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

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Abstract

With the variety of subsurface profiles, diverse geologic conditions, and 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 of failures are presented so the audience can learn the correct application of helical piles and helical anchors.

Among the case histories are an underpinning project that resulted in a temporary moratorium on helical piles in New York City, a tie-back wall at a stadium, a sea wall with poor load test results, excessive settlement of grouted helical piles, and a residential underpinning project where a worker was unfortunately killed. Among the lessons learned are improper lateral bracing, torque miscalibration, relying too much on load tests, and design changes during construction.

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- "The minute you think you know it all, senility has set in." Karl Terzaghi

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Disclaimer

The case histories include helical piles/anchors manufactured by different companies collected over 18 years of experience by Howard Perko, Ph.D., P.E. The presentation is not meant to critisize any particular installer or manufacturer’s systems and is certainly not a criticism of helical piles/anchors in general. Any interpretation of this sort is purely accidental. Rather, Dr. Perko has dedicated much of his career to understanding these devices, is a proponent of them, and believes the best way to promote the industry is to teach about potential pitfalls in design and application through a discussion of case histories. Some of the case histories are ongoing litigation wherein Dr. Perko has been retained as an expert consultant and the name and location of the projects has been withheld.

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- “A smart man learns from his mistakes, but a wise man learns from the mistakes of others.”

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)

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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

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- 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

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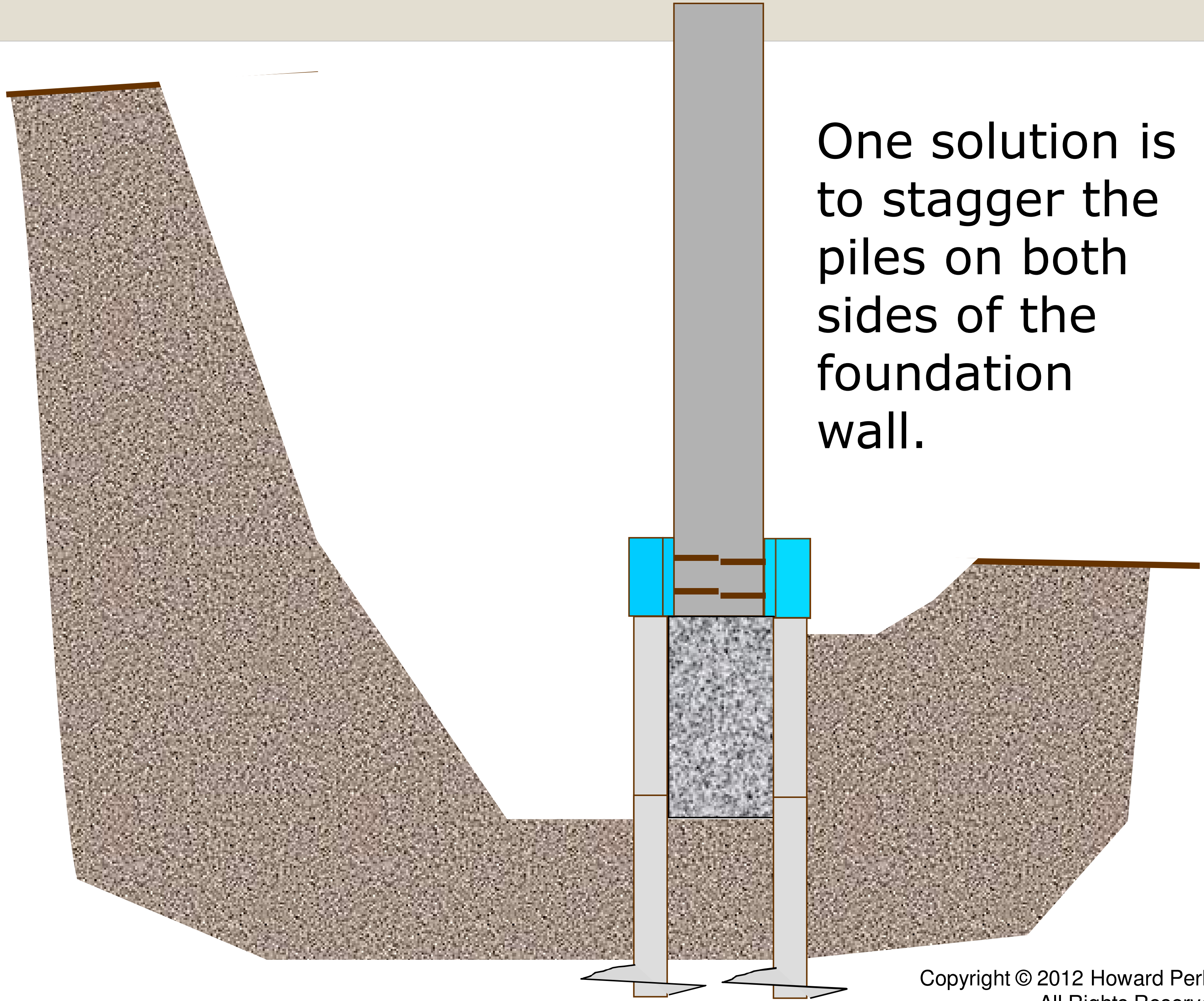
Potential Cause of Failure

- Failed to follow existing code provisions regarding stability and bracing of the tops of piles

Per IBC2006: 1807.2.4 Pile or Pier Stability (Similar Section in NYC BC)

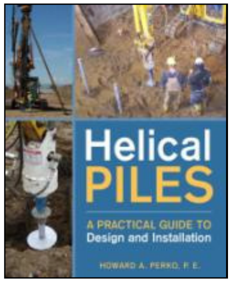
- All piles shall be braced for lateral stability
- Three or more piles per cap is considered braced
- Piles staggered under a wall are considered braced
- Otherwise provide engineered means of lateral bracing



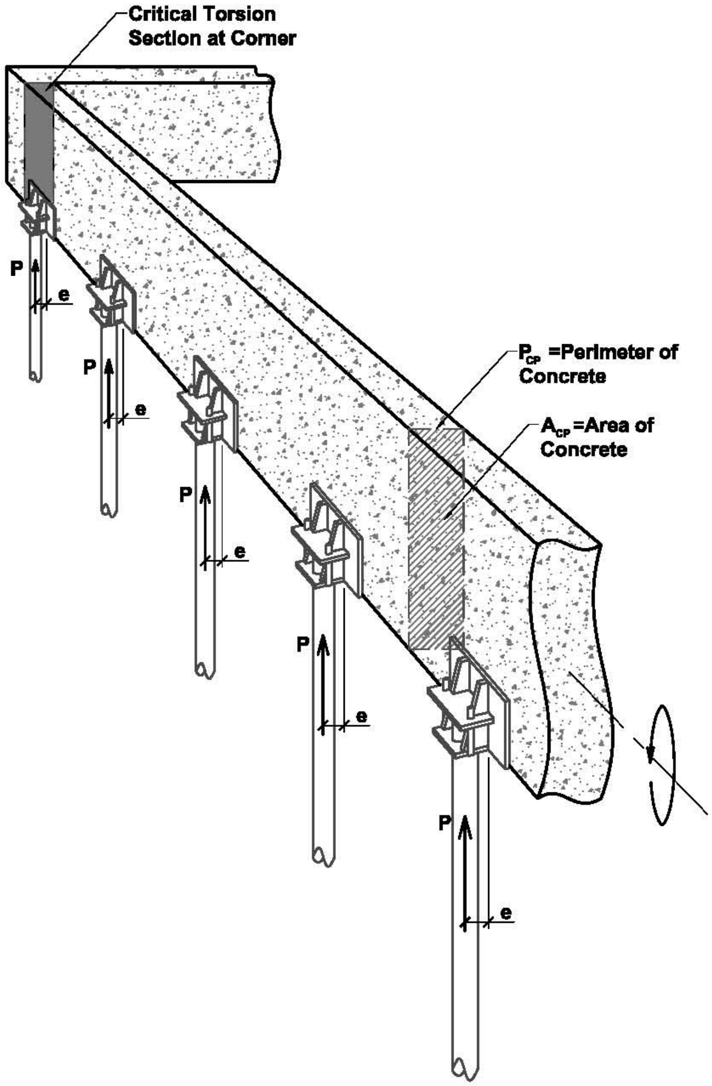
One solution is to stagger the piles on both sides of the foundation wall.

- 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.



From Perko (2009)
Helical Piles, Wiley, NY



- On smaller structures, bracing can be achieved internally.

Stadium Soil Nail Wall Failure

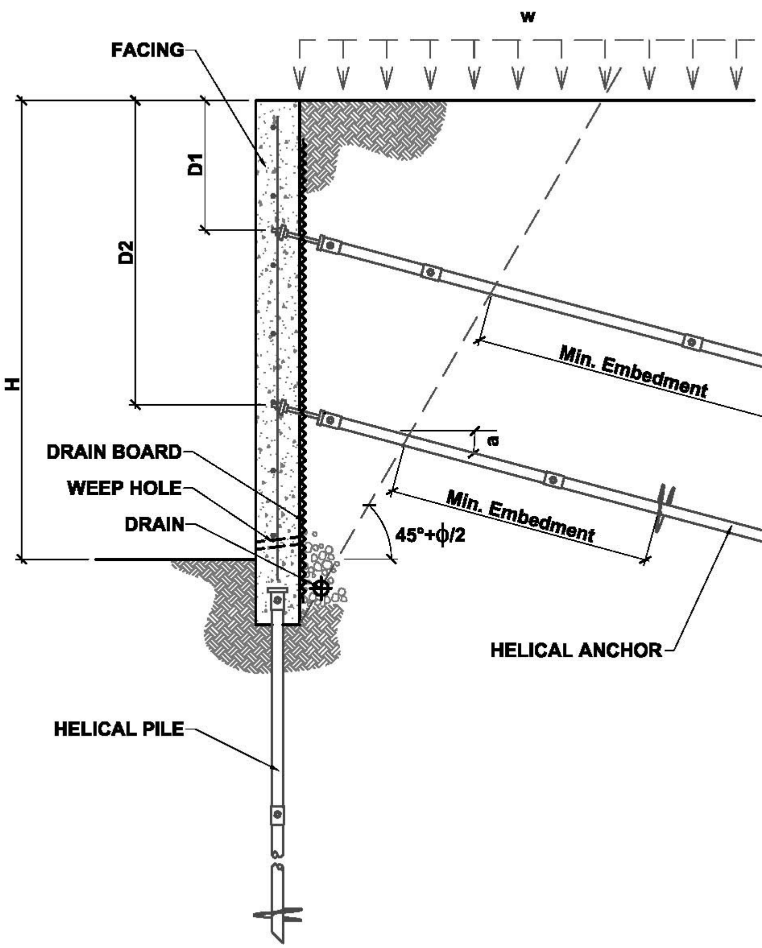
- 3 rows of helical soil nails
- Approximately 15-foot cut between bleachers
- Reportedly a progressive failure

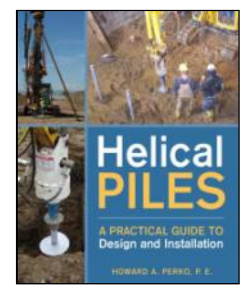
Potential Causes of Failure

- Misunderstanding between anchored wall and soil nail wall
- Bearing capacity failure
- Improper reinforcing steel

Typical soil “anchor” wall

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





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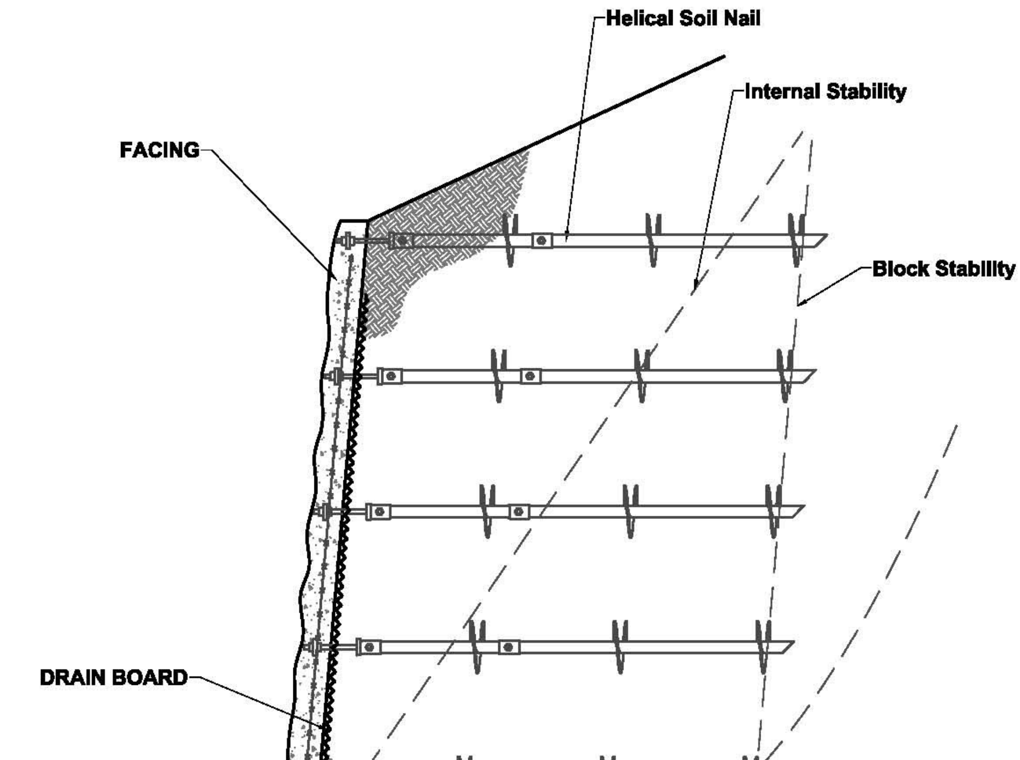
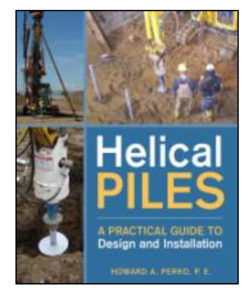
- Typical soil “nail” wall
- Purpose of nails is to reinforce soil block
- Minimal facing that simply resists raveling
- Generally not post-tensioned
- Helical bearing plates located within failure plane
- Anchors often horizontal
- Minimal foundation
- Small anchor spacing
- Low capacity, short anchors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





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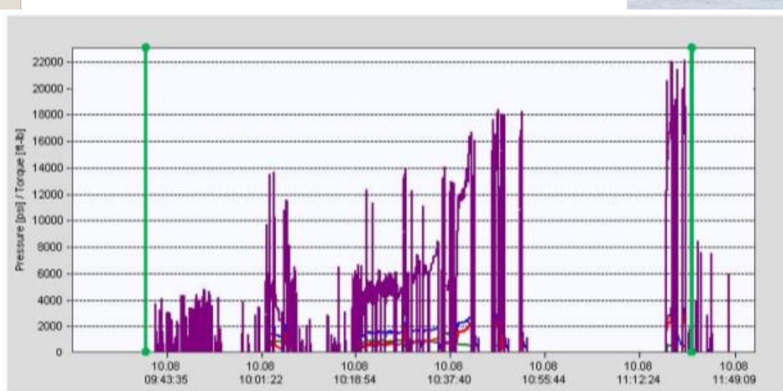
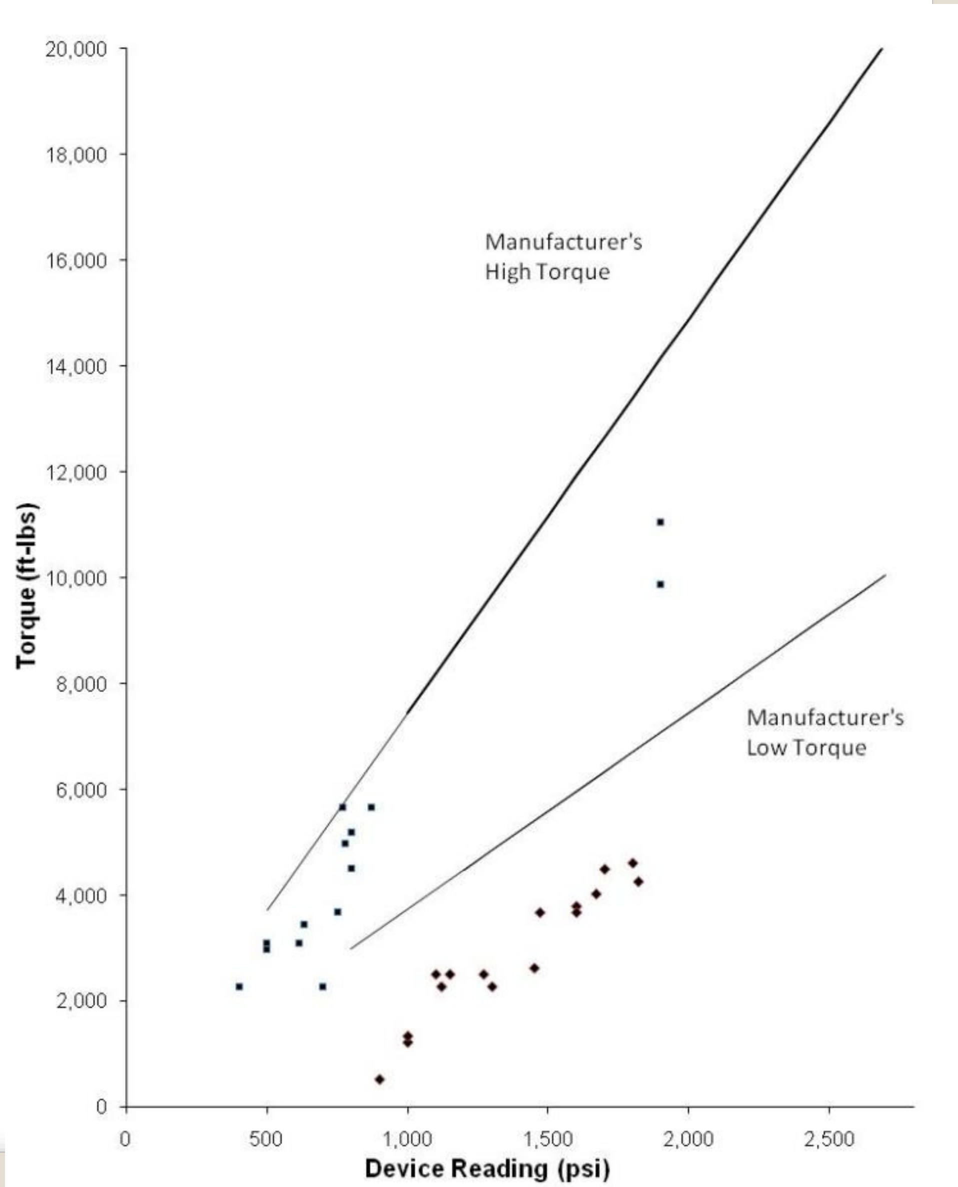
Out-of-Spec Sea Wall Anchors

- 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

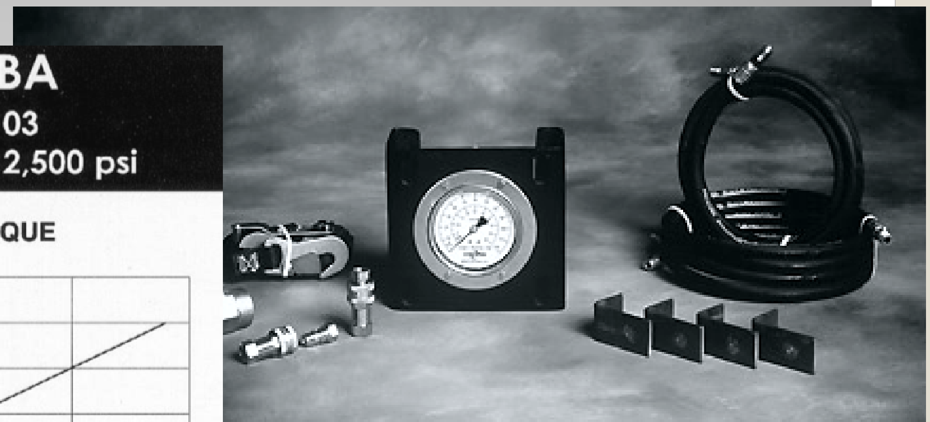


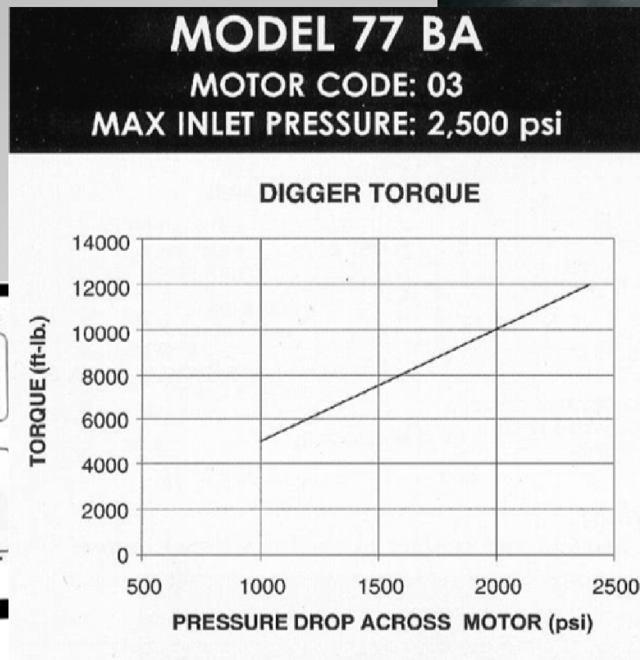
Potential Cause of Failure

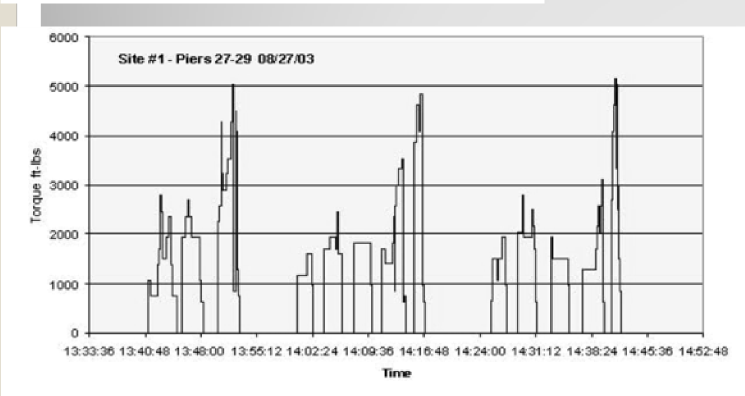
- Flawed torque motor calibration

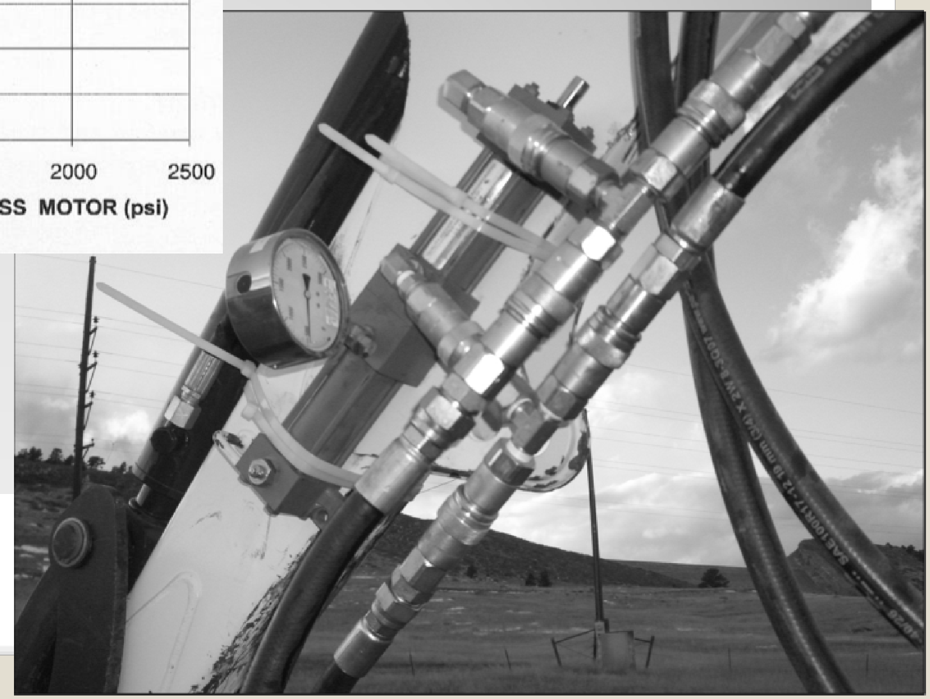


Other Torque Measuring Devices



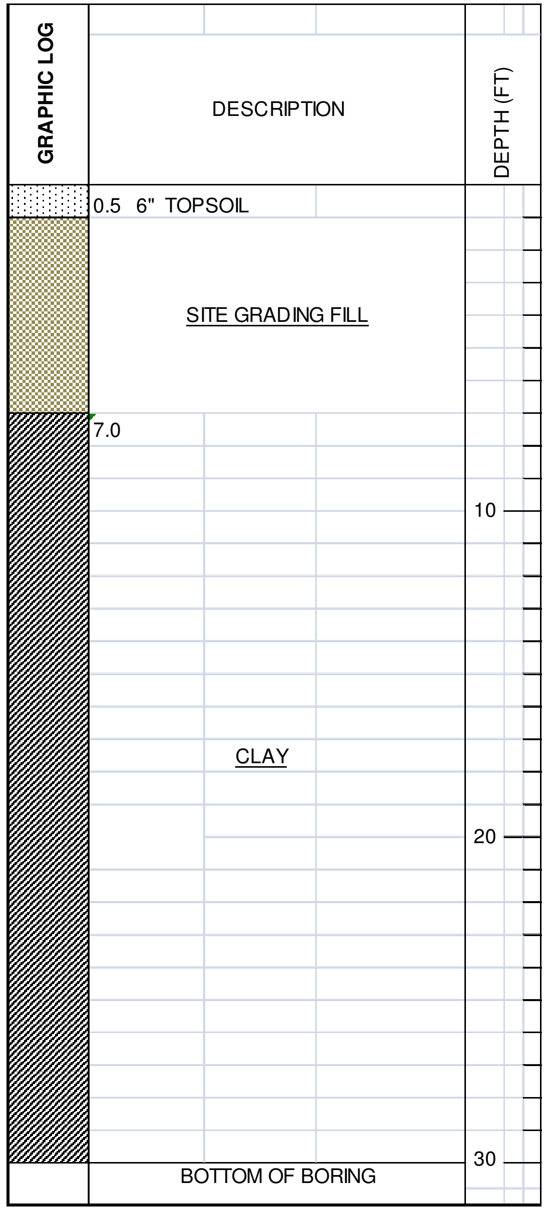


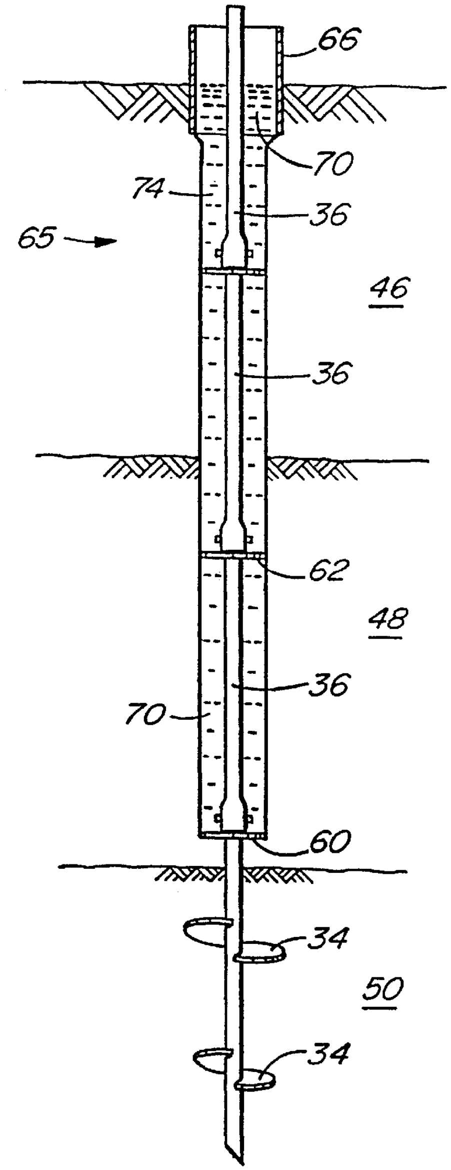




Down-Drag of Grouted Helical Piles

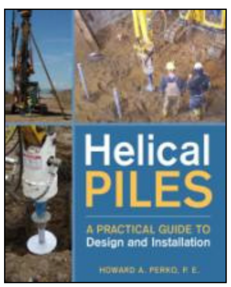
- Grouted pull-down piles
- Houses settled several inches
- Approximately 7-feet of site grading fill
- Piles bottomed in soft clay, grouted full depth





Potential Cause of Failure

- Down-drag of site grading fill on grouted pile



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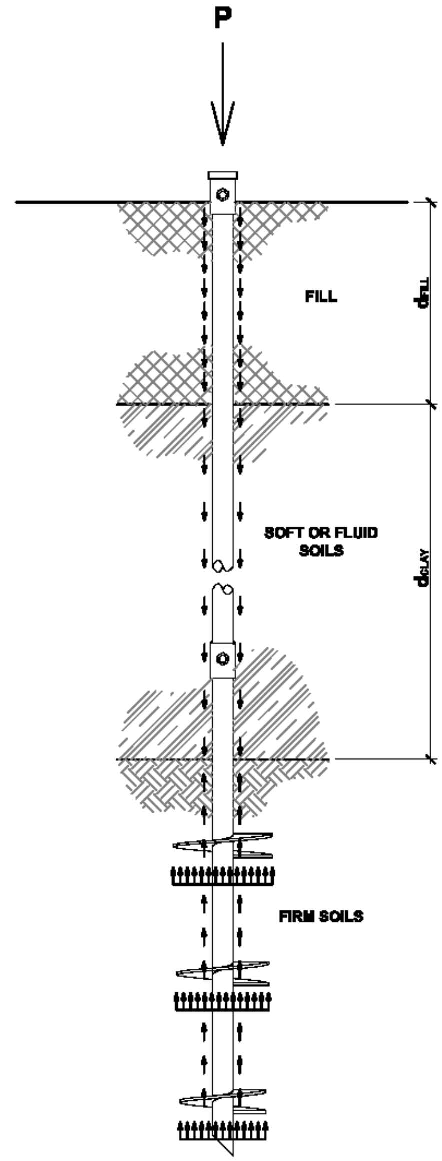

Settlement of Apartment Buildings

- Approximately 140 helical piles installed to support several 5-story apartment buildings
- Design load of helical piles= 45 to 65 tons
- 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

Conforming Helix

Courtesy of Magnum Piering, Inc.

- 3" Pitch
- Parallel Leading & Trailing Edges
- Helix is Perpendicular to Shaft
- Uniform Pitch
- Sharpened Cutting Edge

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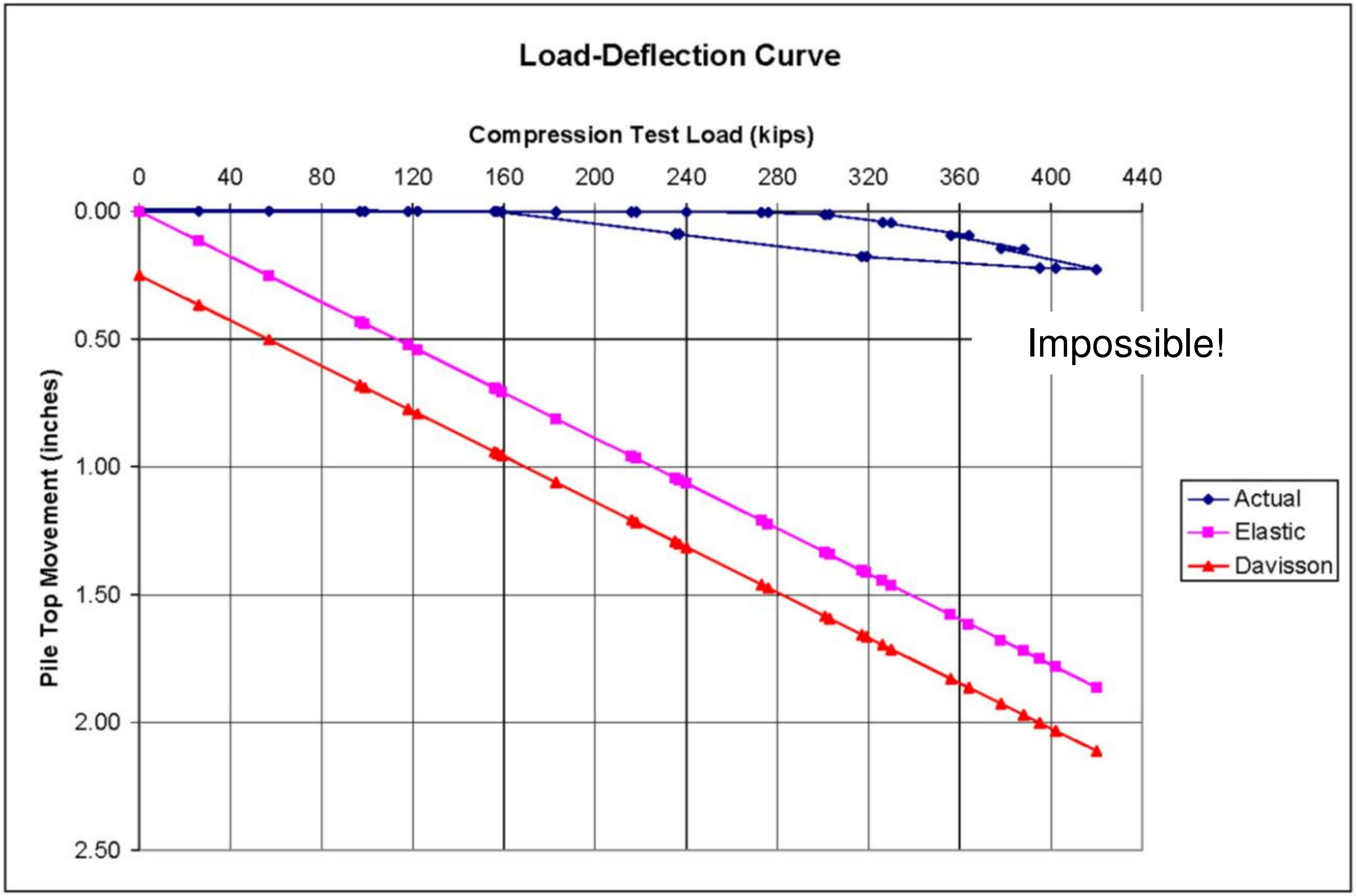

- Flawed load test results

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.

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