LRFD IMPLEMENTATION

The Louisiana Experience

TRB

87TH Annual Meeting

January 13, 2008

Arthur Wagner D'Andrea, PE

BRIDGE DESIGN

Introduction

I. LRFD Implementation Plan and Initial Challenges
II. Phased-in the new method, LFD & ASD for the substructure, LRFD for the superstructure
III. Experiences with local projects
IV. Challenges for the future

I. LRFD Implementation-Team Plan

Implementation committee established

members from academia, structural, geotechnical, rating, document publishing, and FHWA

Committee created plan

- Defined implementation strategies
  pilot projects, substructure and superstructure
- Established a plan for staff and consultant training

LRFD Implementation-Team Plan

- Evaluated available resources like ready to use software
- Defined needs for update of manuals standards and software
- Established an implementation schedule, deadlines
- Sought assistance from FHWA
- Communicated plan to Administration, FHWA and other affected entities

LRFD Implementation, Initial Challenges

1. **Working through the implementation and phasing-out of the metric system**
2. **Unavailable LRFD software tools for project mass production**

LRFD Implementation, Initial Challenges

3. Most of the structural portions of LRFD code were defined first. Many unanswered questions from other sections such as Geotechnical. Initial LRFD Implementation included substructure methodology plan - Service load with FS or factored loads (LFD method)

LRFD Implementation, Initial Challenges

4. Comprehending the new versus the old methodology
5. Understanding the process from design to construction

LRFD Implementation

II. Phased-in the new method

II. Phased-in the new method

LRFD EQUIVALENT FACTOR OF SAFETY

Based on the cleaned up version of the balloted LRFD Section 10
Updated 10/10/05

LRFD Equivalent Factor of Safety for Driven Piles (Axial Compression)																		
R=DI/LL	Φ factor for Dynamic Analysis and Static Load Test Method (LRFD Table 10.5.5.2.3-1)											Φ factor for Static Analysis Methods (LRFD Table 10.5.5.2.2-1)						
	Static Load Test and quality control by dymanic testing (varies between 0.6 to 0.9 per No. of load test and site variability)							Dynamic Test	Wave equation anaylsis w/o pile dynamic measurement or load test	FHWA - modified Gates dynamic pile formula	ENR dynamic pile formula	α method	β method	λmethod	Nordlund/Thurman method	SPT method	CPT	End Bearing in rock
	0.9	0.85	0.8	0.75	0.7	0.65	0.55	0.65	0.4	0.4	0.1	0.35	0.25	0.4	0.45	0.3	0.5	0.45
0.5	1.8	1.9	2	2.1	2.3	2.4	2.9	2.4	4	4	15.8	4.5	6.3	4	3.5	5.3	3.2	3.5
1	1.7	1.8	1.9	2	2.1	2.3	2.7	2.3	3.8	3.8	15	4.3	6	3.8	3.3	5	3	3.3
2	1.6	1.7	1.8	1.9	2	2.2	2.6	2.2	3.5	3.5	14.2	4	5.7	3.5	3.1	4.7	2.8	3.1
3	1.5	1.6	1.7	1.8	2	2.1	2.5	2.1	3.4	3.4	13.8	3.9	5.5	3.4	3.1	4.6	2.8	3.1
4	1.5	1.6	1.7	1.8	1.9	2.1	2.5	2.1	3.4	3.4	13.5	3.9	5.4	3.4	3	4.5	2.7	3
5	1.5	1.6	1.7	1.8	1.9	2.1	2.4	2.1	3.3	3.3	13.3	3.8	5.3	3.3	3	4.4	2.7	3
6	1.5	1.6	1.7	1.8	1.9	2	2.4	2	3.3	3.3	13.2	3.8	5.3	3.3	2.9	4.4	2.6	2.9
7	1.5	1.5	1.6	1.8	1.9	2	2.4	2	3.3	3.3	13.1	3.8	5.3	3.3	2.9	4.4	2.6	2.9
8	1.5	1.5	1.6	1.7	1.9	2	2.4	2	3.3	3.3	13.1	3.7	5.2	3.3	2.9	4.4	2.6	2.9
9	1.4	1.5	1.6	1.7	1.9	2	2.4	2	3.3	3.3	13	3.7	5.2	3.3	2.9	4.3	2.6	2.9
10	1.4	1.5	1.6	1.7	1.9	2	2.4	2	3.2	3.2	13	3.7	5.2	3.2	2.9	4.3	2.6	2.9
11	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.9	3.7	5.2	3.2	2.9	4.3	2.6	2.9
12	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.9	3.7	5.2	3.2	2.9	4.3	2.6	2.9
13	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.9	3.7	5.1	3.2	2.9	4.3	2.6	2.9
14	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8	3.7	5.1	3.2	2.9	4.3	2.6	2.9
15	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8	3.7	5.1	3.2	2.8	4.3	2.6	2.8
16	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8	3.7	5.1	3.2	2.8	4.3	2.6	2.8
17	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8	3.7	5.1	3.2	2.8	4.3	2.6	2.8
18	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8	3.6	5.1	3.2	2.8	4.3	2.6	2.8
19	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8	3.6	5.1	3.2	2.8	4.3	2.6	2.8
20	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.7	3.6	5.1	3.2	2.8	4.2	2.5	2.8

DESIGNER'S CONCERN

FACTOR OF SAFETY CAN FALL BELOW 2.0

LRFD Equivalent Factor of Safety =

1.25DL+1.75LL)/[Φ(DL+LL)=(1.25R+1.75)/[*(1+R)]

Where R=ratio of DL/LL

II. Phased-in the new method

Φ factor for Dynamic Analysis and Static Load Test Method

LRFD Equivalent Factor of Safety for Driven Piles (Axial Compression)											
	Φ factor for Dynamic Analysis and Static Load Test Method (LRFD Table 10.5.5.2.3-1)										
R=Dl/LL	Static Load Test and quality control by dymanic testing (varies between 0.6 to 0.9 per No. of load test and site variability)							Dynamic Test	Wave equation anaylsis w/o pile dynamic measurement or load test	FHWA - modified Gates dynamic pile formula	ENR dynamic pile formula
	0.9	0.85	0.8	0.75	0.7	0.65	0.55	0.65	0.4	0.4	0.1
0.5	1.8	1.9	2	2.1	2.3	2.4	2.9	2.4	4	4	15.8
1	1.7	1.8	1.9	2	2.1	2.3	2.7	2.3	3.8	3.8	15
2	1.6	1.7	1.8	1.9	2	2.2	2.6	2.2	3.5	3.5	14.2
3	1.5	1.6	1.7	1.8	2	2.1	2.5	2.1	3.4	3.4	13.8
4	1.5	1.6	1.7	1.8	1.9	2.1	2.5	2.1	3.4	3.4	13.5
5	1.5	1.6	1.7	1.8	1.9	2.1	2.4	2.1	3.3	3.3	13.3
6	1.5	1.6	1.7	1.8	1.9	2	2.4	2	3.3	3.3	13.2
7	1.5	1.5	1.6	1.8	1.9	2	2.4	2	3.3	3.3	13.1
8	1.5	1.5	1.6	1.7	1.9	2	2.4	2	3.3	3.3	13.1
9	1.4	1.5	1.6	1.7	1.9	2	2.4	2	3.3	3.3	13
10	1.4	1.5	1.6	1.7	1.9	2	2.4	2	3.2	3.2	13
11	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.9
12	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.9
13	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.9
14	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8
15	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8
16	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8
17	1.4	1.5	1.6	1.7	1.8	2	2.3	2	3.2	3.2	12.8

LRFD Equivalent Factor of Safety =

1.25DL+1.75LL)/[Φ(DL+LL)=(1.25R+1.75)/[Φ*(1+R)]

Where R=ratio of DL/LL

II. Phased-in the new method

Φ factor for Static Analysis Methods

LRFD Equivalent Factor of Safety for Driven Piles (Axial Compression)						
Φ factor for Static Analysis Methods (LRFD Table 10.5.5.2.2-1)						
α method	β method	λmethod	Nordlund/Thurman method	SPT method	CPT	End Bearing in rock
0.35	0.25	0.4	0.45	0.3	0.5	0.45
4.5	6.3	4	3.5	5.3	3.2	3.5
4.3	6	3.8	3.3	5	3	3.3
4	5.7	3.5	3.1	4.7	2.8	3.1
3.9	5.5	3.4	3.1	4.6	2.8	3.1
3.9	5.4	3.4	3	4.5	2.7	3
3.8	5.3	3.3	3	4.4	2.7	3
3.8	5.3	3.3	2.9	4.4	2.6	2.9
3.8	5.3	3.3	2.9	4.4	2.6	2.9
3.7	5.2	3.3	2.9	4.4	2.6	2.9
3.7	5.2	3.3	2.9	4.3	2.6	2.9
3.7	5.2	3.2	2.9	4.3	2.6	2.9
3.7	5.2	3.2	2.9	4.3	2.6	2.9
3.7	5.2	3.2	2.9	4.3	2.6	2.9
3.7	5.1	3.2	2.9	4.3	2.6	2.9
3.7	5.1	3.2	2.9	4.3	2.6	2.9
3.7	5.1	3.2	2.8	4.3	2.6	2.8
3.7	5.1	3.2	2.8	4.3	2.6	2.8
3.7	5.1	3.2	2.8	4.3	2.6	2.8
3.6	5.1	3.2	2.8	4.3	2.6	2.8
3.6	5.1	3.2	2.8	4.3	2.6	2.8
3.6	5.1	3.2	2.8	4.2	2.5	2.8

LRFD Equivalent Factor of Safety=
(1.25DL+1.75LL)/[Φ(DL+LL)=(1.25R+1.75)/[Φ*(1+R)] Where R=ratio of DL/LL

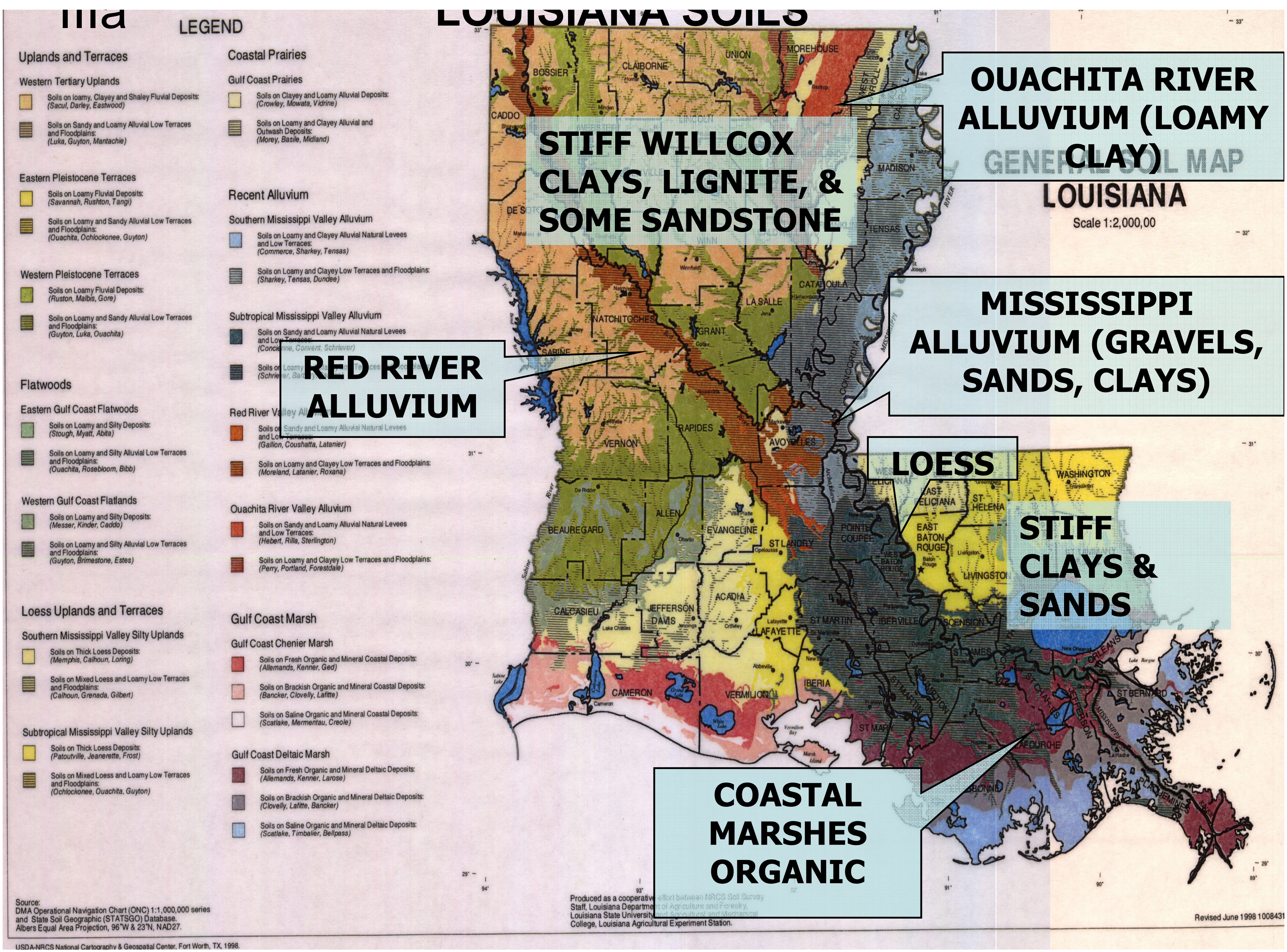
II. Phased-in the new method

•Typical 70’ span substructure loads
ASD with FS=2, pile load=340T
LRFD with Φ=0.7, pile load= 390 TONS
15% more, higher substructure demand

•Long Span bridges 470’ main span
ASD with FS=2 pile load=330T
Same pile layout LRFD Φ=0.7= 260 TONS, 20% less

LRFD Implementation

IIIa. Experiences with local projects Local conditions …


LOUISIANA SOILS
LEGEND
Uplands and Terraces
Western Tertiary Uplands
Soils on loamy, Clayey and Shaley Fluvial Deposits: (Sacul, Darley, Eastwood)
Soils on Sandy and Loamy Alluvial Low Terraces and Floodplains: (Luka, Guyton, Mantachie)
Eastern Pleistocene Terraces
Soils on Loamy Fluvial Deposits: (Savannah, Rushton, Tangi)
Soils on Loamy and Sandy Alluvial Low Terraces and Floodplains: (Ouachita, Ochlockonee, Guyton)
Western Pleistocene Terraces
Soils on Loamy Fluvial Deposits: (Ruston, Malbis, Gore)
Soils on Loamy and Sandy Alluvial Low Terraces and Floodplains: (Guyton, Luka, Ouachita)
Flatwoods
Eastern Gulf Coast Flatwoods
Soils on Loamy and Silty Deposits: (Stough, Myatt, Abita)
Soils on Loamy and Silty Alluvial Low Terraces and Floodplains: (Ouachita, Rosebloom, Bibb)
Western Gulf Coast Flatlands
Soils on Loamy and Silty Deposits: (Messer, Kinder, Caddo)
Soils on Loamy and Silty Alluvial Low Terraces and Floodplains: (Guyton, Brimestone, Estes)
Loess Uplands and Terraces
Southern Mississippi Valley Silty Uplands
Soils on Thick Loess Deposits: (Memphis, Calhoun, Loring)
Soils on Mixed Loess and Loamy Low Terraces and Floodplains: (Calhoun, Grenada, Gilbert)
Subtropical Mississippi Valley Silty Uplands
Soils on Thick Loess Deposits: (Patoutville, Jeanerette, Frost)
Soils on Mixed Loess and Loamy Low Terraces and Floodplains: (Ochlockonee, Ouachita, Guyton)
Coastal Prairies
Gulf Coast Prairies
Soils on Clayey and Loamy Alluvial Deposits: (Crowley, Mowata, Vidrine)
Soils on Loamy and Clayey Alluvial and Outwash Deposits: (Morey, Basile, Midland)
Recent Alluvium
Southern Mississippi Valley Alluvium
Soils on Loamy and Clayey Alluvial Natural Levees and Low Terraces: (Commerce, Sharkey, Tensas)
Soils on Loamy and Clayey Low Terraces and Floodplains: (Sharkey, Tensas, Dundee)
Subtropical Mississippi Valley Alluvium
Soils on Sandy and Loamy Alluvial Natural Levees and Low Terraces: (Convent, Schriever)
Red River Valley Alluvium
Soils on Sandy and Loamy Alluvial Natural Levees and Low Terraces: (Gallion, Coushatta, Latanier)
Soils on Loamy and Clayey Low Terraces and Floodplains: (Moreland, Latanier, Roxana)
Ouachita River Valley Alluvium
Soils on Sandy and Loamy Alluvial Natural Levees and Low Terraces: (Hebert, Rilla, Sterlington)
Soils on Loamy and Clayey Low Terraces and Floodplains: (Perry, Portland, Forestdale)
Gulf Coast Marsh
Gulf Coast Chenier Marsh
Soils on Fresh Organic and Mineral Coastal Deposits: (Allemands, Kenner, Ged)
Soils on Brackish Organic and Mineral Coastal Deposits: (Bancker, Clovelly, Lafitte)
Soils on Saline Organic and Mineral Coastal Deposits: (Scatlake, Mermentau, Creole)
Gulf Coast Deltaic Marsh
Soils on Fresh Organic and Mineral Deltaic Deposits: (Allemands, Kenner, Larose)
Soils on Brackish Organic and Mineral Deltaic Deposits: (Clovelly, Lafitte, Bancker)
Soils on Saline Organic and Mineral Deltaic Deposits: (Scatlake, Timbalier, Bellpass)
GENERAL SOIL MAP
LOUISIANA
Scale 1:2,000,00
OUACHITA RIVER ALLUVIUM (LOAMY CLAY)
STIFF WILLCOX CLAYS, LIGNITE, & SOME SANDSTONE
MISSISSIPPI ALLUVIUM (GRAVELS, SANDS, CLAYS)
RED RIVER ALLUVIUM
LOESS
STIFF CLAYS & SANDS
COASTAL MARSHES ORGANIC
Source: DMA Operational Navigation Chart (ONC) 1:1,000,000 series and State Soil Geographic (STATSGO) Database. Albers Equal Area Projection, 96°W & 23°N, NAD27.
Produced as a cooperative effort between NRCS Soil Survey Staff, Louisiana Department of Agriculture and Forestry, Louisiana State University and Agricultural and Mechanical College, Louisiana Agricultural Experiment Station.
Revised June 1998 1008431
USDA-NRCS National Cartography & Geospatial Center, Fort Worth, TX, 1998.

III- Experiences with local projects

TYPICAL PILE BENT FOUNDATION

III- Experiences with local projects
FOOTING AND PILE BENT FOUNDATION

Data Exchange
among

Geotechnical Experts
Structural Designers
And Construction Staff

soil input parameters-generated by Geotechnical

Soil Layer	Bottom Elevation (ft)	Soil Type	Soil Model [1]	Water Elevation [2] (ft)	Total Unit Weight (pcf)	N	ϕ (degrees)	Subgrade Modulus - K (pci)	Cohesion - c (psf)	ε_{50}	Poisson's Ratio - υ	Young's Modulus - E (ksi)	Shear Modulus - G (ksi)	Vertical Failure Shear (psf)	Torsional Shear Stress (psf)	Axial Bearing Failure [3] (kips)
0	-9.5															
1	-18.5	cohesive	Clay (Soft<Water)	0	120	--	--	20	150	0.028	0.40	0.3	0.1	75	75	5.4
2	-29.5	cohesive	Clay (Soft<Water)	0	114	--	--	133	1,000	0.010	0.45	1.2	0.4	950	950	81.0
3	-33.5	cohesive	Clay (Soft<Water)	0	116	--	--	57	430	0.016	0.40	0.4	0.1	439	439	34.8
4	-39.5	cohesive	Clay (Soft<Water)	0	120	--	--	91	680	0.012	0.40	0.6	0.2	665	665	55.1
5	-45.5	cohesive	Clay (Stiff<Water)	0	113	--	--	266	2,000	0.007	0.45	4.8	1.7	1,385	1,385	162.0
6	-57.5	cohesionless	Sand (Reese)	0	120	51	40	121	--	--	0.35	10.6	3.9	3,795	3,795	1,481.4
7	-71.5	cohesive	Clay (Soft<Water)	0	110	--	--	67	500	0.014	0.45	0.4	0.1	500	500	40.5
8	-75.5	cohesive	Clay (Soft<Water)	0	127	--	--	112	840	0.011	0.40	0.9	0.3	829	829	68.0
9	-81.5	cohesive	Clay (Soft<Water)	0	119	--	--	133	1,000	0.010	0.45	1.2	0.4	1,015	1,015	81.0
10	-93.5	cohesive	Clay (Soft<Water)	0	123	--	--	67	500	0.014	0.45	0.4	0.1	500	500	40.5
11	-98.5	cohesionless	Sand (Reese)	0	120	9	28	38	--	--	0.40	1.9	0.7	2,374	2,374	119.9
12	-126.5	cohesionless	Sand (O'Neill)	0	120	60	40	139	--	--	0.35	12.5	4.6	10,293	10,293	2,417.4
13	-144.5	cohesive	Clay (Stiff<Water)	0	110	--	--	240	1,800	0.007	0.45	3.9	1.3	1,696	1,696	145.8
14	-156.5	cohesive	Clay (Stiff<Water)	0	109	--	--	306	2,300	0.006	0.45	6.5	2.2	1,815	1,815	186.3
15	-161.5	cohesive	Clay (Soft<Water)	0	120	--	--	67	500	0.014	0.40	0.4	0.1	500	500	40.5
16	-167.5	cohesive	Clay (Stiff<Water)	0	100	--	--	492	3,700	0.005	0.45	17.6	6.1	1,360	1,360	299.7
17	-175.5	cohesive	Clay (Stiff<Water)	0	120	--	--	226	1,700	0.007	0.45	3.4	1.2	1,620	1,620	137.7
18	-181.5	cohesive	Clay (Soft<Water)	0	124	--	--	80	600	0.013	0.40	0.5	0.2	600	600	48.6
19	-189.5	cohesive	Clay (Stiff<Water)	0	120	--	--	200	1,500	0.008	0.45	2.7	0.9	1,500	1,500	121.5
20	-199.5	cohesionless	Sand (Reese)	0	120	65	38	149	--	--	0.35	13.5	5.0	18,435	18,435	2,417.4

NOTES:

(1) Soil model designations are from the FB Pier Input Screen. Please reference the FB Pier Manual for a discussion of the specific method referenced.

(2) Water Elevation is assumed to be an average of 0 ft at the site.

(3) Axial Bearing Failure is calculated for a 36-inch square concrete pile.

(4) Boring B-25 is located at Station 349+11.

FB-PIER SOIL INPUT PARAMETERS
I-10 TWIN SPAN PROJECT
B-25 - STA 349+11

III- Experiences with local projects

FB-PIER

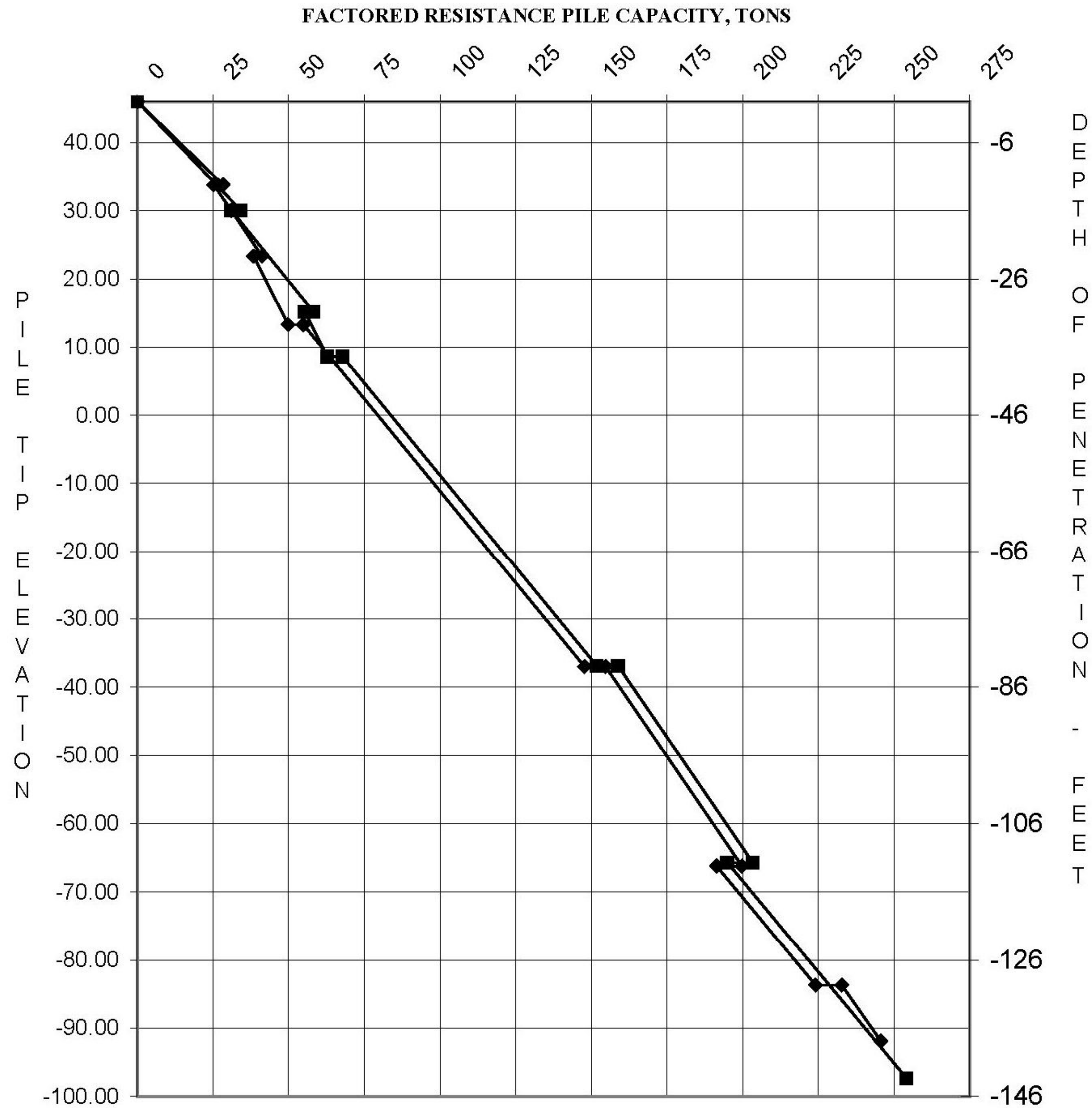
Soil Layer	Bottom Elevation (ft)	Soil Type	Soil Model [1]	Water Elevation [2] (ft)	Total Unit Weight (pcf)	N	ϕ (degrees)	Subgrade Modulus - K (pci)	Cohesion - c (psf)	ε_{50}
0	-9.5									
1	-18.5	cohesive	Clay (Soft<Water)	0	120	--	--	20	150	0.028
2	-29.5	cohesive	Clay (Soft<Water)	0	114	--	--	133	1,000	0.010
3	-33.5	cohesive	Clay (Soft<Water)	0	116	--	--	57	430	0.016
4	-39.5	cohesive	Clay (Soft<Water)	0	120	--	--	91	680	0.012
5	-45.5	cohesive	Clay (Stiff<Water)	0	113	--	--	266	2,000	0.007
6	-57.5	cohesionless	Sand (Reese)	0	120	51	40	121	--	--
7	-71.5	cohesive	Clay (Soft<Water)	0	110	--	--	67	500	0.014
8	-75.5	cohesive	Clay (Soft<Water)	0	127	--	--	112	840	0.011
9	-81.5	cohesive	Clay (Soft<Water)	0	119	--	--	133	1,000	0.010
10	-93.5	cohesive	Clay (Soft<Water)	0	123	--	--	67	500	0.014
11	-98.5	cohesionless	Sand (Reese)	0	120	9	28	38	--	--
12	-126.5	cohesionless	Sand (O'Neill)	0	120	60	40	139	--	--
13	-144.5	cohesive	Clay (Stiff<Water)	0	110	--	--	240	1,800	0.007

From designer, loads combinations for factored and service conditions

Pile Reactions, Service

Pile	Loc(X) ft	X in	Z in	comb	Ovs	P kips	Mxx kft	Mzz kft	Pile Reac. kips
1	-4.00	18.00	-48.0	1374	1.000	-929.67	-745.06	-166.75	141.17
				1250	1.000	-627.23	788.98	-195.42	42.46
2	-4.00	18.00	0.0	1307	1.000	-974.85	336.31	80.91	125.47
				1262	1.000	-580.31	-331.13	-474.58	58.49
3	-4.00	18.00	48.0	1307	1.000	-974.85	336.31	80.91	139.48
				1285	1.000	-582.41	-382.09	-441.69	44.17
4	0.00	66.00	-48.0	1374	1.000	-929.67	-745.06	-166.75	148.12
				1250	1.000	-627.23	788.98	-195.42	50.60
5	0.00	66.00	0.0	1307	1.000	-974.85	336.31	80.91	122.10
				1262	1.000	-580.31	-331.13	-474.58	78.26
6	0.00	66.00	48.0	1211	1.000	-889.30	743.95	-184.24	143.59
				1381	1.000	-667.96	-789.73	-176.54	55.09
7	4.00	114.00	-48.0	1374	1.000	-929.67	-745.06	-166.75	**155.07***
				1251	1.000	-630.51	771.80	-157.16	58.23
8	4.00	114.00	0.0	1278	1.000	-844.12	-337.43	-431.91	125.57
				1345	1.000	-716.26	329.98	112.89	88.66
9	4.00	114.00	48.0	1211	1.000	-889.30	743.95	-184.24	151.27
				1381	1.000	-667.96	-789.73	-176.54	62.45

From geotechnical team, factor resistance capacity curve



III- Experiences with local projects

Pile Data Sheet and testing requirements, contract plans, a team effort

										Plan Values						As-built Values			
	CL Bent	P.P.C. Pile Size	Pile Loads (kN)		Resistance Factor	Non-	Scour Zone Resistance	Ultimate Pile Capacity	Pile	Pile Length	Total Pile Length	Avg. Cutoff Elev.	Avg. Tip Elev.	* Design Scour	Design Scour Elev.	Pile Length	Total Pile Length	Avg. Cutoff Elev.	Avg. Tip Elev.
55	10+383.643	600	**1,175**	**1,727**	0.7	0.7	638	3105	6	26.9	161.4	34.775	7.875	3.658	22.000				
56	10+403.643	600	**1,175**	**1,727**	0.7	0.7	638	3105	4	27.0	108.0	34.806	7.806	3.658	22.000				
57	10+423.643	600	**1,175**	**1,727**	0.7	0.7	638	3105	4	27.1	108.4	34.836	7.736	3.658	22.000				
58	10+443.643	600	**1,175**	**1,727**	0.7	0.7	67	2534	4	24.4	97.6	34.865	10.465	1.524	26.500				
59	10+463.643	600	**1,175**	**1,727**	0.7	0.7	67	4928	6	21.7	130.2	34.880	13.180	1.524	27.000				
60	10+483.643	600	**1,175**	**1,727**	0.7	0.7	67	4928	4	21.7	86.8	34.880	13.180	1.524	27.500				
61	10+503.643	600	**1,175**	**1,727**	0.7	0.7	67	4928	4	21.7	86.8	34.880	13.180	1.524	27.500				
62	10+523.643	600	**1,175**	**1,727**	0.7	0.7	67	4928	4	21.7	86.8	34.880	13.180	1.524	28.000				
63	10+543.643	600	**1,175**	**1,727**	0.7	0.7	104	2820	6	21.7	130.2	34.880	13.180	1.524	28.000				
64	10+563.643	600	**1,175**	**1,727**	0.7	0.7	104	2820	4	21.7	86.8	34.880	13.180	1.524	28.000				
65	10+583.643	600	**1,175**	**1,727**	0.7	0.7	104	2820	4	21.7	86.8	34.880	13.180	1.524	28.000				
66	10+603.643	600	**1,175**	**1,727**	0.7	0.7	104	2820	4	21.7	86.8	34.880	13.180	1.524	28.500				
67	10+623.643	600	**1,175**	**1,727**	0.7	0.7	104	2820	6	21.7	130.2	34.880	13.180	1.524	28.500				
68	10+643.643	600	**1,175**	**1,727**	0.7	0.7	104	2820	4	21.7	86.8	34.880	13.180	1.524	29.000				
69	10+663.643	600	**1,175**	**1,727**	0.7	0.7	44	2892	4	19.8	79.2	34.880	15.080	1.524	30.500				
70	10+683.643	600	**1,175**	**1,727**	0.7	0.7	44	2892	4	19.8	79.2	34.880	15.080	1.524	31.000				
71	10+703.643	600	**1,175**	**1,727**	0.7	0.7	44	2892	6	19.8	118.8	34.880	15.080	1.524	31.000				
72	10+723.643	600	**1,175**	**1,727**	0.7	0.7	44	2892	4	19.8	79.2	34.880	15.080	1.524	31.000				
73	10+743.643	400	**561**	**837**	0.53	0.48	N.A.	2605	8	20.8	166.4	34.818	14.018	N.A.	N.A.				
W.W.	9+299.986	350	**134**	N.A.	0.53	0.48	N.A.	425	2	10.3	20.6	34.971	24.671	N.A.	N.A.				
W.W.	10+747.300	350	**134**	N.A.	0.53	0.48	N.A.	614	2	10.3	20.6	34.971	24.671	N.A.	N.A.				

TEST PILE SIZE = 600 mm (TYP.)

TEST PILE DATA

TEST PILE NO.	STA	PLAN TIP ELEV. (m)	CASE BTM ELEV. (m)	AS-BUILT TIP ELEV. (m)	AS-BUILT STA (m)	AS-BUILT OFFSET (m)
1	9+375	+16.0	+29.5			
2	9+875	+16.0	+28.0			
3	10+350	+12.0	+22.0			
4	10+575	+15.4	+28.0			

TEST PILE AND MONITOR PILE NOTES:

1. TEST PILES SHALL BE TESTED TO FAILURE OR 4500 kN, WHICHEVER COMES FIRST.
2. TEST PILES SHALL HAVE A 1-DAY RESTRIKE AFTER INITIAL PILE INSTALLATION AND A RESTRIKE WITHIN 24 HOURS AFTER THE LOAD TEST WITH THE PILE DRIVING ANALYZER (PDA).
3. TOP OF TEST PILES SHALL EXTEND A MINIMUM OF (2 X PILE DIAMETER + 0.33 METERS) ABOVE THE CASING OR NATURAL GROUND ELEVATION ONCE THE REQUIRED PILE TIP ELEVATION IS ACHIEVED.
4. TEST PILES SHALL BE CASED DOWN TO THE SPECIFIED ELEVATION PRIOR TO DRIVING THE TEST PILE. THE SOIL AND DEBRIS INSIDE THE CASING SHALL BE EXCAVATED TO THE SCOUR ELEVATION.
5. SEVEN (7) PRODUCTION PILES AT EACH OF THE FOLLOWING FOUR (4) SEGMENTS SHALL BE DYNAMICALLY MONITORED FOR A TOTAL OF (28) MONITOR PILES:
   - (7) PRODUCTION PILES AT SEGMENT 1: BENTS 2 - 18
   - (7) PRODUCTION PILES AT SEGMENT 2: BENTS 19 - 49
   - (7) PRODUCTION PILES AT SEGMENT 3: BENTS 50 - 58
   - (7) PRODUCTION PILES AT SEGMENT 4: BENTS 59 - 72

   RESTRIKES AND CAPWAP ANALYSIS SHALL BE PERFORMED AT 14 DAYS OR AT A SCHEDULE APPROVED BY THE GEOTECHNICAL DESIGN SECTION.

STATE OF LOUISIANA
KELLY M. KEMP
License No. 30785
PROFESSIONAL ENGINEER
IN
CIVIL ENGINEERING

BRIDGE AND STRUCTURAL DESIGN | DOTD | BLACK LAKE BRIDGE AND APPROACHES LA 9 | PILE DATA SHEET

NO.	DATE	REVISION DESCRIPTION	BY

DESIGNED / CHECKED	K. KEMP	PARISH	NATCHITOCHES
DETAILED / CHECKED	K. KEMP	FEDERAL PROJECT	
DATE / SHEET	04/12/07 / 1 OF 1	STATE PROJECT	089-01-0018

SHEET NUMBER 114

Pile Data Sheet
1400 m bridge, 4 test piles and 28 PDA tests, restrikes at 14 days with capwap analysis to follow

NOTE: ALL PILE LOADS ARE COMPRESSION.

Bent	CL Bent STA	P.P.C. Pile Size (mm)	Pile Loads (kN)		Resistance Factor		Scour Zone Resistance (kN)	Ultimate Pile Capacity (kN)
			Service	Strength	Cohesive	Non-Cohesive		
1	9+303.643	400	**561**	**837**	0.53	0.48	N.A.	1877
2	9+323.643	600	**1,175**	**1,727**	0.7	0.7	168	2966
3	9+343.643	600	**1,175**	**1,727**	0.7	0.7	168	2966
4	9+363.643	600	**1,175**	**1,727**	0.7	0.7	168	2966
5	9+383.643	600	**1,175**	**1,727**	0.7	0.7	168	2966
6	9+403.643	600	**1,175**	**1,727**	0.7	0.7	168	2635
7	9+423.643	600	**1,175**	**1,727**	0.7	0.7	1718	10143
8	9+443.643	600	**1,175**	**1,727**	0.7	0.7	1718	10143
9	9+463.643	600	**1,175**	**1,727**	0.7	0.7	1718	10143
10	9+483.643	600	**1,175**	**1,727**	0.7	0.7	1718	10143
11	9+503.643	600	**1,175**	**1,727**	0.7	0.7	1718	10143

Pile Data Sheet, test piles, PDA and CAPWAP analysis

TEST PILE SIZE = 600 mm (TYP.)

TEST PILE DATA						
TEST PILE NO.	STA	PLAN TIP ELEV. (m)	CASE BTM ELEV. (m)	AS-BUILT TIP ELEV. (m)	AS-BUILT STA [m]	AS-BUILT OFFSET [m]
1	9+375	+16.0	+29.5			
2	9+875	+16.0	+28.0			
3	10+350	+12.0	+22.0			
4	10+575	+15.4	+28.0			

TEST PILE AND MONITOR PILE NOTES:

1. TEST PILES SHALL BE TESTED TO FAILURE OR 4500 kN, WHICHEVER COMES FIRST.
2. TEST PILES SHALL HAVE A 1-DAY RESTRIKE AFTER INITIAL PILE INSTALLATION AND A RESTRIKE WITHIN 24 HOURS AFTER THE LOAD TEST WITH THE PILE DRIVING ANALYZER (PDA).
3. TOP OF TEST PILES SHALL EXTEND A MINIMUM OF (2 X PILE DIAMETER + 0.33 METERS) ABOVE THE CASING OR NATURAL GROUND ELEVATION ONCE THE REQUIRED PILE TIP ELEVATION IS ACHIEVED.
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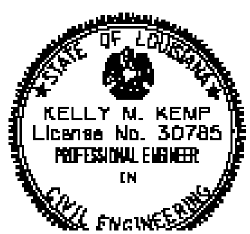
5. SEVEN (7) PRODUCTION PILES AT EACH OF THE FOLLOWING FOUR (4) SEGMENTS SHALL BE DYNAMICALLY MONITORED FOR A TOTAL OF (28) MONITOR PILES:

   (7) PRODUCTION PILES AT SEGMENT 1: BENTS 2 - 18
   (7) PRODUCTION PILES AT SEGMENT 2: BENTS 19 - 49
   (7) PRODUCTION PILES AT SEGMENT 3: BENTS 50 - 58
   (7) PRODUCTION PILES AT SEGMENT 4: BENTS 59 - 72

   RESTRIKES AND CAPWAP ANALYSIS SHALL BE PERFORMED AT 14 DAYS OR AT A SCHEDULE APPROVED BY THE GEOTECHNICAL DESIGN SECTION.

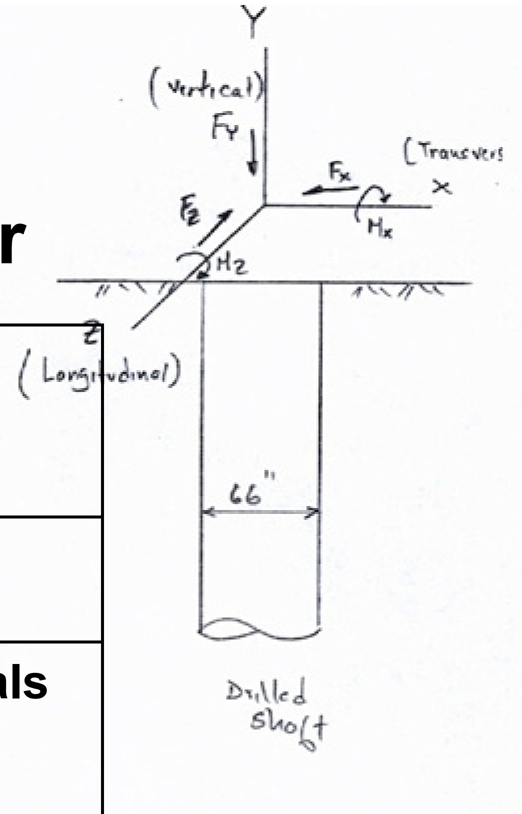


III- Experiences with local projects

TYPICAL DRILLED SHAFT INSTALLATION

III- Experiences with local projects

Drilled shaft load case from designer

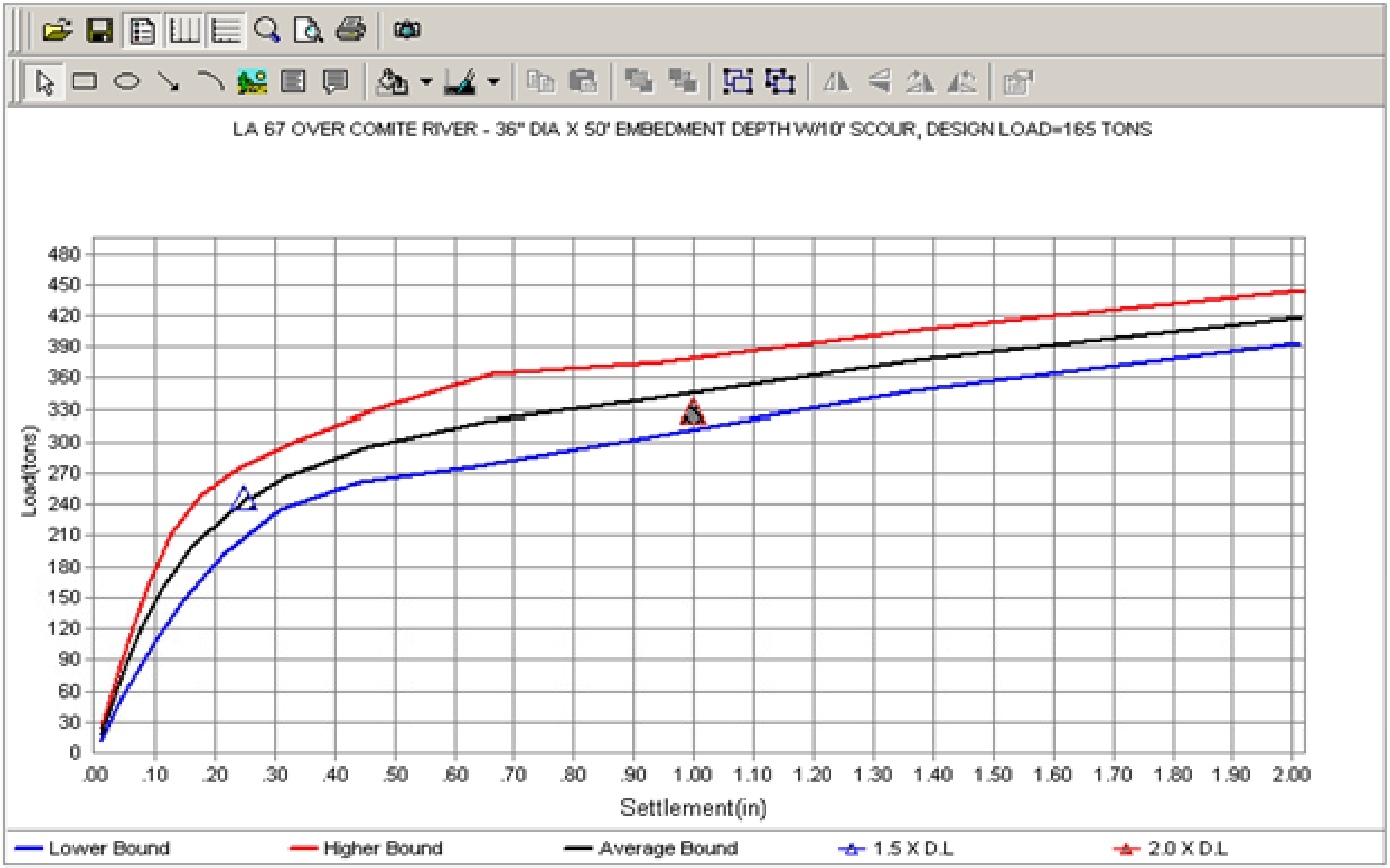


FACTORED SHAFT LOADS, LOAD CASE NO. 444

Group loading strength 5= 1(1.25DC1+1.5DW1+1.35LL10-1.35BR1+0.4WS1+1.0WL1)

	Dead load	**Live load**	**Braking force**	**Wind on struct.**	**Wind on live load**	**totals**
FY	853^{K}	263^{K}	-32^{K}	-47^{K}	-9^{K}	1028^{K}
FX	-23^{K}	-15^{K}	-12^{K}	-8^{K}	-3^{K}	-61^{K}
FZ	-	-	20^{K}	-7^{K}	-3^{K}	10^{K}
MX	$1'^{K}$	$5'^{K}$	$724'^{K}$	$-173'^{K}$	$-74'^{K}$	$483'^{K}$
MZ	$207'^{K}$	$136'^{K}$	$172'^{K}$	$116'^{K}$	$50'^{K}$	$681'^{K}$

NORMALIZED CURVES SHOWING LOAD TRANSFER VS SETTLEMENT

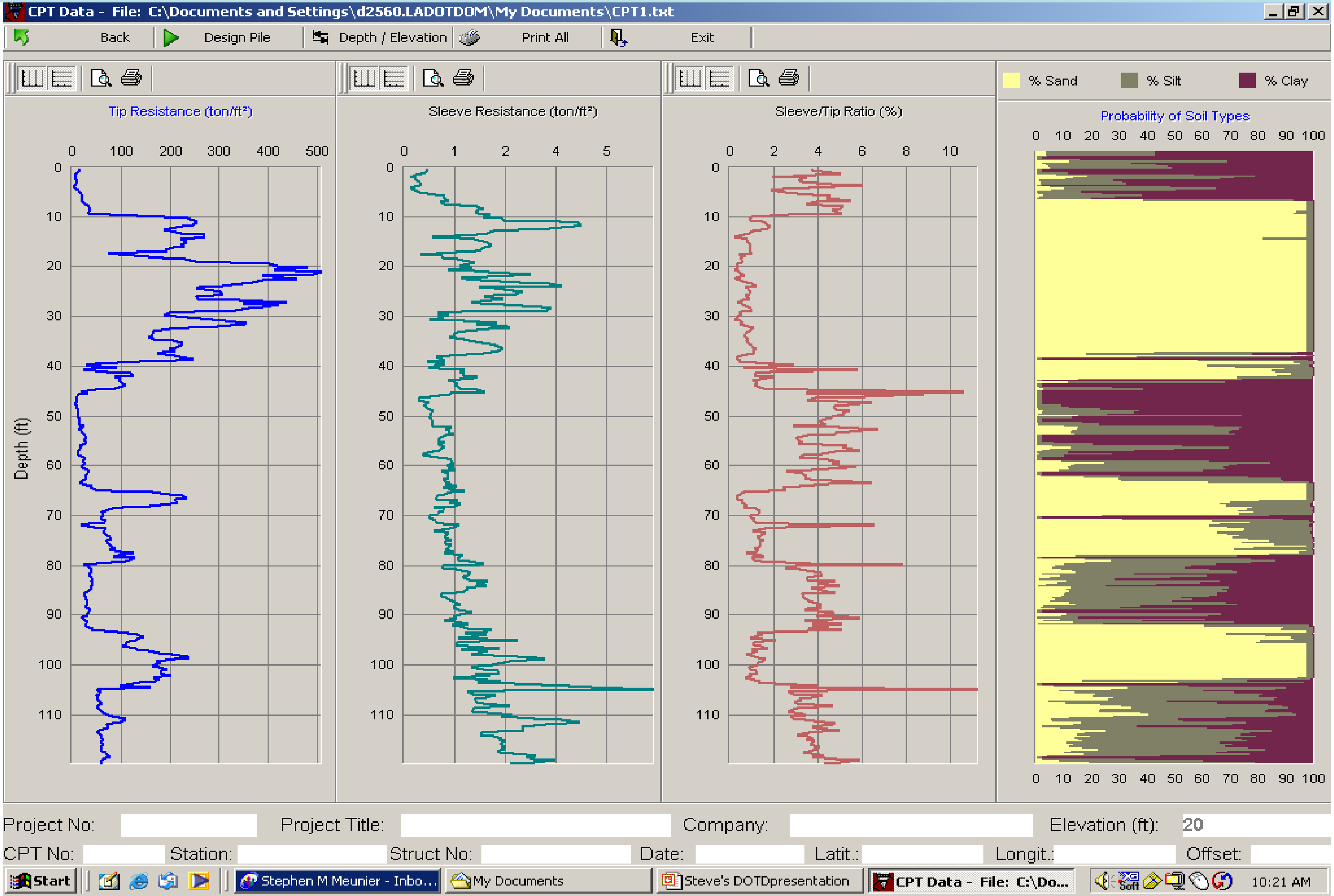


IIIb. Testing deployed in our local projects

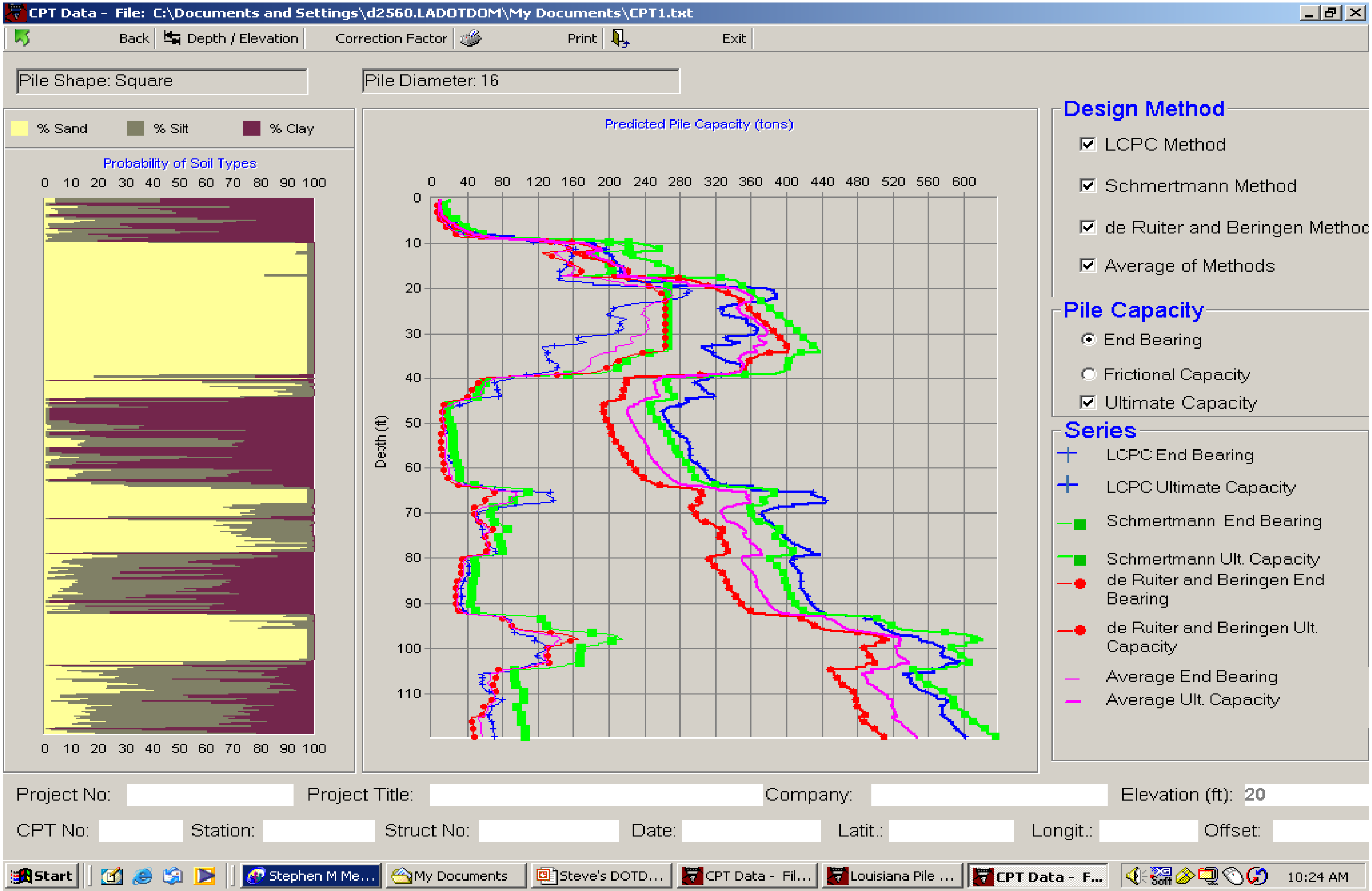
CPT

- STATIC AND DYNAMIC TESTING
- LRFD REWARDS TESTING, IMPROVES THE KNOWNS AND LOWERS RISKS

CPT RESISTANCE



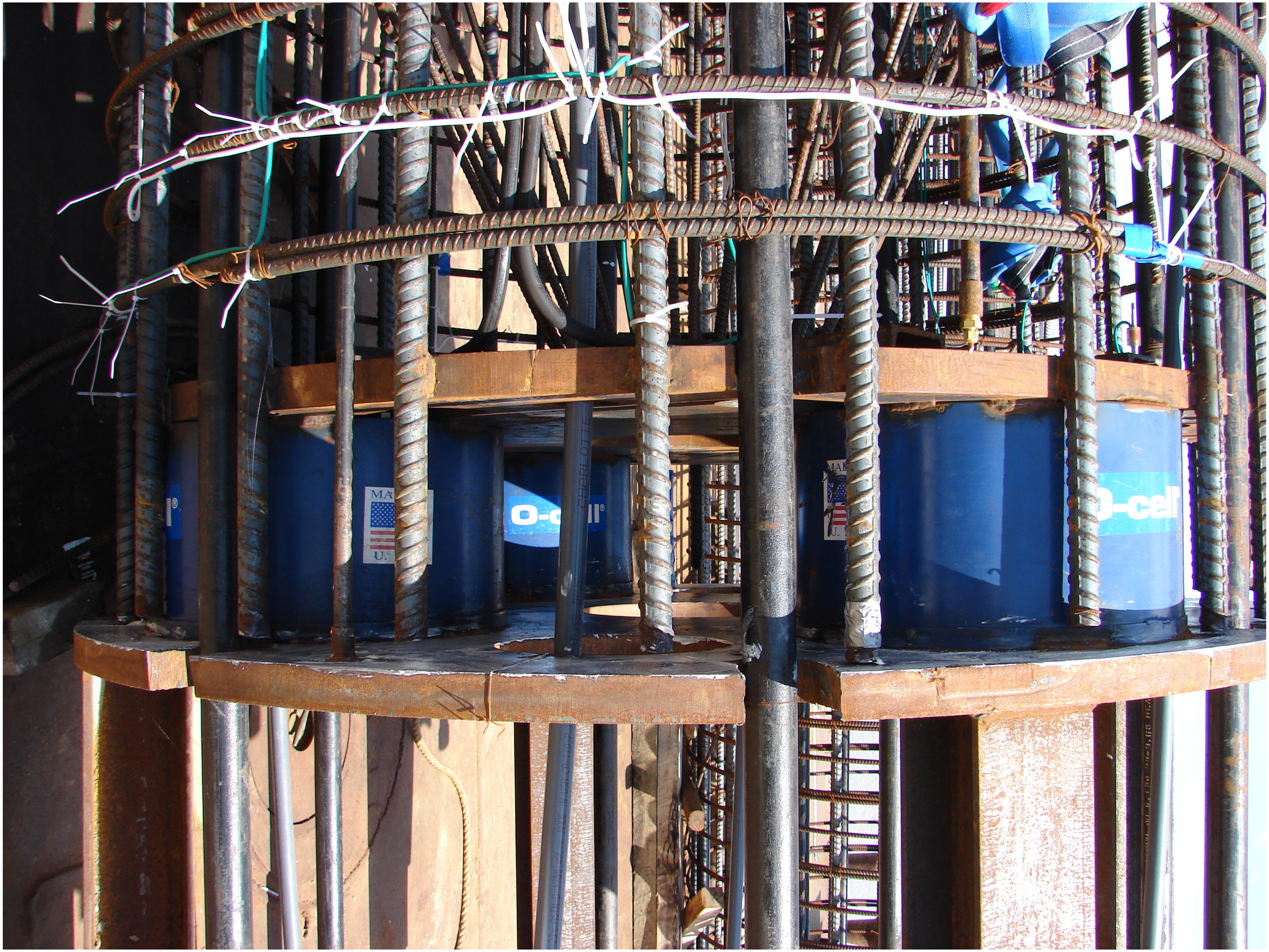
CPT PILE CAPACITY PREDICTION



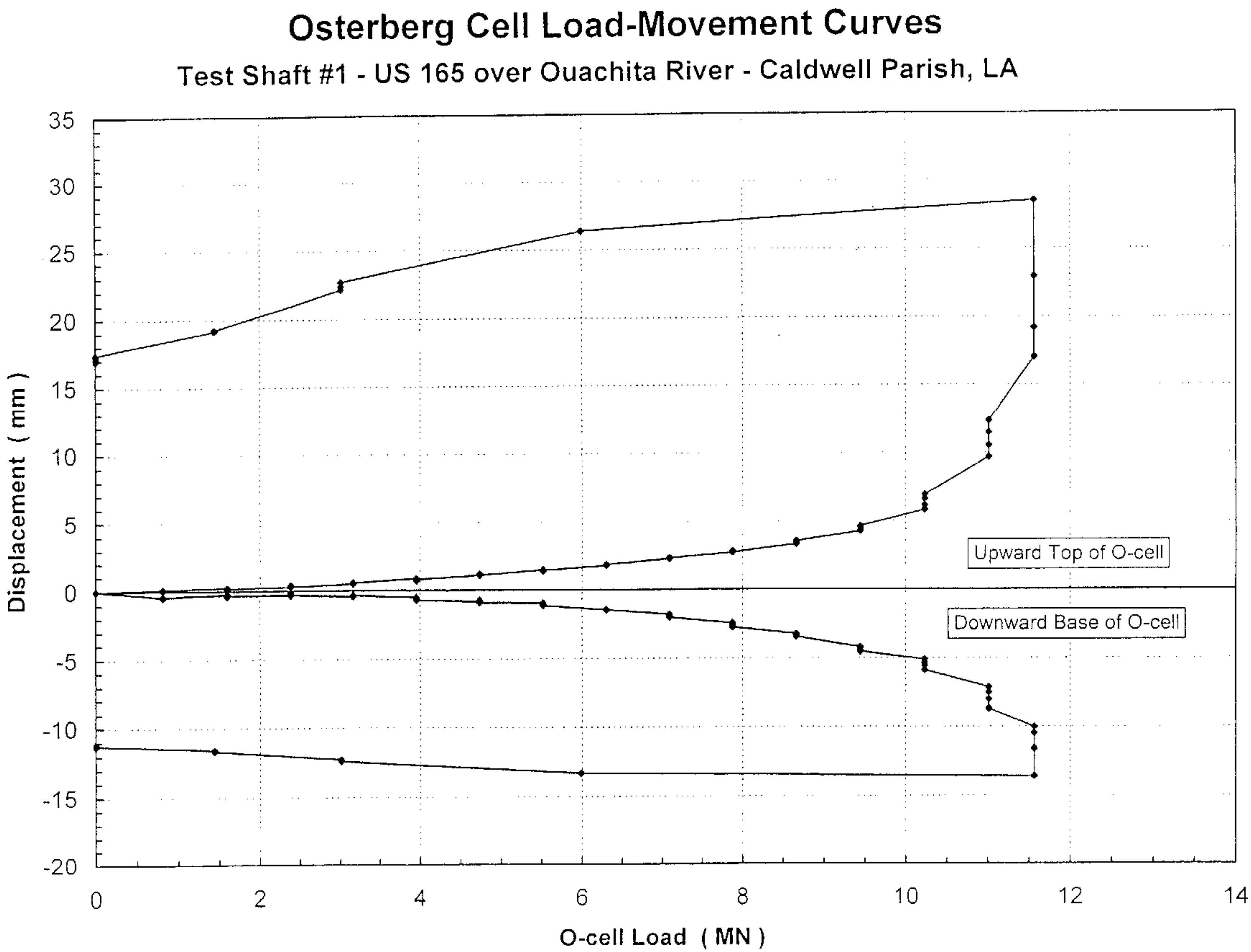
PDA AND CAPWAP ANALYSIS

LATERAL STATNAMIC TEST

OSTERBERG CELL



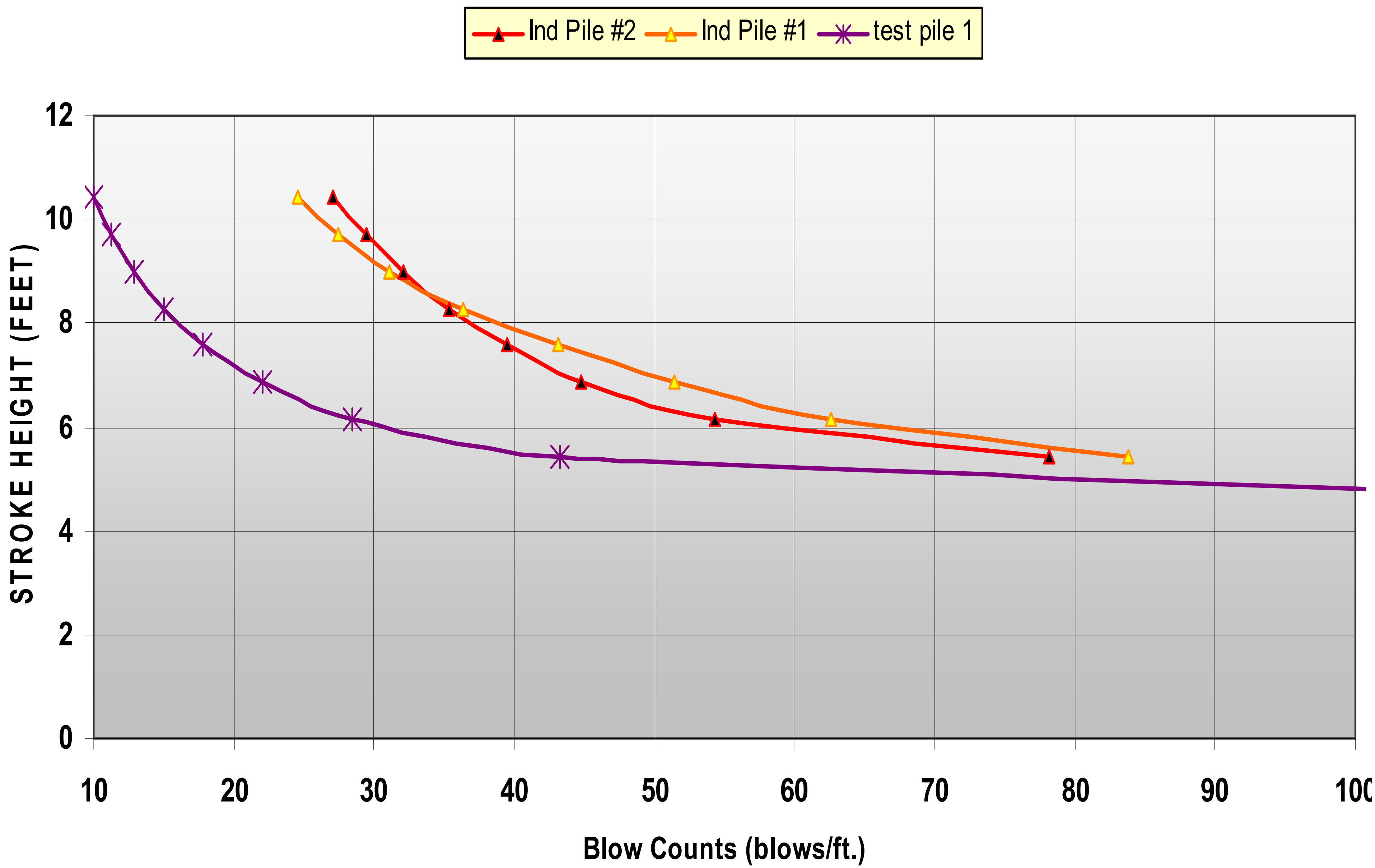
OSTERBERG CELL


Osterberg Cell Load-Movement Curves
Test Shaft #1 - US 165 over Ouachita River - Caldwell Parish, LA
Displacement (mm)
35
30
25
20
15
10
5
0
-5
-10
-15
-20
0
2
4
6
8
10
12
14
O-cell Load (MN)
Upward Top of O-cell
Downward Base of O-cell

CSL-DRILLED SHAFT

PN 022-03-0039
Str. No. 0220308221- TP1
Str. No. 0220305061- IP1
Str. No. 0220305181- IP2

Inspection Chart for Pile Bearing Capacity
16" (400mm) PPC PILES- Initial Drive



Challenges for the future

IV. Goals and Challenges for the future

1. Continue to improve the reliability index by taking advantage of detailed local data collected for the different methods and tests

IV. Goals and Challenges for the future

- To see the resistance factors for Louisiana conditions, please attend presentation titled: LRFD Calibration of Axially-Loaded Concrete Piles Driven into Soft Soils Time: January 14, 2008. 10:15am-12pm (Session 262)

RESISTANCE FACTORS FOR DRIVEN PILES, 10-41

Condition/Resistance Determination Method		Resistance Factor
Nominal Resistance of Single Pile in Axial Compression—Static Analysis Methods, φ_{stat}	Skin Friction and End Bearing: Clay and Mixed Soils	
	α-method (*Tomlinson, 1987*; *Skempton, 1951*)	0.35
	β-method (*Esrig & Kirby, 1979*; *Skempton, 1951*)	0.25
	λ-method (*Vijayvergiya & Focht, 1972*; *Skempton, 1951*)	0.40
	Skin Friction and End Bearing: Sand	
	Nordlund/Thurman Method (*Hannigan et al., 2005*)	0.45
	SPT-method (Meyerhof)	0.30
	CPT-method (Schmertmann)	0.50
	End bearing in rock (*Canadian Geotech. Society, 1985*)	0.45
Block Failure, φ_{bl}	Clay	0.60
Uplift Resistance of Single Piles, φ_{up}	Nordlund Method	0.35
	α-method	0.25
	β-method	0.20
	λ-method	0.30
	SPT-method	0.25
	CPT-method	0.40
	Load test	0.60
Group Uplift Resistance, φ_{ug}	Sand and clay	0.50
Horizontal Geotechnical Resistance of Single Pile or Pile Group	All soils and rock	1.0

IV. Goals and Challenges for the future

Site Variability Determination

In order to justify the use of higher resistance factors using field verification tests, site variability shall be evaluated. Paikowsiky et al. (2004) suggested the following steps to determine the site variability.

- Step 1: For each identified significant stratum at each boring location, determine the average property value, e.g., SPT value, qc value, etc., within the stratum for each boring.
- Step 2: Determine the mean and coefficient of variation (COV) of the average values for each stratum determined in Step 1.
- Step 3: Categorize the site variability as low if the COV is less than 25 percent, medium if the COV is between 25% and 40%, and high if the COV is 40% or more.
- AASHTO specifications do not address how to estimate COVs. Geotechnical Engineering Circular No. 5 provides four techniques in determining variabilities of particular design parameter

Table 10.5.5.2.3-2 Relationship between Number of Static Load Tests Conducted per Site and φ (after *Paikowsky et al., 2004*).

Number of Static Load Tests per Site	Resistance Factor, φ		
	Site Variability[a]		
	Low[a]	Medium[a]	High[a]
1	0.80	0.70	0.55
2	0.90	0.75	0.65
3	0.90	0.85	0.75
≥4	0.90	0.90	0.80

a See commentary.

Interim 2006

Goals and Challenges for the future

2. Strive for consistent reliability for the entire structure in all possible failure modes.

Clearly define redundancy of our conditions and structure types

- For five piles or more, is the cap connecting the piles capable of resisting the load with the possible partial loss of one of the piles ?
- Has AASHTO made clear the implied redundancy is only regarding axial loads, The system may well be non redundant against slope failures, debris, etc…

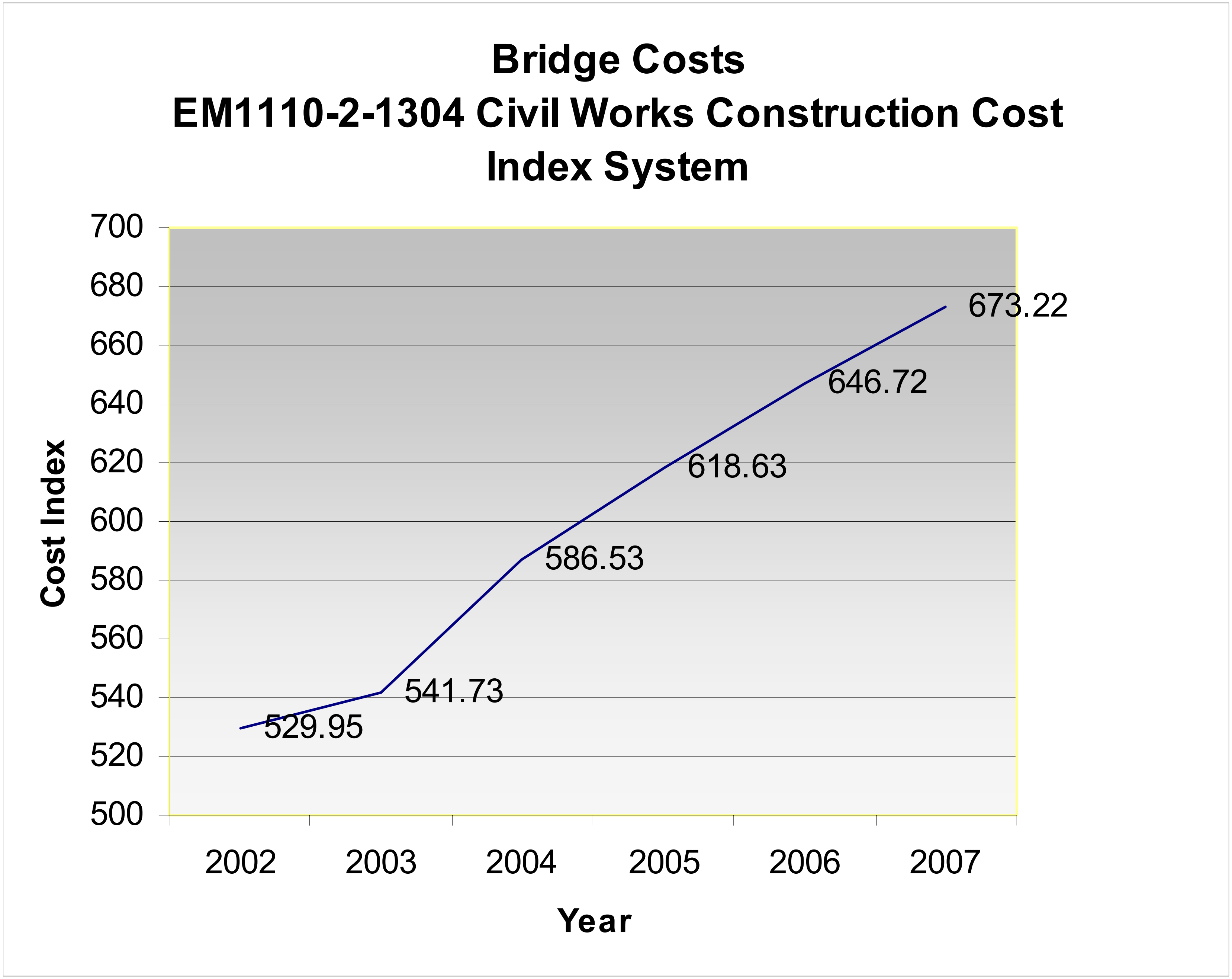
AASHTO SEC 10 page 10-39 explains the choices of β

For the statistical calibrations using reliability theory, a target reliability index, β, of 2.3 (an approximate probability of failure of 1 in 100) was used. The selection of this target reliability assumes a significant amount of redundancy in the foundation system is present, which is typical for pile groups containing at least five piles in the group (*Paikowsky et al., 2004*). For smaller groups and single piles, less redundancy will be present. The issue of redundancy, or the lack of it, is addressed in Article 1.3.4 through the use of η_R. The values for η_R provided in that article have been developed in general for the superstructure, and no specific guidance on the application of η_R to foundations is provided. Paikowsky et al. (*2004*) indicate that a

Goals and Challenges for the future

3. Do not compromise safety, the integrity of the AASHTO code and bridge design life as one attempts to thwart escalating construction costs

Goals and Challenges for the future



IV. Goals and Challenges for the future

- Improve the code to account for the appearance of complex partnerships and new methods of contracting, construction and ownership

We have come a long way….

C-93-101 VESSEL

Gross wt. Of Vehicle	1,025,268 lbs.
Total No. of Axle 18	
Total No. of Tire 144	
Total Length	121 ft.
Width	20' - 10 1/8"
Height	24' - 7 1/4"

questions ?