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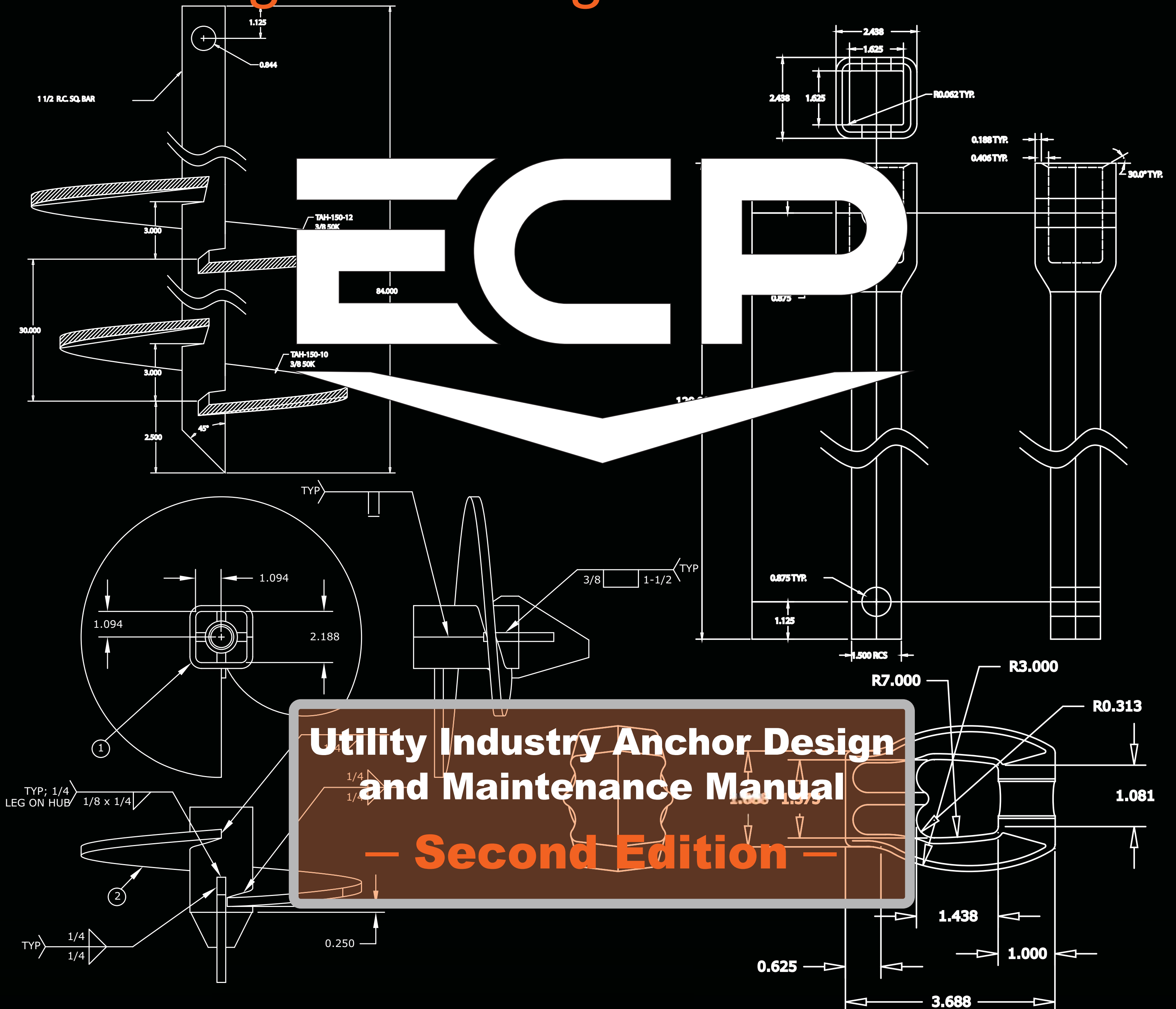

Utility Industry Anchor Design and Maintenance Manual

— Second Edition —

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Utility Industry Anchor Design and Maintenance Manual

By: Donald J. Clayton, PE

"DESIGNED AND ENGINEERED TO PERFORM"

***ECP* UTILITY**

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Preface

Earth Contract Products designs and manufactures quality foundation anchors and support products at competitive prices. The purpose of this manual is to assist the reader to prepare preliminary designs for ECP product selections that will most economically fit a given application. The manual also provides installation guidance and product selection. In this manual we have attempted to take the highly technical engineering theories and distill them into a very user friendly format. We have reduced many complicated equations into simpler terms that relate to the most typical applications where our products have been used. In addition, we have included many graphs and tables that can help the reader to obtain solutions with a minimum of mathematical effort. The reader will find clear and simple explanations, data tables, and many relevant examples in this manual. By taking some knowledge of basic theory to arrive at a relatively accurate product design by following step by step instructions, tables and graphs when using this manual. This manual is in no way intended to replace professional engineering input and judgment; in addition, we require incorporating a factor of safety suitable to the project for each and every preliminary design. We highly recommend that you seek professional engineering input on complicated applications. We also consider it good practice to perform a field load test on any heavily loaded anchors or for placements in critical applications.

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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.

Chapter 1

Introduction to ECP Helical Torque Anchors™ for Electric Utility Applications

- **PITA Helical Torque Anchors™**
- **HD Extreme PITA Torque Anchors™**
- **Solid Square Shaft Torque Anchors™**
- **Tubular Shaft Torque Anchors™**

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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 contact us at 913 393-0007, Fax at 913 393-0008.

Introduction

Screw piles have been in use for more than 162 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 140 years later. The original screw piles were installed at 10 feet per hour using eight 20 foot long torque bars with the force of 32 to 40 men.

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

Thomas Point Shoal Lighthouse

The helical screw piles that support the structure consist of ten inch diameter wrought iron shafts with cast iron helical screw flanges at the end of the shafts. At Thomas Point, the screw piles were advanced into to sandy bottom of Chesapeake Bay a distance of 11-1/2 feet. The 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. They mainly supported 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 soon became the favored product for resisting tensile forces. Soon electric utility companies began to use screw piles for tie down anchors on transmission towers and for guy wires on utility poles. After implementing helical gear motors in the 1960's, the electric utility companies became a leading consumer of helical anchors due to the easy and fast installation of helical screw piles. Initially the helical screw piles were used as guy wire anchors for utility poles and subsequently as tie down anchors for transmission towers. The combination of the gear motor and the helical anchor provided excellent foundation support for utility infrastructures. Such applications are particularly beneficial in times of major storm damage where a rapid foundation support system is necessary to restore power to customers.

Helical screw piles are ideal for applications where there is a need to resist both tensile and axial compressive forces. Some examples of structures having such combination forces are metal building foundations, canopy supports and monopole telecommunication tower foundations. Current uses for helical screw pile foundations include foundations for commercial and residential structures, lighting standards, retaining walls tieback anchors, guy wire anchors, failed foundation restorations, pipeline and pumping equipment supports, elevated walkways, bridge abutments, and numerous other 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.

Our 100,000 square foot state of the art manufacturing facility produces all components and steel assemblies. Earth Contact Products uses only certified welders and robotics for quality fabrication. The only processes not done in our facility are galvanization and hot forge upsetting of couplings.

ECP Torque Anchors™ are part of the complete line of anchoring and underpinning products manufactured for the Electric Utility and Civil Construction industries in our modern manufacturing facility in Olathe, Kansas. Custom products can be designed and configured to your engineered specific applications.

Torque Anchor™ Components

The ECP Torque Anchor™ consists of a shaft fabricated from either solid square steel bar or tubular steel shaft. Welded to the shaft are one or more helix shaped circular plates. The helical plates can vary in diameter from 6 inches to 16 inches and have a thickness of 3/8 or 1/2 inch depending upon the soil and the load to be supported. Typically the plates are attached to the shaft with increasing diameters beginning at the bottom of the shaft, and are spaced at a distance of three times the diameter of the helical plate directly below. The standard thickness for all helical plates is 3/8 inch, except for the 16 inch diameter helical plate which is manufactured only in 1/2 inch thickness. In high load applications or in obstruction laden soils, a helical plate thickness of 1/2 inch may be specified. The pitch of all helical plates is three inches, which means that the anchor shaft advances into the soil a distance of three inches during one revolution.

The available lead lengths for shafts for most products are 10 inches, 3 feet, 5 feet, 7 feet and 10 feet, however, other lengths may be specially fabricated for 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 another extension allowing the Torque Anchor™ assembly to reach any depth requirement. Extensions may also have helical plates installed on the shaft when the length of the lead shaft is not sufficiently long to allow for a proper interval between all of the specified helical plates. The number of the helical plates per Torque Anchor™ is limited only by the capacity of the shaft to transmit the torque required to advance the Torque Anchor™ into the soil.

Torque Anchors™ may terminate with a cable eye for guy applications, or in other applications such as tieback anchors, which terminate at a transition. A transition is a coupling that makes the connection from the top of the anchor shaft to a continuously threaded rod. Transitions are usually specified for connecting to a wall structure or to stabilize and support equipment. Various beams, plates, grillages, etc; can be attached to the threaded bar that is supplied with a transition. This can provide support for structural restoration, for structural stabilization, and/or for resistance to overturning forces.

For other applications such as foundation restorations or equipment pad stabilization, vault, or foundation brackets are available that connect between the Torque Anchor™ and the foundation beam, footing or slab. The purpose of the foundation bracket is to transfer the load from an existing foundation element to the Torque Anchor™, which then provides supplemental support and recovery of lost elevation.

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 Usually 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**
- **Warranted Against Defects in Materials and Workmanship**

Table 1.	**ECP Torque Anchor™ Product Designations**	
Product	**Prefix**	**Product Description**
Helical PITA Lead Sections	TAPL	1-3/8" Power Installed Torque Anchor (PITA)
	TAP	1-1/2 Power Installed Torque Anchor (PITA)
HD Extreme PITA Lead Sections	TAX	2 1/4" Square Hub Extreme Anchor
	HTAX	2-1/2" Square Drive Lead Section
PITA Rods	TAR	Power Installed Rod for PITA Type Anchor
PITA Rod & Coupling	TARC	Power Installed Extension Rod & Coupler
PITA Coupling	TAC	Power Installed Rod Coupling
PITA Terminations	TARN	Power Installed Rod with Eye Nut
Torque Anchor™ Lead	TAF	Lead Section - Solid Square or Tubular Shaft Full Length with 3/8 inch thick helical plates
	HTAF	Lead Section - Solid Square or Tubular Shaft Full Length with 1/2 inch thick helical plates
Torque Anchor™ Extension	TAE	Extension Solid Square or Tubular Shaft Full Length That May Have Additional Helical Plates
Square Bar Adapters	TAA	Termination from Square Shaft to Connection Eye(s)

Table 2.	**Capacities of ECP Helical Torque Anchors™**				
Product Designation	**Useable Torsional Strength**	**Installation Torque Factor (k)**	**Ultimate-Limit Tension Strength Based Rod Strength**		
ITA Leads			**5/8" Dia**	**3/4" Dia**	**1" Dia**
1-3/8" PITA	6,000 ft-lb	9 - 11	16,000 lb.	23,000	36,000
1-1/2" PITA	7,000 ft-lb	9 - 11	16,000 lb.	23,000	36,000
2-1/4" HD Extreme PITA	10,000 ft-lb	9 - 11	16,000 lb.	23,000	36,000
2-1/2" HD Extreme PITA	15,000 ft-lb	9 - 11	16,000 lb.	23,000	36,000
Square Shaft Torque Anchor™ Leads	**Useable Torsional Strength**	**Installation Torque Factor (k)**	**Ultimate-Limit Tension Strength**	**Practical Load Limit**	
1-1/2" Sq. Bar - 1045	5,500 ft-lb	9 - 11	50,000 lb.	Load limited To the rated capacity of the attachments	
1-1/2" Sq. Bar - 1530	7,500 ft-lb	9 - 11	70,000 lb.		
1-3/4" Square Bar	10,000 ft-lb	9 - 11	100,000 lb.		

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

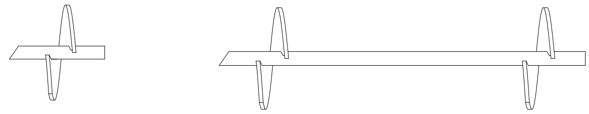
IMPORTANT NOTES:

The capacities listed for Tension and Torsion in Table 2 are mechanical ratings. One must understand that the actual installed load capacities for the product are dependent upon the actual soil conditions on a specific job site. The shaft "Useable 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 to the shaft. In homogeneous soils it might be possible to achieve up to 95% or more of the "Useable Torsional Strength" shown in Table 2. In obstruction-laden soils, torsion spikes experienced by the shaft may cause impact fractures of the couplings or other components. Where impact loading is expected, reduce shaft torsion by 30% or more from the value presented in "Useable Torsional Strength". The amount of useable torque reduction to reduce chance of fracture or damage depends upon site soil conditions.

Attachment of guy wires shall be within five degrees of the anchor shaft installation angle to achieve maximum capacity.

Another advantage of selecting a torsional rating below the values shown in Table 2 is that one may be able to drive the helical anchor slightly deeper after the torsional requirement has been met, thus eliminating the need to cut the anchor shaft in the field.

Power Installed Torque Anchors™ (PITA)



PITA Torque Anchor™ Lead Configurations (6,000 ft-lb*)

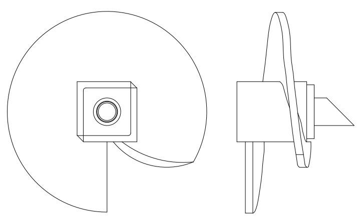
Product Designation	Plate Diameter - inches		Rod Dia. inches	Plate Area sq. ft.	Length
	First	Second			
TAPL-625-10 08	8	--	5/8	0.29	10"
TAPL-625-10 10	10	--	5/8	0.46	10"
TAPL-625-10 12	12	--	5/8	0.66	10"
TAPL-625-10 14	14	--	5/8	0.90	10"
TAPL-100-10 08	8	--	1	0.29	10"
TAPL-100-10 10	10	--	1	0.46	10"
TAPL-100-10 12	12	--	1	0.66	10"
TAPL-100-10 14	14	--	1	0.90	10"
TAPL-100-26 08-08	8	8	1	0.58	26"
TAPL-100-36 10-10	10	10	1	0.92	36"

1-1/2" Square Shaft Standard PITA Torque Anchor™ Lead Configurations (7,000 ft-lb*)

Product Designation	Plate Diameter - inches		Rod Dia. inches	Plate Area sq. ft.	Length
	First	Second			
TAP-625-10 08	8	--	5/8	0.28	10"
TAP-625-10 10	10	--	5/8	0.45	10"
TAP-625-10 12	12	--	5/8	0.65	10"
TAP-625-10 14	14	--	5/8	0.89	10"
TAP-100-10 08	8	--	1	0.28	10"
TAP-100-10 10	10	---	1	0.45	10"
TAP-100-10 12	12	--	1	0.65	10"
TAP-100-10 14	14	--	1	0.89	10"
TAP-150-26 08-08	8	8	1	0.57	26"
TAP-150-36 10-10	10	10	1	0.90	36"

Extreme Power Installed Torque Anchors™ (PITA)

Standard HD Extreme Torque Anchor™ Lead Configurations

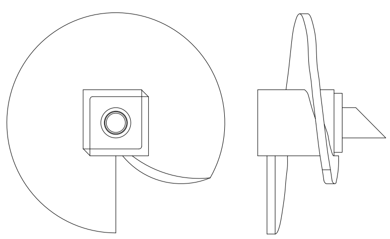


(2-1/4" Coupling – 10,000 ft-lb*)

Product Designation	Plate Dia. inches	Rod Dia. inches	Plate Area sq. ft.
TAX-225-625 08	8	5/8	0.28
TAX-225-625 10	10	5/8	0.48
TAX-225-625 12	12	5/8	0.72
TAX-225-100 08	8	1	0.28
TAX-225-100 10	10	1	0.48
TAX-225-100 12	12	1	0.72

HD Extreme Power Installed Torque Anchors™ (PITA)

Standard HD Extreme Torque Anchor™ Lead Configurations

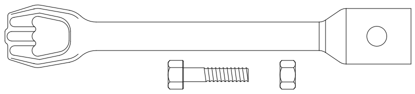


(2-1/2" Coupling – 15,000 ft-lb*)

Product Designation	Plate Dia. inches	Rod Dia. inches	Plate Area sq. ft.
HTAX-250-625 08	8	5/8	0.24
HTAX-250-625 10	10	5/8	0.41
HTAX-250-625 12	12	5/8	0.61
HTAX-250-100 08	8	1	0.24
HTAX-250-100 10	10	1	0.41
HTAX-250-100 12	12	1	0.61

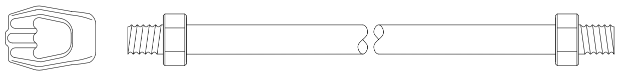
Cable Attachment Eyes

Round Corner Square Bar Adapters



Product Designation		Eye Size	Length
1-1/2" Shaft	1-3/4" Shaft		
TAA-150-002	N/A	Double	18"
TAA-150-003	TAA-175-003	Triple	18"

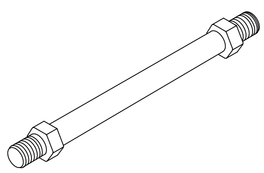
PITA Rod & Eye Assemblies



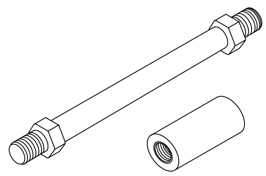
Product Designation			Eye Size	Rod Length
5/8" Rod	3/4" Rod (1" dia. threads)	1" Rod		
TARN-625-421	TARN-750-421	TARN-100-421	Single	3'-6"
TARN-625-422	TARN-750-422	TARN-100-422	Double	3'-6"
TARN-625-423	TARN-750-423	TARN-100-423	Triple	3'-6"
TARN-625-841	TARN-750-841	TARN-100-841	Single	7'-0"
TARN-625-842	TARN-750-842	TARN-100-842	Double	7'-0"
TARN-625-843	TARN-750-843	TARN-100-843	Triple	7'-0"

PITA Accessories

PITA Rods

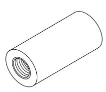


PITA Rod and Coupling Assemblies



PITA Rods – Product Designation			PITA Rod and Coupling Assemblies – Product Designation			Rod Length (PITA Rods and PITA Rods with Couplings)
5/8" Rod	3/4" Rod (1" dia. threads.)	1" Rod	5/8" Rod	3/4" Rod (1" dia. threads)	1" Rod	
TAR-625-42	TAR-750-42	TAR-100-42	TARC-625-42	TARC-750-42	TARC-100-42	3'-6"
TAR-625-84	TAR-750-84	TAR-100-84	TARC-625-84	TARC-750-84	TARC-100-84	7'-0"

PITA Couplings

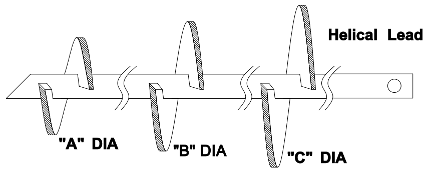


TAC-625	TAC-100	TAC-100	n/a

Note: Products listed in the product tables above are standard items and are usually available from stock.
All product hot dip galvanized per ASTM a123 grade 100

* Torque limits shown in the tables are maximum useable values and assume steady shaft torsion in homogeneous soil. Impact loads from encountering obstructions or stalling into very dense or hard soil could weaken the shaft or damage the helical flight. Always average the shaft torsion over the final three feet of installation when estimating the ultimate capacity of the anchor. Always apply a suitable factor of safety.

Round Corner Square Bar ECP Torque Anchors™



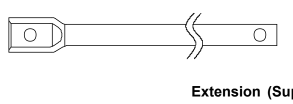
1-1/2" Shaft Standard Lead Configurations (5,500 & 7,000 ft-lb*)

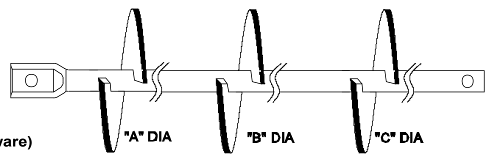
Product Designation		Plate Diameter - inches				Area sq. ft.	Length
1-1/2" Shaft – 1045	1-1/2" Shaft - 1530	"A"	"B"	"C"	"D"		
TAF-150-36 08-10	TAF-150-36 08-10	8	10	--	--	0.86	3'-0"
TAF-150-42 10-12	TAF-150-42 10-12	10	12	--	--	1.30	3'-6"
TAF-150-60 10-12	TAF-150-60 10-12	10	12	--	--	1.30	5'-0"
TAF-150-84 10-12	TAF-150-84 10-12	10	12	--	--	1.30	7'-0"
TAF-150-66 08-10-12	TAF-150-66 08-10-12	8	10	12	--	1.63	5'-6"
TAF-150-84 8-10-12	TAF-150-84 8-10-12	8	10	12	--	1.63	7'-0"
TAF-150-84 10-12-14	TAF-150-84 10-12-14	10	12	14	--	2.35	7'-0"
TAF-150-120 10-12-14	TAF-150-120 10-12-14	8	10	12	--	2.35	10'-0"
TAF-150-120 14-14-14	TAF-150-120 14-14-14	14	14	14	--	3.16	10'-0"
TAF-150-120 8-10-12-14	TAF-150-120 8-10-12-14	8	10	12	14	2.69	5'-6"

1-3/4" Shaft Standard Lead Configurations (10,000 ft-lb*)

Product Designation	Plate Diameter - inches			Area sq. ft.	Length
	"A"	"B"	"C"		
TAF-150-36 08-10	8	10	--	0.85	3'-0"
TAF-150-66 08-10-12	8	10	12	1.62	5'-6"
TAF-150-84 10-12-14	8	10	12	2.66	7'-0"
TAF-150-120 14-14-14	14	14	14	3.14	10'-0"

1-1/2" and 1-3/4" Shaft Standard Extension Configurations





Product Designation			Plate Diameter - inches			Area - ft^2 (1-1/2" / 1-3/4")	Length
1-1/2" Shaft (1045 - 5,500 ft-lb)	1-1/2" Shaft (1530 – 7,000 ft-lb)	1-3/4" Shaft	"A"	"B"	"C"		
TAE-150-36	TAE-150-36	TAE-175-36	--	--	--	n/a	3'-0"
TAE-150-60	TAE-150-60	TAE-175-60	--	--	--	n/a	5'-0"
TAE-150-84	TAE-150-84	TAE-175-84	--	--	--	n/a	7'-0"
TAE-150-120	TAE-150-120	TAE-175-120	--	--	--	n/a	10-0"
TAE-150-36 14	TAE-150-36 14	TAE-175-36 14	14	--	--	1.05 / 1.05	3'-0"
TAE-150-60 14	TAE-150-60 14	TAE-175-60 14	14	--	--	1.05 / 1.05	5'-0"
TAE-150-84 14-14	TAE-150-84 14-14	TAE-175-84 14-14	14	14	--	2.11 / 2.10	7'-0"
TAE-150-120 14-14-14	TAE-150-120 14-14-14	TAE-175-120 14-14-14	14	14	14	3.16 / 3.14	10'-0"

Note: The 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 100
Shaft Weight per Foot – 1-1/2" shaft = 7.7 lb/ft; 1-3/4" shaft = 1.04 lb/ft

Product Limitations

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

Because the products have slender shafts, buckling may occur when helical pile shafts are loaded in compression and must pass through extremely soft soil, which cannot exert sufficient lateral force against the narrow shafts.

When extremely soft soils are present, generally considered Class 8 and Class 7 soils with measured Standard Penetration Test values of "N" ≤ 5 blows per foot, one must take into consideration the axial stiffness of the shaft in the design for compression load.

The slender shafts also render the typical helical anchors ineffective against large lateral loads or overturning moments when used as a compression foundation element.

Soil Types

The most commonly encountered soils that may be suitable for anchoring are clay soils and granular soil types. These soils are generally classified as cohesive or cohesionless by geotechnical engineers. Soils that have fine grained structures such as clay and silt are considered cohesive. Cohesionless soil is the other major soil type and refers to coarse grained soils. Sands and gravels are considered cohesionless soils.

Properties for cohesive soil are generally categorized by geotechnical engineers as soft, stiff, firm or hard soil. Cohesionless soils are usually categorized as loose, medium dense, dense, and very dense soil. These descriptors help to judge the strength of the soil.

Table 3. SOIL CLASSIFICATION TABLE

Class	Soil Description	Geological Classification	Standard Penetration Test Range - "N" (Blows/12")
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; Hard silts and/or clays	Basal till; Boulder clay; Caliche; Weathered laminated rock	45 to 60
3	Dense sands/gravel, Stiff/hard silt and clay	Glacial till; Weathered shale; Schist, Gneiss; Siltstone	35 to 50
4	Medium dense coarse sand/sandy gravels; Stiff/very stiff 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; Medium/stiff 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 classes "0" through "2" and a portion of class "3" 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.

In some instances, one encounters rather thick layers of soils, or strata, that are rather consistent *(homogeneous soil)*; but this is often not the case as many soil strata are created from deposited soils, which have been transported from the area of formation to the present site. Residual soils are formed by physical or chemical forces that have broken down the rocks or the soil into a very fine structure. Residual soils may also be found in layers (strata) of varying soil categories. The process of residual formation of soil is referred to as "weathering", and these soils are called "weathered soils". Many of the cohesionless soils were formed from the sedimentation processes on lake and oceans bottoms millions of years earlier. Geological changes are responsible for the layering of these soils.

The transitioning through layer to layer (stratum to stratum) of the soil can create difficulties when anchoring into this soil, especially when a soft stratum is situated between two hard or dense strata. In cases when an anchor straddles weak strata, the soft soil could fail to provide the anticipated support for one or more helical plates embedded within this soft soil. The result could be creep of the anchor due to the soft soil migrating around the helical plate and possibly overloading the other plates embedded into the denser strata.

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 (Sand or Gravel) is buoyed by the water when it becomes saturated from a rise in the water table above the anchor. This buoyancy of the soil particles in the soil reduces the holding 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 later tensioning.

Anchors should always be installed below the lowest recorded frost depth to a distance of more than three diameters of the uppermost plate. In most cases this is usually 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 here. 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 and possibly cause an anchor failure. In addition, freezing water within the pores of the soil can lead to upward pressure, movement and loss of strength when helical plates are terminated within the freeze-thaw zone.

It is important to know the maximum frost depth and the range of depth for the water table at the job site to insure a solid and stable installation. Monitoring the installation torsion on the shaft (Discussed in Chapter 4) can predict the performance of the anchor at the time of installation, but changes in the soil moisture can affect the long term holding ability of the anchor.

Anchor Holding Capacity

The capacity of a helical anchor can be estimated by accurately measuring the installation shaft torsion. Several methods of measurement are commonly used. Transducers attached to hydraulic lines, strain gauge monitors, shear pins and pressure differential monitoring at the installation motor are all common ways to determine installation torque being applied to the anchor shaft.

ECP recommends installing the anchor at least three feet beyond the point at which the torque requirement is met. The shaft torsion average must be at or above the torque requirement for all of the three feet to confirm meeting the required torque.

The continuation of the installation beyond first reaching the torque requirement insures that all anchor plates are sufficiently embedded into the target soil and this reduces the chance of creep or pullout in the future.

Field load testing is required to verify the actual anchor holding capacity. During a field test, the anchor is pulled in the direction of the intended load or guy installation angle. Fully loaded field tests can measure creep of the tension anchor. The guy anchor creep is generally in the range of 2 to 4 inches. There is normally a small shaft movement when a helical anchor is initially loaded due to the anchor "seating" into the soil. This movement is normally not considered in the creep measurement. Before performing a field load test, a small initial "seating" load of 1,500 to 2,000 pounds is usually applied to the anchor prior to commencing test for creep. During testing, the load on the anchor is incrementally increased and after each load increment is fully applied, the movement at the top of the anchor shaft is measured against a fixed point. If the creep occurs only during the application of the incremental load, the test can continue immediately after measuring the creep increment; however, as the load increases, the anchor may continue to creep for a period of time after the incremental load has been fully applied. During this time the incremental load on the anchor must be maintained as the shaft continues to creep. The creep for the load increment shall not be recorded until the movement ceases and the anchor becomes stable. If after 15 to 20 minutes, the creep continues, or the total measured creep exceeds four inches, the useful capacity of the utility helical anchor has been exceeded.

The maximum anchor holding load is the load that produces four inches creep, or less, is the ultimate capacity. A factor of safety must be applied to this ultimate load to obtain the service tension load.

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

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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.

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 contact us at 913 393-0007, Fax at 913 393-0008.

Chapter 2

Tension Design
Helical Anchors

Tension Design for ECP Helical Torque Anchors™

Including Structural Tieback Design
And Guy Anchoring Design

- **PITA Helical Torque Anchors™**
- **HD Extreme PITA Torque Anchors™**
- **Solid Square Shaft Torque Anchors™**

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Table 4.	Symbols Used In This Manual
α	Tieback installation angle from a pole
A	Projected area of helical plate – ft^2
c	Undrained shear strength of the soil – lb/ft^2
d	Helical plate diameter – ft
$d_{largest}$	Diameter of Largest Helical Plate
γ	Dry Density Of The Soil – lb/ft^3
FS	Factor Of Safety
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
h_{min}	Minimum Depth – The distance from ground surface to the shallowest helical tieback plate. (D = 6 x $d_{largest}$)
k	Shaft efficiency factor – Relates the ultimate capacity of a anchor or pile 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 length of product required by the design
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" – e.g. 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	Compressive Load – lb or lb/Lin. ft
P_u	Ultimate axial pile capacity* – lb.
P_w	Working or design load – lb.
Δp or $p_{in} - p_{out}$	Pressure differential measured across a torque motor
q	Soil overburden pressure (lb/ft^2)
q_{mid}	Overburden pressure at mid-plates (lb/ft^2)
T	Installation or Output Torque – ft-lb
T_u	Ultimate Anchor Tension Capacity – lb
T_w	Working Tensile Anchor Load – lb
X	Product Spacing - ft

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

Design Criteria

The design of Helical Torque Anchors™ uses classical geotechnical theory and analysis along with empirical relationships that have been developed from 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.

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

Bearing Capacity depends upon many factors:

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

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

Soils will vary from site to site and from point to point on most sites. Each analysis must use data relevant to the project at hand as each project has different parameters. In many situations, geotechnical data is not available. Some knowledge of the soil on the site is still necessary to select a product that will produce the desired capacity along with a suitable factor of safety. In Chapter 1 we introduced a table of generalized soil classifications to assist in determining holding capacity. It is reproduced on the following page for reference in this chapter.

Table 3.	SOIL CLASSIFICATION TABLE	(Reproduced from Chapter 1)	
Class	**Soil Description**	**Geological Classification**	**Standard Penetration Test Range - "N" (Blows/12")**
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; Hard silts and/or clays	Basal till; Boulder clay; Caliche; Weathered laminated rock	45 to 60
3	**Dense sands/gravel, Stiff/hard silt and clay**	**Glacial till; Weathered shale; Schist, Gneiss; Siltstone**	**35 to 50**
4	**Medium dense coarse sand/sandy gravels; Stiff/very stiff 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; Medium/stiff 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 classes "0" through "2" and a portion of class "3" 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 in Class 8 soils.

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

Preliminary Design Guideline

The following preliminary design information is intended to assist with the selection of an appropriate ECP Torque Anchor™ configuration for a given project *where the ultimate capacity is defined by deflection not exceeding one inch*.

Later in the chapter Guy Anchors, a special application with larger allowable deflections, will be discussed.

Deep Foundations

Helical anchor systems must be considered as deep foundation elements and as such must be, as a rule of thumb, installed to a minimum depth of at least six times the diameter of the largest helix. The measurement is made vertically from the final surface elevation to the depth of the shallowest helical plate on the helical anchor.

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 least three times the immediately lower helical plate diameter apart, each plate will have full efficiency and develop maximum load transfer capacity in the soil. Spacing the helical plates at less than three diameters apart is possible; however, each helical plate will not be able to develop full capacity due to interference between the stress bulbs from adjacent plates. The designer will have to include a reduced plate efficiency factor in the analysis when conducting a design having plates closer than three diameters apart.

Center to center anchor or pile shaft spacing should be no closer than five times the diameter of the largest helical plate on the shaft. Product spacing as close as three diameters has been successfully installed, but this work requires special installation equipment that can maintain precise installation angle tolerances. The ECP shaft spacing recommendation is five times the diameter of the largest plate when measured at the target depth. It is acceptable to cluster several anchor shafts adjacent to each other at the surface, if during installation each shaft has suitable outward batter angles to achieve the recommended five diameter center to center shaft

Tension Design Helical Anchors

spacing at the final installed depth of the largest helical plate.

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

Equation 1: Ultimate Theoretical Capacity:

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

Where:

T_u or P_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 determined by Equation 1 is the load that when applied to a foundation element results in no more than one inch of deflection. ECP recommends designing the guy anchor capacity to the ultimate cable strength of the guy wire and/or the calculated factored load created by the power lines, whichever is less. In other applications such as temporary shoring, a factor of safety of 1.5 above service load is generally suitable. In critical applications or in soft soil we recommend a Factor of Safety of 2.0 and greater.

This is the standard formula for designing support for a permanent structure such as a tower or building, where the tolerance for creep is more critical. The ultimate axial compressive helical pile capacity shall result in a deformation of no more than one inch. In general, the design should use the working capacity with an added factor of safety of at least 2.0 applied to use as T_u or P_u.

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 may not contain all of these values and the designer must decide which soil type is more likely to control the ultimate capacity. The Soil Classification Table 3 above can be of use in such situations.

In all cases, we highly recommend a field test at the project site to verify the accuracy of the preliminary design to estimate actual load capacities whether from geotechnical data or from an assumed soil class from the Table 1 above.

Soil Behavior

The following information is provided to introduce the reader to basic soil mechanics. Explained here are the terms and theories used to determine soil behavior and how this behavior relates to helical Torque Anchor™ performance. This is not meant as a 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.

Table 5. Cohesive Soil Classification

Soil Description	USCS Symbol	Density Descrip.	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 Soil (Clays)

Cohesive soil is soil that is generally classified as a fine grained clay soil or silt as shown in Table 5. By comparison, granular soils like sands and gravels are referred to as non-cohesive or cohesionless soils.

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.

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, see Table 6. A value for undrained shear strength, "c", can only occur in soils that have cohesive properties, this means that the internal friction "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 with cohesive soils; the greater the shear strength "c" of the soil, the greater will be the bearing capacity. It also follows that the bearing capacity of the cohesive soil sometimes tends to increase with depth.

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 anchors or piles with plate diameters under 18 inches, the value of "N_c" = 9 is generally accepted as a reasonable value by the industry to use when determining capacities of these helical piles and anchors in clay and silt.

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 cohesive soil particles can be assumed to be zero and the cohesive bearing factor, N_c = 9 can be assumed. Equation 1 is modified as follows for use when designing in cohesive soil:

Equation 1a - Ult. Capacity - Cohesive Soil

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

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

Cohesionless Soil (Sand and Gravel)

The particles of sand or gravel in cohesionless soil act independently of each other. This class of soil has fluid-like characteristics. When cohesionless soils are placed under stress they tend to reorganize into a more compact configuration. Cohesionless soils are described in Table 7.

Cohesionless soils achieve their strength and capacity in several ways.

- The soil density,
- The overburden pressure (The density of the soil that exists above the helical anchor multiplied the height above the plate.)
- The internal friction angle of the soil, "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 thickness, "h" of the layer.

Table 6. 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

Table 7. 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

The moist density of the soil shall be 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.

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The submerged density of soil, where all voids in the soil are filled with water, is determined by subtracting the buoyant force of the water (62.4 lb/ft^3) from the dry density of the soil.

To arrive at a 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 surface to the elevation of that particular helical plate, "h_{plate}". The overburden pressure of a multi-plate anchor is often estimated as an average overburden pressure on the multi-plate configuration. This is accomplished by determining the soil overburden, "q_{mid}", at a depth midway between the upper and lowest helical plate, "h_{mid}". This value of "q_{mid}" is used to in the bearing capacity equation to calculate the ultimate capacity of the anchor configuration.

Table 8. 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	Density "γ" lb/ft³ Submerged
Very Loose	≤ 2	28⁰	12	70 to 100	45 - 62
	3 – 4	28⁰	13		
Loose	5 – 7	29⁰	14 – 15	90 to 115	52 - 65
	8 – 10	30⁰	15 – 16		
Medium Dense	11 – 15	30⁰ - 32⁰	17 - 19	110 to 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 to 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 his work the dimensionless empirical value "N_q" was introduced. "N_q" is related to the friction angle of the soil "ϕ" as shown in Table 8.

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. When used for cohesionless soils Equation 1 can be modified as follows:

Equation 1b: Ult. Capacity - Cohesionless Soil

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

Where:

T_u or P_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.

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 area of the helical plates is required. The projected area is the summation of the areas of all helical plates in contact with the soil reduced by the cross sectional area of the shaft. Table 9 provides projected areas in square feet of soil bearing for various plate diameters on different shaft configurations.

Important Note: When a 90⁰ spiral cut leading edge is specified, the projected area listed in Table 9 is reduced by approximately 20%.

Table 9. Projected Areas* of Helical Plates						
Plate Size	6" Dia.	8" Dia.	10" Dia.	12" Dia.	14" Dia.	16" Dia.
Shaft	Projected Area – ft² (See Important Note at Left)					
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
2-1/4" Sq.	0.161	0.314	0.510	0.750	1.034	1.361
2-1/4" HD Extreme	0.146	0.299	0.495	0735	1.019	n/a
2-1/2" HD Extreme	0.128	0.281	0.477	0.717	1.001	n/a
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 area of the shaft.

Allowable Helical Plate Capacity: When conducting a preliminary design, one must also be aware of the mechanical capacity of a helical plate and the shaft weld strength. Average mechanical capacities of helical plates are given in Table 10. 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.

Table 10. Average Ultimate Mechanical Helical Plate Capacities

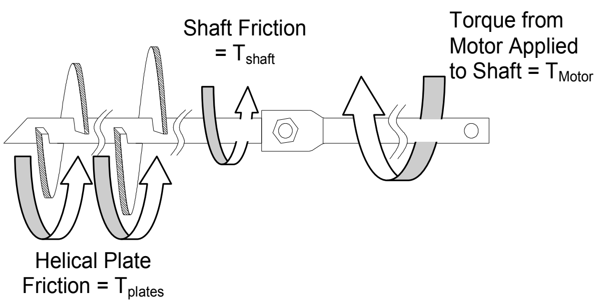
Helical Plate Thickness	Average Ultimate Load	Average Service Load
6” through 14” Diameter Plates		
3/8”	40,000 lb	20,000 lb
1/2”	50,000 lb	25,000 lb
16” Diameter Plate		
1/2”	40,000 lb	20,000 lb

When the design uses 12” or 14” diameter helical plates on solid square shafts, the ultimate mechanical capacities are slightly lower than shown. This variance is usually not a concern except when a small shaft is highly loaded and contains a single or double helix configuration.

Installation Torque

Shaft torsion during installation can provide a reasonably accurate estimate of the ultimate capacity of the helical screw anchor. The relationship between the shaft torsion during installation and the ultimate helical screw anchor capacity is empirical and was developed from results from thousands of tests. When one applies rotational torsion to a 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 is caused by friction between the shaft and the soil.

In the sketch 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 circumference of the shaft and the soil is directly related to the shaft configuration and size, and the properties of the soil. Because of this loss of efficiency in transmitting the motor torque to the plates, an empirical *Torque Efficiency Factor* (“k”) must be employed to arrive at a reasonable estimate of anchor ultimate capacity.



Torque Efficiency Factor – “k”: This is the relationship between installation torque and ultimate capacity of the installed Torque Anchor™. Estimating the ultimate capacity of screw piles based upon the installation torque has been in use for many years.

Unless a load test is performed to provide a site specific value of installation *Torque 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 *Torque Efficiency Factors* (“k”) in Table 11. These values can be used for estimating typical 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 11 lists typical values of “k” for estimating ultimate capacities of Torque Anchors™ based upon the output torque available at the installation motor shaft.

Table 11. Torque Efficiency Factor “k”
(1” Deflection Max.)

Torque Anchor™ Type	Typically Encountered Range “k”	Suggested Average Value, “k”
All Square Shafts	9 - 11	10
2-7/8” Diameter	8 - 9	8-1/2
3-1/2” Diameter	7 - 8	7-1/2
4-1/2” Diameter	6 - 7	6-1/2

Understand that the value of the *Torque 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 design. The “k” value for square bar shafts is generally higher than for tubular shafts. Keep in mind that the suggested values in Table 11 are guidelines.

It is also important to refer to Table 2 (Chapter 1) for the maximum practical shaft torsion that can be applied to the anchor shaft. Being mindful of shaft torsional strength will help to avoid shaft fractures during installation.

Failure to verify that the shaft configuration has sufficient reserve torsional capacity could result in an unexpected shaft fracture during installation.

Equation 2: Helical 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)
(Calculated or measured from field load tests)
k = Torque Efficiency Factor - (ft^{-1})

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

To determine the site specific *Torque Efficiency Factor* ("k") from field load testing, Equation 2 is rewritten as:

Equation 2a: Torque Efficiency Factor

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

Where,
k = Torque Efficiency Factor - (ft^{-1})
$T_u = P_u$ = Ultimate Capacity - (lb)
(Measured from field load tests)
T = Final Installation Torque - (ft-lb)

Table 11 suggests typical ranges of "k" for a given shaft configurations based upon an allowable one inch maximum deflection at ultimate load.

Values for "k" have been shown to be slightly higher for tension guy applications where acceptable deflections may range up to four inches. Graph shown below estimates this higher Torque Efficiency Factor.

Always verify ultimate capacity by performing a field load test on any critical project. Acceptable criterion for guy applications is four inches of creep, maximum. On compressive structural installations or structural tiebacks, a vertical deflection of one inch, maximum is considered the ultimate capacity for the product design.

When in doubt, or when the helical plates are embedded in several strata of differing soils; ECP suggests selecting a value for "k" that is in the mid-range for the shaft configuration.

Minimum Embedment Depth: When a guy or tieback anchor must resist uplift or tension loads, the anchor must be adequately embedded into the bearing stratum to offer resistance to pull out.

In these types of applications there is a possibility of shallow failure for screw anchors. The anchor fails when the soil suddenly erupts from insufficient soil embedment of the anchor. To prevent such failures, Torque Anchors™ must be installed to a sufficient depth to be considered a deep foundation. This is illustrated in Figure 2.

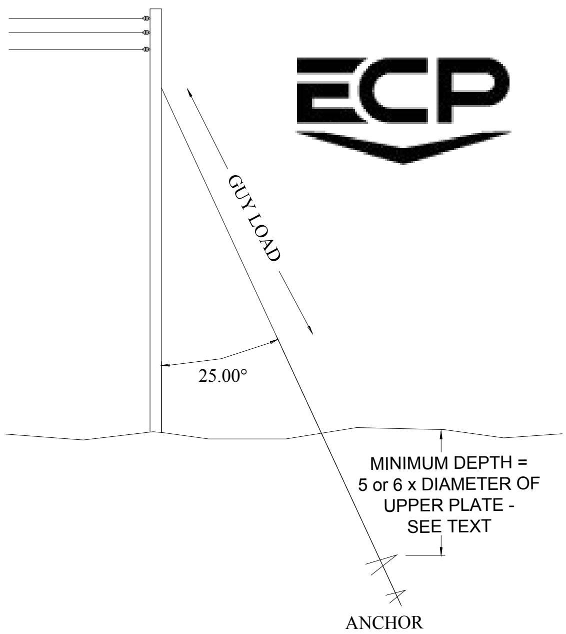


Figure 2. Minimum embedment depth to insure sufficient soil overburden for resistance to pull out.

As a general rule of thumb, many designers use five times the diameter of the largest plate as the minimum embedment depth, "h_{min}" for helical anchors in Soil Classes 4 and 5, and six times the largest plate diameter in Soil Classes 6 and 7.

It is important to understand that in addition to achieving a suitable overburden depth as discussed above, the anchor must be fully embedded into competent soil to resist the working load. To insure that the anchor is fully embedded into competent soil, the torsion applied to the shaft must be applied continuously, averaged and recorded over a distance of no less than the final three feet of installation. This average shaft torsion must meet or exceed the torque requirement set forth in the design.

If the anchor encounters an obstruction or stalls during the final three feet of installation, the final shaft torsion must be considered a false reading and must be discarded. One must use the average shaft torque for the three feet prior to encountering the obstruction as an estimate of anchor capacity.

Preventing "Pull Out" In Tension Applications: A soil boring or installation monitor, on occasion, may report a layer of weak and softer soil overlaying a stratum of competent soil. When designing the Torque Anchor™ to achieve full tensile capacity into the competent soil situated below the weaker soil, one must consider the possibility that the Torque Anchor™ could pull through into the weaker soil when fully loaded.

In such situations, it is recommended that the installation torque requirement be maintained for a minimum distance of three feet in the competent soil layer to prevent "pull out" or "creep" of the anchor from the stronger soil into the softer soil, and ultimately failing.

Torque Anchor™ Installation Limits

Shaft Strength: We offer 1530 low carbon steel for fabrication of our solid square bar anchors. The percentage of carbon in our 1530 square steel bars is 0.30%, while medium carbon steel such as 1045 steel has 0.45% carbon. Welding helical plates onto a medium carbon steel shaft can create brittleness of the shaft near the welded areas. In steels with medium to high carbon content, the tendency toward hardening and brittleness is more prevalent as the amount of carbon increases. This hardening and brittleness caused by welding could lead to fractures at the weld points when the anchor is placed under impact loads or overloaded.

The low carbon 1530 steel bar that is available in our Torque Anchors™ provides an anchor shaft with a high level of toughness and good ductility along with the best weldability of all metals. Medium carbon steel that has carbon content above 0.30% cannot perform as well as low carbon steel (below 0.30%) unless the medium carbon steel is preheated before welding and post heated to relieve the brittle structure formed during the welding process.

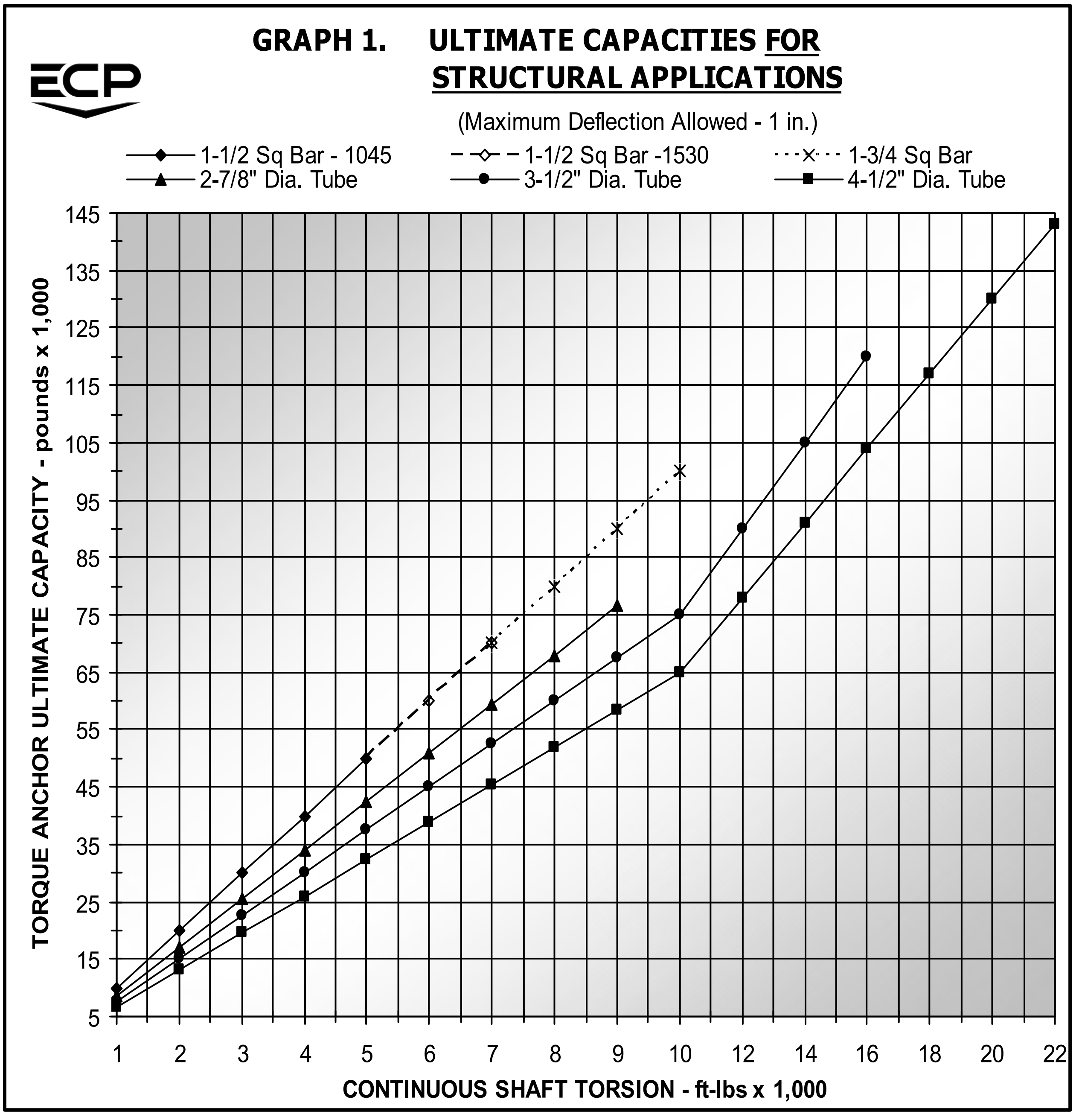
The data in Table 2 in Chapter 1 and Graph 1 below gives the strength ratings for various shaft configurations and different steel compositions for axial tension, compression and the torsion limits. The values are from mechanical testing and not from tests in the soil. Because helical Torque Anchor™ 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 shaft torsion that should be intentionally applied to a Torque Anchor™ shaft during installation in *homogeneous* soil. The risk of product failure dramatically increases when one exceeds these torsional limits.

When choosing a product for a project, the designer should select a shaft that has an adequate margin of torsional strength above the shaft torque estimate 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 in *homogeneous soil* be allowed to insure proper embedment and to prevent fractures from impacts.

It is important to also understand that the *Torque Efficiency Factor* ("k") recommended in Table 11 and shown below in Graph 1, demonstrates that the value for "k" defines the practical limit on the ultimate capacity that can be developed by the shaft in the soil. This is especially important when designing with the larger tubular shaft products because larger diameter tubular shafts pass through the soil less efficiently than do smaller tubular shafts and the solid square bars.

Note: Table 11 and Graph 1 (below) may be used to estimate ultimate anchor capacity relative to installation torque in Guy Anchor applications and the result will be conservative. The Guy Anchoring special application will be discussed after Graph 1.



Important Notes:

1. This graph is for use with structural support applications and could be used for guy anchors if desired. The ultimate loads predicted by the graphs above are based upon the recommended values for torque efficiency to produce a maximum of one inch deflection at ultimate capacity.
2. The data here is provided for guidance. Actual torque efficiency can be determined by on site field tests.
3. **The loads presented in these graphs MUST be reduced by an appropriate factor of safety**.
4. Installation shaft torsion must be averaged over a distance of three feet prior to terminating the install. The soil is assumed to be homogeneous on the site. When installing in soils that are not homogenous or are obstruction laden, proof testing is recommended.
5. Caution: Do not exceed the torsional strength of the shafts. The upper line on Graph 3 is for solid square shafts. The useable torsional limits are: 1-1/2 inch – 1045 bar is 5,500 ft-lb; 1-1/2 inch -- 1530 bar is 7,000 ft-lb: 1-3/4 inch bar is 10,000 ft-lb.

Designing Specifically for Guy Anchoring

Introduction to Guy Anchoring

Helical Torque Anchors™ that are used for resisting guy loads are the exact same products used for other applications such as for resistance to overturning forces on retaining walls, or support of basement walls, or compressive support for support of structures. The difference when working with anchorage for guy loads is that the amount of deflection allowed for the anchor is greater than for structural applications.

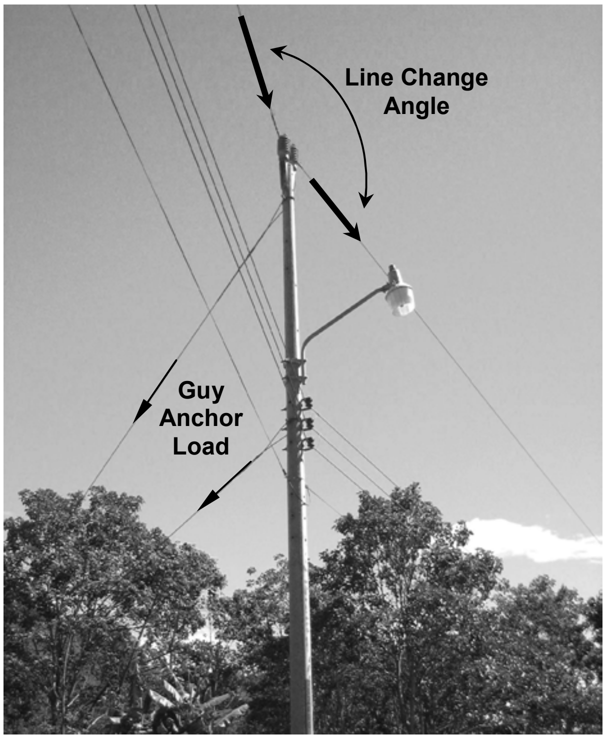
Industry standard is generally to accept between two to four inches of movement under tensile load for guy anchorage before the load is declared to be at the Ultimate Capacity for the guy anchor installation.

Typically in structural applications for retaining walls and vertical compressive structural support the ultimate capacity is declared when the deflection reaches one inch.

Guy Loads

Before one can determine the load on the guy wires, one must know the weight of the conductors, the weight of the arms and insulators, loads from ice and wind, pole height, dead end loads, etc. Proper positioning of the guy will reduce the number of guys required on a particular installation. Where obstructions are encountered, two or more guys are typically installed with the combined capacity equal to the resultant load on the pole. The most efficient position for a guy wire where overhead lines make a sharp change in direction is at the angle that bisects the outside angle of the line direction change. Depending upon the loading and the soil condition, more than one guy may be required at the change in line direction. In windy conditions or heavy icing, side guys may be required on long straight runs.

The photograph at right illustrates guy wire placement on a power pole with a moderate line change angle. This pole is subjected to the overturning force due to the line change plus the weight of the cantilevered street light adds to the guy load. This installation uses a guy anchor that bisects the outside angle of the line angle change.



Angle Line Loads

When a guy is required due to an abrupt change in overhead line direction; and a single guy can be installed, it should be located at one half of the outside angle of the overhead line change angle. One can determine the dead end line load on this pole with the following equation:

Equation 3. $L_a = S \times N$

Where; L_a = Dead End Load on the Pole
S = Ultimate Strength of the conductor (Table 12)
N = Number of conductors used

Torque Anchor™ Holding Capacity Estimates

Graph 2 below was developed to provide estimated ultimate tension capacities for various sizes and configurations of helical plates on commonly used Torque Anchors™ used for Guy Anchor applications when installed into various soil classifications. It must be clearly understood that Graph 2 is not intended to be a substitute for helical pile engineering design that uses project data from a specific job in a specific soil. Graph 2 represent general trends of capacity for guy anchors through different *homogeneous* soil classifications. The graph is based upon conservative estimates based upon testing.

Deflections of up to four inches can be expected at the loads shown on Graphs 2 & 3.

The graph represents the ultimate capacity of the helical plates in the soil.

One must always apply a suitable factor of safety to the service load before using these graphs to insure reliability of any guy anchor or compression pile system.

Graph 2 disregards soil classifications zero through class 2 because these soils are usually to dense for the Torque Anchor™ to advance into these soil classes without pre-drilling. When the rotation of the helical anchor shaft does not advance the product into the soil, the soil usually will not allow the helical plates to fully embed and achieve the capacity level estimated from the guy anchor load testing data.

Likewise soil class 8 was not presented in the Graph 2 because class 8 soils usually contain significant amounts of organics or fill materials that may contain debris and/or may not be properly consolidated.

Graph 2 also shows a shaded area for soils in Class 6 - 7. This is to alert the user that, in some cases, soils that fall within this shaded area on the graph may not be robust enough for heavy loads. If the soil in the shaded area contains fill materials; the fill could have rocks, cobbles, construction debris or trash in it. In addition, this soil may not be fully consolidated and/or could contain organic components. Any of these factors could allow for creep of a foundation anchorage 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 guy anchor or pile be driven deeper so that the Torque Anchor™ will penetrate completely through all weak and possibly unstable soil into a more robust and stable soil stratum underlying these undesirable strata. Proof or load testing is strongly suggested or a larger factor of safety shall be used.

Shaft torsion should always be monitored during the installation of helical screw anchors and piles. Generally, the ultimate holding capacity of the typical *solid square shaft helical anchor* within a given soil stratum for a guy anchor is greater than ten times the average shaft torsion measured over the final three feet of installation for tension anchors with allowable deflections greater than one inch. Assuming the rule of thumb of 10 - 11 times the average installation torsion should provide a conservative capacity estimate for a guy anchor.

When estimating the anchor's capacity, one must not consider any torque readings on an anchor shaft when the shaft becomes stalled or encounters obstructions. If such problem is encountered, use readings from 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 or guy anchor spins on a dense stratum, it must be removed and repositioned. The torsion measurements at the new placement shall be averaged for three feet but the anchor shall not be installed to the spin depth.

Due to larger amount of friction between the soil and tubular shaft configurations, *one cannot use a ten to one relationship mentioned above to estimate ultimate capacity of tubular shafts*. Most tubular shaft configurations are used in compression applications.

The loads estimated in Graphs 2 are not applicable for structural applications or for projects requiring tubular anchors or piles.

A more detailed discussion of the relationship between torque on the tubular shaft and pile capacity for piles in compression will be discussed in Chapter 3.

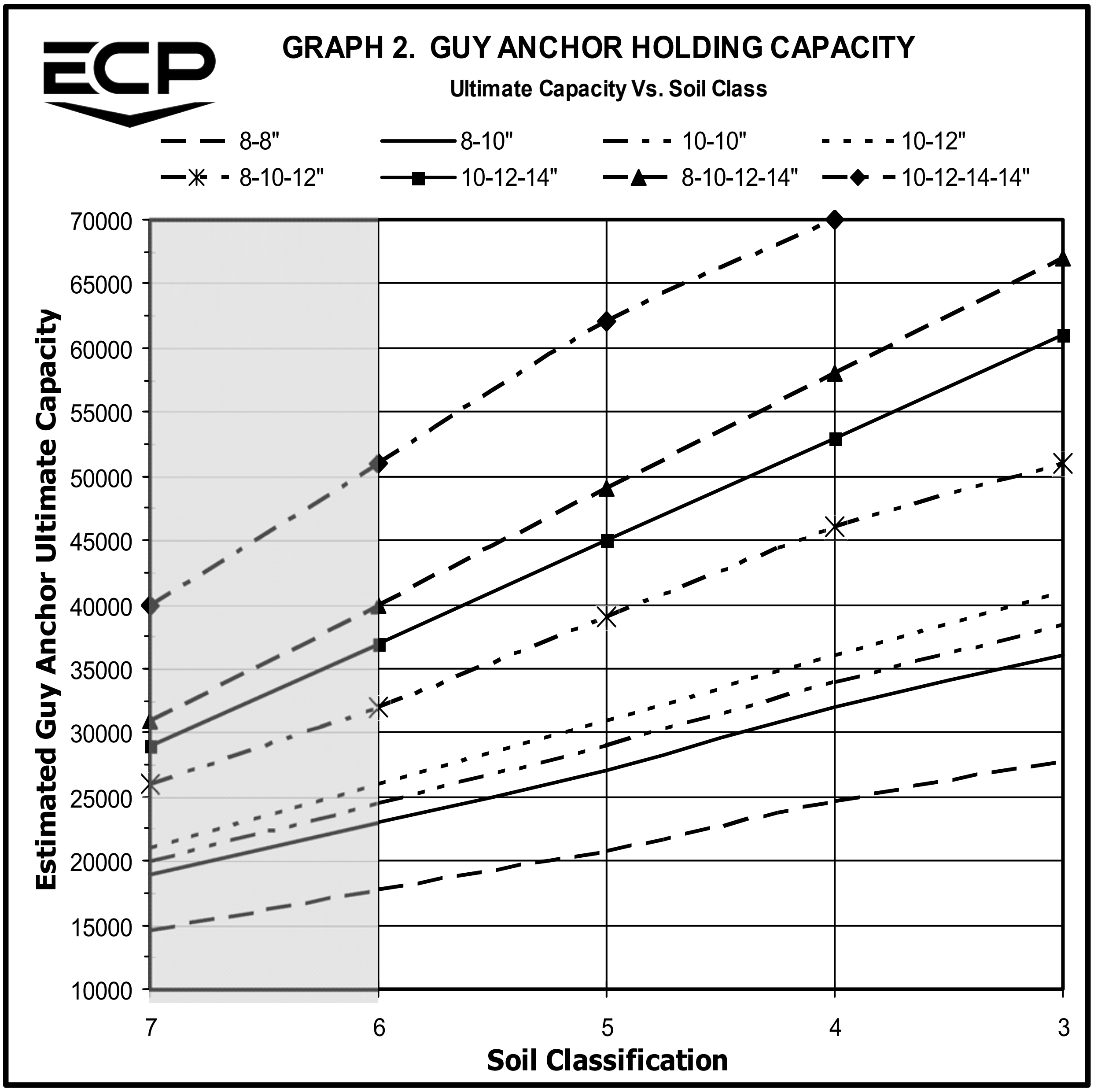
It is also important to understand that Graph 2 does not take into consideration the torque limits on the various shaft sizes being used in conjunction with the helical plate configurations.

As a result, the graph could suggest holding capacities well above the useable torsional capacity of some of the smaller size solid shafts or power installed anchor rods to deliver the capacities shown.

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 Graph 2 if one uses a Torque Anchor™ with one-half inch thick helical plates instead of the standard three-eighth inch thickness. Please check with ECP or your engineer to determine if using thicker helical plates could achieve the ultimate capacity requirement on a particular project.

Important Note: Graphs 2 and 3 are for use with guy anchoring only. Use of these graphs for structural support applications could result in excessive deflection of the structure and/or failure.

Tension Design Helical Anchors



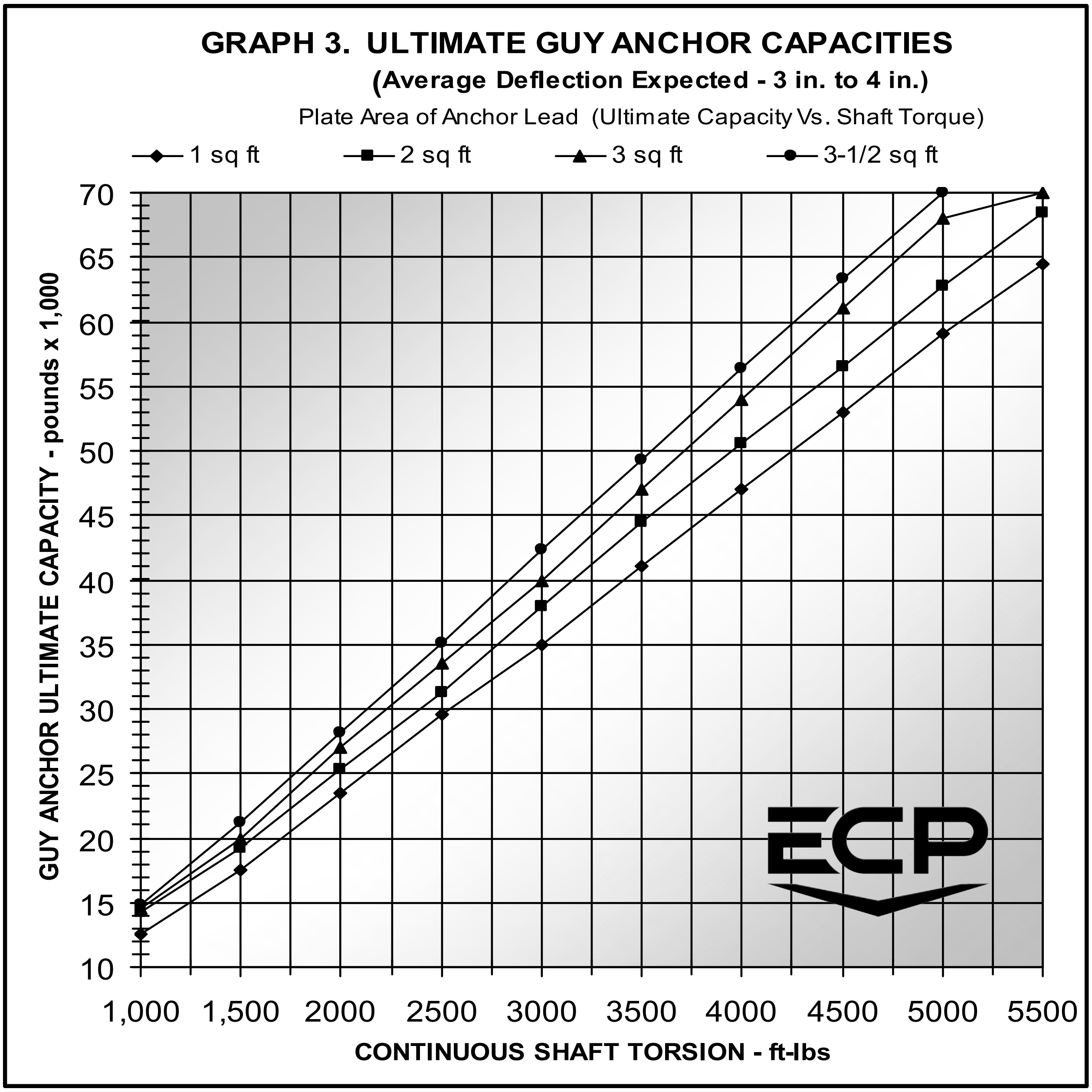
Important Notes:

1. **__This graph is for use with guy anchoring only__**. The ultimate loads predicted by the graph above are based upon averaged load test data and are presented here simply for guidance.

2. The typical deflections of up to four inches can be expected at the indicated ultimate loads. __The loads presented in these graphs MUST be reduced by an appropriate factor of safety__.

3. When working with soil in the shaded area, it is advisable to install Torque Anchors™ deeper into more robust soil for stability and performance. In situations where this is not possible, we recommend using a higher factor of safety on the estimated ultimate loads presented in Graph 1.

Graph 3 is presented for rapid estimation of the Ultimate Pullout Capacity of Guy Anchors where deflections of up to four inches are acceptable. One must determine the projected plate area of the anchor configuration used. The area can be found in the product listings in Chapter 1 or can be determine from Table 9 in this chapter. Locate the required Ultimate Capacity (Service Load plus Factor of Safety) on the left side of the Graph 3. Go horizontally until encountering the projected plate area of the anchor and then read the estimated shaft torque required to achieve the desired capacity at the bottom of the graph.



Important Notes:

1. **This graph is for use with guy anchoring only**. The ultimate loads predicted by the graphs above are based upon averaged load test data and are presented here simply for guidance.
2. The typical deflections of up to four inches can be expected at the indicated ultimate loads.
3. **The loads presented in these graphs MUST be reduced by an appropriate factor of safety**.
4. Installation shaft torsion was averaged over a distance of three feet and the anchors were installed in homogeneous soil. When installing in soils that are not homogenous or obstruction laden, proof testing is recommended.

Design Example 1 – Guy Load

A guy must be installed at a 55 degree change in the overhead line direction at a line pole. The three conductors connected to the pole are 2/0 aluminum stranded cable. The guy wire will be installed at a 25^0 angle to the pole as shown on the sketch below.

Recalling Equation 3, the dead end load is first determined. The ultimate strength of 2/0 AWG Aluminum Cable can be found below in Table 12 at 2,350 lb. Knowing that there are three cables the total load is:

L_a = 2,350 lb x 3 = **7,050 lb**

In the next step takes into consideration the 55 degree change in direction of the overhead lines at the pole. Referring to Table 13, at the end of the chapter, it can be seen that the 7,050 lb load falls between the 6,000 lb and 8,000 lb entries on Table 13. The load is rounded off to 7,000 lb, and the load at 55^0 is estimated to be half way between the two values found on the Table 13.

From Table 13:

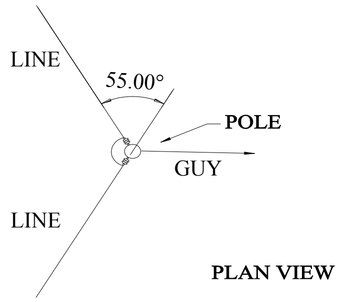
6,000 lb at 55^0 = 5,544 lb
8,000 lb at 55^0 = 7,392 lb

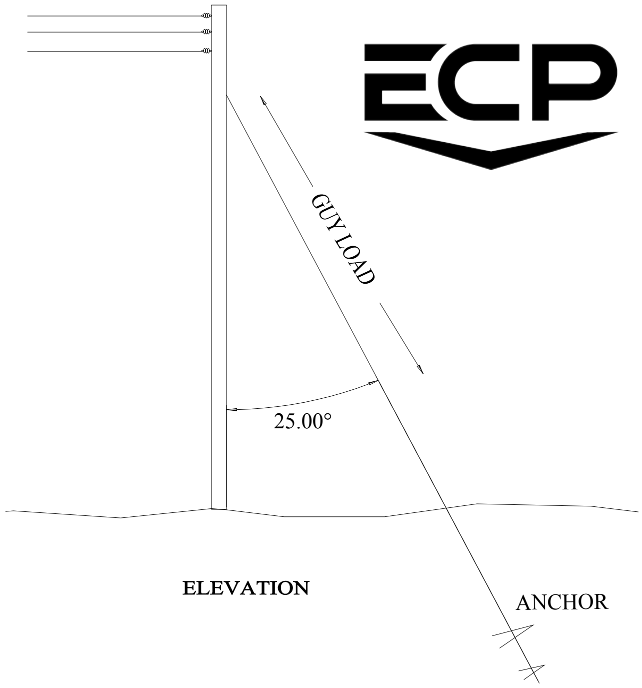
The 7,000 lb load at a 55 degree angle is then estimate by calculating the difference between the two load values from Table 13, and then dividing this difference by two. To determine the load represented by half the difference between the two load values, one adds half the difference to the lower load value. The calculation is shown below:

$L_{55\ deg}$ = [(7,392 lb - 5,544 lb) / 2] + 5,544 lb
= [1,848 lb / 2] + 5,544 lb = **6,468 lb**

This is the load on the pole at the conductor connections taking into consideration the 55^0 change in direction of the overhead cables at the pole connection.

When determining the Guy Load for a guy wire that bisects the change in angle (the angle from the guy to each conductor direction is equal), the load on the guy will be greater than the horizontal force on the pole from the conductor lines. This is because the guy is connected to the pole at an angle. As a result only a portion of the load on the guy resists the horizontal conductor line load.





To determine the guy load in this example, use Table 14. Noting that the calculated conductor line load was determined to be 6,468 lb, it is necessary to be round up to 6,500 pounds for determining the guy load from Table 14.

Once again Table 14 does not offer the exact load that is needed for the design. The guy load will have to be calculated in a similar manner as was done for the overhead conductor load at the direction change that was explained above.

From Table 14:

6,000 lb at 25^0 = 14,197 lb
8,000 lb at 25^0 = 18,930 lb

Using the rounded load of 6,500 lb, it is assumed that the guy load occurs near one fourth of the distance between load value at 6,000 lb and the value at 8,000 lb on Table 14. First, the difference between the two numbers is determined and then this difference is divided by one-forth because 6,468 falls approximately one-fourth of the distance between the two values. This incremental value is added to the lower value from Table 14.

L_{GUY} = [(18,930 lb – 14,197 lb) / 4] + 14,197 lb
= [4,733 / 4] + 14,197 = **15,380 lb**

This is the ultimate load that is expected at the guy wire and must be resisted by the ground anchor. The helical anchor attached to the guy must be able to resist at least 15,380 pounds of tension to safely support the pole connection. A suitable guy cable that has a breaking strength exceeding 15,380 lb can be selected from Table 15, below.

Depending upon the type of cable in inventory, one could select from the following guy wire sizes:

- 7/16 – 7 Utility Grade Steel Cable – Zinc or Aluminum Coated at 18,000 lb
- 7 - #7 Aluminum Clad at 19,060 lb
- 18M Aluminum Clad Steel M-Strand at 18,000 lb.

There are many other selections shown on Table 15 that are suitable for this project. They can be seen listed under the various grades of Zinc or Aluminum Coated Steel Strand Guy Cable. The sizes presented here were just for illustration. One simply can select a guy cable from Table 15 that has a breaking strength greater than the guy load (L_{GUY}) of 15,380 pounds.

End Design Example 1

Design Example 2 – Guy Anchor in Cohesive (Clay) Soil

Design Details:

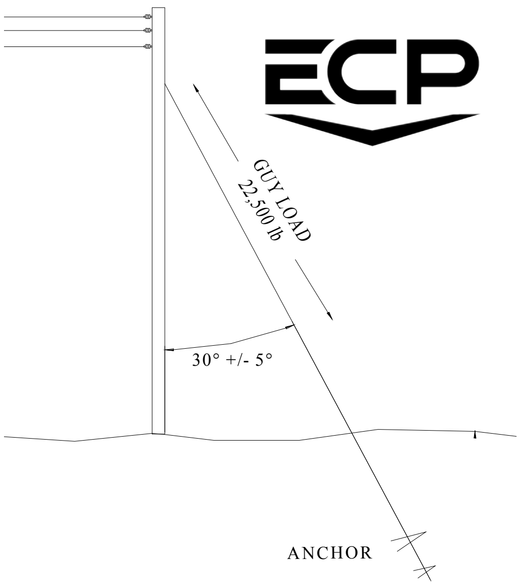
- Ultimate Guy Tension = 22,500 lb.
- The soil report from the site indicated inorganic clay (CL), stiff– 100 pcf
- Soil Class 6 is suggested (Table 3)
- SPT = 7 to 10 blows per foot is estimated

Torque Anchor™ Design: Because little information about the soil on this project was provided, the designer will have to make judgments about the conditions on the site. The design will begin from the estimated holding capacity in Graph 2, presented earlier in this chapter. (Shown below.)

1. Ultimate Tieback Capacity. Because the guy cable capacity was based upon ultimate cable loads given in the Design Details, No factor of safety is added for the helical guy anchor design.

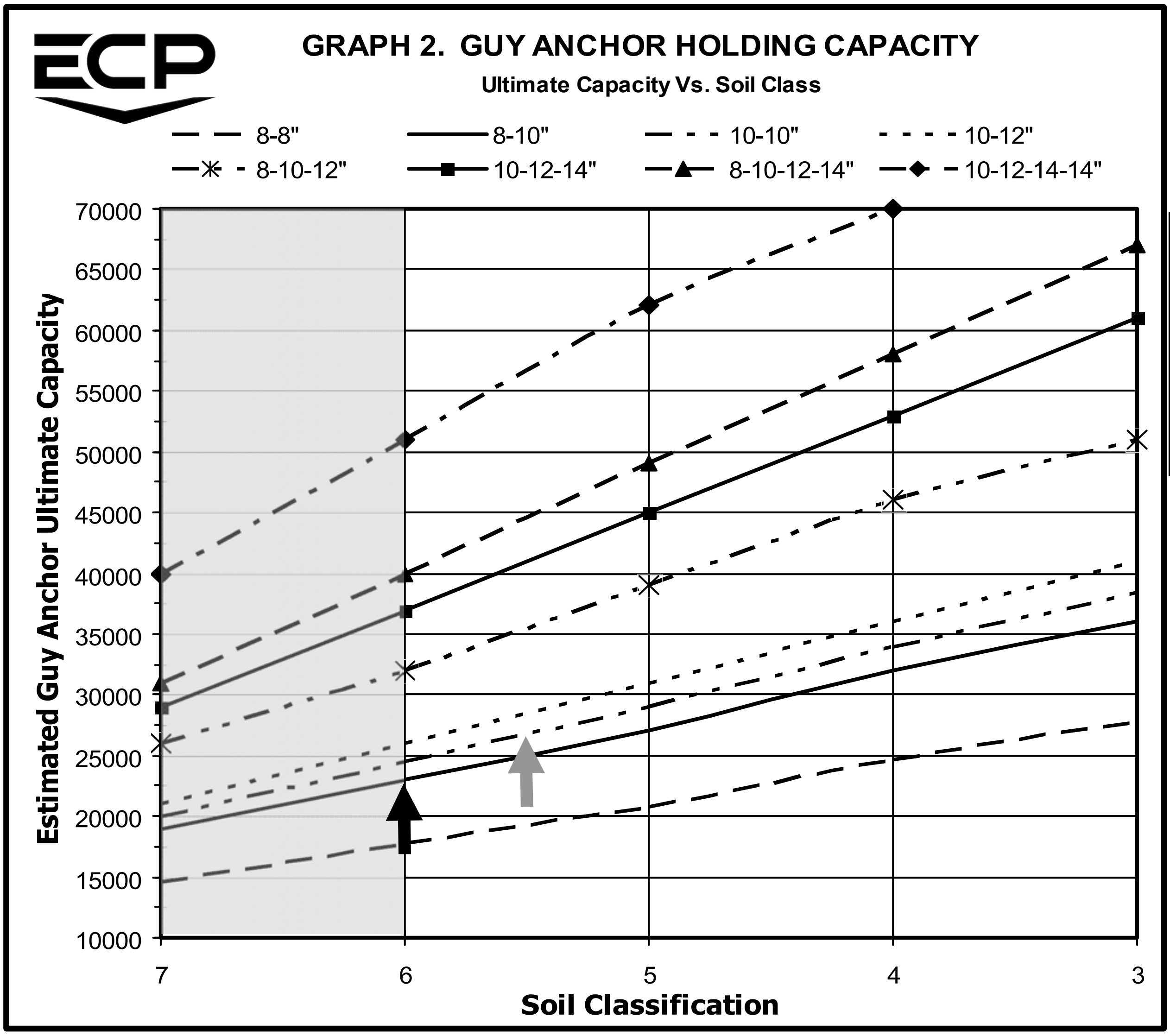
2. Select the proper tieback anchor from the estimated anchor holding capacity graph. Refer to Graph 2 (Reproduced below) and notice that the capacity line for an anchor with an 8” and a 10” diameter plates on the shaft and installed into class 6 soil is approximately 22,500 lb. (Black Arrow) this plate configuration is selected for the design.

3. Check the shaft strength and the torsional strength to see if the shaft is suitable. The ultimate tensile strength for this job was given at 22,500 lb. By referring to Table 2 in Chapter 1, it is found that the 1-1/2” solid square 1045 shaft product has a tensile strength rating of 50,000 pounds and a torsional capacity of 5,500 ft-lbs. This shaft configuration is suitable.



Sketch for Design Example 2 & 3

The 8” & 10” diameter plates attached to the 1-1/2” solid square shaft provides sufficient plate area, torsional capacity and tensile capacity for the stated ultimate load requirement.



4. Installation Torque. Use Graph 3 (Shown below.) to calculate the installation torque estimate for this anchor.

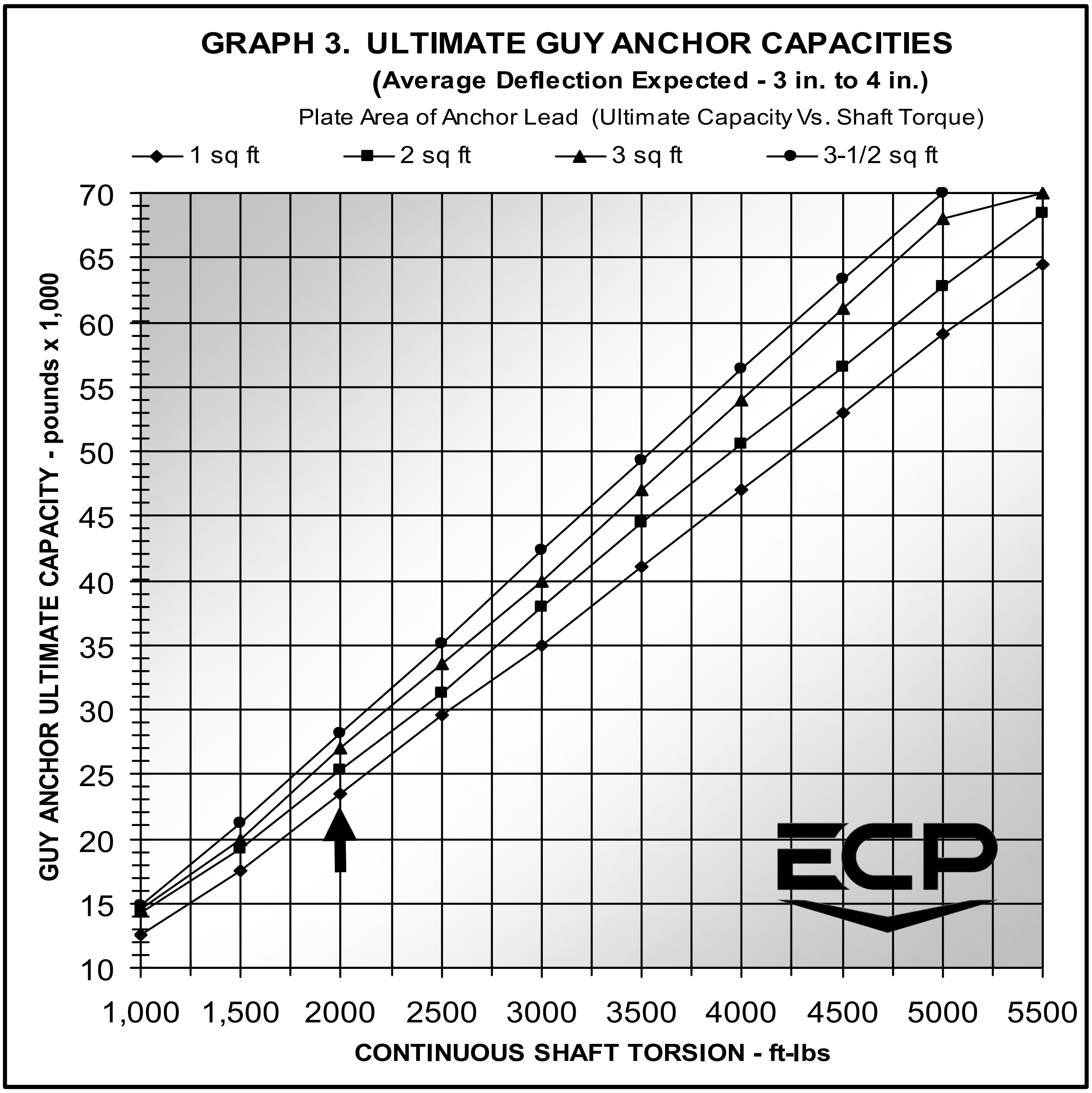
Referring to the product data in Chapter 1 for a 1-1/2 inch solid square lead with an 8" and 10" plate attached has a projected area of 0.86 ft^2. (Table 9 could also be used to determine the area. Referring to Table 9 an 8" diameter helical plate attached to a 1-1/2 inch solid square shaft has a projected area of 0.333 ft^2 and the 10" diameter plate has a projected area of 0.530 ft^2. The total area on the anchor with two plates is 0.863 ft^2.)

The shaft torque must be developed for a sufficient distance to insure that the helical plates are properly embedded to insure developing the ultimate tension capacity of 22,500 lbs. Referring to Graph 3 (Reproduced below) it can be seen that a guy anchor with a projected plate is of one square foot requires approximately 2,000 ft-lb to develop 22,500 lb ultimate capacity. (Black arrow)

Recalling that the 8" & 10" configuration only offers 0.863 ft^2, therefore either the torsion requirement must be increased or the anchor configuration increased to provide at least one square foot of plate area.

The guy anchor configuration is changed to 10" & 12", (TAF-150-42 10-12**)** which provides 1.30 ft^2 of plate area and Graph 3 confirms that the installation shaft torsion of 2,000 ft-lb will provide adequate capacity.

The torque requirement on the shaft must be applied continuously for a minimum distance of 3 feet.



5. Minimum Embedment Depth. From the previous discussion about sufficient soil overburden depth, the minimum requirement of 5 times the diameter of the shallowest plate is required and measured vertically from the ground surface to the upper plate.

Calculate the Minimum Embedment Depth:

Use 6 x $d_{largest\ plate.}$ (Soil Class – 6)
6 x (12" dia/ 12 in) (ft) = 6 feet
Minimum Vertical Depth = 6 feet.

6. Use the Design Installation Angle to Determine Product Length. The design shows the guy wire installation at 30^0 from vertical. The anchor must be installed at 30^0 +/- 5^0 to insure proper alignment to the guy wire. Using the specified installation angle of 30^0 from vertical, the minimum shaft length at 30^0 is determined that will produce a minimum of 5 feet of vertical distance from grade level to shallowest helical plate.

This can be determined as follows:

$L_{30\ Deg}$ = (6 ft / cosine 30^0)
$L_{30\ Deg}$ = 6 ft / 0.866 = 6.9 ft - **Use 7 ft.**

The minimum length of shaft needed before reaching the 12" diameter plate when installed at a 30^0 angle is 7 feet. This distance at a 30^0 angle to the pole will insure meeting the critical vertical depth from the surface of 6 feet. The minimum total shaft length required will be the sum of the 7 foot length from the surface to the 12" plate at 30^0 plus the distance on the shaft from the 12" diameter plate to the bottom of the anchor.

Recall that helical plates are spaced at three times the diameter of the helical plate directly below. In this design there is a 10" diameter plate at the bottom of the shaft and a 12" helical plate at the top. The distance between the two plates must be added to the minimum shaft length from surface to the 10" plate. The total minimum shaft length requirement for this installation is determined:

Minimum Required Shaft Length:

$\mathbf{L} = \mathbf{L}_{30\ Deg} + \mathbf{L}_{tip}$ (Where $\mathbf{L}_{tip}$ = 3 x 10" Plate)

L = 7 ft + (3 x 10" Dia Plate)/12 = **9-1/2 ft**

In order to insure a minimum installed shaft length, an extension that is at least seven feet long (TAE-150-84) must be attached to the 3-1/2 foot long lead section. It would be advised to have additional extensions on hand just in case the soil is softer than expected and the anchor needs to be installed deeper to achieve the calculated shaft torsion requirement of 2,000 ft-lb on the 10" – 12" plate configuration.

8. Torque Anchor™ Specifications. The Torque Anchor™ assembly will consist of:

- **TAF-150-42 10-12** -- 1-1/2" square bar 1045 steel with an 10" and a 12" diameter plate on a shaft that measures 3'-6" long,
- **TAE-150-84** extension – 7' extension bar & hardware, (6'-9" effective length).
- **TAA-150-003** – Triple Eye Adapter, with hardware.

End of Example 2

Design Example 3 – Guy Anchor in Cohesionless (Granular) Soil

Design Details:

- Guy Tension = 22,500 from Example 2.
- The soil information about the site indicated medium to coarse gravelly sand (SP), Loose to Medium dense – 110 pcf
- Standard Penetration Blow count "N" = 15 blows per foot from 10 feet to 20 deep
- $\Phi = 30^0$
- Soil Class 5 to 6
- Specifications call to use PITA guy anchor

Torque Anchor™ Design: This design example uses the same illustration and guy wire load as in the previous example.

1. Ultimate Tieback Capacity. Because the guy cable capacity was based upon ultimate cable load in the Design Details, we will not have to add a factor of safety for the anchor design.

2. Select the proper tieback anchor from the estimated anchor holding capacity graph. **R**efer to Graph 2 (See Graph 2 above - Example 2) and notice that the ultimate capacity line for a PITA guy anchor with two 10" dia. plates attached crosses midway between classes 5 and 6 soils at 26,500 lb. (Gray Arrow) The 10"- 10" dia. configuration is selected because the next smaller available PITA (8"-10") configuration suggests the ultimate capacity to be 19,000 lbs.

Referring to the product tables in Chapter 1 the Power Installed Torque Anchor, (TAPL-100-42 10-10) with two 10" dia. helical plates mounted to a one inch diameter PITA shaft is selected. The projected area of this configuration is 0.92 ft^2.

When installing in cohesionless (granular) soils the capacity of the anchor generally tends to increase with depth. In this example, the soil data suggests homogeneous sand to 20 ft. Increasing the depth of the 10" dia. plates is expected to increase the holding capacity due to increased soil overburden on the plates. By selecting an anchor with a projected area greater than necessary to generate 22,500 lb, the guy anchor may attain a terminal torque value before reaching 20 feet deep.

4. Verify shaft strength and the torsional strength to see if the selected shaft is suitable.

Table 3 shows the PITA lead on a 1" diameter bar has a torsional capacity of 6,000 ft-lbs. In addition, Table 3, Chapter 1 shows the 1" diameter PITA connecting rod offers an ultimate capacity of 36,000 lbs. This ultimate capacity rating exceeds the 22,500 lb. ultimate capacity of the guy wire design. It is a suitable anchor design for the job.

5. Installation Torque. The torque must be developed for a sufficient depth to insure that the helical plates are properly embedded and develop an adequate ultimate tension capacity of 22,500 lbs. Referring to Graph 3 above it can be seen that a guy anchor with a projected plate is of 1 ft^2 requires approximately 2,000 ft-lb to develop 23,000 lb ultimate capacity. (Black arrow) Notice that the 10" & 10" configuration only offers 0.92 ft^2, therefore the torsion requirement must be increased slightly. Adding 10% to the shaft torsion suggested on Graph 2 seems reasonable. **An installation torque of 2,200 ft-lb is selected**.

The torque must be developed for enough shaft length to insure that the helical plates are properly embedded and able to develop full tension capacity. The torque applied to the shaft must be applied continuously for a minimum distance of 3 ft. and the average torsion over this shaft length must meet or exceed the determined torque requirement of 2,200 ft-lb.

6. Minimum Embedment Depth. From the previous discussion about sufficient soil overburden depth, the minimum requirement of five times the diameter of the shallowest plate is required and is to be measured vertically from the surface to the upper plate.

Calculate the Minimum Embedment Depth:

Use 5 x $d_{largest\ plate.}$ (Soil Class – 5-6)
5 x (10" dia/ 12 in) (ft) = 4.2 feet
Minimum Vertical Depth = 4-1/2 feet.

However, from the Design Details given at the beginning of the design example, the target soil exists between 10 and 20 feet, and possibly deeper. Therefore, the calculated Minimum Embedment Depth for this example cannot be considered because the anchor must install deeper to reach suitable bearing soil. It is suggested to consider installing to a depth 18 to 20 feet to be conservative.

6. Use the Design Installation Angle to Determine Product Length. The design shows the guy wire installation at 30^0 from vertical. The anchor must be installed at 30^0 +/- 5^0 to insure proper alignment to the guy wire. Using the specified installation angle of 30^0 from vertical, the minimum shaft length at 30^0 is determined that will produce a maximum vertical distance of 20 feet from grade level to tip of the shaft.

This can be determined as follows:

$L_{30\ Deg}$ = (20 ft / cosine 30^0)
$L_{30\ Deg}$ = 20 ft / 0.866 = **23 ft. maximum**

For the guy anchor to remain within the target soil the maximum installation length of shaft installed at a 30^0 angle to the pole is needed to reach the verified depth of the medium to dense gravelly sand. The minimum total shaft length required will be the sum of the 3-1/2 foot length TAPL-100-36 10-10 plus one TARC-100-42 (3-1/2 ft. PITA Rod and Coupling Assembly) and two TARC-100-84 (7 foot PITA Rod and Coupling Assembly.) plus a 3-1/2 foot extension with a double eye adaptor (TARN-100-422) The total length of the assembled product is 24 feet. It is suggested to have some additional PITA Rod and Coupling Assemblies on hand to use if the torsion reaches the 2,200 ft-lb torque requirement either shallower or deeper than anticipated.

7. Torque Anchor™ Specifications. The Torque Anchor™ assembly will consist of:

- **TAPL-100-36 10-10** – 1-3/8 inch diameter PITA shaft with twin 10" diameter plates 3-1/2 ft. long with a connecting rod that measures one inch diameter,
- **TARC-100-42** extension – 3-1/2' extension bar & coupling assembly.
- **TARC-100-84** extension – 7' extension bar & coupling assembly. (two required)
- **TARN-100-422** – 3-1/2' Double Eye Adapter, with hardware.

End of Example 3

Tables for Estimating Guy Anchor Loads

Table 12. **Ultimate Strengths of Conductors**

Aluminum Stranded				ACSR Conductors							
Cir. Mils or AWG	No. Strands	Dia. (inch)	Ultimate Strength pounds	Cir. Mils or AWG	No. Strands	Dia. (inch)	Ultimate Strength pounds	Cir. Mils or AWG	No. Strands	Dia. (inch)	Ultimate Strength pounds
6	7	0.184	528	6	6x 1	0.198	1,170	477	30x 7	0.883	23,300
4	7	0.232	826	6	6x 1	0.223	1,490	556.5	30x 7	0.914	19,850
3	7	0.260	1,022	4	6x 1	0.250	1,830	556.5	26x 7	0.927	22,400
2	7	0.292	1,266	4	7x 1	0.257	2,288	556.5	30x 7	0.953	27,200
1	7	0.328	1,537	3	6x 1	0.281	2,250	605	24x 7	0.953	21,500
1/0	7	0.368	1,865	2	6x 1	0.316	2,790	605	26x 7	0.996	24,100
2/0	7	0.414	2,350	2	7x 1	0.325	3.525	605	30x 19	0.994	30,000
3/0	7	0.464	2,845	1	6x 1	0.355	3,480	636	24x 7	0.977	22,600
4/0	7	0.522	3,590	1/0	6x 1	0.398	4,280	636	26x 7	0.990	25,000
266.8	7	0.586	4,525	2/0	6x 1	0.447	5.345	636	30x 19	1.019	31,500
266.8	19	0.593	4,800	3/0	6x 1	0.502	6,675	666.6	24x 7	1.000	23,700
336.4	19	0.666	5,940	4/0	6x 1	0.563	8,420	715.5	54x 7	1.036	26,300
397.5	19	0.724	6,880	266.8	18x 1	0.609	7,100	715.5	26x 7	1.051	28,100
477	19	0.793	8,090	266.8	6x 7	0.633	9,645	715	30x 19	1.081	64,600
477	37	0.795	8,600	266.8	26x 7	0.642	11,250	795	54x 7	1.093	28,500
556.5	19	0.856	9,440	300	26x 7	0.680	12,650	795	26x 7	1.108	31,200
556.5	37	0.858	9,830	336.4	18x 1	0.684	8,950	795	30x 19	1.140	38,400
636	37	0.918	11,240	336.4	26x 7	0.721	14,050	874.5	54x 7	1.146	31,400
715.5	37	0.974	12,640	336.4	30x 7	0.741	17,040	900	54x 7	1.132	62,300
715.5	61	0.975	13,150	397.5	18x 1	0.743	10,400	954	54x 7	1.196	64,200
795	37	1.026	16,770	397.5	26x 7	0.783	16,190	1033.5	54x 7	1.246	37,100
795	61	1.028	14,330	397.5	30x 7	0.806	19,980	1113	54x 19	1.292	40,200
874.5	37	1.077	14,830	477	18x 1	0.814	12,300	1272	54x 19	1.382	44,800
874.5	61	1.078	15,760	477	24x 7	0.846	17,200	1431	54x 19	1.465	50,400
954	37	1.124	16,180	477	26x 7	0.858	19,430	1590	54x 19	1.545	56,000
954	61	1.126	16,860								
1033.5	37	1.170	17,530								
1033.5	61	1.172	18,260								
1113	61	1.215	19,660								
1272	61	1.300	22,000								
1431	61	1.379	24,300								
1590	61	1.424	27,000								
1590	91	1.454	28,100								

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Table 13.	Bisected Line Load To Be Guyed														
Line Load (lb)	Line Change Angle														
	20^0	25^0	**30^0**	35^0	40^0	**45^0**	50^0	55^0	**60^0**	65^0	70^0	**75^0**	80^0	85^0	**90^0**
	Resulting Line Load At One-Half Of The Angle Formed By The Line Change (pounds)														
2,000	694	866	**1,036**	1,202	1,368	**1,530**	1,690	1,848	**2,000**	2,150	2,294	**2,436**	2,572	2,702	**2,828**
4,000	1,388	1,732	**2,072**	2,404	2,736	**3,060**	3,380	3,696	**4,000**	4,300	4,588	**4,872**	5,144	5,404	**5,656**
6,000	2,082	2,598	**3,108**	3,606	4,104	**4,590**	5,070	5,544	**6,000**	6,450	6,882	**7,308**	7,716	8,106	**7,070**
8,000	2,776	3,464	**4,144**	4,808	5,472	**6,120**	6,760	7,392	**8,000**	8,600	9,176	**9,744**	10,288	10,808	**11,312**
10,000	3,470	4,330	**5,180**	6,010	6,840	**7,650**	8,450	9,420	**10,000**	10,750	11,470	**12,180**	12,860	13,250	**14,140**
12,000	4,164	5,196	**6,216**	7,212	8,208	**9,180**	10,140	11,088	**12,000**	12,900	13,764	**14,616**	15,432	16,212	**16,968**
14,000	4,858	6,062	**7,252**	8,414	9,576	**10,710**	11,830	12,936	**14,000**	15,050	16,058	**17,052**	18,004	18,914	**19,796**
16,000	5,552	6,928	**8,288**	9,616	10,944	**12,240**	13,520	14,784	**16,000**	17,200	18,352	**19,488**	20,576	21,616	**22,624**
18,000	6,246	7,794	**9,324**	11,818	12,312	**13,770**	15,210	16,632	**18,000**	19,350	20,646	**21,924**	23,148	24,318	**25,452**
20,000	6,940	8,660	**10,360**	12,020	13,680	**15,300**	16,900	18,480	**20,000**	21,500	22,940	**24,360**	25,720	27,720	**28,280**
22,000	7,634	9,526	**11,396**	13,222	15,048	**16,830**	18,590	20,328	**22,000**	23,650	25,234	**26,796**	28,292	29,722	**31,108**
24,000	8,328	10,392	**12,432**	14,424	16,416	**18,360**	20,280	22,176	**24,000**	26,800	27,528	**29,232**	30,864	32,424	**33,936**
26,000	9,022	11,258	**13,468**	15,626	17,784	**19,890**	21,970	24,024	**26,000**	27,950	29,822	**31,668**	33,436	35,126	**36,764**
28,000	9,716	12,124	**14,504**	16,828	19,152	**21,420**	23,660	25,872	**28,000**	30,100	32,116	**34,104**	36,008	37,828	**39,592**
30,000	10,410	12,990	**15,540**	18,030	20,520	**22,950**	25,350	27,720	**30,000**	32,250	34,410	**36,540**	38,580	40,530	**42,420**
32,000	11,104	13,856	**16,576**	19,232	21,888	**24,480**	27,040	29,568	**32,000**	34,400	36,704	**38,976**	41,152	43,232	**45,248**
34,000	11,798	14,722	**17,612**	20,434	23,256	**26,010**	28,730	31,416	**34,000**	36,550	38,998	**41,412**	43,724	45,934	**48,076**
36,000	12,492	15,558	**18,648**	21,636	24,624	**27,540**	30,420	33,264	**36,000**	38,700	41,292	**43,848**	46,296	48,636	**50,904**
38,000	13,186	16,454	**19,684**	22,838	25,992	**29,070**	32,110	35,112	**38,000**	40,850	43,586	**46,284**	48,868	51,338	**53,732**
40,000	13,880	17,320	**20,720**	24,040	27,630	**30,600**	33,800	36,960	**40,000**	43,000	45,880	**48,720**	51,440	54,040	**56,560**
42,000	14,574	18,186	**21,756**	25,242	28,728	**32,130**	35,490	38,808	**42,000**	45,150	48,174	**51,156**	54,012	56,742	**59,388**
44,000	15,268	19,052	**22,792**	26,444	30,096	**33,660**	37,180	40,656	**44,000**	47,300	50,468	**53,592**	56,584	59,444	**62,216**
46,000	15,962	19,918	**23,828**	27,646	31,464	**35,190**	38,870	42,504	**46,000**	49,450	52,762	**56,028**	59,156	62,146	**65,044**
48,000	16,656	20,784	**24,864**	28,848	32,832	**36,720**	40,560	44,352	**48,000**	51,600	55,056	**58,464**	61,728	64,848	**67,872**
50,000	17,350	21,650	**25,900**	30,050	34,200	**38,250**	42,250	46,200	**50,000**	53,750	57,350	**60,900**	64,300	67,550	**70,700**

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Table 14.	**Guy Load**														
Line or Dead End Load (lb)	**Guy Wire Angle From Pole**														
	15°	20°	**25°**	30°	35°	**40°**	45°	50°	**55°**	60°	65°	**70°**	75°	80°	**85°**
	Resulting Guy Load At Install Angle (pounds)														
2,000	7,727	5,848	**4,732**	4,000	3,487	**3,111**	2,828	2,611	**2,442**	2,309	2,207	**2,128**	2,071	2,031	**2,008**
4,000	15,455	11,695	**9,465**	8,000	6,974	**6,223**	5,657	5,222	**4,883**	4,619	4,414	**4,257**	4,141	4,062	**4,015**
6,000	23,182	17,543	**14,197**	12,000	10,461	**9,334**	8,485	7,832	**7,325**	6,928	6,620	**6,385**	6,212	6,093	**6,023**
8,000	30,910	23,290	**18,930**	16,000	13,948	**12,446**	11,314	10,443	**9,766**	9,238	98,827	**8,513**	8,282	8,123	**8,031**
10,000	38,637	29,288	**23,662**	20,000	17,434	**15,557**	14,142	13,054	**12,208**	11,547	11,034	**10,642**	10,353	10,154	**10,038**
12,000	46,364	35,086	**28,394**	24,000	20,921	**18,669**	16,971	15,665	**14,649**	13,856	13,241	**12,770**	12,423	12,185	**12,046**
14,000	54,092	40,933	**33,127**	28,000	24,408	**21,780**	19,799	18,276	**17,091**	16,166	15,447	**14,898**	14,494	14,216	**14,053**
16,000	61,819	46,781	**37,859**	32,000	27,895	**24,892**	22,627	20,887	**19,532**	18,475	17,654	**17,027**	16,564	16,247	**16,061**
18,000	69,547	52,628	**42,592**	36,000	31,382	**28,003**	25,456	23,497	**21,974**	20,785	19,861	**19,155**	18,635	18,278	**18,069**
20,000	77,274	58,476	**47,324**	40,000	34,869	**31,114**	28,284	26,108	**24,415**	23,094	22,068	**21,284**	20,706	20,309	**20,076**
22,000	85,001	64,234	**52,056**	44,000	38,356	**34,226**	31,113	28,719	**26,857**	25,403	24,274	**23,412**	22,776	22,339	**22,084**
24,000	92,729	70,171	**56,789**	48,000	41,843	**37,337**	33,941	31,330	**29,299**	27,713	26,481	**25,540**	24,847	24,370	**24,092**
26,000	100,456	76,019	**61,521**	52,000	45,330	**40,449**	36,770	33,941	**31,740**	30,022	28,688	**27,669**	26,917	26,401	**26,099**
28,000	108,184	81,867	**66,254**	56,000	48,817	**43,560**	39,598	36,551	**34,182**	32,332	30,895	**29,797**	28,988	28,432	**28,107**
30,000	115,911	87,714	**70,986**	60,000	52,303	**46,672**	42,426	39,162	**36,623**	34,641	33,101	**31,925**	31,058	30,463	**30,115**
32,000	123,639	93,562	**75,718**	64,000	55,790	**49,783**	45,255	41,773	**39,065**	36,950	35,308	**34,054**	33,129	32,494	**32,122**
34,000	131,366	99,409	**80,451**	68,000	59,277	**52,895**	48,083	44,384	**41,506**	39,260	37,515	**36,182**	35,199	34,525	**34,130**
36,000	139,093	105,257	**85,183**	72,000	62,764	**56,006**	50,912	46,995	**43,948**	41,569	39,722	**38,310**	37,270	36,555	**36,138**
38,000	146,812	111,105	**89,916**	76,000	66,251	**59,118**	53,740	49,605	**46,389**	43,879	41,928	**40,439**	39,340	38,856	**38,145**
40,000	154,548	116,952	**94,648**	80,000	69,738	**62,229**	56,569	52,216	**48,831**	46,188	44,135	**42,567**	41,411	40,617	**40,153**
42,000	162,276	122,800	**99,380**	84,000	73,225	**65,340**	59,397	5,827	**51,273**	48,497	46,342	**44,695**	43,482	42,648	**42,160**
44,000	170,003	128,674	**104,113**	88,000	76,712	**68,452**	62,225	57,438	**53,714**	50,807	48,549	**46,824**	45,552	44,679	**44,168**
46,000	177,730	134,495	**108,845**	92,000	80,199	**71,563**	65,054	60,049	**56,156**	53,116	50,755	**48,952**	47,623	46,710	**46,176**
48,000	185,458	140,343	**113,578**	96,000	83,685	**74,675**	67,882	62,660	**58,597**	55,426	52,962	**51,081**	49,693	48,740	**48,183**
50,000	193,185	146,190	**118,310**	100,000	87,172	**77,786**	70,711	65,270	**61,039**	57,735	55,169	**53,209**	51,764	50,771	**50,191**

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Table 15. Breaking Strengths of Stranded Guy Wire (pounds)

Zinc Coated Steel Wire Strand

Diameter-Strands	Utilities Grade	Common Grade	Siemens Martin Grade	High Strength Grade	Ex High Strength Grade
1/8" – 7	N/A	540	910	1,330	1,830
5/32" - 7		870	1,470	2,140	2,940
3/16" - 7	2,400	1,150	1,900	2,850	3,990
7/32" – 3	N/A	1,400	2,340	3,500	4,900
7/32" -7		1,540	2,560	3,850	5,400
1/4" – 3	3,150	1,860	3,040	4,730	6,740
1/4" -7	N/A	1,900	3,150	4,750	6,650
9/32" – 3		2,080	3,380	5,280	7,500
9/32" – 7	4,600	2,570	4,250	6,400	8,950
5/16" – 3	6,500	2,490	4,090	6,350	9,100
5/16" - 7	6,000	3,200	5,350	8,000	11,200
3/8" – 3	8,500	3,330	5,560	8,360	11,800
3/8" – 7	11,500	4,250	6,950	10,800	15,400
7/16" – 7	18,000	5,700	9,350	14,500	20,800
1/2" – 7	25,000	7,400	12,100	18,800	26,900
1/2" – 19	N/A	7,620	12,700	19,100	26,700
9/16" – 7		9,600	15,700	24,500	25,000
9/16" -19		9,640	16,100	24,100	33,700
5/8" – 7		11,600	19,100	29,600	42,400
5/8" – 19		11,000	18,100	28,100	40,200
3/4" – 19		16,000	26,200	40,800	58,300
7/8" – 19		21,900	35,900	55,800	79,700
1" – 19		28,700	47,000	73,200	104,500
1" – 37		28,300	46,200	71,900	102,700
1-1/8" -37		36,000	58,900	91,600	130,800
1-1/4" -37		44,000	73,000	113,300	162,200

Aluminum Coated Steel Wire Strand

Diameter-Strands	Utilities Grade	Common Grade	Siemens Martin Grade	High Strength Grade	Ex High Strength Grade
3/16" – 7	2,400	1,150	1,900	2,850	N/A
1/4" – 3	3,150	N/A	N/A	N/A	N/A
1/4" – 7	N/A	1,900	3,150	4,750	6,650
9/32" -7	4,600	N/A	N/A	N/A	N/A
5/16" – 3	6,500	N/A	N/A	N/A	N/A
5/16" – 7	6,000	3,200	5,350	8,000	11,200
3/8" -3	8,500	N/A	N/A	N/A	N/A
3/8" - 7	11,500	4,250	6,950	10,850	15,400
7/16" -7	18,000	5,700	9,350	14,500	20,800
1/2" - 7	25,000	7,400	12,100	18,800	26,900

Aluminum-Clad Steel Wire Strand

No. & (AWG)	Dia.	Breaking Strength	No. & (AWG)	Dia.	Breaking Strength
3 - #10	0.220"	4,532	7 - #5	0.546"	27,030
3 - #9	0.247"	5,715	19 - #10	0.509"	27,190
3 - #8	0.277"	7,206	19 - #9	0.572"	34,290
3 - #7	0.311"	8,621	19 - #8	0.642"	43,240
3 - #6	0.349"	10,280	19 - #7	0.721"	51,730
3 - #5	0.392"	12,230	19 - #6	0.810"	61,700
7 - #12	0.242"	6,301	19 - #5	0.910"	73,350
7 - #11	0.272"	7,945	37 - #10	0.713"	59,950
7 - #10	0.306"	10,020	37 - #10	0.801"	66,770
7 - #9	0.343"	12,630	37 - #10	0.899"	84,180
7 - #8	0.385"	15,930	37 - #10	1.010"	100,700
7 - #7	0.433"	19,060	37 - #10	1.130"	120,100
7 - #6	0.486"	22,730	37 - #10	1.270"	142,900

Aluminum-Clad Steel Wire M-Strand

Size	Dia.	Breaking Strength	Size	Dia.	Breaking Strength	Size	Dia.	Breaking Strength	Size	Dia.	Breaking Strength
4M	0.220"	4,000	8M	0.277"	7,000	12.5M	0.343"	12,500	18M	0.417"	18,000
5M	0.247"	5,000	9M	0.272"	8,000	14M	0.363"	14,000	20M	0.444"	20,000
6M	0.242"	6,000	10M	0.306"	10,000	16M	0.386"	16,000	25M	0.519"	25,000

Chapter 3

Compression
Pile Design

Compressive Design for ECP Helical Torque Anchors™

- **Tubular Helical Torque Anchors™**
- **Solid Square Shaft Torque Anchors™**
- **Helical Torque Anchors™ for Light Poles**

ECP

"Designed and Engineered to Perform"

Compressive Helical Torque Anchor™ Design Considerations

The bearing capacity theory equations, tables and Graph 1 can all be used when designing for support of compressive loads.

Helical Torque Anchors™ are found in many axial compression applications such as underpinning for structures, equipment frames, etc. Most of the design information from the previous tension application chapter is applicable for compressive load applications but there are some additional considerations that must be discussed.

> Take care not to use tables and graphs that were provided for use only with guy anchor loads.

Table 16. 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	Helical Pile Shaft to Threaded Bar
New Construction Pile Caps	TAB–NC	New Construction Compression Pile Cap
	TAB-T	New Construction Tension Pile Cap
	TAB–TS	New Construction Pile Cap with Alignment Stud

Table 17. 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 Torsional Strength
1-1/2" Square Bar	9 - 11	70,000 lb.	70,000 lb.	7,000 ft-lb	Load limited to the rated capacity of the attachments and the lateral soil strength against the shaft
1-3/4" Square Bar	9 - 11	100,000 lb.	100,000 lb.	10,000 ft-lb	
2-1/4" Square Bar	10 - 12	200,000 lb.	200,000 lb.	23,000 ft-lb	
2-7/8" Tube – 0.262" Wall	8 - 9	100,000 lb.	100,000 lb.	9,500 ft-lb	80,000 lb
3-1/2" Tube – 0.300" Wall	7 - 8	115,000 lb.	120,000 lb.	13,000 ft-lb	97,000 lb
4-1/2" Tube – 0.337" Wall	6 - 7	160,000 lb.	160,000 lb.	22,000 ft-lb	143,000 lb

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

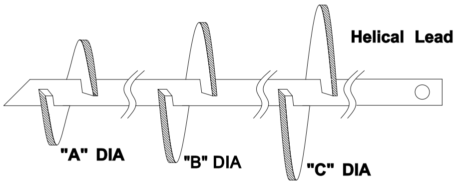
IMPORTANT NOTES:

The capacities listed for Axial Compression, Tension and Torsion in Table 17 are mechanical ratings. One must understand that the actual installed load capacities for the product are dependent upon the actual soil conditions on a specific job site. The shaft "Useable 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 to the shaft. In homogeneous soils it might be possible to achieve up to 95% or more of the "Useable Torsional Strength" shown in Table 17. In obstruction-laden soils, torsion spikes experienced by the shaft may cause impact fractures of the couplings or other components. Where impact loading is expected, reduce shaft torsion by 30% or more from "Useable Torsional Strength" depending upon site soil conditions to reduce chance of fracture or damage.

Another advantage of selecting a torsional rating below the values shown in Table 17 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 on the following pages. Special configurations to fit your project can be fabricated to your specifications upon request.

Round Corner Square Bar ECP Torque Anchors™



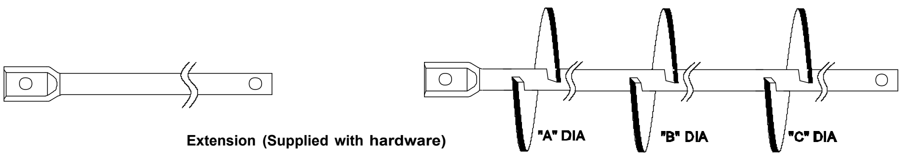
1-1/2” Shaft Standard Lead Configurations – 7,000 ft-lb

Product Designation	Plate Diameter - inches			Plate Area sq. ft.	Length
	“A”	“B”	“C”		
TAF-150-36 08-10	8	10	--	0.86	3’-0”
TAF-150-42 10-12	10	12	--	1.30	3’-6”
TAF-150-60 10-12	10	12	--	1.30	5’-0”
TAF-150-84 10-12	10	12	--	1.30	7’-0”
TAF-150-66 08-10-12	8	10	12	1.63	5’-6”
TAF-150-84 10-12-14	10	12	14	2.35	7’-0”
TAF-150-120 10-12-14	8	10	12	2.35	10’-0”
TAF-150-120 14-14-14	14	14	14	3.16	10’-0”

1-3/4” Shaft Standard Lead Configurations – 11,000 ft-lb

Product Designation	Plate Diameter - inches			Plate Area sq. ft.	Length
	“A”	“B”	“C”		
TAF-150-36 08-10	8	10	--	0.85	3’-0”
TAF-150-66 08-10-12	8	10	12	1.62	5’-6”
TAF-150-84 10-12-14	8	10	12	2.66	7’-0”
TAF-150-120 14-14-14	14	14	14	3.14	10’-0”

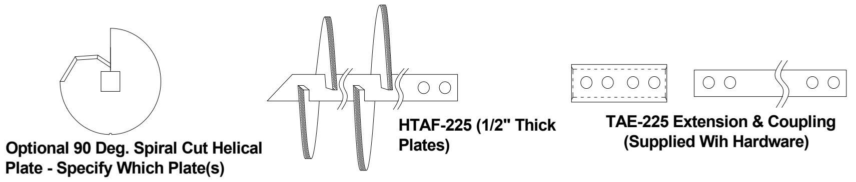
1-1/2” and 1-3/4” Shaft Standard Extension Configurations



Product Designation		Plate Diameter - inches			Plate Area - ft² (1-1/2” / 1-3/4”)	Length
1-1/2” Shaft	1-3/4” Shaft	“A”	“B”	“C”		
TAE-150-36	TAE-175-36	--	--	--	n/a	3’-0”
TAE-150-60	TAE-175-60	--	--	--	n/a	5’-0”
TAE-150-84	TAE-175-84	--	--	--	n/a	7’-0”
TAE-150-120	TAE-175-120	--	--	--	n/a	10-0”
TAE-150-36 14	TAE-175-36 14	14	--	--	1.05 / 1.05	3’-0”
TAE-150-60 14	TAE-175-60 14	14	--	--	1.05 / 1.05	5’-0”
TAE-150-84 14-14	TAE-175-84 14-14	14	14	--	2.11 / 2.10	7’-0”
TAE-150-120 14-14-14	TAE-175-120 14-14-14	14	14	14	3.16 / 3.14	10’-0”

Note: The 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 100
Shaft Weight per Foot – 1-1/2” shaft = 7.7 lb/ft; 1-3/4” shaft = 10.4 lb/ft

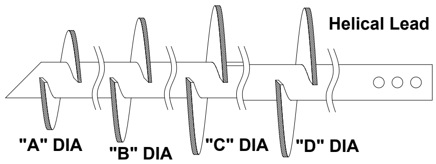
2-1/4” Shaft Standard Extension Configurations – 23,000 ft-lb



2-1/4” Square Bar Torque Anchor™ Extensions				
Shaft Length	36”	60”	84”	120”
Part Number	**TAE-225-36**	**TAE-225-60**	**TAE-225-84**	**TAE-225-120**

Note: All 2-1/4” square bar lead sections are available as special order – Inquire for pricing and delivery
Helical plates are 1/2” thick and spaced at three times the diameter of the preceding plate.
Extensions supplied with coupling and SAE J429 grade 8 bolts and nuts.
Product is hot dip galvanized per ASTM A123 grade 100. Shaft weight per foot – 17.2 lb.

Tubular Shaft Torque Anchor™ Lead Sections



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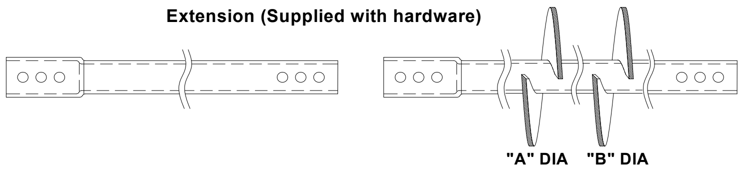
2-7/8” Dia. x 0.262” Wall Tubular Shaft Torque Anchor™ Configurations – 9,500 ft-lb						
Product Designation	**Plate Diameter - inches**				**Plate Area sq. ft.**	**Length**
	“A”	**“B”**	**“C”**	**“D”**		
TAF-288-60 10-12	10	12			1.24	5’-0”
TAF-288-60 12-14	12	14			1.76	5’-0”
TAF-288-84 10-12-14	10	12	14		2.26	7’-0”
TAF-288-120 12-14-14	12	14	14		2.79	7’-0”
TAF-288-126 08-10-12-14	8	10	12	14	2.57	10’-0”
TAF-288-126 10-12-14-14	10	12	14	14	3.29	10’-0”
TAF-288-174 12-14-14-14	12	14	14	14	3.81	14’-6’

3-1/2” Dia. x 0.300” Wall Tubular Shaft Torque Anchor™ Configurations – 13,000 ft-lb						
Product Designation	**Plate Diameter - inches**				**Plate Area sq. ft.**	**Length**
	“A”	**“B”**	**“C”**	**“D”**		
TAF-350-60 10-12	10	12			1.20	5’-0”
TAF-350-60 12-14	12	14			1.72	5’-0”
TAF-350-84 10-12-14	10	12	14		2.20	7’-0”
TAF-350-120 12-14-14	12	14	14		2.72	7’-0”
TAF-350-126 08-10-12-14	8	10	12	14	2.48	10’-0”
TAF-350-126 10-12-14-14	10	12	14	14	3.20	10’-6”
TAF-350-180(12-14-14-14	12	14	14	14	3.73	15’-0”

4-1/2” Dia. x 0.337” Wall Tubular Shaft Torque Anchor™ Configurations – 22,000 ft-lb						
Product Designation	**Plate Diameter - inches**				**Plate Area sq. ft.**	**Length**
	“A”	**“B”**	**“C”**	**“D”**		
TAF-450-60 10-14	10	14			1.39	5’-0”
TAF-450-84 08-10-14	8	10	14		1.63	7’-0”
TAF-450-84 10-12-14	10	12	14		2.07	7’-0”
TAF-450-126 08-10-12-14	8	10	12	14	2.31	10’-0”
TAF-450-180 10-12-14-14	10	12	14	14	3.03	15’-0”

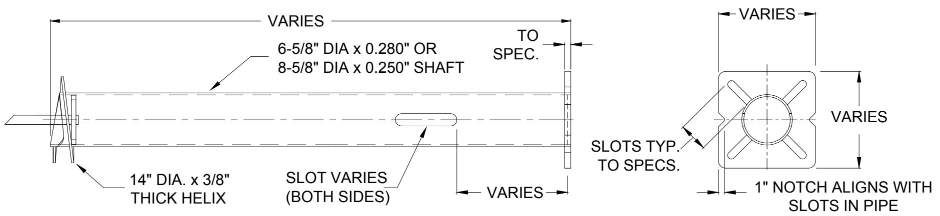
Tubular Shaft Standard Extension Configurations



Product Designation			Plate Diameter		Plate Area - ft² (2-7/8" / 3-1/2" / 4-1/2)	Length
2-7/8" Shaft	3-1/2" Shaft	4-1/2" Shaft	"A"	"B"		
TAE-288-36	TAE-350-36	TAE-450-36	--	--	n/a	3'-0"
TAE-288-60	TAE-350-60	TAE-450-60	--	--	n/a	5'-0"
TAE-288-84	TAE-350-84	TAE-450-84	--	--	n/a	7'-0"
TAE-288-120	TAE-350-120	TAE-350-120	--	--	n/a	10-0"
TAE-288-60 14	TAE-350-60 14	TAE-450-60 14	14"	--	1.02 / 1.00 / 0.96	5'-0"
TAE-288-84 14-14	TAE-350-84 14-14	TAE-450-84 14-14	14"	14"	2.05 / 2.00 / 1.92	7'-0"

Note: The tubular 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 6" less than overall dimension due to coupling overlap
All product hot dip galvanized per ASTM A123 grade 100
Shaft Weight per Foot – 2-7/8" dia, shaft = 7.7 lb/ft; 3-1/2" dia. shaft = 10.2 lb//ft; 4-1/2" dia. shaft = 15.4 lb/ft

Light Pole Anchor Configurations



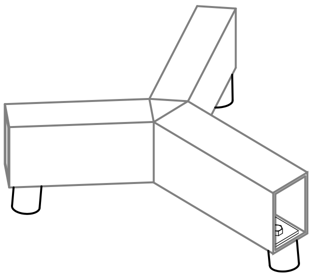
NOTE: 4" DIA FOUNDATION ANCHOR CONFIGURATION IS SIMILAR - NOT SHOWN

Product Designation		Shaft Size	Plate Diameter	Length	Ultimate-Limit Capacity at SPT ≥ 5 bpf	
Stinger End	Double Chamfer				Overturning Moment	Lateral Load
LPS-400-60 12	LPC-400-60 12	4"	12"	5'-0"	< 5,000 ft-lb	< 500 lb
LPS-663-60 14	LPC-663-60 14	6-5/8" x 0.280" Wall	14"	5'-0"	< 12,000 ft-lb	< 1,000 lb
LPS-663-84 14	LPC-663-84 14			7'-0"		
LPS-663-120 14	LPC-663-120 14			10'-0"		
LPS-863-60 14	LPC-863-60 14	8-5/8" X 0.250" Wall	14"	5'-0"	< 17,500 ft-lb	< 1,200 lb
LPS-863-84 14	LPC-863-84 14			7'-0"		
LPS-863-120 14	LPC-863-120 14			10'-0"		

Notes: Standard Product Shown Includes:
Standard Integral Pile Cap - 1" thick x 15-3/4" Square pile cap welded to shaft
Standard 1-1/8" slots are designed for 1" diameter mounting bolts
Cable Access Slot available on both sides of shaft – (2" x 10" Standard)
Supplied Hot Dip Galvanized Per ASTM A123 Grade 100.
Stinger End (LPS) has single chamfer on bottom of shaft with a "stinger" for alignment
Double Chamfer on bottom of LPC product shafts to ease installation - No "Stinger" on LPC (Not Shown)
Special Product Designs Are Available: We fabricate custom light pole supports to your design specifications
Please allow extra time for Special Product Designs.

EARTH CONTACT PRODUCTS - *"Designed and Engineered to Perform"*

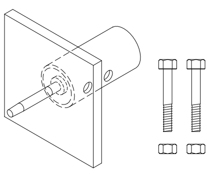
Foundation Grillages



Product Designation	Configuration	Ultimate Capacity kips	Max Service Load kips
2-7/8" Diameter Shafts			
ZTAG-288-336	Tripod – 36" Legs	250	125
ZTAG-288-436	Quad pod – 36" Legs	320	160
3-1/2" Diameter Shafts			
ZTAG-350-336	Tripod – 36" Legs	275	135
ZTAG-HD-350-336	Tripod – 36" Legs	300	150
ZTAG- 350-436	Quad pod – 36" Legs	390	195
4-1/2" Diameter Shafts			
ZTAG-450-336	Tripod – 36" Legs	360	180
ZTAG-HD-450-336	Tripod – 36" Legs	430	215
ZTAG-450-436	Quad pod – 36" Legs	575	285

Notes: Foundation grillages are custom fabricated to specification.
The appearance of the grillage will vary from the illustration depending upon the project load capacity requirement.
The recommended service load includes a factor of safety of 2.0.

Tubular Pile Cap



Part Number	TAB-288 075 TS 08	TAB-350 075 TS 08	TAB-450 1 TS 10
Pile Size	2-7/8" Dia. Tubular	3-1/2" Dia. Tubular	4-1/2" Dia. Tube
Bearing Plate	3/4" x 8" x 8"		1" x 10" x 10"
Alignment Pin	1 in. Dia x 4 in Long		
Pier Sleeve	3-1/2" Dia. x 7-3/4"	4" Dia. x 7-3/4"	5-9/16" Dia. x 9-3/4"
Ultimate-Limit Capacity	70,000 lb.	70,000 lb.	120,000 lb.

Pile Cap Notes:
1. Part numbers for "TS" Pile Caps include attachment holes and SAE J429 Grade 8 hardware and alignment pin as shown
2. Compressive capacity ratings of some pile caps are limited by compressive pile shaft capacity.
3. Pile caps are supplied hot dip galvanized per ASTM A123 Grade 100.
*Custom fabricated pile caps are available for all shaft sizes by special order – allow extra time for processing.

Preventing "Punch Through" in Compression Applications: A soil boring on occasion may report a layer of competent soil overlaying a soft, weaker stratum of soil. When designing the Torque Anchor™ pile to achieve axial compressive bearing in the competent soil that is situated above a weaker soil layer, one must consider the possibility that the Torque Anchor™ could "punch through" to the weaker soil when fully loaded.

It is recommended when designing a helical pile in compressive loading that one be aware of the soil characteristics that exist below the bottom of the pile to a depth that is at least five times the diameter of the lowest (smallest) helical plate (**5 x d_{lowest}**). If the soil below the lowest helical plate is as good as or better than the soil where the other helical plates reside for at least five diameters, the opportunity of "punch through" (pile failure) into the weaker soil stratum is very unlikely.

Minimum Embedment Depth: In Chapter 2 it was explained that the bearing capacity equation presented in this manual accurately predicts ultimate capacity only when the helical pile qualifies as a deep foundation. A deep helical foundation element is defined as having a minimum depth from finished grade to the shallowest plate of five times the diameter of the shallowest helical plate in Soil Classes 4 and 5 and six times the diameter in Soil Classes 6 and 7.

When a helical plate or plates are less than this minimum vertical depth from the finished grade, the foundation acts as if it is a shallow footing and the bearing capacity equation presented here may not accurately predict ultimate pile capacity.

Torque Anchor™ Compressive Installation Limits

Shaft Strength: The data in Table 17 gives the strength ratings for various shaft configurations in axial tension, compression and in torsion. The values are from mechanical testing and not from tests to soils. Because Torque Anchor™ products are installed by rotating the shaft into the soil; the torsional strength of the shaft can limit the ultimate capacity of the product. The "*Useable Torsional Strength*" column in Table 17 indicates the maximum installation torque that should be intentionally applied to the Torque Anchor™ shaft during installation into ***homogeneous*** soil. The risk of product failure dramatically increases when one exceeds these limits or encounters obstructions.

When choosing a helical 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 safety margin will provide for the increased torque experienced during the final embedment length after the design shaft torsion 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 installation torque requirement be allowed to insure proper embedment, and to prevent impact fractures when installing into non-homogeneous soils.

It is important to also understand that the "*Empirical Shaft Efficiency*" factor, "k", reduces the practical limit on ultimate capacity that can be developed by a pile shaft in the soil. This is especially important when designing with the larger tubular products because large tubular shafts pass through the soil less efficiently than smaller tubular shafts or solid square bars. One can see from the Table 11 in Chapter 2 that more torque energy is lost due to soil friction as shaft diameters increase. Because tubular shafts produce greater friction against the soil during installation, one cannot use the same "*ten times the torsion"* rule of thumb used with square shaft products to estimate ultimate tubular pile capacity. Please refer to Equation 2 and Table 11 in Chapter 2 for details.

Buckling Loads in Weak Soil: When a slender column does not have adequate lateral support from the soil, the load carrying capacity of the column is reduced as buckling of the shaft becomes an issue. When the tubular Torque Anchor™ is installed through a soft soil that has a Standard Penetration Test (SPT) value "N" ≤ 4 blows per foot ("N" ≤ 5 for square shafts), the possibility of shaft buckling must be considered in assessing available axial compressive capacity of the pile design.

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

Another situation where shaft buckling should be considered is when both axial compression and lateral forces are acting upon the pile at the surface. If the pile terminates within a concrete footing, lateral restraint is usually not a problem because the designer is able to constrain the lateral movement with the concrete footing design.

When the pile is not fixed at the surface, there may be factors present that affect shaft buckling. These factors include shaft diameter, length, soil density soil strength, and pile cap attachment design.

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 method of estimating critical buckling is by hand calculations using the 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 assumed to be straight. Davisson's formula is presented as Equation 4.

Table 18 Torque Anchor™ Shaft Stiffness Comparison			
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	22%
TA-175 (1-3/4" Square)	3.00	0.74	40%
TA-225 (2-1/4" Square)	5.00	2.04	110%
TA288L (2-7/8" Dia x 0.203")	1.70	1.53	82%
TA288 (2-7/8" Dia x 0.262")	**2.08**	**1.85**	**100%**
TA350 (3-1/2" Dia x 0.300")	3.02	3.89	206%
TA450 (4-1/2" Dia x 0.337")	4.41	9.61	519%

Computer analysis of shaft buckling is the recommended method to achieve the most accurate results. Many times, however, one must have general buckling information to prepare a preliminary design or budget proposal. Table 19 presented at right provides critical buckling load estimates for various shaft sizes penetrating through different types of weak *homogeneous soil*.

Equation 4: Critical Buckling Load

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

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
$R = \sqrt[4]{E_p I_p / k_H d}$
k_H = Modulus of Sub grade Reaction (10 – 75 pci)
d = Shaft Diameter – in

Shaft Stiffness: It is important to understand that tubular shafts have superior buckling resistance than solid square bars when used in axial compression applications. This is because tubular shafts have greater flexural stiffness and have more resistance to buckling under load. Engineers say tubular shafts have larger *Moment of Inertias*. In most tubular pile configurations, a larger shaft diameter will provide greater resistance to lateral deflection and/or shaft buckling within the soil.

Table 18 illustrates how the tubular piles have superior shaft stiffness when compared to solid square bars. It is interesting to note in Table 17 at the beginning of this chapter that when the 2-7/8 inch diameter, 0.262 inch wall tubular shaft or the 1-3/4 inch solid square bar anchor, which have similar potential capacities, are installed into soils that have sufficient lateral soil support on the shaft; both exhibit similar compressive capacities. Notice, however, in Table 18 that a helical pile fabricated with a 1-3/4 inch solid square bar is only 40% as stiff as the 2-7/8 inch diameter, 0.262 inch thick wall, tubular product. The 2-7/8 inch tubular product is obviously the better choice when designing a compression pile that must pass through very weak soils that can not provide sufficient lateral shaft support.

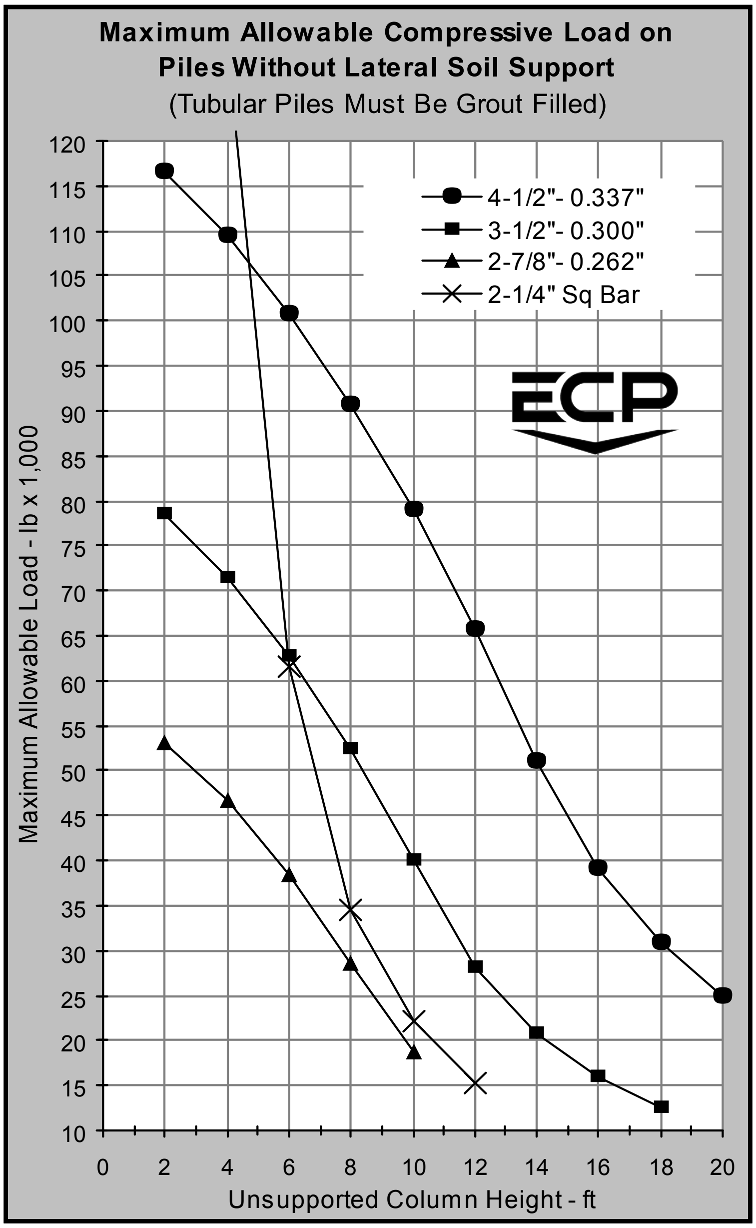
Table 18 also shows 4-1/2 inch diameter tubular shaft has superior resistance to buckling because the large diameter shaft has an axial stiffness of more than five times that of the 2-7/8 inch diameter, 0.262 inch wall tubular shaft.

In Table 19 the load capacities for buckling of the 4-1/2 inch and 3-1/2 inch diameter shafts can

Table 19 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	26,000 lb	29,000 lb	33,000 lb	37,000 lb
1-3/4" Sq.	39,000 lb	43,000 lb	48,000 lb	55,000 lb
2-1/4" Sq.	74,000 lb	81,000 lb	90,000 lb	104,000 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 0.262"	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

be compared to the 2-7/8 inch diameter, 0.262 inch wall tubular shaft when each passes through various kinds of soft soils. Notice that a 4-1/2 inch diameter tubular shaft has 2.9 times more buckling resistance, and a 3-1/2 inch diameter shaft has more than 1.6 times greater buckling resistance of the 2-7/8 inch diameter shaft when passing through soils containing organics that have blow counts of one blow per foot and under.

When weak soils are encountered such as peat or other organic soils, improperly consolidated fill soil, or where the pile may become fully exposed in air or water; the pile will not be able to support the full rated capacity listed in Table 17.



Graph 4. Ultimate loads on piles with no lateral shaft support.

Earth Contact Products recommends using solid square shafts in axial compression only in soils having SPT, "N" > 5 blows per foot through the entire depth of the installation.

The reason is solid square shafts offers relatively little buckling strength when subjected soils with low SPT values. When designing piles in axial compression that penetrate weak soils, it is good practice to select tubular products for the application.

Allowable Compressive Loads - Pile in Air or Water: Graph 4 shows the reduction in allowable axial compressive loading relative to the length of the pier shaft that is without any lateral support. In addition, Graph 4 demonstrates that a 4-1/2 inch diameter tubular shaft has an ultimate capacity of nearly six times that of the 2-7/8 inch diameter tubular shaft when each installation has ten feet of exposed column height without any lateral support.

Earth Contact Products recommends that a Registered Professional Engineer conduct the design of Helical Torque Anchors™ where shaft buckling may occur due to transiting upper layers of weak soil, unconsolidated fill or in situations where the shaft extends fully exposed above grade level without any lateral support to the pile shaft.

Torque Anchor™ Compressive Capacity Estimates

The graphs below were developed to provide estimated compressive capacities for various sizes and configurations of helical plates of commonly used Torque Anchors™ when they are installed into various soil classifications. It must be clearly understood that Graphs 5 to 8 are provided to help estimate a pile or anchor configuration that can provide required support for a particular project. The graphs are not intended to be a substitute for helical pile engineering design that uses project data from a specific job in a specific soil. Graphs 5 to 8

Compression Pile Design

represent general trends of capacity through different *homogeneous* soil classifications. The graphs are based upon conservative estimates.

These graphs represent the ultimate capacity of the helical plates in the soil. **A suitable factor of safety must always be applied to the service load before using these tables to insure reliability of any tieback or compression pile system.** The graphs disregard soil classifications zero through class 2 because these soils are usually to dense for the Torque Anchor™ to advance into these soil classes without pre-drilling. When rotation of the helical anchor does not advance the product into the soil, the soil usually does not allow the helical plates to fully embed to achieve the capacity level predicted by Terzaghi's bearing capacity formula for deep foundation elements.

Likewise soil class 8 was not presented in these graphs because class 8 soils usually contain significant amounts of organics or fill materials that may contain debris and/or may not be properly consolidated.

Graphs 5 - 8 presented here also show a shaded area for soils in Class 7 and part of soil class 6. This is to alert the user that, in some cases, soils that fall within this shaded area of the graphs may not be robust enough for heavy loads. If the soil in the shaded areas contain fill; the fill could have rocks, cobbles, construction debris and/or trash in it. In addition, this soil may not be fully consolidated and/or could contain organic components. Any of these could allow for creep of a foundation anchorage 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 completely through all weak and possibly unstable soil into a more robust and stable soil stratum underlying these undesirable strata.

Shaft torsion should always be monitored during the installation of helical screw anchors and piles. Generally, the ultimate holding capacity of the typical *solid square shaft helical anchor* 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 encounters obstructions; use readings for three feet before 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 a new placement shall be averaged for three feet but the anchor shall not be installed to the spin depth.

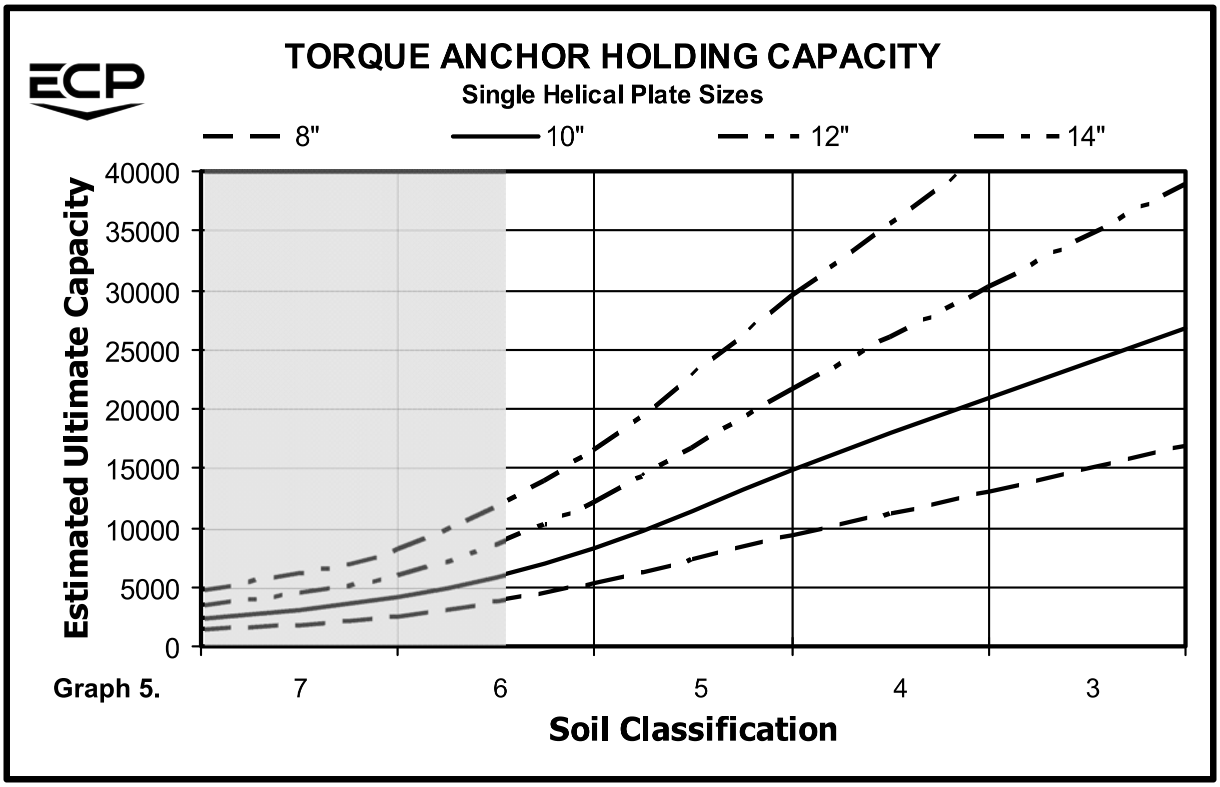
Due to larger friction between the soil and tubular shaft configurations, *one cannot use the ten to one relationship mentioned above to estimate ultimate capacity of tubular shafts*.

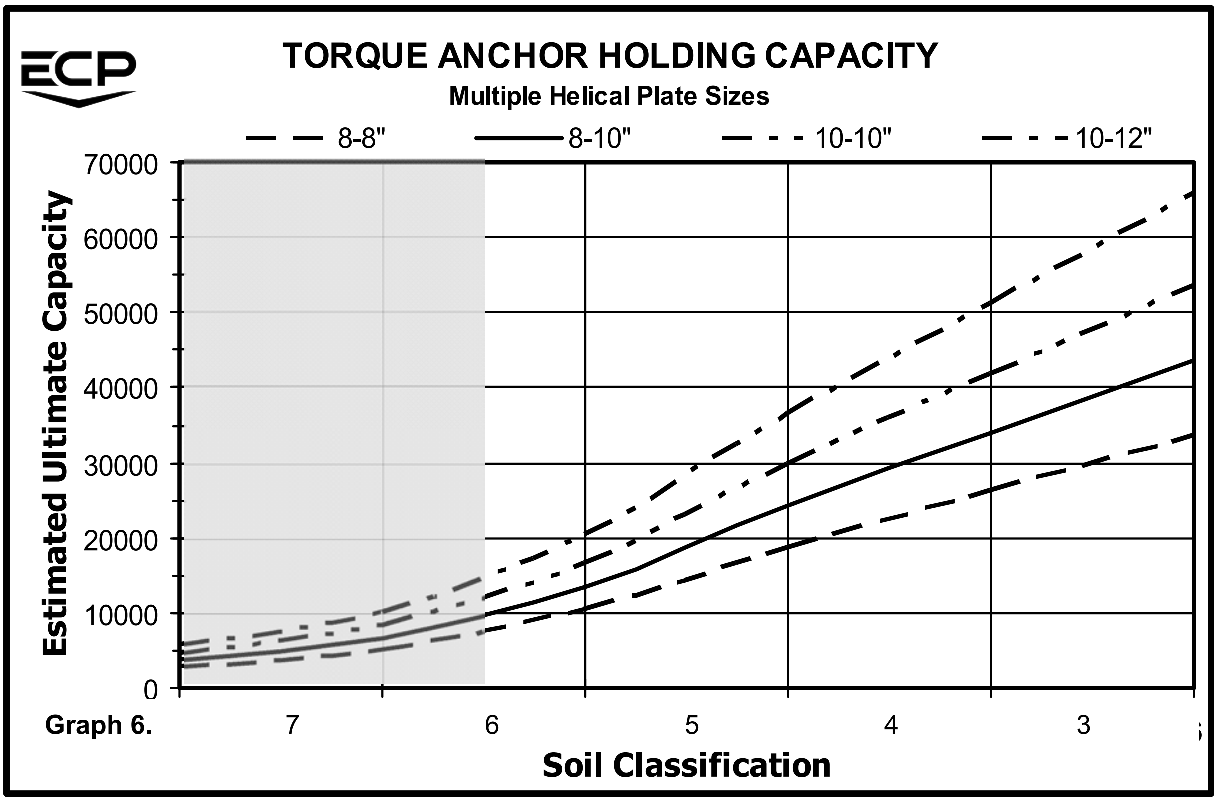
A more detailed discussion of the relationship between torque on the shaft and anchor capacity was discussed in Chapter. Refer to Table 11 and/or Graph 1.

It is also important to understand that the Graphs 5 to 8 below do not take into consideration the shaft size or configuration being used in conjunction with the helical plate configurations.

As a result, these graphs can suggest holding capacities well above the torsional capacity of some of the smaller size helical shafts or power installed anchor rods to deliver that capacity.

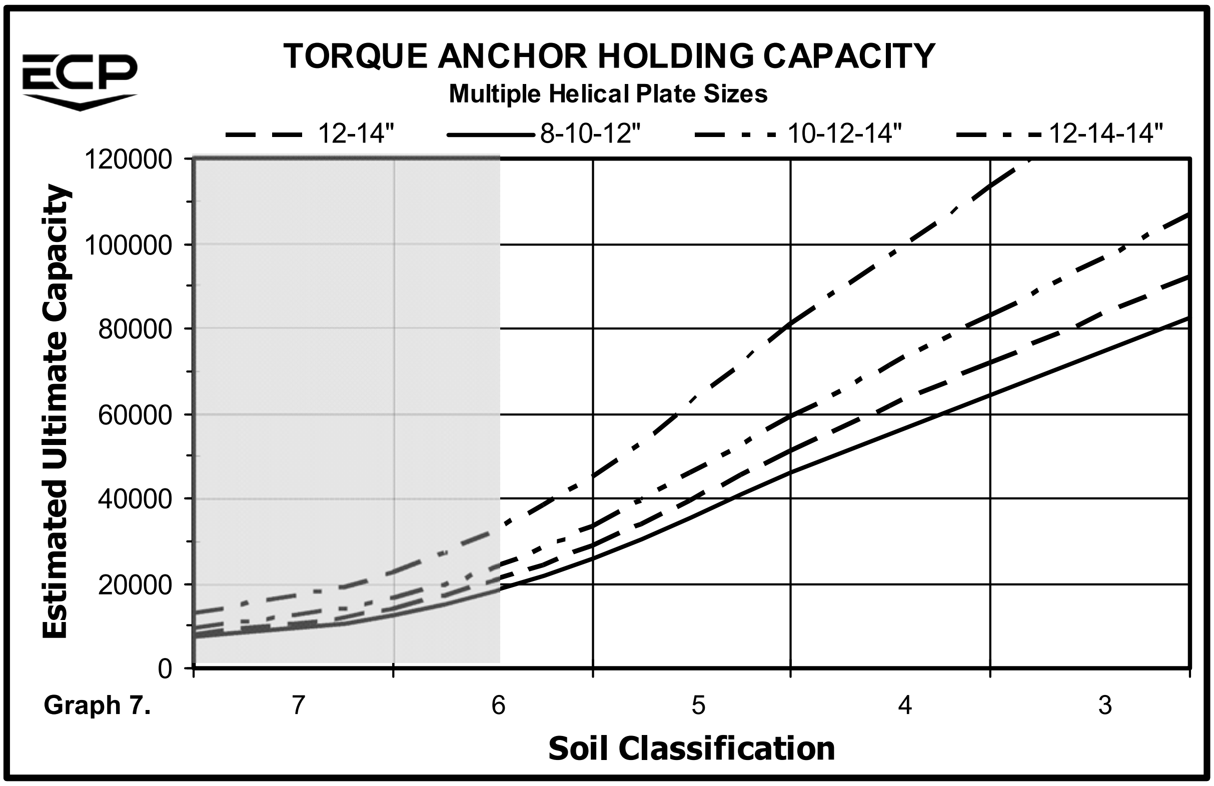
Where the graph line is truncated at the top of the graph for a particular helical plate configuration, one should not try to extrapolate a higher capacity than indicated by the top line because these plate configurations have reached the ultimate mechanical capacity for that particular configuration 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-eight inch thickness. Please check with ECP or your engineer to determine if using thicker helical plates could achieve the ultimate capacity requirement on a particular project.

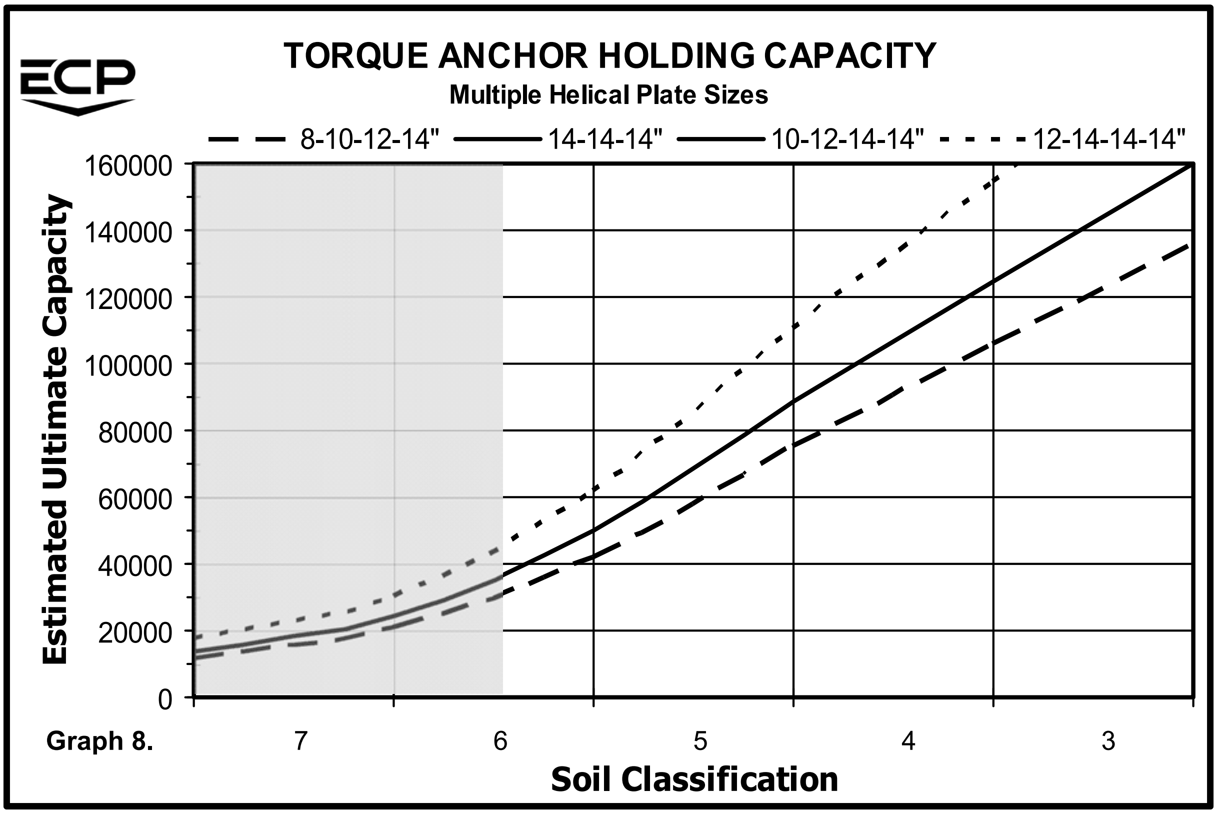




Compression Pile Design

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





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

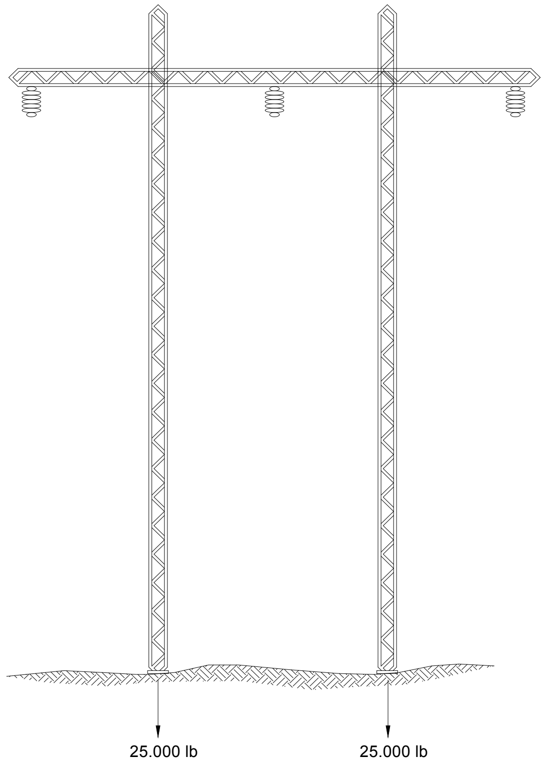
Design Example 4 – Transmission Tower in Cohesive (Clay) Soil

Design Details:

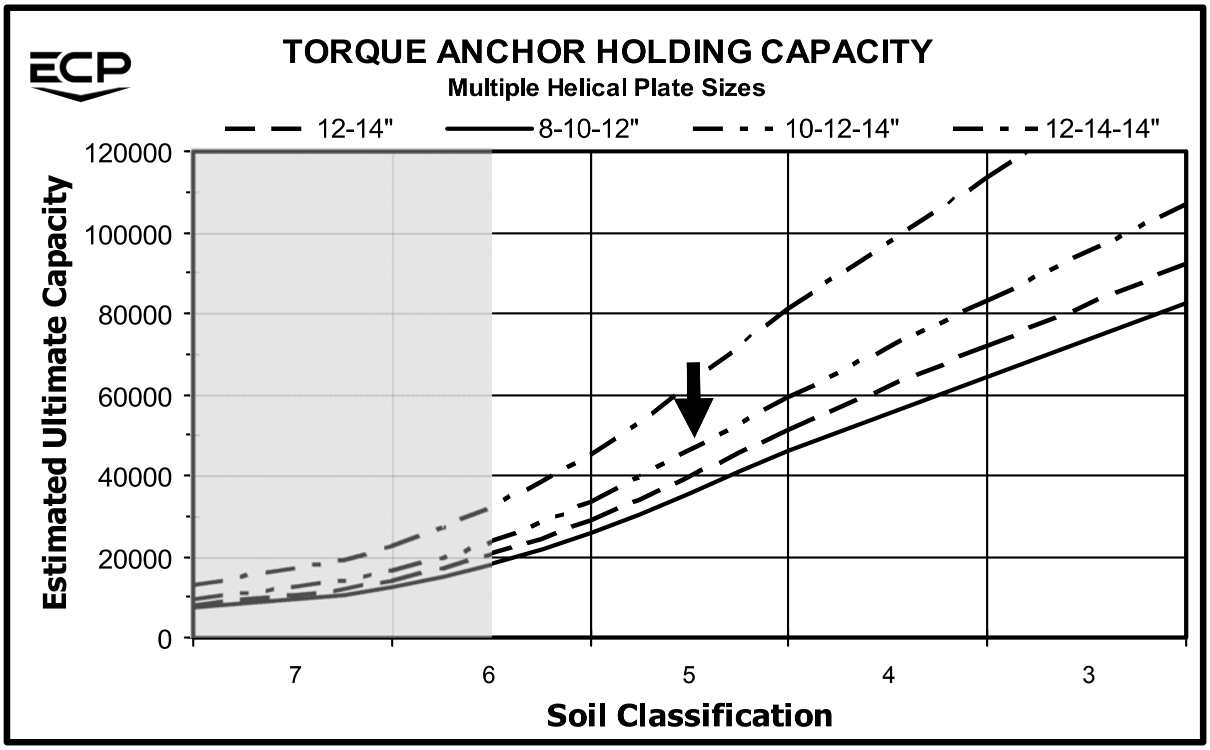
- Compressive Service Load = 25,000 lb at each leg.
- The soil information about the site indicated very stiff inorganic clay (CL),
- Standard Penetration Test, "N" = 20 blows per foot (average)
- Soil Class - 5

ECP Torque Anchor™ Design: The soil data provides only an average value for the Standard Penetration Test of the soil on the site; the quick estimating method for designing the compression piles to support the tower is presented first. Then the design will be verified using Equation 1a introduced in Chapter 2. Design verification is not required, but reinforces confidence in Graphs 5 to 8.

1. Ultimate Helical Pile Capacity. The tower manufacturer provided the service or working capacity on this project based upon his knowledge of the loading to be placed on the tower. 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 obtain the ultimate capacity of the pile design. In this case a factor of safety of 2.0 or 50,000 pounds per leg was used.



Sketch for Design Examples 4, 5 & 6



Graph 7. Multi-Plate Holding Capacity

2. Select the proper compression pile from the estimated anchor holding capacity graph. Referring to Graph 7 from this chapter (reproduced above), notice that the capacity line for an anchor with 10", 12" and 14" diameter helical plates attached crosses the middle of Soil Class 5 at 50,000 lb. The 10", 12" and 14" diameter plate configuration is selected.

For Verification of the Projected Helical Plate Area Suggested by Graph 8 Use Bearing Capacity Equation 1a (Optional):

Equation 1a: $\Sigma A_H = P_u / (9c)$,

Where:

P_u = 50,000 lb
c = 2,500 lb/ft^2 (Estimated from Table 10 – Very Stiff with N = 15 to 32 bpf)

$\Sigma A_H = P_u / (9 \times 2{,}500\ \text{lb/ft}^2)$

$\Sigma A_H = 50{,}000\ \text{lb} / 22{,}500\ \text{lb/ft}^2$

$\Sigma A_H = \underline{2.22\ \text{ft}^2}$

Referring to the product listings at the beginning of this chapter, notice that the TAF-288-84 (10-12-14) product has a 10" plate, a 12" plate and a 14" plate mounted to a 2-7/8 inch diameter tubular shaft. The projected area of this configuration is 2.20 ft^2 from the product listing. Helical plate area can also be determined from Table 9. The result of the calculation for required plate area from Table 9 confirms the configuration indicated from Graph 7.

3. Check the Shaft Strength and Torsional Strength to see if the Shaft is Suitable:

Refer to Table 17 to verify that the 2-7/8 inch diameter tubular shaft has sufficient capacity to support the load, and has sufficient torsional shaft strength for installation. The required ultimate capacity for each leg of the tower is 50,000 lbs. The 2-7/8 inch tubular product, with 0.262 inch wall thickness, has a compressive strength rating of 100,000 pounds and a practical load limit of 80,000 pounds based upon an installation torsional limit of 9,500 ft-lbs.

The selected helical pile provides suitable plate area, torsional capacity and a sufficient practical load limit to exceed the ultimate load requirement of 50,000 pounds. The choice is verified.

4. Installation Torque: Use Graph 1 (Reproduced below) or Equation 2 (Introduced in Chapter 2) to calculate the installation torque requirement for this pile.

Graph 1 can be used to estimate the installation torque requirement without calculations. Notice the 2-7/8 inch diameter shaft is designated by the "▲" symbol in Graph 1. The ultimate capacity requirement of 50,000 pounds can be seen on the left side. Move horizontally from 50,000 pounds to reach the curve for the 2-7/8 inch diameter tubular shaft, then read downward until the installation torque of 5,900 ft-lb is determined.

Equation 2 can be used to calculate the installation torque (Optional):

Equation 2: $T = P_u / k$,

Where,

P_u = 50,000 lb
k = 8.5 (Table 11)

$T = 50{,}000\ \text{lb}/8.5\text{ft}^{-1} = 5{,}882$ ft-lb

T = <u>5,900 ft-lb</u>, minimum

5. Minimum Embedment Depth: From the discussion earlier about sufficient soil overburden depth, the minimum depth requirement of six times the diameter of the shallowest plate measured vertically from the surface to the shallowest plate must occur. The **Minimum Embedment Depth**, **"D"** can be determined as follows:

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

D = 6 x (14 in/ 12 in) (ft) = 7 feet

D = Minimum Vertical Depth = 7 feet.

Recall that helical plates are spaced at three times the diameter of the next lower plate. The design configuration selected has a 10" and a 12" diameter plate below the shallowest 14" helical plate. The shaft length from the bottom plate on the pile up to the 14 inch plate must be determined and added to the 7 foot *Minimum, Vertical Depth* requirement from grade level to the 14 inch plate.

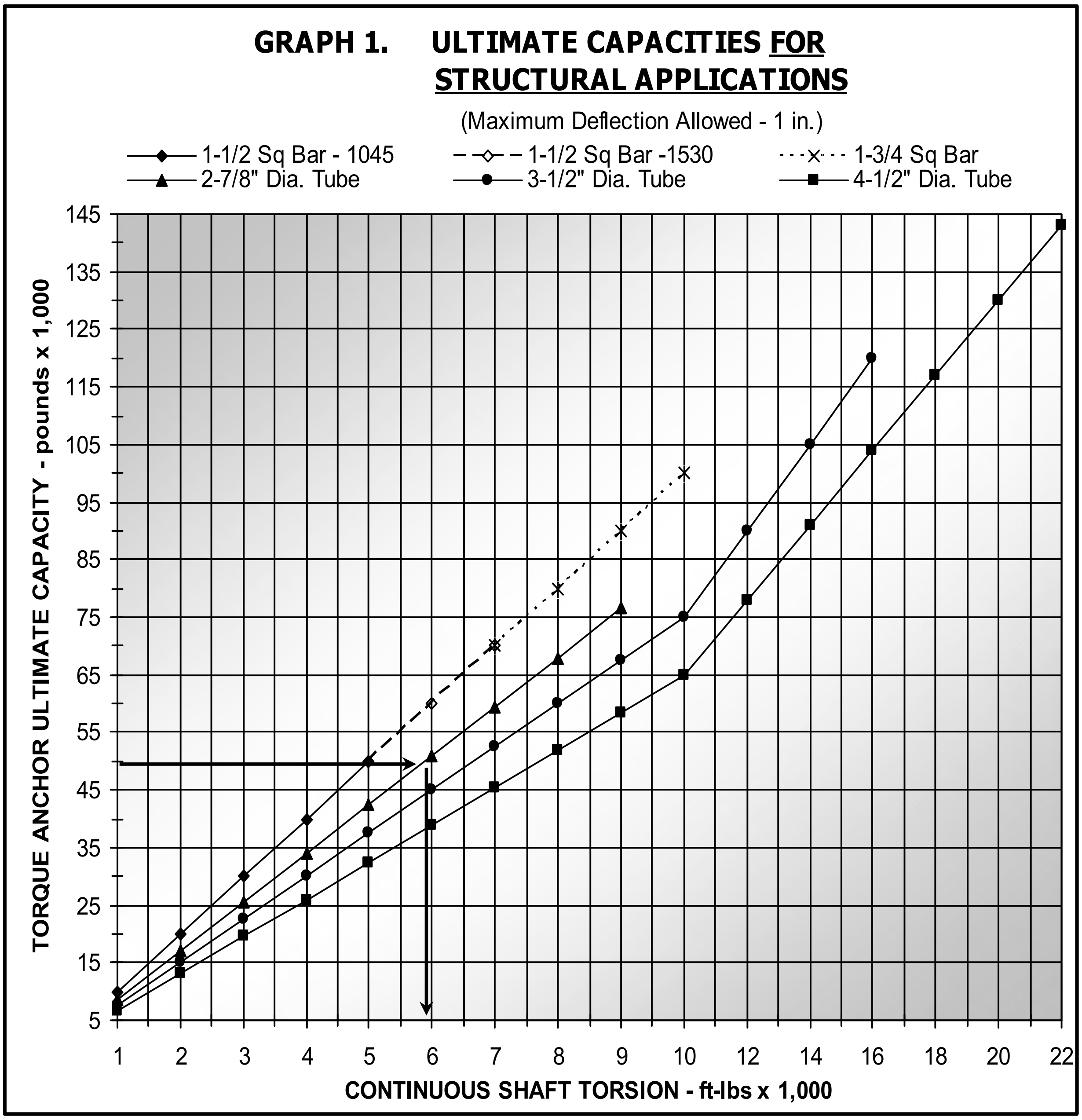
6. Minimum Required Shaft Length:

$\mathbf{L} = \mathbf{D_{14"}} + \mathbf{L_{tip}}$ (Distance from 10" to 14" plate)

L = 7' + (3 x 10" Dia)/12" + (3 x 12" Dia)/12"

L = 7' + (30"/12") + (36"/12") = **12-1/2 ft**

Specify the required minimum installed length by selecting an extension that is at least seven feet long. The 7 foot lead section plus a 7 foot extension (with a coupled length of 6-1/2 feet) provides the shortest standard length that can be ordered that exceeds the 12-1/2 foot minimum. Additional extensions may be required if the torsion requirement of 5,900 ft-lb is not achieved when 13-1/2 feet of shaft is fully installed.



Compression Pile Design

7. Torque Anchor™ Specifications. The Torque Anchor™ assembly will consist of:

- **TAF-288-84 10-12-14** – 2-7/8” diameter tubular shaft with 0.262” wall thickness that has a 10”, a 12” and a 14” diameter plate on a 7’-0” long shaft,
- **TAE-288-84** extension – 7’ extension shaft & hardware, (6’-6” effective length).

End of Example 4

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 contact us at 913 393-0007, Fax at 913 393-0008.

Design Example 5 – Transmission Tower in Cohesionless (Granular) Soil

Structural Details:

- Compressive Service Load = 25,000 lb at each leg from Example 4.
- The soil information about the site indicated fine sand (SP), Loose – 95 pcf
- Standard Penetration Blow count "N" = 8 blows per foot below 10 feet deep
- Water table was not encountered
- $\Phi = 30^0$
- Soil Class 6

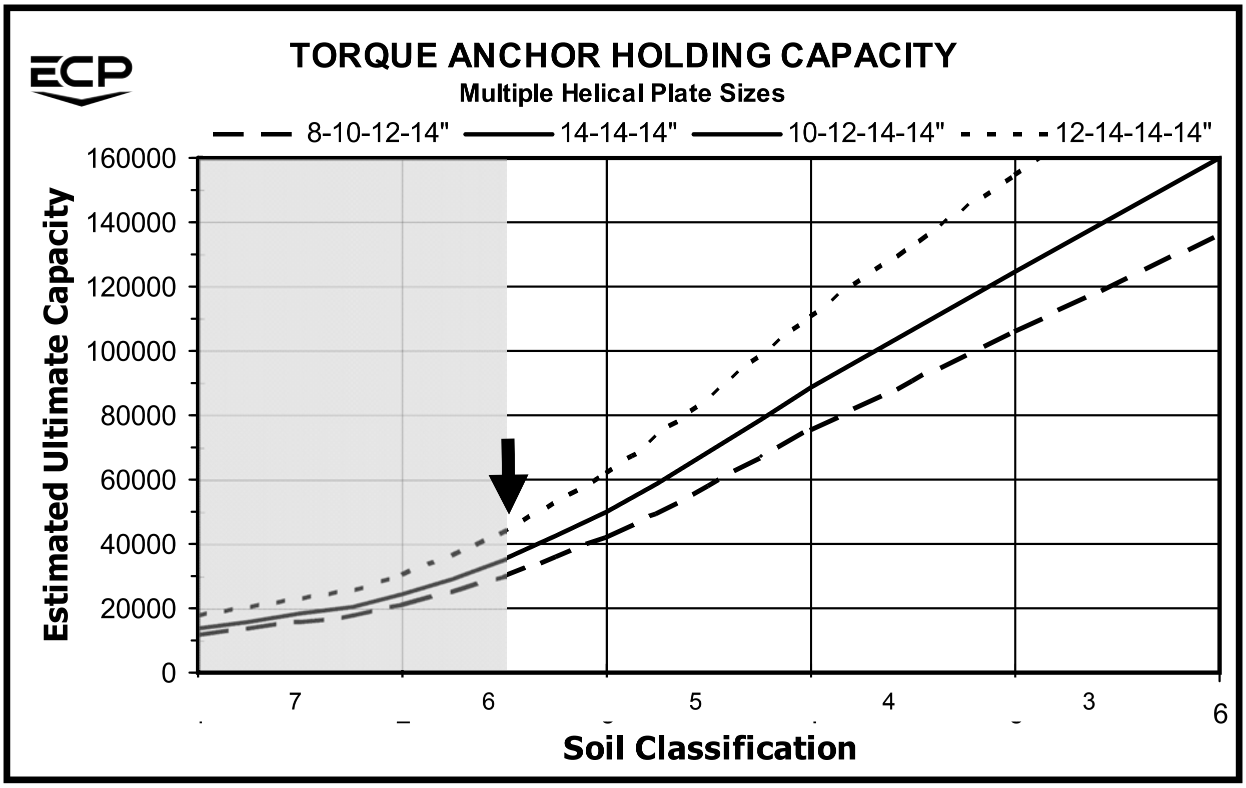
ECP Torque Anchor™ Design: The same load requirement and illustration from Design Example 4 is used for this foundation support design example. Because this is a compressive load application, a tubular helical shaft will be selected to begin the design. The capacity of the product selection will be verified later.

1. Ultimate Compressive Capacity: As explained in the Design Example 4, the load requirement for the tower was given as a service load. A factor of safety must be added to prepare the design. A 50,000 pound ultimate pile capacity on each leg is needed when a factor of safety of 2.0 is applied to the given service load.

2. Select the Pile Design from the Estimated Anchor Holding Capacity Graph 4: Referring to Graph 8 from this chapter (Reproduced below), the capacity line for an anchor with 12-14-14-14 inch diameter plate configuration attached to the shaft provides an estimated ultimate capacity range from 30,000 to 62,000 pounds in the Class 6 soil. These capacities are within an acceptable capacity range for the design requirement.

Because the soil is granular, the capacity can be expected to increase with depth. If the 50,000 pound ultimate capacity is not achieved with this design when the shallowest 14 inch plate is situated at least seven feet below grade, the Torque Anchor™ could be installed deeper with the reasonable expectation of the ultimate capacity increasing with depth.

3. Verification of the Estimated Ultimate Pile Capacity Suggested by Graph 8 with the Bearing Capacity Equation: While this step is not required, it predicts more accurately the ultimate capacity than the graphs. In addition, by illustrating the result of the calculated result here



Graph 8. Multi-plate Holding Capacity

provides the reader with confidence in the graphs.

Because the soil on the site is cohesionless, Equation 4 is used:

Equation 4: $P_u = \Sigma A_H (q\ N_q)$; Where:

P_u = Ultimate Capacity - 50,000 lb

$\Sigma A_{H\ 12\text{-}14\text{-}14\text{-}14}$ = **3.81 ft^2** (from product tables)

γ = Soil Density - **95 lb/ft^3**

h_{min} = **7 feet**

h_{mid} **12-14-14-14" configuration**.

= [(36" + 42" + 42") / 12]/2 = **5 feet**

$h_{mid\ 10\text{-}12\text{-}14\text{-}14}$ = 7 ft + 5 ft = **12 feet**

q = γ x h_{mid} = 95 lb/ft^3 x 12 ft = **<u>1,140</u> lb/ft^2**

N_q = **15** (Use Table 8 – "N" = 8 & $\Phi = 30^0$)

$P_{u\ 12\text{-}14\text{-}14\text{-}14}$ = 3.81 ft^2 x 1,140 lb/ft^2 x 15

$P_{u\ 12\text{-}14\text{-}14\text{-}14}$ = **<u>65,151 lb</u>** > 50,000 lb

The result from solving the capacity equation for this pile configuration suggests that the pile design selected by Graph 8 is stronger than needed for this project. The pile must be installed with the upper most plate below 7 feet (Step 5 - Example 4). The depth of the entire pile configuration will be 17 feet. This is determined by adding the distance along the shaft from the first to last helical plate. The sum equals 17 feet. (Please refer to Step 6 – Example 4.)

Alternate Design: One of the big advantages of calculating the capacity rather than using the graphs is the possibility of alternate designs. The calculation above predicted a substantially higher capacity than predicted by Graph 8. Helical piles generally experience increasing capacity with increasing depth in cohesionless (sand/gravel) soils. In this example, the soil data reported that the soil was homogeneous below 10 feet. If a lead section with a smaller projected helical plate area is selected, it could satisfy the load capacity requirement at lower cost. To illustrate this point, a 12-14-14 plate configuration is selected as a substitute. In the alternate design it will be assumed that the pile will install slightly deeper than the design predicted by the table. The following is a capacity calculation of this configuration at an assumed depth of 18 feet.

12-14-14 Configuration Installed to 18 ft:
Equation 4: $P_u = \Sigma A_H (q\ N_q)$; Where:

P_u = Ultimate Capacity (50,000 lb needed)

$\Sigma A_{H\ 12\text{-}14\text{-}14}$ = **2.79 ft^2** (Product Tables)

h_{mid} - **12-14-14"** (Between plates)

= [(36" + 42") / 12] / 2

= (78" / 12) / 2 = 3.25 feet

$h_{mid\ 12\text{-}14\text{-}14}$ at 18 feet deep = **14.75 ft**

(18 ft – 3.25 ft = 14.75 ft)

γ = Soil density = **95 lb/ft^3**

N_q = **15** (Use Table 8 – "N" = 8 & $\Phi = 30^0$)

$P_{u\ 12\text{-}14\text{-}14}$ = 2.79 ft^2 (95 lb/ft^3 x 14.75 ft) x 15

$P_{u\ 12\text{-}14\text{-}14}$ = **<u>58,642 lb</u>** (Installed to 18 ft)

Based upon material cost and installation labor this solution is a less expensive option, because it the less costly configuration installs only slightly deeper than the larger 12-14-14-14 configuration. This second analysis suggests that the pile would likely achieve a 50,000 pound ultimate capacity prior to reaching 18 feet below grade because 58,642 lb > 50,000 lb. It is not possible to install the larger 12-14-14-14 configuration to a shallower depth because the upper plate was already positioned at the <u>minimum</u> allowable depth. This new configuration might be installed as shallow as 14 feet, and still have more than 7 feet embedment to the shallowest plate. Of course the torque requirement must be satisfied.

4. Check Shaft Capacity and Torsional Limit for Shaft Suitability. From Design Example 4, a TAF-288 series Torque Anchor™, 2-7/8 inch diameter tubular shaft with a 0.262 inch wall thickness with sufficient strength was selected. The axial compressive load limit is 100,000 and the torsional limit is 9,500 ft-lb, which provides a practical load limit of 80,000 pounds when installed in homogeneous soil. It is confirmed that the shaft is suitable for the 50,000 pound ultimate capacity requirement.

The average Standard Penetration Test (SPT) value measured on this site is "N" = 8 blows per foot. Recalling the discussion of shaft buckling in weak soil in the text just prior to Design Example 4, shaft buckling is determined not to be a concern on this site.

The product designation for the helical pile design is TAF-288-120 12-14-14, which describes a 10 foot long, 2-7/8 inch diameter tubular shaft with wall thickness of 0.262 inch. Attached to the shaft is one 12" and two 14" diameter 3/8 inch thick helical plates.

5. Installation Torque. Use Graph 3 or Equation 5 from Chapter 2 to determine the installation torque for this helical compression pile. The process and solution for this example is exactly the same as for Design Example 4.

T = 5,882 ft-lb (Specify **5,900 ft-lb**)

6. Minimum Installation Depth. The calculations suggest that the single TAF-288-120 12-14-14 pile will reach capacity when the total length of the lead and extension are between 14 feet and 18 feet below grade. Keep in mind that the soil was assumed to be *homogeneous* with an average SPT value, "N" = 8 blows per foot at the depth of all helical plates. The actual installed depth at each placement could vary due to soil conditions.

7. Torque Anchor™ Specifications. The tubular Torque Anchor™ assembly can now be specified:

- **TAF-288-120 12-14-14-14 Lead Section or** (Recommended by Graph 8)
- **TAF-288-120 12-14-14 Lead Section** – (Recommended by aalternate calculated analysis) This consists of a 2-7/8 inch diameter with 0.262 inch wall thickness tubular shaft measuring 10'-0" long lead with a 12" and two 14" diameter plates on the shaft.
- **TAE-288-120 Extension Section –** This is a tubular extension fabricated from the same material as the lead. The extension is 10'-0" long and is supplied with connecting hardware. There is an overlap of six inches at the coupling.

These products will assemble and provide a total shaft length of 19-1/2 feet, which is below the depth predicted by the calculations. A 7'-0" long extension would provide 16-1/2 foot long pile, which probably would be satisfactory, but the longer extension is recommended should the actual soil capacity not sustain the load requirement at the predicted depth.

End of Example 5

Design Example 6 – Transmission Tower in Wetland Soil

Design Details:

- Compressive Service Load = 25,000 lb at each leg from Example 4.
- The soil information about the site revealed a minimum of five feet of soil organic soil exists at the surface. Standard Penetration Test values were, "N" = 1 to 3 blows per foot - Soil Class = 8
- Below the five feet of swamp deposits is very stiff inorganic clay (CL), with SPT, "N" = 20 blows per foot (average) - Soil Class = 5

ECP Torque Anchor™ Design: The soil data suggests that below the initial five feet, the soil is similar to the soil in Example Design 4. Referring to Example 4, it can be recalled that the pile configuration required to support the 50,000 pound ultimate load on each tower leg was a 10-12-14 inch diameter plate configuration. The 2-7/8 inch diameter tubular shaft, with 0.262 inch wall thickness, had sufficient compressive strength support the design load and sufficient torsional strength to install the pile.

Knowing that on this site there exists extremely weak (Class 8) soil near the surface is important information to know because helical piles have slender shafts and with insufficient lateral soil support against the sides of the shaft, buckling could occur.

1. Determine the Buckling Strength. Table 17 lists full load helical pile shaft capacities when installed into soil that provides sufficient lateral support along the helical shaft.

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

In this design example there exists a five foot layer of very weak Class 8 organic soil located near the surface. This very weak soil overlays

Table 19 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	26,000 lb	29,000 lb	33,000 lb	37,000 lb
1-3/4" Sq.	39,000 lb	43,000 lb	48,000 lb	55,000 lb
2-1/4" Sq.	74,000 lb	81,000 lb	90,000 lb	104,000 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 0.262"	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

inorganic clay that is able to support the required load. In addition, the piles will be installed in a designated wetland area that could be subjected to flooding. Flooding could make the weak Class 8 soil become even weaker when saturated. Shaft buckling on this site must be considered.

The *"Axial Compressive Load Limit"* of 100,000 pounds that is shown in Table 17 for a 2-7/8 inch diameter with 0.262 inch wall tubular shaft configuration is not valid when this shaft passes through the Class 8 soil on this site.

Instead of using Table 17 for load limit on this shaft, determine a conservative estimated buckling strength for the 2-7/8 inch diameter, 0.262 inch wall helical Torque Anchor™ shaft from Table 19, "*Conservative Critical Buckling Load Estimates"*. The geotechnical soil description of the upper five feet stated that the soil is very soft clay with organics and was designated as Class 8 soil. The SPT values ranged from "N" = 1 to 3 blows per foot at the time of the soil testing. Should the area be subjected to flooding, the SPT, "N", value drop due to soil saturation.

Referring to Table 19 for a 2-7/8 inch diameter tubular shaft with 0.262 inch wall under the column heading *"Very Soft Clay"*, the buckling strength is rated at approximately 48,000 pounds. This soil might be marginally acceptable for support of the 50,000 pound ultimate load; however, consider that this installation will be located in a wetland area where organics were reported in the soil sample. If the site becomes covered with water in the future, the SPT values could drop to one blow per foot or less. Referring to Table 19 (at right) under the column heading *"Organics N $\geq$ 1"*, notice that the buckling strength of the 2-7/8" diameter with 0.262 inch wall tubular shaft drops to only 39,000 pounds. This value is judged to be unacceptable to support our ultimate capacity requirement of 50,000 pounds.

2. Select a Pile Shaft with Suitable Buckling Strength. The ultimate capacity requirement for this project is 50,000 pounds axial compressive ultimate load at each leg of the transmission tower. The buckling strength of our shaft must be increased to be able to successfully pass through the very week upper organic clay strata. The solution is to select a larger diameter tubular shaft that can offer more shaft stiffness (*Larger moment of inertia*), or resistance to buckling. Now, referring to Table 19; notice under the column labeled *"Organics N $\geq$ 1"*, the 3-1/2 inch diameter tubular shaft with a 0.300 inch wall thickness offers a conservative estimated buckling load capacity of 63,000 pounds. Because of the weak wetland soil that exists at this site, the pile shaft diameter must be increased to provide resistance to the threat of shaft buckling when soil in the wetland becomes saturated and the pile is fully loaded.

3. Torque Anchor™ Specifications. The Torque Anchor™ plate configuration remains as originally determined in Design Example 4 to support the tower 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 10-12-14** Lead Section
- **TAE-350-84** Extension Section

Earth Contact Products recommend that a Registered Professional Engineer conduct the evaluation and design of Helical Torque Anchors™ where shaft buckling may occur when the shaft is to be installed through weak soil or the shaft may become fully exposed with no lateral shaft support.

Table 19 Conservative Critical Buckling Load Estimates

Shaft Size	Uniform Soil Condition			
	Organics N $\leq$ 1	Very Soft Clay N = 1 - 2	Soft Clay N = 2 - 4	Loose Sand N = 2 - 4
1-1/2" Sq	26,000 lb	29,000 lb	33,000 lb	37,000 lb
1-3/4" Sq.	39,000 lb	43,000 lb	48,000 lb	55,000 lb
2-1/4" Sq.	74,000 lb	81,000 lb	90,000 lb	104,000 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 0.262"~~	~~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

4. Installation Torque. The larger 3-1/2 inch diameter tubular shaft specified to prevent shaft buckling passes less efficient when passing through the soil. As a result, when the design requires a change in shaft size, the installation torque requirement must be recalculated.

Graph 1 or Equation 2 may be used to estimate the installation shaft torsion requirement.

Graph 1 estimates the installation torque requirement without making calculations, the 3-1/2 inch diameter shaft is designated by the "●" symbol on the graph. The ultimate capacity requirement of 50,000 pounds is read on the left side. Read to the left from 50,000 lb to the curve for the 3-1/2 inch shaft, then read downward until the installation torque of 6,650 ft-lb is determined. **Specify T = 7,000 ft-lb**

The installation torque requirement could be calculated. Check Table 11 and select an efficiency factor, "k" = 7-1/2 for the 3-1/2 inch diameter shaft. Previously a "k" = 8-1/2 was used to estimate installation shaft torsion for the 2-7/8 inch diameter tubular shaft.

Use Equation 2 introduced in Chapter 2 to calculate the installation torque requirement for this new, larger diameter shaft size.

Equation 5: $T = P_u / k$, Where,

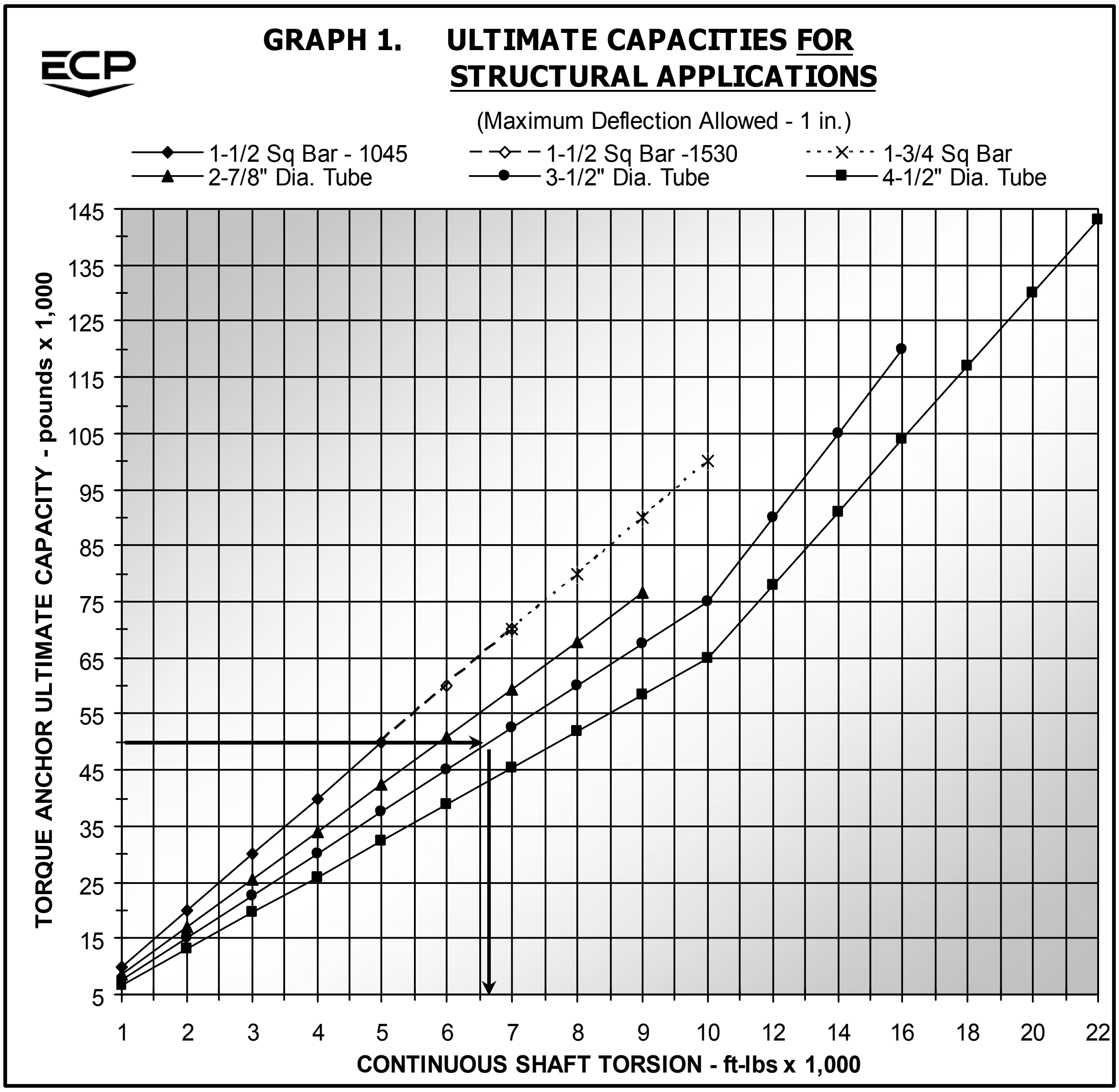
P_u = 50,000 lb

k = 7.5 (Table 11)

T = 50,000 lb / 7.5 ft^{-1} = 6,667 ft-lb

Specify T = 7,000 ft-lb

End of Example 6



Chapter 4

Installation Guidelines
and
Testing Procedures for
ECP Helical Torque Anchors™

Installation and Testing

ECP

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Hydraulic Torque Motors

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. Once approximately 75% of the design installation torque is achieved, the rotational speed is reduced to between 5 and 20 rpm until the final torque is achieved over the required embedment distance.

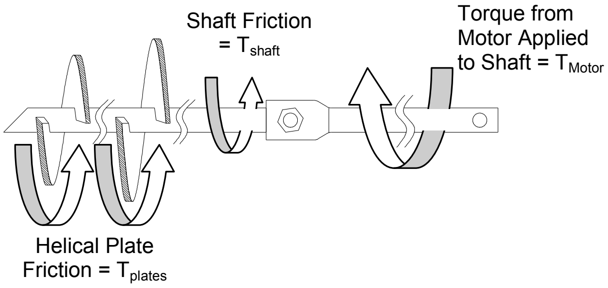
Installation Torque

Installation torque for both guy anchors and structural applications were introduced and discussed in Chapter 2. Graph 2 in Chapter 2 presents the relationship of anticipated ultimate capacity of typical guy anchors that 2 inches to 4 inches of deflection are allowed.

For structural applications where the ultimate capacity is determined by a maximum deflection of one inch is the industry standard, the installation torque, *Torque Efficiency Factor* (“k”) and Table 15 were also introduced and discussed in Chapter 2. Table 15 is reproduced below for reference.

Shaft torsion during installation can provide a reasonably accurate estimate of the ultimate capacity of the helical screw anchor. The relationship between the shaft torsion during installation and the ultimate helical screw anchor capacity 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.

In the sketch 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 circumference of



the shaft and the soil is directly related to the shaft configuration and size, and the properties of the soil. Because of this lost energy in transmitting the motor torque to the helical plates, an empirical *Torque Efficiency Factor* (“k”) must be employed to arrive at a reasonable estimate of anchor ultimate capacity.

Torque Efficiency Factor – “k”: This is the relationship between installation torque and ultimate capacity of the installed Torque Anchor™. Estimating the ultimate capacity of screw pile based upon the installation torque has been in use for many years.

Unless a load test is performed to provide a site specific value of the actual *Torque 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 *Torque Efficiency Factors* (“k”) in Table 15. These values can be used for estimating typical 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 15 lists typical values of “k” for successful estimations of ultimate capacities of Torque Anchors™ based upon the output torque at the installation motor shaft.

Understand that the value of the *Torque 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 design. The “k” value for square bars is generally higher than for tubular shafts**.** Keep in mind that the suggested values in Table 15 and on Graph 3 are only guidelines for ultimate capacities with no more than one inch of deflection at ultimate load.

When installing Guy Anchors that allow for deflections of up to four inches, Graph 2 estimates the ultimate capacity of the guy anchor. Important**: Graph 2 is only to be used to determine ultimate anchor capacity for Guy Anchoring applications.**

Always reduce the ultimate capacity by a suitable Factor of Safety to prevent unexpected failures.

It is also important to refer to Table 2 –Chapter 1, or Table 17 (Chapter 3) for the maximum practical shaft torsion that can be applied to the anchor shaft. Be mindful that higher torsional strength will help to avoid shaft fractures during installation. Failure to verify that the shaft configuration has sufficient reserve torsional capacity could result in an unexpected shaft failure during installation.

Equation 5: Helical 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)
$T_u = P_u$ = Ultimate Capacity - (lb)
(Measured from field load tests)
k = Torque Efficiency Factor - (ft^{-1})

An appropriate factor of safety must always be applied to the design or working loads when using Equation 5 and 5a.

To determine the site specific *Torque Efficiency Factor* ("k") from field load testing, Equation 5 is rewritten as:

Equation 5a: Torque Efficiency Factor

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

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

Table 15. Torque Efficiency Factor "k"

Torque Anchor™ Type	Typically Encountered Range "k"	Suggested Average Value, "k"
All Square Shafts	9 - 11	10
2-7/8" Diameter	8 - 9	8-1/2
3-1/2" Diameter	7 - 8	7-1/2
4-1/2" Diameter	6 - 7	6-1/2

Determining Installation Torque

Shaft torsion can be determined in several ways:

- **Twisting of the Solid Square Bar:** This method of torque control is the least accurate method to determine the amount torsion that is being applied to the shaft. This method is inaccurate and not recommended is because the point at which twisting occurs will vary with the steel chemistry fluctuations during bar fabrication and the differences in torsional strength from bar to bar varies within a mill run of bars and the tolerances in the steel compositions from mill run to mill run 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. The control of shaft torsion is controlled 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 as a less desirable 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 because in nearly every hydraulic system there is a back pressure. This back pressure represents energy that enters the gear motor, but is not used by the motor. The unneeded pressure simply causes oil to flow from the motor back into the reservoir. Typically, back pressures range from 200 to 500 psi. In some cases it is higher. The danger in using a single gauge is that the back pressure is unknown. As a result, the shaft torsion can be overestimated, which results in an anchor capacity prediction that is overstated. Anchors installed with a single

gauge system in general will not support as large of load 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 a gauge is installed at both ports on the gear motor, the actual pressure drop across the motor is revealed. This is an accurate 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 that is provided by the motor manufacturer.

It is especially important to have the gauges calibrated regularly. Under field conditions, gauges can become damaged and inaccurate.

- **Strain Gauge Monitor:** This torque transducer provides a direct display of installation torsion that is 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. It includes a remote handheld PDA based digital indicator. The strain gauge monitor measures the torsion applied between two flanges at the motor output shaft and the helical anchor shaft. The data is transmitted to a hand held readout device for display and logging. This method of measuring the applied torque is highly accurate (+/- 0.25%). The torque sensor is built into the housing of the flanges and the data is transferred by a wireless signal transmitter fitted into the housing.

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

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

Converting Motor Pressure to Shaft Torque

When a pressure differential is measured across the motor ports, it must be converted to motor output shaft torque. This can be accomplished by using torque output curves for the specific motor being used on site, or one can use the motor specific *Torque Conversion Multiplier.* Both are available from the motor manufacturer.

Torque Motor Conversion Factor – "K" Each motor has a unique "*Torque Motor Conversion Factor*", which is the relationship between the differential pressure measured across the hydraulic ports of the hydraulic motor and the shaft output torque of that particular motor. This factor, which is referred to as "K", may be used to calculate the output torque of a motor. In Table 20 on Page 61, the manufacturers' data on several commonly used hydraulic torque motors are provided. The important column in this table is the "*Torque Motor Conversion Factor*" ("K").

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

Equation 7 below is used to convert pressure differential across the motor into output torque.

Equation 7: Motor Output Torque

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

Where,
T = Torque Output of the Hydraulic Motor - ft-lb
K = Torque Motor Conversion Factor – (Table 20)
$\Delta P = p_{in} - p_{out}$ = Pressure Differential Across Motor

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

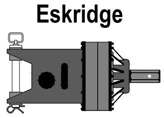
In Table 20 below the *Torque Motor Conversion Factor* ("K") is presented for some commonly used hydraulic torque motors.

Caution: If one is measuring the output shaft torsion in the middle range of the motor output curve using the *Torque Motor Conversion Factor*, the results are generally quite accurate. Determining output shaft torsion using a *Torque Motor Conversion Factor* when operating at very low motor output torque should be approached with caution. Hydraulic torque motor curves are not exactly straight lines. Errors are possible at the low end of the motor output curve when using a fixed value of "K".

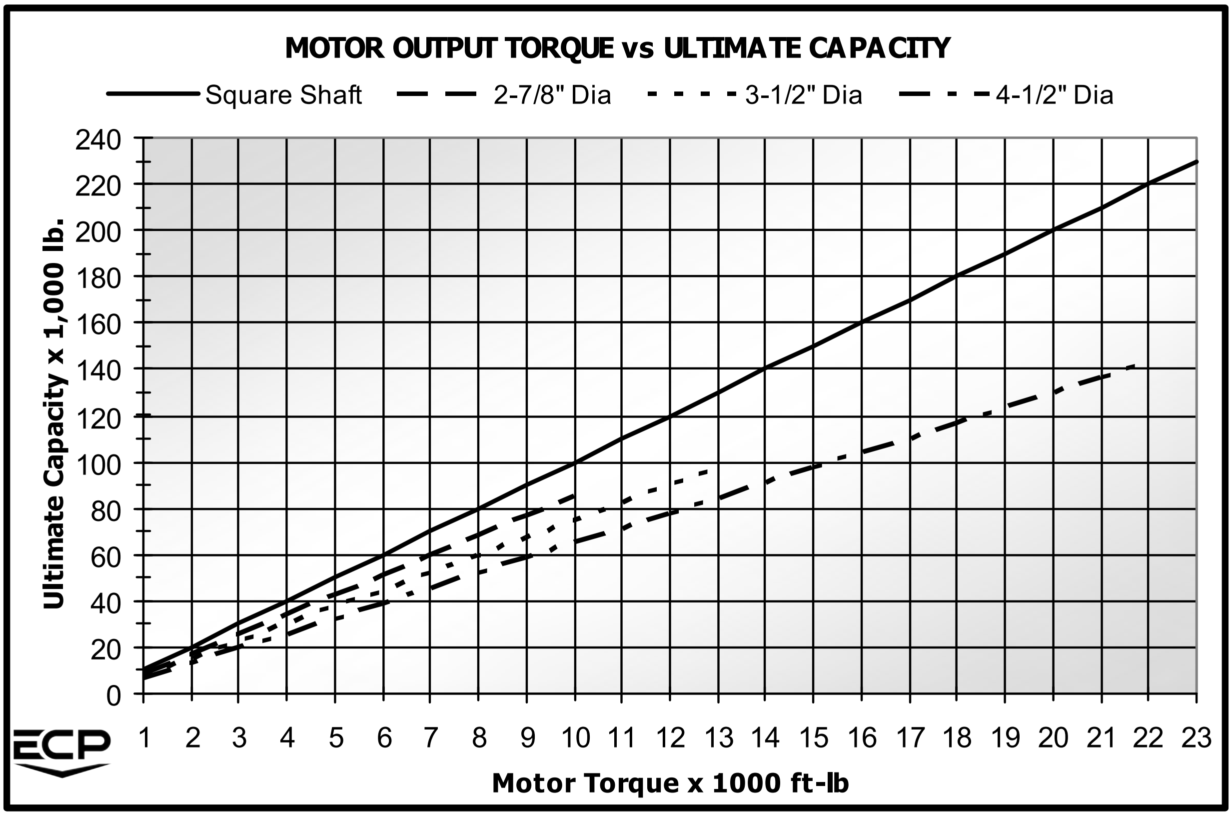
One also must be cautioned that it is very important to capture the pressure differential across the motor directly at the motor ports.

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 your data is only as accurate as the gauges. Calibrate the pressure gauges regularly to insure accurate results.

Table 20. Hydraulic Torque Motor Specifications

Illustration	Model Number	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 	**PDU 76**	12,612	**4.20**	3,000	40	21	2-1/2"	366
	PDU 76B	6,335	**2.53**	2,500	16	13.8	2	132
	78	4,030/12,128	**2.24 / 4.85**	2,500	65	73 / 33	2-1/2"	382
Eskridge 	**76BA**	12,000	**5.00**	2,400	40	19	2-1/2"	250
	76BC	8,000	**3.33**	2,400	40	24	2-1/2"	250
	78-48	12,000	**1.33 / 5.00**	2,400	40	21 / 18	2-1/2"	370

IMPORTANT: Torque Motor Conversion Factors tend to become lower than shown in this table when pressure differentials are below 1,000 psi. As a guideline, use only 90% of "K" shown when pressure differentials are between 750 and 900 psi; use 50% of "K" shown for pressure differentials between 500 and 750 psi.



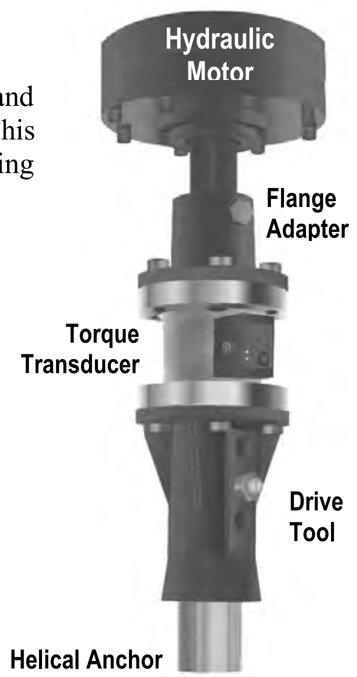
Graph 9. This quick reference can be used to estimate the ultimate capacity of a Torque Anchor™ when the motor output torque and the shaft configuration are known.

Torque Motor Accessories			
1.50 inch Square Shaft Drive Tool	1.75 inch Square Shaft Drive Tool	2 inch Hex Drive Tool	2.50 inch Hex Drive Tool
			
2.88 inch Drive Tool (Two Hole Drive)	2.88 inch Drive Tool (Three Hole Drive)	3-inch Dia. Drive Tool (Three Hole Drive)	Link Arm
			
Pipe Install Tool	Hydraulic Motor Pressure Monitor	Shear Pin Torque Indicator	Smart Anchor Monitor
			

ECP Smart Anchor Monitor and Assembly Configuration (Strain Gauge Monitor)

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

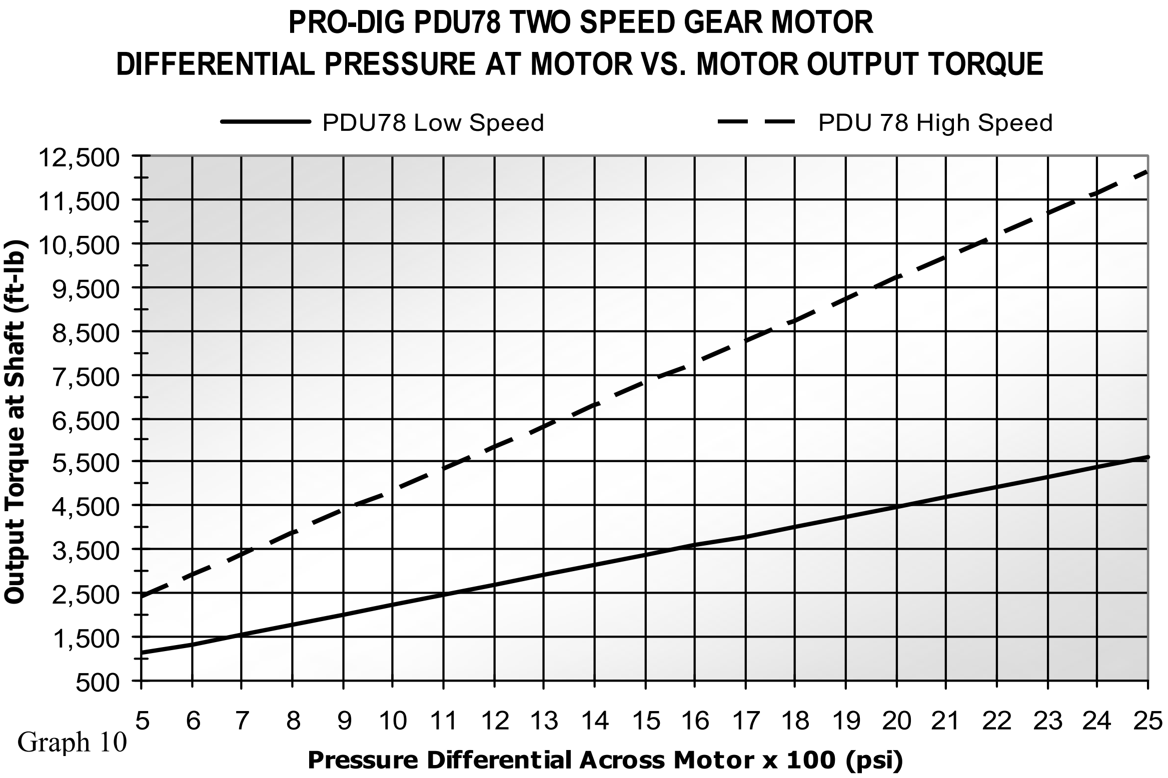
- Highly accurate (+/-0.25%) torque monitoring capabilities
- Angle and depth monitoring
- GPS data recorder for exact location of the anchor
- Multiple wireless PDA’s can be used to view one drive
- Data can be exported to third party software
- Shaft RPM Indicator
- Calibrated to NIST (National Institute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



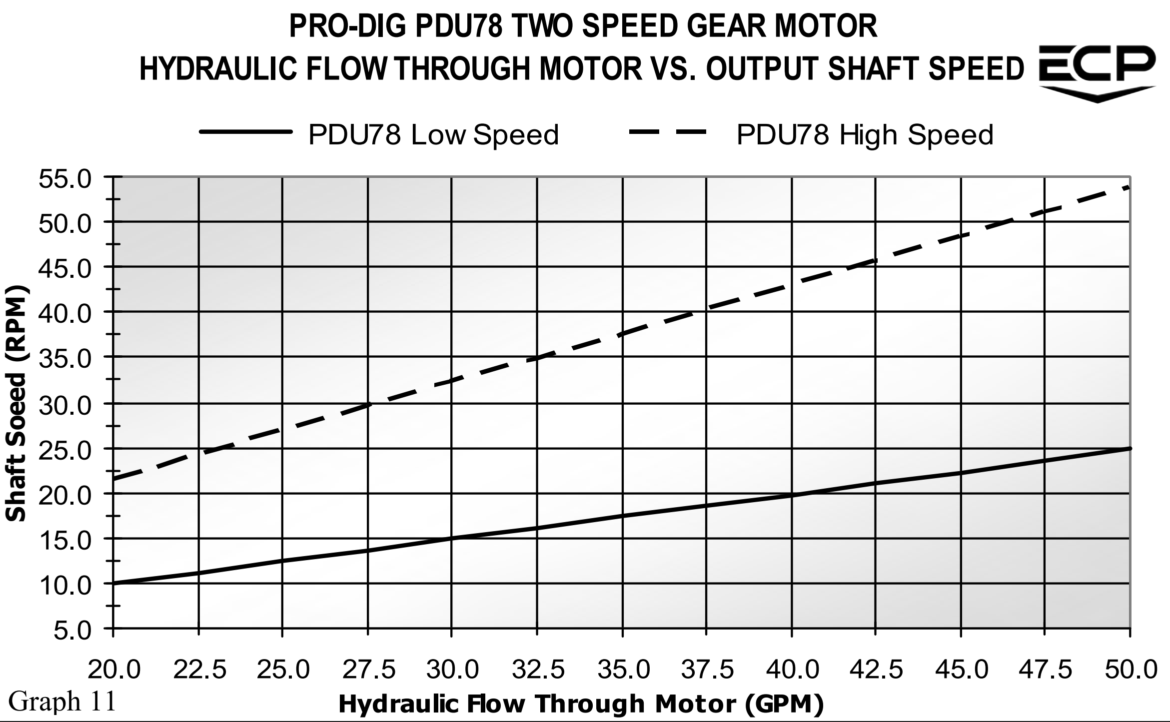
ECP Hydraulic Torque Motor Performance Curves

The following graphs provide hydraulic motor performance curves for Pro-Dig gear motors that are normally stocked for immediate delivery.

These graphs provide a quick source for motor output based upon **pressure differential across the motor ports** as a result of oil flow through the motor.



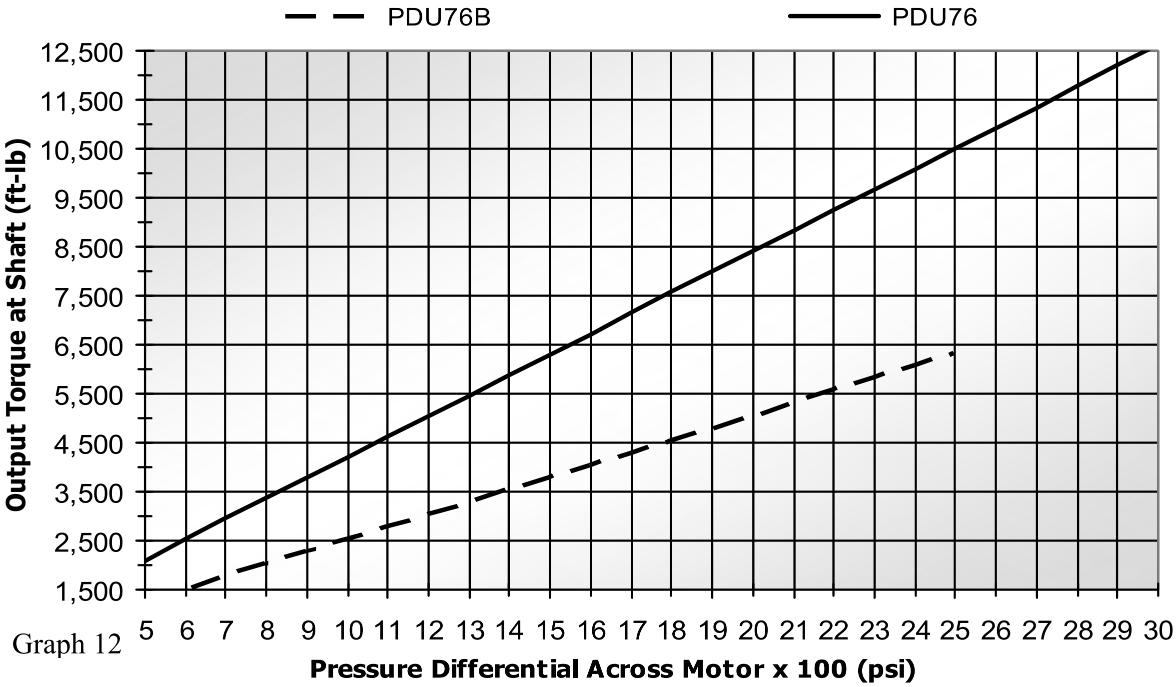
Graph 10



Graph 11

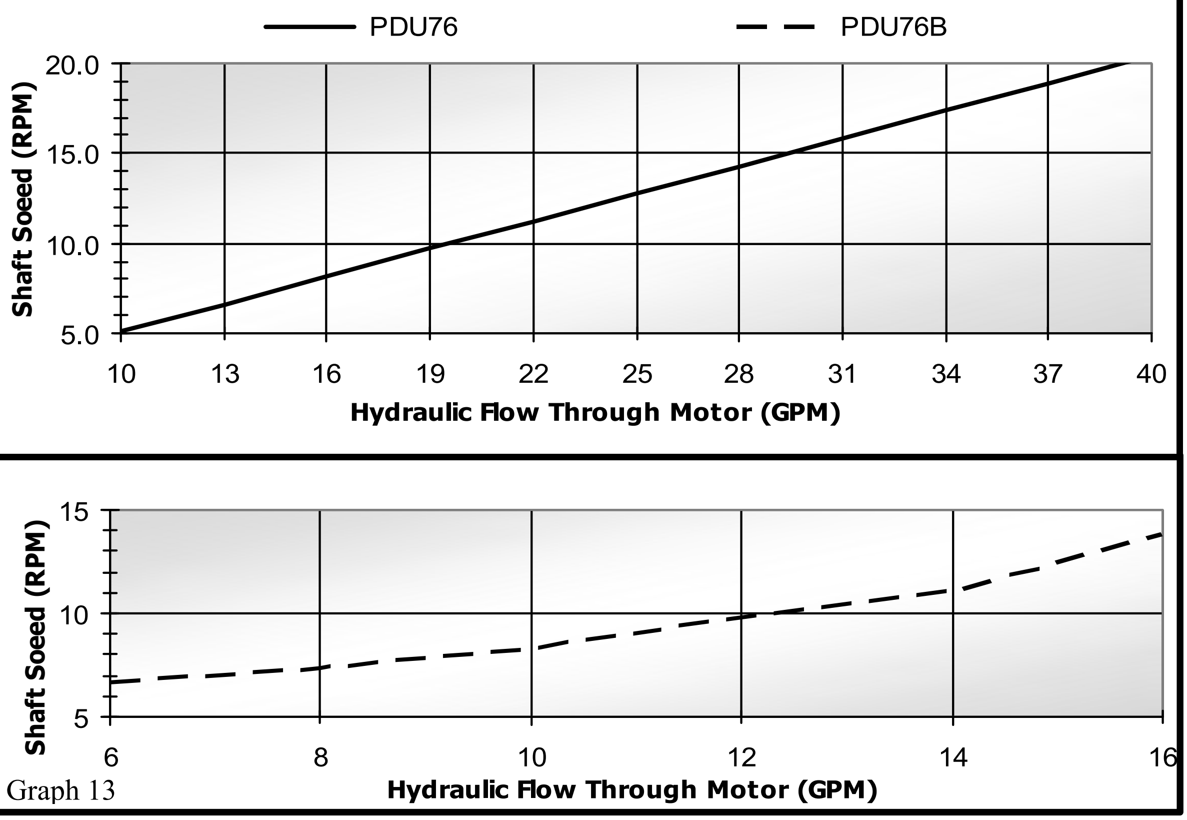
Installation and Testing

PRO-DIG PDU76 & PDU76B SINGLE SPEED GEAR MOTORS
DIFFERENTIAL PRESSURE AT MOTOR VS. MOTOR OUTPUT TORQUE



Graph 12

PRO-DIG PDU76 & PDU76B SINGLE SPEED GEAR MOTORS



Graph 13

Design Example 7 – Motor Output Torque

The transmission tower design presented in Design Example 4 specified that when installed on this site, a shaft torsion of 5,900 ft-lb was needed at the Torque Anchor™ shaft to satisfy the ultimate capacity requirement of 50,000 pounds at each leg of the tower.

In this example, the installation motor that will be used to install these Torque Anchors™ is a Pro-Dig PDU76 hydraulic torque motor. The averaged inlet and outlet pressures at the motor ports were reported from the field to be 1,650 psi and 200 psi respectfully as the installation reached the design depth.

Referring to Graph 12, above; the output torque of the PDU76 motor can be determined directly. The average *Pressure Differential* across the PDU76 motor was reported from the field as ΔP = 1,450 psi. (Equation 7: $\Delta P = p_{in} - p_{out}$)

At the bottom of Graph 12 find the 1,450 psi pressure differential on the horizontal axis, then read upward until the motor curve line is reached. Then read across to the vertical axis where the torque output can be found. The intersection of the line for 1,450 psi and the column for the PDU76 motor shows the output shaft torsion is 6,000 ft-lb at a motor differential pressure of 1450 psi.

Equation 7 and Table 20 can also be used to determine output torque:

T = K x ΔP (Equation 7)

Where,

T = Torque Output of the Hydraulic Motor - ft-lb
K = 4.20 (See Table 20 – Pro-Dig PDU76)
$\Delta P = p_{in} - p_{out}$ = 1,650 psi – 200 psi = 1,450

T = 4.20 x 1,450
T = 6,090 ft-lb > 5,900 ft-lb

The results from of both methods have confirmed that the helical pile installation exceeds the torque requirement determined by the design.

End Design Example 7

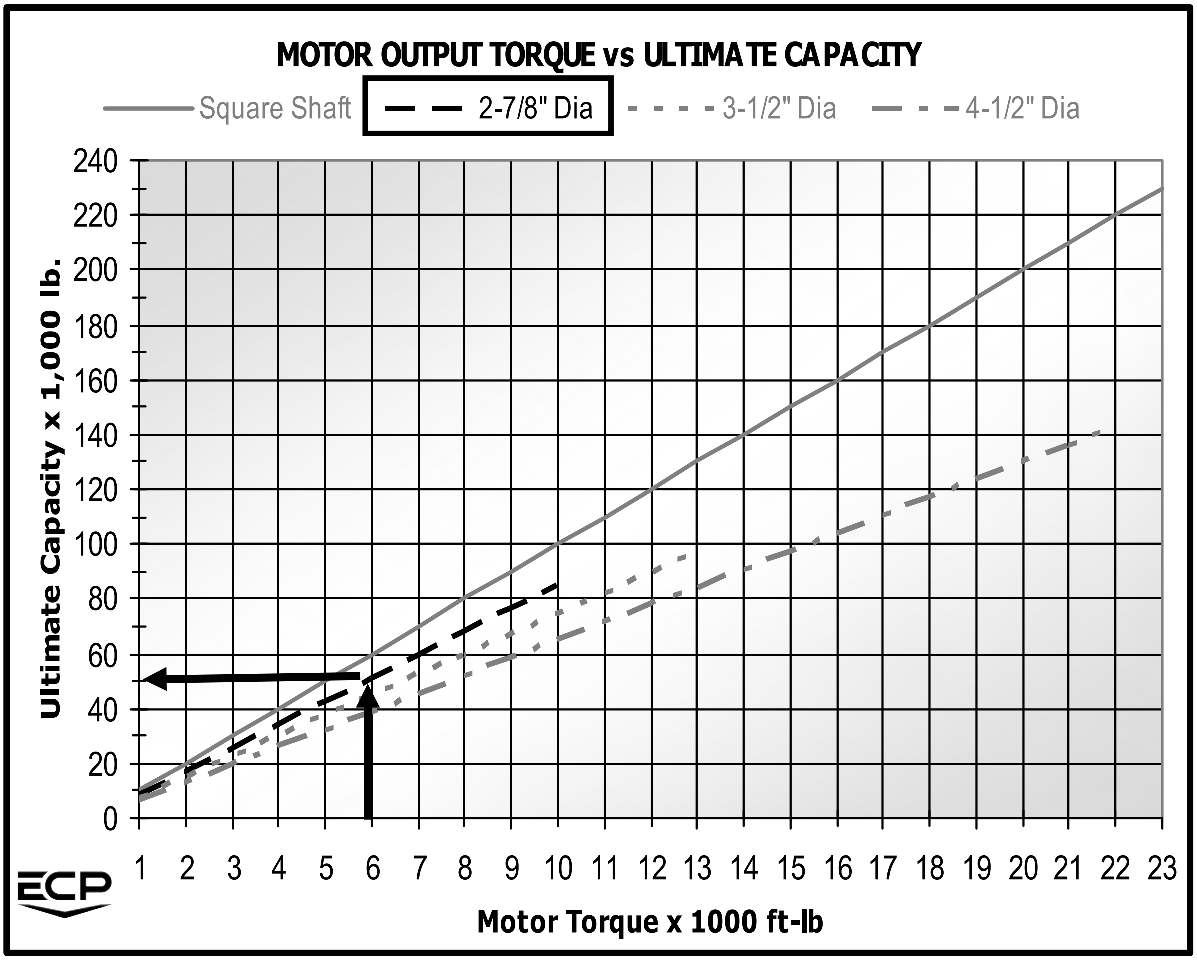
Design Example 8 – Estimated Ultimate Capacity

The estimated ultimate capacity of the pile design determined in Design Examples 4 and 5 in the previous chapter will be confirmed in this exercise using the shaft torque from Example 7 above. Recalling that the transmission tower project required an ultimate capacity at each leg of 50,000 pounds, this example will calculate an ultimate capacity based upon the reported field data. A comparison with the design requirement will verify whether the pile installation is satisfactory. In the previous design example a Pro-Dig PDU76 motor was used to install the pile. The calculation in Example 7 verified that the torque output at the motor shaft of 6,000 ft-lb exceeded the stated design requirement of 5,900 ft-lb. Graph 9 (Reproduced Next Page) can estimate the ultimate capacity of the installed helical product. Use the plot line for the shaft configuration and read the ultimate capacity at the left axis at the installation torque on the anchor shaft. First, the specific line that represents the shaft configuration must be found on Graph 9. The legend near the top of the graph provides choices between solid square shafts and three sizes of tubular shafts. In Design Examples 4 and 5 a tubular shaft measuring 2-7/8 inch diameter with a 0.262 inch wall was selected as the most economical shaft configuration for supporting the ultimate load requirement of 50,000 pounds per leg.

The ultimate capacity estimate for the pile based upon field data from the site can be determined by reading upward from the 6,000 ft-lb motor torque line until the dashed line that represents the 2-7/8 inch diameter shaft configuration is encountered.

Proceed horizontally to the left axis, where the ultimate capacity estimate is located. It can be seen that shaft torsion of 6,000 ft-lb produced a 50,000 pound ultimate capacity. The pile installed on the site has indeed met the load requirement specified. (Actual field data suggested torsion on the shaft was 6,090 ft-lb. By using 6,000 ft-lb on the graph presents a conservative estimate.)

End Design Example 8



This copy of Graph 9 illustrates how to estimate the installed ultimate capacity for Design Example 8.

The design examples in this chapter and Chapter 3 were based upon an actual transmission tower installation project that is currently supported by ECP Torque Anchor™ helical pile foundations.

ECP Helical Guy Anchor Installation Procedure

General Considerations:

- Always inspect adapters, drive tool assembly and anchors for damage or contamination
- Be sure all equipment and accessories are available before starting installation procedures
- Verify that no underground or above ground utilities exist that can interfere with planned placements of Helical Anchors
- Verify the minimum torque requirement and depth for the anchor
- Verify that Installation Torque Record form is available (Sample form below)
- Use moderate crowd (downward pressure) on anchor during installation for proper advancement
- Control installation rotation speed between 5 rpm and 20 rpm when approaching the target depth
- Always maintain proper alignment between torque motor shaft, drive tool assembly and the anchor shaft during installation
- Goal: Advance three inches per revolution to match the helix pitch

Before a helical anchor can be installed, the installation equipment must be outfitted with the appropriate tooling. The Kelly Bar adapter is attached directly to the motor output shaft by a single bolt. The locking assembly that holds the drive end assembly shall be securely bolted to the Kelly Bar adapter.

STEP 1 — Insert Helical Lead Section

Position the anchor at the desired guy location and begin installation by rotating the helical anchor with the motor and helical shaft in a vertical position. Once the first helical plate is fully engaged into the soil, begin to make an installation angle adjustment to the boom and motor to bring the anchor shaft to the required guy angle. The final anchor angle within a tolerance of $+5^0$ to -5^0 shall be accomplished before the second helix penetrates the ground.

STEP 2 — Attach Helical Extension

When the lead anchor section is installed such that the helical adapter assembly is approximately 12" from the ground, disconnect the adapter from the lead section. An extension shaft shall be connected between the top of the anchor lead shaft and the adapter assembly using the hardware supplied with the extension. Continue to advance the anchor into the ground using the hydraulic gear motor. Additional extensions may be required as described above until the helical anchor achieves the required shaft torsion and/or depth is reached. A record of the torque applied to the shaft shall be maintained on the Installation Torque Record form. Keep in mind the terminal torsion requirement must be achieved and maintained for a minimum of three feet before terminating the installation. The minimal embedment depth, measured vertically from the final grade to the depth of the uppermost helical plate shall be six times the diameter of the uppermost helical plate.

STEP 3 — Attach Guy Adapter

Once the helical anchor has achieved the shaft torque requirement and satisfied the minimum embedment, the guy adapter shall be attached to the helical anchor shaft using the hardware supplied.

If the helical anchor minimum embedment depth cannot be achieved without reaching the maximum allowable shaft torsion for the particular shaft, the anchor should be removed and replaced with an anchor having smaller or fewer helices. When rocks or trash are encountered during the installation, a lead section with spiral cut leading edge modification might allow transit through the obstructions in difficult soils. A standard helical plate may be field modified if an ECP approved layout is used to form the spiral modification.

If the shaft torsion requirement is not achieved at the anticipated depth, the installer may choose to continue to add extension sections in order to embed the lead section is a denser stratum of soil that may be situated at a lower elevation. Another option is to remove the lead and replace the lead with one having a greater projected area from more or larger helical plates. One may also continue to use the original lead and change the first extension section from a plain shaft to one containing one or more helical plates.

If the anchor is installed into the original placement, the anchor must be advanced a minimum of three feet beyond the lowest depth of the previous installation prior to recording shaft torsion.

Installation torque must be monitored and recorded to ensure that sufficient anchor capacity has been achieved. Torque monitoring can be achieved by several methods such as a strain gauge instrument, pressure differential across the installation motor and/or shear pin hub. Strain gauges usually provide the most accurate indication of torque, and thus a more accurate estimation of ultimate anchor capacity. It is recommended that installation shaft torsion be measured and recorded in one foot increments. Accurate field installation data will provide valuable documentation if anchor design changes are required.

To insure proper installation:

- The anchor angle must be within a tolerance of $+5^0$ to -5^0. Adjustments must be accomplished before the second helix penetrates the ground.
- Maintain rotation of the shaft between 5 and 10 rpm when nearing the seating depth of the anchor
- Use moderate crowd (downward pressure). Do not use more crowd than sufficient to keep the anchor advancing into the soil.
- Once the shaft torque requirement has been met, it must be maintained continuously for a minimum of three feet of shaft length before terminating the installation.
- Install the anchor to a minimum embedment depth of six times the diameter of the largest plate as measured from the surface to the uppermost helical plate.
- Record shaft torsion using measurement devices that have been recently calibrated to insure accurate data.
- Record and maintain accurate installation records

End Procedure

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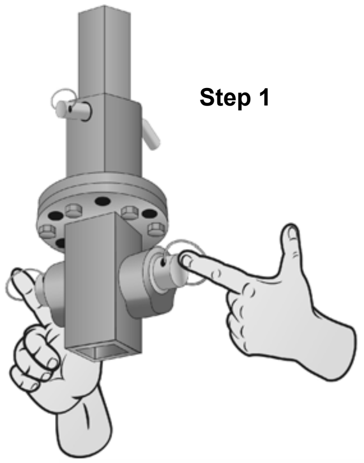
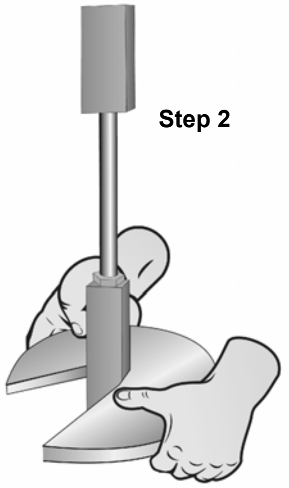
General Considerations:

- Always inspect adapters, drive tool assembly and anchor for damage or contamination
- Be sure all equipment and accessories are available before starting installation procedures
- Verify that no underground or above ground utilities exist that can interfere with planned placements of PITA Anchors
- Verify the minimum torque requirement and depth for the anchor
- Verify that Installation Torque Record form is available (Sample form below)
- Use moderate crowd (downward pressure) on anchor during installation for proper advancement
- Control installation rotation speed between 5 rpm and 10 rpm when approaching the target depth
- Always maintain proper alignment between torque motor shaft, drive tool assembly and the anchor shaft during installation
- Goal: Advance three inches per revolution to match the helix pitch



Before a Power Installed Torque Anchor (PITA) can be installed, the installation equipment must be outfitted with the appropriate tooling. The Kelly Bar adapter is attached directly to the motor output shaft by a single bolt. The locking assembly that holds the drive end assembly shall be securely bolted to the Kelly Bar adapter. If the anchor depth requirement can be met using one 7 foot rod length, only the square drive end tool is required. If anchor is to be installed deeper than 7 feet, 3-1/2 or 7 foot long extension assembly shall be attached between the drive end assembly and the locking dog assembly to accomplish the added depth requirement. PITA anchors shall not be installed beyond 14 feet.



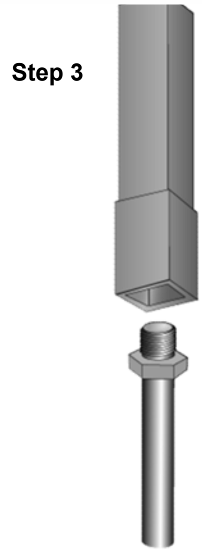
STEP 1 — Open Locking Pins

Before installing the drive tool assembly into the locking assembly, open the spring activated pins by pulling outward and twisting the pins to the outside position. The locking assembly has three distinct pin positions.

- The middle position holds wrench drive end assembly
- The in ring position allows locking pins to hold anchor rod
- The out position releases drive end assembly from locking pin assembly

STEP 2 — Attach Pita Anchor Rod to the PITA anchor lead

Attach the PITA rod to the PITA lead by rotating the threaded pieces together

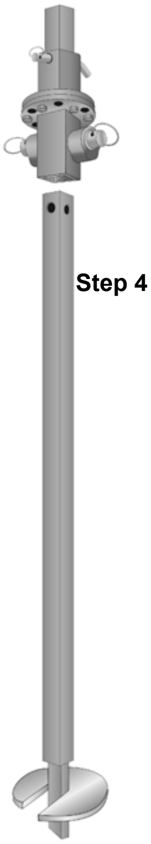


STEP 3 — Insert Pita Anchor Rod into the Drive Tool Assembly

With the locking pins now positioned at the "in" position, the assembly will hold anchor rod. Rotate the threaded end of the rod to attach it into the threaded hole located in the hub of the PITA anchor. Insert the rod into drive tool assembly until locking pins engage.

STEP 4 — Insert Drive Tool Assembly

With locking pin rings in the "out" position, insert the square tubular drive tool assembly into the locking pin assembly. Rotate the rings to the "middle" position. The drive tool assembly will be secured in the locking pin assembly. Next rotate locking pins to the "in" position to accept the PITA anchor rod.

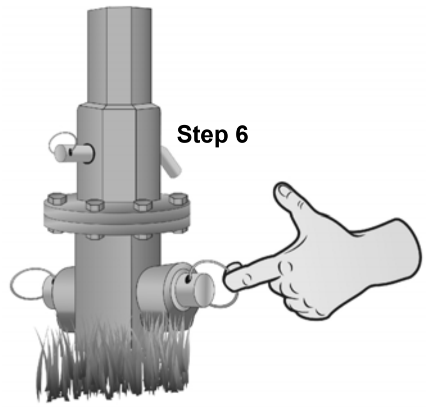


STEP 5 — Install Pita Anchor

Begin rotating the anchor assembly with the shaft in a vertical position. When anchor has become engaged into the soil, orient the boom and motor to meet the shaft angle specified in the design. Final installation angle tolerance shall be $+5^{0}$ to -5^{0}. Continue to advance the anchor into the soil until the predetermined depth of 7, 10-1/2 or 14 feet is achieved. Maintain the rate of advancement of the anchor of three inches per revolution. Discontinue the installation when the locking pin assembly reaches ground level. Record installation data on the Installation Torque Record form.

STEP 6 — Retrieve Drive Tool

Position the locking pin rings in the "middle" position and remove the tool assembly. The PITA anchor rod and hub will remain in ground.



STEP 7 — Attach Pita Anchor Eye Nut

Complete the installation by installing the eye nut on the end of the PITA anchor rod.

End Procedure

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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 to length and install the pile cap or wall support assembly and load as required
- Load test as required to verify design and capacity
- Remove equipment from work area and clean work areas

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 on the helical torque anchor™
- 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 torques 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, do the following:
  - **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 the review and approval by the engineer and/or owner
- If the target 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™ deeper 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™ 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.
- 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 a minimum of three feet farther.
- 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. It is not permissible to reverse the installation to reach the desired coupling elevation.

STEP 2 – Torque Anchor™ Installation:

The hydraulic installation motor shall be installed to portable equipment or to 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 locations. 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 down pressure 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 continue 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, 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 using bolt(s) and nut(s) supplied by the manufacturer having the same size and strength 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 threaded bar is attached between the transition and the equipment base. If required, the installer may place a center hole ram over the continuously threaded bars 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 is 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			16		
2			17		
3			18		
4			19		
5			20		
6			21		
7			22		
8			23		
9			24		
10			25		
11			26		
12			27		
13			28		
14			29		
15			30		

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 a maximum of one inch of movement for permanent structural support applications is allowed.

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" and "Quick Test" outlines are conservative and designed for tests on supports for permanent buildings and retaining walls.

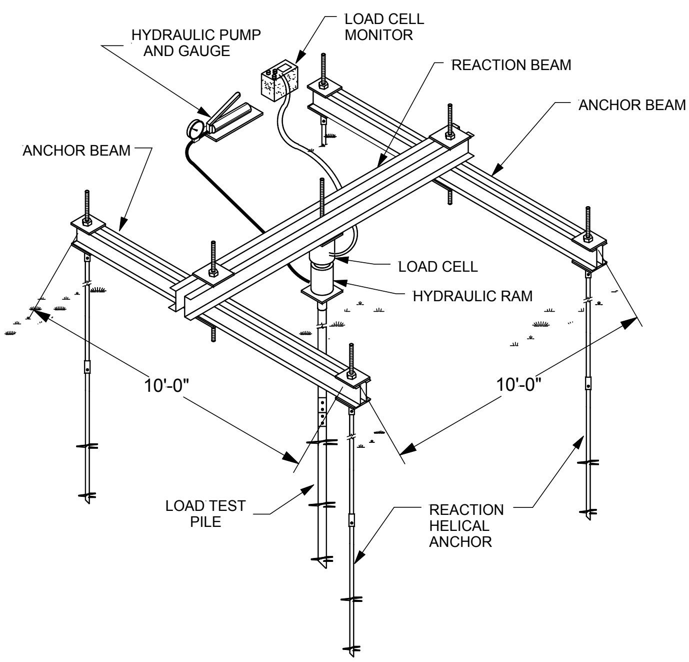
When determining acceptable criteria for guy wire anchorage or for other temporary anchorages, the failure criterion could differ from the test procedures presented here because significantly more creep is usually acceptable in utility anchor applications. For this reason, the engineer in charge should 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 test will provide more accurate load information than by relying only upon the torque efficiency factor, "k" of the shaft as it penetrates the soil.

A sample field test reporting form is provided at the end of this chapter.

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 centroid of 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.
5. Install a load cell (or certified pressure gauge) and hydraulic ram. The center hole load ram will 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 .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 as 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 a 8 and 15 minutes when permitted by longer intervals. The monitoring can 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 five to ten 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 an after unloading permanent deflection of "d" < 0.5".

    A failure criterion is often different than outlined in the typical procedure. The failure criteria should be reviewed and established by the project engineer. He will provide project specific test acceptance conditions for the specific application. Acceptance criteria are sometimes quite different for applications such as guy wire anchorage and for temporary tension anchors.

    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 to review the actual performance of the screw anchor in the soil under changing load conditions.

End Test Procedure

Installation and Testing

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:	

Chapter 5

Corrosion Considerations for ECP Torque Anchor™ Products

"Designed and Engineered to Perform"

Corrosion Considerations

Steel Underground -- How Long Does It Last? Galvanized steel anchor products are subjected to a range of corrosive forces that are quite different from steel exposed to atmospheric conditions. The performance of underground steel and galvanized structural steel elements 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 any one of these items is absent, corrosion will not occur.

Soil Resistivity: One of the simplest classifications for soil corrosivity is based upon the resistivity of the soil. To obtain the soil resistivity, one passes a current through the soil and measures the resistivity of the soil in ohm-centimeters. Table 21 illustrates the general range of corrosivity for typical soil classes, and Table 22 provides a measure of the soil corrosivity based upon soil resistivity. In general, sandy soils have high resistivity values and are considered the least corrosive. Clay soils and especially clay with saline water are sometimes highly corrosive to steel.

Table 22. Soil Resistivity and Relative Corrosivity Rating

Resistivity (ohm-cm)	Corrosivity Rating
> 10,000	Non-Corrosive
5,000 to 10,000	Mildly Corrosive
3,000 to 5,000	Moderately Corrosive
1,000 to 3,000	Corrosive
500 to 1,000	Highly Corrosive
< 500	Extremely Corrosive

Soil pH: The measure of acidity or alkalinity in a solution is given as pH. Values of pH < 7 are considered acidic and values from pH = 7 to pH = 14 are alkaline. Pure distilled water is neutral or has a pH = 7. Doctors Laboratories, a division of the Royal Military College of Canada exposed

Table 21. SOIL CLASSIFICATION TABLE - RESISTIVITY

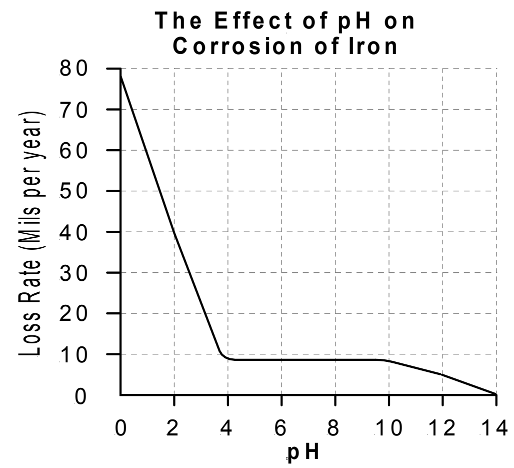
Class	Soil Description	Geological Classification	Resistivity Range (ohm-cm)
0	Solid Hard Rock (Unweathered)	Granite; Basalt; Massive Sedimentary	200,000+
1	Very dense/cemented sands; Coarse gravel and cobbles	Caliche	40,000 to 200,000
2	Dense fine sands; Hard silts and/or clays	Basal till; Boulder clay; Caliche; Weathered laminated rock	10,000 to 100,000
3	Dense sands/gravel, Stiff/hard silt and clay	Glacial till; Weathered shale; Schist, Gneiss; Siltstone	5,000 to 50,000
4	Medium dense coarse sand/sandy gravels; Stiff/very stiff silt/clay	Glacial till; Hardpan; Marl	5,000 to 20,000
5	Medium dense coarse sand and sandy gravel; Stiff/very stiff silt and clay	Saprolites; Residual soil	2,000 to 10,000
6	Loose/medium dense fine/coarse sand; Stiff clay and silt	Dense hydraulic fill; Compacted fill; Residual soil	1,000 to 5,000
7	Loose fine sand; Medium/stiff clay; Fill	Flood plain soil; Lake clay; Adobe; Clay gumbo; Fill	500 to 5,000
8	Peat, Organic silts, Fly ash, Very loose sand; Very soft/soft clay	Unconsolidated fill; Swamp deposits; Marsh soil	50 to 2,000

Notes:

1. Resistivity is highly variable from site to site and from place to place on the same site. These ranges are only guidelines and overlapping across soil classes is to be expected. Field test to verify resistivity.
2. High soil moisture content decreases the resistivity making the soil more corrosive.
3. Freezing the soil dramatically raises the resistivity, thus reducing the corrosivity

iron to aerated water at room temperature and determined the corrosion rate as a function of the pH.

As the water became more acidic (pH < 4), the steel corroded more quickly than steel did in a more alkaline environment (pH > 10). It is also interesting to note that zinc used for galvanization provides the best protection to steel in a somewhat similar environment. Zinc provides the most effective protection through a range of pH = 5.5 to pH = 12.5. In the absence of air, the zinc oxide film does not form on the zinc surface and corrosion can be more rapid when moisture is present.

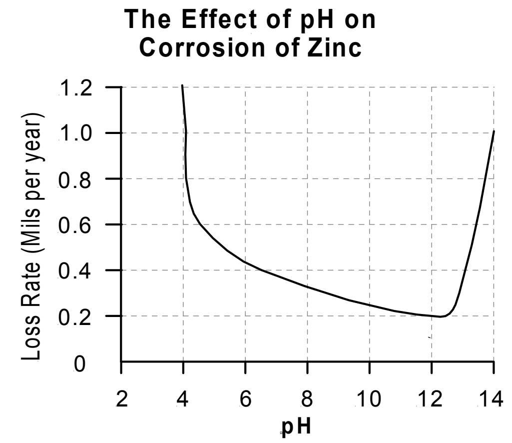


Graph 13.

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 illustrated in Graph 13 suggest that in the range of pH = 4 to 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 condition dissolves the iron oxide as it forms leaving the iron in direct contact with the water.

Zinc Galvanizing for Corrosion Protection: Frank Porter determined that the chloride content in water is most corrosive to zinc. When zinc is



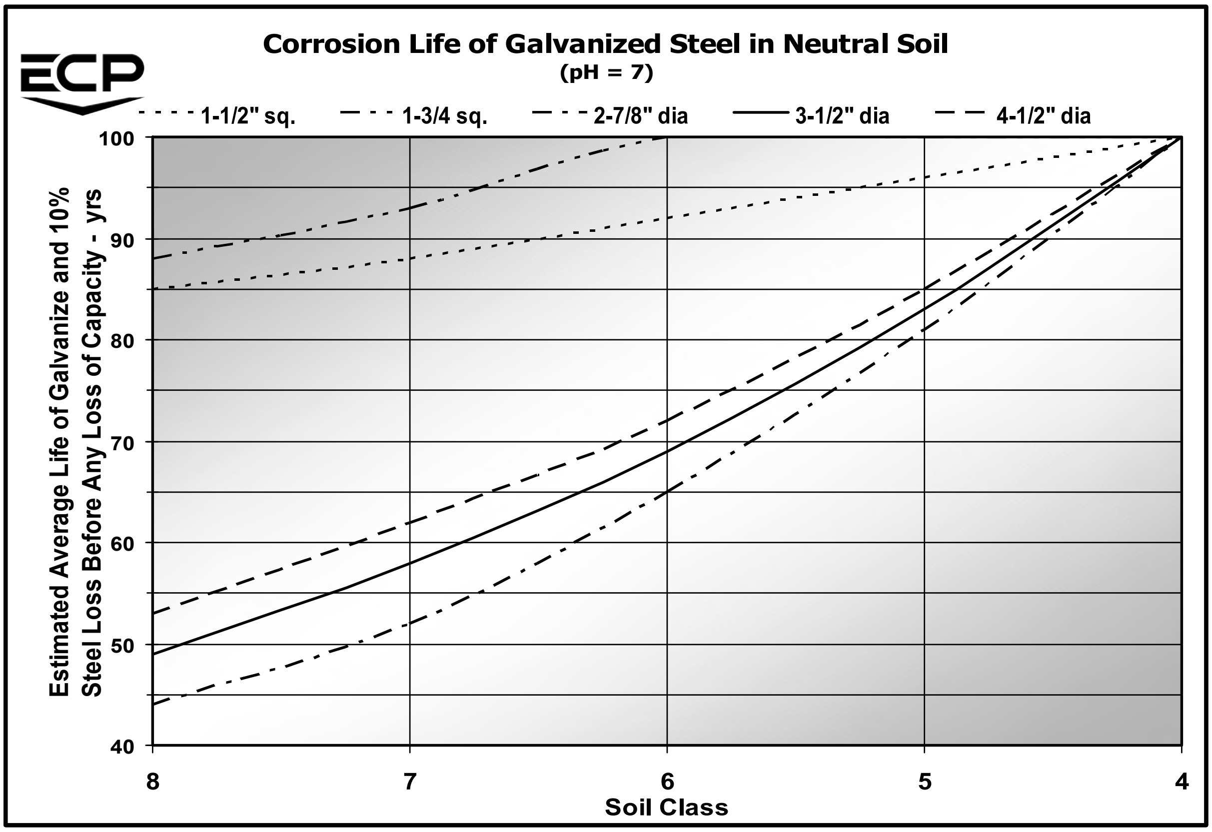
Graph 14.

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, which provides a protective barrier against attack from free chloride anions.

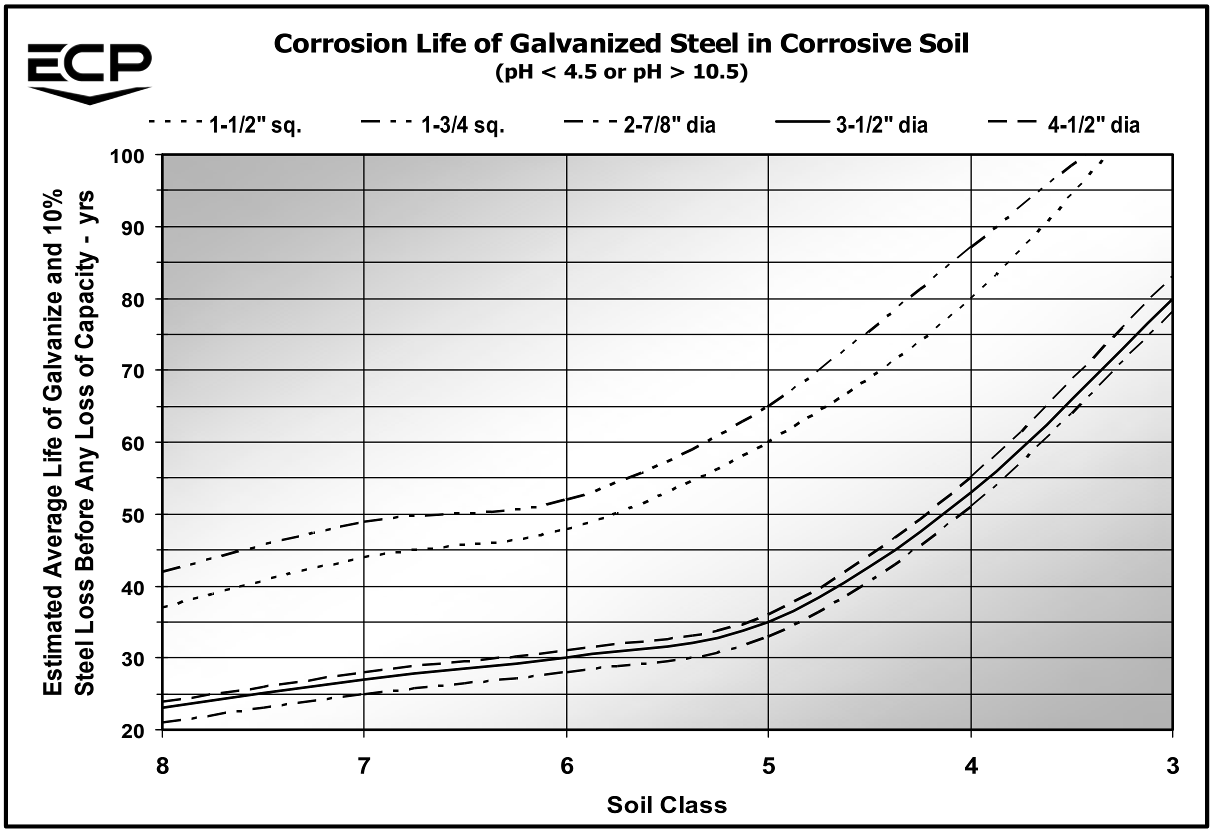
In Porter's "Corrosion Resistance of Zinc and Zinc Alloys", he attributes this insoluble scale for the significantly increased corrosion free life of galvanized piles in soils with values of "pH" between 5.5 and 12.5. Roathali, Cox and Littreal in "Metals and Alloys", 1963, presented data showing the corrosion rate of zinc as a function of pH as illustrated on Graph 14.

Life of Galvanized Coating: The National Bureau of Standard conducted testing of corrosion of metals in soils. As early as 1924, research on 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 test also found that the galvanization prevented pitting of the steel even after the visible 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.

The key to look for when there is concern about corrosion is soil that is highly acidic or highly alkaline. In most cases acidic soils will contain high amounts of organics. Fill soils, industrial waste areas, etc, are also areas for corrosion concern as are tidal areas. The second component to look at is the resistivity or ability of the soil to conduct electricity. Well drained granular soils are less of a threat than wet silt or clay.

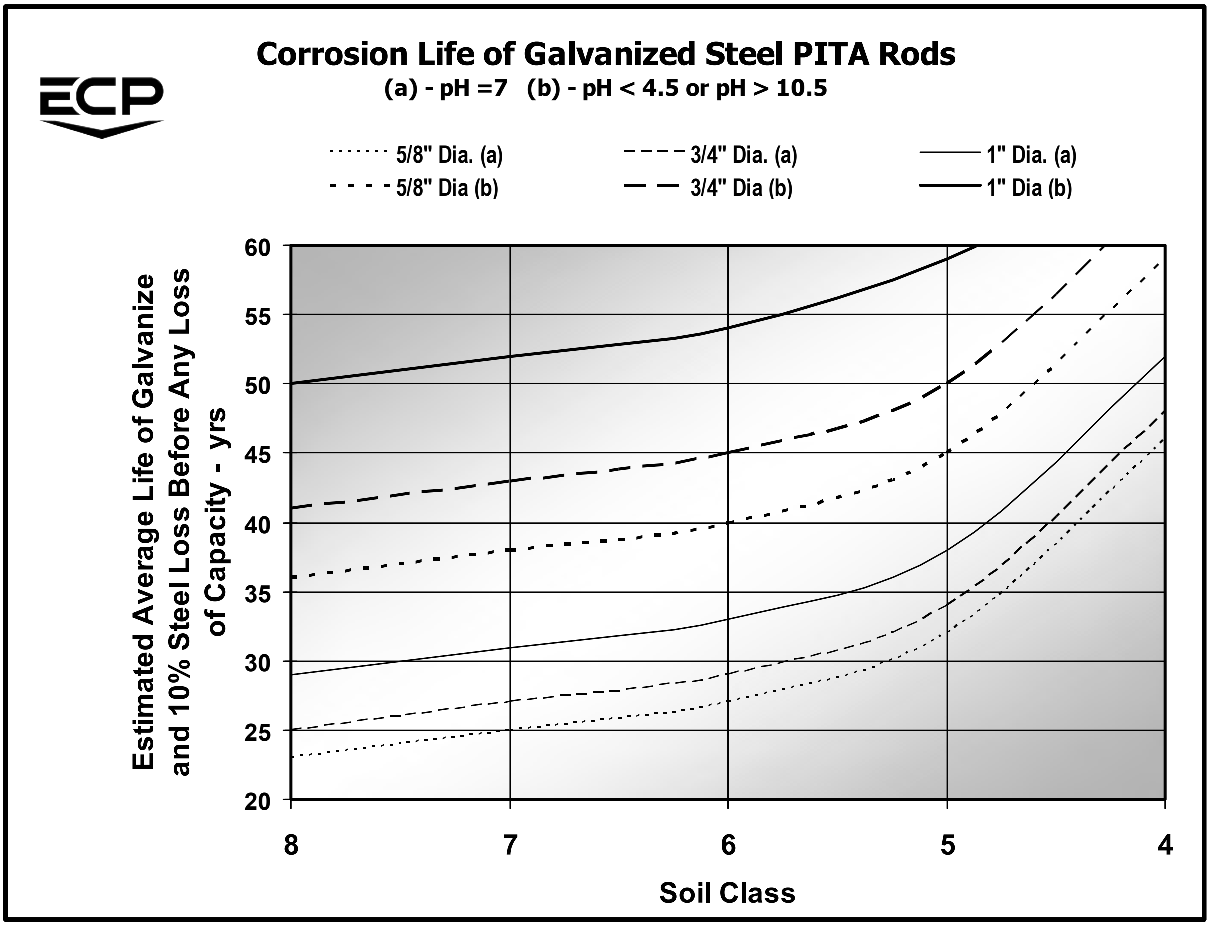


Graph 15. Estimated average corrosion life of galvanized steel (ASTM-123 Gr. 100) in neutral soil



Graph 16. Estimated average corrosion life of galvanized steel (ASTM-123 Gr. 100) in corrosive soil

PLEASE SEE THE IMPORTANT NOTES ON THE NEXT PAGE



Graph 17. Estimated average corrosion life of galvanized steel (ASTM-123 Gr. 100) PITA Rods in neutral and corrosive soil.

PLEASE SEE THE IMPORTANT NOTES BELOW

IMPORTANT NOTES:

1. Graphs 15, 16 &17 and Table 23 (below) are designed to suggest to the reader basic corrosion life expectancies of galvanized steel elements assumed to be installed in homogeneous soil with constant soil moisture. These illustrations are not intended to be used for corrosion design and are not to be considered a substitute for field measurements of pH and resistivity, and a site specific corrosion analysis.

2. Both the resistivity of the soil and the pH of the soil dramatically affect the corrosion life of the helical anchor product. This can be seen in Table 23. Notice that a change from pH = 8 to pH = 5 can cause a increase the corrosion life by as much as two to three times.

The life expectancies illustrated in the graphs and predicted in Table 23 were calculated using recognized engineering principles and are for general information only. While believed to be accurate for the specific conditions indicated, this information should not be used or relied upon for any specific application without field testing and corrosion analysis by a registered professional engineer in order to determine suitability of the product on the site.

3. Reaching the end of the stated corrosion life does not suggest that the product will fail. At the end of the corrosion life estimate presented here, the product will still possess the full rated capacity along with the design factor of safety. Once reaching the end of the corrosion life, a slow reduction of the product factor of safety will occur over time as the ultimate capacity of the product reduces.

4. The graphs and Table 23 have an allowance for 10 percent steel loss on the cross section of the shaft due to corrosion of the solid steel bars and on the wall thickness of the tubular sections. This extra material is required for torsional strength when initially installing the helical anchor. The anchor should retain the original design capacity with the full factor of safety intact even with this fractional amount of

metal loss. The exception is Graph 11, which shows corrosion life of PITA rods and adapter connectors. No reduction in rod area was considered on these products because the products are not subjected to torsion stress during installation.

5. Variations in soil moisture content from season to season and year to year can adversely affect service life. Low field moisture content produces lower corrosion rates even in aggressive soils. Stray currents from pipe lines, power lines, etc may also affect life due to imposed currents. Corrosivity testing is always recommended in problem soils.

6. Hot Dip Galvanize process was assumed to meet or exceed ASTM A123 – Grade 100 in the preparation of these illustrations.

7. As the life expectancy increases beyond 40 years the margins for error increases dramatically because these life expectancy estimates are calculated from empirical equations derived from field testing and are projected beyond the actual length of the actual corrosion testing. Predictions above 50 years should be evaluated cautiously.

TABLE 23. ECP Torque Anchor™ Estimated Average Life Expectancy at Full Load

Soil pH	Plain Steel Life Expectancy at Full Load						Hot Dip Galvanize 2.3 oz/ft^2 3.9 Mils (Min.)
	1-1/2” Square Bar	**1-3/4” Square Bar**	**2-1/4” 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	39 yrs	9 yrs	11 yrs	12 yrs	Add 12 years to life shown at left
5	100+ yrs	100+ yrs	125+ yrs	48 yrs	57 yrs	63 yrs	
8	45 yrs	52 yrs	67 yrs	15 yrs	17 yrs	19 yrs	
10.5	25 yrs	30 yrs	39 yrs	9 yrs	11 yrs	12 yrs	
Soil Resistivity – 1,000 ohm-cm							
4.5	29 yrs	34 yrs	43 yrs	10 yrs	12 yrs	13 yrs	Add 15 years to life shown at left
5	100+ yrs	100+ yrs	125+ yrs	57 yrs	67 yrs	73 yrs	
8	47 yrs	57 yrs	73 yrs	17 yrs	20 yrs	22 yrs	
10.5	29 yrs	34 yrs	43 yrs	11 yrs	12 yrs	13 yrs	
Soil Resistivity – 2,000 ohm-cm							
4.5	34 yrs	39 yrs	51 yrs	12 yrs	14 yrs	15 yrs	Add 20 years to life shown at left
5	125+ yrs	125+ yrs	150+ yrs	85 yrs	100 yrs	100+ yrs	
8	49 yrs	67 yrs	86 yrs	19 yrs	22 yrs	24 yrs	
10.5	34 yrs	39 yrs	51 yrs	12 yrs	14 yrs	15 yrs	
Soil Resistivity – 5,000 ohm-cm							
4.5	45 yrs	52 yrs	67 yrs	16 yrs	18 yrs	20 yrs	Add 34 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	67 yrs	16 yrs	18 yrs	20 yrs	

It is interesting to note that once the resistivity becomes higher than 1,000 ohm-cm, the galvanized solid square shaft helical pile product provides an excellent service life exceeding 44 years, when not subjected to soil pH values outside the range of the tables 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.

PLEASE SEE THE IMPORTANT NOTES ABOVE

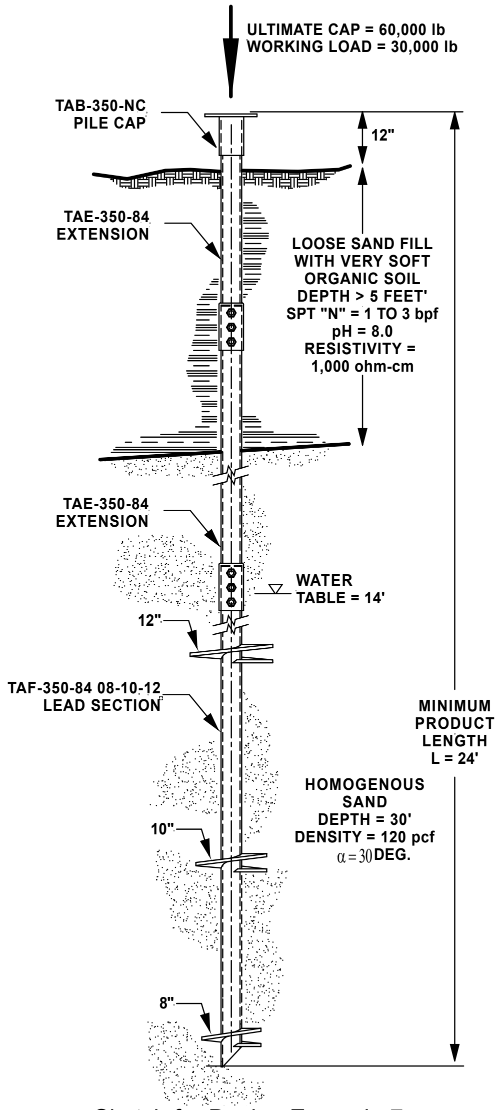
Hot Dip Galvanizing: The products manufactured by Earth Contact Products that are offered with hot dip galvanizing are coated with molten zinc that contains not less than 98% pure zinc metal. The hot dip galvanization process meets or exceeds ASTM A123 Grade 100 for steel plate, tubular or bar products. Specification ASTM A123 Grade 100 requires 3.9 mils (0.004") or 2.3 oz/ft^2 of zinc is the minimum allowed. Most galvanized coatings will have a thickness in excess of these values.

Design Example 7 – Corrosion Life of Tubular Torque Anchor™

Structural and Soil Details:

- Anchorage for Equipment Support
- 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.
- Standard Penetration Test values for this weak layer were: "N" = 1 to 3 blows per foot - Soil Class = 8
- Below approximately five feet, a layer of very stiff inorganic clay (CL), with SPT, "N" = 20 blows per foot (average) and the water table remains at 14 feet - Soil Class = 5
- Soil pH in the sand fill and soft organic soil was reported to be: pH = 8.0 and the resistivity measured 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

> 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 or absence of stray currents**



Sketch for Design Example 7

This analysis considers the performance life of the galvanized coat along with the time required to corrode 10% of wall thickness of the pile shaft after exhausting the galvanized coating.

"Ball Park" Corrosion Life Estimate

1. Estimate Life of Helical Shaft in pH = 7 Soil: Soil with pH = 7 is considered neutral and not likely to cause excessive corrosion. This corrosion life estimate can quickly be obtained from Graph 15 above.

Locate Soil Class 8 at the bottom right of the graph. Read upward until the solid graph line is encountered, which represents the 3-1/2 inch diameter by 0.300 galvanized tubular shaft. The rough life expectancy of the pile shaft without compromising the support strength is 48 years.

2. Estimate Life of Helical Shaft in pH < 10.5 Soil: There is corrosive soil located a distance of five feet below grade on this site. The reported pH = 8 with a resistivity of 750 to 1,000 ohm-cm. There is likely a reduction in corrosion life of this pile shaft in this soil because the soil contains organics which can conduct corrosive currents and the pH is more alkaline than the neutral pH = 7.

There is no graph to illustrate this particular soil condition. A judgment must be made between the corrosion of the shaft in neutral soil and in corrosive soil soils that exceed pH < 10.5.

The corrosion life estimate for corrosive soil can quickly be obtained from Graph 16 above.

Locate Soil Class 8 at the bottom right of the graph. Read upward until the solid graph line is encountered, which represents the 3-1/2 inch diameter by 0.300 galvanized tubular shaft. The rough life expectancy of the pile shaft in highly corrosive soil without compromising the support strength is 23 years.

3. Estimate Life of Helical Shaft in pH = 8 Soil: A quick "Ball Park" corrosion life can be obtained by assuming that the corrosion rate for the low resistivity soil with pH = 8 is approximately half way between noncorrosive soil and the highly corrosive soil.

$L = [L_{pH=7} + L_{pH<10.5}]/2 + L_{pH=7}$

L = [48+23 years]/2 + 23 years = 35-1/2 years

Corrosion Life = 30+ years*

Alternate "Rough Estimate" of Corrosion Life

1. Estimated Life of Steel. 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 23 and reproduced below.

Many times the exact field resistivity and pH will not be found on Table 23. The average life will have to be estimated based from between the pH values in the table.

The resistivity was reported at 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.

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 for corrosion in the soil on the site of 1,000 ohm-cm and pH = 8 will be used here. The soil pH = 8 is located at the left column. Looking at the table for soil with 1,000 ohm-cm, the corrosion life estimate for the steel is 23 years.

CL_P = 23 years

TABLE 23. Sample ECP Torque Anchor® & Soil Nail Life Expectancy Estimates at Full Load

Soil pH	Plain Steel Life Expectancy at Full Load						Hot Dip Galvanize 2.3 oz/ft² - 3.9 Mils (Minimum)
	1-1/2" Square Bar	1-3/4" Square Bar	2-1/4" 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	39 yrs	9 yrs	11 yrs	12 yrs	Add 12 years to life shown at left
5	100+ yrs	100+ yrs	125+ yrs	48 yrs	57 yrs	63 yrs	
8	45 yrs	52 yrs	67 yrs	15 yrs	17 yrs	19 yrs	
10.5	25 yrs	30 yrs	39 yrs	9 yrs	11 yrs	12 yrs	
Soil Resistivity – 1,000 ohm-cm							
4.5	29 yrs	34 yrs	43 yrs	10 yrs	12 yrs	13 yrs	**Add 15 years to life shown at left**
5	100+ yrs	100+ yrs	125+ yrs	57 yrs	67 yrs	73 yrs	
8	49 yrs	57 yrs	73 yrs	17 yrs	**20 yrs**	22 yrs	
10.5	29 yrs	34 yrs	43 yrs	11 yrs	12 yrs	13 yrs	

2. Estimated Life of the galvanization. The average corrosion life of hot dip galvanize to ASTM A123 Grade 100 can be found at the right column. It is necessary determine the corrosion life at 1,000 ohm-cm resistivity on the lower table.

CL_G = **15 yr** (1,000 Ω-cm)

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 = $CL_P + CL_G = 23 + 15 = 38$ **years**

Corrosion Life = <u>30+ years</u>*

Review of Results of Example 1 & 1A

The result obtained by the "Ball Park" analysis and the result that was calculated by the "Rough Estimate" table report similar results. Larger differences can be expected when making estimates for values that fall between soil types on the graphs and between the data boxes in the table.

It is important to remember that the corrosion life predicted by these equations provide an <u>average life expectancy</u> for the foundation support product when installed under the given conditions. Furthermore, AT THE END OF THE CALCULATED CORROSION LIFE, THERE WILL BE NO LOSS OF STRUCTURAL INTEGRITY OR ORIGINAL DESIGN FACTOR OF SAFETY. In roughly estimating corrosion life by these methods, conservative decisions should always be used.

*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 and distilled into graphs and tables. Both corrosion lives determined in this example are accurate within the range of error and were rounded down to be conservative. Please review the *"Important Notes"* on pages 81 -82. **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.**

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ECP "ONE Step" Solar Foundation System

The ECP "ONE Step" Solar Foundation System gives the convenience of replacing traditional methods of installing solar bases with a more economic and greener footprint. ECP Helical Torque Anchors™ have shown to be a proven success in allowing contractors to save time and money while not disturbing the surrounding terrain or ecosystem. The "ONE Step" Solar Foundations may be easily removed without scarring the soil when used for temporary applications.

Advantages of the ONE Step Solar Foundations:

- **Economical**
- **Rapid Installation**
- **All Weather Installation**
- **No Concrete Curing Time**
- **Environmentally Friendly**
- **No Spoils Created While Installing**
- **Vibration Free Installation**
- **Immediate Loading Capabilities After Installation**
- **May Be Used for Permanent or Temporary Applications**
- **Made in the USA**

ECP's Design and Engineering Department offers the most trusted service in the industry. ECP caters to development of products that reduce greenhouse gases and is working toward creating smaller carbon footprints, while maintaining modern living standards.

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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. The text of our warranty is shown below:

> *"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 in 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. Because our products are sometimes exposed to extremely corrosive environments, we defined what we consider "normal" soil conditions below:

> **Normal Soil Condition is defined as soil having a resistivity greater than 2,000 ohm-cm and between pH 5 and pH 8. Excessive corrosion due to aggressive soil or corrosive environment is NOT considered a manufacturing defect. In corrosive environments, additional corrosion protection may be required for extended service life.*

If you suspect that the environment on a site would be 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 a 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.

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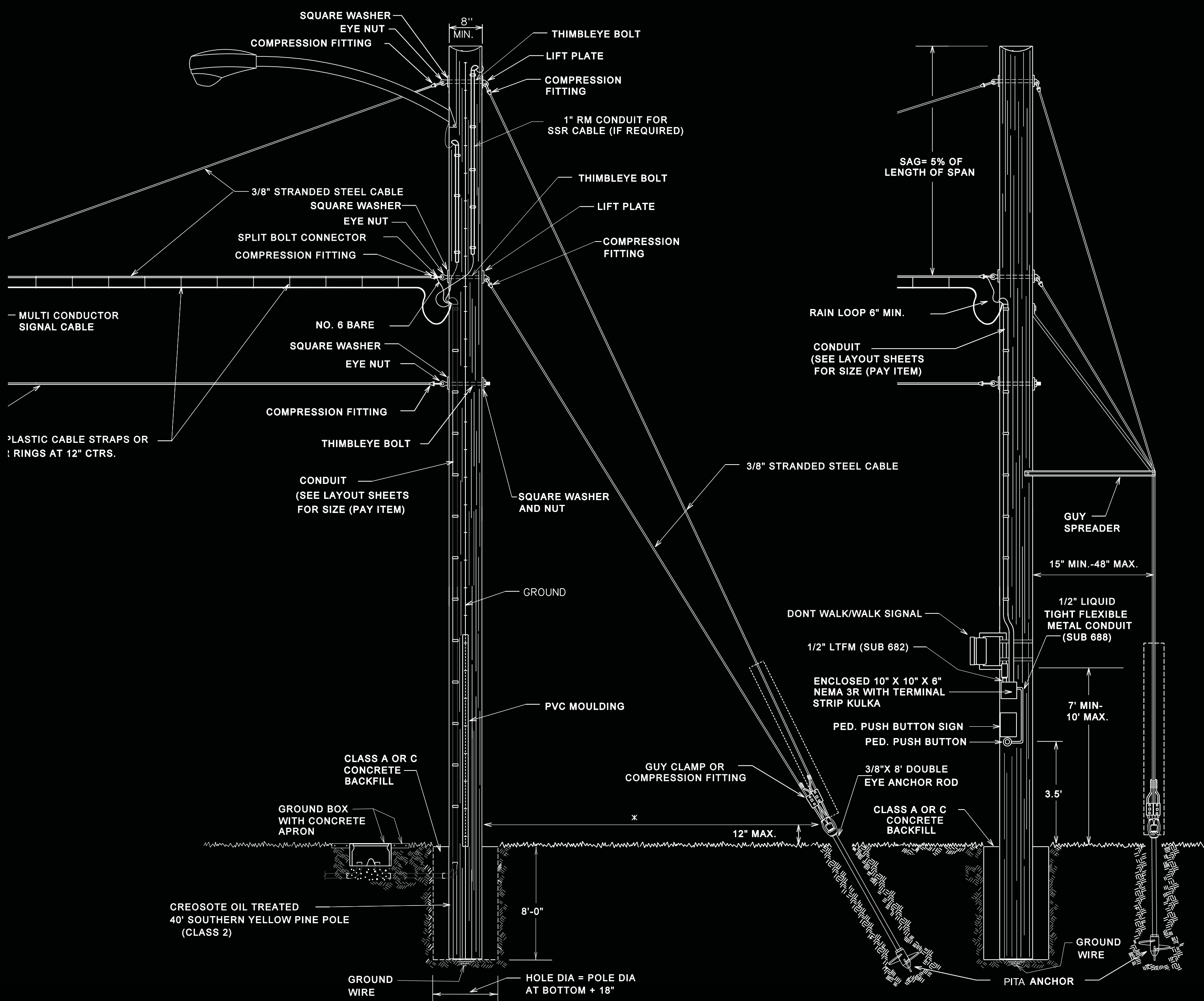

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