The Application of Cast-in-Place Piles in Intermediate Geomaterials

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To

GEO-Omaha

2021 02 05

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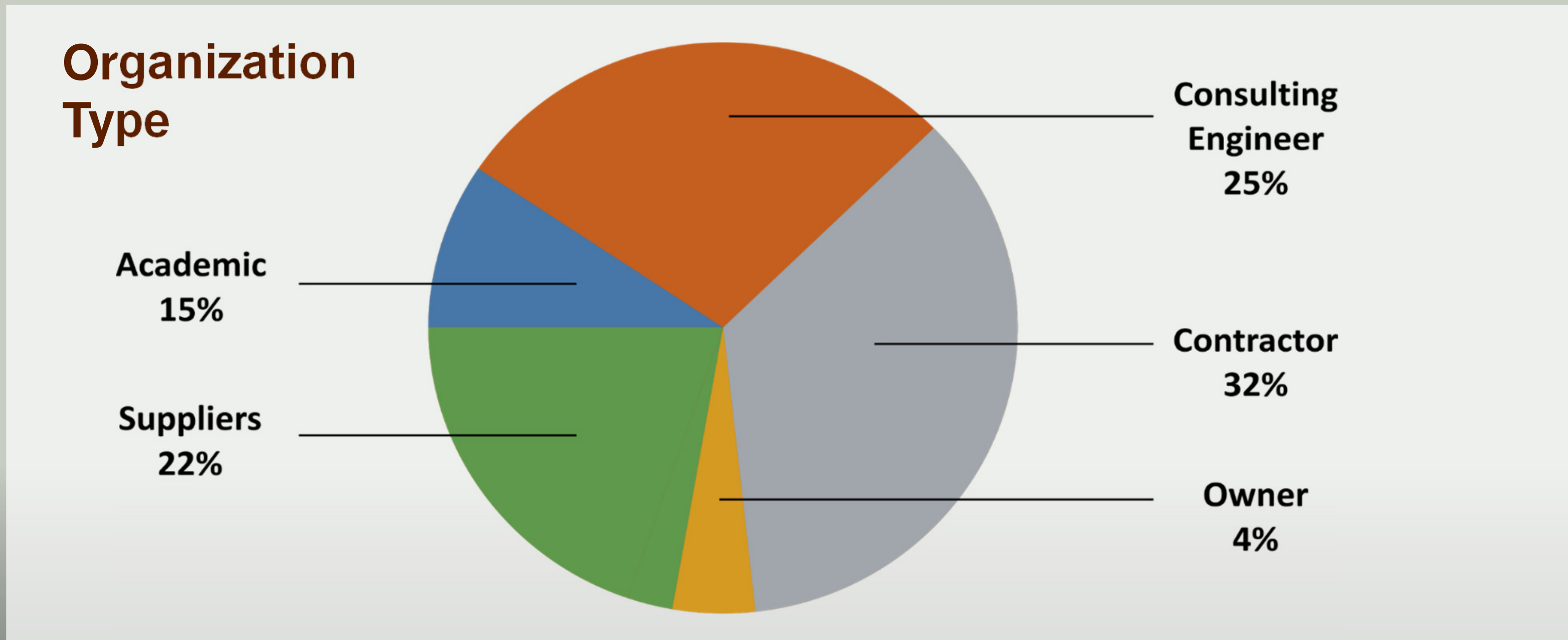

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- **BIM/Digitalisation (Europe)**
- Codes and Standards
- Deep Foundations for Landslides and Slope Stabilization
- Driven Piles
- Drilled Shafts
- Electric Power System Foundations
- Energy Foundations
- Ground Improvement
- Helical Foundations and Tiebacks
- **International Grouting**
- Manufacturers, Suppliers and Service Providers
- Marine Foundations
- Micropiles (Joint w/ ADSC)
  - International Society for Micropiles
- **Project Information Management Systems**
- **Risk and Contracts**
- Seepage Control Working Group
- Seismic and Lateral Loads
- Slurry Walls
- Soil Mixing
- Subsurface Characterization
- Sustainability
- Testing and Evaluation
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- **Tunneling and Underground**
- Women in Deep Foundations
- **Industry Wide – Risk Working Group**
- **Industry Wide – Working Platforms**

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May 10-14, 2021 Dallas, Texas	International Foundations Congress and Equipment Exposition
June 1-17, 2021 ONLINE CONFERENCE	Deep Mixing 2021
June 23-25, 2021 Philadelphia, Pennsylvania	SuperPile 2021
July 26, 2021 Pittsburgh, Pennsylvania	DFI Educational Trust Pennsylvania Golf Outing
August, 2021 Royce Brook Golf Club, Hillsborough, New Jersey	2021 ACE Mentor Program & DFI Educational Trust NJ Golf Outing
August 3-5, 2021 San Francisco, California	S3: Slopes, Slides and Stabilization
September 2021 Dublin, California	DFI Educational Trust Annual California Golf Outing
October 12-15, 2021 Las Vegas, Nevada	46th Annual Conference on Deep Foundations

November 2021 Cairo, Egypt	DFI Middle East Workshop at GeoMEast2021
November 4, 2021 Corona, New York	DFI Educational Trust 15th Annual Gala Fundraising Dinner
November 8-11, 2021 Austin, Texas	International Symposium on Frontiers in Offshore Geotechnics
November 12-15, 2021 Dubai, UAE	DFI Middle East Geotechnical Engineering Summit at The Big 5 Heavy
Nov. 18-20, 2021 Subject to Change Chennai, Tamil Nadu, India	DFI-India 2021: 10th Anniversary Conference on Deep Foundation Technologies for Infrastructure Development in India
February 13-16, 2022 New Orleans, Louisiana	6th International Conference on Grouting & Deep Mixing
February 23-25, 2022 Sydney, Australia	DFI-PFSF Piling & Ground Improvement Conference
May 18-20, 2022 Berlin, Germany	DFI-EFFC International Conference on Deep Foundations and Ground Improvement: *Smart Construction for the Future*

Scope of Presentation

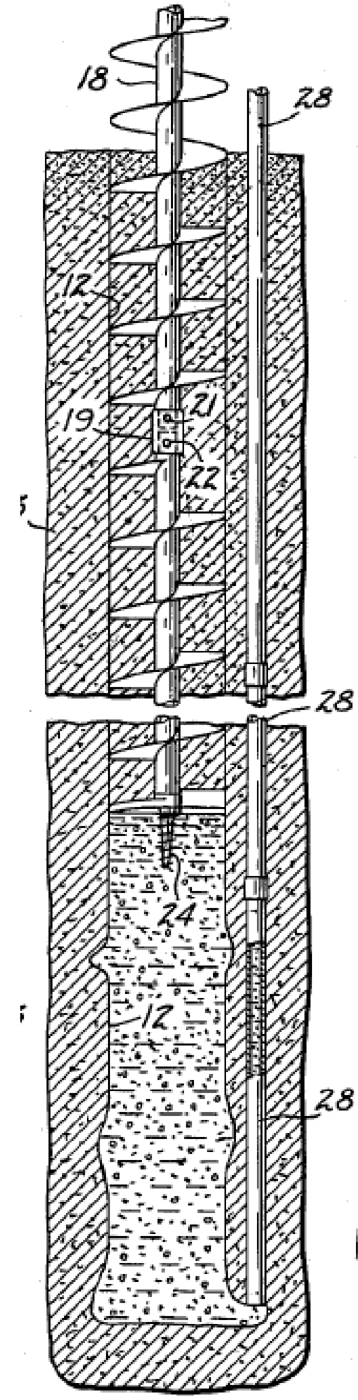
Evolution of Augered Cast-in-Place Pilling Equipment and Processes

What is an "Intermediate Geomaterial" (IGM)

Example Applications

Auger Pressure Grouted (APG) Pile System

- Cast-in-place piles grew out of pressure-grouting processes at Intrusion-Prepakt, late 1940s, early 1950s
- Patent granted to Raymond Patterson for construction of cast-in-place piles by pumping grout through a hollow-stem auger.
- Licenses granted to Lee Truzillo and Charles Berkel



"The Evolution of Cast in Place Piles"
November/December 2013 DFI Magazine

STATE OF THE ACIP INDUSTRY early 1960s

- Augers advanced by power units that developed +- 15,000 ft-lbs
- On-site grout batching using bagged cement, fly ash and grouting agent, and masonry sand (to allow grout to be pumped by pneumatic powered piston pumps)
- Consistent production of 3000 psi grout was a challenge (fine masonry sand)
- Installation of 500 linear feet of piling in a single day was considered a great accomplishment.

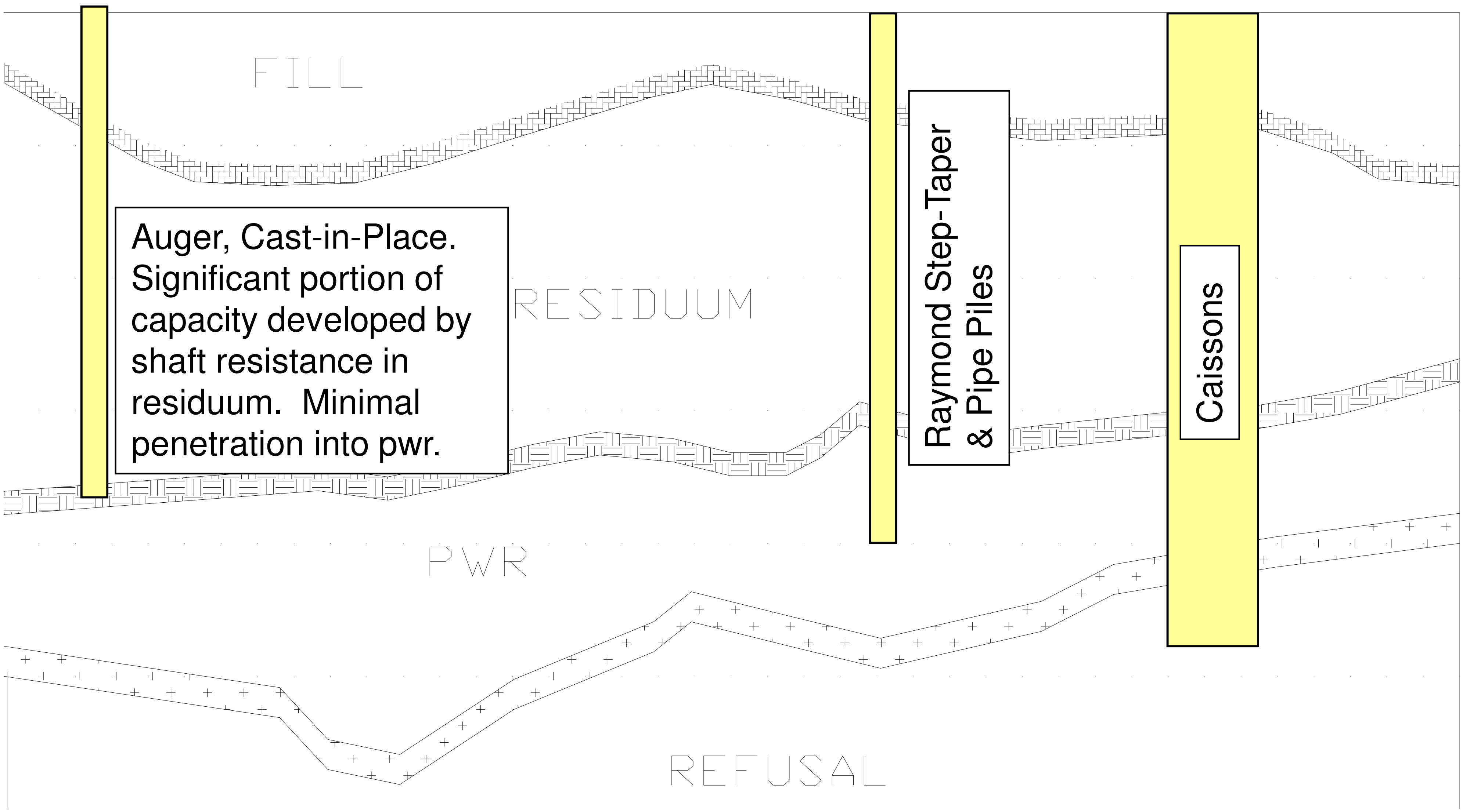
STATE OF THE DEEP FOUNDATION INDUSTRY EARLY 1960S

- Deep foundations for most major structures are either **driven piles** or **drilled shafts**
- Raymond Concrete Pile Company has offices throughout the U.S.

STATE OF THE ACIP INDUSTRY1970s

- Augers advanced by power units that developed +- 30,000 ft-lbs
- ASTM C-33 sand used in grout mixes
- Higher volume, more powerful pumps are available
- Redi-mix grout common.
- Original patent for ACIP piles expires – new installers enter the market

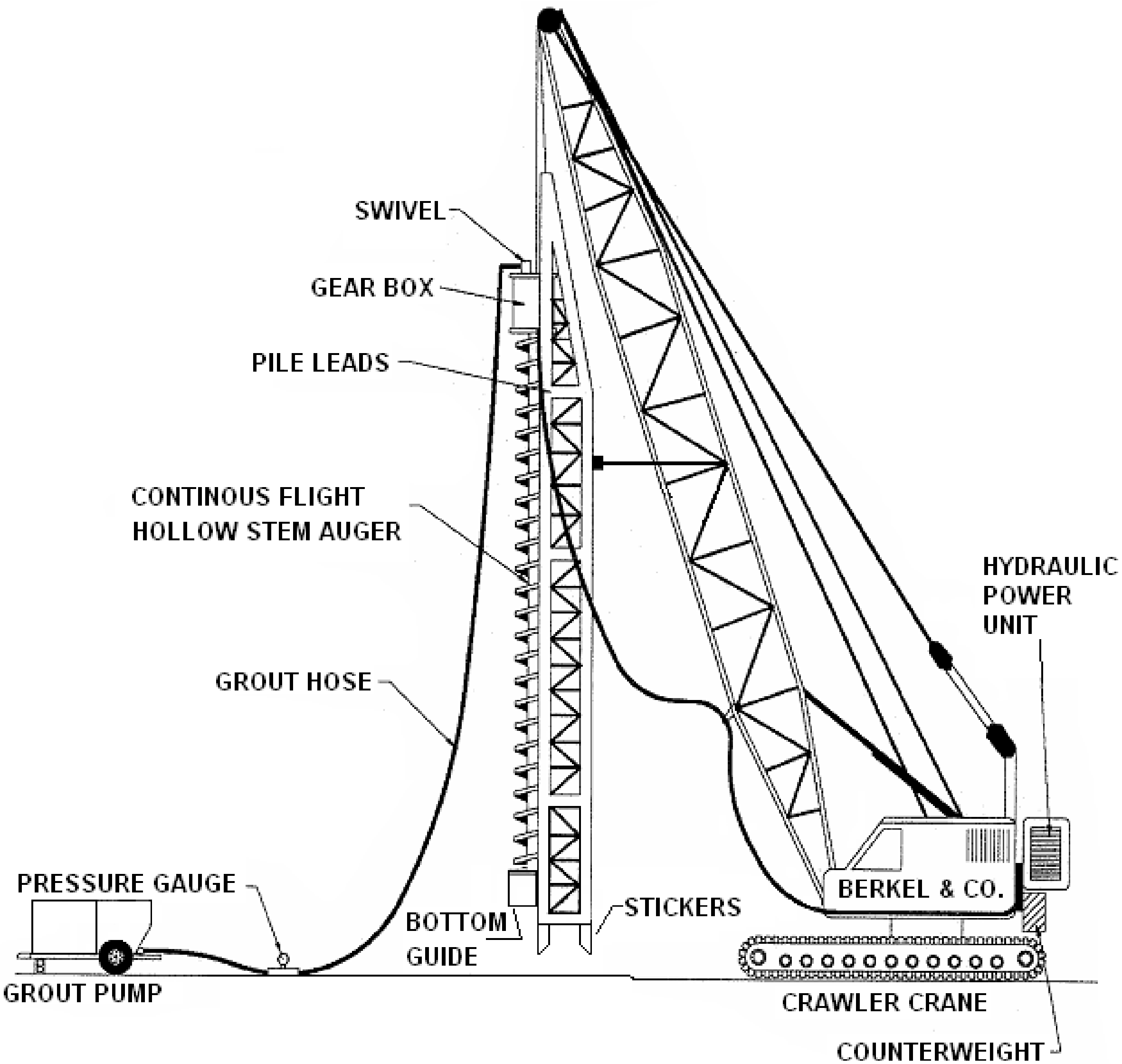
Piedmont Physiographic Profile
Deep Foundation Approach [1970's]



ACIP Piles in the1980s

- Substantial knowledge base in the Geotechnical Community.
- Continued advancement of installation platforms and grout delivery systems leads to application in a wider variety of geologic settings.
- Application in Intermediate Geomaterials
  - Miami Rapid Transit System-Piles in soft limestone
  - Georgia World Congress Center-Piles in partially weathered rock
  - Conventional Crane-Mounted Equipment

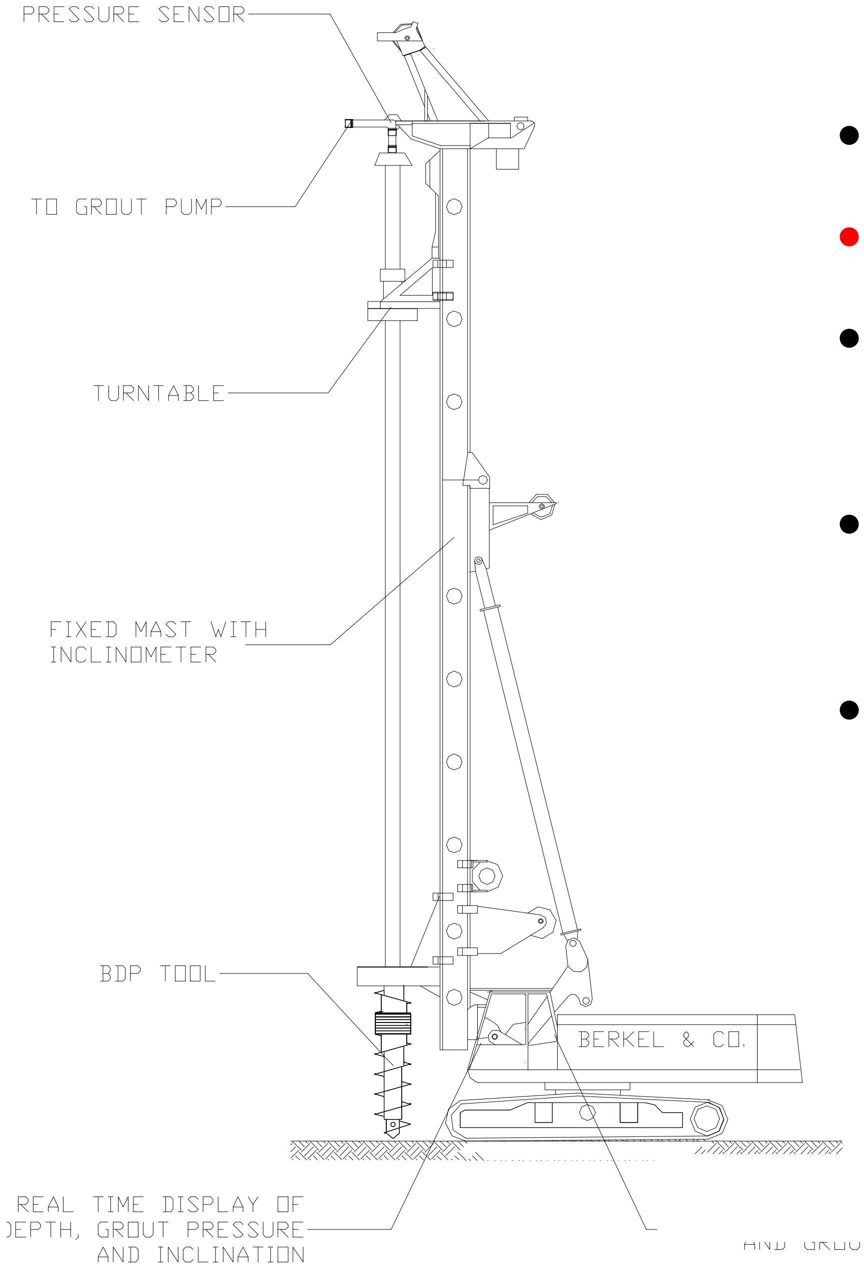
Crane-Supported ACIP Pile Rig




BigB

Fixed Mast Platforms

INSTALLATION PLATFORM



- 150,00 to 200,000+ ft-lb torque
- 40,000 to 80,000+ lb crowd
- Fixed mast for stability, inclinometer with display in operator's compartment
- Grout pressure, measured at top of tools, is displayed in operator's compartment
- Real-time display of installation parameters (depth, KDK pressure, Installation Effort, grout pressure) pressure

Primary Drilling Parameters (Recorded at 1 Reading per Second)

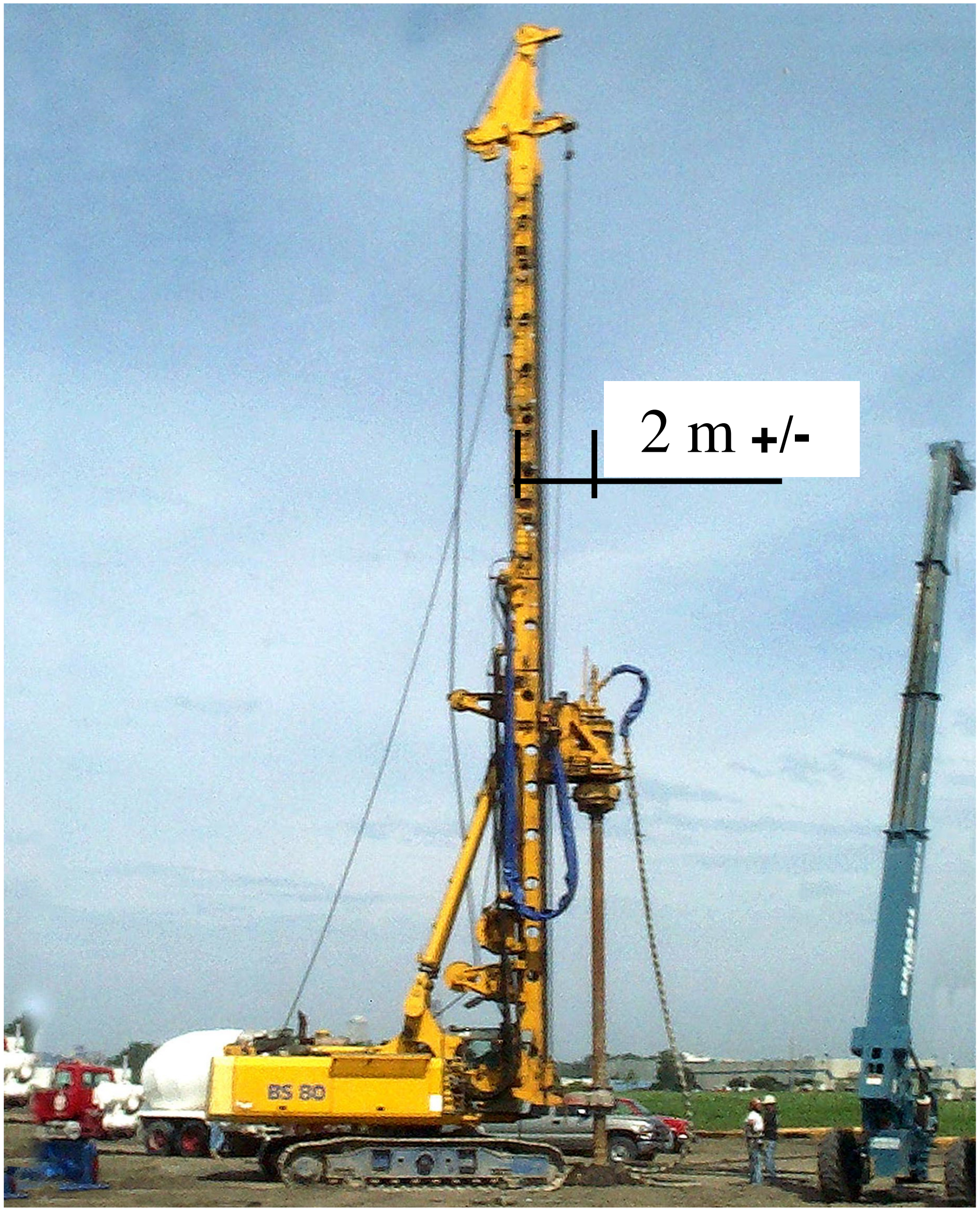
- Time: Recorded by an internal counter and referenced to the initial date and time input by the operator at the beginning of the project.

- Depth: From proximity switch that measures rotation of the main winch supporting the drilling turntable and drilling tools.

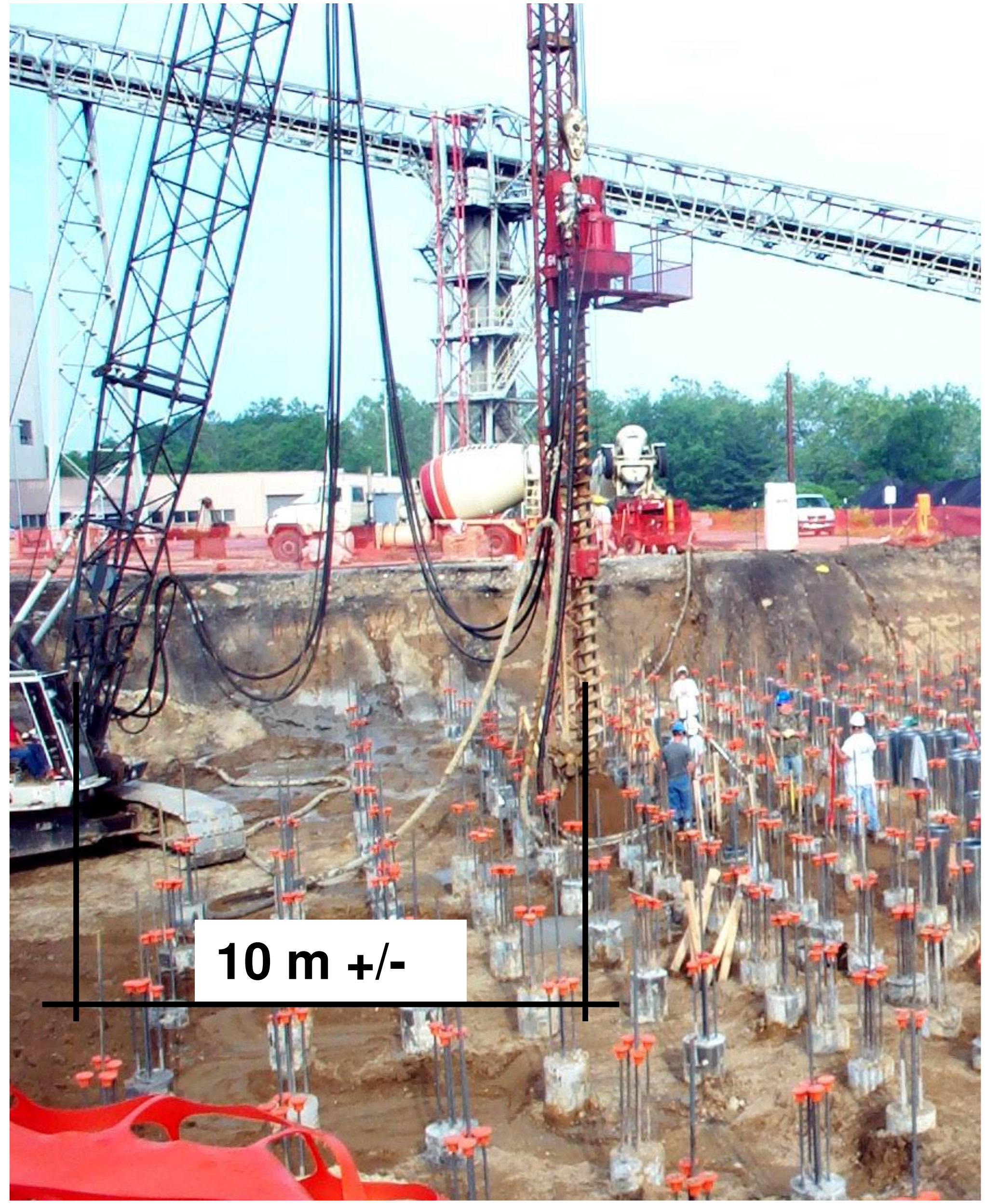
- Hydraulic Fluid Pressure driving turntable (i.e. KDK Pressure): From in-line pressure transducer.

- Rotations (of drilling tools): From proximity switch on turntable.

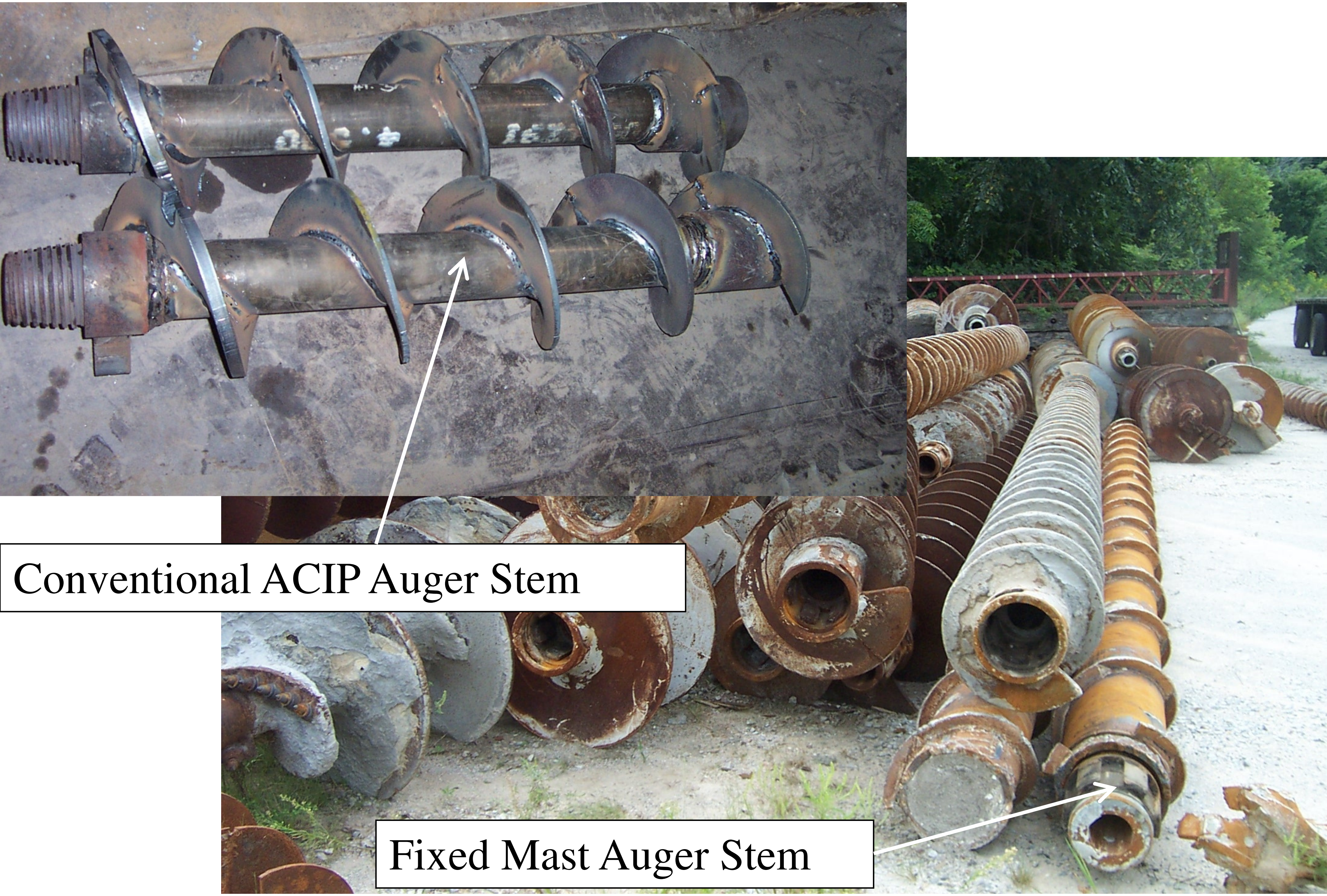
On-Site Logistics Considerations



Fixed-Mast Piling Rig



APG Crane-Mounted Rig


Conventional ACIP Auger Stem
Fixed Mast Auger Stem

TERMINOLOGY

GEC #8

1.1 PURPOSE

The purpose of this document is to develop a state-of-the-practice manual for the design and construction of continuous flight auger (CFA) piles, including those piles commonly referred to as augered cast-in-place (ACIP) piles, drilled displacement (DD) piles, and screw piles. An

Basically, any system for installing cast-in-place piles by a single-pass, rotary drilling process is a “CFA” pile.

DFI

Augered-Cast-in-Place (ACIP) Piles, a.k.a. Augercast, Auger Pressure-Grouted Piles- Piles installed by single-pass, rotary drilling processes where the tooling includes a continuous flight auger.

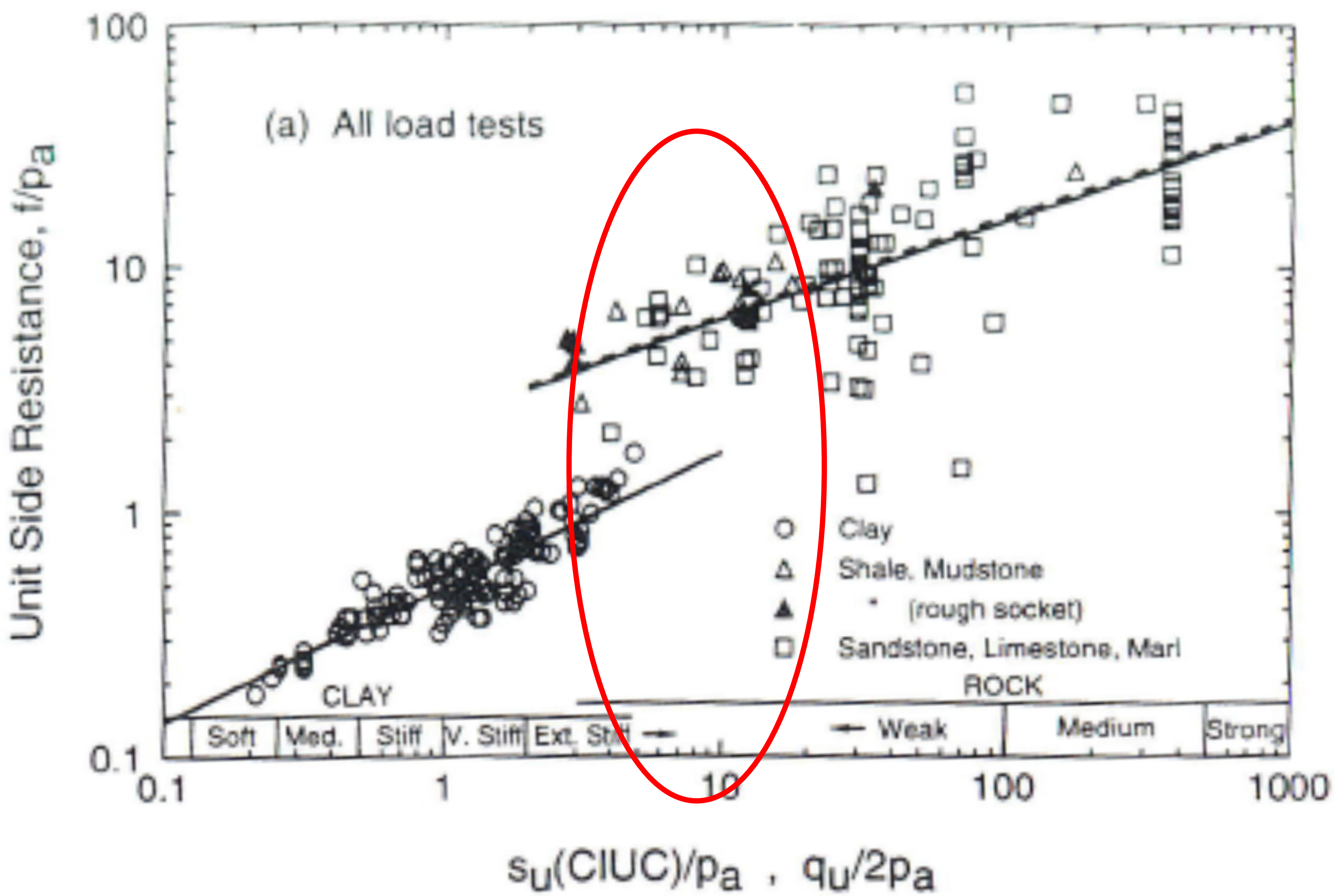
Drilled Displacement (DD) Piles, Propriety names Berkel Displacement Piles, DeWaal, Omega-Piles installed by single-pass, rotary drilling processes where the tooling includes a displacing element that creates a cylindrical pile of more or less uniform diameter.

What are Intermediate Geomaterials?

(a) Cohesive soil (clay or plastic silt with s_u<0.25 MPa (+- 2.5 tsf)
(b) Granular Soil (sand, gravel or non-plastic silt with N_{avg} < 50 blows.0.3 m)
(c) Intermediate Geomaterials
    (a) Cohesive: clay shales or mudstones with .025 MPa (2.5 tsf) < s_u <2.5 MPa (25 tsf)
    (b) Cohesionless: granular tills, granular residual soils with N>50 B/0.3 m
(d) Rock [cohesive, cemented geomaterial with s_u>2.5 MPa (25 tsf) or q_u > 5.0 MPa (50 tsf)]

Source: U.S. Department of Transportation, FHWA-IF-99-025, Vol. II, p 266

Side Resistance in Soft Rock



Ref: Kulhawy and Phoon (1993)

Types of IGMs

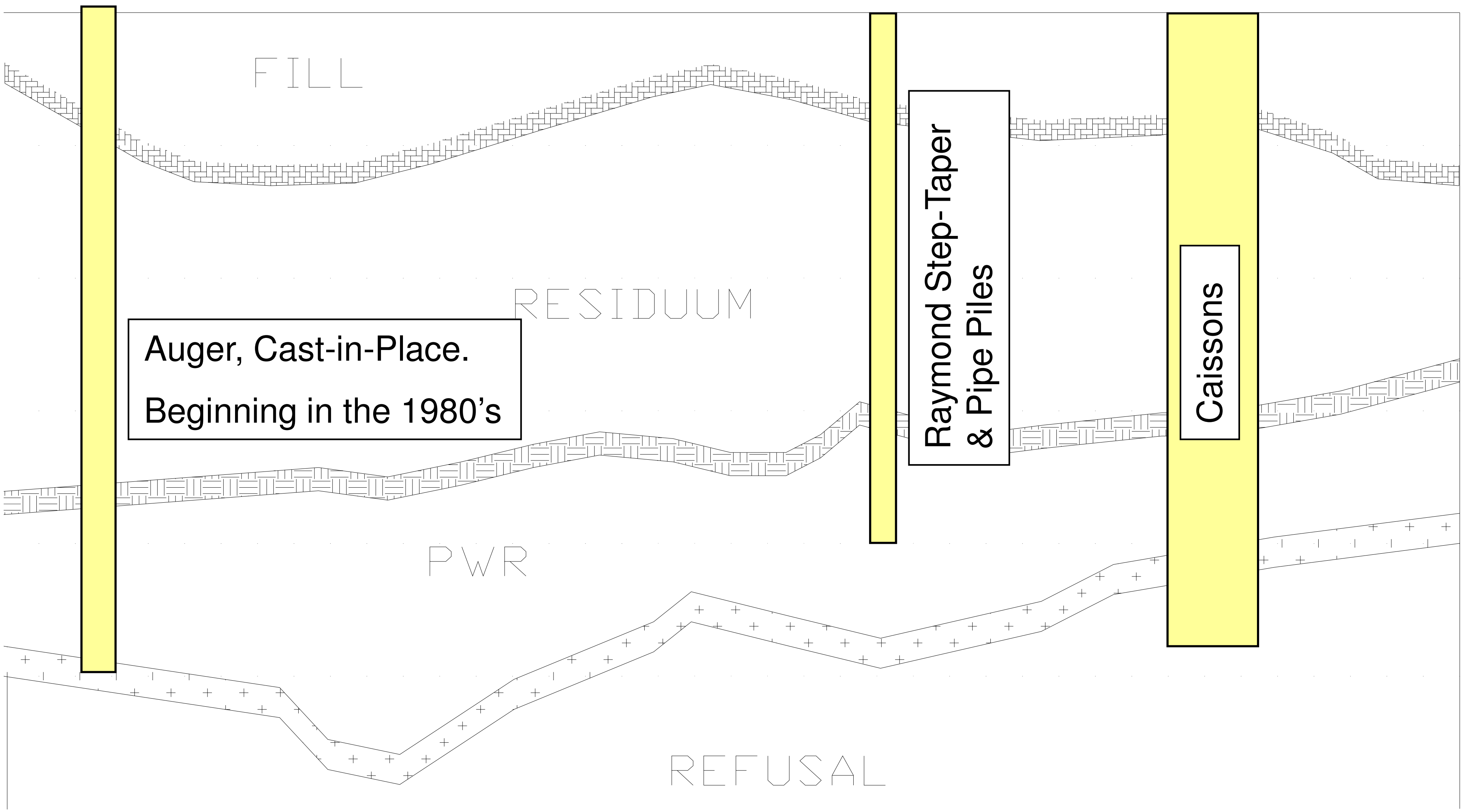
- Materials that were on their way to becoming rock but were not indurated to the point that they could be classified as “rock”. **[Soft limestone, Mudstone, Clay Shale]**
- Materials that were once rock but have been weathered to the point that they have lost some of their rock characteristics. Residual materials **[Partially Weathered Rock, Altered Rock]**
- Materials that have been acted upon by physical or physiochemical processes that cause them to meet the criteria for IGMs. **[Till, Marl]**

A common feature among IGMs is difficulty in obtaining boring data and samples that accurately reflect the character of the in-situ mass

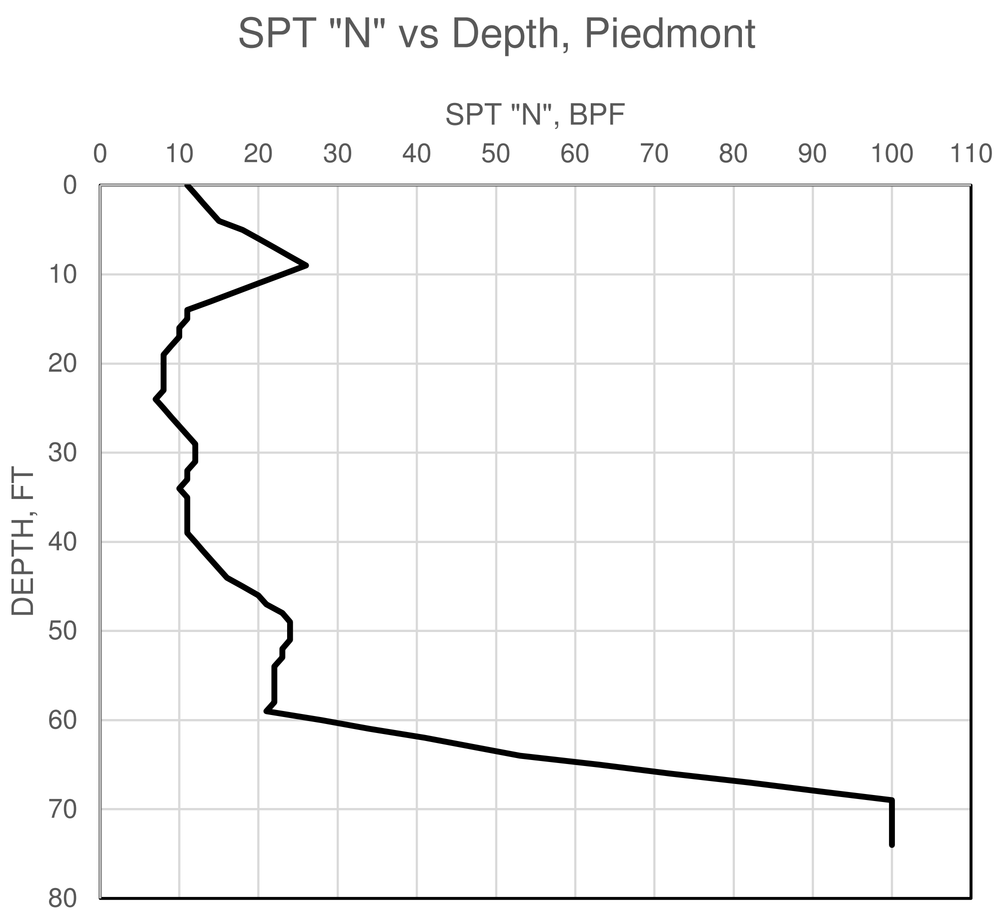
Partially Weathered Rock

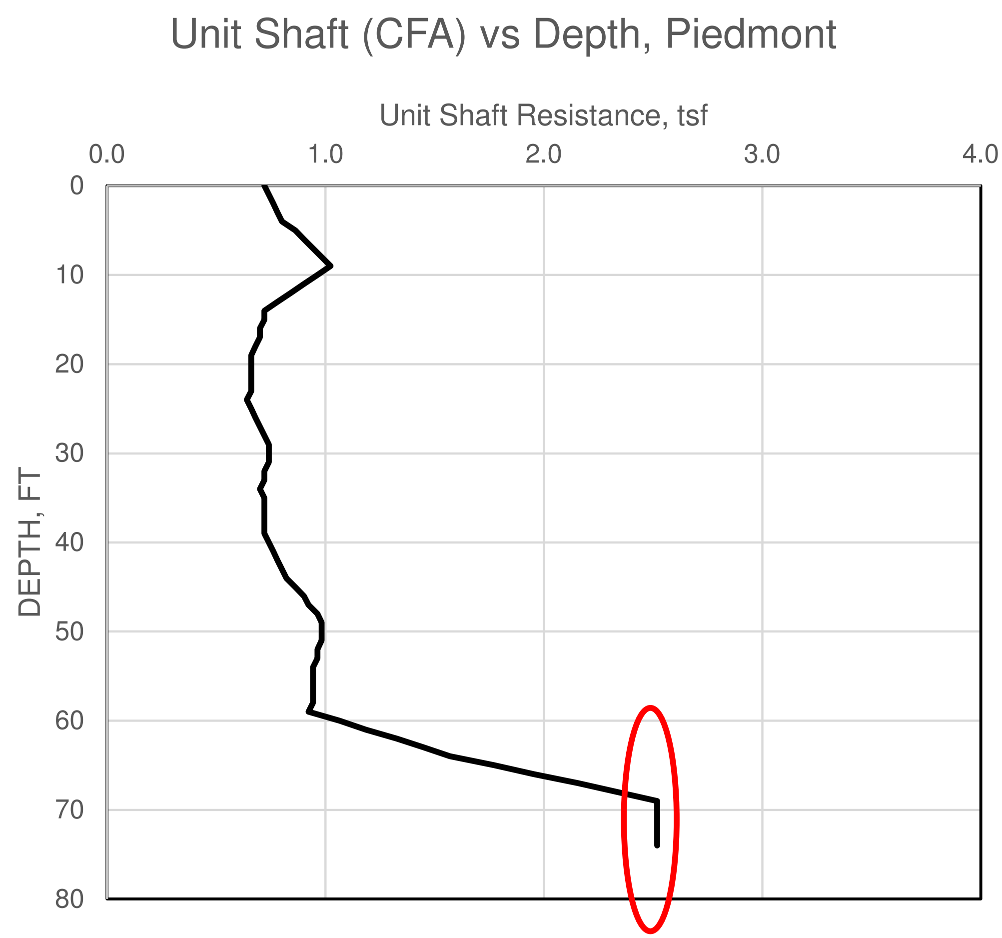
Piedmont Profile

Deep Foundation Approach 1990's

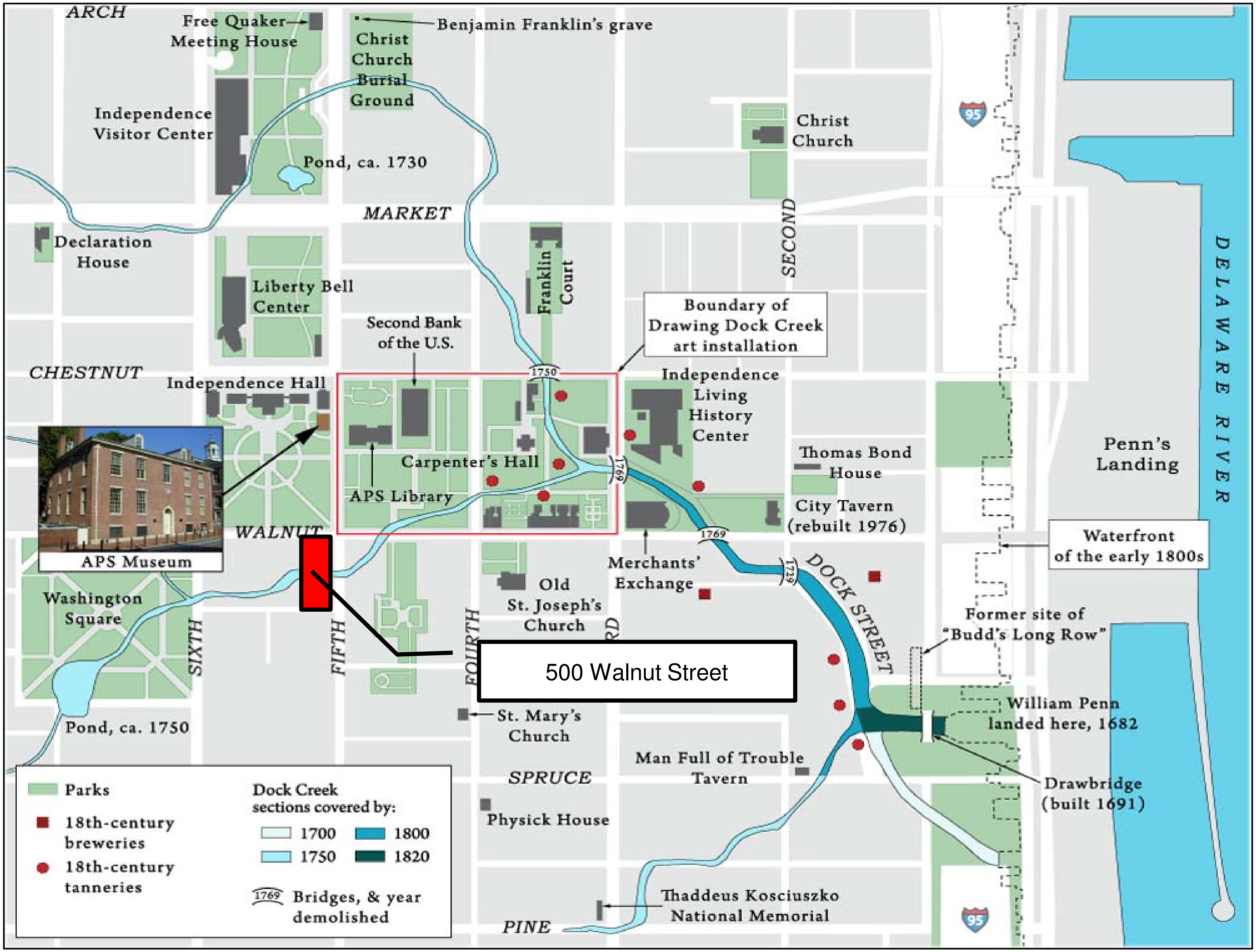


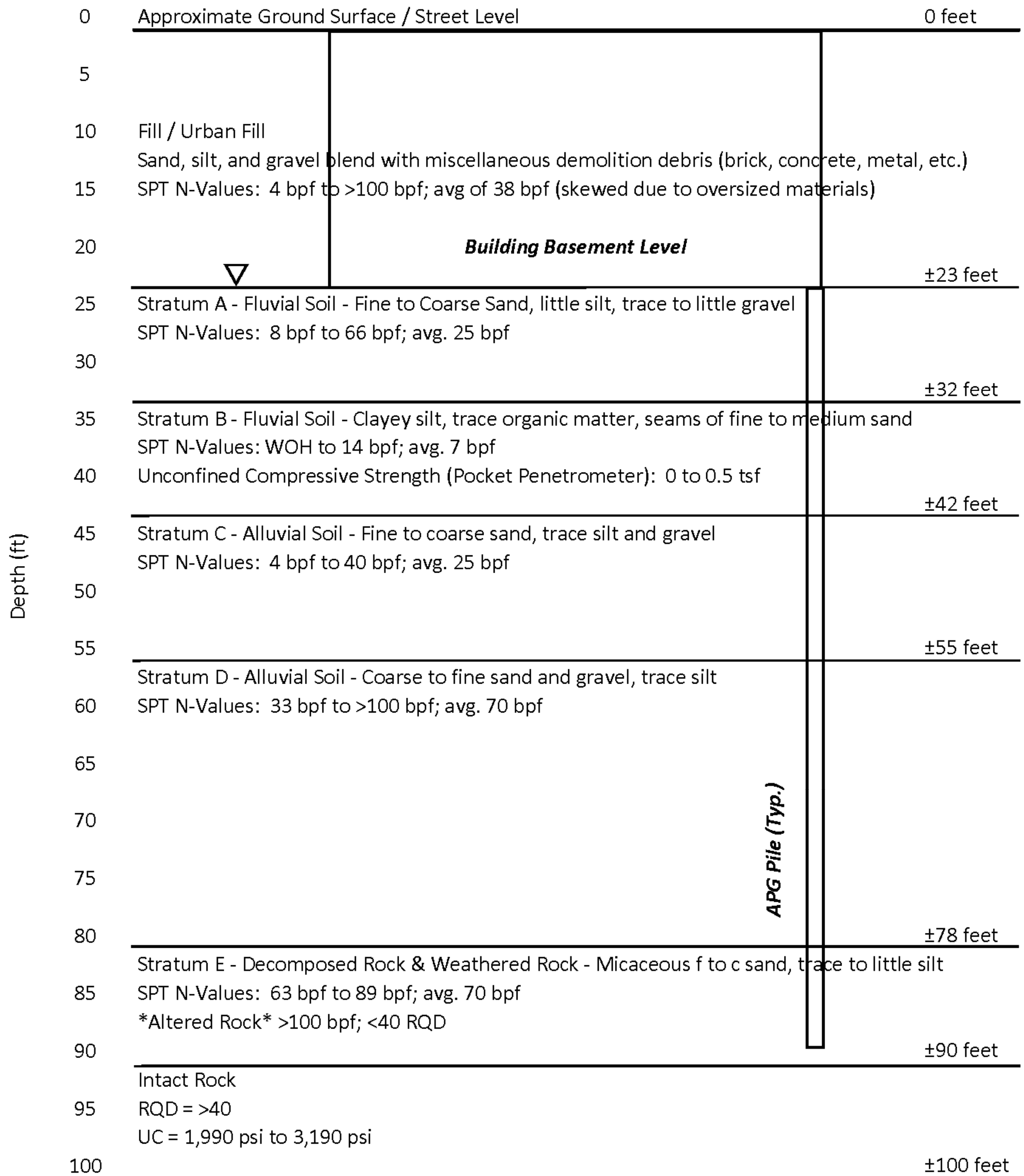
Benefit of Penetrating PWR?



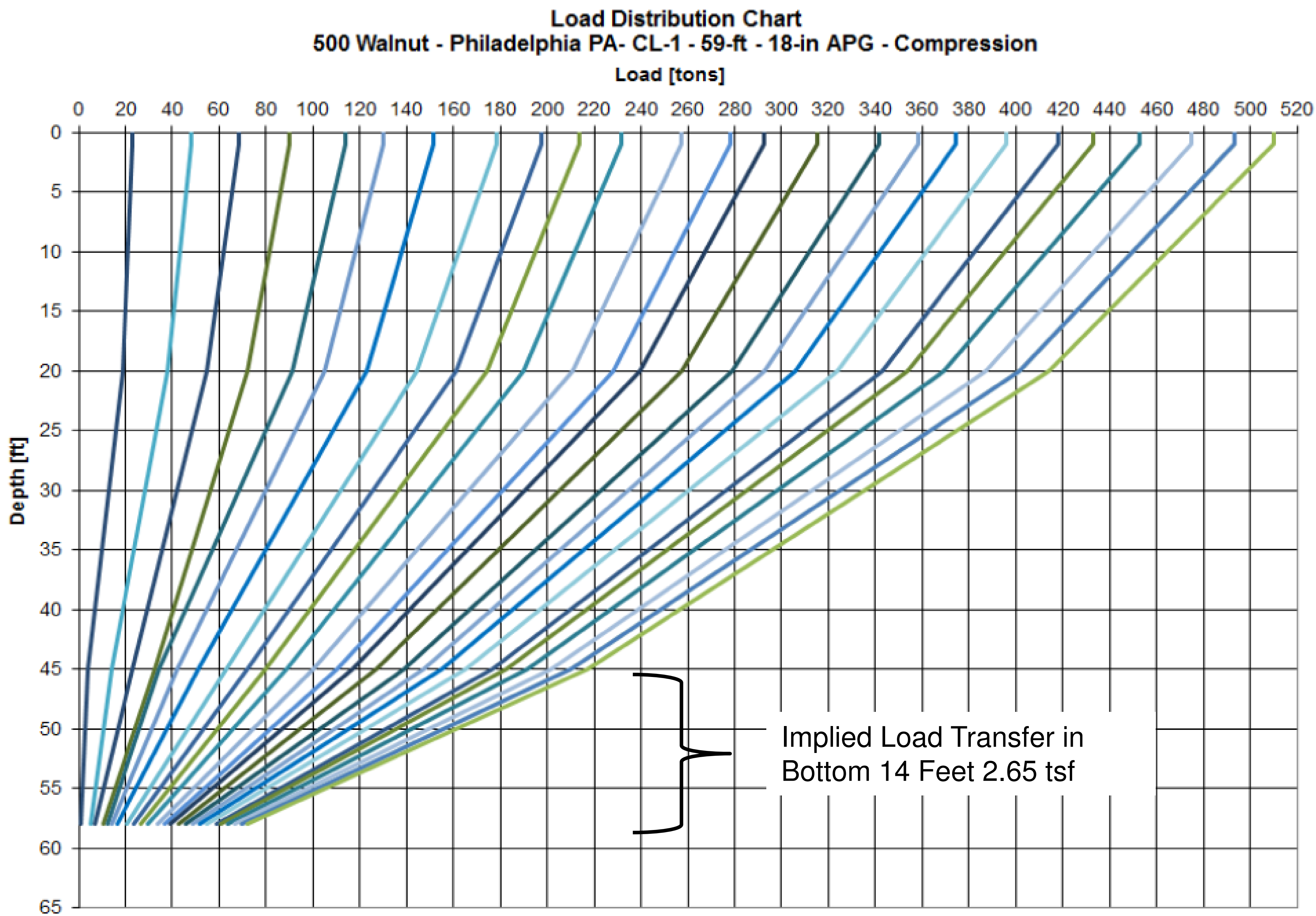


500 Walnut St, Philadelphia



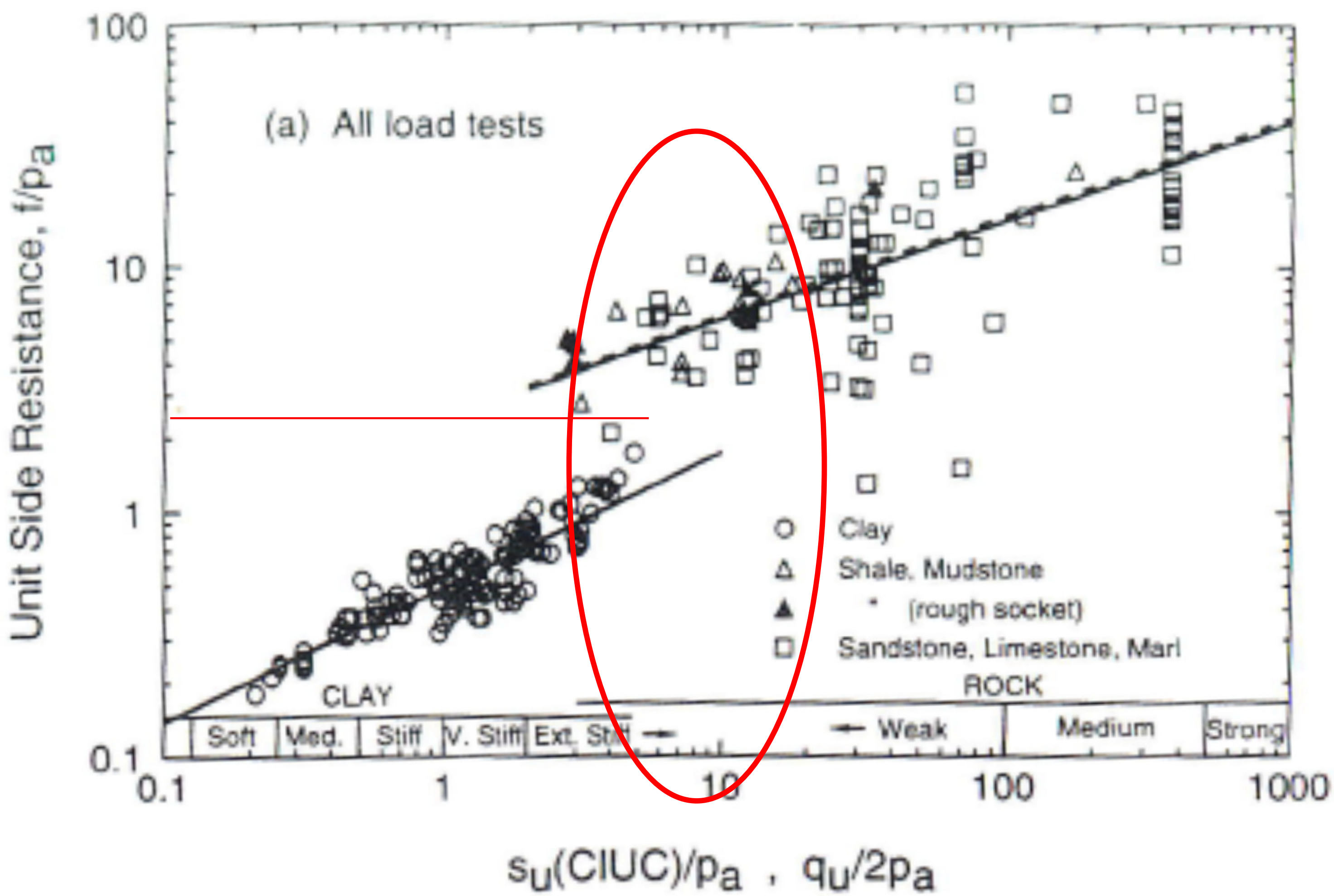


Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Approximate Ground Surface / Street Level
0 feet
Fill / Urban Fill
Sand, silt, and gravel blend with miscellaneous demolition debris (brick, concrete, metal, etc.)
SPT N-Values: 4 bpf to >100 bpf; avg of 38 bpf (skewed due to oversized materials)
Building Basement Level
±23 feet
Stratum A - Fluvial Soil - Fine to Coarse Sand, little silt, trace to little gravel
SPT N-Values: 8 bpf to 66 bpf; avg. 25 bpf
±32 feet
Stratum B - Fluvial Soil - Clayey silt, trace organic matter, seams of fine to medium sand
SPT N-Values: WOH to 14 bpf; avg. 7 bpf
Unconfined Compressive Strength (Pocket Penetrometer): 0 to 0.5 tsf
±42 feet
Stratum C - Alluvial Soil - Fine to coarse sand, trace silt and gravel
SPT N-Values: 4 bpf to 40 bpf; avg. 25 bpf
±55 feet
Stratum D - Alluvial Soil - Coarse to fine sand and gravel, trace silt
SPT N-Values: 33 bpf to >100 bpf; avg. 70 bpf
APG Pile (Typ.)
±78 feet
Stratum E - Decomposed Rock & Weathered Rock - Micaceous f to c sand, trace to little silt
SPT N-Values: 63 bpf to 89 bpf; avg. 70 bpf
Altered Rock >100 bpf; <40 RQD
±90 feet
Intact Rock
RQD = >40
UC = 1,990 psi to 3,190 psi
±100 feet

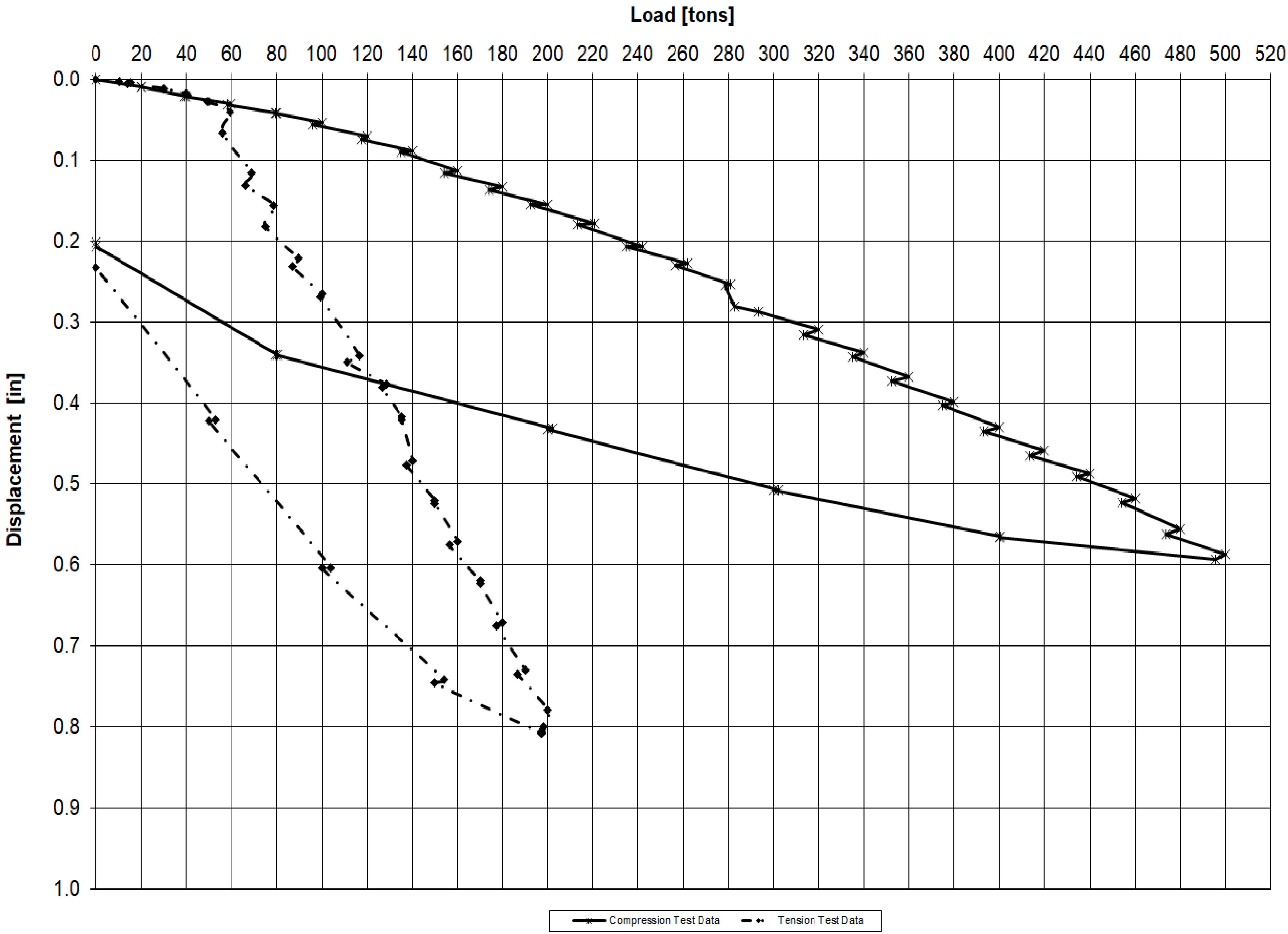


Load Distribution Chart
500 Walnut - Philadelphia PA- CL-1 - 59-ft - 18-in APG - Compression
Load [tons]
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520
Depth [ft]
0 5 10 15 20 25 30 35 40 45 50 55 60 65
Implied Load Transfer in Bottom 14 Feet 2.65 tsf

Side Resistance in Soft Rock

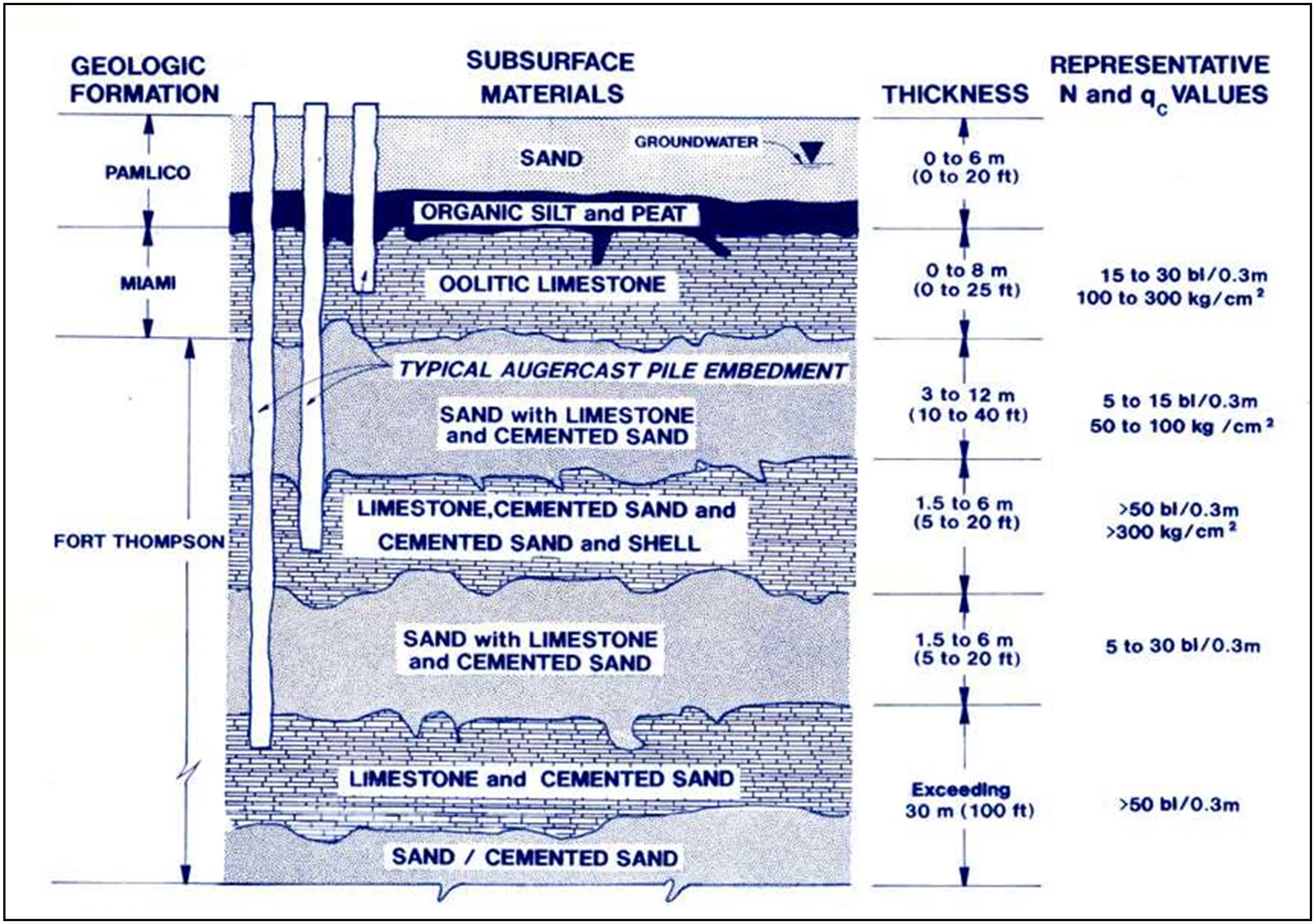


Ref: Kulhawy and Phoon (1993)



Load [tons]
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
Displacement [in]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Compression Test Data
Tension Test Data

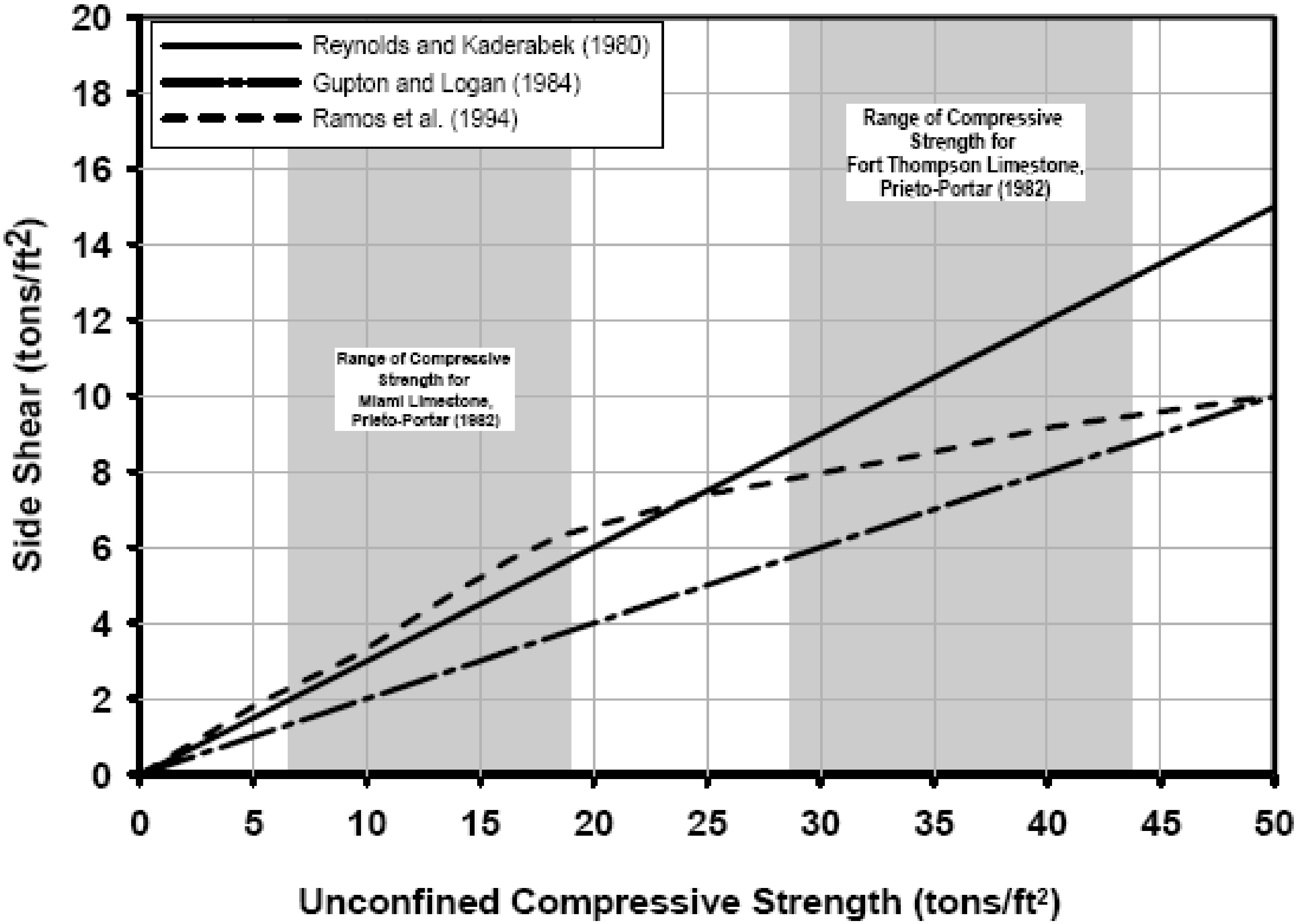
Soft Rock Subsurface Profile, South Florida



Ref: Frizzi & Meyer (2000)

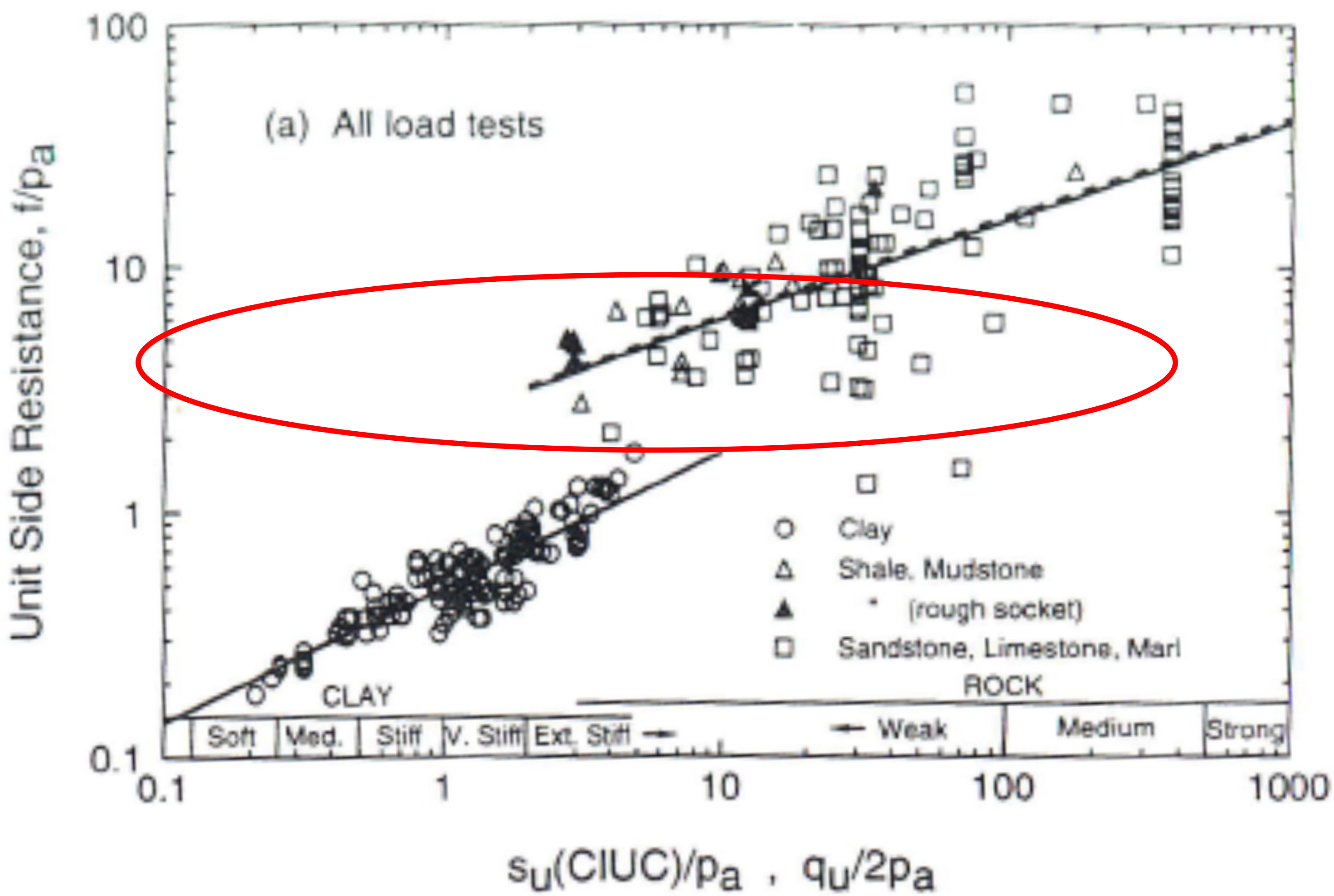
Shaft Resistance

South Florida Limestone Experience



Source: Frizzi and Meyer (2000)

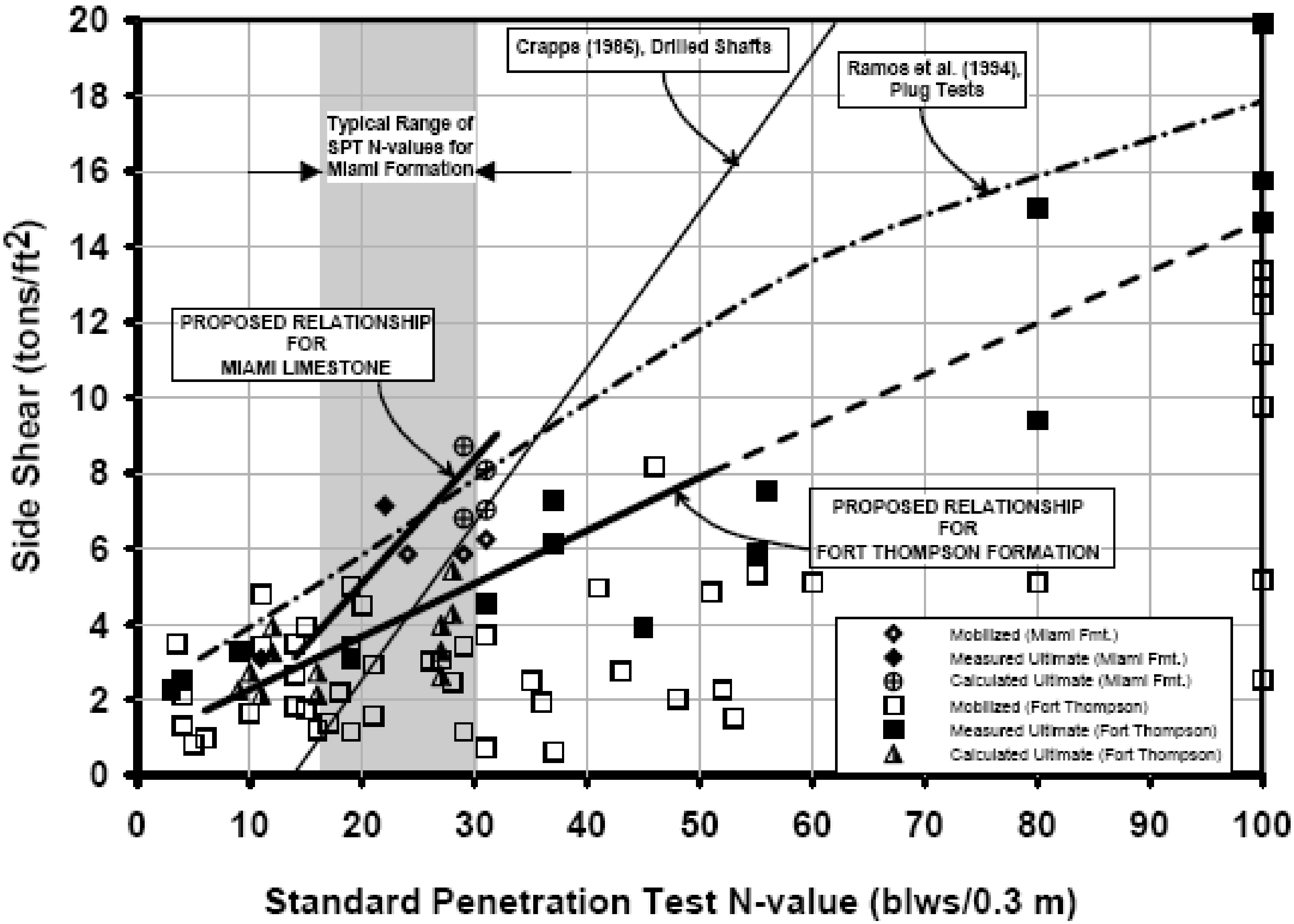
Side Resistance in Soft Rock



Ref: Kulhawy and Phoon (1993)

Shaft Resistance

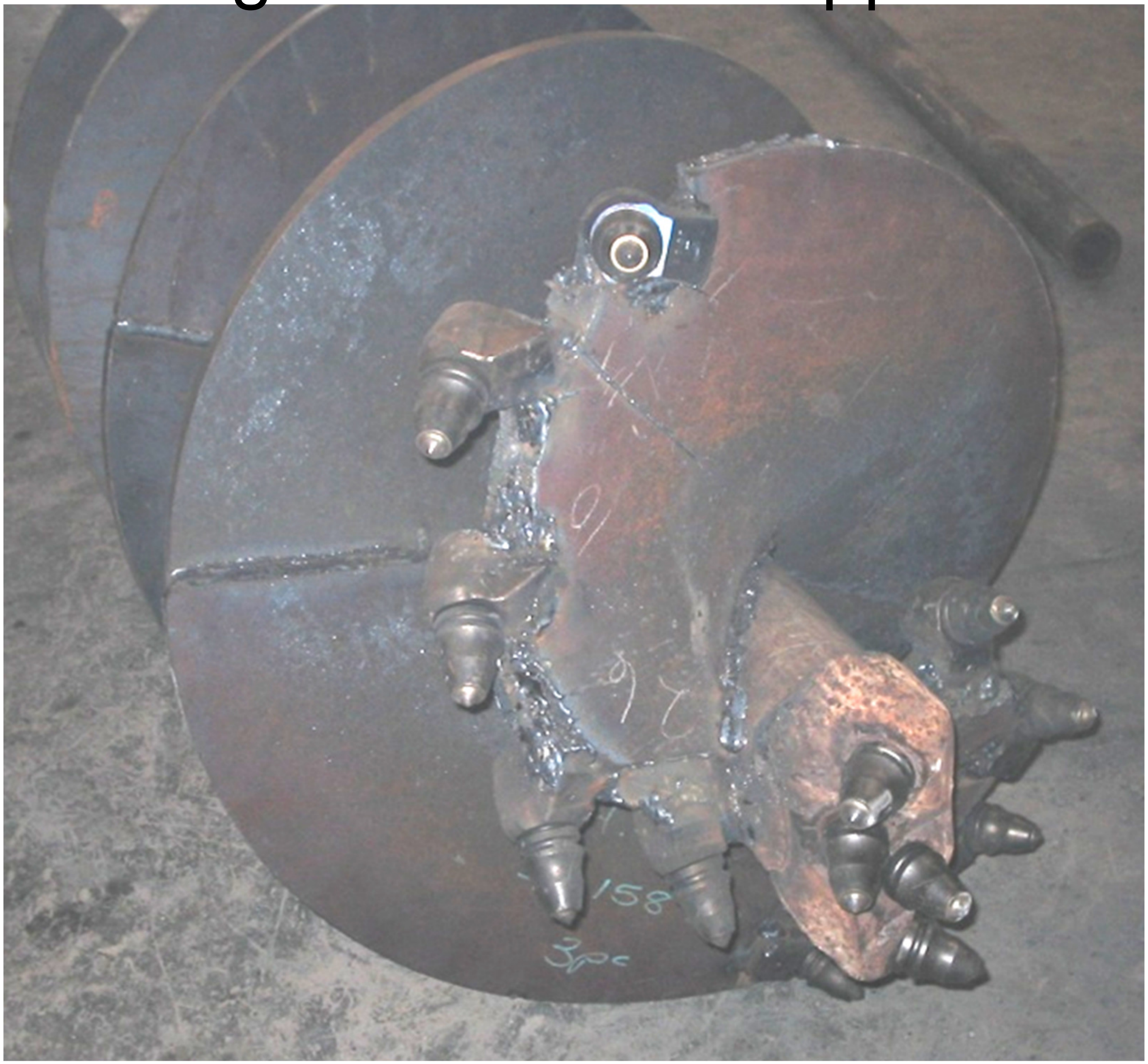
South Florida Limestone Experience



Source: Frizzi and Meyer (2000)

36-in x 155-ft
South Florida

Cutting Head for IGM Application



Shale

Highly Dependent on Local Geology

May or May Not Have a Transitional (Weathered) Zone

May be Fissile or Thick Bedded

Highly Variable Strength

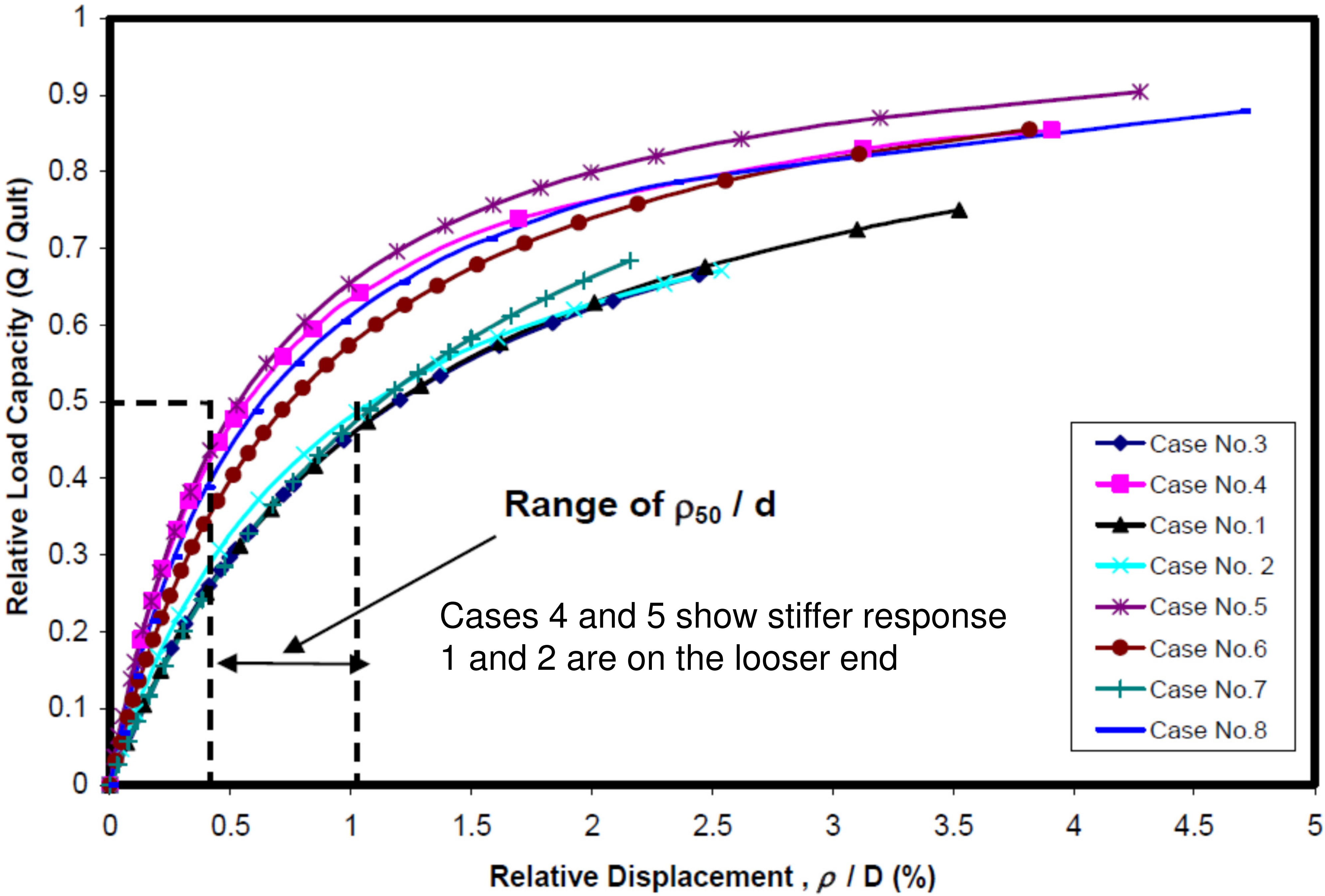
May be Interbedded with (Hard) Limestone and/or Sandstone

Good Place To Start (Shales)?

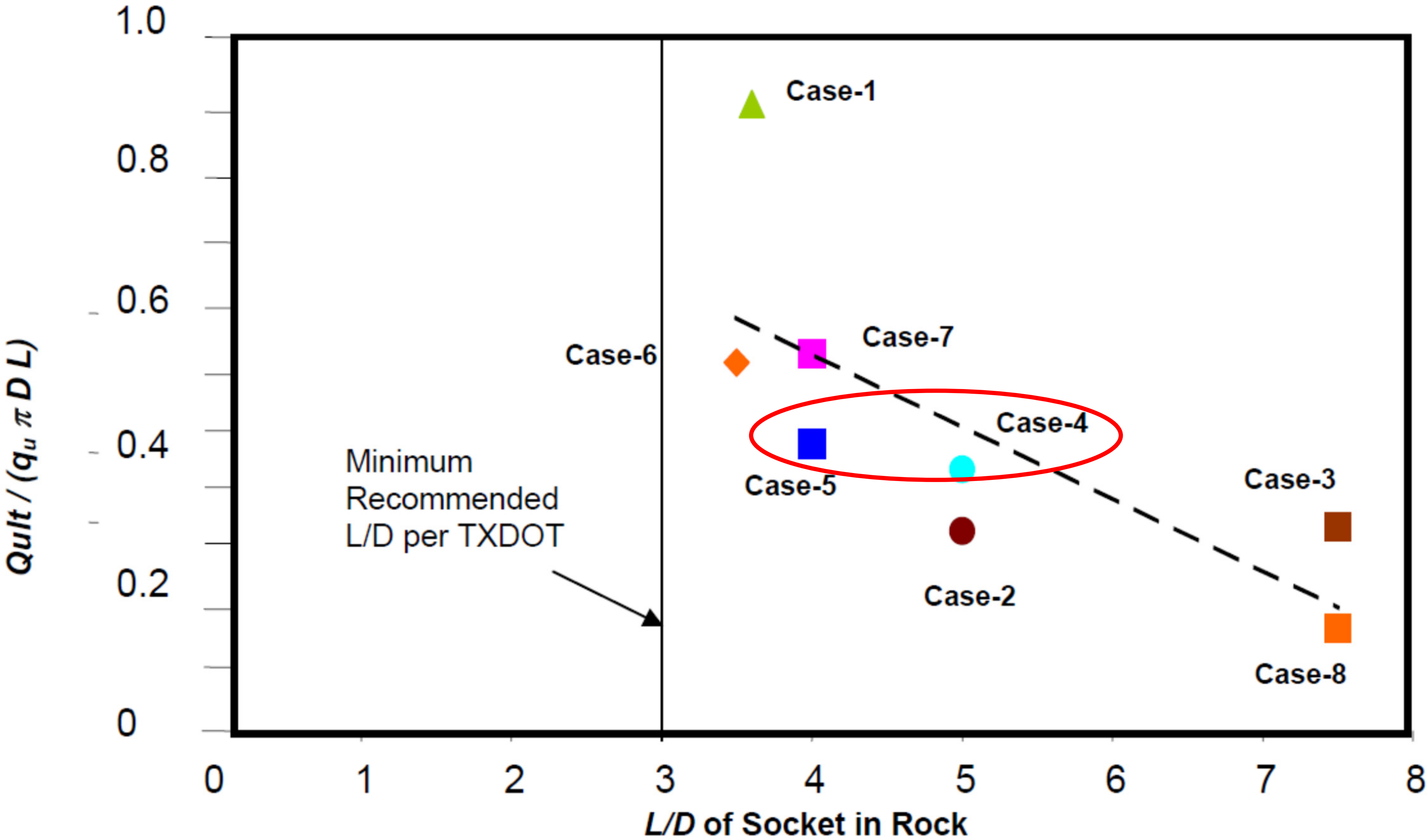
GEC-8, Section 5.3.3.3. From Vipulamamdan 2005 Paper.

Method described is based on results of 8 load tests on ACIP piles socketed into clay-shale with qu ranging from 1 to 30 tsf.

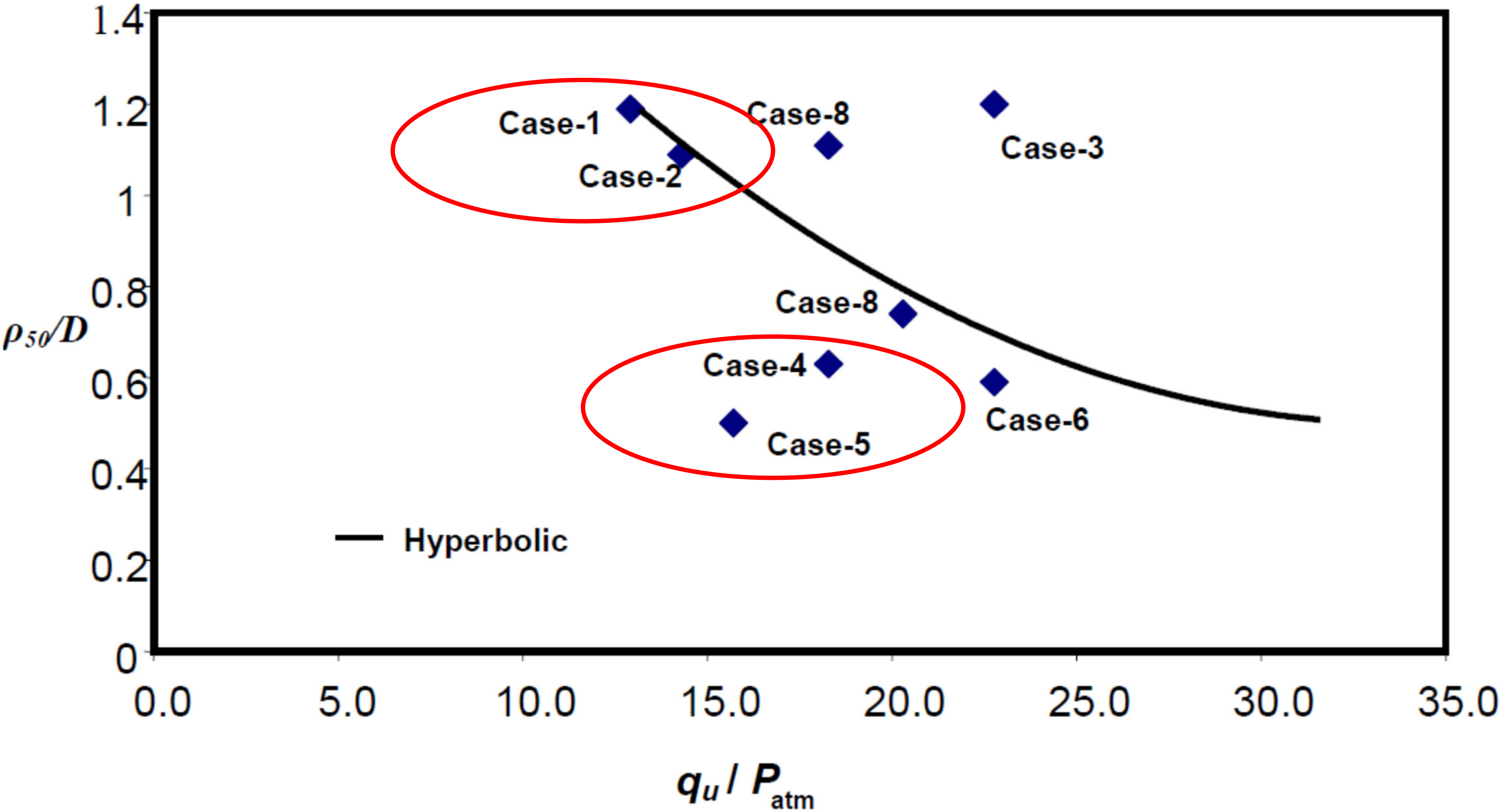
Capacity is given in terms of pile head displacement.



Relative Load Capacity (Q / Qult)
Relative Displacement , ρ / D (%)
Range of ρ_{50} / d
Cases 4 and 5 show stiffer response
1 and 2 are on the looser end
Case No.3
Case No.4
Case No.1
Case No. 2
Case No.5
Case No.6
Case No.7
Case No.8



1.0
0.8
0.6
0.4
0.2
0
Qult / (qu π D L)
Case-1
Case-7
Case-6
Case-4
Case-5
Case-3
Case-2
Case-8
Minimum
Recommended
L/D per TXDOT
0
1
2
3
4
5
6
7
8
L/D of Socket in Rock


1.4
1.2
1
0.8
0.6
0.4
0.2
0
ρ50/D
Case-1
Case-2
Case-8
Case-3
Case-8
Case-4
Case-5
Case-6
Hyperbolic
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
qu / Patm

Shale Example

Assume a 1.5 ft diameter (D) pile drilled 4.5 ft (L) into clay shale with qu =20 tsf. So L=3D.

$$\frac{\rho_{50}}{D}[\text{in}\,\%] = \frac{15.8}{\frac{q_u}{P_{atm}}} \qquad \text{(Equation 5.27)}$$

for ratio $q_u/P_{atm} = 20$;

Equation 5.27 results $\rho_{50}/D = 0.79\%$.

$$\frac{Q_{ult}}{q_u\ \pi\ D\ L} = -0.11\frac{L}{D} + 0.96 \qquad \text{(Equation 5.26)}$$

$Q_u = q_u\ \pi D\ L\ (-0.11 \times L/D + 0.96) = 20 \times 3.14 \times 1.5 \times 4.5\ (-0.11 \times 3 + 0.96) = 267$ tons.

Shale Example (continued)

Take a pile head displacement of 0.25” and use Equation 5.25 to calculate the mobilized load capacity at that displacement

$$\frac{Q}{Q_{ult}} = \frac{\frac{\rho}{D}}{\frac{\rho_{50}}{D} + \frac{\rho}{D}} \qquad \text{(Equation 5.25)}$$

$$\begin{aligned} Q &= Q_{ult}\,[\rho/D \div (\rho_{50}/D + \rho/D)] = \\ &= 267 \times [0.25/18 \div (0.0079 + 0.25/18)] = 0.64 \times 267 = 170 \text{ tons.} \end{aligned}$$

Ultimate capacity of 267 tons. Mobilized capacity with pile head movement of 0.25 in, 170 tons.

No need to consider (worry about) what the toe contribution is. It’s built in. Designer selects the level of pile head movement for conditions.

Shaft Resistance

FHWA Micropiles Guidelines

Soil / Rock Description	Typical Range of Grout-to-Ground Bond Nominal Strengths (kPa)			
	Type A	Type B	Type C	Type D
Silt & Clay (some sand) (soft, medium plastic)	35-70	35-95	50-120	50-145
Silt & Clay (some sand) (stiff, dense to very dense)	50-120	70-190	95-190	95-190
Sand (some silt) (fine, loose-medium dense)	70-145	70-190	95-190	95-240
Sand (some silt, gravel) (fine-coarse, med.-very dense)	95-215	120-360	145-360	145-385
Gravel (some sand) (medium-very dense)	95-265	120-360	145-360	145-385
Glacial Till (silt, sand, gravel) (medium-very dense, cemented)	95-190	95-310	120-310	120-335
Soft Shales (fresh-moderate fracturing, little to no weathering)	205-550	N/A	N/A	N/A
Slates and Hard Shales (fresh-moderate fracturing, little to no weathering)	515-1,380	N/A	N/A	N/A
Limestone (fresh-moderate fracturing, little to no weathering)	1,035-2,070	N/A	N/A	N/A
Sandstone (fresh-moderate fracturing, little to no weathering)	520-1,725	N/A	N/A	N/A
Granite and Basalt (fresh-moderate fracturing, little to no weathering)	1,380-4,200	N/A	N/A	N/A

EXAMPLE

ACIP Pile in **Shale**

16-in Diameter, 50-ft Deep

Shale below 35-ft depth

Shelby Tube / Split Spoon

APPROX. SURFACE ELEV. (ft): 1570.5

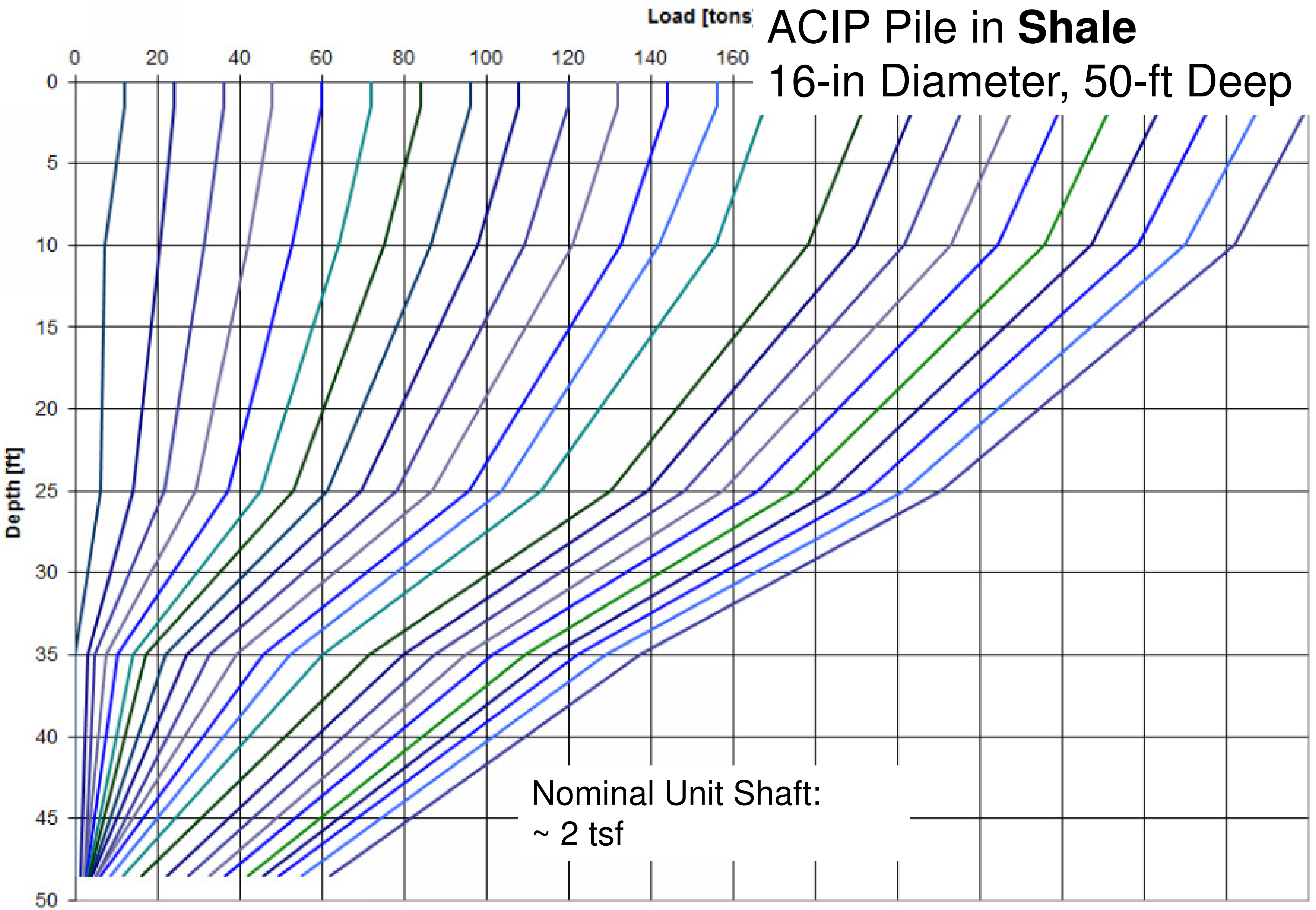
ELEVATION (ft)	MATERIAL DESCRIPTION	GRAPHIC LOG	DEPTH (ft)	SAMPLE TYPE NUMBER	CLASSIFICATION (USCS)	BLOWS/6" N-VALUE RQD	UNC. STR. (tsf)	MOISTURE (%)	DRY DENSITY (pcf)	LL/PI (%)	ADDITIONAL DATA/ REMARKS
1570	***DEVELOPED ZONE*** 0.4'		0								
	ALTERED PEORIA LOESS *Lean to fat clay (CL/CH)* *Firm, dark brown, very moist, mostly lean to fat clay* 3.5'			U 1			0.7	28.4	93.4		
1565	***PEORIA LOESS*** *Lean clay (CL)* *Stiff, brown, very moist, mostly lean clay, trace silt, trace fine sand*		5	U 2							
				U 3			1.3	28.7	90.1		
1560	*Lean clay (CL)* *Stiff, brown, very moist, mostly lean clay, trace silt, trace fine sand* 12.0'		10	U 4							
1555	*Lean clay (CL)* *Firm, brown, very moist, mostly lean clay* 17.0'		15	U 5				26.2	95.0		
	Silty lean clay (CL/ML) *Stiff, brown, very moist, mostly silty lean clay, trace fine sand* 19.0'										
	ALLUVIUM		20	U 6				18.4	102.2		

CONTINUED NEXT PAGE

Shelby Tube / Split Spoon

ELEVATION (ft)	MATERIAL DESCRIPTION	GRAPHIC LOG	DEPTH (ft)	SAMPLE TYPE NUMBER	CLASSIFICATION (USCS)	BLOWS/6" N-VALUE RQD	UNC. STR. (tsf)	MOISTURE (%)	DRY DENSITY (pcf)	LL/PI (%)	ADDITIONAL DATA/ REMARKS
1550	***ALLUVIUM*** *Silty sand (SM)* *Medium dense, brown, moist, mostly fine sand, few silt*		20								
1545	*Silty sand (SM)* *Medium dense, brown, wet, mostly fine to medium sand, trace coarse sand* 28.0'		25	SS 7		9-8-11 N=19					
1540	*Poorly graded sand (SP)* *Medium dense, light yellowish grey, wet, mostly fine to coarse sand*		30	SS 8		7-9-7 N=16		15.1			P-200 = 1.3%
	Poorly graded sand (SP) *Medium dense, light yellowish grey, wet, mostly fine to coarse sand* 35.0'		35	SS 9		6-9-12 N=21					
1535	***SHALE*** *Fat clay (CH)* *Hard, grey, wet, mostly fat clay*		40	SS 10		17-25-40 N=65					

EXAMPLE
ACIP Pile in **Shale**
16-in Diameter, 50-ft Deep



EXAMPLE
ACIP Pile in **Clay Till**
16-in Diameter, 55-ft Deep

BORING LOG No. 1

PROJECT	SITE
New Grain Bin	Swea City, IA

Approx. Surface Elevation (ft): 101.2
Site Datum: Train Tracks (100.0')
Drilling Method: HSA

Depth (ft.)	Elev.	DESCRIPTION	USCS SYMBOL
0–1.5	99.7	Fill - Clayey SAND, trace gravel, very dark gray and dark brown	SC
1.5–3.5	97.7	Fill - Sandy lean CLAY, with brick debris, trace gravel, dark brown	CL
3.5–6.0	95.2	Glacial Till - Sandy lean CLAY, trace gravel, light olive brown, grayish brown, and gray, soft	CL
6.0–18.5	82.7	Glacial Till - Sandy lean CLAY, trace gravel, gray and yellowish brown, stiff to very stiff -- color changes to dark grayish brown after 11' -- color changes to dark gray after 16'	CL
18.5–		Glacial Till - Sandy lean CLAY, trace gravel, dark gray, hard -- becomes very stiff after 37' -- becomes hard after 42' -- becomes very stiff after 52'	CL

SAMPLES: NUMBER	TYPE	RECOVERY	SPT - N (BLOWS / FT.)	TESTS: MOISTURE, %	DRY DENSITY (PCF)	UNCONFINED STRENGTH (PSF)	OTHER
1	AS			25.2			
2	SS	10	6	24.8			
3	SS	8	2	21.3		1500*	
4	ST	16		20.2	106	6500*	
5	SS	18	9	21.2		5000*	
6	ST	15		20.2	106	5500*	
7	SS	12	12	20		6000*	
8	SS	18	13	18.1		2000*	
9	SS	18	20	16.4		9000*	
10	SS	14	24	19.4		9000*	
11	SS	14	36	18.8		9000*	
12	SS	18	31	19.3		9000*	
13	SS	18	22	21.6		5500*	
14	SS	18	23	19.5		9000*	
15	SS	16	22	21		9000*	
16	SS	18	17	18.3		5000*	
17	SS	18	16	18.5		5000*	
18	SS	18	16	19.1		5500*	
19	SS	18	17	17.7		5500*	

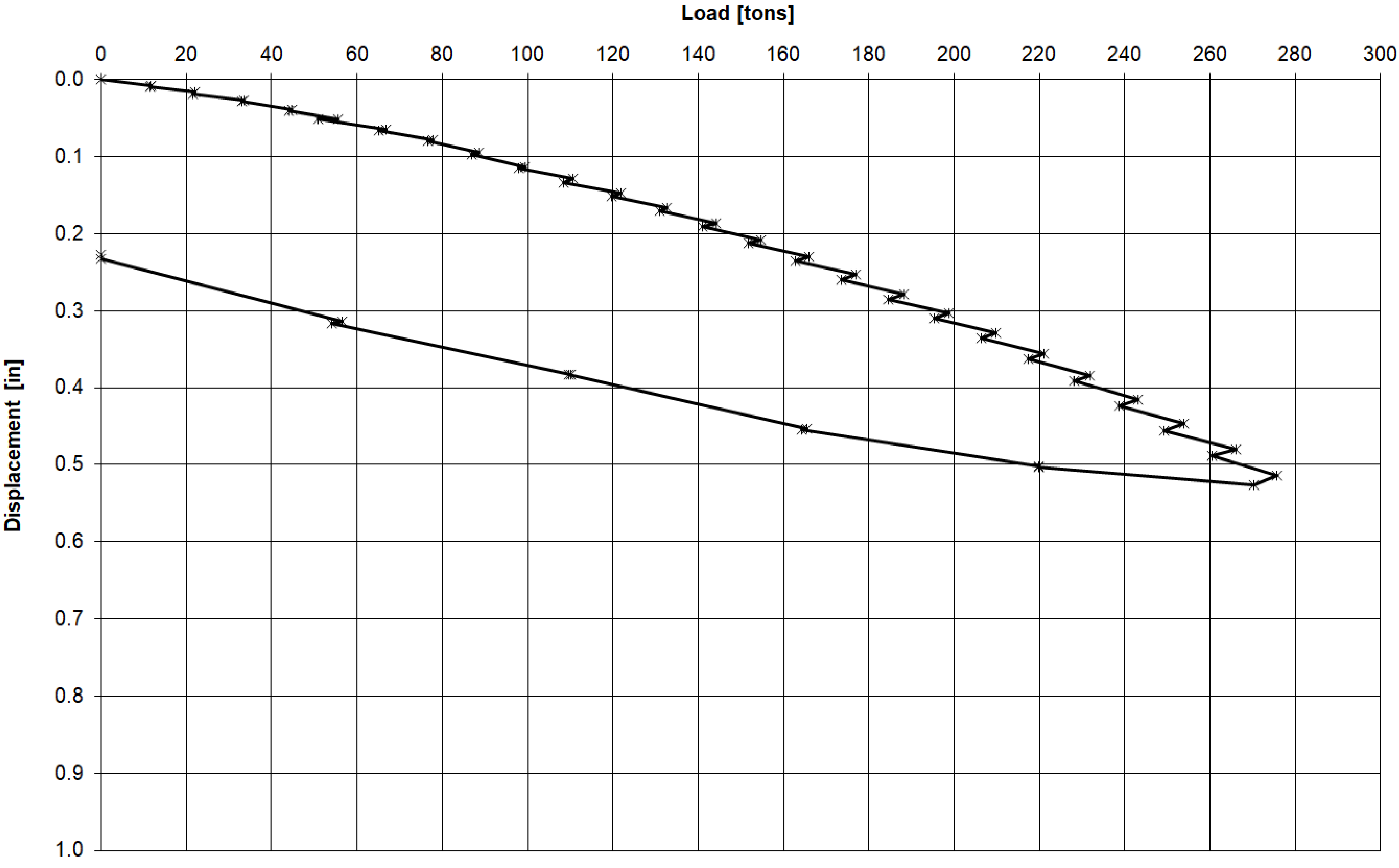
	Top of	Bottom of	Soil	For clays:					Unit Shaft
101	Layer	Layer	Type	Su (psf)	α	N*c	Nfield	ER	Resist [tsf]
100.0	0	1	Clay	347	1.3	5	2	1.3	0.2
99.0	1	2	Clay	347	1.3	6.5	2	1.3	0.2
98.0	2	3	Clay	347	1.3	6.5	2	1.3	0.2
97.0	3	4	Clay	347	1.3	6.5	2	1.3	0.2
96.0	4	5	Clay	347	1.3	6.5	2	1.3	0.3
95.0	5	6	Clay	347	1.3	6.5	2	1.3	0.3
94.0	6	7	Clay	1560	0.72	8.7	9	1.3	0.7
93.0	7	8	Clay	1560	0.72	8.7	9	1.3	0.7
92.0	8	9	Clay	1560	0.72	8.7	9	1.3	0.7
91.0	9	10	Clay	1560	0.72	8.7	9	1.3	0.7
90.0	10	11	Clay	1560	0.72	8.7	9	1.3	0.7
89.0	11	12	Clay	1733	0.65	8.7	10	1.3	0.7
88.0	12	13	Clay	1733	0.65	8.7	10	1.3	0.7
87.0	13	14	Clay	1907	0.59	8.7	11	1.3	0.7
86.0	14	15	Clay	2080	0.54	8.9	12	1.3	0.7
85.0	15	16	Clay	2080	0.54	8.9	12	1.3	0.7
84.0	16	17	Clay	2080	0.54	8.9	12	1.3	0.7
83.0	17	18	Clay	2080	0.54	8.9	12	1.3	0.7
82.0	18	19	Clay	3467	0.45	8.9	20	1.3	0.9
81.0	19	20	Clay	3467	0.45	8.9	20	1.3	0.9
80.0	20	21	Clay	3467	0.45	8.9	20	1.3	0.9
79.0	21	22	Clay	3640	0.45	8.9	21	1.3	1.0
78.0	22	23	Clay	3813	0.45	8.9	22	1.3	1.0
77.0	23	24	Clay	3987	0.45	8.9	23	1.3	1.1
76.0	24	25	Clay	4160	0.45	9	24	1.3	1.1
75.0	25	26	Clay	4507	0.45	9	26	1.3	1.2
74.0	26	27	Clay	4853	0.45	9	28	1.3	1.3
73.0	27	28	Clay	5200	0.45	9	30	1.3	1.4
72.0	28	29	Clay	5720	0.45	9	33	1.3	1.5
71.0	29	30	Clay	6240	0.45	9	36	1.3	1.5
70.0	30	31	Clay	6067	0.45	9	35	1.3	1.5
69.0	31	32	Clay	5893	0.45	9	34	1.3	1.5
68.0	32	33	Clay	5720	0.45	9	33	1.3	1.5
67.0	33	34	Clay	5547	0.45	9	32	1.3	1.5
66.0	34	35	Clay	5373	0.45	9	31	1.3	1.5
65.0	35	36	Clay	5027	0.45	9	29	1.3	1.4
64.0	36	37	Clay	4680	0.45	9	27	1.3	1.3
63.0	37	38	Clay	4333	0.45	9	25	1.3	1.2
62.0	38	39	Clay	3987	0.45	8.9	23	1.3	1.1
61.0	39	40	Clay	3813	0.45	8.9	22	1.3	1.0
60.0	40	41	Clay	3813	0.45	8.9	22	1.3	1.0
59.0	41	42	Clay	3813	0.45	8.9	22	1.3	1.0
58.0	42	43	Clay	3813	0.45	8.9	22	1.3	1.0
57.0	43	44	Clay	3987	0.45	8.9	23	1.3	1.1
56.0	44	45	Clay	3987	0.45	8.9	23	1.3	1.1
55.0	45	46	Clay	3987	0.45	8.9	23	1.3	1.1
54.0	46	47	Clay	3987	0.45	8.9	23	1.3	1.1
53.0	47	48	Clay	3813	0.45	8.9	22	1.3	1.0
52.0	48	49	Clay	3813	0.45	8.9	22	1.3	1.0
51.0	49	50	Clay	3813	0.45	8.9	22	1.3	1.0
50.0	50	51	Clay	3640	0.45	8.9	21	1.3	1.0
49.0	51	52	Clay	3467	0.45	8.9	20	1.3	0.9
48.0	52	53	Clay	3293	0.45	8.9	19	1.3	0.9
47.0	53	54	Clay	3120	0.45	8.9	18	1.3	0.8
46.0	54	55	Clay	2947	0.45	8.9	17	1.3	0.8
45.0	55	56	Clay	2947	0.45	8.9	17	1.3	0.8
44.0	56	57	Clay	2947	0.45	8.9	17	1.3	0.8
43.0	57	58	Clay	2773	0.45	8.9	16	1.3	0.7
42.0	58	59	Clay	2773	0.45	8.9	16	1.3	0.7
41.0	59	60	Clay	2773	0.45	8.9	16	1.3	0.7
40.0	60	61	Clay	2773	0.45	8.9	16	1.3	0.7
39.0	61	62	Clay	2773	0.45	8.9	16	1.3	0.7
38.0	62	63	Clay	2773	0.45	8.9	16	1.3	0.7
37.0	63	64	Clay	2773	0.45	8.9	16	1.3	0.7
36.0	64	65	Clay	2773	0.45	8.9	16	1.3	0.7
35.0	65	66	Clay	2773	0.45	8.9	16	1.3	0.7
34.0	66	67	Clay	2773	0.45	8.9	16	1.3	0.7
33.0	67	68	Clay	2773	0.45	8.9	16	1.3	0.7
32.0	68	69	Clay	2947	0.45	8.9	17	1.3	0.8
31.0	69	70	Clay	2947	0.45	8.9	17	1.3	0.8

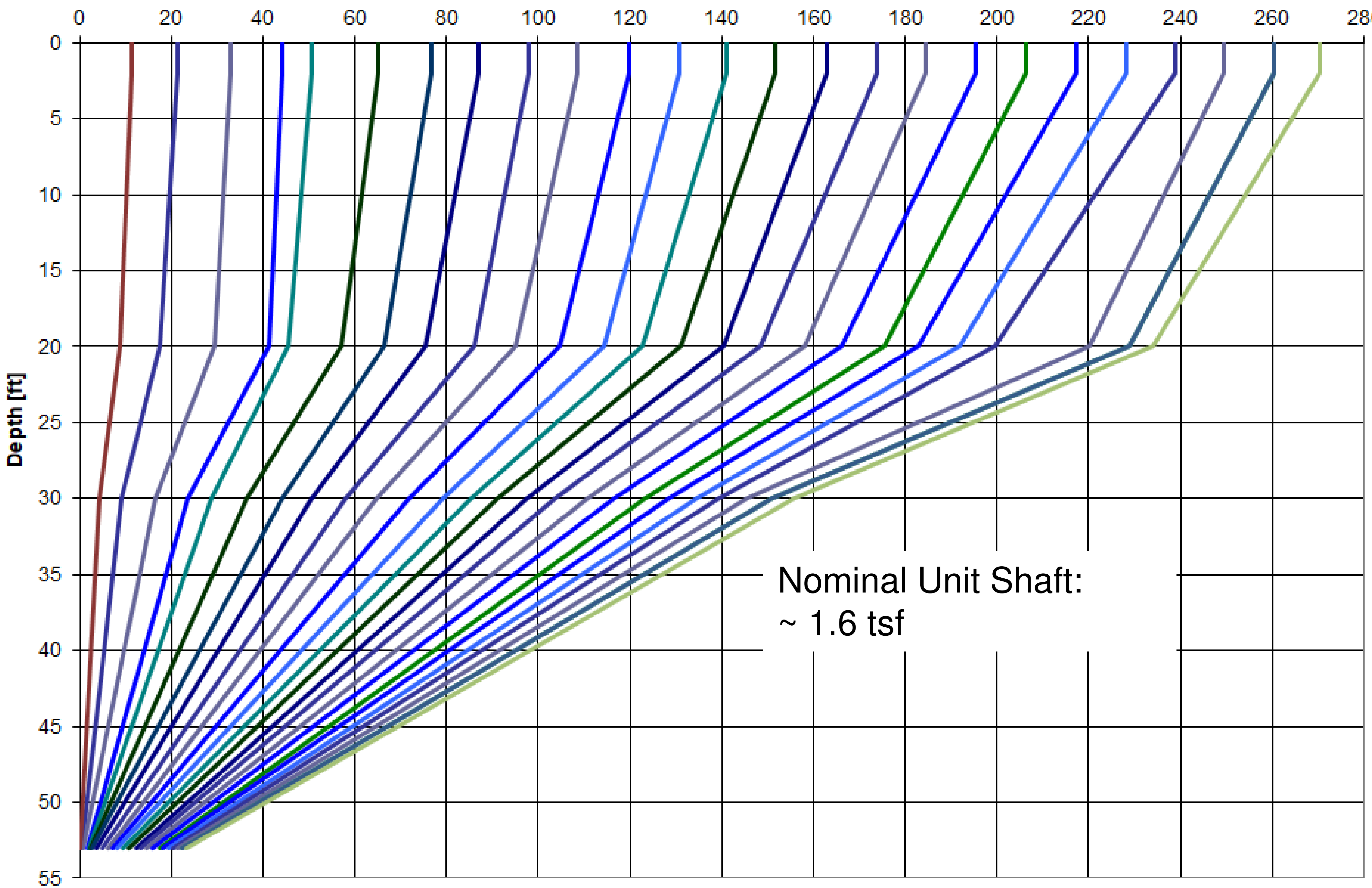
EXAMPLE
Estimated Nominal Shaft 16-in Diameter ACIP Pile

Coleman and Arcement alpha values

Increased estimated unit shaft by 20%

EXAMPLE
ACIP Pile in Clay Till
16-in Diameter, 55-ft Deep





0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
0
5
10
15
20
25
30
35
40
45
50
55
Depth [ft]
Nominal Unit Shaft:
~ 1.6 tsf

Q&A- Something on your mind?