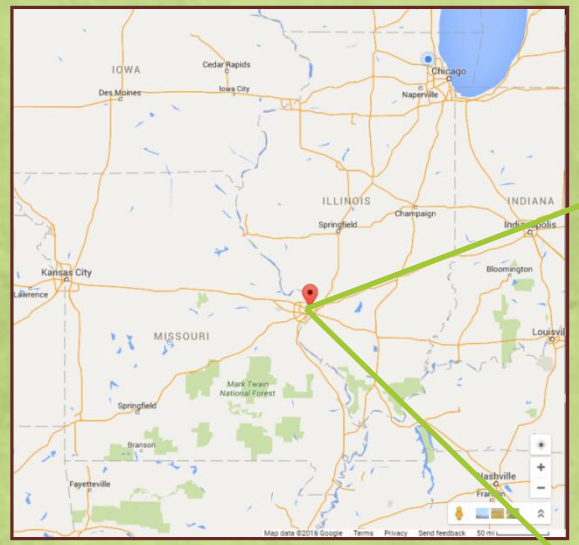
Large Diameter Pipe Piles, Driven Open-Ended

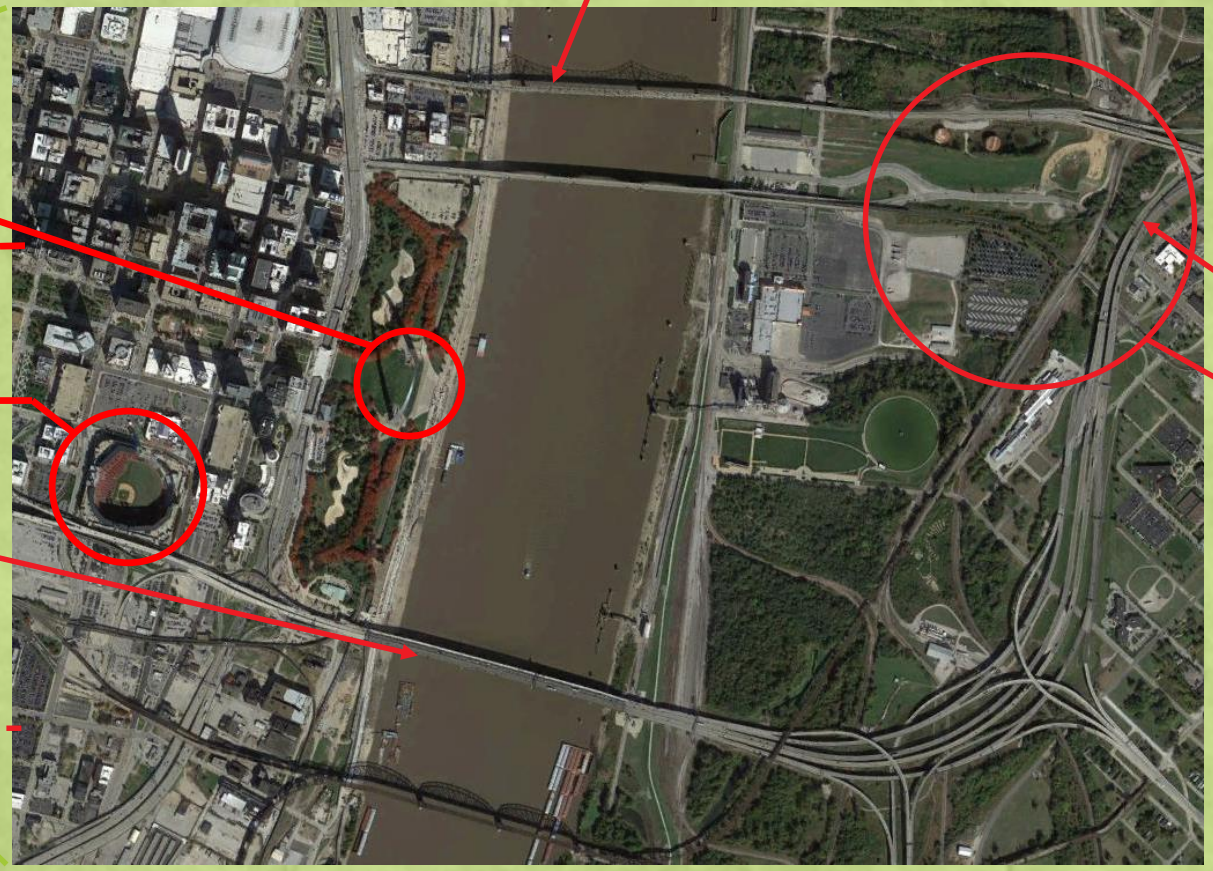
MLK Connector Project

By: Joel Cumby, P.E.

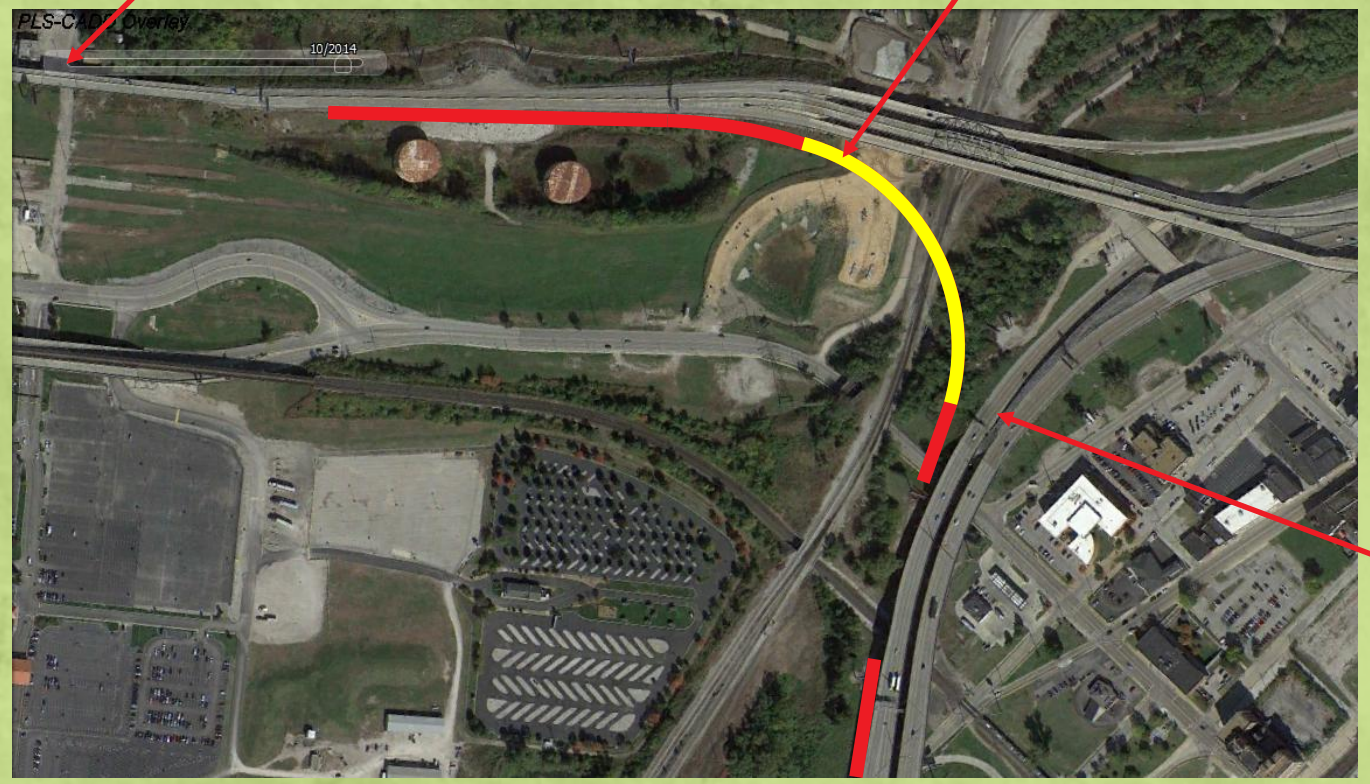
October 18, 2016

Project Overview

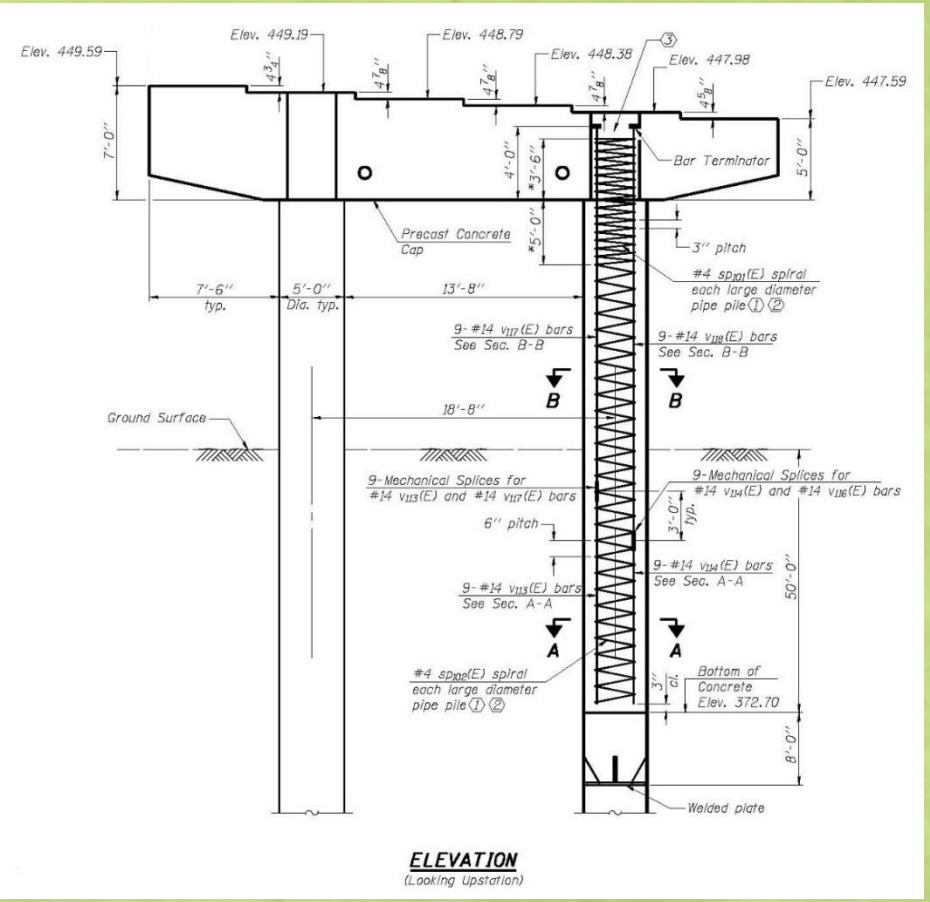




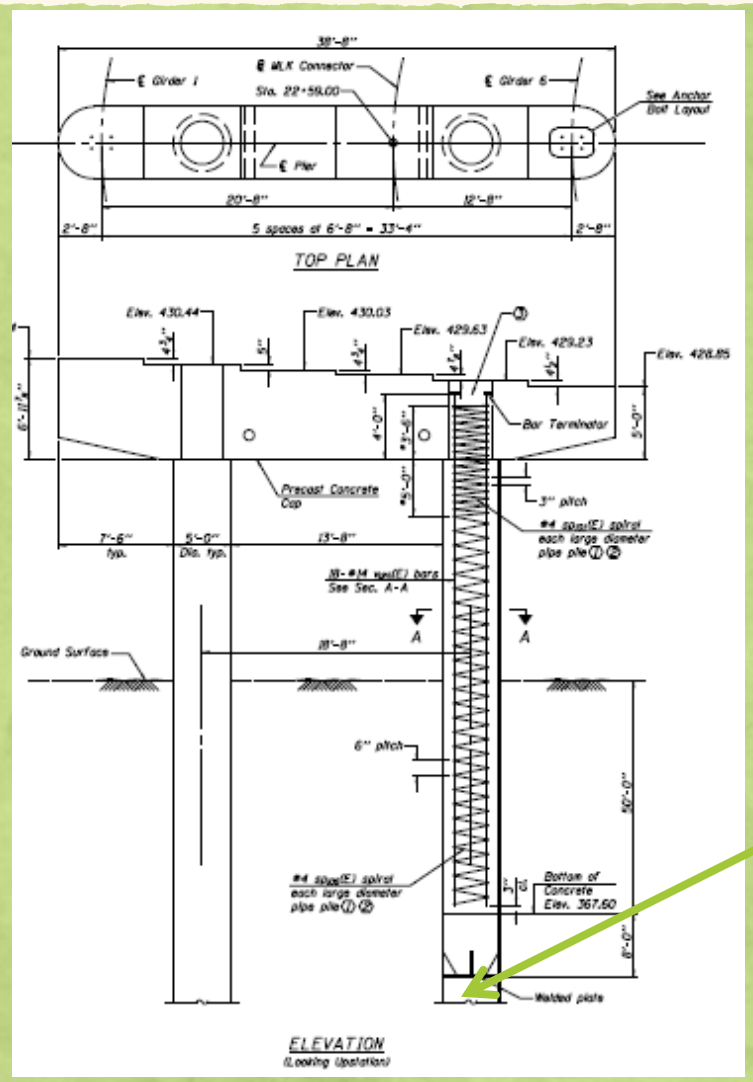
Project Limits

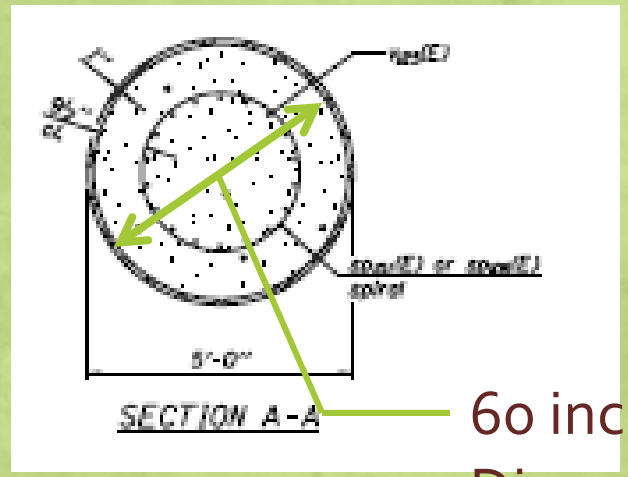


Accelerated Bridge Construction (ABC)



Pile Details

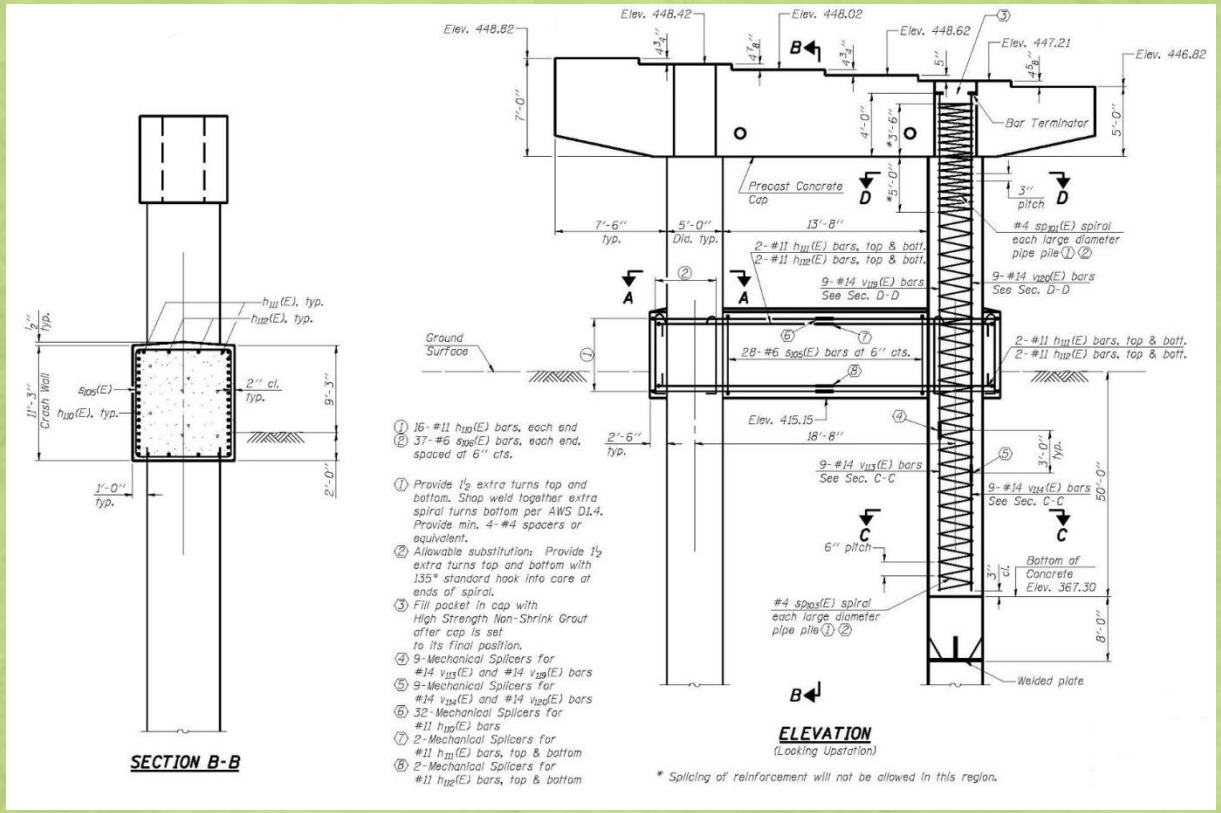


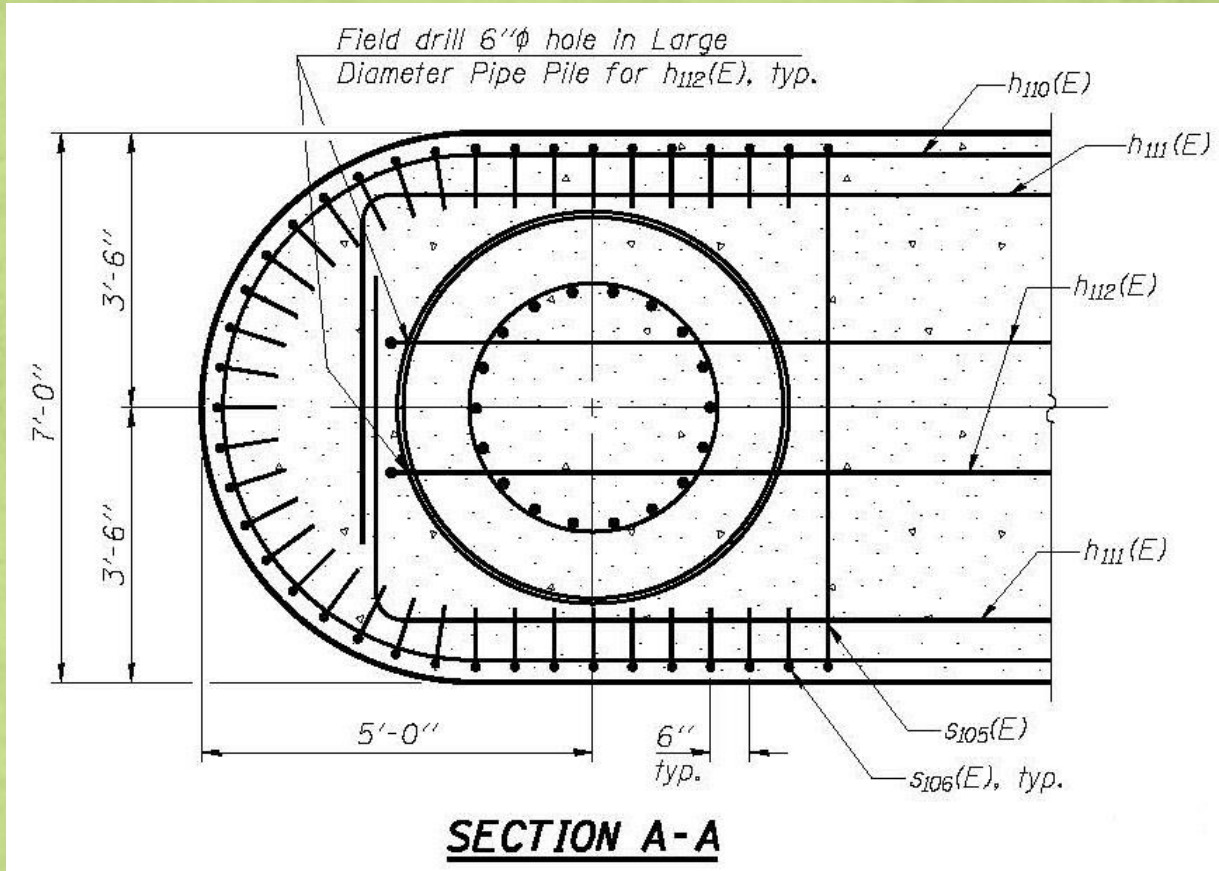


60 inch Diameter

Driven Open-ended

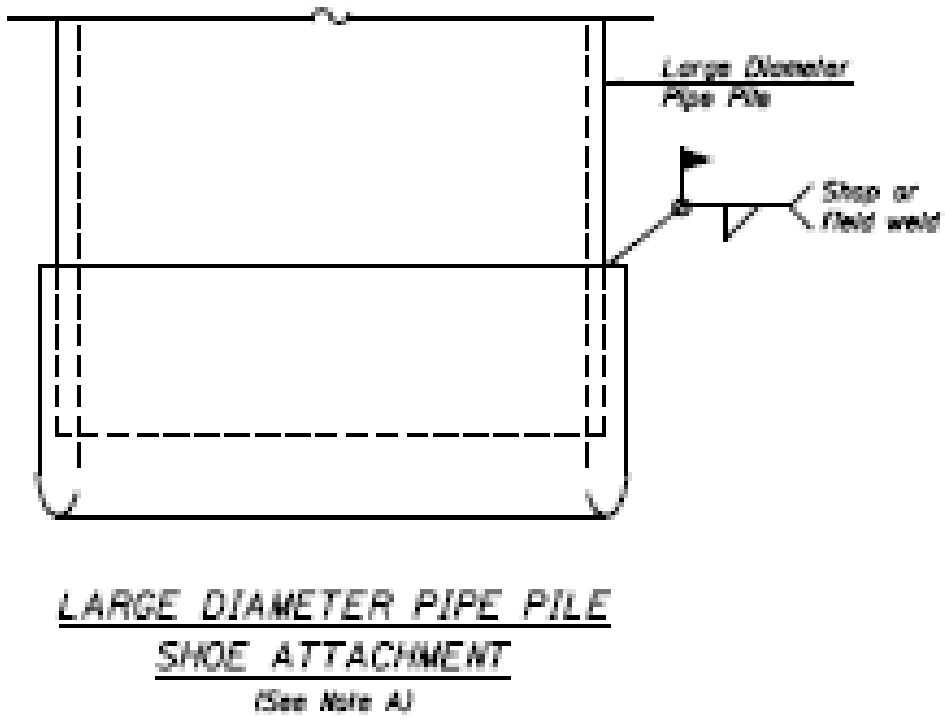
Pile Details





Pile Details – Driving Shoe

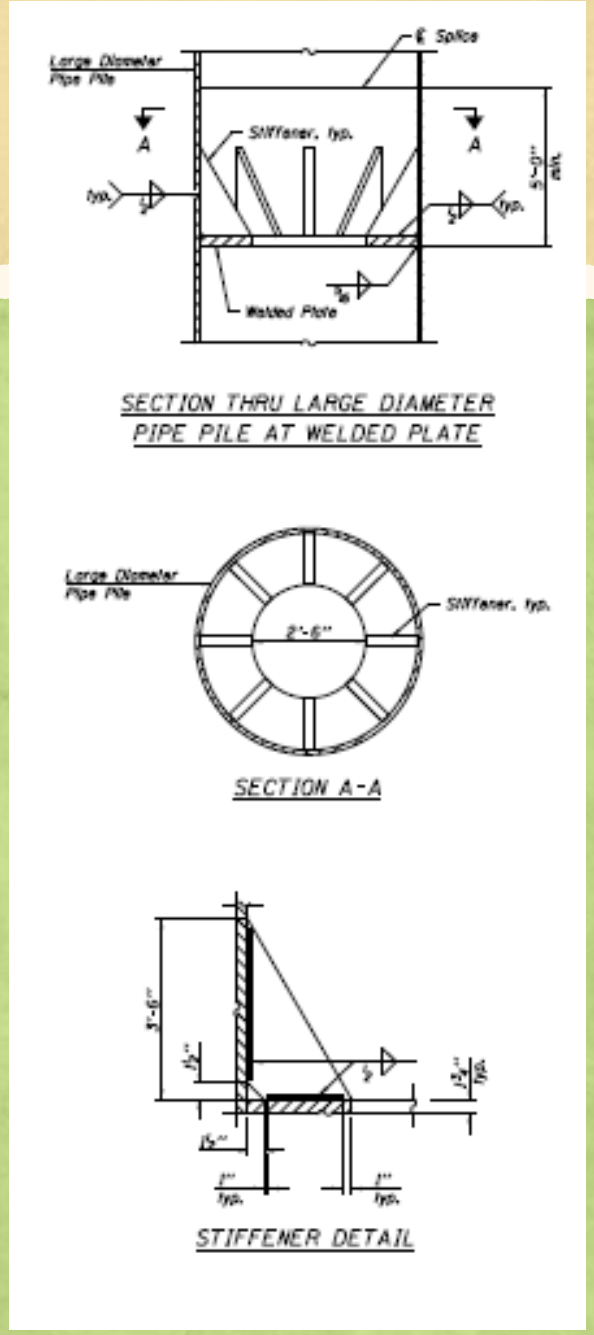
Plan Detail - Cast



As Built - Fabricated

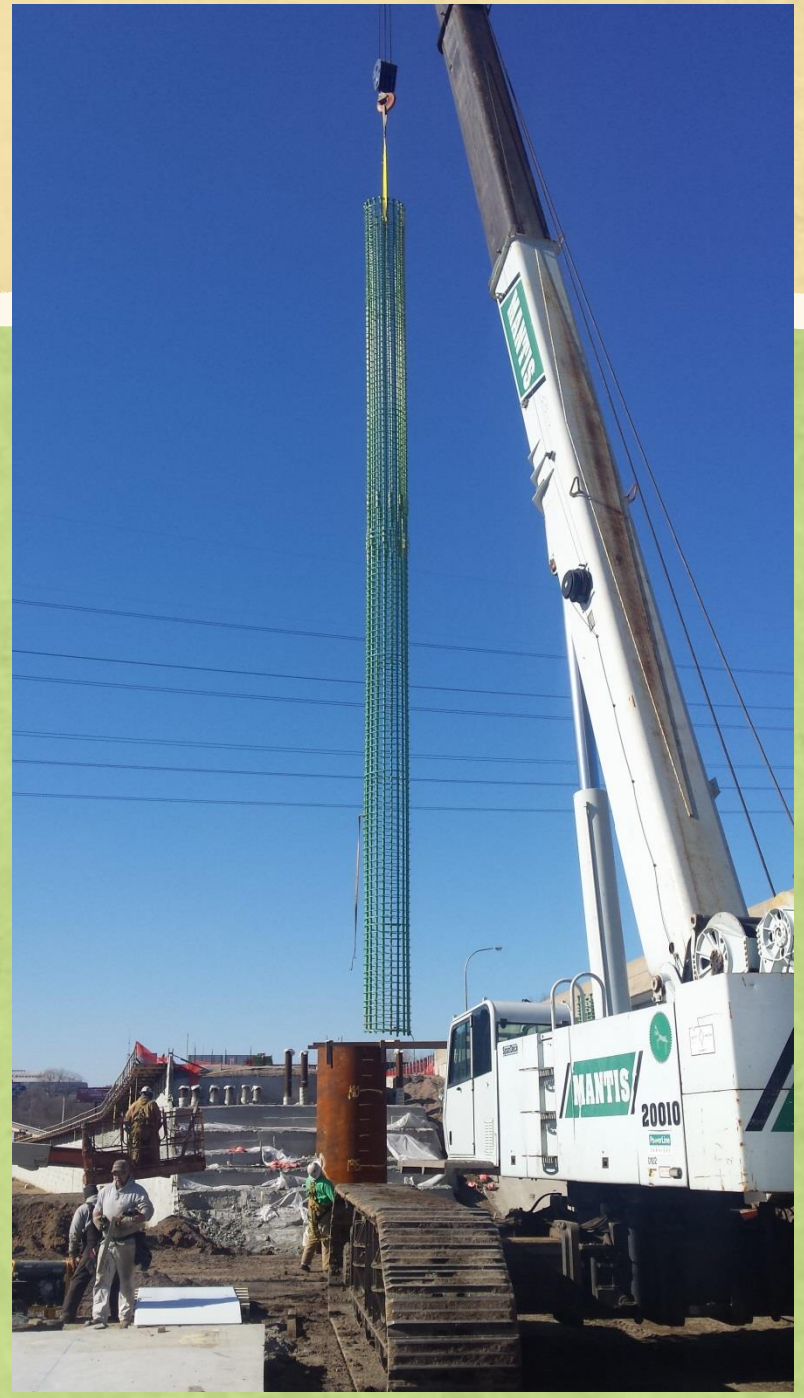
Pile Details – Constrictor Plate

Photo courtesy of Horner & Shifrin, Inc.



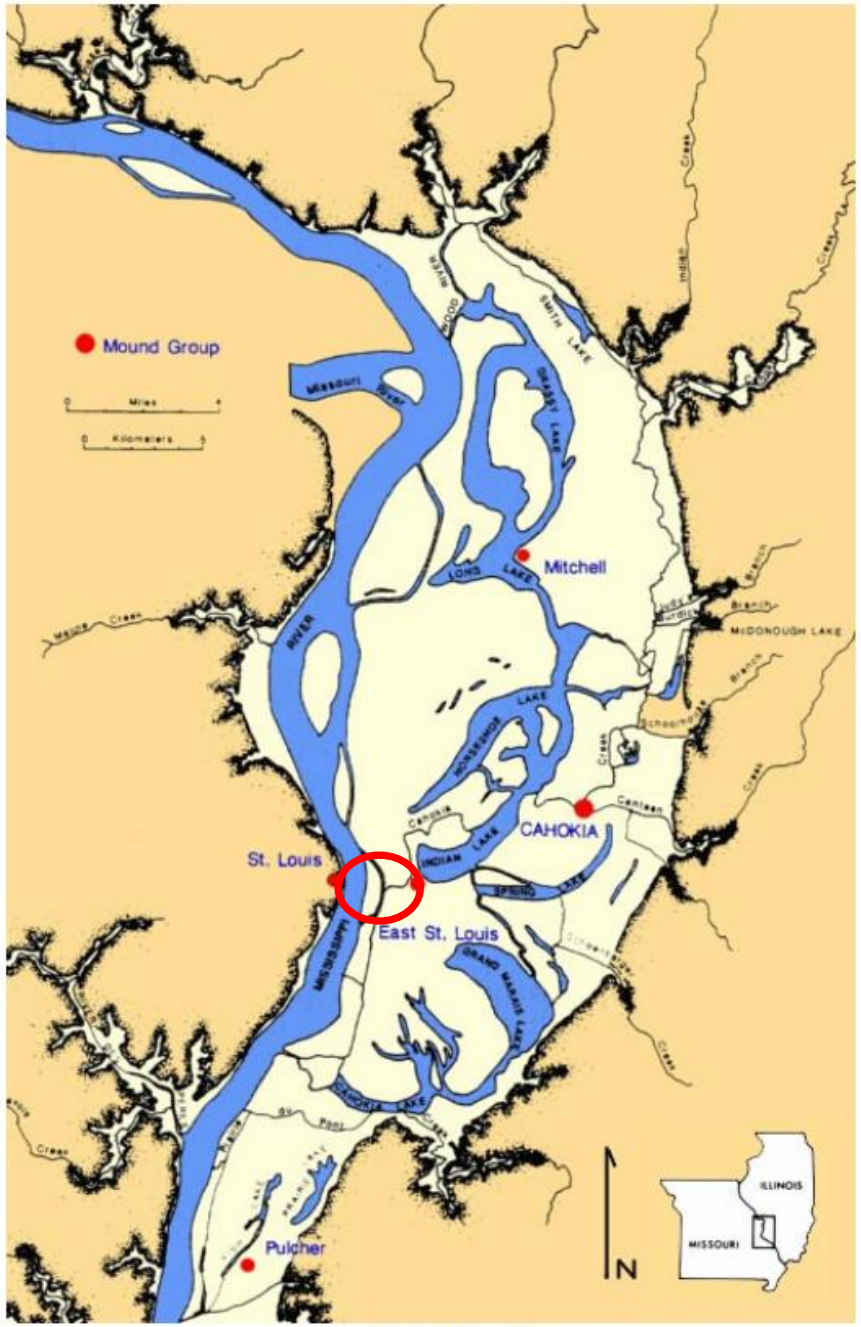
Structural Design

- At time of Design
  - Only 1 project in midwest
    - US 34 over Missouri River
- AASHTO LRFD 6.9.5 – Composite Members
  - Design as concrete column
  - F'c between 3.0 and 8.0 ksi
  - F'y shall not exceed 60 ksi
  - Must transfer loads from cap
- Seismic design
  - 14 - #14 vertical rebar required

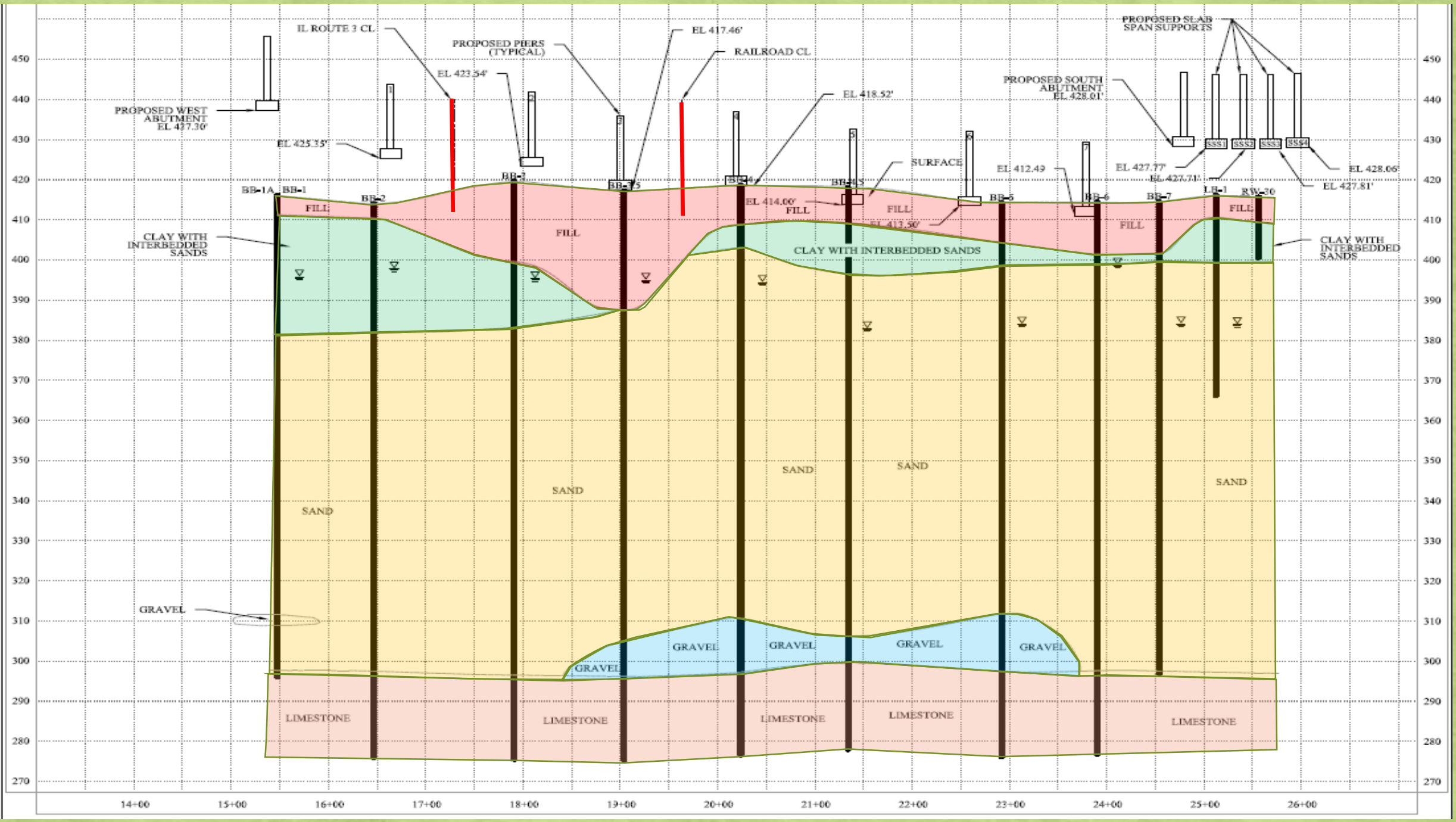


Geotechnical Overview

- "American Bottoms"
- Fluvial Floodplain Soils from the Mississippi River
- Typically Silts, Clays, Sands & Gravels
- Bedrock
  - Limestone
  - 115 to 120 foot down
- Industrial Area
  - +/- 200 years of development



American Bottom Map


IL ROUTE 3 CL
PROPOSED PIERS (TYPICAL)
EL 417.46'
RAILROAD CL
EL 423.54'
PROPOSED SLAB SPAN SUPPORTS
PROPOSED SOUTH ABUTMENT EL 428.01'
EL 418.52'
PROPOSED WEST ABUTMENT EL 427.30'
EL 425.35'
SURFACE
EL 412.49
EL 427.77'
EL 427.71'
EL 428.06'
EL 427.81'
BB-1A
BB-1
BB-2
BB-3
BB-3.5
BB-4
BB-4.5
BB-5
BB-6
BB-7
LB-1
RW-30
SSS1
SSS2
SSS3
SSS4
EL 414.00'
EL 413.50'
FILL
CLAY WITH INTERBEDDED SANDS
SAND
GRAVEL
LIMESTONE
450
440
430
420
410
400
390
380
370
360
350
340
330
320
310
300
290
280
270
14+00
15+00
16+00
17+00
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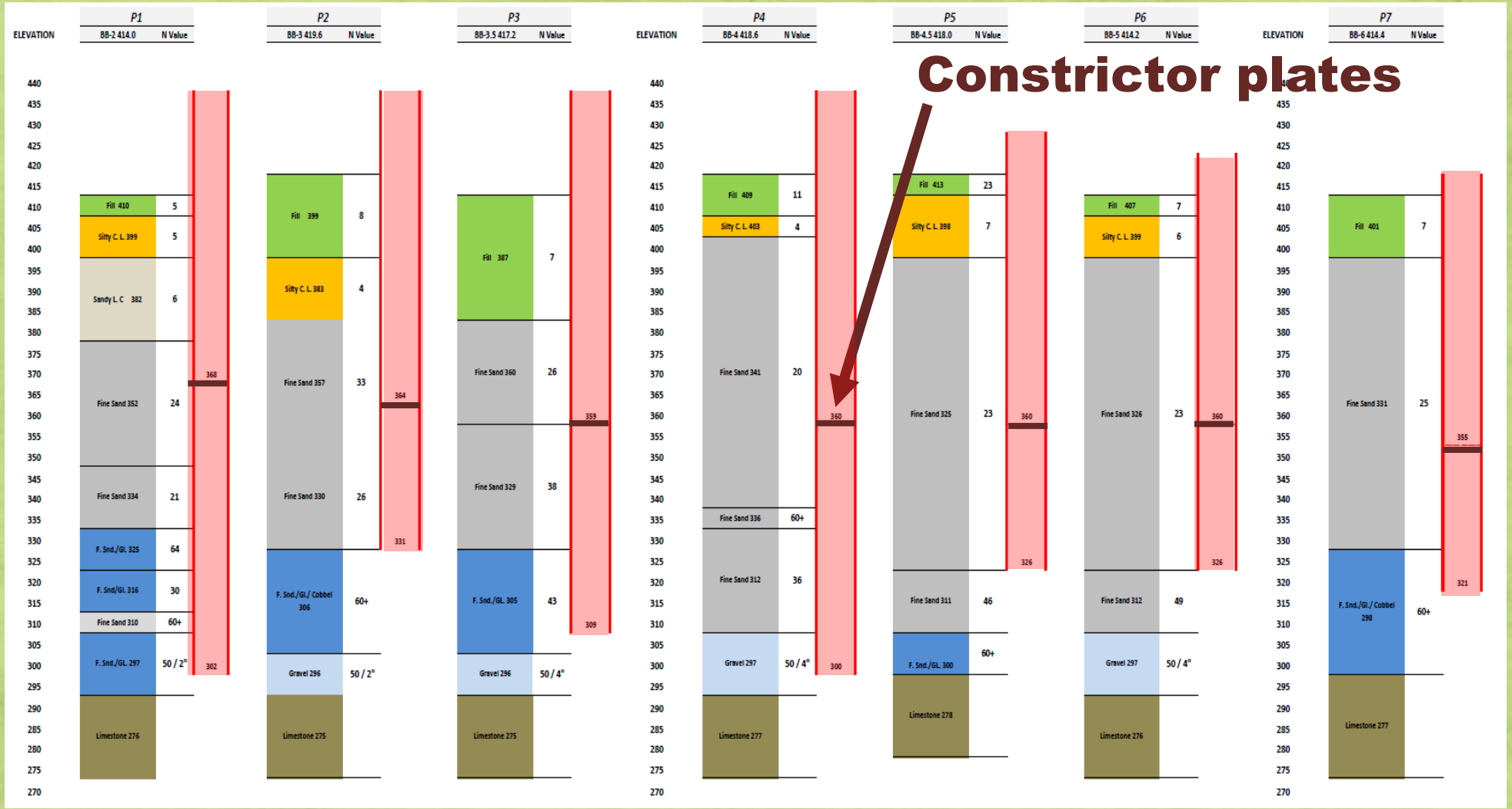
25+00
26+00

Soil Profile with Piles shown



Geotechnical Design Methodology

- IDOT Pile Design spreadsheet
- Modified with American Petroleum Institutes (API) design guidelines
  - API Recommended Practice 2A-WSD
    - Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design
  - Limiting values from API Table 6.4.3.1
- Modified with AASHTO LRFD Bridge Design Manual
- Geotechnical Resistance Factor = 0.65
- Seismic Geotechnical Resistance Factor = 1.0

API Table 6.4.3.1

Table 6.4.3-1—Design Parameters for Cohesionless Siliceous Soil*

Density	Soil Description	Soil-Pile Friction Angle, δ Degrees	Limiting Skin Friction Values kips/ft^2 (kPa)	N_q	Limiting Unit End Bearing Values kips/ft^2 (MPa)
Very Loose	Sand	15	1.0 (47.8)	8	40 (1.9)
Loose	Sand-Silt**				
Medium	Silt				
Loose	Sand	20	1.4 (67.0)	12	60 (2.9)
Medium	Sand-Silt**				
Dense	Silt				
Medium	Sand	25	1.7 (81.3)	20	100 (4.8)
Dense	Sand-Silt**				
Dense	Sand	30	2.0 (95.7)	40	200 (9.6)
Very Dense	Sand-Silt**				
Dense	Gravel	35	2.4 (114.8)	50	250 (12.0)
Very Dense	Sand				

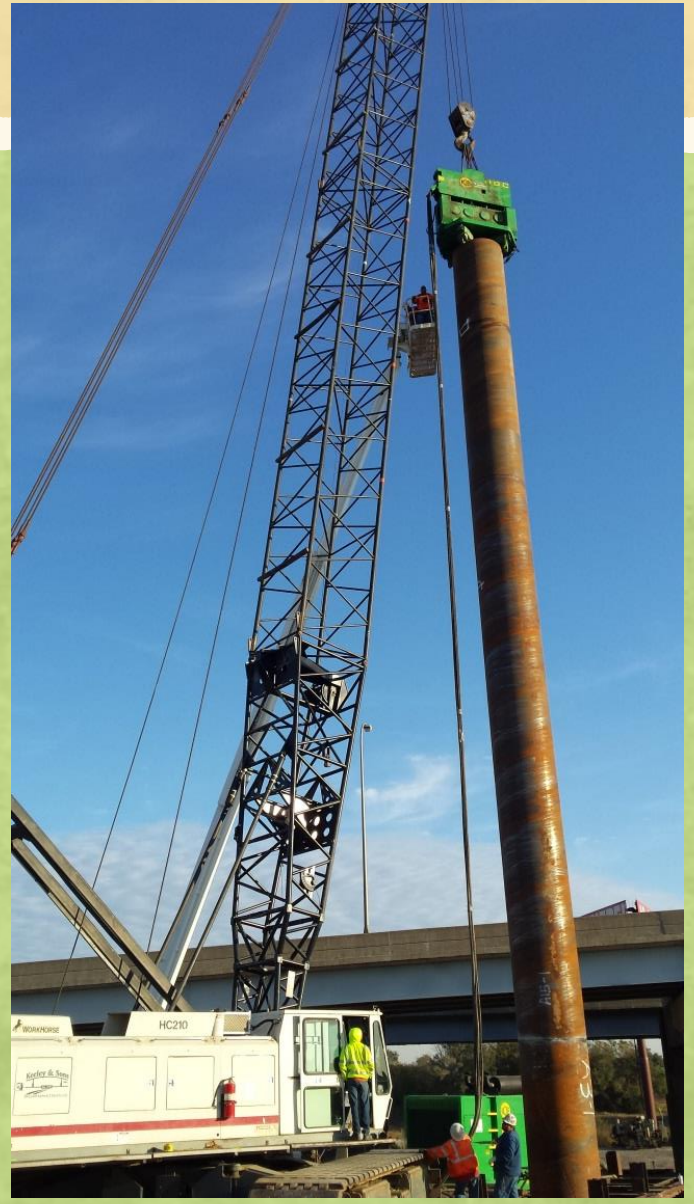
Pipe Pile Design Table for Pier 2 (BB-3)

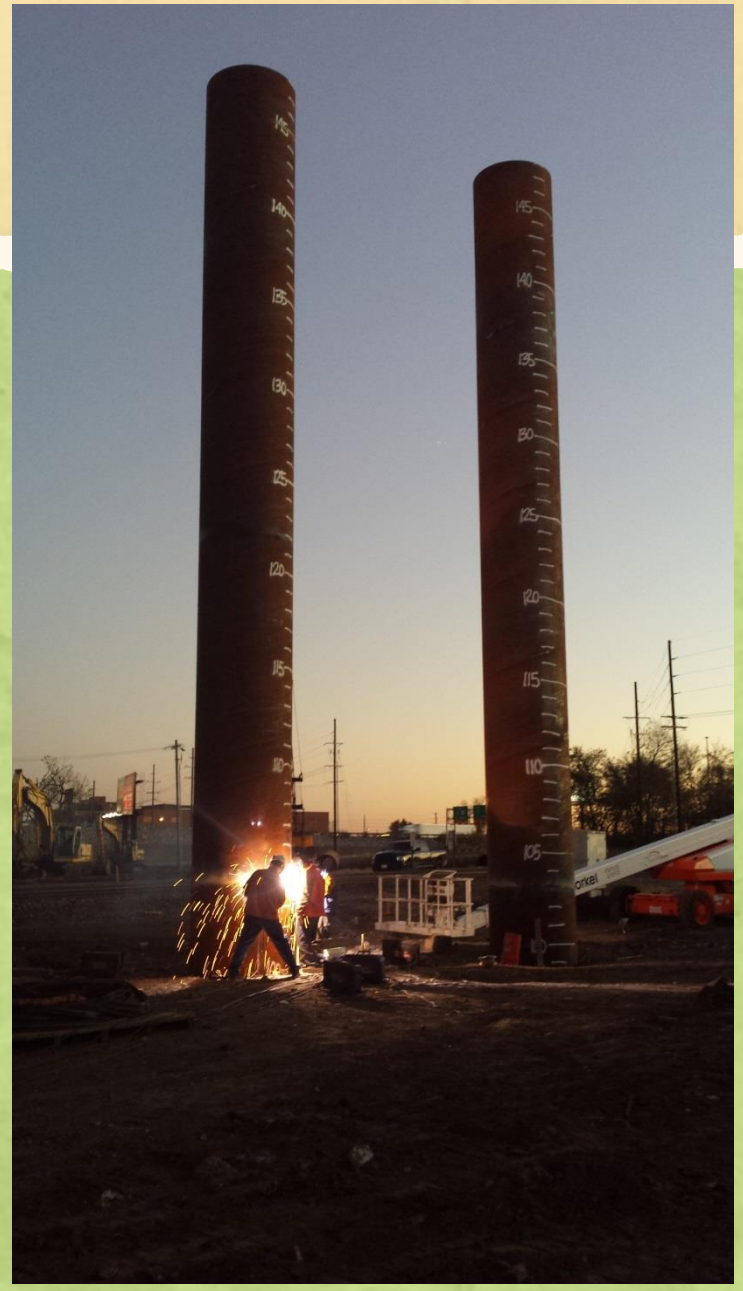
Nominal Req.'d Bearing (Kips)	Factored Resistance Available (Kips)	Est. Pile Length (FT)	Pile End Brg. Mat.'l
36" Diameter Pipe			
1316	855	72	Soil
1415	920	77	Soil
1517	986	82	Soil
1622	1054	87	Soil
1729	1124	92	Soil
1829	1189	97	Soil
1909	1241	102	Soil
1990	1293	107	Soil
2070	1345	112	Soil
2150	1397	117	Soil
3380	2197	128	Rock
3425	2226	129	Rock
3471	2256	130	Rock
3516	2285	131	Rock
42" Diameter Pipe			
1648	1071	72	Soil
1769	1150	77	Soil
1893	1230	82	Soil
2021	1314	87	Soil
2150	1398	92	Soil
2272	1477	97	Soil
2365	1537	102	Soil
2459	1598	107	Soil
2552	1659	112	Soil
2646	1720	117	Soil
3959	2573	128	Rock
4012	2608	129	Rock
4066	2643	130	Rock
4119	2677	131	Rock

Nominal Req.'d Bearing (Kips)	Factored Resistance Available (Kips)	Est. Pile Length (FT)	Pile End Brg. Mat.'l
48" Diameter Pipe			
2006	1304	72	Soil
2156	1401	77	Soil
2304	1498	82	Soil
2456	1596	87	Soil
2610	1697	92	Soil
2753	1790	97	Soil
2860	1859	102	Soil
2967	1929	107	Soil
3074	1998	112	Soil
3181	2067	117	Soil
4539	2950	128	Rock
4600	2990	129	Rock
4661	3029	130	Rock
4722	3069	131	Rock

Nominal Req'd Bearing (Kips)	Factored Resistance Available (Kips)	Est. Pile Length (FT)	Pile End Brg. Mat.'l
54" Diameter Pipe			
2262	1470	72	Soil
2479	1611	77	Soil
2705	1758	82	Soil
2928	1903	87	Soil
3108	2020	92	Soil
3274	2128	97	Soil
3394	2206	102	Soil
3515	2284	107	Soil
3635	2363	112	Soil
3755	2441	117	Soil
5118	3327	128	Rock
5187	3371	129	Rock
5256	3416	130	Rock
5324	3461	131	Rock
60" Diameter Pipe			
2518	1637	72	Soil
2759	1794	77	Soil
3011	1957	82	Soil
3274	2128	87	Soil
3542	2302	92	Soil
3808	2475	97	Soil
3968	2579	102	Soil
4101	2666	107	Soil
4235	2753	112	Soil
4368	2839	117	Soil
5697	3703	128	Rock
5774	3753	129	Rock
5850	3803	130	Rock
5927	3853	131	Rock

Construction





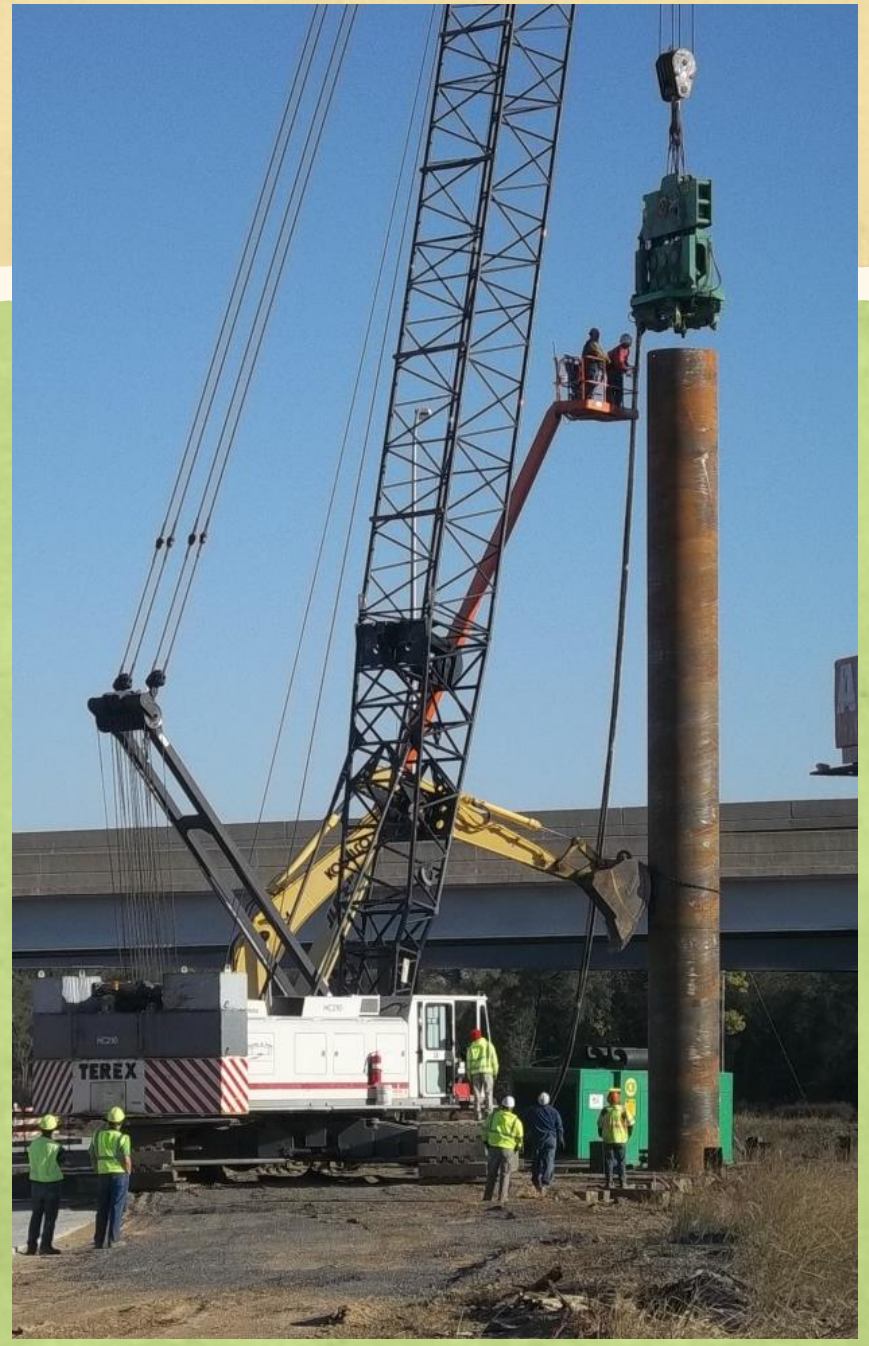
Piling Program

- Pre-Construction drivability analysis performed for each pier
- Dynamic testing to be performed on one pile per pier during final driving
- Restrikes contingent upon final driving conditions

Pile Delivery

Vibratory Driving

ICE 110C w/1200E power pack



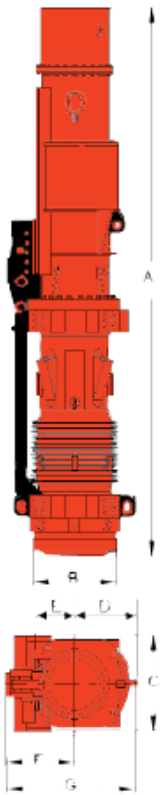
Impact Driving

Pileco D225-22

PILECO

D225-22

Technical Data Sheet 01/2013



Specifications*		
Technical Data	**Metric**	**Standard**
Impact weight (Piston) approx.	22,504 kg	49,612 lbs.
Energy per blow (adjustable)	766 - 397 kNm	564,970 - 292,811 lbs.ft.
Number of blows	36-50 Blow/min	36-50 Blow/min
Batter piling foward & backward up to	1 : 2	1 : 2
Diesel oil consumption	64 l/h	16.9 gal./h
Lube oil consumption	5.8 l/h	1.53 gal./h
Capacities		
Diesel oil tank	458 l	121 gal.
Lube oil tank	100 l	26.4 gal.
Approx. Weights		
Approx weight of Hammer	45,508 kg	100,328 lbs.
Approx weight of tripping device	1,300 kg	2,867 lbs.
Dimensions		
A - Length	816.9 cm	26.8 ft.
B - Outer diameter of impact block	115.8 cm	3.8 ft.
C - Width of Diesel Pile Hammer	134.1 cm	4.4 ft.
C - Width for connection of guide jaws	106.7 cm	3.5 ft.
D - Center of Diesel Pile Hammer up to pump guard	70.1 cm	2.3 ft.
E - Center of Diesel Pile Hammer up to center of threaded hole for fastening screws of the guide jaws	42.7 cm / 51.8 cm	1.4 ft. / 1.7 ft.
F - Center of Diesel Pile Hammer up to the tripping device	76.2 cm	2.5 ft.
G - Depth of Diesel Pile Hammer	164.6 cm	5.4 ft.
Powerpack Specifications		
Max. operating pressure	250 bar	3,625 psi
Max. oil flow	75 l/min	20 gal./min
Diesel engine	49 kW	66 hp

Technical data are subject to change without prior notice

BAUER PILECO

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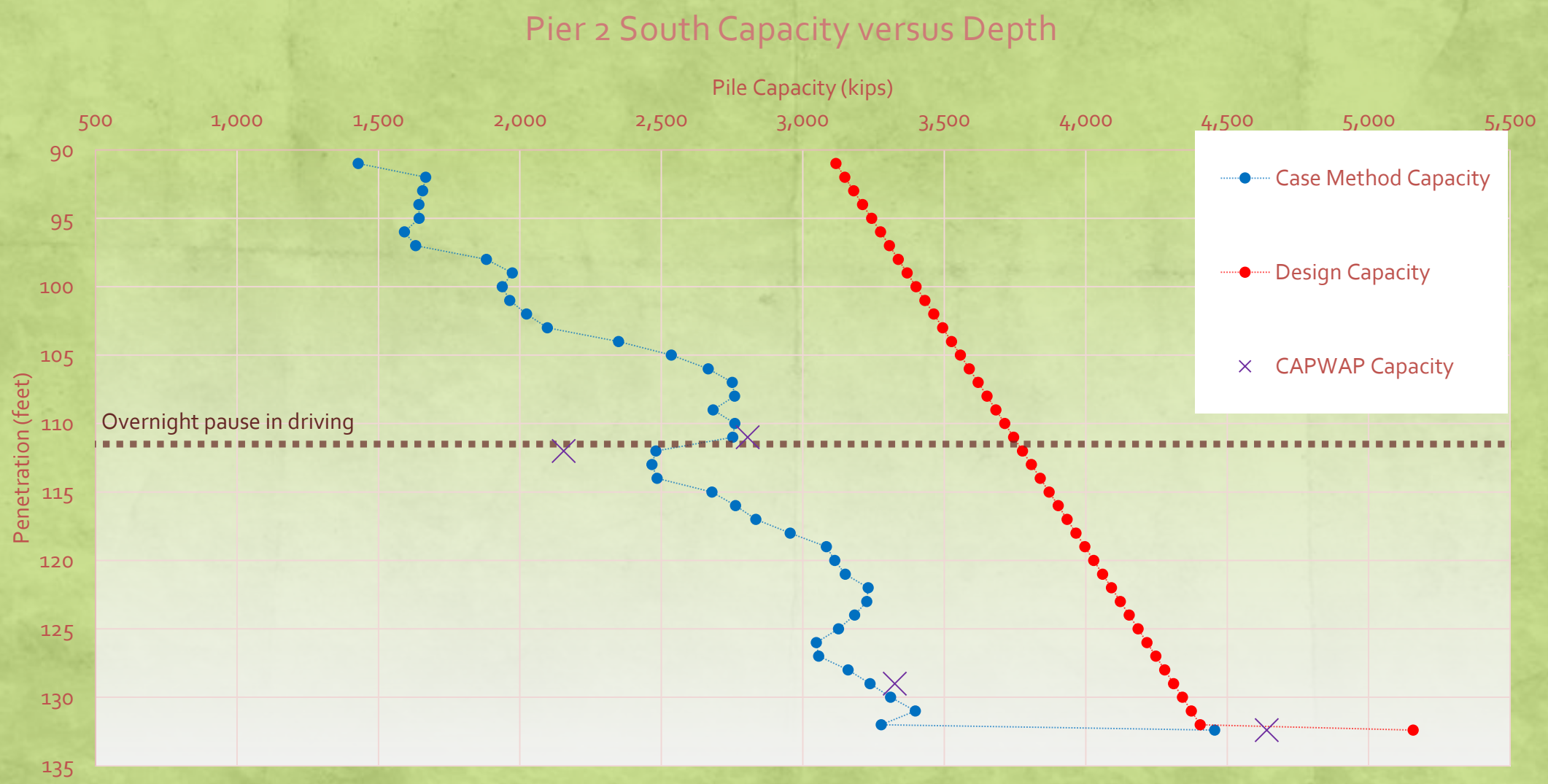
E-mail: info@bauerpileco.com
www.bauerpileco.com

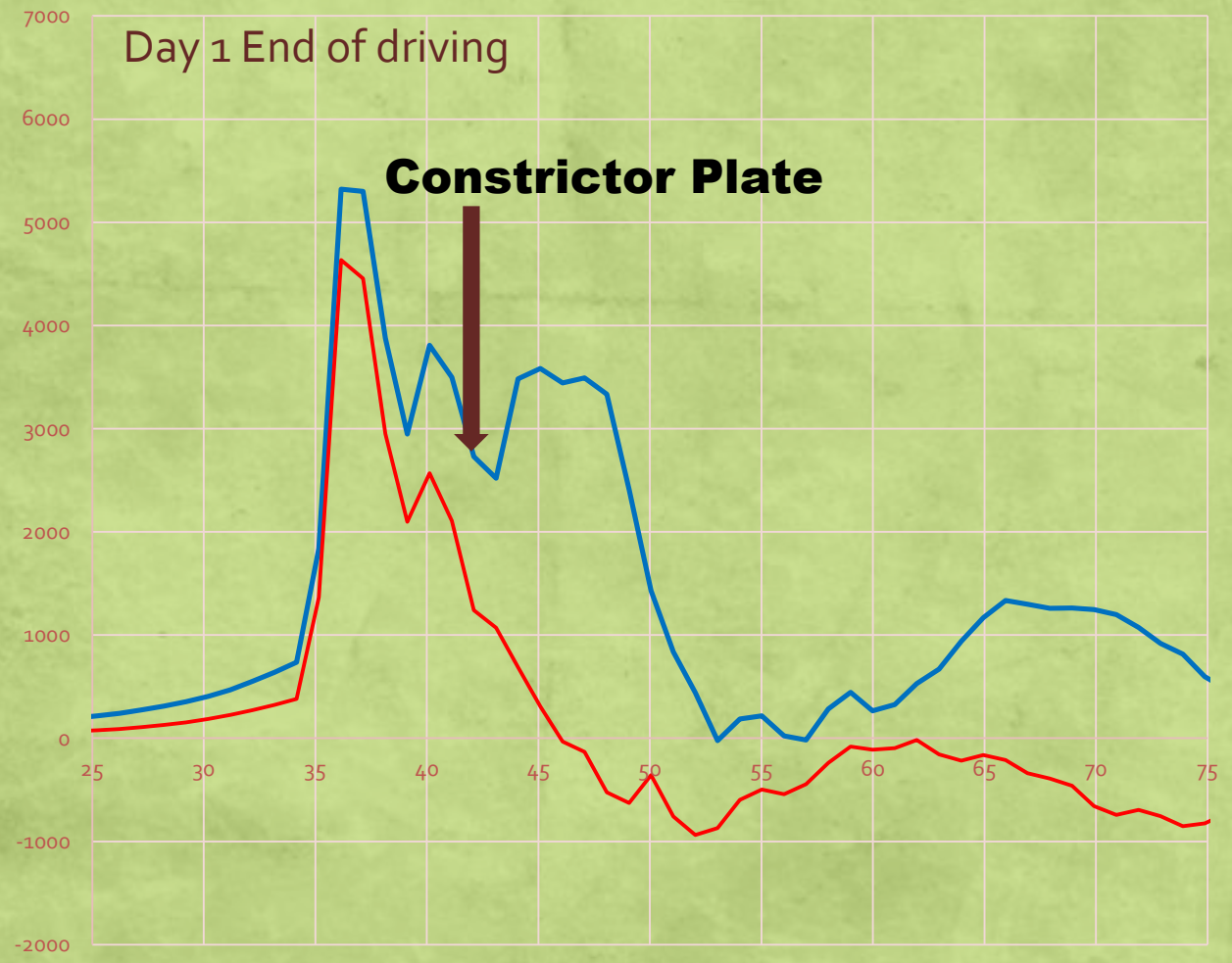
Pile Capacities

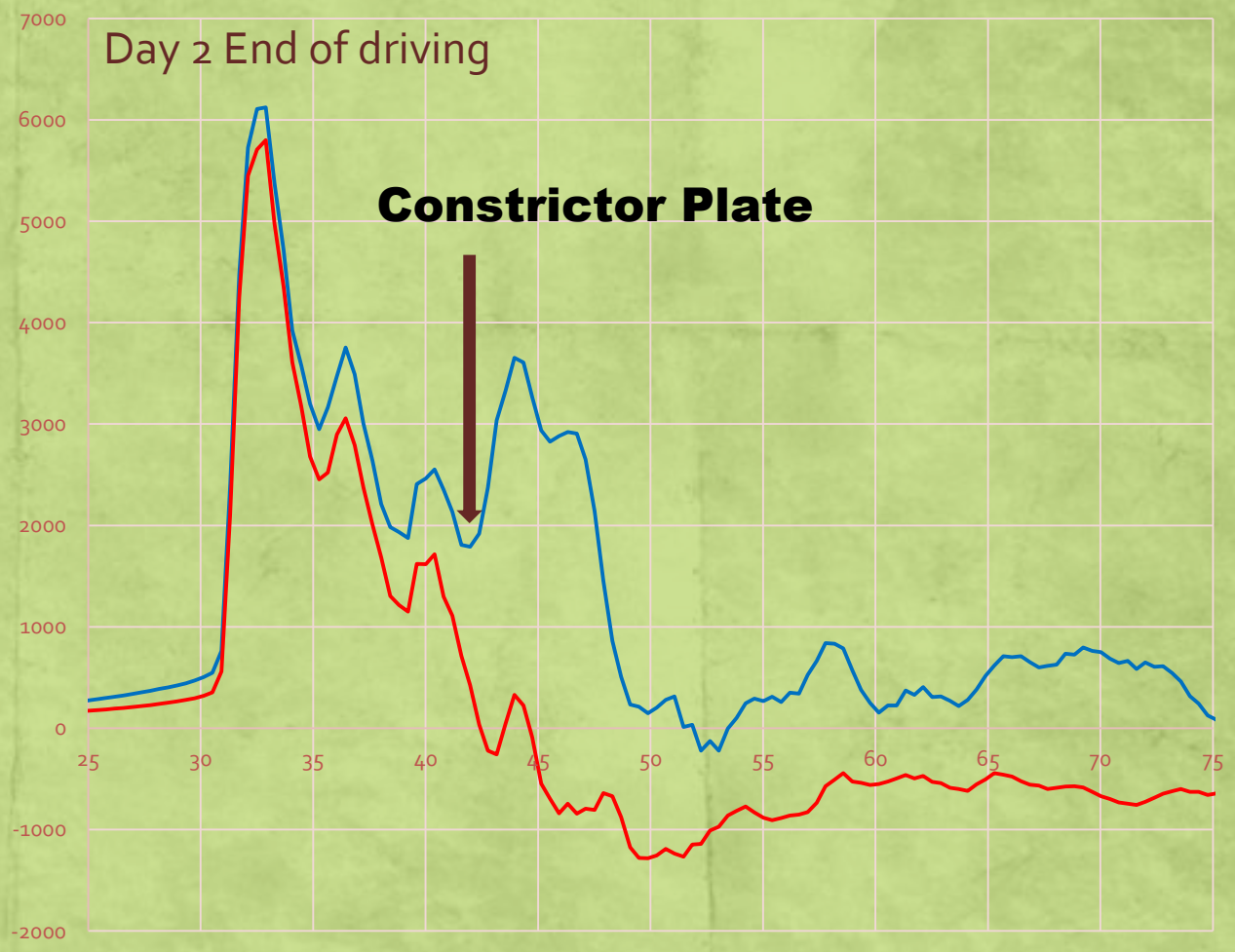
Predicted vs. Achieved



Dynamic Test Data

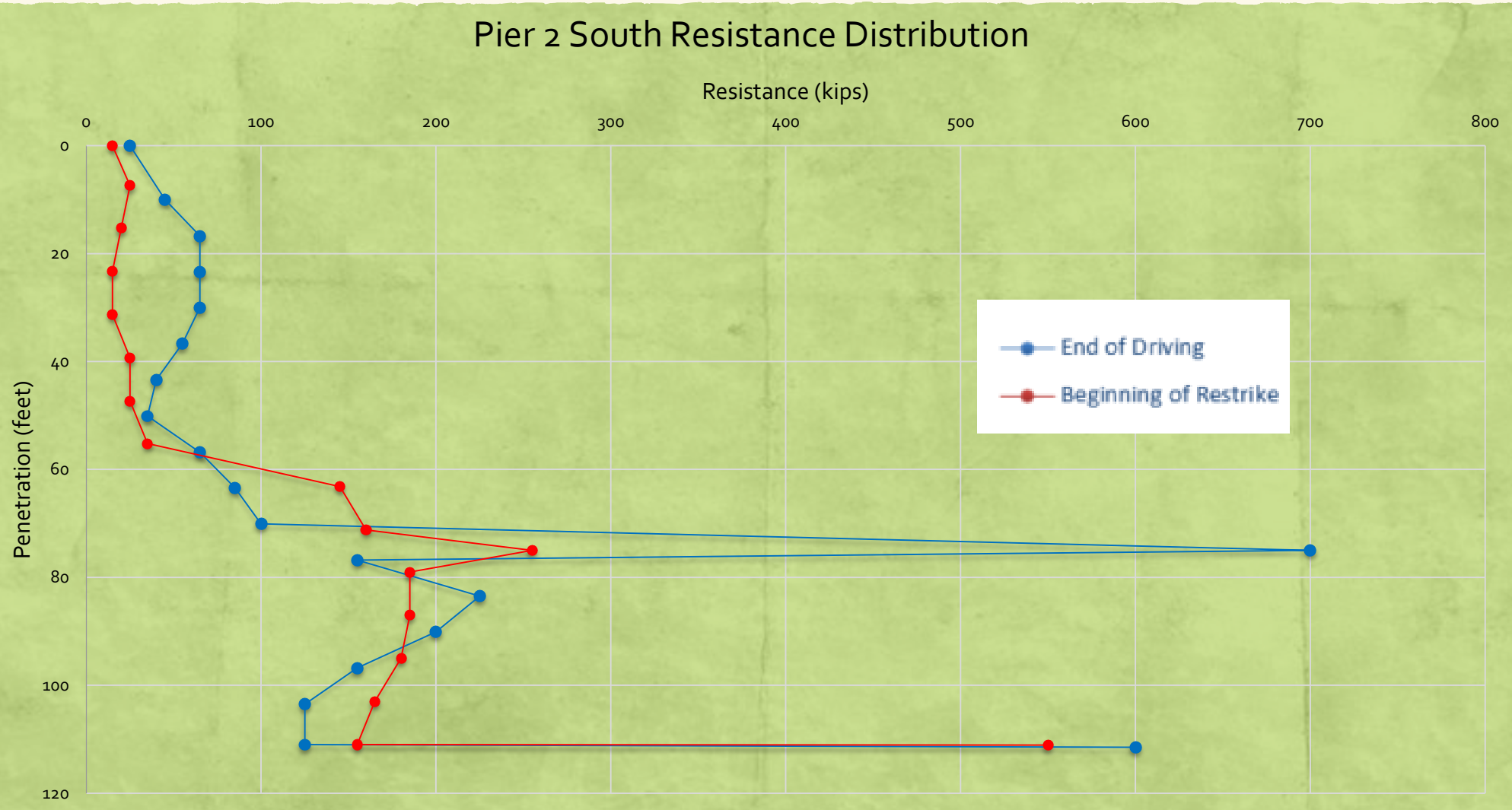
Pier 2 South





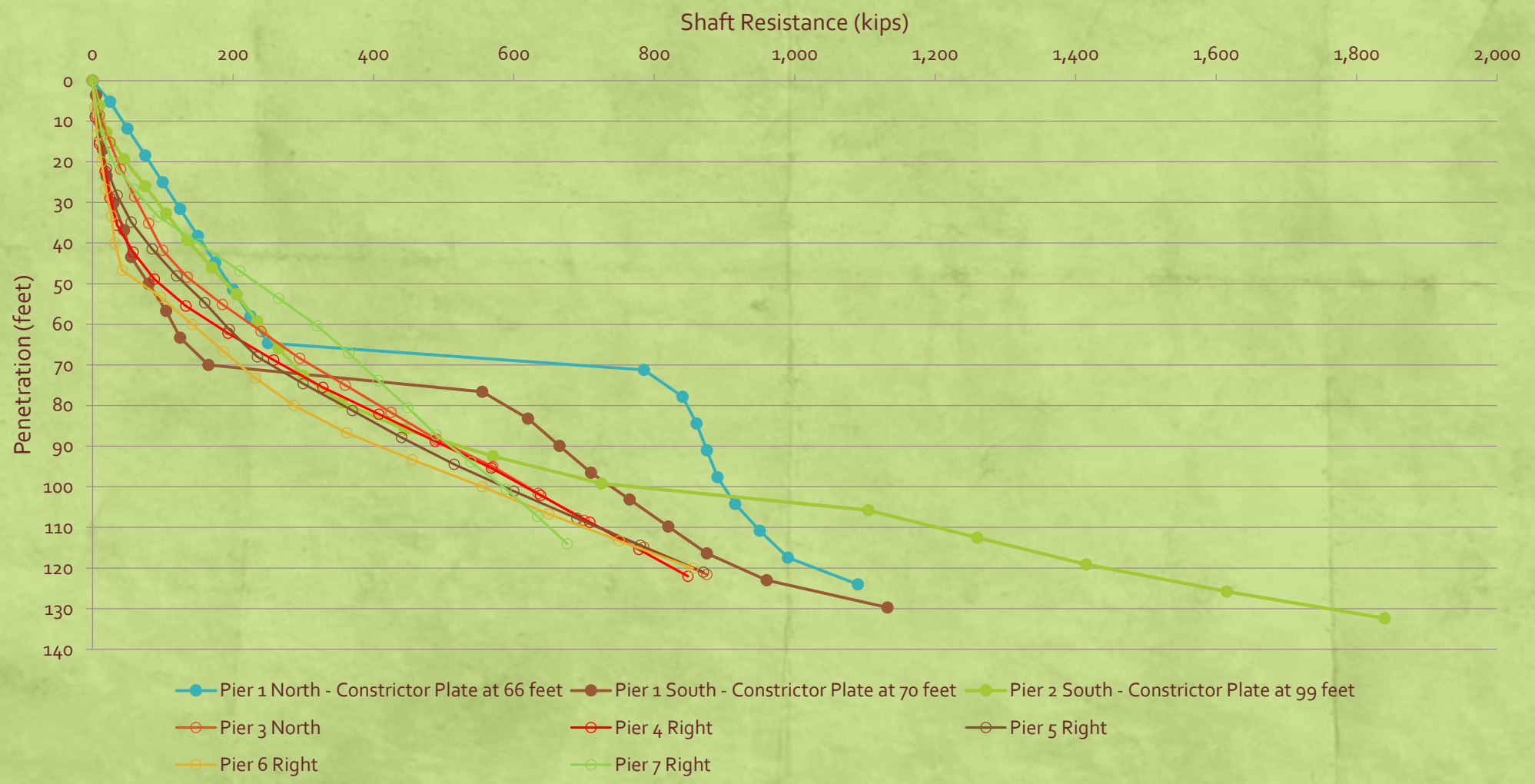
Pile Capacities

Pier 2 South, End of day 1 vs. day 2 restrike



Pile Capacities

Dynamic Test Data at Final Driving

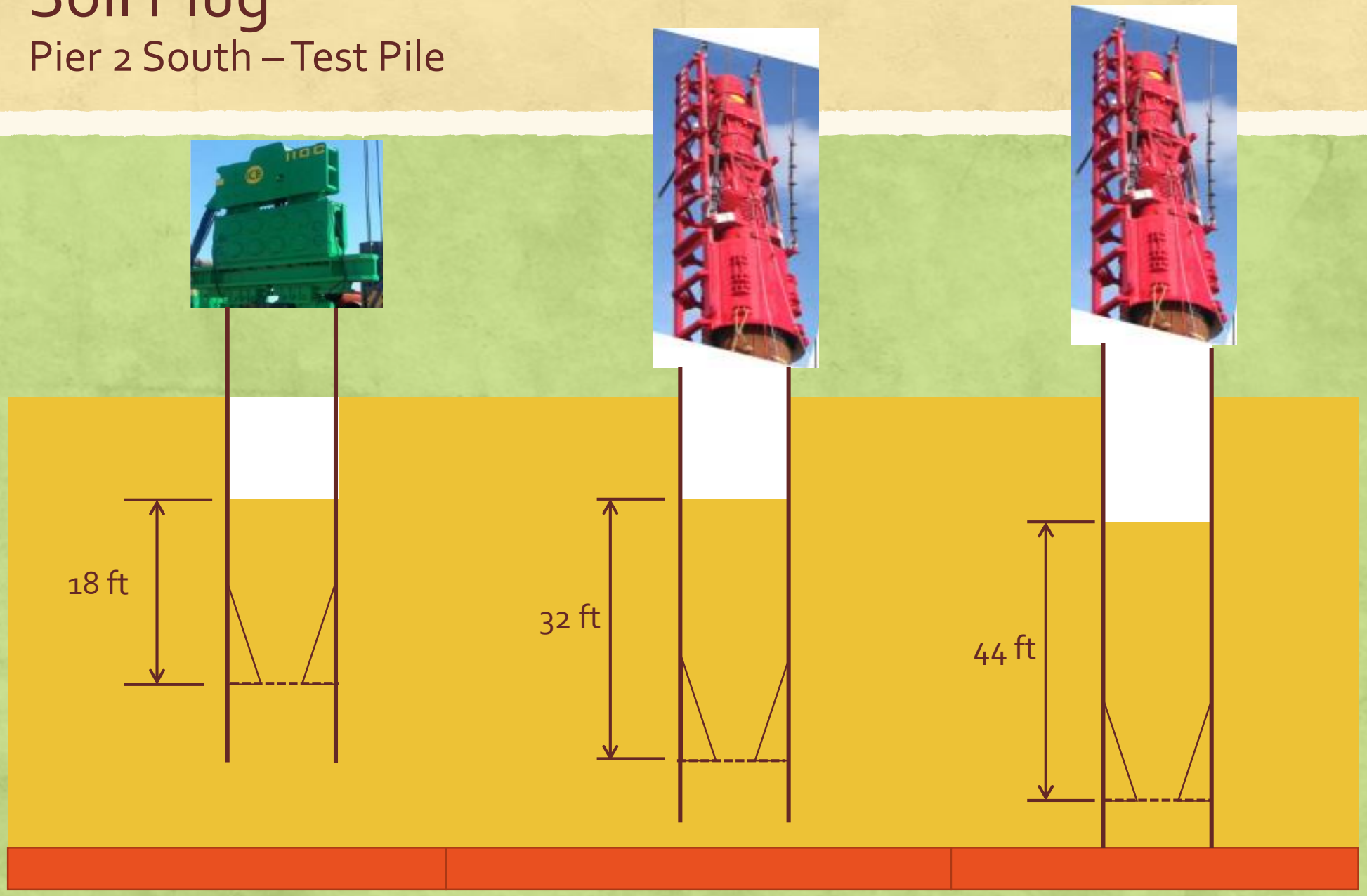


Bearing/Resistance Distribution

	Nominal Required Bearing (kips)	Mobilized Nominal Resistance (kips)	Shaft Resistance (%)	Resistance on Constrictor Plate (%)	End Bearing (%)
Pier 1 Left	4,496	5,840	14%	8%	78%
Pier 1 Right	4,496	4,982	16%	7%	77%
Pier 2 – Test	3,243	4,640	35%*	5%	60%*
Pier 3	3,999	5,675	15%		85%
Pier 4	4,258	5,148	16%		84%
Pier 5	3,301	5,470	16%		84%
Pier 6	3,257	4,655	18%		82%
Pier 7	3,217	5,076	13%		87%
Averages w/			**15%**	**7%**	**78%**
Averages w/o			**16%**		**84%**

Soil Plug

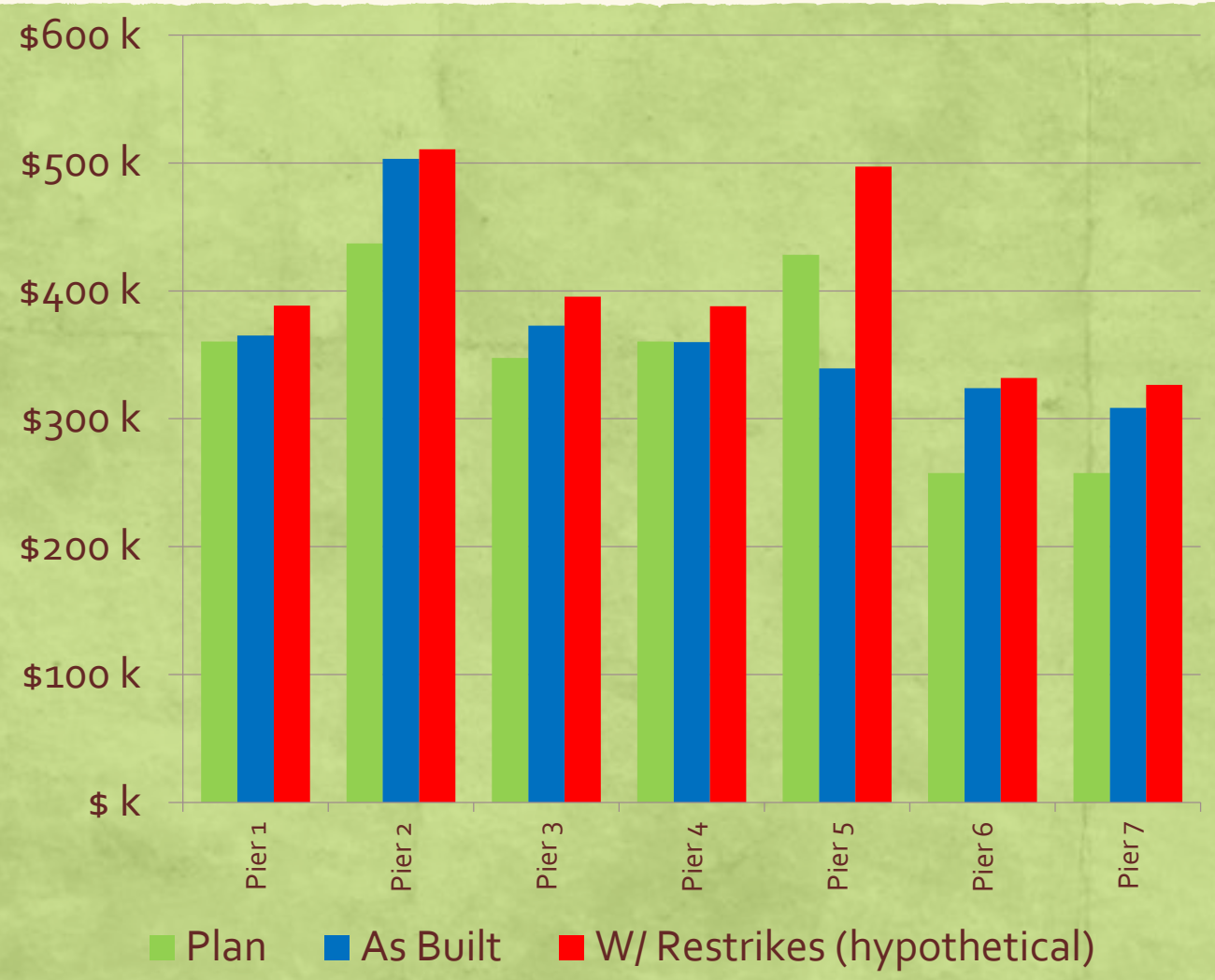
Pier 2 South – Test Pile

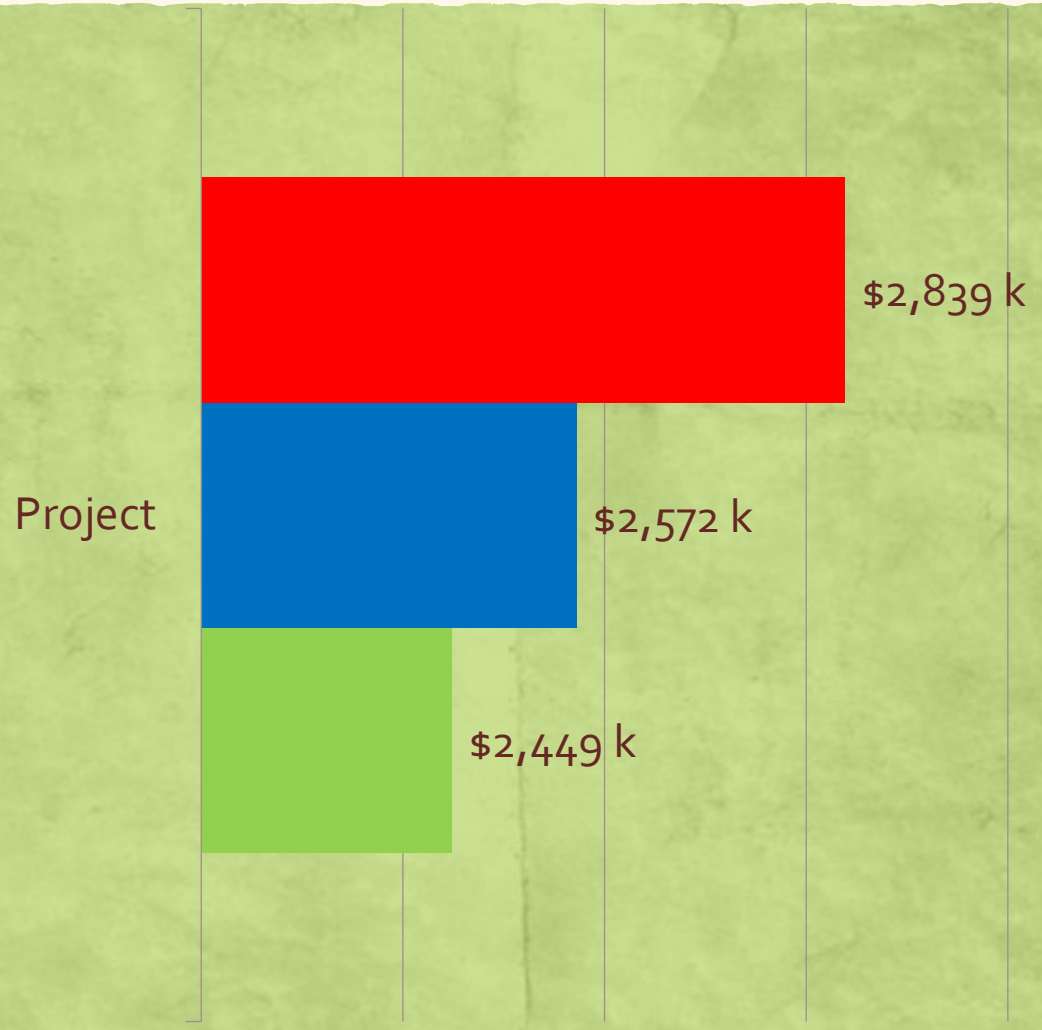


Constrictor Plate Results

- Did not provide substantial plugging effects
- Inflated blow counts and drive time with negligible added benefit
- False capacity due to pore water pressures, which quickly dissipated upon termination of driving
- Removed constrictor plates in remaining production pile

Cost Analysis





Obstructions

Missouri
Ave
MULLIKIN AVE.
Broadway
TERMINAL R.R.
L.&N.R.R.
BOGY AVE.
C.C.C.&ST.L. R.R.
PRATTE AVE.
CHURCH AVE.
M.&O.R.R.
Trendley
Ave
Collinsville
Ave.
Illinois
St. Louis
Ave.
Fifth Street
Sixth Street
Seventh Street
Eight Street
Ninth Street
Tenth Street
Kansas
Division
Main
Fourth
Market
Trendley
Pigeot
Converse
Bond
Street
Broady
CITY PARK

Conclusions

- These pile are a good alternative to drilled shafts when ease and speed of installation are considered
- Capacities – Actual vs. Predicted
- Availability of equipment and material
- Good seismic design and load resistance even in relatively poor soil conditions

Thank You!

Illinois Department of Transportation

HORNER SHIFRIN

SCI Engineering, Inc.

Keeley & Sons Inc. Est. 1947

GRL engineers, inc. Dynamic Measurements and Analyses

Questions?

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