INTRODUCTION

Definition: Helical Screw Foundation

The helical screw foundation can be devised into a deep foundation system to support or resist any load or application. Installed by lightweight mobile equipment, it can be loaded immediately.

The helical screw foundation's elegant simplicity is its greatest asset. Its mechanical design and manufacture balance the capacities of its three basic parts and maximize the efficient use of their material.

Essential Elements

1. **At least one bearing plate**
   Matching dies form each steel bearing plate into a true helix. This is to minimize soil disturbance during installation (as opposed to the inclined plane of an auger which mixes soil as it excavates). Properly formed helical plates do not measurably disturb the soil. On the lower end of an installed screw foundation, the helical bearing plates transfer the load to the bearing stratum deep below the ground surface. "Deep" is defined by A.B. Chance Company as five helix diameters vertically below the surface where the helical plate can develop full capacity of the plate-to-soil interaction.

2. **A central shaft**
   During installation, the central steel shaft transmits torque to the helical plate(s). Once in place, the shaft transfers the axial load to the helical plate(s) and on to the bearing stratum. Theoretically, the shaft needs to be only large enough for stress in the shaft to remain below the shaft material's allowable stress level. Realistically, the shaft also needs to be strong enough to resist the torque required for installation and large enough in section for the soil to resist buckling.

3. **A termination**
   The termination connects the structure to the top of the helical screw foundation and transfers the load down the shaft to the helical plate(s) and on to the bearing soil. To evenly distribute the structure load to the helical screw foundations, the termination may be a manufactured bracket or an attachment produced on site as prescribed by the structural designer. Such aspects dictate the termination's configuration as a function of its application and may range from a simple threaded bar to a complex weldment, as is appropriate to interface with the structure.

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History and Science of Helical Screw Foundations

In 1833, the helical screw foundation was patented as the "screw pile" by English inventor Alexander Mitchell. Soon after, he installed screw piles to support lighthouses in tidal basins of England. The concept also was used for lighthouses off the coasts of Maryland, Delaware and Florida. One is still in use offshore at Key Biscayne, FL.

From this practical worthy start, innovations of the helical screw foundation have been promulgated by both its academic and commercial advocates. Notable university and industry proponents on record who have expanded the science of earth anchors and foundations include: J.I. Adams, Ontario Hydro; S.P. Clemence, Syracuse University; T.H. Hanna, University of Sheffield; J. A. Howie, University of British Columbia; A.J. Luetenegger, University of Massachusetts; T.E. Rodgers, Virginia Power; and Bill Summerfield, SWEPCO.

Today, relatively small and readily available construction equipment can install helical screw foundations almost anywhere. Backhoes, skid-steer loaders and mini-excavators are easily fitted with the necessary hydraulically driven torque motors to place helical screw foundations in construction sites inaccessible by the larger equipment required for other methods. According to site conditions, installation equipment also can include guided-head and articulated-head torque-head machinery, self-propelled, carrier-mounted, tracked, wheeled or floating.

Chief Contributor: A.B. Chance Company

The following summarizes a short list of A.B. Chance Co. contributions to the helical screw anchor/foundation. The first commercially offered screw anchor was sold by the Chance Co. in 1940. For tension applications, it was installed by hand using a small tubular wrench. Other early developments include soil classifying measurement devices.

• PISA® (Power Installed Screw Anchors)

In the late 1950's, the Chance Co. introduced the patented PISA® system. This coincided with the advent of truck-mounted hole-digging equipment following World War II. The PISA system since has become the worldwide method of choice for guying pole lines of electric and telephone utilities.

The PISA system's all-steel components include one or two helix plates welded to a square hub, a rod threaded on both ends, a forged guy wire eye nut, and a special installing wrench. The square-tube anchor wrench attaches to the Kelly bar of a digger truck, fits over the rod, engages the helical hub and typically installs a PISA® anchor in eight to 10 minutes. Rod and wrench extensions may be added to reach soil layers which develop enough resistance to achieve competent anchorage. PISA rods come in $^{5}/_{8}$", $^{3}/_{4}$" and 1" diameters.

Through Chance Co. testing and close contact with utilities, the PISA® anchor family soon expanded to develop higher strengths capable of penetrating harder soils including glacial till. This quickly gave rise to the Company's development of screw anchors with higher capacities and larger dimensions.

More recent developments include the SQUARE ONE® (1980) and the TOUGH ONE® (1989) patented guy anchor families with 10,000 and 15,000 ft-lb installing torque capacities. Unlike previous PISA® designs, these anchor designs are driven by a wrench that engages inside, rather than over, their welded socket hubs. Both use the PISA extension rods with threaded couplings.

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• RR (Round Rod) Anchors

In 1961, Chance developed extendable Type RR multi-helix anchors, originally for use as tiedowns for underground pipelines in poor soil conditions on the Gulf of Mexico coast. These anchors are not driven by a wrench; instead, installing torque is applied directly to their 1$^1/_4$" diameter shafts. Type RR anchors worked well in weak surficial soils, but their shaft (although extendable by plain shafts with bolted upset couplings) did not provide enough torque strength to penetrate very far into firm bearing soils.

• SS (Square Shaft) Anchors

Development of a high-torque, shaft-driven, multi-helix anchor began in 1963, culminating in the Chance Company's introduction of Type SS 1$^1/_2$" Square-Shaft multi-helix anchors in 1964-65. The SS anchor family since has expanded to include higher-strength 1$^3/_4$", 2" and 2$^1/_4$" square shafts. Extension shafts with upset sockets also lengthen these anchors to penetrate most soils at significant depths for many civil construction applications including guying, foundations, tiebacks and, more recently, soil nails (Chance® SOIL SCREW® Retention Wall System, 1997).

• HS (High-Strength) Anchors

Later in the 1960's, Type HS anchors developed first for high-torque guying requirements later were applied as foundation anchors for utility substations and transmission towers. The HS anchor family has 3$^1/_2$" pipe shafts which may be lengthened by extensions with swaged couplings. HS anchors now are used for a wide array of foundation applications.

• PIF (Power Installed Foundation) Anchors

Also launched in this timeframe were non-extendable anchors termed Power Installed Foundations. PIF sizes and load capacities match support requirements for a broad range of equipment, platforms and field enclosures.

Most versatile are the 5-ft to 10-ft-long PIF with pipe shafts of 3$^1/_2$", 4", 6$^5/_8$", 8$^5/_8$" and 10$^3/_4$" diameters, each with a single helix of 10", 12", 14" or 16" diameter. Integral baseplates permit direct bolt-up connections on either fixed or variable bolt-circle patterns.

Bumper Post anchors are similar to the 3$^1/_2$"-shaft PIF, but with fence-type caps instead of baseplates, to serve as traffic barriers around booths, cabinets, doorways, etc.

One with a 2$^3/_8$" pipe shaft 69" long is called a Square-Drive Foundation for its 2"-square drive head. The solid head is internally threaded for adding a straight stud or adjustable leveling pad after installation.

A smaller non-extendable 35"-long version with a $^3/_4$" solid shaft, driven by such hand tools as a deep socket and ratchet wrench, also accepts the straight stud or leveling pad.

•Pad-Pod Foundation Anchors

Originally conceived for supporting padmounted underground electrical distribution transformers, Pad-Pod Foundation Anchors, are flange-driven with 2"-diameter extendable pipe shafts, each with an 8" or 10" helix.

• SLF (Street Light Foundation) Anchors

1972 introduced SLF (Street Light Foundation) anchors with pipe shaft diameters of 6$^5/_8$", 8$^5/_8$" and 10$^3/_4$" in fixed lengths of 5, 8 and 10 feet. Complete with an internal cableway, these foundations with bolt-up baseplates deliver the quick solution their name implies and now are used to support similar loads for a variety of applications.

• T/C (Tension/Compression) Foundation Anchors

Especially designed for utility transmission tower foundations and known as T/C anchors

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for their resistance to such uplift-tension, compression, bending and lateral loads, these 8" pipe shaft anchors may be extended by a unique bolted coupling of their helical plates.

• HELICAL PIER Foundation Systems

In 1985, Chance® introduced this patented remedial method for repairing foundations of residential and commercial buildings. Originally based on Type SS helical screw foundation anchors, its special foundation repair brackets transfer structural loads to stable soil strata below weak surface conditions. Since then, the method also has been used to deepen foundations for new construction by installing the helical screw foundations at intervals between footing forms prior to pouring reinforced concrete.

• HELICAL PULLDOWN™ Micropiles

Developed in 1997, for sites with especially weak surface soils, this Chance® patented innovative application of the helical screw foundation integrates Portland-cement-based grout to stiffen its upper shaft. By "pulling down" a special flowable grout as the foundation is screwed into the soil, the result is a pile with both a friction-bearing central shaft and end-bearing helical plates in competent substrata. Where needed for poor surface conditions, this performance combination converts "impossible" sites to sound, for not only building construction but also telecom tower foundations in areas inaccessible by equipment for other methods. It employs SS, HS and combinations of these two types of helical screw foundations.

Applied Research and Development: A.B. Chance Company

In addition to products developed for specific applications, Chance® contributions to applied science of helical screw anchors and foundation have been outstanding. Among subjects expanding the body of knowledge are these noteworthy milestones:

• A.B. Chance Co. Soil Classification Chart

In 1945, the Chance Company's first earth anchoring manual classified soils according to holding capacities as related to proper anchor selection. At sites where soil data was available, either by sample excavation or some rudimentary means of probing subsurface strata, this chart imparted a valuable basis for recommending the proper helical screw anchor or foundation for a given load. The chart, as refined over the years and produced here, still serves as a useful reference today.

Soil Classification Data

Class	Common Soil-Type Description	Geological Soil Classification	Probe Values in.-lbs. (NM)	Typical Blow Count "N" per ASTM-D1586
0	Sound hard rock, unweathered	Granite, Basalt, Massive Limestone	N.A.	N.A.
1	Very dense and/or cemented sands; coarse gravel and cobbles	Caliche, (Nitrate-bearing gravel/rock),	750 - 1600 (85 - 181)	60-100+
2	Dense fine sands; very hard silts and clays (may be preloaded)	Basal till; boulder clay; caliche; weathered laminated rock	600-750 (68 - 85)	45-60
3	Dense sands and gravel; hard silts and clays	Glacial till; weathered shales, schist, gneiss and siltstone	500 - 600 56 - 68	35-50
4	Medium dense sand and gravel; very stiff to hard silts and clays	Glacial till; hardpan; marls	400 - 500 (45 - 56)	24-40
5	Medium dense coarse sands and sandy gravels; stiff to very stiff silts and clays	Saprolites, residual soils	300 - 400 (34 - 45)	14-25
6	Loose to medium dense fine to coarse sands to stiff clays and silts	Dense hydraulic fill; compacted fill; residual soils	200 - 300 (23 - 34)	7-14
**7	Loose fine sands; Alluvium; loess; medium - stiff and varied clays; fill	Flood plain soils; lake clays; adobe; gumbo, fill	100 - 200 (11 - 23)	4-8
**8	Peat, organic silts; inundated silts, fly ash very loose sands, very soft to soft clays	Miscellaneous fill, swamp marsh	less than 100 (0 - 11)	0-5

Class 1 soils are difficult to probe consistently and the ASTM blow count may be of questionable value.
**It is advisable to install anchors deep enough, by the use of extensions, to penetrate a Class 5 ot 6, underlying the Class 7 or 8 Soils.

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• Torque-to-Capacity Relationships
Installation torque-to-load capacity relationship is an empirical method originally developed by A.B. Chance Company. Chance has long promoted the idea that the installation energy (torque) required to install a helical screw foundation can be correlated to its ultimate load capacity in soil. The analogy is similar to screwing a wood screw into a piece of wood. It takes more torsional energy to screw into dense wood, such as oak, than it does to screw into a soft wood, such as pine. Likewise, a wood screw in oak will require more effort to pull out than the same wood screw in pine. The same is true for helical screw foundations in soil. Dense soil requires more torque to install compared to a soft soil; and dense soil will generate more load capacity compared to a soft soil. This relationship is discussed in detail in Step 9.

For the torque correlation method to work, torque must be measured. Chance Engineers have developed both mechanical and electronic indicators over the years, many of which are commercially available for torque measurement in the field.

• Soil mechanics principles
In the 1970s and early 1980s, changes in design philosophy led A.B. Chance Company engineers to recognize that a deep buried plate (i.e., screw anchor helix) transferred load to the soil in end-bearing. Theoretical capacity could then be calculated based on Terzaghi's general bearing capacity equation. The individual bearing method, discussed in detail in Step 4, calculates the unit bearing capacity of the soil and multiplies it by the projected area of the helix plate. The capacity of individual helix plate(s) is then summed to obtain the total ultimate capacity of a helical screw foundation. Today, the individual bearing method is commonly used in theoretical capacity calculations.

• 90+ years of field test data
A.B. Chance Company has a long standing tradition of proving theory in the field by conducting literally thousands of load tests. It has been said that soil occurs in infinite variety whose engineering properties can vary widely from place to place. This variability makes in-situ testing a vital part of sound geotechnical engineering judgment. Test results are available from Chance for typical capacity of helical screw foundations in soil. Refer to Step 11 for more information about load testing.

• HeliCAP™ Engineering Software
Developed by Chance engineers, HeliCAP® Engineering Software was designed to assist the designer select the correct helical lead configuration and overall screw foundation length. It also estimates the installation torque. This program, exclusive in the industry, makes the selection of helical screw foundations easier and quicker than any other method. The Appendix contains an application form for HeliCAP® Engineering Software. To obtain a copy of the software, fill out the application form and contact your local A.B. Chance Company Civil Construction Distributor. Contact information for each distributor in the network can be found at www.abchance.com.

• Inter-helix spacing
Load transfer either above or below the helix plate results in a stress zone within a defined soil volume. For individual bearing to work properly, the helix plates must be spaced far enough apart to avoid overlapping their stress zones. The key is to space the helix plates just far enough apart to maximize the bearing capacity of a given soil. This works to reduce the overall length of the screw foundation and increases the likelihood for all helix plates to be located in the same soil layer; which in turn leads to more predictable torque-to-capacity relationships and better load/deflection characteristics. Through years of research, A.B. Chance Company determined that the optimal spacing for helix plates is

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three diameters. More specifically, the optimum space between any two helical plates on a helical screw foundation is three times the diameter of the lower helix. Today, all A.B. Chance helical screw foundations are manufactured using the industry standard of three-diameters spacing.

- **Industry Standard: Helical screw foundation form fits function**

The helical screw foundation is not a sophisticated product, but it continues to serve ever-expanding roles in civil construction applications. However, you will not likely find helical screw foundations mentioned in foundation engineering textbooks, at least not as of the publication of the first edition of this design manual. Nor will you find helical screw foundations mentioned in the pile foundation, or pier foundation sections of model building codes. As a result, education about helical screw foundations and anchors is lacking – which is one reason for the development of this manual. However, A.B. Chance Company is the only manufacturer of helical screw foundations and anchors to obtain evaluation reports from all three model building code agencies – ICBO, BOCA, and SBCCI. Copies of all three evaluation reports are in the Appendix.

Applications

In its simplest form, the screw foundation is a deep foundation element, i.e., it transfers structure dead and live loads to competent soil strata deep below grade. This is the same for any deep foundation element such as driven piles, drilled shafts, grouted tendons, auger-cast piles, belled piers, etc. Therefore, helicals can be used as a replacement for alternative methods such as drilled shafts and driven piles. Practical constraints primarily related to installation currently limit the maximum design load to 200 kip in compression and 100 kip in tension, which means helical screw foundations can resist relatively light to medium loads, not heavy loads. But as is the case with virtually all engineering problems, more than one solution exists. It is the responsibility of the engineer to evaluate all possible alternatives, and to select the most cost-effective solution.

Today, helical screw foundations are commonly used for residential and light commercial construction, machinery/equipment foundations, telecommunication and transmission towers, tiedowns for wind and/or seismic forces, and virtually any application where site access is limited or remote. They have become the foundation of choice for walkways and boardwalks in environmentally sensitive areas, such as wetlands and protected forestland. In expansive soil areas, screw foundations can save money and time when compared to expensive over-excavation and fill options. Helical screw foundations do have several advantages (see following section) that make them the foundation of choice for many applications including these general categories:

- **Machinery/equipment foundations**
- **Limited access sites**
- **Wind and seismic loading**
- **Replacement for drilled/driven piles**

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Advantages of Helical Screw Foundations

Each project has unique factors that determine the most acceptable foundation system. The following summarizes situations where helical screw foundations present sensible solutions.

• Projects requiring deep foundations due to weak surface soil

Helical screw foundations are designed as end-bearing piles which transfer loads to competent, load-bearing strata. **Advantages over other deep foundation systems:** Eliminates high-mobilization costs associated with driven piles, drilled shafts or auger-cast piles. Helical screw foundations don't require spoils to be removed and for flowable sands, soft clays and organic soils, no casings are required, unlike drilled shafts or caissons.

• Flooded and/or poor surface conditions

When surface conditions make spread footings impossible and equipment mobilization difficult, helical screw foundations are a good alternative since installation requires only a mini-excavator, a rubber-tired backhoe or small tracked machine.

• Limited access

In confined areas with low overhead, helical screw foundations can be installed with portable equipment. This is particularly useful for rehabilitation work.

• Expansive soils

The depth of expansive soils from the surface varies, but a typical depth is approximtely 10 feet. The bearing plates of a helical screw foundation are usually placed well below this depth. This means that only the small-cross-section shaft of the helical screw foundation is affected by the expansive soils. The swell force on the shaft is directly proportional to the surface area between the soil and the shaft, and the swell adheasion value. Since helical screw foundations have much smaller shafts than driven piles or auger-cast piles, uplift forces on screw anchors are much smaller. Research by R.L. Hargrave and R.E. Thorsten (1993, Dallas area) demonstrated helical screw foundations' effectiveness in expansive soils.

• Bad weather installation

Because helical screw foundations can be installed in any weather, work does not need to be interrupted.

• Contaminated soils

Helical screw foundations are ideal for contaminated soils because no spoils need to be removed.

• Temporary structures

Helical screw foundations can easily be removed by reversing the installation process. This makes removal of temporary structures simple.

• Remedial applications

Helical screw foundations can supplement or replace existing foundations distressed from differential settlement, cracking, heaving, or general foundation failure. Patented systems such as Chance® Helical Pier Foundation Systems provide a complete solution. Chance uses a patented system to attach the helical screw foundation to existing foundations and either stabilize the structure against further settlement or lift it back to near original condition. This system is only installed by trained and authorized certified contractors.

Helical screw foundations are ideal for remedial work since they can be installed by portable equipment in confined, interior spaces. Additionally, there is no need to worry

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about heavy equipment near existing foundations. And, unlike driven piles, helical screw foundations are vibration-free. The building can continue to operate with little inconvenience to its occupants. Other deep foundation systems such as auger-cast piles disturb the soil, there`by undermining existing foundations. Helical screw foundations do not disturb existing conditions.

Summary of Helical Screw Foundation Advantages

- No need for concrete to cure
- Quick, easy turnkey installation
- Immediate loading
- Small installation equipment
- Pre-engineered system
- Easily field modified
- Torque-to-capacity relationship for production control
- Install in any weather
- Solution for:
  - -Restricted access sites
  - -High water table
  - -Weak surface soils
- Environmentally friendly
- No vibration
- No spoils to remove

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