).

P_u = 2,900 lb x 2 x ("X") = Ultimate Load - lb

5. The maximum spacing of tiebacks shall be no more than 5 feet on center with a downward install angle 15^0 unless specified.

6. A minimum installed shaft length of 22 feet from the wall to the tip of the tieback assembly shall be used when the largest helical plate on the shaft is 12 inches diameter. If the largest plate diameter is 14 inches the minimum installed shaft length at a 15^0 downward is 25 feet.

IMPORTANT: If the tieback reaches maximum torque before obtaining the minimum length requirement, the plate area of the tieback MUST be reduced. **The anchor MUST be installed to minimum lengths stated above**, or there is the possibility that the anchor will fail.

CAUTION: If any conditions are encountered that are substantially different from what is normally expected for embedment into homogenous soil, an analysis and design shall be performed by a Registered Professional Engineer, or the engineer needs to review and approve your *Quick*-Solve™ design.

Structural Details: The only data available:

- Cast concrete basement wall is 8 feet tall and 10 inches thick.
- Backfill against the wall is 7 feet
- Soil information given: Soil is believed to be inorganic clay (CL), "stiff to very stiff" – 115 pcf (approximate) in the area

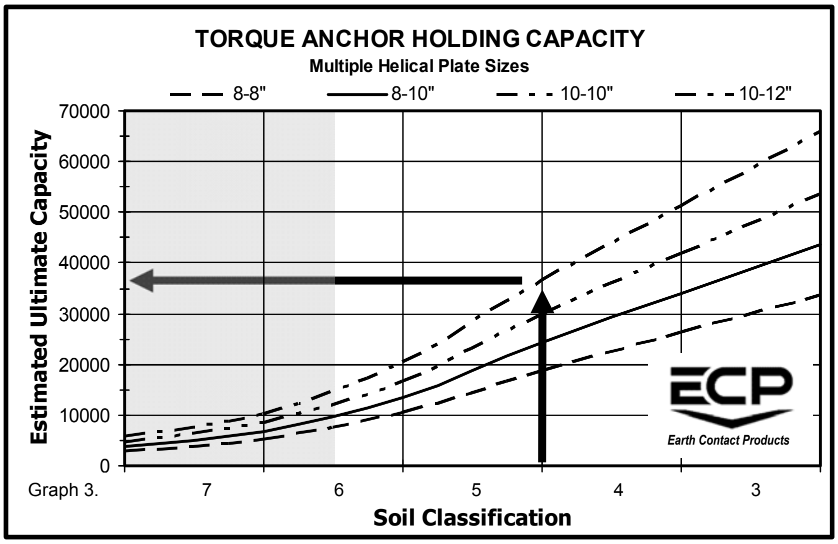
1. Determine the Soil Class: Referring to the Soil Classification Table (Chapter 1 - Table 9) a soil class of 4 - 5 is selected based upon the soil description being "stiff to very stiff clay".

2. Ultimate Helical Pile Capacity: In this design the largest spacing allowed is selected – five feet on center. The Ultimate Design Load for the project is estimated at:

T_u = 2,900 lb/lin ft x FS x "X" = 2,900 x 2 x 5 ft =

T_u = **29,000 lb** per anchor

3. Select the proper tieback anchor from the estimated capacity graphs: Referring to Graph 3, below (reproduced from Chapter 1), notice that the capacity line for an anchor with a 10"



Graph 3.

and 12” diameter helical plate suggests a capacity of 36,000 lb at a Soil Class 4 - 5. The 10”-12” diameter plate configuration is selected for the design.

4. Check the Shaft Strength and Torsional Strength: Refer to Table 2 to verify that the 1-1/2 inch solid square shaft has sufficient capacity to support the tensile load, and has sufficient torsional shaft strength for installation. The required ultimate capacity for each anchor is 29,000 lbs. (Step 2.) The 1-1/2 inch solid square shaft has an *Ultimate Limit Tension Strength* rating of 70,000 pounds and a *Useable Torsional Strength* of 7,000 ft-lbs. The selected anchor shaft provides suitable torsional capacity and a sufficient practical load limit to exceed the ultimate load requirement of 29,000 pounds. **The shaft selection is verified.**

5. Installation Torque: Use Equation 2 - Chapter 1, (or Graph 1 demonstrated in Design Example 2A) to determine the installation torque requirement for this anchor.

$\mathbf{T = P_u / k}$, Where,

P_u = 29,000 lb

k = 10 (See Table 12 in Design Example 3)

T = 29,000 lb / 10 ft^{-1} = 2,900 ft-lb

T = 2,900 ft-lb, minimum

6. Torque Anchor™ Product Selection:

- **TAF-150-84 10-12** – 1-1/2 inch round corner solid square shaft with a 10 inch diameter and a 12” diameter plate attached to a 7’-0” long shaft,
- **TAE-150-60** extension – 5’-0 extension section & hardware. This extension has a coupled length of 4’-9”. The installation will need four extensions to exceed 22 feet total length.
- **TAT-150** – Light Duty Transition that connects from 1-1/2” square bar to a 20” length of continuous threaded rod, with hardware.
- **PA-LWP** – Stamped steel wall plate that measures 12” x 26”

7. Mandatory Installation Requirements:

(See notes at beginning of this design example.)

- **Anchors shall be installed at 3 to 6 feet from the floor of the standard 8 foot basement wall.**
- **Anchors shall have a minimum of two feet of soil cover from point of penetration of the wall to the ground surface.**
- **Anchors shall be installed with a declination of 15^0.**
- **The anchors with 12” diameter largest helical plates shall be installed to a length not less than 22 feet.**
- **Anchors shall achieve installation shaft torsion of at least 2,900 ft-lb over the final three feet of installation prior to termination.**

End of Example 3A

Review of Results from Example 3 and Example 3A

One can see that the result obtained by the *Quick*-Solve™ analysis suggested a similar anchor configuration to that predicted by Design Example 3, which used the bearing capacity equation to calculate results.

Because this *Quick*-Solve™ design has been prepared for general use, there are design parameters put in place to cover most situations where a typical eight foot tall basement wall exists. (or nine foot wall with no more than eight feet of soil overburden).

In addition, when using the *Quick*-Solve™ design method the ***Mandatory Installation Requirements* MUST be followed** to insure a *Safe Use* Design.

Please refer to, and review, the Mandatory Installation Requirements listed at the beginning of Design Example 3A before proceeding with a *Quick*-Solve™ design.

IF THE JOB IS NOT TYPICAL OR DOES NOT CONFORM TO THE MANDATORY INSTALLATION REQUIREMENTS, DO NOT USE *QUICK*-SOLVE™ DESIGN METHODS. PLEASE CONSULT A REGISTERED PROFESSIONAL ENGINEER.

Design Example 4 – Retaining Wall Tieback Anchor -- Cohesionless Soil

Structural Details:

- New construction steel reinforced cast concrete retaining wall – 12 ft tall
- Backfilled with granular fill at the wall with free flow drainage tiles at the footing
- The soil information about the site indicated medium to coarse gravelly sand (SP), Medium dense – 130 pcf
- Standard Penetration Blow count "N" = 20 blows per foot at 10 feet deep
- $\Phi = 32^0$

1. Estimate the lateral soil force against the wall. Equation 6 from Chapter 1 is selected because the design specifies that the hydrostatic pressure is relieved by the drainage system.

$\mathbf{P_H = 24 \times (H^2),}$ Where, H = 12 ft.

$\mathbf{P_H}$ = 24 x (12' x 12') = 3,456 (Use 3,500)

$\mathbf{P_H}$ = **3,500 lb/lineal foot**

2. Select a Torque Anchor™ and perform an analysis to see if it is suitable. In this example the TAF-175-60 08-10-12 is tried, this is a 1-3/4" solid square bar product with an 8", 10" and a 12" diameter helical plate attached. The available soil reports the soil is cohesionless; Equation 1b from Chapter 1 is used:

$\mathbf{T_u = \Sigma A_H\ (q\ N_q)}$ Where,

$\mathbf{\Sigma A_H} = A_{8"} + A_{10"} + A_{12"}$

$A_{8"}$ = 0.328 ft^2 (Ref. Table 10 in Example 3
$A_{10"}$ = 0.524 ft^2 also Table 10 – Chapter 1)
$A_{12"}$ = 0.764 ft^2

$\mathbf{\Sigma A_H}$ = 0.328 + 0.524 + 0.764 = **1.62 ft^2**

q = γ x h_{mid}

h = Design Embedment = 10 ft. is selected

(This is the measurement from the ground surface to where the 12" diameter helical plate is located when the tieback is fully installed - See Figure 10, below.)

γ = Soil density = **130 lb/ft^3**

N_q = **23** ("N"= 20 & $\Phi = 33^0$) Table 7 - Chapter 1

$\mathbf{T_u}$ = 1.62 ft^2 x (130 lb/ft^3 x 10 ft) x (23)

$\mathbf{T_u}$ **= 48,438 lb**

3. Torque Anchor™ Spacing. Determine the Torque Anchor™ spacing along the wall for the configuration selected. Use Equation 4 from Chapter 1.

"X" = $\mathbf{T_u}$ / [$\mathbf{P_H}$ x (FS)], Where,

"X" = Product Spacing
T_u = Ultimate Capacity on Torque Anchor™
P_H = Lateral Force on Wall (lb/lin.ft)
FS = Factor of Safety (Typically 2.0:1)

"X" = 48,438 lb/[3,500 lb/lin.ft x 2 (FS)] = **6.9'**

4. Installation Torque & Embedment. Use Equation 3 from Chapter 1 to calculate the installation torque required for this anchor.

T = $\mathbf{T_u}$ / k Where,

T_u = 48,438 lb (Step 3)
k = 10 (Table 12 – Chapter 1 or Example 3)

T = 48,438 lb/10 ft^{-1} = 4,844 ft-lb.

T = 4,900 ft-lb

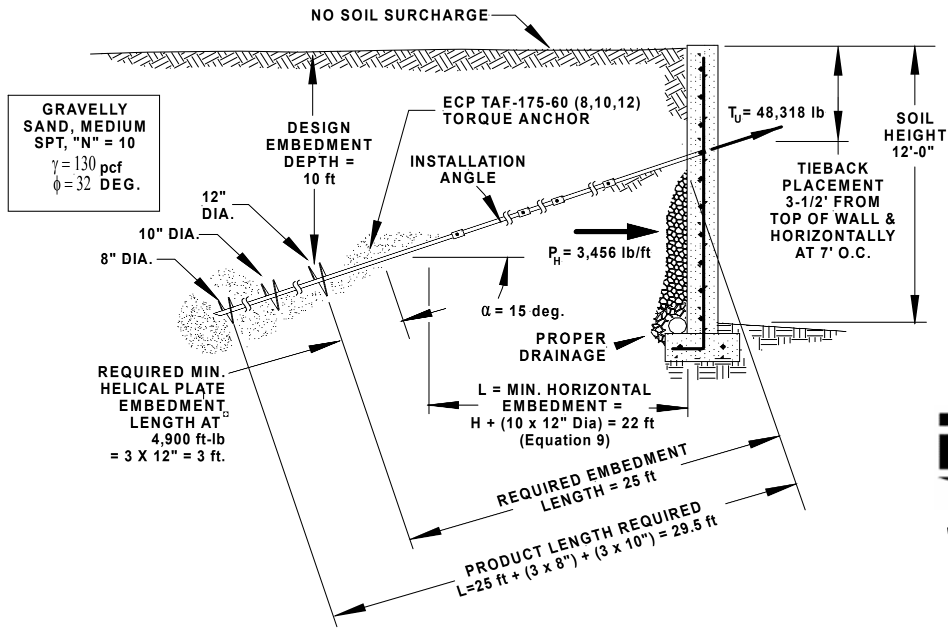


Figure 10. Design Example 4.

"Designed and Engineered To Perform"

The torque must be developed for a distance great enough to insure that the helical plates are properly embedded to insure adequate tension capacity. The installer must average at least 4,900 ft-lbs over a minimum distance of 3 feet. (Three times the 12" diameter plate = 3 ft.)

5. Select Installation Angle and Product Length. The anchors shall penetrate the wall at 3-1/2 feet below the soil surface. (This is approximately 0.3 times the wall height.) Recall that embedment depth was selected at 10 ft in Step 2. This means that the depth below the soil surface to the location of the 12" helical plate must be at least 10 feet. Try using an installation angle of 15^0 and determine the product length that will provide the 10 feet of vertical embedment required. (Recall that the distance from the top of grade level to where the anchors will penetrate the wall is 3-1/2 feet. The additional depth required by the anchor is therefore (10 ft - 3-1/2 ft) = 6-1/2 feet.

The shaft length required at 15^0 to achieve the 6-1/2 foot vertical depth is calculated using the equation given in Table 13 in Chapter 1 for a declination angle of 15^0.

$\mathbf{L_{15}}$ = (6-1/2 ft/sine 15^0) = 6-1/2 ft/0.259 = **25 ft**

The minimum shaft length at 15^0 installation angle is 25 feet, which will insure that the 12" diameter plate is located at a total embedment depth of 10 feet below the surface.

Comparing the *Minimum Horizontal Embedment* length from Equation 9 to the *Minimum Embedment Depth* (Step 5):

$\mathbf{L_0}$ = H + [10 x (d"$_{largest}$/12")]

L_0 = Minimum Horizontal Embedment Length from Wall to the Shallowest Plate – (ft)

H = Height of Soil Against Wall - (ft)

$d_{largest}$ = Diameter Of Largest Plate - (ft)

$\mathbf{L_0}$ = 12 + [10 x 1'] = **22 ft**.

It is clear that L_{15} = 25 ft (Length to insure required 10' soil embedment depth determined in Step 5) exceeds the *Minimum Horizontal Embedment* requirement.

The 10 ft depth of embedment also exceeds the Critical Depth, "D" = 6 x d_{12} = 6 x 12"/12 = **6 ft**

L_{15} = 25' > L_0 = 22' using D = 6 ft

L_{15} = 25 ft must be used

Minimum Required Shaft Length:

L = L_{15} + L_{Tip} (Distance nearest plate to tip)

Where: L_{Tip} = (3 x $d_{plate\ 1}$) + (3 x $d_{plate\ 2}$)

$\mathbf{L_{Tip}}$ = [(3 x 8" dia)+(3 x 10" dia)]/12 = **4-1/2 ft**

L = L_{15} + L_{Tip} = 25 ft + 4-1/2 ft = **29-1/2 ft**

L = 29-1/2 feet min. at **$\alpha = 15^0$**

6. Torque Anchor™ Capacity Verification: A review of Table 2 – Chapter 1 indicates that the 1-3/4" solid square bar Torque Anchor™ has a *Ultimate Limit Tension Strength* of 100,000 lb and a *Useable Torsional Strength* of 10,000 ft-lb. The project ultimate tension capacity and torsional requirement are approximately one-half of the mechanical and torsional capacity of the product. There was no mention about rocks, debris or other obstructions in the soil so installation should be smooth. A check of Table 11 – Chapter 1 indicates that three 3/8" thick helical plates have an ultimate capacity of 120,000 pounds (3 x 40,000 lb), so the total mechanical capacity of the anchor is satisfactory.

7. Torque Anchor™ Specifications. The required Torque Anchor™ assembly consists of:

- **TAF-175-84 08-10-12** - 1-3/4" solid square bar, on a standard 7' long shaft with 8", 10" & 12" dia. plates,
- **TAE-175-84** extensions - 7 feet long & hardware (6'-9" effective length) – **Three extensions are required**.
- **TAE-175-60** extensions - 5' long with hardware (4'-9" effective length) – **One extension is required.**
- **TAB-175 T** Tension Pile Cap – 3/4" x 8" x 8" pile cap with bolt and nut. The pile cap bolts to the anchor shaft and will be incorporated into the new construction concrete wall.

The actual assembled length of the specified Torque Anchor™ system is 32 ft.

The anchors shall mount along the wall at 7 feet center to center and at a vertical distance of 3-1/2 feet from the top of the proposed wall. The anchors shall be installed at a downward angle of 15^0 from horizontal.

The tiebacks must be installed to a length greater than 29-1/2 feet

The anchor must be installed to an average installation torque of 4,900 ft-lb or more for a minimum distance of at least 3 feet beyond an installed length of 26 feet, if less than 4,900 ft-lb, the anchor shall be driven deeper until the torque requirement is satisfied.

End of Example 4

Design Example 5 – Basement Tieback Using Plate Anchors

Field data that was collected from the jobsite:

- Concrete Block Basement Wall – 8 ft. – Wall bowing at 4 feet above the floor
- Overburden height of soil (H) – 6-1/2 ft.
- Field Estimated Soil Properties: Soft, Sandy Clay – "N"= 3 bpf

While all of the graphs and equations may seem confusing, it all can be easily understood from this illustrative example. It will be seen that an earth anchor design can be accomplished in a matter of minutes. While the result is not a rigorous engineering analysis, the process provides general guidance that is valuable information for the installer and field estimators.

1. Determine the Horizontal Force: By referring to the graph, <u>*Horizontal Force Against Basement Wall*</u> presented at right we estimate the horizontal force on the wall.

Locate soil overburden of 6-1/2 feet on the wall on the "X" axis and read vertically to the solid "Saturated Soil" line. Then read horizontally to the "Y" axis to determine that the horizontal force on the wall is **<u>1,800 pounds per lineal foot of wall</u>.**

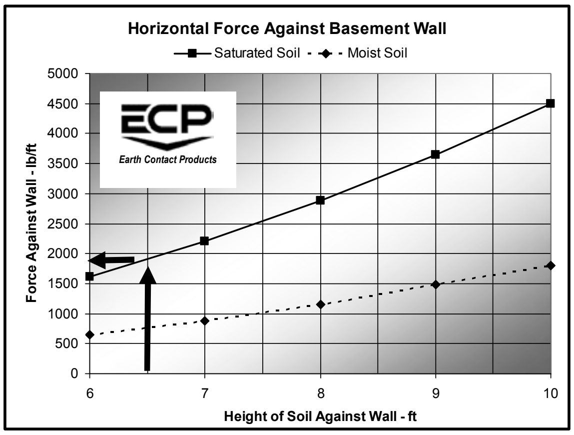
2. Determine the Service Load Capacity: Referring to the graph, <u>*Anticipated Service Load Range*</u>, a capacity range of the PAL (2.96 ft^2) Earth Anchor is determined. A field technician inspected, estimated and reported the soil to be soft, sandy clay with "N" = 3 +/- blows per foot. Locate "N" = 3 bpf on the "X" axis. Because the soil is believed to be Soft, Sandy Clay, we choose the area below the dashed line and above the 100% clay line. Reading across to the "Y" axis the estimated Service Load Range for a PAL Earth Plate is between 7,000 and 8,000 pounds.

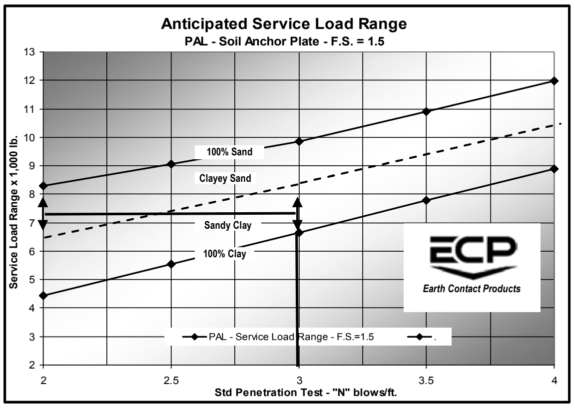
What we have determined:

- Load on wall – **1,800 lb/ft**
- Service Load **–** <u>7,000-8,000 lb</u> **(Use 7,500 lb)**
- Concrete Block Basement Wall - **6-1/2 ft overburden**

3. Determine the Wall Plate spacing based upon the known data. Table 3 – Chapter 2 suggests spacing at 4 to 5 feet on center. We must refine this by use of the data we have obtained about this project.

$X = T_{SL}/(P_{HS} \times FS)$ 7,500 lb/1,800 lb/ft = <u>4.2 ft</u>
(Use 4 ft on center)





4. Complete the design by determining the embedment:

- Calculate Minimum Horizontal Embedment = **L_{min} = H x 1.5** = 6.5 ft x 1.5 = <u>9.75 feet</u>
  (Use 10 ft)
- Calculate Minimum Vertical Embedment = **$D_{min} = d_w \times 1$ ft,** Where
  d_w = 6-1/2 ft (Soil height) - 4 ft (Bow in wall)

  D_{min} = 2-1/2 ft + 1 ft = **<u>3-1/2 ft</u>** (to top of earth plate)

  (Note: Actual depth to rod hole at the center of Earth Plate is 4-1/2 ft deep, minimum.)

The preliminary design:

- Use ECP PAL Earth Plate Anchors spaced at 4 ft O.C. at 4 ft above the floor
- Bury the Earth Anchor Plate: 3-1/2 ft (Below grade <u>to top of plate</u>, minimum)
- Locate the plate at a horizontal distance: 10 feet, minimum from outside the basement wall.

End of Example 5.

Design Example 6 – Foundation Restoration – Cohesive Soil

Structural Details:

- Two story wood frame house with wood composition siding.
- Foundation consists of 20” wide by 18” tall steel reinforced concrete perimeter beam with a 4” thick concrete slab cast with the perimeter beam.
- The corner of structure has settled 2”
- Top of pile will be 12” below the soil surface
- Soil data: There are two feet of consolidating, poorly compacted fill overlaying 20 feet of inorganic clay (CL), stiff.
- SPT “N” blow count was measured between 8 to 12 blows per foot increasing with depth

1. Determine the foundation load: Breaking down weights of structural elements can be found in the *Simplified Tables of Structural Foundation Loads* located in Chapter 6, ECP Steel Piers™ Design in Tables 2 through 9.

The foundation loads are estimated below:

Footing – 20” x 18”	360 lb/lf
Slab Floor, Carpet & Pad	195
Wood Frame Walls – 2 Story	176
2nd Floor – 14’ Span, Carpet & Pad	98
Roof – 6” in 12” Composition, 14’ Span	171
Total Dead Load	**1,000 lb/lf**
Live Load – Slab	120
Live Load – 2nd Floor, 14’ Span	180
Total Live Load	**300 lb/lf**

w = Distributed Load = 1,000 + 300 = 1,300 lb/lf

w = 1,300 lb/lineal foot

2. Select a Suitable Pile Spacing and Determine Ultimate Torque Anchor™ Load: This is not a heavy structure, so for economy the solid square bar Torque Anchor™ configuration is chosen with TAB-150-SUB Utility Brackets to transfer the structural load to the pile shaft. See Graph 2 - Chapter 6 reproduced at right and select pile spacing, “X”, at 7-1/2 feet on the perimeter beam. Determine the working load on the piles from Equation 4 – Chapter 1.

$\mathbf{P_u = “X” \times w \times (FS)}$:

Where, “X” = Spacing = 7-1/2 feet
w = 1,300 lb/lineal foot (Step 1)
FS = Factor of Safety (Use 2.0)

$\mathbf{P_u = 7\text{-}1/2’ \times 1{,}300\ lb/ft \times 2 = 19{,}500\ lb}$

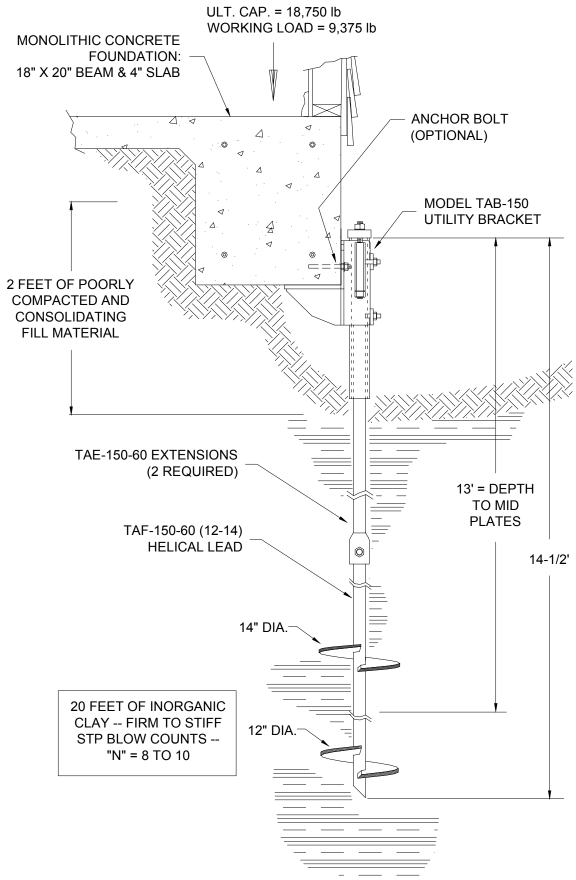


Figure 13. Design Example 6.

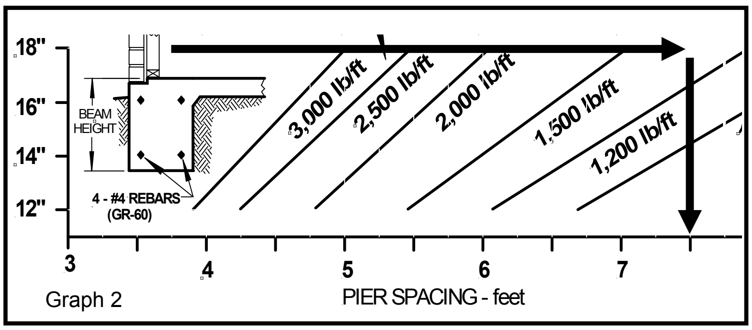
3. Determine the helical plate area required based upon P_u = 19,500 lb: Because the soil on the site is cohesive, Equation 1a from Chapter 1 is used:

$\mathbf{\Sigma A_H = P_u\ /\ (9c)}$ Where:

P_u = 19,500 lb (Step 2)
c = 1,250 lb/ft^2 Average “N” = 10 (assumed) (Table 5 - Chapter 1)

$\Sigma A_H = P_u / (9 \times 1{,}250) = 19{,}500\ lb / 11{,}250\ lb/ft^2$

$\mathbf{\Sigma A_H = 1.73\ ft^2}$



4. Select the ECP Helical Torque Anchor™ suitable to support the load: Referring to Table 2 – Chapter 1 the 1-1/2" solid square pile shaft is selected. It has an <u>*Axial Compression Load Limit*</u> rating of 70,000 pounds and a <u>*Useable Torsional Strength*</u> of 7,000 ft-lbs.

Viewing the product data table on Chapter 1 – Page 9, one can see that the **TAF-150-60 12-14** is a good fit. As an alternate, Table 10 - Chapter 1, (below) can be used to select a combination of plates from row opposite the 1-1/2" shaft size.

Table 10.	**Projected Areas* of Helical Torque Anchor™ Plates**					
Helical Plate	**6" Dia.**	**8" Dia.**	**10" Dia.**	**12" Dia.**	**14" Dia.**	**16" Dia.**
Shaft	**Projected Area – ft²**					
1-1/2" Sq.	~~0.181~~	~~0.333~~	~~0.53[illegible]~~	**0.770**	**1.053**	1.381
1-3/4" Sq.	0.175	0.328	0.524	0.764	1.048	1.375
2" Sq.	0.168	0.321	0.518	0.758	1.041	1.396
2-7/8" Dia	0.151	0.304	0.500	0.740	1.024	1.351
3-1/2" Dia	0.130	0.282	0.478	0.719	1.002	1.329
4-1/2" Dia	0.086	0.239	0.435	0.675	0.959	1.286

We must provide at least 1.73 ft^2 of bearing area. The combination of 12" & 14" diameter plates on the 1-1/2" solid square shaft provides a total area of 1.82 ft^2. Select - **TAF-150-60 12-14**

5. Installation Torque: Use Equation 2 – Chapter 1 to calculate the installation torque for this anchor.

$\mathbf{T = T_u / k}$ Where,

T_u = 19,500 lb (Step 2)

k = 10 (Table 12 – Chapter 1)

$T = 19{,}500 \text{ lb} / 10 \text{ ft}^{-1}$

T = 1,950 ft-lb **– Use 2,000 ft-lb**

6. Torque Anchor™ Capacity Verification: A review of Table 2 – Chapter 1 indicates that the 1-1/2" solid square bar Torque Anchor™ has a <u>*Useable Torsional Strength*</u> of 7,000 ft-lb, which is more than adequate for this application. The product selection should work based upon the soil report stating that the firm to stiff clay becomes more dense as the depth increases. There was no mention of rocks, debris or other obstructions. Table 11 – Chapter 1 verifies that two 3/8" thick helical plates have a mechanical ultimate capacity of 80,000 pounds. The mechanical capacity of the pile is excellent.

7. Installed Product Length: Termination depth for the helical plates is targeted within the stiff silty clay. The data indicates that the soil has a variance in the Standard Penetration Test (SPT) blow count, "N", between 8 and 12 blows per foot. It is estimated that the pile would reach the desired shaft torsion at a mid-plate depth of about 13 feet.

Minimum Required Shaft Length:

$\mathbf{L = h_{mid} + L_{Tip}} - h_F$

Where: h_{mid} = 13 ft (The depth from the surface to midway between plates on the shaft.)

$\mathbf{L_{Tip}} = (3D_{\text{Plate 1}})/2$

$\mathbf{L_{Tip}}$ = (3 x 12" dia / 2) = 18 in

$\mathbf{L_{Tip}}$ **= 1-1/2 ft**

$h_F =$ **-1 ft** (The pile cap will terminate at the Utility Bracket approximately 12 Inches below grade level.)

L = 13 ft + 1-1/2 – 1 ft

L = 13-1/2 feet = Shaft length

8. Torque Anchor™ Specifications:

- **TAF-150-60 12-14** - 1-1/2" solid square bar lead section on a standard length 5 feet long shaft with a 12" and 14" diameter plate.
- **TAE-150-60** Extension – 1-1/2" solid square bar extension 5 feet long with hardware, **2 required** (The coupling overlaps 3 inches providing an effective length of 4'-9")
- **TAB-150-SUB** Utility Bracket Assembly. This foundation bracket fits over the 1-1/2" square bar and mounts to the perimeter beam. The bearing plate provides 68-1/4 in^2 at the under side of the foundation for load transfer.

The total length of the assembled Torque Anchor™ is **14-1/2 ft**.

Torque Anchors™ shall be spaced at 7-1/2 feet center to center

Installation Torque shall be 2,000 ft-lb or more averaged during the last 3 feet of the installation.

Target depth is 13-1/2 feet or more.

Note: It is recommended to order additional extension sections because the shaft torque might not be achieved at 14-1/2 feet deep.

9. Foundation Restoration: Once all of the Torque Anchor™ piles have been installed and the Utility Brackets mounted, the structure may be restored to as close to the original elevation as the construction will permit.

- A pile cap, lift assembly and hydraulic jack are installed at each placement.

- All hydraulic jacks shall be connected to a hand pump and gauge through a manifold system that distributes equal pressure to all jacks.
- The hand pump is actuated, transferring the structural load from the soil below the footing to the Torque Anchor™ shafts. As the structure responds and a portion of the foundation reaches the desired elevation, the jack(s) supporting the restored area(s) are isolated and the pressure at these jack(s) is recorded.
- The restoration process continues until the structure is satisfactorily restored, and all jacks have been isolated and their pressures recorded.
- All installation and restoration data is transferred to a Project Installation Report. This report should include, but is not limited to, project identification, equipment used, product installed, final installation torque, installed depth, lifting force required to restore the structure and lift measurement. This data must be recorded for each placement.
- Review the report and calculate actual factors of safety on the installation to see if the design requirements have been satisfied.

10. Actual Load vs. Calculated Load and Installed Factor of Safety: The installation data must be compared to the calculated values. This enables the designer to verify the accuracy of the design. In addition, actual project factors of safety should be verified, as shown below.

The actual factor of safety for each pile installation is calculated, a slight variation of the typical factor of safety formula is used.

Project Factor of Safety Equation:

$$\mathbf{FS_{job} = P_{u\text{-}job} / P_{w\text{-}job}}$$

Where: $P_{u\text{-}job}$ = Installed Estimated Ult. Capacity – lb
= Installation Torque x k)
$P_{w\text{-}job}$ = Lifting Force to Restore – lb
= Jack Pressure x Cylinder Area)

The Project Installation Report data is used to calculate the actual factors of safety for each Torque Anchor™ placement:

$\mathbf{FS_{Actual} = T_{Final}\ x\ k}$ (Table 12)/ $\mathbf{P_{Lift}}$

Pile 1: FS = (2,000 ft-lb x 10 ft^{-1}) lb / 9,000 lb
$\mathbf{FS_{pile\ 1} = 2.22}$

Pile 2: FS = (1,950 ft-lb x 10 ft^{-1}) lb / 9,400 lb
$\mathbf{FS_{pile\ 2} = 2.07}$

Pile 3: FS = (2,050 ft-lb x 10 ft^{-1}) lb / 7,700 lb
$\mathbf{FS_{pile\ 3} = 2.66}$

PROJECT INSTALLATION REPORT

Project Name: Design Example 5
Project Address: 123 Anywhere, Mid-America, USA

Products Installed: TAF-150-60 12-14 Lead
TAE-150-60 Extensions
TAB-150-SUB Utility Bracket

Torque Motor: Model LW6K – 6,000 ft-lb
Lifting Jack: Model RC254 – 25 Ton

Calculated Ultimate Pile Capacity: **P_u = 19,500 lb**
Calculated Working Pile Load: **P_w = 9,750 lb**

Placement Identification	Pile 1	Pile 2	Pile 3
Final Install Torque, ft-lb	**2,000**	**1,950**	**2,050**
Pile Depth, ft	18.5	16	16.5
Force to Lift, lb	9,000	9,400	7,700
Amount of Lift, in	1-1/2	1-3/4	2
Actual Factor of Safety	**2.22**	**2.07**	**2.66**

Soil tended to be non-homogeneous and it is not unusual for the installation torque to vary from point to point on a project; in addition, the load on a footing is usually not uniform due to different architectural elements in the design of the structure. Pile 2 had slightly lower shaft torsion than required and had a slightly higher working load. This resulted in the lowest Factor of Safety. Pile three was on a lightly loaded part of the building and developed a large Factor of Safety.

End Design Example 6

Review of Results of Example 6

Comparing the calculated design working load of 8,818 lb per pile (P_w = w (Step 1) x "X" (Step 2) = 1,300 lb/ lineal ft x 7-1/2 ft = 9,750 lb) to the actual lifting forces one can see that all working pile loads are slightly lower than predicted by the calculations. These differences between calculated and actual working loads are not significant and are related to the fact that actual loads on the footing are not uniform along the footing. The actual factors of safety for the installation on this project demonstrate that the project has factor of safeties within normal tolerances. The project has a safe design.

Design Example 6A – Foundation Restoration – *Quick*-Solve™ Design Method

Design Details from Design Example 6:

- Two story wood frame house with wood composition siding.
- Foundation consists of 20” wide by 18” tall steel reinforced concrete perimeter beam with a 4” thick concrete slab cast with the perimeter beam.
- Top of pile will be 12” below the soil surface
- Soil data: There are two feet of consolidating, poorly compacted fill overlaying 20 feet of inorganic clay (CL), stiff.
- SPT “N” blow count was measured between 8 to 12 blows per foot increasing with depth

1. Determine the foundation load: Use Table 11, <u>*Ranges for Typical Average Residential Building Loads*</u> that can be found in Chapter 6 of this manual. A portion of Table 11 - Chapter 6 is shown below.

Table 11. Ranges for Typical Average Residential Building Loads

Building Construction (Slab On Grade)	Estimated Foundation Load Range (DL = Dead – LL = Live)
One Story Wood/Metal/Vinyl Walls with Wood Framing -- Footing with Slab	DL 750 – 850 lb/ft LL 100 – 200 lb/ft
One Story Masonry Walls with Wood Framing – Footing with Slab	DL 1,000 – 1,200 lb/ft LL 100 – 200 lb/ft
Two Story Wood/Metal/Vinyl Walls with Wood Framing – Footing with Slab	**DL 1,050 – 1,550 lb/ft LL 300 – 475 lb/ft**
Two Story 1st Floor Masonry, 2nd Wood/Metal/Vinyl with Wood Framing – Footing with Slab	DL 1,300 – 2,000 lb/ft LL 300 – 475 lb/ft
Two Story Masonry Walls with Wood Framing – Footing with Slab	DL 1,600 – 2,250 lb/ft LL 300 – 475 lb/ft

From the description of the project, the total foundation load (except snow loads) can be roughly estimated from Table 11. Only a portion of Table 11 is shown above and is only for slab on grade foundation loads, which is the type of foundation on this project. The structure is a two story residence with wood composition siding.

To determine the estimated foundation load, look down the first column until you find a *Two Story* description that most closely matches the house on the project. Reading across, the other columns provide a range of foundation dead load weights for this kind of residential structure. Notice that dead loads range between 1,050 and 1,550 lb/lin.ft and live load estimates are shown from 300 to 475 lb/lin.ft.

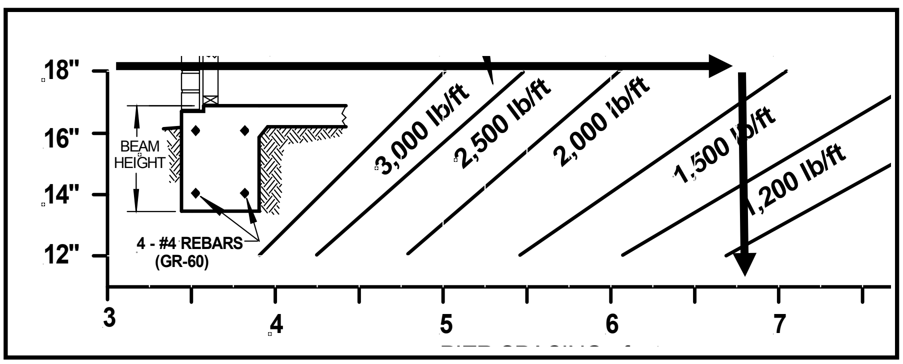
Your judgment about the quality of construction is needed to estimate a foundation load from within the ranges. In this Design Example careful judgment (after physically inspecting the construction) suggests using DL = 1,200 lb/lin.ft and LL = 375 lb/lin.ft. The average perimeter loading for the *Quick*-Solve™ design is:

W = DL + LL = 1,575 lb/lin.ft.

2. Determine the Soil Class. The soil was reported only as stiff clay. Referring to Table 9 - Chapter 1 <u>*Soil Classification Table*</u>, Soil Class 6 is selected. Keep in mind that little soil information available and keep in mind there is poorly compacted fill near the surface.

3. Select a Suitable Pile Spacing and Determine Ultimate Torque Anchor™ Load: This is not a heavy structure so the solid square bar Torque Anchor™ configuration along with TAB-150-SUB Utility Brackets are the most economical products to use to transfer the structural load from the foundation to the pile shaft. Use Graph 2 from Chapter 6, to select pile spacing, “X”. (Copy of graph is below)

A loading of 1,575 lb/lin.ft is slightly higher than the 1,500 lb/ft line on the graph. This line will be used to select the spacing and then the spacing will be adjusted to reflect the load higher than the graph curve. Read across from the 18 inch footing height to an estimated 1,575 lb/ft position, then drop down to see the pile spacing of 6-3/4 feet. 6-3/4 feet center to center is selected for “Safe Use” design. **“X” = 6-3/4 feet**



4. Determine Ultimate Torque Anchor™ Load: Use Equation 3 from Chapter 1 to determine the ultimate capacity per pile:

P_u = ("X") x (w) x (FS):

Where,
"X" = Product Spacing = 6-3/4 feet
w = 1,575 lb/lineal foot (Step 1)
FS = Factor of Safety (Use 2.0)

P_u = 6-3/4 ft x 1,575 lb/ft x 2 = 21,263 lb

5. Select the proper pile configuration: Referring to Graph 4 - Chapter 1 (reproduced below), notice that the capacity line for 12" and 14" diameter helical plates attached to shaft crosses just above 20,000 pounds at the center of Soil Class 6. The 12" and 14" diameter plate configuration is selected for the design.

6. Check Shaft Strengths and Torsional Strengths to see which shaft is suitable: Refer to Table 2 in Chapter 1 to verify the shaft selection has a suitable *Axial Compression Load Limit* and sufficient *Useable Torsional Strength*. The 1-1/2 inch solid square shaft is verified because it has an *Axial Compression Load Limit* rating of 70,000 pounds based upon an installation torsional limit of 7,500 ft-lbs. This pile exceeds the ultimate job load requirement of 21,263 pounds. The selected and verified pile configuration is **TAF-150-60 12-14**.

7. Installation Torque. Use Graph 1 from Chapter 4, shown on next page to determine the installation torque requirement for the piles. The Ultimate Capacity from Step 4 is 21,263 pounds. Find 22,000 pounds at the left side of Graph 2 look horizontally to the graph line for solid square shafts, read down to torque of 2,200 ft-lb.

T = 2,200 ft-lb

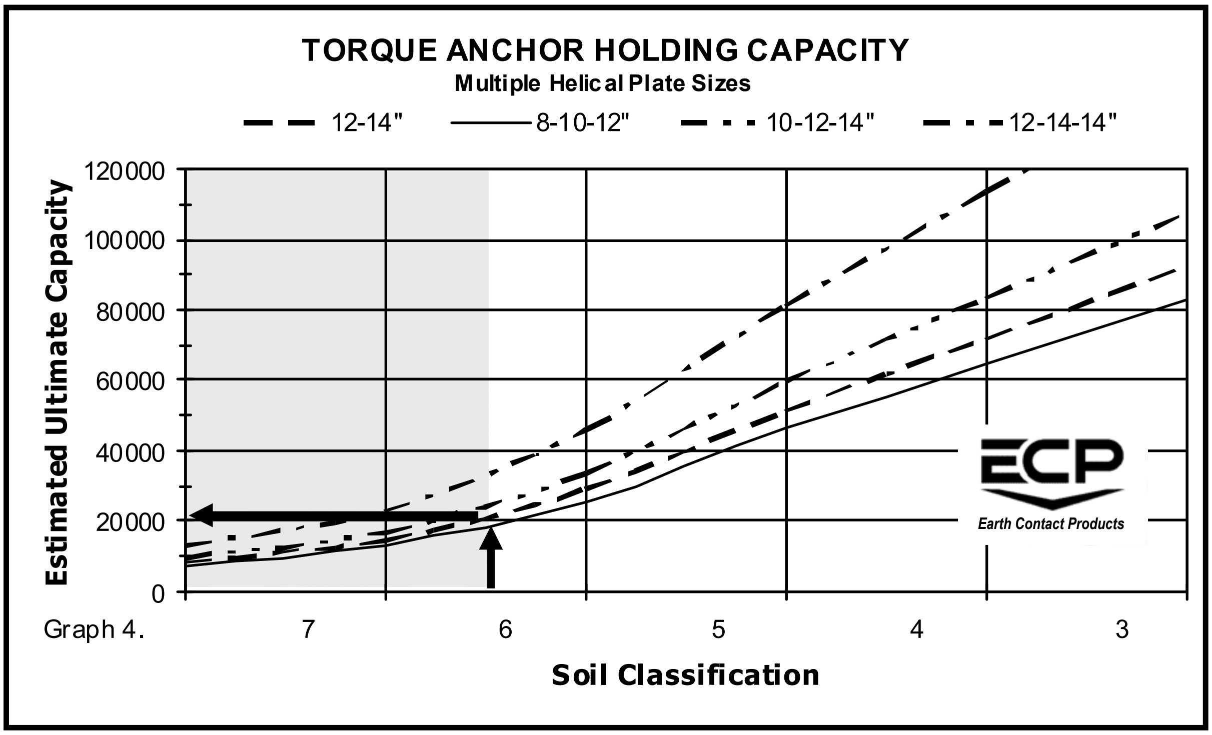
By comparison, the installation torque is calculated: from Equation 2 in Chapter 1:
Equation 2: T = P_u / k,
P_u = 21,263 lb k = 10 (Table 12)
T = 21,263 lb/10 ft^{-1} = 2,127 ft-lb

8. Installed Product Length. Termination depth is the stiff clay. It is likely that the pile would reach the desired shaft torsion at a depth somewhere beyond the unconsolidated soil near grade. The minimum depth is the summation of the *Critical Depth,* defined as 6 x diameter of largest plate plus the distance to the lowest plate.

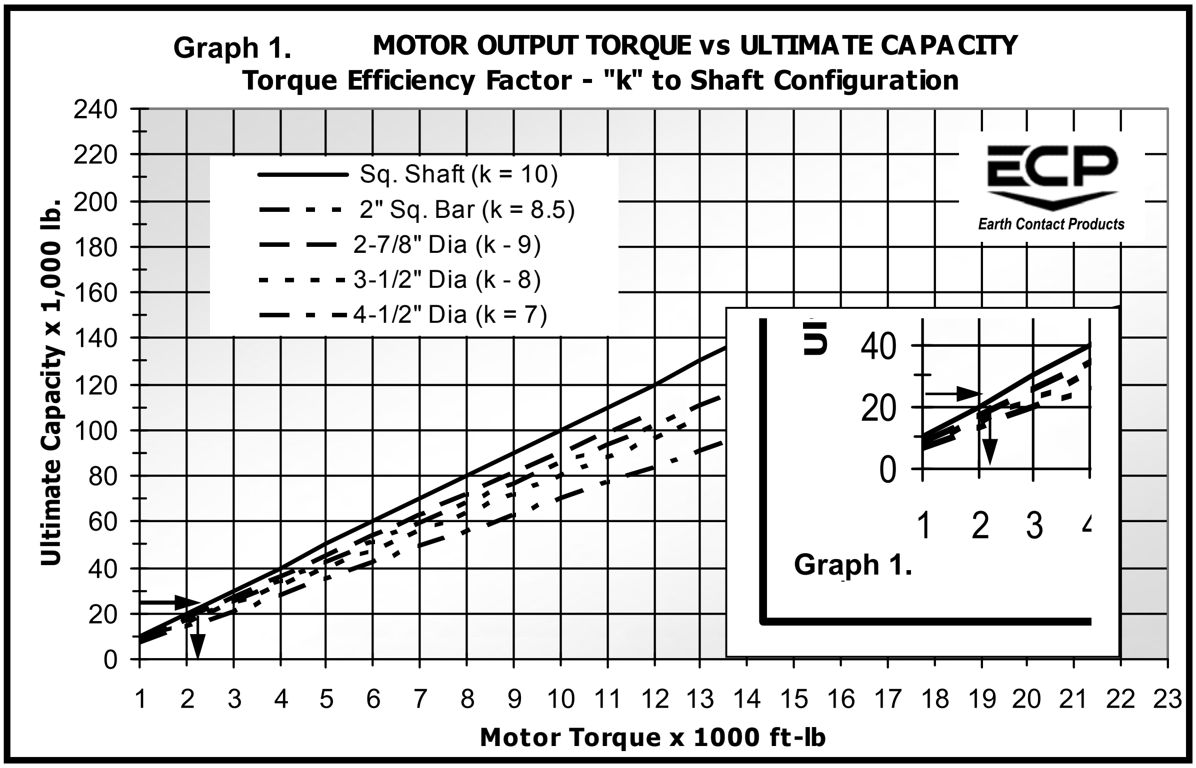
Minimum Required Shaft Length:

L_{min} = $D_{Critical}$ + L_{Tip} Where:
$D_{Ccritical}$ = 6 x (14" dia./12")
L_{Tip} = 14" dia./12" x 3 = 3.5 ft
(Plates spaced at 3 x diameter.)

L_{min} = 6 x (14"/12")+(14"/12" x 3) = **10-1/2 ft**



Graph 4.



* "Safe Use" design suggests that the piles be installed deeper than 10-1/2 feet below grade **because there is weak and consolidating fill soil near the surface. The "Safe Use" design suggests a longer standard shaft length be installed.**

9. Torque Anchor™ Specifications:

- **TAF-150-60 12-14** – 1-1/2 inch solid square shaft that has a 12" and a 14" diameter plate on the 5'-0" long shaft,
- **TAE-150-84** extension – 7 foot extension section & hardware. (6'-9" effective length)
- **TAB-150-SUB** Standard Utility Bracket. This foundation bracket fits over the 1-1/2" square bar and mounts to the perimeter beam.

Depth for pile becomes 11-3/4 ft + 1 ft (below grade termination) **Total depth = 12-3/4 ft.**

It is recommended that additional extensions are on hand should the final shaft torque requirement of 2,200 ft-lb is not achieved at 12 feet.

End of Example 6A

Review of Results of Example 6 & 6A

One can see that the result obtained by the *Quick*-Solve™ analysis clearly suggested the same pile that was determined by the analysis using the bearing capacity equations. There were some variations in the design because the *Quick*-Solve™ design method predicted a higher footing load and higher installation torque. This was caused in part by the higher ultimate load suggested by the *Quick*-Solve™ design using "*Structural Load Estimating Tables"* from Chapter 6. Once again, similar results were determined in this example, but success when using *Quick*-Solve™ designing requires that good judgment be used in the estimating the quality of construction (structural weight estimate). This is very important because if one can select highly accurate data from the tables and graphs in Chapter 6. This result will be more accurate design results.

Design Example 7 – Motor Output Torque

Design 1A: The heavy weight new construction pile design presented in Design Example 1 required shaft torsion of 6,700 ft-lb applied to the 2-7/8 inch diameter Torque Anchor™ shaft to achieve the ultimate capacity requirement of 60,000 pounds.

Design 1B: In Design Example 1B, weak soil was present and the torsion requirement was determined to be 6,900 ft-lb on a 3-1/2 inch diameter tubular shaft to be able to achieve the same 60,000 pound ultimate pile capacity.

Project Details Provided from the Field:

- New Building – 2 story house with basement
- Ultimate Capacity = 60,000 lb
- Torque Motor Available = Pro-Dig X12K5
- Pressures averaged over final three feet of depth

Design 1 – Average Pressures at termination depth, 2-7/8" dia = 1,900 psi at inlet & 200 psi at outlet

Design 1B – Average pressures at termination depth, 3-1/2" dia = 2,150 psi at inlet & 200 psi at outlet

Equation 3 introduced in Chapter 4 is used to convert pressure differential across the hydraulic gear motor into shaft output torque.

Equation 3: Motor Output Torque
$T = K \times \Delta P$

1. Differential Pressures, "ΔP": Before using Equation 3, the pressure differential, or ΔP, must be determined from the field. The *Motor Torque Conversion Factor* – "K" must also be identified for the Pro-Dig X12K5 that is being used.

The Differential Pressure, "ΔP", across the motor is determined as follows:

ΔP = Inlet psi – Outlet psi

$\Delta P = p_{in} - p_{out}$

ΔP for Design Example 1:

$\Delta P_{Design\ 1} = 1{,}900 \text{ psi} - 200 \text{ psi}$

$\mathbf{\Delta P_{Design\ 1} = \underline{1{,}700 \text{ psi}}}$

ΔP for Design Example 1B:

$\Delta P_{Design\ 1B} = 2{,}150 \text{ psi} - 200 \text{ psi}$

$\mathbf{\Delta P_{Design\ 1B} = \underline{1{,}950 \text{ psi}}}$

2. Motor Torque Conversion Factor, "K": The *Motor Torque Conversion Factor* – "K" is found on Table 2 in Chapter 4. (A portion of the table is shown right.)

Looking in the *"Model Number"* column of Table 2, the X12K5 Torque Motor data is found. Reading to the right the value for the *Motor Conversion Factor*, "K", for this motor is determined to be "K" = 4.20.

3. Motor Output Torque: Once the differential pressure across the hydraulic torque motor has been calculated (Step 1) and the value for "K" determined (Step 2), the values can be used in Equation 3 to determine the actual Motor Output Torque that is applied to the pile shaft at during installation.

Equation 3: $T = K \times \Delta P$

Where,

T = Hydraulic Motor Output Torque - ft-lb

K = Torque Motor Conversion Factor

(Table 2 – Chapter 4 Also see below.)

ΔP = Motor Pressure Differential = $p_{in} - p_{out}$

Design Example 1: Confirm proper installation torque for the 2-7/8' diameter shaft.

$T_{Design\ 1} = 4.20 \times (1{,}700 \text{ psi} - 200 \text{ psi})$

$\mathbf{T_{Design1} = \underline{7{,}140 \text{ ft-lb}}}$

Verified - 7,140 ft-lb > 7,100 ft-lb - O.K.

Design Example 1B: Confirm proper installation torque for the 3-1/2" diameter pile shaft that was installed into weak soil.

$T_{Design\ 1B} = 4.20 \times (2{,}150 \text{ psi} - 200 \text{ psi})$

$\mathbf{T_{Design\ 1B} = \underline{8{,}190 \text{ ft-lb}}}$

Verified - 8,190 ft-lb > 8,000 ft-lb - O.K.

End Design Example 6

Table 2. Hydraulic Torque Motor Specifications

Illustration	Model Number	Torque Output ft-lb	Motor Torque Conversion Factor – "K"	Maximum Pressure psi
PRO-DIG 	L6K5	6,335	2.53	2,500
	L7K5	7,644	2.55	3,000
	X9K5	9,663	3.22	3,000
	X12K5	12,612	**4.20**	3,000
	T12K	5,597/ 12,128	2.24/4.85	2,500

Design Example 7A – Motor Output Torque *Quick*-Solve™ Design Method

Design 1A: The heavy weight new construction pile design presented in Design Example 1 specified that when installed on the site, torsion of 6,700 ft-lb was needed on the 2-7/8 inch diameter Torque Anchor™ shaft to reach the ultimate capacity requirement of 60,000 pounds.

Design 1B: In Design Example 1B, weak soil was present and the torsion requirement increased to 7,500 ft-lb on the 3-1/2 inch diameter tubular shaft to achieve the same 60,000 pound ultimate pile capacity.

1. Determine Motor Output Torque: Graph 2 *Motor Output Torque vs. Ultimate Capacity* introduced in Chapter 4 is used to convert pressure differential, "ΔP", at the hydraulic gear motor to shaft output torque. Referring to Graph 2 (below); the output torque of the X12K5 motor can be determined once the pressure differential across the installation motor is determined.

ΔP = Inlet psi – Outlet psi = $\Delta P = p_{in} - p_{out}$

ΔP for Design Example 1 – 2-7/8" dia. shaft:

$\Delta P_{\text{Design 1}}$ = 1,800 psi - 200 psi = **1,600 psi**

ΔP - Design Example 1B - 3-1/2" dia. shaft:

$\Delta P_{\text{Design 1B}}$ = 2,000 psi – 200 psi = **1,800 psi**

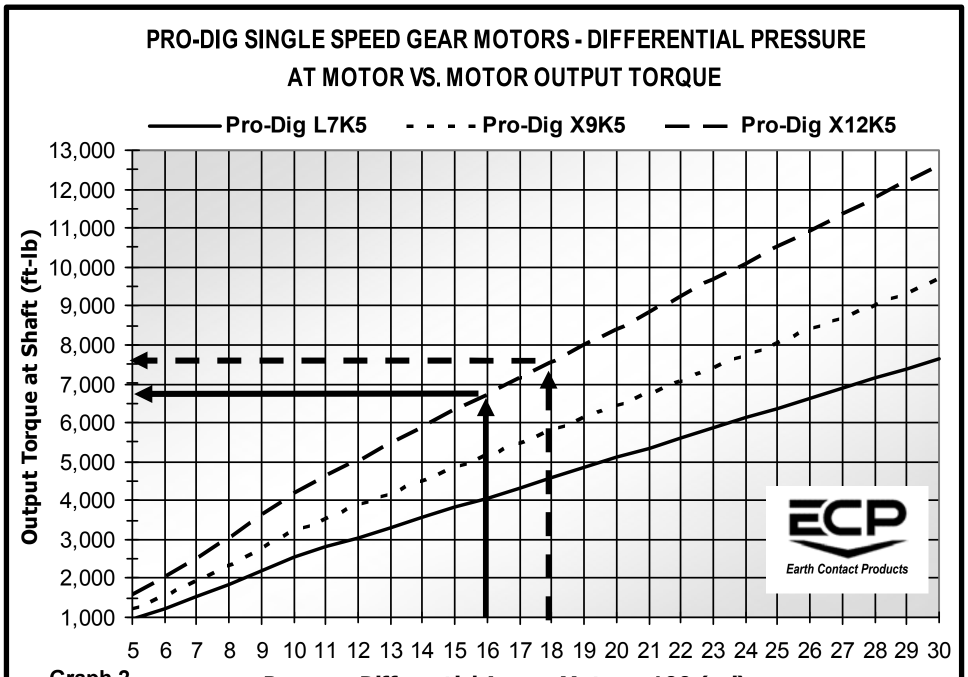
With the actual field measured pressure differentials calculated, one can find the actual installation motor torque on Graph 2 from Chapter 4. (shown below.) Locate 1,700 psi and 1,950 psi values at the bottom of the graph. Then read upward until the motor curve line for the X12K5 motor is reached. Read horizontally to the left where the "***Output Torque at the Shaft"*** can be found.

A. Design Example 1 Output Torque at the Shaft torsion is estimated at **6,750 ft-lb**. (2-78" diameter shaft)

B. Design Example 1B had a pressure differential of 1,950 psi, which produced an Output Torque at Shaft estimated at **7,600 ft-lb**. (3-1/2" diameter shaft)

Proper installation shaft torque is confirmed for Design Examples 1 and 1B

End Design Example 7A.



Graph 2.

Review of Results of Example 7 & 7A

One can see that the result obtained by the *Quick*-Solve™ design analysis suggested the shaft torsion from field data was sufficient to provide the required load capacity. The results were similar from the calculated method, and from the *Quick*-Solve™ solution, for the installation shaft torque at the motor.

Design Example 8 – Ultimate Capacity from Field Data

In this exercise the anticipated ultimate capacities of the pile designs from Design Example 1 and Design Example 1B will be determined. This information is used to confirm that the installed piles meet or exceed the requirements set out in the original designs

Equation 2 from Chapter 1 is used to calculate the ultimate compressive capacity of the pile based upon data provided from the field. Recall that in *Design Example 1 - Heavy Weight New Construction Project* required an ultimate capacity at each pile of 60,000 pounds.

Equation 2: Ultimate Capacity - $P_u = k \times T$

Where,

P_u = Ultimate Capacity of Torque Anchor™ - (lb)
T = Final Installation Torque - (ft-lb)
(Averaged Over the Final 3 to 5 Feet)
k = Empirical Installation Torque Factor - (ft^{-1})

Design Example 1 - Calculate the Ultimate Pile Capacity of the 2-7/8" Diameter Pile:

$\mathbf{P_{u\text{-}Design\ 1}}$ = Ult. Capacity of the 2-7/8" dia. piles

Where,
k = 9 (Table 12)
$T_{Example\ 1}$ = 7,140 ft-lb (Design Example 6)

$P_{u\text{-}Design\ 1}$ = 9 x 7,140 ft-lb

$\mathbf{P_{u\text{-}Design\ 1}}$ = **<u>64,260 lb</u>**

Design 1: Verified – 64,260 lb > 60,000 lb

Design Example 1B - Calculate the ultimate pile capacity of the 3-1/2" Diameter Pile:

$\mathbf{P_{u\text{-}Design\ 1B}}$ = Ult. Capacity of the 3-1/2" piles:

Where, k = 8 (Table 12 – Chapter 1)
$T_{Design\ 1B}$ = 8,190 ft-lb (Design Example 6)

$\mathbf{P_{u\text{-}Design\ 1B}}$ = 8 x 8,190 ft-lb

$\mathbf{P_{u\text{-}Design\ 1B}}$ = **<u>65,520 lb</u>**

Design 1B: Verified – 65,520 lb > 60,000 lb

The results of the calculations confirm the ultimate capacity determined from the field data exceeds the design ultimate capacity stated in the specifications of Design Examples 1 and 1B.

End Design Example 8

Design Example 8A – Ultimate Capacity from Field Data – *Quick*-Solve™ Design Method

This exercise will determine the ultimate pile capacity based upon field data using the *Quick*-Solve™ design method. The comparison between the calculated design specifications and the actual field capacity will verify whether the pile installation is satisfactory.

Design Example 7A determined that the output torque at the motor shaft was 6,750 ft-lb at the termination of the pile installation. Graph 1 from Chapter 4 (shown on page below) provides a method to estimate the Ultimate Capacity of the installed helical products. A comparison to the design requirement will determine if the installed pile capacity exceeds the specified Ultimate Capacity.

Estimate the location on the horizontal axis for shaft torsion of 6,750 ft-lb (Slightly to the left of the 7,000 ft-lb grid line). The legend near the top of the graph provides choices between various shaft sizes. Read upward from the 6,750 ft-lb "*Motor Torque*" until reaching bold dashed graph line that represents the 2-7/8 inch diameter shaft configuration. Then move horizontally to the axis at left to check if installed pile ultimate capacity exceeds 60,000 pounds.

Looking carefully at the point where the horizontal plot intersects the *"Ultimate Capacity"* axis, the field generated shaft torsion at the termination of the pile installation shows to be approximately 60,000 lb. This verifies that the actual installed pile capacity meets design specification of 60,000 ft-lbs.

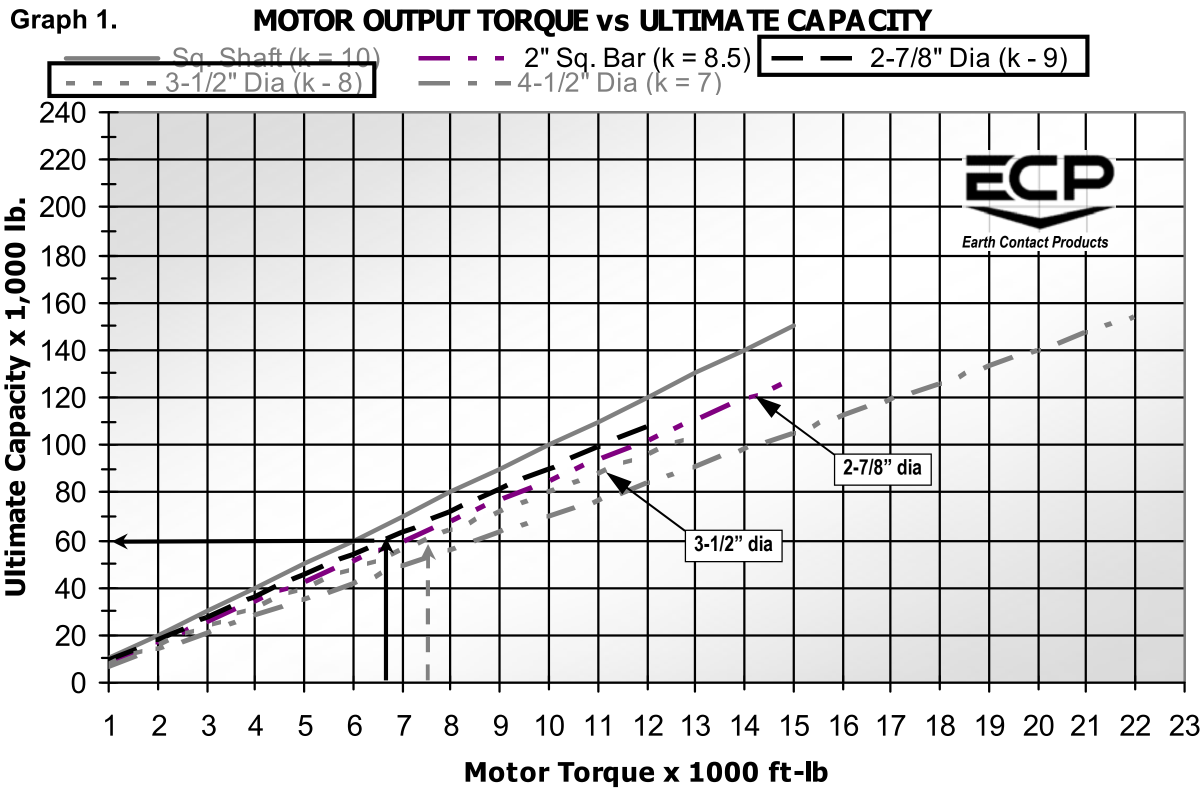
The capacity for the 3-1/2" diameter pile is similarly determined from Graph 1 at 8,200 ft-lb and reading up to the short dashed line, then to the left to see the ultimate capacity estimate of 60,000 lbs.

End Design Example 8

Review of Results of Example 8 & 8A

The value in using the *Quick*-Solve™ design method is that by using graphs it provides rapid field results. This method will not exactly determine the field installation capacity, but it quickly indicates whether the installation is meeting or exceeding specifications. If the engineer requires the actual installed ultimate capacity, then it must be calculated from the field data.

Graph 1.



Technical Design Assistance

Earth Contact Products, LLC. has a knowledgeable staff that stands ready to help you with understanding how to prepare preliminary designs, installation procedures, load testing, and documentation of each placement when using ECP Torque Anchors™. If you have questions or require engineering assistance in evaluating, designing, and/or specifying Earth Contact Products, please call us at 913 393-0007, Fax at 913 393-0008.

EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

Earth Contact Products

Chapter 6

ECP Steel Piers™

Technical Design Manual

- **PPB-166 Slab Bracket System**
- **PPB-250 Under Footing Pier System**
- **PPB-300 ECP Steel Pier™ System**
- **PPB-350 ECP Steel Pier™ System**
- **PPB-400 ECP Steel Pier™ System**
- **PPB-350-TTA Resistance Pier & Tieback System**

EARTH CONTACT PRODUCTS

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Table of Contents

Chapter 6 - ECP Steel Piers™ Technical Design Manual

EARTH CONTACT PRODUCTS
"Designed and Engineered to Perform"

Earth Contact Products, LLC reserves the right to change design features, specifications and products without notice, consistent with our efforts toward continuous product improvement. Please check with Engineering Department, Earth Contact Products to verify that you are using the most recent information and specifications.

Introduction

The ECP Steel Pier™ belongs to a family of underpinning products that are sometimes referred to as micropiles, push piers, or resistance piers. These underpinning products are hydraulically driven into the soil using the structural weight of the building as a reaction force. A friction reduction collar is attached to the bottom of the lead section of pier pipe. The purpose of the friction collar is to create an opening in the soil that has a larger diameter than the pier pipe that follows. This dramatically reduces the skin friction on the pier pipe as it is driven into the soil. This feature allows the pier pipe to reach firm bearing and for the installer to load test to verify that the pier has encountered suitable end bearing or rock that is suitable to support the design load.

The ECP Steel Pier™ like other resistance piers is an end-bearing pier that does not rely upon, nor requires skin friction to produce support. The piers are able to develop a factor of safety against failure or creep because the piers are installed and load tested individually using a reaction force provided by the structural weight from a substantial part of the building. The ability of the steel pier system to develop a significant factor of safety comes from the pier during pier installation experiencing a much higher load than the lower working load after the service load is transferred to the pier during restoration. The piers are required to be driven <u>one at a time</u> using the structural building weight as the reaction during the installation. During load transfer and restoration, hydraulic jacks are placed at <u>multiple pier locations</u>, which place a lower design/working load on each pier. A building with substantial construction and rigidity can develop greater factor safety on each pier than a structure with a weaker and more flexible structure.

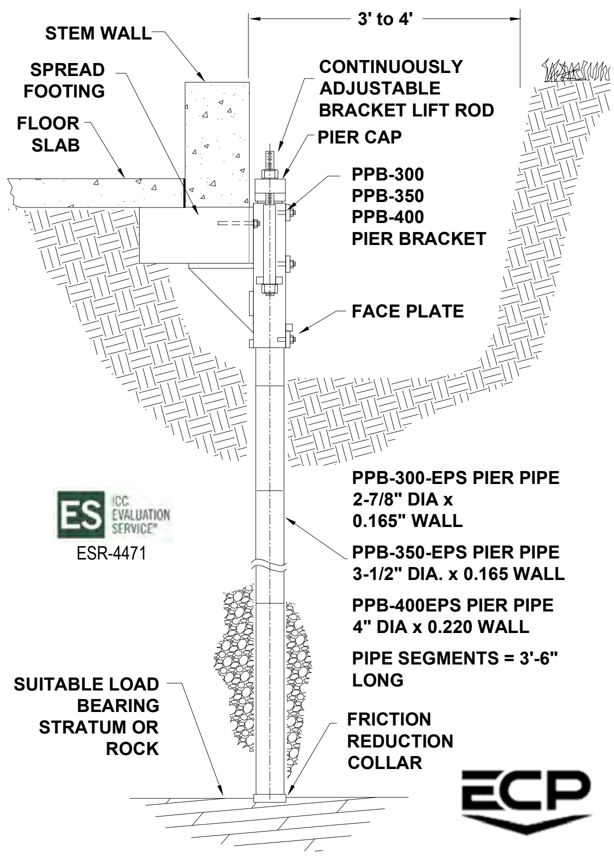


Figure 1. Typical configuration for the ECP Steel Pier™ System with Type PPB Eccentric Underpinning Bracket attachment to the footing.

Features and Innovations

The patented ECP Steel Pier™ is the fourth generation of a product invented by Don May dating back to the 1970's. The current ECP Steel Pier™ incorporates many advances over previous versions. An important improvement to the ECP Steel Pier™ system is a reduction in the eccentricity between centerline of the pier pipe and the foundation bracket. This means that there is less moment (twisting) at the pier bracket when it is loaded. This feature translates to greater load capacities. The system offers nearly unlimited elevation recovery as the adjustment of the pier bracket elevation is accomplished by hex nuts attached to continuously threaded rods as opposed to the limitations imposed by the use of shims and pins that are found on some other systems. The ECP Steel Pier™ is also more "installer friendly" because the inner chamber of the drive stand is quickly accessible by temporarily removing face plates on the pier bracket and drive stand. In addition, a pier alignment guide is integral with one of the drive stand face plates. The retaining plate that safely secures the heavy hydraulic drive cylinder to the drive stand is a large advancement for operator safety over other systems. The drive cylinder had a tendency to work loose in earlier designs. Other than a control sleeve that is only used on the PPB-350, all of the pier brackets are designed to securely align and guide the pier pipe without additional tools.

Another innovation on the ECP PPB-300 & PPB-350 Steel Pier™ Systems is the patented "Inertia Sleeve". This state of the art method of increasing the moment of inertia (stiffness) of the pier pipe, in addition the "Inertia Sleeve" strengthens the coupled joints, which is unmatched in the industry. The combination of pier pipe and "Inertia Sleeve" produces a more rigid pier system that is stiffer (It has a higher moment of inertia.) than with only the pier pipe.

The "Inertia Sleeve" does not carry any of the axial compressive pier loads; the function of this product is only to increase moment of inertia of the pier pipe (pipe stiffness). This can be used to prevent shaft buckling in weak soils, or fully exposed in water or air. (See Figure 3, below)

The "Inertia Sleeve" consists of a pipe that fits snugly inside the existing pier pipe. One end the "Inertia Sleeve" has a nine inch long coupling that fits through, and spans across, the coupled pier pipe joint. The "Inertia Sleeve" is installed concurrent with the pier pipe and only takes the time necessary to pick up a section of Inertia Sleeve and to let it drop by gravity into the pier pipe prior to installing the next length of pier pipe into the ground.

The installed cost of this pier strengthening product is hardly more than the purchase price of the "Inertia Sleeve" product, yet it creates a stiffer pier system that is more resistant to buckling when installed through weak soil.

Product Benefits

- **Ultimate-Limit Capacities: Up to 115,000 lb.**
- **Proof Test Loads: Up to 86,000 lb.**
- **Standard Lift – 4" Fully Adjustable**
- **Greater Lift Capability With Optional Longer Bracket Rods**
- **Installs From Outside or Inside the Structure**
- **Installs With Portable Hydraulic Equipment**
- **Installs With Little or No Vibration**
- **Friction Reduction Collar On Lead Pier Section Reduces Skin Friction**
- **Installs To Rock or Verified End Bearing Stratum**
- **100% of Piers Are Field Load Tested to Verify Capacity During Installation**
- **Manufacturer's Warranty**
- **ICC-ES Evaluation ESR 4771 applies to Model 300 & 350 ECP Steel Pier™ Eccentric Bracket Systems and Inertia Sleeves.**

Pier Installation Sequences

Quiet, vibration free hydraulic equipment is used to install ECP Steel Piers™. All installation equipment is portable and can be carried in a wheelbarrow. After all of the piers are installed and then proof load tested, the structure can be immediately restored after pier installation by transferring the structural load to the piers. No wasted time waiting for concrete to cure, and no spoils to remove and transport from the site. Projects are usually completed in days, not weeks.

All piers are proof load tested prior to being put in service. A proof test load is a test load placed on the pier system that is greater than the actual working load. A factor of safety is determined and recorded. The pier capacity is verified. Should geologic conditions change, the piers can be easily inspected, tested and/or adjusted.

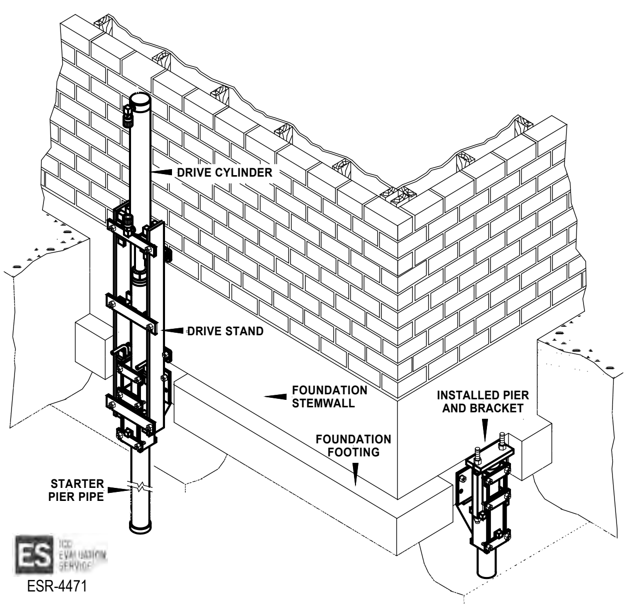


Figure 2. Typical ECP Steel Pier™ Installation Using An Eccentric Underpinning Bracket.

The following nine steps illustrate the typical installation procedure for the PPB-300, PPB-350 or PPB-400 Eccentric Underpinning Brackets. Figure 2 shows a structure with a spread footing. The detail on the left side of Figure 2 illustrates the configuration used when installing the resistance pier system and driving the pier pipe. On the right side of Figure 2 is the configuration of the installed pier system following the transfer of the structural load to the pier. *ECP Typical Specifications* are available and provide the specific and detailed product installation requirements and procedures. Please contact ECP engineering department for more information.

1. **Site survey:** Pier placements are determined and locations of all underground utilities are verified.
2. **Excavation:** Small excavations are dug for access at each placement location. The excavation required at the foundation is usually about 3 feet square.
3. **Preparation of the foundation:** The footing is notched (if required) to situate the Eccentric Underpinning Bracket under the stem wall. The area under the footing is chipped a smooth and level condition. The face of the stem wall is adjusted to be vertical (plumb) at the bracket attachment location.
4. **Bracket Attachment:** The Eccentric Underpinning Bracket is secured to the footing using two anchor bolts. The drive stand and the hydraulic cylinder are mounted to the bracket. (See left side of Figure 2.)
5. **Pier Pipe Installation:** The pier pipe is advanced into the soil using a small portable high-pressure hydraulic pump. Pier installation continues until rock or suitable bearing is encountered below any unstable soil near the surface. The piers may be installed from outside or inside the structure. Low overhead clearance is not a problem during installation because each pier section is 3-1/2 feet long.
6. **Proof Load Test:** Every pier is field load tested to insure that rock or other firm bearing is verified to be substantial enough to withstand the load required to restore and support the structure. The structure provides the reaction force for installing, and for proof testing. Factor of Safeties from 1.25 to 3.0 are typically generated during installation.
7. **Preparations for Restoration:** Once all piers have been installed, load tested, and the installation data recorded; lifting head assemblies and hydraulics are placed at each bracket. All are connected to hydraulic hand pumps and one or more manifolds.
8. **Restoration:** Under careful supervision, the structural load is transferred from the failing soil under the foundation to the ECP Steel Piers™. The structure is gently and evenly lifted to the specified design elevation. The hex nuts at the pier caps are secured at each placement to secure the load. The lifting equipment is then removed.
9. **Clean Up:** The soil that was excavated at each pier placement location is replaced and compacted. The site is left clean and neat.

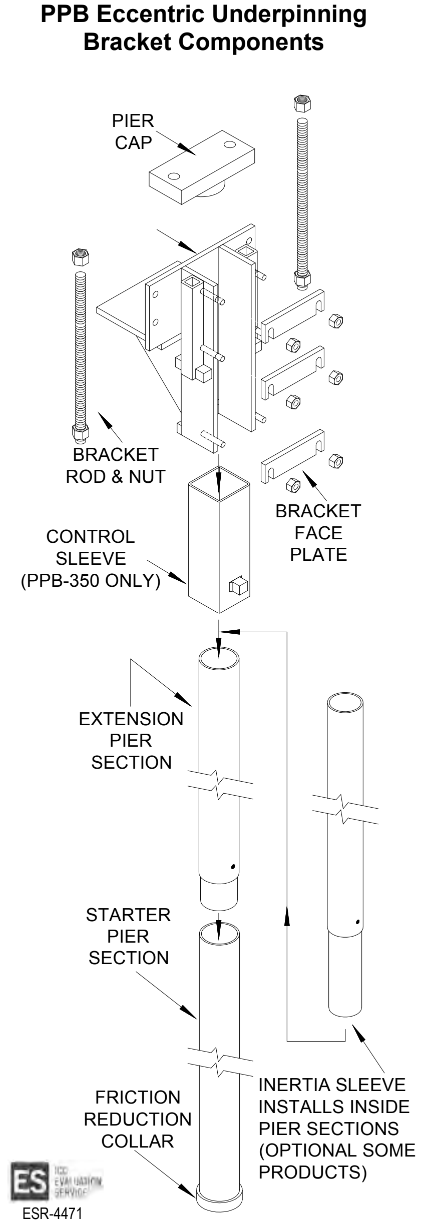


Figure 3. Component Configuration for Typical PPB-300, PPB-350 & PPB-400 Eccentric Underpinning Brackets.

ECP Steel Pier™ – Product Configurations

PPB-300 Eccentric Underpinning Bracket

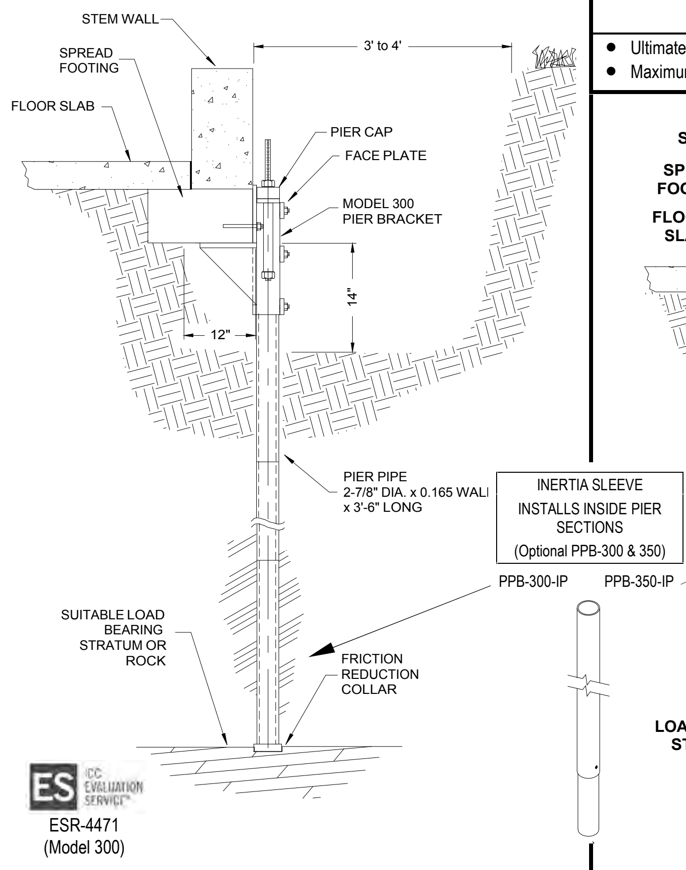
- Ultimate Capacity – 68,000 lb
- Maximum Proof Load – 51,000 lb
- 68 in^2 Bearing Surface
- 2-7/8" dia. High Strength Tube

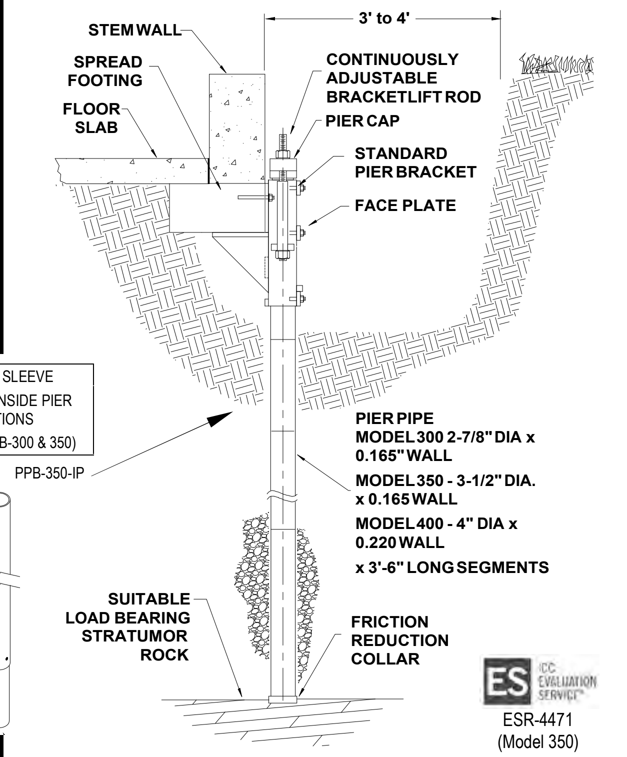
PPB-350 Eccentric Underpinning Bracket

- Ultimate Capacity – 86,000 lb
- Maximum Proof Load – 64,500 lb
- 74 in^2 Bearing Surface
- 3-1/2" dia. High Strength Tube

PPB-400 Eccentric Underpinning Bracket

- Ultimate Capacity – 99,000 lb
- Maximum Proof Load – 74,000 lb
- 74 in^2 Bearing Surface
- 4" dia. High Strength Tube





Part Number	Description	Wt Each	Bundl Qty
PPB-300	PPB-300 Assembly Black Bracket[1] 14 ft. Galvanized Pier Pipe[2]	137 lbs	8
PPB-300-G	PPB-300 Assembly Galvanized Bracket[1 3] 14 ft. Galvanized Pier Pipe[2]	137 lbs	8
PPB-300-EPS	Extra Pier Sections 2-7/8" OD - Galvanized	17.3 lbs	19
PPB-300-IP	Inertia Pier Sleeve	16.5 lbs	1
PPB-300-PC	Pier Coupler	2.5 lbs	20
PPB-300-S	Starter Pier Section 2-7/8" OD - Galvanized	17 lbs	1
PPB-300-DS	Drive Stand	68 lbs	1

1.. PPB-300, PPB-350 & PPB-400 Bracket Assemblies Include Pier Cap, (2) 18" All-Thread Rods, (4) Heavy Hex Nuts, and a Control Sleeve on PPB-350
2. 14' of Pier Pipe includes: (1) Starter Section w/ Friction Reduction Collar 42" long and (3) Extra Pier Sections 42" long with coupler. Total length 14 ft. – PPB-300 & PPB-350 – Galvanize corrosion protection - ASTM A653/A G90
3. PPB-400-SG, PPB-400-EPSG and All Galvanized Eccentric Underpinning Brackets - ASTM A123, Grade 75 Hot Dip Galvanize

- 4" Standard Lift – Fully Adjustable Higher Lift Capability
- Installs From Outside or Inside Structure
- Manufacturer's Warranty
- U.S. Patent No. 6,193,422
- ICC-ES ESR-4471 Evaluation report on the above PPB-300 & PB 350 Eccentric Bracket Systems

Part Number	Description	Wt Each	Bndl Qty
PPB-350	PPB-350 Assembly Black Bracket[1] 14 ft. Galvanized Pier Pipe[2]	206 lbs	8
PPB-350-G	PPB-350 Assembly Galvanized Bracket[1 3] 14 ft. Galvanized Pier Pipe[2]	206 lbs	8
PPB-350-EPS	Extra Pier Sections 3-1/2" OD Galvanized[2]	22 lbs	19
PPB-350-IP	Inertia Pier Sleeve	23 lbs	1
PPB-350-PC	Pier Coupler	3.5 lbs	20
PPB-350-S	Starter Section 3-1/2" OD Galvanized[2]	20 lbs	1
PPB-350-SB	4" OD x 36" Sleeve Black	27 lbs	1
PPB-400	PPB-400 Assembly Black Bracket[1] 14 ft. Galvanized Pier Pipe[2]	235 lbs	8
PPB-400-G	PPB-350 Assembly Galvanized Bracket[1 3] 14 ft. Hot Dip Galvanized Pier Pipe[3]	235 lbs	8
PPB-400-EPSG	Extra Pier Sections 4" OD - HDG[3]	34 lbs	19
PPB-400-EPSB	Extra Pier Sections Black	34 lbs	19
PPB-400-SG	Starter Sections 4" OD Hot Dip Galvanized[3]	32 lbs	1
PPB-400-SB	Starter 4" OD Black	32 lbs	1
PPB-350/400-DS	Drive Stand	115 lbs	1

ECP Steel Pier™ – Product Configurations

PPB-350-EP2 - 2” Eccentric Offset Underpinning Bracket

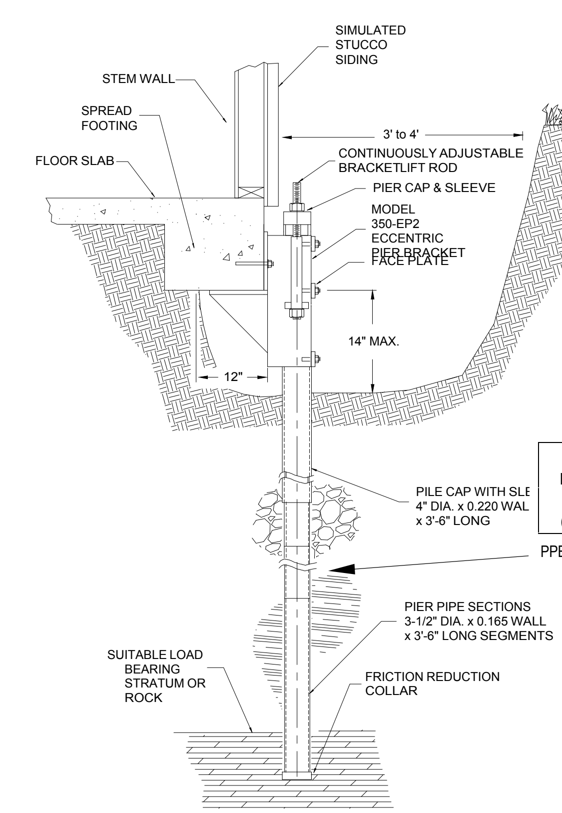
- Ultimate Capacity – 53,000 lb
- Maximum Proof Load – 37,750 lb
- 74 in^2 Bearing Surface
- 3-1/2” dia. High Strength Tube

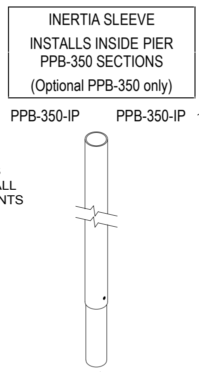
PPB-350-EP4 - 4” Eccentric Offset Bracket

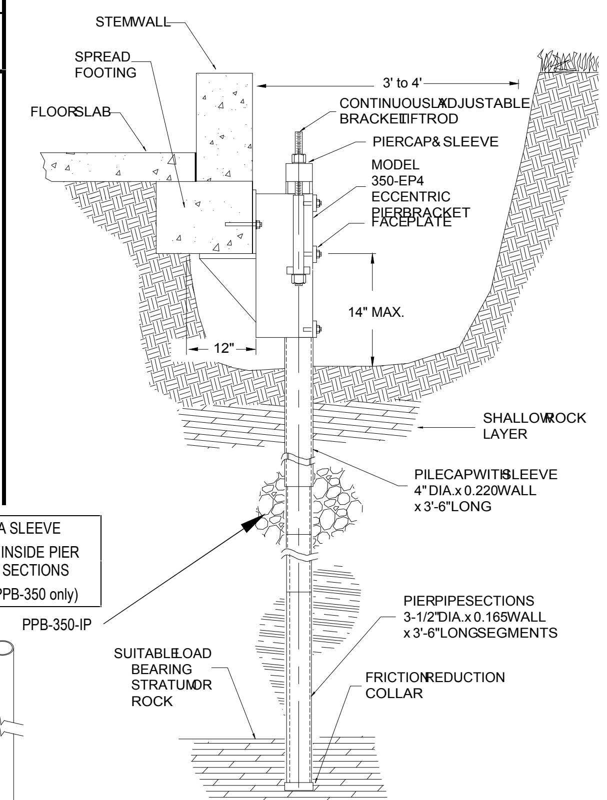
- Ultimate Capacity – 42,000 lb
- Maximum Proof Load – 31,500 lb
- 74 in^2 Bearing Surface
- 3-1/2 dia. High Strength Tube

PPB-400-EP2 - 2” Eccentric Offset Underpinning Bracket

- Ultimate Capacity – 54,000 lb
- Maximum Proof Load – 40,500 lb
- 74 in^2 Bearing Surface
- 4” dia. High Strength Tube







Part Number	Description	Wt Each	Bundl Qty
PPB-350-EP2	PPB-350-EP2 Assembly Black Bracket[1] 14 ft. Galvanized Pier Pipe[2]	254 lbs	1
PPB-350-EP2G	PPB-350-EP2 Assembly Galvanized Brkt[1] 14 ft. Galvanized Pier Pipe[2]	254 lbs	1
PPB-350-EPS	Extra Pier Sections 3-1/2” OD Galvanized	22 lbs	19
PPB-350-IP	Inertia Pier Sleeve	23 lbs	1
PPB-350-PC	Pier Coupler	3.5 lbs	20
PPB-350-S	Starter Section 3-1/2" OD Galvanized	20 lbs	1
PPB-400-EP2	PPB-400-EP2 Assembly Black & Black Pipe[3]	280 lbs	1
PPB-400-EP2G	PPB-400-EP2 Assy Galvanized & HDG Pipe[3]	280 lbs	1
PPB-400-EPSG	Extra Pier Sections 4” OD Galvanized	34 lbs	19
PPB-400-SG	Starter Section 4" OD Galvanized	34 lbs	1
PPB-350/400-DS	Drive Stand	115 lbs	1

Part Number	Description	Wt Each	Bundl Qty
PPB-350-EP4	PPB-350-EP4 Assembly Black Bracket[1] 14 ft. Galvanized Pier Pipe[2]	259 lbs	1
PPB-350-EP4G	PPB-350-EP4 Assembly Galvanized Brkt[1] 14 ft. Galvanized Pier Pipe[2]	259 lbs	1
PPB-350-EPS	Extra Pier Sections 3-1/2” OD Galvanized	22 lbs	19
PPB-350-IP	Inertia Pier Sleeve	23 lbs	1
PPB-350-S	Starter Section 3-1/2" OD Galvanized	20 lbs	1
PPB-350/400-DS	Drive Stand	115 lbs	1

- Bracket Offset Allows for Siding or Stucco that is Overhanging the Footing
- 4” Standard Lift With Fully Adjustable Higher Lift Capability
- Manufacturer’s Warranty

1. PPB-350-EP2, PPB-400-EP2 and PPB-350-EP4 Bracket Assemblies Include: (1) Pier Cap, (2) 18" All-Thread Rods, (4) Heavy Hex Nuts, and (1) Control Sleeve (on PPB-350 only). PPB-350-EP2 & PPB-400-EP2 Supplied with Black Bracket (Mill Finish). PPB-300-EP2G & PPB-400-EP2G * PPB-350-EP4 Supplied with Galvanized Corrosion Protection – ASTM A123, Grade 75 Hot Dip Galvanize
2. PPB-350 EP2 & PPB-350-EP4 - 14' of Galvanized Pier Material Includes: (1) Starter Section w/ Friction Reduction Collar 42" long and (3) Extra Pier Sections 42" long with coupler. Galvanize corrosion protection - ASTM A653/A G90
3. PPB-400-EP2 - 14' of Galvanized Pier Material includes: (1) Starter Section w/ Friction Reduction Collar 42" long and (3) Extra Pier Sections 42" long with coupler. Black Pipe is Mill Finish Steel. Galvanized Corrosion Protection – ASTM A123, Grade 75 Hot Dip Galvanize

ECP Steel Pier™ – Product Configurations

PPB-350-WM Wall Mount Bracket

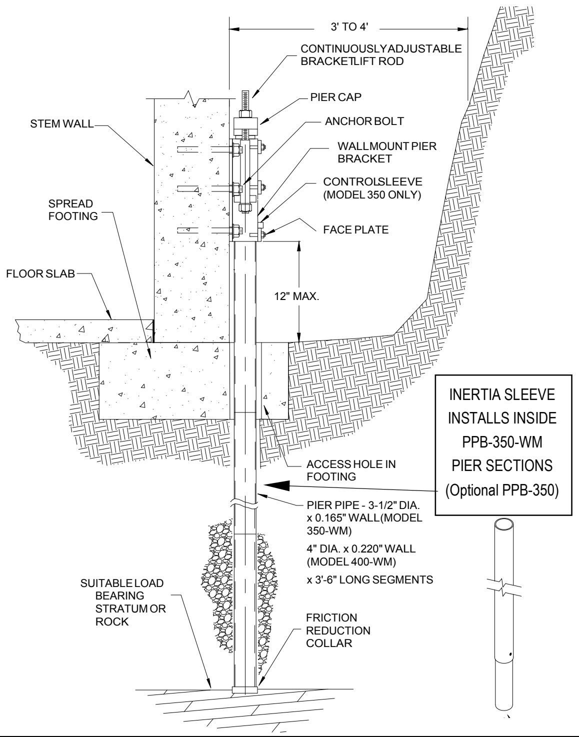
- Ultimate Capacity – 86,000 lb
- Maximum Proof Load – 64,500 lb
- 244 in^2 Mounting Plate Area
- 3-1/2" dia. High Strength Tube

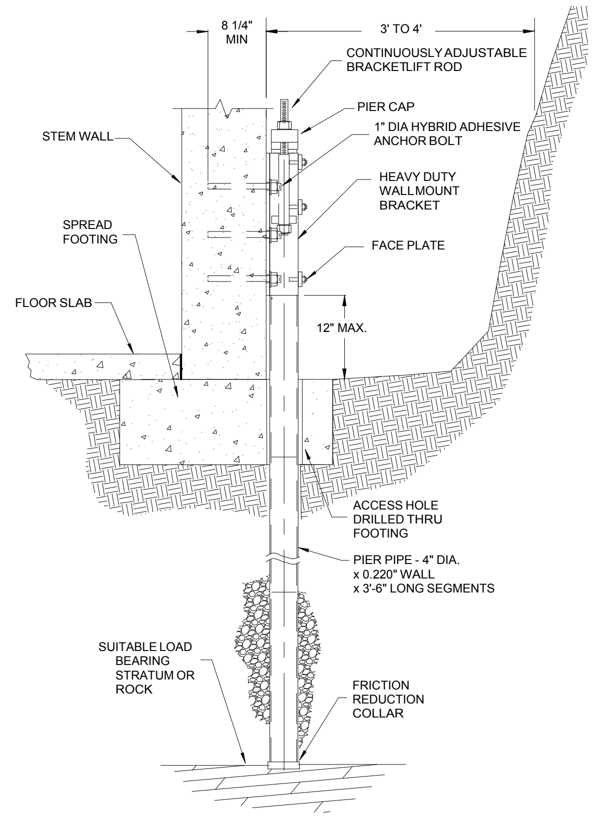
PPB-400-WMHD Wall Mount Bracket

- Ultimate Capacity – 115,000 lb
- Maximum Proof Load – 86,000 lb
- 320 in^2 Mounting Plate Area
- 4" dia. High Strength Tube

PPB-400-WM Wall Mount Bracket

- Ultimate Capacity – 107,000 lb
- Maximum Proof Load – 80,000 lb
- 244 in^2 Mounting Plate Area
- 4" dia. High Strength Tube





Part Number	Description	Wt Each	Bundl Qty
PPB-350-WM	PPB-350-WM Assembly Black Bracket[1] 14 ft. Galvanized Pier Pipe[2]	183 lbs	1
PPB-350-WMG	PPB-350-WM Assembly Galvanized Brkt[1] 14 ft. Galvanized Pier Pipe[2]	183 lbs	1
PPB-350-EPS	Extra Pier Sections 3-1/2" OD Galvanized	22 lbs	19
PPB-350-IP	Inertia Pier Sleeve	23 lbs	1
PPB-350-PC	Pier Coupler	3.5 lbs	20
PPB-350-S	Starter Section 3-1/2" OD Galvanized	20 lbs	1
PPB-400-WM	PPB-400-WM Assembly Black Bracket[1] 14 ft. Galvanized Pier Pipe[2]	215 lbs	1
PPB-400-WMG	PPB-400-WM Assembly Galvanized Brkt[1] 14 ft. Galvanized Pier Pipe[2]	215 lbs	1
PPB-400-WMB	PPB-400-WM Assembly Black Bracket[1] 14 ft. Black Pier Pipe[3]	215 lbs	1
PPB-400-EPS	Extra Pier Section 4" OD Galvanized - HDG	34 lbs	19
PPB-400-EPSB	Extra Pier Section 4" OD Black (Mill Finish)	34 lbs	19
PPB-400-SB	Starter Section 4" OD Black (Mill Finish)	32 lbs	1
PPB-400-S	Starter Section 4" OD Galvanized - HDG	32 lbs	1
PPB-350/400-DS	Drive Stand	115 lbs	1

Part Number	Description	Wt Each	Bundl Qty
PPB-400-WMHD	PPB-400-WMHD Assembly Black Bracket[1] 14 ft. Galvanized Pier Pipe[2]	230 lbs	1
PPB-400-WMHDG	PPB-400-WMHD Assy Galvanized Brkt[1] 14 ft. Galvanized Pier Pipe[2]	230 lbs	1
PPB-400-WMHDB	PPB-400-WMHD Assembly Black Bracket[1] 14 ft. Black Pier Pipe[3]	230 lbs	1
PPB-400-EPS	Extra Pier Section 4" OD Galvanized	34 lbs	19
PPB-400-EPSB	Extra Pier Section 4" OD Black (Mill Finish)	34 lbs	19
PPB-400-SB	Starter Section 4" OD Black (Mill Finish)	32 lbs	1
PPB-400-S	Starter Section 4" OD Galvanized	32 lbs	1
PPB-350/400-DS	Drive Stand	115 lbs	1

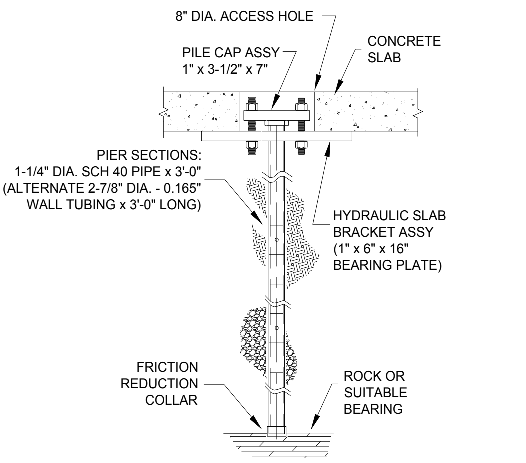
- Installs from Outside or Inside Structure
- 4" Standard Lift With Fully Adjustable Higher Lift Capability
- Manufacturer's Warranty

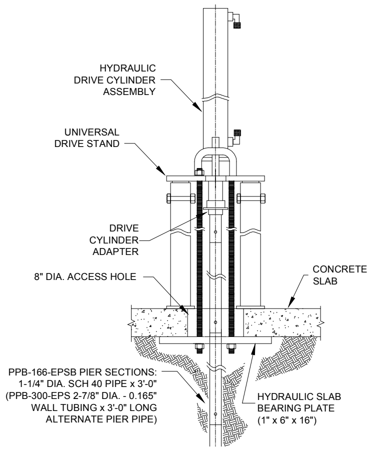
1. PPB-350-WM, PPB-400-WM and PPB-400-WMHD Bracket Assemblies Include: (1) Pier Cap, (2) 18" All-Thread Rods, (4) Heavy Hex Nuts, and (1) Control Sleeve (on PPB-350 only) (Mill Finish Bracket) - PPB-400-WMG & PPB-400-WMHDG Corrosion Protection — ASTM A123, Grade 75 Hot Dip Galvanize
2. PPB-350-WM - 14' of Galvanized Pier Material Includes: (1) Starter Section w/ Friction Reduction Collar 42" long and (3) Extra Pier Sections 42" long with couplers. – Galvanize corrosion protection - ASTM A653/A G90.
3. PPB-400-WMB & PPB-400-WMHDB - 14' of Black Pier Material Includes: (1) Starter Section w/ Friction Reduction Collar 42" long and (3) Extra Pier Sections 42" long with coupler. All Mill Finish Steel.

ECP Steel Pier™ – Product Configurations

PPB-166 Slab Pier

- Ultimate Capacity – 22,000 lb
- Maximum Proof Load – 16,500 lb
- 4" Standard Lift – Fully Adjustable Higher Lift Capability
- 46 in² Bearing Surface
- 1-5/8" OD – Sch 40 Pipe or 2-7/8" OD. High Strength Tube
- Manufacturer's Warranty





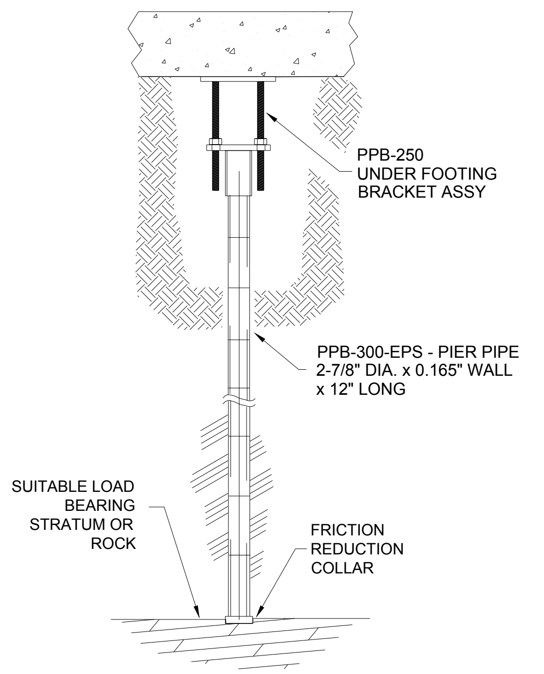
Part Number	Description	Wt Each	Bndl Qty
PPB-166	PPB - 166 Assembly Black (Mill Finish) ¹	37 lbs	1
PPB-166-G	PPB - 166 Assembly Galvanized (HDG) ²	37 lbs	1
PPB-166-EPSB	Extra Pier Section 1-5/8" OD Black	8 lbs	19
PPB-166-S	Starter Section 1-5/8" OD Black	7 lbs	1
PPB-300-EPS	Extra Pier Sections 2-7/8" OD Galvanized²	17.3 lbs	19
PPB-300-S	Starter Section 2-7/8" OD Galvanized	17 lbs	1
PPB-166-DS	Slab Drive Stand	N/A	1

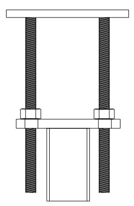
1. PPB -166 includes: (1) Pier Cap and (2) 18" All -Thread and (4) Heavy Hex Nuts.
2. Corrosion Protection: PPB-166G – ASTM A123, Grade 75 Hot Dip Galvanize - PPB-300-S & PPB-300 EPS – Galvanize corrosion protection - ASTM A653/A G90

Starter and Extra Pier Sections Sold Separately.

PPB-250 Concentric Bracket

- Ultimate Capacity – 54,000 lb
- Maximum Proof Load – 40,500 lb
- 4" Standard Lift – Fully Adjustable Higher Lift Capability
- 100 in² Bearing Surface
- 2-7/8" dia. High Strength Tube
- .PatentNo.7,044,686
- Manufacturer's Warranty





PPB-250 BRACKET ASSY

Part Number	Description	Wt Each	Bndl Qty
PPB-250	PPB-250 Assembly Black, Galv Pipe¹	60 lbs	8
PPB-200-EPS	Extra Pier Sections 2-7/8" OD Galvanized²	6.5 lbs	19
PPB-200-PC	Pier Coupler	2.5 lbs	20
PPB-200-S	Starter Section 2-7/8" OD Galvanized	4.5 lbs	1

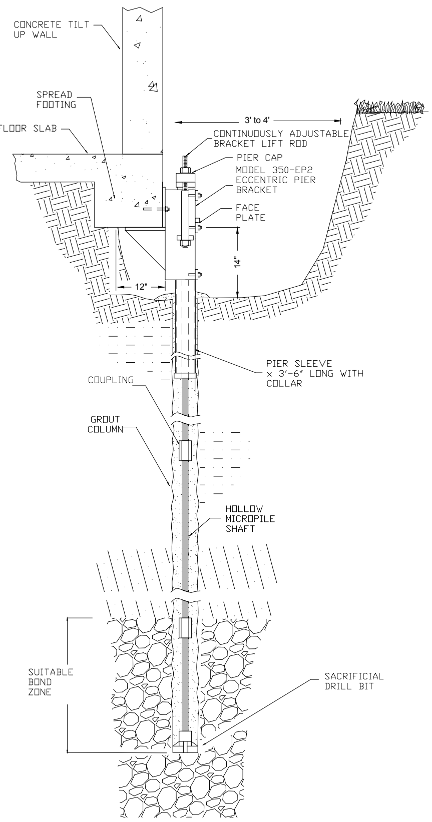
1. PPB-250 Bracket includes (1) Pier Cap, (1) Bearing Plate, (4) All Thread bars – 15" Long, (4) Heavy Hex Nuts, and (1) Starter Section with Friction Reduction Collar – 12" Long. (Mill Finish Steel)
2. PPB-200-S & PPB-200-EPS are 12" Long - Galvanize corrosion protection - ASTM A653/A G90

Extra Piers Sections Sold Separately

ECP Steel Pier™ – Product Configurations

PPB-300-MP2 Eccentric Underpinning Bracket

- Ultimate Capacity – 68,000 lb
- Installs Into Rock Through a Predrilled and Grouted Hole
- 74 in^2 Bearing Surface
- Hollow Micro Pile Shaft
- 4" Standard Lift – Fully Adjustable Higher Lift Capability

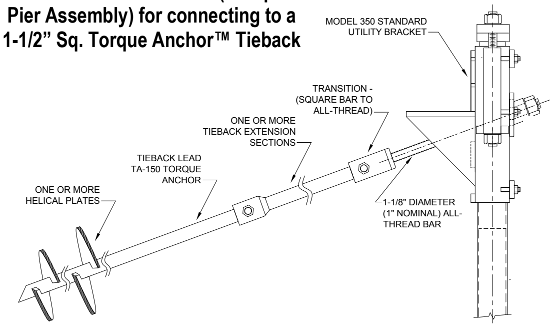


Part Number	Description	Wt Each	Bundl Qty
PPB-350-MP2	PPB-350-MP2 Assembly Black Bracket	157 lbs	1
PPB-350-MP2G	PPB-350-MP2 Assembly Galvanized Bracket	157 lbs	1

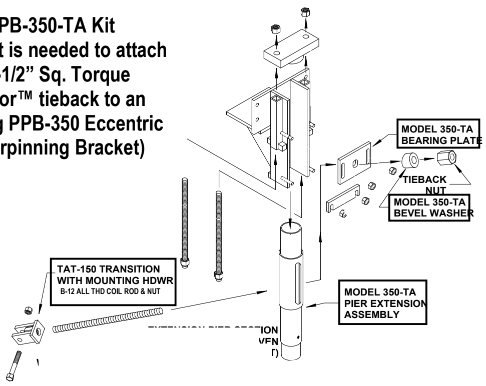
PPB-350-TTA Resistance Pier Tieback

- Ultimate Capacity – 86,000 lb
- Maximum Proof Load – 64,500 lb
- 74 in^2 Bearing Surface
- 3-1/2 dia. High Strength Tube
- 1-1/2" Sq Shaft Helical Torque Anchor™ for Lateral Support
- Ultimate Tieback Capacity – 70,000 lb.

PPB-350-TAA Steel Pier™ (Complete Pier Assembly) for connecting to a 1-1/2" Sq. Torque Anchor™ Tieback



PPB-350-TA Kit (This Kit is needed to attach a 1-1/2" Sq. Torque Anchor™ tieback to an existing PPB-350 Eccentric Underpinning Bracket)



Part Number	Description	Wt Each	Bundl Qty
PPB-350-TTA	PPB-350 Assembly Black Bracket[2] 14 ft. Galvanized Pier Pipe	206 lbs	1
PPB-350-TAGA	PPB-350 Assembly Galvanized Bracket[3] 14 ft. Galvanized Pier Pipe	206 lbs	1
PPB-350-TA	TA Assy Kit *(Only parts in boxes above)*	52 lbs	1
PPB-350-EPS	Extra Pier Sections 3-1/2" OD - Galvanized	22 lbs	19
TAT-150	Transition Assembly[4]	5 lbs	1

1. PPB-350-MP2 includes: (1) Bracket (1) Pier Cap and (2) 18" All-Thread and (4) Heavy Hex Nuts. Note: Pier Hollow Bar Sold Separately
2. PPB-350-TTA & PPB-350-TAGA Bracket Assemblies Includes: (1) Pier Cap, (2) 18" All-Thread Rods, (4) Heavy Hex Nuts, (1) Control Sleeve and (1) PPB-350-TA Kit. PPB-350-TTA is supplied with Black Underpinning Bracket (Mill Finish) PPB-350-TAGA is supplied with Galvanized Corrosion Protection – ASTM A123, Grade 75 Hot Dip Galvanize.
3. 14' of Galvanized Pier Material includes: (1) Starter Section w/ Friction Reduction Collar 42" long and (3) Extra Pier Sections 42" long with coupler. Total length 14 ft. – Galvanize corrosion protection - ASTM A653/A G90
4. TAT-150 Transition Assembly – (1) 1-1/2" Sq. Shaft Anchor Shaft to B-12 All Thd Coil Rod Transition, (1) B12 Rod x 22" Long, (1) 3/8x5x5" Plate Washer and (1) Nut.
5. Manufacturer's Warranty

Table 1.	ECP Steel Pier™ System Ratings				
Pg	Product Designation – Pipe Size	Ultimate-Limit [1] Bracket Only Capacity	Ultimate-Limit [1] Mechanical System Capacity	Maximum Drive Force - "Proof Test" [2]	Recommended Design / Service Load
5	PPB-300 Steel Pier – 2-7/8" dia. x 0.165" Wall	79,000 lb	68,000 lb	51,000 lb	34,000 lb
5	PPB-350 Steel Pier – 3-1/2" dia. x 0.165" Wall	99,000 lb	86,000 lb	64,500 lb	43,000 lb
5	PPB-400 Steel Pier – 4" dia. x 0.220" Wall	99,000 lb	99,000 lb	74,000 lb	49,500 lb
6	PPB-350-EP2 – 3-1/2" dia. x 0.165" Wall	68,000 lb	53,000 lb	39,750 lb	26,500 lb
6	PPB-400-EP2 – 4" dia. x 0.220" Wall	68,000 lb	54,000 lb	40,500 lb	27,000 lb
6	PPB-350-EP4 – 3-1/2" dia. x 0.165" Wall	55,000 lb	42,000 lb	31,500 lb	21,000 lb
7	PPB-350-WM – 3-1/2" dia. x 0.165" Wall	107,000 lb	86,000 lb	64,500 lb	43,000 lb
7	PPB-400-WM – 4" dia. x 0.220" Wall	107,000 lb	107,000 lb	80,000 lb	53,500 lb
7	PPB-400- WMHD – 4" dia. x 0.220" Wall	115,000 lb	115,000 lb	86,000 lb	57,500 lb
8	PPB-166 – Slab Jack – 1-5/8" O.D.[3] (1-1/4" Sch. 40)	22,000 lb	22,000 lb	16,500 lb	11,000 lb
8	PPB-250 Concentric Brkt – 2-7/8" dia x 0.165" Wall	54,000 lb	54,000 lb	40,500 lb	27,000 lb
9	PPB-350-MP2 – Micro Pile Bracket	68,000 lb	Note: Capacity depends upon drill dia, bar dia & grout strength		

1. Unfactored Failure Limit, use as nominal, "P_n" value per design codes
2. Maximum recommended load to confirm suitable end bearing capacity of pipe
3. Alternate pier pipe – 2-7/8" dia. x 0.165" Wall

"Suitable Load Bearing Stratum"

While field load testing of each resistance pier verifies that the pier has encountered suitable end bearing, several definitions can be found for the word "*Rock*". Many times when a soil boring log is available one may want to estimate the approximate depth to load bearing. Presented here are guidelines to assist with the estimating depth to "suitable bearing".

When material described in a soil boring reflects a Standard Penetration Test, "N", greater than 50 blows per foot, the stratum is generally consider being "weathered rock" or a very hard soil stratum.

Field load tests over the years have confirmed that resistance piers will provide long term support in strata such as these. In many cases suitable bearing can be achieved in less dense material depending upon the pile loading requirements, the type of soil and the soil density.

Thousands of comparisons between soil boring logs and field load tests suggest that *Suitable Load Bearing* is generally achieved in soils where "N" > 35 blows per foot at the termination depth.

Why Should You Determine Structural Loads?

Before one can begin to prepare a foundation underpinning design, an accurate estimate of the foundation loading is required. All loads that are placed upon a structure eventually transfer to the soil through the foundation. Many times all of these loads are not considered during the design. This can lead to an underestimation of the total structural load on the foundation. The result may be a pier design that has insufficient strength to support and restore the structure. Several problems surface when underestimated structural loads are used in the project design. The first indication of a problem is when the structure cannot be lifted, whereby the contractor usually tries to explain away the problem to the owner or engineer by saying that he is only trying to "stabilize" the structure or that there is too much "suction" under the slab. Other indications of underestimated foundation loads are the future appearance of new foundation fractures and/or the continued settlement (downward creep) of the underpinning piers after project completion.

The cost to the foundation contractor due to improperly estimating structural loads can be high. First and foremost is the likelihood of a customer complaint and lack of referrals. In addition, expensive callbacks cut into the company's profits. Finally, the long term solution usually involves installing additional underpinning between the existing piers, which means that the project could easily cost the contractor twice as much as originally planned.

Two structural loads are usually specified in the design. "Dead Loads" (DL) are permanent weights that are always applied to the foundation. Examples of *Dead Loads* are loads associated with components like the roof framing, the floor structure and the masonry. "Live Loads" are weights on the foundation that can change. *Live Loads* (LL) are the weights associated with the occupants, storage, snow and wind force, etc. The goal is to achieve an accurate estimated weight along the perimeter of the structure and interior where foundation restoration is needed. The easiest way to accomplish a foundation load estimate is to break the structure into components, one estimates weight for each component and then adds all of the results together. One only needs to inspect the structure and be familiar with typical building codes in the area to be able to calculate the loads from construction details or use the tables provided here to estimate the foundation loads.

Symbols Used In This Chapter	
A_{cyl}	Piston area of hydraulic cylinder – in^2
DL	Dead Load – lb/ft
F_{cyl}	Force from hydraulic cylinder - lb
FS	Factor Of Safety (Generally FS = 2)
H	Wall Height - ft
LL	Live Load – lb/ft
N	Standard Penetration Test (SPT) Results. N = Number of blows with a 140 lb hammer to penetrate the soil a distance of one foot. (Note: "N" may be given directly or in 3 segments. Always add the last two segment counts to get value for "N" is 4/**5**/**7**; Use N = 12.)
P_{cyl}	Pressure applied to hydraulic cylinder - psi
P_{DSL}	Recommended design service load – lb.
P_L	Pier lifting load – lb.
P_u	Ultimate pier capacity* – lb.
P_w	Working or design load – lb.
W	Distributed load along foundation – lb/lin.ft.
W_d	Permanent soil load on footing toe
W_T	Temporary soil load
X	Pier Spacing - ft

* Unfactored Limit, use as nominal, "P_u" value per design codes

Benefits of Estimating Foundation Loads

- The design will be more accurate and there will be greater restoration success with less chance of a call back from the owner later.
- The designer will have greater confidence presenting his design to owners and engineers when he has prepared a load estimate.
- Pier placements are easily justified because the load analysis determines the pier placement design that can provide immediate restoration and long term support.
- The owner will perceive the designer as being a more competent contractor because he was careful and thorough with the design, showed attention to details, a prepared a solid design.

Highly detailed proposals are generally more readily accepted than general repair outlines, which translate to more work for the company.

There will be greater client satisfaction with the final product when an accurate structural weight estimate is calculated at the perimeter and interior (if needed) of the structure where foundation restoration is required. We suggest that the easiest way to accomplish a quick foundation load estimate is to break the structure into general components, estimate the weight for each component and then add all of the results together. Tables 2 through 9 provide estimated general component loads on a foundation perimeter. After inspecting the structure and having knowledge of typical construction techniques and building codes, the tables provided can be used to estimate the foundation loads.

Estimating Commercial Building Loads

Because commercial construction and building use is so varied, it is not practical to produce tables similar to Table 2 through Table 7 for commercial structures, but using the <u>*Typical Weights of Common Building Materials*</u> provided in Table 10, the designer should be able to estimate perimeter and footing loads based on his knowledge about the construction materials and techniques used to construct the distressed structure. To prepare a load estimate, simply use the component weights shown in Table 10 to create loads for each structural element of the building, and then sum these loads to arrive at an estimated perimeter load. **We recommend that this load be increased by 10-15% to account for unknown or underestimated items.**

Simplified Tables of Structural Foundation Loads

When attempting a foundation load calculation for the first time, it often seems complicated and imposing. Once the basics are learned, estimating structural loads is quite easy. The simplest way to prepare a foundation load estimate is to break the structure into components, determine the estimated weight for each component and then add all of the results together. The simplified tables below have been prepared for the most common residential structural elements. **(See note regarding Building Codes after Table 7 below.)**

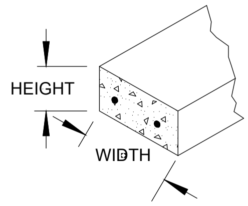


Table 2. Reinforced Concrete Spread Footings

HEIGHT \ WIDTH	8”	12”	15”	18”	20”	24”
	Perimeter Weight – lb/ft					
6”	24	72	90	108	120	144
9”	72	108	135	162	180	216
12”	96	144	180	216	240	288
15”	120	180	225	270	300	360
18”	144	216	270	324	360	432
20”	160	240	300	360	400	480
24”	192	288	360	432	480	576

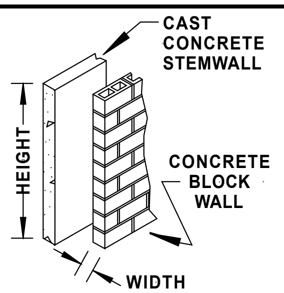


Table 3. Walls, Stem Walls, Basement Walls

WALL WIDTH \ WALL HEIGHT	18”	24”	36”	48”	96”	108”
	Perimeter Weight – lb/ft					
6” Conc. Block	65	86	129	172	344	387
8” Conc. Block	83	110	165	220	440	495
8” Cast Concrete	144	192	288	384	768	964
10” Cast Concrete	180	240	360	480	960	1,080
12” Cast Concrete	216	288	432	576	1,152	1,296

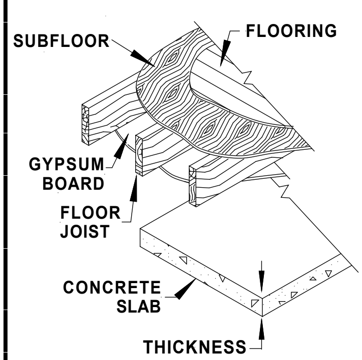


Table 4. Wood Floors & Concrete Slabs

Wood Floor – Span To Girder (2 X 6 or 2 X 8 Joist Framing @ 12” O.C.)	8’	10’	12’	14’	16’
	Perimeter Weight – lb/ft				
3/4” Sub Floor , 3/4” Hardwood & 1/2” Gypsum	48	60	78	91	96
1-1/2” Sub Floor, Carpet, Pad & 1/2” Gypsum	52	65	84	98	104
1-1/2” Sub Floor, 1/4” Ceramic Tile, 1/2” Gypsum	64	80	102	119	128

Concrete Slab	Perimeter Weight
4” Slab – Unfinished	191 lb/ft
4” Slab, Carpet & Pad	195 lb/ft
4” Slab & 1/4” Ceramic Tile	198 lb/ft
6” Slab – Unfinished	432 lb/ft

Table 5. Exterior Walls (8 ft tall)

		Perimeter Weight
Conc. Block	8” Heavy Weight Concrete Block, 1/2” Drywall & Insulation Fill (Not Illustrated)	425 lb/ft
Conc. Block Brick Veneer	8” Heavy Weight Concrete Block, Clay Brick, 1/2” Drywall & Insulation Fill	815 lb/ft
Wood Frame	1/2” Ship Lap or Plywood, 1/2” Sheathing, 2 x 4 Studs @ 16” o.c., 1/2” Drywall & 3-1/2” Insulation	88 lb/ft
Stucco Veneer	1-1/2” Concrete Stucco, 2 x 4 Studs @ 16” o.c., 1/2” Drywall & 3-1/2” Insulation	200 lb/ft
Brick Veneer	Clay Brick, 1/2” Sheathing, 2 x 4 Studs @ 6” o.c., 1/2” Drywall & 3-1/2” Insulation	390 lb/ft

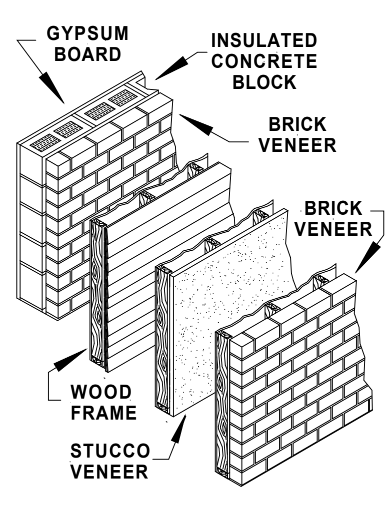
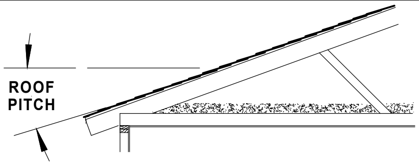


Table 6. Roof & Ceiling



Roof -- Rafter Framing (2 X 6 or 2 X 8 @ 12" O.C.), 1/2" Wafer Decking, 15# Felt, & 240# Asphalt Shingles (1' Roof Overhang)
Ceiling – Joist Framing (2 X 6 or 2 X 8 @ 12" O.C.), 1/2" Dry Wall & 10" Blown Insulation (No Attic Storage)

ROOF PITCH \ SPAN TO INTERIOR SUPPORT	8'	10'	12'	14'	16'
	Perimeter Weight – lb/ft				
2" in 12"	91	116	143	164	185
3" in 12" or 4" in 12"	92	123	145	166	187
6" in 12"	95	127	149	171	193
12" in 12"	107	154	168	193	218

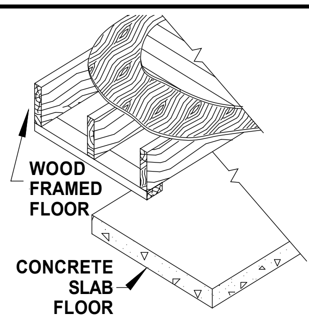


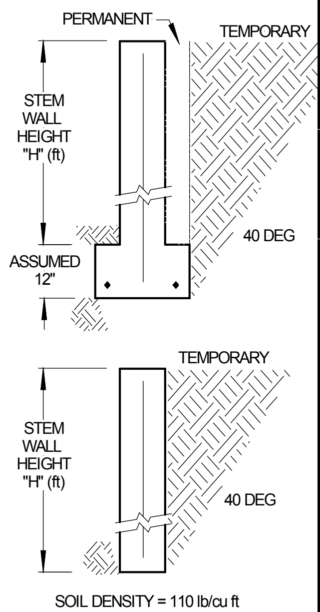
Table 7. Live Loads (LL) on Floors and Attics

Residential Occupant Live Loads – Span to Interior Support or Girder	6'	8'	10'	12'	14'
	Perimeter Weight – lb/ft				
First Floor – Wood Framing -- 40 lb/ft^2	120	160	200	240	280
Second Floor -- 30 lb/ft^2	90	120	150	180	210
Habitable Attics -- 30 lb/ft^2	90	120	150	180	210
Uninhabitable Attics -- 20 lb/ft^2	60	80	100	120	140
4" Slab on Grade – 40 lb/ft^2	120				

Reference: Excerpts from American Standard Building Code Requirements for Minimum Design Loads in Buildings – A58.1 – 1955

Note: Building techniques and Codes vary across the country; these tables are only to be used as a general guide for structural load estimations on preliminary design work. When in doubt about the construction elements, add 10% to 20% to load estimate or increase factor of safety of the design to 2.2 to 2.5 for "Safe Use" Design.

Table 8. Estimated Soil Loads on Footings



Permanent Soil Load on a Footing Toe – W_d

Soil Height Against Wall	2'	4'	6'	7'	8'	9'	10'
Soil Load per inch of Footing Width	18 lb	37 lb	55 lb	64 lb	73 lb	83 lb	92 lb

To determine the permanent soil load on a footing toe, multiply the actual width of the footing toe (in inches) by the unit weight shown above for the soil height against the wall.

Graph 1. Temporary Soil Load (One Side) – W_t

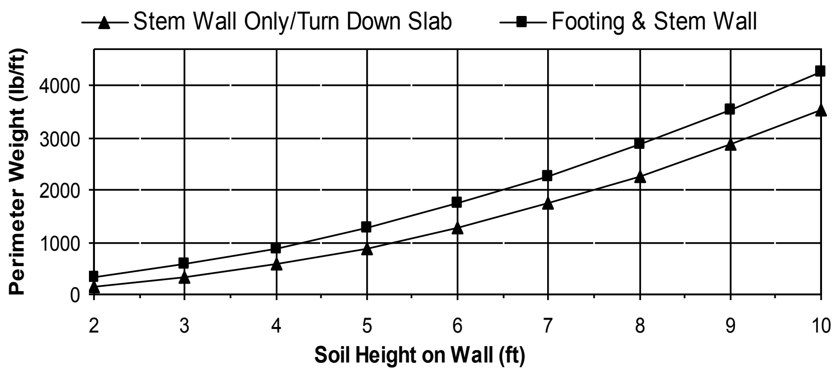


Table 9.	Estimating Snow Loads*			
0 – 18" Snow = 10 lb/ft²	19" – 38" Snow = 20 lb/ft²	39" – 57" Snow = 30 lb/ft²	58" – 76" Snow = 40 lb/ft²	77" – 96" Snow = 50 lb/ft²

Snow Load Along Perimeter Footing With Hip Style Roof – [(L x W) / 2 (L + W)] x (Snow Load Factor)

Snow Load Along Perimeter – Rafter Side of Roof With Gable Ends – (L x W / 2L) x (Snow Load)

– Gable End of Roof – [1.5 + (Roof overhang)] x (Snow Load)

L = Length of the perimeter wall to be underpinned -- W = Span of roof from exterior wall plus roof overhang

*** Verify the locally approved Snow Load Factor with a Building Official in your area**.

Table 10.	Weights of Building Materials				
Materials	**Weight** lb/sq. ft.	**Materials**	**Weight** lb/sq. ft.	**Materials**	**Weight** lb/sq. ft.
Brick Masonry:		**Wood Framing:**		**Roof:**	
4" Brick	40	2x4 @ 12 – 16" o.c.	2	Asphalt	3
8" Brick	80	2x6 @ 12 – 16" o.c.	3	Wood	2
12" Brick	120	2x8 @ 12 – 16" o.c.	4	3-ply Felt & Gravel	5-1/2
Concrete: (per inch thick)		**Sheathing:**		**Insulation** (per inch)	
Standard Concrete	12.5	1/2" Wood	2	Blown	1/2
Slag Concrete	11.5	3/4" Wood	3	Batts	3/4
Lightweight Concrete	6 to 10	1/2" Gypsum	2	Rigid	1-1/2
Soil:	**lb/cu. ft.**	**Floors:**		**Hollow Conc. Block:**	
Clay (Dry)	63	Vinyl	1	4" Light Wt	21
Clay (Damp)	110	7/8" Hardwood	4	4" Heavy Wt	30
Sand, Gravel (Dry, Loose)	90 - 105	3/4" Softwood	2-1/2	6" Light Wt	30
Sand, Gravel (Dry, Packed)	100 - 120			6" Heavy Wt	43
Sand, Gravel (Wet)	118 - 120	Carpet & Pad	2	8" Light Wt	38
Earth (Dry, Loose)	76			8" Heavy Wt	55
Earth (Dry / Wet, Packed)	95 - 96	3/4" Ceramic Tile	10	12" Light Wt	55
Earth (Mud, Packed)	115	1" Terrazzo	13	4" Stone	55

Reference: Excerpts from American Institute of Steel Construction, "Manual of Steel Construction" - 1989

Quick-Solve™ Structural Load Estimating

Table 11 offers empirical load estimates over a range of typical residential construction techniques from light to heavily built structures.

The estimated loads presented in Table 11 are rough load estimates. Please use this data only for determining *Quick*-Solve™ budget estimates.

Table 11.	Ranges for Typical Average Residential Building Loads*		
Building Construction (Slab On Grade)	Estimated Foundation Load Range (DL = Dead – LL = Live)	Building Construction (Basement or Crawlspace & Footing)	Estimated Foundation Load Range (DL = Dead – LL = Live)
One Story Wood/Metal/Vinyl Walls with Wood Framing -- Footing with Slab	DL 750 – 850 lb/ft LL 100 – 200 lb/ft	**One Story** Wood/Metal/Vinyl Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,250 – 1,500 lb/ft LL 300 – 475 lb/ft
One Story Masonry Walls with Wood Framing – Footing with Slab	DL 1,000 – 1,200 lb/ft LL 100 – 200 lb/ft	**One Story** Masonry Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,500 – 2,000 lb/ft LL 300 – 475 lb/ft
Two Story Wood/Metal/Vinyl Walls with Wood Framing – Footing with Slab	DL 1,050 – 1,550 lb/ft LL 300 – 475 lb/ft	**Two Story** Wood/Metal/Vinyl Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,400 – 1,900 lb/ft LL 600 – 950 lb/ft
Two Story 1st Floor Masonry, 2nd Wood/Metal/Vinyl with Wood Framing – Footing with Slab	DL 1,300 – 2,000 lb/ft LL 300 – 475 lb/ft	**Two Story** 1st Masonry, 2nd Wood/Metal/Vinyl – Wood Framing, Basement or Crawlspace & Footing	DL 1,650 – 2,200 lb/ft LL 600 – 950 lb/ft
Two Story Masonry Walls with Wood Framing – Footing with Slab	DL 1,600 – 2,250 lb/ft LL 300 – 475 lb/ft	**Two Story** Masonry Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,900 – 2,500 lb/ft LL 600 – 950 lb/ft

*** Table 10 load estimates DO NOT Include Snow Loads – See Table 9 for Snow Loads.**

Determining Pier Spacing

When locating piers on a structure, two factors must be considered that can limit the center-to-center distance between piers. The spacing between piers cannot be so large such that:

- **The spacing between piers exceeds the pier capacity. (*Pier Strength Spacing*)**

- **The spacing between piers overloads the footing. (*Footing Strength Spacing*)**

Pier Spacing Based Upon *Pier Strength*

The strength of the pier system is usually of concern when supporting and restoring a heavy structure such as a commercial building or a heavy, two-story residence with a full basement. **"Safe Design" dictates that the designer applies a suitable factor of safety.** Table 1 provides a quick reference to selecting a ***Recommended Design / Service Load***. In other cases the ***Factor of Safety*** may be dictated by the project. Equation 1 is used to determine the pier spacing relative to pier capacity.

Equation 1: Pier Spacing

$$\text{“X”} = P_{DSL} / P_L \quad \text{or} \quad P_{DSL} = \text{“X”} \times P_L$$

Where:
"X" = Pier Spacing (ft.)
P_{DSL} = Recommended Design/Service Load (Table 1)
P_L = Estimated Lifting Load

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Pier Spacing Based Upon *Footing Strength*

The strength of the footing is of great importance in lighter structures. These structures generally have small footings with little or no rigid stem wall for strength. If Equation 1 were used to estimate the spacing for a single story with slab on grade, the result would suggest a huge pier spacing distance that the footing cannot span. This issue is explained in **Design Examples 3-3A in Chapter 7**, a typical light structure is shown. Using Equation 1 to estimate the pier spacing for the light structure in Design Example 3, the pier capacity is 34,000 lb. and the foundation load was only 1,141 lb/lin.ft. Using Equation would suggest 29'-10" pier spacing. The small monolithic concrete foundation simply cannot support such a long span between piers. Therefore, in this Example 3 – Chapter 7, **the foundation strength determines the maximum pier spacing.**

Graph 2 is provided to assist with estimating pier spacing when dealing with:

1. Monolithic ("turned down") footings and/or,
2. Steel reinforced spread footings, no stem wall or,
3. When hollow masonry stem walls are present.

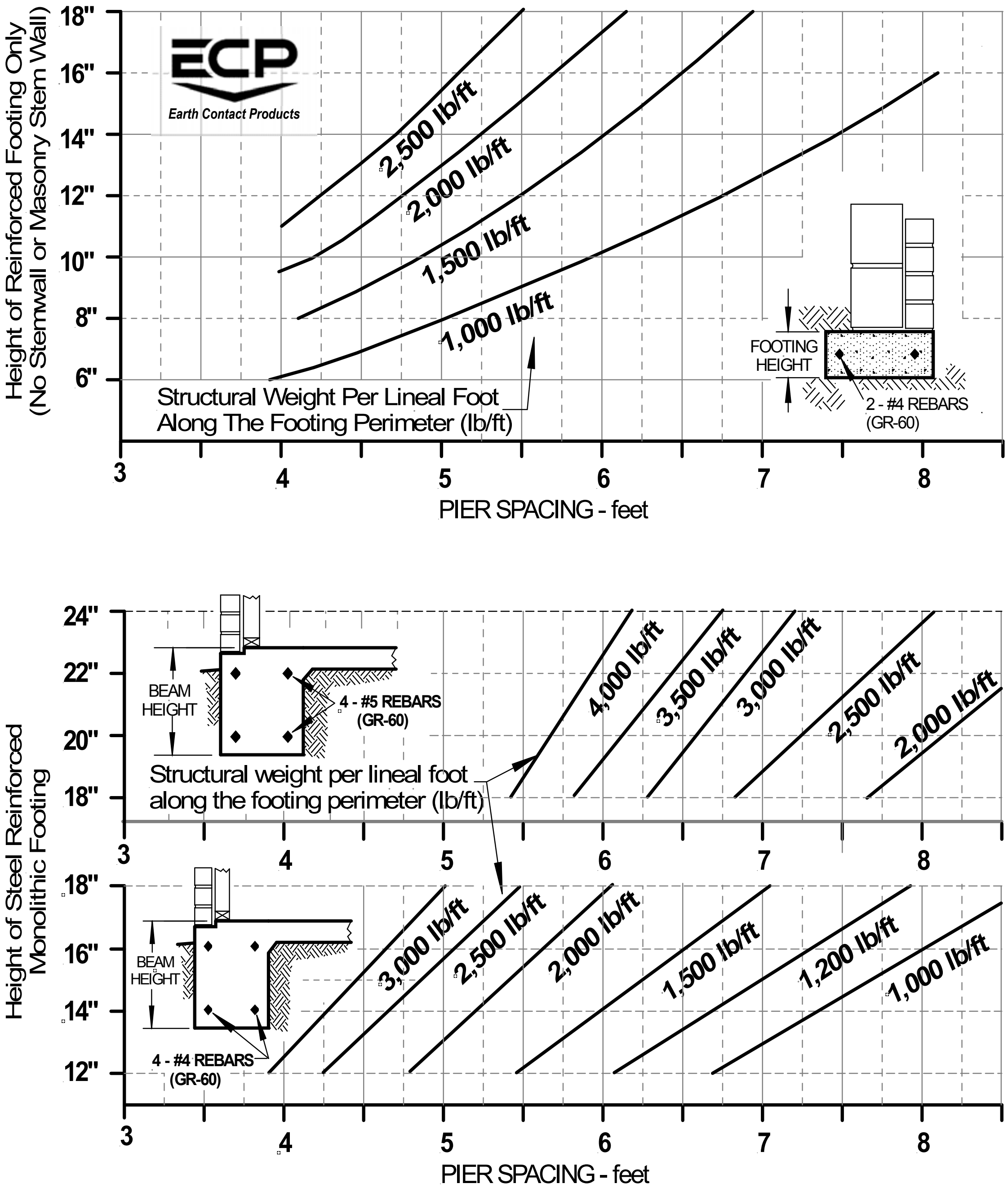
Graph 3 is provided to help estimate pier spacing when estimating footings with steel reinforced footings with integral short concrete stem walls.

These graphs assume generally accepted good construction techniques, adequate steel reinforcement that is properly embedded into the concrete, and concrete with a compressive strength of 2,500 psi or more. (28 day strength)

Technical Design Assistance

Earth Contact Products, LLC, has a knowledgeable staff that stands ready to help you with understanding how to design using ECP Steel Piers™, installation procedures, load testing, and documentation of each pier placement. If you have questions about structural weights, product selection or require engineering assistance in evaluating, designing, and/or specifying Earth Contact Products, please call 913 393-0007, Fax at 913 393-0008.

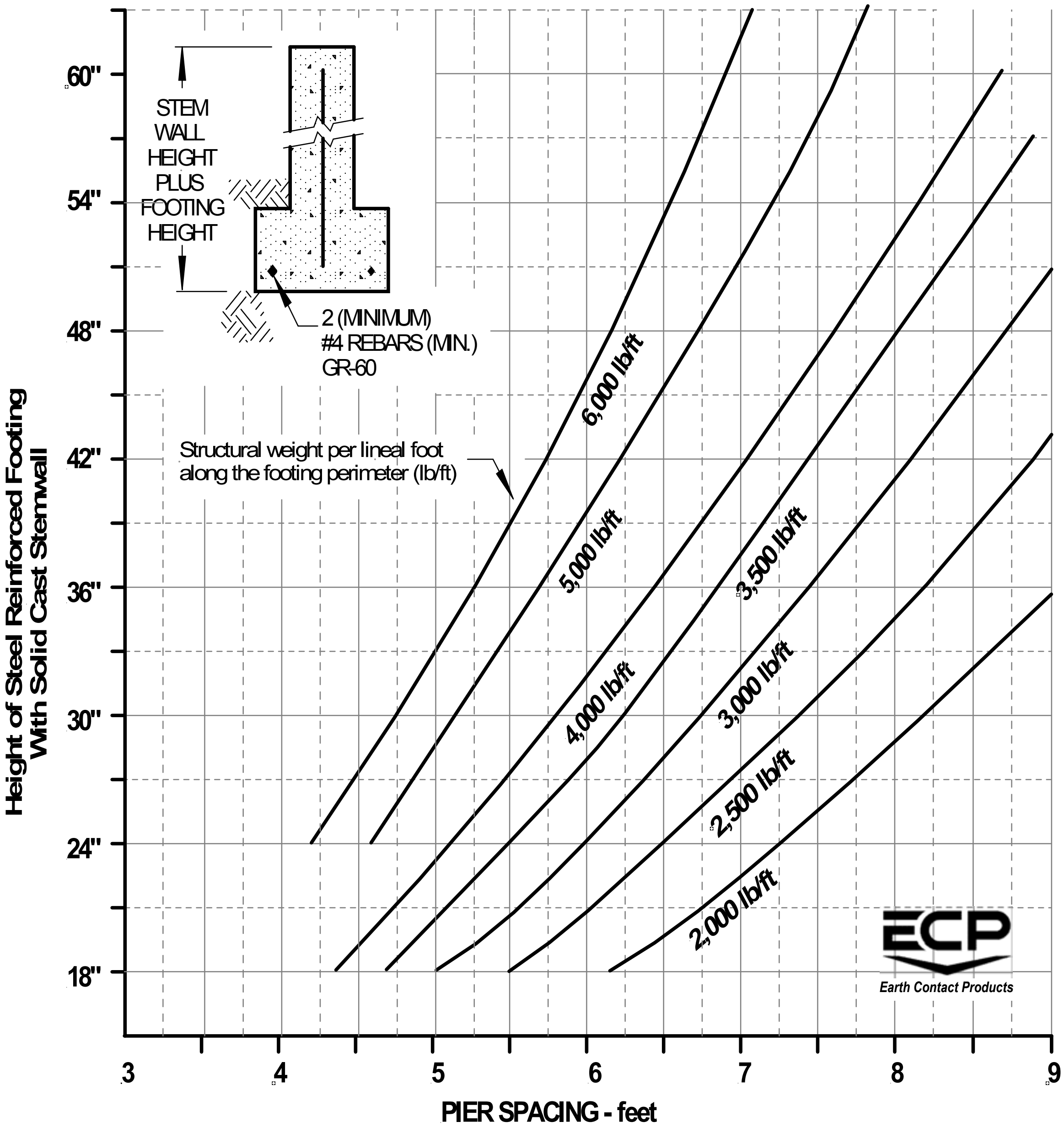
Graph 2. Estimating Pier Spacing Based Upon Foundation Strength of Spread Footing or Monolithic Slab Only (No Stem Wall or Hollow Masonry Stem Walls)



Important Note:

Building techniques and Building Codes vary across the country; the graphs presented here are to be used only as a general guide for spacing requirements, for preliminary designs, and for estimation purposes. It is recommended that a registered professional engineer conduct the final design and supervise the installation.

Graph 3. **Estimating Pier Spacing Based Upon Foundation Strength of Spread Footing with Short Integrally Cast Concrete Stem Walls**

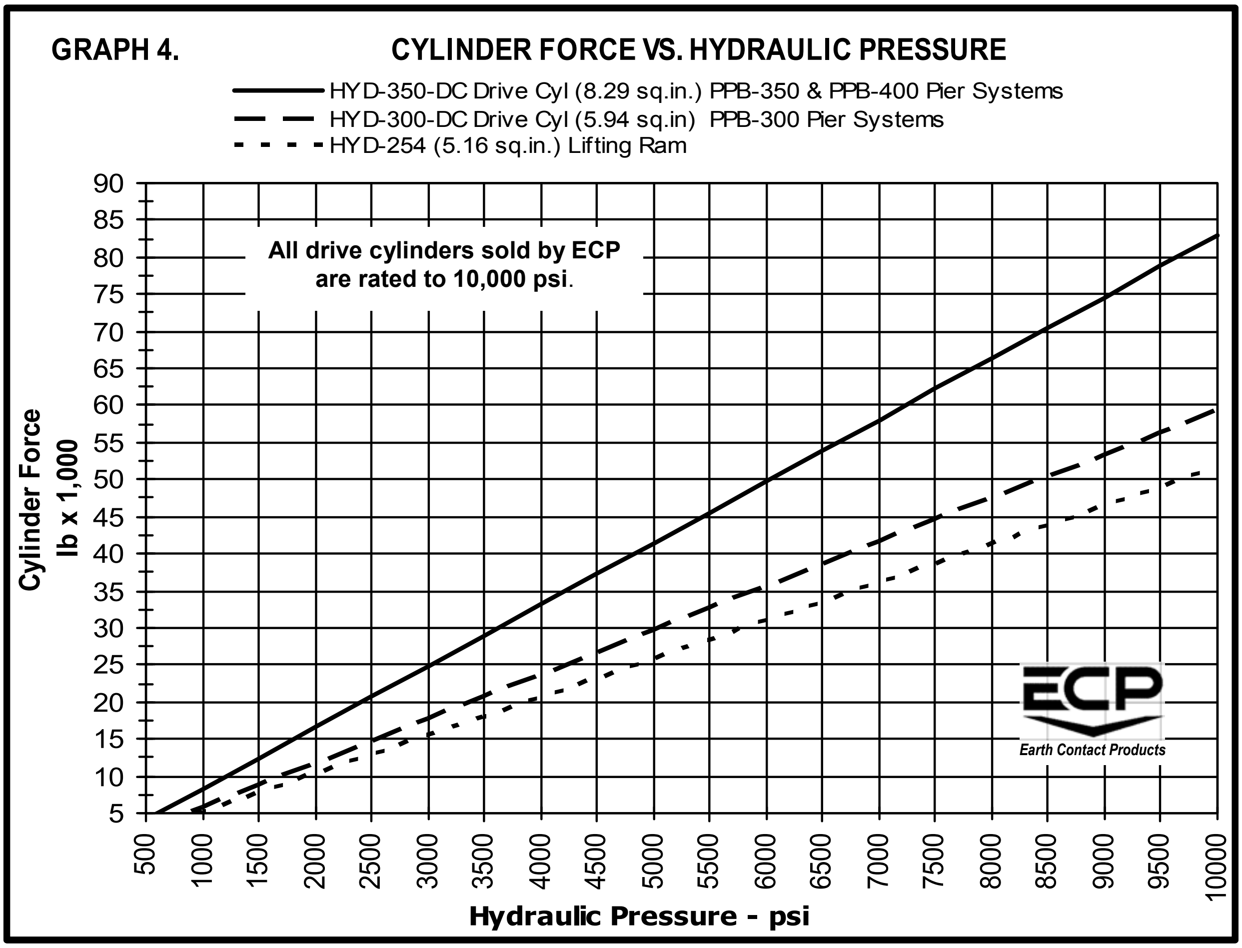


Important Note:

Building techniques and Building Codes vary across the country; the graphs presented here are to be used only as a general guide for spacing requirements, for preliminary designs, and for estimation purposes. It is recommended that a registered professional engineer conduct the final design and supervise the installation.

Pier Installation: Pier installation consists of forcing the pier pipe into the soil until end bearing resistance is encountered. Once this occurs, the strength of the bearing stratum is verified by field load testing. The pier is subjected to a *proof load test* that is greater than the pier design (working) load.

Graph 4 below provides a quick reference to determine the actual downward force generated on the pier pipe at a various pressures on the drive cylinder.



WARNING: If a drive cylinder from different source is used, VERIFY MAXIMUM PRESSURE RATING WITH MANUFACTURER PRIOR TO INSTALLING PIERS. Exceeding pressure rating could cause Injury or death.

Graph 4 shows maximum pressure allowed on ECP cylinders only.

Caution! When operating near the maximum cylinder pressure, the amount of actuator rod extension should be restricted to less than full length to prevent damage to the drive cylinder or actuator rod.

Equation 2: Hydraulic Cylinder Force

$$F_{Cyl} = A_{cyl} \times P_{cyl}$$

Where, F_{Cyl} = Cylinder force on pier – lb
P_{cyl} = Hydraulic Pressure -- psi
A_{cyl} = Effective Cylinder Area – in^2

Effective Areas of ECP Hydraulic Cylinders

- HYD-350-DC (3-1/2" & 4" dia) = 8.29 in^2
- HYD-300-DC (3" dia) = 5.94 in^2
- Lifting Ram = 5.16 in^2

IMPORTANT! Earth Contact Products, LLC does not recommend exceeding maximum working pressure ratings of hydraulic cylinders.

When in doubt about a pressure rating of other cylinders contact the cylinder manufacturer.

Proof Testing and Project Documentation:

The big advantage when using hydraulically installed ECP Steel Piers™ is that each pier is field *Proof Tested* to a load that is greater than force that is required to restore and support the structure. This *Proof Testing* of each and every pier placement verifies that firm bearing stratum or rock upon which the pier pipe is founded is sufficient to support the working load requirement plus a factor of safety.

It is recommended that the installer document the following data at each pier placement:

1. The installation force used to drive each 3-1/2 foot long section of pier pipe into the soil.
2. The *Proof Test* force that was applied against the bearing stratum. This force shall be either the force required to slightly lift the structure using only the drive cylinder or the application of the maximum allowable test load shown in Table 1, whichever is less.
3. The length of time the pier was subjected to the *Proof Test* load.
4. The depth to load bearing.
5. After all pier placements have been installed and *Proof Tested*, the force required to recover lost elevation to restore the structure at each placement shall be recorded.
6. The amount of lift at each placement.

At the end of the project, this data shall be compiled into a project report and retained by the installer for future reference. The installer should provide a copy of the project report to the engineer of record or owner's representative upon request.

Buckling Loads on the Pier Shaft in Weak Soil

Whenever a slender column (Pier Pipe) does not have adequate lateral support from the surrounding soil, the load carrying capacity of the column is reduced as pipe buckling becomes a risk. In the case of ECP Steel Piers™, the full ultimate-limit capacity shown in Table 1 is available provided the soil through which the pier penetrates maintains a Standard Penetration Test value "N" $\geq$ 5 blows per foot through the entire depth of the pier installation. The pier must also be firmly secured to a foundation bracket..

The most accurate way to determine the buckling load of a pier shaft in weak soil is by performing a buckling analysis by finite differences. There are several specialized computer programs that can perform this analysis and allow the introduction of shaft properties and soil conditions that can vary with depth. Another, method of estimating critical buckling which is less accurate is by using Davisson Method, "*Estimating Buckling Loads for Piles*" (1963). In this method, Davisson assumes various combinations of pile head and tip boundary conditions and a constant modulus of sub-grade reaction, "k_H". Load transfer to the soil due to skin friction is assumed negligible and the pile is assumed straight. Equation 3 below is Davisson's formula.

Equation 3: Critical Buckling

$$P_{cr} = U_{cr}\, E_p\, I_p / R^2$$

Where:

P_{cr} = Critical Buckling Load – lb
U_{cr} = Dimensionless ratio (Assume = 1)
E_p = Shaft Mod. of Elasticity = 30 x 10^6 psi
I_p = Shaft Moment of Inertia = in^4
$R = \sqrt[4]{E_p\, I_p / k_H\, d}$
d = Shaft Diameter – in

Computer analysis of shaft buckling is the recommended method to achieve the most accurate results. Many times, however, one must have information rapidly to prepare a preliminary design or budget proposal.

Table 12, below, provides budgetary conservative critical buckling load estimates for various shaft sizes that penetrate through different types of homogeneous soils.

Graph 5 on the following page presents visual representation of Buckling Strength of various pier configurations when **fully exposed in air, or water**; that is, no lateral shaft support is present.

It is recommended that a Registered Professional Engineer conduct the design of ECP Steel Piers™ where the pipe column is likely to be in weak soil and shaft buckling may occur.

Table 12	**Working Loads Under Weak Soil Conditions** (Factor of Safety = 2) Recommended for Budgetary Estimating			
Shaft Size	**Uniform Soil Condition**			
	Organics N < 1	**Very Soft Clay N = 1 - 2**	**Soft Clay N = 2 - 4**	**Loose Sand N = 2 - 4**
PPB-300-EPS (2-7/8" dia.)	19,000 lb	22,000 lb	31,000 lb	26,000 lb
PPB-300-EPS + PPB-300-IS	23,000 lb	27,000 lb	39,000 lb	32,000 lb
PPB-350-EPS (3-1/2" dia.)	26,000 lb	30,000 lb	43,000 lb	35,000 lb
PPB-400-EPS (4" dia.)	34,000 lb	40,000 lb	57,000 lb	46,000 lb
PPB-350-EPS + PPB-350-IS	36,000 lb	42,000 lb	59,000 lb	48,000 lb
PPB-350-EPS + PPB-350-ES	50,000 lb	58,000 lb	82,000 lb	67,000 lb
PPB-350-EPS + PPB-350-ES + PPB-350-IS	56,000 lb	66,000 lb	93,000 lb	76,000 lb

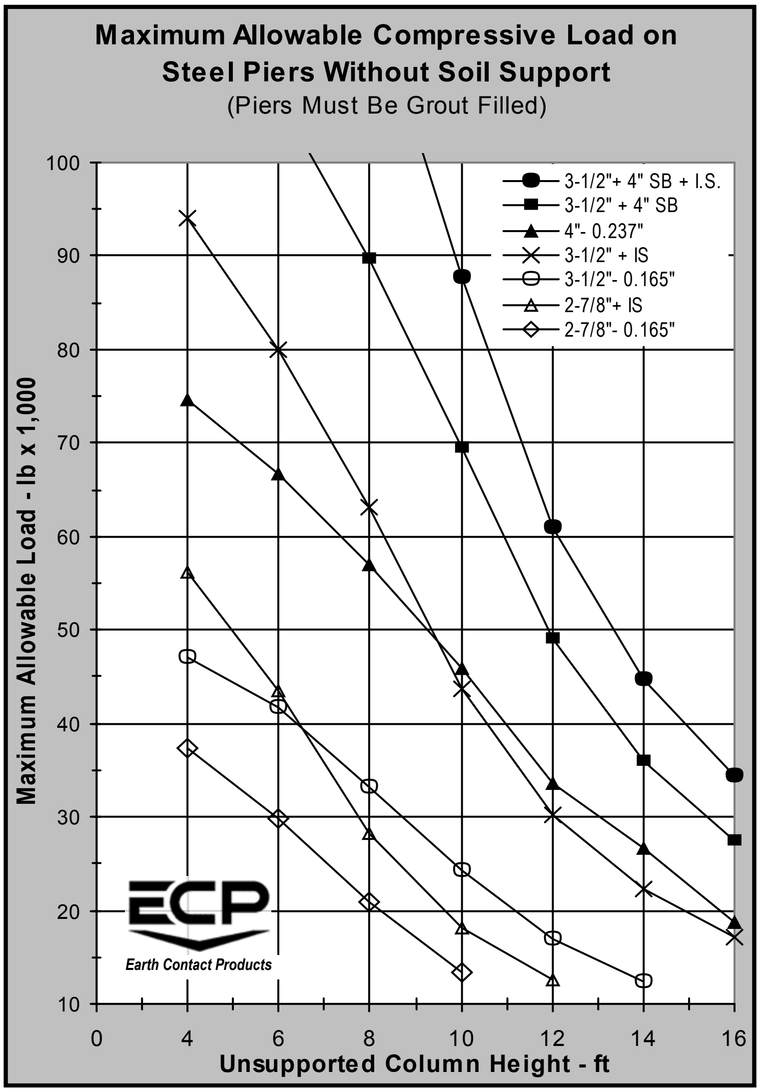
EPS = Pier Pipe Section IS = Internal "Inertia" Sleeve ES = 4" External Sleeve

Allowable Compressive Loads - "P" in Air: Graph 5 shows the reduction in allowable axial compressive loading where the pier shaft has no lateral support.

Table 13 illustrates demonstrates how the ECP PPB-400-EPS (4 inch diameter) pier pipe provides an axial stiffness of more than 3-1/2 times that of a PPB-300-EPS (2-7/8 inch diameter) pier pipe. In addition, Graph 5 demonstrates that the PPB-400-EPS pier pipe has a maximum compressive load capacity of more than three times that of the PPB-300-EPS pier pipe when each has ten feet of exposed column height without any lateral support.

Whenever weak soil is encountered such as peat or other organic soils, improperly consolidated soil, or a situation where a portion of the pier shaft may become fully exposed; consideration MUST be given to the reduction in capacity that is brought on by lack of sufficient lateral support to the pier pipe.

In situations where insufficient lateral pier pipe support is provided by the soil, the pier is not able to support the full rated capacity. The length of pier pipe that is passing through the weak soil and the amount of stiffness provided by the pier pipe will affect the load capacity reduction that must be considered.



Graph 5. Maximum Unfactored Load* on piers with NO soil support

*** Caution: When selecting a pier configuration for a specific application, ONE MUST APPLY A FACTOR OF SAFETY TO THE CAPACITIES SHOWN ON GRAPH 5 to insure "Safe Use" design.**

Pier pipe stiffness (Moment of Inertia) increases with increasing diameter and/or wall thickness.

Graph 5 shows reductions in allowable axial compressive loading relative to the exposed length of the pier pipe in air or water for various pier diameters and with sleeved pier configurations. When ECP Steel Pier™ pipe is fully exposed or passes through very weak soils, we recommend installing sleeving over and/or inside the pier pipe to increase the bending strength of the pier; in addition, it is good practice for the designer to consider using a larger diameter pier pipe in weak soil applications.

Installing a pier sleeve or selecting a larger diameter pier pipe is used to prevent buckling of the pier pipe.

- Pipe Sleeves may be needed in poor soil conditions generally recognized as soil having Standard Penetration Test (SPT) blow counts less than, or equal to, five blows per foot ("N" ≤ 5),
- Pipe Sleeves may be needed where the strength of the coupled joints or stiffness (axial moment of inertia) of the pier pipe are a concern.
- Pipe Sleeves are usually installed where the pier pipe is exposed, or may become exposed.

There are several ways to reinforce pier pipe in such situations. One of the simplest to slightly improve pier stiffness and to strengthen the coupled joints is to grout the pier pipe after installation. Many designers also require that the contractor install a reinforcing bar in the center of the pier pipe along with the grouting to improve joint strength.

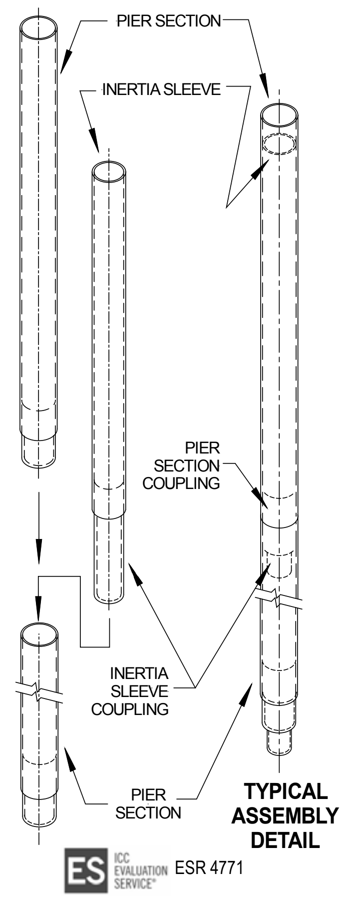


Figure 4. Details of ECP's PPB-300-IS patented "Inertia Sleeve" and how the pier coupling is strengthened

"Inertia Sleeve" – Earth Contact Products offers a patented product called the *Inertia Sleeve* to improve shaft stiffness. This unique product is shown in Figure 4, and is the most economical way to quickly enhance the axial moment of inertia (stiffness) of the pier system. The *Inertia Sleeve* is easy to install, but must be installed concurrent with driving the pier pipe. One simply drops an *Inertia Sleeve* section into the most recently installed section of pier pipe. This must be done prior to coupling together and driving the next section of pier pipe. Inertia sleeves have an ICC evaluation and ICC-ES 4771 has been issued.

The low cost *Inertia Sleeve* takes nearly no labor to install and instantly increases the rigidity and strength of the pier shaft through weak soil. The unique design of the patented "Inertia Sleeve" also strengthens the coupled joints.

The coupling connection of the *Inertia Sleeve* passes through the pier pipe coupling completely and engages with the previously installed section of *Inertia Sleeve*. The couplings are therefore doubled and staggered, providing a strengthened coupled joint.

Table 13 STEEL PIER SHAFT STIFFNESS COMPARISON

Steel Pier Pipe Configuration	Cross Section Area - in^2	Moment of Inertia - in^4 (Stiffness)	Pier Stiffness Relative to PPB-350-EPS
PPB-300-EPS (2-7/8" dia.)	1.41	1.29	0.55%
PPB-300-EPS + PPB-300-IS	2.65	1.81	0.77%
PPB-350-EPS (3-1/2" dia.)	1.68	2.35	**100%**
PPB-350-EPS + PPB-350-IS	3.46	4.22	180%
PPB-400-EPS (4" dia.)	2.60	4.66	198%
PPB-350-EPS + PPB-350-ES	4.27	7.01	298%
PPB-350-EPS + PPB-350-ES + PPB-350-IS	5.12	8.88	379%

EPS = Pier Pipe Section IS = Internal "Inertia" Sleeve ES = 4" External Sleeve

External Sleeve: Another means of increasing the axial moment of inertia of the pier shaft is to install external pier sleeving. Many designers like this method because it provides a significantly larger increase in pier rigidity than other methods discussed here. This is because the external sleeve increases the diameter of the pier shaft.

When installing external sleeves, the sections must be positioned such that the joints of the external sleeving are staggered away from the pier pipe couplings. The external sleeving must be hydraulically driven over the installed pier pipe prior to field load testing. The time required to drive the external pier sleeving is generally equivalent to the time required to initially install the pier pipe.

> **External Sleeving** is economical because it is only required where the pier pipe is exposed or where the pipe passes through weak soil having insufficient lateral support for the axial load on the pipe shaft.

Table 13 on the previous page presents shaft stiffness relative to different pier pipe and sleeve configurations.

It is interesting to note that the combination of the PPB-350-EPS, 3-1/2" diameter pier pipe, plus the PPB-350-IS *Inertia Sleeve* provides axial stiffness equal to 91% of the of the PPB-400 system (4" diameter) system.

If the designer chooses PPB-350-SB (4" diameter exterior sleeve) over the PPB-350-EPS (3-1/2 inch diameter) pier pipe and grout fills pier pipe, the allowable load on the system will increase 51% higher than using the PPB-400 (4" diameter) pier system. The cost savings should be very evident especially on projects that require extra rigidity only in the upper several feet of soil.

When specifying either type of pipe sleeve, the designer must extend the sleeving a <u>minimum</u> depth of three feet beyond the zone of weak soil and into the competent material.

For example, if a site has 6 feet of peat with Standard Penetration Test (SPT), "N" = 0 bpf ("Weight of Hammer") to 2 bpf and this peat is overlaying sand with a SPT, "N" > 5 blows per foot; the designer should specify sleeving to a depth of at least 9 feet in order to provide adequate sleeve embedment beyond the 6 foot stratum of weak peat.

Quick-Solve™ Buckling Load Estimates for Weak Soil Conditions

A method for instantly estimating **Estmated Maximum Conservative Working Loads in Weak Soil** can be found in Table 12 above. General soil types and SPT, "N", values are provided in four columns. On the left side of Table 12 are available pier pipe and sleeving configurations. Read horizontally until the column with soil that most closely matches the soil conditions at the job site. At the intersection of the product line and soil column is the maximum **Design Load** (Working Load) for that pier or pier combination. If the capacity is unsufficient, drop down to a stiffer pier for the job.

> Please remember that the values given in Table 12 are <u>working loads</u>. A Factor of Safety of 2.0 has already been applied to the loads shown.

ECP Steel Pier™ PPB-350-TTA Utility Bracket System, With TAF-150 Torque Anchor™ Tieback Assembly

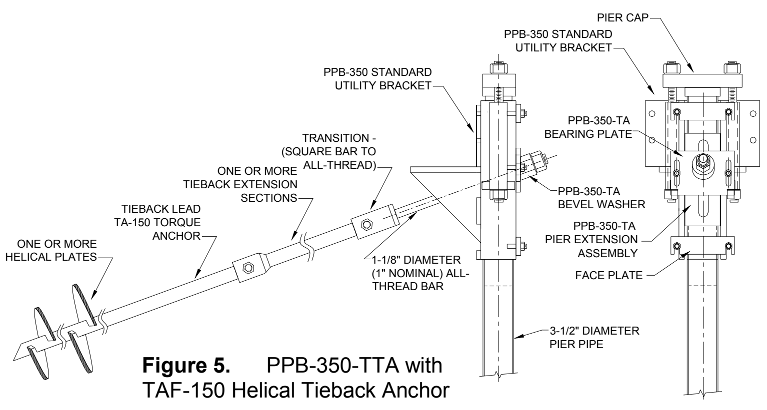


Figure 5. PPB-350-TTA with TAF-150 Helical Tieback Anchor

The PPB-350-TTA Steel Pier Assembly is used to connect a 1-1/2" Square ECP Torque Anchor™ to provide lateral stabilization to the steel pier system. The connection can also be made to a standard PPB-350 eccentric underpinning bracket by purchasing a PPB-350-TA Adapter Kit. Please contact ECP for full specifications for the installation.

PPB-166 Slab Jack Installation

The following nine steps illustrate the typical installation procedure for the ECP PPB-166 Slab Jack Bracket. Figure 6 shows the configuration used to install the pier pipe and the installation tools mounting configuration. Please contact ECP engineering department for *ECP Typical Specifications* that provide the specific and detailed product installation requirements and procedures.

1. Site survey: Pier placements are determined and locations of all underground utilities verified.

2. Core Drill/Excavation: Core drill an eight inch diameter hole through the slab. Excavate soil below hole to a depth of 14 to 16 inches.

3. PPB-166 Bracket Placement: The Bearing Plate shall be temporarily placed on the soil at the bottom of the hole and aligned with the center of the hole in the concrete. The drive stand and hydraulic cylinder are connected to the bracket using 3/4 inch diameter B7 all-thread rods.

4. Pier Pipe Installation: Each 36 inch or 42 inch long section of pier pipe is advanced into the soil using a portable high-pressure hydraulic pump. Overhead clearance is usually not a problem when using short pier sections. The pier pipe is advanced into the soil until rock or suitable bearing is encountered below the failing unstable soil directly under the slab.

5. Proof Load Test: Every pier is load tested to insure that rock or other firm bearing is verified to be substantial enough to withstand a load greater than required to restore and support the slab. Some slabs can provide sufficient reaction force for installation and testing, but supplement weights around the access hole are sometime necessary to develop addition reaction force and to reduce slab stress cracks. Tests typically apply no more than 75% of the ultimate capacity.

6. Preparations for Restoration: Once pier pipe has been installed, load tested, and the data recorded for all placements; the all of the bearing plates, lifting head assemblies and hydraulics are installed on the piers. Hydraulic rams are connected to one or more manifolds and hydraulic hand pumps.

7. Restoration: Under careful supervision, the load is transferred from the failing soil under the slab to the steel pier system. The slab is gently and evenly lifted to as close to the original elevation as the construction will allow or to the specified elevation. The nuts at the pier caps are secured at each placement, and then the lifting equipment is removed.

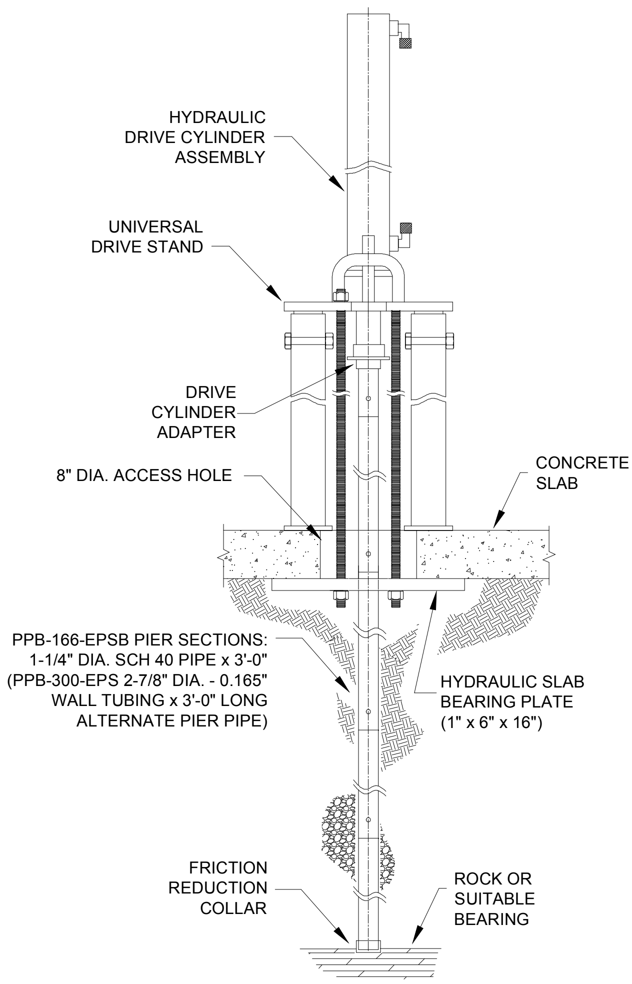


Figure 6. PPB-166 Slab Jack installation configuration

8. Filling the Voids: Lean concrete (2-1/2 sack mix) mud slurry must always be pumped under low pressure to fill all voids created when the slab was lifted.

9. Clean Up: The soil that was excavated from each pier placement shall be removed and disposed of in a safe and legal manner. The core drilled holes shall be filled with structural concrete and finished to match the existing floor. The site shall be left clean and neat.

Earth Contact Products

Chapter 7

ECP Steel Piers™

Resistance Pier Design Examples

- **Calculate Foundation Load – Two Story Residence**
- **Calculate Foundation Load – *Quick*-Solve™ Design Method**
- **Calculate Maximum Pier Spacing for Design Example 1**
- **Adjusting for Pier Buckling in Weak Soil**
- **Determine Foundation Load – Single Story Slab on Grade**
- **Determining Maximum Pier Spacing**
- **Calculate the Foundation Load and Determine Pier Spacing – Three Story Office Building**
- **Estimating Drive Cylinder and Lifting Ram Pressures**
- **Determining Force Applied to Pier**

EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

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Chapter 7 - ECP Steel Piers™ Design Examples

EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

Design Example 1 – Calculate Foundation Load

Two Story Brick with Full Basement

- The foundation consists of a 12 in. tall x 24 in. wide reinforced footing with a 10 in. thick x 8'-0" tall cast concrete basement wall. (Footing toe = 7 in.)
- The house is located in Indiana with 30+ inches of snow.
- The basement floor is 4" thick concrete.
- The soil depth to the basement floor elevation is 7 feet.
- The upper floors consist of 2 x 8 joists spaced 12" on center that span 12 feet to a steel beam supported by columns. The floors are carpeted.
- The house is 40' long x 24' wide with 2 x 4 studs on 16" centers, sheathing, insulation and drywall and brick veneer.
- The hip roof is framed with 2 x 8 rafters and 2 x 6 ceiling joists with a 3" in 12" pitch. There is no attic storage. There is 10" of blown insulation. The ceiling span is 12 feet plus a one foot roof overhang.

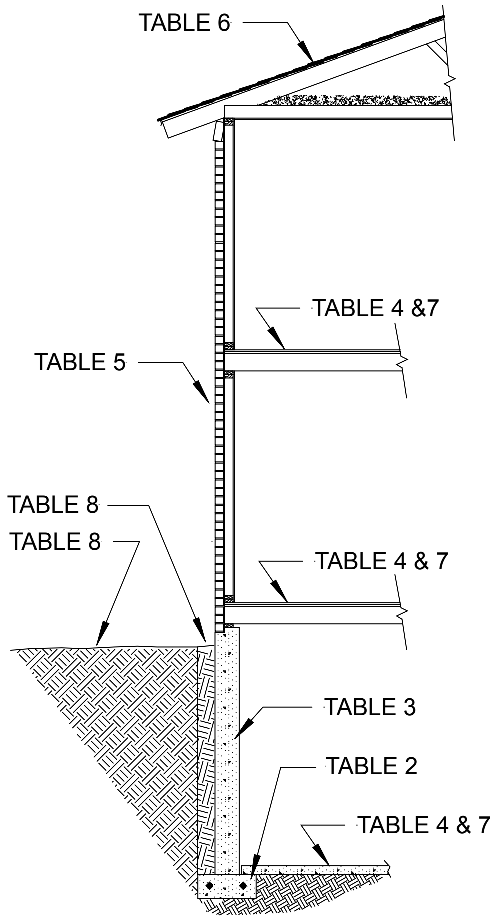


Figure 6. Load Estimate Sketch Example 1 & 1A.

Calculate the Foundation Loads - Referring to the Load Tables in Chapter 6 estimate the foundation service (working) load, the live load and the temporary soil load on the footing.

1. **Dead Load** (DL):
   Footing = 288 lb/ lin. ft (Table 2)
   Stem Wall = 960 lb/ lin. ft (Table 3)
   Slab = 191 lb/ lin. ft (Table 4)
   1st Floor = 84 lb/ lin. ft (Table 4)
   1st Exterior Wall =390 lb/ lin. ft (Table 5)
   2nd Floor = 84 lb/ lin. ft (Table 4)
   2nd Exterior Wall = 390 lb/ lin. ft (Table 5)
   Roof & Ceiling = 145 lb/ lin. ft (Table 6)
   Perm. Soil Load = 384 lb/ lin. ft [64# x 7" Toe] (Table 8)
   Dead Load (DL) = **2,916 lb. per lineal foot**

2. **Live Loads** (LL):
   Live Load = (240+180+120) = 540 lb/ lin. ft (Table 7)
   Snow Load = [(40x24)/2(40+24)] x (20#/sf) = SL = 150 lb/ lin. ft (Table 9)
   Live Load (LL) **=** 540 + 150 = **690 lb/lin.ft**

3. Working Load (P_w) = DL + LL = 2,916 lb/lin. ft + 690 lb/lin. ft = 3,606 lb/lin. ft.
   Working Load (P_w) = 3,600 lb. per lineal foot

4. **Lifting Load** (P_L) = Working Load (P_w) + Temporary Soil Load (W_T)
   P_L = 3,606 lb/lin. ft + 2,950 lb/lin. ft (Table 8)
   (Graph 1 is reproduced in Example 1A below.)
   (P_L) = 6,556 lb./lin.ft.
   (See note: Chapter 6 – Page 13)

5. **Factored Lifting Load** (P_{LF}) – The factored lifting load adds a percentage to the calculation to help compensate for possible omissions in the weight calculations, unexpected structural elements and the initial force to break the footing away from the surrounding soil. Depending upon confidence 10% to 20% is usually added.
   (P_{LF}) = Lifting Load (P_L) + FS
   (10% F.S. (656 lb.) added to cover uncertainties)
   (P_{LF}) = 6,556 + 656 lb/lin.ft = **7,212 lb./lin.ft**
   Factored Lifting Load = 7,200 lb/lin.ft.

End Design Example 1

Design Example 1A – Calculate Foundation Load – *Quick*-Solve™ Design Method

Two Story Brick with Full Basement

- The house is 40' long x 24' wide with an 8'-0" tall cast concrete basement wall.
- The house is located in Indiana with 30+ inches of snow.
- The basement floor is concrete.
- The soil depth at the basement is 7 feet.

TABLE 11.	Ranges for Typical Average Residential Building Loads*
Building Construction (Basement or Crawlspace & Footing)	Estimated Foundation Load Range (DL = Dead – LL = Live)
One Story Wood/Metal/Vinyl Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,250 – 1,500 lb/ft LL 300 – 475 lb/ft
One Story Masonry Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,500 – 2,000 lb/ft LL 300 – 475 lb/ft
Two Story Wood/Metal/Vinyl Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,400 – 1,900 lb/ft LL 600 – 950 lb/ft
Two Story 1st Masonry, 2nd Wood/Metal/Vinyl – Wood Framing, Basement or Crawlspace & Footing	DL 1,650 – 2,200 lb/ft LL 600 – 950 lb/ft
Two Story Masonry Walls with Wood Framing on Basement or Crawlspace and Footing	**DL 1,900 – 2,500 lb/ft LL 600 – 950 lb/ft**

1. Estimate the Dead Load and Live Load on the footing:

A. Using Table 11 from Chapter 6, (only part of table shown here) select the column that most closely identifies the foundation construction. In this case the description column on right side of the full table is selected because the house has a basement with a concrete slab floor.

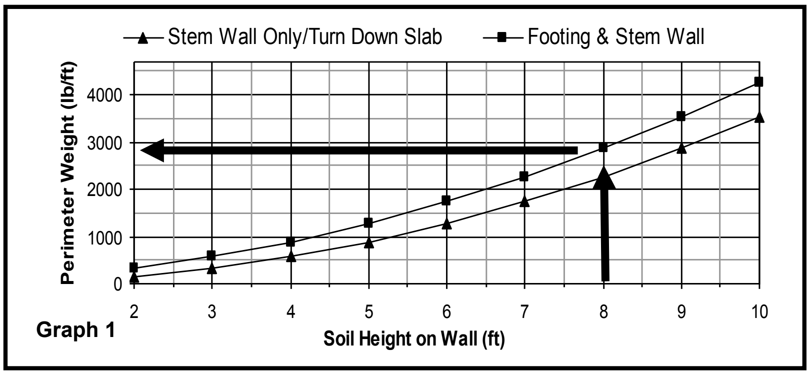
B. Determine which row most closely describes the structure. In this case the closest match is the lowest row. The construction consists of two story framed construction with brick veneer siding.

C. The Dead Load for a typical two story house of this description ranges from 1,900 to 2,500 lb/lin.ft and the Live Load averages between 600 and 950 lb/lin.ft. A physical inspection of the house was made to determine the construction quality and type of contents. The loads are selected from within the ranges given in Table 11. **Dead Load (DL) = <u>2,200 lb/lin.ft</u> & Live Load (LL) = <u>750 lb/lin.ft</u>** (Both Selected)

D. Snow Load = [(40'x24')/2(40+24')] x (20#/sf) = **<u>150 lb/lin.ft</u>** (See Table 9 Chapter 6)

2. Estimate the Temporary Soil Load on the footing:

The Temporary Soil Load may be estimated using Graph 1 (shown here) was presented in Chapter 6. The graph line that represents ***"Footing & Stem Wall"*** construction is selected because the footing construction is unknown. The Temporary Soil Load can be estimated by reading upward from a soil height of 8 feet (7' of soil on the basement wall + 1' for soil height against the side of the footing.)



Graph 1

Temporary Soil Load = <u>2,950 lb/ lin.ft</u>

3. <u>Factored</u> Lifting Load (P_{LF}) = DL + LL + Snow Load + Soil Load + Uncertainty Factor (Choose 15%)

Factored Lifting Load (P_{LF}) = (2,200+750+150) + 2,950 lb/ft = **6,050 lb/ft** + 908 lb/lf (15% of 6,050 lb/ft)

Factored Lifting Load (P_{LF}) = 6,958 lb/lin.ft. **(Use <u>7,000 lb./lin.ft.</u>)**

End Design Example 1A

Review of Results of Design Examples 1 & 1A

One can see that the result obtained by the *Quick*-Solve™ analysis underestimated the foundation load by 3% compared to the more thorough weight analysis. Caution must be taken when using the *Quick*-Solve™ design method because the load estimates are based upon where the designer <u>believes the structural weight falls within the ranges provided</u>. Choices made in this example were in the "middle range". It is quite evident that this structure is more robust than average construction. In the future for similar structures the loads should be selected nearer to the higher end of the ranges in the table and/or increase the percentage used for the "Factor of Uncertainty" in the weight estimate.

Design Example 2 -- Calculate the Maximum Pier Spacing for Design Example 1

- An inspection of the property suggests that the structure is well built and the foundation appears sound.
- A "Safe Use" Design Load of 43,000 pounds is selected with the use of the PPB-350 Steel Pier™. This represents a strong and economical pier for this project. (Table 1 – Chapter 6)
- A Factor of Safety of 2:1 is used.
- According to the analysis in Example 1 the structure requires a Factored Lifting Force of 7,200 pounds per lineal foot of perimeter beam.

Equation 1 from Chapter 6 is used to determine the pier spacing relative to pier capacity.

X = Pier Spacing = P_{DSL}/P_L (Equation 1)

Where:

X = Pier Spacing (ft)

P_{DSL} = 43,000 lb "Design Service Load"

P_L = Estimated Lifting Load = 7,200 lb/lin.ft

X = 43,000 lb / 7,200 lb/ft = 5.97 feet

X = Use 6 feet, (maximum)

The pier placement design may now be prepared and a pricing estimate for this project is possible with piers spaced not to exceed 6 feet on center.

End Design Example 2

Design Example 2A – Adjusting for Pier Buckling in Weak Soil

- When discussing this project the engineer mentioned that consolidation of a weak soil layer caused the settlement. Upon further investigations of the soil data, the soil analysis reported approximately six feet of uncompacted loose fill with Standard Penetration Test values, "N" = 1 to 3 blows per foot.
- Below six feet, the soil is firm clay with SPT values exceeding "N" = 5 blows per foot.
- According to the analysis in Example 1 the structure requires a factored lifting force of 7,300 pounds per lineal foot of perimeter beam.

First Method: There are two ways to handle this new information. The first method accounts for the reduction in pier pipe capacity due to buckling and adjust the spacing accordingly.

Example 2 determined that the PPB-350 Steel Pier™ should be installed at 6 feet on center for full foundation support with a F.S. of 2:1.

1. Determine the "*Working Load Under Buckling Conditions*" for PPB-350 Steel Pier™.

Table 1 in Chapter 6 lists the *Recommended Design/Service Load* in good soil for a PPB-350 pier pipe at 43,000 lb, but referring to Table 12 in Chapter 6 (shown at right, #1) indicates that the Critical Buckling of PPB-350 pier pipe in clay with, SPT, "N" = 1 is 30,000 lbs.

2. Calculate New Pier Spacing, X:

X = $P_{SU\ Des}/P_L$ (Equation 1)

X = 30,000 lb / 7,300 lb/ft = 4.11 ft

Use "X" = 4 feet, (maximum)

Second Method: Choose a new product configuration that offers a more rigid pier section and maintain the original pier placement spacing.

Look for a Pier Configuration in Table 12 with a *Working Load* greater than 43,000 lb in weak soil with "N" at 1 bpf and higher:

Notice that the **PPB-350-EPS** with **PPB-350-SB** External Sleeve (shown below, #2) will provide working load capacity that is 58,000 lb. This pier configuration is suitable.

Table 12 Working Loads Under Buckling Conditions For Budgetary Estimating (Factor of Safety = 2)

Shaft Size	Uniform Soil Condition: Organics N < 1	Uniform Soil Condition: Very Soft Clay N = 1 - 2
PPB-300-EPS (2-7/8" dia.)	19,000 lb	22,000 lb
PPB-300-EPS + PPB-300-IP	23,000 lb	27,000 lb
PPB-350-EPS (3-1/2" dia.) 1	26,000 lb	**30,000 lb**
PPB-400-EPS (4" dia.)	34,000 lb	40,000 lb
PPB-350-EPS + PPB-350-IP	36,000 lb	42,000 lb
PPB-350-EPS + PPB-350-SB 2	50,000 lb	**58,000 lb**
PPB-350-EPS + 350-IP + 350-SB	99,000 lb	66,000 lb

2. Specify the sleeved pier pipe configuration with the original placement spacing of 6 feet on center. The PPB-350-EPS Steel Pier™ will be installed to the full depth and have three 42" long sections of PPB-350-SB external pipe sleeves installed at the upper 10-1/2 feet to strengthen the pier pipe through the 6 ft of very weak soil and into competent soil.

The three pieces of PPB-350-SB sleeve shall be installed after the 3-1/2" diameter pier pipe is driven to load bearing, but prior to proof testing. The three sleeve sections will stiffen the pier pipe and joints to a depth of 10-1/2 feet, which means that sleeve extends more than three feet beyond the depth of the weak fill soil.

End Design Example 2A

Design Example 3 – Calculate Foundation Load

Single Story Slab on Grade

- The single story house is located in Texas
- The foundation consists of an 18” tall x 15” wide turned down footing reinforced with #4 rebars.
- The concrete slab floor is 4” thick and is carpeted.
- The exterior walls are 2 x 4 studs on 16” centers with sheathing, insulation and drywall. The exterior is typical brick veneer,
- The roof has a 3” in 12” pitch and is framed with 2 x 8 rafters and 2 x 6 ceiling joists. There is no attic storage, but there is 10” of blown in insulation. The span is 12 feet with a 2 foot overhang.

Calculate the Foundation Loads - Referring to the Load Tables in Chapter 6, estimate the foundation service (working) load, the live load and the temporary soil load. (No Snow Load)

1. **Dead Load** (DL):
   Footing = 270 lb./lineal foot (Table 2)
   Slab = 195 lb/ lin. ft (Table 4)
   Exterior Wall = 390 lb/ lin. ft (Table 5)
   Roof & Ceiling = 166 lb/ft (12’+ 2’= 14’) (Table 6)
   Perm. Soil Load = 0 lb/ lin. ft
   Dead Load (DL) = 1,021 lb. per lineal foot

2. **Live Loads** (LL):
   Live Load = 120 lb/ lin. ft (Table 7)
   Snow Load = 0 lb/ lin. ft
   Live Load (LL) **= 120 lb. per lineal foot**

3. **Working Load** (P_w) = DL + LL
   Working Load (P_w) = 1,021 lb/lin ft + 120 lb/lin ft
   Working Load (P_w) = 1,141 lb. per lineal foot

4. **Lifting Load** (P_L) = (P_w) + Temp. Soil Load (W_T)
   W_T = 80* lb/lin. ft x 2 (inside + outside turn down)
   W_T = 160 lb/lin.ft (Table 8 – Graph 1)
   *Note: Estimated to be 80 lb/lin.ft because Graph 1 does not show 18” soil height. (See at right)

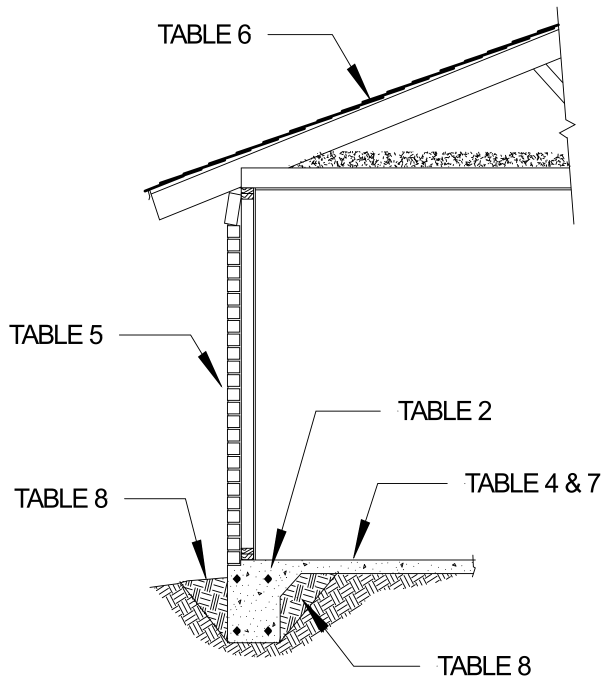


Figure 7. Sketch for Load Estimate Example 3 & 3A.

Lifting Load (P_L) = P_w + W_T
(P_L) = 1,141 + 160 lb. per lineal foot
(P_L) = 1,301 lb/lin.ft (See Review of Results, next page)

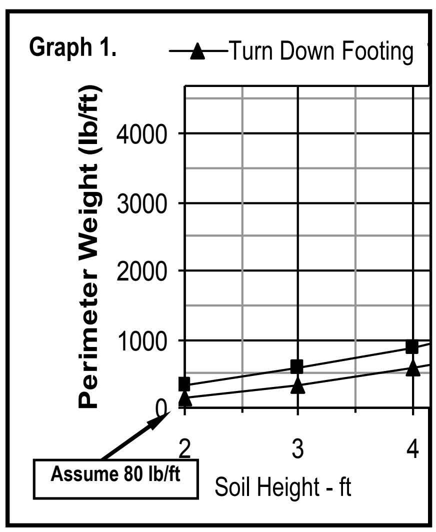
5. **Factored Lifting Load** (P_{LF}) = (P_L) + FS**
   (P_{LF}) = 1,301 lb/lin,ft + 130 lb/lin.ft = 1,431 lb/ lin.ft

**“Safe Use” Design – We assumed on this project 10% additional for incorrect assumptions about loads.

(P_{LF}) = 1,431 lb/lin.ft.

Use (P_{LF}) = 1,450 lb/lin. ft)

End Design Example 3



Technical Design Assistance

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Design Example 3A – Calculate Foundation Load – *Quick*-Solve™ Design Method

Single Story Slab on Grade

1. Estimate footing Dead Load and Live Load:

A. Using Table 11 from Chapter 6, select the column that most closely identifies the foundation construction. (Only a portion of Table 11 is reproduced at right.) The first column is selected on Table 11 because the house has a slab on grade.

B. Second, determine which of the five rows most closely describes the structure. In this case the closest match is the second row. The construction of the house consists of single story framed construction with brick veneer siding.

C. The Dead Load for a typical single story house of this description ranges from 1,000 to 1,200 lb/lin.ft and the Live Load averages between 100 and 200 lb/lin.ft. Based upon inspection of the house, the load values are chosen from within these load ranges. The choices are based on the quality of construction and contents in house.

Dead Load (DL) = 1,100 lb/ft (Selected Table 11)

Live Load (LL) = 150 lb/ft (Selected Table 11)

2. Temporary Soil Load, (W_T): is estimated at 80 lb/lin.ft inside, and 80 lb/lin.ft outside, of the turn down footing. Graph 1 is inside Table 8 - Chapter 6. (A small version of Graph 1 was reproduced in Design Example 3 above. One must rough estimate the temporary soil load value because the graph does not go as low as 18" soil height.

Table 11. Ranges for Residential Building Loads

Building Construction **(Slab On Grade)**	Estimated Foundation Load Range (DL = Dead – LL = Live)
One Story Wood/Metal/Vinyl Walls with Wood Framing -- Footing with Slab	DL 750 – 850 lb/ft LL 100 – 200 lb/ft
One Story **Masonry Walls with Wood Framing – Footing with Slab**	**DL 1,000 – 1,200 lb/ft** **LL 100 – 200 lb/ft**
Two Story Wood/Metal/Vinyl Walls with Wood Framing – Footing with Slab	DL 1,050 – 1,550 lb/ft LL 300 – 475 lb/ft
Two Story 1st Floor Masonry, 2nd Wood/Metal/Vinyl with Wood Framing – Footing with Slab	DL 1,300 – 2,000 lb/ft LL 300 – 475 lb/ft
Two Story Masonry Walls with Wood Framing – Footing with Slab	DL 1,600 – 2,250 lb/ft LL 300 – 475 lb/ft

Temporary Soil Load (W_T) = 160 lb/ft (Estimated)

3. **Estimated Lifting Load** (P_L)
   P_L = Dead Load + Live Load + Soil Load
   P_L = 1,100 + 150 + 160 = **<u>1,410 lb/lin.ft</u>**

4. **Factored Lifting Load: $P_{LF} = P_L$ + F.S.**
   F.S. = 10% "Safe Use" = 140 lb/ft. (Selected*)
   * Structural loads may not be accurate because they were guessed from a load range table.
   P_{LF} = 1,410 + 140 lb/ft = <u>1,550 lb/lin.ft</u>

End Design Example 3a

Review of Results of Design Examples 3 & 3A

The result obtained by the *Quick*-Solve™ analysis on Design Example 3A overestimated the foundation load by 7% when compared to the more thorough weight analysis. Once again use caution when using the *Quick*-Solve™ design tables and load ranges to select load estimates. The values selected are based upon the designer's "best estimate" of where the actual structural weight falls within the ranges provided by the *Quick*-Solve™ design Table 11. Had you selected DL = 1,050 and LL = 130 lb/ft, the result would have been very close to the calculated value from Example 3. The thing to remember is that one must always be conservative to insure a successful project. **Overestimating the structural weight slightly is not a bad thing.**

Keep in mind that when using the *Quick*-Solve™ design method shown in this example, the estimates can vary depending upon where the loads are selected within the ranges shown on Table 11. This example demonstrated that the *Quick*-Solve™ design method provided a conservative estimate and the difference between the two methods is only 100 lb/ft. This difference is a not significant, and does not affect foundation load estimates and ultimately the pier spacing. **The *Quick*-Solve™ design method has quickly returned a conservative and useful result in a very short time.**

Design Example 4 – Calculate the Maximum Pier Spacing for Design Example 3

Because the structure in Example 3 has only a small footing with very light loads:

Foundation strength is limiting pier spacing on this project.

The load determined in Example 3 predicted 1,450 lb/ft. In Example 3A the load estimate was 1,550 lb/ft. In this example we will use 1,500 lb/ft for determining pier spacing.

1. Determine Pier Spacing, X: Maximum spacing for pier placement can be found in the lower portion of Graph 2 - Chapter 6. (Below) Referring to Graph 2, locate the line for an 18" tall monolithic footing in lowest graph and find the load line representing 1,500 lb/ft. Read downward to see the recommended maximum center-to-center pier spacing. It is slightly over seven feet, which will load the reinforcing steel in the concrete to yield strength. Prepare the preliminary design with a "safe" distance between placements**.** X" = 7.1 feet (Maximum)

Use - X = 7 feet

The estimated pier loading can now be calculated, and an appropriate ECP Steel Pier™ is selected for this project.

$\mathbf{P_W} = (\mathbf{X}) \times \mathbf{P_L}$ (Chapter 6 - Equation 1),

Where;

$\mathbf{P_L}$ = Lifting Load = 1,500 lb/lf

$\mathbf{X}$ = Pier spacing, feet

$\mathbf{P_W}$ = 7 ft x 1,500 lb/ft = **10,500 lb**

- The ECP Steel Pier™ PPB-300 Eccentric Underpinning Bracket System is selected for the project.
- Pier spacing shall be 7 feet O.C.

The ECP Steel Piers™ on this project will have a calculated Factor of Safety of 6.5:1. Pier Ultimate = 68,000 lb (P_{ULT}) / 10,500 (P_W) = 6.5 F.S.

END DESIGN EXAMPLE 4

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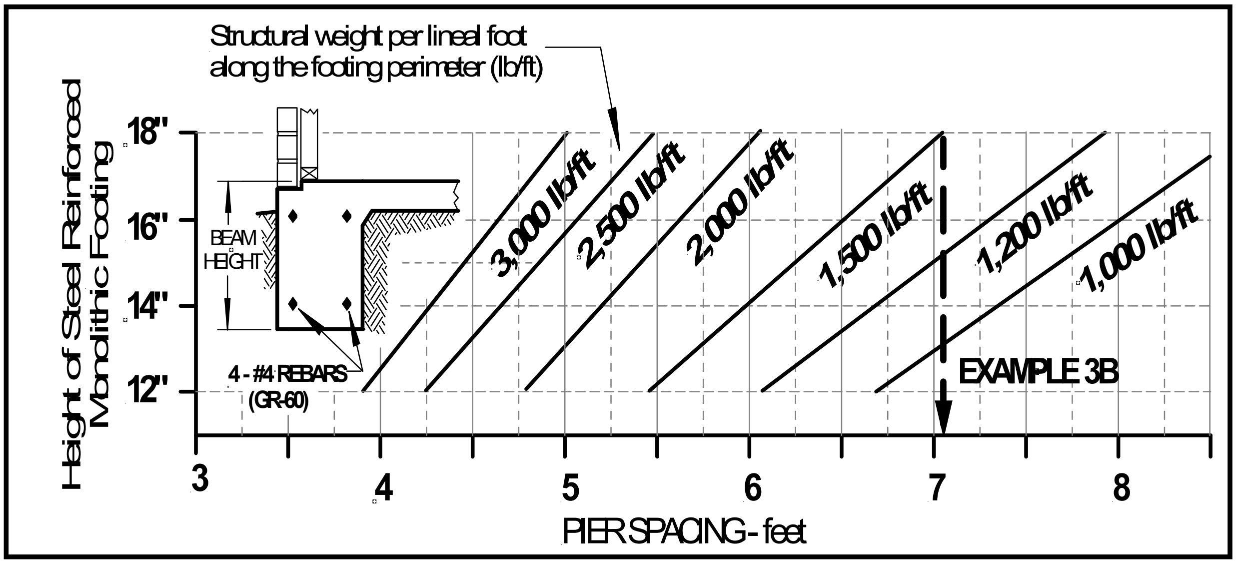

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Design Example 5 – Calculate the Foundation Load and Determine Pier Spacing Three Story Office Building

- The three story structure has settled toward the corner. The largest elevation loss was measured at 1-1/2 inches. The engineer requested a pier design and placement proposal based on a steel pier system to support the structure and recover lost elevation.
- The engineer specified a factor of safety of at least 2.0.
- The foundation consists of an 18” tall x 28” wide reinforced footing with a 10” thick x 3’-0” tall cast concrete stem wall. (Footing toe = 8”) The first floor slab is 6” thick concrete.
- The upper floors are constructed of light weight concrete and the roof consists of multi-layer tar and gravel over an insulated metal roof deck.
- The exterior walls are 30 feet tall and consist of heavy weight concrete blocks that are filled and reinforced. The outer surface has a 1-1/2 inch thick simulated stucco covering. Inside the walls consist of steel studs, insulation, and pre-finished drywall.
- The engineer has calculated the dead load at 7,000 lb/lf on the heavy, load bearing side and 4,700 lb/lf on the adjacent wall. The live loads are estimated at 2,600 lb/lf and 1,800 lb/lf respectfully.

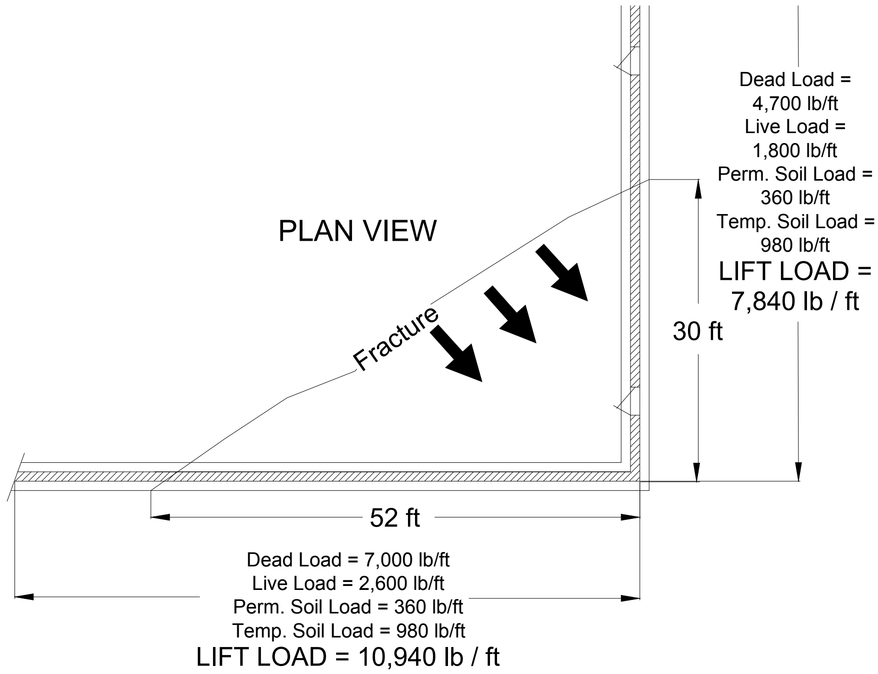


Figure 8. Sketch for Example 5.

1. Engineer Specified Loads:

Working Load (P_W) = Dead Load + Live Load

Side 1 - P_{W1} = 7,000 + 2,600 = **9,600 lb/lf**

Side 2 - P_{W2} = 4,700 + 1,800 = **6,500 lb/lf**

2. Adjust the Working Loads due to Soil Loads:

It was noticed when reading through the project information provided that the engineer did not include a value for the temporary soil load in the working load calculations. A review of Table 8 presented in Chapter 6 provides soil load data that we need to include with the Working Load specification.

It is necessary to consider the permanent and temporary soil loads when a structure must be lifted.

3. Permanent Soil Load on Footing Toe: Table 8 is used to estimate the **permanent soil load** on the footing toes. There are 8 inches of footing toe inside, and outside, of the stem wall that are subjected to a permanent soil load. The soil height is assumed to be 2-1/2 feet above the top of the footing. Referring to Table 8, notice that there is no weight provided for a soil height of 2-1/2 feet. The solution is to use the permanent soil load for 2 feet and then add an additional soil load for additional 1/2 foot.

Looking at Table 8 (A portion is below), the weight for two feet of soil per inch of footing toe is 18 lb/in. Estimating the additional weight for the 1/2 foot of soil, it is necessary to divide the weight of 2 feet of soil by 4 to arrive at the weight of 1/2 foot of permanent soil load. This calculates to an additional weight of 4-1/2 lb/in of footing toe. Therefore, the estimated permanent soil load per inch of footing toe is:

W_{toe} = 18 + (18/4) lb/ft = 22-1/2 lb/in of footing toe.

$\mathbf{W_d}$ = 22-1/2 lb/in x 8 in x 2 toes = **360 lb/ft**

Table 8.	Estimated Soil Loads on Footings						
	Permanent Soil Load on a Footing Toe – W_d						
Soil Height Against Wall	**2’**	4’	6’	7’	8’	9’	10’
Soil Load per inch of Footing Width	**18 lb**	37 lb	55 lb	64 lb	73 lb	83 lb	92 lb
To determine the permanent soil load on a footing toe, multiply the actual width of the footing toe (in inches) by the unit weight shown above for the soil height against the wall.							

Adjusted Working Load ($P_{W\text{-}Adj}$)

$P_{W\text{-}Adj}$ = (DL + LL) + W_d

Side 1 – $P_{W\text{-}Adj\ 1}$ = 9,600 + 360 lb/lin.ft

$P_{W\text{-}Adj\ 1}$ = **<u>9,960 lb/ lin. ft</u>**

Side 2 – $P_{W\text{-}Adj\ 2}$ = 6,500 + 360 lb/lin. ft

$P_{W\text{-}Adj\ 2}$ = **<u>6,860 lb/lin.ft</u>**

4. Temporary (Lifting) Soil Load:
In addition to the permanent soil load, lifting the structure will include raising a temporary soil load that is resists the lifting of the stem wall (inside and outside). Table 8 - Graph 1 (partly shown below from Chapter 6), suggests that the 2-1/2 foot **temporary soil load** is approximately 490 lb/ft per side.

W_t = 490 lb/ft x 2 = **<u>980 lb/ft</u>**

Estimated Actual Lifting Loads (P_L):

P_L = Adj. Working Load + Temp. Soil Load

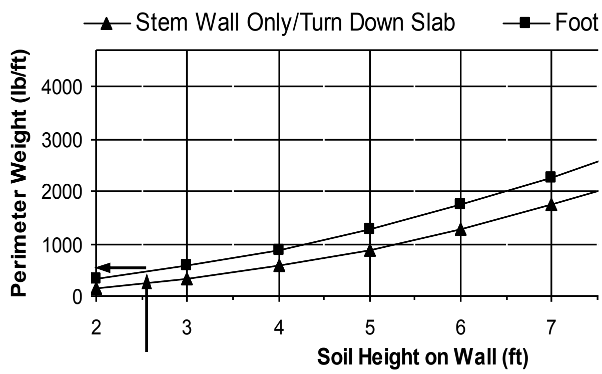
$P_L = P_{W\text{-}Adj} + W_t$

$P_{L\text{-}Side\ 1}$ = 9,960 + 980 = **<u>10,940 lb/ft</u>**

$P_{L\text{-}Side\ 2}$ = 6,860 + 980 = **<u>7,840 lb/ft</u>**

Table 8. Estimated Soil Loads on Footings

Graph 1. Temporary Soil Load (One Side) – W_t



5. Select the Steel Pier System for the project: The engineer specified a required <u>minimum</u> factor of safety of 2.0. Referring to the pier ***Recommended Design / Service Load Ratings*** in Table 1 - Chapter 6, the **PPB-400 Eccentric Underpinning Steel Pier™** system was selected because it has a maximum "Safe Use" service load rating of 49,500 lb. Although this system is slightly more expensive than the PPB-350, this system will use fewer placements and incur lower labor costs. (The PPB-360 could be used, but will require closer pier spacing, "X".)

6. Determine the pier spacing requirements: Use Equation 1 - Chapter 6, to determine the maximum pier spacing, "X":

Equation 1: Pier Spacing
$X = P_{DSL} / P_L$ **or** $P_{DSL} = (X) \times P_L$

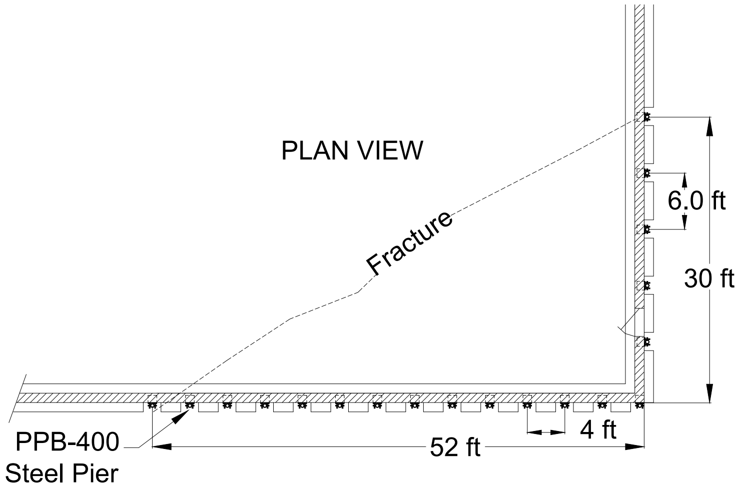


Figure 9. Pier Layout for Example 5.

Pier Spacing: $X = P_{DSL} / P_L$, Where,

X = Pier Spacing

P_{DSL} = 49,500 lb (Model 400 at 2.0 FS)

$P_{L\ Side\ 1}$ = 10,940 lb/ lf (Side 1) Step 4

$P_{L\ Side\ 2}$ = 7,840 lb/ lf (Side 2)

Pier Spacing = "X" = $P_{SU\ Des} / P_L$

Side 1: X_{Side} 1 = 49,500 lb/10,940 lb/lf = 4.52 ft

X_{Side} 1 = Use <u>4 ft. O.C.</u> (Side 1 - Conservative)

Lifting Load on the Piers Side 1:

$P_{L\text{-}Side\ 1}$ = 10,940 lb/ft x 4 ft = **<u>43,760 lb</u>**

Side 2: X_{Side} 2 = 49,500 lb/7,840 lb/lf = 6.31ft

X_{Side} 2= Use <u>6.0 ft. O.C.</u> (Side 2 - Conservative)

Lifting Load on the Piers Side 2:

$P_{L\text{-}Side\ 2}$ =7,840 lb/ft x 6 ft = **<u>47,040 lb</u>**

7. Prepare a pier layout plan - (See sketch above.) Piers along the lower side (Side 1 - heaviest load) are spaced 4 feet on center for a total of 14 placements along 52 lineal feet of foundation. This design places pier supports starting from the point of the foundation fracture up to, and including, the corner.

Piers on the right side (Side 2 - lighter load) are spaced at 6 feet on center for a total of 5 placements. The first pier is located 6 feet away from the corner and the last pier is at the foundation fracture.

Calculate the pier working loads:

$P_{W\text{-}Side\ 1} = P_{W\text{-}Adj\text{-}1}$ x 4 ft = **9,960 x 4 = <u>38,840 lb</u>**

$P_{W\text{-}Side\ 2} = P_{W\text{-}Adj\text{-}2}$ x 6 ft = **6,860 x 6 = <u>41,160 lb</u>**

A total of 19 PPB-400 ECP Steel Piers™ are proposed to support the structure and to recover lost elevation. This design provides a continuous service load of approximately 38,840 pounds per pier on the heavy side at the bottom of the sketch, and provides continuous service load support of approximately 41,160 pounds per pier placement on the lighter side of the structure on the right side of the sketch.

The calculated working load values include the design live and dead loads provided by the engineer along with the permanent soil loads on the footing toes.

8. Determine the Working Load Factor of Safety: The *ECP Pier System Load Ratings* for the **PPB-400 Eccentric Underpinning Steel Pier™** system on Table 1 in Chapter 6 has a "Safe Use" *Recommended Design/Service Load* rating of **49,500 pounds** and the *Ultimate-Limit Mechanical System **Capacity*** of **99,000 pounds**. The Lifting Load F.S. is determined by divided the Ultimate-Limit Capacity by the Service Loads, **(P_W),** from Step 7.

Factor of Safety = Ult. Capacity/Working Load

$\mathbf{F.S._{Side\ 1}} = 99{,}000/38{,}840 = \mathbf{\underline{2.5:1}}$ (Side 1 – FS WL)

$\mathbf{F.S._{Side\ 2}} = 99{,}000/41{,}160 = \mathbf{\underline{2.4:1}}$ (Side 2 – FS WL)

This design exceeds the engineer's minimum factor of safety = 2.0. The design also insures that there will be sufficient pier capacity to break the footing loose from the soil and lift the structure and the temporary soil load without exceeding "Safe Use" design.

9. Determine the Lifting Factor of Safety: The F.S. for lifting the structure can be calculated by dividing the **Ultimate-Limit Mechanical System Capacity** by the Lifting Load determined in Step 6.

Factor of Safety = Ult. Capacity/Lifting Load

$\mathbf{F.S_{L\ Side\ 1}} = 99{,}000/43{,}760 = \mathbf{\underline{2.3:1}}$ (Side 1- FS Lift)

$\mathbf{F.S_{L\ Side\ 2}} = 99{,}000/47{,}040 = \mathbf{\underline{2.1:1}}$ (Side 2 – FS Lift)

10. Determine Field Proof Test Load Requirement for the Piers: The design calls for the piers to support a maximum continuous working load of up to 41,160 pounds (Side 2 Heaviest Load). According to ECP guidelines, it is recommended to perform a proof test of each pile once the pile reaches firm bearing. The ECP field proof test loading recommendation is to load the pier to 1-1/2 times the anticipated working load or until slight lifting of the foundation is observed.

Proof Load = Working Load x 1.5

$P_T = 41{,}160 \text{ lb} \times 1.5 = 61{,}740 \text{ lb}$

$\mathbf{P_T} =$ **62,000 lbs (**Maximum for Proof Test Load)

11. Estimating Driving Cylinder Pressure: The designer should always calculate the hydraulic pressure requirement needed to proof test load each pier. At the same time the hydraulic pressure required to lift and recover the lost elevation should be calculated. This is valuable information to make available to the field technicians.

The ECP HYD-350-DC Drive Cylinder has a piston area of 8.29 in^2 as stated in *Pier Installation, Load Testing & Project Documentation* in Chapter 6. Equation 2 is used to determine the hydraulic pressure required on the drive cylinder to produce a Proof Load of 62,000 pounds,

Equation 2: Hydraulic Cylinder Force

$$\mathbf{F_{Cyl} = A_{cyl} \times P_{cyl}}$$

Where: F_{Cyl} = Cylinder force on pier = 62,000 lb
P_{cyl} = Hydraulic Pressure, psi
A_{cyl} = Effective Cylinder Area = 8.29 in^2
(HYD-350-DC Cylinder Area - 8.29 in^2)

Change Equation 2 to solve for the cylinder pressure:

$\mathbf{P_{cyl} = F_{Cyl} / A_{cyl}} = 62{,}000 \text{ lb} / 8.29 \text{ in}^2$

$\mathbf{P_{cyl} = 7{,}479}$ **psi – Use 7,500 psi** (Proof Load Test)

12. Estimating Lifting Cylinder Pressures: While all of the project design data are at hand, the necessary hydraulic pressure on the HYD-254 Lifting Ram to raise the structure should be determined in a similar manner as in Step 11.

$\mathbf{P_{cyl} = F_{Cyl} / A_{cyl}}$

Where: F_{Cyl} = Max. lift force on pier:
$F_{Cyl\ Side\ 1}$ = 43,760 lb
$F_{Cyl\ Side\ 2}$ = 47,040 lb
P_{cyl} = Hydraulic Pressure -- psi
A_{cyl} = Effective Cylinder Area – 5.16 in^2
(HYD-254 Ram Area = 5.16 in^2)

$P_{cyl\ Side\ 1} = 43{,}760 \text{ lb} / 5.16 \text{ in}^2 = 8{,}480$

$\mathbf{P_{cyl\ Side\ 1}} =$ **8,500 psi**

$P_{cyl\ Side\ 2} = 47{,}040 \text{ lb} / 5.16 \text{ in}^2 = 9{,}125$

$\mathbf{P_{cyl\ Side\ 2}} =$ **9,100 psi**

The pressure estimates for the pier proof test once the pier reaches firm bearing has been calculated along with the expected structural lifting pressures for elevation recovery. These values should be supplied to the field personnel to assure a smooth installation and restoration.

End Design Example 5

Technical Design Assistance

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Design Example 5A – Estimate the Drive Cylinder and Lifting Ram Pressures
Quick-Solve™ Design Method for Design Example 5

Quick-Solve™ estimating can quickly determine the cylinder pressure required to "Proof Test" the piers and determine the "Structural Lift" pressures for restoration of the structure. We will use Graph 4 - Chapter 6. (Reproduced below)

1. Proof Test Pressure: Begin by locating 62,000 pounds at the left edge of Graph 4. Read horizontally to the right until encountering the solid line (HYD-350-DC Cylinder). Read to the down to determine the Drive Cylinder pressure required for a force of 62,000 pounds.

$P_{Cyl\ Proof\ Test}$ = **7,500 psi.**

2. The Structural Lifting pressure: Begin by locating the Lift Load – Side 1 requirement of 44,000 lb. at the left edge of Graph 4. Read horizontally to the right until encountering the short dashed line (HYD-254 Lifting Ram). Read to the down to determine the estimated maximum pressure requirement.

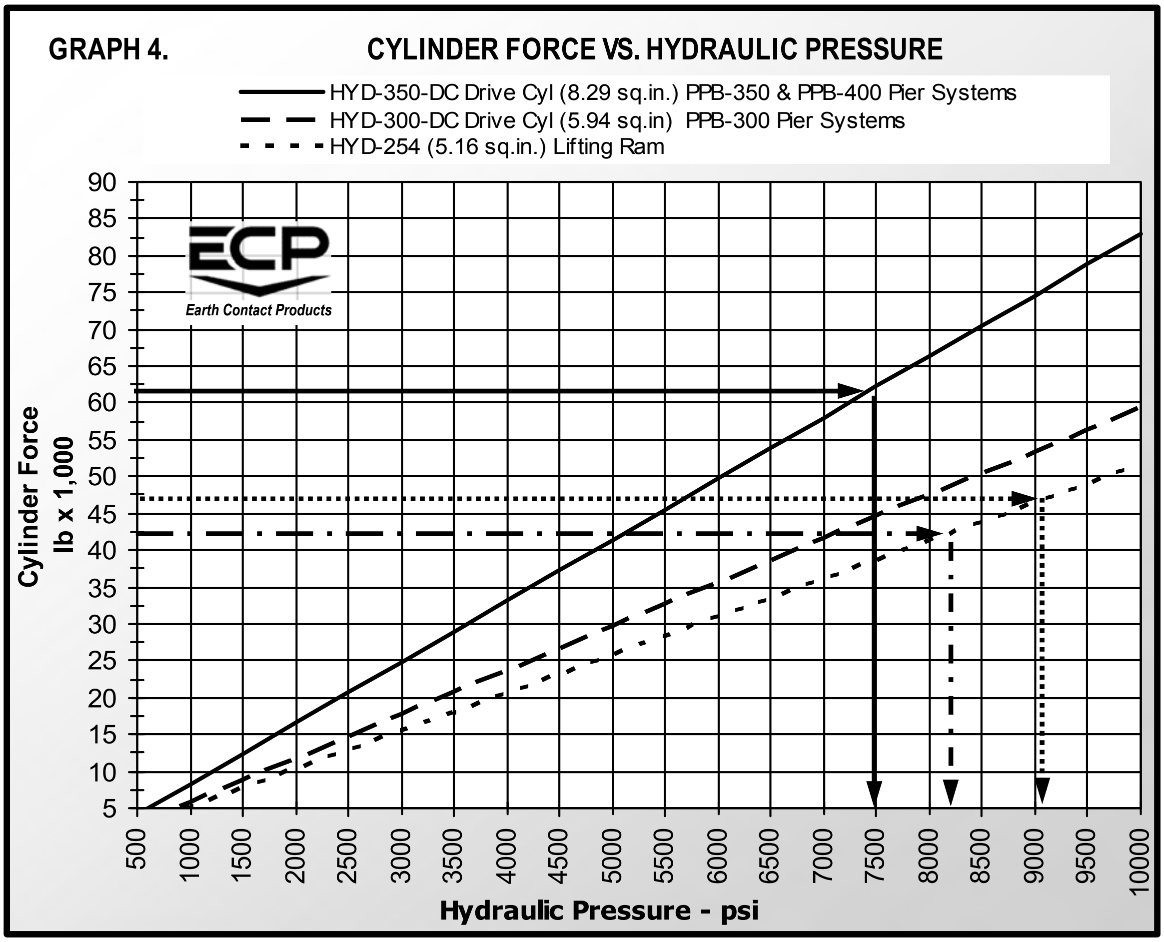
$P_{Cyl\ Side\ 1}$ = **8,250 psi**. (Lifting pressure Side 1)

Similary for Side 2 read from 47,000 lb. on left side until encountering the short dashed line find the lifting

$P_{Cyl\ Side\ 2}$ = **9,100 psi**. (Lifting pressure Side 2)

This information should be supplied to the field personnel to assist with the installation.

End Design Example 5A



Review of Results of Design Example 5A

The result obtained by the *Quick*-Solve™ design analysis on Design Example 5A underestimated the lifting pressure on Side 1 of the building by 3% when compared to the calculated lifting pressure. The 3% difference is not significant and the lift pressure usually varies from pier to pier on the job site due to differences in structural loading. Simply use caution when using the *Quick*-Solve™ design tables.

Design Example 6 – Determining Force Applied to Pier from Field Data

For this example it is assumed that the technician in his field report states a driving pressure on a **PPB-300-EPS** pier pipe of **5,500 psi**. The actual installation force on the pier pipe needs to be determined and is required to be submitted to the engineer.

Use Equation 2 from Chapter 5 to determine the downward force on the pier pipe:

Equation 2: Hydraulic Cylinder Force

$$F_{Cyl} = A_{cyl} \times P_{cyl}$$

Where: F_{Cyl} = Cylinder force on pier –lb
P_{cyl} = Hydraulic Pressure – 5,500 psi
A_{cyl} = Effective Cylinder Area – 5.94 in^2
(HYD-300-DC Cylinder = 5.94 in^2)

$F_{Cyl} = 5.94\ in^2 \times 5{,}500\ lb/in^2$

$\mathbf{F_{Cyl}}$ = **32,670 lb.**

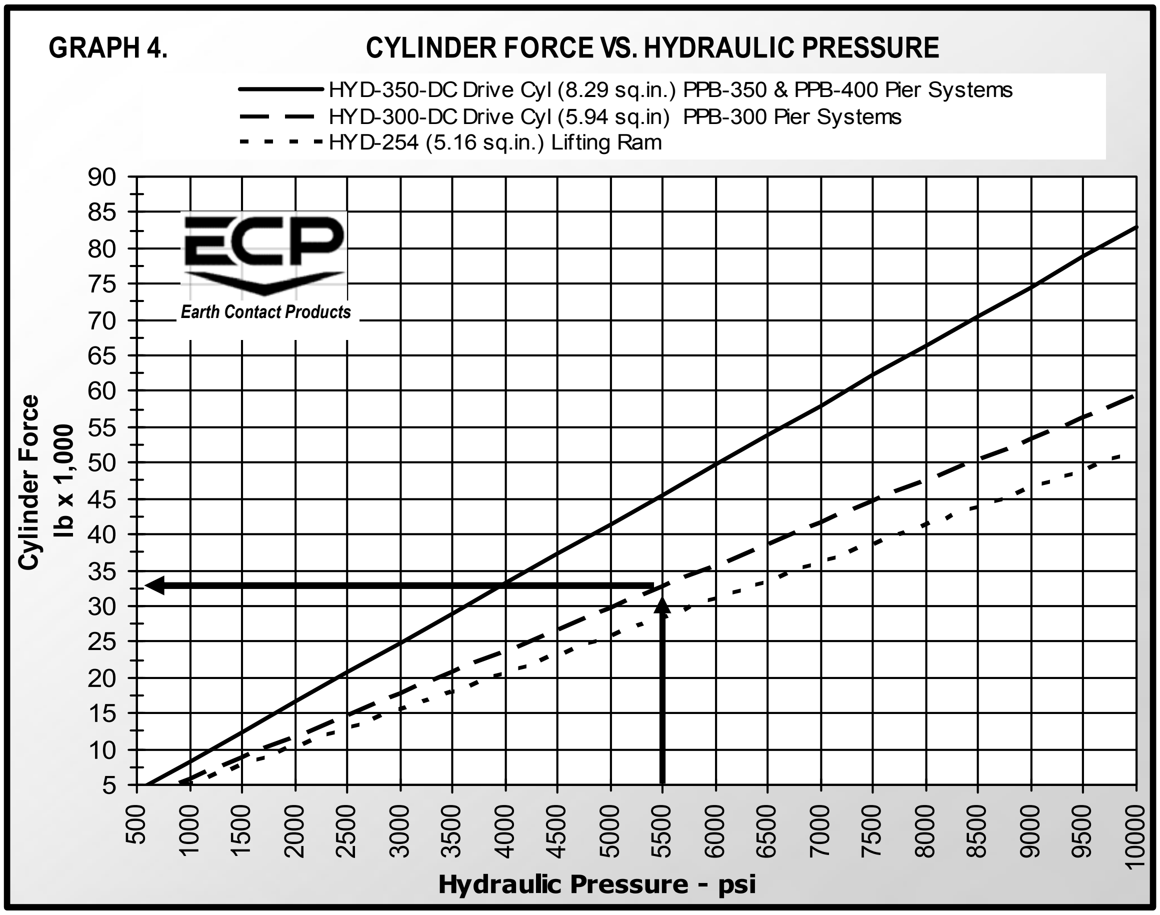
End Design Example 6

Design Example 6A – Determining Force Applied to Pier - Quick-Solve™ Design Method

Quick-Solve™ estimating to determine the force on the pier when the cylinder pressure being applied is known. Use Graph 4 from Chapter 6. Begin by locating "5,500 psi" pressure on the HYD-300-DC cylinder on the lower edge of the graph. Read upward from the bottom of the graph until encountering the line with long dashes. Read to the left to determine the force on the pier.

$\mathbf{F_{Cyl}}$ = **33,000 lb.**

End Design Example 6A



Review of Results of Example 6 & 6A

The result obtained by the *Quick*-Solve™ design analysis on this example shows that it is possible to obtain results very quickly that are relatively accurate. It is important to accurately lay out the lines on the graph to obtain best results. The *Quick*-Solve™ design method is a great tool because it returned useful results quickly without requiring any mathematical calculations.

NOTES:

Chapter 8

Corrosion Life of Steel Foundation Products

Torque Anchors™
ECP Steel Piers™

EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

Table of Contents

Chapter 8 – Corrosion Life of Steel Foundation Products

EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

Corrosion is defined as the deterioration of a metallic structure due to its interaction with the surrounding environment.

Steel Underground - How Long Does It Last? Steel foundation supports are subjected to a range of corrosive forces that are quite different from steel exposed to atmospheric conditions. The performance of steel and galvanized structural steel elements underground are not as well understood as is the life expectancy of steel products in above ground applications.

For corrosion to initiate, steel requires not only oxygen but also the presence of dissolved salts in water. If either of these items is absent, corrosion will not occur.

The causes of corrosion on buried metallic structures are generally understood, but this knowledge base does not always permit an accurate prediction of a design life when placed in a corrosive environment. This chapter is not intended as a rigorous technical text; rather it provides general knowledge to help the reader to establishing whether corrosion could be a critical factor in a specific foundation support application.

A qualified engineer, knowledgeable in design for corrosion environments, should be consulted when foundation support products are to be used in a known corrosive environment.

Corrosion occurs by an electrochemical process. In order for corrosion of an underground metallic structure to occur, the following must be present: 1.) Electrical potential, 2.) Dissolved salts in water (electrolyte) and 3.) Aeration

- **Electrical Potential:** Corrosion is initiated by a difference in electric potential (electric charge) between two points on a buried metallic structure. This electrical potential can be caused by strains in the metal or between component parts, or contact with different soil types along the shaft, or non-homogeneities in metal, etc. A difference in electrical potential causes the development of "anodes" and "cathodes" along the surface of the metal. There must be an electrical connection between the anodes and cathodes for corrosion to occur.

- **Electrolyte:** Water or moisture in the soil that surrounds the pile or pier shaft may contain dissolved chemical elements (ions) and serve as the electrical connection between different parts of the structural element. The water containing dissolved chemical elements is called an <u>electrolyte</u>. The presence (or absence) of these ions, as well as their nature and concentration, determines the electrical conductivity, or resistivity, of the electrolyte.

- **Aeration:** The availability of oxygen (aeration) in the soil surrounding the metal is also essential to the corrosion process. The cyclic process of wetting and drying of the soil causes oxygen to be present in the soil. It is also the reason that most corrosion usually occurs near the surface where the wet-dry cycle is more severe.

Under these conditions, metal ions will migrate from the anodic (+) locations on a metallic object and transfer to the cathodic (-) locations. It is this loss in metal at the anodic locations that results in the degradation of the underground metallic structure.

Controlling Factors for Corrosion

Soil Type: Some soil types are more corrosive than others. The physical and mineralogical composition of soils, which are a result of:

- ♦ Their origin, decomposition and deposition
- ♦ The plant life and its decomposition
- ♦ Topography of the land

All of these influence the soil's corrosivity potential. The soils having greatest concern are those which produce water soluble acid forming chemical elements. Example are carbonates, bicarbonates, chlorides, nitrates and sulfates, or base (alkaline) forming chemical elements such as sodium, potassium, calcium or magnesium.

<u>The soils that have the highest corrosive potential, are soils described or classified by geotechnical engineers as silty, loamy, clay, organic (peats, cinders and ashes), and soils which are poorly aerated</u>. Granular soils (sands and gravels) which are highly aerated can drain water away rapidly. In well drained soil the electrolyte is not constantly in contact with the steel and the corrosion process is reduced.

Soil Resistivity: The resistivity of the soil is one of the simplest tests for soil corrosivity. To obtain the soil resistivity, one passes a current through the soil and measures the resistivity of the soil. Generally, when the soil resistivity is high (measured in ohm-cm); the rate of corrosion and loss of steel is low. Corrosive soil characteristically has low soil resistivity. Low soil resistivity usually occurs in fine-grained soils such as silts, loams, clays, and peat; and therefore has the greatest corrosion susceptibility. Table 1 below illustrates the average corrosivity range for common soil types, and Table 2 provides a measure of soil corrosivity based upon the soil resistivity.

Sandy soils have the higher resistivity values are most often found to be the least corrosive. Clay soils generally have higher corrosivity especially when clay soil is in an area of saline water. In this case the soil can be highly corrosive to steel.

Soil resistivity can be measured in the field using a soil resistivity meter or by obtaining a soil sample from the site and testing it in a laboratory using a resistivity meter and a soil box. This equipment is generally available to the geotechnical engineer.

Soil pH: This is the measure of acidity or alkalinity in a solution and is given a pH number. Values of pH < 7 are considered acidic and values of pH > 7 to 14 are alkaline. Pure distilled water is neutral and has a pH = 7. pH is a measure of the degree of hydrogen ion concentration in the water. When a sample of soil is mixed with distilled water in the lab, the solution can then be tested with a pH meter to arrive at the soil pH number.

Table 1. Soil Resistivity Ranges For General Soil Types

Soil Type[1]	Resistivity Range (ohm-cm)	Soil Type[1]	Resistivity Range (ohm-cm)
Gravel	40,000 to 200,000	Fine Silts & Organics	2,000 to 10,000
Sand	10,000 to 100,000	Loams	3,000 to 10,000
Silt	1,000 to 2,000	Humus	1,000 to 4,000
Clay with Silt	3,000 to 5,000	Ashes – Cinders	500 to 5,000
Clay	500 to 2,000	Peat	100 to 2,000
Heavy Plastic Clay	5,000 to 20,000	Marshy Deposit	50 to 300

Notes: 1. High soil moisture content decreases the resistivity making the soil more corrosive.
2. Freezing the soil dramatically raises the resistivity, thus reducing the corrosivity

Table 2. Soil Resistivity and Relative Corrosivity Rating

Resistivity (ohm-cm)	Corrosivity Rating
> 10,000	Non-Corrosive
5,000 to 9,999	Mildly Corrosive
3,000 to 4,999	Moderately Corrosive
1,000 to 2,999	Corrosive
500 to 999	Highly Corrosive
< 500	Extremely Corrosive

While soil corrosivity can exist within a broad range of soil conditions, the amount of acidity, pH < 7 (organic reducing soils) or alkalinity, pH > 7 influences corrosion susceptibility and corrosion rates. Most soils have a pH that falls within the range of pH 3-1/2 to pH 10.

Soils that are highly acidic (pH < 4-1/2) or highly alkaline (8 < pH < 10-1/2) have significantly higher corrosion rates than soils within the mid-range 4-1/2 < pH < 8.

Alkaline soils that have a pH greater than 10-1/2 will have a significantly decreased corrosion rate due to passivation.

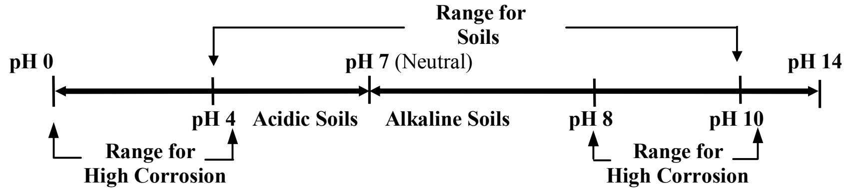


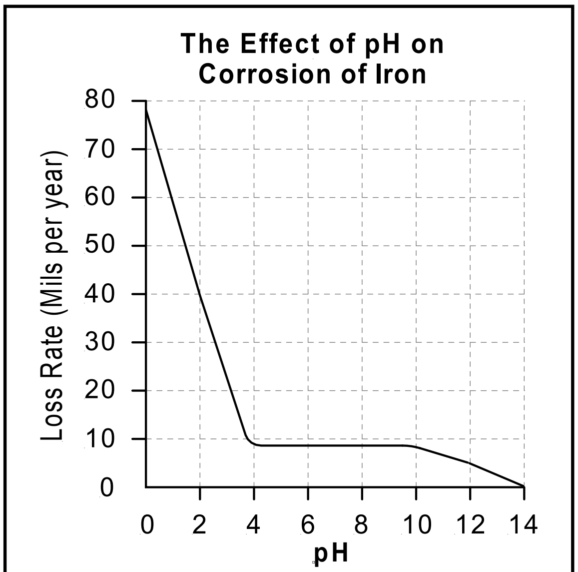
Figure 1. Corrosion of metals within soils can occur over a broad range of pH.

Corrosion Test Results: Doctors Laboratories, a division of the Royal Military College of Canada exposed iron to aerated water at room temperature and determined the corrosion rate as a function of the pH of the water.

As the water became highly acidic (pH less than 4), the steel corroded more quickly than the steel did in a highly alkaline environment (pH greater than 10). It is also interesting to note that zinc used for galvanization provides the best protection to steel subjected to these environments. Zinc provides the most effective protection through a range of $5.5 < pH < 12.5$. In the absence of air, a zinc oxide film does not form on the zinc galvanized surface and corrosion can be more rapid when moisture is present.

The corrosion rate of steel in soil can range from less than 0.79 mils per year (0.0008 in/yr) under favorable conditions to more than 7.87 mils per year (0.0079 in/yr) in very aggressive soils. There are similarities in the corrosion rates of galvanized coatings. Under favorable conditions, the zinc may corrode at less than 0.20 mils per year under mild conditions to more than 0.98 mils in unfavorable soil conditions.

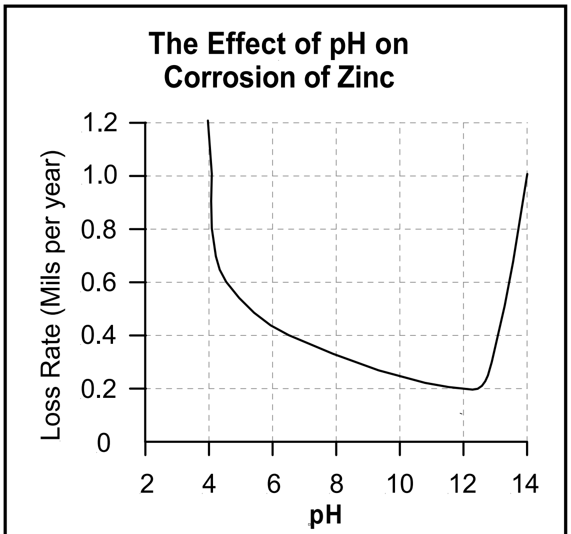
The results of the testing are shown in Graph 1. The data suggests that in the range of $4 < pH < 10$ the corrosion rate of iron is independent of the acidity or alkalinity (pH) of the environment. In acidic conditions ($pH < 4$) the corrosion rate dramatically increases. The scientists concluded that the acidic conditions dissolve the iron oxide as it forms leaving the iron in direct contact with the water.



Graph 1.

Zinc Galvanizing for Corrosion Protection: In Frank Porter's *"Corrosion Resistance of Zinc and Zinc Alloys"*, he determined that dissolved chloride content in water is highly corrosive to zinc. When zinc is subjected to hard (alkaline) water, the insoluble salts in the water form a scale of calcium carbonate and zinc carbonate on the surface of the zinc coating that provides a protective barrier against attack from free chloride anions.

Frank Porter attributes this insoluble scale for the significantly increased corrosion free life of galvanized piles in soils where pH ranges between 5.5 and 12.5. Roathali, Cox and Littreal, the authors of *"Metals and Alloys"*, 1963; presented data showing the corrosion rate of zinc is a function of pH. Excerpts from their data are presented in Graph 2.



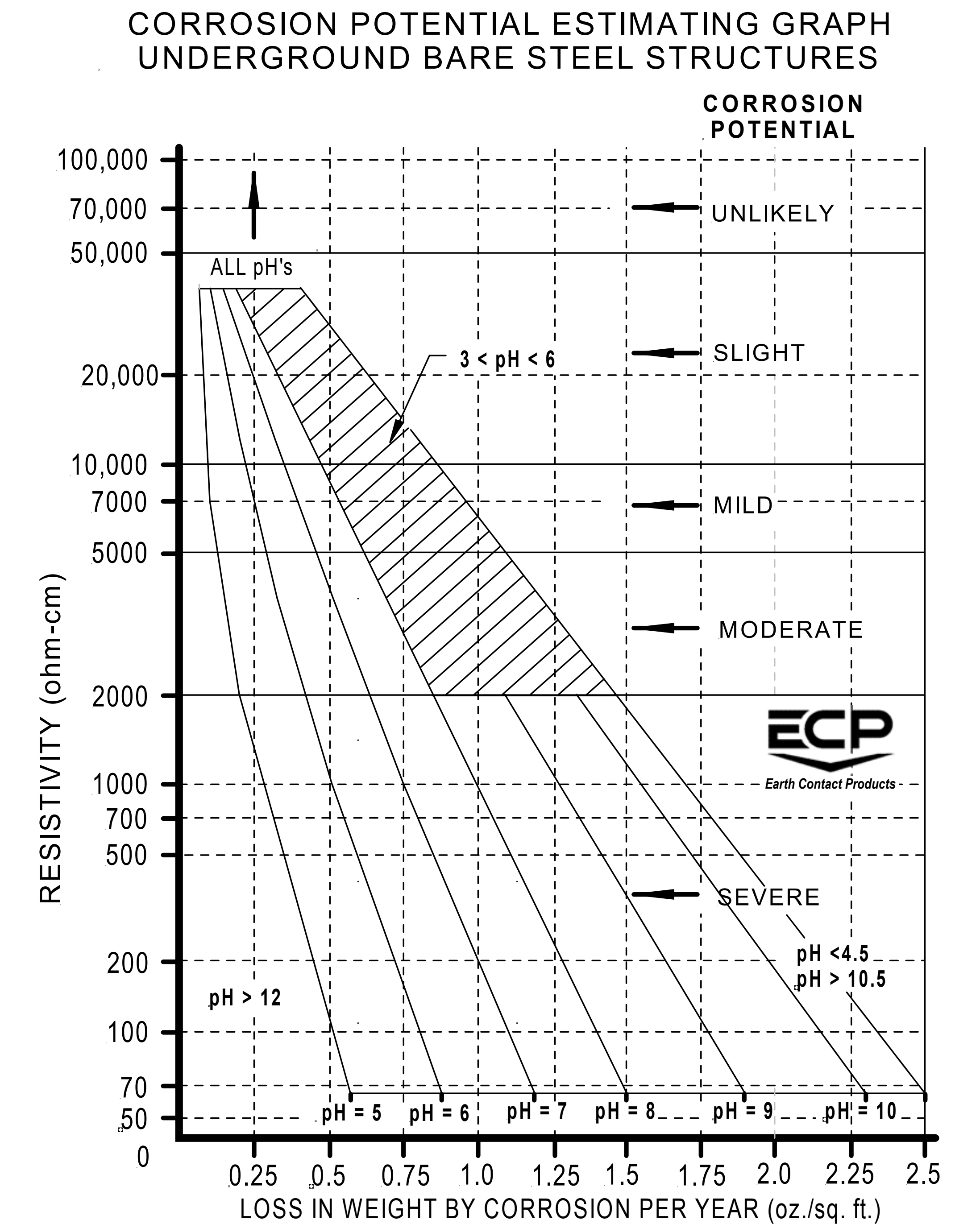
Graph 2.

Oxygen Availability: In addition to soil moisture, free oxygen must be available to complete the corrosion process. Oxygen combines with the metal ions to form oxides, hydroxides and metal salts.

Corrosion rates will drop significantly when the steel structure is below a ground water table (GWT), and the water is relatively stagnant (low to no flow velocity) since available free oxygen is much reduced under these conditions.

Estimating Corrosion Potential

There are a number of variables that influence the corrosion potential for underground metallic structures. Melvin Romanoff has conducted extensive field testing of buried metal structures to evaluate the corrosion levels related to the more significant variables. These results, published by Romanoff in *"Underground Corrosion",* National Bureau of Standards circular 579, Houston TX, 1989; along with data published in the proceedings of the *"Eighth International Ash Utilization Symposium, Vol. 2"*, American Coal Ash Association, Washington, DC, October, 1987. These data were used to develop Graph 3, which allows during the design process for an empirical calculation to estimate losses due to corrosion.



Graph 3. Prediction of steel loss due to corrosion relative to soil resistivity and pH.

If specific information on a soil is available to the designer (soil type, pH & resistivity), a preliminary estimate for metal corrosion loss of bare steel can be determined. The NBS publication can also be used to find a comparable soil and condition for estimating the rate of corrosion. It should be noted that when hot-dipped galvanizing is used as a form of corrosion protection, the resulting corrosion rate for steel (once the galvanized coating is lost due to corrosion) will be lower than the rates shown in Graph 3 on the previous page. (The estimated reduction rate of corrosion is in the 20% to 100% range).

Special Corrosion Conditions: Soil resistivity and pH are strong influencing factors on corrosion rates; however, there are other special soil conditions which may increase the corrosion rate such as: 1.) excessive salt content of water (seawater), 2.) velocity of water flow and 3.) atmospheric conditions. Uhilig's "*Corrosion Handbook",* Edited by R. Winston Revie, 2nd Edition, provided the following reference material:

1. **Corrosion Rates in Seawater**
   (Pipe Piles, H-Piles, Etc.)
   a. Splash Zone (Average) = 6.9 oz/ft^2 / yr
   b. Tidal Zone (Average) = 2.0 oz/ft^2 / yr
   c. Immersed (Average) = 2.3 oz/ft^2 / yr
   d. Immersed Zone (Range) = 0.5 to 9.0 oz/ft^2/yr

2. **Influence Of Velocity In Fresh Water**

Velocity (m/s)	Corrosion Rate Multiplier
1/2 to 3	4
3 to 15	1.2 to 0.8

3. **Atmospheric Corrosion Rates**
   (Pipe Piles, H-Piles, Etc.)
   Atmospheric = 3.2 oz/ft^2/yr (Average)
   (< 500 Meters to Seashore)

Soil Corrosion Ratings: In over 90% of foundation underpinning projects corrosion is not a problem, but one needs to recognize the warning signs of problem soils. The American Water Works Association developed a numerical rating to determine the severity of corrosion for cast iron pipes. While ECP products are not constructed from cast iron, a numerical rating system similar to the AWWA system was developed by ECP that provides guidance for steel foundation products in soil. The numerical corrosivity score is designed only as a *Quick*-Solve™ design method to warn of a possible corrosive environment in which the life of galvanized steel product may be accelerated due to aggressive corrosion conditions.

Using the information gathered from a specific job site, an indication of the likelihood of corrosion is suggested based upon point values that is assigned to the three soil parameters linked to increased corrosion rates. Notice in Table 3 that the three elements that influence the rate of corrosion must be known before an assessment of soil corrosivity can be predicted from Table 4.

The sum of these point values gives the numerical corrosivity score for the site. The score suggests the likelihood of slight, moderate or high corrosion potential of the soil. As the score approaches 10, the soil becomes more aggressive.

> When the numerical corrosivity score equals 10, or higher, it is strongly recommended to seek the advice of a corrosion engineer who can evaluate the project to determine what additional corrosion protective measures (in addition to galvanization) are might be required for extended service life.

Table 3. Numerical Corrosivity Score

Soil Parameter	
Soil Resistivity (ohm-cm)	**Points**
< 500	10
500 – 999	8
1,000 – 1,999	5
2,000 – 4,999	2
5,000 – 10,000	1
>10,000	0
pH	**Points**
2 – 4.5	6
5 – 6	0
7 – 9	2
10.5 -- 12	6
Moisture	**Points**
Tidal or Salt Water Exposure	5
Poor Drainage – Always Wet	2
Fair Drainage - Moist	1
Good Drainage – Usually Dry	0

Table 4. Soil Corrosion Potential

Unlikely			Slight		Mild		Moderate		Aggressive					Severe						
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Depending upon the corrosion potential for a given soil environment, several alternatives are available to reduce the corrosion cycle and extend the performance life of the underground steel element. These control measures can be divided into general categories:

- **Passive Control** – Used in soils classified as having mild to moderate corrosion potential
- **Active Control** – Used in soils classified as having moderate to severe corrosion potential

Passive Control

Hot Dip Galvanizing: The products manufactured by Earth Contact Products and offered with **Hot Dip Galvanizing** are coated with molten zinc that contains not less than 98% pure zinc metal. The hot dip galvanization process meets or exceeds ASTM A123 Grade 75 which is 1.7 oz/ft^2 of zinc (3.0 mils minimum thickness) for steel plate, structural tubing or bar products..

Continuous Sheet High Speed Hot Dip Mill Galvanized Corrosion Protection: The pier pipe for ECP Steel Piers™ foundation support systems are supplied with a ASTM A563 G90 hot dip galvanize process that is applied prior to tube formation. This corrosion protection process treats both sides of the steel sheet with a high speed continuous galvanization process that consists almost entirely of pure zinc. During the process the steel sheet is passed through the cleaning tanks and then into the zinc kettles at high speed. The speed through the process determines the coating thickness of almost pure zinc with very little intermetallic growth of crystals. This corrosion protection coating has sufficient ductility to withstand the tube forming process without damage to the coating.

The pier pipe used for PPB-350 and PPB-300 Steel Piers™ is supplied with ASTM A563 G90 hot dip mill galvanization.

In the case of the G90 corrosion protection the total thickness of both sides is specified at a minimum of 0.90 oz/ft^2 or nominally 0.45 oz/ft^2 per side. The maximum thickness per side is approximately 0.76 mils. The ASTM A653 specification allows variations in thickness from one side of the steel sheet to the other side. <u>The minimum thickness allowed per side is 0.32 oz/ft^2</u>.

The American Galvanizers Association discussed in their publication, “Zinc Coatings” that when comparing zinc coats produced by different process, the thickness of zinc coating cannot be used without considering the amount of available zinc per unit volume. The coating densities of different types of zinc coating can differ. So given the thickness representing the same weight per unit area would be expected to provide equivalent service lives.

Hot Dip Galvanizing to ASTM A123-Grade 75 provides a 3.0 mil coating, 1.7 oz/ft^2 of zinc. Continuous mill galvanized sheet material to ASTM A653-Class G90 specifications provide a 0.76 mil per side coating, 0.45 oz/ft^2 of zinc per side. While one might think that per side coating thickness would always be 0.45 oz/ft^2, the ASTM A653 G90 specification allows for galvanized coating to be unequal per side. The specification accepts a minimum one side coating of 0.32 oz/ft^2 as acceptable. As a result corrosion life could vary between mill runs of G90 material.

When making a comparison of corrosion life vs. thickness of zinc, the ASTM A654 G90 coating offered up to 20% of the corrosion life when compared to Hot Dip Galvanized product to ASTM A123-100 under similar conditions.

Because no controlled in-soil corrosion testing is available for the continuous sheet high speed pre-galvanize corrosion protected pier pipe, a zinc equivalence of 0.76 mils (0.45 to 0.32 oz/ft^2) on one side appears to be reasonable value to be used when estimating corrosion life the a pier pipe fabricated from the high speed hot dip pre-galvanized sheet steel.

Thicker coatings (5 mils) used in field testing have shown extended life, depending on the corrosion potential of the soil environment. The galvanized coating serves as an anode to provide cathodic protection to the steel. The results of the studies conducted by Romanoff and by Porter indicate that a galvanized (zinc) coating was effective in delaying the onset of corrosion in the buried steel structures. Typical conclusions drawn from this study for the 5 mil (3 oz/ft^2) galvanized coating includes:

- Adequate for more than 10 years corrosion protection for inorganic oxidizing soils.

- Adequate for more than 10 years corrosion protection for inorganic reducing soils.
- Insufficient for corrosion protection in highly reducing organic soils (pH < 4) and inorganic reducing alkaline soils or cinders (8 < pH < 10.5) lasted typically only 3 to 5 years.
- **It was also noted, however, that the use of a galvanized coating significantly reduced the rate of corrosion of the underlying steel structure once the zinc coating was destroyed**. This was observed in Romanoff's study where the rates of corrosion for the previously galvanized coated steel were less than the corrosion rates for never galvanized bare steel.

Active Control

Cathodic Protection: As indicated previously, corrosion is an electrochemical process that involves a flow of direct electrical current from the anodic (corroding) areas of the underground metallic structure into the electrolyte and back onto the metallic structure at the cathodic (non-corroding) areas. In situations where helical piles or steel piers are to be placed in a soil environment classified as severely corrosive, Active Control technique of corrosion control should be used. This Active Control technique is termed *Active Cathodic Protection*.

The basic principle of *Active Cathodic Protection* is to apply an electrical current equal to and opposite to the electrical current generated by the corroding metallic structure, thus effectively eliminating the corrosion process on the foundation element.

Sacrificial Anodes: The sacrificial (galvanic) anode is attached to each underground metallic structure by an electrical conductor (cable) and the anode is placed within the common soil medium (electrolyte) adjacent to the foundation element. The sacrificial anode works best when only a small amount of electrical current is needed for corrosion control and/or when the soil resistivity is low. Anodes are usually installed about three feet below the surface and 3 to 6 feet from the steel subject to corrosion. Magnesium, zinc and aluminum are the most commonly used galvanic sacrificial anodes.

The use of cathodic protection using sacrificial anodes connected to underground metallic structures offers the following advantages:

- no external power supply is required
- low cost for anode bags and installation
- minimum maintenance costs

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, length and type of the anode canister. After the anode is exhausted, a new anode needs to be installed. Otherwise the underground steel will begin to corrode.

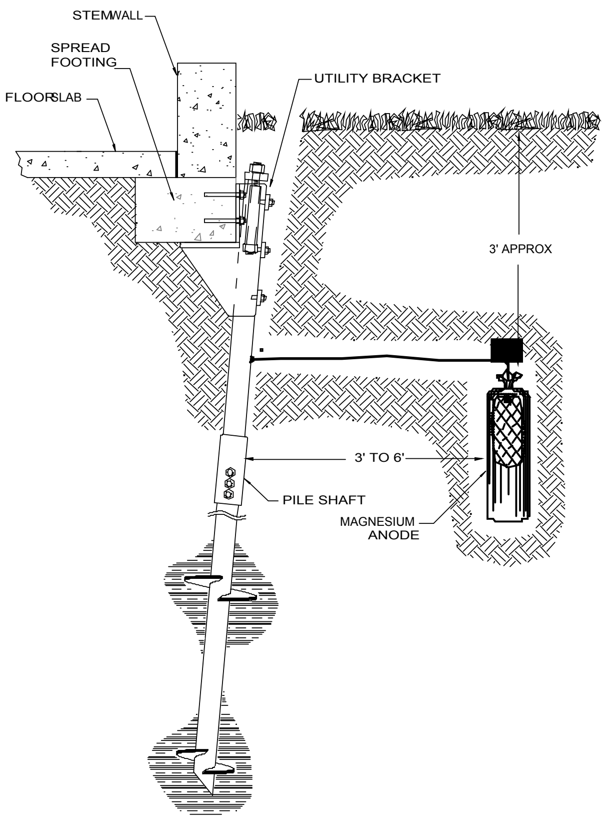


Figure 2. Active corrosion protection with a magnesium anode.

Impressed Current: In areas that have the most severe corrosion potential, requires a large electrical current and in places with high resistance electrolytes; an impressed current system is generally recommended. This system requires a power source, rectifier and a ground bed of impressed current anodes. These systems require a continuous external power source to provide corrosion protection.

The majority of applications where foundation underpinning is installed will not require an active corrosion protection system. In most cases where there is corrosive soil and/or adverse electrolyte conditions, the sacrificial anode protection system will likely be the most economical approach for corrosion protection.

All corrosion protection systems require technical expertise and training to design and install the products for the specific job site conditions. As long as the system is properly designed and installed; and the system remains in operation, the underground steel will have unlimited corrosion life.

Corrosion Life Analysis

The estimated corrosion life is based on the following factors:

1. The life of the galvanized coating, (CL_G)
2. The life of a limited amount of steel loss in the pier wall without losing structural integrity of the pile, (CL_P) (The recommended allowance is 10 %.)
3. The life when cathodic protection is present, (Use the life analysis provided by the sacrificial anode manufacturer.)

There is a high degree of variability in the performance life of steel piers and helical piles in the soil. Including, but not limited to:

- multiple strata soils through the depth of installation,
- soil variations within a given stratum
- variability of the water content of soil both vertically and seasonally
- presence or absence of salt ions in the soil due to leaching, etc.
- non-uniformity of the galvanized coating thickness and areas of stress concentration
- imperfections in the steel
- damage to the steel or the galvanized coating
- presence or absence of stray currents

Corrosion Life of Galvanized Coating: The observed rates of corrosion for the galvanized coating were found to be less than that for bare steel in Romanoff's NBS study. Equation 1 can be used to estimate the corrosion (weight loss) rate for galvanized coatings.

Equation 1 - Corrosion Life Zinc:

$$CL_G = G / [0.25 - 0.12 \log_{10} (R/150)]$$

Where:
CL_G = Weight loss (oz/ft^2)
G = Amount of galvanize coating (oz/ft^2)
R = Soil resistivity (ohm-cm)

Corrosion Life of Steel Pier or Pile: Once the protection offered by the galvanized coating has been exhausted, the steel begins to corrode and lose thickness. "Safe Use Design" states that a factor of safety of 2.0 or greater shall be used when designing foundation supports. Experience has shown that the structural integrity of the steel pier system is not be compromised after a corrosion loss of steel not exceeding ten per cent. This is because greater strength is needed for product installation than for support. The formula for estimating average time for ten percent corrosion loss in steel wall thickness (10% of W_S) is given in Equation 2, which estimates corrosion loss per year.

Equation 2 - Corrosion Loss Steel Shaft:

$$CL_P = W_{S\text{-}10\%} / K_C$$

Where:
CL_P = Life expectancy of steel tube (years)
$W_{S\text{-}10\%}$ = 10% shaft weight loss – (oz/ft^2)
$K_{C\text{-}1\,yr}$ = Corrosion loss per year - oz/ft^2
$W_{S\text{-}10\%}$ can be determined by Equation 3.

Equation 3 – 10% Loss of Steel:

$$W_{S\text{-}10\%} = 10\% \times t \text{ ft} \times 489.6 \text{ lb/ft}^3 \times 16 \text{ oz/lb}$$

Where:
t = Tubular shaft wall thickness or one-half the thickness of the solid bar - ft.
$K_{C\text{-}1yr}$ can be estimated from the data in Graph 3, which estimates of corrosion loss per year based upon the resistivity and pH of the soil.

At the end of the calculated corrosion life determined by these equations, there will be no loss of structural integrity.

It is important to remember that corrosion life predictions provide an average life expectancy for the foundation support product when installed under the given conditions.

After the end of the corrosion life predicted here, corrosion to the structural element will begin to reduce the factor of safety built into the design of the product. If left unprotected, corrosion will eventually cause failure sometime in the future.

Caution: Predictions of performance life beyond 50 years may not be accurate.

The equations herein provide results that are average corrosion life predictions. The corrosion process is affected by variations in ground water adjacent to the pile or pier shaft. It is also affected by soil strata typically not homogenous, along with other factors such as dissolved minerals, imperfections in the galvanization, imperfections in the steel and/or damage to the products during shipping and installation, etc.

Quick-Solve™ Corrosion Life Estimating

Corrosion Life Tables: The tables that follow were developed from Equations 1 and 2 presented earlier. The values for the pH used in the tables were based upon the values at which corrosion potential generally changes.

Corrosion of the Torque Anchor™ Shafts: The first two columns of Table 5 estimate the corrosion life of an ungalvanized Torque Anchor™ shaft before the pile deterioration affects capacity. This table estimates the time for corrosion to destroy ten percent of the of the pile shaft thickness.

Find the shaft configuration under the heading of the graph. Next, locate the row that most closely matches the soil pH on the job site. Read downward from the shaft configuration and horizontally from the selected pH value until the column and row intersect. This is the *Quick*-Solve™ design estimate of corrosion life of the steel prior to any loss in capacity.

Life of Torque Anchor™ Galvanizing: The vast majority of steel foundation support products are specified with corrosion protection applied. At the far right column of Table 5 estimates the corrosion life of the galvanized coating. Simply read horizontally across from the pH that most closely matches the pH at the job site until the estimated life of the galvanization is found at the far right column. Add these two values together to arrive at the *Quick*-Solve™ product corrosion life.

TABLE 5. ECP TORQUE ANCHOR™ & SOIL NAIL LIFE EXPECTANCY ESTIMATES AT FULL LOAD*

Soil pH	Plain Steel Life Expectancy at Full Load						Hot Dip Galvanize 1.7 oz/ft² - 3.0 Mils (ASTM A123 Grade 75)
	1-1/2" Square Bar	1-3/4" Square Bar	2" Square Bar	2-7/8" Dia x 0.262" Tube	3-1/2" Dia x 0.300" Tube	4-1/2" Dia x 0.337" Tube	
Soil Resistivity – 500 ohm-cm							
4.5	25 yrs	30 yrs	34 yrs	9 yrs	11 yrs	12 yrs	Add 9 years to life shown at left
5	100+ yrs	100+ yrs	125+ yrs	48 yrs	57 yrs	63 yrs	
8	45 yrs	52 yrs	59 yrs	15 yrs	17 yrs	19 yrs	
10.5	25 yrs	30 yrs	34 yrs	9 yrs	11 yrs	12 yrs	
Soil Resistivity – 1,000 ohm-cm							
4.5	29 yrs	34 yrs	38 yrs	10 yrs	12 yrs	13 yrs	Add 11 years to life shown at left
5	100+ yrs	100+ yrs	150+ yrs	57 yrs	67 yrs	73 yrs	
8	49 yrs	57 yrs	65 yrs	17 yrs	20 yrs	22 yrs	
10.5	29 yrs	34 yrs	38 yrs	11 yrs	12 yrs	13 yrs	
Soil Resistivity – 2,000 ohm-cm							
4.5	34 yrs	39 yrs	47 yrs	12 yrs	14 yrs	15 yrs	Add 15 years to life shown at left
5	125+ yrs	125+ yrs	150+ yrs	85 yrs	100 yrs	100+ yrs	
8	47 yrs	67 yrs	77 yrs	19 yrs	22 yrs	24 yrs	
10.5	34 yrs	39 yrs	47 yrs	12 yrs	14 yrs	15 yrs	
Soil Resistivity – 5,000 ohm-cm							
4.5	45 yrs	52 yrs	65 yrs	16 yrs	18 yrs	20 yrs	Add 25 years to life shown at left
5	150+ yrs	150+ yrs	175+ yrs	100+ yrs	100+ yrs	100+ yrs	
8	82 yrs	95 yrs	100 yrs	29 yrs	33 yrs	37 yrs	
10.5	45 yrs	52 yrs	65yrs	16 yrs	18 yrs	20 yrs	

***SEE IMPORTANT NOTES AFTER TABLE 6.**

Torque Anchor™ products are hot dip galvanizing to ASTM A123, Grade 75. This puts a minimum of 1.7 oz/ft² of zinc, which is 3.0 mils (minimum) thickness.

Corrosion Life of ECP Steel Piers™: The ECP PPB-300-EPS and PPB-350-EPS pier pipe is fabricated from mill pre-galvanized steel sheet. This steel sheet carries a corrosion coating to ASTM A653/A G90. This is coating is equivalent to 0.32 (minimum) to 0.45 oz/ft^2 of zinc, or 0.76 mils thickness per side.

Estimating corrosion life for the most commonly used ECP Steel Piers™ can be found using Table 6. Because the PPB-300-EPS (2-7/8 inch diameter with 0.165 inch wall pier pipe) and the PPB-350-EPS (3-1/2 inch diameter with 0.165 pier pipe) are fabricated from factory applied G90 galvanized sheet, the values in Table 6 include the corrosion protection offered by the G90 steel sheet in the corrosion life estimates.

At the top of Table 6 locate the PPB-300-EPS or PPB-350-EPS pier pipe configuration being used in one of the first two columns. Next, determine the soil pH that most closely matches the pH at the job site. Read downward from the pier pipe Configuration and horizontally from the most relevant pH value until the column and row intersects. This is the *Quick*-Solve™ estimate of the corrosion life expectancy of the ECP Steel Pier™ pipe for the particular job site.

The PPB-400-EPS is an option of the same pier pipe with Hot Dip Galvanizing to ASTM A123 – Grade 75, which is 2.3 oz/ft^2 of zinc (3.9 mils minimum thickness). The PPB-400-EPSB pier pipe is supplied with black, mill finish. This pier pipe has NO corrosion protection.

The corrosion lives for the PPB-400-EPS and PPB-400-EPSB pier pipe is determined from Table 6 in the same manner as discussed earlier. Locate the 4 inch diameter pier pipe in one of the right two columns at the top heading of Graph 6. Read downward until reaching the intersection with the row that represents the closest value of the soil pH found on the job site.

At the end of the corrosion life estimated by *Quick*-Solve™ Tables 5 and 6, there will be no loss of structural integrity.

It is important to remember that corrosion life predictions provide an average life expectancy for the foundation support product when installed under the given conditions.

TABLE 6. ECP STEEL PIER™ PIPE LIFE EXPECTANCY ESTIMATES AT FULL LOAD*

Soil pH	**PPB-300-EPS** **2-7/8" Dia. x 0.165" Tube** High Speed-coating (0.76 oz.ft^2 – 0.32 Mils)	**PPB-350-EPS** **3-1/2" Dia. x 0.165" Tube** High Speed-coating (0.76 oz.ft^2 – 0.32 Mils)	**PPB-400-EPSB** **4" Dia. x 0.220" Tube** Mill Finish – No Corrosion Protection	**PPB-400-EPS** **4" Dia. x 0.220" Tube** **HDG -** (1.7 oz/ft^2 - 3.0 Mils ASTM A123 Grade 75)
Soil Resistivity – 500 ohm-cm				
4.5	7 yrs	7 yrs	7 yrs	16 yrs
5	33 yrs	33 yrs	40 yrs	49 yrs
8	13 yrs	13 yrs	13 yrs	21 yrs
10.5	7 yrs	7- yrs	7 yrs	16 yrs
Soil Resistivity – 1,000 ohm-cm				
4.5	8 yrs	8 yrs	8 yrs	19 yrs
5	38 yrs	38 yrs	48 yrs	59 yrs
8	13 yrs	13 yrs	14 yrs	25 yrs
10.5	8 yrs	8 yrs	8 yrs	19 yrs
Soil Resistivity – 2,000 ohm-cm				
4.5	10 yrs	10 yrs	10 yrs	22 yrs
5	57 yrs	57 yrs	72 yrs	68 yrs
8	15 yrs	15 yrs	17 yrs	27 yrs
10.5	10 yrs	10 yrs	10 yrs	22 yrs
Soil Resistivity – 5,000 ohm-cm				
4.5	15 yrs	15 yrs	13 yrs	35 yrs
5	77 yrs	77 yrs	96 yrs	100+ yrs
8	23 yrs	23 yrs	24 yrs	43 yrs
10.5	15 yrs	15 yrs	13 yrs	25 yrs

*** SEE IMPORTANT NOTES BELOW.**

*IMPORTANT NOTES FOR TABLE 5 AND TABLE 6:

1. The tables above are designed to suggest to the reader basic life expectancies assuming homogeneous soil and constant soil moisture. These tables are not intended to be used in place of a corrosion analysis and design. This table is not to be considered a substitute for field measurements of pH and resistivity; and a site specific corrosion analysis.

2. The life expectancies predicted in Tables 5 & 6 were calculated using recognized engineering principles and are for general information only. While believed to be accurate, this information should not be used or relied upon for any specific application without competent professional examination by a registered professional engineer and verified for accuracy or suitability to the application and site.

3. Reaching the end of the stated life does not indicate that the pile will fail; rather a slow reduction of the factor of safety will occur as the ultimate pile capacity decreases. Failure could occur in months or many years later depending upon the soil conditions and the installed product.

4. The tables allow for ten percent of the cross-section of the product to corrode away from the solid steel bars and ten per cent of wall thickness from the tubular sections. This extra material was required for torsional strength when installing the helical pile, or for field load testing the steel pier pipe. The Torque Anchor™ or ECP Steel Pier™ should retain the original design capacity with the full factor of safety intact even with this small amount of metal loss.

5. Variations in soil moisture content from season to season and year to year can adversely affect service life. Low field moisture content produces low corrosion rates even if corrosion elements are present. Stray currents from pipe lines, power lines, etc may also affect the life of the pile or pier. Corrosivity, resistivity and pH testing is always recommended in problem soils.

6. Hot Dip Galvanize process on brackets and other products and the 4 inch diameter ECP Steel Pier™ pipe products meet or exceed ASTM A123 – Grade 75. The 3 inch and 3-1/2 inch diameter by 0.165 inch wall ECP Steel Pier™ pipe uses a high speed galvanizing process of sheet steel. These piers offer corrosion protection to ASTM A653/A G90. The galvanizing is equivalent to 0.32 oz/ft^2 (minimum) to 0.45 oz/ft^2 of zinc, or 0.76 mils thickness per side.

7. Once the resistivity becomes higher than 1,000 ohm-cm, the galvanized solid square shaft helical pile product provides a minimum service life exceeding 44 years, when not subjected to soil pH values outside the range of Table 5 or to stray underground currents. Life expectancies exceeding 50 years can be expected for galvanized helical tubular products when the resistivity is above 5,000 ohm-cm.

8. As the predicted life expectancy increases beyond 40 years, the margin for error increases dramatically because the life expectancy estimates are calculated from empirical equations derived from field testing and projected beyond the length of time for the actual corrosion testing.

Results of Field Tested Galvanized Coating Life: The National Bureau of Standard conducted testing of corrosion of metals in soils. As early as 1924, research on corrosion of galvanized pipe was in progress. In 1937 a zinc corrosion study began using 1-1/2 inch diameter galvanized steel pipe with a 5.3 mil (0.0053") zinc coating. The results from the testing are shown in Table 7. The test also found that the galvanization prevented pitting of the steel even after the zinc coating was completely consumed. The bare steel that was formally under the galvanization corroded at a much slower rate than comparable bare steel under identical conditions.

* Test of buried 1-1/2" diameter steel pipe with 5.3 mils of zinc galvanizing -- National Bureau of Standards – 1937. Life expectancy is only for galvanize coating and not any loss of steel.

Table 7. Corrosion of Galvanized Steel Pipe* in Contact with Various Soils

Inorganic Soils	Zinc Loss /yr (mil per year)	Life of Zinc** (years)
Acid Soils – Oxidizing		
Cecil Clay Loam	0.08	66
Hagerstown Loam	0.08	66
Susquehanna Clay	0.11	48
Acid Soils – Reducing		
Sharkey Clay	0.15	35
Acadia Clay	0.91	6
Alkaline Soils – Oxidizing		
Chino Silt Loam	0.15	35
Mohave Fine Gravelly Loam	0.15	35
Alkaline Soils – Reducing		
Docas Clay	0.22	24
Merced Silt Loam	0.10	53
Organic Acid Soil - Reducing		
Carlisle Muck	0.44	12
Tidal Mush	0.38	14
Muck	1.42	4
Rifle Peat	2.64	2
Cinders	1.64	3

ECP EARTH CONTACT PRODUCTS
"Designed and Engineered to Perform"

Notes:

Earth Contact Products

Chapter 9

Corrosion Life Design Examples

ECP Torque Anchors™
ECP Steel Piers™

Table of Contents

EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

Design Example 1 – Corrosion Life of Tubular Torque Anchor™

Structural and Soil Details:

- Details are from Design Example 1, Chapter 5
- New Building – 2 story house with basement
- Estimated weight 3,700 lb/ft
- Working load on foundation piles – 30,000 lb
- Top of pile to be 12" above the soil surface.
- The soil data revealed a least five feet of very loose sand fill and very soft clay organic soil near the surface.
- Below approximately five feet, a layer of very stiff inorganic clay (CL), with SPT, "N" = 20 blows per foot (average) exists as stated in Design Example 1 in Chapter 5 and the water table remains at 14 feet - Soil Class = 5

Different corrosive soil data for this example:

♦ Standard Penetration Test values for this weak layer were: "N" = 1 to 3 blows per foot - Soil Class = 8

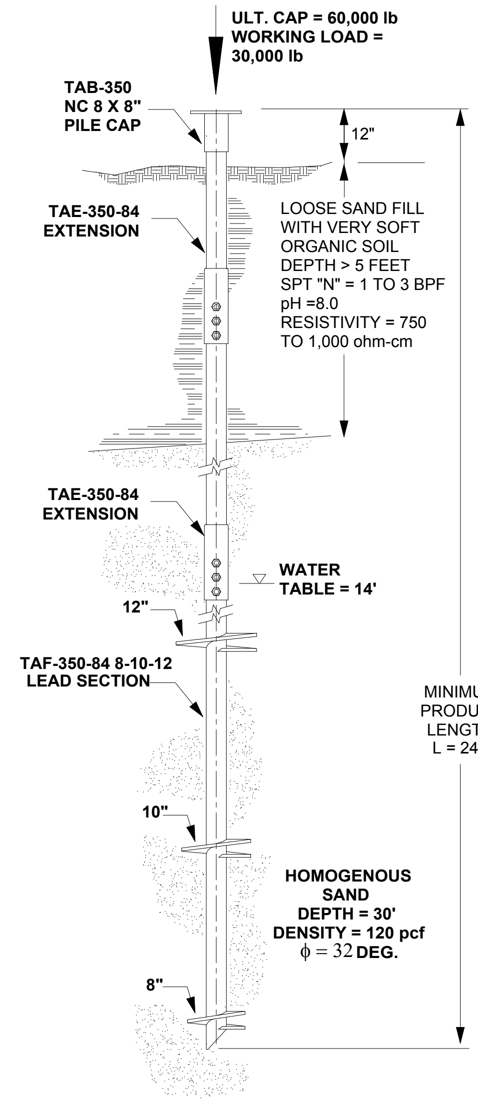
♦ Soil pH in the sand fill and soft organic soil was reported to be: pH = 8.0 and the resistivity measured from 750 to 1,000 ohm-cm to ten feet.

♦ The helical Torque Anchor™ required to support the load without bucking in the loose fill was determined to be TAF-350-84 08-10-12

ECP Corrosion Life Analysis: The equations provided in the previous chapter will be applied to estimate the average life expectancy of the hot dip galvanization and a time for a corrosion loss of 10% of wall thickness of the 3-1/2 inch diameter pile shaft.

> The results from this analysis provide an estimate of average life expectancy. When dealing with soil conditions on a job site, there is always a degree of variability in the performance life of steel piles. In general, the following can affect the life of the pile in the soil:
>
> - **Multiple strata nature of foundation soils**
> - **Variability within the soil stratum**
> - **Variability of the water content of soil both vertically and seasonally**
> - **Presence or absence of salt ions in the soil due to leaching, etc.**
> - **Non-uniformity of the galvanized coating thickness and areas of stress concentration**
> - **Imperfections in the steel**
> - **Presence of stray currents**

This analysis considers the performance life of the galvanized coat along with the time required



Sketch for Design Example 1

to corrode only 10% of wall thickness of the pile shaft after the galvanized coating is exhausted.

1. Corrosion Evaluation of the Galvanized Coating: A soil study of the jobsite revealed that the upper stratum of soil has Standard Penetration Test (SPT) - "N" = 1 to 3 blows per foot, the pH = 8.0 and the soil resistivity to a depth of ten feet ranges from 750 to 1,000 ohm-cm.

A ***Corrosivity Score*** for the soil on this site was determined to be 10. (See Tables 3 & 4 in Chapter 8) This suggests that the soil be considered to be ***Aggressively Corrosive***. This corrosion potential raises a concern about corrosion effects on the useful life of the helical pile at this site.

2. Estimated Life -- Galvanize Loss: Estimate the average life of galvanized coating at the location that has the lowest soil resistivity. Use Equation 1 introduced in Chapter 8 to estimate the average life of the galvanized coating.

Equation 1 - Corrosion Life Zinc:
$$\mathbf{CL_G = G / [0.25 - 0.12 \log_{10} (R/150)]}$$

Where:
CL_G = Weight loss (oz/ft^2)/year
$G = 1.7\ oz/ft^2$ (HDG – ASTM A123 Gr.75)
$R = 750$ ohm-cm (Lowest soil resistivity)

Determine CL_G using Equation 1:

$$\mathbf{CL_G = 1.7 / [0.25 - 0.12 \log_{10} (750/150)]}$$
$$= 1.7 / [0.25 – 0.12 \log_{10} 5.0]$$
$$= 1.7 / [0.25 – 0.12 (0.699)$$
$$= 1.7 / 0.166$$

CL_G = <u>10.2 years</u>

3. Corrosion Life Estimated – Steel Loss: The formula for estimating average time for 10% loss of wall thickness of steel tube is given in Equation 2 from Chapter 8:

Equation 2 - Corrosion Life Steel Shaft:
$$\mathbf{CL_P = W_{S\text{-}10\%} / K_C}$$

Where:
CL_P = Life expectancy of steel tube (years)
$W_{S\text{-}10\%}$ = 10% pile weight loss – (oz/ft^2)
K_C = Corrosion loss per year - oz/ft^2

- **$W_{S\text{-}10\%}$** is the amount of steel loss equal to 10% of the wall thickness of a 3-1/2 inch diameter with 0.300 inch wall thickness must first be determined.

Equation 3:
$$W_{S\text{-}10\%} = 10\%\ [t''/12] \times 489.6\ lb/ft^3 \times 16\ oz/lb$$

Where: t = Wall thickness of shaft - inches

The pile shaft used for this example is a TAF-350 tubular shaft, which is 3-1/2 inches diameter with 0.300 inch wall thickness. Using Equation 3, the value of $W_{S\text{-}10\%}$ is calculated:

$$W_{S\text{-}10\%} = 0.10 \times [0.300''/12] \times 489.6 \times 16$$
$$W_{S\text{-}10\%} = \underline{19.6\ oz/ft^2}$$

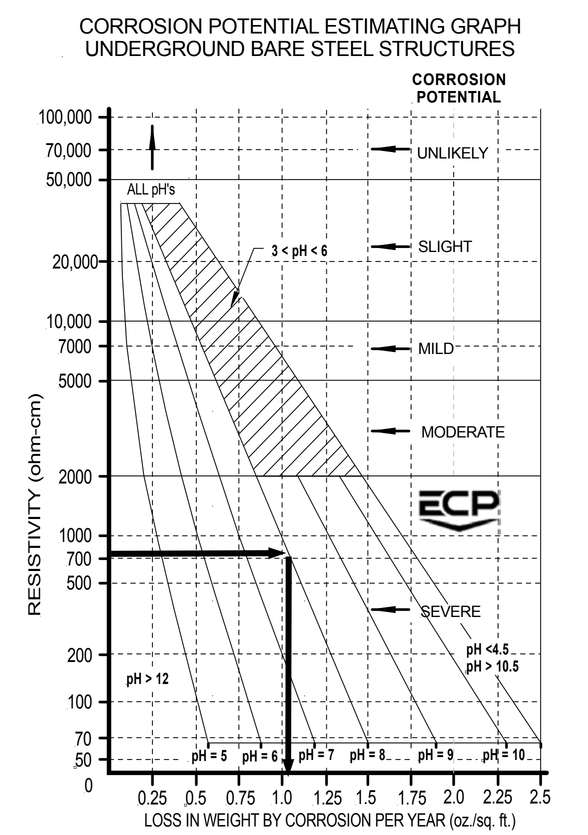
Next, the corrosion loss rate (K_C) must be determined using Graph 3 presented in Chapter 8. It is reproduced at right for reference. Knowing that the lowest resistivity relates to highest rate of corrosion, locate 750 ohm-cm on the left axis. Reading horizontally to the right find the curved line that represents pH = 8.0. Reading directly downward, the corrosion loss in weight of steel per year is estimated to be 1.04 oz/ft^2 per year.

Using Equation 2, the corrosion life for the steel tube is determined.

$$\mathbf{CL_P = W_{S\text{-}10\%} / K_C}$$

Where:
CL_P = Life expectancy of steel tube (years)
$W_{S\text{-}10\%}$ = 19.6 oz/ft^2 (Weight loss of steel pier)
K_C = 1.04 oz/ft^2 (Corrosion loss per year.)

CL_P = 19.6 / 1.04 = <u>18.8 years</u>



Graph 3.

4. Determine the corrosion life of the pile: The time for the galvanized coating to corrode and for ten percent corrosion loss of the steel is the average corrosion life expectancy of the steel pile shaft when installed at the job site.

Life = $CL_G + CL_P$ = 10.2 + 18.8 = <u>29 years</u>

Based upon the data and the assumptions, the analysis suggests that the Torque Anchor™ helical pile shafts specified for this project will support the design load, plus a full 2.0 factor of safety with no loss in capacity for an estimated <u>average corrosion life exceeding 29 years.</u>

Corrosion Life = <u>29+ years*</u>

Design Example 1A – Corrosion Life of Tubular Torque Anchor™ "Quick and Rough Method"

All of the structural and soil data is the same as stated in Design Example 1 above.

1. Corrosion Life Estimated – Steel Loss: The estimated average amount of time for ten percent of the wall thickness of a TAF-350 tube to corrode can be estimated from Table 5 presented in Chapter 8, and reproduced below.

Many times the exact field resistivity and pH will not be found on Table 5. The average life will have to be estimated based from between the pH values in the table.

The resistivity was reported between 750 and 1,000 ohm-cm and the pH is 8. To estimate the corrosion life of the pile, it is necessary to find the pile configuration at the top of the table.

In determining corrosion life, conservative decisions should always be used.

The specified TAE-350 Torque Anchor™ shaft can be found at the sixth column from the left. There are two sub-tables; resistivity of 500 ohm-cm and 1,000 ohm-cm. A value half way between 500 and 1,000 ohm-cm (750 ohm-cm) will be used here. The soil pH = 8 is located at the left column. The corrosion life estimate is **17 years** at 500 ohm-cm and pH = 8. The corrosion life at 1,000 ohm-cm and pH = 8 is **20 years**.

An average value can estimate corrosion life at 750 ohm-cm between 17 and 20 years. The average value for steel corrosion life is:

$\mathbf{CL_P}$ = [17 + 20] years / 2 = **18.5 years**

2. Estimated Life -- Galvanize Loss: The average corrosion life of hot dip galvanize to ASTM A123 Grade 75 can be found at the right column. It is necessary determine the corrosion life at 750 ohm-cm resistivity, or midway between 12 and 15 years:

CL_G = [9 yr (500 Ω-cm)+11 yr (1,000 Ω-cm]/2
$\mathbf{CL_G}$ **=** <u>**10.0 yrs**</u>

3. Determine the corrosion life of the pile. The estimated average corrosion life expectancy of the steel pier when installed at the job site after all of the galvanizing is depleted and ten percent of the steel has been lost is the sum of the corrosion values from Steps 1 and 2.

Life = $\mathbf{CL_P + CL_G}$ = 18.5 + 10.0 = 28.5 years

Corrosion Life = <u>**28.5 years***</u>

TABLE 5. Sample ECP Torque Anchor® & Soil Nail Life Expectancy Estimates at Full Load

Soil pH	Plain Steel Life Expectancy at Full Load						Hot Dip Galvanize 1.7 oz/ft² - 3.0 Mils (Minimum)
	1-1/2" Square Bar	1-3/4" Square Bar	2" Square Bar	2-7/8" Dia. x 0.262" Tube	3-1/2" Dia. x 0.300" Tube	4-1/2" Dia. x 0.337" Tube	
Soil Resistivity – 500 ohm-cm							
4.5	25 yrs	30 yrs	34 yrs	9 yrs	11 yrs	12 yrs	Add 9 years to life shown at left
5	100+ yrs	100+ yrs	125+ yrs	48 yrs	57 yrs	63 yrs	
8	45 yrs	52 yrs	59 yrs	15 yrs	17 yrs	19 yrs	
10.5	25 yrs	30 yrs	34 yrs	9 yrs	11 yrs	12 yrs	
Soil Resistivity – 1,000 ohm-cm							
4.5	29 yrs	34 yrs	38 yrs	10 yrs	12 yrs	13 yrs	Add 11 years to life shown at left
5	100+ yrs	100+ yrs	150+ yrs	57 yrs	67 yrs	73 yrs	
8	49 yrs	57 yrs	65 yrs	17 yrs	20 yrs	22 yrs	
10.5	29 yrs	34 yrs	38 yrs	11 yrs	12 yrs	13 yrs	

Review of Results of Example 1 & 1A

The result obtained by the *Quick*-Solve™ design analysis and the result that was calculated are very similar. Larger differences can occur when making estimates for values that fall between the data boxes with larger corrosion lives in the tables.

***One must be cautioned not to consider the result of either analysis as <u>an exact answer</u> because the formulas were derived from empirical data. Both corrosion lives determined in Example 1 & 1A are accurate within the range of error and were rounded down to be conservative. Please review the *"Important Notes"* in Chapter 8.**

Design Example 2 – Corrosion Life of ECP Steel Pier™ Pipe

Structural and Soil Details:

- This settled structure was presented as Design Examples 1 and 2 in Chapter 8, but now there is a concern about corrosion.
- When discussing this project with the engineer, he mentions that consolidation of a layer of weak soil caused the settlement. Upon further investigations of the soil data, it is learned that there is approximately six feet of uncompacted loose fill with Standard Penetration Test values, "N" = 1 to 3 blows per foot.
- Below six feet of fill soil there is firm clay with SPT values exceeding "N" = 5 blows per foot.
- Further soil testing suggested that corrosion might be an issue on this job. The soil resistivity at five feet below grade was 700 ohm-cm and at a depth of ten feet below grade the resistivity climbed to 1,500 ohm-cm. Soil testing reported averaged value for pH = 5.5 down to ten feet.
- The underpinning specified in Design Example 2 was ECP PPB-350-EPS Steel Pier Pipe at the settled area.

ECP Corrosion Life Analysis: The equations provided in the previous chapter will be applied to estimate the average life expectancy of the hot dip galvanization and loss of 10% of wall thickness of the 3-1/2 inch diameter by 0.165 inch wall corrosion protected tube.

The result from this analysis provides an estimate of average life expectancy. When dealing with soil conditions on a job site, there is always a degree of variability in the performance life of steel piles.

Please refer to the list in the shaded box presented in Design Example 1 above.

The corrosion life analysis will consist of two parts; first is the corrosion live analysis of the zinc coating on the pier pipe, and second is the corrosion loss of 10% of the wall thickness of the pier pipe.

1. Soil Report and Corrosivity: A soil study of the five feet of fill material suggested that this soil may be corrosive. Reviewing Tables 3 and 4 in Chapter 8, a ***"Corrosivity Score"*** of 8/9 was found. This fill soil can be considered ***"Moderately Corrosive"*** to ***"Aggressively Corrosive"***. The Standard Penetration Test soil analysis of the stratum of fill reported "N" = 1 to 3 blows per foot, the pH = 5.5 and the soil resistivity was 700 ohm-cm. These values from the soil study confirm the engineer's concern about corrosion effects of the earth on steel.

2. Estimated Life -- Galvanize Loss: The first calculation estimates the average life for the galvanized coating on the pier pipe in soil with a resistivity of 700 ohm-cm. Use Equation 1 introduced in Chapter 8 to estimate the average life of the mill pre-galvanized sheet corrosion protection coating.

Equation 1 - Corrosion Life Zinc:

$$\mathbf{CL_G = G / [0.25 - 0.12 \log_{10} (R/150)]}$$

Where: CL_G = Weight loss (oz/ft^2)
G = 0.32 oz/ft^2 (High Speed Mill Galvanize)
R = 700 ohm-cm (Soil resistivity)

Determine CL_G using Equation 1:

$$\mathbf{CL_G = 0.32 / [0.25 - 0.12 \log_{10} (700/150)]}$$
$$= 0.32 / [0.25 - 0.12 \log_{10} 4.67]$$
$$= 0.32 / [0.25 - 0.080] =$$
$$= 0.32 / 0.170 = 1.88 \text{ years}$$

$\mathbf{CL_G =}$ **<u>1.9 years</u>**

3. Estimated Life -- Steel Loss: The formula for estimating average time for 10% loss in steel wall thickness is given in Equation 2 from Chapter 8:

Equation 2 - Corrosion Life Steel Shaft

$\mathbf{CL_P = W_{S\text{-}10\%} / K_C}$ Where:
CL_P = Life expectancy of steel tube (years)
$W_{S\text{-}10\%}$ = 10% steel pier weight loss (oz/ft^2)
K_C = Corrosion loss per year- oz/ft^2

- $\mathbf{W_{S\text{-}10\%}}$ is the amount of steel loss equal to 10% of the wall thickness of the 3-1/2 inch diameter by 0.165 inch wall pier pipe. $W_{S\text{-}10\%}$ is determined using Equation 3:
  $W_{S\text{-}10\%}$ = 10% [t"/12] x 489.6 lb/ft^3 x 16 oz/lb
  W_S = 0.10 x [0.165/12] x 489.6 x 16
  $\mathbf{W_S}$ **=** <u>10.8 oz/ft^2</u>
- $\mathbf{K_C}$ is the corrosion loss rate that is determined by using Graph 3 - Chapter 8, also shown below.

The highest rate of corrosion within the fill soil will occur at the lowest resistivity - 700 ohm-cm. Read horizontally from the left side of Graph 3 (shown below) to the point that represents a pH = 5.5. Then read directly down to determine the loss in weight of steel per year. A corrosion loss of 0.45 oz/ft^2 per year is determined.

$\mathbf{K_C}$ = <u>0.45 oz/ft^2 per year</u>

Using Equation 2, the corrosion life for the steel pier pipe can now be determined:

$\mathbf{CL_P = W_{S\text{-}10\%} / K_C}$ Where:

CL_P = Life expectancy of steel tube (years)
W_S = 10.7 oz/ft^2 (Weight loss of steel pier)
K_C = 0.45 oz/ft^2 (Corrosion loss per year.)

$\mathbf{CL_P}$ = 10.8 / 0.45 = <u>24 years</u>

4. Determine the corrosion life of the pier: The corrosion life consists of the life of the galvanization and the loss of ten percent of the wall thickness of the steel pipe. When installed at this job site, the average corrosion life expectancy of the ECP PPB-350-EPS pier pipe:

Life = $CL_G + CL_P$ = 1.9 + 24 = <u>25.9 years</u>

Based upon the data and our assumptions, the result of this analysis suggests that the ECP PPB-350-EPS Steel Pier™ specified for this project will support the design load plus a factor of safety of 2.0 <u>with no loss in capacity</u> for an estimated average corrosion life of 26 years.

Use Corrosion Life = <u>25 years</u>

BONUS: Suggest an Alternate Product to the customer for longer corrosion life

It is always to the advantage of the installer to offer a different product if he thinks it will benefit the client or engineer. The alternate product may or may not be accepted, but it does give the engineer another option to select another product that offers a longer corrosion life.

The PPB-400-EPS Pier is a hot dip galvanized pier pipe that can be used with the same foundation bracket. The thicker HDG zinc coating along with the larger diameter and thicker wall pier pipe can offer a significant increase in corrosion life with only a small added cost to the project as the labor will be identical.

Estimated Life -- Galvanize Loss: PPB-400-EPS pipe:

Equation 1 - Corrosion Life Zinc:

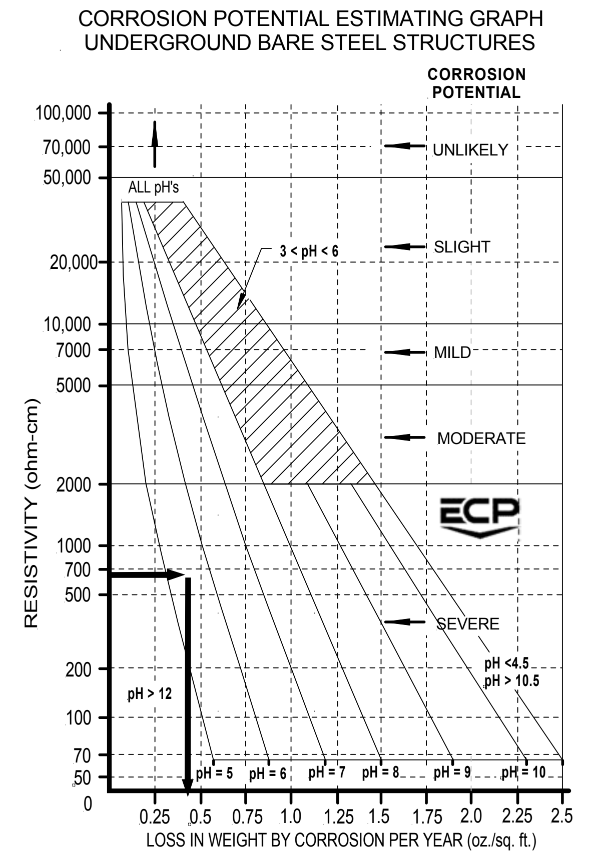
$$\mathbf{CL_G = G / [0.25 - 0.12 \log_{10} (R/150)]}$$

Where:
G = 1.7 oz/ft^2 (HDG – ASTM A123 Gr. 75)

Determine $\mathbf{CL_G}$ using Equation 1:

$$\mathbf{CL_G} = 1.7 / [0.25 - 0.12 \log_{10} (700/150)]$$
$$= 1.7 / [0.25 - 0.12 (0.669)] = 2.3 / 0.170$$

$\mathbf{CL_G}$ = <u>10 years</u>



Graph 3.

Estimated Life -- Steel Loss: PPB-400-EPS pipe:

The amount of steel loss equal to 10% of the 0.220 inch wall thickness of the 4 inch diameter pier pipe is determined as follows using Equation 2 - Corrosion Life Steel Shaft:

$\mathbf{CL_P = W_{S\text{-}10\%} / K_C}$.

$\mathbf{W_{S\text{-}10\%}}$ = 0.10 x [0.220/12] x 489.6 x 16
$\mathbf{W_{S\text{-}10\%}}$ = <u>14.4 oz/ft^2</u>

Equation 2 - Corrosion Life of Steel Shaft:

$$\mathbf{CL_P = W_{S\text{-}10\%} / K_C}$$

Where: $W_{S\text{-}10\%}$ = 14.4 oz/ft^2 (PPB-400-EPS 10% loss)
K_C = 0.45 oz/ft^2 (Corrosion loss per year.)

$\mathbf{CL_P}$ = 14.4 / 0.45 = 32 years

Determine the corrosion life of the PPB-400-EPS pier pipe. The time to exhaust the galvanization and for ten percent loss of the steel from the pipe wall is the average corrosion life expectancy of this alternate steel pier system when installed at this job site.

Life = $CL_G + CL_P$ = 10 + 32 = <u>42 yrs</u>

Use Corrosion Life = <u>40+ years</u>**

(See important notes bottom page 7.)

Design Example 2A – Corrosion Life of ECP Steel Pier™ Pipe "Quick and Rough Method"

All of the structural and soil data was given in Design Example 2 above.

Estimated Corrosion Life of the PPB-350-EPS Pipe: The estimated average corrosion life for the pier pipe installed in fill soil with resistivity of 700 ohm-cm and pH = 5.5 can be estimated from Table 6 in two steps.

1. Estimated Life - PPB-350-EPS Pier Pipe at pH = 5 and 700 Ω-cm: Notice in Table 6 the corrosion life at 500 ohm-cm is **33 years** and the corrosion life increases to **38 years** when the resistivity rises to 1,000 ohm-cm. The 700 ohm-cm resistivity at this site is approximately 2/5 of the difference between the two values given in Table 6, 1,000 Ω-cm = 38 years and 500 Ω-cm = 33 years.

Estimate the corrosion at 700 Ω-cm as 2/5 times the difference of 5 years.

$\mathbf{CL_{pH=5.0}}$ = 33 years + [2/5 x (38 - 33 years)]
$\mathbf{CL_{pH=5.0}}$ = 33 years + 2 years = <u>35 years</u>

2. Estimated Life - PPB-350 Pier at pH = 5.5 and 700 Ω-cm: An adjustment must also be made to adjust to the actual pH = 5.5. (We found pH = 5 shown in the tables) There are six increments of 0.5 pH between pH = 5 and pH = 8. The **"<u>ball park</u>"** estimate for reduction in corrosion life due to the higher pH (5.5) at the site can be roughly estimated as follows:

$\mathbf{CL_{pH=5.0\ to\ 5.5}}$ = [33 yr (pH=5) -13 yr (pH=8)] / 6

$\mathbf{CL_{pH=5.0\ to\ 5.5}}$ = **<u>3.3 years</u>** (Life reduction)

By combining Step 1 and 2, the *Quick*-Solve™ corrosion life is determined:

$\mathbf{CL_P}$ = $\mathbf{CL_{pH=5}}$ - $\mathbf{CL_{pH=5.0\ to\ 5.5}}$

$\mathbf{CL_P}$ = 35 years – 3.3 years = <u>31.7 years</u>

Life PPB-350-EPS = <u>30 years*</u>

(See important notes bottom page 7.)

BONUS – ALTERNATE PRODUCT:

1A. Corrosion Life Estimate - PPB-400-EPS Pier Pipe at pH = 5 and 700 Ω-cm: Using the column for the PPB-400-EPS in Table 6, the *Quick*-Solve™ design estimated corrosion life for the Model 400-EPS pier pipe at pH = 5 and 500 ohm-cm is **72 years**. The difference in corrosion life between resistivity 500 and 1,000 ohm-cm is found to be 12 **years**. Considering that 700 ohm-cm is 2/5 of the distance between 500 and 1,000 ohm-cm,

$\mathbf{CL_{pH=5.5}}$ = 72 yr + (2/5 x 12) yrs = <u>76.8 years**</u>

2A. Estimated Life - PPB-400-EPS Pier Pipe at pH = 5.5 and 700 Ω-cm: An adjustment must also be made to account for the actual pH = 5.5 instead of result at pH = 5 above. There six increments of 0.5 pH between pH = 5 and pH = 8. The reduction in corrosion life due to a higher pH of 5.5 is determined below:

$CL_{pH=5.0\ to\ 5.5}$ = [72 yr (pH=5) - 44yr (pH=8)] / 6

$\mathbf{CL_{pH=5.0\ to\ 5.5}}$ = <u>4.7 years</u> (Life decrease)

By combining Steps 1A and 2A, the rough estimated corrosion life is determined:

$\mathbf{CL_P}$ = $\mathbf{CL_{pH=5.0}}$ - $\mathbf{CL_{pH=5.0\ to\ 5.5}}$
$\mathbf{CL_P}$ = 76.8 years – 4.7 years = <u>71.1 years</u>

Use Life PPB-400 EPS = 4<u>0+ years</u>**

(See important notes bottom page 7.)

TABLE 6. Sample ECP Steel Pier® Pipe Life Expectancy Estimates At Full Load

Soil pH	PPB-300-EPS 2-7/8" Dia. Tube HS-coating (0.32 Mils)	PPB-350-EPS 3-1/2" Dia. Tube HS-coating (0.32 Mils)	PPB-400EPSB 4" Dia. Tube (Plain Steel)	PPB- 400-EPS 4" Dia. Tube (HDG – 2.3 oz/ft^2)
Soil Resistivity – 500 ohm-cm				
4.5	7 yrs	7 yrs	12 yrs	21 yrs
5	33 yrs	33 yrs	63 yrs	72 yrs
8	13 yrs	13 yrs	19 yrs	28 yrs
10.5	7 yrs	7- yrs	12 yrs	21 yrs
Soil Resistivity – 1,000 ohm-cm				
4.5	8 yrs	8 yrs	13 yrs	24 yrs
5	38 yrs	38 yrs	73 yrs	84 yrs
8	13 yrs	13 yrs	22 yrs	33 yrs
10.5	8 yrs	8 yrs	13 yrs	24 yrs

2 2A 1 1A

Review of Results of Example 2 & 2A

Discussion of the Results of Design Examples 2 & 2A:

The results obtained by the *Quick*-Solve™ design analysis on Example 2A under estimates the corrosion life expectancy slightly compared to the calculated results for corrosion life. The inaccuracy is due to attempting to "read between the boxes" in the corrosion tables to determine a life expectancy when the soil at the project has a soil resistivity "between the lines" of the boxes. The values, 700 ohm-cm and pH = 5.5, do not appear in the tables. The inaccuracy occurred in or prediction because the change in life expectancy between boxes is not linear. **This clearly demonstrates a flaw in the *Quick*-Solve™ design method of corrosion life estimating when it is necessary to extract data fr**om **"between the boxes".** In this case both results exceeded 40 years and it is "Safe Use" design to round down.

Design Example 2A was designed as a complicated problem. The goal was to be able to demonstrate a simple method of linear interpolation to extract data from "between the boxes" on the tables. The linear interpolation method demonstrated in Design Example 2A caused some discrepancies between the two methods of corrosion life expectancies. Point of interest is that one must SUBTRACT life when interpolating between boxes because the corrosion life decreases between pH = 5 and pH = 8. This is something to keep in mind when using *Quick*-Solve™ design tables. We are dealing with complicated relationships when using the tables. There are three parameters involved that one can appreciate by looking at Graph 3, shown above and in Chapter 8. This table was used to determine the *"Weight of Steel Loss by Corrosion"* for the steel support products installed in corrosive soils. Looking at Graph 3, notice that the resistivity data are logarithmically plotted on the left axis and the curved pH boundary lines in the body of the graph are not linear. The interpolations used in Design Example 2A assumed that the changes in life expectancy "between boxes" in Tables 5 and 6 are linear. **The values are not linear** and making the assumption of linear relationships created variances in the life expectancies estimated by the *Quick*-Solve™ design method. The advantage in using *Quick*-Solve™ design tables is that determining a corrosion life estimate is faster.

The reader is cautioned to be very careful and conservative when reporting corrosion life expectancies that have been interpolated "between the boxes" when one uses the *Quick*-Solve™ design method demonstrated here. Always round down the results.

Review of Results of Bonus – Alternate Product:

The bonus solution was provided to illustrate that substituting a larger diameter pier pipe with a thicker wall and with a thicker galvanized coating will result in a substantial increase in corrosion life of the pier pipe with very little increase in cost. In the calculated result for Design Example 2, the corrosion life increased by 75% simply by changing from the PPB-350-EPS (3-1/2" diameter) to the PPB-400-EPS (4" diameter - HDG) pier system. This recommendation method to extend corrosion life by substituting a larger pipe and using the same foundation bracket is simple. This solution is less expensive than specifying and installing cathodic protection at each pier placement to increase the corrosion life. Offering a product substitution can save the customer money. It is also a valuable tool to use when the engineer is not satisfied with the result obtained from the corrosion life estimate for the system.

***One must be cautioned not to consider the result of either analysis as an exact answer because the formulas were derived from empirical data. Both corrosion lives determined in the examples are accurate within the range of error, and were rounded down to be conservative. Please review the *"Important Notes"* in Chapter 8.**

**** Important Note: Keep in mind that the corrosion life results are only the average corrosion life estimate. ECP recommends rounding down the results of the analysis, especially when the predicted corrosion life results with an estimate EXCEEDING 40 YEARS, and use extra caution when reporting results that were obtained from interpolation using the *Quick*-Solve™ design system. The best suggestion is always round down the results for "Safe Use" design.**

EARTH CONTACT PRODUCTS
"Designed and Engineered to Perform"

MANUFACTURER'S WARRANTY

ECP Torque Anchors™
ECP Steel Piers™

EARTH CONTACT PRODUCTS

"Designed and Engineered to Perform"

MANUFACTURER'S WARRANTY

Earth Contact Products strives to provide quality foundation support products at competitive prices. We are proud that our products are providing long term foundation support to structures across the nation. We are so confident in our products that we offer a manufacturer's limited 25 year warranty against defects in materials and workmanship.

ECP MANUFACTURER'S WARRANTY

"Earth Contact Products, L.L.C. offers a 25 year warranty from the date of installation against any defects in manufacturing and workmanship on ECP Steel Piers™ and ECP Torque Anchors™ when installed by an authorized ECP installer the product is exposed to normal soil conditions*. Earth Contact Products, L.L.C. will furnish new product replacement, if any ECP Steel Pier™ or ECP Torque Anchor™ should fail to function due to defects in its quality of manufacturing material or workmanship. All replacement materials will be furnished F.O.B. from the point of manufacture. This is a product warranty provided by the manufacturer and does not include installation or service of the product. Installation and service shall be furnished by the selling contractor as a service warranty on his installation workmanship. This warranty covers only the quality of the manufactured product."

Research shows that our products will meet or exceed this life expectancy in the vast majority of applications and soil environments. There are situations where our products are sometimes exposed to extremely corrosive environments.

We define what we consider "normal" soil conditions as follows:

****Normal Soil Conditions consist of soil having a resistivity greater than 2,000 ohm-cm and between pH 5 and pH 8. Excessive corrosion due to installation into aggressive soil or installed in a corrosive environment is NOT considered a manufacturing defect.***

If you suspect that the environment on a site is corrosive to steel underpinning products, or if you require a service life exceeding 25 years, we strongly recommend that you request a site specific soil resistivity test at intervals to 20 feet below grade and soil pH values from Registered Geotechnical Engineer or soil testing laboratory.

Upon request, ECP offers complementary corrosion life analysis to determine the estimated service life for ECP products specified for a specific site when the request includes the required soil corrosivity data indicated above.

EARTH CONTACT PRODUCTS

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