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FORTIFIED ENGINEERING SOLUTIONS

What You Need to Know About Helical Piles, Capacities and Applications

November 30, 2023

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Introduction

Dr. Ranjith (Sam) Rosenberk, Ph.D., P.E.
Vice President
Fortified Engineering Solutions, LLC

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Helical Piles, Capacities, and Applications

Sam Rosenberk, Ph.D., P.E.

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Common Helical Piles/Anchors Components

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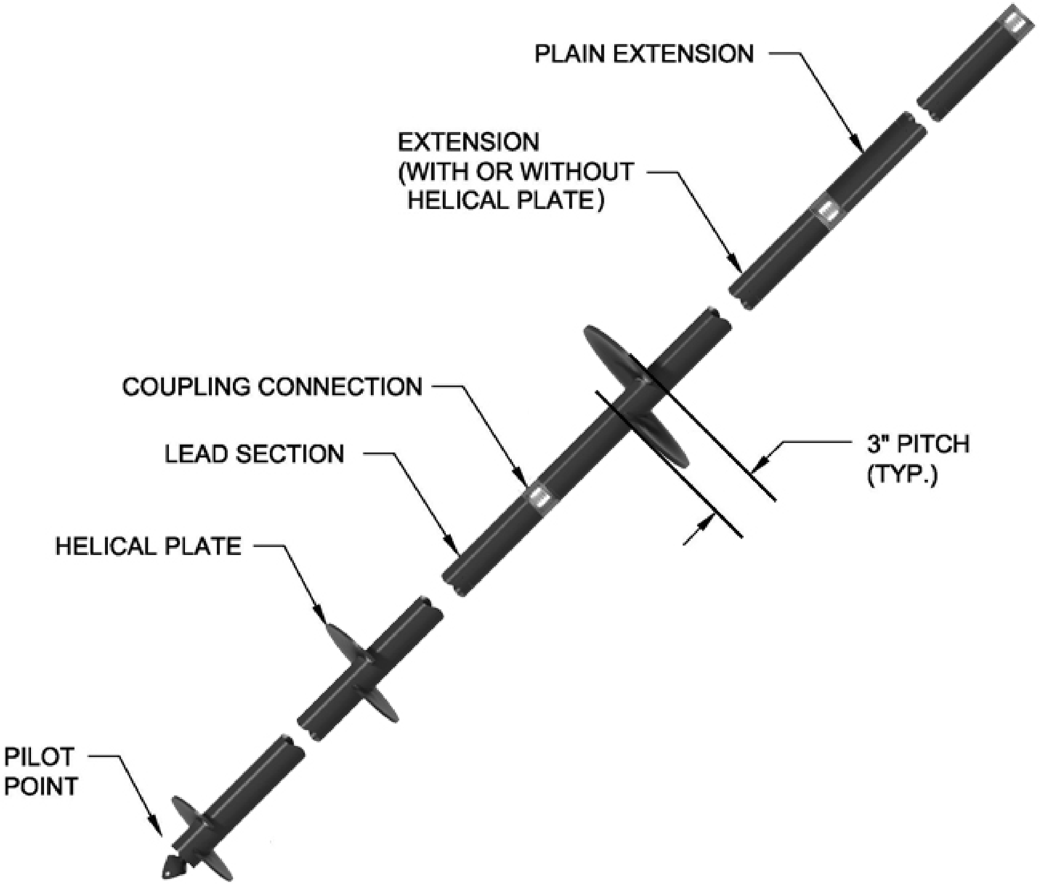

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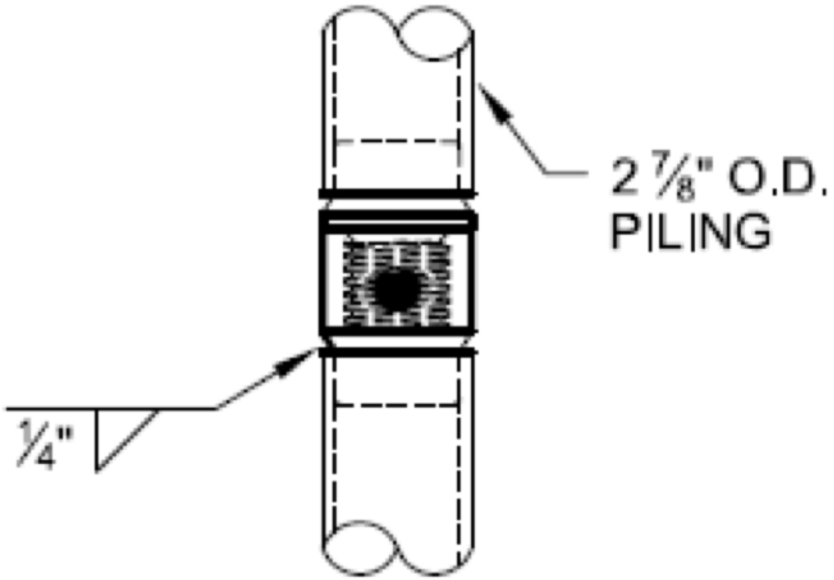
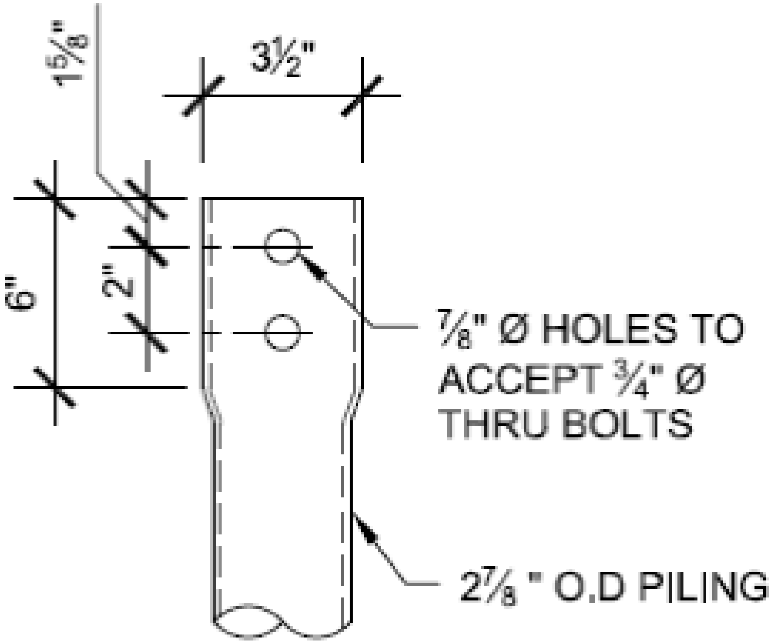
Helical Pile Connections



Threaded Connection



Upset Connection

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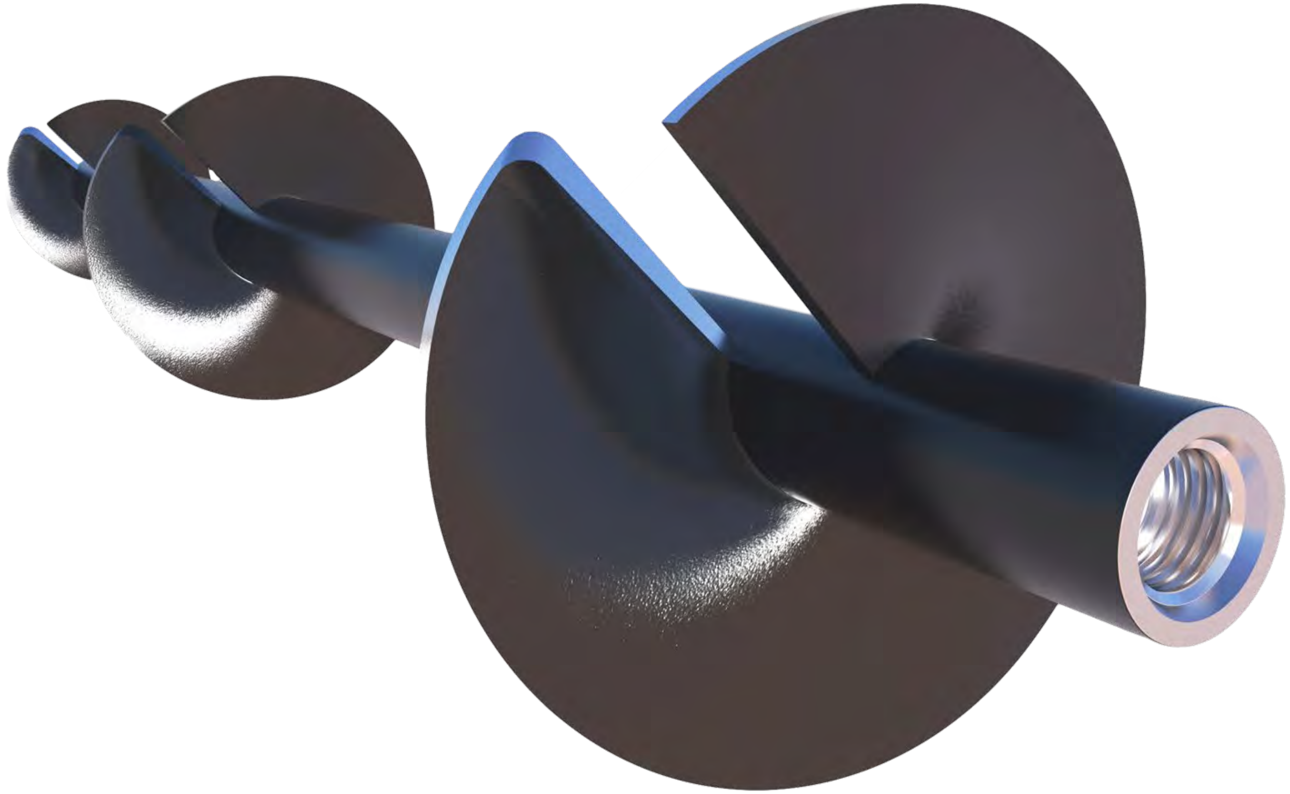
Helical System

Helical System

Twist tip to help pile penetrate hard soil

Helix plates are pressed into true spiral shape so they can be torqued into the soil smoothly with minimal soil disturbance

Helical System



Installation Machines

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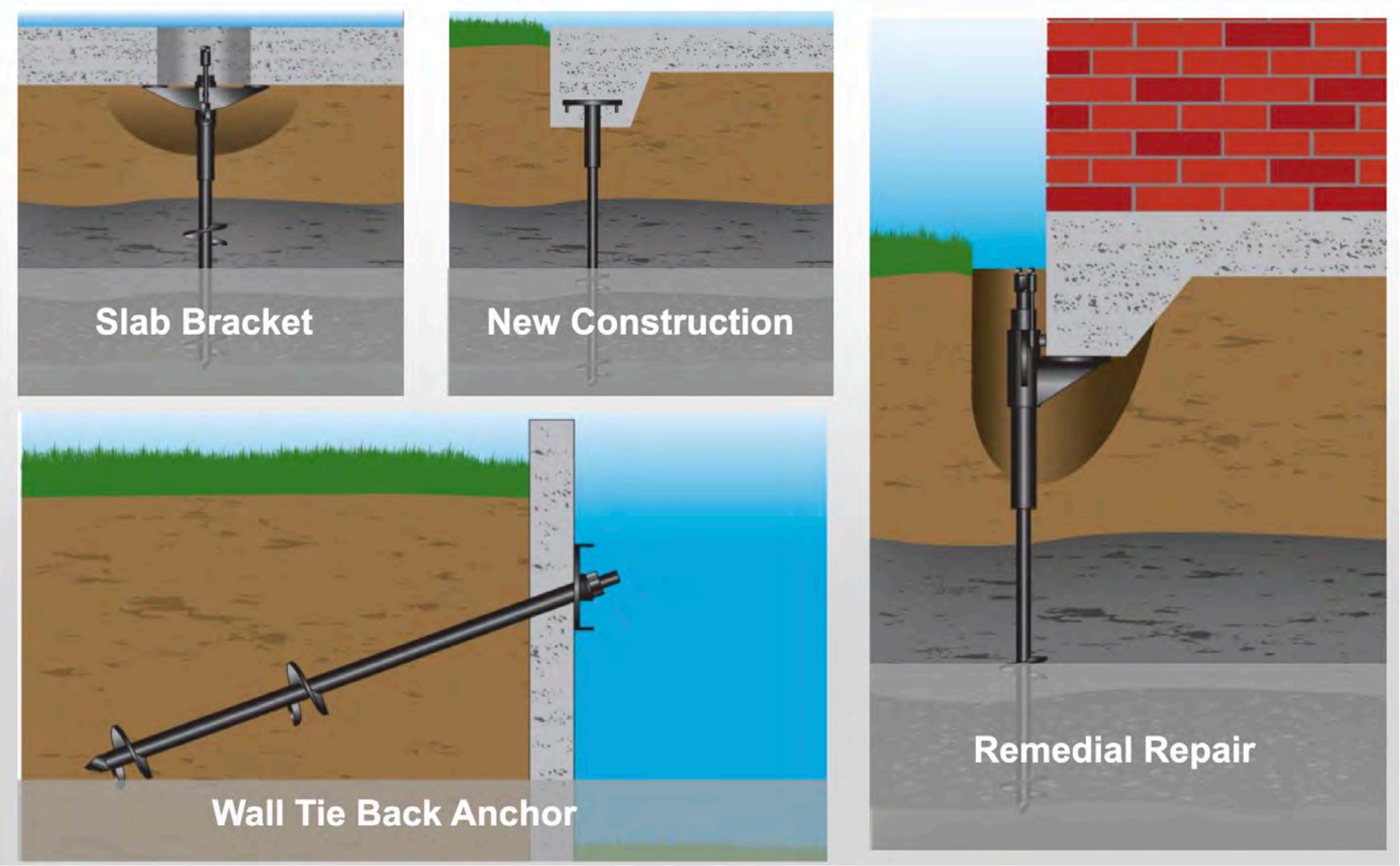
Helical Applications



Additional Applications

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

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

… Endless Applications …

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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

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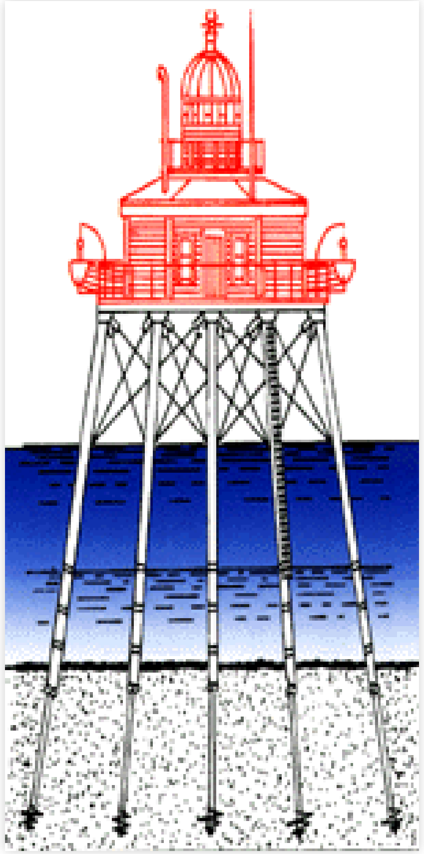
Helical Historical Perspective



- 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 & the Gulf of Mexico.

- Through advancements in installation equipment, geometries & research, helical foundations are now used throughout the world.

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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

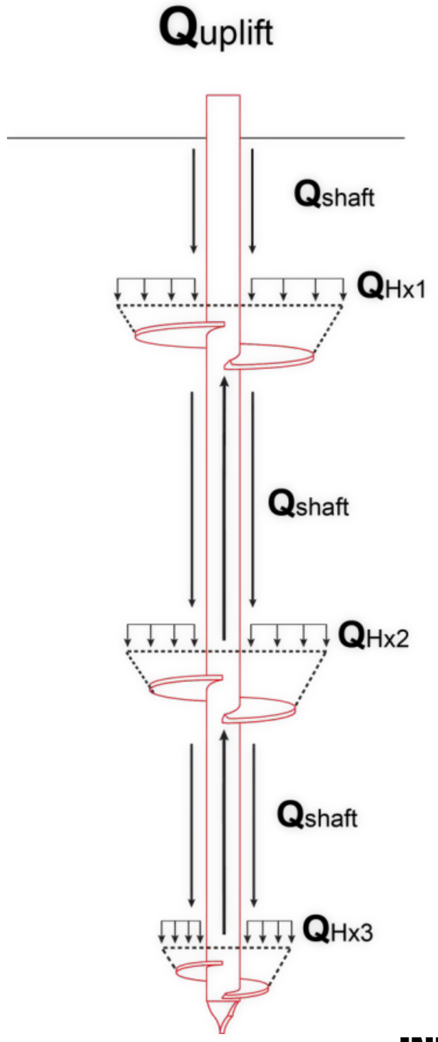
Individual Bearing Method

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

*Terzaghi Bearing Equation

$$Q_u = A_h q_u = \sum A_h (cN_c + q_v N_q)$$

A_h = helix plate area
c = soil cohesion
q_v = overburden stress
N_c & N_v = Meyerhof bearing factors



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Torque Correlation Method

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

$$Q_{ult} = K_t (T)$$

T = *torque [ft-lb]*
*K_t = *helix torque factor [ft-1]*

- *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

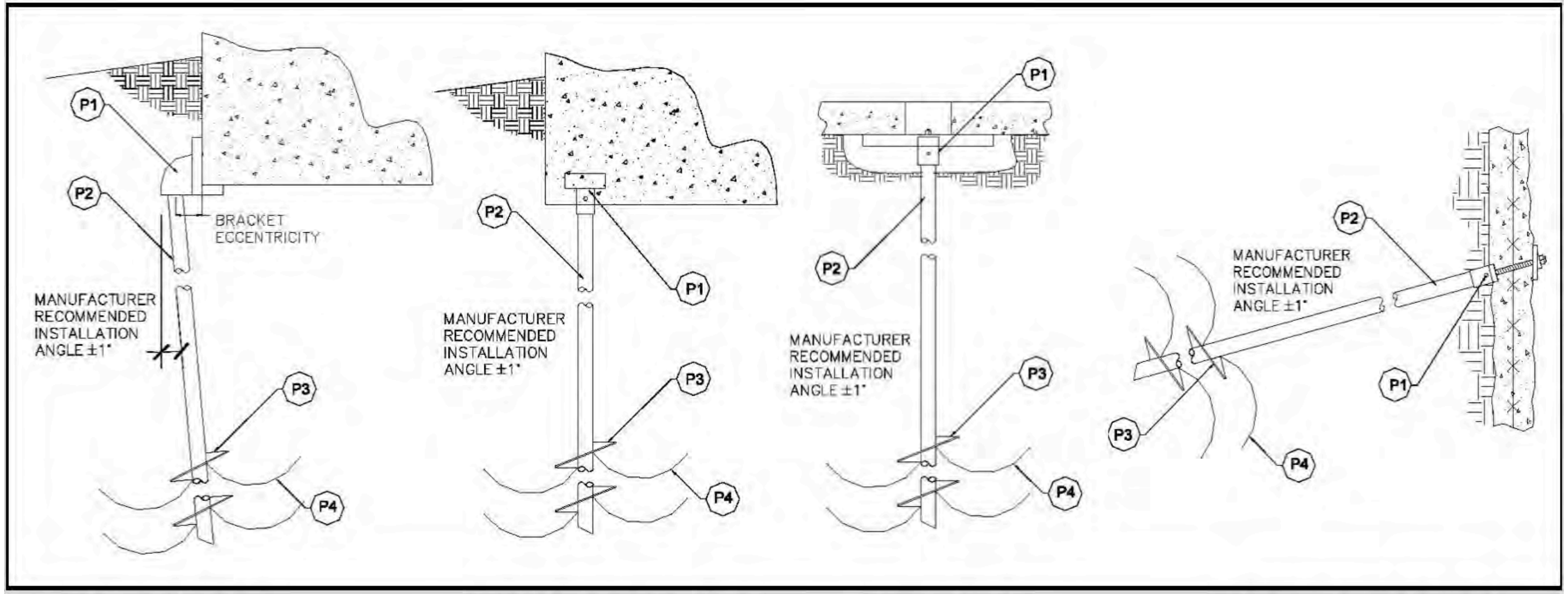
Acceptance Criteria for Helical Foundation Systems
(AC 358)

ICC EVALUATION SERVICE
Ensuring that building products meet code requirements.

- Approved June 2007
- Revised June 2013
- 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

AC358 Acceptance Criteria

Applications covered under AC-358



Side Load Brackets	New Construction Brackets	Floor Slab Brackets	Tension Anchor
**(4021, 4021.55, 4038 and 4039)*	**(4075, 4076 and 4079)*	**(4093)*	**(4550)*

AC358 Acceptance Criteria

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.

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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

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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’.

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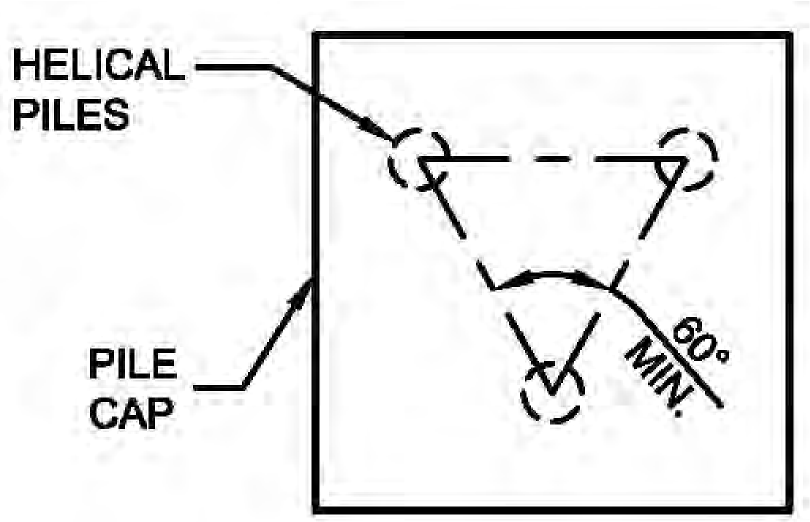
Section 1810.2.2 - Stability

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.



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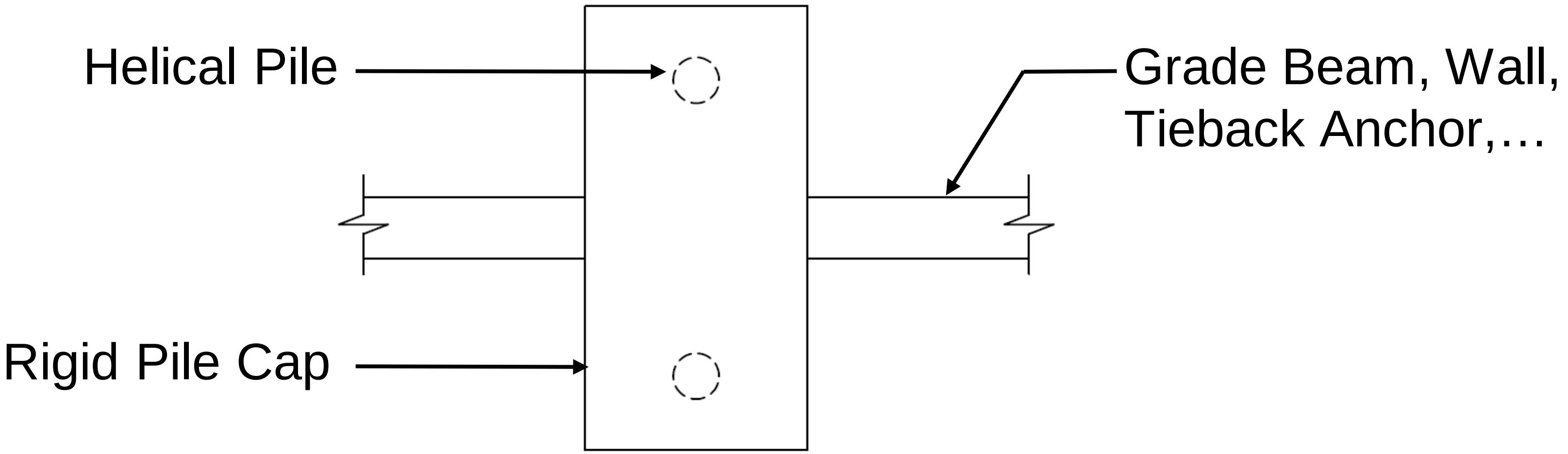
Section 1810.2.2 - Stability

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.



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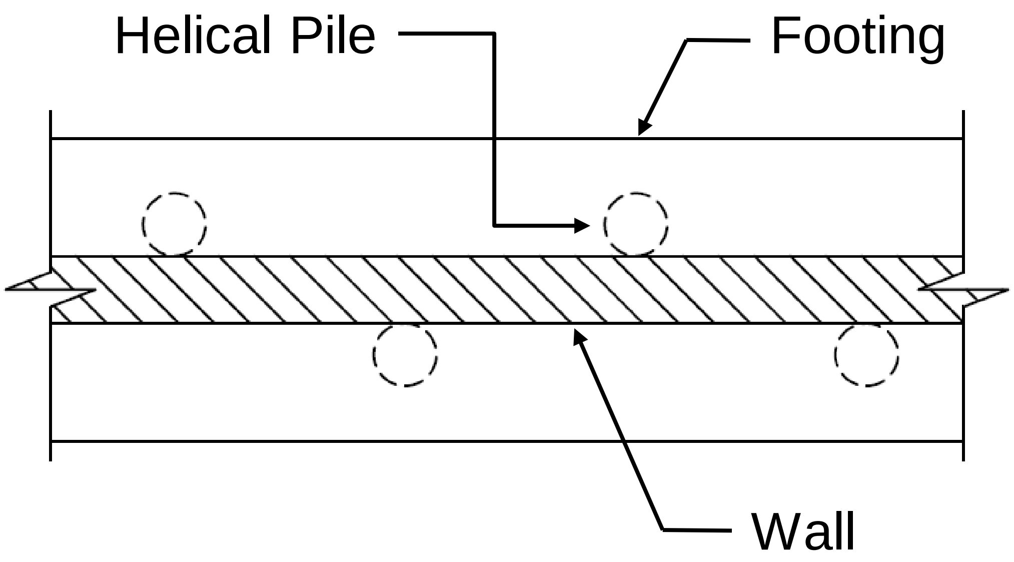
Section 1810.2.2 - Stability

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.

Example of braced piles supporting a wall (new construction):



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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.

2009 & 2012 IBC

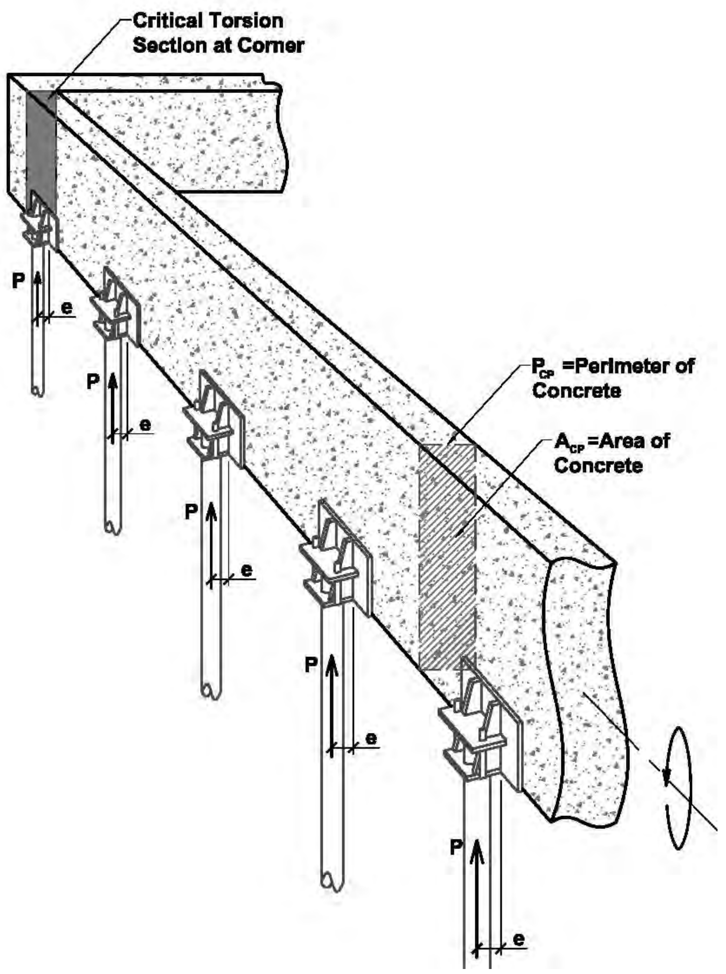
Section 1810.2.2 - Stability

- **Unless measures are taken to provide for:**

- Eccentricity
- Lateral forces
- Piles to be adequately braced to provide lateral stability

2009 & 2012 IBC

Section 1810.2.2 - Stability



Rotational bracing of existing wall:

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

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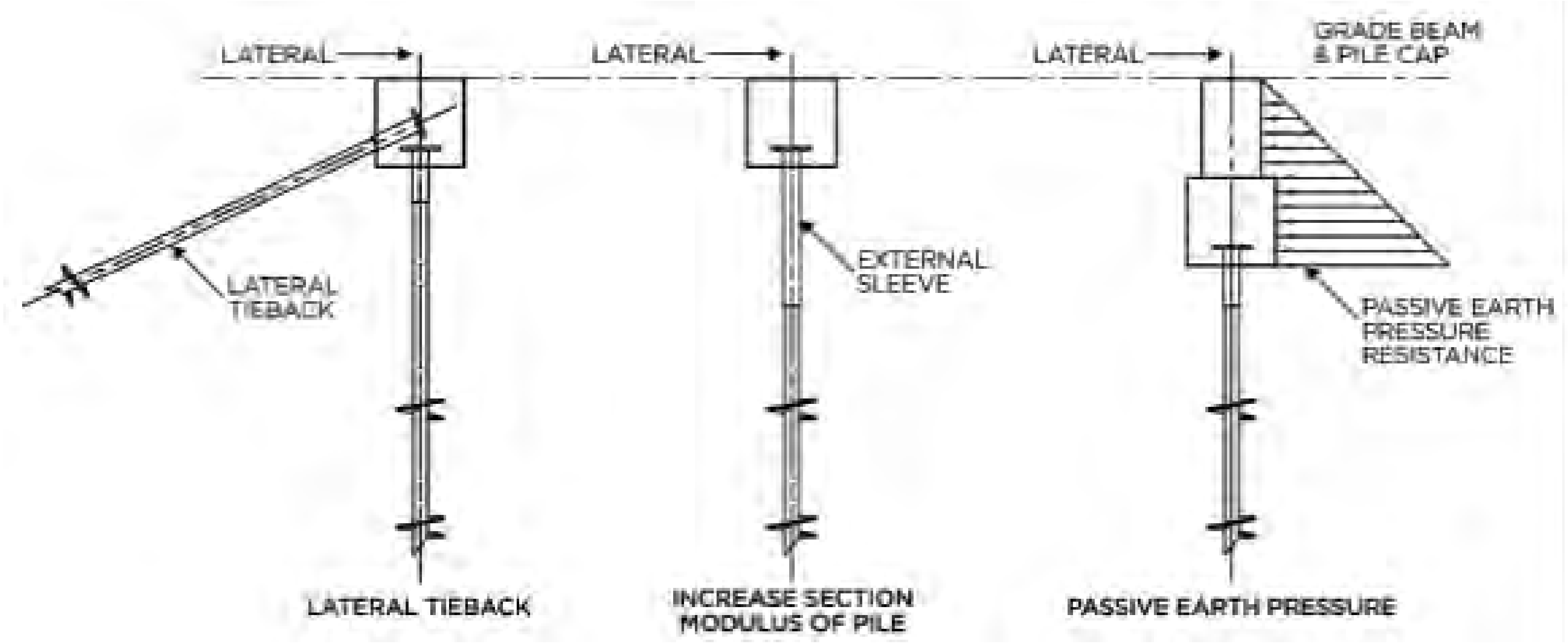
Section 1810.2.2 - Stability



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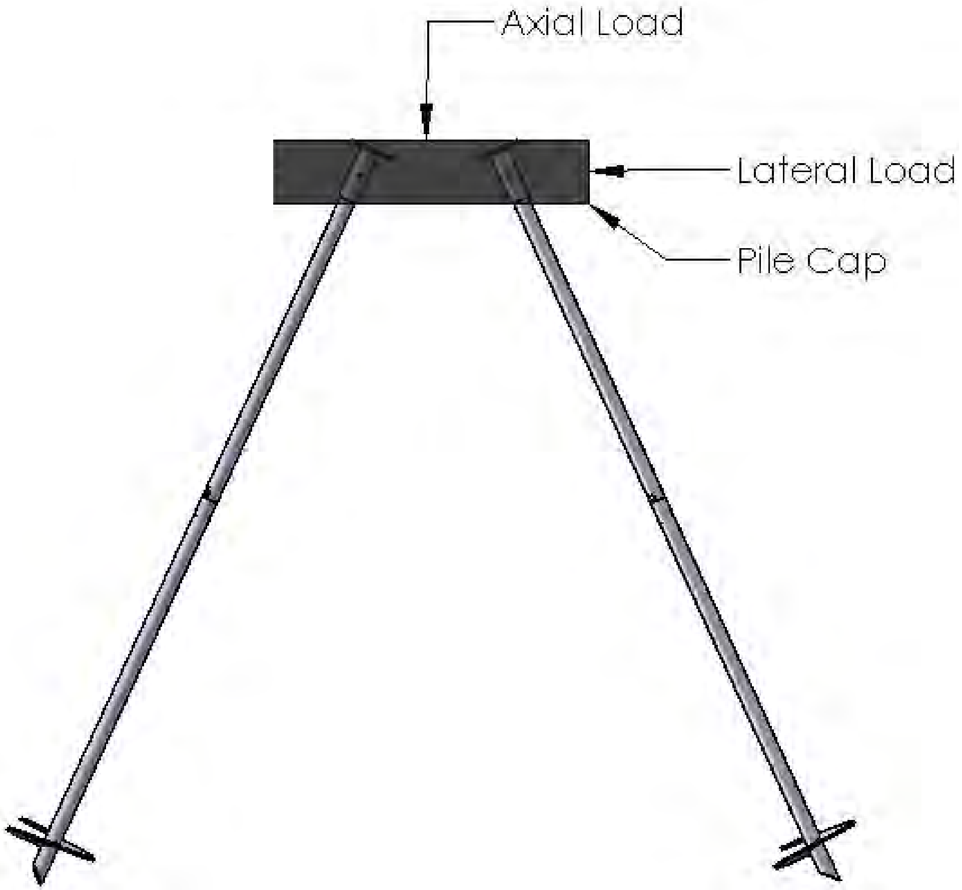
Battered Piles



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Machine Foundation
(Battered Piles)

Design Loads

1,050 kip (4,670 kN) vertical

500 kip (2,224 kN) lateral

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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 $\geq$ 5) are considered laterally braced 5-feet below grade.
- Piles driven into soft soil (N-value $\leq$ 4) are considered laterally braced 10-feet below grade.

UNBRACED LENGTH - EXAMPLES

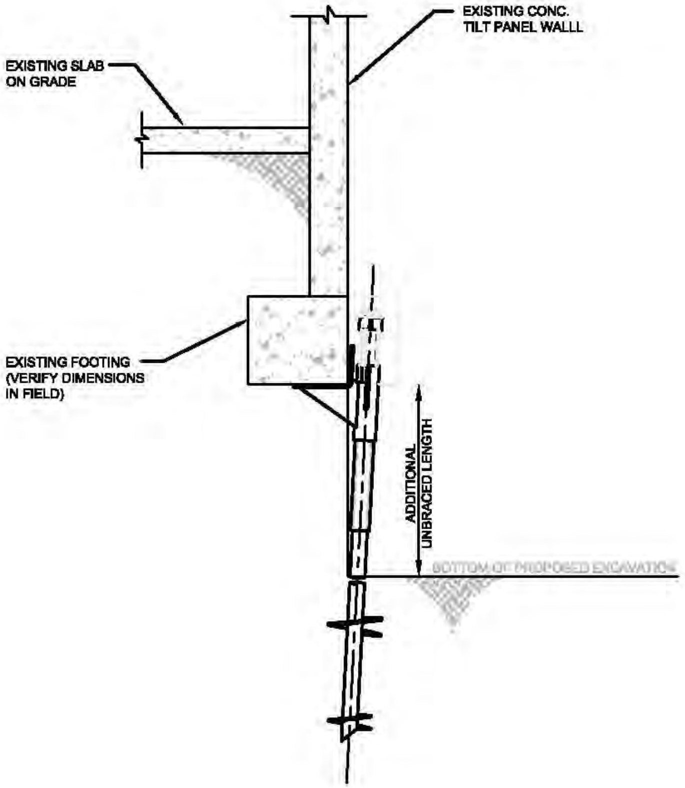


FIG. 1 EXISTING BLDG. UNDERPINNED BY HELICAL PILES

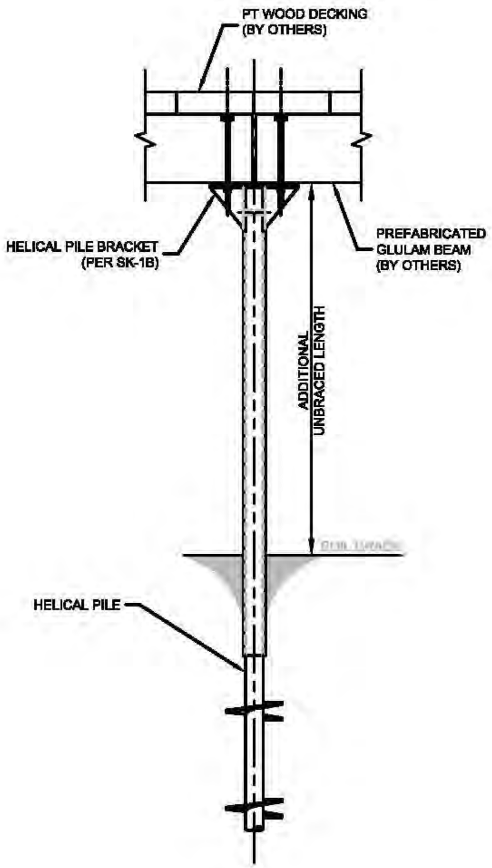


FIG. 2 BOARDWALK SUPPORTED BY HELICAL PILES

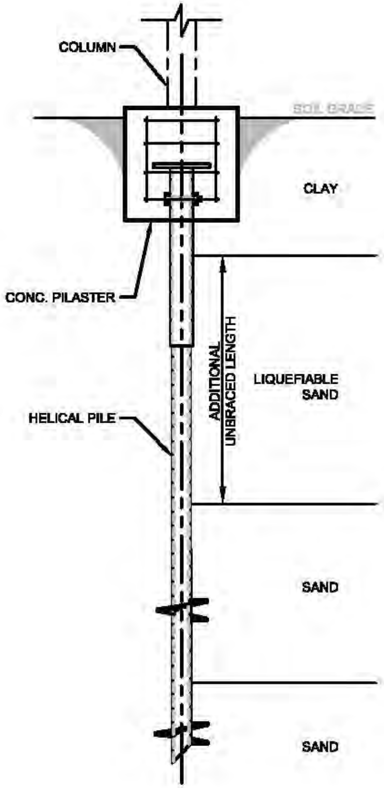
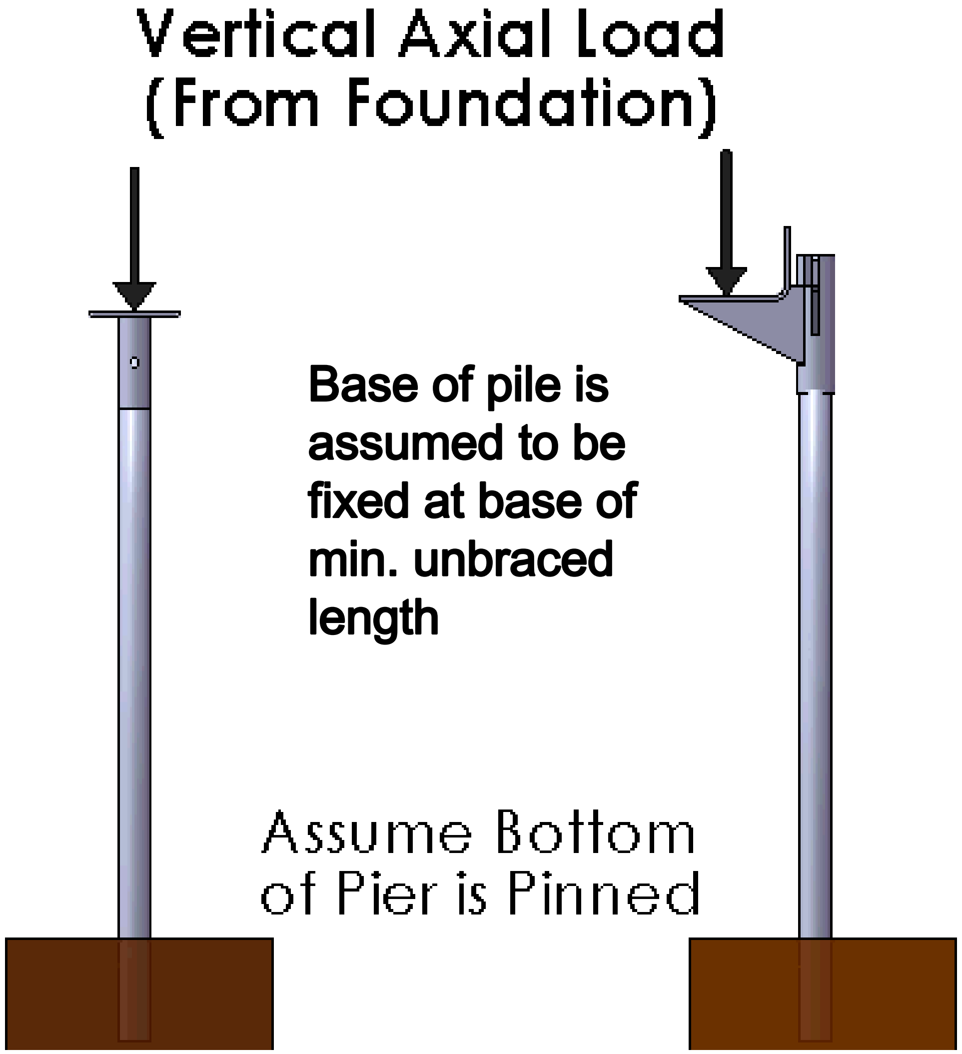


FIG. 2 HELICAL PILE THROUGH LIQUEFIABLE SOIL LAYER

2009 & 2012 IBC



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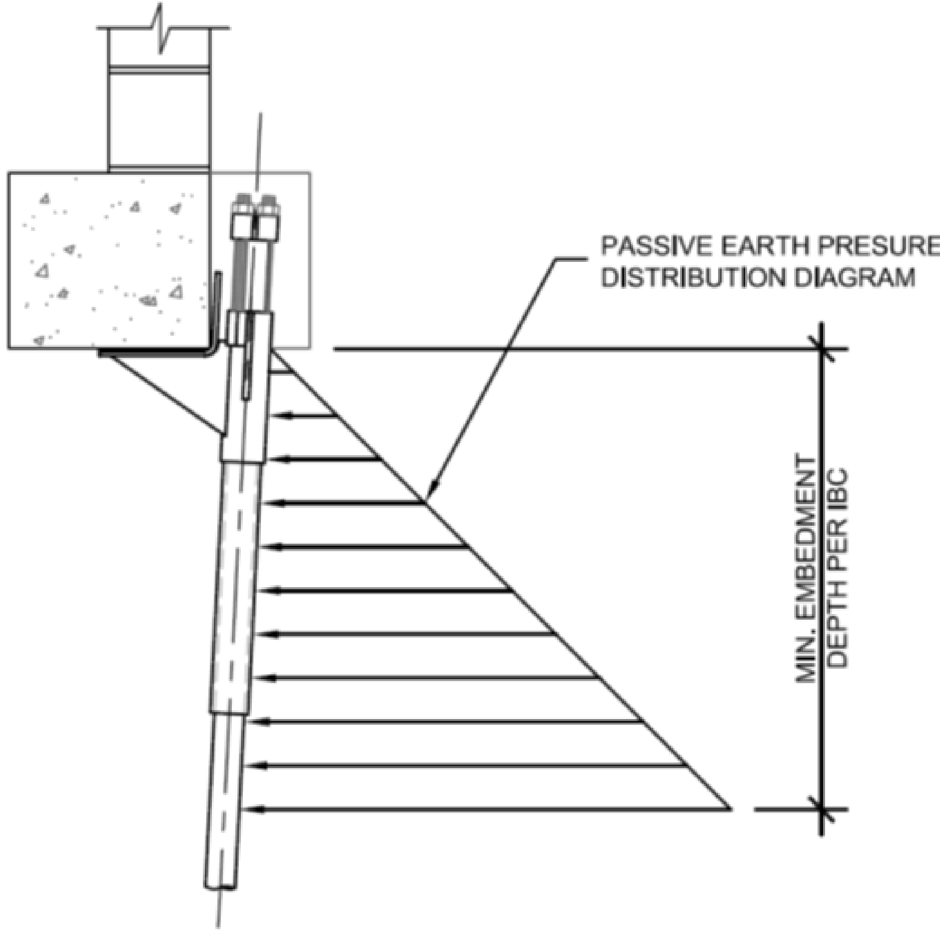
Section 1810.2.1 – Lateral Support

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

- Sufficient embedment is required before the appropriate resistance is reached.



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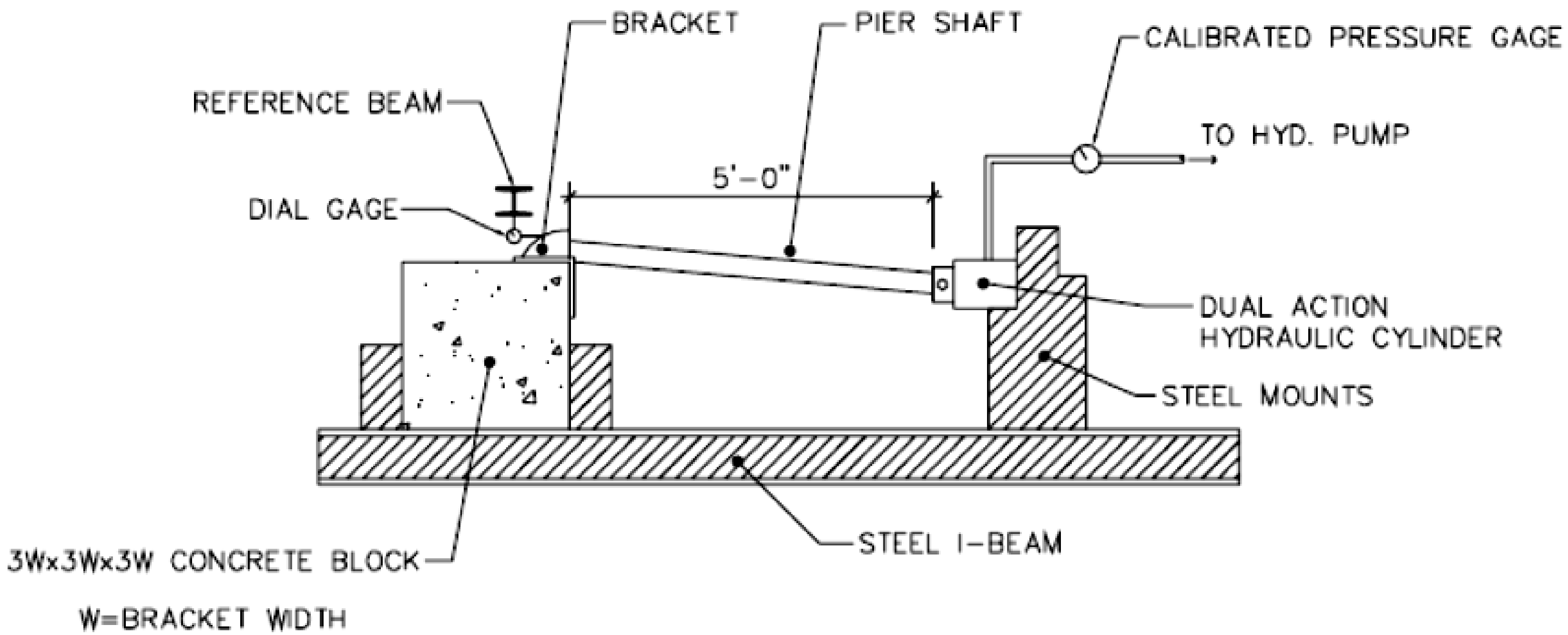
Section 1810.2.1 – Lateral Support



Side Load Bracket Laboratory Test Set-up per AC358

2009 & 2012 IBC

Section 1810.2.1 – Lateral Support

Example of braced piles
supporting an existing wall:

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Scotch Plains, New Jersey

- New cafeteria addition
- Required 13’-0 excavation adjacent to existing bldg
- Loads
  - Column : 25 to 45 kips
  - Wall : 1.8 kips/ft

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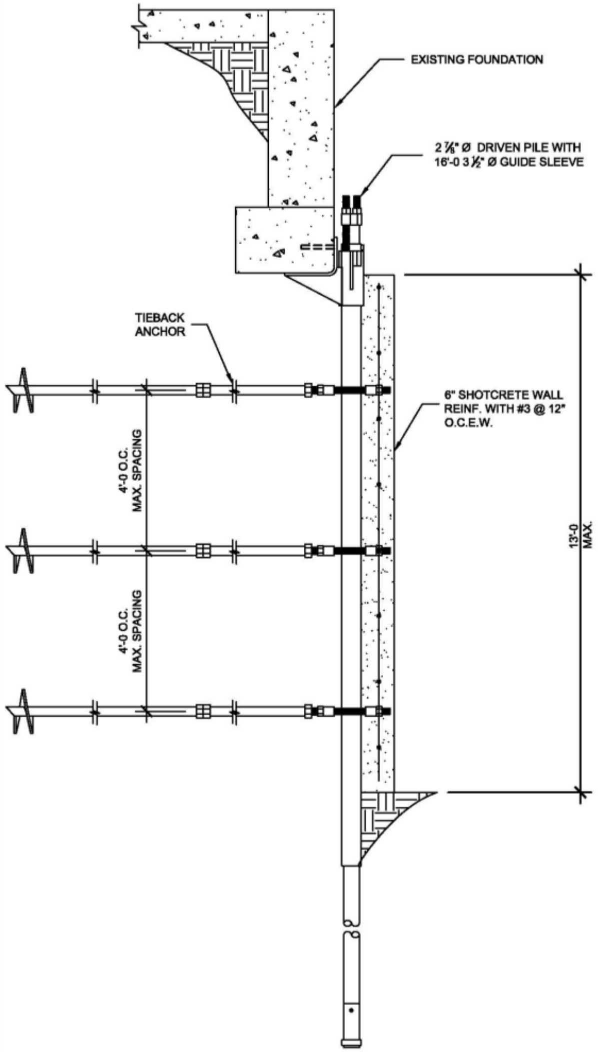
Union County Vo-Tech

Scotch Plains, New Jersey



- 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

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Union County Vo-Tech

Scotch Plains, New Jersey

Three layers of pile tiebacks were installed to provide lateral bracing

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

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Union County Vo-Tech

Scotch Plains, New Jersey

A reinforced 6” thick shotcrete wall was installed at each excavation layer

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Union County Vo-Tech

Scotch Plains, New Jersey

Completion of underpinning and basement wall

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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)

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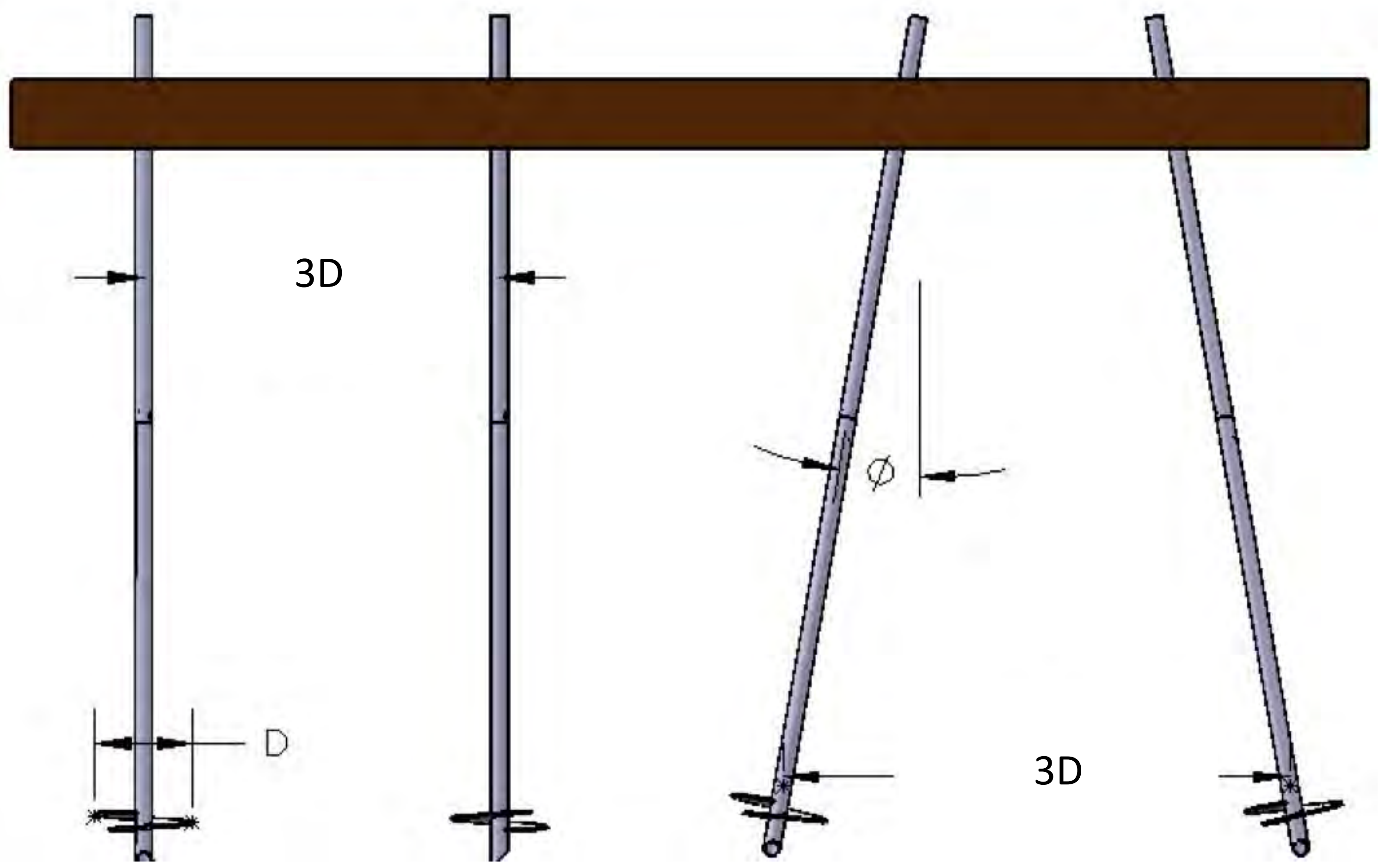
Group Efficiency Effects



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Ram Jack
Foundation Solutions™
Software

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Foundation Solutions™

Helical Design Software

- Automatically estimates soil properties based on SPT “N” values
- One Data File – Various Helical Applications
- Custom Pile Design
- Ult. Torsional Resistance & Ult. Axial Capacity
- Compression & Tension capacities
- Optimization - Helical Pile Design

Foundation Solutions™

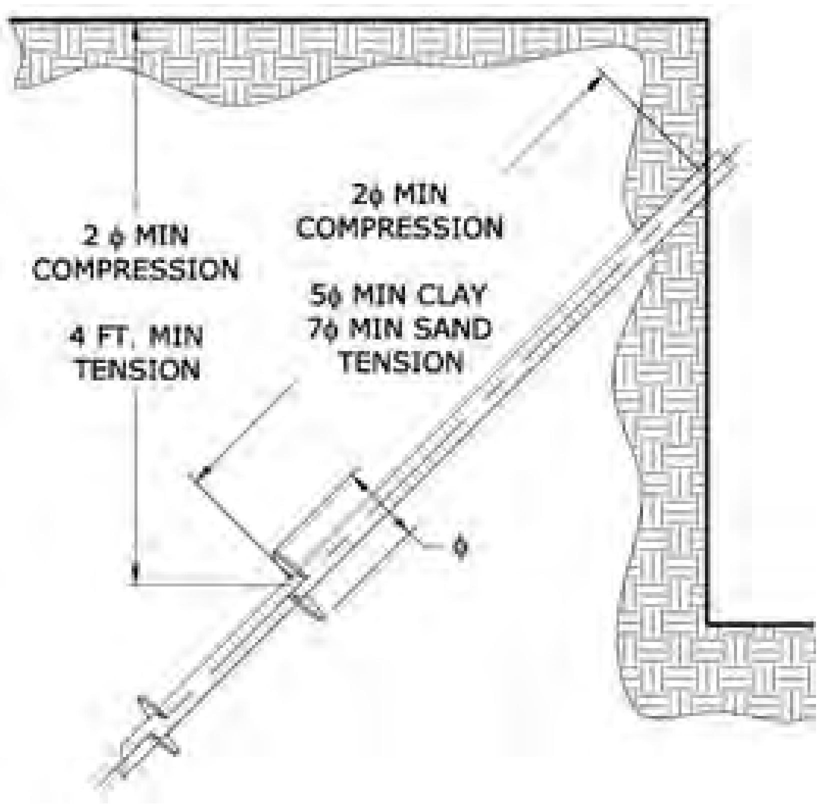
Helical Design Software

- Estimates the Required Approx. Embedment Depth and Installation Torque.
- Professional Output
- Web Based so Current Version is Always Available
- File Sharing
- Does <u>NOT</u> Calculate Buckling Stress

Foundation Solutions™

Helix Capacity

Capacity is calculated at 1'-0 intervals beginning at the recommended minimum embedment



Calculation Results

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Project Name
Northwest Police Sub-Station

Project Address
6000 Teague Road
Houston,TX

Analysis By
Name : Darin Willis, P.E.
Company : Ram Jack Systems Distribution, LLC.
Email : dwillis@ramjack.com

Job Information
Project Type : Underpinning Pier / Project Number :
Pile Specification : Size [2.875] / Helix Configuration : 10-12-14

Client Information
Name : Brian Buchanan
Email :
Address :
Ram Jack of Central & South Texas

Field Notes

PDF Printout

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Analysis Options

Omit Shaft Resistance ✗

Omit Mechianical Strength Checks ✗

Omit Shaft Strength Checks ✗

Soil Information

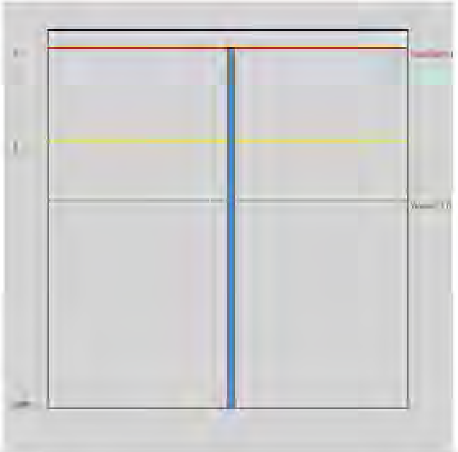
Provided/Performed by:A & R Engineering and Testing
Boring #
Boring Termination Depth, ft
Depth of Ground Water Table,13 ft
Maximum Depth,30ft
Predominant Soil Type, Cohesive

Geometric Data

	1	2	3	4	5
X	0	0	0	0	0
Y	0	0	0	0	0

Inclination Angle 90(deg)

Pile Head Position 0



Soil Profile

Depth (ft)	SPT Blow Count (N)	Layer	Cohesion (psf)	Adhesion Coefficient	Internal Friction Angle (deg)Ø	Friction Co-efficient B	Moist Unit Weight (pcf)	Sat Unit Weight (pcf)	Nc	Nq
0	25	Clay	3066.5	0.39	0	0	100	110	9	1
8	14	Clay	1714.5	0.67	0	0	100	110	9	1

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Helical Pile/Anchor Information:

Req. Allowable Pile Capacity :	28	kip
Applied Factor of Safety	2	
Helical Pile Diameter	2.875	in
Helix Configuration	10-12-14	in
Torque Correlation Factor	9	lbs/ft-lbs

Pile Capacity Theory

End Bearing

$$q_u = cN_c + qN_q$$

q_u - Ultimate End Bearing Capacity, psf

c - Cohesion, psf

N_c & N_q - Bearing Capacity Factors

q - Effective Vertical Stress, psf

Skin Friction

$$f_s = \alpha c + K \sigma_o ' \tan \delta$$

fs = ultimate capacity from skin friction

α = Adhesion Factor

c = cohesion, psf

$\sigma_o '$ = Effective Vertical Stress, psf

δ = Angle of External Friction = 0.34 (ϕ)

Tension Results		
Embedment (ft)	Ultimate Anchor Capacity (lbs)	Torsinal Resistance (lb ft)
12	61624	5729
13	60499	5511
14	56252	5599
15	53952	5725
16	51900	5848
17	52950	5970
18	50876	6091
19	51900	6210
20	52910	6325
21	53906	6441
22	54891	6557
23	55863	6672
24	56837	6788
25	57809	6903
26	58781	7019
27	59753	7134
28	60725	7250
29	61698	7365
30	62671	7481

Compression Results		
Embedment (ft)	Ultimate Anchor Capacity (lbs)	Torsinal Resistance (lb ft)
8	62348	7891
9	59701	7343
10	58575	7472
11	54332	5600
12	52332	5729
13	50322	5511
14	47989	5599
15	49030	5725
16	50048	5848
17	51049	5970
18	52040	6091
19	53019	6210
20	53990	6325
21	54964	6441
22	55937	6557
23	56909	6672
24	57881	6788
25	58852	6903
26	59826	7019
27	60798	7134
28	61770	7250
29	62743	7365
30	63715	7481

Warning

Torsional resistance numbers in bold red font indicate calculated torsional resistance exceeds Ram Jack rating for the selected lead or extension shaft, whichever is less.

Estimated Pile Capacity:

Allowable Frictional Resistance:	11.67	kip
Allowable End Bearing Capactiy:	16.33	kip
Allowable Pile Capactiy:	28.0	kip
Appr. Pile Embedment Depth:	23.0	ft
Required Min. Installation Torque:	6,700	ft-lbs

Additional Tools

www.RamJackEngineering.com

Access to:

- Design software
- Drawings
  - AutoCAD
  - PDF
- Specifications
- Product Catalog
- ESR Report

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Manufacturing Facility

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Applications

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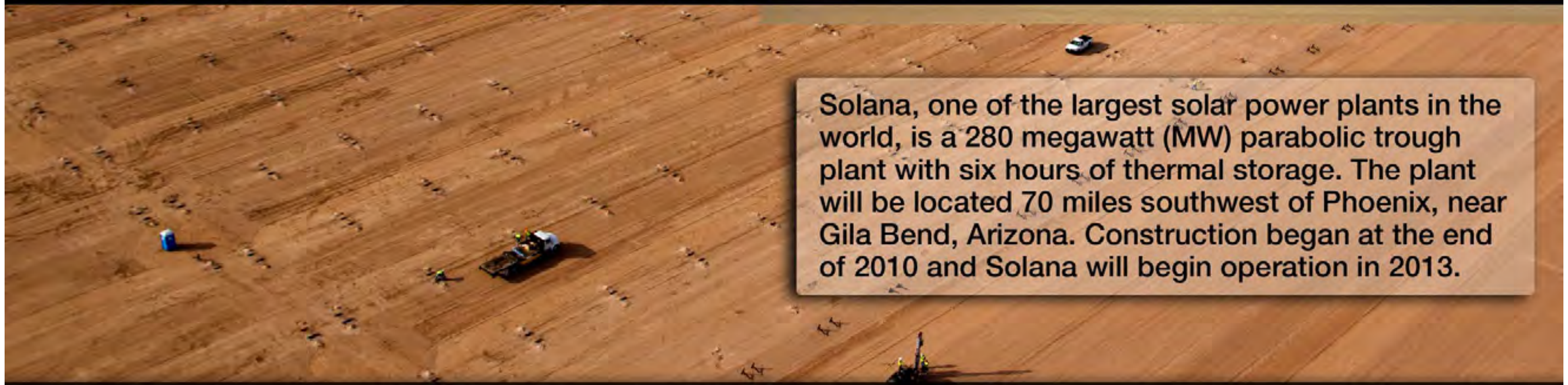
ABENGOA SOLAR

Solana, the largest solar power plant in the world.



Solana, one of the largest solar power plants in the world, is a 280 megawatt (MW) parabolic trough plant with six hours of thermal storage. The plant will be located 70 miles southwest of Phoenix, near Gila Bend, Arizona. Construction began at the end of 2010 and Solana will begin operation in 2013.

Interesting Jobs

RAMJACK™

University of Arizona Medical Center

Phoenix, AZ

- 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 as18 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.

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University of Arizona Medical Center

Phoenix, AZ

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

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Titan Retaining Wall

Houston, TX

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Titan Retaining Wall

Houston, TX

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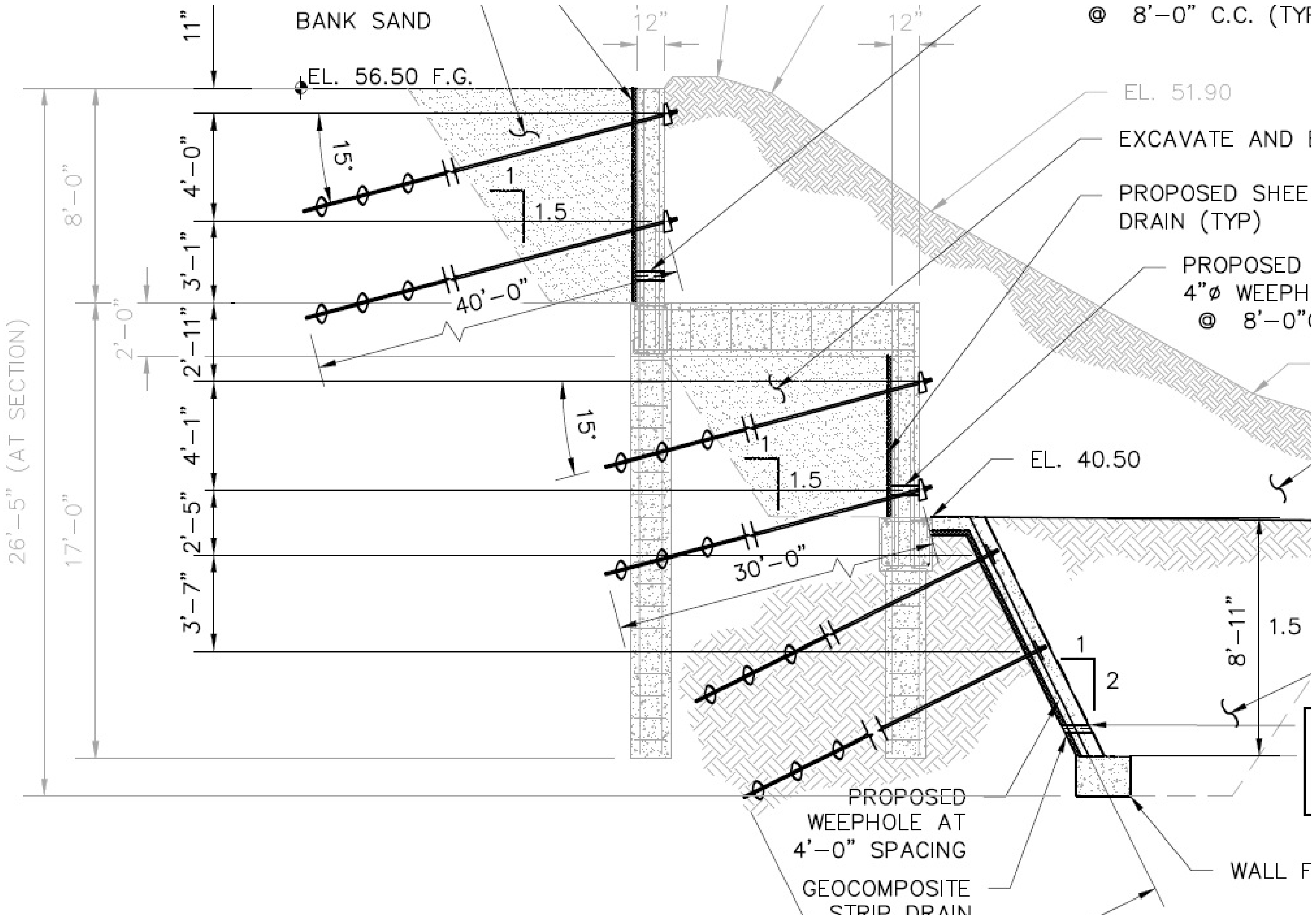
Titan Retaining Wall

Houston, TX



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Titan Retaining Wall

Houston, TX

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Titan Retaining Wall

Houston, TX

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Houston, TX

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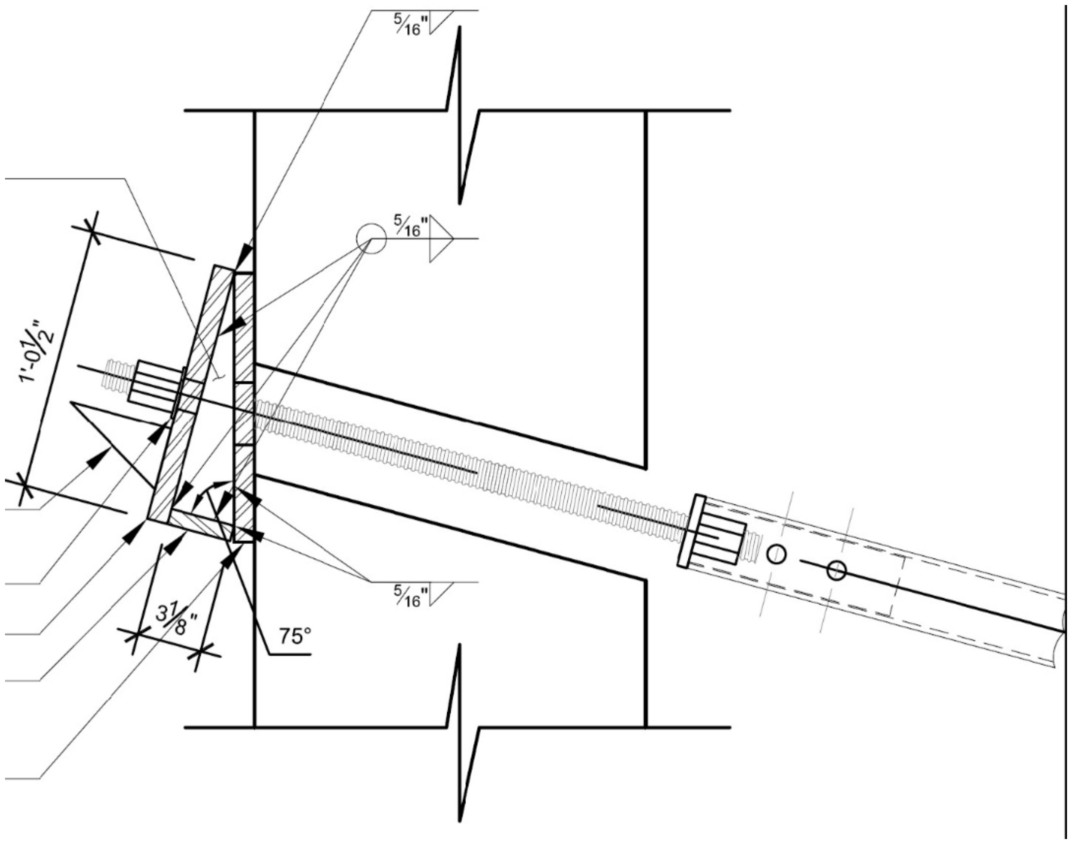
Titan Retaining Wall

Houston, TX



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Titan Retaining Wall

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Meridian
Culvert Failure

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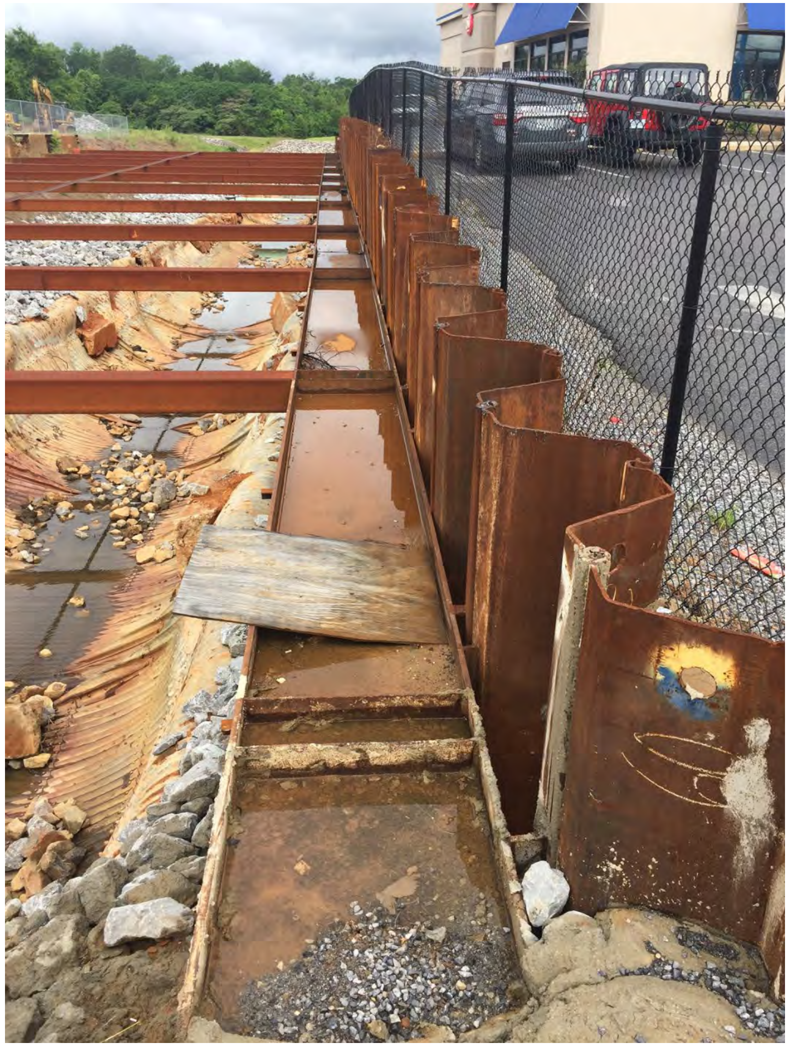
Meridian
Culvert Failure



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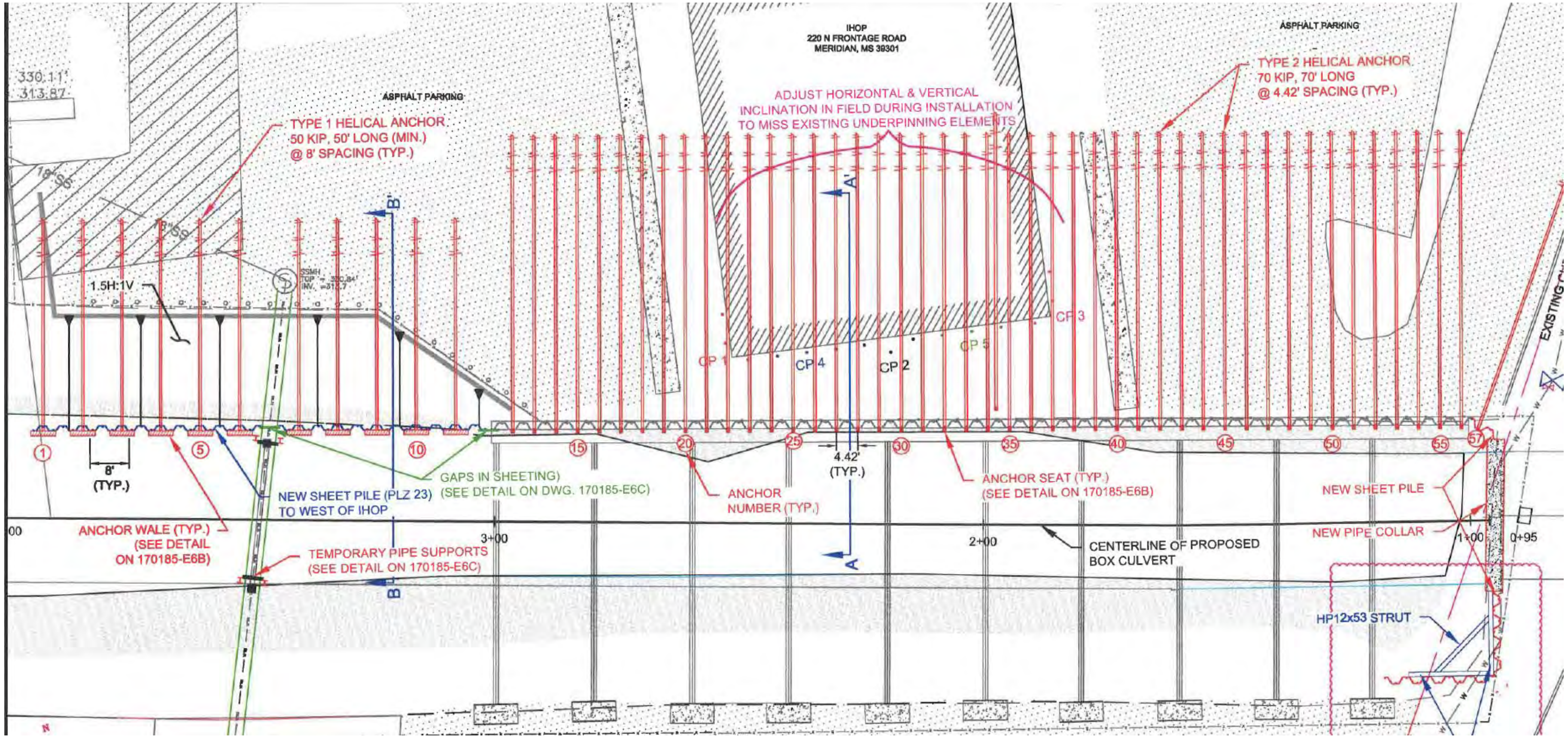

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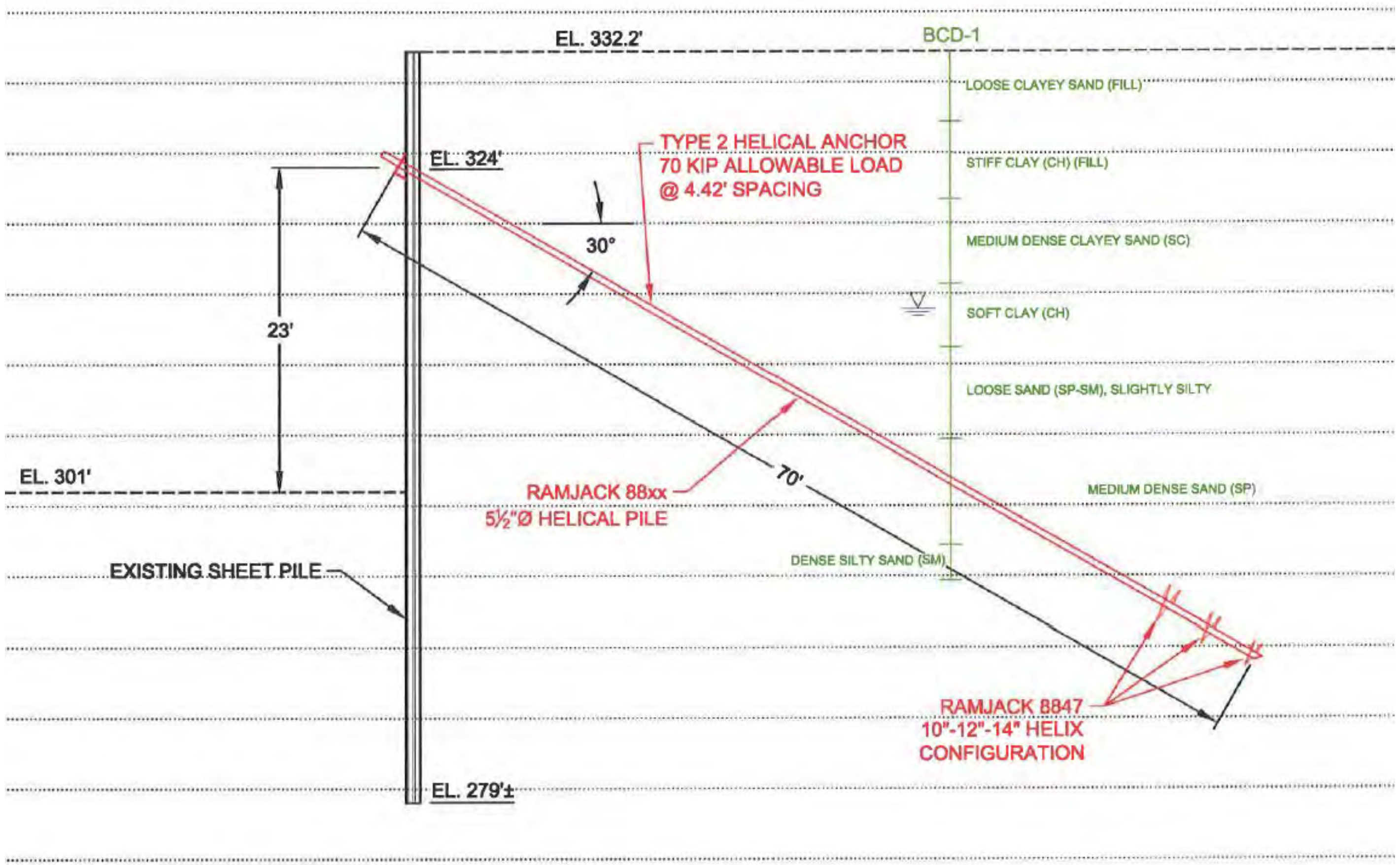

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Questions and Answers with:

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Editorial Director
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