The DFI Institute is organized to serve as a primary means through which members of the Institute may participate in improvement of the planning, design and construction aspects of deep foundations and deep excavations.
Note to Instructor: The DFI does not advocate helical foundations over other types of foundation and anchoring systems. It is intended that this will be one of many instructional tools of the DFI.
The purpose of this presentation is to provide educators and students with information on the evolution of deep foundation systems known as helical piles, helical anchors and helical tiebacks dating back to the product’s invention in the early 19th century. Today helical piles, also known as screw piles, are used in many countries around the world.
Historically helical piles, helical anchors and helical tiebacks have been known by other names as indicated on this slide. The most commonly used name in Canada, Australia, New Zealand and Europe is Screw Pile or Screw Anchor.
The term Helical Foundation is generally used to define an entire foundation in which helical piles or helical anchors are the primary deep foundation element.
Helical Piles, Helical Anchors and Helical Tiebacks are pre-manufactured deep foundations. This slide details the component parts that comprise these products.
Helical piles, anchors and tiebacks are installed using a torque motor attached to a source of hydraulic pressure. The installation process produces no soil spoils, there is no vibration involved and they can be installed in nearly any weather conditions.
Four-helix helical pile about to be installed with a track-hoe excavator. Note torque indicating device located just below the hydraulic torque motor.
Helical piles are typically installed with machine-mounted hydraulic torque motors. The machines can be front end skid-steer loaders, mini-excavators, rubber-tired back hoes, and large track-hoe excavators.
Helical piles can also be installed with portable hydraulic torque motors, which keep mobilization costs down and minimize site disturbance. Portable installation equipment makes it possible to install helical piles in very tight access locations.
Helical piles come in many sizes and shaft types. Shafts range from slender square shafts to large diameter pipe shafts. The majority of helical piles use shaft diameters of 3-1/2” or less. Helical piles can be single or multi-helix configuration. The helix diameters on multi-helix piles usually taper from smaller to larger from the tip of the pile. The helix plates can also be the same diameter. Grout is sometimes used both on the outside and inside the pile shaft.
This slide lists several of the advantages available with helical piles.

- Low mobilization costs due to small and inexpensive installation equipment
- Low noise and minimal vibrations
- Smaller shafts reduce effect of expansive soil heave
- Slender shafts dampen seismic forces
- Year-round installation in any weather
- Helical foundations can be removed and re-used for temporary structures
- Can be installed in confined spaces with minimal damage and disruption making them ideal for remedial work
- Provide both tensile and compressive support
- Does not produce drill spoils
- Installation torque can help to verify capacity
This slide lists several of the possible disadvantages of helical piles.

<table>
<thead>
<tr>
<th>Disadvantages of Helical Foundations</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Unable to penetrate competent bedrock without pre-drilling</td>
</tr>
<tr>
<td>- Potential refusal in heavy cobbles and boulders</td>
</tr>
<tr>
<td>- Installation difficult in trash fill with concrete and other building material debris</td>
</tr>
<tr>
<td>- Low start-up cost can result in less qualified contractors</td>
</tr>
<tr>
<td>- Buckling limits capacity in very soft soils</td>
</tr>
<tr>
<td>- Lower lateral capacity may require augmentation in some cases</td>
</tr>
<tr>
<td>- Use of torque as a verification of capacity needs to be tempered with calculated theoretical capacity, engineering judgment and load tests when applicable</td>
</tr>
<tr>
<td>- Special inspection is recommended</td>
</tr>
</tbody>
</table>
Historical Development
Englishman Alexander Mitchell is recognized as the inventor of the “Screw Pile”. The first recorded use of screw piles was for boat moorings and then for lighthouse structures along the Thames River. Mitchell traveled extensively as a consultant to the United States and to other English speaking countries. The first recorded use of screw piles in the United States was in 1843. Today, helical piles are used world wide.
During the 19th century, screw piles were used as deep foundations for a variety of structures, including lighthouses, buildings, railroad bridge piers, seaside piers, and platforms. The drawing on this slide is the Maplin Sands lighthouse in England.
This slide shows a typical lighthouse structure supported on helical piles. The picture on the right is a spud barge with a large capstan used to install the screw pile.
Mitchell authored several technical papers. This slide show an excerpt from one of his papers published in 1848. Mitchell cites the three basic design parameters required for helical piles – minimum depth, soil strength, and bearing area of the helix.

“on Submarine Foundations; particularly Screw-Pile and Moorings”, by Alexander Mitchell, Civil Engineer and Architects Journal, Vol. 12, 1848

“whether this broad spiral flange, or “Ground Screw,” as it may be termed, be applied … to support a superincumbent weight, or be employed … to resist an upward strain, its holding power entirely depends upon the area of its disc, the nature of the ground into which it is inserted, and the depth to which it is forced beneath the surface.”
Helical, or screw piles entered a quiet period during the first half of the 20th century, primarily due to development of other deep foundation methods and advances in pile driving / installation equipment. After World War II, helical piles made a comeback with the development of high capacity hydraulic torque motors, which greatly improved installation time and cost.
Today, advances in geometry have resulted in more efficient helical pile designs. They are used for foundation repair (underpinning), new construction foundations, earth retention (tiebacks and helical soil nails), tie-downs, guy anchors, seismic retro-fit, and many other applications. Research continues into behavior as related to capacity and serviceability. Helical piles continue to provide cost effective deep foundations in our modern world.
The shaft sizes ranges from 1-1/2” square bar to 12” diameter and larger pipe shaft. Helix plate diameters range from 8” to well over 24”. Lengths vary but can range from 7 feet deep to well over a 100 feet long.
Theory and Design
Many design variables must be considered for helical piles. However, the basic engineering principles used are similar to those considerations made for other deep foundations.
Theoretical capacity models depend on accurate soil properties, tests, and experience. Theoretical models usually depend on soil strength correlations, estimates, and disturbance factors related to the means and method of helical pile installation.
A common theoretical capacity model used with helical piles is the Individual Bearing Plate Model. It assumes each helix plate acts as an individual bearing element in soil. The total capacity is equal to the sum of the capacities of each individual helix plate. Bearing capacity is calculated using the Terzaghi general bearing capacity equation. The designer must make use of the appropriate soil parameter, either effective stress parameters for long term, slow loading in sands & clays, or total stress parameters in rapid loading of saturated clays.
Helical Piles, Anchors and Tiebacks are manufactured in many different sizes with corresponding compression and/or tension capacities. It is precisely this wide spectrum of products and capacities that makes these products such viable deep foundation solutions for many different applications.
Installation torque (resistance to helical pile penetration) can be used to estimate the ultimate capacity of helical piles. Torque correlations have been empirically established based on load tests done over many years in many soil types. This slide shows the relationship between the installation torque and the ultimate capacity of a helical pile. This relationship, i.e. correlation, has been termed “$K_t$”. The torque correlation factor $K_t$ is inversely related to shaft size; and follows the trend that as the helical pile shaft increases, the $K_t$ factor decreases.
This slide gives the main factors that affect $K_t$. Soil conditions and shaft size are the two primary factors.
Researchers Robert Hoyt and Dr. Samuel Clemence published *Uplift Capacity of Helical Anchors in Soil* in 1989. It is considered a landmark paper on torque correlation for helical piles. In this paper, Hoyt and Clemence proposed several $K_t$ factors, which have become commonly used in the industry.
The most common factor of safety used for most permanent helical pile applications is a factor of safety of 2. Applications where extensive testing is required allow for lower factors of safety.

- Select an appropriate Factor of Safety (FS) to be applied to the Ultimate Capacity of the anchor/foundation to develop a design, or Working Capacity per anchor/foundation.
- In general, it is recommended to use a minimum FS = 2.0.
- For helical anchor projects where a significant fraction or all anchors are proof tested a FS = 1.5 is common.
Research shows that buckling is a practical concern only in the softest soils.

- Soil provides lateral support to shaft
- Practical Guideline: Soil with ASTM D-1586 blow count of 4 or less
  - Very soft & soft clays
  - Very loose sands
- Computer programs available for analysis
  - LPILE (ENSOFT, Austin, TX)
  - Finite Element Software - ANSYS®
  - UniPile5 (UniSoft Ltd, Ottawa, ON)
  - Other Software packages are available
The industry-recommended standard for minimum spacing for helical anchors (tension applications) is (4) times the diameter of the largest helix bearing plate with (3) feet being the absolute minimum spacing.
Minimum Depth

- Specification of a minimum depth is required in expansive soils, for frost, and to ensure bearing in a certain stratum.

- Specification of a minimum depth also is required in the case of pullout resistance to ensure a deep mode of behavior:
  - Typically 7 to 10 helix diameters
  - Can be computed by comparing the weight of overburden soils with the required pullout resistance as in the figure to the left.

*from Perko (2009) *Helical Piles*, Wiley, NY*
The lateral capacity of helical piles is calculated the same way as with other types of deep foundations.
Lateral capacity can also be mobilized via other foundation elements, such as the grade beam and optional lateral tieback anchors.
Helical piles can be installed at a batter. The orientation of the piles then allows them to resist lateral loads.
Underground corrosion needs to be evaluated for helical piles, as it should be for all deep foundation systems. Disturbed, unsaturated soils near the surface are generally more corrosive than saturated undisturbed soils deeper below the surface. Near the surface, it is common to use protective coatings, such as hot-dip galvanizing, epoxy, and concrete.
For permanent structures, corrosion may be accounted for adjusting shaft section properties by the sacrificial thickness per ICC-ES AC358.

**AC358 Section 3.9** The thickness of each component shall be reduced by \( \frac{1}{2} T_s \) on each side for a net reduction in thickness of \( T_s \).

\[
T_d = T_n T_s
\]

where \( T_n \) is nominal thickness and \( T_s \) is sacrificial thickness (t=50 yrs).

Zinc-coated steel:\( T_s = 25t^{0.65} = 0.013 \) in

Bare steel: \( T_s = 40t^{0.80} = 0.036 \) in

Powder coated steel: \( T_s = 40(t-16)^{0.80} = 0.026 \) in

*Coating shall conform with ASTM A123/A153*
The following list are factors that affect the installability and load capacity, and performance of helical piles:

- Proper sizing of helical bearing plates for the bearing and pullout capacity of the soil
- Minimum final installation torque
- Minimum overall depth required for frost, expansive soils, or to reach the proper bearing stratum
- Minimum shaft size and section modulus
- Mechanical capacity of pile and anchor components
- Proper connection to structure
- Training and experience level of contractor
- Inspection frequency and duration
- Load test requirements
This slide gives brief definitions of the three most common type of specifications used for the installation and use of helical piles. The most common (and most used) is the performance specification.
Applications
Tieback wall in Omaha, NE. Helical tieback anchors used for earth retention.
Tieback wall at O’Hare Airport in Chicago. Helical tieback anchors installed in very cold weather conditions.
TVA 500 kV substation near Memphis, TN. Helical piles used to support large dead-end structures and transformer pads.
Telecommunication tower guy anchorage with multiple guys and multiple anchors.
Helical anchors are widely used to counteract buoyancy issues for a variety of structures that are below the water table – such as buried gas transmission pipelines (as shown in the photo above), and empty to nearly empty underground storage tanks in high groundwater conditions. They have also been used to anchor plastic septic tanks in situations where the tank, which weighs next to nothing, becomes close to empty, and the water table is high and the ground cover over the tank is only one to two feet.
Helical piles installed to support structural slab inside existing building.
Helical piles being installed to support single family and multi-family structures including structural slabs in regions with heaving soils.
Helical Pile installations are vibration free making them a viable solution for projects with close proximity to existing structures.
Large diameter helical piles being installed at a refinery.
Large diameter piles being installed at a batter angle for above grade pipeline support.
Helical Piles being installed to replace failing wood pilings and cross members for an above grade pipeline.
Helical Piles being installed to support a large grain silo.
Large diameter helical piles being installed using a drill rig to support a multi-story parking garage.
Helical Piles being installed for single family houses.
Helical pile supported walkways to provide public access to wetlands and wildlife areas.
Helical pile supported walkways to provide public access to wetlands and wildlife areas.
Helical Piles being installed to support an addition to a mountain cabin.
Helical Piles are used to support decks, gazebos and other above grade structures.
Helical Piles are used extensively for underpinning existing foundations that have experienced differential settlement.
Helical Piles being installed to support the addition of an MRI system at an existing medical facility.
This slide provides a perspective of the many applications for which helical pile, helical anchors and helical tiebacks are viable solutions.
Case History
Ford Field in Detroit.
Helical tieback anchors used to construct a temporary retaining wall during construction of the stadium.
Elevation view of typical wall face.
Section view of typical wall face.
Load-deflection plot of extended creep test on helical tieback anchor for the Ford Field project.
Continued Study
Industry Organizations

- DFI (Deep Foundations Institute)
- ADSC (International Association of Foundation Drilling)
- ASCE (American Society of Civil Engineering)
- AGA (American Galvanizers Association)
- HelicalPileWorld.com
Trade Shows / Seminars

- DFI Helical Pile & Tieback Conference
- Home Builders Expo
- DFI Annual Conference on Deep Foundations
- World of Concrete
- National Association of Tower Erectors
- Tower Show
- Con Expo
- Light Show
- Small Wind Installers Conference
- Solar Power International
- PV American (solar)
- Utility Solar Conference
Books

- Donald P. Cuduto, *Foundation Design Principles and Practices*
- Gulac Wilson, "The Bearing Capacity of Screw Piles and Screwcrame Cylinders"
- Romanoff, *National Bureau of Standards Monograph 127*
Conclusion

Helical Piles & Anchors Offer a Wide Spectrum of Versatile Deep Foundation Solutions for Consideration by Engineers and Contractors

DFI Disclaimer:
This presentation is intended as an introduction to helical piles and helical anchors. It is neither intended to be comprehensive or exhaustive. The goal of the presentation is to complement undergraduate or graduate coursework in the study of deep foundation and anchor behavior. Helical piles and helical anchors are subject to many of the same limitations as other types of foundation and anchoring systems. There is no one solution for every ground condition. Prior to embarking on the design of helical foundation systems, the student is advised to seek further study in the proper design, installation, and application of helical piles and helical anchors.