Failures of Helical Pile and Helical Anchor Projects and Associated Lessons Learned

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Magnum Geo-Solutions, LLC

- You are mistaken if you are an engineer who believes you make no mistakes.

Disclaimer

By the title of this presentation, some of our competitor's in the deep foundation industry might say "see helical piles don't work". That is not the subject of this presentation. With the variety of subsurface profiles, diverse geologic conditions, and a myriad of structures to be supported, the engineer and contractor need as many resources in their tool belt as possible. Helical piles and helical anchors represent one of those tools which, when used correctly, perform effectively. Like all piles and ground reinforcing elements, helical piles and helical anchors used incorrectly can have less than favorable results. Several case histories with less than favorable results are presented here so the audience can learn the correct application of helical piles and helical anchors.

Case Histories

I. Buckled Underpinning in New York
(a case for lateral bracing)

II. Stadium Soil Nail Wall Failure
(a review of common anchor design mistakes)

III. Out-of-Spec Sea Wall Anchors
(the importance of torque calibration)

IV. Down-Drag of Grouted Helical Piles
(failure to account for consolidation)

V. Settlement of Apartment Buildings
(redesign based on load tests)

VI. Scaffold Collapse on Helical Piles
(death as a result of instability)

VII. Collapse During Foundation Repair
(death as a result of undermining)

Background
Who is Magnum?


MAGNUM PIERING
ROCK SOLID
U.S. Manufacturer of
Foundation Products
Established 1985
Cincinnati, Ohio, USA


Family Owned Business


MAGNUM PIERING, INC.
PRODUCT CATALOG
ISO 9001:2008 CERTIFIED
MAGNUM
Foundation Products
Helical Piles
Push Piers/Jacked Piles
Solar Piers
Pile Caps
Underpinning Brackets
Micropile Brackets
Plate Anchors
Crawl Space Jacks
Drive Tools
MAGNUM PIERING
ROCK SOLID
DYWER

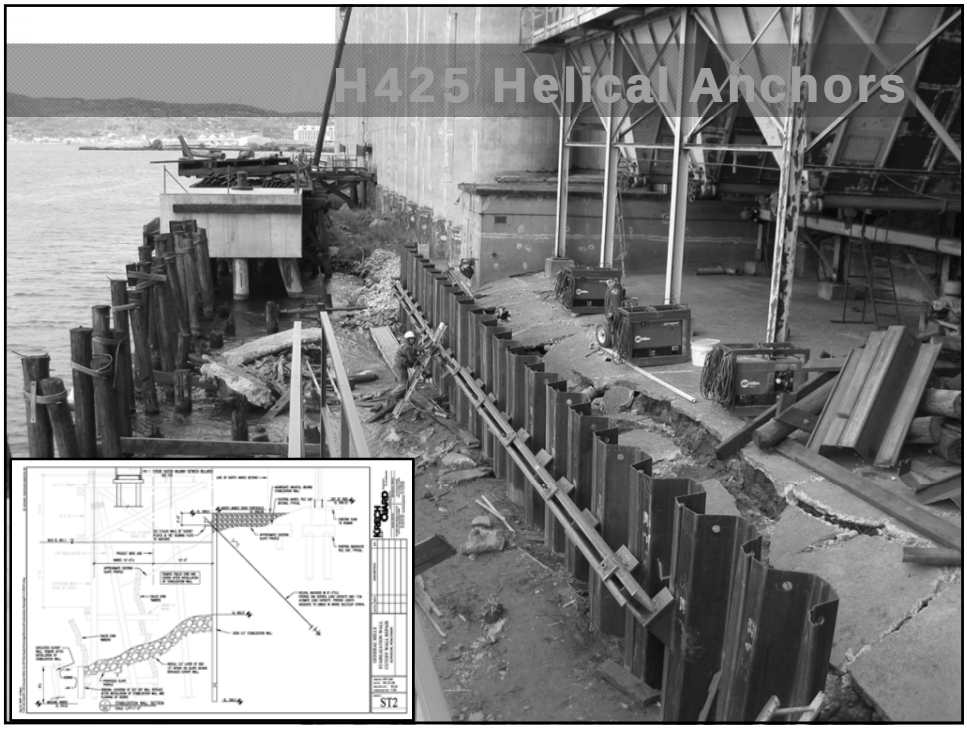

KOMATSU
MH313 Helical Piles


MH325 Helical Piles

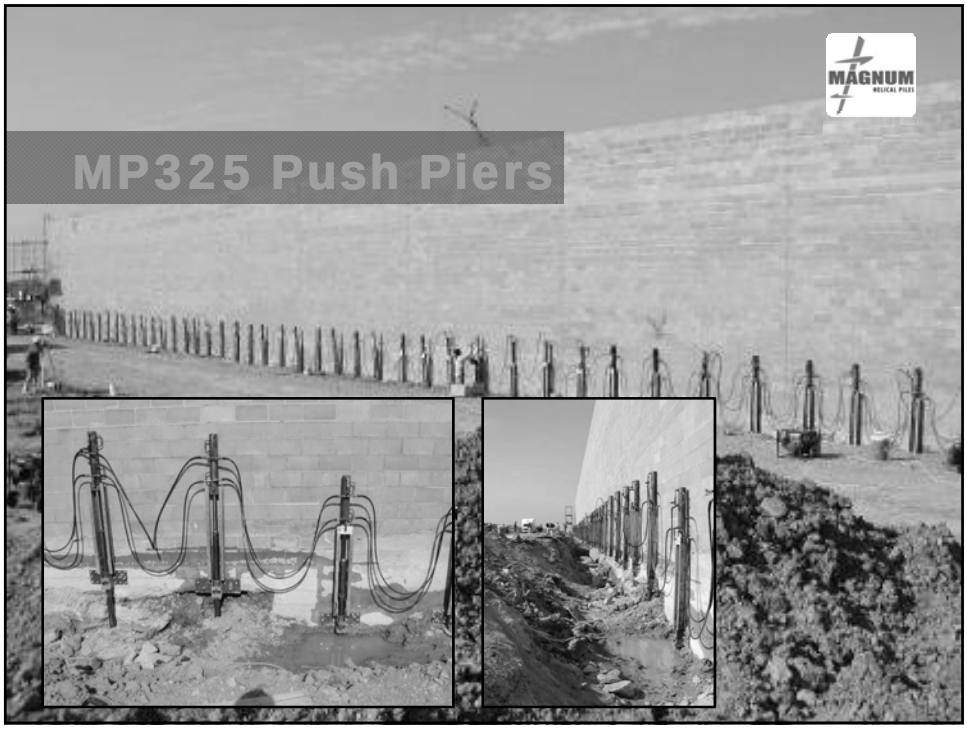

DWYER
1-877-399-3726
MH325R Helical Piles

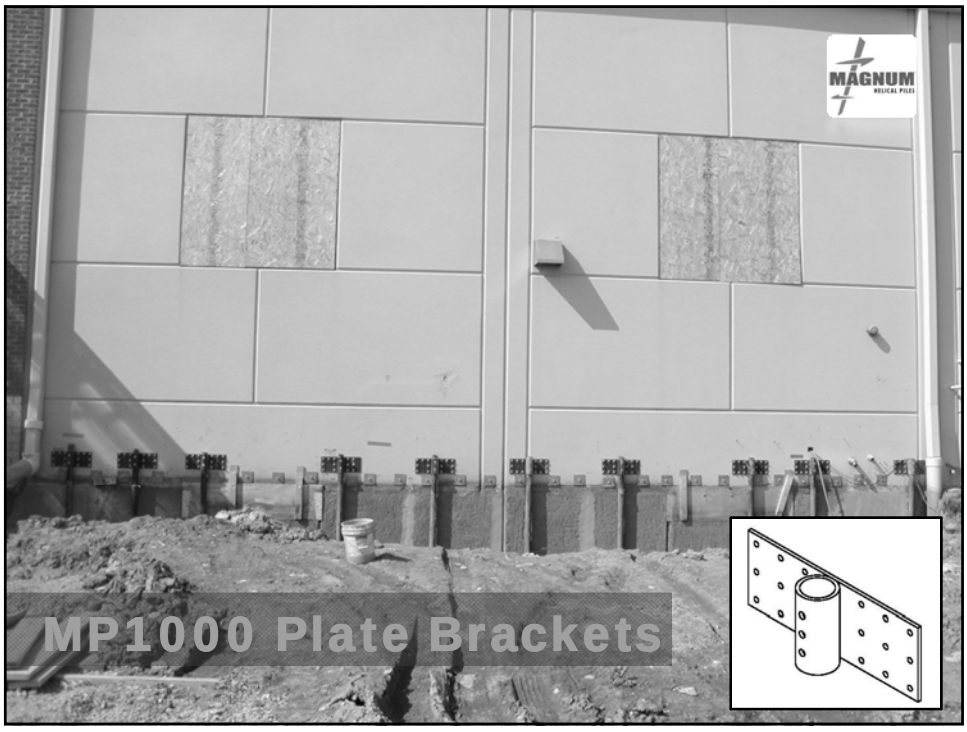

MAGNUM
MH625 Helical Piles

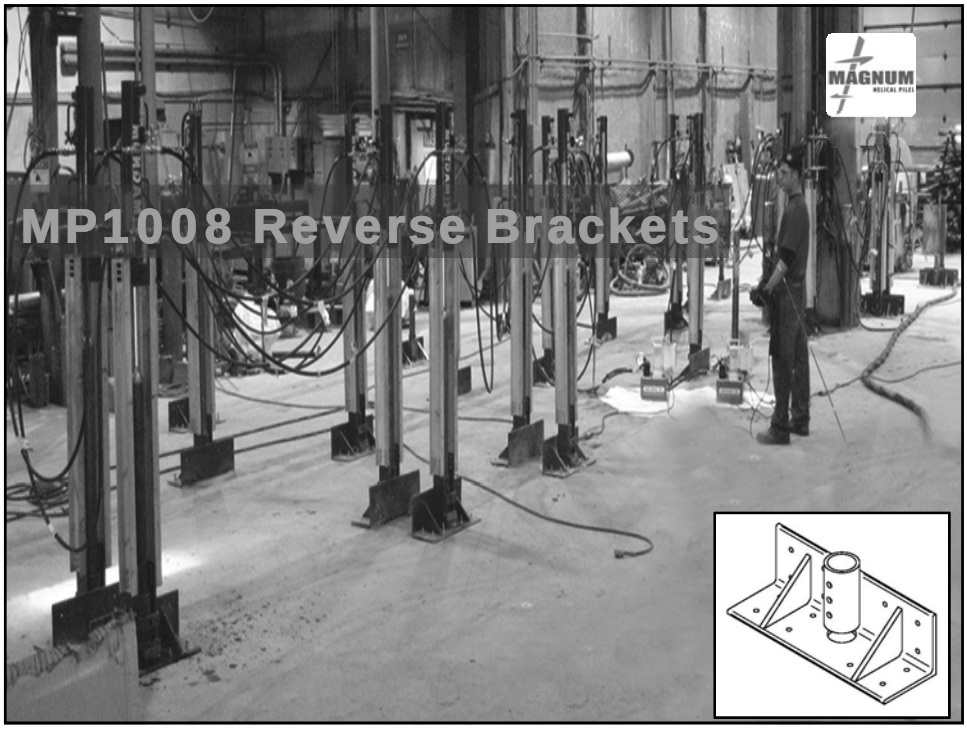

MH325 Helical Anchors


H425 Helical Anchors

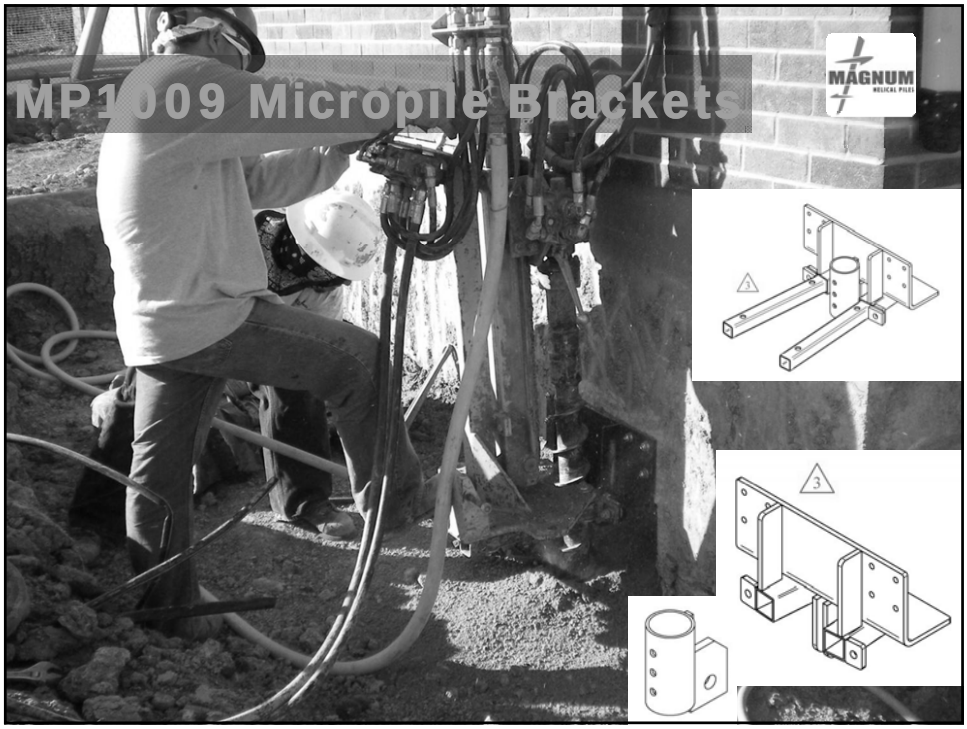

MAGNUM
MP313 Push Piers


MAGNUM
HELICAL PILES
MP325 Push Piers


MAGNUM
HELICAL PILES
MP1000 Plate Brackets


MAGNUM
MP1008 Reverse Brackets


MAGNUM
MHC1200 Caps

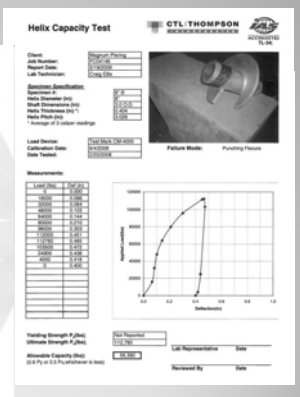


Background
Why Magnum?

Tech Support

- Licensed PE's in 18 States
- Project Submittals
- Design/Build Support
- Engineering Seminars
- Web Tools/Software
- Sample Specifications
- CADD Plans and Details
- Test Data

Quality Assurance

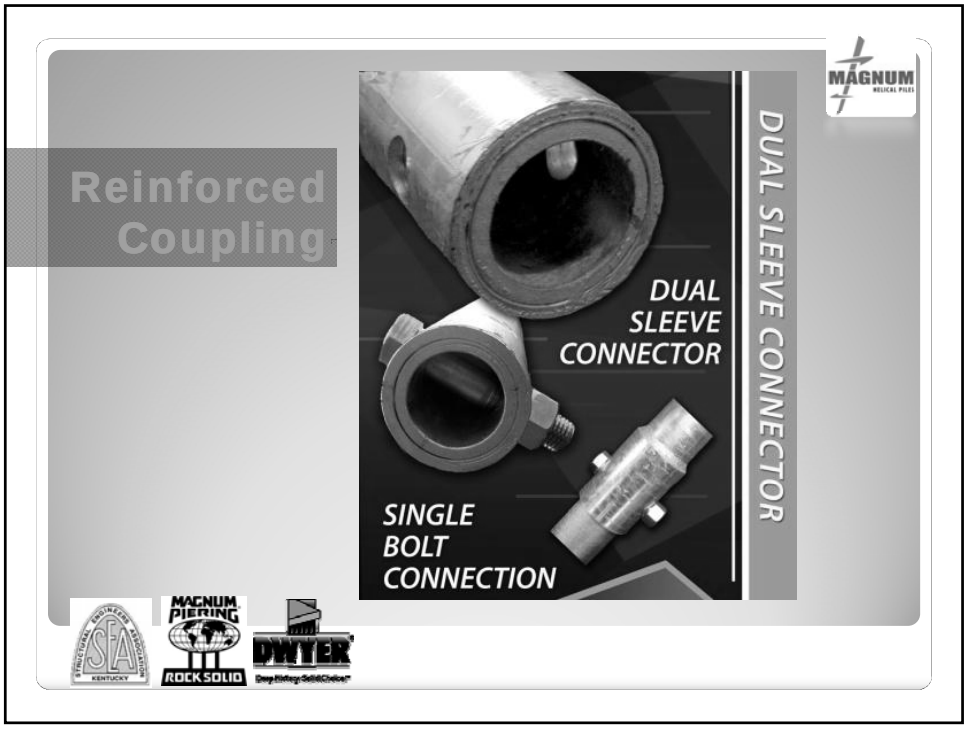


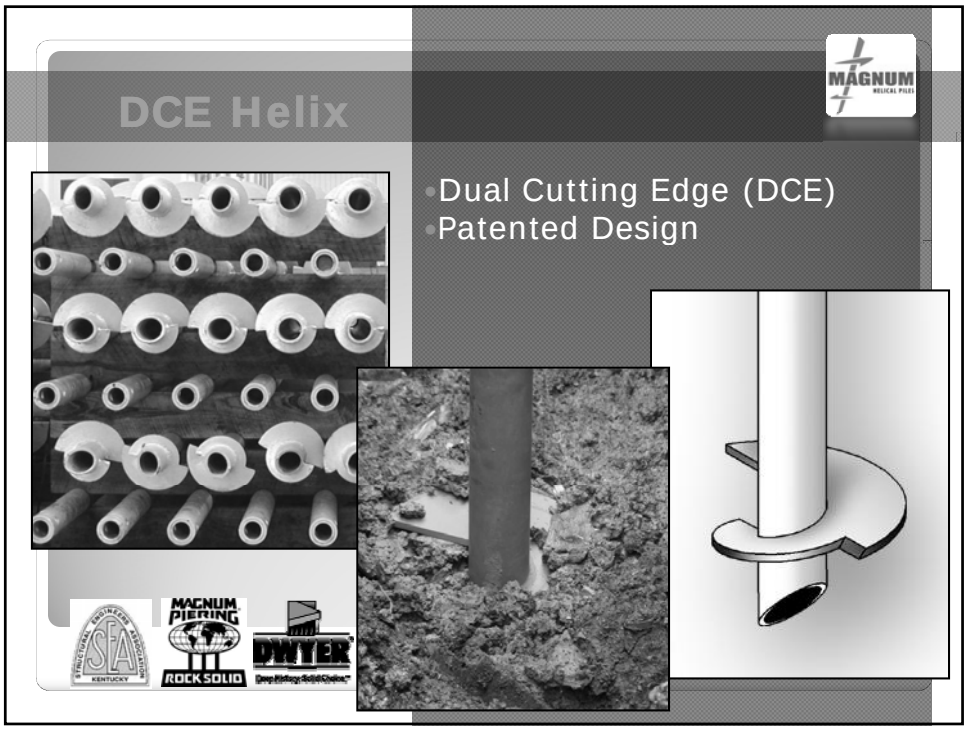
Conforming Helix

- 3” Pitch
- Parallel Leading & Trailing Edges
- Perpendicular
- Uniform Pitch
- Sharpened Cutting Edge

Round Shaft

- Buckling Capacity
- Lateral Capacity
- Depth and Plumbness Inspection
- Grouting

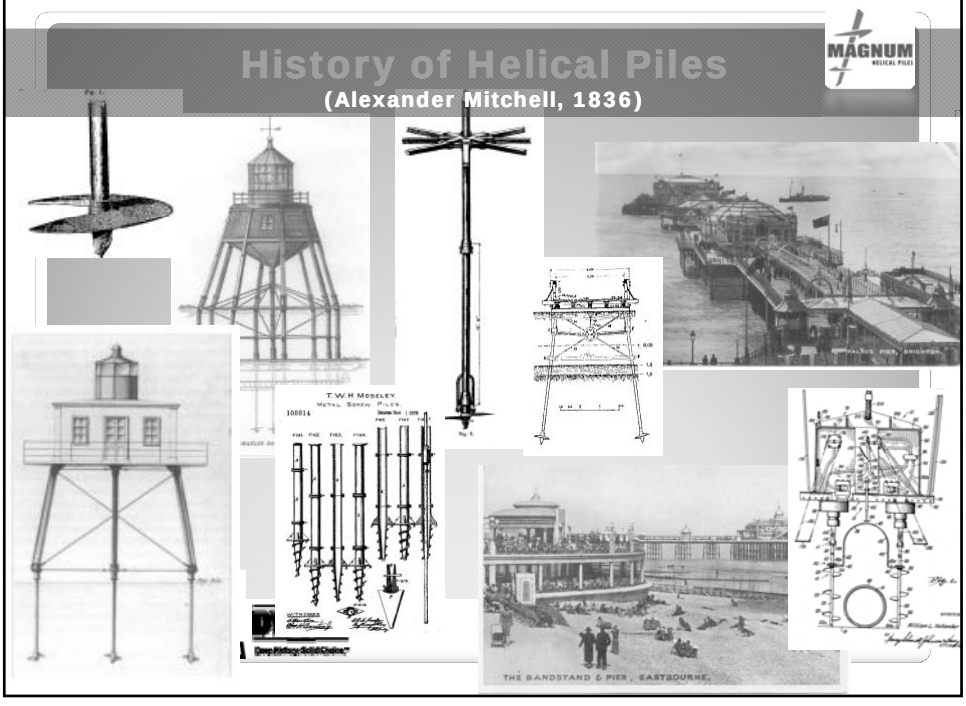

Reinforced Coupling
DUAL SLEEVE CONNECTOR
DUAL SLEEVE CONNECTOR
SINGLE BOLT CONNECTION
MAGNUM
MAGNUM PIERING
ROCK SOLID
DWYER


DCE Helix
•Dual Cutting Edge (DCE)
•Patented Design
MAGNUM
MAGNUM PIERING
ROCK SOLID
DWYER

Overview of Helical Piles

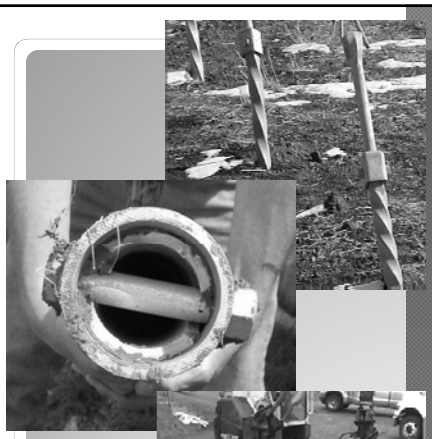
History of Helical Piles

(Alexander Mitchell, 1836)



Advantages

- Low noise and vibrations
- Small, maneuverable installation equipment
- Removal and replacement
- Ease of transport
- Compression or tension
- All-weather installation
- Rapid installation
- Does not produce drill spoil
- Immediate post tensioning
- Shorter bond length
- Do not require casing

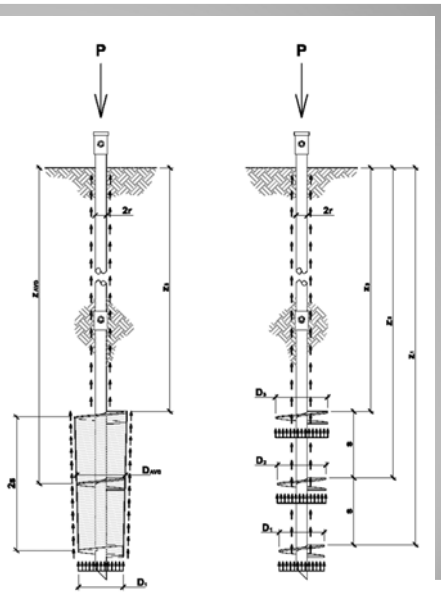


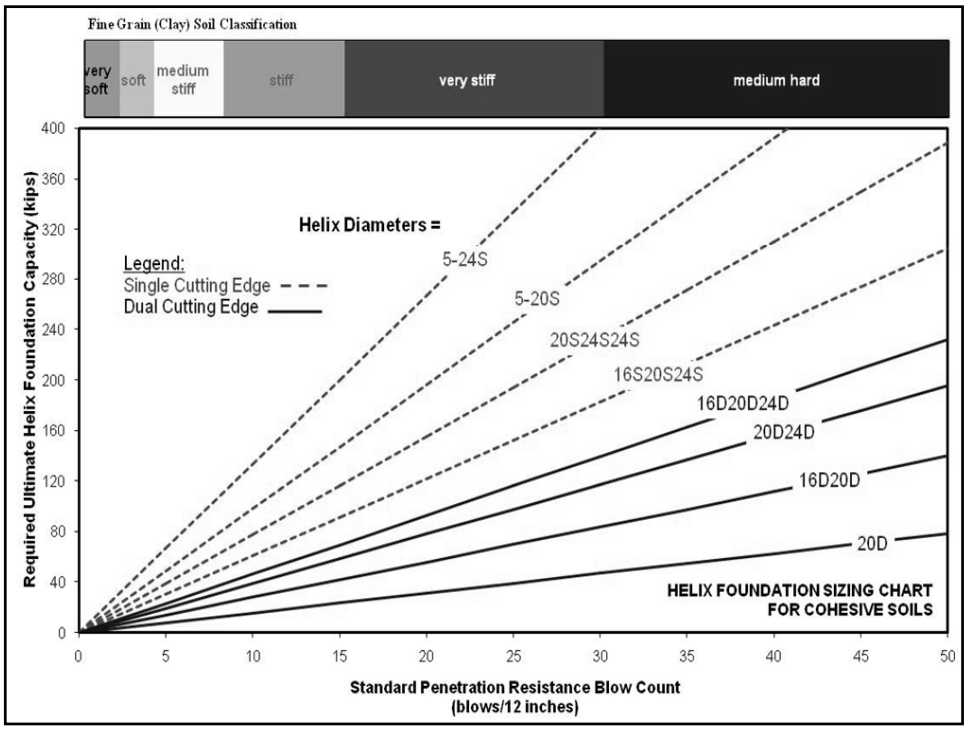
Disadvantages

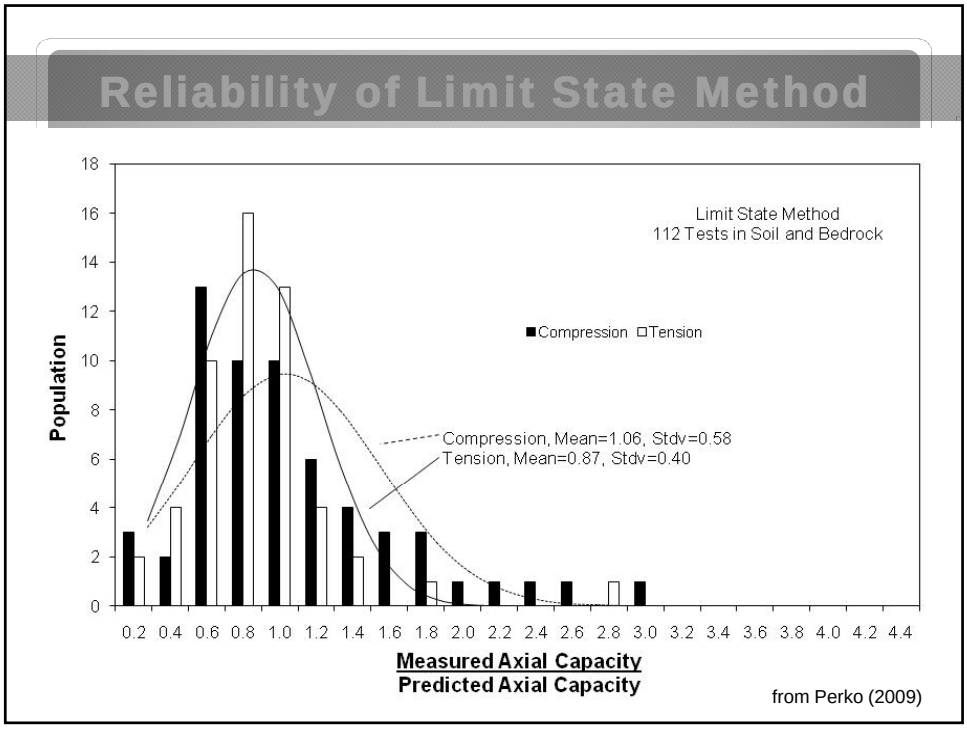
- Cannot penetrate very hard rock (SPT N>100)
- Concrete and construction debris is problematic
- Impossible in cobble and boulders
- Ease of installation means more competition
- Slender shaft makes lateral bracing imperative
- Creep in High Plasticity Clays and Silts

Helix Sizing

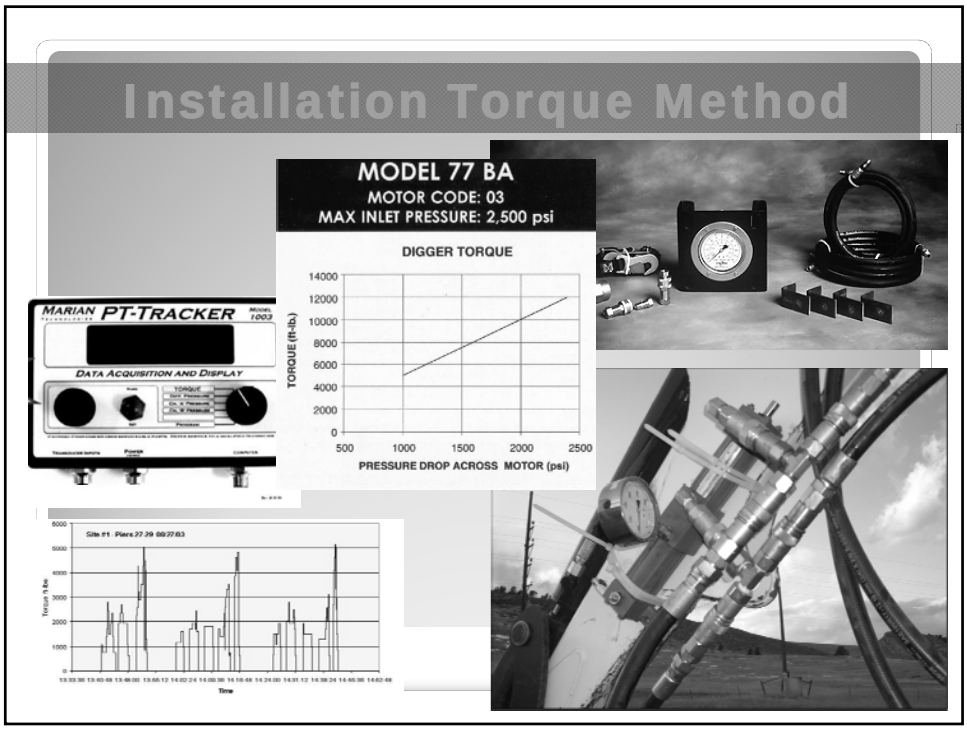
Limit State =
Cylindrical Shear,
or
Individual Bearing,
whichever is less.



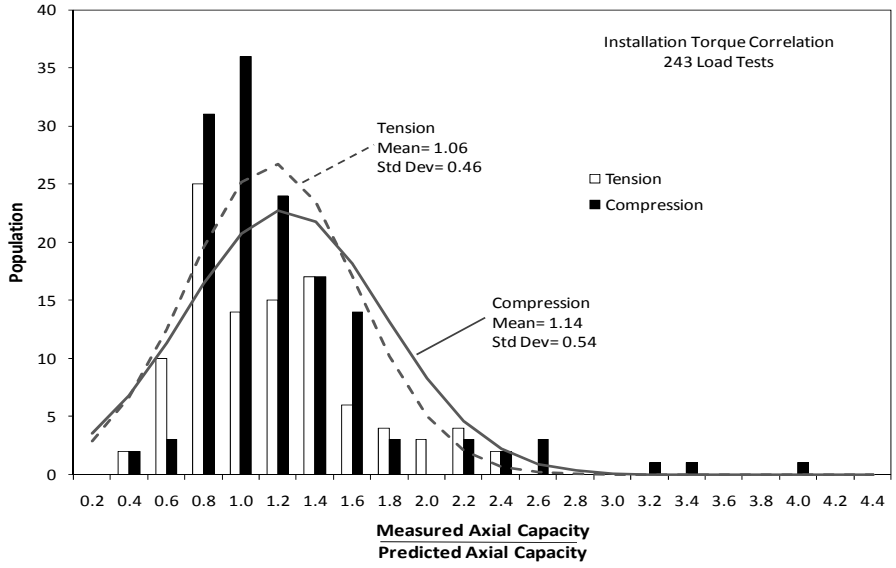




from Perko (2009)

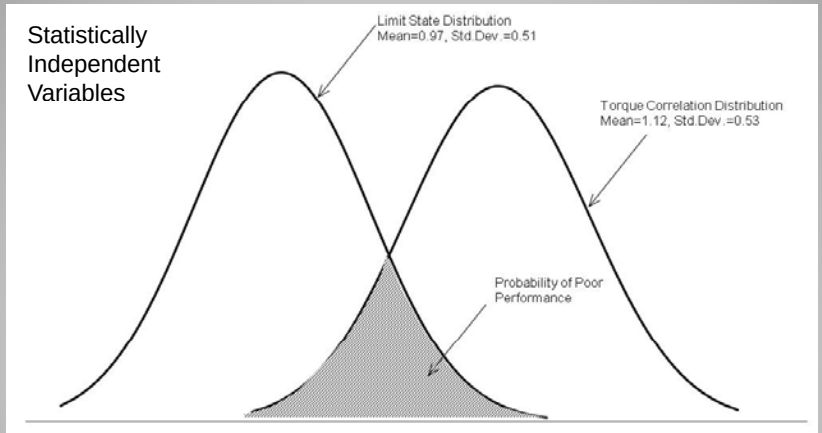


Reliability of Torque Method



Combined Reliability

Statistically Independent Variables



Buckled Underpinning in New York

- Helical piles were installed to reduce settlement during conventional concrete underpinning
- Footing rotated, piles buckled, and building settled severely
- Photo shows supplemental raker bracing system installed with deadmen after settlement

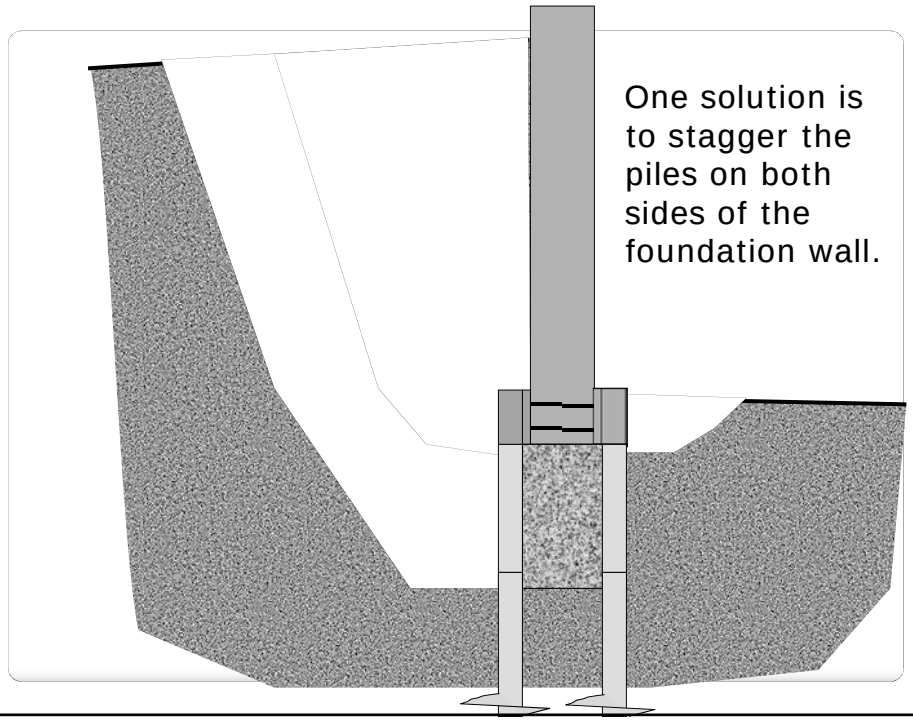
- Photo shows buckled pile and bracket system
- Helical piles were 1-3/4” square shaft with reinforcing sleeves
- All piles were installed along the outside of the building
- This and a similar failure were catalysts to a nearly 2 yr moratorium on helical piles in NYC

Potential Cause of Failure

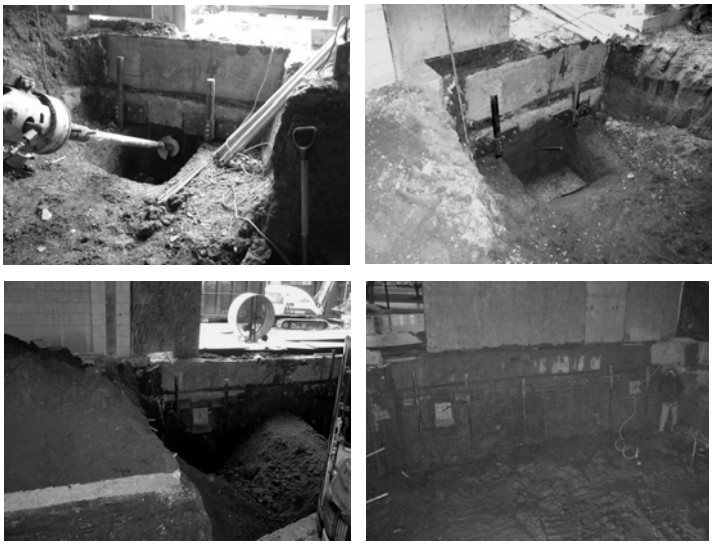
- Failed to brace the tops of piles

Per IBC2006: 1807.2.4 Pile or Pier Stability

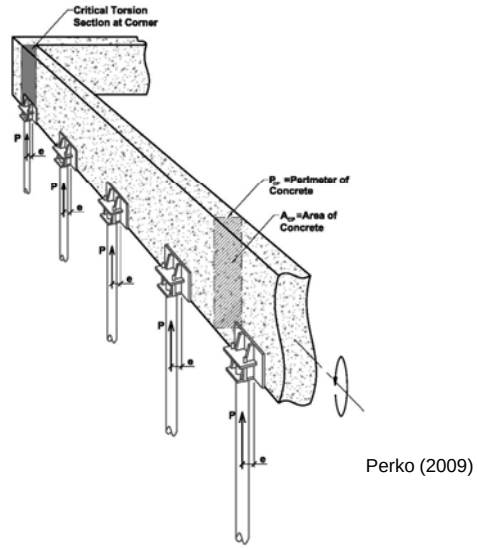
- All piles shall be braced for lateral stability
- Three or more piles per cap is considered braced
- Piles staggered under a wall are considered braced
- Otherwise provide engineered means of lateral bracing



- Another solution is to brace to wall laterally at the top of piles as in this photo.
- Square plates along the base of the wall are concrete anchors extending into the building slab.
- All piles were designed to withstand buckling while excavation was open.



- Another solution is to install tie-back anchors to brace the foundation at the top of the piles.



Perko (2009)

- On smaller structures, bracing can be achieved internally.

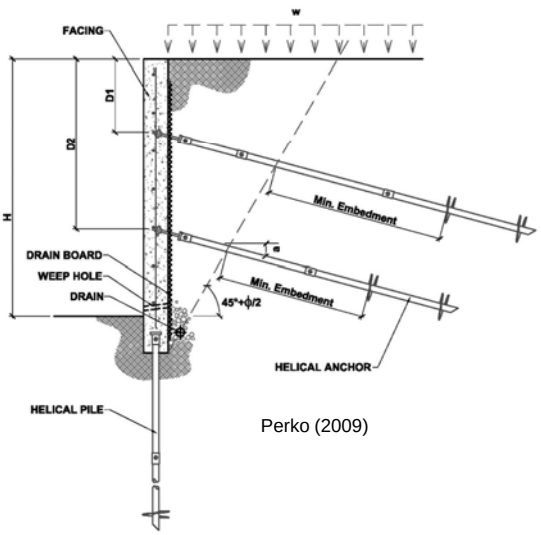
Stadium
Soil Nail Wall Failure

- 3 rows of helical soil nails
- Approximately 15-foot cut between bleachers
- Reportedly a progressive failure

Potential Causes of Failure

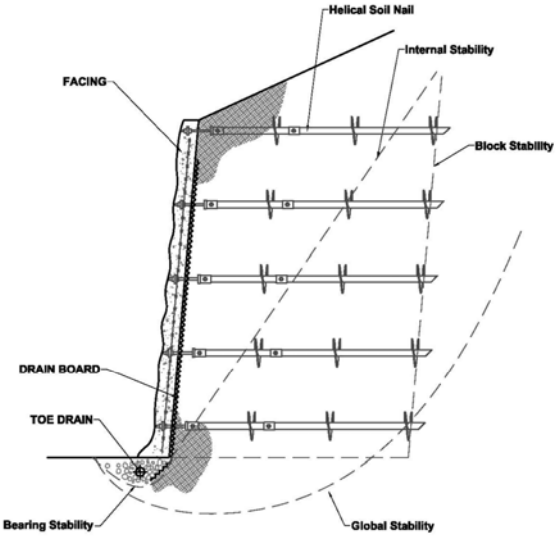
- Soil nails lacked continuous bonding
- Soil nail spacing too far apart
- Soil nail length too short
- Bearing capacity failure
- Insufficient lapping of reinforcing steel
- Poor drainage

- Typical soil “anchor” wall
- Purpose of anchors is to hold back facing
- Rigid facing that spans between anchors
- Post-tension anchors
- Helical bearing plates located far outside failure plane
- Anchors at angle from horizontal
- Foundation resists downward component of anchor force
- Large anchor spacing
- Higher capacity, longer anchors
- Drainage behind wall



Perko (2009)

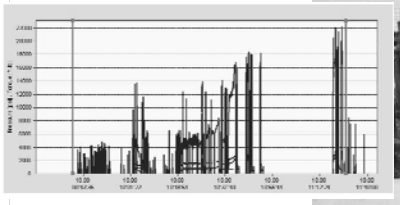
- Typical soil “nail” wall
- Purpose of nails is to reinforce soil block
- Minimal facing that simply resists raveling
- Generally not post-tensioned
- Helical bearing plates located within failure plane
- Anchors often horizontal
- Minimal foundation
- Small anchor spacing
- Low capacity, short anchors
- Drainage behind wall



Perko (2009)

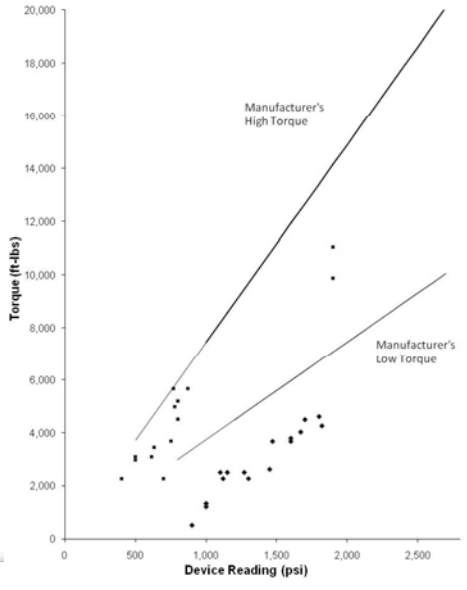
Out-of-Spec Sea Wall Anchors

- 1 row of approximately 35’ long helical tie-backs
- Continuous torque readings during installation
- Approximately 15-foot cut to removed failed timber crib wall
- All 18 helical anchors failed proof test
- Supplemental anchors based on same design methods, installed by same crew using different torque motor passed proof tests



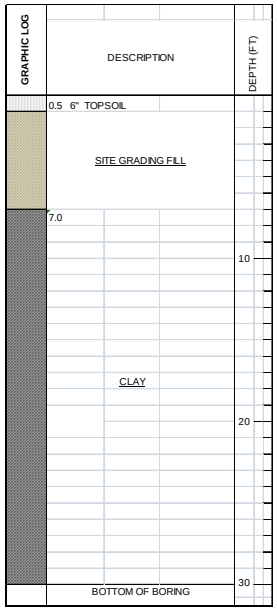
Potential Cause of Failure

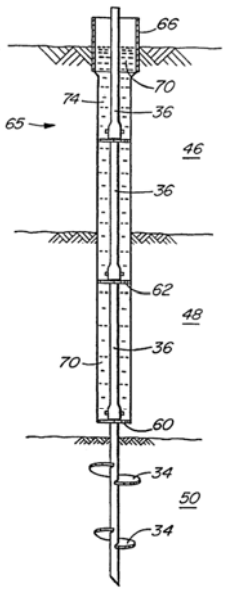
- Flawed torque motor calibration



Down-Drag of Grouted Helical Piles

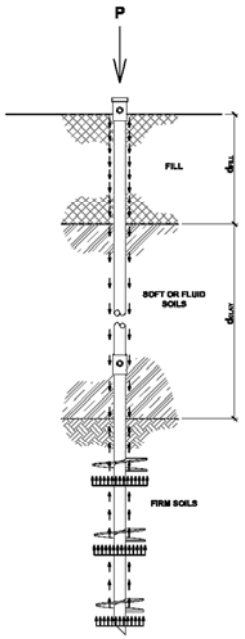
- Grouted pull-down piles
- Houses settled several inches
- Approximately 7-feet of site grading fill
- Piles bottomed in soft clay, grouted full depth





Potential Cause of Failure

- Down-drag of site grading fill on grouted pile

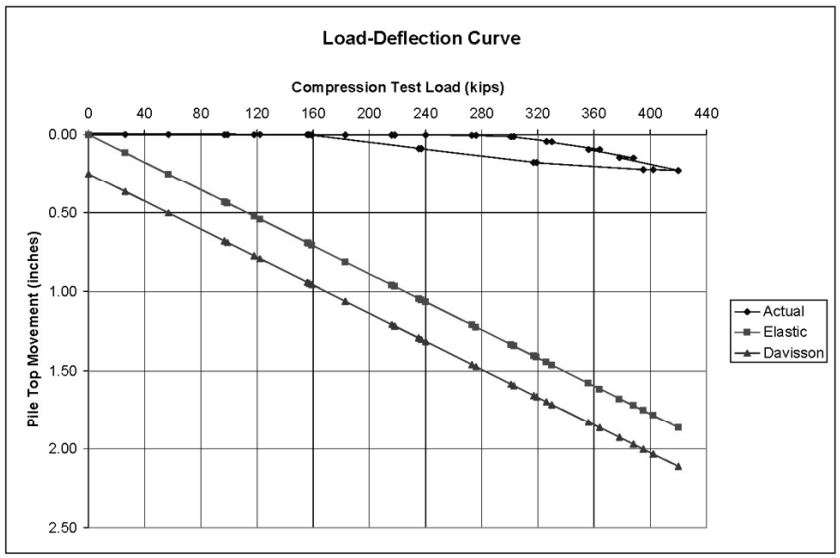


Settlement of Apartment Buildings

- Approximately 140 helical piles installed to support several 5-story apartment buildings
- Design load of helical piles= 90 to 130 kip
- Immediately after construction, several of the buildings exhibited settlement on the order of 4”
- Three of the buildings had to be demolished and re-built. The others were repaired by underpinning.

Potential Causes of Failure

- Non-conforming helix invalidates capacity to torque readings
- Insufficient bearing area; relied on torque alone and did not check theoretical bearing capacity
- Over-reliance on load tests



- Flawed load test results

Scaffold Collapse on Helical Piles

- Example Frame Scaffolding (Note: This is not the actual scaffold that collapsed. Due to confidentiality, actual scaffold cannot be shown.)

- Approximately 4-story tall, temporary, stand-alone scaffold towers were erected to construct an elevated concrete walkway
- Each scaffold tower was supported on 8 helical piles
- During concrete placement, scaffold gave-way killing one worker and injuring 18 others

Potential Causes of Failure

- Structural issues associated with scaffold design
- Lack of lateral stability
- No lateral capacity specification for the piles
- Square-shaft helical piles have negligible lateral capacity

Collapse During Foundation Repair

- An addition was being constructed on the back of this home
- The existing back wall experienced settlement
- A foundation repair contractor was called out to install several piles along the back wall

- During installation of piers, the wall suddenly collapsed, tragically killing one of the workers.

Thank You