Helical Design
Theory, Applications & Seismic Testing
Darin Willis, P.E.
**Helical Applications**

- Slab Bracket
- New Construction
- Wall Tie Back Anchor
- Remedial Repair

**Additional Applications**

- Boardwalks
- Pedestrian Bridges
- Tower / Guy Anchors
- Green Energy
- Light Poles
- Sign Supports
- Pipelines
- Beach Front Properties
- Bulkheads
- ... Endless Applications ...

**Ram Jack’s thermoplastic coating prevents rust and zinc from leaching into the ground water. Making it ideal for environmentally sensitive areas.**

**Helical Pile / Anchor System**

**Benefits:**
- Can be customized to meet capacity requirements
- Can be used in tension or compression
- Quality assurance during installation (monitoring torque)
- Does not require structure for reaction resistance
- No drilling spoils during installation
- No vibration during installation
- Instant Pile (can be loaded immediately)
- Adaptable to almost any foundation
- No welding in the field
- Fast, efficient installation in any weather
Helical Design & Theory

Helical Historical Perspective

- 1st recorded use of helical piles was by Alexander Mitchell in 1836 for Moorings and was then used by Mitchell in 1838 to support Maplin Sands Lighthouse in England.
- In the 1840’s and 50’s, more than 100 helical foundation lighthouses were constructed along the East Coast, Florida Coast and the Gulf of Mexico.
- Through advancements in installation equipment, geometries & research, helical foundations are now used throughout the world.

Pile & Anchor Capacity

Design Considerations

- Pile Capacity
  - Individual bearing method
  - Torque correlation
  - Load tests
- Acceptance Criteria for Helical Piles (AC358)
- Building Code Compliance
- Pile Spacing
Individual Bearing Method

- Total capacity is the sum of the bearing resistance of each helix.
- Capacity due to friction along the shaft is generally assumed negligible and normally omitted.

**Terzaghi Bearing Equation**

\[ Q_u = A_h q_u = \sum A_h (c N_c + q_v N_v) \]

- \( A_h \): helix plate area
- \( c \): soil cohesion
- \( q_v \): overburden stress
- \( N_c \& N_v \): Meyerhof bearing factors

Torque Correlation Method

The torque required to install a pile or anchor is empirically and theoretically related to ultimate capacity:

\[ Q_u = K_t (T) \]

- \( T \): torque [ft-lb]
- \( K_t \): helix torque factor [ft-lb]

- Default value = 10 for 2 3/8” diameter
- Default value = 9 for 2 7/8” diameter
- Default value = 7 for 3 1/2” diameter
- Default value = 6 for 4 1/2” diameter

*\( K_t \) ranges from 3 to 20 – Recommended default values are listed but can only be accurately determined from a load test.

Load Testing

- Tension Test: ASTM 3689
- Compression Test: ASTM 1143
- Lateral Test: ASTM 3966
Acceptance Criteria for Helical Pile Systems and Devices (AC358)

AC358 Acceptance Criteria

Acceptance Criteria for Helical Foundation Systems (AC 358)

- Approved June 2007
- Revised October 2016
- Set industry standard
- Higher quality & reliability
- Requires extensive testing & comprehensive calculations
- Ram Jack is 1st helical manuf. to receive ESR
- ESR-1854 issued on February 1, 2011

Applications covered under AC-358

- Side Load Bracket: *(4021, 4021.55, 4038 and 4039)
- New Construction Bracket: *(4075, 4076 and 4079)
- Floor Slab Bracket: *(4085)
- Tension Anchor: *(4550)
AC358 requires (4) Structural Elements to be Evaluated for Each Application

- P1 – Bracket Capacity
- P2 – Pile Shaft Capacity
- P3 – Helix Plate Capacity
- P4 – Soil Capacity

Note: The capacity from the lowest element controls the capacity of the system.

Key Sections of the Code that affect the Capacity of a Helical Pile

- Section 1810.2.2 – Stability
- Section 1810.2.1 – Lateral Support
- Section 1810.3.3.1.9 – Helical Piles

Section 1810.2.2 - Stability

“Deep foundation elements shall be braced to provide lateral stability in all directions.”

The Section goes on to describe the situations where a foundation element can be considered as a ‘braced system’.
Section 1810.2.2 - Stability

1) Three or more piles connected by a rigid cap provided the piles are located in radial directions from the centroid of the group not less than 60 degrees apart.

2) A two pile group connected by a rigid cap can be considered braced along the axis connecting the two piles. A wall or grade beam would have to be connected perpendicular to the cap.

3) Piles supporting walls shall be staggered on each side of the wall at least 1-foot apart and located symmetrically under the center of gravity of the wall.
Section 1810.2.2 - Stability

Exception:

A single row of piles is permitted without lateral bracing for one- and two-family dwellings and light construction not exceeding two-stories above grade or 35-feet, provided the center of the piles are located within the width of the supported wall.

Section 1810.2.2 - Stability

Unless measures are taken to provide for:

- eccentricity
- lateral forces
- piles to be adequately braced to provide lateral stability

Rotational bracing of existing wall:

- On smaller structures, bracing can be achieved internally.
- Buckling capacity of pile shaft must also be checked.
Section 1810.2.2 - Stability

Machine Foundation (Battered Piles)

Design Loads
1,050 kip (4,670 kN) vertical
500 kip (2,224 kN) lateral
Section 1810.2.1 – Lateral Support
(Unbraced Piles)

- Piles standing in air, water or fluid soil shall be classified as columns and designed from the top to the point where adequate lateral support is provided. (Section 1810.1.3)
- Piles driven into firm soil (N-value ≥ 5) are considered laterally braced 5-feet below grade.
- Piles driven into soft soil (N-value ≤ 4) are considered laterally braced 10-feet below grade.

Passive earth pressure providing lateral buckling resistance has a triangular load distribution.

Sufficient embedment is required before the appropriate resistance is reached.
Section 1810.2.1 – Lateral Support

Example of braced piles supporting an existing wall:

- New cafeteria addition
- Required 13'-0 excavation adjacent to existing bldg
- Loads
  - Column: 25 to 45 kips
  - Wall: 1.8 kips/ft
• Due to the structural loads, driven piles were used to underpin the bldg.
• Driven piers were 2 7/8" dia. driven through a 16'-0 long 3 ½" dia. guide sleeve that would extend beyond the 13'-0 excavation
• Tieback anchors were used to provide lateral bracing
• 6" shotcrete wall was installed to contain the soil and moisture beneath the building

Once a layer of tiebacks were installed the site was excavated 5'-0

A reinforced 6" thick shotcrete wall was installed at each excavation layer
Completion of underpinning and basement wall in Union County Vo-Tech, Scotch Plains, New Jersey.

Group Efficiency Effects

• Group efficiency losses must be taken into account if piles are spaced too close.

• Piles are recommended to be spaced a minimum of 3 times the largest diameter helix to avoid group efficiency effects. (IBC and AC-358)

Group Efficiency Effect

2009 & 2012 IBC
Applications

- Finished floor of main entrance to be lowered 4 feet
- All load bearing walls must be underpinned
- All wall footings were unreinforced
- Wall loads were as much as 18 kip/ft
- Historic bldg. – no work allowed on exterior

University of Arizona Medical Center
Phoenix, AZ
Driven piles with external sleeves were used to underpin the walls.

In order to address stability issues and prevent a torsional moment from being induced to the unreinforced footing, the piles were staggered on each side of the wall per the IBC.

All the piles on the exterior wall had to be installed on the interior.
A strong-back attached to helical anchors was designed to counteract the torsional moment in this situation.
The underpinning work was completed in 5 days.

Installing 25'-0 deep pit adjacent to building column
Column load 133 kips
Water table 12'-0 below finished floor
Pit collapsed on original contractor undermining the building column.
The Plan

- Steel beam was installed beneath grade beam.
- Excavation was performed in 5'-0 stages as tiebacks and shotcrete wall was installed.
- Constant dewatering was required due to high water table.

- (6) 2 7/8” diameter piles installed to 60 kips
- 30'-0 guide sleeves were used
- Owner’s concrete pit and permanent dewatering system was installed
• Two-lane Interamerican Hwy bridge over Rio Chico River
• Main arterial road for Panama
• Column settled 4 ½”
• Bridge forced to be closed

• River has 5th highest velocity in the world
• Imperative piles are installed before rainy season.

• Tired to reroute river
• Added gravity wall to protect bridge columns
• Water got behind gravity wall
• Undermined one side of gravity wall and approach
• Forced bridge to close

Rio Chico Bridge
David, Panama

• After exposing the footer it was discovered a large portion was missing.

• (10) 3 ½” dia. piles were installed on the column
• Access holes were cored through the existing footing
• Column was raised 4 ½”
• Reinforcement was placed & epoxy grouted into existing footer
• Grout was also pumped into void space under footer

• The torsion cracks were generated from the settlement of the adjacent column
• Structural repairs were required

• A mat foundation was placed connecting the two columns.
• Special brackets were designed and cast into the mat.
• (13) 3 ½” dia. piles were installed in the mat. Eight of these were battered.
Project near completion

Seismic Testing of Helical Piles

Seismic Study:
University of Oklahoma
Amy Cerato, Ph. D., P.E.

Study Sponsor:
Deep Foundation Institute (DFI)
Test Piles

- 3 ½" and 5 ½" piles tested
- Ram Jack supplied 3 ½" piles
  - (3) thru bolt connections
  - (1) threaded connection
  - (1) driven pile
- Torc Sill supplied 5 ½" piles
  - Thru bolt connection
- A total of 125 sensors were placed on the piles

Seismic force of test to model 7 seismic events:
- 1994 Northridge, CA (6.7 mag.)
- 1995 Kobe Takatori, Japan (6.9 mag.)

Weights for free head condition
Designed by Ram Jack
Seismic Testing

The End.