PRACTICAL DESIGN AND INSPECTION GUIDE FOR

HELICAL PILES

AND

HELICAL TENSION ANCHORS

Compiled and Prepared by John S. Pack, P.E.
I.M.R., Inc., Denver, Colorado, U.S.A.
(303) 423-0591 Fax: (303) 423-9155 jpack@helipile.com

Revision 2, July 27, 2009

Preface

This design guide was originally prepared for a short course presented by the author and Kevin M. McNeill, P.E., of D&B Engineering Contractors, Inc., on August 3, 2000, in conjunction with the GeoDenver 2000 Geotechnical Engineering Conference sponsored by the American Society of Civil Engineers. This Fourth Edition is an update of the Third Edition published in June, 2004.

The material presented herein is the result of the author's experience and knowledge in designing, specifying, installing, inspecting, and monitoring performance of helical piles and tension anchors since 1986. Much of the author's experience is with helical piles and tension anchors manufactured by Hubbell/Chance. Since 2005, experience has also been with helical piles and helical tension anchors manufactured by International Marketing & Research, Inc. (I.M.R.), Denver, Colorado, U.S.A., under the brand name "HELI-PILE®." This book is intended to be a practical design and inspection guide/reference for engineers and other foundation professionals. This design guide is the sole work of the author. No guarantee or warranty is expressed or implied by the author or I.M.R. As always, the information presented herein must be coupled with sound engineering judgment.

The author acknowledges the contribution of Mr. Robert L. Jones, Chairman of I.M.R. and D&B Engineering Contractors, Denver. Without Mr. Jones' assistance, this book would not have been possible. Mr. Jones is one of a select group of serious pioneers of helical pile technology in the world. His foresight has led his companies to the forefront in the field. Mr. Jones was the first in the world to use helical piles for the repair of failed lightly loaded residential foundations constructed on highly expansive clay soils. He is among the first in the world to seriously use helical piles for construction of new foundations of lightly loaded residential structures on highly expansive soils. Subdivisions of homes are now being constructed on helical piles. Multiple-story commercial structures with heavy loads are now constructed on helical screw piles, thanks largely to Mr. Jones' persistence in showing the engineering and construction community that they work, even over the long haul. It is estimated that in the last 23 years D&B Engineering Contractors has installed nearly 200,000 helical screw piles in the Front Range area of Colorado. As of this writing, no properly designed and installed helical piles installed by D&B have failed. This is a credit to Mr. Jones' demand for high quality control and his insistence on using correct procedures and materials by knowledgeable engineers and trained installation personnel. Mr. Jones has also been involved in countless helical pile and tension anchor projects throughout the Western United States with his manufacturing and distribution company, I.M.R., Inc.

The author acknowledges the contributions of Dale Jones of D&B Engineering Contractors, Sammy Irvin of Foundation Specialists & Repair, and Jared Dalton, Richard Dalton, and Jim Dalton of Intermountain Helical Piers Corporation, all dedicated specialty helical pile installation contractors whose photographs and drawings of structures founded on helical piles and specialized helical pile installation equipment appear herein.

John S. Pack, P.E., July, 2009

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About the Author

A practicing geotechnical constructor/engineer, John Pack began full-time involvement with helical piles and helical tension anchors in 1995 as an engineer with International Marketing & Research, Inc. (IMR), a helical material manufacturer and distributor in Denver, Colorado, U.S.A. He currently serves as IMR's Vice President—Engineering. He has authored or co-authored several professional papers on helical pile technology.*

From 1984 to 1995 he worked as an area manager/engineer for two prominent geotechnical engineering construction companies in the San Francisco Bay Area of California. From 1977 to 1984 he worked as a civil engineer for various industrial and consulting engineering firms in Oregon and Montana. Mr. Pack is a Registered Geotechnical Engineer in California and a registered Civil Engineer in California, Colorado, Hawaii, Montana, Nebraska, Nevada, Oregon, and Utah. He received both a Bachelor and Master of Science Degree in Civil Engineering from Montana State University, Bozeman, in 1976 and 1977, respectively.

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*Papers authored or co-authored by John S. Pack, P.E.:

"Design of Helical Piles for Heavily Loaded Structures," New Technological and Design Developments in Deep Foundations, Geotechnical Special Publication No. 100, the American Society of Civil Engineers, Proceedings of Sessions of GEO-DENVER 2000, August 5-8, 2000, Denver, Colorado, p. 353.

"Design and Performance of Helical Screw Piles in Collapsible and Expansive Soils in Arid Regions," co-authored with David R. Black, P.E., Proceedings of the 36th Symposium—Engineering Geology & Geotechnical Engineering, University of Nevada, Las Vegas, March 28-30, 2001, p. 567.

"Square Shaft Helical Screw Piles in Expansive Clay Areas," co-authored with Kevin M. McNeill, P.E., Soil Rock America, 12th Panamerican Conference on Soil Mechanics and Geotechnical Engineering, Proceedings Volume 2, June 22-26, 2003, Cambridge, Massachusetts, p. 1825.

"Helical Foundations and Tiebacks: Quality Control, Inspection and Performance Monitoring," Deep Foundations Institute, 28th Annual Conference on Deep Foundations, DFI Conference Proceedings, October 22-24, 2003, Miami Beach, Florida, p. 269.

"Performance of Square Shaft Helical Pier Foundations in Swelling Soils," GEO-VOLUTION The Evolution of Colorado's Geological and Geotechnical Engineering Practice, Geotechnical Practice Publication No. 4, the American Society of Civil Engineers, Proceedings of the 2006 Biennial Geotechnical Seminar, November 10, 2006, Denver, Colorado, p. 76.

"Design, Specification and Installation of Square Shaft Helical Piers in Expansive Soils," Deep Foundations Institute, 32nd Annual Conference on Deep Foundations, DFI Conference Proceedings, October 11-13, 2007, Colorado Springs, Colorado, p. 319.

PART 1. INTRODUCTION

The helical pile and helical tension anchor has evolved over the years into what is today a deep foundation element that has attained "standard of practice" status in the United States and expanded use abroad. The 2009 International Building Code attests to this fact (see pages 1-20 and 3-1). The photos that follow are to give the reader an idea of the broad scope of structures that are founded on helical piles or use helical tension anchors.

Examples of New Structures Designed and Constructed on Helical Piles:

Photo 1-1 New multiple-story commercial structure designed and constructed on helical piles.

Photo 1-2 New multiple-story commercial structure designed and constructed on helical piles.

Photo 1-3 New condominium structure in a resort area designed and constructed on helical piles.

Photo 1-4 New multiple-story commercial structure designed and constructed on helical piles.

Photo 1-5 New multiple-story commercial structure designed and constructed on helical piles.

Photo 1-6 New church building designed and constructed on helical piles.

Photo 1-7 New office building designed and constructed on helical piles.

Photo 1-8 New multiple-story commercial structure designed and constructed on helical piles.

Examples of New Structures Designed and Constructed on Helical Piles:

Photo 1-9 New natural gas compressor station designed and constructed on helical piles.

Photo 1-10 New natural gas facility designed and constructed on helical piles.

Photo 1-11 New Industrial facility, all structures, including tanks, designed and built on helical piles.

Photo 1-12 New natural gas facility designed and constructed on helical piles.

Photo 1-13 New office building designed and constructed on helical piles.

Photo 1-14 New gas pump facility. All structures designed and constructed on helical piles.

Photo 1-15 New large grain elevator facility designed and constructed on helical piles.

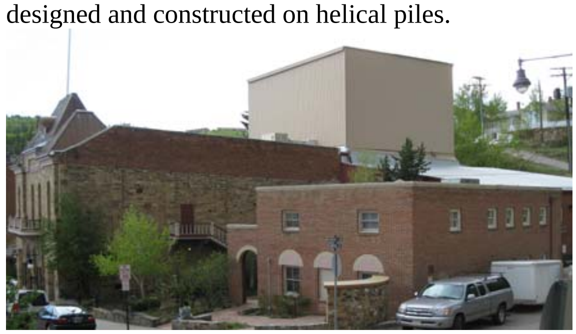

Photo 1-16 New annex to historical structure designed and constructed on helical piles.

Examples of New Structures Designed and Constructed on Helical Piles:

Photo 1-17 New residential structure designed and constructed on helical piles.

Photo 1-18 New residential structure designed and constructed on helical piles.

Photo 1-19 New residential condominium structure designed and constructed on helical piles.

Photo 1-20 New residential structure designed and constructed on helical piles.

Photo 1-21 New residential structure designed and constructed on helical piles.

Photo 1-22 New residential condominium structure designed and built on helical piles.

Photo 1-23 New residential structure designed and constructed on helical piles.

Photo 1-24 New residential structure designed and constructed on helical piles.

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Photo 1-27 Existing residence with 18 inches differential heave in expansive soil underpinned and stabilized with helical piles.

Photo 1-28 The existing nine-story structure was underpinned and shored with helical piles.

Photo 1-29 Existing residence with settle foundation underpinned and stabilized with helical piles.

Photo 1-30 Existing building with settled foundation underpinned and stabilized with helical piles.

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Photo 1-32 Existing building still under construction settled. Foundation underpinned and stabilized with helical piles.

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Photo 1-33 New reinforced concrete multi-lane bridge with abutments supported on helical piles and helical tiebacks.

Photo 1-34 New reinforced concrete multi-lane bridge with abutments supported on helical piles and helical tiebacks.

Photo1-35 New steel bridge with abutments supported on helical piles and helical tiebacks.

Photo 1-36 New pedestrian bridge with abutments supported on helical piles.

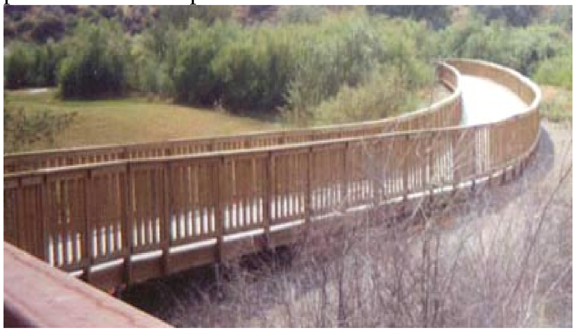

Photo 1-37 New boardwalk in marsh wetland supported on helical piles.

Photo 1-38 New golf cart/pedestrian/vehicle bridge in marsh wetland supported on helical piles.

Photo 1-39 New boardwalk in marsh wetland supported on helical piles.

Photo 1-40 New fishing pier supported on helical piles.

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Photo 1-41 New rock faced retaining wall using helical tension anchors as tiebacks.

Photo 1-42 New reinforced concrete retaining wall using helical tension anchors as tiebacks.

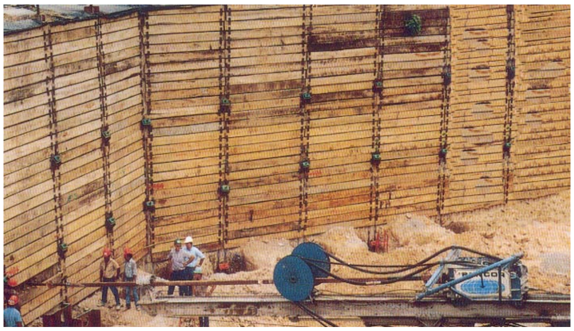

Photo 1-43 New soldier beam and wood lagging shoring wall using helical anchors as tiebacks.

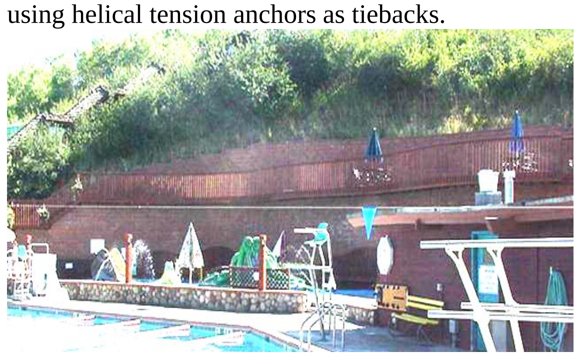

Photo 1-44 New reinforced concrete retaining wall using helical tension anchors as tiebacks.

Photo 1-45 New pre-engineered shoring panel shoring wall using helical tension anchors as tiebacks.

Photo 1-46 Existing foundation/retaining wall laterally supported with helical anchors as tiebacks.

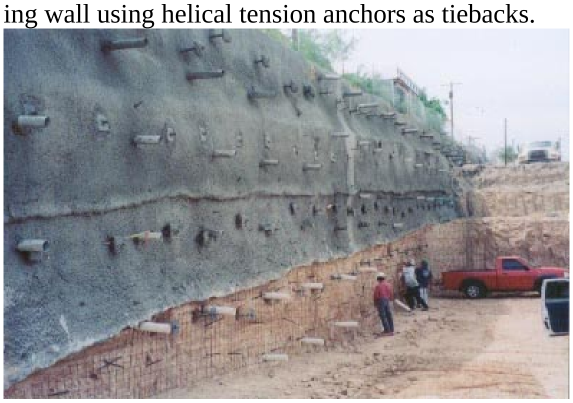

Photo 1-47 New retaining wall under construction using helical tension anchors as soil nails.

Photo 1-48 New pre-engineered shoring panel shoring wall using helical tension anchors as tiebacks.

Installation Methods of Helical Piles and Tension Anchors

The photographs below show a sampling of the variety of installation tools available to install helical piles and helical tension anchors. As can be seen, the equipment sizes range from large excavators down to small hand-carried equipment.

Photo 1-49 Tracked hydraulic excavator capable of installing over 60 helical piles per day.

Photo 1-50 Rubber-tired hydraulic excavator capable of installing over 60 helical piles per day.

Photo 1-51 Two tracked machines each capable of installing over 60 helical piles per day.

Photo 1-52 Tracked machine with adjustable frame installing battered helical piles for lateral loads.

Photo 1-53 This tracked installation machine is ideal in tight access locations and wide open spaces.

Photo 1-54 Rubber-tired hydraulic excavator is capable of installing over 60 helical piles per day.

Photo 1-55 Skid-steer type machines installing helical piles for new construction.

Photo 1-56 Mini-excavator is capable of installing over 60 helical piles per day.

Examples of Installation Equipment for Underpinning:

Photo 1-57 Skid-steer machine installing helical piles for foundation underpinning.

Photo 1-58 Backhoe installing helical piles for foundation underpinning.

Photo 1-59 Mini-excavator installing helical piles for foundation underpin.

Photo 1-60 Mini-excavator installing battered helical piles adjacent to existing building.

Photo 1-61 Skid-steer machine inside garage instal-ling helical piles for foundation underpinning.

Photo 1-62 Backhoe installing helical piles for foundation underpinning.

Photo 1-63 Skid-steer machine installing helical piles for foundation underpinning.

Photo 1-64 Skid-steer machine inside a building installing helical piles for foundation retro-fit.

Examples of Hand-Carried Installation Equipment:

Photo 1-65 Hand-carried torque motor, yoke, and torque arm in tight access location.

Photo 1-67 Hand-carried mast for installation of helical piles in tight access location.

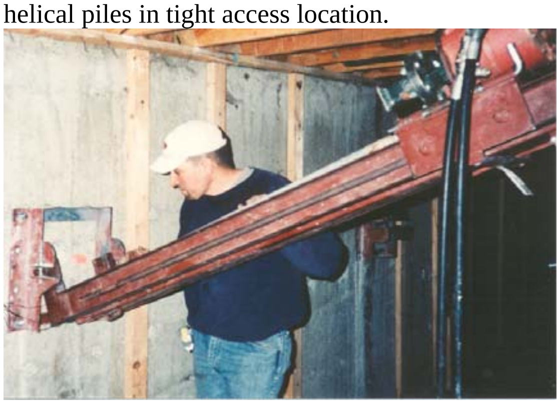

Photo 1-69 Hand-carried mast in near horizontal position to install helical tiebacks in low overhead.

Photo 1-66 Hand-carried mast for installation of helical piles in tight access location.

Photo 1-68 Hand-carried mast for installation of helical piles in tight access location.

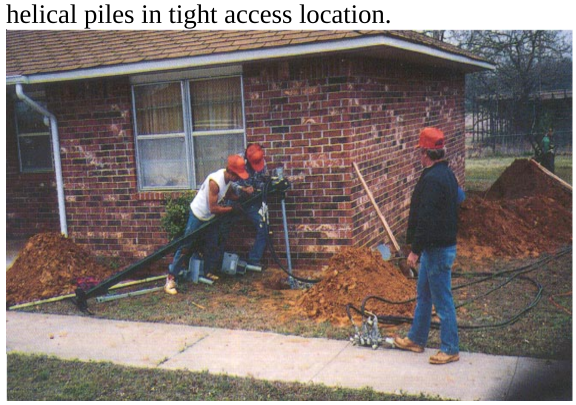

Photo 1-70 Hand-carried torque motor, yoke, and torque arm for tight access location.

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Photo 1-71 Tracked machine to install helical tension anchors as tiebacks for retaining wall repair.

Photo 1-72 Loader mounted torque motor installing helical tension anchors as tiebacks for repair.

Photo 1-73 Skid-steer machine (on right) installing helical tension anchors as tiebacks for structure.

Photo 1-74 Skid-steer machine installing helical tension anchors as tiebacks for new retaining wall.

Photo 1-75 Backhoe mounted torque motor install-ling helical tension anchors as tiebacks for repair.

Photo 1-76 Skid-steer mounted drive head installing helical tension anchors as tiebacks in low overhead.

Photo 1-77 Hand-carried equipment installing helical tension anchors as tiebacks for repair.

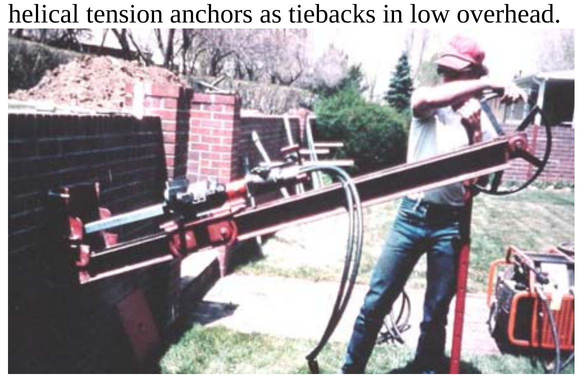


Photo 1-78 Hand-carried mast in near horizontal position installing helical tension anchors as tiebacks.

<u>Examples of Various Types of Installation Equipment</u>:

<u>Photo 1-79</u> Hydraulic excavator installing helical piles for new foundation.

<u>Photo 1-80</u> Hydraulic excavator installing helical piles for new commercial construction.

<u>Photo 1-81</u> Skid-steer mounted torque motor install-ling battered helical tension anchor under itself.

<u>Photo 1-82</u> Backhoe mounted torque motor installng helical screw piles at a slight batter for a sound wall.

<u>Photo 1-83</u> Tracked machine installing battered helical piles for lateral load resistance.

<u>Photo 1-84</u> Tracked machine installing helical tension anchors as tiebacks for retaining wall repair.

<u>Photo 1-85</u> Mini-excavator mounted torque motor installing helical screw piles over wetland.

<u>Photo 1-86</u> Skid-steer mounted torque motor installing helical screw piles.

Examples of Various Types of Installation Equipment (continued):

Photo 1-87 Skid-steer mounted torque motor installing helical piles.

Photo 1-88 Mini-excavator mounted torque motor installing helical piles.

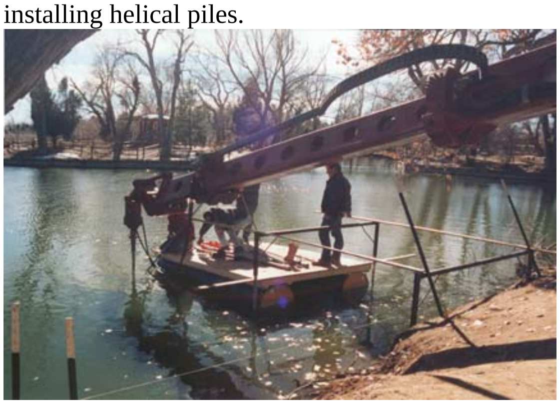


Photo 1-89 Hydraulic excavator boom mounted torque motor installing helical piles in lake.

Photo 1-90 Skid-steer mounted torque motor install-ling helical piles inside existing building.

Photo 1-91 Hydraulic excavator mounted torque motor installing helical piles.

Photo 1-92 Tracked machine installing helical tension anchors as tiebacks for shoring.

Photo 1-93 Hand-carried mast mounted on wall in near horizontal position to install helical tiebacks.

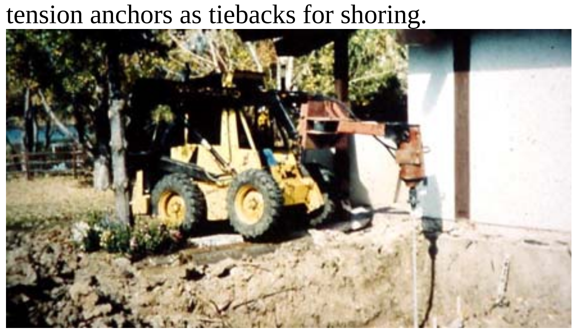


Photo 1-94 Skid-steer mounted torque motor installing helical piles for a new addition.

Detailed Description

Because of the large amount of available technical data and its accessibility via the Internet and in print, the descriptions and specifications given herein are primarily of helical piles and helical tension anchors manufactured by International Marketing & Research, Inc., under the brand name "HELI-PILE®" (see www.helipile.com). Other manufacturers' material typically is dimensionally similar in the solid steel square bar, but use different steels. For comparisons, consult their technical data. As of this edition, tubular and modular helical piles are unique to HELI-PILE®.

Helical piles for compression purposes are exactly identical in everyway to helical tension anchors. The only difference is in how they are used.

Shapes and Sizes

All steel helical piles, including solid steel square shaft, tubular, or pipe style, consist of an initial length of steel shaft (also called a "lead section" or "starter") with one or more split circular steel plates rigidly attached to the shaft. The circular steel plates are sometimes called a "helix" in singular or "helices" in plural. The plates may also be called "helical plates" or "helical bearing plates." Please see Figure 1-1(a through d) and Photos 1-95 and 1-96. The shaft may be manufactured from solid steel square bar, structural tubing (tubular), or pipe. Cross-sectional sizes of the solid steel square shaft typically range from 1.5 inches to 2.25 inches square (38.1 mm to 57.2 mm square). Tubular shafts typically range in cross-sectional size from 2 inches to 4 inches (50.8 mm to 102 mm) with wall thicknesses ranging from 0.25 inch to 0.375 inch (6.35 mm to 9.53 mm). Pipe shafts typically range in cross-sectional size from 3.5 inch OD to 12 inches OD (88.9 mm OD to 305 mm OD) and larger with wall thickness similar to tubular.

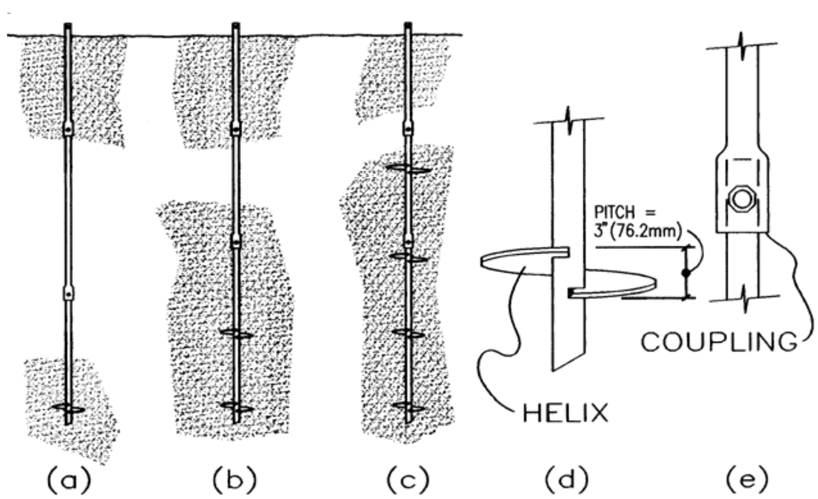


Figure 1-1. Typical helical pile configurations, helix, and coupling.

Figure 1-1(a) is a sketch of a single 8 inch (203 mm) diameter helix welded to a 1.5 inch (38.1 mm) square solid steel shaft with two plain extensions. Figure 1-1(b) shows a double helix lead section with an 8 inch (203 mm) and a 10 inch (254 mm) diameter helix welded to a 1.75 inch (44.5 mm) square solid steel shaft with two plain extensions. Figure 1-1(c) is a sketch of a triple helix lead section with an 8 inch (203 mm), 10 inch (254 mm), and 12 inch (305 mm) diameter helix welded to a 1.75 inch (44.5 mm) square solid steel shaft, plus an extension with a 14 inch (356 mm) diameter helix welded to the 1.75 inch (44.5 mm) square solid steel extension shaft, and one plain extension. Figure 1-1(d) is an expanded view of a typical helix welded to the square shaft. Figure 1-1(e) is an expanded view of a typical bolted coupling. Also see Photo 1-95.

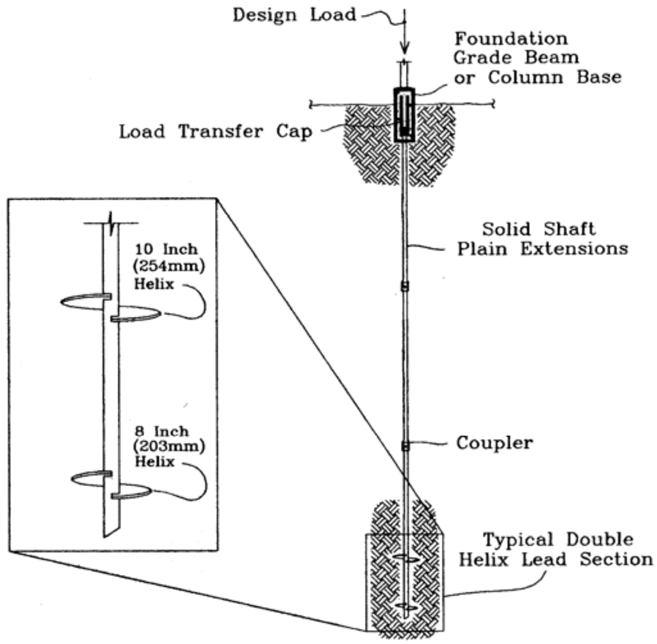


Figure 1-2. Double helix helical pile supporting a foundation grade beam.

<u>Photo 1-95</u> Lead section with helices welded directly to shaft.

Figure 1-2 is a helical pile as it may appear supporting a new foundation grade beam or column base. This figure depicts a double helix lead or starter section, two plain extensions, and a new construction load transfer device or cap. The load transfer cap is embedded within the concrete foundation.

Photo 1-95 is of an 8 inch (203 mm) and 10 inch (254 mm) diameter double helix lead section similar to Figures 1-1(b) and 1-2. Photo 1-95 also shows a cold forged welded coupling similar to Figure 1-1(e). The shaft is solid steel 1.5 inch (38.1 mm) square. All helices are welded directly to the shaft.

Photo 1-96 is of an 8 inch (203 mm) and 10 inch (254 mm) diameter double helix lead section using modular technology patented by International Marketing & Research, Inc., and marketed under

Photo 1-96 Lead section with modular helices keyed to shaft.

the brand name HELI-PILE® Modular Helical Piles and Tension Anchors. This technology gives flexibility to change lead section configurations by adding or removing helices at the job site to conform to actual soil conditions. No field cutting or welding of helices is required. In addition, extension lengths may be altered at the job site to fit field conditions as needed. See www.helipile.com for details.

Photo 1-96 shows each helix and the coupler keyed and locked in preparation for installation. By removal of the keys, each helix and the coupler can be slid up and down the shaft directly, without having to screw them along the shaft. Replacement of the keys locks the each helix and the coupler in position.

Installation of the modular helical pile is identical to any square shaft helical pile. The unique feature is the patented square threadbar that fits all common drive tools.

For all helical piles and tension anchors, each helix is a circular steel plate split radially on one side of the shaft and shaped into the form of a helix, hence the term "helical." This gives each helix a leading and trailing edge as the shaft is rotated, typically clockwise. As the shaft is rotated, the helix leading edge bites into and engages the soil transferring the rotational force, or installation torque, into an axial force driving the helical screw pile into the soil. Helix diameters typically range from 6 inches (152 mm) to 16 inches (406 mm) and larger. Helix thicknesses typically range from 0.375 inch (9.53 mm) to 0.500 inch (12.7 mm). All HELI-PILE® helices are 0.5 inch (12.7 mm) thick. The helices are formed into the shape of a helix with a typical 3 inch (76.2 mm) pitch, the axial distance between the leading and trailing edges (see Figure 1-1(d)). Thus, under ideal soil conditions, helical screw piles and tension anchors with a 3 inch (76.2 mm) pitch should advance into the soil 3 inches (76.2 mm) per revolution.

As mentioned above, the shaft is rotated so the leading edge of a helix bites into and engages the soil forcing the helix deeper into the soil pulling the shaft with it. No hole is created, no drill spoils are generated that must be discarded. When the top of the advancing lead section shaft reaches grade, shaft extensions with or without helices are added, if necessary. The helical pile or tension anchor is advanced in this manner until the required pile capacity, with an appropriate safety factor, is reached as evidenced by the measured installation torque. (The relationship between measured installation torque and pile capacity is discussed in PART 2. CAPACITY CALCULATIONS below.) Extensions typically are available in lengths of 3 ft (0.9 m), 5 ft (1.5 m), 7 ft (2.1 m), and 10 ft (3 m). Figures 1-1(a), 1-1(b), and 1-1(c) show plain extensions in use above the lead sections. Figure 1-1(c) also shows and extension with a 14 inch (356 mm) diameter helix welded to it. Figure 1-2 shows plain extensions in use. Photo 1-95 shows the end of an extension bolted to the double helix lead section. Photo 1-96 is a HELI-PILE® Modular helical pile with modular helices keyed and locked to the shaft.

The lead section and subsequent extensions are typically coupled together by means of a coupling and bolt or modular coupler designed to transfer the ultimate installation torques and axial loads either in tension or compression. See Figure 1-1(e) and Photos 1-95 and 1-96. HELI-PILE® couplings are cold forged welded, other manufacturers are hot-upset forged. Both work well. However, the cold forged welded is not susceptible to shaft steel weakening as occurs on rare occasions with the hot-upset forged couplings.

Because they are readily available over the Internet, the Appendix contains drawings prepared for HELI-PILE® helical piles and helical tension anchors (see www.helipile.com). These drawings indicate the magnitude of sizes and shapes available in this brand. This is to match the almost limitless soil and loading conditions possible. The drawings also give information on bolt sizes and grades. Similar information may be available from other manufacturers.

As mentioned above, the helical screw pile or tension anchor is installed by applying a rotational force, or installation torque, to the shaft. This force is applied typically by a hydraulically powered torque motor mounted on either wheeled or tracked or hand-carried equipment. Please see Photos 1-49 through 1-94 above for various types of installation equipment. Also please see PART 8. INSTALLATION METHODS below.

Materials

The shaft of the square shaft helical screw pile is solid steel or structural tube. For example, it is known that all HELI-PILE® steel minimum shaft yield strength is 90 ksi (621 Mpa) for the solid bar shaft (except the HPC15) and 50 ksi (345 Mpa) for tubular. All HELI-PILE® helix minimum yield strengths are 80 ksi (552 Mpa). See Table 1-1 below for specifics. See other manufacturers' data sheets.

All welding typically is done per American Welding Society (AWS) specifications by AWS certified welders.

Galvanizing is typically per ASTM B633 or ASTM A153.

Mechanical Capacities and Steel Specifications

Because of readily available and accessible information via the Internet, Table 1-1 is a mechanical capacity and steel specification table for HELI-PILE® helical piles and tension anchors (see www.helipile.com). Other manufacturers may have similar specifications. Please consult their technical data.

1 Square Shaft Size and Type (IMR Cat. Number)	2 Shaft and Helix Galvanizing	3 Shaft Steel Minimum Yield Strength, F_y	4 Maximum Shaft Torque	5 New Fdns. Ultimate Capacity, Compr. or Tension[1]	6 Underpin Ultimate Capacity, Bracket Limited	7 Helix Steel Minimum Yield Strength, F_y	8 Ultimate Per Helix Capacity, Compr. or Tension[2]
1.5 inch (38.1 mm) Solid Shaft (HPC15)	ASTM B633	70 ksi (483 Mpa)	5,500 ft-lbs (7.46 kN-m)	55,000 lbs (245 kN)	55,000 lbs (245 kN)	80 ksi (552 Mpa)	70,000 lbs (311 kN)
1.5 inch (38.1 mm) Solid Shaft (HPC15X)	ASTM B633	90 ksi (621 Mpa)	7,000 ft-lbs (9.49 kN-m)	70,000 lbs (311 kN)	70,000 lbs (311 kN)	80 ksi (552 Mpa)	70,000 lbs (311 kN)
1.75 inch (44.5 mm) Solid Shaft (HPC17)	ASTM B633	90 ksi (621 Mpa)	11,000 ft-lbs (14.9 kN-m)	110,000 lbs (489 kN)	110,000 lbs (489 kN)	80 ksi (552 Mpa)	70,000 lbs (311 kN)
2.0 inch (50.8 mm) Solid Shaft (HPC20)	ASTM B633	90 ksi (621 Mpa)	16,000 ft-lbs (21.7 kN-m)	150,000 lbs (667 kN)	Per Application	80 ksi (552 Mpa)	70,000 lbs (311 kN)
2.25 inch (57.2 mm) Solid Shaft (HPC22)	ASTM B633	90 ksi (621 Mpa)	23,000 ft-lbs (31.2 kN-m)	200,000 lbs (890 kN)	Per Application	80 ksi (552 Mpa)	70,000 lbs (311 kN)
1.5 inch (38.1 mm) Modular (HP15X)	ASTM B633	90 ksi (621 Mpa)	7,000 ft-lbs (9.49 kN-m)	70,000 lbs (311 kN)	70,000 lbs (311 kN)	80 ksi (552 Mpa)	70,000 lbs (311 kN)
1.75 inch (44.5 mm) Modular (HP17)	ASTM B633	90 ksi (621 Mpa)	11,000 ft-lbs (14.9 kN-m)	110,000 lbs (489 kN)	110,000 lbs (489 kN)	80 ksi (552 Mpa)	70,000 lbs (311 kN)
2.0 inch (50.8 mm) Tubular (HPFT2)	ASTM B633	50 ksi (345 Mpa)	4,000 ft-lbs (5.42 kN-m)	40,000 lbs (178 kN)	40,000 lbs (178 kN)	80 ksi (552 Mpa)	70,000 lbs (311 kN)
2.5 inch (63.5 mm) Tubular (HPFT25)	ASTM B633	50 ksi (345 Mpa)	7,000 ft-lbs (9.49 kN-m)	70,000 lbs (311 kN)	70,000 lbs (311 kN)	80 ksi (552 Mpa)	70,000 lbs (311 kN)
3.0 inch (76.2 mm) Tubular (HPFT3)	ASTM B633	50 ksi (345 Mpa)	11,000 ft-lbs (14.9 kN-m)	110,000 lbs (489 kN)	110,000 lbs (489 kN)	80 ksi (552 Mpa)	70,000 lbs (311 kN)
4.0 inch (102 mm) Tubular (HPFT4)	ASTM B633	50 ksi (345 Mpa)	20,000 ft-lbs (27.1 kN-m)	200,000 lbs (890 kN)	Per Application	80 ksi (552 Mpa)	70,000 lbs (311 kN)

[1]Recommended default empirical installation torque coefficient (k_t) is 10 ft^{-1} (32.8 m^{-1}) except for the 4.0 inch (102 mm) Tubular. The 4.0 inch (102 mm) Tubular is application specific, testing is recommended. See Eq. 2-1 on p. 2-1 of PART 2.
[2]All HELI-PILE® helices are 0.5 inch (12.7 mm) thick. Helix capacities given are for 12 inch (305 mm) diameter and smaller. Larger helices are rated at 80% of the given value.

Table 1-1. HELI-PILE® Helical Pile and Tension Anchor Mechanical Ratings

Table 1-2 below lists the physical properties of the various HELI-PILE® Helical Piles and Tension Anchors. The table also correlates the shaft sizes, types, and helix sizes to the bearing area, assuming a horizontal projection of helix area. Other manufacturers will have similar properties and areas. Please consult their technical data.

Square Shaft Size and Type	**Overall Cross-sectional Area of the Shaft**	**Steel Area of the Shaft**	**6 inch (152 mm) Diameter Helix Bearing Area[3]**	**8 inch (203 mm) Diameter Helix Bearing Area[3]**	**10 inch (254 mm) Diameter Helix Bearing Area[3]**	**12 inch (305 mm) Diameter Helix Bearing Area[3]**	**14 inch (356 mm) Diameter Helix Bearing Area[3]**	**16 inch (406 mm) Diameter Helix Bearing Area[3]**
1.5 inch (38.1 mm) Solid[1]	2.24 in^2 (1,450 mm^2)	2.24in^2 (1,450 mm^2)	22.9 in^2 (14,800 mm^2)	43.9 in^2 (28,300 mm^2)	71.1 in^2 (45,900 mm^2)	104 in^2 (67,100 mm^2)	143 in^2 (92,300 mm^2)	188 in^2 (121,000 mm^2)
1.75 inch (44.5 mm) Solid[1]	3.05 in^2 (1,970 mm^2)	3.05in^2 (1,970 mm^2)	22.2 in^2 (14,300 mm^2)	43.1 in^2 (27,800 mm^2)	70.3 in^2 (45,400 mm^2)	103 in^2 (66,500 mm^2)	142 in^2 (91,600 mm^2)	187 in^2 (121,000 mm^2)
2.0 inch (50.8 mm) Solid[1]	3.99 in^2 (2,570 mm^2)	3.99in^2 (2,570 mm^2)	21.3 in^2 (13,700 mm^2)	42.3 in^2 (27,300 mm^2)	69.5 in^2 (44,800 mm^2)	102 in^2 (65,800 mm^2)	141 in^2 (91,000 mm^2)	187 in^2 (121,000 mm^2)
2.25 inch (57.2 mm) Solid[1]	5.05 in^2 (3,260 mm^2)	5.05in^2 (3,260 mm^2)	20.3 in^2 (13,100 mm^2)	41.3 in^2 (26,600 mm^2)	68.5 in^2 (44,200 mm^2)	101 in^2 (65,200 mm^2)	140 in^2 (90,300 mm^2)	186 in^2 (120,000 mm^2)
2.0 inch (50.8 mm) Tubular[2]	3.97 in^2 (2,560 mm^2)	1.59in^2 (1,030 mm^2)	21.3 in^2 (13,700 mm^2)	42.3 in^2 (27,300 mm^2)	69.5 in^2 (44,800 mm^2)	102 in^2 (65,800 mm^2)	141 in^2 (91,000 mm^2)	187 in^2 (121,000 mm^2)
2.5 inch (63.5 mm) Tubular[2]	6.22 in^2 (4,010 mm^2)	2.09in^2 (1,350 mm^2)	19.2 in^2 (12,400 mm^2)	40.1 in^2 (25,900 mm^2)	67.4 in^2 (43,500 mm^2)	100 in^2 (64,600 mm^2)	139 in^2 (89,700 mm^2)	184 in^2 (119,000 mm^2)
3.0 inch (76.2 mm) Tubular[2]	8.97 in^2 (5,790 mm^2)	2.59in^2 (1,670 mm^2)	16.6 in^2 (10,700 mm^2)	37.5 in^2 (24,200 mm^2)	64.7 in^2 (41,700 mm^2)	97.7 in^2 (63,000 mm^2)	137 in^2 (88,400 mm^2)	182 in^2 (117,000 mm^2)
4.0 inch (102 mm) Tubular[2]	16.0 in^2 (10,320 mm^2)	5.08in^2 (3,280 mm^2)	N/A	30.7 in^2 (19,800 mm^2)	57.9 in^2 (37,400 mm^2)	90.9 in^2 (58,600 mm^2)	130 in^2 (83,900 mm^2)	175 in^2 (113,000 mm^2)

[1]Solid shaft and Modular shaft have the same physical properties and helix bearing areas.
[2]The wall thickness of the 2.0 inch (57.2 mm), 2.5 inch (63.5 mm), and 3.0 inch (76.2 mm) Tubular is 0.25 inch (6.35 mm). Wall thickness of the 4.0 inch (102 mm) is 0.375 inch (9.53 mm).
[3]Helix bearing area is horizontal projection of the helix less the overall cross-sectional area of the shaft and less the area of the "rock cut" leading edge (see "Refusal Condition in Extremely Dense Soil, Rock, and Cobble" in PART 3. DESIGN CONSIDERATIONS.

Table 1-2. HELI-PILE® Physical Properties and Helix Bearing Areas

History of Helical Piles and Tension Anchors

The helical pile was reportedly invented in the 1700's. Exactly how it was used back then is unknown to this author. In the early 1800's a constructor in England by the name of Alexander Mitchell used hand-installed helical screw piles in the design of foundations for lighthouses. This technology was brought to the U.S. where lighthouses were constructed on helical piles along the East Coast, some of which reportedly can still be visited today. Installation was by hand using brute human force or work animals.

Some time after the introduction of helical piles to the foundation industry, methods of drilling piers and driving piles improved to the point that hand-installed helical screw piles were not as cost-effective so they fell out of use. It was not until the mid-1900's that installation equipment was developed that brought helical piles back into demand. Today, high capacity and rapid installation equipment now routinely install helical piles and tension anchors in projects ranging from heavily loaded commercial and industrial structures to the lightly loaded residential structures. Please see the application list below.

Applications of Helical Piles and Tension Anchor Technology

The list of applications of helical pile and tension anchor technology is endless. The list includes, but is not limited to, the following commercial, industrial, institutional, and residential applications. For photographs of several types of projects, please see pages 1-1 through 1-6 above.

A Few Helical Pile Applications:

1) Permanent new structural foundations under continuous foundation grade beams or column bases, compression and/or tension loads. Typical ultimate capacities for single piles can range from 35 tons (311 kN) to 100 tons (890 kN) and higher. In pile groups, column design loads of 1,000 tons (8,900 kN) and higher can be supported. Examples of this application would be for new single and multiple-story buildings, including high-rise structures, bridges, and residences.
2) Permanent battered piles to take lateral loads including wind and seismic. Lateral loads are taken as axial compression and/or tension loads. Examples of this application would be those listed immediately above but also including sound walls, water towers, communications towers, bill boards, etc.
3) Permanent new structural foundations under new concrete slabs.
4) Permanent retrofit foundations in existing structures and additions where new loads are being added to the structure. An example would be where a new mezzanine level is being added inside a building or where new, larger and heavier machines are being installed in a factory.
5) Permanent retrofit structural foundations under existing concrete slabs.

6) Permanent retrofit foundations for seismic upgrade purposes.
7) Permanent new foundations under heavy artwork such as sculpture.
8) Permanent underpinning of any settled or heaved existing foundations, heavily or lightly loaded. A steel bracket is used to transfer existing loads from the structure to the new helical screw piles.
9) Underpinning for permanent or temporary structural shoring, primarily vertical axial compression loading.
10) Machine foundations.
11) New foundations in tight access or inaccessible areas.
12) Underpinning in tight access or inaccessible areas, primarily vertical axial compression loading.
13 New foundations in hazardous or environmentally sensitive areas where no drill spoils are desired.
14 All locations where drilled or driven piles are specified.

A Few Helical Tension Anchor Applications:

1) Tiebacks for permanent retaining walls constructed of any materials such as cast-in-place concrete, shotcrete, gunite, soldier beams and wood or concrete lagging, railroad ties, etc.
2) Permanent tension hold-downs for wind and seismic loads.
3) Tiebacks for permanent or temporary shoring.
4) Anywhere where lateral loads must be resisted.
5) All locations where grouted tiebacks are specified and the anchor zone is not in competent rock.

2009 International Building Code Introduction

Several years ago the Uniform Building Code (ICBO), Standard Building Code (SBCCI), and BOCA merged into the International Code Council (ICC). The ICC publishes the International Building Code (IBC) that replaces the pre-existing building codes of those respective building code organizations. The 2009 edition of the IBC has portions devoted to helical piles. The 2009 IBC streamlines and simplifies designing helical pile foundations and provides design professionals a method with which to evaluate a helical pile foundation, especially if a particular brand of helical pile does not have an ICC evaluation report. A discussion on designing with the helical pile provisions of the 2009 IBC is given in the PART 3. DESIGN CONSIDERATIONS, starting on p. 3-1.

PART 2. CAPACITY CALCULATIONS
(Compression and Tension)

Installation Torque vs. Capacity Equation

A helical pile is an axially loaded end-bearing deep foundation where, in soils where installation torque can be achieved and measured, compression capacity equals tension capacity. Therefore, this discussion applies equally to helical tension anchors. The compression pile or tension anchor capacity is the total load that can be transmitted to the soil via the helices. The load each helix transmits to the soil is dependent upon the strength of the soil. A small percentage of the load is transmitted to the soil by the shaft but is usually neglected in capacity calculations.

The simplest and most accurate method to determine the capacity of helical piles is called "torque vs. capacity," an empirical method developed over the years by the A.B. Chance Company and now used by most manufacturers. The principle is: As a helical pile is rotated into denser and denser soil, the resistance to rotation, called "torque" or "installation torque," is measured. The higher the installation torque, the higher the pile capacity because higher installation torque is an indication of denser and stronger soil.

Full-scale load testing has proven that, where installation torque can be achieved and measured, helical piles or tension anchors have the same capacity in tension as in compression. This is because the helices penetrate the soil by slicing without auguring. Soil is displaced, not removed.

Helical pile or tension anchor capacity is determined by measuring the installation torque. The empirical relationship between ultimate pile or anchor capacity in installation torque is

$$Q_u = k_t\, T \qquad \text{(Eq. 2-1)}$$

where Q_u = Ultimate capacity of the helical pile or tension anchor, lbs (kN)
k_t = Empirical installation torque coefficient, ft^{-1} (m^{-1})
T = Measured installation torque, ft-lbs (kN-m)

The actual empirical torque coefficient for a particular pile or anchor will vary from soil to soil and by manufacturer depending on helix shape, size, spacing, shaft cross-sectional shape, etc. What is now accepted in the industry is that for 1.5 inch (38.1 mm), 1.75 inch (44.5 mm), 2.0 inch (50.8 mm), and 2.25 inch (57.2 mm) square shaft helical piles and tension anchors, the empirical torque coefficient k_t has a default value of 10 ft^{-1} (32.8 m^{-1}). This value is accepted in the industry and has been verified by the writer through his own full-scale load testing. Thus, in <u>all</u> soils, this value for the installation torque coefficient results in a conservative ultimate capacity. For example, if a helical pile is installed to 20,000 ft-lbs (27.1 kN-m) of installation torque, the ultimate capacity of that pile would be

$$Q_u = 10\ \text{ft}^{-1} \times 20{,}000\ \text{ft-lbs} = 200{,}000\ \text{lbs}$$
$$(Q_u = 32.8\ \text{m}^{-1} \times 27.1.6\ \text{kN-m} \cong 890\ \text{kN})$$

(The empirical torque coefficient of 10 ft^{-1} in English units is often called the "rule of ten.")

Using a factor of safety of 1.5, the design capacity of this helical pile would be 133,000 lbs (592 kN). Using a factor of safety of 2, the design capacity of this helical screw pile would be 100,000 lbs (445 kN). (For a discussion on safety factors, please see the "Safety Factors and Minimum Installation Torque" section below.)

Please note, the torque coefficient value is empirical, i.e., determined after sufficient full-scale load testing for proof. In addition, the writer has conducted many full-scale loads tests to verify this empirical torque coefficient. Some manufacturers use empirical torque coefficients that range from 7 to18 ft^{-1} (23.0 to 59.0 m^{-1}). Specific manufacturers should be consulted.

The number of helices on the shaft beyond the mechanical minimum required to take the ultimate load does not increase the load capacity when the torque vs. capacity relationship is adhered to. By placing more helices on a shaft, or helices with larger diameters, the result is that higher torques will be achieved. For example, if a shallower pile is required, then more helices and/or helices with greater diameters should be used. If a deeper pile is required, then less helices and/or helices with smaller diameters should be used.

The torque vs. capacity relationship may not be valid where the lead helix grinds into a hard material as evidenced by the helix (or helices) advancing substantially less than the helix pitch, typically 3 inches (76.2 mm) per revolution (see Figure 1-1(d) above). If the helix or helices seem to not advance at all, it is called the refusal condition. Refusal, or grinding, does not mean that the pier will not take its rated capacity. It simply means that the capacity cannot necessarily be predicted by measuring the installation torque. For a more detailed discussion, see "Refusal Condition in Extremely Dense Soil, Rock and Cobble" section in PART 3. DESIGN CONSIDERATIONS below.

Full-scale load testing has shown that helical piles may be installed with up to a five degree batter (five degrees out of plumb) and still take their full rated capacities. This is to facilitate a batter that may be required to install adjacent to eaves or other obstructions during underpinning operations. This also facilitates new foundation installations where pile groups are used as described below under "Heavy Load Considerations (e.g., high rise structures) using Pile Groups"(Figure 2-1).

Installation Torque Measurement

Accurate measurement of installation torque is accomplished in two basic ways:

1) Mechanical Torque Measurement: The shear pin torque indicator is a mechanical device used to measure installation torque (see Photo 2-1). The device is mounted between the helical screw pile or tension anchor shaft and the installing torque motor. Short small diameter steel shear pins are placed in the holes around the circumference of the device to keep the normally free spinning cylinders from spinning. When torque is applied to the device, the shear pins will break when the torque exceeds the shear strength of the total number of shear pins inserted in the device. For the shear pin torque indicator supplied by IMR, each individual shear pin is worth 500 ft-lbs (680 N-m). If, for instance, 20 shear pins were loaded into the Shear Pin Torque Indicator, upon applying installation torque to the helical pile, torque force will transfer through the device until it increases to 20 x 500 ft-lbs (680 N-m) = 10,000 ft-lbs (13.6 kN-m) whereupon the shear pins will shear or break.

Photo 2-1 Shear Pin Torque Indicator

This device is typically used only when actually measuring torque. In other words, it is usually not placed on the helical pile shaft until the torque measurement is taken. However, some installing contractors prefer to leave the device on during the entire installation of the pile. When this is done, it is possible the originally loaded shear pins will slightly shear from wear during the installation process. When they finally shear completely, they may shear at a slightly reduced torque value because of this wear that occurs during the installation process. In such cases, immediately upon shearing the original pins, a new set of shear pins must be loaded into the shear pin torque indicator and sheared again. This ensures the desired installation torque.

Mechanical torque indicators are also available. The author has found some to be fragile and not suitable for long-term field use. However, the author is aware of new products that are more durable and utilize automatic data recording. Check the Internet.

2) Hydraulic Pressure Measurement: Measurement of the hydraulic pressure drop across the installing hydraulic torque motor allows one to convert this pressure to installation torque using torque motor manufacturer supplied conversion data.

Bearing Capacity Equations and Computer Programs

The bearing area capacity method is the theoretical method to determine helical pile capacity by using the bearing area of the helix (or helices) multiplied by the bearing capacity of the soil into which each helix is installed. Determination of actual soil bearing capacity is critical to the proper use of this method. Conservatively low calculated soil bearing capacities or soil bearing capacities with a high factor of safety will inordinately affect calculated helical pile capacity.

Helical piles and tension anchors are installed to torque, not depth. This means they find the soil that matches the required pier capacity as they are installed. Drilled concrete pier installation provides no reliable way to determine soil strength or bearing capacity. Therefore, utilizing conservative soil strength parameters is absolutely appropriate. However, this is not necessary with helical screw piles and tension anchors.

Computer programs have been developed that use bearing capacity equations to design helical piles and tension anchors. It should be recognized that the results of such programs can be ultra-conservative, misleading, and unreliable depending on actual soil conditions at a particular site. Use of such programs must be carefully coupled with experience with helical devices and knowledge of the site.

Because of the inaccuracies of the bearing capacity equation method, this method of determining helical pile and tension anchor capacity is not recommended. Rather, it is recommended to predict such capacity via the "Helical Screw Pile Test Probe" and "Standard Penetration Test (SPT)" methods described under "Soil Investigation Parameters" in the PART 3. DESIGN CONSIDERATIONS section below. Also see "Estimating Pile or Anchor Depth" in PART 3 below.

Safety Factors, Minimum Installation Torque, and Minimum Depth

The use of safety factors with helical piles and tension anchors is to ensure that the design load capacity is met with a reasonable margin for error. It is to account primarily for unknowns in the soil but also the rare but potential imperfections in manufacture and installation.

Generally, manufacturers do not recommend nor dictate to engineers what safety factor to use with their helical piles and tension anchors. The industry standard and common safety factor used in the field and in the examples given herein is 2. However, nowhere in the industrial literature is it stated that a safety factor of 2 must be used. The reason no certain safety factor is recommended is because it is left to the engineer to decide what safety factor to use. In some permanent vertical compression helical piles, for instance, engineers have used safety factors as low as 1.5. It is common in all types of permanent tieback construction, not just helical tiebacks, to use a safety factor of 1.5 or less. While this writer feels a safety factor of 2 should be used whenever possible for vertical piers, especially in cohesive soils, a lower safety factor can be used when engineering judgment calls for it. At no time in this writer's company's experience since 1986 with helical screw piles has the use of a safety factor less than 2, when logically and prudently considered, caused a problem in any structure. A safety factor greater than 2 is extremely rare in helical pile and tension anchor technology and generally not necessary.

Minimum Installation Torque: Through experience, this writer recommends a minimum installation torque of 3,000 ft-lbs (4.1 kN-m) for all structural applications, even if the design load is very light, such as from a residential deck. This rule of thumb has proven successful for since 1986 and thousands of installations with zero failures.

Other deep foundation technologies use higher factors of safety to account for the uncertainty in soil data and manufacture of the foundation element itself. For instance, in drilled concrete pier design it is not unusual to a factor of safety of 3 or more. This is unnecessary in helical technology.

Minimum Depth: The A.B. Chance Company has found that in cohesive and fine granular soils, the helices must be installed at least five diameters of the largest helix below the ground surface for their torque vs. capacity relationship to be valid. (A.B. Chance Company "Technical Manual," 2000, p. 10). In dense granular soils such as sands and gravels, compression capacity may remain valid at depths less than five helix diameters below ground surface but tension capacity may not. Careful evaluation and/or testing may be necessary.

Heavy Load Considerations (e.g., high rise structures) using Pile Groups

As with any type of deep foundation, where the design load is greater than the capacity of any single helical screw pile, a group of two or more piles is used. For instance, a common helical screw pile shaft used for heavy foundations is the 1.75 in (44.5 cm) square shaft. This helical pile typically has an ultimate compression capacity of 110,000 lbs (489 kN). If a column design load were, say, 660,000 lbs (2,940 kN), then 12 such helical screw piles would be required if a factor of safety of 2 were used. This is based on each pile having a design capacity of 55,000 lbs (245 kN). Using high capacity pile groupings, such as the piles shown in Table 1-1 above, design loads of 1,000,000 lbs (4,450 kN) and higher are supportable.

Through full-scale load testing by the writer and other manufacturers, the minimum axial center to center horizontal spacing of the lead section required to achieve the maximum capacity of each individual helical pile in a group within the bearing formation to be three diameters of the largest helix, see Figure 2-1. There is no vertical spacing requirement. For instance, if a double helix helical pile were to be used that had an 8 inch (203 mm) and a 10 inch (254 mm) helix lead section on it, the mini-mum horizontal center to center spacing within the bearing formation would be 30 inches (762 mm). Other manufacturers' minimum spacing may differ from that shown herein.

The top of the pile shafts in a group need not meet the minimum horizontal center to center spacing requirement (see Figure 2-1), only the helices on the lead sections and subsequent extensions with helices on them, if any, within the bearing formation. By battering the pile shafts up to 5 degrees maximum for full vertical load carrying capability, the tops of the shaft may be confined in a smaller pile cap. Figure 2-1 depicts such a condition where the tops of the helical pile shafts are closer together than the embedded helix lead sections. This reduces pile cap size and economizes foundation costs.

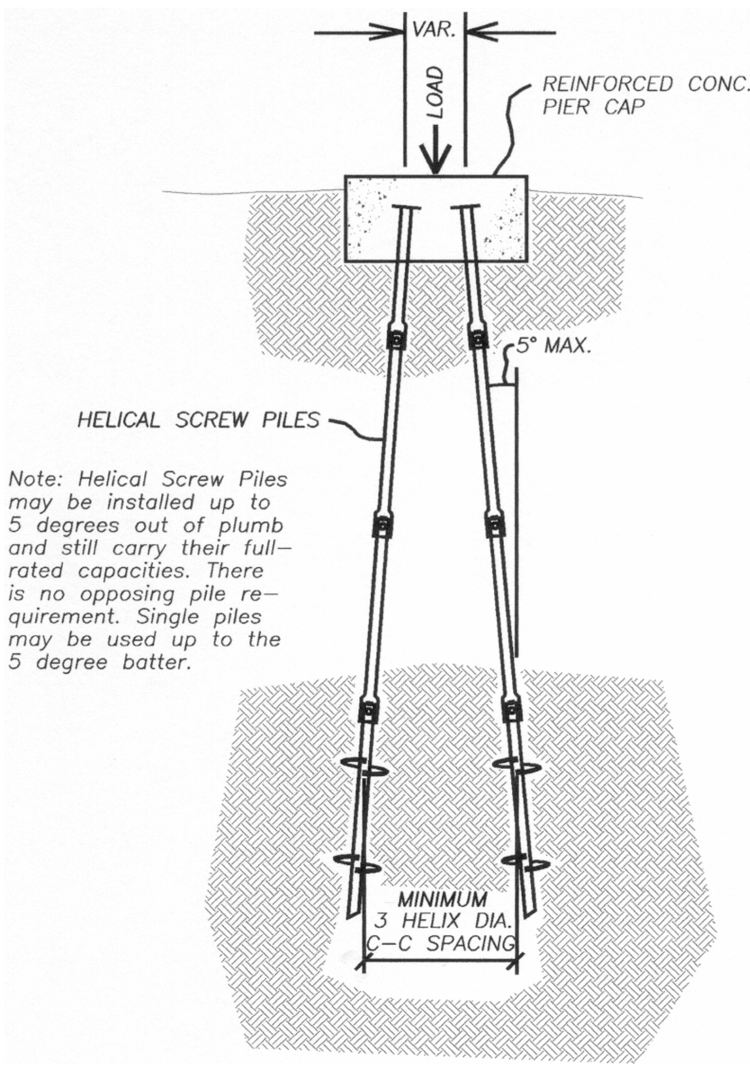


Figure 2-1. Battered Helical Piles for New Foundation

Design of the pile cap, typically performed by the structural engineer, is identical to any multiple-pile cap which distributes load from the structure above to the piles below. Hardware for concrete to steel helical pile load transfer is discussed in the "Load Transfer Devices" section under PART 3. DESIGN CONSIDERATIONS below.

Pile caps are also used to transfer lateral loads, such as wind and seismic loads, from the structure to battered helical piles as discussed in the "Lateral Loading" section under PART 3. DESIGN CONSIDERATIONS below. Since helical piles take axial load in both tension and compression, economies can be realized if piles battered up to 45 degrees or more are used to take both lateral tension and compression loads (see Figure 3-5). This is a common practice.

PART 3. DESIGN CONSIDERATIONS

Designing with the 2009 International Building Code Helical Pile Provisions

The 2009 International Building Code (IBC) is published by the International Code Council (ICC). The ICC was formed several years ago from the merger of several regional building codes: The International Conference of Building Officials (Uniform Building Code), Building Officials and Code Administrators International (BOCA), and the Southern Building Code Congress International (Standard Building Code). The IBC has taken the place of the building codes formerly published and administered by those organizations. The IBC is now accepted virtually throughout the United States. Although a number of jurisdictions have not as of yet adopted the 2009 IBC, they soon will. Therefore, helical pile design professionals must come to know the helical pile provisions of the IBC.

The 2009 IBC streamlines and simplifies designing helical pile foundations and provides design professionals a method with which to evaluate a helical pile foundation, especially if a particular brand of helical pile does not yet have an ICC evaluation report.

It is recommended that all helical pile design professionals obtain a copy of the 2009 International Building Code and begin designing with it immediately.

Chapter 18 "Soils and Foundations" of the IBC contains provisions for the design of helical pile foundations. The commentary below discusses each helical pile provision in Chapter 18 and brings to bear other sections outside Chapter 18 that are referred to in Chapter 18. This commentary is non-exhaustive; there may be other elements to the IBC, whether in Chapter 18 or elsewhere, that must be considered. As those elements are brought to light, this author would appreciate being made aware of them.

Subsection 1801.2, Design basis: This section provides that loading be in accordance with *allowable stress design* and the load combinations and load provisions given in **Section 1605.3**. **Section 1605.3** should be carefully reviewed to be sure the proper load combinations are being considered for the project.

Section 1802, Definitions: The definition of a helical pile: "Manufactured steel deep foundation element consisting of a central shaft and one or more helical bearing plates. A helical pile is installed by rotating it into the ground. Each helical bearing plate is formed into a screw thread with a uniform defined pitch." Helical piles are defined along with "Deep Foundation," "Drilled Shaft," "Micropile," and "Shallow Foundation" thus placing the helical pile along side the other common foundation systems in use today. Helical piles are a standard of practice in the United States and are growing in use world-wide.

Section 1803, Geotechnical Investigations: Helical piles are not specifically mentioned in this section. However, as indicated herein below under "Soil Investigation Parameters," the use of the "Helical Screw Test Probe" within geotechnical investigations would greatly assist in determining depth, capacity, installation time, and ultimately the cost of a helical pile foundation. Use of the test probe would be allowed and welcomed under paragraph **Subsection 1803.5.5 Deep Foundations** wherein several data categories are listed and information is required. The reader is referred to the "Helical Screw Test Probe" section below within this book.

Subsection 1803.5.11, Seismic Design Categories C through F: Special geotechnical investigation provisions are listed in this section. Per **Section 1613**, any structures constructed in these categories shall have a geotechnical investigation performed that addresses the geologic and seismic hazards listed. There is nothing to prevent helical piles from being used within these seismic zones as long as evaluation of the geologic and seismic hazards is performed. The hazards include slope instability, liquefaction, differential settlement, and surface displacement due to faulting or lateral spreading. Liquefaction will be of particular concern considering the slender nature of helical piles and the lack of lateral bracing along the shaft momentarily during a liquefaction event.

(On a side note: AC358, the International Code Council (ICC) acceptance criteria for evaluation of helical piles, excludes helical piles from evaluation for ICC Seismic Design Categories D, E, and F. It <u>does not</u> exclude helical piles from being designed and used in those category areas. Helical piles have been used successfully for decades in Southern and Northern California and other areas of high seismic loading. This just means there will be no evaluation report from ICC for any helical piles to be used in Seismic Design Categories D, E, and F. Helical pile designs in those areas will rely solely on the IBC, methodology that has already become a standard of practice.)

Subsection 1803.5.12, Seismic Design Categories D through F: This section provides additional requirements for the geotechnical investigation in these seismic category areas. Design of helical piles within these categories will be required to account for the provisions given.

Section 1804, Excavation, Grading and Fill: This section does not apply to helical piles.

Section 1805, Dampproofing and Waterproofing: This section does not apply to helical piles.

Section 1806, Presumptive Load-bearing Values of Soils: This section of the IBC provides presumed load bearing values of soils "unless data to substantiate the use of higher values are submitted and *approved*." (**Subsection 1806.2**) A "Helical Screw Test Probe" as described below, will provide such data. A helical pile installation where torque vs. depth is recorded, along with the torque vs. capacity relationship, also provides such data. Care must be exercised to be sure presumptive load-bearing values are NOT applied to **Subsection 1810.3.3.1.9** where axial design load values for helical piles are determined.

Section 1807, Foundation Walls, Retaining Walls and Embedded Posts and Poles: This section applies to helical piles insofar as loading from these structures may be transmitted helical piles. **Subsection 1807.1, Foundation walls** indicates that "foundation wall shall be supported by foundations designed in accordance with **Section 1808, Foundations**. Therefore, it is recommended the provisions of this section be reviewed and applied as needed, especially as the provisions pertain to Seismic Design Categories C through F.

Sub-section 1807.2, Retaining Walls: Retaining walls using helical piles for vertical support and/or helical tension anchors as tiebacks must follow the provisions of this section. Per **Subsection 1807.2.2, Design lateral soil loads**, lateral loading (active pressure) shall be in accordance with **Section 1610, Soil Lateral Loads**. The remainder of **Section 1807** deals with important considerations on safety factors and embedded posts and pole. Helical piles are frequently used to support posts and poles.

Section 1808, Foundations: These are general requirements for all foundations as they relate to capacity, settlement, design loads, seismic overturning, and vibratory loads such as machinery. Helical piles have been used successfully for years for machine foundations. Settlement is covered under "Predicted Settlement and Long-term Creep" below.

Subsection 1808.6, Design for expansive soils: For assistance in this portion of the IBC the reader is directed to "Expansive Clay Soils (with two Case Histories)" below.

Subsection 1808.8, Concrete foundations: Most load distribution members used in conjunction with helical piles are made of concrete such as group pile caps, foundation walls, column bases supported by helical piles, etc. Therefore, many provisions of this section will apply to the overall design of helical pile foundations.

Section 1809, Shallow Foundations: Only **Subsection 1809.5, Frost protection** applies to helical piles. Some building officials have allowed the fact that helical piles extend below frost depth to satisfy the requirement that a foundation wall be founded at a depth below frost depth for frost protection. This allows the bottom of foundation walls to be constructed at grade with no need to excavate a trench. It is recommended that void form be used under all concrete structures in similar fashion to expansive soil sites in order to accommodate frost heave.

Section 1810, Deep Foundations: This is the meat of Chapter 18. It deals specifically with helical piles along with the other types of deep foundations.

Subsection 1810.1, General: This subsection deals with provisions that apply to all deep foundations.

Subsection 1810.2, Analysis: This subsection deals with lateral support for slenderness buckling purposes. As pointed out below under "Slenderness Buckling (soft soil)," the helical pile industry standard is that soils with SPT N values (blow counts) of 4 or greater provide sufficient lateral bracing to precluded slenderness buckling to the rated capacity of the helical pile to any depth. Methods exist for soils with N values less then 4, see "Slenderness Buckling (soft soil)," below.

Subsection 1810.2.2, Stability: This subsection states that all deep foundations must be "braced to provide lateral stability in all directions." Types of bracing are defined. It should be pointed out that for helical pile underpinning, attachment of the pile shaft to an existing structure by means of an underpinning load transfer bracket is considered sufficient lateral bracing to satisfy this subsection. For new foundations, embedment within or attachment to a foundation element is sufficient.

Subsection 1810.2.4.1, Seismic Design Categories D through F: Helical piles must be designed and constructed to withstand maximum imposed curvatures from earthquake ground motions and structure response as described in this subsection.
The remainder of **Subsection 1810.2** must be considered in terms of settlement, lateral loads, and group effects, all of which are covered below within this book.

Subsection 1810.3, Design and detailing: Helical piles are specifically called out in **Subsection 1810.3.1.5, Helical Piles:** "Helical piles shall be designed and manufactured in accordance with accepted engineering practice to resist all stresses induced by installation into the ground and service loads." The information in this book should help in satisfying the requirements of this subsection. If it does not, please inform the author what areas need amplification and coverage.

Subsection 1810.3.2.5, Protection of materials: This subsection covers material corrosion protection. As stated below under "Corrosion," most helical piles are galvanized, some per ASTM B633, other per ASTM A153. In either case, it has been found that these galvanizing specifications should satisfy this subsection.

Subsection 1810.3.2.6, Allowable Stresses: This subsection refers to Table 1810.3.2.6 wherein helical piles are called out in the category "3. Structural steel in compression" and the category "5. Structural steel in tension." In each case, the allowable stresses are identical: 0.6 $F_y \leq$ 0.5 F_u. This means the maximum allowable stress is 0.6 F_y, as long as it is less than or equal to 0.5 F_u. F_y is the specified minimum yield stress, F_u is the specified minimum tensile stress. As an example, for most HELI-PILE® solid steel square shaft helical piles, minimum F_y = 90 ksi (621 Mpa) and minimum F_u = 120 ksi (827 Mpa). Therefore, maximum allowable stress is 0.6(90 ksi) = 54 ksi (0.6(621 Mpa) = 372 Mpa) which is less than 0.5(120 ksi) = 60 kips (0.5(827 Mpa) = 414 Mpa).

Subsection 1810.3.2.8, Justification of higher allowable stresses: Higher stresses are allowed if they can be justified through soil investigation and load testing under the direct supervision of a registered design professional knowledgeable in the field of soil mechanics and deep foundations

Subsection 1810.3.3, Determination of allowable loads: This subsection sets forth the method to determine the allowable helical pile loads via approved formulas and load testing. In addition, provisions are given for single pile uplift capacity and pile group uplift capacity (**Subsections 1810.3.3.1.5 and 1810.3.3.1.6**). **Subsection 1810.3.3.1.7, Helical piles**, specifies the use of a factor of safety of 2.

Subsection 1810.3.3.1.9, Helical piles: This subsection provides for determination of the allowable axial design load using a factor of safety of 2 (Equation 18-4). The axial design load P_a is the least value of the six given methods to determine axial load. Controversy is apt to follow just how these six methods are interpreted. In the judgment of the author, Method 3, "ultimate capacity determined from load tests" should be incontrovertible. What is better than an on-site full-scale load test? When compared to Method 1, "the sum of the areas of the helical bearing plates times the ultimate bearing capacity of the soil or rock comprising the bearing stratum," great disparity could ensue if the method of determining the soil bearing capacity is ultra conservative or just plain incorrect. Needless costs could be realized if good engineering judgment is not exercised with this subsection.

Subsection 1810.3.3.2, Allowable lateral load: This subsection provides methods for acceptable lateral load determination for a single pile and a pile group. Helical piles require checking just as any other deep foundation system.

Subsection 1810.3.4, Subsiding soils: This subsection provides for the determination of any downdrag forces that helical piles may experience.

Subsection 1810.3.5, Dimensions of deep foundation elements: Dimensions of helical piles are actually addressed in **Subsection 1810.3.5.3.3, Helical piles**, wherein it is stated, "Dimensions of the central shaft and the number, size and thickness of helical bearing plates shall be sufficient to support the design loads."

Subsection 1810.3.11, Pile caps: The design of the pile cap or load transfer device is governed by this subsection. Minimum cap dimensions are specified. In addition, pile cap design in Seismic Design Categories C through F are given. It should be repeated that none of the provisions in this subcategory preclude the use of helical piles in the highest of seismic areas, only that the design be carried out as specified.

Subsection 1810.4, Installation: Various provisions for installation are give that apply to all deep foundation systems. **Subsection 1810.4.11, Helical piles**, states: "Helical piles shall be installed to specified embedment depth and torsional resistance criteria as determined by a *registered design professional*. The torque applied during installation shall not exceed the maximum allowable installation torque for the helical pile."

Subsection 1810.4.12, Special inspection: This subsection states: "*Special inspections* in accordance with **Section 1704.10** shall be provided for helical piles." **Subsection 1704.10, Helical pile foundations** states: "*Special inspections* shall be performed continuously during installation of helical pile foundations. The information recorded shall included installation equipment used, pile dimensions, tip elevations, final depth, final installation torque and other pertinent installation data as required by the *registered design professional in responsible charge*. The *approved* geotechnical report and the *construction documents* prepared by the *registered design professional* shall be used to determine compliance."

Soil Investigation Parameters

As in any foundation design process, a thorough soil investigation is recommended. The following tests and parameters are important for helical pile or tension anchor applications:

Helical Screw Test Probe: The preferred procedure to determine depth, capacity, and cost of a helical pile or tension anchor is to perform test installs at the site with the helical screw test probe using actual helical pile material. Helical piles screw out as easily as they screw in. Therefore, performing a helical screw test probe is fast and relatively inexpensive because all helical steel is removed and there is no permanent site impact. The speed allows many test probes to be performed where only a few borings might be completed in a given day. The more helical screw test probes performed at a site, the more knowledge is obtained, and the more likely it is that an installing contractor can give a fixed price without contingency. This is a great advantage to an owner and/or general contractor.

In the helical screw test probe, a log is kept of torque vs. depth. A suggested helical screw test probe procedure and recording sheet is given in the Appendix. This information can be correlated to boring logs. The torque values provide capacity information throughout the soil profile which aids in the determination of pile or anchor depth, shaft size, and helix size. Speed of installation, which also relates directly to cost, can be measured.

For the helical screw test probe, it is recommended to use a single 0.5 inch (12.7 mm) thick, 8 inch (203 mm) diameter helix on a 1.75 inch (44.5 mm) square shaft lead section. This is because it will penetrate deeper into the soil profile than larger diameter helices, or multiple helices, before its maximum torque is reached. If project loading conditions will require a multiple helix lead section for the production piles or anchors, a direct proportion of helix area to torque can be used to estimate the torque at various depths where the larger diameter or multiple helix lead sections might bear. For example, suppose a helical screw test probe using a 1.5 inch (38.1 mm) helical pile with a single 8 inch (203 mm) diameter helix (area = 43.9 in^2 (28,300 mm^2)) achieved 3,000 ft-lb (4.07 kN-m) of torque at a depth of 15 ft (4.6 m). What would be the estimated torque for a 1.5 inch (38.1 mm) 8 inch–10 inch (203 mm–254 mm) double helix lead section at the same depth? Using a direct proportion, the estimated torque would be

$$\frac{43.9\text{ in}^2\ (28{,}300\text{ m}^2)}{3{,}000\text{ ft-lb}\ (4.07\text{ kN-m})} = \frac{43.9\text{ in}^2\ (28{,}300\text{ mm}^2) + 71.1\text{ in}^2\ (45{,}900\text{ mm}^2)}{x}$$

$$x = 7{,}860\text{ ft-lb}\ (10.7\text{ kN-m})$$

This estimated torque assumes essentially a linear relationship between helix area and torque which is not always the case. Engineering judgment is required.

The presence of unforeseen obstructions, such as cobbles, boulders, construction debris, etc., or, conversely, soft or loose soil, or other conditions which might affect helical screw pile or tension anchor capacity can be discovered with a helical screw test probe. Making known the presence of such anomalies in the soil formation before construction commences reduces the possibility of delays during construction and/or price contingencies that could raise the cost of the project.

Helical Pile Test Install: A helical pile test install is merely installing the designed lead section and recording depth vs. installation torque. This allows the design professionals to evaluate the designed lead section, make adjustments as necessary, and make cost evaluations. This test has nearly all the benefits of the "Helical Screw Test Probe" and can be extremely beneficial.

Exploration Borings: If helical test probes are not performed, then the information derived from borings can be useful. It is important to log soil types, take samples, perform field and laboratory testing, determine groundwater elevation, etc. Boring logs allow ongoing correlation with the production helical pile and tension anchor installation logs. Pile and anchor depths can be correlated with boring logs to act as a check to insure the pile is not bearing on an anomaly in the formation such as fill debris, tree stumps, car bodies, etc.

Standard Penetration Test (SPT), ASTM D-1586: Accurate SPT blow counts (N Values) can be useful for estimating helical screw pile or tension anchor depth.

Helical piles and helical tension anchors can be installed into any soil, however, soils with blow counts of 0 to 15 will typically require more helices on the lead section to obtain installation torques commensurate with most structural loads. Where blow counts exceed 15 to 25, typical structural loads are typically supported with single, double, or triple helix lead sections. The higher the blow counts, the higher the installation torques that will be achieved with a given lead section configuration.

Helical piles and tension anchors with common lead section helix configurations are readily installed into soils with SPT blow counts up to 90+. It is difficult to install helical piles or tension anchors where SPT blow counts are greater than 100.

For soils with high SPT blow counts, compression pressure (also called "crowd") should be applied to the pile or anchor shaft by the installation equipment to keep the pile or anchor advancing. Just as screwing a wood screw into pine is easy, when screwed into oak, higher compression pressure must be applied for the screw to continue advancing. The same principle applies to helical piles and tension anchors. The denser or more hard the soil, the more crowd must be applied to the shaft to keep it advancing.

Active Zone Determination: As with any deep foundation, the helix or helices of the pile or anchor must extend beyond the active zone into stable material. Helical screw test probes are the preferred method to identify the active zone because the installation torque feedback indicates where tight stable formations exist or where the formation will limit water infiltration thus keeping the formation stable into which the helix or helices are embedded. See the discussion on this topic in the "Expansive Clay Soils" section below. Other methods, if accurate, are acceptable.

Groundwater Depth: Knowledge of groundwater conditions is valuable but not critical to successful helical screw pile or tension anchor installation or performance. Since no hole is created, no casing is required. The presence of groundwater does not affect the torque vs. capacity relationship, although depth of the pile may be affected since groundwater can affect shear strength. Natural groundwater fluctuations do not adversely affect helical pile or tension anchor capacities.

Field Description: The presence of conditions that may affect the installation of helical piles and tension anchors needs to be known. Such items include cobbles, boulders, dense coarse gravel lenses, soft soil lenses, debris, bedrock, etc.

Estimating Pile or Anchor Depth

Estimating helical pile or tension anchor depth is an exercise in estimating the depth where the required installation torque or refusal condition will be achieved. The following methods provide reasonable depth estimates. No other methods, even those with manufacturer prepared computer programs, have proven consistently reliable.

Helical Screw Test Probe: Pile or anchor depth is best estimated by the helical screw test probe as described in the "Soil Investigation Parameters" section above and detailed in the Appendix. The helical screw test probe uses a single 8 inch (203 mm) diameter helix on the lead section. The torque achieved throughout the soil profile with this test probe is used to calculate expected installation torques for other helix lead section configurations by direct proportion of the surface area of the 8 inch (203 mm) probe helix to the surface areas of the production helices. Hence, it is possible to estimate the depth at which the anticipated final installation torque will be reached with the production piles or anchors. This method is by far the most accurate of all methods to estimate helical screw pile or helical tension anchor depth.

Helical Pile Test Install: As with the "Helical Screw Test Probe," a helical pile test install using the design lead section can be invaluable in predicting depth and cost. It is recommended.

Standard Penetration Test (SPT), ASTM D-1586: Accurate SPT blow counts (N Values) can be useful for estimating helical pile or tension anchor depth.

Helical piles and helical tension anchors can be installed into any soil, however, soils with blow counts of 0 to 15 will typically require more helices on the lead section to obtain installation torques commensurate with most structural loads. Where blow counts exceed 15 to 25, typical structural loads are typically supported with single, double, or triple helix lead sections. The higher the blow counts, the higher the installation torques that will be achieved with a given lead section configuration.

By knowing the required installation torque and knowing the soil SPT blow count profile, an estimate can be made of the depth where the required installation torque will be achieved. One must take into account the number and size of the helices on the lead section.

Helical piles and tension anchors with common lead section helix configurations are readily installed into soils with SPT blow counts up to 100. It is difficult to install helical piles or tension anchors where SPT blow counts are greater than 100.

Where accurate N values are near or over 100, the "refusal condition" may be encountered during installation. Helical piles and tension anchors might not penetrate such material. If not, for compression piles, the lead section will bear on this material, an acceptable condition so long as the bearing material is stable. See the "Refusal Condition in Extremely Dense Soil, Rock and Cobble" section below. This section also describes how to deal with tension anchors in the refusal condition.

Software: Software is available that reports to analyze geotechnical data and determine predicted depth and installation torque requirements. It is this author's experience that this software can be very misleading if not used properly. The creators and distributors of this software make it clear that it is just a guide, not necessarily accurate. There is a tendency in the industry to treat the results of such software as gospel, the "It came from a computer so it must be right" syndrome. Nothing is further from the truth in this industry. Software results can be useful when used in conjunction with experience and sound engineering judgment. Let the user beware.

Such software will become more useful as its ability to deal with the myriad of soil and loading conditions increases. This author believes that the day will come when good reliable software will be available to the helical pile industry.

Predicted Settlement and Long-term Creep

Based on thousands of full-scale load tests and the historical record since 1986 of thousands of structures founded on helical piles manufactured by I.M.R. and the A.B. Chance Company, vertical compression loaded helical screw piles properly designed and installed to a factor of safety of 2 do not settle beyond limits typically set by structural engineers. This means settlements are always less than 1 inch (25 mm). Differential settlements during construction have never been a concern.

Long-term Creep: Full-scale long-term load testing has shown that a helical pile or tension anchor properly designed and installed in cohesive soils, with the installation torque required to carry the design load with a factor of safety of 2, does not experience long-term creep (Chapel, Thomas A., "Field Investigation of Helical and Concrete Piers in Expansive Soils," Colorado State University Master's Thesis, 1998). Helical piles do not experience long-term creep in granular soils. Many years of helical pile history across the United States bear this out. If the reader has any experience to the contrary, this author would welcome the knowledge.

Expansive Clay Soils (with two Case Histories)

Two recent professional papers by the author on this subject are presented below. This is done with permission of the publishers.

Paper No. 1: The following paper is reprinted from GEO-VOLUTION, The Evolution of Colorado's Geological and Geotechnical Engineering Practice, pp. 76-85; proceedings of the 2006 Biennial Geotechnical Seminar, November 10, 2006, Denver, Colorado; Geotechnical Practice Publication No. 4 by the American Society of Civil Engineers; reprinted by permission from ASCE. This material may be downloaded and used for personal use only. Other use requires prior permission of the American Society of Civil Engineers.

Performance of Square Shaft Helical Pier Foundations in Swelling Soils

John S. Pack, P.E., M. ASCE[1]

[1]Vice President – Engineering, D&B Engineering Contractors, 5135 Ward Road, Wheat Ridge, Colorado 80033; phone (303) 423-6834; fax (303) 423-0603; email: imrpack@aol.com.

Abstract

The use of square shaft helical pier foundations in swelling soils is a standard of practice in Colorado. Since 1986 it is estimated approximately 130,000 square shaft helical piers of the type described herein have been installed for both remedial repair and foundations for new construction in swelling soils, including the highly expansive steeply dipping bedrock areas of the Front Range. There are no documented failures or adverse performance of correctly specified and installed square shaft helical piers. The underlying principles for this performance are: 1) Installing square shaft helical piers to a minimum of 4,000 ft-lbs (5.4 kN-m) of installation torque, or refusal, ensures that the helical bearing plate (helix) is embedded below the active zone (depth of seasonal moisture change), 2) The use of only a single helix lead section ensures that no helical bearing plates embed within the active zone, 3) The small surface area of the square shaft reduces uplift forces on the pier to levels that eliminate heave, even where there is no dead load, 4) The smooth steel shaft surface may reduce uplift forces on the pier, 5) The square shaft shape may reduce uplift forces on the pier, 6) Water does not migrate along the sides of the shaft down to the soil in which the helix is embedded, 7) Specifying IBC and ISO 9001 listed square shaft helical piers ensures the correct material is furnished and installed for swelling soil conditions and 8) The use of trained and experienced installing contractors ensures that square shaft helical piers are correctly installed in swelling soils.

Introduction

The modern square shaft helical pier is a derivative of the helical screw pile that was invented some 300 years ago in Europe. In recent times, the helical screw pile concept has been refined in shape and size and adapted to high-strength, low-alloy steels to produce the deep foundation system in use today.

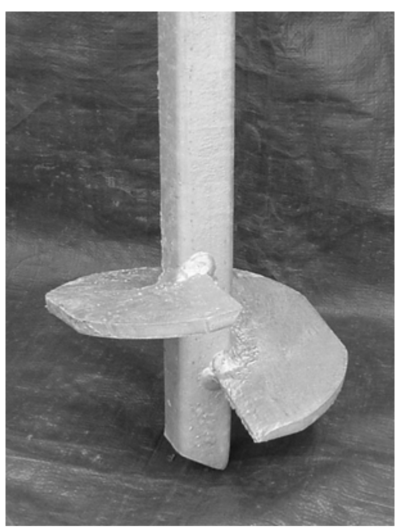
Square shaft helical piers for structural foundations were introduced to the United States in the 1960's and introduced to Colorado in the 1980's. Their use is a standard of practice in Colorado. Numerous manufacturers have a presence in Colorado along with corresponding installing contractors.

Since 1986 it is estimated approximately 130,000 square shaft helical piers of the type described herein have been installed for both remedial repair and foundations for new construction in swelling soils, including steeply dipping expansive bedrock found along the Front Range. There are no documented failures or adverse experiences with correctly specified and installed square shaft helical piers. The underlying principles for this performance are detailed below.

Swelling Soil in Colorado

The presence of swelling soils in Colorado is well documented (Chen, 1988, p. 14; Nelson and Miller, 1992, p. 4; Day, 2006, p. 9.1). It could be said that certain areas of Colorado, especially along the Front Range, are among the finest natural laboratories in North America for the examination of foundation performance in swelling soils. Steeply dipping bedrock formations are notorious for adverse effects on structural foundations. Bentonitic clays exist with swell pressures that can range as high as 40,000 psf (1,900 kPa) with Plasticity Indices (PI) exceeding 50. While most swelling soils usually do not exhibit characteristics as high as the aforementioned, problematic swelling soils through-out Colorado continue to adversely affect many types of foundation systems causing differential heave, structural distress and cosmetic damages. It is within this geological and historical setting that square shaft helical pier foundation performance is examined.

Square Shaft Helical Pier Description



[Paper No. 1] **Figure 1. Single Helix Square Shaft Helical Pier.**

The type of square shaft helical pier examined in this paper is shown in Figure 1. It consists of a central, square, solid-steel shaft to which a single split circular steel helical bearing plate, stamped in the shape of a helix, is welded. This steel bearing plate is simply called a “helix”. Shaft cross-section size typically ranges from 1.50 in square to 1.75 in square (38.1 mm square to 44.5 mm square). Lead section and extension length typically ranges from 3 ft to 10 ft (0.9 m to 3 m) long. Helix diameter typically ranges from 6.0 in to 14.0 in (150 mm to 360 mm). Helix thickness typically ranges from 0.375 in to 0.500 in (9.53 mm to 12.7 mm).

Square shaft helical piers for new construction are typically installed using a hydraulically powered drive head attached to wheeled or tracked equipment. Figure 2 shows a typical square shaft helical pier installation using hydraulic torque drive heads attached to the jibs of two tracked skid steer type machines. The drive head’s torque force is transferred to the helical bearing plate, or helix, via the square shaft. The leading edge of the helix engages the soil which causes the helix to screw into the soil thus guiding and pulling the shaft with it. As the top end of the shaft reaches grade, an extension is attached and installation continues. Successive extensions are attached until, in swelling soils, a minimum of 4,000 ft-lbs (5.4 kN-m) of installation torque, or refusal, is achieved.

[Paper No. 1] **Figure 2. Square Shaft Helical Pier Installation.**

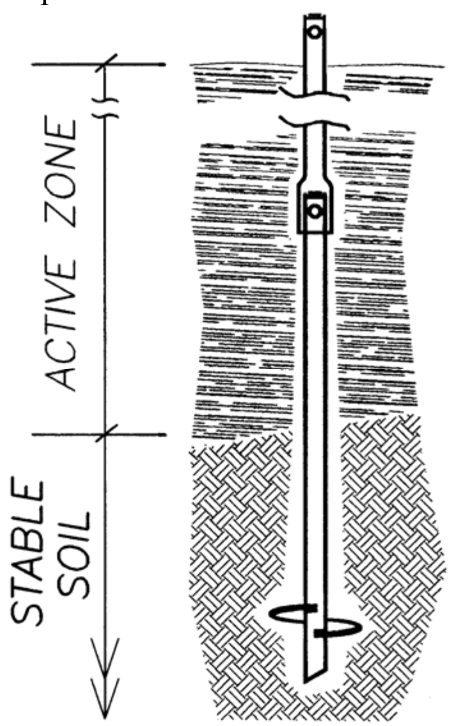
Underlying Performance Principles

There are no documented failures or adverse performance of correctly specified and installed square shaft helical piers in swelling soils. The underlying principles for this performance are given by the eight findings described below:

1. Installing square shaft helical piers to a minimum of 4,000 ft-lbs (5.4 kN-m) of installation torque, or refusal, ensures that the helical bearing plate (helix) is embedded below the active zone (depth of seasonal moisture change).

Any deep foundation, be it helical pier, drilled pier, driven pile, etc., must embed and transfer load through the active zone to stable material below. The active zone is defined as that zone or depth of seasonal moisture change, sometimes also called the "depth of wetting." It is the depth or zone where soil expansion or shrinkage forces adversely affect deep foundation performance. Swelling soils expand when the moisture content increases and contract or shrink when moisture content decreases. If the deep foundation is not sufficiently installed below the active zone, as moisture content changes, heave or shrinkage forces will be applied to the deep foundation which may cause it and the structure above to move.

Through monitoring thousands of square shaft helical pier installations in swelling soils over the 20 year period since 1986, it has been empirically found that if the square shaft helical pier is installed to a minimum of 4,000 ft-lbs (5.4 kN-m) of installation torque, or to the refusal condition, it is ensured that the helix is embedded in stable soil below the active zone. Figure 3 depicts a square shaft helical pier installed below the active zone.



[Paper No. 1] **Figure 3. Stable Square Shaft Helical Pier Installed Below the Active Zone.**

It will be noted that a certain depth of embedment is not required in square shaft helical pier technology. A minimum installation torque of 4,000 ft-lbs (5.4 kN-m) or refusal is specified, not an embedment length.

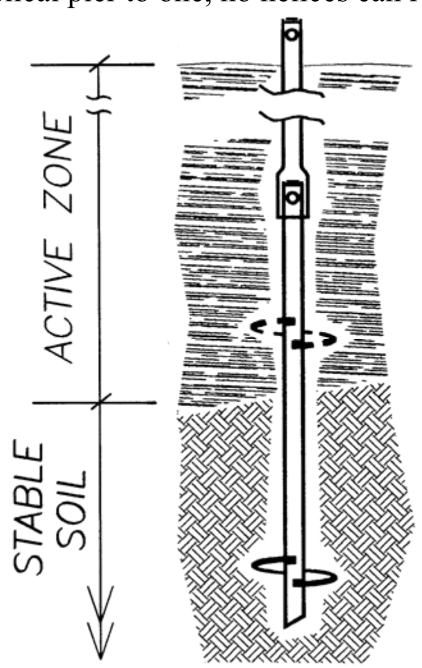
When a square shaft helical pier is installed to 4,000 ft-lbs (5.4 kN-m) of installa-tion torque or refusal, it has been found that the soil into which the helix is embedded is very dense, so dense, in fact, that moisture will not reach the soil into which the helix is installed, even over the potential many years of primary and secondary swell. The extremely low permeability of such soil does not allow moisture to ever penetrate to the soil surrounding the helix. Thus, the square shaft helical pier remains stable.

Refusal. Refusal condition is defined as that point at which the square shaft helical pier will not penetrate or advance further into the formation because the material is too dense or hard. At refusal, installation torque typically reduces below the torque achieved just prior to reaching refusal. This occurrence does not indicate lower compression capacity of the pier. Rather, because advancement cannot continue, high compression capacity in a formation not susceptible to water infiltration is achieved.

2. The use of only a single helix ensures that no helical bearing plates (helices) embed within the active zone.

If helical bearing plates are embedded in an active soil zone that swells or shrinks, swelling or shrinkage forces will be applied to the plates which could lead to movement of the helical pier. Excluding helical plates from the active zone ensures that no such forces will be applied to any helices.

Figure 4 shows a single helix helical pier embedded in stable soil below the active zone. If the soil below the active zone is so dense that a second helix (shown in dashed lines) were embedded in the active zone, helical pier movement could possibly occur. By limiting the number of helices on a helical pier to one, no helices can remain in the active zone.



[Paper No. 1] **Figure 4. Helices Installed Below the Active Zone.**

3. The small surface area of the square shaft reduces uplift forces on the pier to levels that eliminate heave, even where there is no dead load.

Any portion of a deep foundation shaft within the active zone of swelling soil is susceptible to an uplift force due to vertical swell pressure. The uplift force magni-tude depends on the coefficient of uplift between the shaft and the soil (see Section 4), and the surface area of the shaft (Nelson and Miller, 1992, p. 130). The uplift force is proportional to the shaft surface area.

As an example, suppose a 1.5 in (38.1 mm) square shaft helical pier were installed through a 30 ft (9.1 m) active zone with a vertical swell pressure of 20,000 psf (960 kPa), a high swelling soil. Using a coefficient of uplift of 0.10 for the smooth steel shaft, the total uplift force on the square shaft helical pier is given by

$$U = (4)(s)(f)(u)(D) \quad (1)$$

where U = Total uplift force
4 = Number of sides on the square shaft
s = Square shaft size
f = Coefficient of uplift
u = Vertical Swell Pressure
D = Depth of the Active Zone

$$U = (4)(1.5 \text{ in} / 12 \text{ in} / \text{ft})(0.10)(20{,}000 \text{ psf})(30 \text{ ft}) = 30{,}000 \text{ lbs}$$
$$(U = (4)(38.1 \text{ mm})(0.10)(960 \text{ kPa})(9.1 \text{ m}) \approx 130 \text{ kN})$$

Through thousands of full-scale load tests, it has been empirically shown that a square shaft helical pier installed to 4,000 ft-lbs (5.4 kN-m) of installation torque has a compression and tension ultimate capacity of 40,000 lbs (180 kN)(Pack, 2004, p. 19). Therefore, even with no dead load, this helical pier has an ultimate uplift capacity of 40,000 lbs (180 kN). The factor of safety, *F.S.*, against heaving of this particular helical pier is

$$F.S. = 40{,}000 \text{ lbs} / 30{,}000 \text{ lbs} = 1.3$$
$$(F.S. = 180 \text{ kN} / 130 \text{ kN} \approx 1.3)$$

Thus, even with no dead load in a high swelling soil with a deep active zone, this square shaft helical pier will not heave. Experience corroborates this finding. Since 1986 thousands of lightly loaded structures, such as single-story wood frame structures and wood decks, have been founded on square shaft helical piers in swelling soils where little dead load is imposed on the piers. To date, no documented failures or adverse performances of correctly specified and installed square shaft helical piers have occurred.

When the refusal condition is reached (see definition above), the tension capacity cannot be determined by installation torque. Since 1986 it has been empirically shown that in the refusal condition square shaft helical piers do not heave, even with no dead load and even at shallow depths, such as 10 feet (3 m) or less. While the mechanics of the refusal condition for square shaft helical piers warrant study, it is felt by this writer that the combination of findings in this paper (excluding the 4,000 ft-lb (5.4 kN-m) installation torque requirement) all contribute to the performance of square shaft helical piers in the refusal condition. It is recommended that further investigation be undertaken to ascertain the reasons why square shaft helical piers in the refusal condition still perform.

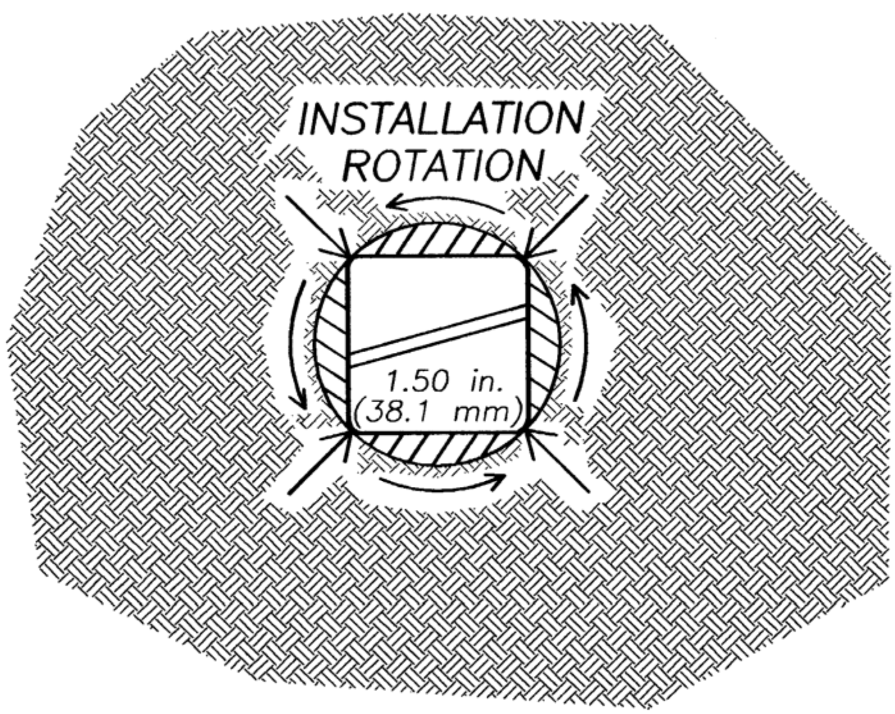
4. The smooth steel shaft surface may reduce uplift forces on the pier.

It has been experimentally determined that the coefficient of uplift between concrete and soil of a drilled cast-in-place concrete pier (caisson) is on the order of 0.15 (Chen, 1988, p. 136). Another estimate of this coefficient ranges from 0.10 to 0.25 (Nelson and Miller, 1992, p. 130). These values were determined for concrete piers that typically have relatively rough surfaces as compared to the smooth steel surface of a square shaft helical pier. Therefore, it stands to reason that the smooth steel sur-face of the square shaft helical pier would have a coefficient of uplift on the low end of the range, perhaps below 0.10. A value of 0.10 was used for Equation (1) above.

Due to the lack of a rough surface, it can be said that total uplift force on square shaft helical piers may be reduced. Quantifying the reduction in uplift force has not been studied but it is expected that some reduction occurs.

5. The square shaft shape may reduce uplift forces on the pier.

Figure 5 shows a cross-section of a 1.50 inch (38.1 mm) square shaft helical pier. It will be noted that, as the shaft is installed, only the rounded corners of the shaft shear the sides of the disturbed zone adjacent to the shaft. Between corners is a zone of soil against the sides of the steel shaft that does not directly impact the shaft. Uplift forces impact the shaft directly on the corners only, not the straight sides between the corners. Between the corners uplift forces from swelling soil must act on the soil in the undisturbed zone between corners then transmit forces through this zone to the shaft. The amount of uplift force reduction has not been studied. However, it stands to reason that some reduction is actually occurring when the geometry of the square shaft is considered.



[Paper No. 1] **Figure 5. Square Shaft Helical Pier Cross-section.**

6. Water does not migrate along the sides of the shaft down to the soil in which the helix is embedded.

There have been no documented cases where water has migrated down the shaft to soil surrounding the helix, even where the helix less than 10 ft (3 m) deep.

Swelling soils swell upon wetting. The very phenomenon that makes swelling soils a challenge for foundation engineers makes them advantageous to square shaft helical piers. As water starts to penetrate along side the square shaft, the presence of swelling soils self-seals any water avenues thus preventing water from migrating down the shaft to soil surrounding the helix.

This finding is corroborated by a study completed between 1995 and 1998 at Colorado State University (Chapel, 1998, p. 107-108). The study found that water did not migrate along the shaft of square shaft helical pier any more than water migrated along the shaft of drilled cast-in-place concrete piers (caissons). Due to lack of natural rainfall, an irrigation system was set up during the last two years of the study to ensure that water was available to migrate. The result of this study is in agreement with field experience in swelling soils.

7. Specifying International Building Code (IBC) and ISO 9001 listed square shaft helical piers ensures the correct material is furnished and installed for swelling soil conditions.

Swelling soils require helical pier shaft and helix material that is sufficiently strong to withstand high installation crowd (compression pressure from the installation equipment) and high installation torque. Specifying IBC listed square shaft helical pier material allows the designer to review the specifications to ascertain whether the material being considered meets the recommended minimum strength requirements given below.

To match the performance standard given in this paper (no failures or adverse performance), shaft steel for 1.50 in (38.1 mm) square shaft should have a minimum 70 ksi (480 Mpa) tensile strength. Shaft steel for 1.75 in (44.5 mm) square shaft should have a minimum 90 ksi (660 Mpa) tensile strength. Helix steel for all square shaft helical piers should have a minimum 80 ksi (550 Mpa) tensile strength. All welds should be certified per American Welding Society guidelines.

The manufacturer of square shaft helical piers should rate their products for ultimate installation torques and ultimate tension and compression capacities. All ratings must be backed by test results.

Square shaft helical piers should be manufactured by an ISO 9001:2000 listed manufacturer. ISO, the International Organization for Standardization headquartered in Geneva, Switzerland, lists companies in 157 nations. According to the ISO website (www.iso.org), “ISO 9001:2000 is one of a family of quality management standards” that “has become an international reference for quality requirements in business to business dealings.” ISO 9001:2000 “is concerned with ‘quality management’. This means what the organization [manufacturer] does to enhance customer satisfaction by meeting customer and applicable regulatory requirements and continually to improve its performance in this regard." The ISO family of standards represents an international consensus on good management practices with the aim of ensuring that the manufacturer can time and time again deliver the product or services that meet the client's quality requirements.

8. The use of trained and experienced installing contractors ensures that square shaft helical piers are correctly installed in swelling soils.

As in all geotechnical construction, the use of a trained and experienced installing contractor is one of the most important steps that can be taken to ensure a properly performing square shaft helical pier foundation in swelling soils. Trained and experienced contractors know the balance between soil conditions, installation equipment and techniques, and helical pier material to ensure a correct foundation in swelling soils.

Manufacturer certification is not sufficient, in and of itself, to ensure correct installation. Owners and designers should ascertain qualifications by pre-qualifying prospective installing contractors based on specific project experience in swelling soils and longevity in the industry. It is not unusual for installing contractors of square shaft helical piers who are long experienced in swelling soils to guarantee the performance of the foundations they install for both new construction and repair of existing foundations.

Conclusion

Structures in swelling soil regions of Colorado and other swelling soil regions of the world remain stable if founded on correctly specified and installed square shaft helical piers. This is true for new construction and for foundations requiring repair. The underlying principles presented above prove why this is so. Owners, designers and constructors should consider the use of square shaft helical piers wherever swelling soils are encountered.

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DESIGN, SPECIFICATION AND INSTALLATION OF SQUARE SHAFT HELICAL PIERS IN EXPANSIVE SOILS

John S. Pack, P.E., I.M.R., Inc., Wheat Ridge (Denver), Colorado, USA

The application of square shaft helical piers in expansive soils is a standard of practice in many areas of the United States. Over 20 years of performance monitoring show exceptional performance and economy will result if proper design procedures, specification requirements and installation procedures are followed. This is true for new foundations and the repair of existing foundations, including lightly loaded wood-frame structures on expansive soils. Proper design includes: 1) site geotechnical characterization, 2) pier layout such that each pier is loaded to its maximum design capacity, 3) maximize spans between piers, 4) minimize the number of piers, 5) isolate the structure from the expansive soil with an appropriate void zone below all grade beams, slabs or other components that would otherwise be in soil contact and 6) utilize only single helix piers. Proper specification employs a performance specification that specifies: 1) the design load on each pier with a suitable safety factor, 2) the minimum installation torque, typically 4,000 ft-lbs (5.4 kN-m), or refusal, 3) a minimum pier shaft steel F_y = 70 to 90 ksi (483 to 621 Mpa) and pier helix steel F_y = 80 ksi (552 Mpa), 4) 1.5 to 1.75 inch (38.1 to 44.5 mm) square shafts, 5) smooth shaft surface, 6) the ICC Evaluation Report (ER) number of the manufacturer and 7) the manufacturer ISO 9001 certification for material quality control. Proper installation requires: 1) equipment with sufficient axial compression force (crowd) on the pier shaft so the helix engages the soil and advances to the specified minimum installation torque or refusal, 2) additional specialized techniques for expansive soils and 3) qualified specialty helical pier installation contractors experienced in expansive soils who submit and utilize pier configurations, techniques and equipment that will most effectively and economically meet the specified performance.

INTRODUCTION

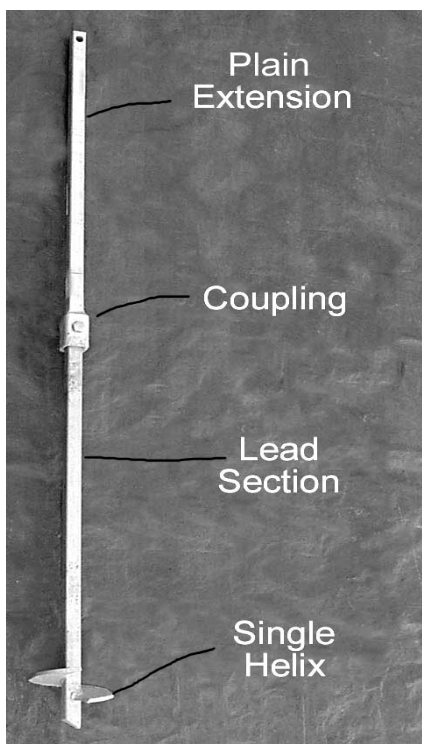
Performance monitoring, ongoing since 1986, proves that any structure founded on properly designed, specified and installed square shaft helical piers in expansive soils of even the highest severity will maintain long-term stability, i.e., will not heave. This includes lightly loaded wood-frame structures. It is true for new foundations and the repair of existing foundations. The underlying principles for this performance are well documented (Hargrave and Thorsten, 1992; Black and Pack, 2001; Pack and McNeill, 2003; Pack, 2006).

Due to exceptional performance, square shaft helical pier applications in expansive soil regions have become common throughout the United States, predominately in the states of Colorado, Montana, Texas, Utah and Wyoming. In most of these areas, the use of square shaft helical piers is a standard of practice.

This paper outlines design, specification and installation procedures and requirements for square shaft helical piers that will result in long-term stable foundations in expansive soils. These practices have been derived primarily through the experience gained since square shaft helical piers began to be installed in the highly expansive clays of the Denver and Front Range areas of Colorado in 1986. Most of the structures that are the result of these methods are light wood-frame residences, the very structures that are the most susceptible to differential heave because of their low dead loads. Large commercial, Industrial, institutional and multiple-story structures in expansive soils have also been successfully designed and constructed using these procedures and requirements.

Brief Description

The square shaft helical piers that are the subject of this paper have shaft dimensions that range from 1.5 inch (38.1 mm) to 1.75 inch (44.5 mm) square. The helix is a split circular steel plate, ⅜ to ½ inch (9.5 to 12.7 mm) thick, stamped in the shape of a helix and welded to the central square shaft (Figure 1). The helix has a leading edge that engages the soil when it is rotated, or screwed, such that an axial thrust is created driving the helix and shaft into the soil. Lead sections typically come in lengths of 3, 5, and 7 feet (0.9, 1.5, and 2.1 m). As the lead section advances farther into the soil, plain shaft extensions are added until the desired depth is reached. Extensions also come in 3, 5, and 7 feet (0.9, 1.5, and 2.1 m) lengths. Shaft sections are typically connected with a bolted connection. Helix diameters typically range from 6 to 14 inches (152 to 356 mm), however, the most common helices used in expansive soils are the 6 and 8 inch (152 and 203 mm). Figure 1 is a photograph of a single helix square shaft helical pier with the different parts labeled.



[Paper No. 2] Figure 1. Single Helix Square Shaft Helical Pier

The helix serves dual purposes: 1) It is the installation tool, i.e., as it is rotated it drives the shaft deeper into the soil. 2) It is the bearing plate for load transfer to the soil.

Typical individual ultimate capacities of the square shaft single helix helical piers that are the subject of this paper range from 50 kips (222 kN) for the 1.5 inch (38.1 mm) shaft to 60 kips (267 kN) for the 1.75 inch (44.5 mm) shaft. A typical factor of safety of 2 (Specification Requirement 1 below) is applied to pier ultimate capacities to determine design capacities.

For new construction, square shaft helical piers are typically installed with specialized hydraulic torque motors mounted to mobile equipment such as backhoes, trackhoes, or any mobile equipment able to carry and power the torque motor. Figure 2 is a photograph of a typical square shaft helical pier installation using a wheeled excavator with the hydraulic torque motor mounted to the excavator boom.

[Paper No. 2] Figure 2. Square Shaft Helical Pier Installation Using a Wheeled Hydraulic Excavator

For a detailed description of square shaft helical piers and installation equipment for new construction and foundation repair, the reader is referred to Pack (2004).

DESIGN PROCEDURES

The design, specification and installation procedures and requirements outlined below are specific to square shaft helical piers in expansive soils; they are not exhaustive for deep foundation design and installation. In addition to the methods presented herein, other techniques pertaining to deep foundations may be applicable.

These procedures and requirements are not necessarily sequential, however, some logically should occur before others.

Design Procedure 1: Site Geotechnical Characterization

The logical first design step is to determine the existence and extent of expansive soils at a site. A detailed discussion of the nature of expansive soils and methods to perform site exploration and characterization is beyond the scope of this paper. For such information, the reader is directed to Chen (1988) and Nelson and Miller (1992) as well as other sources of information available in the literature.

Where site characterization is to be performed, it is recommended that a geotechnical engineer familiar with 1) expansive soils in the area and 2) square shaft helical pier technology be consulted. Experience has shown that unfamiliarity with square shaft helical pier technology in expansive soils can lead to the inappropriate application of other foundation technologies to square shaft helical piers.

For example, in expansive soils, the requirement of a minimum length of pier embedment into the stable formation below the active zone, such as bedrock, does not apply to properly designed, specified and installed square shaft helical piers. To ensure long-term stability, square shaft helical piers typically are installed to a minimum of 4,000 ft-lbs (5.4 kN-m) of installation torque or refusal (see Specification Requirement 2 below). For reasons detailed in Pack (2006), this ensures 1) the helices embed in stable soil below the active zone and 2) piers will maintain long-term stability (not heave). No minimum length of embedment is required.

In contrast, drilled cast-in-place concrete piers (caissons) where installed in expansive soils, are typically socketed a certain minimum length into the stable formation below the active zone to counteract uplift forces. This is due to the concrete pier's large surface area in contact with expansive soil in the active zone. Embedment below the active zone attempts to anchor the concrete pier down and keep it from heaving.

While this practice is appropriate for drilled pier technology, it is <u>not</u> for square shaft helical pier technology and should be avoided. Insistence that square shaft helical piers be installed deeper than necessary causes delays and increased costs.

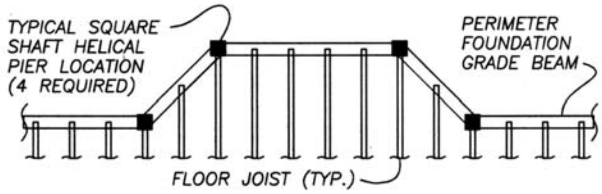
<u>Design Procedure 2: Pier Layout such that Each Pier is Loaded to Its Maximum Design Capacity</u>

Research and monitoring since 1986 have shown that properly designed, specified and installed square shaft helical piers will maintain long-term stability in expansive soils even with <u>no</u> dead load (Chapel, 1998; Pack, 2006). However, in spite of this experience, in expansive soils, loading helical piers to their maximum design capacities is prudent engineering. An additional benefit of this procedure is that it minimizes the number of piers which maximizes economy. Minimizing the number of piers further aids in long term foundation stability in expansive soils by lowering the number of soil/foundation contact points, further described in Design Procedures 3 and 4 below.

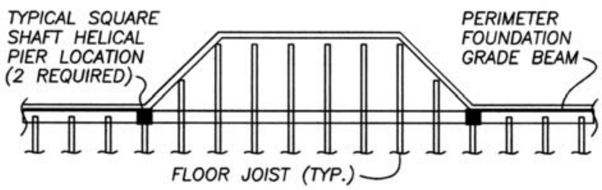
Detailing methods to layout piers such that each is loaded to its maximum design capacity is beyond the scope of this paper. Such information is available in the literature. The structural engineer responsible for the superstructure may defer pier layout and load distribution design to specialty square shaft helical pier contractors or suppliers. The structural engineer must be satisfied specialty contractors or suppliers are qualified to work in expansive soils (See Installation Procedure 3 below).

Experience has shown that there is a tendency of some structural engineers to place more helical piers in the foundation than necessary. Much of this tendency comes from a misperception that square shaft helical piers with such slender shafts may require an added factor of safety beyond what is typical. Testing and decades of experience show this practice is unfounded and may, in fact, add to overall foundation instability in expansive soils.

Structural engineers and architects should work together so the foundation plan lends itself to maximizing pier loads. For example, a residential structure may have a bay window alcove as shown in Figure 3a. Foundation plans frequently call for the perimeter grade beam to follow the plan of the bay. To avoid eccentric loading of the perimeter grade beam, two lightly loaded helical piers are required at the bay outside corners. As shown in Figure 3b, a way to eliminate these two piers is to have the perimeter grade beam continue straight and have the bay alcove floor joists cantilever beyond the perimeter grade beam. By following this concept, the structural engineer and architect work together to maintain architectural aesthetics while maximizing the design load on each pier, minimizing the number of piers and reducing the number of soil/foundation contact points.



[Paper No. 2] Figure 3a. Perimeter Foundation Grade Beam With 4 Square Shaft Helical Piers



[Paper No. 2] Figure 3b. Perimeter Foundation Grade Beam With 2 Square Shaft Helical Piers

Design Procedure 3: Maximize Spans Between Piers

Design Procedures 3, 4 and 5 have identical purposes: 1) Minimize the contact area of the foundation with expansive soil and 2) isolate the foundation, insofar as practical, from the expansive soil. Minimal soil/foundation contact and maximum foundation isolation results in foundation stability because total expansion forces that act on the foundation are minimized. This procedure should be used for new construction and for the repair of existing foundations on expansive soils.

Design Procedure 3 assumes a structural grade beam and raised floor system or a structural slab is used, regardless of the purpose or size of the structure. Spans between piers should first be designed to maximize pier loads (Design Procedure 1 above). Once this criterion is met, then grade beam or slab design proceeds per normal design methods.

Design Procedure 4: Minimize the Number of Piers

It is the author's opinion that the foundation sys-tem best suited to minimize contact with expansive soil consists of 1) perimeter and interior load bearing grade beams (reinforced concrete, steel, glulam, timber, etc.) supported on maximum spaced square shaft helical piers, 2) raised structural floors (reinforced concrete, wood, etc.) over a crawl space, the floors supported by clear-span joists or girders and 3) an appropriate void depth under all grade beams, slabs or other building components between piers that would otherwise be in soil contact (Design Procedure 5 below). In summary, the only soil/foundation contact should be where the helical pier shafts enter the subgrade.

Slabs-on-grade should be avoided in expansive soils. The only exception to this may possibly be for residential garage slabs where 1) the slab is isolated from the surrounding foundation grade beams and 2) the subgrade below the garage slab is prepared appropriately for the specific expansive soil at the site.

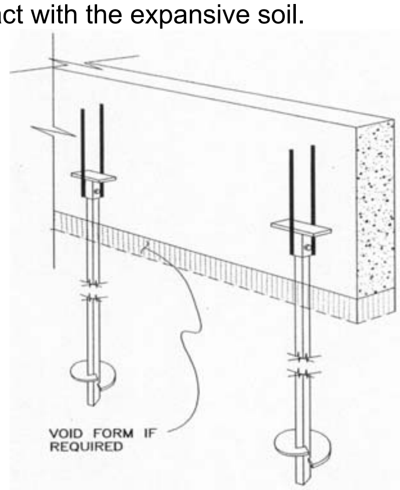
Project Economy: An important side benefit to maximizing spans between piers and minimizing the number of piers is economy. Logically, minimizing the total number of piers in a project promotes economy.

<u>Design Procedure 5: Isolate the Structure from Expansive Soil with an Appropriate Void Zone</u>

The placement of a void zone or space below grade beams and structural floors that otherwise would be in contact with the soil is a standard of practice in expansive soil areas. Void space gives the expansive soil a place to expand into without impacting the foundation or structure. The thickness of the void space is dependent on the expansion or heave potential of the soil. This determination should be made in consultation with a geotechnical engineer familiar with the site expansive soils.

For example, for new construction, under new concrete members, the void space is typically created with a void form (Figure 4). This is typically a corrugated paper box placed below the forms that is specifically sized for the location. The box is treated to withstand the moist environment and weight of wet concrete until the concrete cures. After the concrete cures, the void form paper gradually disintegrates to create a void below the member.

For retrofit construction, such as in foundation repair, the void space must be excavated so as not to leave the foundation in contact with the expansive soil.



[Paper No. 2] Figure 4. Void Form Below Grade Beam

<u>Design Procedure 6: Utilize Only Single Helix Piers</u>

For reasons documented in Pack (2006) only single helix square shaft helical piers should be used in expansive soils. (See Figure 1) Manufacturer ratings of single helix helical piers should be followed when maximizing design loads per Design Procedure 2 above. It is recommended that pier layout be such that single helix helical piers are used exclusively.

Typical individual ultimate capacities of the square shaft <u>single helix</u> helical piers that are the subject of this paper range from 50 kips (222 kN) for the 1.5 inch (38.1 mm) shaft to 60 kips (267 kN) for the 1.75 inch (44.5 mm) shaft. A typical factor of safety of 2 (Specification Requirement 1 below) is applied to ultimate capacities to determine design capacities.

If pier loads exceeding the capacity of a single helix square shaft helical pier absolutely cannot be avoided, then a double helix helical pier may be used. Experience has shown that where double helix helical piers are required for higher loads, and are installed to installation torques commensurate with those loads, or refusal, they also exhibit long-term stability in expansive soils. Great care should be exercised when using a double helix helical pier in expansive soils because of the ease of installing the pier incorrectly. A qualified specialty installation contractor should be employed. (See Installation Procedure 3 below).

Lead sections with three or more helices should typically never be used in expansive soils unless special circumstances arise. On rare occasions, some expansive soil formations may contain active zones underlain by relatively soft soils that, in order to provide an economical pier, warrant the use of multiple helix lead sections to keep the pier from installing deeper than necessary. Great care must be exercised to ensure all helices are below the active zone. A qualified specialty installation contractor should be employed (Installation Procedure 3 below).

SPECIFICATION REQUIREMENTS

Performance specifications are recommended. They ensure that the project requirements are met at the least cost. They allow qualified specialty installation contractors the most flexibility in bringing to bear the most cost-effective materials, methods and equipment.

Performance specification guidelines are found in Pack (2004). It is the author's experience that the key ingredients to successful foundation construction using a performance specification are 1) a well defined performance specification, 2) timely submittals by the installation contractor, and 3) constant and complete communication between the installation contractor and the engineer-of-record during construction.

Specification Requirement 1: The Design Load on Each Pier with a Suitable Safety Factor

Manufacturers publish the ultimate capacity ratings for their square shaft helical piers. Typical individual ultimate capacities of the square shaft single helix helical piers that are the subject of this paper range from 50 kips (222 kN) for the 1.5 inch (38.1 mm) shaft to 60 kips (267 kN) for the 1.75 inch (44.5 mm) shaft. Multiple helix helical piers will have higher ultimate capacities.

Factors of safety are used in foundation design to take into account uncertainties in soil load bearing capacities. In square shaft helical pier technology, each pier is tested during installation by measuring installation torque or refusal. Therefore, much of the uncertainty in the load carrying capability in the helical pier is alleviated. Thus, lower safety factors are allowed.

In square shaft helical pier technology, the typical factor of safety is 2. Experience over many decades has proven that higher factors of safety are not necessary. This is unlike many foundation systems where higher factors of safety are common. Those safety factors should not be applied to square shaft helical piers.

To arrive at the design capacity, a factor of safety is applied to the ultimate capacity. For example, if a pier has an ultimate capacity of 60 kips (267 kN), the design capacity is calculated by

60 kips(267 kN) / 2 = 30 kips(133 kN) design capacity

It is within the prerogative of the designer to use a lower the factor of safety if the structure warrants it. Safety factors of 1.5 to 1.8 for temporary or non-critical structures are common.

Another circumstance when the factor of safety may be lowered is where the design load is slightly higher than that required for a safety factor of 2. For example, for a permanent structure, if a square shaft helical pier with an ultimate capacity of 50 kips (222 kN) must carry a design load of 26 kips (116 kN), the safety factor would be

50 kips(222 kN) / 26 kips(116 kN) = 1

To use this slightly lower factor of safety, the designer must be confident in the load carrying capability of the soil and in the design loads applied to the structure. Other factors may be present that might affect the decision to lower a factor of safety. Experienced engineers and/or installing contractors should be consulted.

Specification Requirement 2: Minimum Installation Torque, Typically 4,000 ft-lbs (5.4 kN-m), or Refusal

Monitoring and testing since 1986 has proven that the minimum installation torque for square shaft helical piers in expansive soils typically should be 4,000 ft-lbs (5.4 kN-m)(Pack, 2006). This ensures that the helices are below the active zone and the piers will maintain long-term stability. Installation torques down to 3,000 ft-lbs (4.1 kN-m) may be permissible in some situations as long as specific site and structural loading conditions are evaluated. Consultation with a qualified installation contractor is recommended (see Installation Procedure 3 below).

Refusal is the condition when, during installation, the helix encounters soil so dense that, in spite of maximum axial compression force on the shaft (crowd) from the installing equipment, the helix does not engage the soil and advance. Refusal is an indication that the soil is sufficiently dense to provide adequate bearing capacity and ensure the helix is below the active zone.

Monitoring and testing of the refusal condition since 1986 has proven that square shaft helical piers installed to refusal as defined above in expansive soils maintain long-term stability (Pack, 2006).

Minimum Depth: Square shaft helical piers are installed to minimum torques or refusal, not minimum depths, except as follows: In cohesive soils, square shaft helical piers typically have an absolute minimum depth of 5 times the diameter of the largest helix on the lead section. For example, a single 8 inch (203 mm) diameter helix lead section would have a minimum depth of 40 inches (1 m). Or, formations or strata may be identified that, for any number of reasons, the lead section must penetrate. This may constitute a minimum depth deeper than the above 5 diameter rule. These exceptions are rare.

Specification Requirement 3: Minimum pier Shaft and Helix Steel Strengths

The square shaft helical piers that are the subject of this paper have shaft steel F_y = 70 to 90 ksi (483 to 621 Mpa) minimum and pier helix steel F_y = 80 ksi (552 Mpa) minimum. The use of high strength steel has been found to be crucial for long-term stability in expansive soils, primarily to aid in proper installation.

During installation, lower strength helices are susceptible to tearing off the shaft or folding or coning. Any of these occurrences damages the helical pier and renders it ineffective. Lower strength shafts could be susceptible to premature shaft twist breakage prior to achieving the typical 4,000 ft-lbs (5.4 kN-m) minimum installation torque.

None of the aforementioned occurrences are visible from the ground surface. Inexperienced installation contractors may not realize a problem exists. Experience since 1986 shows the use of high strength steels ensures that these circumstances do not occur (Pack, 2006).

Appearance Differences: From manufacturer to manufacturer, all square shaft helical piers essentially look alike. It is difficult for the uninformed to differentiate one manufacturer from another. Some manufacturers will have identifying marks on the shaft. For example, at least one manufacturer stamps on the shaft the source steel mill, heat number, date of manufacture and shaft steel strength. At least one manufacturer stamps a code letter on the helix indicating its steel strength. Others place building code ER numbers on their shafts.

Because of the appearance similarities, the designer should know the identification marks of the various manufacturers. The designer must be able to determine in the field that the helical piers specified show up at the site.

Specification Requirement 4: 1.5 to 1.75 Inch (38.1 to 44.5 mm) Square Shafts

The square shape of the shaft is the optimum for expansive soils for reasons documented in Pack (2006). The square shaft helical piers that are the subject of this paper have square dimensions that range from 1.5 to 1.75 inch (38.1 to 44.5 mm). These sizes of square shafts, monitored and tested since 1986, have proven to provide long-term stability in expansive soils.

In expansive soils, in a perfect world, the absolute optimum deep foundation would have an infinitely thin and infinitely strong shaft with a sufficiently large bearing plate embedded in stable material below the active zone. The infinitely thin shaft could not be affected by expansive soil in the active zone. While this optimum deep foundation is impossible, it is approximated by the square shaft helical piers that are the subject of this paper.

Specification Requirement 5: Smooth Shaft Surface

The square shaft helical piers that are the subject of this paper have smooth steel shaft surfaces. As documented in Pack (2006), the smooth surface results in less friction and adhesion. This may further aid long-term stability in expansive soils.

Specification Requirement 6: The ICC Evaluation Report (ER) Number of the Manufacturer

Specifying that a manufacturer of square shaft helical piers has an International Code Council-Evaluation Report (ICC-ER) Number helps assure the designer that the pier material specified will be what is supplied on the project. ICC Evaluation Service, Inc., (www.icc-es.org) performs evaluations and writes reports for manufacturers' products. These reports contain evaluations and conclusions as to the products' materials and capacities.

It is estimated that there are currently about 50 manufacturers of helical pier material world-wide (Helical Pier World Website, 2007). Not all these manufacturers make square shaft helical piers. Of those that do, not all make the high strength square shaft steel helical piers that are the subject of this paper. An ICC-ER Number certifies what is manufactured. The use of ICC-ER numbers for manufactured products in the construction industry is a standard of practice.

Specification Requirement 7: Manufacturer ISO 9001 Certification for Material Quality Control

Specifying that a manufacturer of square shaft helical pier material has ISO 9001 certification helps assure the designer that the manufacturer is able to consistently manufacture products that will meet the quality, strength and dimensions advertised. The use of ISO 9001 certification for manufactured products is a standard of practice.

ISO is the International Organization for Standardization, headquartered in Geneva, Switzerland, dedicated to assuring quality control. The reader is directed to the ISO web site (www.iso.org) for further information.

INSTALLATION PROCEDURES

Proper installation of square shaft helical piers in expansive soils is crucial. All the forgoing procedures and requirements are of no value if the piers are not installed properly.

Installation Procedure 1: Equipment With Sufficient Axial Compression Force (Crowd)

The amount of axial compression force (crowd) on the pier shaft required during installation must be sufficient to allow the helix to engage the soil and advance to the specified minimum installation torque or refusal. The amount of axial compression force required is dependent upon the soil being penetrated. It is similar to screwing a wood screw into wood. In pine, a wood screw typically installs easily without much compression force applied to the screw driver. However, in oak, higher compression force and increased torque is required to keep the screw advancing.

Similar action is required in soils. The denser the soil, the more axial compression force (crowd) and installation torque must be applied to the pier to keep it advancing. In a perfect world, the helical pier will advance a distance equal to the helix pitch for each revolution, typically 3 inches (76 mm). In actual installations, the advancement length per revolution can vary from less than 0.5 inch (13 mm) up to 3 inches (76 mm). The reason is that different soils and densities will cause the helix installation to proceed differently. In all cases, it has been found by experience that the torque versus ultimate capacity relationship still holds.

Heavier installation machines (Figure 5) in the 30,000 to 40,000 lbs (133 to 178 kN) range are preferred in expansive soils for two reasons: 1) they provide greater crowd and 2) they are faster. Lighter weight machines (Figure 6) in the 8,000 to 15,000 lbs (36 to 67 kN) range, and those in between, are acceptable but slower.

Figure 5 is a photograph of a square shaft helical pier installation in expansive soils. The installing machine is a wheeled hydraulic excavator that weighs about 40,000 lbs (178 kN). This is an ideal installation machine because of its ability to impart high axial compression force (crowd) to the helical pier shaft and it is fast.

Figure 6 is a photograph of a relatively light 8,500 lbs (38 kN) tracked type machine about to install a square shaft helical pier. Although not capable of the high crowed of a heavier machine, it is still capable of installing proper square shaft helical piers in expansive soils.

The lighter the machine, the more important role the operator plays to ensure properly installed piers. Detailed operator instructions for expansive soils are beyond the scope of this paper. A qualified specialty installing contractor should be consulted. See Installation Procedure 3 below.

Installation Torque versus Capacity: Regardless of the installation machine weight and the amount of crowd placed on the pier shaft, the torque versus capacity relationship still holds.

[Paper No. 2] Figure 5. Square Shaft Helical Pier Installation in Expansive Soils.
40,000 lb (178 kN) Machine

[Paper No. 2] Figure 6. Square Shaft Helical Pier Installation. 8,500 lb (38 kN) Machine

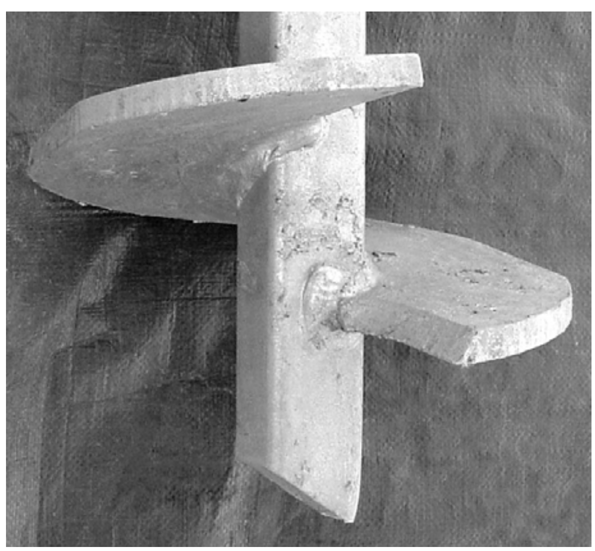
As explained in Hoyt and Clemence (1989), Hargrave and Thorsten (1992) and Pack (2004), there is an empirical relationship between installation torque and ultimate capacity. For the square shaft helical piers that are the subject of this paper, the empirical torque coefficient is 10 ft^{-1} (32.8 m^{-1}). For example, if a square shaft helical pier is installed to 5,000 ft-lbs (6.8 kN-m) of installation torque, the ultimate capacity is

$$10\ ft^{-1} \times 5{,}000\ ft\text{-}lbs = 50{,}000\ lbs\ \text{Ult. Capacity}$$
$$(32.8\ m \times 6.8\ kN\text{-}m = 222\ kN\ \text{Ult. Capacity})$$

Installation Procedure 2: Additional Specialized Techniques for Expansive Soils

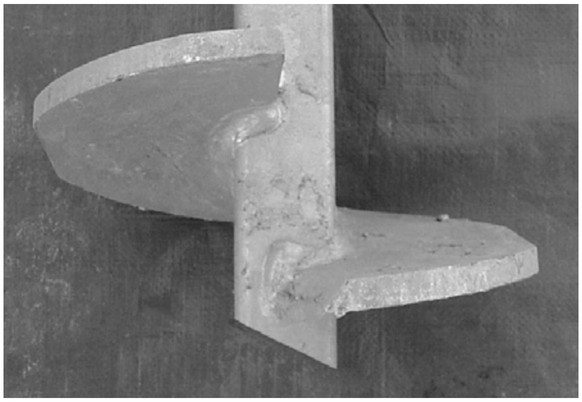
Helix Sizing: To obtain additional helix depth in a dense formation a smaller helix may be used. However, diameters less than 6 inches (152 mm) have an empirical torque coefficient different from the 10 ft^{-1} (32.8 m^{-1}) mentioned in Installation Procedure 1 above and should be avoided. It is permissible to field trim a helix to a smaller diameter.

Bevel the Leading Edge: To obtain additional helix depth in a dense formation, the helix leading edge may be beveled as shown in Figure 7. This may be a factory or field modification.



[Paper No. 2] Figure 7. Helix Beveled Leading Edge

Shorten the Stinger: To obtain additional helix depth in a dense formation, the "stinger", or portion of the shaft extending below the helix, may be shortened as shown in Figure 8. This is typically a field modification.



[Paper No. 2] Figure 8. Portion of the Shaft Below the Helix, called the "Stinger", Has Been Shortened

Rock Cut the Leading Edge: To obtain additional helix depth in a dense formation, the leading edge may be modified as shown in Figure 9. This procedure is primarily used in cobble formations but may assist in dense formations as well. This may be a factory or field modification.

[Paper No. 2] Figure 9. Helix Leading Edge Rock Cut

Other techniques exist that are beyond the scope of this paper. Consult qualified specialty square shaft helical pier installation contractors experienced in expansive soils. See Installation Procedure 3 below.

<u>Installation Procedure 3: Qualified Specialty Installation Contractors Experienced in Expansive Soils</u>

As in all geotechnical construction, qualified specialty square shaft helical pier installation contractors experienced with expansive soils will provide the greatest assurance of the long-term foundation stability described in the first paragraph of this paper.

"Qualified" vs. "Certified": Some manufacturers of square shaft helical piers "certify" contractors to install their piers through training and examination. While manufacturer certification is highly recommended, it should be noted that "certified" does not equate to "qualified". Manufacturer certification does not qualify a contractor to install square shaft helical piers in expansive soils any more than ground school qualifies a pilot to fly through a hurricane. Specialized training and experience in expansive soils is a requirement.

A potential specialty contractor's experience and long-term results in expansive soils must be ascertained. Specialty contractors should be pre-qualified by supplying the owner, architect or engineer-of-record their experience in expansive soils. Owners of their past helical pier projects in expansive soils should be contacted to deter-mine long-term results.

In the Specification Requirements portion of this paper, a performance specification is recommended. Experienced and qualified specialty square shaft helical pier installation contractors will submit to the owner or engineer-of-record the materials, procedures and equipment that will most economically meet the performance specification. Such contractors will be familiar with those helical pier lead section configurations best suited for the site conditions. They will be familiar with the necessary installation equipment and installation techniques to install the proper square shaft helical piers that are the subject of this paper.

Submittals: The owner, architect or engineer-of-record should require submittals of all materials, procedures and equipment proposed by the specialty contractor to meet the performance specification. Some specialty contractors offer to provide stamped engineered shop drawings of pier layout and connections within the foundation plan provided by the structural engineer. This allows the structural engineer responsible for the superstructure to concentrate on it while allowing the specialty square shaft helical pier contractor to design the most economical helical pier layout and load transfer devices to meet the requirements of the performance specification.

CONCLUSION

The design procedures, specification requirements and installation procedures for square shaft helical piers discussed in this paper will result in foundations with long-term stability (no heave) in even the most severe expansive soils. Most of the structures that are the result of these procedures and requirements are light wood-frame residences, the very structures that are the most susceptible to differential heave in expansive soils because of their low dead loads. Large commercial, industrial, institutional and multiple-story structures in expansive soils have also been successfully designed and constructed using these methods. Wherever expansive soils are encountered, square shaft helical piers installed per the procedures and requirements outlined in this paper should be considered.

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Case History 1: New Foundation on Highly Expansive Clays

In July of 1995 a total of 47 square shaft helical piles were installed for the foundation of a new residential structure. The location is in a neighborhood called "The Preserve," just west of the Interstate 25 freeway in the town of Greenwood Village about 10 miles (16 kilometers) south of downtown Denver, Colorado, U.S.A.

According to the soil exploration report, two test holes were drilled at the site using a 4 inch (102 mm) diameter continuous flight power auger. The test holes were field logged and samples were obtained for examination, classification and testing in the laboratory. Field testing included penetration test blow counts, i.e., the number of blows required to drive the sampler 12 inches (0.3 m) using a 140 lb (63 kg_f) hammer falling 30 inches (0.76 m). The sampler was a 2 inch (51 mm) I.D. California liner. Laboratory testing included the determination of natural moisture contents, dry unit weights, grain size analysis, liquid and plastic limits, unconfined compressive strength and swell-consolidation characteristics.

The subsurface profile generally consisted of the following:
1 to 6 ft (0.3 to 1.8 m) deep: Man-made fill composed mainly of sandy clay, medium to highly plastic, very stiff, moist to very moist, and brown in color, penetration test blow counts ranging from 20 to 25. Swell-consolidation testing indicated a swell potential of 2.4 percent.
6 to 9 ft (1.8 to 2.7 m) deep: Natural clay that was sandy, medium plastic, very stiff, slightly moist to moist, brown in color and calcareous. Penetration test blow counts ranged from 25 to 45. Swell-consolidation testing indicated a swell potential of 6.2 percent.
9 to 25 ft (2.7 to 7.6 m) deep (the exploration hole was terminated at 25 ft (7.6 m)): Claystone bedrock with penetration test blow counts of 45 at 9 ft (2.7 m), 60 at 13 ft (4 m), and 75 at 25 ft (7.6 m). This claystone was occasionally sandy, highly plastic, hard to very hard, moist, olive brown or gray in color, and occasionally calcareous. Swell-consolidation testing indicated this material was highly expansive with swell potentials ranging from 4.2 to 8.7 percent.

No free groundwater was encountered at the time of exploration drilling.

Of the 47 square shaft helical screw piles installed on the project, 39 were 1.5 inch (38.1 mm) square shaft with installation torques ranging from 3,000 to 5,000 ft-lbs (4.07 to 6.78 kN-m) for design loads ranging from 15,000 to 25,000 lbs (66.7 to 111 kN). All of these piles used a single 8 inch (203 mm) helix on the lead section.

Eight of the helical piles were 1.75 inch (44.5 mm) square shaft with installation torques ranging from 6,000 to 8,000 ft-lbs (8.14 to 10.8 kN-m) for design loads ranging from 30,000 to 40,000 lbs (133 to 178 kN). Four of these piles used a single 8 inch (203 mm) helix on the lead section and four others used an 8 inch-10 inch (203-254 mm) double helix lead section.

All helical piles ranged in depth from 13 to 31.5 feet (4.0 to 9.60 m) with an average depth of 19.4 ft (5.91 m). All piles were installed in two days by a solo hydraulic excavator with the drive head mounted on the boom.

Performance: This foundation has been monitored by the property owners for nearly nine years. As of July, 2009, no helical screw pile movement has been reported.

Case History 2: Underpin of an Existing Failed Foundation on Highly Expansive Clays

In September of 1998 five square shaft helical piles were installed to underpin the failed portion of an existing foundation for a residential structure. The location is in the Ken Caryl Ranch neighborhood of Littleton, Colorado, U.S.A., about 13 miles (21 kilometers) southwest of downtown Denver. The structure, originally constructed in 1978, was founded on 10 ft (3 m) deep straight shaft cast-in-place concrete piers (caissons) 10 in (254 mm) and 12 inch (305 mm) in diameter. The structure is constructed with an approximately 8 ft (2.4 m) deep basement. Soon after original construction was completed the structure began experiencing heave of the basement floor and foundation, cracks in the walls and around the windows, sticky doors and uneven main floor elevations. In the summer of 1998, 5 inches (130 mm) of differential floor elevation was measured throughout the structure. Some remedial work was done during the 1980's, but no underpinning was performed until the five square shaft helical screw piles were installed in 1998.

According to the original soil exploration report written in 1977, two test holes were drilled at the site. The test holes were field logged and samples were obtained for examination, classification and testing in the laboratory. Field testing included penetration test blow counts, i.e., the number of blows required to drive the sampler 12 inches (0.30 m) using a 140 lb (64 kg_f) hammer falling 30 inches (0.76 m). Laboratory testing included the determination of natural moisture contents, dry unit weights, grain size analysis, unconfined compressive strength and swell-consolidation characteristics.

The subsurface profile generally consisted of the following:

0 to 6 ft (0 to 1.8 m) deep: Plastic clays that were calcareous, stiff and blocky, and ranged in color from weathered gray-brown to weathered orange-gray-brown. Penetration test blow counts ranged from 25 to 40. Swell-consolidation testing indicated highly expansive clay soil with swell potentials ranging from 9.9 to 10.1 percent.

6 to 21 ft (1.8 to 6.4 m) deep: Very dense, slightly weathered claystone bedrock in a blocky high plastic state, becoming more dense with depth. Penetration test blow counts ranged from 55 to 75. Swell-consolidation testing indicated highly expansive clay soil with swell potentials ranging from 3.6 to 11.5 percent.

No free groundwater was encountered at the time of exploration drilling.

All five square shaft helical piles installed on the project were 1.5 inch (38.1 mm) square shaft with installation torques ranging from 3,000 to 5,000 ft-lbs (4.07 to 6.78 kN-m) for design loads ranging from 15,000 to 25,000 lbs (66.7 to 111 kN). All of these piles used a single 8 inch (203 mm) helix on the lead section.

The helical piles ranged in depth from 28.5 to 53.5 ft (8.69 to 16.3 m) with an average depth of 41 ft (12.5 m). All piles were installed by hand maneuvered portable installation equipment inside the basement.

Performance: This foundation has been monitored by the property owners for about 5.5 years. As of July, 2009, no pile movement has been reported.

Slenderness Buckling and Soft Soil Conditions

According to the A.B. Chance Company, soils with Standard Penetration Test (SPT), ASTM D-1586, blow counts (N values) of 4 or greater provide sufficient continuous lateral bracing to allow axially loaded compression square shaft helical piles to carry their rated ultimate capacities to any depth. They have calculated this N value by computer modeling and checked empirically by full-scale load testing. There are installations where square shaft helical piles with 50,000 lb (222 kN) design loads have been installed to depths nearly 200 feet (61 m) and are performing as designed. The reason for this is that soil with SPT blow counts greater than 4 have sufficient passive or confining lateral pressure to not allow the shafts to buckle under their maximum rated loads. Figure 3-1 depicts the lateral soil support conditions.

The above applies to all shaft conditions and takes into account the fact that the helical pile shaft is coupled together.

Occasionally during installation a thin annulus is created around the shaft in the upper two to three feet below ground surface due to a slight eccentric rotation of the shaft. This annulus has never affected pier capacity. It is generally filled in with adjacent soil during installation of the helical pile. The annulus need not be filled with grout.

For soils with SPT blow counts less than 4, the interval length of this layer must be checked. If it is a short length, it is probable the length of low braced shaft is short enough that slenderness buckling will not occur. The kl/r ratio must be checked for the interval. If a slenderness buckling issue exists, a helical pile with a larger section modulus, such as a tubular helical pile, may be used (see Figure 3-2). Alternatively, the design load on the pile could be reduced to a low enough value for eliminate slenderness buckling. For soft soil intervals up to 5 feet (1.5 m) thick, usually no slenderness buckling issue exists up to the rated capacities of helical piles of any size .

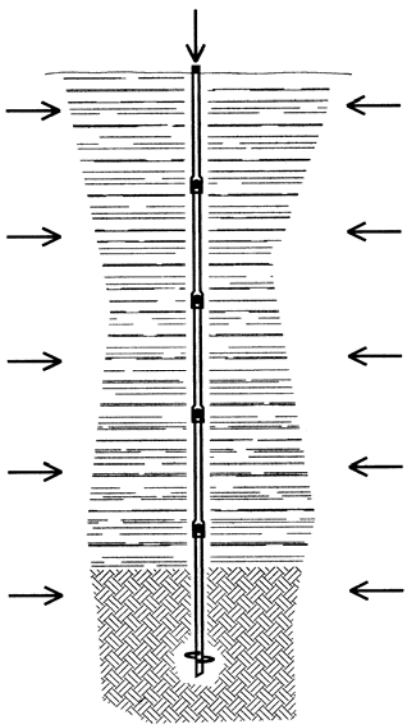


Figure 3-1. Helical Screw Pile with Lateral Soil Support to prevent buckling.

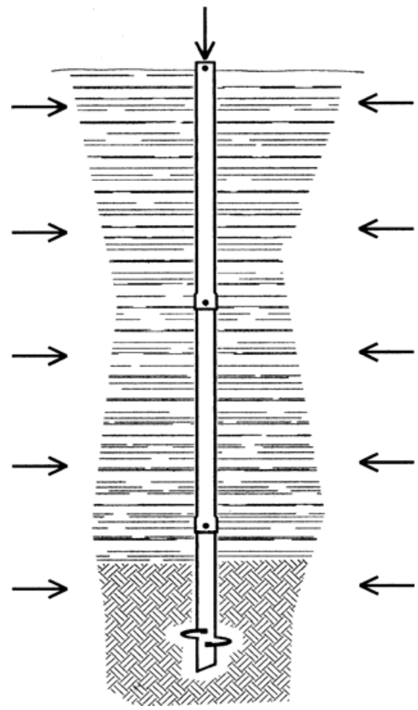


Figure 3-2. Helical Screw Pile with Large Section Modulus to prevent buckling.

Some manufacturers advocate using a grout column surrounding the shaft in lieu of helical piles with a larger section modulus in soft soils. This author feels that such an approach, while technically acceptable, is not cost effective.

To avoid any misunderstanding, it should be said that slenderness buckling is of no concern for pure tension anchors or tiebacks because these members are in tension and not subject to compression loads and slenderness buckling.

Refusal Condition in Extremely Dense Soil, Rock and Cobble

The refusal condition occurs when a helical pile or tension anchor does not advance as it is being rotated into the earth. The reason for the non-advancement of the pile or anchor is the presence of an earth bearing material so dense that the helix does not engage the material and does not advance under the installation rotational or torque force. The bearing material may be bedrock or other competent rock material, heavy cobble, dense coarse gravel, or some other dense material. See Figures 3-3(a) and 3-3(b). Another term used for this refusal condition is "grinding."

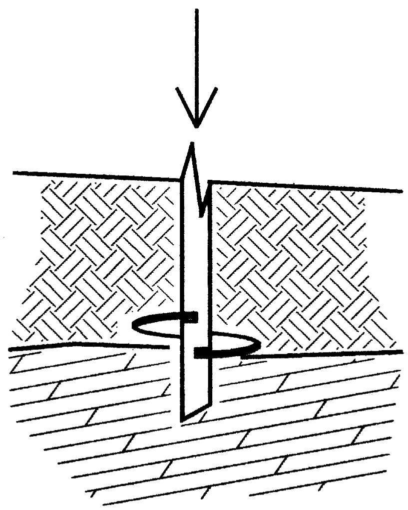


Figure 3-3(a). Refusal Condition in Claystone

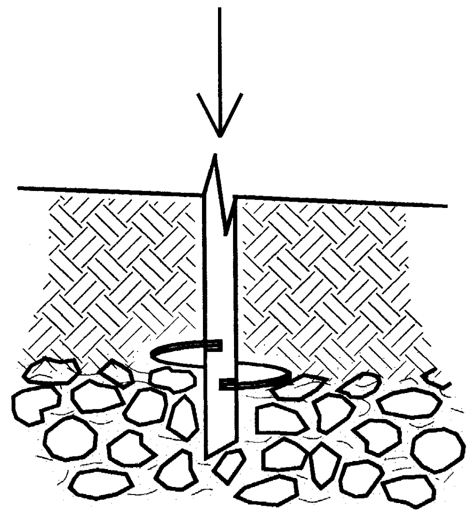


Figure 3-3(b). Refusal Condition in Coarse Gravels

Associated with the refusal condition is usually a reduction in installation torque. In this case, it has been empirically found the reduction in torque does not mean a reduction in compression capacity of the pile, even with a multiple-helix pile. The reason is that the presence of the hard earth material indicates a very good bearing stratum.

The exact nature of the hard bearing material will dictate whether the helical pile is bearing on the shaft point or on the first helix. In either case, even though unit bearing pressures are high, experience has shown the pressures are within the capacity of the bearing material and <u>the published rated capacities of the piles can be relied upon</u>. In the case of a multiple helix pile, some bearing should be attributed to the helices above.

From experience, in most cases it is probable that the pile capacity, even for a single helix pile, is actually greater than the manufacturer's rated capacity. However, because the excess capacity of a single helix or the additional capacity from the other helices is indeterminate unless field tested, one can only rely on the manufacturer's published rated capacities. If field testing if performed, it is allowable for the test results to supersede manufacturers' ratings.

Encountering the refusal condition for a helical tension anchor does not mean low tension capacity. It must be remembered that no soils are removed during installation, rather, soil is displaced by the shaft and the helical plates. Soil disturbance may cause some take-up in the anchor zone during initial tensioning. From experience, tension capacity in the refusal condition can be predicted from the installation torque just prior to encountering the refusal condition. Or, tension capacity can be measured with a tension load test as described in "Load Testing Methods" below.

The A.B. Chance Company has found that in cohesive and fine granular soils, the helices must be installed at least five diameters of the largest helix below the ground surface for the torque vs. capacity relationship to be valid.

The presence of hard material causing the refusal condition should be correlated with known soil borings or other sources of soil profile knowledge (such as other helical screw piles installed at the site) to be sure an anomaly in the soil profile has not been encountered and that stable material exists below the pile.

If the hard material consists of a cobble formation, a common practice to assist in penetrating the cobble is to use a helix with a leading edge designed to aid in penetrating such formations. Such a leading edge is shown in Figure 3-4. Most manufacturers supply lead sections with such helices or helices may be field cut. Neither the torque vs. capacity relationship nor the rated capacity of the helical screw pile is affected by this procedure, although final depth may be increased, but only slightly if at all. See "Shop or Field Modifications to Helices" below.

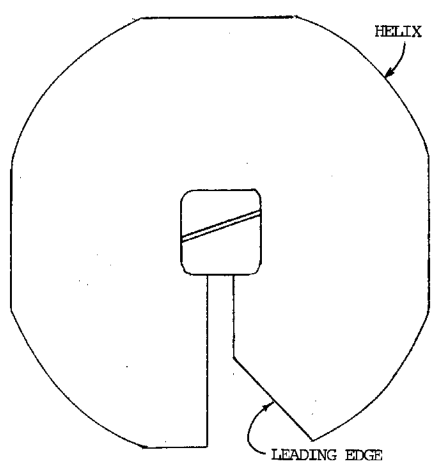


Figure 3-4. Cross-section of Helical Screw Pile Helix Designed for Cobble

If cobble conditions are present, the engineer and installing contractor must ensure that the helical piles have sufficient steel and weld strength to not fold or tear during installation. While extremely rare, such folding and tearing is easily detectable during installation by an experienced operator and a replacement pile can be installed. However, prevention is the best policy. Folding and tearing is eliminated by using helical piles with sufficiently high steel strength and thickness to withstand the buffeting of a cobble formation. As an example, because such conditions can be encountered unexpectedly, IMR produces all of its HELI-PILE® helical piles with 80 ksi (552 Mpa) helices that are 0.5 inch (12.7 mm) thick and rock cut as shown in Figure 3-4. This specification, used in conjunction with the leading edge designed as described above, has proven successful in even the densest of cobble formations.

An experienced installation contractor can do things to aid the installation of helical piles in cobble. One tactic is to use a cyclical motion during installation of backing out the pile slightly, perhaps only one revolution of the drive head, then proceeding with the installation. Repeating this action several times can aid in passing the helices through tough cobble conditions. Another tactic is to change the installation angle slightly (up to five degrees out of plumb maximum for vertical piles) to attempt to bypass the obstruction. Another successful tactic is to change the location of the pile slightly. This must be known and approved by the structural engineer. Moving a pile location a few inches, even up to a foot, one way or another within the foundation is usually not a problem. It is important to maintain high compressive pressure (called "crowd") during installation in cobble formations. Other tactics have been tried that are beyond the scope of this book.

The empirical information mentioned above is based on the results of thousands of successful helical pile installations in the refusal condition. It is common in many areas.

Shop or Field Modifications to Helices

If the leading edge as supplied by the manufacturer is not shaped as shown in Figure 3-4, <u>it is allowed to shop cut or field cut</u> the leading edge as shown. Shop or field cutting may affect the galvanizing; however, because of the fact the helix is embedded in tight soil where oxygen is mostly excluded, corrosion protection is not critical. See the "Corrosion" section below for a more detailed discussion. In addition, shop or field reduction of helix diameter is allowed down to a minimum of 6 inches (152 mm) in diameter. See "Field Modifications" under PART 9. QUALITY CONTROL, INSPECTION AND PERFORMANCE MONITORING below.

Maintaining Shaft Alignment During Installation

In cohesive and granular soils, installation rotation of the helix lead section pulls the pile or anchor shaft into the soil. In this case, compressive shaft pressure, or "crowd", is not relied upon as it is for drilled pier installations and always is for driven piles. Because the shaft follows the helix lead section into the formation and is not being driven or pushed, shaft alignment does not change. Where cobbles or other hard materials exist, because the helical pile or tension anchor is screwed into the formation, not driven or pushed, even where "crowd" is being used, the tendency of the shaft to deflect out of alignment is small. This writer is not aware of any installations where shaft alignment deflection has been detrimental to the load carrying capability of the helical pile or tension anchor.

Rotational forces on a horizontal or nearly horizontal helical tension anchor, such as a tieback, can cause the anchor shaft to occasionally drift slightly off alignment. This is also true with drilled and grouted tension anchors. In this writer's experience, in neither case has the drifting ever presented a capacity or performance concern.

Lateral Loading including Seismic and Wind Loading

Helical piles and tension anchors primarily take axial compression or tension loading with limited lateral capacity in bending. However, helical piles and tension anchors are regularly used for seismic and wind loading applications, including in the high seismic zones of California. The reader is directed to the design example listed in "Design Steps for Seismic and Wind Loading Applications, including Liquefaction" under PART 5. DESIGN METHODS, DESIGN EXAMPLES, ENGINEER'S ESTIMATES below.

For structural foundations where lateral loading from any source is a consideration, lateral loads are taken by the following methods:

Passive soil pressure (most cost-effective). Passive pressure against the perimeter foundation or grade beams, key interior grade beams, or other structural elements, may be sufficient alone to transfer lateral loads to the soil without using any additional piles. If it is not, helical piles or tension anchors strategically placed in the foundation will augment the passive pressure resistance. This should be analyzed in all cases since it is the most economical method of transferring lateral loads to the soil because no additional helical screw piles for lateral capacity are required.

Diagonally installed helical screw piles. When passive soil pressure is not sufficient, lateral loads from shear walls or other laterally loaded structural members may be transferred to the soil via strategically placed helical screw piles installed at an appropriate angle off vertical, usually 45 degrees. These members take axial loads in tension as well as compression. (See Figure 3-5, Photos 1-52, 1-60, and 1-81) Pile layout and load transfer is analyzed by the structural engineer.

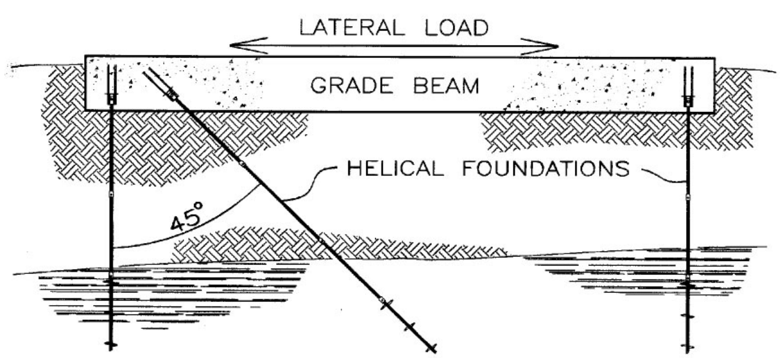


Figure 3-5. Battered Helical Pile for Lateral Loads for New Foundations

Helical tiebacks. Helical tiebacks strategically placed around a structure transfer lateral loads to the soil.

Seismic and wind generated lateral loads are transferred to the soil as described above. The structural engineer calculates the lateral loads, analyses the foundation for resistance to these loads, then adds strategically placed battered helical piles or tiebacks as appropriate.

As an example, Figure 3-5 shows a helical screw pile battered at 45 degrees. If this pile were installed to 10,000 ft-lbs (13.6 kN-m) of installation torque, it would have an axial tension and compression design capacity of 50,000 lbs (222 kN) with a factor of safety of 2. The lateral load that could be taken by this pile, with a factor of safety of 2, would be cos 45° x 50,000 lbs (222 kN) = 35,400 lb (157 kN).

Load transfer of lateral loads from the structure to helical devices uses the same load transfer devices as tiebacks or vertical piers. See "Load Transfer Devices" below.

Cyclical Loading (Seismic Conditions & Machine Foundations)

Cyclical loading from any source involves oscillations of axial compression and tension loading. As mentioned earlier, in nearly all soils, tension capacity of a helical pile or tension anchor is the same as compression capacity. Questions arise about soil disturbance as the tension and compression cycles progress. Load testing has shown that when installed to the required torque for a given design load, and using a factor of safety of 2, square shaft helical piles and tension anchors maintain their ability to take both compression and tension loads. The challenge to the engineer is to calculate the expected cyclic loads, a task beyond the scope of this volume.

In solid square shaft couplings, shims may be required to eliminate axial movement at the coupling under cyclic loading. Shims usually consist of small steel plates inserted inside the coupling box prior to inserting and bolting the end of the square shaft. Shims are not required where the cycles do not oscillate between axial compression and tension loading such as with heavy machinery. For example, heavy machinery foundations exhibit cyclical loading but never in tension due to the heavy weight of the machinery.

HELI-PILE® solid square shaft helical pile couplings typically do not require shims because of an axially tight coupling. Tubular style helical piles typically do not require shims for the same reason.

Corrosion

Much research has been conducted on the corrosion of helical pile and tension anchor material. The method used by IMR is based on research by the A.B. Chance Company. Determination of corrosion rates of bare steel helical piles and anchors is based on the soil pH and soil resistivity. Because there is a possibility that galvanizing will abrade off during installation, all corrosion rate calculations are based on bare steel with no galvanizing or other coating. However, experience shows that galvanizing lengthens steel service life about 15%.

A shaft metal loss of ⅛ inch (3.2 mm) has been designated as the "life limit" of its steel helical pile or tension anchor shaft, i.e., ⅛ inch (3.2 mm) can corrode away and the pile or anchor will still take its rated axial capacity, tension or compression. The extra ⅛ inch (3.2 mm) of steel is needed for installation torque strength, <u>not</u> for service capacity.

Reaching the life limit does not mean the helical pile or anchor will suddenly fail, rather, it means from that time forward, the rated ultimate capacity of the pile or anchor may gradually start to reduce. Generally, in soils with pH values higher than 7 and resistivities greater than 1,500 ohm-cm, a shaft metal loss of a bare non-galvanized HELI-PILE® helical screw pile of ⅛ inch (3.2 mm) may require more than 200-250 years. In soils with pH values of about 6 and resistivities of about 800 ohm-cm, a shaft metal loss of ⅛ inch (3.2 mm) may require more than 75 years. Life limit times may vary from manufacturer to manufacturer.

Figure 3-6 is a copy of a corrosion rate nomograph from adapted by the A.B. Chance Company from the 1977 British Corrosion Journal that allows the user to estimate the life limit by knowing the soil pH and resistivity. <u>CAUTION: To avoid misusing the nomograph, use *field* soil pH and resistivity values, not *lab* values. Lab testing procedures that use soil samples with moisture contents higher than field can yield lower resistivities. The soil will appear more corrosive than it actually is</u>. If soil moisture content is low, the corrosion rate will be low. Low <u>field</u> moisture contents equate to low field corrosion rates even if corrosive chemical constituents are present.

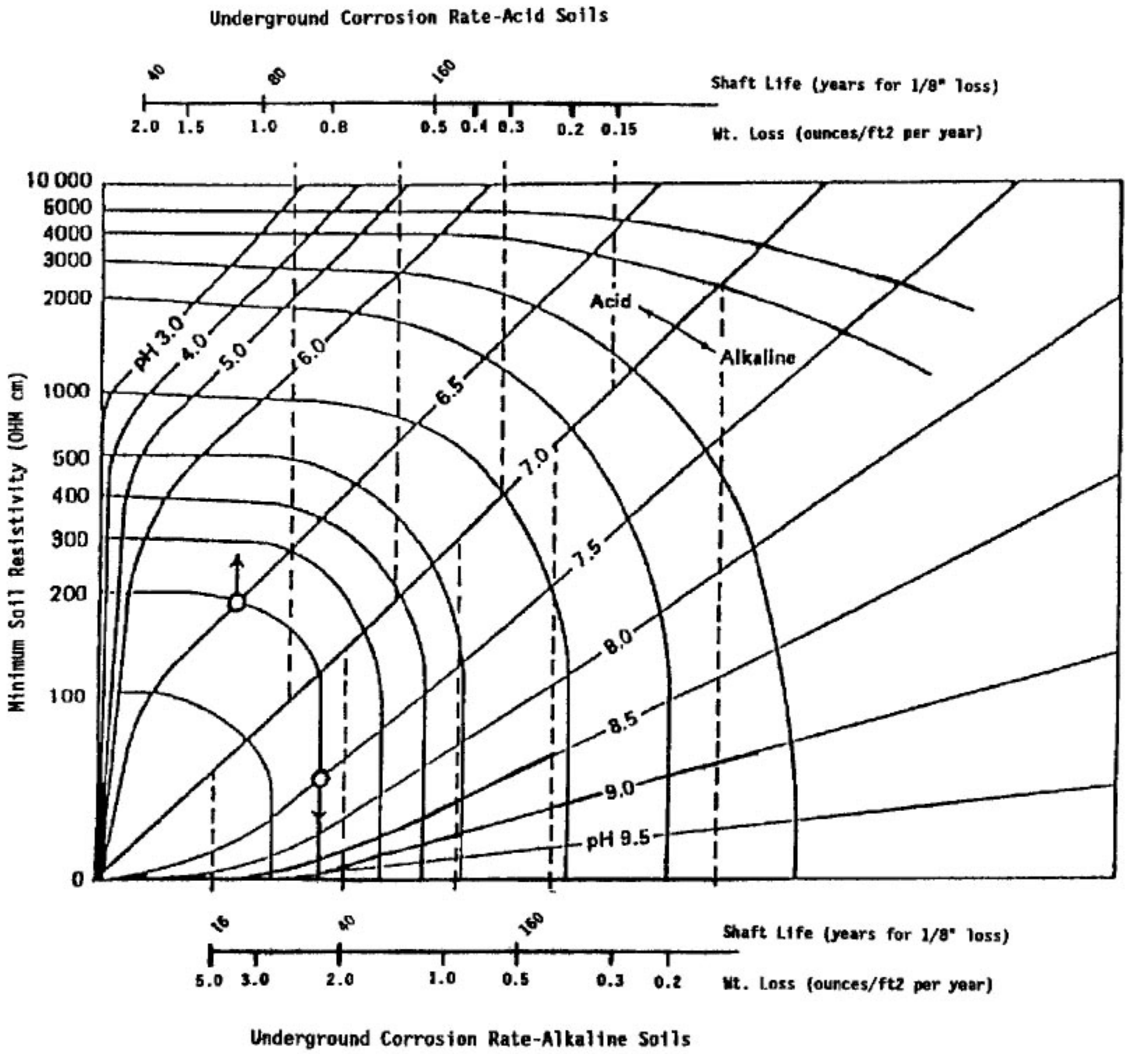
The helix lead section has a longer life limit than the remainder of the shaft, even if the galvanizing is abraded off, because it is embedded in dense soil where oxygen is mostly excluded which causes the corrosion rate to be low. Corrosion rates may be higher near the ground surface, however, in this zone, the shaft extensions are the last to be installed and the galvanizing is intact.

Where abrasion occurs on a helical screw shaft, the zinc concentration will be reduced where abrasion has occurred, it does not necessarily mean no galvanizing is present. Temporary or permanent shaft wrap of the pile or anchor shaft does not adversely affect the galvanizing by cracking, strain or any other phenomenon.

Experience has shown that corrosion of helical piles and tension anchors has not been a problem. Galvanization has been the most reliable method of corrosion protection. HELI-PILE® helical piles and anchors are galvanized by electrodepositing in accordance with ASTM B633 which is RoHS compliant. Hot-dip galvanizing has come under attack recently due to potential soil contamination with hexavalent chromium.

On rare occasions if soils of extreme corrosion potential are encountered, relatively inexpensive methods of cathodic protection are available.

Recent years have seen a movement toward black steel (non-galvanized) helical piles and tension anchors where corrosion potential is low and pile or anchor life expectancy exceeds the life expectancy of the structure. Today the use of black steel helical piles and helical tension anchors is common.



Examples: pH = 6.7 and resistivity = 700 ohm-cm
Expected life (for 1/8 inch (3.2 mm) shaft loss) is approx. 150 years.

pH = 7.5 and resistivity = 700 ohm-cm
Expected life (for 1/8 inch (3.2 mm) shaft loss) is approx. 140 years.

<u>CAUTION: To avoid misusing this nomograph, use *field* soil pH and resistivity values, not *lab* values. Lab testing procedures that use soil samples with moisture contents higher than field can yield lower resistivities. The soil will appear more corrosive than it actually is</u>. If soil moisture content is low, the corrosion rate will be low. Low <u>field</u> moisture contents equate to low field corrosion rates even if corrosive chemical constituents are present.

Figure 3-6. Corrosion Rate Nomograph Adapted by the A.B. Chance Company from the British Corrosion Journal

Mechanical Axial Deformation and Permanent Shaft Wrap or Twist

Mechanical axial shortening of helical piles during compression loading or lengthening of helical tension anchors during tension loading (termed "mechanical axial deformation") comes from two primary causes: 1) shaft axial elastic deformation and 2) crushing of the galvanizing coating at metal to metal contact points at each bolted coupling.

Shaft Axial Elastic Deformation: The equation for shaft axial elastic deformation under load is

$$e = PL/AE \qquad \text{(Eq. 3-1)}$$

where
e = shaft axial elastic deformation
P = the load
L = shaft length
A = the cross-sectional area of the shaft
E = the modulus of elasticity of steel (29,000 ksi)(200,000 Mpa).

For example, the 1.75 inch (44.5 mm) shaft has a cross-sectional area of 3.05 in^2 (1,970 mm^2). For a pile that is 26.5 feet (8.08 m) deep under a compression load of 50,000 lbs (222 kN) the shaft elastic shortening, e, would be 0.18 inches (4.6 mm). If the load were increased to 100,000 lbs (445 kN), the shaft elastic shortening would be 0.36 inches (9.1 mm).

Crushing of the Galvanizing: Helical pile or tension anchor mechanical axial deflection also takes place at each bolted coupling where the galvanized bolt shaft meets the galvanized coupling box and bolt hole in the shaft. As the load increases in either axial compression or axial tension, the galvanizing coating crushes along with other metal to metal contact points due to unevenness of the metal. It is estimated by the A.B. Chance Company that about 0.06 inch (1.5 mm) of axial deflection per coupling is due to this galvanizing/metal crushing effect. For example, If an axially loaded compression helical screw pile were installed with three couplings in the shaft, a total of about 0.18 inches (4.6 mm) of mechanical shaft shortening in the pier could be due to this galvanizing/metal crushing effect.

Crushing of the galvanizing in compression loading may be eliminated by inserting steel shims within each coupling box on a pile. The shims transfer all load to the shaft taking the load off the bolts and bolt holes thus eliminating axial deflection from crushing of the galvanizing.

Combined Effects: For the compression loaded helical screw pile example from above with three couplings in the shaft under a 100,000 lb (445 kN)(45,400 kg_f) load, the addition of the 0.36 inches (9.1 mm) due to shaft elastic shortening and the 0.18 inches (4.6 mm) of shaft shortening due to galvanizing/metal crushing totals 0.54 inches (13.7

mm). Thus, it is possible to attribute over half an inch of vertical shortening to mechanical axial deformation and not soil compression or shearing.

To the author's knowledge, helical piles have not historically had a performance problem in spite of mechanical axial deformation. For compression piles, as a building is constructed, the dead load is slowly applied to the pile and the shaft axial elastic shortening and galvanizing/metal crushing effect occur slowly such that, when the construction process is complete, all the mechanical shortening has taken place and the pile shortening is not perceived. Where helical piles are used for underpinning, the load transfer process is much faster than in new construction but still gradual enough to allow the mechanical shortening to occur slowly such that it is not perceived either. For tension anchors, mechanical lengthening is not a concern if the standard practice of pre-loading the anchors is followed.

When a helical pile or anchor is tested, a seating load of about 15% of the design load should be placed upon it prior to the start of the test to allow the galvanizing/metal crushing effect to occur. The load should then be released and the test begun. Typically, use the steel areas given in Table 1-2 and repeated here:

1.5 inch (38.1 mm) square solid shaft: Steel area = 2.24 in^2 (1,450 mm^2)
1.75 inch (44.5 mm) square solid shaft: Steel area = 3.05 in^2 (1,970 mm^2)
2.0 inch (50.8 mm) square solid shaft: Steel area = 3.99 in^2 (2,570 mm^2)
2.25 inch (57.2 mm) square solid shaft: Steel area = 5.05 in^2 (3,260 mm^2)

2.0 inch (50.8 mm) square tubular shaft: Steel area = 1.59 in^2 (1,030 mm^2)
2.5 inch (63.5 mm) square tubular shaft: Steel area = 2.09 in^2 (1,350 mm^2)
3.0 inch (76.2 mm) square tubular shaft: Steel area = 2.59 in^2 (1,670 mm^2)
4.0 inch (102 mm) square tubular shaft: Steel area = 5.08 in^2 (3,280 mm^2).

Permanent Shaft Wrap or Twist: Another form of shaft deflection is permanent shaft wrap or twist. Visually, this is detected when the shaft looks twisted, kind of like a thin barber's pole. Permanent shaft wrap occurs when the torque force applied to the shaft exceeds the shaft's torsion elastic limit. A certain amount of shaft wrap is permissible and inevitable under the allowable torque forces. HELI-PILE® helical piles and tension anchors are rated well within their ranges, far below yield stress points or approaching any failure points. Consult other manufacturers.

Permanent shaft wrap is a welcomed sight on any helical pile project because of its visual indication of high torque. However, the inspector must be sure the shafts are not being overtorqued. This is accomplished by reviewing installation torque logs. Or, visually, if the shaft appears to be twisted more than 1.5 revolutions in any five foot (1.5 m) length, the shaft may have been overtorqued. The manufacturer should be consulted in such instances.

Water Migration Along the Shaft

Research has shown that where helical piles are installed in expansive clay soils, water migration along the shaft is essentially the same as migration along the sides of drilled shafts (Chapel, Thomas A., "Field Investigation of Helical and Concrete Piers in Expansive Soils," Colorado State University Master's Thesis, 1998.). Since no soil is removed during installation (no hole is created), the helical screw pile densifies the soil as it passes through. Disturbance of the soil is generally in the form of densification, not the opposite. The expansive nature of clay soil may have a tendency to seal the area surrounding both helical pile shafts and drilled shafts to limit water migration.

Regardless of soil type, expansive or not, experience and research has shown that water tends to not migrate down the shaft to the point where it impacts the tight soils into which the helices have been embedded. To the knowledge of this writer, there are no documented cases where water migration along the shaft of a helical screw pile has adversely affected the performance of the helical pile.

Helix Durability During Installation

This section deals with the durability of the helix or helices as they are being installed. For instance, if a helical pile or tension anchor were being installed into cobble material by a large piece of equipment producing high compression pressure, or "crowd", the helix itself and the weld of the helix to the shaft must be strong enough so the helix will not reverse deflect creating a coned shaped helix or so the helix weld will not sever separating the helix from the shaft.

While rare, detection of such an occurrence by an experienced installing contractor is easy. Both circumstances create a disturbance in rotation of the shaft such that the installation operator immediately knows something is wrong and the pile can be removed and inspected.

The remedy is just as easy since another pile can be installed in place of the damaged pile.

The writer has found that in heavy cobble and gravel formations, helices made from 0.5 inch (12.7 mm) thick 80 ksi (552 Mpa) steel rarely cone and never separate from the shaft. Helices less than 0.5 inch (12.7 mm) thick or less than 80 ksi (552 Mpa) should NEVER be used in cobble or heavy gravel formations due to the very real possibility of coning or severing from the shaft.

In any cobble or heavy gravel formation, the leading edge of all helices should have the modified leading edge as shown in Figure 3-4 in the "Refusal Condition in Extremely Dense Soil, Rock and Cobble" section above.

Merits of Square Shaft vs. Pipe Shaft

Square shaft helical piles have the advantage of greater torque energy transfer to the helical plates than round pipe shaft. To date, no specific detailed studies have been performed that prove the preceding statement. However, the logic proceeds as follows:

Square shaft is in direct soil contact at the corners only. During installation the soil is disturbed on the flats of the shaft between the corners. It is logical that this action will minimize the shear stress between the shaft side and the soil. Ideally, all torque energy imparted by the torque motor reaches the helical plates. However, a certain amount of torque energy is dissipated along the shaft sides. Because of minimal shear stress along the sides of the square shaft, energy dissipation will be minimized too making more energy reaching the helical plates for embedment in the bearing stratum.

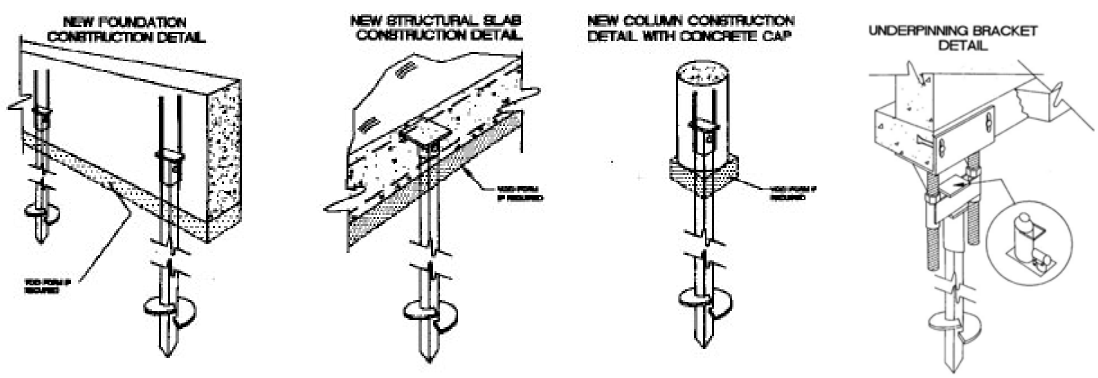
The round pipe shaft is in soil contact around its entire circumference and entire pile length. Even though the magnitude nor the percentage have been quantified, it is this author's opinion that in some soils more torque energy is dissipated with the round shaft than with the square shaft. In no case is would the reverse be true.

This author knows of a project where pipe helical piles about 4 inches (102 mm) in diameter were installed to an installation torque thought to be commensurate with the intended loads. The piles were then full-scale load tested and passed. After completion of the structure the piles settled. The investigating geotechnical engineer concluded that the piles were initially transmitting load along the sides of the shaft via friction to the soil. It was felt that a significant portion of the installation torque went into shear along the sides of the shaft. Over time, the shear stresses relaxed through creep and more and more of the load was transferred to helical plates, plates that had not, in fact, been sufficiently embedded into the soil to take the load. The reason is too much installation torque was dissipated along the sides of the shaft and did not reach the helical plates.

Another advantage of the square shaft appears during installation. It is visually easy to detect and monitor permanent shaft wrap or twist in the square shaft helical pile. As noted in the section "Mechanical Axial Deformation and Permanent Shaft Wrap or Twist," above, a certain amount of permanent shaft wrap or twist is allowable and desirable. However, too much is not good. Fortunately, with the square shaft, too much shaft wrap or twist is visually easily detectible. It is not so easy to detect shaft wrap or twist in the round pipe shaft. This inability to visually easily detect permanent shaft wrap can lead to catastrophic failure, such as suddenly weakening or even severing the shaft. Great care must be taken during installation to monitor installation torque of the round pipe shaft helical screw pile.

Load Transfer Devices

Four representative examples of concrete to pile shaft load transfer devices are shown in Figure 3-7. Each of these devices has been tested and is commonly used for design loads up to 50,000 lbs (222 kN). There are unlimited configurations of load transfer devices that can accomplish the desired load transfer. Several more are shown in the Appendix. The configurations shown in Figure 3-7 and the Appendix are in common use and will transfer the rated capacity loads for the various sizes of helical screw piles. However, the structural engineer has the prerogative to design whatever load transfer device is desired. All the devices shown are typically constructed of ASTM A36 structural steel and Gr 40 reinforcing steel. If these devices are embedded in concrete, no galvanizing or coating protection for the device itself is required. Qualified distributors and installing contractors of helical piles and tension anchors should be contacted for details. Figure 3-7(a) is a typical new construction bracket embedded in a reinforced concrete grad beam. Figure 3-7(b) is a new structural concrete slab bracket. Figure 3-7(c) is a new construction bracket embedded within a concrete column base. Figure 3-7(d) is an underpinning bracket.



(a) (b) (c) (d)

Figure 3-7. Examples of Concrete to Pile Shaft Load Transfer Devices

Final depth of a helical pile or tension anchor depends on the soil profile at each location and the desired installation torque. In some cases the end of the shaft protruding out of the soil must be cut so the load transfer device is at the correct elevation or location. If the bolt hole is cut off, then the load transfer device can be attached by 1) Field drilling a new hole and bolting the load transfer device on, 2) Welding the load transfer device on, 3) Epoxy gluing the load transfer device on, or 4) In the case of the modular helical pile, the square threadbar allows the load transfer device to the screwed on wherever the pile shaft is cut, no drilling, welding, or gluing. In all compression load applications and in most tension load applications, epoxy gluing has never been a problem in this author's experience. In tension load applications a rigid connection is preferred and will preclude gluing. Underpinning brackets do not require any rigid connection such as bolting, welding or gluing.

Load Testing Methods

Load capacity of helical piles and tension anchors can be tested by two methods: 1) Measurement of installation torque, and 2) Direct load test.

Load Testing Through Measurement of Installation Torque

The great advantage of helical pile and helical tension anchor technology is that the ultimate capacity of every pile or anchor is measured during installation.

Utilizing the torque vs. capacity relationship (Eq. 2-1), it is possible to determine the capacity of a properly installed helical pile or tension anchor by measuring the installation torque. For instance, if a particular pile is installed to 20,000 ft-lbs (27.1 kN-m) of installation torque, and if the appropriate empirical torque coefficient were 10 ft^{-1}, ($32.8m^{-1}$) then the ultimate capacity of the pile would be 10 ft^{-1} x 20,000 ft-lbs = 200,000 lbs. (32.8 m^{-1} x 27.1 kN-m = 890 kN). By using this relationship, the capacity of each and every properly installed helical pile or tension anchor can be determined.

A properly installed helical pile or tension anchor is a pile or anchor correctly designed and installed with installation torque as measured in accordance with the section "Installation Torque Measurement" under PART 2. above.

Direct Load Test

It is allowed to supersede manufacturers' rated capacities for helical piles and tension anchors based on the results of direct load testing.

Full-scale compression load testing of helical screw piles can be performed as with any deep foundation system. Photo 3-1 and Figures 3-8(a) and 3-8(b) show a typical layout of compression load test equipment that would be in conformance with ASTM D1143 as applied to helical piles.

Photo 3-1 Compression load test set-up for helical pile.

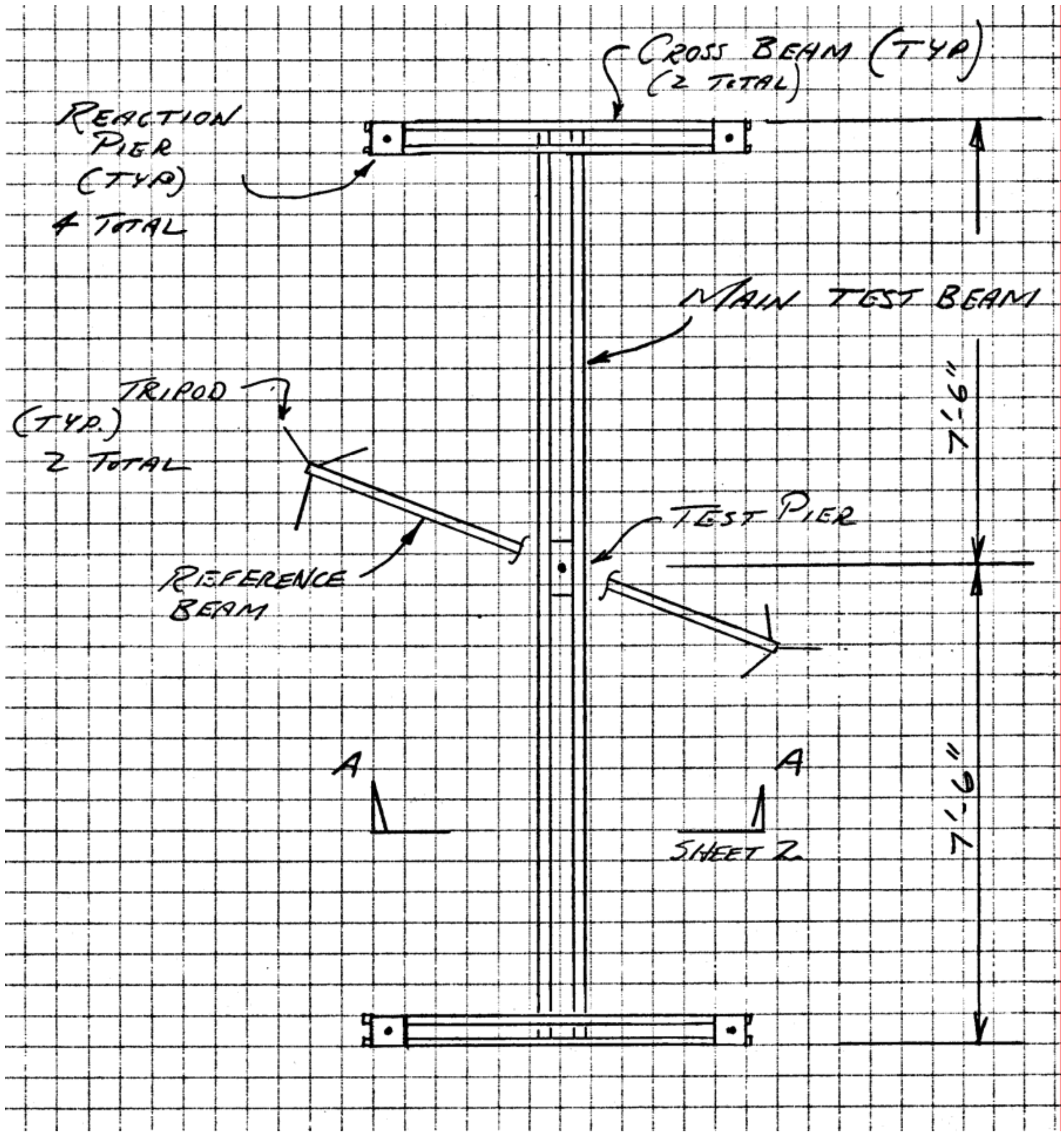


Figure 3-8(a). Plan View of Compression Load Test Equipment

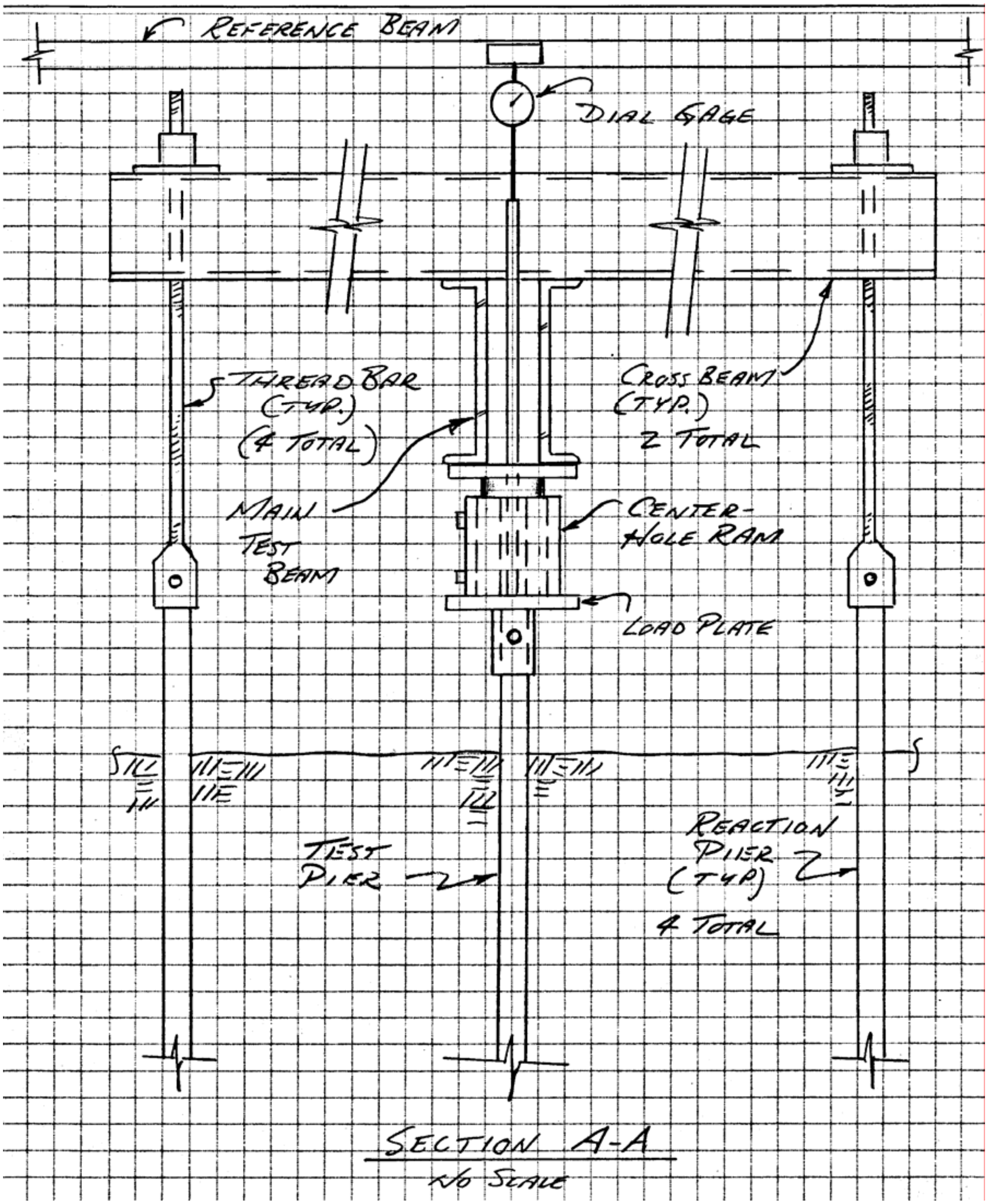


Figure 3-8(b). Cross-section View of Compression Load Test Equipment

A typical tension load test layout is shown in Photo 3-2 and Figure 3-10.

Photo 3-2 Tension load test set-up for Helical Tension Anchor.

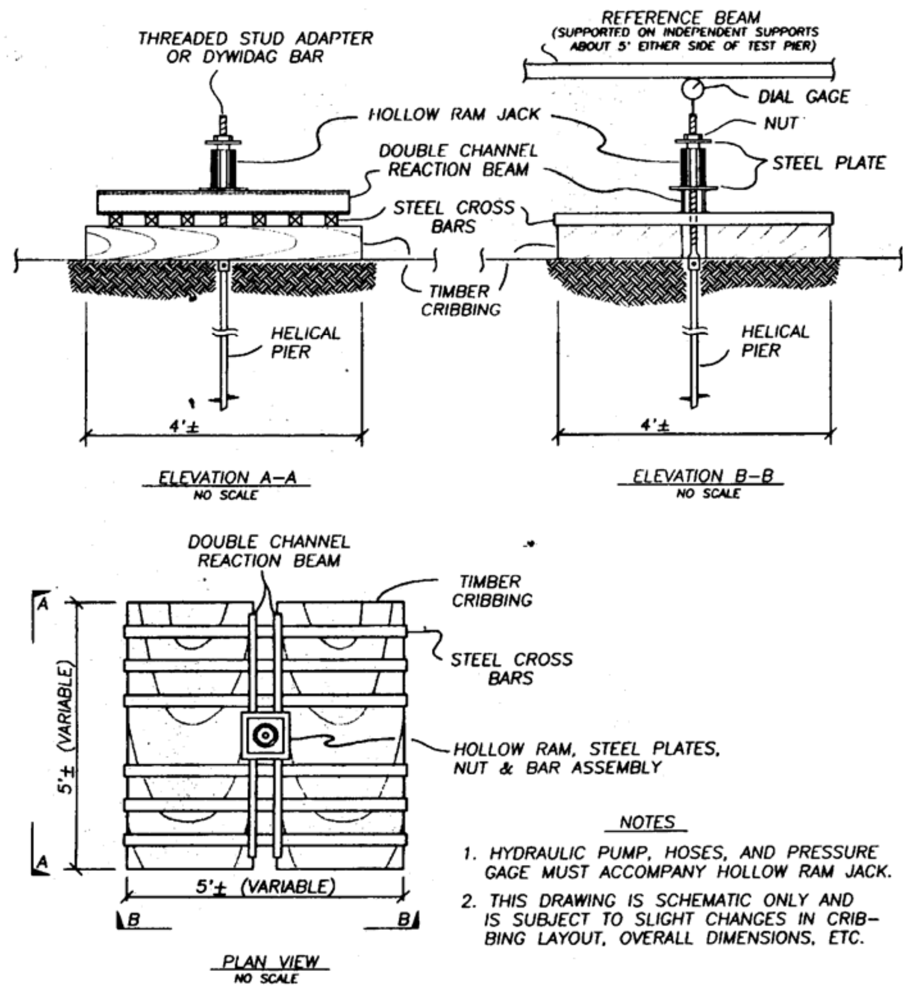


Figure 3-9. Typical Tension Load Test Layout

Photo 3-3 shows a typical tieback test set-up with a center-hole ram surrounding the visible tension threadbar. The test frame between the wall and the ram allows for a connection of the visible threadbar to the actual tieback threadbar not visible within the frame. Typically a dial indicator is set up at the end of the threadbar to measure deflection (not shown).

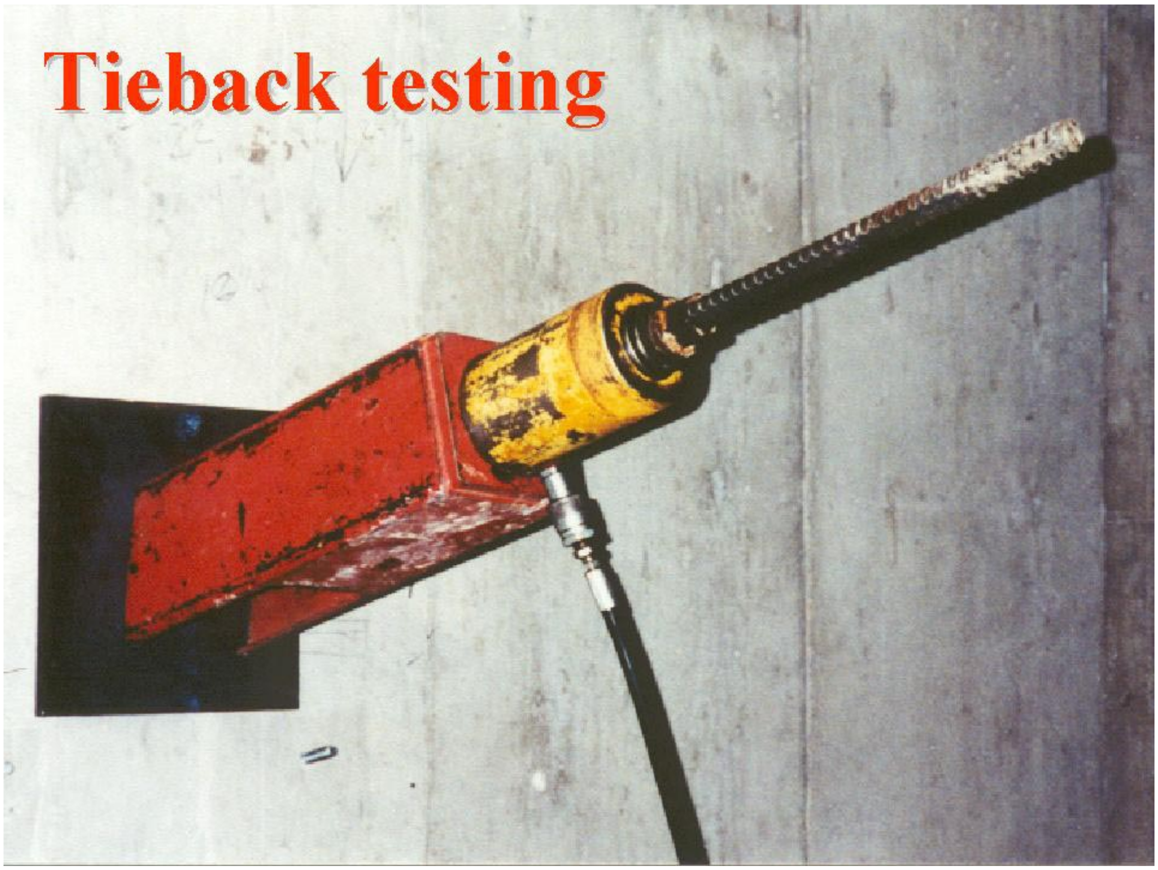


Photo 3-3 Typical tieback test set-up.

PART 4. TIEBACKS, OTHER TENSION ANCHORS & HELICAL SOIL NAILS

Helical tiebacks are devices used in a tension mode to support an earth retention structure. Helical tiebacks can be used for retaining walls, basement walls, excavation shoring, etc., the same as any type of tieback. Helical tiebacks, because no concrete or grout is used nor is any soil excavated, can be installed at any angle, even up from the horizontal. They can be tensioned to the design load immediately because there is no concrete or grout cure time.

Helical tieback capacities are determined identically to vertical helical piles using the torque vs. capacity method discussed in PART 2. CAPACITY CALCULATIONS above. For load transfer, a thread bar adapter is attached to the anchor shaft and to the retaining structure with a plate and nut. Other load transfer mechanisms are available as outlined below.

Other tension anchors, such as structural hold downs, are designed and installed just like tiebacks except in a vertical orientation.

Figure 4-1 shows a reinforced concrete retaining wall founded on vertical helical screw piles and restrained by helical tiebacks.

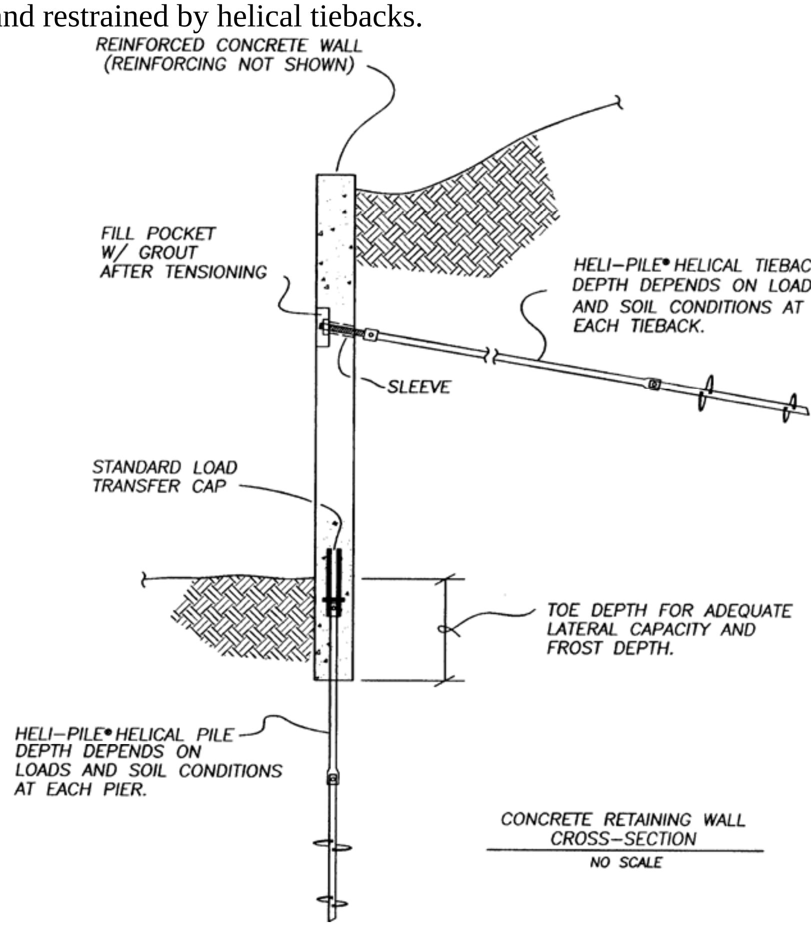


Figure 4-1. Retaining Wall with Helical Screw Piles and Helical Tiebacks

The repair of existing deflected (leaning) retaining walls can be done as shown in Figures 4-2 and 4-3.

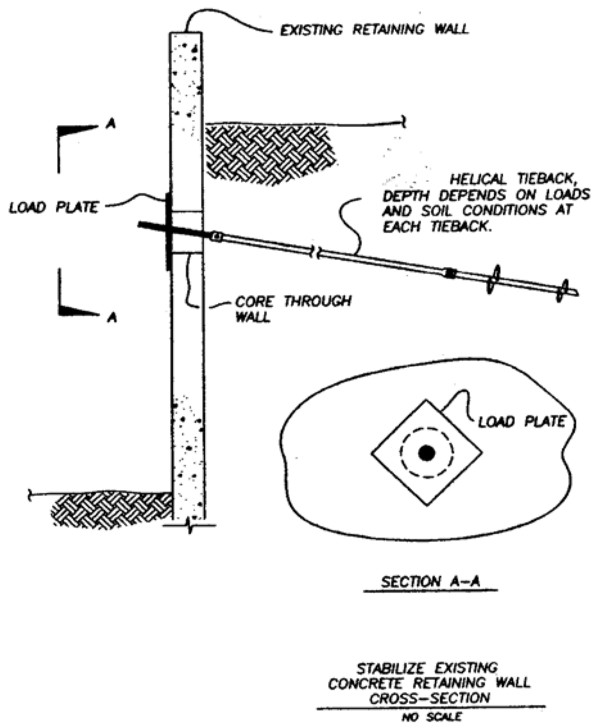


Figure 4-2. Retaining Wall Repair using Helical Tieback and Load Plate

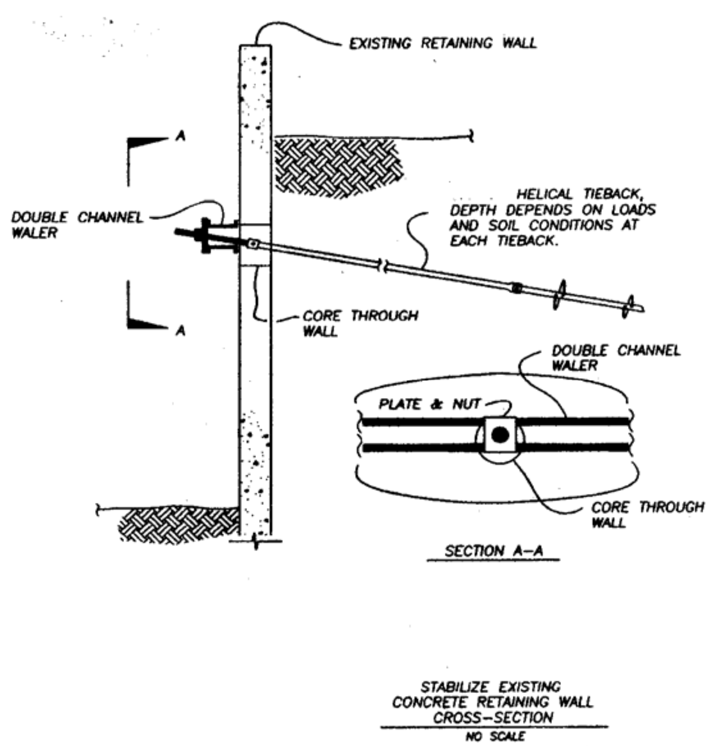


Figure 4-3. Retaining Wall Repair using Helical Tieback and Double Channel Waler

Figure 4-4 shows a typical shoring panel (load plate) using a helical tension anchor as a tieback. See Photo 1-48. The great advantage of using helical tiebacks in shoring applications is that no concrete is introduced into the ground, thus, no waiting for cure time.

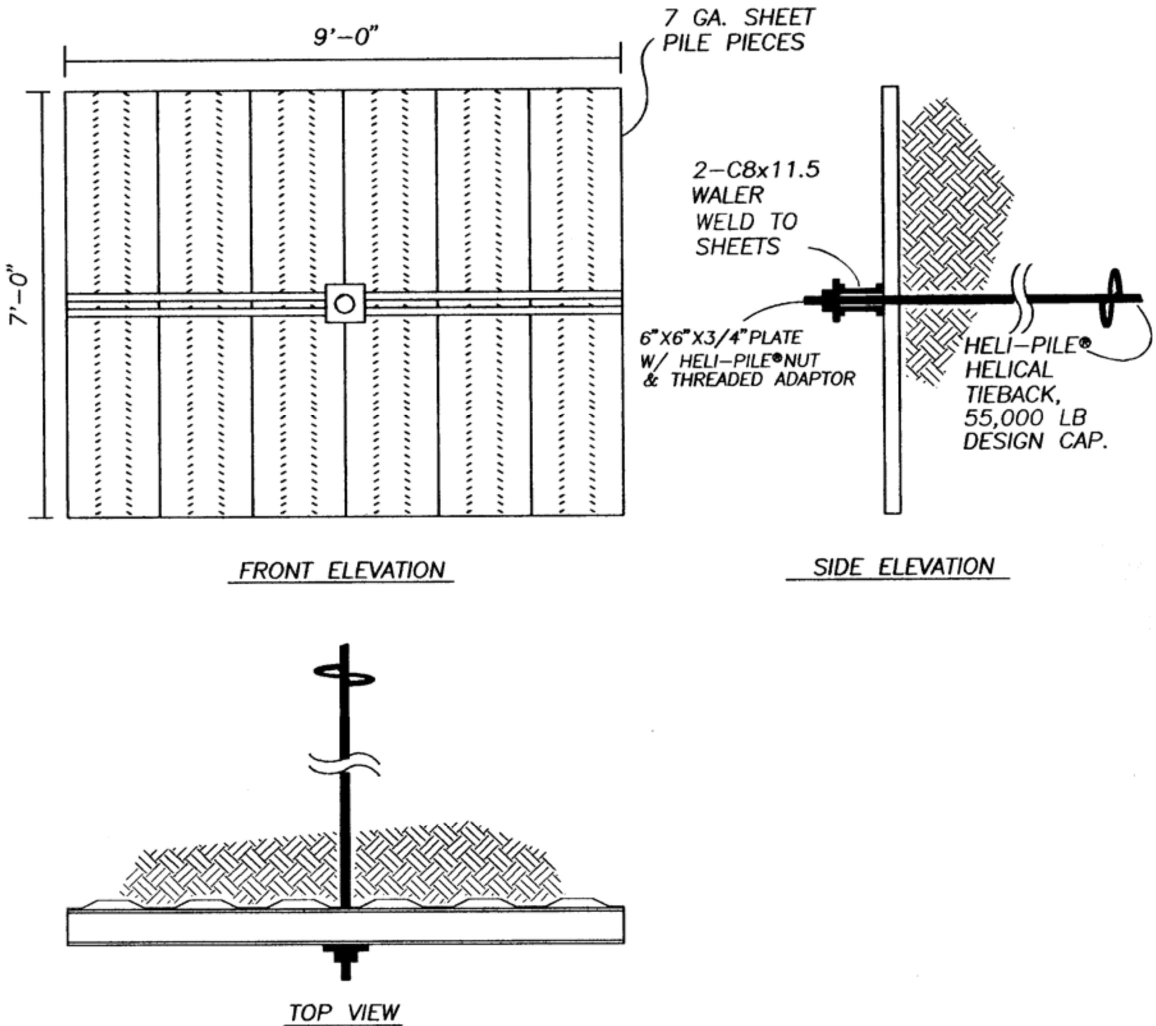


Figure 4-4. Example of Shoring Panels using Helical Tension Anchors as Tiebacks
(See Photos 1-45 and 1-48 to see this shoring panel in place in shoring walls.)

Figure 4-5 show the use of vertical compression loaded helical piles to support the bridge abutment and helical tension anchors as tiebacks to provide lateral support. For a photographic example of this concept see Photos 1-33 and 1-34.

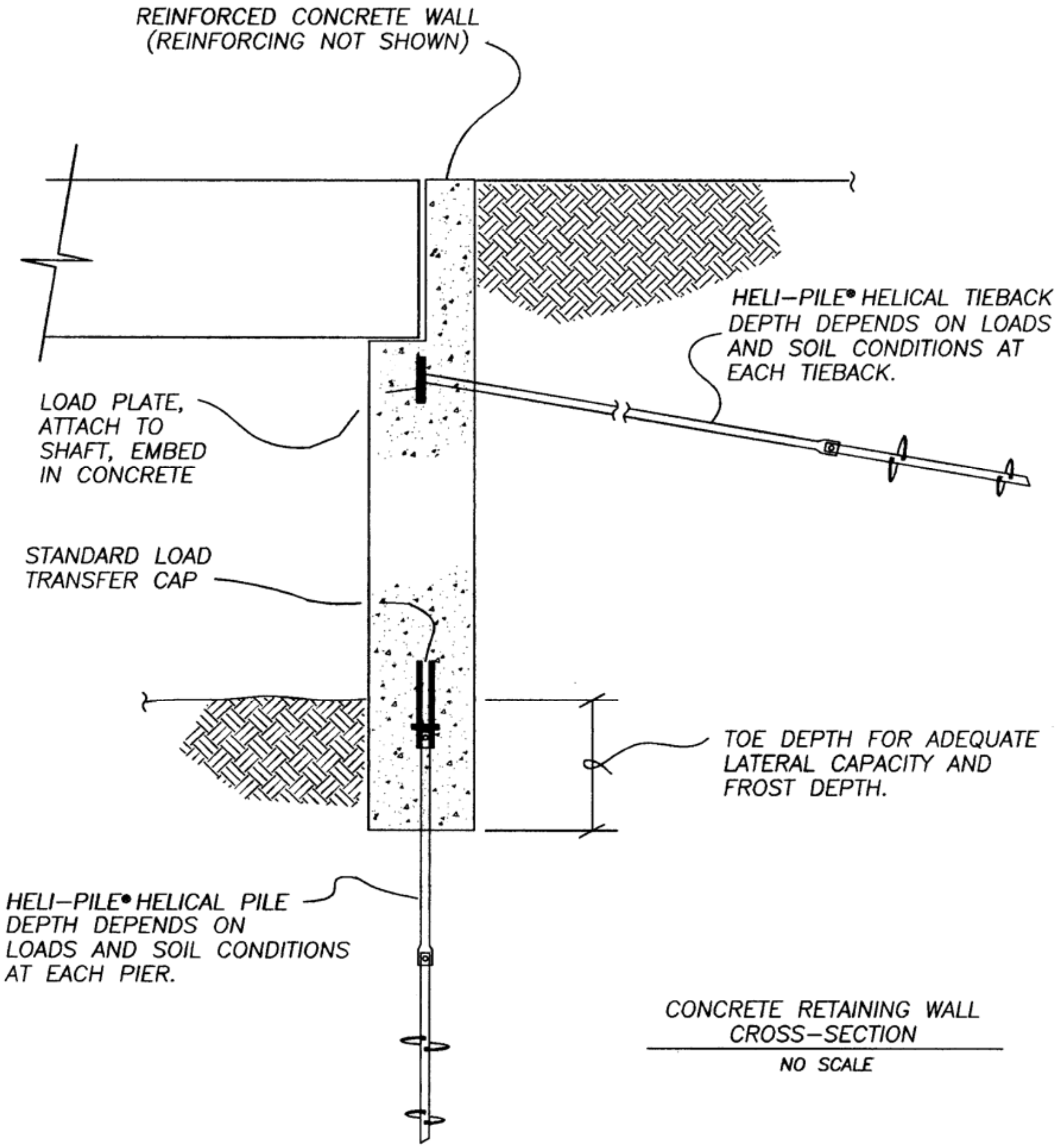


Figure 4-5. Vertical Helical Piles and Helical Tension Anchors as Tiebacks for Bridge Abutment (See Photos 1-33 and 1-34)

Helical Soil Nails: Developments in soil nail technology have made this system of earth retention popular for excavation shoring, slope stability, and retaining walls. This is a cost-effective method of ground reinforcement for earth retention without excavating. See Photo 1-47 for an example of a helical soil nail wall.

A helical soil nail is installed identically to a tieback. However, the philosophy of earth retention is not the same as a tieback. A detailed discussion of the differences is beyond the scope of this volume. Generally, the purpose of helical soil nails is to bind a soil mass together to create a large gravity retaining wall. Figure 4-6 shows how the presence of the nails creates a gravity retaining wall essentially the size of the height H and the length of the helical soil nails.

The helical soil nail consists of helices attached at regular intervals to the entire shaft, including extensions (see Figure 4-6). The result is a helical device with helices spread along the entire length of shaft. The common helical soil nail is a 7 ft (2.1 m) long lead or extension with 8-inch (203 mm) diameter helices spaced at 30-inch (760 mm) intervals along the shaft. The 7 ft (2.1 m) lead section plus any number of 7 ft (2.1 m) extensions can result in a soil screw installed to any length.

Soil screw capacity is determined in the identical manner as tiebacks or piers. However, large soil screw tension capacities are not required because of the way they are used. Soil screws are installed to depth, not torque. Usually, a small tension capacity is all that is required. Figure 4-6 shows a typical helical soil nail installation with typical dimensions. The specific soil conditions will dictate what actual spacing and helical soil nail length to use.

A detailed discussion on helical soil screw design is beyond the scope of this book. Several references are available on the Internet search engines for helical soil nails.

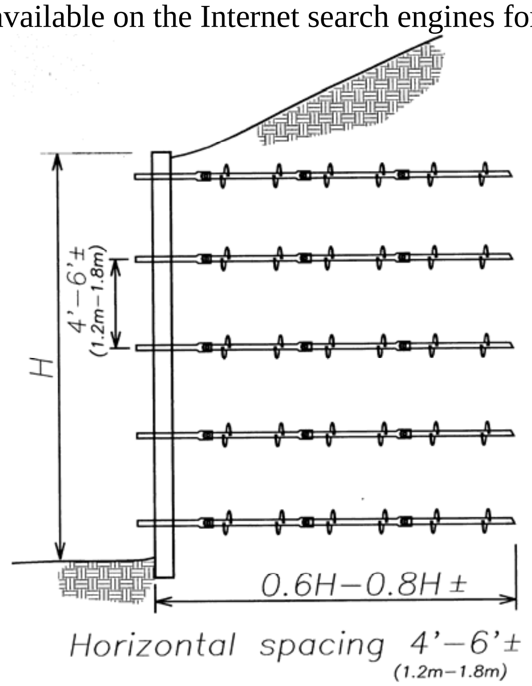


Figure 4-6. Cross-section of Helical Soil Nail Wall with Typical Dimensions

PART 5. DESIGN METHODS, DESIGN EXAMPLES, ENGINEER'S ESTIMATES, and DESIGN RESPONSIBILITY

The design methods given below are general steps only. They should not be thought of as "cookbook" methods. As in all geotechnical design and construction, wise judgment based on experience must be exercised. Helical foundation technology appears simple at the outset, but, upon closer scrutiny, helical screw piles and tension anchors are no different than any type of deep foundation in that successful long-term performance requires careful examination of the site, accurate structural loading information as outlined below, and sound design methods. Then proper installation is required.

The design methods presented herein are based on the author's experience over many years. However, other approaches may be just as successful. The author welcomes dialog and knowledge of other successful methods to the design of helical piles and tension anchors.

In the design methods, the term "qualified installing contractor" refers to an installing contractor who is experienced and trained to properly install helical piles and tension anchors. In some instances, a qualified installing contractor may be a contractor certified by the manufacturer. It should be recognized, however, that, in this author's experience, manufacturer certification alone does not necessarily constitute training and experience. Potential installing contractors should be required to show proof of training, experience, and manufacturer certification.

The term "performance specification" is used in the methods below. Please refer to PART 6. SAMPLE SPECIFICATIONS below for further enlightenment on this specification philosophy.

<u>All the design steps given below assume the designer knows the helical pile loading based on the designed pile spacing and/or layout, including lateral and cyclical considerations</u>.

Design loads and soil profile will indicate what pile material to use. The minimum required installation torque and soil profile will determine pile depth. By knowing the density of the soil via a helical screw test probe, or via N values (STP blow count information), the depth of piles can be estimated. See "Soil Investigation Parameters" and "Estimating Pile or Anchor Depth" under PART 3. DESIGN CONSIDERATIONS above.

<u>ENGINEER'S ESTIMATES</u>: Recognizing that providing a client an "engineer's estimate" is one of the prime tasks of a designer, engineer's estimates are given in each design example. Rather than try to explain the process in this paragraph, it is better for the reader to observe how the engineer's estimate simply comes together in the design examples.

DESIGN RESPONSIBILITY: Design responsibility for helical screw piles and tension anchors is typically taken by the project structural engineer-of-record who designs, specifies, and seals or stamps the project drawings. Alternatively, the project geotechnical engineer-of-record may take responsibility for helical piles and anchors and seal the project drawings for them only. This assumes the structural and geotechnical engineers are qualified to do so.

If neither the structural nor geotechnical engineer-of-record is qualified to take design responsibility specifically for helical piles or tension anchors, another qualified licensed professional engineer may be hired to do so.

In some cases, the helical screw pile and tension anchor installation contractor may have engineers on staff who are licensed in the project's jurisdiction and are able to design, specify and seal shop drawings for helical piles and tension anchors. These shop drawings are then submitted to the project engineer-of-record and become part of the sealed and approved project documents.

The helical pile provisions and procedures in the 2009 International Building Code (IBC), Chapter 18 on foundation design, provide a framework for engineers and building officials to base designs and design reviews. For guidelines in using the 2009 IBC, please see the section herein entitled "2009 International Building Code Design Provisions" in PART 3. above. Registered engineer stamped plans prepared in accordance with the 2009 IBC should alleviate concerns over some brands of helical piles and tension anchors that do not have a building code evaluation report.

Some jurisdictions require no specific design analysis or engineer's seal for helical screw piles or tension anchors where the manufacturer has a building code evaluation report and the installation contractor is certified by the manufacturer to install its helical screw piles or anchors. In this case, the designer calls out on the project drawings the manufacturer's published building code evaluation report numbers, catalog numbers or other published descriptions of the helical devices desired and states that they must be installed in accordance with the manufacturer's instructions.

<u>Design Steps for **New Structural Foundations**</u>

STEP 1: Determine or obtain helical pile design load.

STEP 2: Compile or obtain appropriate site soil data. (Helical screw test probe data is preferred, SPT N value data is acceptable. For helical screw test probe information, see the "Soil Investigation Parameters" section above and the "Helical Screw Test Probe Procedure" sheets in the Appendix.)

STEP 3: Determine or obtain minimum depth of pile, if any (other than manufacturers' minimum depth requirements).

STEP 4: Compute the minimum installation torque based on Eq (2-1) and the appropriate factor of safety.

STEP 5: Select helical pile shaft size based on soil conditions, design load, and installation torque requirement.
(This step can be performed directly by the designer. Alternatively, the pile shaft size can be proposed by qualified installing contractors during the bid phase based on a performance specification provided by the designer. The qualified installing contractors then submit details of the proposed helical screw pile shaft and how it will meet the designer's performance specification.)

STEP 6: Select number and size of helices based on soil conditions and design load.
(This step can be performed directly by the designer. Alternatively, the number and size of helices can be proposed by qualified installing contractors during the bid phase based on a performance specification provided by the designer. The qualified installing contractors then submit details on the number, size, and material of the proposed helices and how the designer's performance specification will be met.)

STEP 7: Estimate pile depth based on helical screw test probe data or SPT N value data. (See the "Estimating Pile or Anchor Depth" section above.)

STEP 8: Evaluate any other design aspects such as corrosion, presence of cobble, presence of expansive soil, ground water table, etc. Make adjustments or revisions as necessary.

STEP 9: Select or design the load transfer device based on the design load and configuration of the structural foundation at each pile location (i.e., grade beam, slab, wall, etc.).

STEP 10: Design complete. Prepare drawings and specifications. See sample drawings in the Appendix and PART 6. SAMPLE SPECIFICATIONS.

ENGINEER'S ESTIMATE: See design example below.

Design Example for **New Structural Foundations**

Given information: A new commercial building is to be constructed on a sloping (10% grade) site. The design calls for a perimeter grade beam, interior floor slab with isolated interior roof support columns. The structural engineer has determined the optimum helical pile spacing for the perimeter grade beam will impose a 40,000 lbs (178 kN) design load on each pile. The structural engineer has also determined the interior roof support columns will impose a design load of 50,000 lbs (222 kN) per interior helical screw pile.

The soil profile is:
Helical Screw Test Probe Data:
Probe Description: Single 8 inch (203 mm) diameter helix. Probe taken 3' away from boring.

Probe Depth	Torque	Install Description
1 ft (0.3 m)	500 ft-lbs (0.7 kN-m)	Loose /smooth install
3.4 ft (1.0 m)	1,000 ft-lbs (1.4 kN-m)	Moderately stiff / smooth install
5 ft (1.5 m)	1,500 ft-lbs (2.0 kN-m)	Moderately stiff / smooth install
6.5 ft (2.0 m)	500 ft-lbs (0.7 kN-m)	Loose / smooth install
10 ft (3.0 m)	1,000 ft-lbs (1.4 kN-m)	Moderately stiff / smooth install
11.7 ft (3.6 m)	1,500 ft-lbs (2.0 kN-m)	Moderately stiff / smooth install
13 ft (4.0 m)	2,000 ft-lbs (2.7 kN-m)	Moderately stiff / smooth install
15.8 ft (4.8 m)	2,500 ft-lbs (3.4 kN-m)	Moderately stiff / smooth install
16.6 ft (5.1 m)	3,000 ft-lbs (4.1 kN-m)	Stiff / smooth install
17.5 ft (5.3 m)	3,500 ft-lbs (4.7 kN-m)	Stiff / smooth install
18 ft (5.5 m)	4,000 ft-lbs (5.4 kN-m)	Stiff / smooth install
18.4 ft (5.6 m)	4,500 ft-lbs (6.1 kN-m)	Stiff / smooth install
19.1 ft (5.8 m)	5,000 ft-lbs (6.8 kN-m)	Stiff / smooth install
19.8 ft (6.0 m)	5,500 ft-lbs (7.5 kN-m)	Stiff / smooth install
20.4 ft (6.2 m)	6,000 ft-lbs (8.1 kN-m)	Very stiff / smooth install
20.6 ft (6.3 m)	6,500 ft-lbs (8.8 kN-m)	Very stiff / smooth install
20.8 ft (6.3 m)	7,000 ft-lbs (9.5 kN-m)	Very stiff / smooth install
21.0 ft (6.4 m)	7,500 ft-lbs (10.2 kN-m)	Very stiff / smooth install
21.3 ft (6.5 m)	8,000 ft-lbs (10.8 kN-m)	Extremely stiff / smooth install
21.6 ft (6.6 m)	8,500 ft-lbs (11.5 kN-m)	Extremely stiff / smooth install
22 ft (6.7 m)	9,000 ft-lbs (12.2 kN-m)	Extremely stiff / smooth install
22.3 ft (6.8 m)	9,500 ft-lbs (12.9 kN-m)	Extremely stiff / smooth install
22.5 ft (6.9 m)	10,000 ft-lbs (13.6 kN-m)	Extremely stiff / smooth install

<u>Exploration Boring Log Data</u>:

0-5'	(0-1.5 m)	Fill, some gravel, silty clay	SPT: 12 blows/ft (N=12) @ 5'
5'-10'	(1.5 m-3.0 m)	Silty clay (collapsible soils)	SPT: 7 blows/ft (N=7) @ 10'
10'-17'	(3.0 m-5.2 m)	Sandy Silt	SPT: 25 blows/ft (N=25) @ 17'
17'-21'	(5.2 m-6.4 m)	Weathered claystone	SPT: 60 blows/ft (N=60) @ 21'
22'	(6.7 m) End of boring		SPT: 100 blows/ft (N=100) @ 22'

Groundwater 5 feet (1.5 m) deep.

<u>Required</u>: Design the helical screw piles and load transfer devices for the exterior grade beam and interior roof support columns:

STEP 1: Per the "given information" above, the design load per pile has been provided by the structural engineer: 40,000 lbs (178 kN) for the each perimeter grade beam pile and 50,000 lbs (222 kN) for each interior roof support column pile.

STEP 2: Soil information has been provided by the soil engineer in the Helical Screw Test Probe Data and Exploration Boring Log Data provided above.

STEP 3: According to the soil engineer, the helical pile lead section (the lead portion of the shaft with the helix or helices welded to it) must penetrate beyond the collapsible silty clay into the sandy silt, a minimum depth of 10 feet (3 m). This is far beyond a manufacturer's minimum depth, typically five diameters of the largest helix on the lead section, approximately 5 feet (1.5 m) depending on the actual helix or helices used. Therefore, <u>use a 10 ft (3 m) minimum depth</u> unless individual pile conditions dictate otherwise.

STEP 4: For the exterior perimeter grade beam piles, using a factor of safety of 2, the design load of 40,000 lbs (178 kN) equates to an ultimate load of 80,000 lbs (356 kN). Using Eq. 2-1 and the "rule of ten" in English units, the minimum installation torque requirement would be calculated as follows:

$$Q_u = k_t T \qquad \text{(Eq. 2-1)}$$

where

Q_u = Ult. capacity of the helical pile or tension anchor, lbs (kN)

k_t = Empirical installation torque coefficient, ft $^{-1}$ (m $^{-1}$)

T = Minimum installation torque, ft-lbs (kN-m)

Therefore, $T = Q_u / k_t$

$T = 80{,}000 \text{ lbs} / 10 \text{ ft}^{-1} = \underline{8{,}000 \text{ ft-lbs}}$

$(T = 356 \text{ kN} / 32.8 \text{ m}^{-1} = 10.8 \text{ kN-m})$

Therefore, <u>the minimum installation torque for the exterior piles is 8,000 ft-lbs</u> (10.8 kN-m).

For the interior roof support column piles, using a factor of safety of 2, the design load of 50,000 lbs (222 kN) equates to an ultimate load of 100,000 lbs (445 kN). Using Eq. 2-1 and the "rule of ten" in English units, the minimum installation torque requirement would be calculated as follows:

$$T = Q_u / k_t$$
$$T = 100{,}000 \text{ lbs} / 10 \text{ ft}^{-1} = \underline{10{,}000 \text{ ft-lbs}}$$
$$(T = 445 \text{ kN} / 32.8 \text{ m}^{-1} = 13.6 \text{ kN-m})$$

Therefore, the minimum installation torque for the interior piles is 10,000 ft-lbs (13.6 kN-m).

STEP 5. For the perimeter grade beam piles with design loads of 40,000 lbs (178 kN) each, using a factor of safety of 2, the ultimate load is 80,000 lbs (356 kN). Per Table 1-1, column #5 for "New Foundations Ultimate Capacity," the HELI-PILE® 1.75 inch (44.5mm) (HPC17) will take that ultimate load. For the interior roof support column piles with design loads of 50,000 lbs (222 kN), using a factor of safety of 2, the ultimate load is 100,000 lbs (445 kN). Again, per Table 1-1, column #5 for "New Foundations Ultimate Capacity," the HELI-PILE® 1.75 inch (44.5 mm) (HPC17) will take that ultimate load. Therefore, use the HELI-PILE® 1.75 inch (44.5 mm) HPC17 for both the perimeter grade beam piles and the interior column support piles.

(This step can be performed directly by the designer. Alternatively, the designer may elect to provide a performance specification to qualified installing contractors. The qualified installing contractors then submit to the designer for approval their proposed helical pile shaft details that meet the designer's performance specification.)

STEP 6: Per Table 1-1, for HELI-PILE® helical piles, each helix has an ultimate capacity of 70,000 lbs (311 kN). For the perimeter grade beam piles, each with an ultimate load of 80,000 lbs (356 kN), two helices minimum are required.

Regarding helix diameter, by a review of the helical test probe and exploration boring log data, an experienced designer or qualified installation contractor would probably choose an 8 in-10 in (203 mm-254 mm) diameter double helix lead section. This is the most common double helix lead section in the industry. It is small enough to penetrate most formations yet has sufficient surface area to not go too deep. Of course, actual soil conditions will dictate depth, however, in the experience of this author, this would be the lead section of choice. Other double helix lead sections would satisfy the loading requirements, but, as stated, the 8 in-10 in (203 mm-254 mm) diameter double helix lead section is the section of choice.

For the interior roof support column piles, each with an ultimate load of 100,000 lbs (445 kN), two helices minimum are required.

Regarding helix diameter, as with the perimeter piles mentioned above, after a review of the helical screw test probe and exploration boring log data, an experienced designer or qualified installation contractor would probably choose an 8 in-10 in (203 mm-254 mm) diameter double helix lead section. As noted above, this is the most common double helix lead section in the industry. It is small enough to penetrate most formations yet has sufficient surface area to not go too deep. Actual soil conditions will dictate depth, however, in the experience of this author, this would be the lead section of choice. Other double helix lead section would satisfy the loading requirements, but, as stated, the 8 in-10 in (203 mm-254 mm) diameter double helix lead section is the section of choice.

(This step can be performed directly by the designer. Alternatively, the designer may elect to provide a performance specification to qualified installing contractors. The qualified installing contractors then submit to the designer for approval their proposed helical screw pile helix details (number, thickness, steel material, etc.) that meet the designer's performance specification.)

STEP 7: Based on a review of the Helical Screw Test Probe and SPT N value data, it is anticipated by the designer or the qualified installation contractor that the pile will extend to a depth ranging from about 20 to 22 feet (6.1 to 6.7 m). This is because test probe install torques and the N values rapidly increase at that depth to magnitudes that will probably equate to high installation torque calculated in Step 4 for the 8 in-10 in (203 mm-254 mm) diameter double helix lead section determined in Step 6.

If the lead section is 7 ft (2.1 m) long, it will require two 7 ft (2.1 m) plain extensions to reach the estimated depths. This allows for the load transfer device (see Step 9) to extend up and be embedded into the perimeter grade beam concrete and into the interior roof support column concrete pile cap. Therefore, for costing purposes use a 7 ft (2.1 m) lead section and two 7 ft (2.1 m) plain extensions.

Remember, the piers will extend to the depth necessary to get the required torque. Therefore, the number and length of extensions could vary from pile to pile. A qualified and experienced installing contractor will be prepared for this eventuality.

STEP 8: No mention is made of corrosion potential at this site for either steel or concrete. Therefore, it is assumed the potential for steel corrosion is low and either black steel (non-galvanized helical piles) or galvanizing in accordance with ASTM B633 is sufficient. No mention is made of cobble or expansive clay soil or any other geologic constraint, so no precautions must be taken for other or additional installation techniques.

STEP 9: For the perimeter grade beam piles, the structural engineer has designed a reinforced concrete grade beam to be supported by the helical piles. The New Foundation Construction Bracket is selected. It will be attached to the top of each pile shaft that embeds into the reinforced concrete grade beam. A sketch of this bracket is shown in Figure 3-7(a) and a detailed sketch in the Appendix. This bracket's load capacity is discussed in detail in the Appendix. This bracket has a design capacity up to 50,000 lbs (222 kN) and an ultimate capacity up to 100,000 lbs (445 kN). The bracket is routinely used for applications such as this design example.

For the interior roof support column piles, the structural engineer has also selected the New Foundation Construction Bracket to attach to the top of each pile shaft and embed into the reinforced concrete pile cap (Figure 3-7(c)). As mentioned above, this bracket is used for design loads up to 50,000 lbs (222 kN).

SIDE NOTE: The structural engineer determined that lateral loading is a concern with this structure. Two shear walls were designed to carry lateral loads to the soil. Additional diagonally oriented (45 degrees down from the horizontal, see Figure 3-5) helical screw piles were strategically placed to take these loads. Even though the loads and other details are not given here, it is important to point out that the method to design these piles is identical to the step by step method given herein.

STEP 10: Design for these particular piles is complete. Repeat these steps for any additional piles that may be added during construction. See Appendix for sample drawings. For sample specifications, see PART 6. SAMPLE SPECIFICATIONS below.

ENGINEER'S ESTIMATE: A reasonable "engineer's estimate" of the material requirements for this project is to figure each helical screw pile will consist of a 7 ft (2.1 m) lead section and two 7 ft (2.1 m) plain extensions plus the load transfer device. The quantity is calculated by multiplying the quantity per pile times the number of piles.

(Installed cost can only be determined after labor and equipment costs are added to the material costs. It is recommended that qualified installation contractors be contacted for the installed cost. They will best know the equipment requirements and capabilities and the time it will take to install the piles once they know something about the soils at the site. Of course, once sufficient experience is obtained, the designer will be able to make these estimates him or herself.)

Design Steps for **Underpinning Existing Structures**

STEP 1: Determine or obtain helical pile design load.

STEP 2: Compile or obtain appropriate site soil data. (Helical screw test probe data is preferred, SPT N value data is acceptable. For helical screw test probe information, see the "Soil Investigation Parameters" section above and the "Helical Screw Test Probe Procedure" sheets in the Appendix.)

STEP 3: Determine or obtain minimum depth of pile, if any (other than manufacturers' minimum depth requirements).

STEP 4: Compute the minimum installation torque based on Eq (2-1) and the appropriate factor of safety.

STEP 5: Select helical pile shaft size based on soil conditions, design load, and installation torque requirement.
(This step can be performed directly by the designer. Alternatively, the pile shaft size can be proposed by qualified installing contractors during the bid phase based on a performance specification provided by the designer. The qualified installing contractors then submit details of the proposed helical pile shaft and how it will meet the designer's performance specification.)

STEP 6: Select number and size of helices based on soil conditions and design load.
(This step can be performed directly by the designer. Alternatively, the number and size of helices can be proposed by qualified installing contractors during the bid phase based on a performance specification provided by the designer. The qualified installing contractors then submit details on the number, size, and material of the proposed helices and how the designer's performance specification will be met.)

STEP 7: Estimate pile depth based on helical screw test probe data or SPT N value data. (See the "Estimating Pile or Anchor Depth" section above.)

STEP 8: Evaluate any other design aspects such as corrosion, presence of cobble, presence of expansive soil, ground water table, etc. Make adjustments or revisions as necessary.

STEP 9: Select or design the appropriate underpinning bracket or load transfer device based on the design load and configuration of the structural foundation at each pile location (i.e., grade beam, slab, wall, etc.).

STEP 10: Design complete. Prepare drawings and specifications.

ENGINEER'S ESTIMATE: See the design example below.

Design Example for **Underpinning Existing Structures**

Given information: An existing single-story commercial structure has suffered about 3 inches (76 mm) of differential settlement along one wall. This structure has an exterior spread "T" footing with an interior floor slab. A small portion of the interior slab adjacent to the affected wall has settled as well. The structural engineer has determined that the exterior footing has sufficient reinforcing steel in it to span about 7 feet (2.1 m) unsupported given the load per foot (0.305 m) of wall above the footing. This result is a design load per helical screw pile of 19,000 lbs (84.5 kN)(8,620 kg_f).

The soil profile is:

Exploration Boring Log Data: This exploration boring log data was taken prior to original construction. The data is about 2 years old.

0-3'	(0-0.9 m)	Compacted granular material	SPT: 20 blows/ft (N=20) @ 3'
3'-10'	(0.9 m-3.0 m)	Medium to stiff clay	SPT: 26 blows/ft (N=26) @ 10'
10'-15'	(3.0 m-4.6 m)	Soft Clay	SPT: 4 blows/ft (N=4) @ 15'
15'-19'	(4.6 m-5.8 m)	Medium to stiff clay	SPT: 24 blows/ft (N=24) @ 19'
19'-25'	(5.8 m-7.6 m)	Stiff clay with gravel lenses	SPT: 39 blows/ft (N=39) @ 25'
25'-28'	(7.6 m-8.5 m)	Weathered claystone	SPT: 52 blows/ft (N=52) @ 28'
28'	(8.5 m)	Refusal	SPT: 100+blows/ft (N=100) @ 28'

Groundwater 12 feet (3.7 m) deep.

The site has a history of industrial development so a soil pH and resistivity test yielded the following corrosion parameters: Soil pH = 6.5 Soil resistivity = 502 ohm-cm

Required: Design the helical screw piles and underpinning load transfer bracket:

STEP 1: Per the "given information" above, the design load per pile has been provided by the structural engineer: 19,000 lbs (84.5 kN) per pile.

STEP 2: Soil information has been provided by the soil engineer in the Exploration Boring Log Data provided above.

STEP 3: According to the soil engineer, the building settlement probably occurred from consolidation of the soft clay layer 10 ft-15' ft (3.0 m-4.6 m) deep. Therefore, the helical pile lead section (the lead portion of the shaft with the helix or helices welded or keyed and locked to it) must penetrate the soft clay, a minimum depth of 15 feet (4.6 m). This is far beyond a manufacturer's minimum depth, typically five diameters of the largest helix on the lead section, approximately 5 feet (1.5 m) depending on the actual helix or helices used. Therefore, use a 15 ft (4.6 m) minimum depth unless individual pile conditions dictate otherwise.

STEP 4: Using a factor of safety of 2, the design load of 19,000 lbs (84.5 kN) equates to an ultimate load of 38,000 lbs (169 kN). Using Eq. 2-1 and the "rule of ten" in English units, the minimum installation torque requirement would be calculated as follows:

$$Q_u = k_t\,T \qquad \text{(Eq. 2-1)}$$

where

Q_u = Ultimate capacity of the helical screw pile or tension anchor, lbs (kN)

k_t = Empirical installation torque coefficient, ft $^{-1}$ (m $^{-1}$)

T = Minimum installation torque, ft-lbs (kN-m)

Therefore, $T = Q_u / k_t$

$T = 38{,}000 \text{ lbs} / 10 \text{ ft}^{-1} = \underline{3{,}800 \text{ ft-lbs}}$

$(T = 169 \text{ kN} / 32.8 \text{ m}^{-1} = 5.15 \text{ kN-m})$

Therefore, the minimum installation torque for the exterior piles is 3,800 ft-lbs (5.15 kN-m).

STEP 5. For a helical pile design load of 19,000 lbs (84.5 kN), using a factor of safety of 2, the ultimate load is 38,000 lbs (169 kN). Per Table 1-1, for column #6 "Underpin Ultimate Capacity, Bracket Limited", either HELI-PILE® 1.5 inch (38.1 mm) solid steel shaft (HPC15 or HPC15X) will take that ultimate load. IMR sells both piles for the same price, therefore use the HELI-PILE 1.5 inch (38.1 mm) extra high strength HPC15X.

(This step can be performed directly by the designer. Alternatively, the designer may elect to provide a performance specification to qualified installing contractors. The qualified installing contractors then submit to the designer for approval their proposed helical screw pile shaft details that meet the designer's performance specification.)

STEP 6: Per Table 1-1, use a single HELI-PILE® 80 ksi (552 Mpa) helix with an ultimate capacity of 70,000 lbs (311 kN).

With an ultimate capacity of 70,000 lbs (311 kN), one 80 ksi (552 Mpa) helix minimum is required. Regarding helix diameter, a review of the helical test probe and exploration boring log data, an experienced designer or qualified installation contractor would probably choose an 8 in (203 mm) diameter single helix lead section. This is the most common single helix lead section in the industry. It is small enough to penetrate most formations yet has sufficient surface area to not go too deep. Of course, actual soil conditions will dictate depth, however, in the experience of this author, this would be the lead section of choice. Other single or multiple helix lead sections would satisfy the loading requirements, but, as stated, the 8 in (203 mm) diameter single helix lead section is the section of choice.

(This step can be performed directly by the designer. Alternatively, the designer may elect to provide a performance specification to qualified installing contractors. The qualified installing contractors then submit to the designer for approval their proposed helical pile helix details (number, thickness, steel material, etc.) that meet the designer's performance specification.)

STEP 7: Based on a review of the SPT N value data, it is anticipated by the designer or the qualified installation contractor that the helical pile will extend to a depth ranging from about 19 to 25 feet (5.8 to 7.6 m). This is because the N values increase to the 20 to 40 range at that range of depths to magnitudes that will probably equate to 3,800 ft-lbs (5.15 kN-m) of installation torque calculated in Step 4 for the 8 in (203 mm) diameter single helix lead section determined in Step 6.

If the lead section is 5 ft (1.5 m) long, it will require three or four 5 ft (1.5 m) plain extensions to reach the estimated depths. Depending on the installation equipment used, it may be advantageous to use either 5 ft (1.5 m) or 7 ft (2.1 m) long pieces. Often, but not always, 5 ft (1.5 m) lead sections and extensions are preferred for underpinning work due to the usually limited access conditions. (Qualified installing contractors are able to provide much information on installation equipment; it is recommended they be contacted.) Therefore, for costing purposes, use a 5 ft (1.5 m) lead section and four 5 ft (1.5 m) plain extensions.

STOP.

The estimated 19 to 25 foot (5.8 to7.6 m) depth is too deep, the pier at this depth is too costly when a minimum depth of 15 feet is sufficient to put the helices below the soft (N=4) clay and into stable bearing material. Therefore, the designer or installing contractor re-selects (with designer approval) an 8 in-10 in (203 mm- 254 mm) diameter double helix HELI-PILE® HPC15X lead section 5 feet (1.5 m) long. It is now anticipated the pier will extend to a depth of about 18 to 20 feet (5.5 to 6.1 m). Thus, three 5 foot (1.5 m) HPC15X plain extensions will be required. The installing contractor will submit to the designer all appropriate manufacturers data for the helical pile configuration proposed.

Remember, the piers will extend to the depth necessary to get the required torque. Therefore, the number and length of extensions could vary from pile to pile. A qualified and experienced installing contractor will be prepared for this eventuality.

STEP 8: This particular site was field tested for corrosion potential because it has a history of industrial development. The soil pH and resistivity values can be used to check life expectancy of HELI-PILE® helical piles using the "Corrosion Nomograph" on p. 3-43 above. The soil pH of 6.5 is on the acid side of neutral. By entering the soil pH of 6.5 and the soil resistivity of 502 ohm-cm in the nomograph, the shaft life comes to about 110 years. This means that after about 110 years the factor of safety of the shaft will drop below 2. Therefore, there is another long period of time before that factor of safety will fall below 1 and a failure could occur. Because this time frame of somewhere around 200 years, corrosion is deemed not a problem and no extra measures for corrosion protection are required. Galvanizing in accordance with ASTM B633 is sufficient.

No mention is made of cobble or expansive clay soil or any other geologic hazard or constraint, so no precautions must be taken for other or additional installation techniques.

STEP 9: Per Table 1-1, the IMR underpinning bracket underpinning bracket would be used since it has an ultimate capacity over 38,000 lbs (169 kN). The bracket bolts onto the existing "T" footing and rests on the top of the installed helical pile shaft. (The outboard portion on the "T" must be clipped so the bracket is fastened to the stem wall. This minimizes eccentric loading on the bracket/pile combination.)

STEP 10: Design for these particular piles is complete. Repeat these steps for all piles added during construction. See Appendix for sample drawings. For sample specifications, see PART 6. SAMPLE SPECIFICATIONS below.

ENGINEER'S ESTIMATE: A reasonable "engineer's estimate" of the material requirements for this project is to figure each helical screw pile will consist of a 5 ft (1.5 m) double helix lead section and three 5 ft (1.5 m) plain extensions plus the underpinning bracket.

(Installed cost can only be determined after labor and equipment costs are added to the material costs. It is recommended that qualified installation contractors be contacted for the installed cost. They will best know the equipment requirements and capabilities and the time it will take to install the piles once they know something about the soils at the site. Of course, once sufficient experience is obtained, the designer will be able to make these estimates him or herself.)

Design Steps for **Tiebacks and Other Tension Anchors**

STEP 1: Determine or obtain helical tieback or tension anchor design load.

STEP 2: Compile or obtain appropriate site soil data. (Helical screw test probe data is preferred, SPT N value data is acceptable. For helical screw test probe information, see the "Soil Investigation Parameters" section above and the "Helical Screw Test Probe Procedure" sheets in the Appendix.)

STEP 3: Determine or obtain minimum depth of tieback behind the retaining wall or minimum depth of helical tension anchor below the structure, if any (other than manufacturers' minimum depth requirements).

STEP 4: Compute the minimum installation torque based on Eq (2-1) and the appropriate factor of safety.

STEP 5: Select helical tieback or tension anchor shaft size based on soil conditions, design load, and installation torque requirement.
(This step can be performed directly by the designer. Alternatively, the tieback or anchor shaft size can be proposed by qualified installing contractors during the bid phase based on a performance specification provided by the designer. The qualified installing contractors then submit details of the proposed helical tieback or tension anchor shaft and how it will meet the designer's performance specification.)

STEP 6: Select number and size of helices based on soil conditions and design load.
(This step can be performed directly by the designer. Alternatively, the number and size of helices can be proposed by qualified installing contractors during the bid phase based on a performance specification provided by the designer. The qualified installing contractors then submit details on the number, size, and material of the proposed helices and how the designer's performance specification will be met.)

STEP 7: Estimate helical tieback or anchor depth based on helical screw test probe data or SPT N value data. (See the "Estimating Pile or Anchor Depth" section above.)

STEP 8: Evaluate any other design aspects such as corrosion, presence of cobble, presence of expansive soil, ground water table, etc. Make adjustments or revisions as necessary.

STEP 9: Select or design the appropriate tieback or tension anchor head or other load transfer device based on the design load and configuration of the retaining wall or structural foundation at each tieback or tension anchor location.

STEP 10: Design complete. Prepare drawings and specifications.

ENGINEER'S ESTIMATE: See design example below.

Design Example for **<u>Tiebacks and Other Tension Anchors</u>**

This design example is applicable to retaining wall tiebacks, shoring tiebacks, basement wall tiebacks, etc. The process is applicable to any helical tension anchor.

<u>Given information</u>: A commercial building is to be constructed adjacent to a hillside. The rear wall of the commercial building is to serve dual purpose as a retaining wall and foundation wall. It is to be constructed of cast-in-place reinforced concrete. The structural engineer has determined that the best way to laterally support this wall is with the use of tiebacks. Based on optimum tieback spacing, it has been determined that each tieback load will be 40,000 lbs (151 kN). The new retaining wall is to be 14 feet (4.3 m) tall. The new tiebacks are to be placed 4 ft-8 in (1.42 m) below the top of the wall.

NO SOIL INFORMATION is available on the soils into which the tiebacks are to be installed. The use of tiebacks was not anticipated and the owner did not have the soil engineer explore that area. There is no money in the project budget to allow for additional exploration. However, general knowledge of the area says the slope into which the tiebacks will be installed probably consists of about 10 to 20 feet (3.0 to 6.1 m) of silty gravels with occasional cobbles underlain by progressively competent claystone/sandstone. This is based on exploration borings about 50 ft (15 m) away. There is a property line constraint that will limit the maximum tieback lengths to no more than 29 feet (8.8 m).

Required: Design the helical tiebacks and load transfer mechanism to the new retaining wall.

STEP 1: Per the "given information" above, the design load per tieback has been provided by the structural engineer: 40,000 lbs (151 kN) per tieback.

STEP 2: There is no specific soil data for the soils into which the tiebacks will be installed, only general site knowledge.

STEP 3: Because there is no detailed soil information, for this type of soil an assumed failure plane extends at a 45 degree angle up from the base of the wall back into the formation behind the wall. The tieback helices must extend three feet beyond this plane to be into theoretically stable anchorage material. This is a minimum of about 10 feet (3.0 m) from the back of the wall if the tieback is placed 4 feet-8 in (1.42 m) below the top of the wall and angled about 15 degrees down from the horizontal.

STEP 4: Using a factor of safety of 1.5 for these tiebacks, the design load of 40,000 lbs (151 kN) equates to an ultimate load of 60,000 lbs (267 kN). Using Eq. 2-1 and the "rule of ten" in English units, the minimum installation torque requirement would be calculated as follows:

$$Q_u = k_t T \qquad \text{(Eq. 2-1)}$$

where

Q_u = Ultimate capacity of the helical screw pile or tension anchor, lbs (kN)

k_t = Empirical installation torque coefficient, ft $^{-1}$ (m $^{-1}$)

T = Minimum installation torque, ft-lbs (kN-m)

Therefore, $T = Q_u / k_t$

$T = 60{,}000 \text{ lbs} / 10 \text{ ft}^{-1} = \underline{6{,}000 \text{ ft-lbs}}$

$(T = 267 \text{ kN} / 32.8 \text{ m}^{-1} = 8.14 \text{ kN-m})$

Therefore, <u>the minimum installation torque for the tiebacks is 6,000 ft-lbs</u> (8.14 kN-m).

STEP 5. For a helical tieback design load of 40,000 lbs (151 kN), using a factor of safety of 1.5, a common factor of safety for any variety of permanent tieback, not just helical, the ultimate load is 60,000 lbs (267 kN). Per Table 1-1, column #5 for "New Foundations Ultimate Capacity,", the HELI-PILE® 1.5 inch (38.1 mm) (HPC15X) material will take that ultimate load. Therefore, use HELI-PILE® HPC15X material.

(This step can be performed directly by the designer. Alternatively, the designer may provide a performance specification to qualified installing contractors. The qualified installing contractors then submit to the designer for approval their proposed helical tieback shaft details that meet the designer's performance specification.)

STEP 6: Per Table 1.1, HELI-PILE® 1.5 inch (38.1 mm) (HPC15X) material, with an ultimate capacity of 50,000 lbs (222 kN) per helix, two helices minimum are required to take the 60,000 lbs (267 kN) ultimate load. Regarding helix diameter, since there is no soil data for this site, it is wise to select a lead section with much surface area. This can be accomplished by using a multiple helix lead section. When in doubt about the soil conditions, it is wise to estimate high, i.e., select a lead section with more surface area than thought needed. During installation it might be found that the minimum depth cannot be reached because the soil is more dense than anticipated. Too much helix surface area may be on the lead section. If it is found that too much surface area is on the lead section, it is easy to cut down helix diameters or cut a helix completely off a multiple helix lead section. Therefore, an 8 in-10 in-12 in (203 mm-254 mm-305 mm) diameter triple helix lead section is selected for this project.

Alternatively, the HELI-PILE® Modular Helical Pile could be used. Once the lead section to best fit site conditions is known, it could be built on-site without cutting or welding.

Actual soil conditions will dictate depth; however, in the experience of this author, this would be the lead section of choice. Other single or multiple helix lead sections would satisfy the loading requirements, but, as stated, the 8 in-10 in-12 in (203 mm-254 mm-305mm) diameter double helix lead section is the configuration of choice.

(This step can be performed directly by the designer. Alternatively, the designer may elect to provide a performance specification to qualified installing contractors. The qualified installing contractors then submit to the designer for approval their proposed helical tieback helix details (number, thickness, steel material, etc.) that meet the designer's performance specification.)

Step 7: Accurately estimating tieback depth, or the depth of any helical device, without soil information is difficult. In this particular case, some nearby soil data sheds some light on the site, but could be very inaccurate and misleading. It is usual in such cases to put forth a best “guesstimate” based on the best data available and make sure the owner is aware of the potential inaccuracy.

At this site, it would not be unreasonable to estimate the tieback depth at 21 ft (6.4 m). This would require the 7 ft (2.1 m) triple helix lead section and two 7 ft (2.1 m) plain extensions. In addition, a threaded adapter would be required for load transfer from the retaining wall to the helical tieback shaft.

Remember, the tiebacks will extend to the depth necessary to get the required torque. Therefore, the number and length of extensions could vary from tieback to tieback, but they can be no longer than 29 feet (8.8 m) due to property line constraints. A qualified and experienced installing contractor will be prepared for this eventuality.

Step 8: No mention is made of corrosion potential at this site for either steel or concrete. Therefore, it is assumed the potential for steel corrosion is low and galvanizing in accordance with ASTM B633 is sufficient. No mention is made of cobble or expansive clay soil or any other geologic constraint, so no precautions must be taken for other or additional installation techniques.

Step 9: A load transfer plate attached to the threaded adapter on the shaft end of each helical tieback has been designed by the structural engineer similar to the helical tiebacks shown in Figure 4-2.

STEP 10: Design for these particular helical tiebacks is complete. Repeat these steps for all tiebacks. See Appendix for sample drawings. For sample specifications, see PART 6. SAMPLE SPECIFICATIONS below.

ENGINEER’S ESTIMATE: A reasonable “engineer’s estimate” of the material requirements for this project is to figure each helical tieback will consist of a 7 ft (2.1 m) triple helix lead section and two 7 ft (2.1 m) plain extensions plus the threaded adapter load transfer device..

(Installed cost can only be determined after labor and equipment costs are added to the material costs. It is recommended that qualified installation contractors be contacted for the installed cost. They will best know the equipment requirements and capabilities and the time it will take to install the piles once they know something about the soils at the site. Of course, once sufficient experience is obtained, the designer will be able to make these estimates him or herself.)

During installation, the depths and installation torques were monitored to ensure the minimum 10 feet (3.0 m) depth. 6,000 ft-lbs (8.14 kN-m) of torque was reached at about 20 feet (6.1 m) into the formation. Therefore, by knowing the torque of each tieback, both the structural and soil engineer were assured of tiebacks that will perform to the design criteria.

Design Steps for **Seismic and Wind Loading Applications, including Liquefaction**

STEP 1: Determine or obtain helical pile or tension anchor design load from seismic and/or wind sources. The structural engineer has determined helical screw pile and tension anchor placement locations and horizontal and vertical orientation.

STEP 2: Compile or obtain appropriate site soil data. (Helical screw test probe data is preferred, SPT N value data is acceptable. For helical screw test probe information, see the "Soil Investigation Parameters" section above and the "Helical Screw Test Probe Procedure" sheets in the Appendix.). Site data must include identification, including depth, of any liquefiable zones.

STEP 3: Determine or obtain minimum depth of helical screw pile or minimum depth of helical tension anchor below the structure, if any (other than manufacturers' minimum depth requirements).

STEP 4. Determine depth of liquefiable zone where helical screw pile shaft in compression will loose all lateral bracing for shaft slenderness buckling purposes.

STEP 5: Compute the minimum installation torque based on Eq (2-1) and the appropriate factor of safety.

STEP 6: Select helical screw pile or tension anchor shaft size based on soil conditions, design load, and installation torque requirement.
(This step can be performed directly by the designer. Alternatively, the helical screw pile or tension anchor shaft size can be proposed by qualified installing contractors during the bid phase based on a performance specification provided by the designer. The qualified installing contractors then submit details of the proposed helical pile or tension anchor shaft and how it will meet the designer's performance specification.)

STEP 7: Select number and size of helices based on soil conditions and design load.
(This step can be performed directly by the designer. Alternatively, the number and size of helices can be proposed by qualified installing contractors during the bid phase based on a performance specification provided by the designer. The qualified installing contractors then submit details on the number, size, and material of the proposed helices and how the designer's performance specification will be met.)

STEP 8: Estimate helical screw pile or anchor depth based on helical screw test probe data or SPT N value data. (See the "Estimating Pile or Anchor Depth" section above.)

STEP 9: Evaluate the compression capacity affects of liquefaction on those portions of the helical pile shaft within the liquefiable zone. Determine if shaft slenderness buckling bracing in the form of steel pipe sleeving is required.

STEP 10: Evaluate any other design aspects such as corrosion, presence of cobble, presence of expansive soil, ground water table, cyclical loading, etc. Make adjustments or revisions as necessary.

STEP 11: Select or design the appropriate helical screw pile or tension anchor load transfer device based on the design load and configuration of the structural foundation at each screw pile or tension anchor location.

STEP 12: Design complete. Prepare drawings and specifications.

ENGINEER'S ESTIMATE: See design example below.

Design Example for **Seismic and Wind Loading Applications, including Liquefaction**

Given information: A new 22 story commercial structure is to be constructed on a helical screw pile foundation. The construction site is identified by the International Building Code (IBC) as a Site Class F containing soils with liquefiable potential. The geotechnical engineer has identified a liquefiable soil zone beginning at a depth of about 5 feet (1.5 m) and extending to a depth of about 20 feet (6.1 m). The site is in a location mapped by the IBC has having high maximum considered earthquake spectral response accelerations. The structural engineer has calculated that all vertical helical piles for supporting column and load bearing wall vertical loads will have a design load of 50,000 lbs (222 kN). The vertical piles could be of a large enough section modulus by using a tubular or pipe style helical pile to prevent slenderness buckling in the liquefiable zones. However, the engineer has decided that the vertical helical piles will be sleeved with 4 inch (102 mm) diameter schedule 40 pipe in the upper 20 feet (6.1 m) to provide lateral slenderness buckling bracing in the liquefiable soil zone thus allowing the full 50,000 lbs (222 kN) capacity of the vertical helical screw piles (see the "Slenderness Buckling (soft soil)" section under PART 3. DESIGN CONSIDERATIONS above).

Even though wind loading is high at this site, the structural engineer has determined that seismic lateral loading governs. The maximum lateral seismic loads on the foundation of this structure are such that passive pressure on exterior and interior basement walls and grade beams is not sufficient to dissipate seismic loads to the soil. Therefore, the structural engineer is calling for several helical piles battered at a 45 degree angle (similar to Figure 3-5 above) to be placed at locations determined by the structural engineer to take these lateral loads. The structural engineer has considered seismic lateral loading from all directions. Each battered helical screw pile is to be installed to take a 50,000 lbs (222 kN) axial design load in both compression and tension. Therefore, the lateral component of that axial load is cos 45° x 50,000 lbs (222 kN) = 35,400 lbs (157 kN), both compression and tension.

The soils at the site are:

Helical Screw Test Probe Data:

Probe Description: Single 8 inch (203 mm) diameter helix. Probe taken 3' away from boring.

Probe Depth	Torque	Install Description
0.5 ft (0.2 m)	500 ft-lbs (0.7 kN-m)	Loose / smooth install
3 ft (0.9 m)	1,000 ft-lbs (1.4 kN-m)	Mod. stiff / smooth install
4 ft (1.2 m)	1,500 ft-lbs (2.0 kN-m)	Mod. stiff / smooth install
10 ft (3.0 m)	1,000 ft-lbs (1.4 kN-m)	Mod. stiff / smooth install
17 ft (5.2 m)	1,000 ft-lbs (1.4 kN-m)	Mod. stiff / smooth install
20 ft (6.1 m)	1,500 ft-lbs (2.0 kN-m)	Mod. stiff / smooth install
21 ft (6.4 m)	2,000 ft-lbs (2.7 kN-m)	Mod. stiff / smooth install
21.5 ft (6.6 m)	2,500 ft-lbs (3.4 kN-m)	Mod. stiff / smooth install
22 ft (6.7 m)	3,000 ft-lbs (4.1 kN-m)	Stiff / smooth install
22.5 ft (6.9 m)	3,500 ft-lbs (4.7 kN-m)	Stiff / smooth install
23 ft (7.0 m)	4,000 ft-lbs (5.4 kN-m)	Stiff / smooth install
24 ft (7.3 m)	4,500 ft-lbs (6.1 kN-m)	Stiff / smooth install
24.5 ft (7.5 m)	5,000 ft-lbs (6.8 kN-m)	Stiff / smooth install
25 ft (7.6 m)	5,500 ft-lbs (7.5 kN-m)	Stiff / smooth install
27 ft (8.2 m)	6,000 ft-lbs (8.1 kN-m)	Very stiff / smooth install
28 ft (8.5 m)	6,500 ft-lbs (8.8 kN-m)	Very stiff / smooth install
29 ft (8.8 m)	7,000 ft-lbs (9.5 kN-m)	Very stiff / smooth install
30 ft (9.1 m)	7,500 ft-lbs (10.2 kN-m)	Very stiff / smooth install
31 ft (9.4 m)	8,000 ft-lbs (10.8 kN-m)	Extrem. stiff / smooth install
35 ft (10.7 m)	8,500 ft-lbs (11.5 kN-m)	Extrem. stiff / smooth install
38 ft (11.6 m)	9,000 ft-lbs (12.2 kN-m)	Extrem. stiff / smooth install
39 ft (11.9 m)	9,500 ft-lbs (12.9 kN-m)	Extrem. stiff / smooth install
40 ft (12.2 m)	10,000 ft-lbs (13.6 kN-m)	Extrem. stiff / smooth install

Exploration Boring Log Data:

0-5'	(0-1.5 m)	Fill, some gravel, silty clay	SPT: 14 blows/ft (N=14) @ 4'
5'-20'	(1.5 m-6.1 m)	Sandy silt (liquefiable)	SPT: 9 blows/ft (N=9) @ 15'
20'-27'	(6.1 m-8.2 m)	Sand with gravel	SPT: 35 blows/ft (N=35) @ 25'
27'-32'	(8.2 m-9.8 m)	Weathered sandstone	SPT: 60 blows/ft (N=60) @ 31'
32'-45'	(9.8 m-13.7m)	End of boring	SPT: 100 blows/ft (N=100) @ 38'

Groundwater 22 feet (6.7 m) deep.

Corrosion Field Data at a depth of 25 ft (7.6 m): Soil pH: 8.1, Soil Resistivity: 890 ohm-cm

Required: Design the battered helical screw piles and load transfer device. Take into account the liquefiable soil zone and the need for shaft slenderness buckling bracing (steel sleeving) for those times when the piles are compression loaded to the maximum during an earthquake.

STEP 1: Per the "given information" above, the design load per battered helical screw pile has been provided by the structural engineer: 50,000 lbs (222 kN) per pile, tension and compression.

STEP 2: The geotechnical engineer has provided subsurface soil data as indicated above in the Helical Test Probe data and the exploration boring log data.

STEP 3: The geotechnical engineer has determined all piles must penetrate the liquefiable zone and bear in the sands and gravels or sandstone below. If helical screw piles manufactured by IMR (HELI-PILE® brand) are used, this far exceeds the manufacturer's minimum depth of 5 diameters of the largest helix on the lead section, approximately 5 feet (1.5 m).

STEP 4: Per the exploration boring log data, the geotechnical engineer has determined the extent of the liquefiable zone. In the 15 ft (4.6 m) layer between the depth of 5 and 20 ft (1.5 and 6.1 m), slenderness buckling bracing must be provided to the shaft to prevent buckling if the soil liquefies during an earthquake (N = 0).

STEP 5: Using a factor of safety of 2, the design load of 50,000 lbs (222 kN) equates to an ultimate load of 100,000 lbs (445 kN). Using Eq. 2-1 and the "rule of ten" in English units, the minimum installation torque requirement would be calculated as follows:

$$Q_u = k_t\, T \qquad \text{(Eq. 2-1)}$$

where

Q_u = Ultimate capacity of the helical pile or tension anchor, lbs (kN)

k_t = Empirical installation torque coefficient, ft^{-1} (m^{-1})

T = Minimum installation torque, ft-lbs (kN-m)

Therefore, $T = Q_u / k_t$

$T = 100{,}000 \text{ lbs} / 10 \text{ ft}^{-1} = \underline{10{,}000 \text{ ft-lbs}}$

$(T = 445 \text{ kN} / 32.8 \text{ m}^{-1} = 13.6 \text{ kN-m})$

Therefore, <u>the minimum installation torque for the battered helical piles is 10,000 ft-lbs</u> (13.6 kN-m).

STEP 6. For a helical pile design load of 50,000 lbs (222 kN), using a factor of safety of 2, the ultimate load is 100,000 lbs (445 kN). Per Table 1-1, column #5 for "New Foundations Ultimate Capacity, the HELI-PILE® 1.75 inch (44.5 mm)(HPC15) material will take that ultimate load. Therefore, <u>use HELI-PILE® HPC17 material</u>.

(This step can be performed directly by the designer. Alternatively, the designer may provide a performance specification to qualified installing contractors. The qualified installing contractors then submit to the designer for approval their proposed helical tieback shaft details that meet the designer's performance specification.)

STEP 7: Per Table 1.1, column No. 8, "Ultimate Per Helix Capacity," with an ultimate capacity of 50,000 lbs (222 kN) per helix, two helices minimum are required to take the 100,000 lbs (445 kN) ultimate load. Reviewing the helical screw test probe log, it appears sufficient torque will be achieved with a double helix lead section at a depth of about 30 feet (9.1 m). Since the soil increases in density rapidly with depth, using a triple helix lead section does not seem to be worth the extra money, therefore a double helix lead section is selected. The diameter of the helices is not critical so long as the lead section bears in the sands and gravels or sandstones below the liquefiable zone and the minimum installation torque is achieved (Step 7). The most common double helix lead section is the 8 in-10in (203 mm-254 mm) double helix. This is selected.

(This step can be performed directly by the designer. Alternatively, the designer may provide a performance specification to qualified installing contractors. The qualified installing contractors then submit to the designer for approval their proposed helical tieback helix details (number, thickness, steel material, etc.) that meet the designer's performance specification.)

STEP 8: Based on a review of the Helical Screw Test Probe and SPT N value data, it is anticipated by the designer or the qualified installation contractor that the pile will extend to a depth of approximately 30 feet (9.1 m). This is because probe install torques and the N values rapidly increase at that depth to magnitudes that will probably equate to high installation torque calculated in Step 5 for the 8 in-10 in (203 mm-254 mm) diameter double helix lead section determined in Step 7.

Since these piles are battered at a 45 degree angle, the total estimated pile length will be 30 ft (9.1 m) / cos 45° = 42.4 ft (12.9 m). If the lead section is 7 ft (2.1 m) long, it will require five 7 ft (2.1 m) plain extensions and one 3 ft (0.9 m) plain extension to reach the estimated depths. This allows for the load transfer device (see Step 11) to extend up and be embedded into the basement wall concrete as determined by the structural engineer. Therefore, <u>for costing purposes use a 7 ft (2.1 m) lead section and five 7 ft (2.1 m) plain extensions and one 3 ft (0.9 m) plain extension</u>.

Remember, the piers will extend to the depth necessary to get the required installation torque. Therefore, the number and length of extensions could vary from pile to pile. A qualified and experienced installing contractor will be prepared for this eventuality.

STEP 9: Since these piles are to be placed at a 45 degree angle, the length of braced shaft in the liquefiable zone is 15 ft (4.6 m) / cos 45° = 21.2 ft (6.5 m). According to Table 3-1 above, for a 21.2 ft (6.5 m) thickness of N = 0 soil, by using a 4 inch (102 mm) diameter schedule 40 steel pipe sleeve, the HELI-PILE® HPC17 will still take its full rated axial compression design load of 50,000 lbs (222 kN). Therefore, a 4 inch (102 mm) diameter schedule 40 steel pipe sleeve must be used in the length of these battered helical screw piles where they pass through the liquefiable zone, plus through the overburden material above the liquefiable zone. Therefore the total length of sleeve is 25 ft (7.6 m) / cos 45° = 35.4 ft (10.7 m). The steel pipe sleeves may be installed in sections but all sleeve connections must be rigid by welding or threading.

STEP 10: This particular site was <u>field</u> tested for corrosion potential. The soil pH and resistivity values can be used to check life expectancy of the HELI-PILE® Helical Pile using the "Corrosion Nomograph" on p. 3-43. The soil pH of 8.1 is on the alkaline side of neutral. By entering the soil pH of 8.1 and the soil resistivity of 890 ohm-cm in the nomograph, the shaft life comes to about 180 years. This means that after about 180 years the factor of safety of the shaft will start to drop below 2. Therefore, there is another long period of time before that factor of safety will fall below 1 and a failure could occur. Because this total time frame is somewhere around 250+ years, corrosion is deemed not a problem and no extra measures for corrosion protection are required. Hot-dip galvanizing in accordance with ASTM B633 is sufficient.

No mention is made of cobble or expansive clay soil or any other geologic constraint, so no precautions must be taken for other or additional installation techniques

STEP 11: The structural engineer has designed the reinforced concrete basement walls. At each load transfer point within the walls where the battered helical piles are placed, a hybrid New Foundation Construction Bracket will be installed on the pile shaft for load transfer. This hybrid New Foundation Bracket, similar to the New Foundation Bracket shown in the Appendix, has 4 reinforcing steel bars rather than 2. The structural engineer has analyzed the load transfer points within the basement walls and has placed sufficient reinforcing steel and ensured that there is sufficient concrete confinement for proper compression and tension load transfer from the structure to the battered helical piles. The bracket will be attached to the top of each battered pile shaft that embeds into the reinforced concrete basement wall similar to Figure 3-5. This bracket has a design capacity up to 50,000 lbs (222 kN) in compression and tension and an ultimate capacity up to 100,000 lbs (445 kN) in compression and tension.

STEP 12: Design for these particular battered helical piles is complete. For sample specifications, see PART 6. SAMPLE SPECIFICATIONS below.

ENGINEER'S ESTIMATE: A reasonable "engineer's estimate" of the material requirements for this project is to figure each battered helical pile will consist of a 7 ft (2.1 m) double helix lead section, five 7 ft (2.1 m) plain extensions, and one 3 ft (0.9 m) plain extension plus the New Construction Bracket load transfer device.

(Installed cost can only be determined after labor and equipment costs are added to the material costs. It is recommended that qualified installation contractors be contacted for the installed cost. They will best know the equipment requirements and capabilities and the time it will take to install the piles once they know something about the soils at the site. Of course, once sufficient experience is obtained, the designer will be able to make these estimates him or herself.)

<u>PART 6. SAMPLE SPECIFICATIONS</u>

Because specific data is readily available, the sample specifications given are for HELI-PILE® helical piles manufactured by International Marketing & Research, Inc. however, the specifications are easily adapted to other manufacturers. The sample specifications are for the 1.5 inch (38.1 mm) and 1.75 inch (44.5 mm) square shaft HELI-PILE® helical piles. However, these specifications can be adapted for other sizes as well.

<u>A performance specification is preferred</u>. This is best accomplished as follows: the designer specifies the performance criteria: 1) pile or anchor location, 2) design loads and 3) minimum depth on the drawings, and provides site soil data. This information is given to all qualified installing contractors bidding the project. All qualified installing contractors bidding the project, or just the successful qualified installing contractor, at the designer's discretion, then submit to the designer for approval the helical screw piles or tension anchors proposed that will meet the performance criteria. It is expected that all qualified installing contractors will propose helical screw pile or tension anchor material that will most economically meet the designer's performance criteria.

Specifications should be flexible by allowing the installing contractor to propose several helical lead section configurations that will meet the performance criteria during the course of installation work, subject to the approval of the designer. This reduces field down-time and improves the schedule.

The sample specifications presented below allow for the performance specification of size, shape, and depth of helical piles and tension anchors while detailing material quality, manufacturer, building code listing, and installation procedure, etc.

Four sample specifications are presented below: two sample specifications for vertical helical piles and two sample specifications for tiebacks which could be applied to any tension anchor. They have worked well in the past. Of course, the designer may modify these specifications as necessary to fit the specific project requirements.

1. SIMPLIFIED HELICAL PILE SPECIFICATION:

This is the preferred specification wherever possible. It serves well on drawings or in a specification package.

[The SIMPLIFIED SPECIFICATION starts on the next page.]

IMR HELI-PILE® HELICAL PILE SPECIFICATION

Helical piles shall be manufactured by International Marketing & Research, Inc. (IMR), Denver, Colorado, USA, under the trade name HELI-PILE®.

HELI-PILE® helical piles shall be installed by an authorized IMR installing contractor who has satisfied the certification requirements relating to the technical aspects of the product and the ascribed installation techniques. Proof of current certification by IMR must be provided.

- All work as described herein shall be performed in accordance with all applicable safety codes in effect at the time of installation.
- HELI-PILE® helical piles shall be designed in accordance with the helical pile provisions of the 2009 International Building Code.
- The helical lead sections and extensions shall be solid steel, rounded corner square shaft configuration, with one or more helical bearing plates welded to the shaft.
- All piles must be corrosion protected by galvanization per ASTM B633.
- Installation units shall consist of a rotary type torque motor with forward and reverse capabilities. These units shall be either electrically or hydraulically powered.
- Installation units shall be capable of developing the minimum torque as required.
- Installation units shall be capable of positioning the HELI-PILE® helical pile at the proper installation angle. This angle may vary between vertical and 5 degrees depending upon application and type of load transfer device specified or required.
- Installation torque shall be monitored throughout the installation process.
- HELI-PILE® helical piles shall be installed to the minimum torque value required to provide the load capacities shown on the plans.
- The appropriate steel underpinning bracket or new construction load transfer device shall be used.
- Appropriate HELI-PILE® helical pile selection will consider load plus safety factor (which may be specified on the plans), soil parameters and the installation torque versus capacity equation as per the manufacturer's recommendations.

END OF SPECIFICATION

2. EXTENDED HELICAL PILE SPECIFICATION ORGANIZED IN ACCORDANCE WITH CSI SPECIFICATIONS.

SECTION___________ STEEL HELICAL PILES

PART 1: GENERAL

1.1 DESCRIPTION:

1. The work of this section consists of furnishing and installing HELI-PILE® steel helical piles manufactured by International Marketing & Research, Inc. (I.M.R.), Denver, Colorado, U.S.A.

2. HELI-PILE® steel helical piles shall be designed and installed to resist the unfactored design loads as shown on Sheet S-__. The geotechnical report ____ for the site dated ___________ by ___________ is included in this project manual as specification section ______________.

3. Related Work Specified Elsewhere:

1.2 QUALITY ASSURANCE

1. Installer Qualifications: Installation shall be done by an I.M.R. authorized installation contractor. Proof of current certification with I.M.R., Inc., shall be submitted to the Owner prior to starting installation.

2. A qualified inspector shall be present during HELI-PILE® helical pile installation in accordance with the local building code.

3. Welding: Meet requirements of AWS "Structural Welding Code," D1.1, latest edition. All welders shall be AWS certified.

1.3 SUBMITTALS

1. Submit shop drawings indicating shaft and helix sizes, and include manufacturer's catalog cut and data sheets.

PART 2: PRODUCTS

2.1 MATERIAL

1. Pier Shafts (Lead Section and Extensions):

    1. The 1.5 inch (38.1 mm) round cornered square (RCS) solid steel shafts shall conform to the general requirements of ASTM A29 and the following descriptions:

a. Modified medium carbon steel grade with improved strength due to fine grain size and structure having a torsional strength rating of 5,500 ft.-lbs. (7.46 kN-m), or

b. High strength low alloy (HSLA), low to medium carbon steel grade with improved strength due to fine grain size and structure having a torsional strength rating of 7,000 ft.-lbs (9.49 kN-m).

2. The 1.75 inch (44.5 mm) round cornered square (RCS) solid steel shafts shall conform to the general requirements of ASTM A29 and the following descriptions:

High strength low alloy (HSLA), low to medium carbon steel grade with improved strength due to fine grain size and structure having a torsional strength rating of 11,000 ft.-lbs (14.9 kN-m).

3. Helices: Carbon steel sheet, strip, or plate formed on matching metal dies to true helical shape, 0.5 inch (12.7 mm) thick, and shall conform to the following ASTM specifications:

1. 5,500 ft.-lbs(7.46 kN-m) 1.5 inch (38.1 mm) piles: ASTM A656 Grade 80.
2. 7,000 ft-lbs(9.49 kN-m) 1.5 inch (38.1 mm) piles: ASTM A656 Grade 80.
3. 11,000 ft.-lbs.(14.9 kN-m) 1.75 (44.5 mm) inch piles: ASTM A656 Grade 80.

4. Bolts: The sizes and types of bolts used to connect the HELI-PILE® helical pile extensions to lead sections or another extension shall conform to the following ASTM specifications:

1. 1.5 inch (38.1 mm) HELI-PILE® helical piles: 0.75 inch (19.1 mm) diameter bolt per ASTM A449.
2. 1.75 inch (44.5 mm) HELI-PILE® helical piles: 0.875 inch (22.2 mm) diameter bolt per ASTM A193 Grade B7.

5. Couplings: Couplings shall be cold-forged welded to the shaft.

6. Finish: All material shall be galvanized per ASTM B633.

PART 3: EXECUTION

3.1 EQUIPMENT:

1. Installation Equipment:

    1. Shall be a rotary type motor with equal forward and reverse torque capabilities. This equipment shall be capable of continual adjustment of the torque drive unit's revolutions per minute (RPM's) during installation. Percussion drilling equipment will not be allowed.

    2. Shall be capable of applying installation torque equal to the torque required to meet the pier loads.

    3. Equipment shall be capable of applying axial compression (crowd) pressure and torque simultaneously.

2. Torque Monitoring Devices:

    1. The torque being applied by the installing units shall be monitored throughout the installation by the installer. The torque monitoring device shall either be a part of the installing unit or an independent device in-line with the installing unit. Calibration for either unit shall be available for review by the Owner.

3.2 INSTALLATION PROCEDURES:

1. Advancing Sections:

    1. Engage and advance the HELI-PILE® helical pile sections in a smooth, continuous manner with the rate of pile rotation in the range of 5 to 35 RPM.

    2. Apply sufficient axial compression (crowd) pressure to uniformly advance the helical sections to approximately 3-inches (76.2 mm) per revolution. The rate of rotation and magnitude of crowd pressure must be adjusted for different soil conditions and depths in order to maintain the penetration rate.

    3. If the helical section ceases to advance, refusal will have been reached and the installation shall be terminated.

2. Termination Criteria:

    1. The torque as measured during the installation shall not exceed the torsional strength rating of the steel helical lead and extension sections.

2. The minimum depth criteria indicated on the Drawings must be satisfied prior to terminating the HELI-PILE® steel helical pile.

3. The top helix is to be located not less than five (5) feet (1.5 m) below the grade elevation unless otherwise approved by the Owner.

4. If the torsional strength rating of the pier and/or installing unit has been reached prior to satisfying the minimum depth required, the installing contractor shall have the following options:

   a. Terminate the installation at the depth obtained with the approval of the Owner, or,

   b. Remove the existing pier and install a pier with smaller and/or fewer helices. This revised pier shall be terminated deeper than the terminating depth of the original pier as directed by the Owner.

5. In the event the minimum installation torque is not achieved at minimum depth, the Contractor shall install the foundation deeper using additional plain extension sections.

6. The minimum specified installation torque shall have been met when the measured installation torque meets or exceeds the minimum specified installation torque in two successive readings of the measuring device, unless otherwise specified by the Owner.

7. The installer shall keep a written installation record for each HELI-PILE® helical pile. This record shall include the following information as a minimum:

   a. Project name and location.
   b. Name of authorized and certified dealer and installer.
   c. Name of installer´s foreman or representative witnessing the installation.
   d. Date of installation.
   e. Location of HELI-PILE® helical pile.
   f. Description of lead section including number and diameter of helices and extensions used.
   g. Overall depth of installation from a known reference point.
   h. Installation torque at termination of pier.
   i. Load transfer device

END OF SPECIFICATION

3. HELICAL TIEBACK SIMPLIFIED SPECIFICATION:

IMR HELI-PILE® HELICAL TIEBACK SPECIFICATION

Helical tiebacks shall be manufactured by International Marketing & Research, Inc. (IMR), Denver, Colorado, USA, under the trade name HELI-PILE®.

HELI-PILE® helical tiebacks shall be installed by an authorized IMR installing contractor who has satisfied the certification requirements relating to the technical aspects of the product and the ascribed installation techniques. Proof of current certification by IMR must be provided.

- All work as described herein shall be performed in accordance with all applicable safety codes in effect at the time of installation.
- The helical lead sections and extensions shall be solid steel, rounded corner square shaft configuration, with one or more helical bearing plates welded to the shaft.
- All tiebacks must be corrosion protected by galvanization per ASTM B633.
- Installation units shall consist of a rotary type torque motor with forward and reverse capabilities. These units shall be either electrically or hydraulically powered.
- Installation units shall be capable of developing the minimum torque as required.
- Installation units shall be capable of positioning the HELI-PILE® helical tiebacks at the proper installation angle.
- Installation torque shall be monitored throughout the installation process.
- HELI-PILE® helical tiebacks shall be installed to the minimum torque value required to provide the load capacities shown on the plans.
- The appropriate steel underpinning bracket or new construction load transfer device shall be used.
- Upon completion of installation, tiebacks shall be tensioned and locked off at a percentage of the design load as specified by the Owner.
- Appropriate HELI-PILE® helical tieback selection will consider load plus safety factor (which may be specified on the plans), soil parameters and the installation torque versus capacity equation as per the manufacturer's recommendations.

END OF SPECIFICATION

4. EXTENDED HELICAL TIEBACK SPECIFICATION ORGANIZED IN ACCORDANCE WITH CSI SPECIFICATION:

SECTION___________ STEEL HELICAL TIEBACKS

PART 1: GENERAL

1.1 DESCRIPTION:

1. The work of this section consists of furnishing and installing HELI-PILE® steel helical tiebacks manufactured by International Marketing & Research, Inc. (I.M.R.), Denver, Colorado, U.S.A.

2. HELI-PILE® steel helical tiebacks shall be designed and installed to resist the unfactored design loads as shown on Sheet S-__. The geotechnical report ____ for the site dated ___________ by ____________ is included in this project manual as specification section ______________.

3. Related Work Specified Elsewhere:

1.2 QUALITY ASSURANCE

1. Installer Qualifications: Installation shall be done by an I.M.R. authorized installation contractor. Proof of current certification with I.M.R., Inc., shall be submitted to the Owner prior to starting installation.

2. A qualified inspector shall be present during HELI-PILE® helical tiebacks installation in accordance with the local building code.

3. Welding: Meet requirements of AWS "Structural Welding Code," D1.1, latest edition. All welders shall be AWS certified.

1.3 SUBMITTALS

1. Submit shop drawings indicating shaft and helix sizes, and include manufacturer's catalog cut and data sheets.

PART 2: PRODUCTS

2.1 MATERIAL

1. Pier Shafts (Lead Section and Extensions):

1. The 1.5 inch (38.1 mm) round cornered square (RCS) solid steel shafts shall conform to the general requirements of ASTM A29 and the following descriptions:

    a. Modified medium carbon steel grade with improved strength due to fine grain size and structure having a torsional strength rating of 5,500 ft.-lbs. (7.46 kN-m), or

    b. High strength low alloy (HSLA), low to medium carbon steel grade with improved strength due to fine grain size and structure having a torsional strength rating of 7,000 ft.-lbs (9.49 kN-m).

2. The 1.75 inch (44.5 mm) round cornered square (RCS) solid steel shafts shall conform to the general requirements of ASTM A29 and the following descriptions:

    High strength low alloy (HSLA), low to medium carbon steel grade with improved strength due to fine grain size and structure having a torsional strength rating of 11,000 ft.-lbs (14.9 kN-m).

3. Helices: Carbon steel sheet, strip, or plate formed on matching metal dies to true helical shape, 0.5 inch (12.7 mm) thick, and shall conform to the following ASTM specifications:

    1. 5,500 ft.-lbs(7.46 kN-m) 1.5 inch (38.1 mm) tiebacks: ASTM A656 Grade 80.
    2. 7,000 ft-lbs(9.49 kN-m) 1.5 inch (38.1 mm) tiebacks: ASTM A656 Grade 80.
    3. 11,000 ft.-lbs(14.9 kN-m) 1.75 inch (44.5 mm) tiebacks: ASTM A656 Grade 80.

4. Bolts: The sizes and types of bolts used to connect the HELI-PILE® helical tieback extensions to lead sections or another extension shall conform to the following ASTM specifications:

    1. 1.5 inch (38.1 mm) HELI-PILE® helical tiebacks: 0.75 inch (19.1 mm) diameter bolt per ASTM A449.
    2. 1.75 inch (44.5 mm) HELI-PILE® helical tiebacks: 0.875 inch (22.2 mm) diameter bolt per ASTM A193 Grade B7.

5. Couplings: Couplings shall be cold-forged welded to the shaft.

6. Finish: All material shall be galvanized per ASTM B633.

PART 3: EXECUTION

3.1 EQUIPMENT:

1. Installation Equipment:

   1. Shall be a rotary type motor with equal forward and reverse torque capabilities. This equipment shall be capable of continual adjustment of the torque drive unit's revolutions per minute (RPM's) during installation. Percussion drilling equipment will not be allowed.

   2. Shall be capable of applying installation torque equal to the torque required to meet the pier loads.

   3. Equipment shall be capable of applying axial compression (crowd) pressure and torque simultaneously.

2. Torque Monitoring Devices:

   1. The torque being applied by the installing units shall be monitored throughout the installation by the installer. The torque monitoring device shall either be a part of the installing unit or an independent device in-line with the installing unit. Calibration for either unit shall be available for review by the Owner.

3.2 INSTALLATION PROCEDURES:

1. Advancing Sections:

   1. Engage and advance the HELI-PILE® helical tieback sections in a smooth, continuous manner with the rate of pile rotation in the range of 5 to 35 RPM.

   2. Apply sufficient axial compression (crowd) pressure to uniformly advance the helical sections to approximately 3-inches (76.2 mm) per revolution. The rate of rotation and magnitude of crowd pressure must be adjusted for different soil conditions and depths in order to maintain the penetration rate.

   3. If the helical section ceases to advance, refusal will have been reached and the installation shall be terminated.

2. Termination Criteria:

   1. The torque as measured during the installation shall not exceed the torsional strength rating of the steel helical lead and extension sections.

2. The minimum depth criteria indicated on the Drawings must be satisfied prior to terminating the HELI-PILE® steel helical tieback.

3. The top helix is to be located not less than five (5) feet (1.5 m) from face of wall.

4. If the torsional strength rating of the pier and/or installing unit has been reached prior to satisfying the minimum depth required, the installing contractor shall have the following options:

   a. Terminate the installation at the depth obtained with the approval of the Owner, or,

   b. Remove the existing pier and install a pier with smaller and/or fewer helices. This revised pier shall be terminated deeper than the terminating depth of the original pier as directed by the Owner.

5. In the event the minimum installation torque is not achieved at minimum depth, the Contractor shall install the foundation deeper using additional plain extension sections.

6. The minimum specified installation torque shall have been met when the measured installation torque meets or exceeds the minimum specified installation torque in two successive readings of the measuring device, unless otherwise specified by the Owner.

7. The installer shall keep a written installation record for each HELI-PILE® helical tieback. This record shall include the following information as a minimum:

   a. Project name and location.
   b. Name of authorized and certified dealer and installer.
   c. Name of installer´s foreman or representative witnessing the installation.
   d. Date of installation.
   e. Location of HELI-PILE® helical tieback.
   f. Description of lead section including number and diameter of helices and extensions used.
   g. Overall depth of installation from a known reference point.
   h. Installation torque at termination of pier.
   i. Load transfer device

END OF SPECIFICATION

PART 7. SAMPLE DRAWING DETAILS

Sample drawing details appear in the Appendix.

The reader is directed to www.helipile.com where *.pdf, *.dwg, and *.dxf files will be found of various details.

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PART 8. INSTALLATION METHODS

Please see PART 1. INTRODUCTION, pages 1-7 through 1-12 for photographs of various methods of installation.

Photo 8-1 shows a hydraulically powered drive head (also called a "power head", "torque head, "torque motor"). Bolted or pinned to the kelly bar that protrudes from the drive head is hex or square kelly adapter. Bolted or pinned to the kelly adapter is the helical pile drive tool. The top of the helical pile shaft inserts into the drive tool.

Photo 8-1 Helical pile drive head with kelly bar adapter and drive tool.

Helical piles may be installed with many different pieces of equipment ranging from large tracked excavator/backhoes to small hand-carried installers. There are four requirements for a piece of installation equipment: 1) Sufficient torque for the required pile capacity, 2) Sufficient axial compression pressure (or "crowd") to maintain an advancement rate of about 3 inches (76.2 mm) per revolution, 3) A revolution rate of about 5 to 35 rpm, and 4) Proper size to access the work site.

For projects where access allows, installation is accomplished by attaching a hydraulically driven drive head to the boom of a backhoe, trackhoe, excavator, or skid steer loader, as in Photo 8-1. For tight-access or low overhead projects the drive head may be attached to a carriage frame or merely hand-held.

Drive heads ideal for helical pile installation typically operate with about 2,700 psi (18.6 Mpa) maximum hydraulic pressure. For large pieces of equipment, a drive head with 11,000 ft-lbs (14.9 kN-m) of torque should have from 30 to about 60 gpm (114 to 227 liter/min) hydraulic fluid flow. For smaller pieces of equipment, about 2700 psi (18.6 Mpa) pressure is still required, however, the hydraulic fluid flow requirements will reduce to as little as about 8 to 15 gpm (30.2 to 56.8 liters/min).

With the advent of larger helical piles on the market today, drive heads in excess of 30,000 ft-lbs (40.7 kN-m), even reportedly over 100,000 ft-lbs (136 kN-m), are available.

In soils of high ground water or in highly caving soils where casing would be required for drilled shafts, helical piles are economical because no hole is created, no casing is required. Regarding schedule, it has been shown that in such conditions approximately ten helical piles can be installed to over 40 ft (12 m) deep in the time it takes to install one cased drilled shaft, and that does not include the concreting time for the drilled shaft. Helical piles require no concrete in the ground.

In tight access locations and environmentally sensitive areas, helical piles can be installed with small skid steer type loaders, small excavators, or hand-carried equipment. Specialty helical pile contractors have installed deep foundations with a 100,000 lbs (445 kN) ultimate capacity per pile inside areas as small as telephone booths and in crawl spaces under existing floors. For hand-carried equipment being used inside an existing building, the hydraulic pump and engine stay outside the building; only the torque motor and hydraulic hoses go inside, thus noise and dust is kept outside.

PART 9. QUALITY CONTROL, INSPECTION AND PERFORMANCE MONITORING

This section is adapted from the paper by John S. Pack, P.E., entitled, "Helical Foundations and Tiebacks: Quality Control, Inspection and Performance Monitoring," published in Deep Foundations Institute 28th Annual Conference on Deep Foundations, Deep Foundations Institute Conference Proceedings, October 22-24, 2003, Miami Beach, Florida, pp. 271-284. This section is designed as a stand alone field inspection manual for helical piles and tension anchors. Therefore, there is some repetition of material already presented above. This section has been updated for this edition.

INTRODUCTION

Helical piles and tiebacks are a several hundred million dollars per year segment of the deep foundation industry that is expected to continue rapid growth. The driving forces behind this growth include 1) An excellent performance record over nearly 30 years of monitoring and 2) Cost competitiveness with its deep foundation cousins: drilled shafts, driven piles and grouted micro-piles. In addition, inclusion of helical piles in the 2009 International Building Code has spurred acceptance in the engineering and construction community. Specified projects ranging from heavily loaded new foundations under high-rise structures down to lightly loaded residential structures are common. Helical piles and tiebacks are now a standard practice for deep foundations and earth retention projects in many parts of the United States, Canada, and elsewhere in the world.

As the use of helical piles and tiebacks accelerates, local building departments and consulting engineers are being called upon in greater numbers to provide quality control, inspection and performance monitoring services for these projects. Also, there is a high demand for manufacturers, distributors, and installation contractors to police their own products and services to ensure the highest quality and performance for helical piles and tiebacks.

While guidance on design and installation techniques is readily available in the literature, detailed information on quality control, inspection and performance monitoring is lacking. This section is an attempt to fill the void. It is based on the experience of the engineers and constructors at D & B Drilling, Inc., Engineering Contractors, and I.M.R., Inc., both of Denver, Colorado, U.S.A., who, since 1986, have directly installed or been involved in the installation of nearly 200,000 individual helical screw piles and tiebacks in a myriad of soil conditions with all types of structures. Specific techniques for quality control, inspection and performance monitoring have been developed that are presented herein.

BRIEF DESCRIPTION

For a detailed description of helical piles and tiebacks, please refer to the other sections in this book or literature available from the various manufacturers of helical pile and tieback material. This section assumes some prior familiarity with helical piles and tiebacks and only briefly describes them as a refresher for the reader.

Helical piles are also referred to as “helical piers,” “helical foundations,” “helical anchors”, “helix piers,” “helix piles,” “helical screw piles” etc. These terms typically refer to the helical pile used primarily as a compression or tension member under a structure where the loads are usually, but not always, vertical. Sometimes the loads are lateral, especially for wind and seismic loading. Helical tiebacks, on the other hand, are the identical type of device that are used solely in a tension mode for earth retention structures. Figure 9-1 depicts helical piles supporting vertical compression loads and lateral loads (wind or seismic, tension or compression). Figure 9-2 depicts a helical tieback supporting lateral soil loads imposed on a retaining wall.

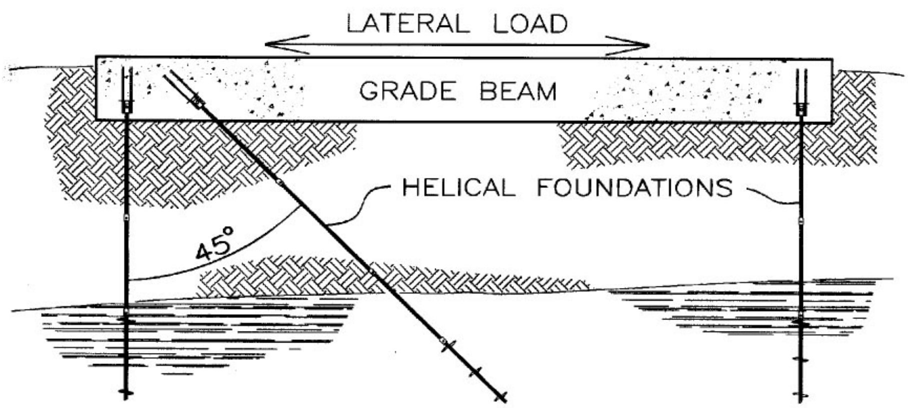

Figure 9-1. Helical Piles Under a Structure

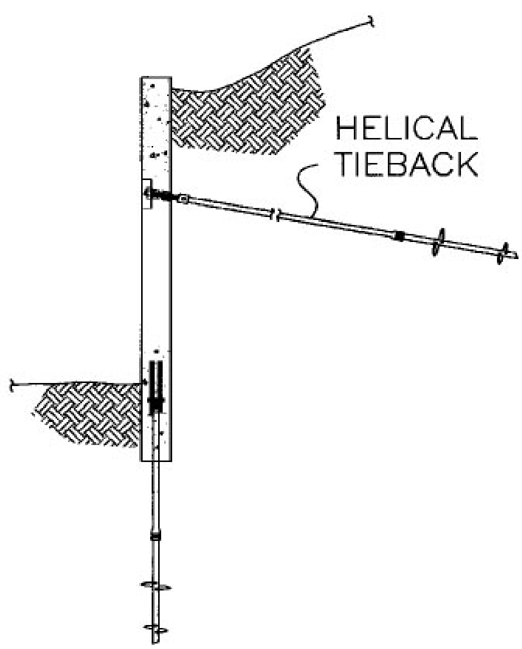

Figure 9-2. Helical Tieback in Retaining Wall

A helical pile or tieback is comprised of one or more circular steel plates split along one radial line and welded to a central solid steel square or pipe shaft, sometimes called a hub. Each plate is shaped in the form of a helix with a leading and trailing edge such that when torsional rotation force (torque) is applied to the central shaft the helix engages the soil and is driven axially into the soil (see helix in Photo 9-10). The helical pile or tieback is installed in segments typically ranging from 3 to 10 feet (1 to 3 m) long. The first segment to engage the soil is called the "lead section" with subsequent segments called "extensions." Extensions may or may not have helices welded to them. Figure 9-1 depicts helical screw piles with three helices welded to the lead section and various plain extensions. Figure 9-2 depicts a helical tieback with two helices welded to the lead section and two plain extensions; the concrete retaining wall is supported by a vertical helical pile with two helices on the lead section and one plain extension.

Each lead section and extension is typically connected by a bolted coupling (see Photo 9-8).

Helical piles and tiebacks use primarily solid steel square bars for the central shaft, however, round pipe shafts are also available. Most manufacturers galvanize their material for corrosion protection (more on this below).

Torque is applied to the helical pile or tieback typically by a hydraulically powered torque drive head mounted to the boom of mobile equipment such as skid-steers or backhoes or mounted on hand-carried equipment. Photograph 9-1 is of a helical screw pile installation using the hydraulic torque drive head mounted on a backhoe boom. Photograph 9-2 is of a helical tieback installation using a torque drive head but in a near horizontal orientation. Photograph 9-5 is a helical tieback installation at a difficult access site using a torque drive head mounted on hand carried equipment.

Photo 9-1 Installation with hydraulic drive head mounted on a backhoe boom.

Photo 9-2 Helical tieback installation with drive head mounted on a skid-steer machine.

APPLICATIONS

It is important for inspecting and quality control personnel to know some of the profusion of applications of helical piles and tiebacks. Photograph 9-3 is of a multiple-story structure designed and constructed on helical piles. The use of helical piles for new foundations for heavily loaded structures is expanding (Pack, John S. (2000). "Design of Helical Piles for Heavily Loaded Structures," ASCE Geotechnical Special Publication Number 100: 353-367). Photograph 9-4 is of a new residential structure designed and constructed on helical piles. Other applications include, but are not limited to:

<u>Helical Pile Applications</u>:

1. Permanent new structural foundations under continuous foundation grade beams or column bases, compression and/or tension loads. Typical ultimate capacities for single helical screw piles range from 50,000 to over 200,000 lbs. (222 to 890 kN). In pile groups, column design loads of 2,000,000 lbs. (8,900 kN) or larger can be supported. Examples of this application would be for single and multiple story buildings, including high-rise structures, new homes and bridges.
2. Permanent battered helical piles to take lateral loads including wind and seismic. Lateral loads are taken as axial compression and/or tension loads. Examples of this application would be those listed in Item 1 above but also including sound walls, bill boards, water towers, etc.
3. Permanent new structural foundations under new concrete slabs.
4. Permanent retrofit foundations in existing structures and additions where new loads are being added to the structure. An example would be where a new mezzanine level is being added inside a building or where new, larger and heavier machines are being installed in an existing factory.
5. Permanent retrofit structural foundations under existing concrete slabs.
6. Permanent retrofit foundations for seismic upgrade purposes.
7. Permanent new foundations under heavy artwork and sculpture.
8. Permanent underpinning of settled or heaved foundations. A steel bracket is used to transfer existing loads from the structure to the helical foundation.
9. Underpinning for permanent or temporary structural shoring, primarily vertical axial compression loading.

Photo 9-3 Multiple-story bldg on helicals.

Photo 9-4 Residential struct. on helicals.

10. Permanent tension hold downs for wind and seismic loads.
11. Machine foundations.
12. Hazardous waste sites where excavation soil or drill spoils are undesirable.
13. New foundations in tight access or inaccessible areas, including boardwalks.
14. Underpinning in tight access or inaccessible areas, primarily vertical axial compression loading.
15. All locations where drilled piers, driven piles or grouted micro-piles are specified.

Helical Tieback Applications:

1. Permanent retaining walls constructed of any materials such as cast-in-place concrete, shotcrete, gunite, soldier beams and wood or concrete lagging, railroad ties, etc.
2. Temporary or permanent shoring.
3. Anywhere where lateral loads must be resisted.
4. All locations where grouted tiebacks are specified and the anchor zone is not in solid rock.

Photograph 9-5 is of a helical tieback installation to repair a low retaining wall in a residential neighborhood. It is being installed with hand-carried equipment. Photograph 9-6 is of an excavation shoring project using helical tiebacks with pre-engineered and pre-fabricated steel shoring panels.

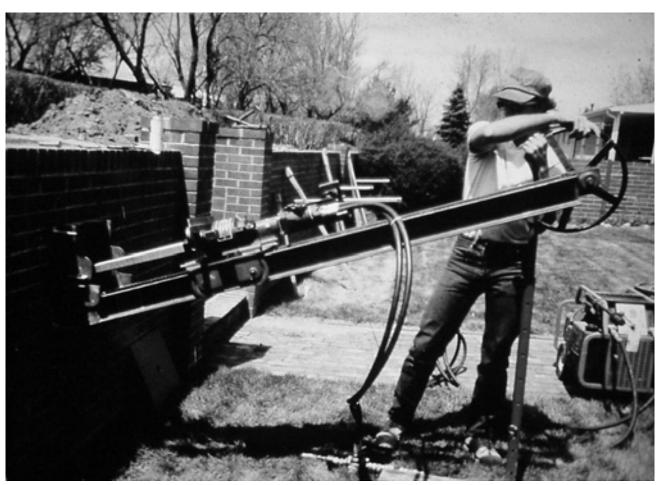

Photo 9-5 Helical tieback in low retaining wall using hand-carried equipment.

Photo 9-6 Excavation shoring using helical tiebacks and pre-engineered shoring panels.

DESIGN RESPONSIBILITY

Design responsibility for helical piles and tension anchors is typically taken by the project structural engineer-of-record who designs, specifies, and seals or stamps the project drawings. Alternatively, the project geotechnical engineer-of-record may take responsibility for helical piles and anchors and seal the project drawings for them only. This assumes the structural and geotechnical engineers are qualified to do so.

If neither the structural nor geotechnical engineer-of-record is qualified to take design responsibility specifically for helical piles or tension anchors, another qualified licensed professional engineer may be hired to do so.

In some cases, the helical pile and tension anchor installation contractor may have engineers on staff who are licensed in the project's jurisdiction and are able to design, specify and seal shop drawings for helical piles and tension anchors. These shop drawings are then submitted to the project engineer-of-record and become part of the sealed and approved project documents.

Many jurisdictions require no specific design analysis or engineer's seal for helical piles or tension anchors where the manufacturer is building code listed and the installation contractor is certified by the manufacturer to install its helical piles or anchors. In this case, the designer calls out on the project drawings the manufacturer's published building code evaluation report numbers, catalog numbers or other published descriptions of the helical devices desired and states that they must be installed in accordance with the manufacturer's instructions.

QUALITY CONTROL PHILOSOPHY

The approach to quality control, inspection and performance monitoring of helical piles and tiebacks is no different than any other type of deep foundation or tieback: layout, penetration into the correct soil formation, capacity, and load transfer from the structure to the pile or tieback are basic. Only some specialized details as covered herein should be added in the inspection process. Performance monitoring techniques are identical to those used for any type of deep foundation or tieback.

Therefore, the inspector who is already familiar with quality control, quality assurance, inspection and performance monitoring of other types of deep foundations and tiebacks is already nearly prepared to deal with helical piles and tiebacks. One must learn only a few specialized techniques and terminology as presented herein to be fully prepared.

PROCEDURES PRIOR TO FIELD WORK

Underpinning vs. New Foundations

"Underpinning" refers to the installation of helical piles under existing structures for the purposes of stabilizing and re-leveling the structures. "New foundations" refers to the installation of helical piles and tiebacks for new structures. Quality control, inspection and performance monitoring techniques are identical for both. Correct layout, penetration into the correct soil formation, capacity, and load transfer from the structure itself to the helical pile or tieback are central to successful performance.

2009 International Building Code

The recently published 2009 International Building Code contains requirements for helical piles. It is recommended that all helical pile projects be designed in accordance with this code. For assistance on using this code, please refer to the section in PART 3. DESIGN CONSIDERATIONS herein entitled "Designing with the 2009 International Building Code Helical Pile Provisions."

Building Code Evaluation Reports

Several years ago the three original building code organizations in the U.S., BOCA, ICBO, and SBCCI merged to form the International Code Council (ICC). ICC now publishes the International Building Code (IBC) that is used by many cities and other jurisdictions. Prior to formation of the ICC several helical pile and tension anchor manufacturers obtain building code evaluation reports that have been grandfathered under the new IBC as Legacy Reports. Those evaluation reports are available at www.icc-es.org. However, under the new IBC, all manufacturers are required to have new evaluations reports written for the IBC, even if they already have a Legacy Report. As of this writing no manufacturers have such a report, although several are working on it. A current update of the status of new evaluation reports may be obtained at www.ecc-es.org.

Until new evaluation reports are written, engineers and building officials may use the helical pile provisions contained in the 2009 International Building Code. Even after the reports are written, the provisions of the code will still be in effect. This is because evaluation reports do not take the place of the 2009 International Building Code, they supplement it.

Manufacturing Process and Quality Control During Manufacture

Quality control and inspection personnel should ascertain the method of manufacture. Such methods will have a direct bearing on the quality and performance of the installed helical pile or tieback.

All manufacturers of helical piles and tension anchors obtain the shaft and helix material from outside steel suppliers. Manufacturers should keep records of the steel supplier, steel strength, and heat number. Thus, if a problem occurs in material, the original component supplier can be contacted to prevent further problems.

All welded connections should be shop welded by certified welders to American Welding Society standards and to the correct strengths required for the helical pile or tieback factory rated capacities. All manufacturers should provide proof of weld certification and weld strength upon request.

Couplings are typically constructed by a cold-forged welded process (Photo 9-7), a modular keyed and locked process (Photo 9-8), or a hot-forged upset process (Photo 9-9).

The manufacturer should certify the coupling (and bolt, where used) is of correct steel strength and size to meet the factory rated capacity of the helical pile or tieback in both axial tension and compression loads and for installation torque transfer.

Photo 9-7
Cold-forged welded

Photo 9-8
Modular keyed and locked

Photo 9-9
Hot-forged Upset

Photo 9-10 Helix welded to the central shaft

The weld of the helix to the shaft is a critical element. The manufacturer must be able to certify this weld is compatible with the intended rated capacity of the helical pile. The helix must be able to withstand forces imposed upon it during installation, especially in dense soil and/or cobbles. Photograph 9-10 is of a typical helix welded to the shaft. Note the leading (lower) and trailing (upper) edges indicating clockwise installation. Photograph 9-10 shows an essentially straight leading edge with a beveled “rock cut.” However, some manufacturers prefer a straight or rounded leading edge. Some field conditions may necessitate modifying a portion of the leading edge as shown in Figure 9-3 below to aid installation in cobble formations, although the helix shown above in Photo 9-10 is manufactured with the cut already on the leading edge.

Material and Installation Specifications

Most manufacturers have developed specifications for their particular helical pile or tieback. Outside organizations such as Spec-Data® and Manu-Spec®, both of the Construction Specifications Institute, have been hired by some manufacturers to assist in developing specifications.

Specifications should include all components of the helical pile or tieback and installation requirements. Alternatively, specifications may call out manufacturers' names and their respective catalog numbers. Building code evaluation report numbers should be included.

Upon review of the various manufacturers' specifications, it will be noted that between manufacturers helical pile and tieback material is not equal, even if it has an equal visual appearance. Engineers and quality control and inspection personnel should familiarize themselves with the respective specifications and make their own evaluations as to the suitability of a particular manufacturer's material for their project.

Sample helical pile and tieback specifications are presented in PART 6. SAMPLE SPECIFICATIONS above.

Galvanization

It will be noted in the sample specifications given in PART 6. SAMPLE SPECIFICATIONS above that galvanizing in accordance with ASTM B633 is specified. This is the method typically used by most manufacturers. Proof of the galvanization process should be supplied by the manufacturer upon request.

Other corrosion protection coatings, or no coating whatsoever, as approved by the designer, are allowed and occasionally specified.

Installation Contractor Certification

The installation contractor should be required to show proof of certification to install the specified manufacturer's helical pile or tieback material if such is required by the manufacturer or the specification. Certification is confirmation that the installation contractor is trained and familiar with the installation of that manufacturer's material. Certification acknowledges the contractor has specialized knowledge beyond what is required for general construction. In addition to certification, the installation contractor should show project experience or, if new in the business, show that qualified personnel, either from the distributor or manufacturer, will be present for part, if not all, of the project.

Proof of certification is usually in the form of a pocket certificate card bearing the manufacturer's name, contractor's name, date of certificate expiration and the signature of the manufacturer's representative certifying the installation contractor is trained and qualified to install their helical piles or tiebacks.

It is recommended that, in addition to initial certification, the installation contractor be re-trained and re-certified at least every two years.

PROCEDURES DURING FIELD WORK

Field Layout

Field layout of helical piles and tiebacks may be performed by the design engineer, his or her representative, the general contractor, or the helical screw pile installation contractor. As on any project, quality control and inspection personnel must check layout work to ensure the piles or tiebacks are properly located.

At commencement of installation, it is important to maintain precise pile or tieback location. In most cases, however, especially if the designer has accounted for slight misalignment (±0.5 inch (±12.7 mm)), this is not a problem.

Experienced installation contractors have ways of ensuring alignment during installation. The more cobbley the formation, the more difficult it is to hold alignment during installation; the shaft can have a tendency to "walk" off its original location. Procedures have been developed to keep the shaft in place at commencement and while it is being installed. Experienced installation contractors should be consulted about such procedures.

Installation Requirements and Procedures

Installation Torque Measurement:

Helical piles and tiebacks are typically installed with hydraulic torque drive heads mounted to mobile equipment such as the boom of a backhoe or skid-steer type machine (see Photographs 9-1 and 9-2) or hand-carried equipment (see Photograph 9-5). Also, please see the "IMR Installation Equipment Photographs" pages 1-7 through 1-12 in PART 1. INTRODUCTION at the beginning of this book. Other types of installation equipment are acceptable as long as they can impart the necessary torque to the helical pile or tieback shaft.

Installation torque is a direct measurement of helical screw pile or tieback capacity (see PART 2. CAPACITY CALCULATIONS above). It is an indicator that the pile or tieback has penetrated the correct soil formation. Therefore, it is important that accurate torque measurements be made.

There are two ways to measure installation torque:

1. A mechanical device can be inserted between the installation torque drive head and the helical pile or tieback shaft. The most common device is called a "shear pin torque indicator." Photograph 9-11 is of a shear pin torque indicator. It utilizes short steel pins inserted in holes spaced around the circumference of a transversely split free-spinning cylinder. The holes penetrate the two halves of the cylinder such that when pins are inserted free-spinning cannot occur until the pins are sheared. The more pins inserted, the more force, or torque, is required to shear the pins.

Photo 9-11 Shear-pin torque indicator.

The shear pin torque indicator shown in Photo 9-11 has holes for 20 pins. For this particular device, each pin is worth 500 ft-lbs (0.68 kN-m) of installation torque. Therefore, if pins were inserted in all 20 holes simultaneously, it would require 10,000 ft-lbs (13.6 kN-m) of installation torque to shear all 20 pins.

In a typical helical pile or tieback installation, the procedure is to insert the number of pins required to measure the desired installation torque. Once the pins shear, the shear-pin torque indicator is loaded with a fresh set of pins and they are sheared again. Therefore, by shearing pins two times in immediate succession, one is assured that a correct and not false torque reading is obtained.

2. The second way to measure installation torque is by reading torque directly from the installation device. In the case of a hydraulic torque drive head, there is a direct relationship between installation torque and the pressure drop across the motor. Most drive head manufacturers publish charts of output torque vs. hydraulic pressure drop.

As opposed to using published charts, sometimes precise torque vs. pressure measurements are not possible due to motor wear, weather conditions, and high hydraulic oil temperature. However, the torque vs. pressure relationship may be calibrated using the shear-pin torque indicator. This is done by reading the system pressure gauge at the moment pins are sheared and correlating the torque to the pressure. This method is used regularly on projects where it will be time consuming to use the shear-pin torque indicator on every pile or tieback. One merely correlates torque vs. pressure from time to time with the shear-pin torque indicator while the majority of piles or tiebacks are install-led by determining installation torque from reading the calibrated system pressure gauge.

Refusal

Refusal occurs when the helical pile or tieback does not advance further into the soil as it is rotated due to encountering hard earth material. Many helical piles are installed to this condition as this is usually an indicator of high compression load capacity. Low installation torque values occasionally accompany the refusal condition. This does not mean low compression capacity. Determination of the adequacy of the refusal condition should be made by the engineers involved in consultation with the installation contractor. Inspectors need to be aware that refusal is a common occurrence. See the “Refusal Condition in Extremely Dense Soil, Rock and Cobble” section under PART 3. DESIGN CONSIDERATIONS above for a detailed discussion of refusal.

Permanent Shaft Wrap or Twist

Most helical pile and tieback shafts are designed to undergo permanent shaft wrap or twist as the installation torque increases to the maximum factory rating. This occurrence is normal, acceptable, and is a visual indicator of high installation torque. However, the degree of permanent shaft wrap is not used as a precise measure of torque. Most manufacturers have published maximum torque ratings for their helical piles and tiebacks that are below the torque magnitude that could cause damage to the shaft. For example, to avoid damaging the shaft, the A.B. Chance Company has stated to this author that permanent shaft wrap should never exceed 1.5 revolutions in any five foot (1.5 m) length. Permanent shaft wrap does not adversely affect the galvanizing performed per ASTM B633.

Field Observations and Installation Log

To assist the field inspector in recording accurate site observations during the installation of helical piles and tiebacks, an installation log should be kept and recorded by the inspector. The log should contain the field observation data listed in Section 3.2.2.7 of the sample extended specification given in PART 6. SAMPLE SPECIFICATIONS. These items include, but are not necessarily limited to: a) Project name and location, b) Name of authorized and certified dealer and installer, c) Name of installer's foremen or representative witnessing the installation, d) Date of installation, e) Location of helical pile or tieback, f) Description of lead section including number and diameter of helices and extensions used, g) Overall depth of installation from a known reference point, h) Installation torque at termination of pile or tieback and i) Load transfer device. In addition, the pile or tieback field layout locations should be verified and recorded by the inspector.

Field Modifications

Shaft Field Modification: Helical pile and tieback depth will equal the depth of the soil formation where the desired installation torque will be reached. Because this depth is usually not exactly predictable, the top of the shaft left protruding above grade may not be at the correct elevation or position to attach to the structure properly. This necessitates cutting the shaft to the correct elevation or length. If the shaft is cut for a new foundation, it may then be necessary to drill a new hole in the shaft to bolt on the load transfer device, or the device must be epoxy glued or welded onto the shaft, depending on the specification. For underpinning, typically no rigid connection to an underpinning bracket is required because structure dead load is sufficient to keep the underpinning bracket rigid and in place.

Helix Field Modifications: It is allowable to reduce helix diameter in the field. Example: A 10 inch (254 mm) diameter helix may be reduced in diameter to 8 or 6 inches (203 or 152 mm) if the pile or tieback must penetrate into a denser formation than anticipated. The helix diameter should not be reduced below 6 inches (152 mm). For cobble conditions, the leading edge of the helix may be modified as shown in Figure 9-3 to ease penetration into the formation. Figure 9-3 shows a cross-section of the shaft and the helix where the leading edge has been modified, termed a "rock cut," for cobble conditions. I.M.R. produces all of its helices in this shape in the factory.

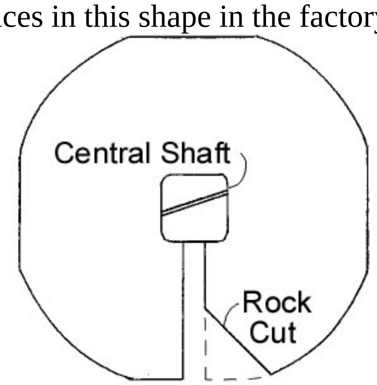

Figure 9-3. Shaft Cross Section, Rock Cut on Helix

Load Transfer Devices

Load transfer devices transfer structural loads to the helical pile or tieback shaft. These devices are typically designed by the structural engineer. They bolt, weld, epoxy glue to or slide over the end of the helical pile or tieback shaft. Figure 9-4 shows two load transfer devices used for new construction attached to the top of helical piles embedded in a new reinforced concrete grade beam (reinforcing not shown for clarity). Tiebacks typically transfer load via a threaded rod adapter with load plate and nut. See the “A.B. Chance Company Drawings” in the Appendix for threaded adapters. For further load transfer device information, please see “Load Transfer Devices” under PART 3. DESIGN CONSIDERATIONS above.

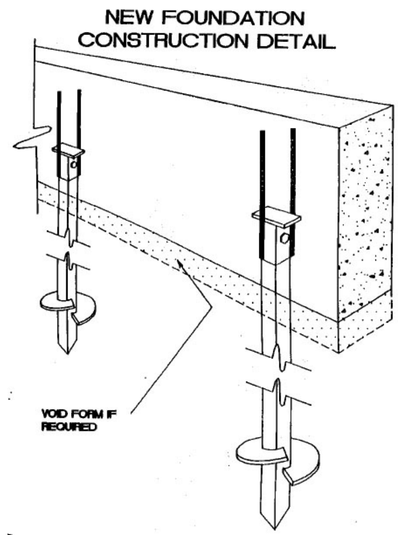

Figure 9-4. New Construction Bracket Embedded within a Reinforced Concrete Grade Beam

Figure 9-5 shows a load transfer device used for underpinning an existing foundation. In this particular bracket, a bottle jack is temporarily inserted in the bracket to allow the existing concrete foundation to be raised for re-leveling purposes.

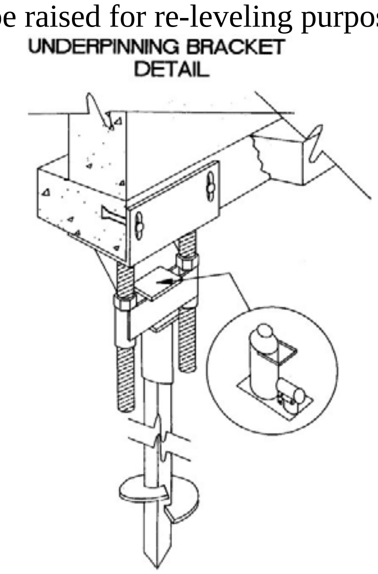

Figure 9-5. Underpinning Bracket with Existing Foundations

Building Code and Specification Compliance and Special Inspection

As with any construction project, quality control and inspection personnel must be familiar with the building code having jurisdiction and the project specification. Prior to helical foundation or tieback installation, plan check personnel should review construction drawings and calculations for compliance. During installation, inspection personnel must check field materials and construction activities for compliance. Special inspection may be required. For the most part, the field inspection requirements are similar to those indicated in Section 3.2.2.7 of the sample extended specification given in PART 6. SAMPLE SPECIFICATIONS above. These items include, but are not necessarily limited to: a) Project name and location, b) Name of authorized and certified dealer and installer, c) Name of installer's foremen or representative witnessing the installation, d) Date of installation, e) Location of helical pile or tieback, f) Description of lead section including number and diameter of helices and extensions used, g) Overall depth of installation from a known reference point, h) Installation torque at termination of pile or tieback and i) Load transfer device. In addition, the pile or tieback field layout locations should be verified and recorded by the inspector.

PERFORMANCE MONITORING

Field Survey

Performance monitoring of helical piles and tiebacks is identical to the performance monitoring of any foundation or tieback system.

Since the purpose of the structural foundation is to provide a stable base upon which structural loads are transferred to the soil, performance monitoring measures the ability of the foundation to perform this purpose over the period of time of interest.

The key to effective performance monitoring of any foundation system used for the repair of existing failed foundations or for new construction is to first obtain the base data. Base data usually includes elevations of floors or other prominent points of the structure measured at the time of project completion. The points used must be accessible such that subsequent elevations can be measured from time to time throughout the monitoring period.

Many devices are available to perform floor elevation surveys such as a water manometer, surveyor's level and rod and a commercial device called a "Ziplevel®", a self-contained elevation measurement device accurate to 0.1 inch (2.5 mm) that can be operated by one man even in a building with doors, walls, and corners. (See www.ziplevel.com)

An example of the results of a floor elevation survey in a residential structure is shown in Figure 9-6, the floor plan of an existing building with elevations indicated at certain points. In subsequent years further surveys can be run to verify that the foundation continues to remain stable. This method is adaptable to any project.

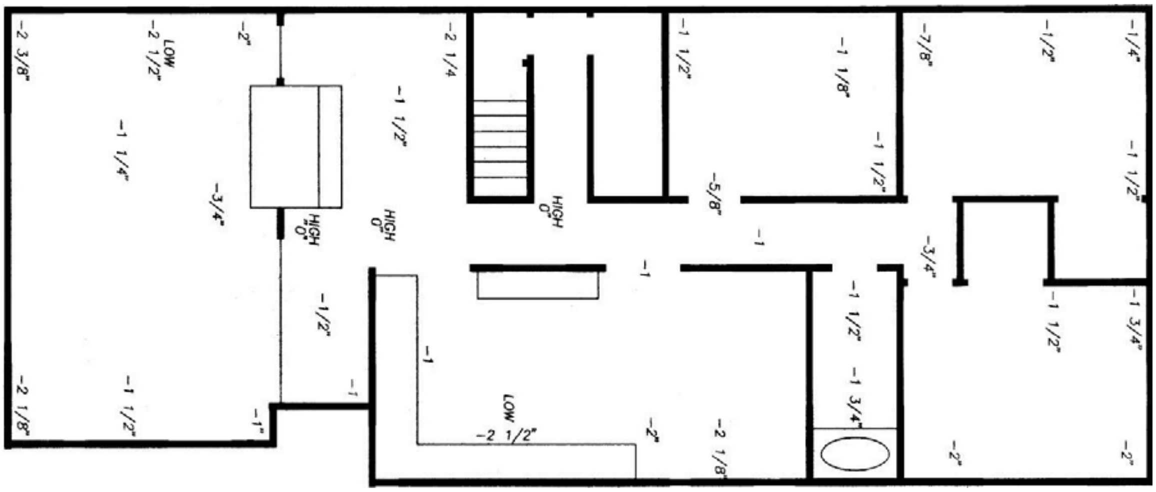

Figure 9-6. Sample Floor Level Survey for Base Data

Visual Monitoring

The most common method of performance monitoring is through visual observation. The most common observations made in new structures and existing repaired structures include, but are not limit to:

Buildings

Observe that:

1. Floors remain level.
2. Cracks in interior floors, walls, and ceilings remain the same size and do not reappear.
3. Cracks in exterior walls remain the same size and do not reappear.
4. Doors continue to fully open or close.
5. Doors continue to not swing open or closed.
6. Windows continue to fully open or close.
7. Cracks I foundation walls remain the same size and do not reappear.
8. Gaps under walls or between concrete porches and walks and the building wall remain the same size and do not reappear.

Earth Retention Structures

Observe that:

1. Retaining wall remains plumb.
2. Cracks in the retaining wall remain the same size and do not reappear.
3. Wall does not settle or heave.
4. There is no subsidence of soil behind the wall.

Cracks in walls, ceilings, floors, etc., can be monitored over time using crack measuring devices available from most engineering supply companies.

EXAMPLE OF A STEP BY STEP QUALITY CONTROL, INSPECTION AND PERFORMANCE MONITORING PROGRAM

A new three-story office building is to be constructed in an office park. The building is designed with a helical pile deep foundation in a city where the 2009 International Building Code (IBC) governs. The building was designed by a local architect who enlisted the services of local consulting geotechnical and structural engineers. The foundation plan containing the helical screw pile design is prepared by the structural engineer and bears his/her professional engineer stamp. The building permit was issued by the city where the building is located.

The helical screw piles are to be installed by "John Doe Foundation Company," a company licensed in the state to do helical pile work.

A step by step quality control, inspection and performance monitoring program for this project is given below:

1. Who is inspecting this helical screw pile installation?
Inspection is being provided by a consulting engineering firm specializing in construction inspection who is also designated as a "special inspector" per the IBC and the city building official.

2. Are the geotechnical and structural engineers involved with any inspection on this project as related to the helical piles?
Yes, but on an intermittent basis. The primary responsibility for inspection is with the inspection firm.

3. What helical screw piles are to be used?
The helical piles to be used in this building have been designed in accordance with the provisions of the 2009 International Building Code. The structural engineer has submitted shop drawings proving the manufacturer meets the project specification for helical screw piles.

4. What quality control programs are followed by the manufacturer to ensure a high quality product?
All welders are AWS certified. Shop drawings indicate the helical screw pile steel meets the project specifications.

5. What are the specific project requirements: helical pile sizes, torque requirements, layout, load transfer devices, etc.?
The drawings and specification prepared by the consulting engineers indicate the general family of helical screw piles to be used and their specific material identifiers (see sample specification in the PART 6. SAMPLE SPECIFICATIONS), design load for each pile, factor of safety to be used (typically 2), installation torque, layout and load transfer device. The specification requires the installation contractor to submit to the engineer specifics on what material he will install that will meet the engineer's specification, i.e.,

description of helical piles, catalog numbers, size and number of helices, size of shaft, etc. A written description or shop drawing with this information must be submitted to the engineer for approval.

The owner's surveyor is responsible for helical pile layout.

6. Who has design responsibility for the helical piles themselves?
The structural engineer-of-record is qualified to design and specify helical piles. His professional stamp appears on the drawings. If the structural engineer had not felt qualified, the soil engineer or a qualified engineer hired by the installation contractor or the manufacturer could stamp the drawings.

7. Is John Doe Foundation Company qualified?
The installation contractor is certified by the helical pile manufacturer to be qualified as evidenced by the certification card.

8. When John Doe Foundation Company shows up to install the helical piles, is the correct material being brought on-site?
The helical pile material has a visual appearance of galvanization. Most important, it is marked with the manufacturer's identification mark or code identifying it as the correct material. The dimensions of the material are verified to meet the specification. Therefore, the correct material is on-site.

9. Is the correct installation equipment being utilized by John Doe Foundation Company?
Being a certified installation contractor, it can be assumed the correct installation equipment for the helical pile material specified is to be used and that the equipment meets the project specification. However, the equipment should be observed during installation to verify it meets the specification and the installation procedures meet the specification.

10. Is the shear-pin torque indicator prepared for measuring installation torque?
Yes.

11. Is the installation log ready for use?
The installation log designed as described above under "Field Observations and Installation Log" is prepared for recording the pile lead section description, number of extensions and extension description, pile total depth, load transfer bracket or device, etc., for each helical pile installed.

12. Is the helical pile layout correct?
The owner's surveyor is responsible for the field layout of the helical screw piles. However, just prior to commencement of each helical pile installation, the field layout is observed and compared to the construction drawings to be reasonably sure the layout looks correct.

13. <u>During installation, are all parameters being recorded as given on the log?</u>
All parameters are being recorded.

14. <u>Are the specified parameters being reached?</u>
Yes, as shown by observation and recorded from the shear-pin torque indicator or pressure gauge on the hydraulic drive head calibrated by the shear-pin torque indicator.

15. <u>Is permanent shaft wrap occurring?</u>
Yes, but it is within the limits indicated by the manufacturer.

16. <u>Are load transfer devices being installed as specified?</u>
Yes.

17. <u>Is special inspection being done if required?</u>
Yes, the inspector is a certified IBC inspector.

18. <u>Who will "sign off" on the helical piles after completion of the project as required by the city?</u>
The structural engineer-of-record signs off on the helical piles as the original designer.

19. <u>Who is responsible for performance monitoring?</u>
The owner has contracted with the inspection firm to do the performance monitoring.

20. <u>How is the performance monitoring base data being procured?</u>
A level survey will be performed where the elevation of certain points will be measured and recorded. It has been determined that points on the main floor throughout the building are best. Therefore, a floor level survey will be performed immediately upon completion of the project.

21. <u>How will performance over time be measured?</u>
A new floor level survey will be performed six months after completion of the project. The owner will then decide when to do the next survey, if at all, based on the results of the new floor level survey and advice from the geotechnical and structural engineers of record.

CONCLUSION: QUALITY CONTROL, INSPECTION AND PERFORMANCE MONITORING

Quality control, inspection and performance monitoring for helical piles and tiebacks is a straight forward process easily learned and executed. Most of the process is identical to all deep foundation construction projects, only a few procedures are unique to the helical pile and tieback industry. The information contained in this section will allow all design and construction professionals to properly and accurately perform the quality control, inspection and performance monitoring function.

PART 10. CONTRACTS

Helical pile contracts are organized similarly to those of drilled shafts, except they are written to furnish and install material. If much sub-surface information is known about a particular site, especially the results of helical pile test installs, the contractor may lump sum bid the piles or tiebacks, regardless of depth. If there is not sufficient sub-surface information available, the contractor may bid each pile or tieback on a per foot basis of installed pile or tieback. However, the most common contract calls for a base depth plus an overrun of a certain number of dollars per foot deeper than the base depth.

It should be emphasized that, as in all geotechnical construction, the more that is known about a site, the more economical the project will be. Sub-surface soil investigations, especially where test helical piles or tiebacks have been installed, are welcomed.

PART 11. COSTS

The existence of thousands of specialty helical pile contractors in business throughout the world attests to the fact that helical piles are competitive with other types of deep foundations. This is true for new foundations, including heavily loaded foundations, as well as the repair of existing foundations. It is impossible to delineate representative costs herein because, as any experienced geotechnical engineer and/or contractor knows, each site is so different, each case so unique, it is impractical to give "rules of thumb" or even representative guidelines. Local specialty contractors are willing and able to provide bids. In preparing engineer's estimates, these local specialty contractors should be contacted directly. Local specialty contractors know the soils in a particular area which allows them to give responsive bids and estimates.

PART 12. CONCLUSION

The helical pile is a viable and accepted deep foundation for the construction of new and the repair of heavy and lightly loaded structures. The design methodology for helical piles is similar to the design methodology for any deep foundation system. Helical piles are pure axially loaded member and must be used only as such. Proper placement of vertical and battered helical piles allows all vertical and lateral loads to be transferred from the structure to the soil. The designer must utilize the data provided by a soil investigation to check the helical piles for minimum depth, minimum installation torque requirements, load capacity, slenderness buckling, and corrosion. By following the straight forward procedures presented herein, the designer can design an economical and rapidly installed deep foundation system.

Whenever soil conditions at a particular site suggest that a deep foundation system should be considered, the wise design professional should consider helical piles along with the other deep foundation alternatives available. As long as all technical requirements of the project are met, the economics and schedule requirements and constraints should dictate which foundation system is selected.

APPENDIX

Most of the drawings in the Appendix may be downloaded from www.helipile.com in *.pdf, *.dwg, and *.dxf formats.

Table of Contents

I.M.R. HELI-PILE® Helical Pile Drawings

I.M.R. Load Transfer Device Drawings, Test Data, and Sample Calculations

Appendix Table of Contents (continued)

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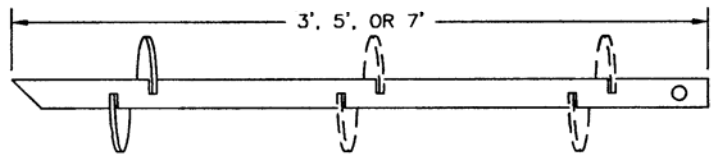
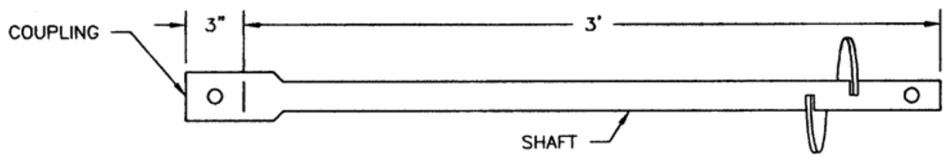
HPC-15X

1.5" HELI-PILE® CONVENTIONAL HELICAL PILE

CATALOG NUMBERS BEGINNING WITH HPCL-15X AND HPCE-15X
(EXTRA HIGH STRENGTH SHAFT STEEL, Fy=90 KSI)



LEAD SECTION
SINGLE OR MULTIPLE HELIX
NO SCALE



HELIX EXTENSION
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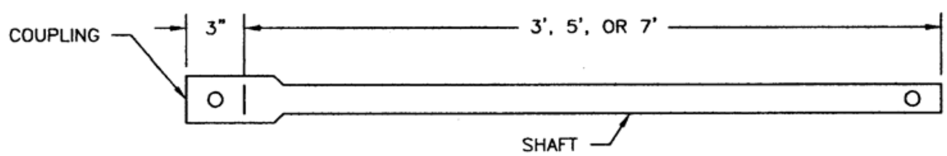

PLAIN EXTENSION
NO SCALE

1. THIS DRAWING COVER 1.5" HELI-PILE ® SOLID ROUND CORNER SQUARE SHAFT HELICAL PILES. (CATALOG NUMBERS BEGINNING WITH HPCL-15X & HPCE-15X)
2. SOLID ROUND CORNER SQUARE SHAFT MATERIAL IS PER ASTM A29 OR AISI 1530, Fy=90 KSI
3. ALL HELIX MATERIAL IS 0.5" THICK AND IS PER ASTM A656 Gr 80 TYPE 7 (Fy=80 KSI).
4. CONNECTION BOLTS ARE 0.75" DIAMETER ASTM A449, 3" LONG, THREADS OUTSIDE THE SHEAR ZONE.
5. ALL WELDS MINIMUM 0.25" FILLET WITH ER70S ELECTRODE.
6. ALL STEEL IS GALVANIZED PER ASTM B633-85 FE/ZN 5, TYPE III
7. ULTIMATE AXIAL MECHANICAL CAPACITY IS 70,000 LBS.
8. ULTIMATE SHAFT TORQUE CAPACITY IS 7,000 FT-LBS.
9. ULTIMATE HELIX MECHANICAL CAPACITY: 6"-12" DIAMETER = 70,000 LBS, 14" DIAMETER = 56,000 LBS

HELI-PILE®	SPECIFICATION SHEET		1.5" CONVENTIONAL EXTRA HIGH STRENGTH HELICAL PILES	
IMR, Inc. - DENVER 5135 Ward Road, Wheat Ridge, Colorado, USA 303-423-0591 Fax: 303-423-9155 www.helipile.com			HPC-15X.DWG	SHEET 1 OF 1
	DRAWN BY: CSM	ENGINEER: JSP	DATE: 05/19/09	REVISION: 1

HPC-17

1.75" HELI-PILE® CONVENTIONAL HELICAL PILE

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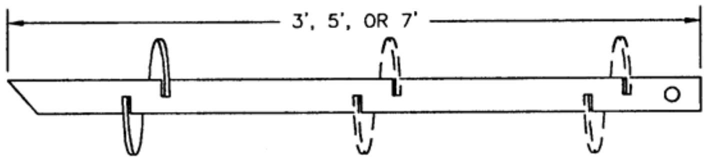

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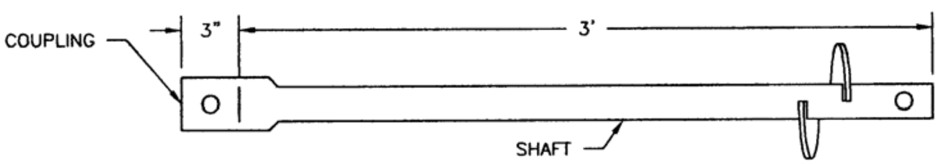

HELIX EXTENSION
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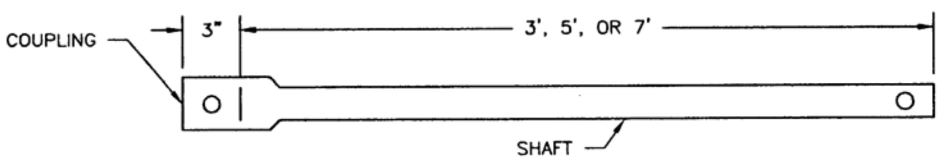

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2. SOLID ROUND CORNER SQUARE SHAFT MATERIAL IS PER ASTM A29 OR AISI 1530, Fy=90 KSI
3. ALL HELIX MATERIAL IS 0.5" THICK AND IS PER ASTM A656 Gr 80 TYPE 7 (Fy=80 KSI).
4. CONNECTION BOLTS ARE 0.875" DIAMETER ASTM A193 GRADE B, 3.5" LONG, THREADS OUTSIDE THE SHEAR ZONE.
5. ALL WELDS MINIMUM 0.25" FILLET WITH ER70S ELECTRODE.
6. ALL STEEL IS GALVANIZED PER ASTM B633-85 FE/ZN 5, TYPE III
7. ULTIMATE AXIAL MECHANICAL CAPACITY IS 110,000 LBS.
8. ULTIMATE SHAFT TORQUE CAPACITY IS 11,000 FT-LBS.
9. ULTIMATE HELIX MECHANICAL CAPACITY: 6"-12" DIAMETER = 70,000 LBS, 14" DIAMETER = 56,000 LBS

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			HPC-17.DWG	SHEET 1 OF 1
	DRAWN BY: CSM	ENGINEER: JSP	DATE: 05/19/09	REVISION: 1

HPC–20

2.0" HELI–PILE® CONVENTIONAL HELICAL PILE

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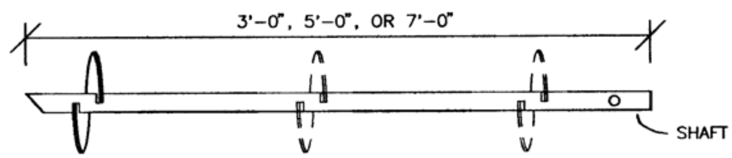

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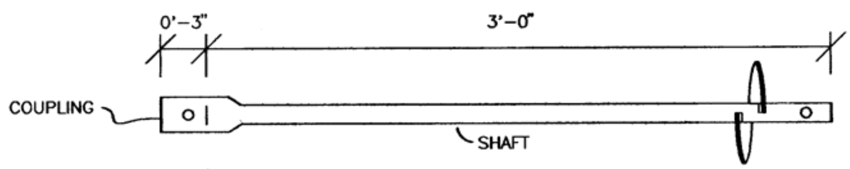

HELIX EXTENSION
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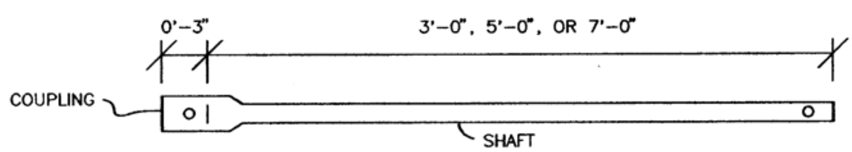

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1. THIS DRAWING COVERS 2.0" HELI–PILE® SOLID ROUND CORNER SQUARE SHAFT HELICAL PILES. (CATALOG NUMBERS BEGINNING WITH HPCL–20 & HPCE–20)
2. SOLID ROUND CORNER SQUARE SHAFT MATERIAL IS PER ASTM A29 OR AISI 1530, Fy = 90 KSI.
3. ALL HELIX MATERIAL IS 0.5" THICK AND IS PER ASTM A656 Gr 80 TYPE 7 (Fy = 80 KSI).
4. ALL CONNECTION BOLTS ARE 1.0" DIAMETER A193 GRADE B7, THREADS OUTSIDE THE SHEAR ZONE.
5. ALL WELDS MINIMUM 0.25" FILLET WITH ER70S ELECTRODE.
6. ALL STEEL IS GALVANIZED PER ASTM B633–85 FE/ZN 5, TYPE III.
7. ULTIMATE AXIAL MECHANICAL CAPACITY IS 150,000 LBS.
8. ULTIMATE SHAFT TORQUE CAPACITY IS 16,000 FT–LBS.
9. ULTIMATE HELIX MECHANICAL CAPACITY: 6" THROUGH 12" DIAMETER = 70,000 LBS, 14" DIAMETER = 56,000 LBS.

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2.0" CONVENTIONAL EXTRA HIGH STRENGTH HELICAL PILES
DWG. HPC–20
SHEET 1 OF 1

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JSP	JSP	07/15/09	0

HPC–225

2.25" HELI–PILE® CONVENTIONAL HELICAL PILE

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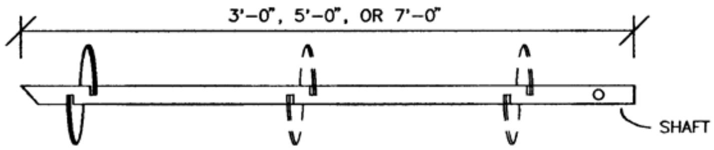

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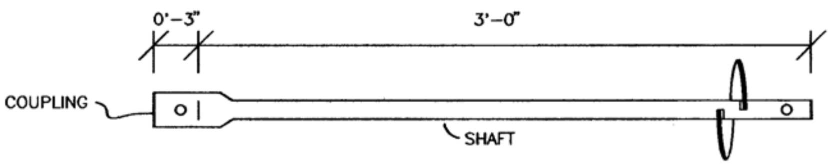

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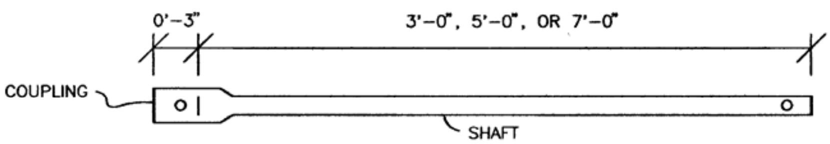

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1. THIS DRAWING COVERS 2.25" HELI–PILE® SOLID ROUND CORNER SQUARE SHAFT HELICAL PILES. (CATALOG NUMBERS BEGINNING WITH HPCL–225 & HPCE–225)
2. SOLID ROUND CORNER SQUARE SHAFT MATERIAL IS PER ASTM A29 OR AISI 1530, Fy = 90 KSI.
3. ALL HELIX MATERIAL IS 0.5" THICK AND IS PER ASTM A656 Gr 80 TYPE 7 (Fy = 80 KSI).
4. ALL CONNECTION BOLTS ARE 1.25" DIAMETER A193 GRADE B7, THREADS OUTSIDE THE SHEAR ZONE.
5. ALL WELDS MINIMUM 0.25" FILLET WITH ER70S ELECTRODE.
6. ALL STEEL IS GALVANIZED PER ASTM B633–85 FE/ZN 5, TYPE III.
7. ULTIMATE AXIAL MECHANICAL CAPACITY IS 200,000 LBS.
8. ULTIMATE SHAFT TORQUE CAPACITY IS 23,000 FT–LBS.
9. ULTIMATE HELIX MECHANICAL CAPACITY: 6" THROUGH 12" DIAMETER = 70,000 LBS, 14" DIAMETER = 56,000 LBS.

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SPECIFICATION SHEET

2.25" CONVENTIONAL EXTRA HIGH STRENGTH HELICAL PILES
DWG. HPC–225
SHEET 1 OF 1

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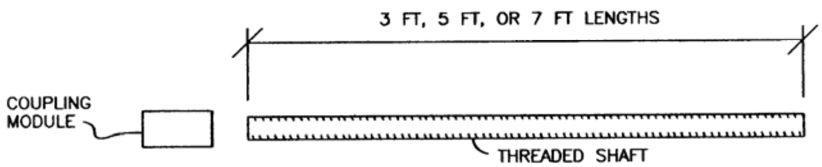

EXTENSION

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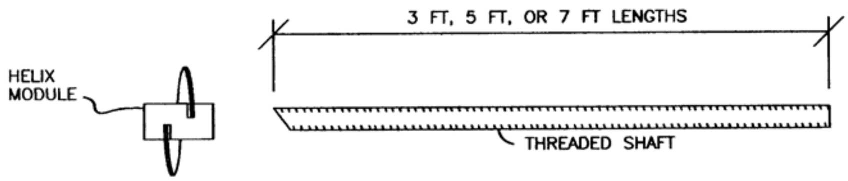


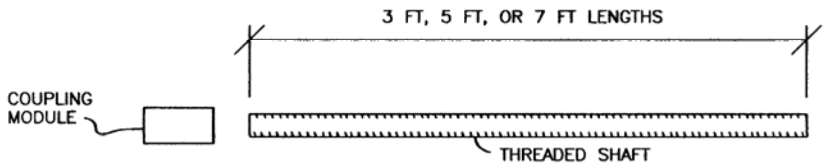
LEAD SECTION – SINGLE OR MULTIPLE HELIX

NO SCALE

NOTES:

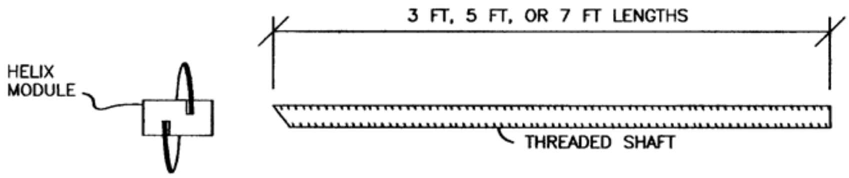
1. ALL SHAFTS PER ASTM A29, Fy = 90 KSI, 1.5 INCH SQUARE.
2. ALL HELICES 0.5 INCH THICK AND ARE PER ASTM A656, Gr 80 TYPE 7 (Fy = 80 KSI).
3. HELIX MODULES COME IN 8 INCH, 10 INCH, 12 INCH, AND 14 INCH DIAMETERS.
4. ALL HELIX AND COUPLING MODULES ATTACHED TO THE THREADED SHAFT VIA STEEL KEYS.
5. LOAD TRANSFER MODULES (NOT SHOWN) SCREW TO THE THREADED SHAFT.
6. LOAD TRANSFER MODULES ARE DESIGNED FOR 70 KIP ULTIMATE CAPACITY, TENSION OR COMPRESSION.
7. ULTIMATE CAPACITY OF SHAFT/HELIX/LOAD TRANSFER MODULES IS 70 KIPS, TENSION OR COMPRESSION.
8. ULTIMATE INSTALLATION TORQUE IS 7,000 FT–LBS.
9. ALL STEEL GALVANIZED PER ASTM B633–85 FE/ZN 5, TYPE III, APPLIED BY AN ISO 9000 COMPANY.

HELI-PILE®	SPECIFICATION SHEET	1.5 INCH MODULAR EXTRA HIGH STRENGTH HELICAL PILES DWG. HP–15X SHEET 1 OF 1
IMR, Inc. – DENVER 5135 Ward Road, Wheat Ridge, Colorado, USA 303–423–0591 Fax: 303–423–9155 www.imrpiers.com	DRAWN BY: JSP	CHECKED: RLJ	DATE: 05/05/09	REVISION: 0



EXTENSION

NO SCALE



LEAD SECTION – SINGLE OR MULTIPLE HELIX

NO SCALE

NOTES:
1. ALL SHAFTS PER ASTM A29, Fy = 90 KSI, 1.75 INCH SQUARE.
2. ALL HELICES 0.5 INCH THICK AND ARE PER ASTM A656, Gr 80 TYPE 7 (Fy = 80 KSI).
3. HELIX MODULES COME IN 8 INCH, 10 INCH, 12 INCH, AND 14 INCH DIAMETERS.
4. ALL HELIX AND COUPLING MODULES ATTACHED TO THE THREADED SHAFT VIA STEEL KEYS.
5. LOAD TRANSFER MODULES (NOT SHOWN) SCREW TO THE THREADED SHAFT.
6. LOAD TRANSFER MODULES ARE DESIGNED FOR 110 KIP ULTIMATE CAPACITY, TENSION OR COMPRESSION.
7. ULTIMATE CAPACITY OF SHAFT/HELIX/LOAD TRANSFER MODULES IS 110 KIPS, TENSION OR COMPRESSION.
8. ULTIMATE INSTALLATION TORQUE IS 11,000 FT-LBS.
9. ALL STEEL GALVANIZED PER ASTM B633-85 FE/ZN 5, TYPE III, APPLIED BY AN ISO 9000 COMPANY.

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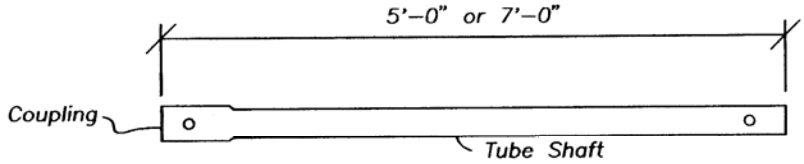
SPECIFICATION SHEET

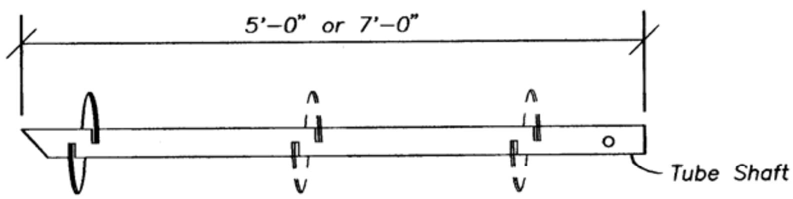
1.75 INCH MODULAR EXTRA HIGH STRENGTH HELICAL PILES
DWG. HP-17
SHEET 1 OF 1

DRAWN BY:	CHECKED:	DATE:	REVISION:
JSP	RLJ	05/05/09	0



Extension

No Scale



Lead Section

Single or Multiple Helix

No Scale

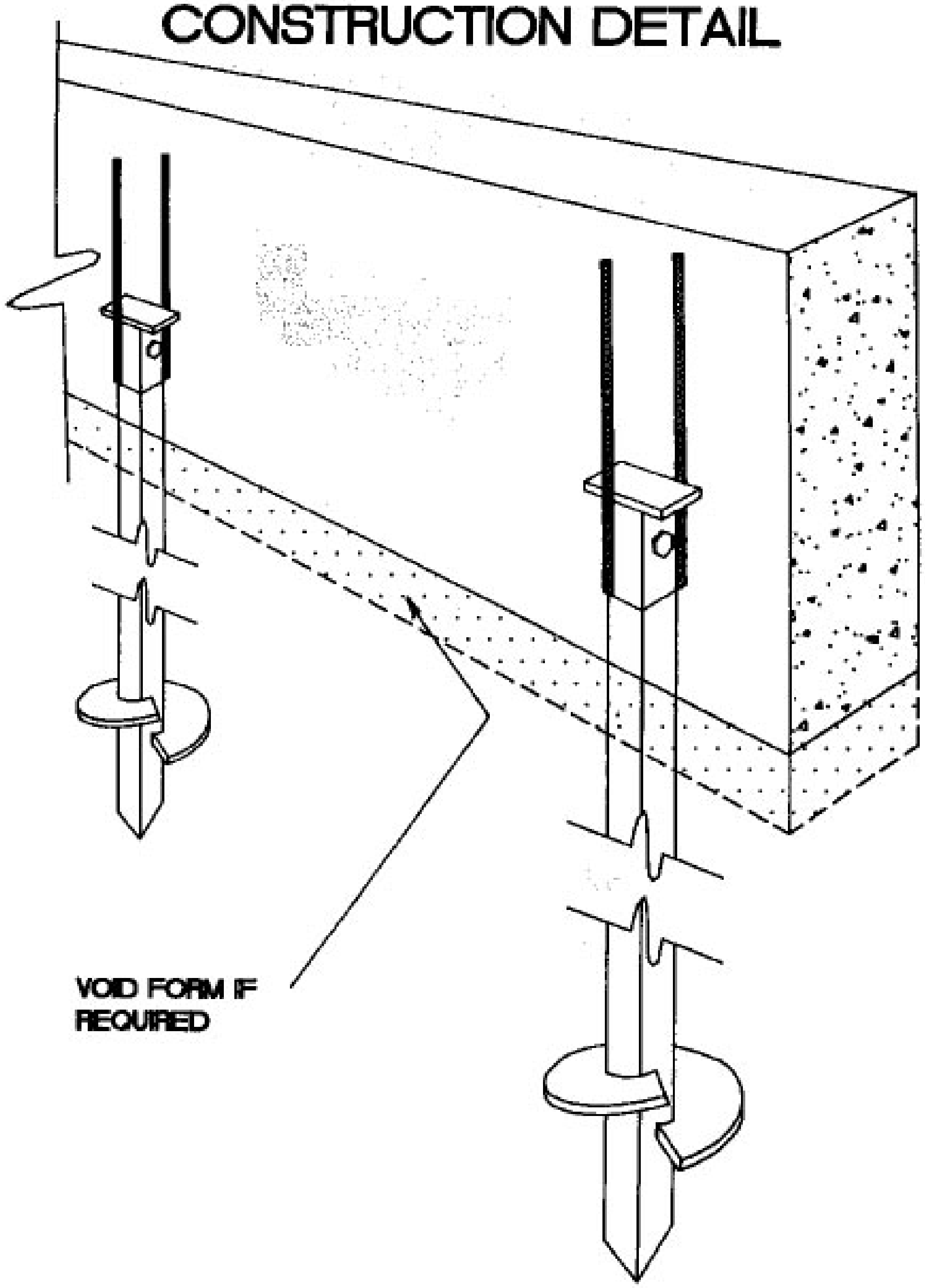
NOTES:

1. THIS DRAWING COVERS 2", 2.5", 3", AND 4" TUBULAR HELICAL PILE MATERIAL MANUFACTURED BY IMR.
2. 2" TUBULAR IS 2"x2" STRUCTURAL TUBING, 0.25" WALL THICKNESS. THE CONNECTION BOLT IS 0.75" DIAMETER SAE J429 Gr 5 STEEL (Fy=120 KSI) OR EQUIVALENT.
3. 2.5" TUBULAR IS 2.5"x2.5" STRUCTURAL TUBING, 0.25" WALL THICKNESS. THE CONNECTION BOLT IS 0.75" DIAMETER SAE J429 Gr 5 STEEL (Fy=120 KSI) OR EQUIV.
4. 3" TUBULAR IS 3"x3" STRUCTURAL TUBING, 0.25" WALL THICKNESS. THE CONNECTION BOLT IS 0.875" DIAMETER SAE J429, Gr 5 STEEL (Fy=120 KSI) OR EQUIV.
5. 4" TUBULAR IS 4"x4" STRUCTURAL TUBING, 0.375" WALL THICKNESS. THE CONNECTION BOLT IS 1.25" DIAMETER SAE J429, Gr 5 STEEL (Fy=120KSI). OR EQUIV.
6. ALL STRUCTURAL TUBING IS PER ASTM A500 Gr C.
7. ALL HELIX MATERIAL IS 0.5" THICK AND IS PER ASTM A656 Gr 80 TYPE 7.
8. ALL WELDS ARE 0.25" FILLET MINIMUM WITH ER70S ELECTRODE.
9. ALL STEEL MATERIAL IS GALVANIZED PER ASTM B633–85 FE/ZN, TYPE III.
10. ULTIMATE MECHANICAL CAPACITY: 2" TUBULAR: 40,000 LBS COMPR., 40,000 LBS TENSION.
    2.5" TUBULAR: 70,000 LBS COMPR., 70,000 LBS TENSION.
    3" TUBULAR: 110,000 LBS COMPR., 110,000 LBS TENSION.
    4" TUBULAR: 200,000 LBS COMPR., 200,000 LBS TENSION.

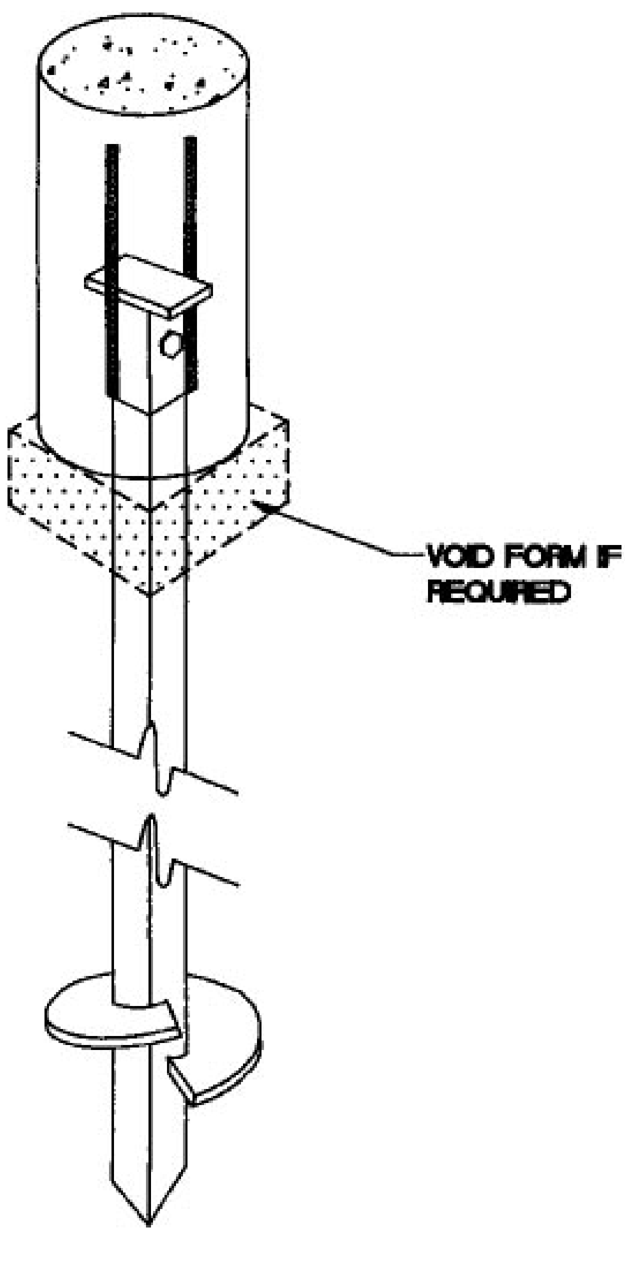
THIS DRAWING SUPERSEDES ALL PREVIOUS IMR DRAWINGS FOR TUBULAR HELICAL PILES.

HELI-PILE® IMR, Inc. – DENVER 5135 Ward Road, Wheat Ridge, Colorado, USA 303–423–0591 Fax: 303–423–9155 www.imrpiers.com	JSP 07/15/09	TUBULAR HELICAL PILES Sheet 1 of 1

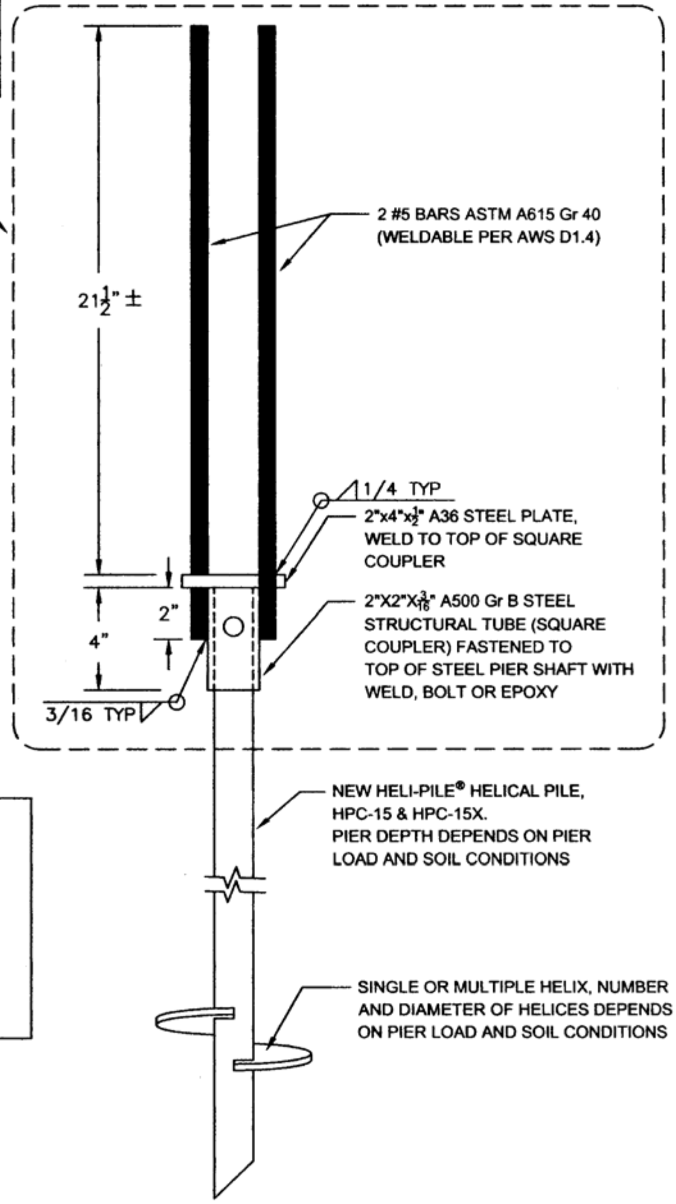
NEW FOUNDATION CONSTRUCTION DETAIL



NEW COLUMN CONSTRUCTION DETAIL WITH CONCRETE CAP



RC-150
FOR HPC-15 & HPC-15X



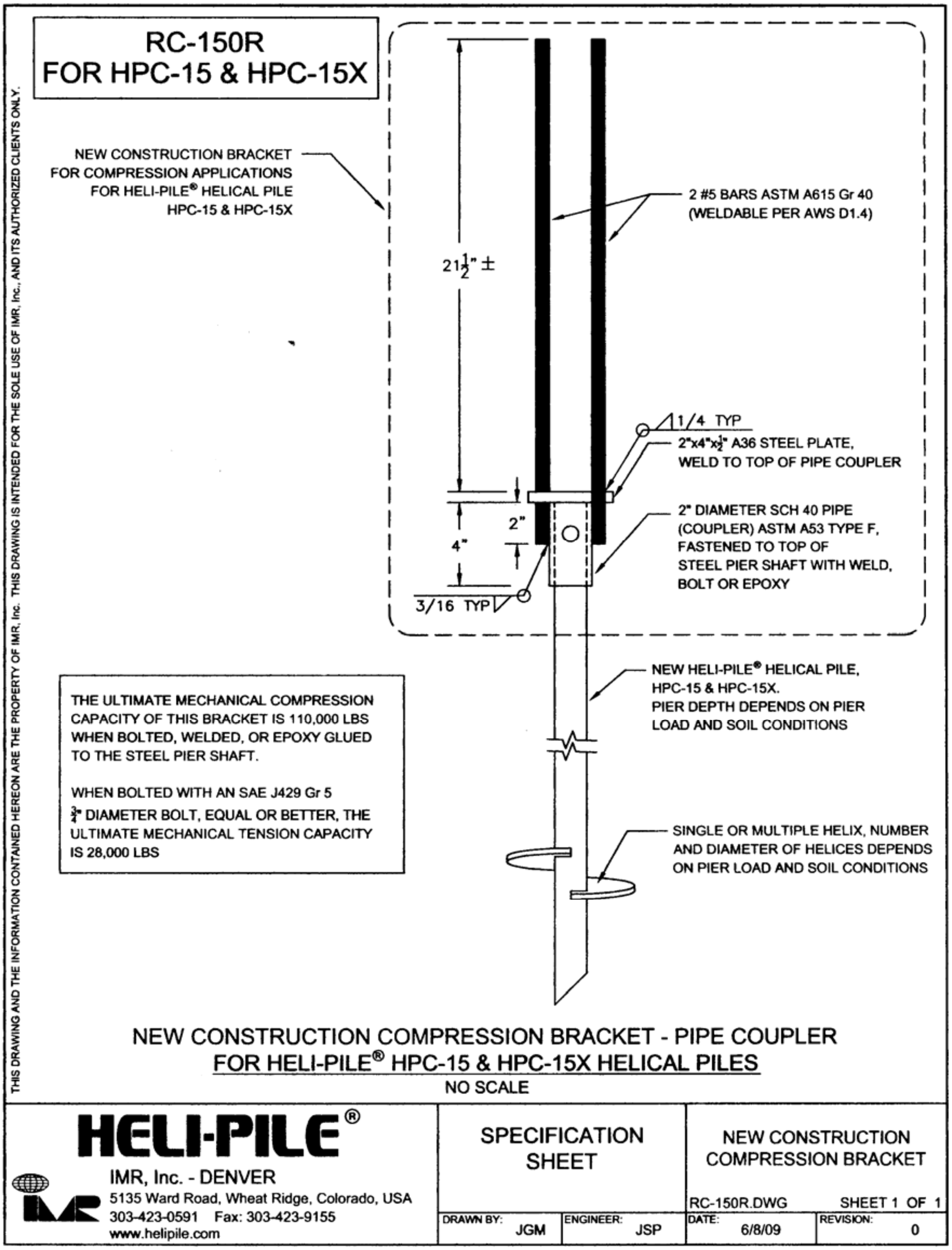
THE ULTIMATE MECHANICAL COMPRESSION CAPACITY OF THIS BRACKET IS 110,000 LBS WHEN BOLTED, WELDED, OR EPOXY GLUED TO THE STEEL PIER SHAFT.

WHEN BOLTED WITH AN SAE J429 Gr 5 ¾" DIAMETER BOLT, EQUAL OR BETTER, THE ULTIMATE MECHANICAL TENSION CAPACITY IS 46,000 LBS

NEW CONSTRUCTION COMPRESSION BRACKET - SQUARE COUPLER
FOR HELI-PILE® HPC-15 & HPC-15X HELICAL PILES

NO SCALE

HELI-PILE®	SPECIFICATION SHEET		NEW CONSTRUCTION COMPRESSION BRACKET	
IMR, Inc. - DENVER 5135 Ward Road, Wheat Ridge, Colorado, USA 303-423-0591 Fax: 303-423-9155 www.helipile.com			RC-150.DWG	SHEET 1 OF 1
	DRAWN BY: JGM	ENGINEER: JSP	DATE: 6/8/09	REVISION: 0



RC-150R
FOR HPC-15 & HPC-15X
NEW CONSTRUCTION BRACKET FOR COMPRESSION APPLICATIONS FOR HELI-PILE® HELICAL PILE HPC-15 & HPC-15X
2 #5 BARS ASTM A615 Gr 40 (WELDABLE PER AWS D1.4)
21½" ±
1/4 TYP
2"x4"x½" A36 STEEL PLATE, WELD TO TOP OF PIPE COUPLER
2" DIAMETER SCH 40 PIPE (COUPLER) ASTM A53 TYPE F, FASTENED TO TOP OF STEEL PIER SHAFT WITH WELD, BOLT OR EPOXY
2"
4"
3/16 TYP
NEW HELI-PILE® HELICAL PILE, HPC-15 & HPC-15X. PIER DEPTH DEPENDS ON PIER LOAD AND SOIL CONDITIONS
THE ULTIMATE MECHANICAL COMPRESSION CAPACITY OF THIS BRACKET IS 110,000 LBS WHEN BOLTED, WELDED, OR EPOXY GLUED TO THE STEEL PIER SHAFT.
WHEN BOLTED WITH AN SAE J429 Gr 5 ¾" DIAMETER BOLT, EQUAL OR BETTER, THE ULTIMATE MECHANICAL TENSION CAPACITY IS 28,000 LBS
SINGLE OR MULTIPLE HELIX, NUMBER AND DIAMETER OF HELICES DEPENDS ON PIER LOAD AND SOIL CONDITIONS
NEW CONSTRUCTION COMPRESSION BRACKET - PIPE COUPLER
FOR HELI-PILE® HPC-15 & HPC-15X HELICAL PILES
NO SCALE
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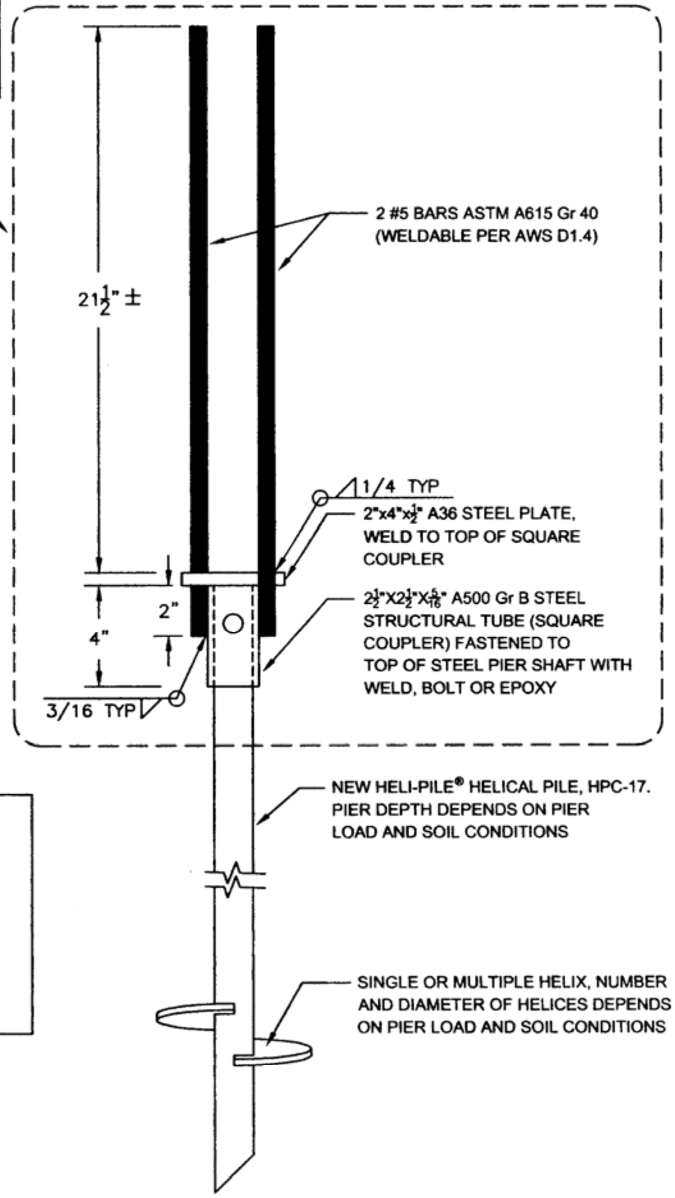
SPECIFICATION SHEET
NEW CONSTRUCTION COMPRESSION BRACKET
RC-150R.DWG
SHEET 1 OF 1
DRAWN BY: JGM
ENGINEER: JSP
DATE: 6/8/09
REVISION: 0

RC-175
FOR HPC-17

NEW CONSTRUCTION BRACKET
FOR COMPRESSION APPLICATIONS
FOR HELI-PILE® HELICAL PILE HPC-17



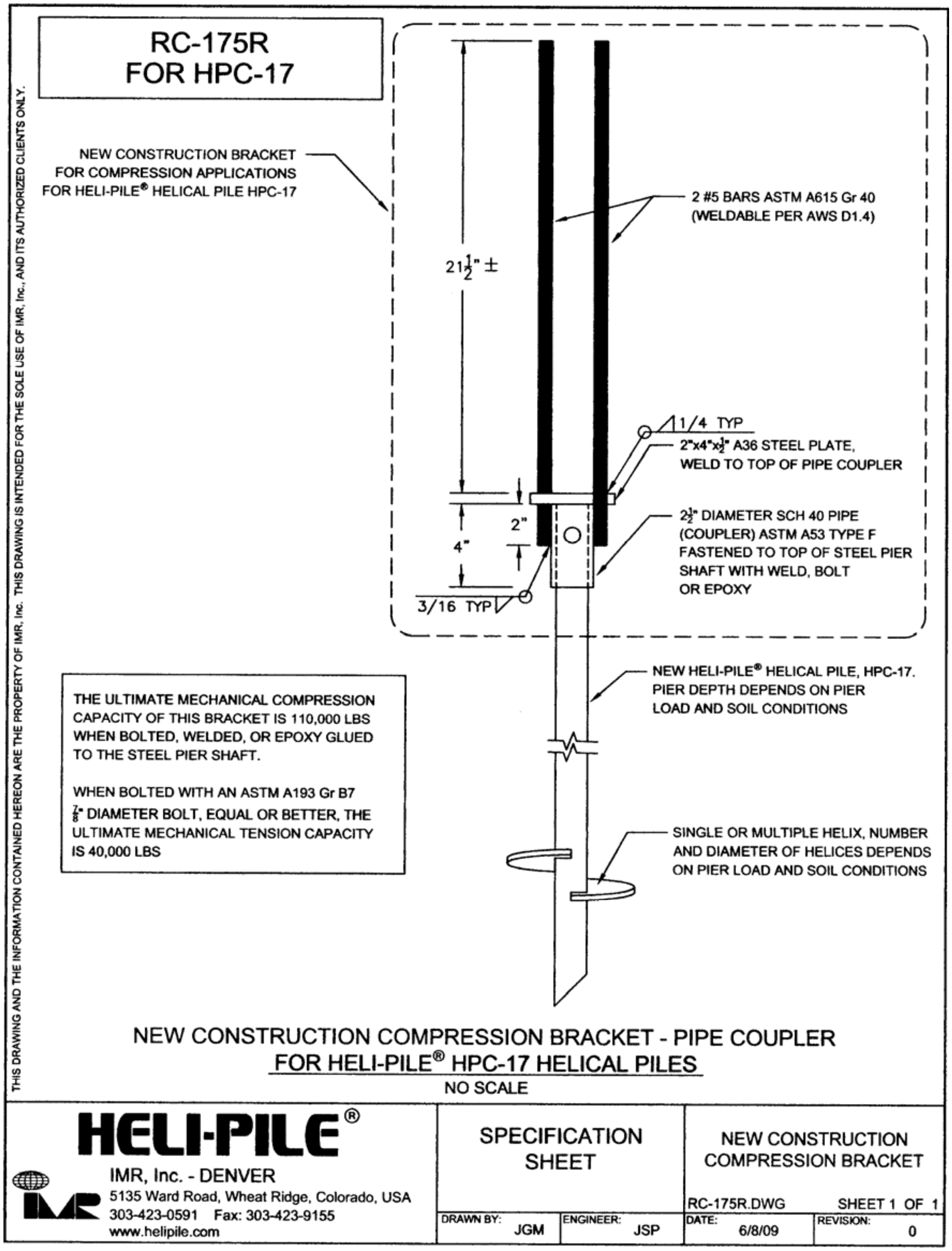
THE ULTIMATE MECHANICAL COMPRESSION CAPACITY OF THIS BRACKET IS 110,000 LBS WHEN BOLTED, WELDED, OR EPOXY GLUED TO THE STEEL PIER SHAFT.

WHEN BOLTED WITH AN ASTM A193 Gr B7 7/8" DIAMETER BOLT, EQUAL OR BETTER, THE ULTIMATE MECHANICAL TENSION CAPACITY IS 90,000 LBS

NEW CONSTRUCTION COMPRESSION BRACKET - SQUARE COUPLER
FOR HELI-PILE® HPC-17 HELICAL PILES

NO SCALE

HELI-PILE®	SPECIFICATION SHEET		NEW CONSTRUCTION COMPRESSION BRACKET	
IMR, Inc. - DENVER 5135 Ward Road, Wheat Ridge, Colorado, USA 303-423-0591 Fax: 303-423-9155 www.helipile.com			RC-175.DWG	SHEET 1 OF 1
	DRAWN BY: JGM	ENGINEER: JSP	DATE: 6/8/09	REVISION: 0


RC-175R
FOR HPC-17
NEW CONSTRUCTION BRACKET
FOR COMPRESSION APPLICATIONS
FOR HELI-PILE® HELICAL PILE HPC-17
2 #5 BARS ASTM A615 Gr 40
(WELDABLE PER AWS D1.4)
21½" ±
1/4 TYP
2"x4"x½" A36 STEEL PLATE,
WELD TO TOP OF PIPE COUPLER
2½" DIAMETER SCH 40 PIPE
(COUPLER) ASTM A53 TYPE F
FASTENED TO TOP OF STEEL PIER
SHAFT WITH WELD, BOLT
OR EPOXY
2"
4"
3/16 TYP
NEW HELI-PILE® HELICAL PILE, HPC-17.
PIER DEPTH DEPENDS ON PIER
LOAD AND SOIL CONDITIONS
THE ULTIMATE MECHANICAL COMPRESSION
CAPACITY OF THIS BRACKET IS 110,000 LBS
WHEN BOLTED, WELDED, OR EPOXY GLUED
TO THE STEEL PIER SHAFT.
WHEN BOLTED WITH AN ASTM A193 Gr B7
⅞" DIAMETER BOLT, EQUAL OR BETTER, THE
ULTIMATE MECHANICAL TENSION CAPACITY
IS 40,000 LBS
SINGLE OR MULTIPLE HELIX, NUMBER
AND DIAMETER OF HELICES DEPENDS
ON PIER LOAD AND SOIL CONDITIONS
NEW CONSTRUCTION COMPRESSION BRACKET - PIPE COUPLER
FOR HELI-PILE® HPC-17 HELICAL PILES
NO SCALE
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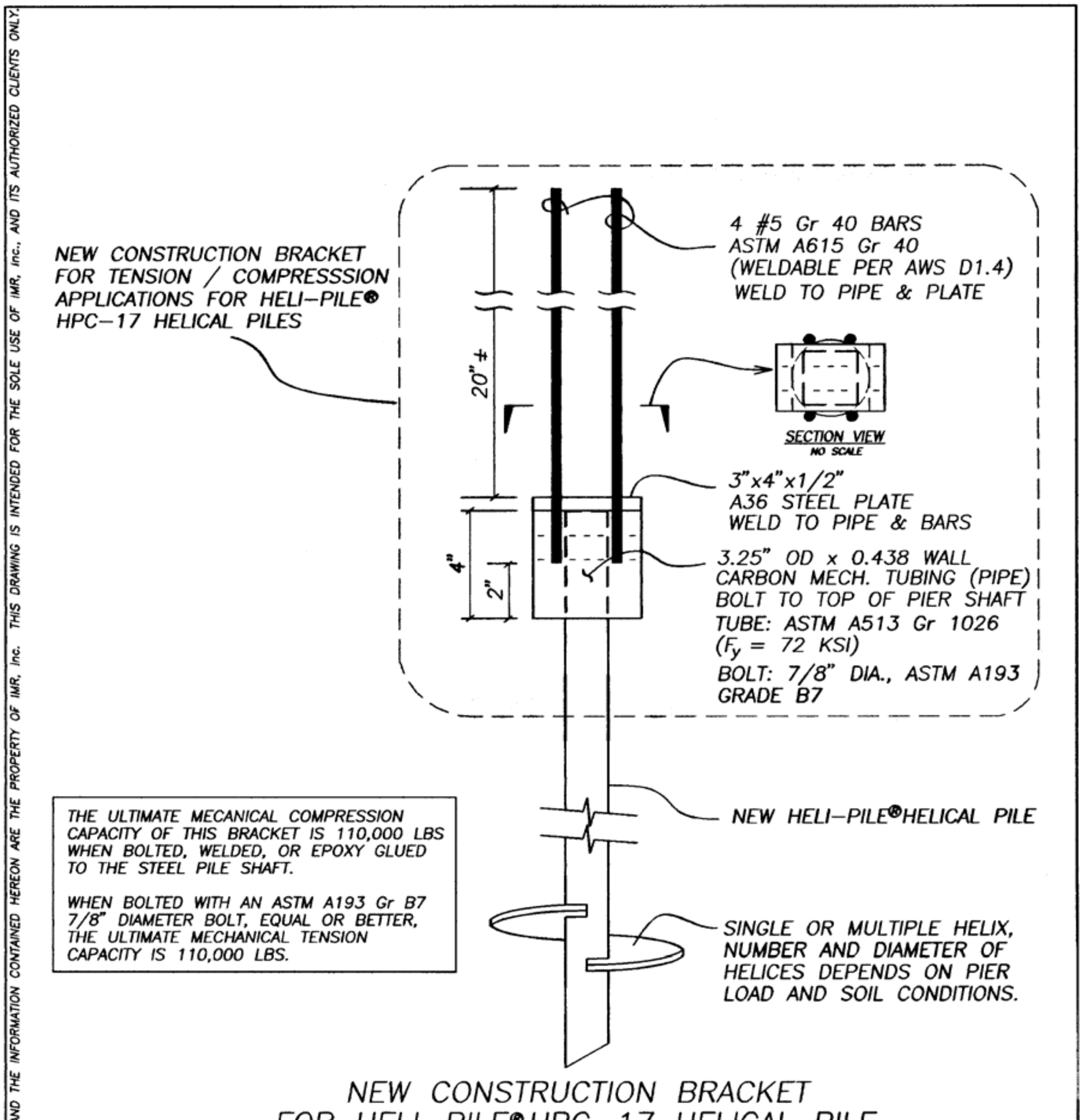
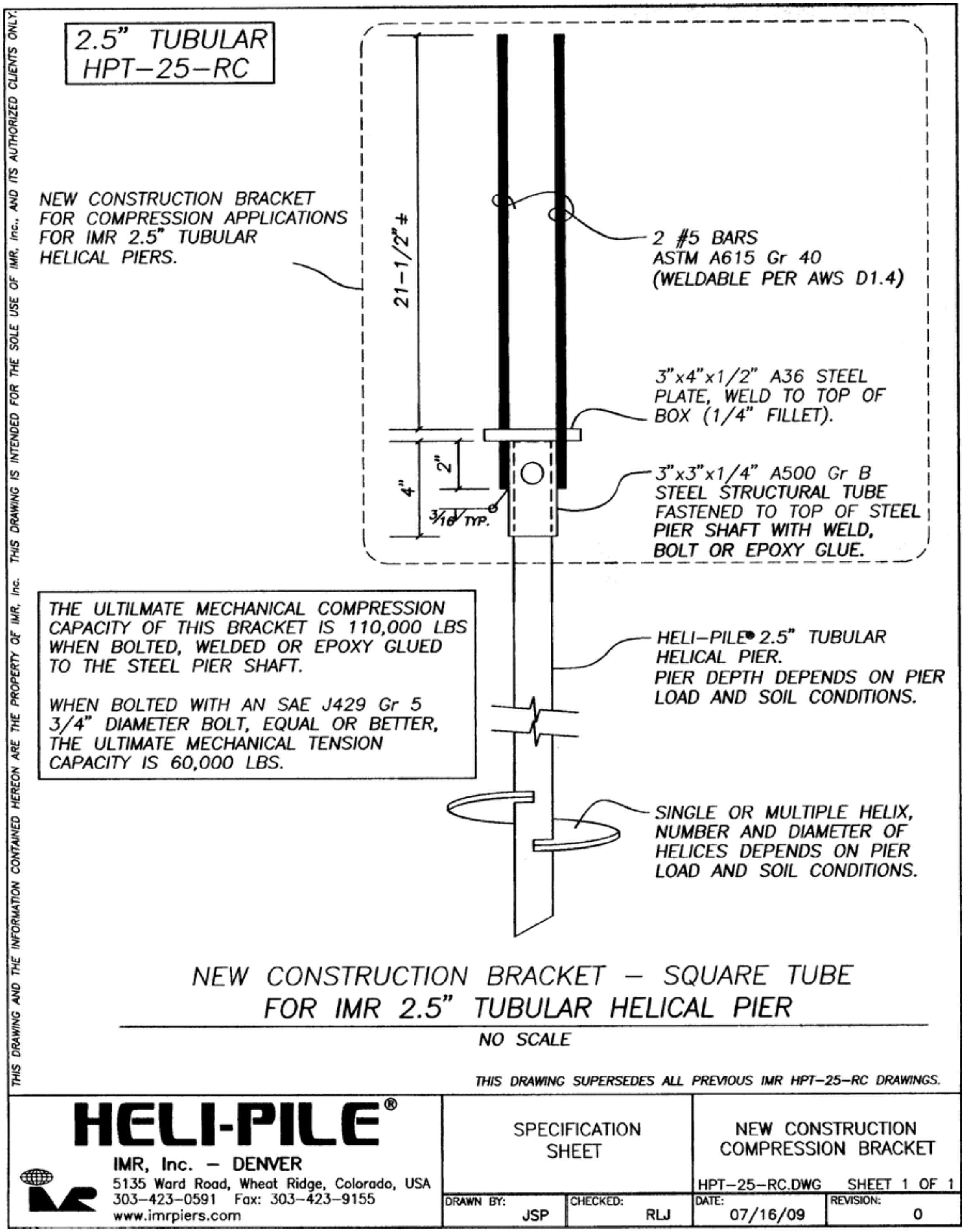
SPECIFICATION
SHEET
NEW CONSTRUCTION
COMPRESSION BRACKET
RC-175R.DWG
SHEET 1 OF 1
DRAWN BY: JGM
ENGINEER: JSP
DATE: 6/8/09
REVISION: 0



NEW CONSTRUCTION BRACKET
FOR HELI-PILE® HPC-17 HELICAL PILE

NO SCALE

HELI-PILE® IMR, Inc. – DENVER, 5135 Ward Road, Wheat Ridge, Colorado, USA, 303-423-0591 Fax: 303-423-9155, www.imrpiers.com	SPECIFICATION SHEET	NEW CONSTRUCTION TENSION / COMPRESSION BRACKET
		RC-175RT.DWG SHEET 1 OF 1
	DRAWN BY: JSP / CHECKED: RLJ	DATE: 07/16/09 / REVISION: 0


2.5" TUBULAR
HPT-25-RC
NEW CONSTRUCTION BRACKET FOR COMPRESSION APPLICATIONS FOR IMR 2.5" TUBULAR HELICAL PIERS.
21-1/2"±
2 #5 BARS
ASTM A615 Gr 40
(WELDABLE PER AWS D1.4)
3"x4"x1/2" A36 STEEL PLATE, WELD TO TOP OF BOX (1/4" FILLET).
2"
4"
3/16 TYP.
3"x3"x1/4" A500 Gr B STEEL STRUCTURAL TUBE FASTENED TO TOP OF STEEL PIER SHAFT WITH WELD, BOLT OR EPOXY GLUE.
THE ULTILMATE MECHANICAL COMPRESSION CAPACITY OF THIS BRACKET IS 110,000 LBS WHEN BOLTED, WELDED OR EPOXY GLUED TO THE STEEL PIER SHAFT.
WHEN BOLTED WITH AN SAE J429 Gr 5 3/4" DIAMETER BOLT, EQUAL OR BETTER, THE ULTIMATE MECHANICAL TENSION CAPACITY IS 60,000 LBS.
HELI-PILE® 2.5" TUBULAR HELICAL PIER.
PIER DEPTH DEPENDS ON PIER LOAD AND SOIL CONDITIONS.
SINGLE OR MULTIPLE HELIX, NUMBER AND DIAMETER OF HELICES DEPENDS ON PIER LOAD AND SOIL CONDITIONS.
NEW CONSTRUCTION BRACKET – SQUARE TUBE
FOR IMR 2.5" TUBULAR HELICAL PIER
NO SCALE
THIS DRAWING SUPERSEDES ALL PREVIOUS IMR HPT-25-RC DRAWINGS.
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SPECIFICATION SHEET
NEW CONSTRUCTION COMPRESSION BRACKET
HPT-25-RC.DWG SHEET 1 OF 1
DRAWN BY: JSP
CHECKED: RLJ
DATE: 07/16/09
REVISION: 0

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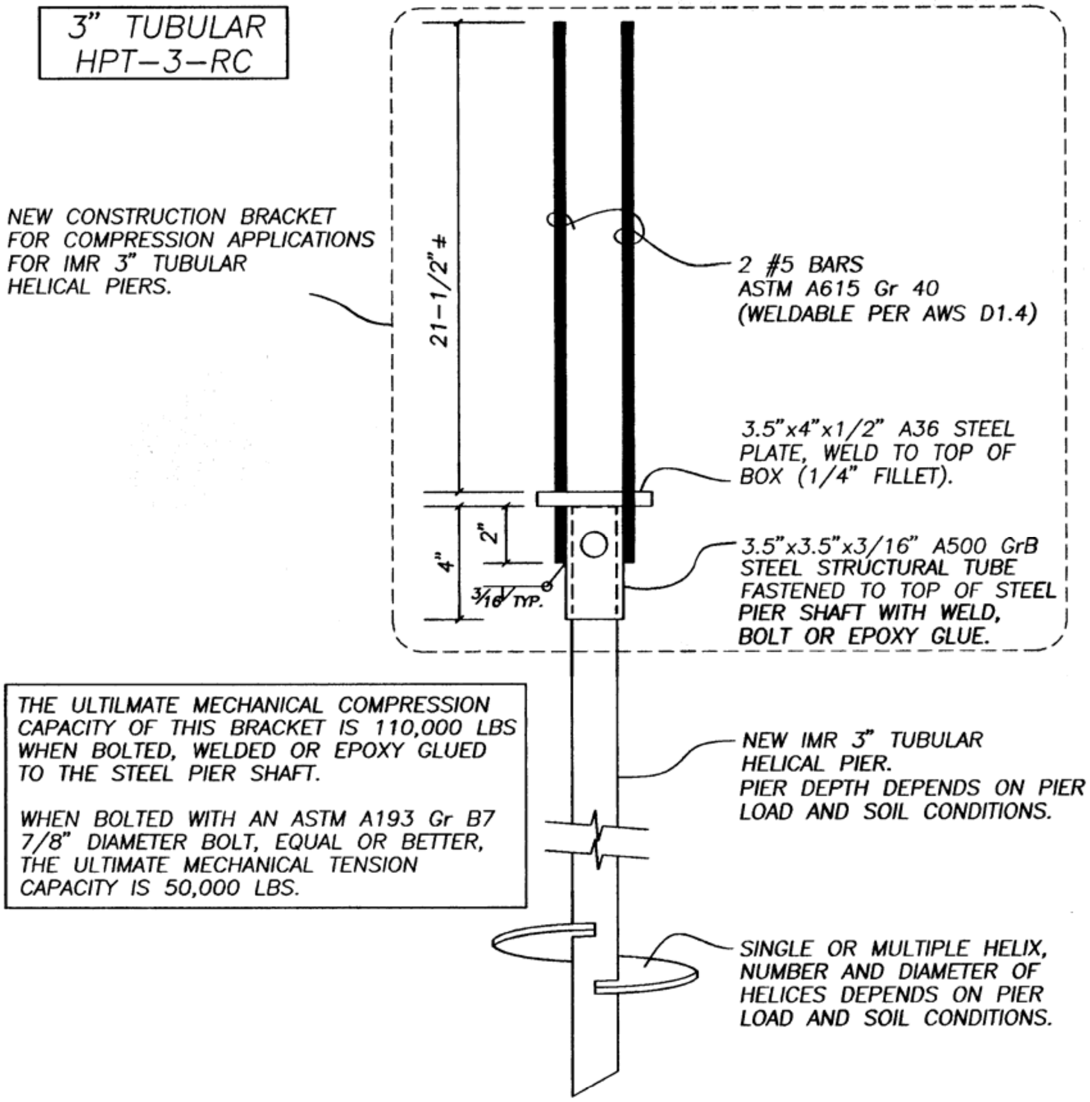
3" TUBULAR
HPT-3-RC



NEW CONSTRUCTION BRACKET – SQUARE TUBE
FOR IMR 3" TUBULAR HELICAL PIER

NO SCALE

THIS DRAWING SUPERSEDES ALL PREVIOUS IMR HPT-3-RC DRAWINGS.

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DRAWN BY: JSP	CHECKED: RLJ	DATE: 05/18/09 REVISION: 1

This load test letter dated July 29, 1994, is the report of testing of the RC-150 New Construction Bracket. This bracket is misidentified in the letter as an "A.B. Chance Imbedment Connection." It is, in fact, the RC-150 except there were only 12 inches (305 mm) of reinforcing steel protruding above the flat plate. As can be seen on p. 2 of the letter, this bracket was tested to 106,000 lbs (471 kN) load transfer, concrete to steel.

A. G. WASSENAAR, INC. GEOTECHNICAL CONSULTANTS

PHONE: 303/759-8100 FAX: 303/756-2920 2180 S. IVANHOE, SUITE 5 DENVER, COLORADO 80222

July 29, 1994

D&B Drilling, Inc.
5135 Ward Road
Wheat Ridge, CO 80033

Attention: Mr. Tim Spencer

Subject: A.B. Chance Imbedment Connection Testing
Delivered Specimen
Project Number 24499

Gentlemen:

As requested, we have conducted compressive strength testing on the A.B. Chance imbedment connection as well as on standard 6-inch by 12-inch concrete test cylinders from concrete placed within the imbedment connection specimen.

The concrete was placed on June 21, 1994. Based on the mix design submitted (attached), this is a 3000 psi concrete.

The concrete test cylinders (cast by D&B) as well as the imbedment connection specimen were delivered on June 22, 1994. All specimen were moist room cured. The cylinders were tested for compressive strength at 7, 14 and 28 days. The compressive strength at these ages were 3250, 4090 and 4780 psi, respectively. No slump or air content data was provided on this concrete. The imbedment connection was tested for compressive strength on July 8, 1994. A total load of 106,000 pounds was applied at failure. A schematic drawing of the imbedment is attached. The observed failure was totally contained within the concrete. No deformation of the 2"x2" tube steel or the No. 5 reinforcing steel was observed. The concrete fractures were evenly distributed and vertical to conical in shape.

After failure the concrete was removed to measure all imbedments within the concrete. The dimensions shown on the D&B Drilling detail are accurate to the assembly tested. The grade of reinforcing steel is unknown but believed to be grade 40 as this is a softer steel and more easily welded. The connection of the No. 5 rebar to the 2"x4"x½" plate was a full weld.

Conclusions regarding calculations on strength are not included with the exception of the "Gross" strength.

Page 1 of 3

The "Gross" strength for this report is defined as:

$$\frac{\text{Total Load}}{\text{Maximum Area}} = \frac{106{,}000 \text{ Pounds}}{78.54 \text{ IN}^2} = 1{,}350 \text{ PSI}$$

As it was the concrete that failed in compression and sheared from all imbedments, any increase in this value should be reviewed by a structural engineer.

If you have any questions regarding the test procedures or conclusions made, please do not hesitate to call.

Sincerely,

A. G. WASSENAAR, INC.

Thomas A. Hastings, C.E.T.
Senior Technician

Donald L. Taylor, Jr., P.E.
Vice President

COLORADO REGISTERED PROFESSIONAL ENGINEER DONALD L. TAYLOR JR. 20465

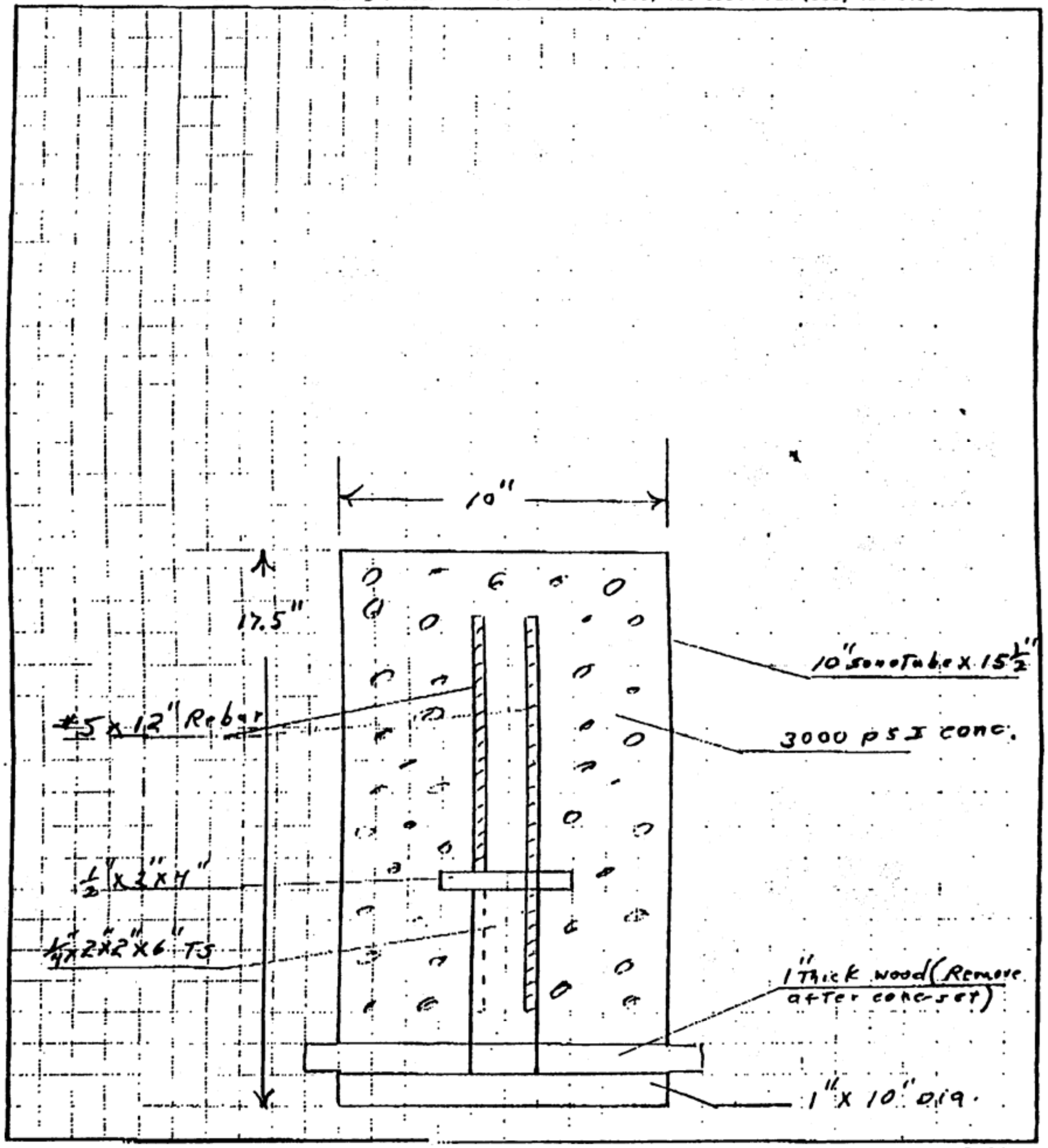
TAH/DLT/pg

Statement of Services

D&B DRILLING, INC.
ENGINEERING CONTRACTORS

JOB: Rabbit Ears Test
SHEET NO. ____ OF ____
CALCULATED BY: RJT DATE: 6-15-94
CHECKED BY: ____ DATE: ____

5135 Ward Road · Wheat Ridge, Colorado 80033 · Office (303) 423-6834 / Fax (303) 423-8185



TOTAL P.04

Page 3 of 3

IMR RC-150 and RC-175 New Construction Brackets
2003 International Building Code (IBC) Compliance

This report documents 2003 International Building Code (IBC) compliance and design capacity calculations of the New Construction Compression Brackets supplied by IMR. Hundreds of thousands of these brackets have been installed since 1986. IMR asserts that the brackets will transfer a 50 kip maximum design load and a 100 kip maximum ultimate load from a concrete pile cap, slab, grade beam, or other concrete member to a helical screw pile shaft. The reasons for these assertions follow.

On pages A-12, A-13, A-14, and A-15 are sketches of the RC-150 and RC-175 New Construction Compression Brackets. As can be seen, this bracket attaches to the top of helical screw pile shafts and is embedded in concrete. The RC-150 is for 1.5 inch square shaft helical screw piles, and the RC-175 is for 1.75 inch square shaft helical screw piles. Two grade 40 #5 bars, minimum 12 inches long, are welded to the sides of the coupling box. Grade 40 steel is weldable steel. A 2"x4"x½" plate, A36 steel, is welded to the top of the coupling box.

This report is written for a concrete strength of f_c' = 3,000 psi but also applies to concrete strengths as low as f_c' = 2,500 psi.

Load is transferred from the concrete pile cap, slab, grade beam, or other concrete member to the helical screw pile shaft in two ways: 1) Via load bearing from the concrete through the plate to the pile shaft, and 2) Via load transfer from the concrete to the reinforcing steel bars to the coupling box to the pile shaft. Both load transfers are discussed in detail below.

Load bearing

Chapter 19 "Concrete" of the 2003 IBC is copyrighted by the American Concrete Institute (ACI). The chapter is an adaptation of and heavily refers to ACI 318. The references that follow are ACI 318 designations of the 2003 IBC.

ACI 10.17.1 prescribes the allowable bearing strength on concrete supports. The New Construction Bracket is a concrete support where the grade beam above bears on the 2"x4"x½" plate. ACI 10.17.1 allows the bearing area to be increased when the "supporting surface is wider on all sides than the loaded area." The loaded area is 2"x4" = 8 in^2. The amount of allowed bearing area increase is given by the formula in ACI 10.17.1 but is limited to a maximum of 2 times. The width of the supporting surface above the plate is controlled by the width of the concrete member into which the New Construction Bracket is embedded. For purposes of discussion, assume the concrete member is a grade beam 8 inches wide. Therefore, increasing the width of the bearing area to 8 inches allows the length to be increased to 10 inches, an area of 80 in^2. By the formula, the increase could be $\sqrt{80/8}$ = 3.16. However, since the increase is limited to 2, use 2. Therefore, the allowable bearing area is 2"x4"x2 = 16 in^2. The allowable bearing capacity is (0.7)(0.85)(3,000psi)(16 in^2) = 28.6 kips.

Reinforcing Steel

Per ACI 12.3.2, the development length of the #5 bar (diameter = 0.625 in) in compression is

$$(0.02)(0.625\text{ in})(40{,}000\text{ psi})/\sqrt{3{,}000\,psi} = 9.13\text{ in}$$

Also, the development length cannot be less than (0.0003)(0.625 in)(40,000 psi) = 7.5 in. Therefore, 9.13 in is the allowable development length. Since the New Construction Bracket is constructed with a minimum of 12 inches of reinforcing steel above the plate, the full development length can be used to transfer load. Each #5 bar has a cross-sectional area of 0.307 in^2. Therefore, the amount of load that can be transferred is (0.85)(2 bars)(0.307 in^2)(40,000 psi) = 20.9 kips. Per the commentary under 212.0 Notation at the beginning of Chapter 12 of ACI 318, "the strength reduction factor φ is not used in this chapter."

Therefore, the total capacity of the New Construction Compression Bracket is the sum of 28.6 kips and 20.9 kips which equates to 49.5 kips. IMR rounds this up to 50 kips.

Ties are usually recommended in conjunction with vertical bars in compression. Since the vertical bars are welded to the sides of the coupling box, this weld serves as a tie. Per ACI 7.10.5.2, "Vertical spacing of ties shall not exceed 16 longitudinal bar diameters, 48 tiebar or wire diameters, or least dimension of the compression member." 16 longitudinal bar diameters = (16 x 0.625 in) = 10 in. 48 tiebar diameters, using #3 bar ties, = (48 x 0.375 in) = 18 in. The least dimension of the compression member in this case is 8 inches, the width of the grade beam. For the 8 inch wide grade beam, the vertical tie spacing would be 8 inches, sufficiently close to the 9.13 inch development length that an additional tie is not required. Nor are additional ties required for concrete members wider than 8 inches (see the next paragraph). The portions of the reinforcing steel bars longer than 9.13 inches above the plate are superfluous.

Further to the previous paragraph, ACI 7.10.3 states that "it shall be permitted to waive the lateral reinforcement requirements of 7.10, 10.16, and 18.11 where tests and structural analysis show adequate strength and feasibility of construction." On page A-28 is a copy of letter with test results where the RC-150 New Construction Compression Bracket was load tested to 106,000 lbs concrete to steel load transfer, further showing no additional ties are required. See letter on pages A-16, A-17, and A-18. The testing was done with concrete of f_c' = 3,000 psi using two grade 40 #5 bars extending 12 inches above the plate. The cylinder into which the New Construction Bracket was cast was 10 inches in diameter. The testing substantiates IMR's assertion the New Construction Compression Bracket will take a 100 kip ultimate load and that no additional ties are required.

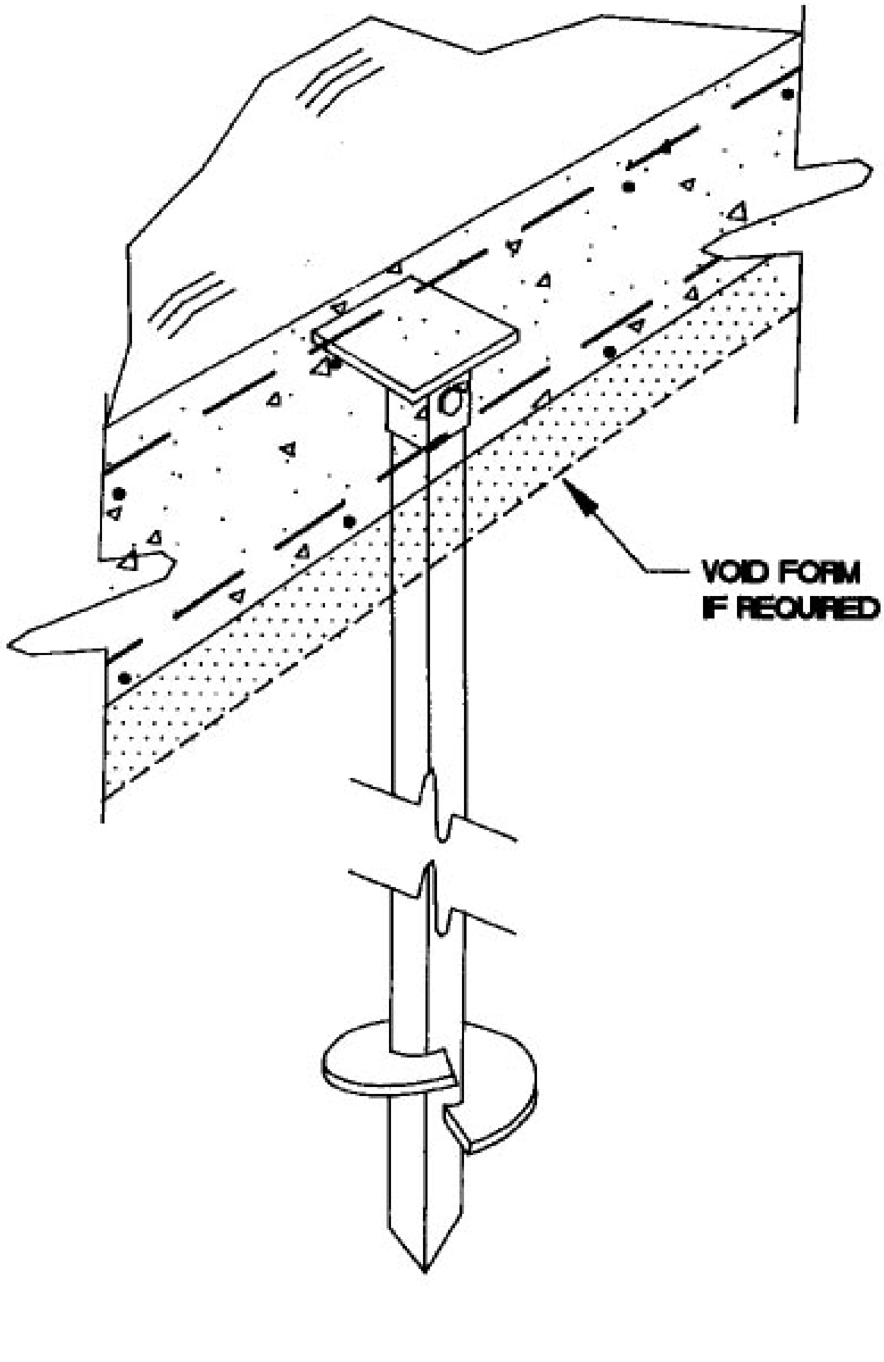
Regarding welding of the reinforcing steel to the coupling box, as can be seen in the sketch, two inches of each bar are welded to the side of the box. Each weld is a ¼ inch minimum fillet weld with a throat width of 0.177 inches. E70 electrodes (70 ksi) are used. Each bar has two welds that are two inches long. Therefore, the ultimate strength of the reinforcing steel welds is (2 bars)(2 welds each)(0.177 in throat width)(2 inch weld length)(70 ksi) = 99.1 kips. For a design load of 50 kips, the applicable strength reduction factor would be 50 kips / 99.1 kips = 0.505. This is acceptable.

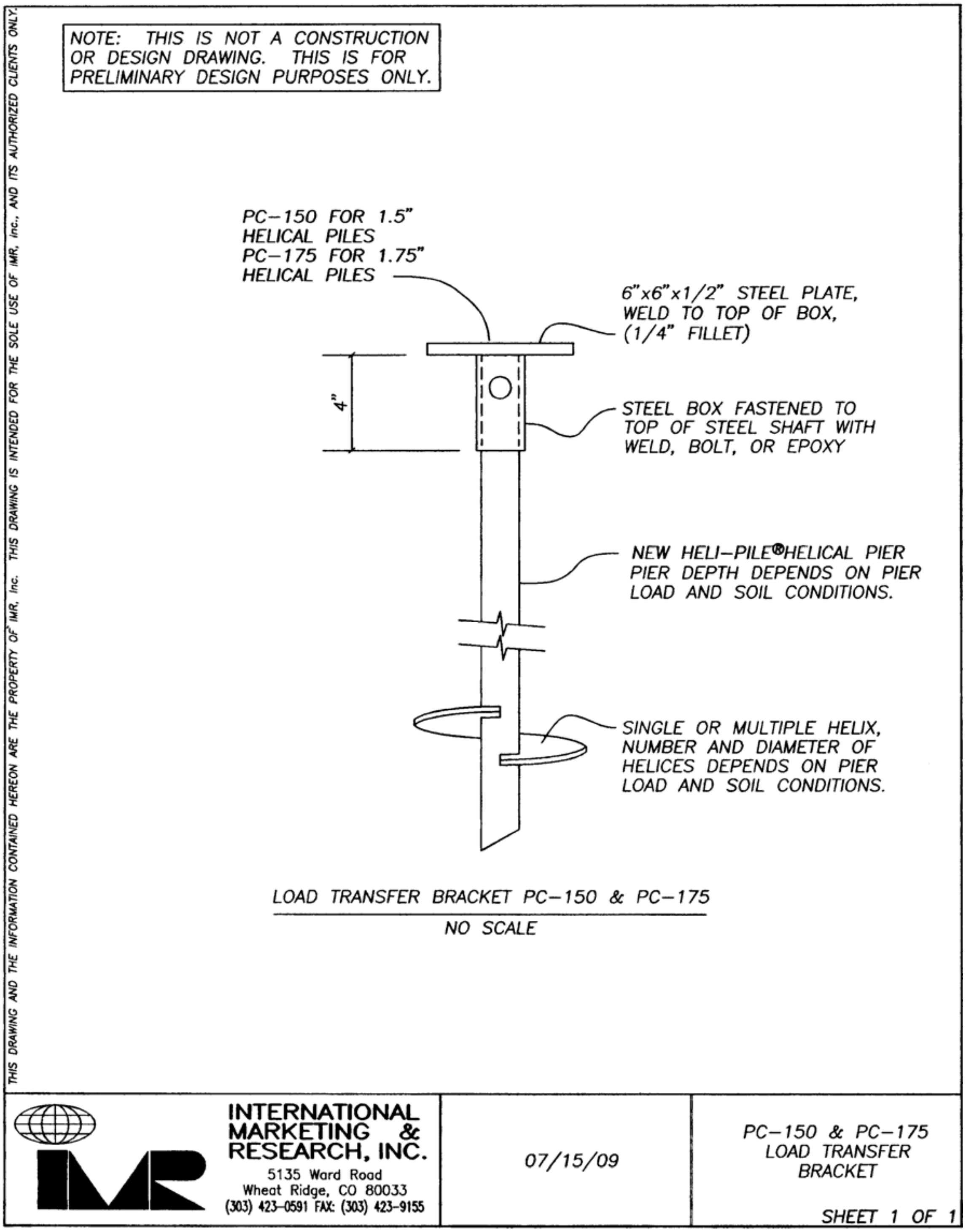
In no cases has it been found the plate thickness should exceed ½ inch.

Conclusions

The IMR RC-150 and RC-175 New Construction Compression Brackets are in compliance with the 2003 International Building Code and each has an allowable design capacity of 50 kips and an ultimate capacity of 100 kips.

NEW STRUCTURAL SLAB CONSTRUCTION DETAIL

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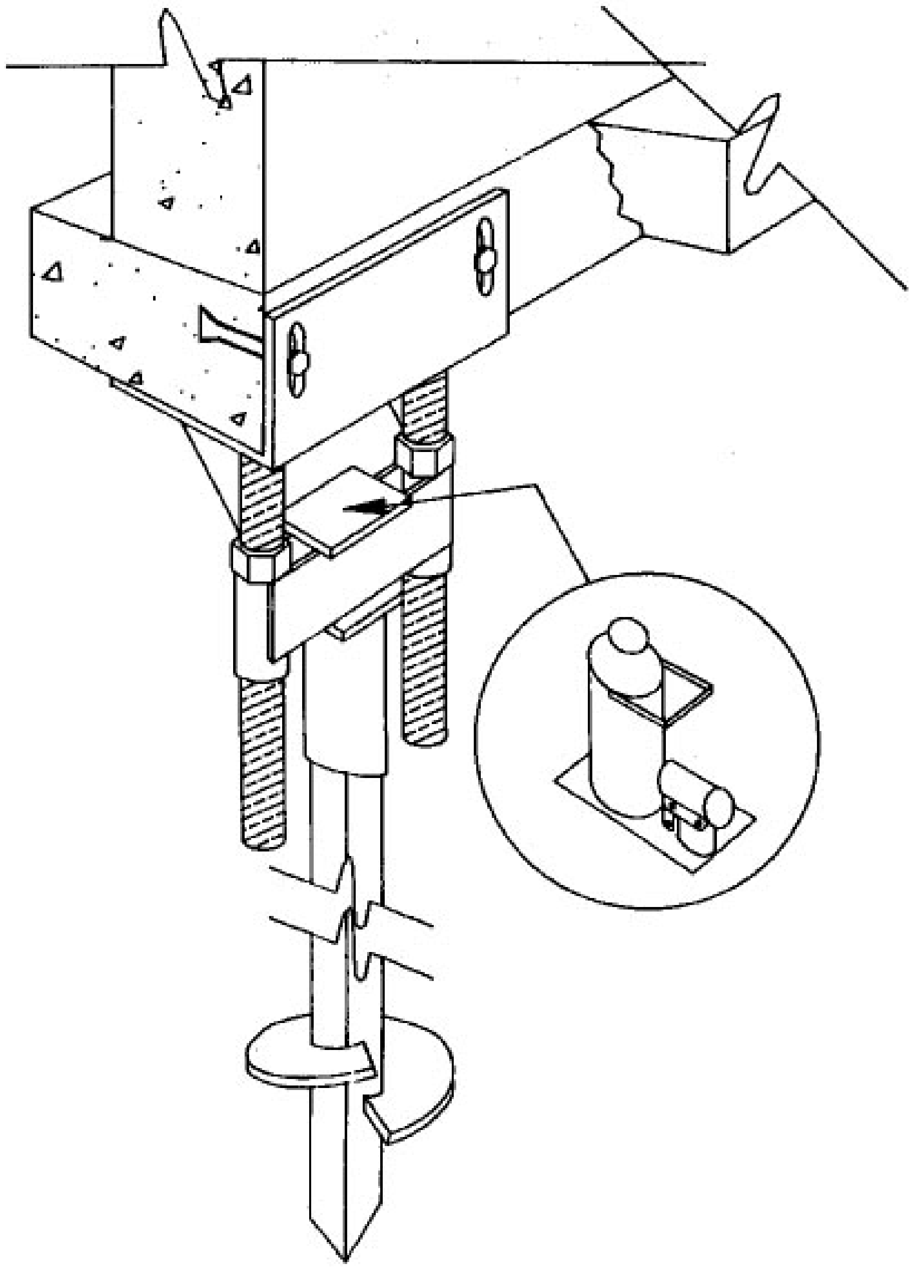
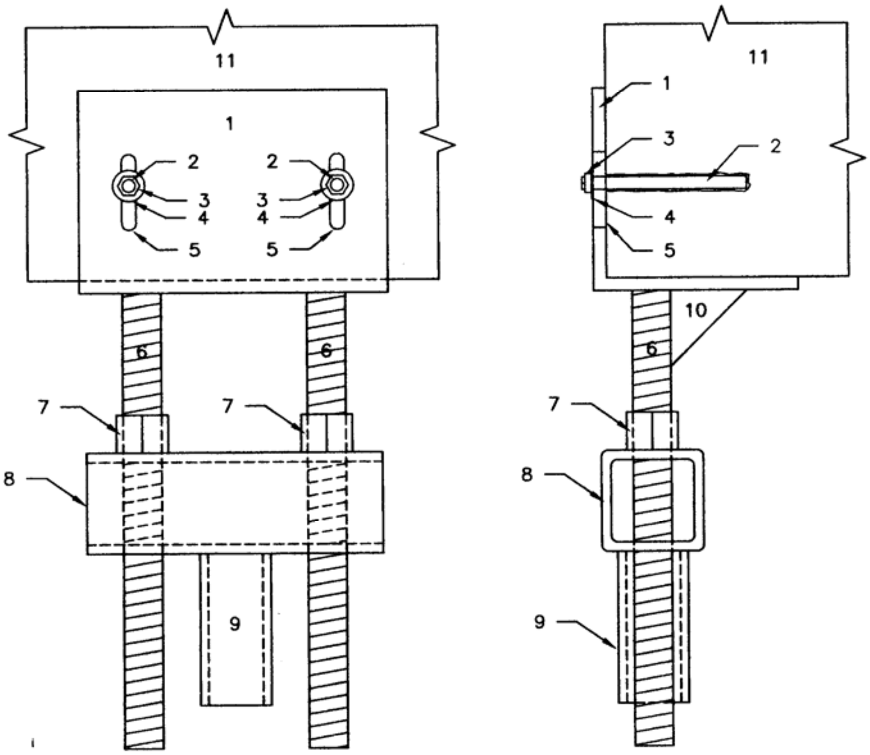
NOTE: THIS IS NOT A CONSTRUCTION OR DESIGN DRAWING. THIS IS FOR PRELIMINARY DESIGN PURPOSES ONLY.
PC–150 FOR 1.5" HELICAL PILES PC–175 FOR 1.75" HELICAL PILES
6"x6"x1/2" STEEL PLATE, WELD TO TOP OF BOX, (1/4" FILLET)
4"
STEEL BOX FASTENED TO TOP OF STEEL SHAFT WITH WELD, BOLT, OR EPOXY
NEW HELI–PILE® HELICAL PIER PIER DEPTH DEPENDS ON PIER LOAD AND SOIL CONDITIONS.
SINGLE OR MULTIPLE HELIX, NUMBER AND DIAMETER OF HELICES DEPENDS ON PIER LOAD AND SOIL CONDITIONS.
LOAD TRANSFER BRACKET PC–150 & PC–175
NO SCALE
INTERNATIONAL MARKETING & RESEARCH, INC.
5135 Ward Road
Wheat Ridge, CO 80033
(303) 423–0591 FAX: (303) 423–9155
07/15/09
PC–150 & PC–175 LOAD TRANSFER BRACKET
SHEET 1 OF 1

UNDERPINNING BRACKET DETAIL



UP-150

UNDERPINNING BRACKET



FRONT ELEVATION
NO SCALE

SIDE ELEVATION
NO SCALE

1. STRUCTURAL ANGLE: 8" X 8" X 1/2", 12" LONG
2. CONCRETE EXPANSION BOLT: 1/2" X 5-1/2" REDHEAD OR EQ.
3. NUT ON EXPANSION BOLT
4. WASHER ON EXPANSION BOLT
5. SLOTTED HOLE: 3" X 9/16"
6. THREAD ROD: 1-1/2" WILLIAMS GR 75, 18" LONG
7. NUT: 1-1/2"
8. STRUCTURAL TUBE: 4" X 4" X 3/8", 11.5" LONG
9. PIPE SLEEVE: CARBON MECHANICAL TUBING:
   2.75" OD, 2.125" ID, 0.313" WALL TH., 6" LONG
10. GUSSET PLATE: 3" X 3" X 1/2"
11. CONCRETE FOOTING OR GRADE BEAM

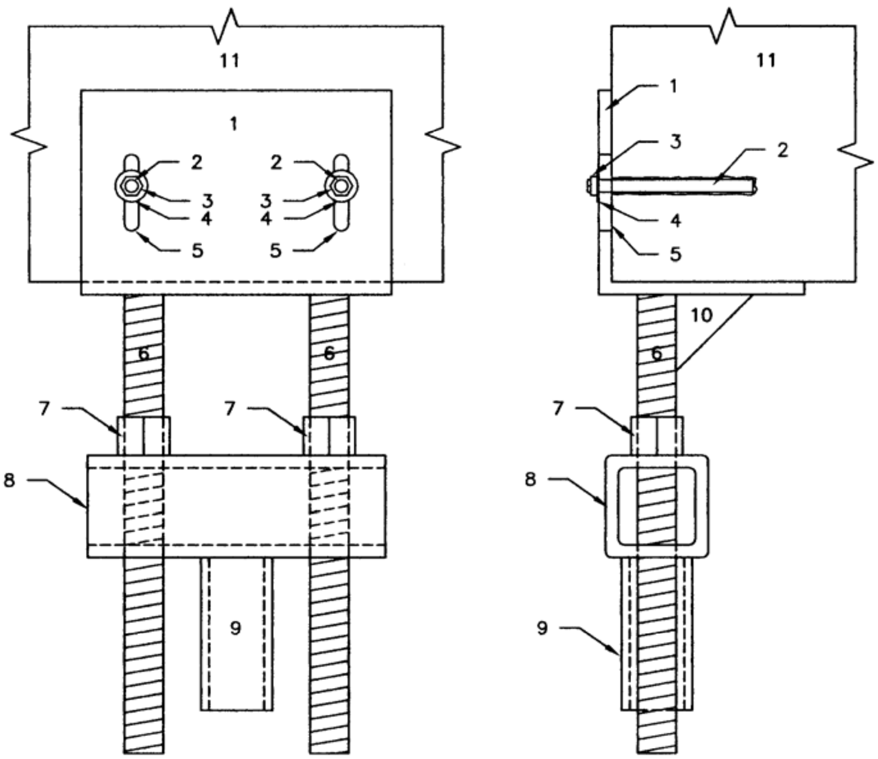
NOTE: ALL ANGLE STEEL, PLATE STEEL, & STRUCTURAL TUBING IS A36.
ALL PIPE IS 35 KSI MIN YIELD.
ULTIMATE CAPACITY 200,000 LBS

U.S. PATENT NO. 5,800,094

HELI-PILE® IMR, Inc. - DENVER 5135 Ward Road, Wheat Ridge, Colorado, USA 303-423-0591 Fax: 303-423-9155 www.helipile.com	SPECIFICATION SHEET	UP-150 UNDERPINNING BRACKET
		UP-150.DWG — SHEET 1 OF 1
	DRAWN BY: RJV — ENGINEER: JSP	DATE: 05/19/09 — REVISION: 1

UP-175

UNDERPINNING BRACKET



FRONT ELEVATION
NO SCALE

SIDE ELEVATION
NO SCALE

1. STRUCTURAL ANGLE: 8" X 8" X $\frac{1}{2}$", 12" LONG
2. CONCRETE EXPANSION BOLT: $\frac{1}{2}$" X 5-$\frac{1}{2}$" REDHEAD OR EQ.
3. NUT ON EXPANSION BOLT
4. WASHER ON EXPANSION BOLT
5. SLOTTED HOLE: 3" X $\frac{9}{16}$"
6. THREAD ROD: 1-$\frac{1}{2}$" WILLIAMS GR 75, 18" LONG
7. NUT: 1-$\frac{1}{2}$"
8. STRUCTURAL TUBE: 4" X 4" X $\frac{1}{2}$", 11.5"LONG
9. PIPE SLEEVE: 2-$\frac{1}{2}$" SCH 80 PIPE, 6" LONG
10. GUSSET PLATE: 3" X 3" X $\frac{1}{2}$"
11. CONCRETE FOOTING OR GRADE BEAM

NOTE: ALL ANGLE STEEL, PLATE STEEL, & STRUCTURAL TUBING IS A36.
ALL PIPE IS 35 KSI MIN YIELD.
ULTIMATE CAPACITY 200,000 LBS

U.S. PATENT NO. 5,800,094

HELI-PILE®	SPECIFICATION SHEET	UP-175 UNDERPINNING BRACKET
IMR, Inc. - DENVER 5135 Ward Road, Wheat Ridge, Colorado, USA 303-423-0591 Fax: 303-423-9155 www.helipile.com		UP-175.DWG SHEET 1 OF 1
	DRAWN BY: RJV / ENGINEER: JSP	DATE: 05/19/09 / REVISION: 1

This letter, dated August 10, 1995, is the report of a load test on a UP-150 underpinning bracket. The bracket is misidentified. It was given a new catalog number subsequent to this test. It was tested to 200,000 lbs. (890 kN).

A. G. WASSENAAR, INC. GEOTECHNICAL CONSULTANTS

PHONE: 303/759-8100 FAX: 303/756-2920 2180 S. IVANHOE, SUITE 5 DENVER, COLORADO 80222

August 10, 1995

D & B Drilling, Inc.
5135 Ward Road
Wheat Ridge, Colorado 80033

Attention: Mr. Tim Spencer

Subject: Deflection Testing
Chance Underpinning Bracket No. UP-100
Project Number 11762-2

Gentlemen:

As requested, we have completed our laboratory testing for the Chance underpinning bracket assembly delivered to our office on August 10, 1995. The testing was conducted using a Forney compression machine. The testing program included loading the bracket haunch and measuring load applied, total travel distance and deflection. The test results are summarized below.

Load (lbs)	Measured Travel Distance	Measured Deflection (in.)
10,000	.024	.016
20,000	.032	.020
30,000	.039	.023
40,000	.045	.026
50,000	.050	.029
60,000	.056	.032
70,000	.060	.034
80,000	.067	.037
90,000	.072	.040
100,000	.077	.043
110,000	.083	.046
120,000	.089	.049
130,000	.096	.053
140,000	.105	.058
150,000	.117	.066
160,000	.151	.084
165,000	.173	.095

Page 1 of 2

Load (lbs)	Measured Travel Distance	Measured Deflection (in.)
170,000	.191	.104
175,000	.211	.106
180,000	.237	.130
185,000	.265	.145
190,000	.292	.160
195,000	.324	.178
200,000	.370	.197

We have appreciated the opportunity of providing you this service. If we can be of further service, do not hesitate to call our office.

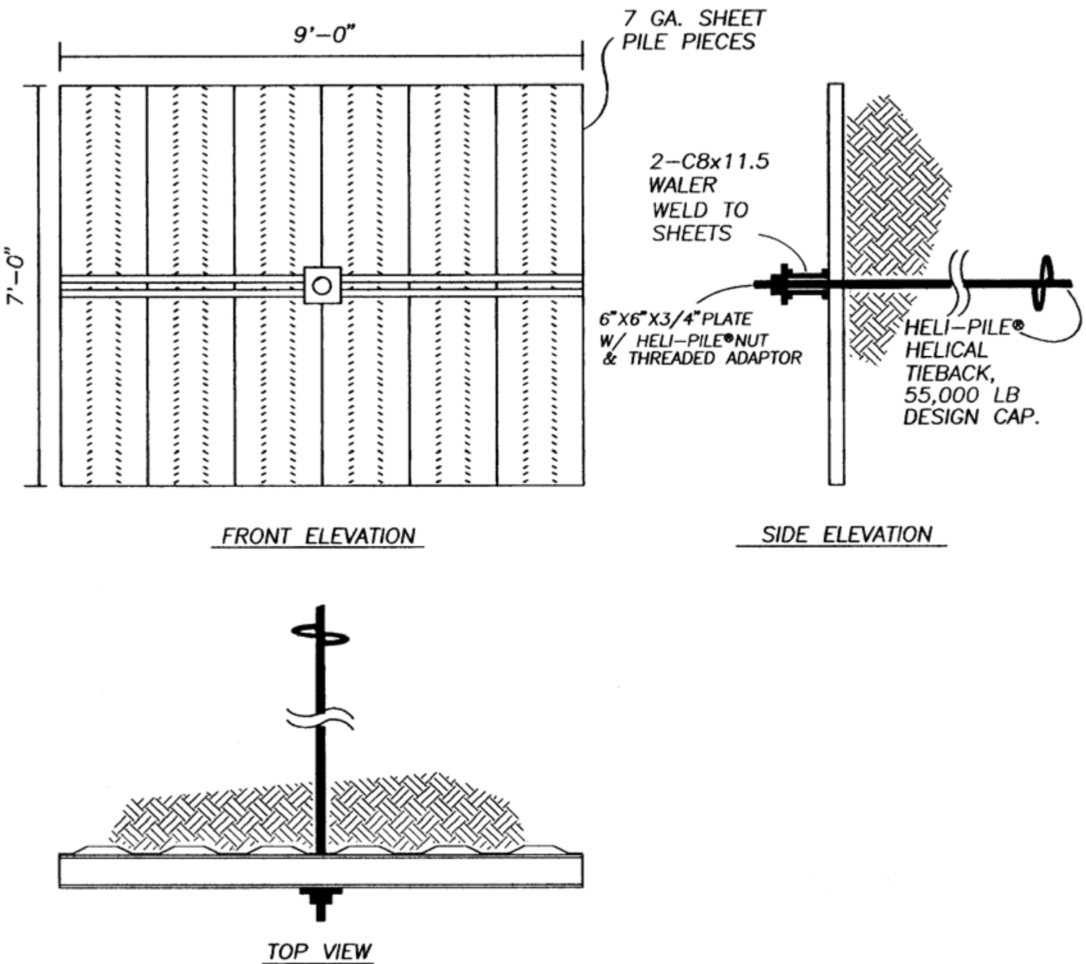
Sincerely,

A. G. WASSENAAR, INC.

Donald L. Taylor, Jr., P.E.
Vice President

DLT/kak

Statement of Services



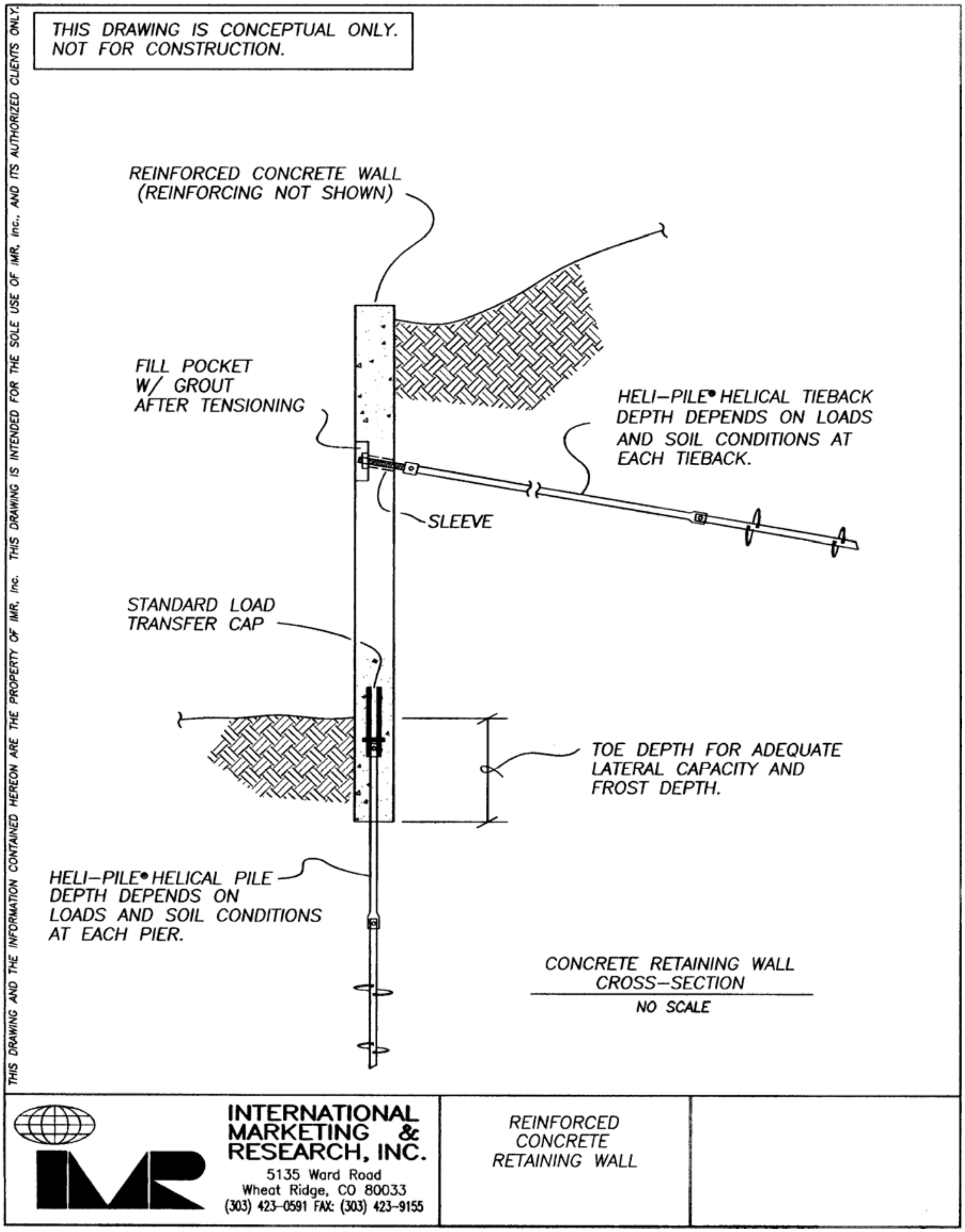
HELI-PILE®
IMR, Inc. – DENVER
5135 Ward Road, Wheat Ridge, Colorado, USA
303-423-0591 Fax: 303-423-9155
www.imrpiers.com

SPECIFICATION SHEET

SHORING PANEL
7 FT x 9 FT

SHORPAN.DWG SHEET 1 OF 1

DRAWN BY:	CHECKED:	DATE:	REVISION:
JSP	RLJ	07/16/09	1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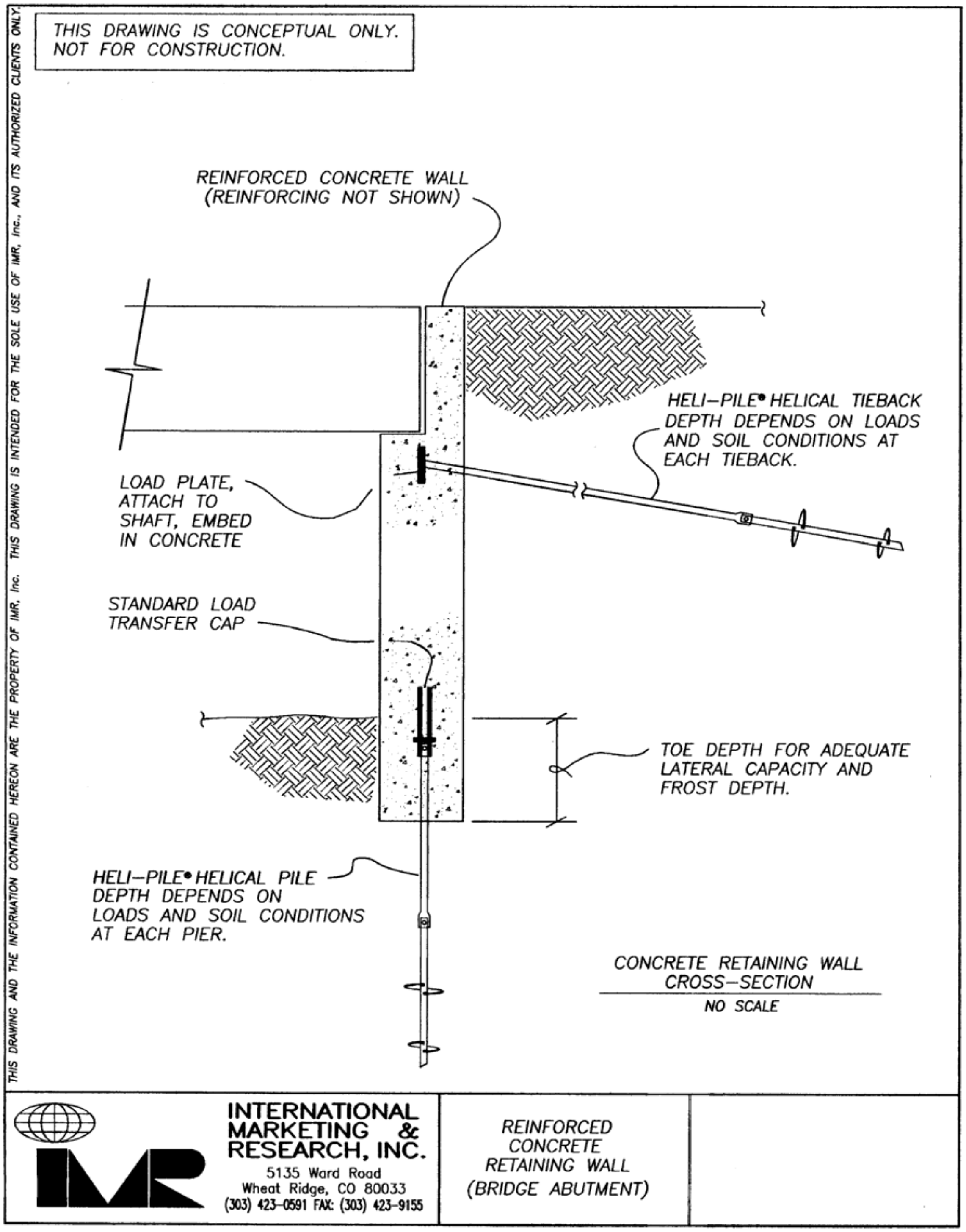
THIS DRAWING IS CONCEPTUAL ONLY. NOT FOR CONSTRUCTION.
REINFORCED CONCRETE WALL (REINFORCING NOT SHOWN)
FILL POCKET W/ GROUT AFTER TENSIONING
HELI-PILE® HELICAL TIEBACK DEPTH DEPENDS ON LOADS AND SOIL CONDITIONS AT EACH TIEBACK.
SLEEVE
STANDARD LOAD TRANSFER CAP
TOE DEPTH FOR ADEQUATE LATERAL CAPACITY AND FROST DEPTH.
HELI-PILE® HELICAL PILE DEPTH DEPENDS ON LOADS AND SOIL CONDITIONS AT EACH PIER.
CONCRETE RETAINING WALL CROSS-SECTION
NO SCALE
INTERNATIONAL MARKETING & RESEARCH, INC.
5135 Ward Road
Wheat Ridge, CO 80033
(303) 423-0591 FAX: (303) 423-9155
REINFORCED CONCRETE RETAINING WALL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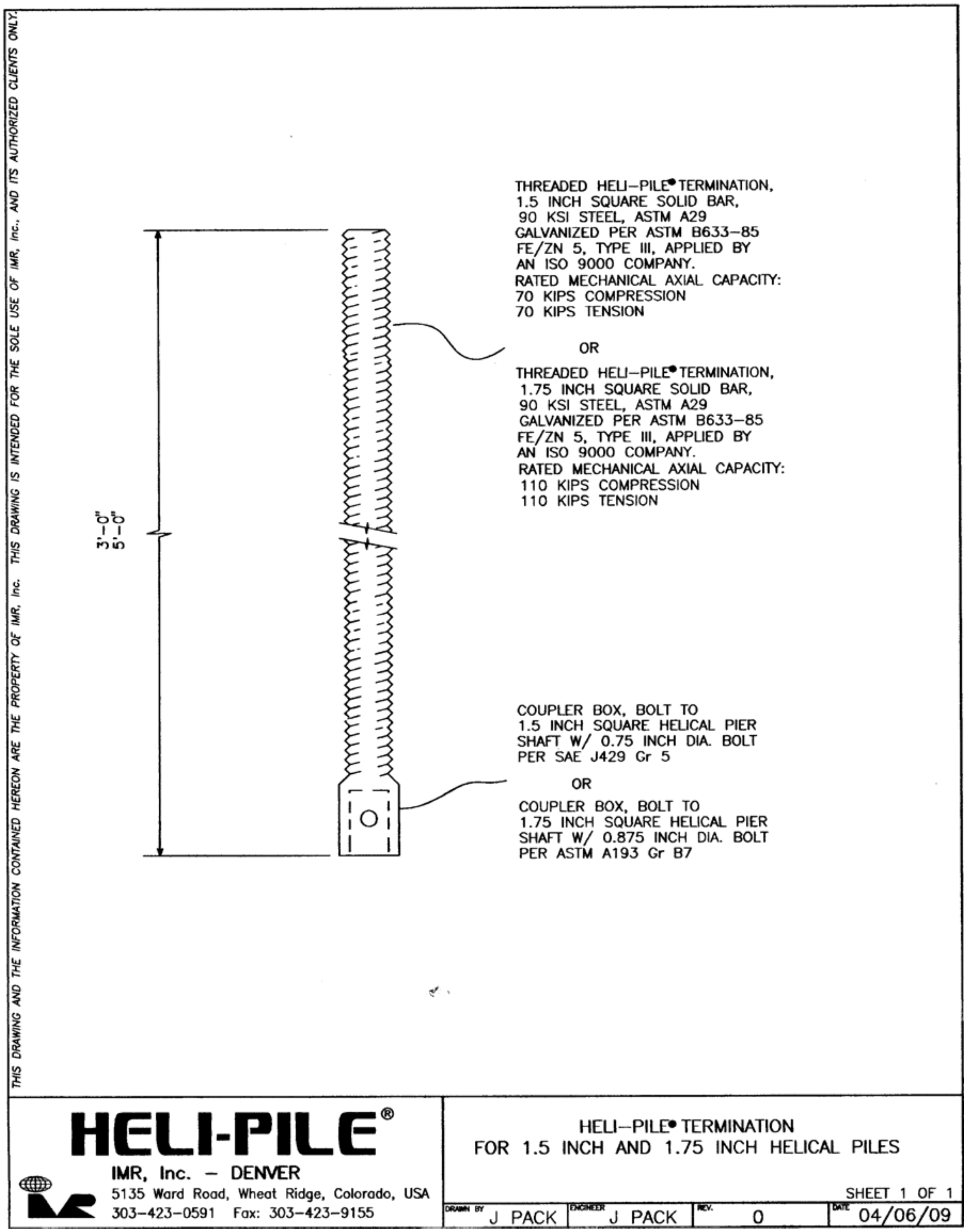
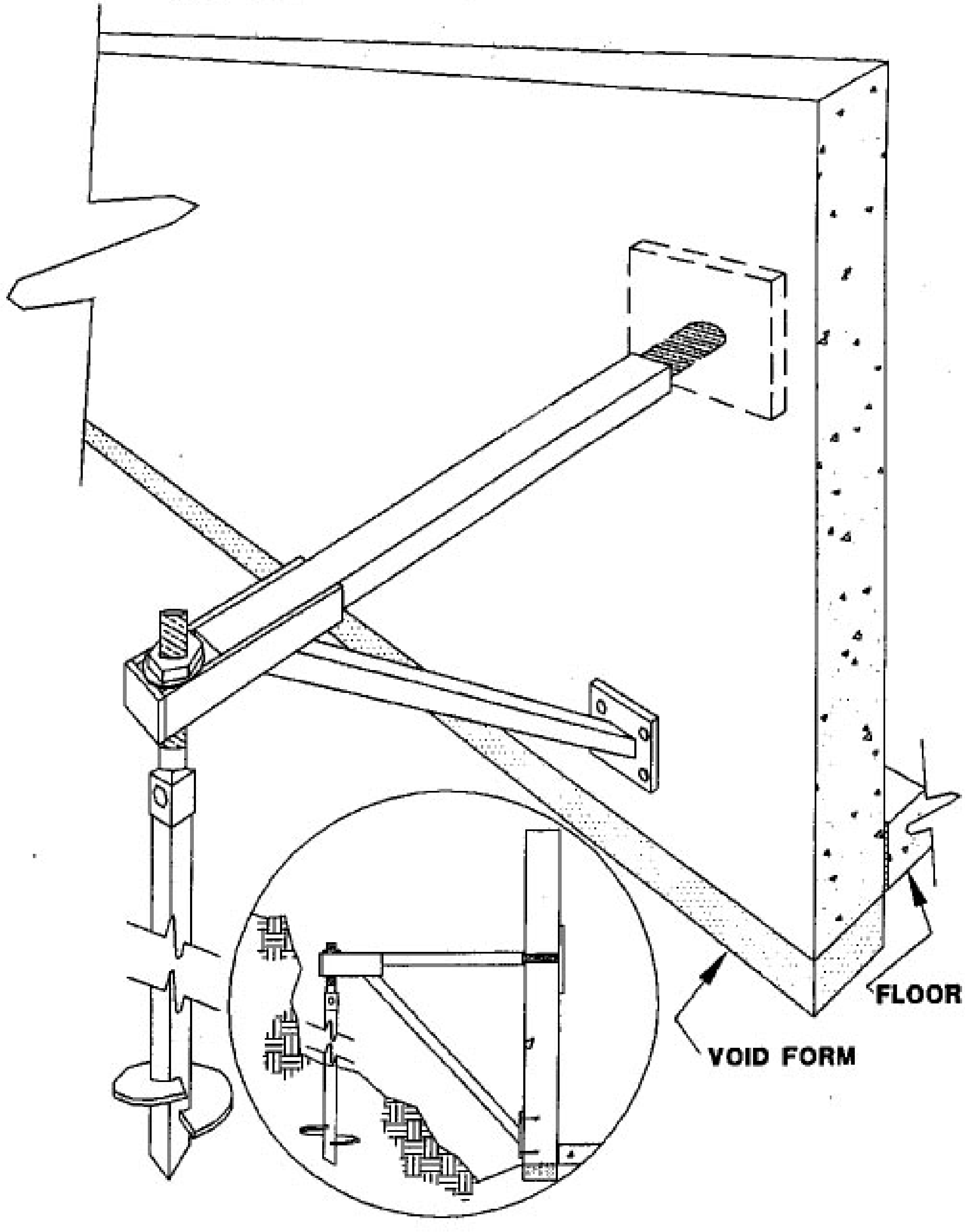
THIS DRAWING IS CONCEPTUAL ONLY. NOT FOR CONSTRUCTION.
REINFORCED CONCRETE WALL (REINFORCING NOT SHOWN)
HELI–PILE® HELICAL TIEBACK DEPTH DEPENDS ON LOADS AND SOIL CONDITIONS AT EACH TIEBACK.
LOAD PLATE, ATTACH TO SHAFT, EMBED IN CONCRETE
STANDARD LOAD TRANSFER CAP
TOE DEPTH FOR ADEQUATE LATERAL CAPACITY AND FROST DEPTH.
HELI–PILE® HELICAL PILE DEPTH DEPENDS ON LOADS AND SOIL CONDITIONS AT EACH PIER.
CONCRETE RETAINING WALL CROSS–SECTION
NO SCALE
INTERNATIONAL MARKETING & RESEARCH, INC.
5135 Ward Road
Wheat Ridge, CO 80033
(303) 423-0591 FAX: (303) 423-9155
REINFORCED CONCRETE RETAINING WALL (BRIDGE ABUTMENT)

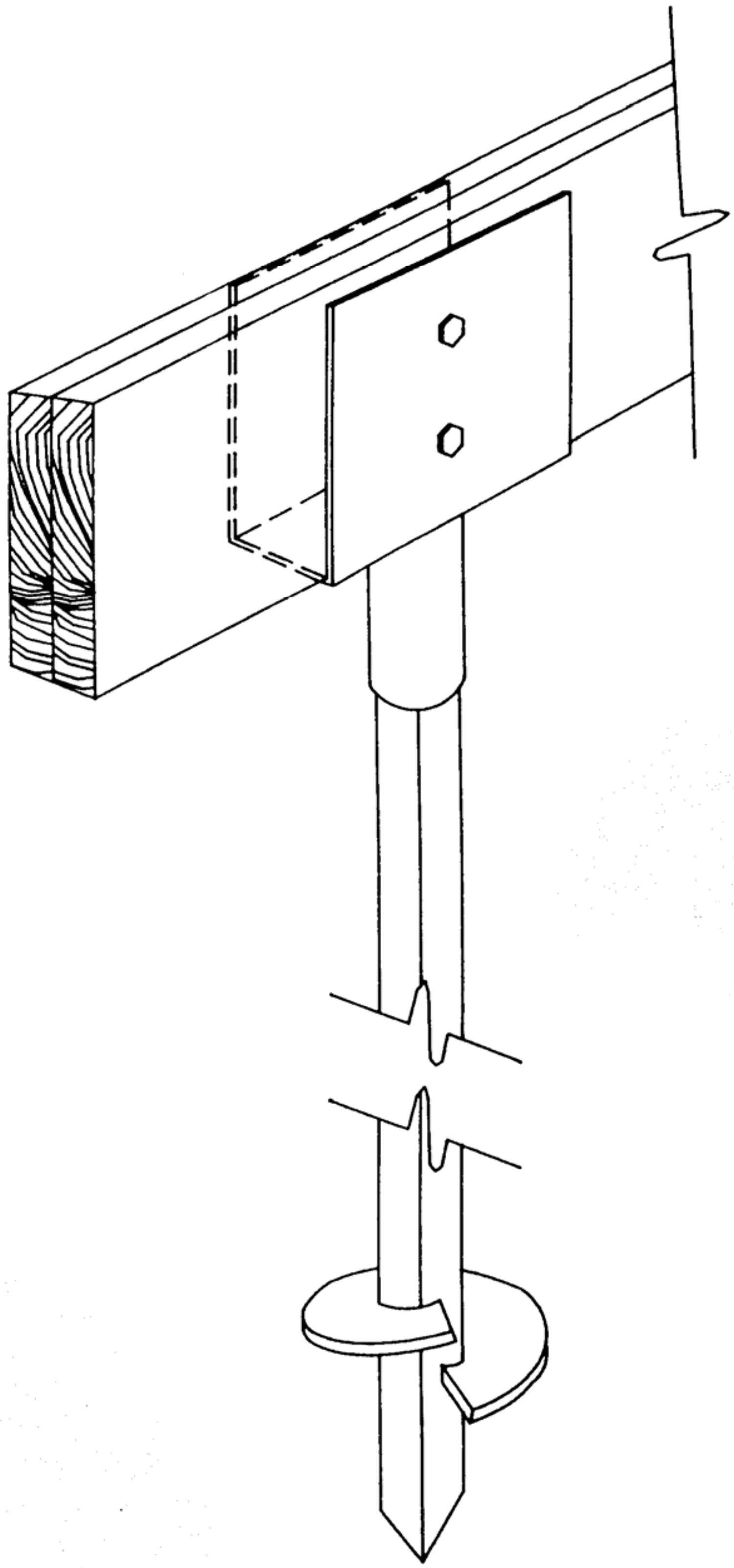
This threaded termination is actually a patented square bar threaded adapter. Given the square shape, it can be installed as any helical pile shaft using the square drive tool. It can be used to terminate vertical helical piles where the load transfer device is merely threaded on. It can be used as a threadbar to terminate a tieback with a nut and a load plate.

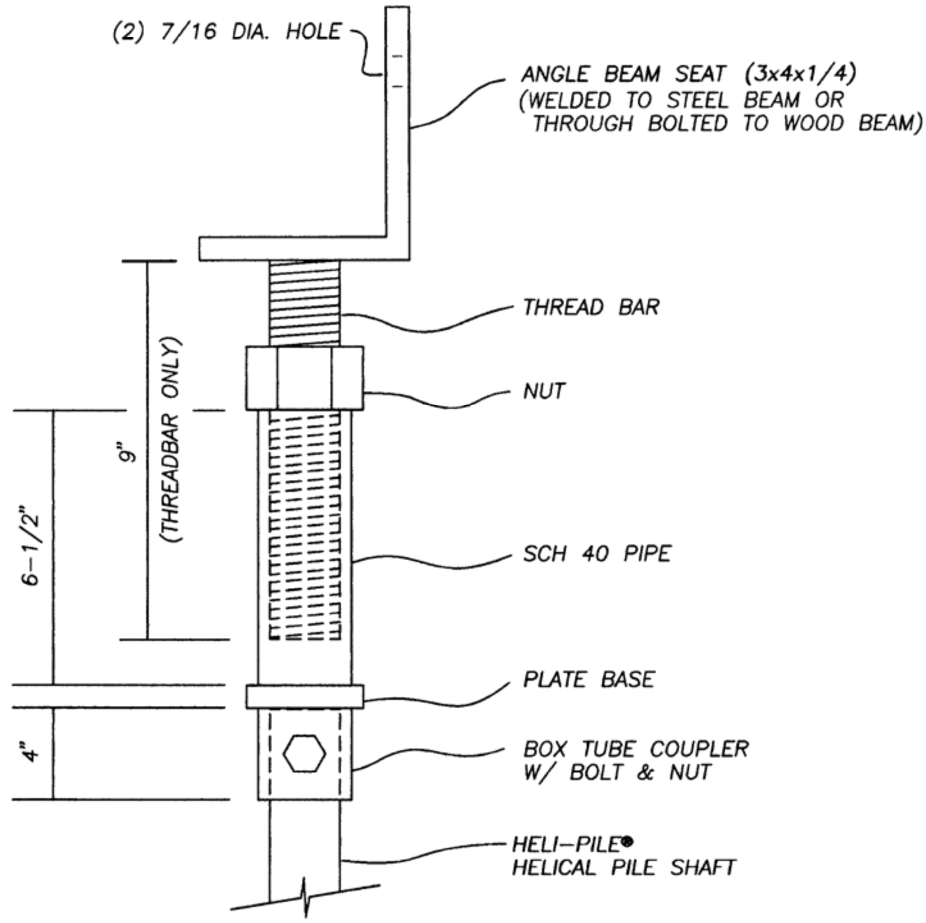


COUNTERFORT DESIGN

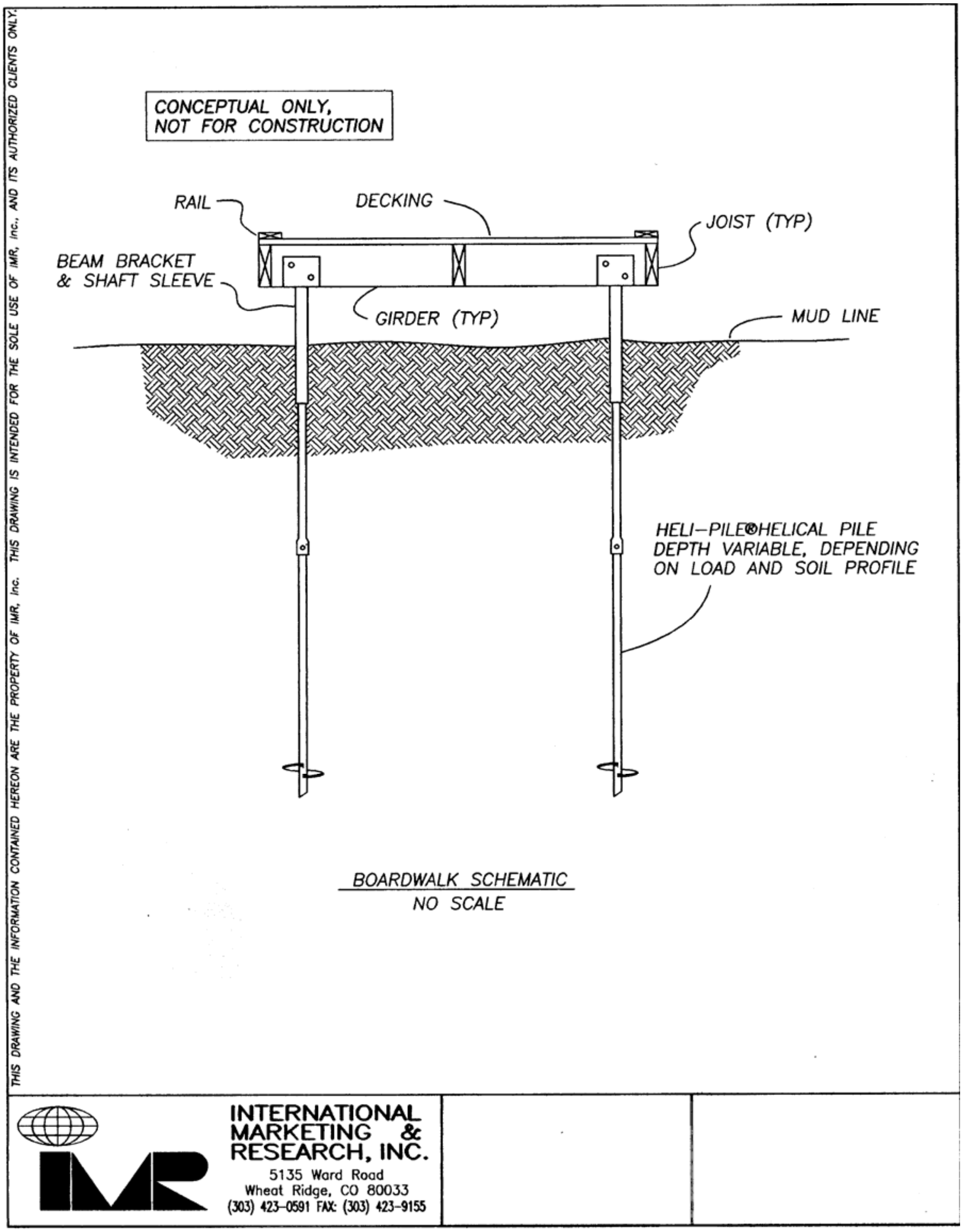


TYPICAL WOOD BEAM BRACKET





INTERNATIONAL MARKETING & RESEARCH, INC. 5135 Ward Road Wheat Ridge, CO 80033 (303) 423-0591 FAX: (303) 423-9155	JSP 7/16/09 NO SCALE	ADJUSTABLE STEEL OR WOOD BEAM UNDERPINNING BRACKET 1 OF 1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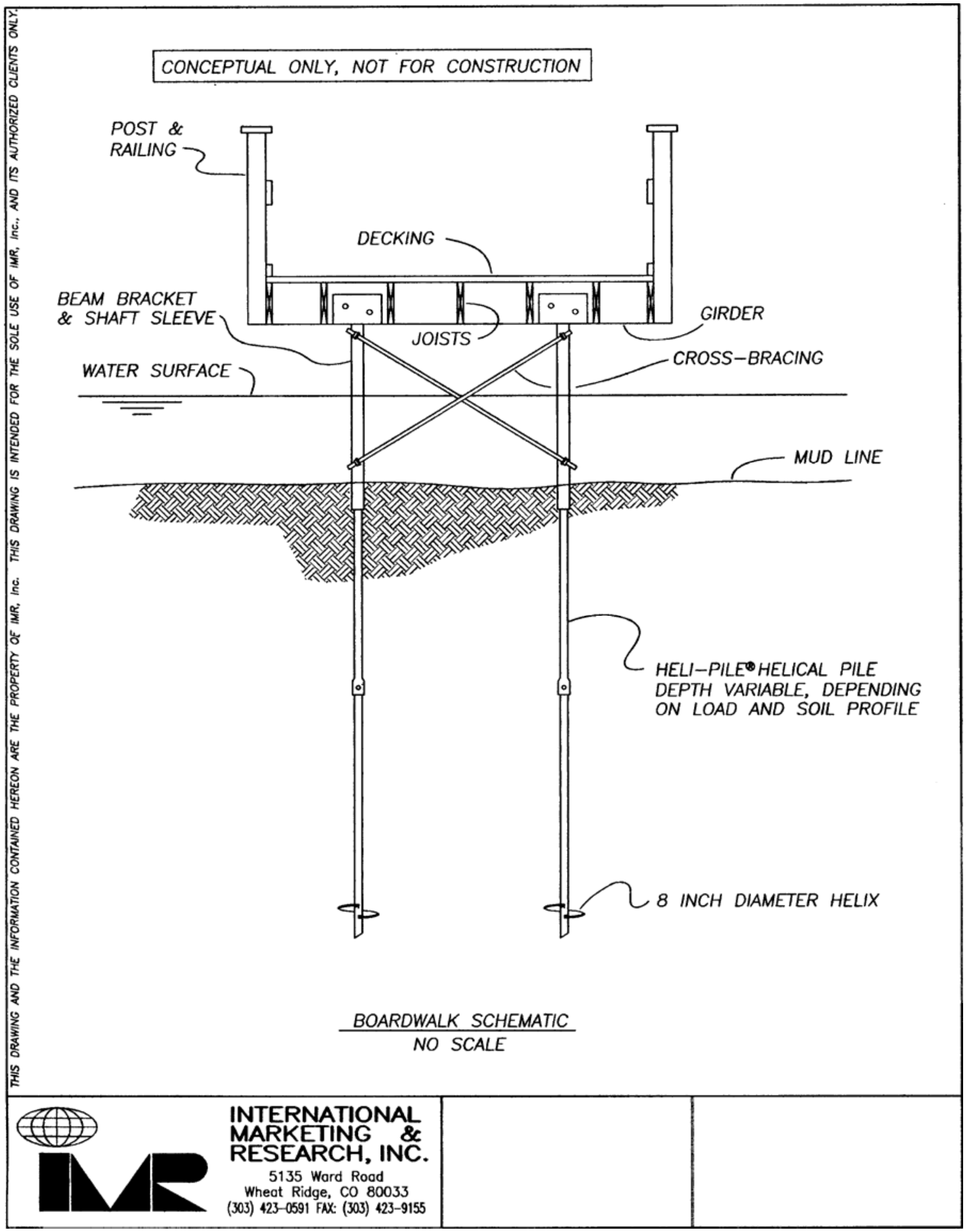
CONCEPTUAL ONLY, NOT FOR CONSTRUCTION
RAIL
DECKING
JOIST (TYP)
BEAM BRACKET & SHAFT SLEEVE
GIRDER (TYP)
MUD LINE
HELI-PILE® HELICAL PILE DEPTH VARIABLE, DEPENDING ON LOAD AND SOIL PROFILE
BOARDWALK SCHEMATIC
NO SCALE
INTERNATIONAL MARKETING & RESEARCH, INC.
5135 Ward Road
Wheat Ridge, CO 80033
(303) 423-0591 FAX: (303) 423-9155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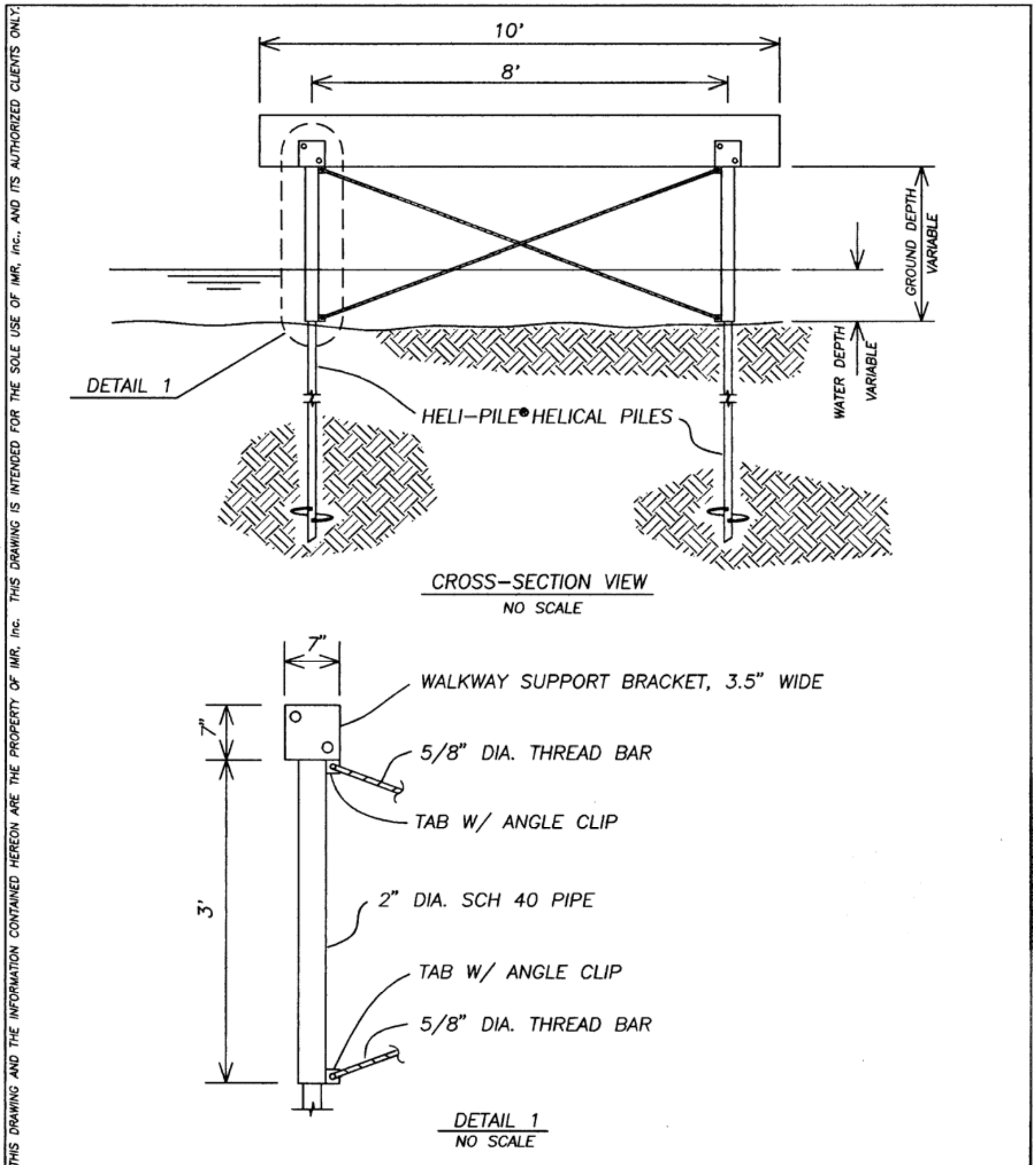
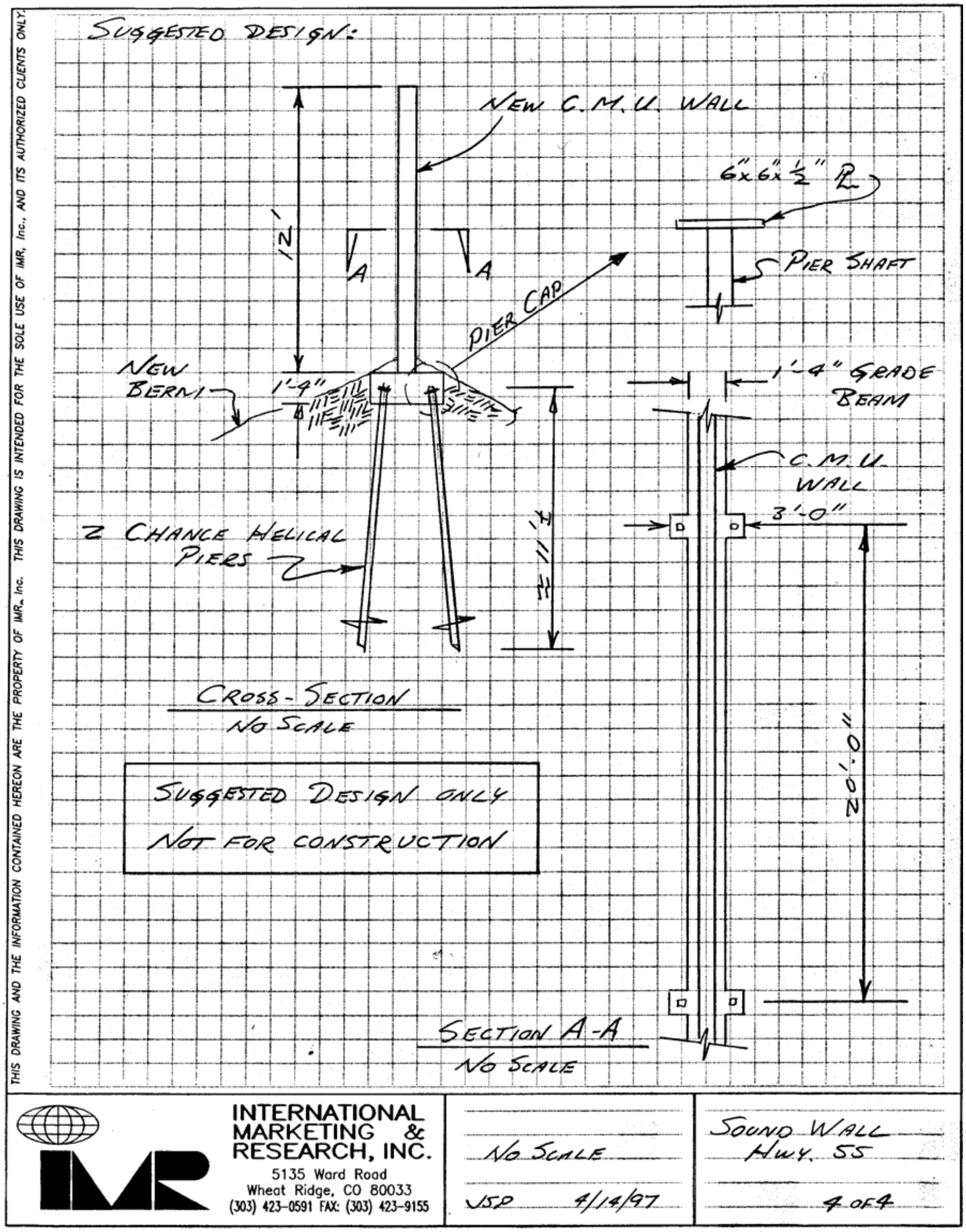
CONCEPTUAL ONLY, NOT FOR CONSTRUCTION
POST & RAILING
DECKING
BEAM BRACKET & SHAFT SLEEVE
JOISTS
GIRDER
CROSS-BRACING
WATER SURFACE
MUD LINE
HELI-PILE® HELICAL PILE DEPTH VARIABLE, DEPENDING ON LOAD AND SOIL PROFILE
8 INCH DIAMETER HELIX
BOARDWALK SCHEMATIC
NO SCALE
INTERNATIONAL MARKETING & RESEARCH, INC.
5135 Ward Road
Wheat Ridge, CO 80033
(303) 423-0591 FAX: (303) 423-9155



INTERNATIONAL MARKETING & RESEARCH, INC. 5135 Ward Road Wheat Ridge, CO 80033 (303) 423-0591 FAX: (303) 423-9155	WALKWAY SUPPORT BRACKET W/ 3' PIPE & TABS W/ ANGLE CLIPS NO SCALE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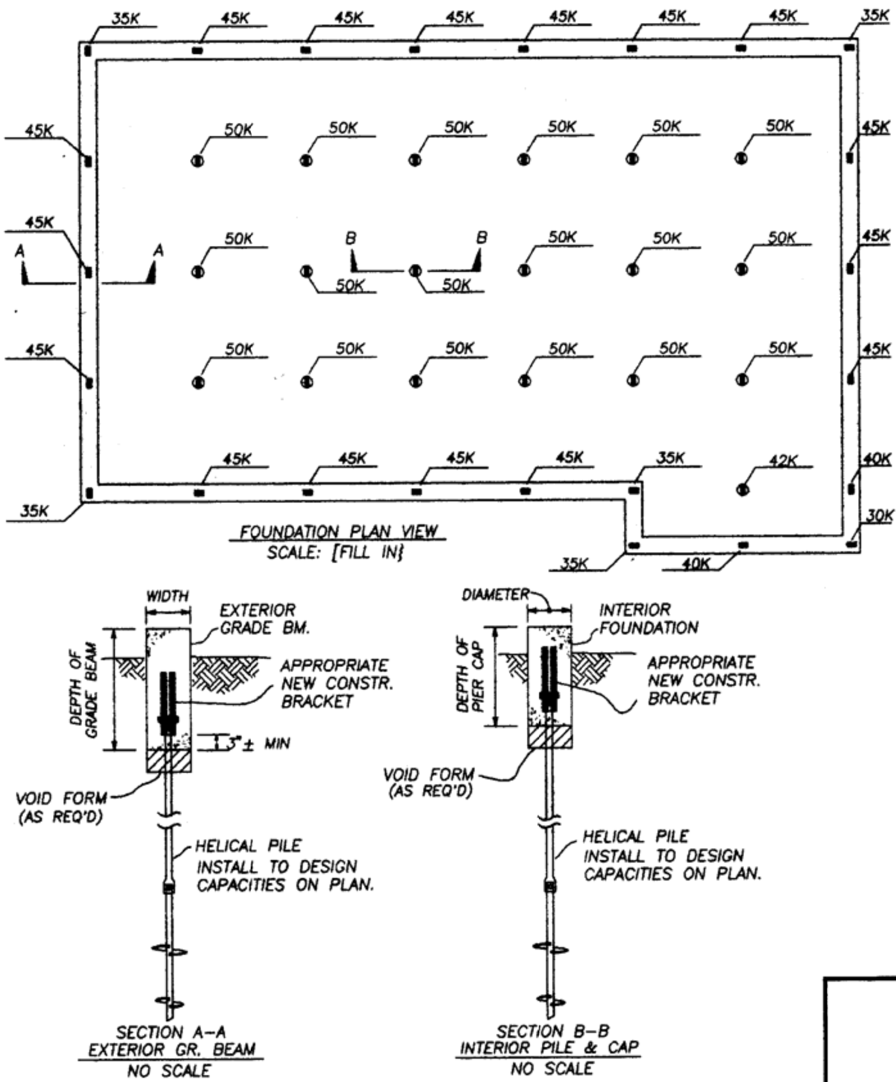
SUGGESTED DESIGN:
NEW C.M.U. WALL
12'
A
A
PIER CAP
6"x6"x½" PL
PIER SHAFT
NEW BERM
1'-4"
1'-4" GRADE BEAM
C.M.U. WALL
3'-0"
2 CHANCE HELICAL PIERS
11'-4"
20'-0"
CROSS-SECTION
NO SCALE
SUGGESTED DESIGN ONLY
NOT FOR CONSTRUCTION
SECTION A-A
NO SCALE
INTERNATIONAL MARKETING & RESEARCH, INC.
5135 Ward Road
Wheat Ridge, CO 80033
(303) 423-0591 FAX: (303) 423-9155
NO SCALE
JSP 4/14/97
SOUND WALL
HWY. 55
4 OF 4



NOTES TO THIS SAMPLE DRAWING:

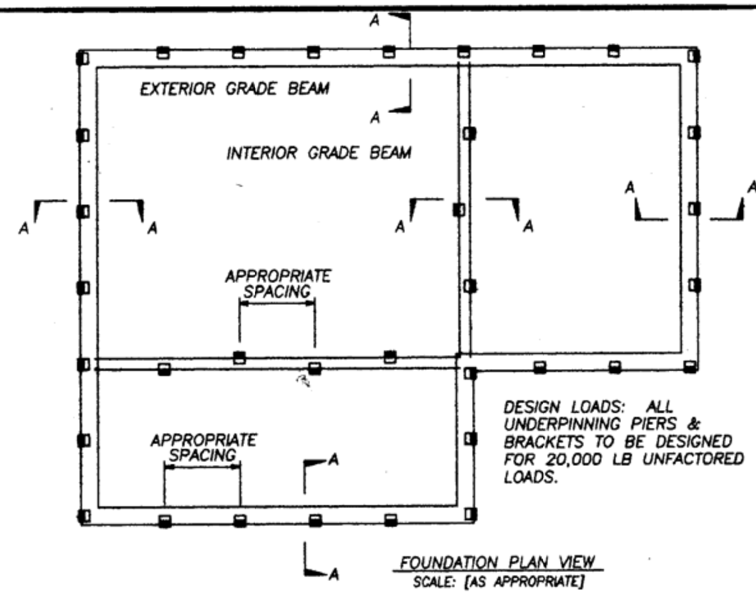
1. THIS IS ONLY A SAMPLE. CERTAIN VITAL DIMENSIONS HAVE BEEN OMITTED FOR CONVENIENCE. ENGINEER WILL PROVIDE SUCH DIMENSIONS AS APPROPRIATE. SINCE THIS IS A SAMPLE, BUILDING LENGTH & WIDTH ARE OMITTED.
2. THE LOADS SHOWN ON THE PLAN VIEW ARE DESIGN LOADS, I.E., DEAD AND LIVE LOADS, UNFACTORED.
3. THE FOLLOWING SPEC. IS A SAMPLE THAT IS FITS WELL ON A DRAWING. THIS SPEC. WOULD BE THE ONLY SPEC. USED FOR HELICAL SCREW PILES.

HELICAL SCREW PILE SPECIFICATION

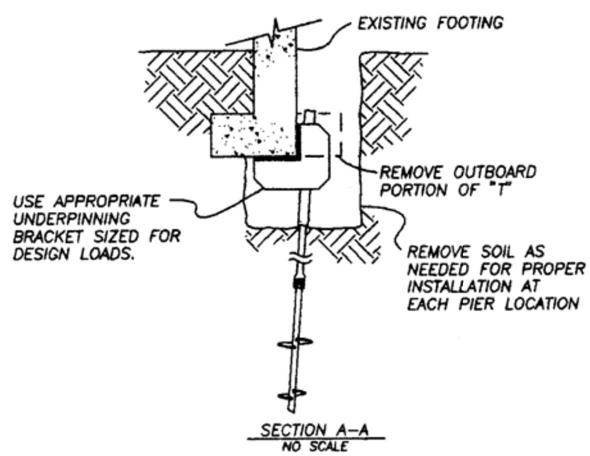
1. HELICAL PILES SHALL BE HELI–PILE® MANUFACTURED BY IMR, DENVER, CO.
2. PILES SHALL BE INSTALLED BY AN AUTHORIZED HELI–PILE® INSTALLING CONTRACTOR WHO HAS SATISFIED THE CERTIFICATION REQUIREMENTS RELATING TO THE TECHNICAL ASPECTS OF THE PRODUCT AND THE ASCRIBED INSTALLATION TECHNIQUES. PROOF OF CURRENT CERTIFICATION BY IMR MUST BE PROVIDED.
3. ALL WORK AS DESCRIBED HEREIN SHALL BE PERFORMED IN ACCORDANCE WITH ALL APPLICABLE SAFETY CODES IN EFFECT AT THE TIME OF INSTALLATION.
4. HELICAL PILES SHALL BE DESIGNED IN ACCORDANCE WITH THE 2009 IBC.
5. THE HELICAL LEAD SECTIONS AND EXTENSIONS SHALL BE SOLID STEEL, ROUNDED CORNER SQUARE SHAFT CONFIGURATION, WITH ONE OR MORE HELICAL BEARING PLATES WELDED TO THE SHAFT.
6. ALL HELICAL PILES SHALL BE GALVANIZED PER ASTM B633.
7. INSTALLATION UNITS SHALL CONSIST OF A ROTARY TYPE TORQUE MOTOR WITH FORWARD AND REVERSE CAPABILITIES. THESE UNITS SHALL BE EITHER ELECTRICALLY OR HYDRAULICALLY POWERED.
8. INSTALLATION UNITS SHALL BE CAPABLE OF DEVELOPING THE MINIMUM TORQUE AS REQ'D.
9. INSTALLATION UNITS SHALL BE CAPABLE OF POSITIONING THE HELICAL PILE AT THE PROPER INSTALLATION ANGLE. THIS ANGLE MAY VARY BETWEEN VERTICAL AND 5 DEGREES DEPENDING UPON APPLICATION AND TYPE OF LOAD TRANSFER DEVICE SPECIFIED OR REQUIRED.
10. INSTALLATION TORQUE SHALL BE MONITORED THROUGHOUT THE INSTALLATION PROCESS.
11. HELICAL PILES SHALL BE INSTALLED TO THE MINIMUM TORQUE VALUE REQUIRED TO PROVIDE THE LOAD CAPACITIES SHOWN ON THE PLANS.
12. THE APPROPRIATE STEEL NEW CONSTRUCTION LOAD TRANSFER DEVICE SHALL BE USED.
13. APPROPRIATE HELICAL PILE SELECTION WILL CONSIDER DESIGN LOAD PLUS SAFETY FACTOR,3 SOIL PARAMETERS AND THE INSTALLATION TORQUE VS. CAPACITY EQUATION AS PER THE MANUFACTURERS RECOMMENDATIONS.

SAMPLE ONLY. NOT FOR CONSTRUCTION.

	NEW FOUNDATION PLAN BY: JSP	SAMPLE DRAWING DRAWING NO.________



FOUNDATION PLAN VIEW
SCALE: [AS APPROPRIATE]



SECTION A–A
NO SCALE

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2. THE LOADS SHOWN ON THE PLAN VIEW ARE DESIGN LOADS, I.E., DEAD AND LIVE LOADS, UNFACTORED.
3. THE FOLLOWING SPEC. IS A SAMPLE THAT IS FITS WELL ON A DRAWING. THIS SPEC. WOULD BE THE ONLY SPEC. USED FOR HELICAL SCREW PILES.

HELICAL SCREW PILE SPECIFICATION

1. HELICAL PILES SHALL BE HELI–PILE® MANUFACTURED BY IMR, DENVER, CO.
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3. ALL WORK AS DESCRIBED HEREIN SHALL BE PERFORMED IN ACCORDANCE WITH ALL APPLICABLE SAFETY CODES IN EFFECT AT THE TIME OF INSTALLATION.
4. HELICAL PILES SHALL BE DESIGNED IN ACCORDANCE WITH THE 2009 IBC.
5. THE HELICAL LEAD SECTIONS AND EXTENSIONS SHALL BE SOLID STEEL, ROUNDED CORNER SQUARE SHAFT CONFIGURATION, WITH ONE OR MORE HELICAL BEARING PLATES WELDED TO THE SHAFT.
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8. INSTALLATION UNITS SHALL BE CAPABLE OF DEVELOPING THE MINIMUM TORQUE AS REQ'D.
9. INSTALLATION UNITS SHALL BE CAPABLE OF POSITIONING THE HELICAL PILE AT THE PROPER INSTALLATION ANGLE. THIS ANGLE MAY VARY BETWEEN VERTICAL AND 5 DEGREES DEPENDING UPON APPLICATION AND TYPE OF LOAD TRANSFER DEVICE SPECIFIED OR REQUIRED.
10. INSTALLATION TORQUE SHALL BE MONITORED THROUGHOUT THE INSTALLATION PROCESS.
11. HELICAL PILES SHALL BE INSTALLED TO THE MINIMUM TORQUE VALUE REQUIRED TO PROVIDE THE LOAD CAPACITIES SHOWN ON THE PLANS.
12. THE APPROPRIATE STEEL UNDERPINNING BRACKET SHALL BE USED.
13. APPROPRIATE HELICAL PILE SELECTION WILL CONSIDER DESIGN LOAD PLUS SAFETY FACTOR,3 SOIL PARAMETERS AND THE INSTALLATION TORQUE VS. CAPACITY EQUATION AS PER THE MANUFACTURERS RECOMMENDATIONS.

SAMPLE ONLY. NOT FOR CONSTRUCTION.

	FOUNDATION UNDERPINNING PLAN BY: JSP	SAMPLE DRAWING DRAWING NO.________

Helical Screw Test Probe Procedure

1. Use a single 8 inch (203 mm) diameter helix on a 1.75 inch (44.5 mm)shaft. If possible, use a 0.50 inch (12.7 mm) thick helix.

2. Have enough extensions to go the desired depth plus a few extra extensions in case it becomes necessary to go deeper.

3. Use a 10,000 ft-lb (13.6 kN-m)(1,380 kg_f-m) drive head minimum.

4. Have a pressure gauge plumbed into the system so hydraulic pressure can be read the instant pins are sheared in the shear pin torque indicator. The gauge should have a maximum pressure needle.

5. Start with two pins in the shear pin torque indicator. Start installing the helical screw pile probe. The instant two pins break read the pressure gauge. On a piece of paper record the depth of the probe, the torque for two pins (1,000 ft-lbs)(1.36 kN-m)(138 kg_f-m), the pressure reading on the pressure gauge the instant the pins broke, and describe any observed soil quality such as "cobbles," or "grinding," etc.. The recording paper should look something like the attached recording sheet.

6. Now place three pins in the shear pin torque indicator. Continue installing the helical screw pile probe while monitoring the pressure gauge. Record the pressure on the pressure gauge every 2 feet (0.61 m) as the probe screws deeper and deeper into the soil. Record this pressure on the recording sheet. Continue installing the probe until three pins break. The instant three pins break read the pressure gauge. On the recording sheet, record the depth of the probe, the torque for three pins (1,500 ft-lbs)(2.04 kN-m)(207 kg_f-m), the pressure reading on the pressure gauge the instant the pins broke, and describe any observed soil quality.

7. Now place four pins in the shear pin torque indicator. Continue installing the helical screw pile probe while monitoring the pressure gauge. Record the pressure on the pressure gauge every 2 feet (0.61 m) as the probe screws deeper and deeper into the soil. Record this pressure on the recording sheet. Continue installing the probe until four pins break. The instant four pins break read the pressure gauge. On the recording sheet, record the depth of the probe, the torque for four pins (2,000 ft-lbs)(2.72 kN-m)(276 kg_f-m), the pressure reading on the pressure gauge the instant the pins broke, and describe any observed soil quality.

8. Repeat this procedure for five pins, then six and so on up to 20 pins or until you run out of extensions, whichever comes first.

9. Be sure to record all data on the recording sheet. Also, on the recording sheet be sure to write down the probe location, the date the test was performed, the names of the people who performed the test, and the names of anybody else who observed the test.

Rev. 03/01/04 Sheet 1 of 1

Helical Screw Test Probe
Recording Sheet

Probe No.________
Sheet _____of_____

Location (be specific):___________________________________ Date:_________________

Test Performed By:____

Test Observed By:____

Description of Helical Screw Pile Probe:____

Probe Depth	No. of pins sheared	Torque	Pressure	Description

Rev. 03/01/04