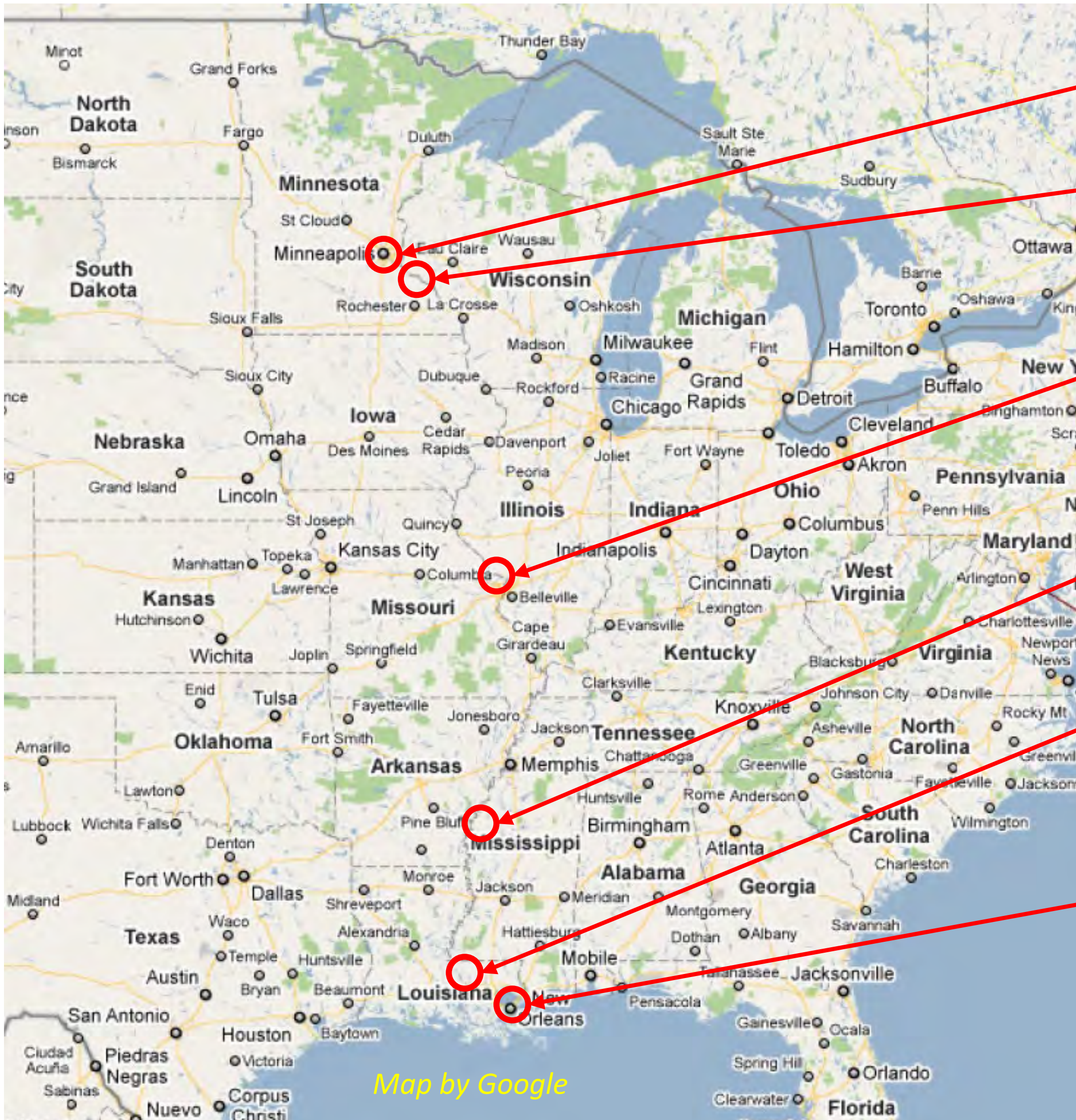
A Foundation Engineering Trip down the Mississippi River

Dan Brown, P.E.
Dan Brown and Associates

DAN BROWN AND ASSOCIATES

Our Tour Stops



I-35W Minneapolis

U.S. 61 Bridge, Hastings, MN

Eads Bridge and Stan Musial Bridge (I-70), St. Louis

Greenville Bridge, Greenville, MS

John James Audubon Bridge, St. Francisville, La.

Huey P. Long Bridge, New Orleans

Characteristics of Miss. River

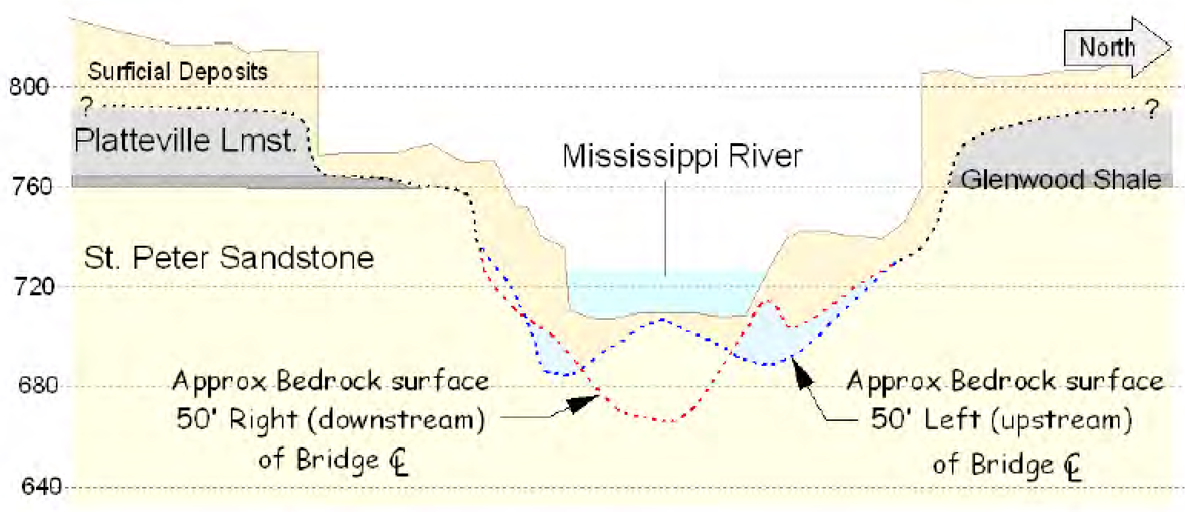
- Deep scour
- Vessel collision
- High flow velocities
- River fluctuations

MN I-35W Replacement

- Emergency Design-Build Contract
- ***$200,000/day*** bonus/penalty

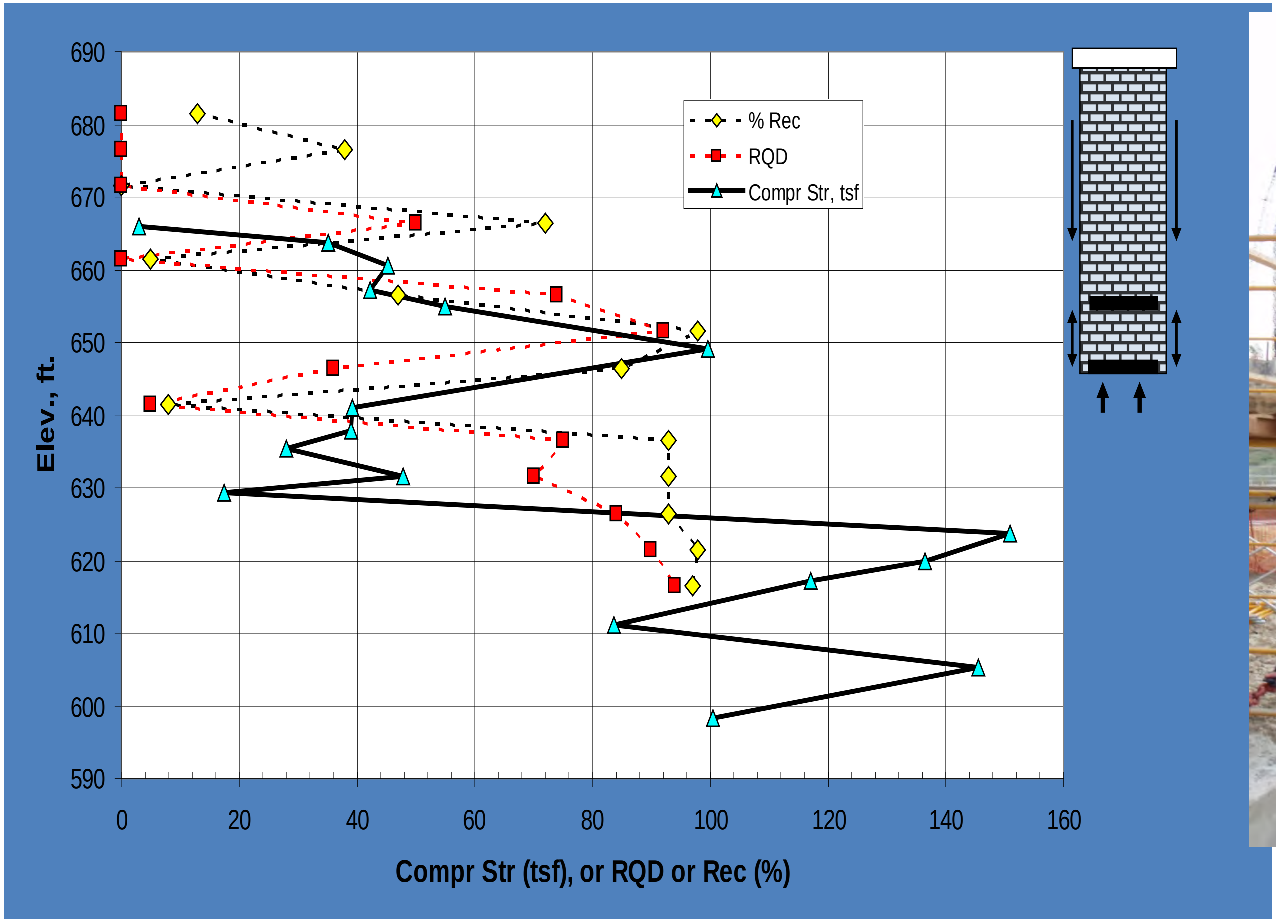
Testing Plan

- Testing important to:
  - Verify required embedment into sandstone
  - Demonstrate reliability of installation
- But timing was critical
- Allowed contractor to test prototype shaft



Early Issue – Artesian Groundwater

Test Shaft



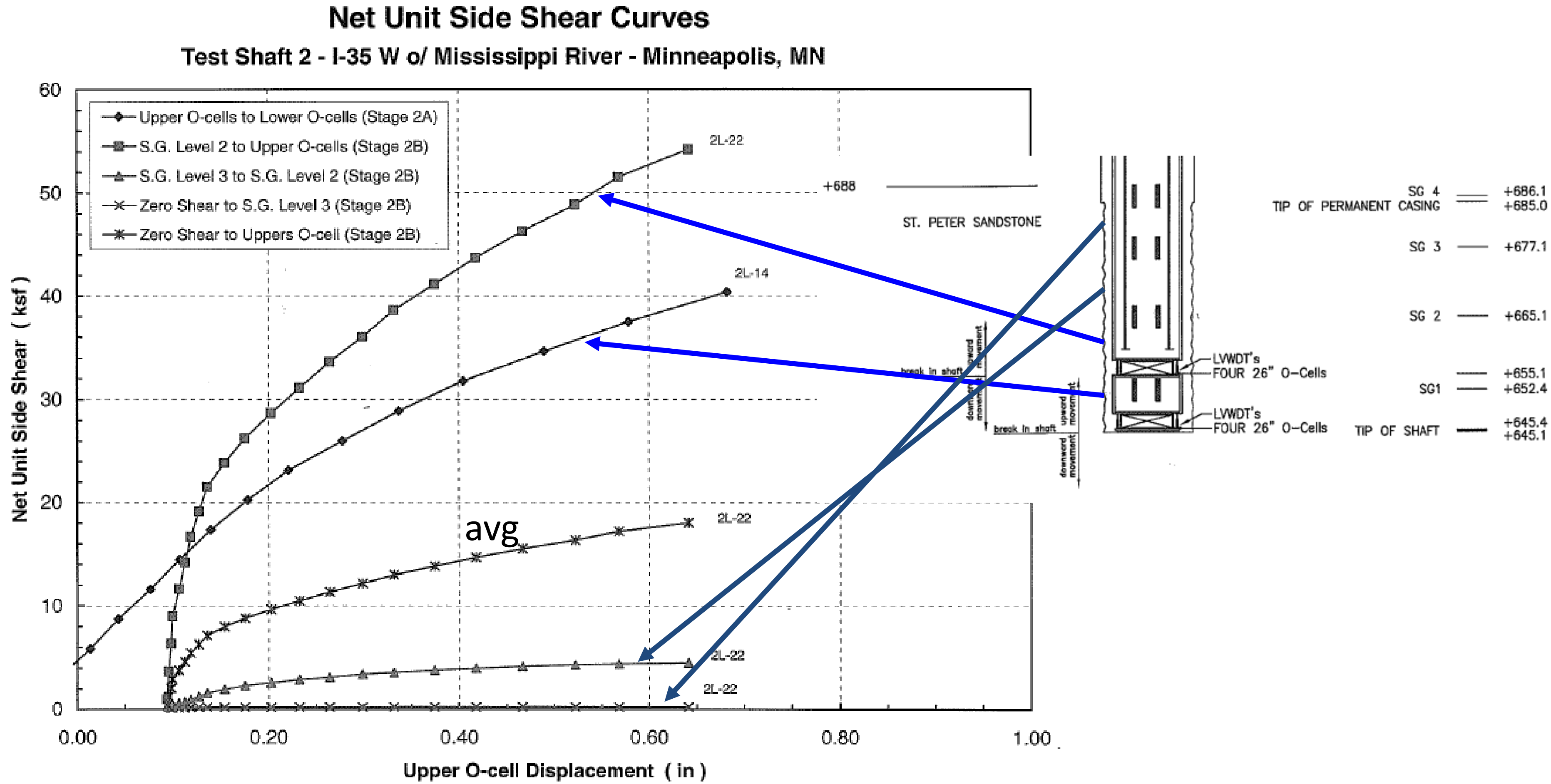
% Rec
RQD
Compr Str, tsf
Elev., ft.
Compr Str (tsf), or RQD or Rec (%)
690
680
670
660
650
640
630
620
610
600
590
0
20
40
60
80
100
120
140
160

O-cell
O-cell

Key Issues

- Top portion of rock extremely weathered & “soil-like”, easy to drill with earth auger
- Socket defined from “good rock” as indicated by drilling resistance with rock auger

35W – Side Resistance



35W Side Resistance

$$\frac{f_{SN}}{p_a} = C\sqrt{\frac{q_u}{p_a}}$$

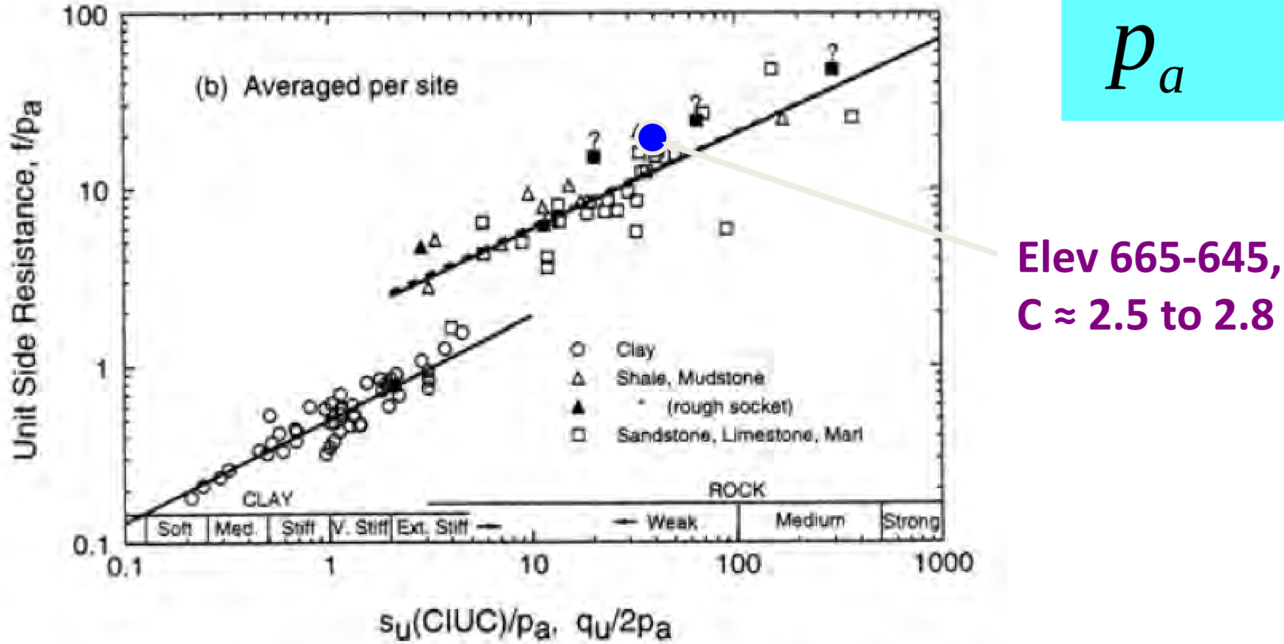
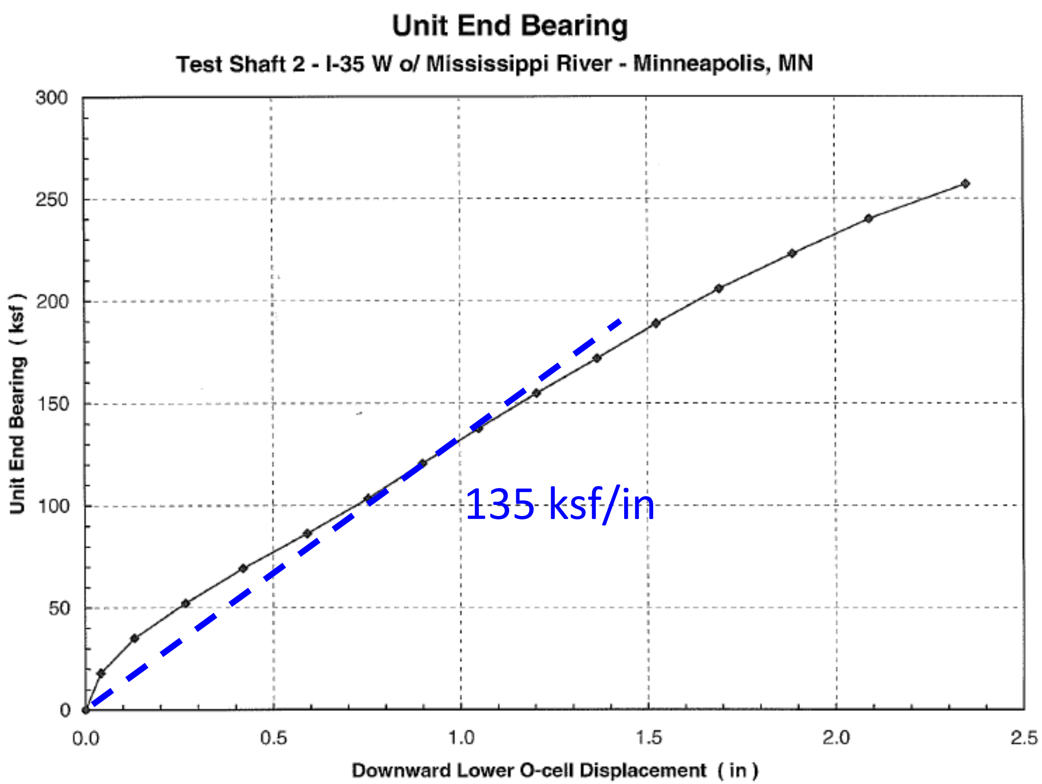


FIGURE 24 Unit side resistance versus strength (Kulhawy and Phoon 1993).

35W Base Resistance



With 78" dia,
ρ/B ≈ 0.01 at ρ=0.78"

For rigid circular footing on elastic half-space:

With ν = ¼ :

E = 7,800ksf = 54 ksi

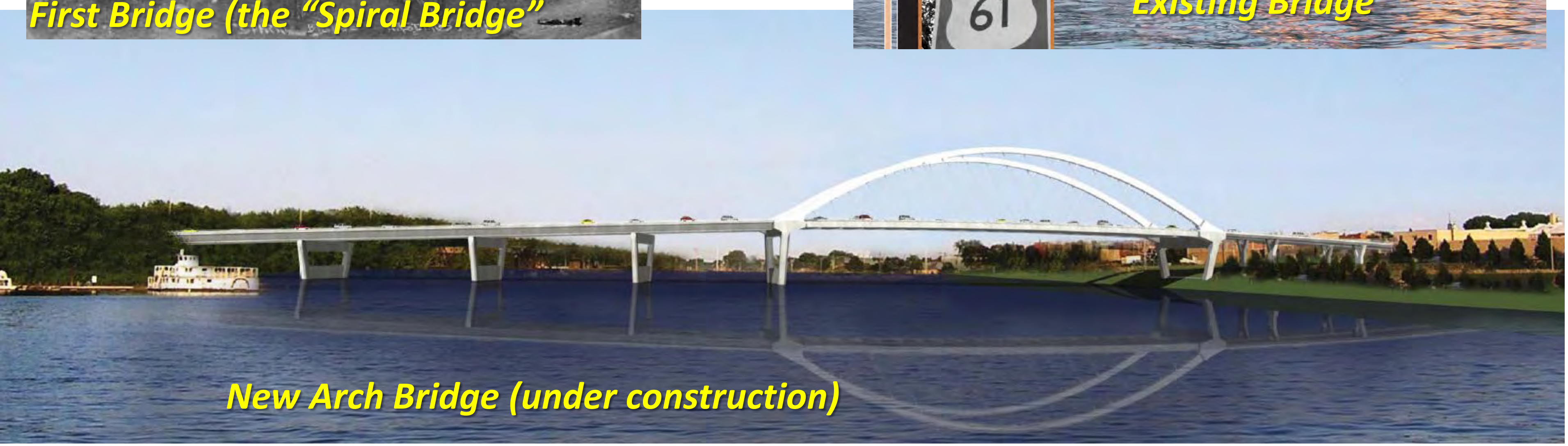
E ≈ 100q$_u$ for q_u ≈ 550psi

$$\rho_s = 0.79 \cdot \frac{qB\left(1-\nu^2\right)}{E}$$

U.S. 61 Bridge over Mississippi River
Hastings, Minnesota

First Bridge (the "Spiral Bridge")

Existing Bridge

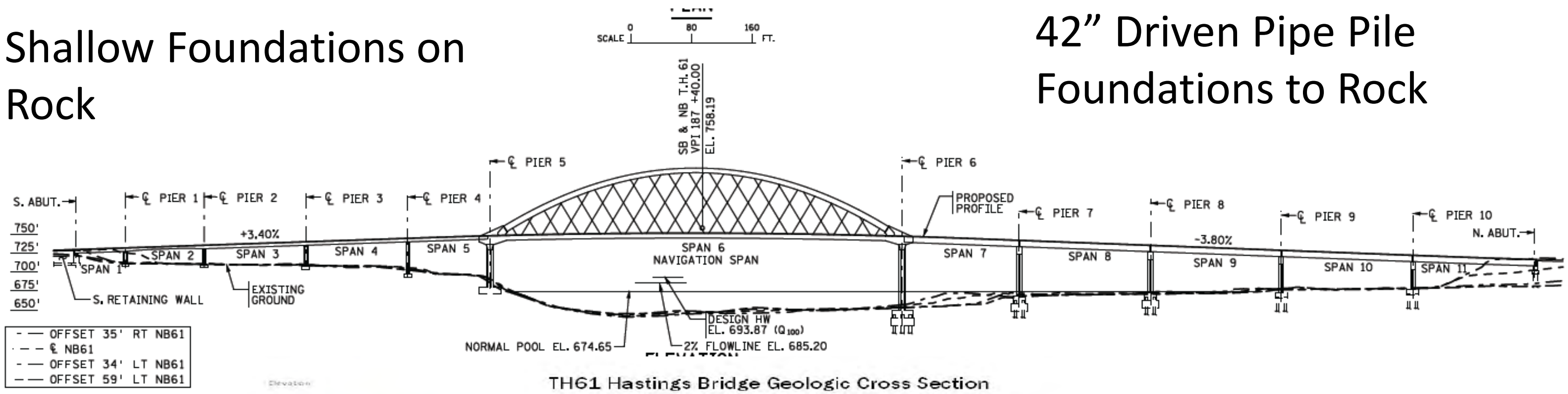


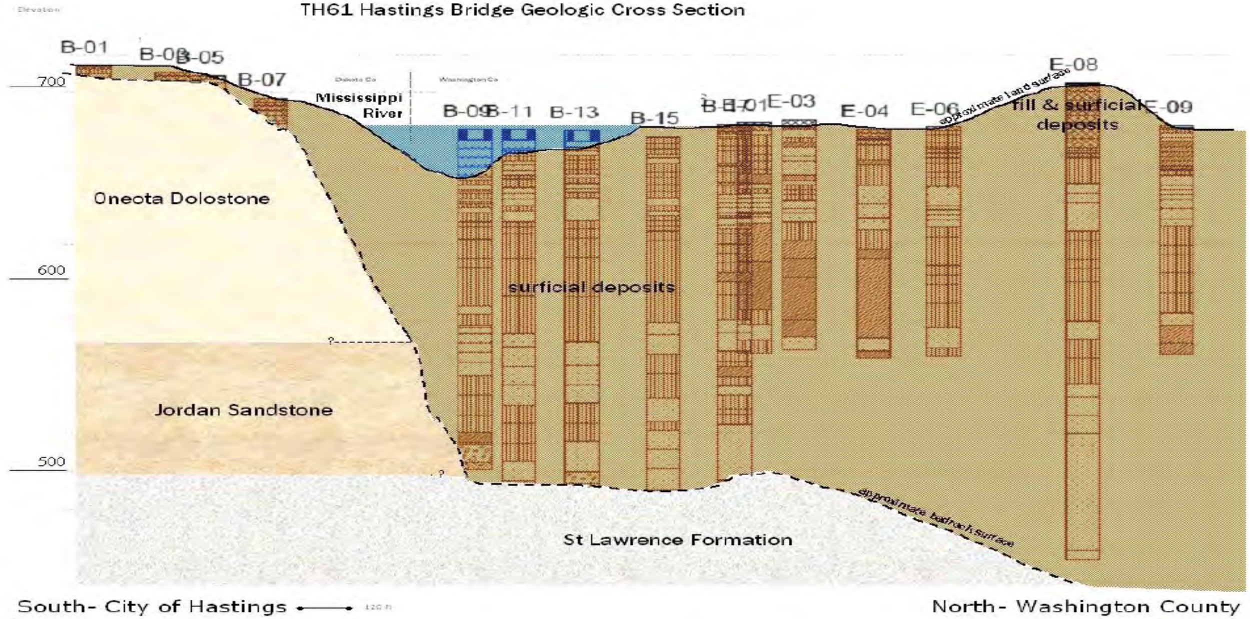
New Arch Bridge (under construction)

Subsurface Profile at Bridge

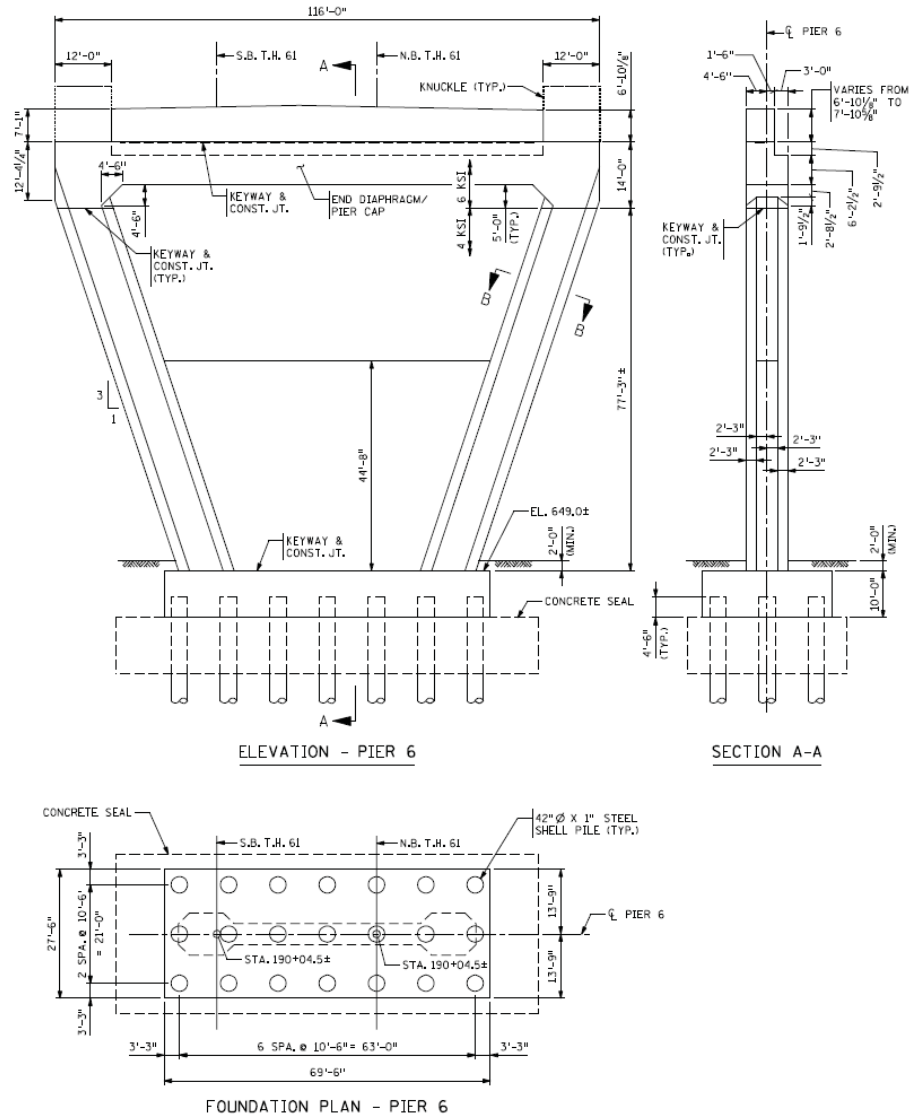
Shallow Foundations on Rock

42” Driven Pipe Pile Foundations to Rock

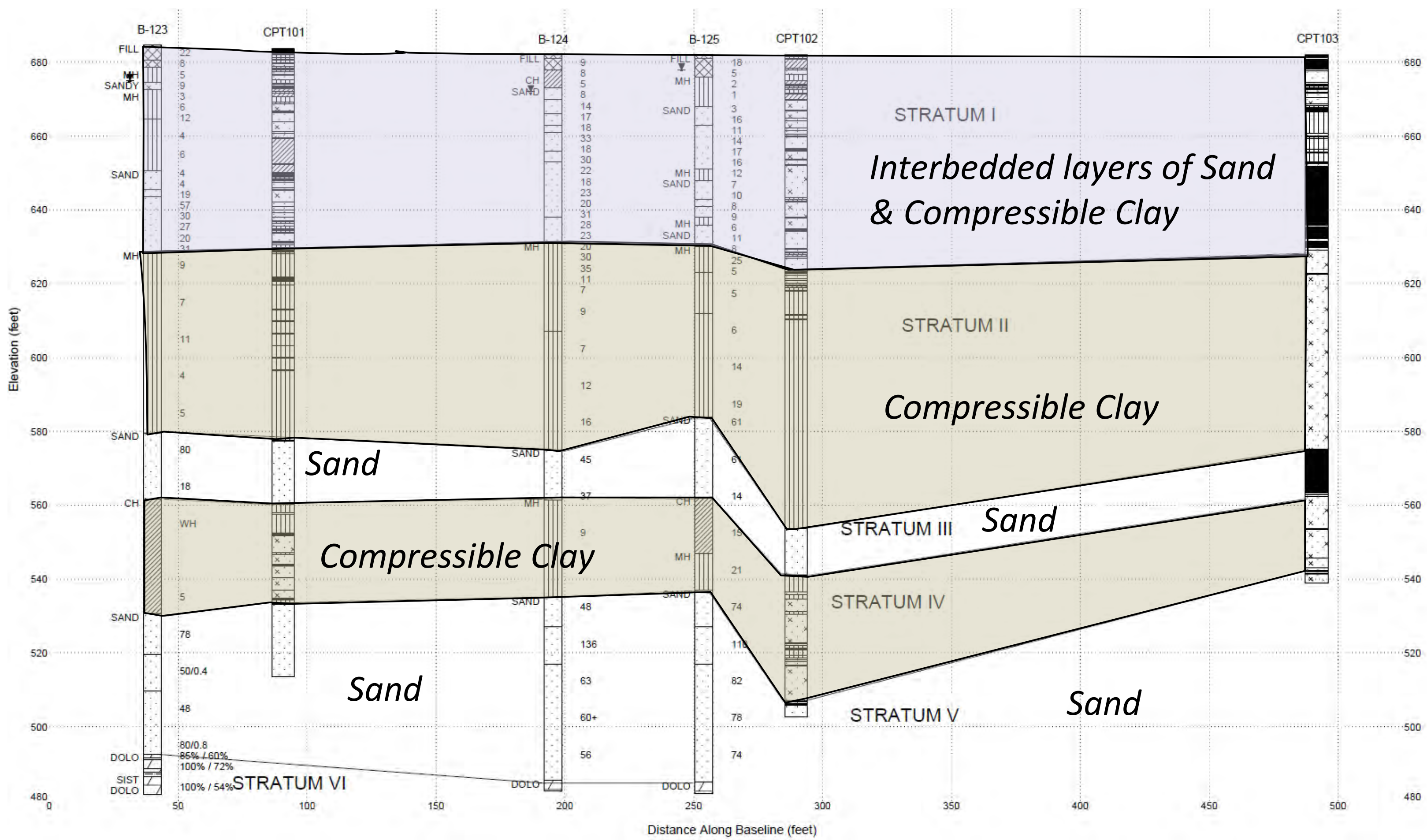




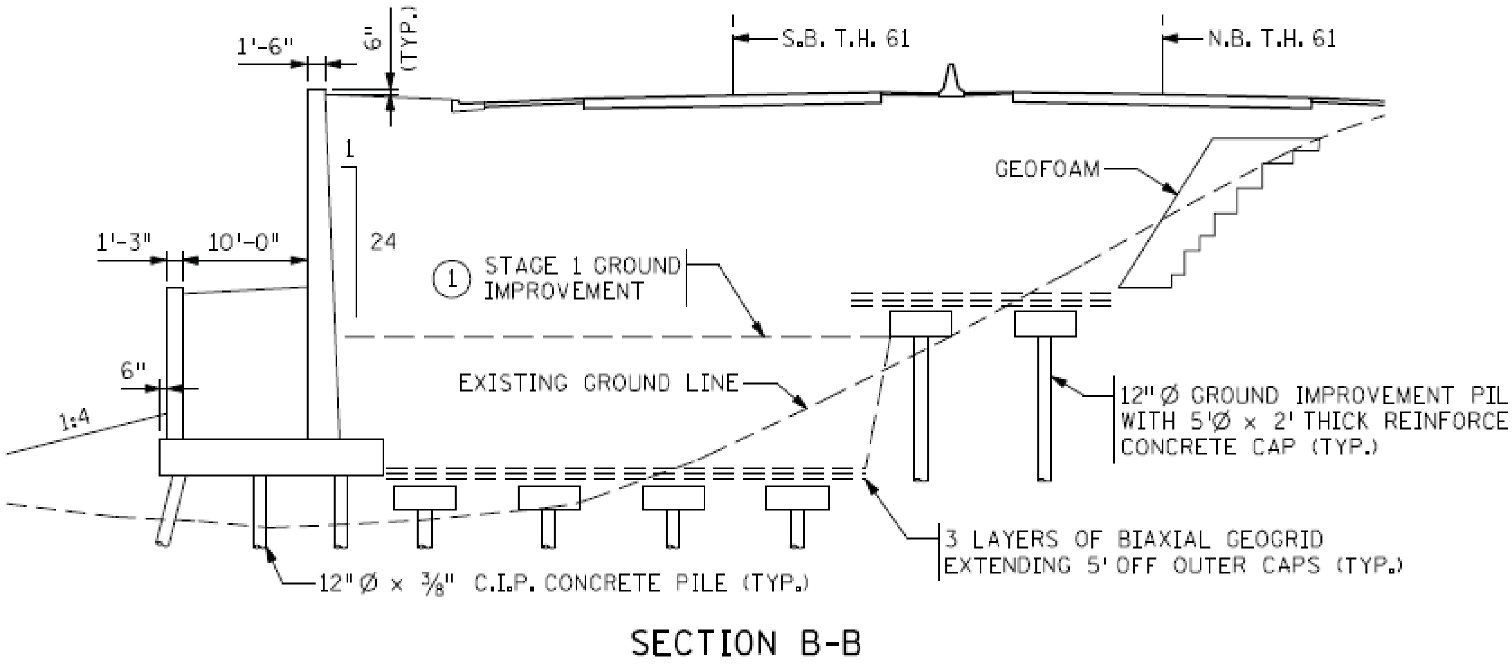
LDOEP Bridge Foundations



North Embankment

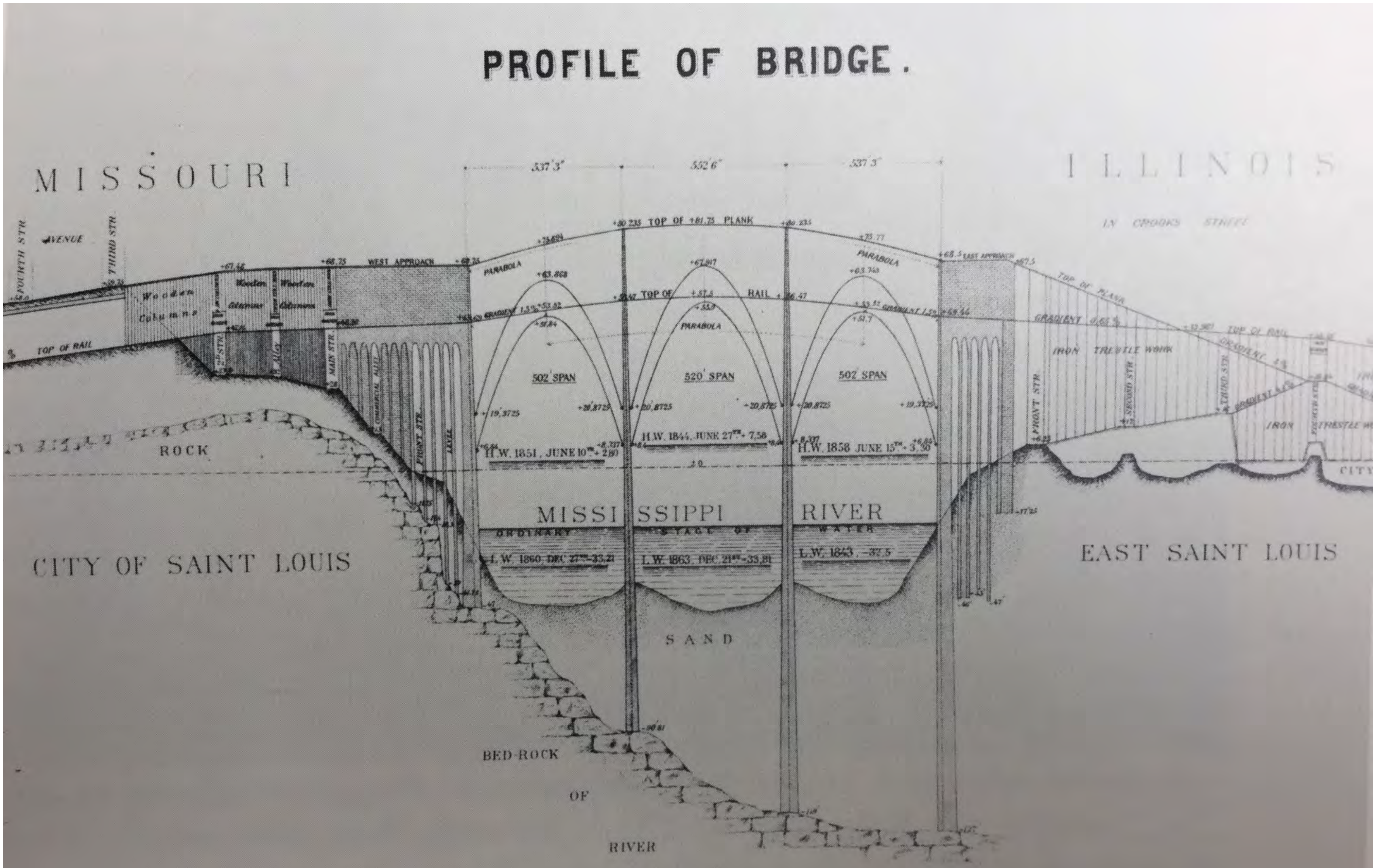


Column Supported Embankment Plan



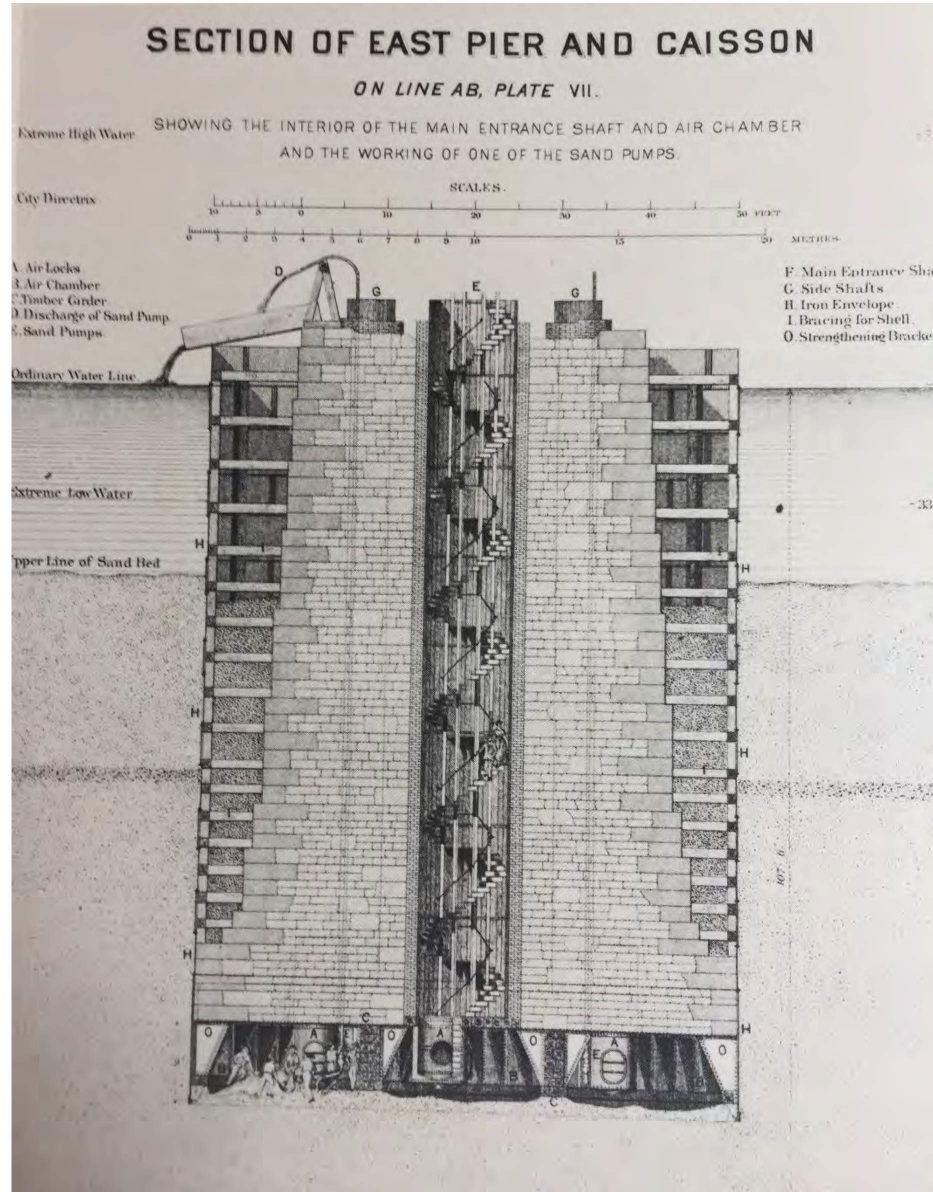
Welcome to St. Louis!

Eads Bridge


PROFILE OF BRIDGE.
MISSOURI
ILLINOIS
537' 3"
552' 6"
537' 3"
TOP OF +81.75 PLANK
WEST APPROACH
TOP OF RAIL
PARABOLA
GRADIENT
IRON TRESTLE WORK
502' SPAN
520' SPAN
502' SPAN
ROCK
H.W. 1851, JUNE 10TH + 2.89
H.W. 1844, JUNE 27TH + 7.58
H.W. 1858 JUNE 15TH + 3.30
MISSISSIPPI RIVER
ORDINARY STAGE OF WATER
L.W. 1860 DEC 27TH -33.21
L.W. 1863, DEC 21ST -33.81
L.W. 1843 -37.5
CITY OF SAINT LOUIS
EAST SAINT LOUIS
SAND
BED-ROCK
OF
RIVER

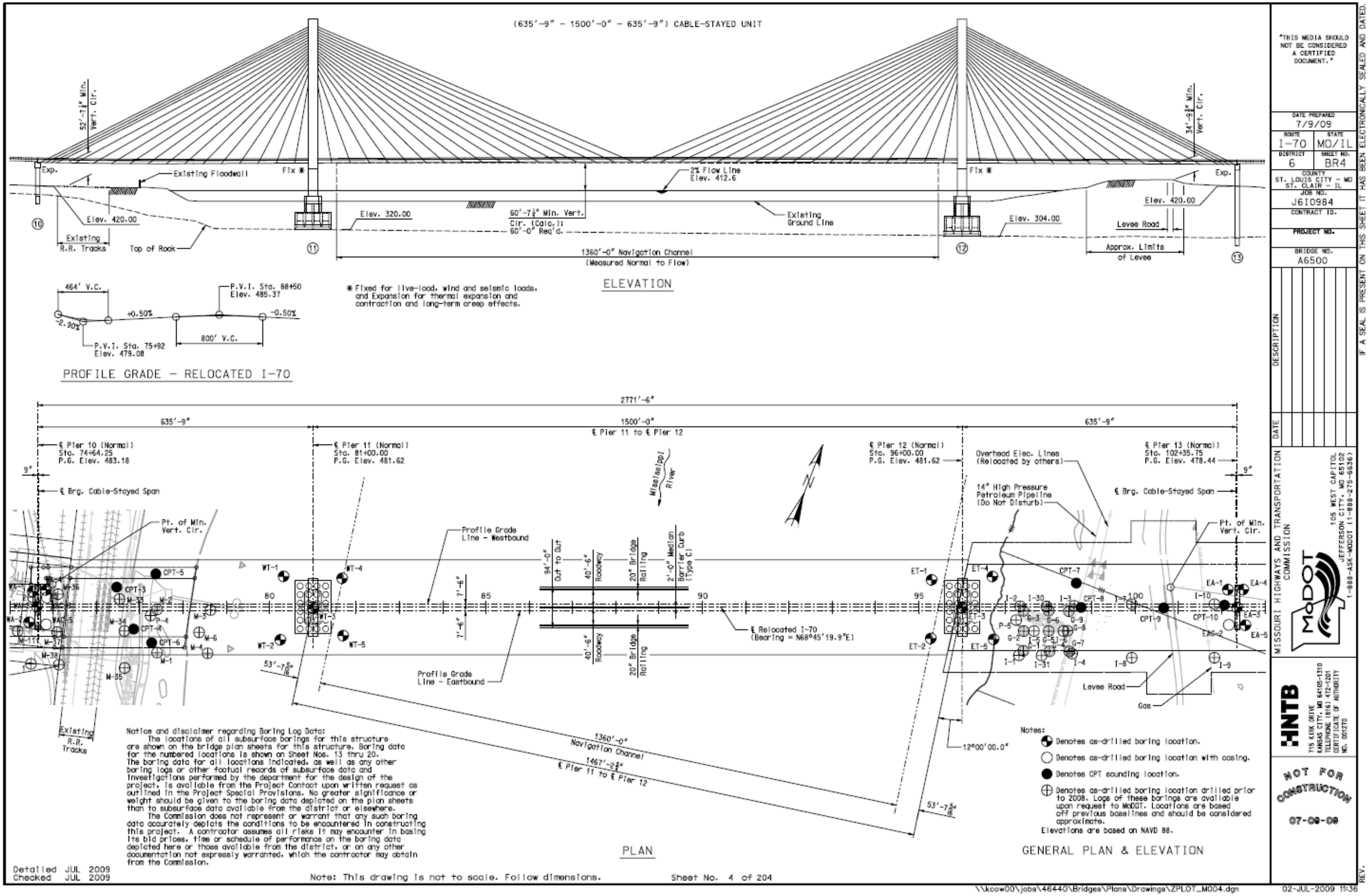
Eads Bridge (Constr 1868-74)

- National historic landmark
- Pioneering use of pneumatic caissons
- Eads adopted techniques from salvage diving
- Per Alphonse Jaminet (physician)
  - 600 men worked in the caissons;
  - 119 were stricken with "caisson disease";
  - 14 died



Sketches and photos from Miller and Scott, *The Eads Bridge*, Missouri Historical Press

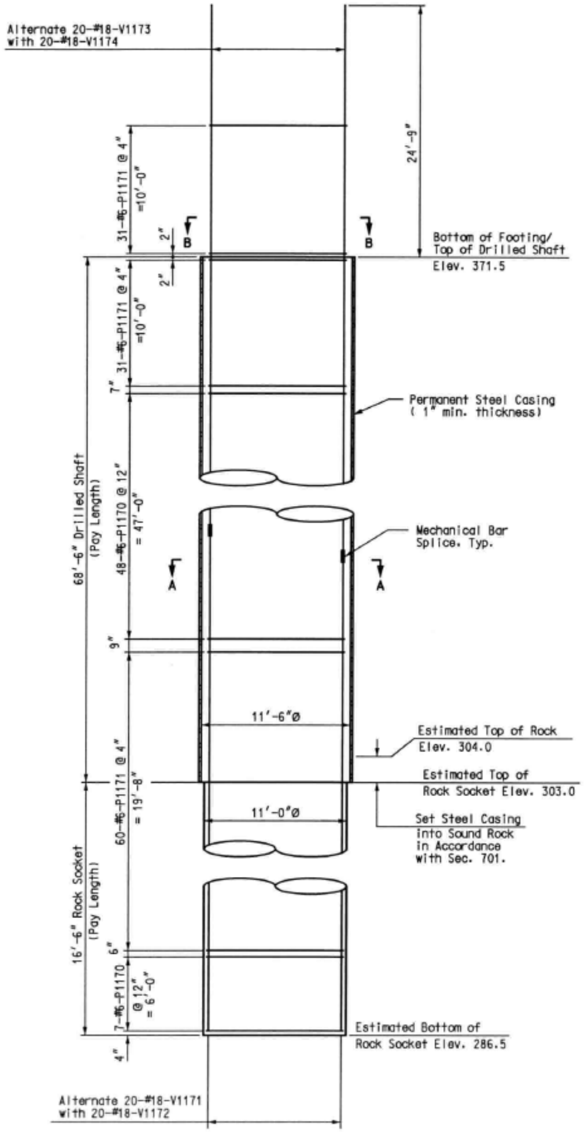
Stan Musial/Veterans Memorial Bridge

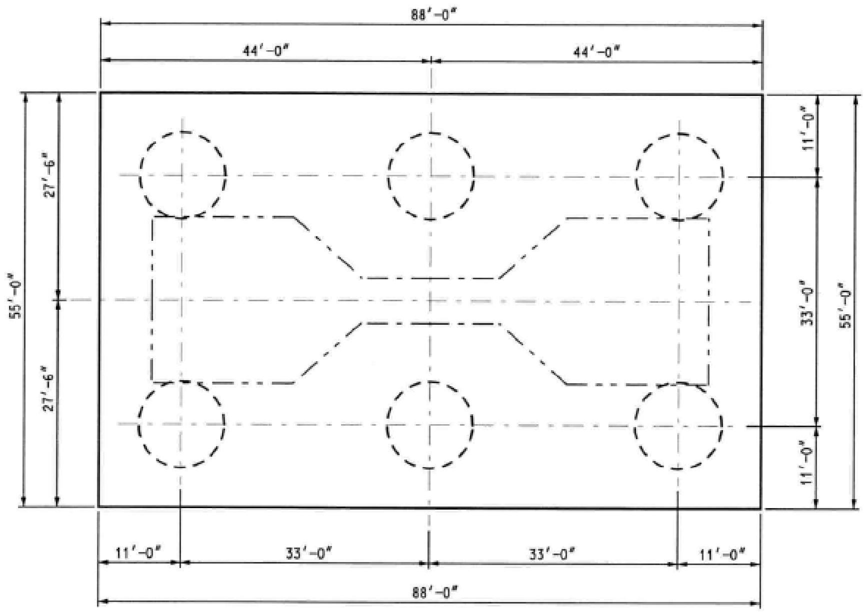


Alternate Technical Concept (ATC)

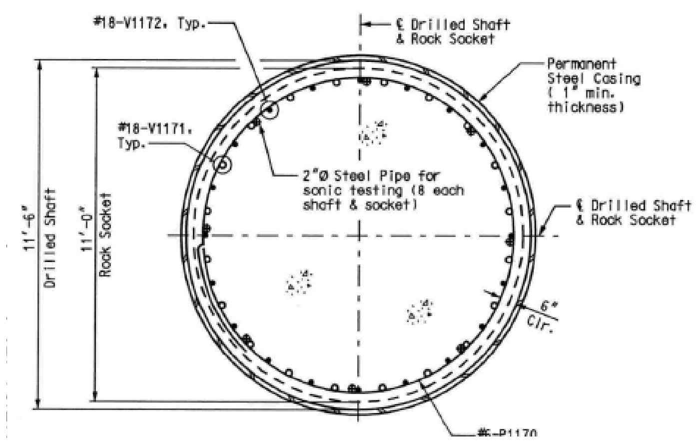
- Prequalified Contractors only
- Pre-bid *confidential* submittal of ATC for owner evaluation & approval
- Contractor may bid base design and/or pre-approved ATC design
- DBA worked for Massman-Traylor-Alberici to develop ATC foundation design

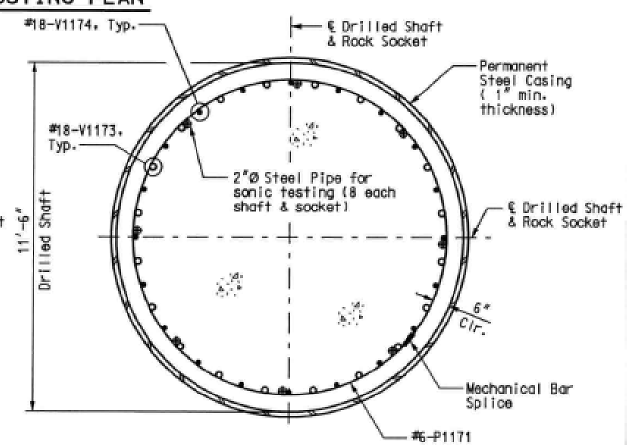
Alternate Design



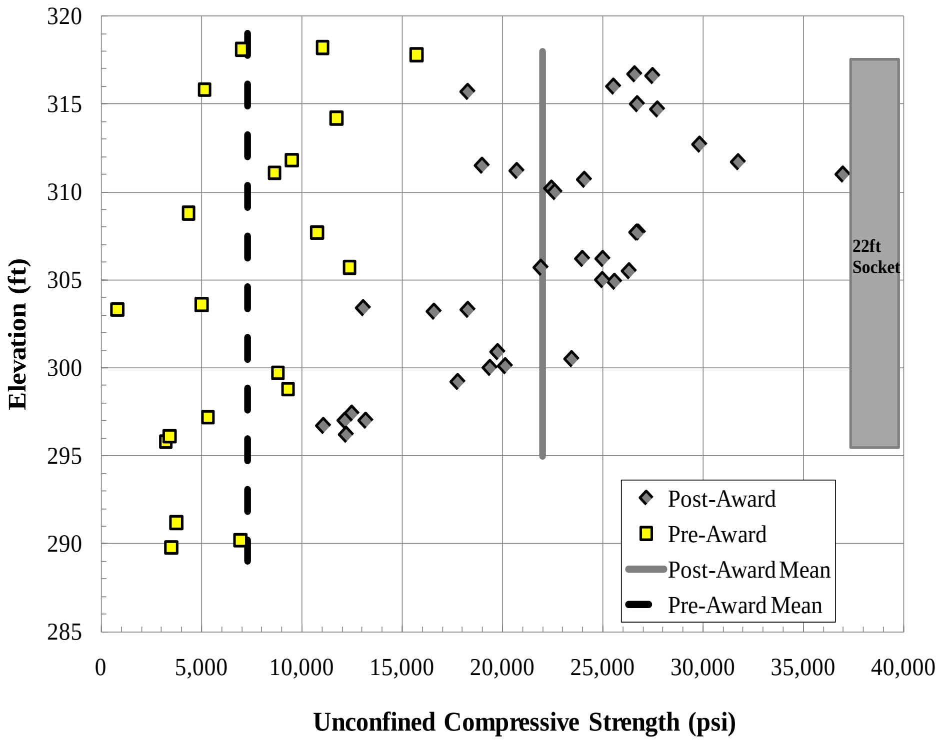


FOOTING PLAN

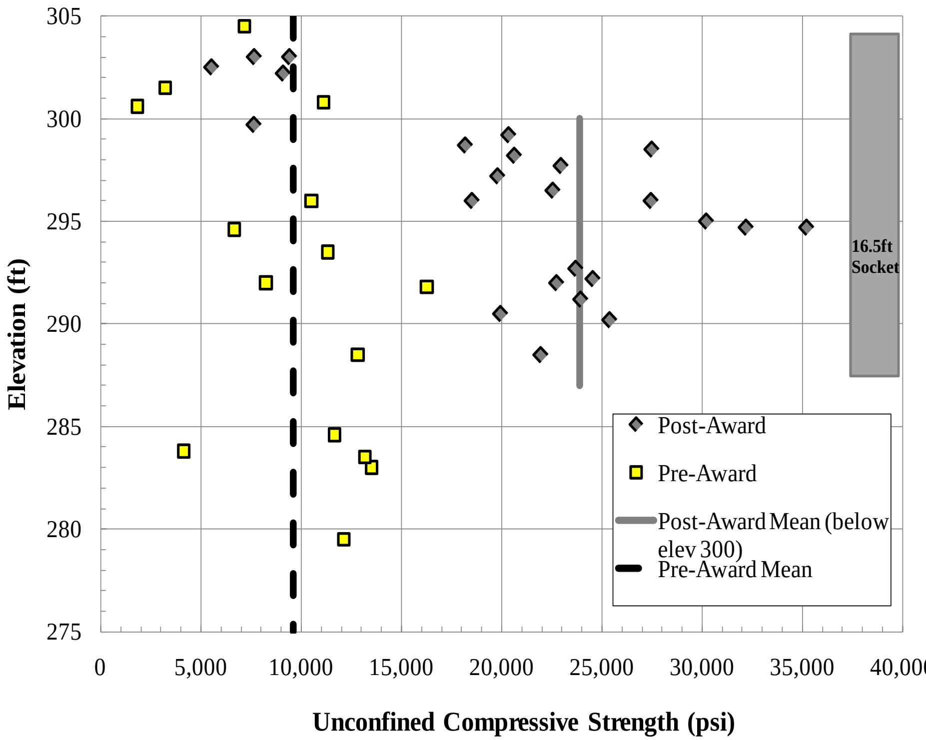




Limestone Bedrock Compressive Strength Data



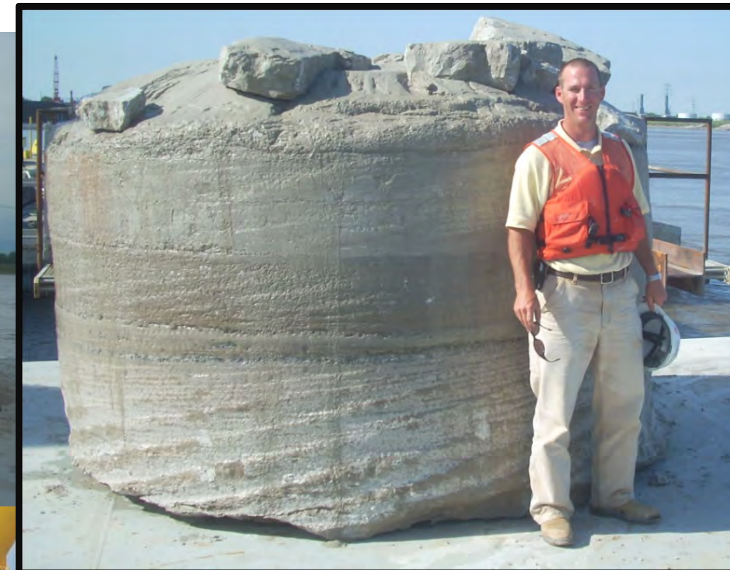
Pier 11



Pier 12

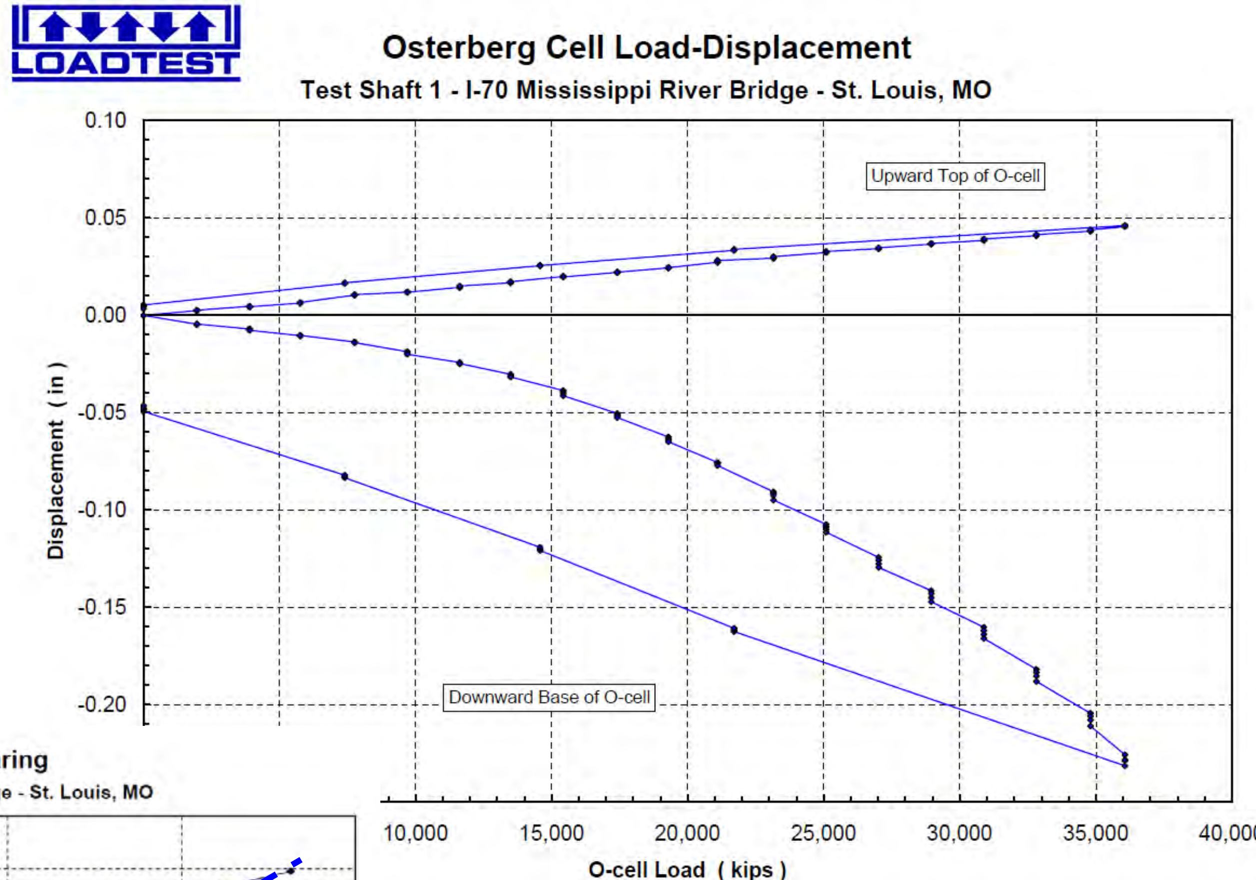
Load Test Shaft Construction

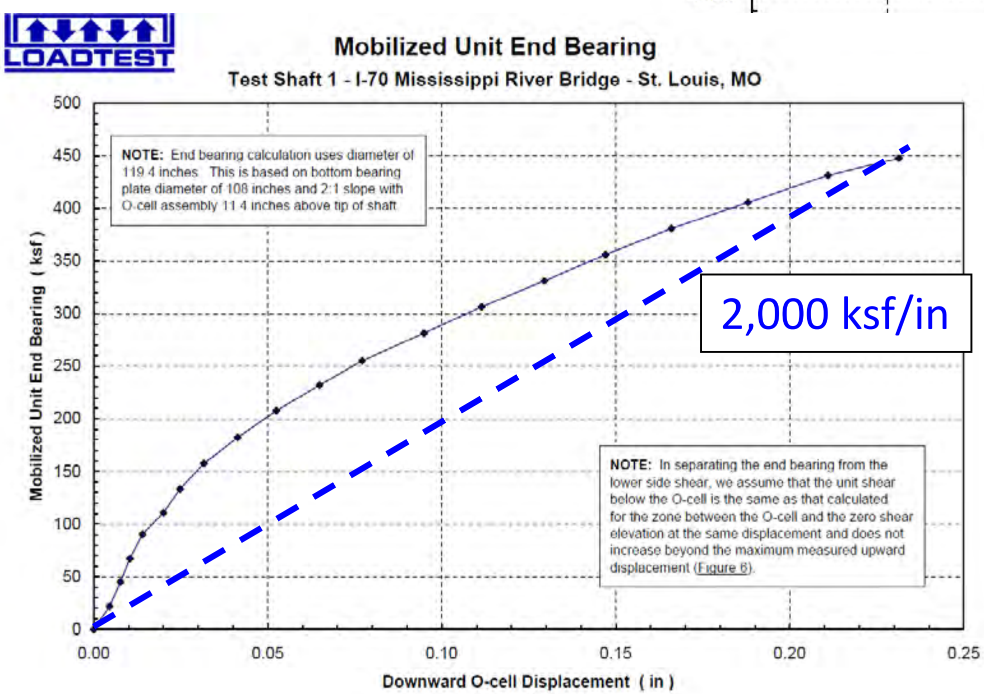
Load Test Shaft Construction



Over 40ksf avg mobilized unit side resistance

450ksf base resistance mobilized at < ¼ inch displ





$$\rho_s = 0.79 \cdot \frac{qB\left(1-\nu^2\right)}{E}$$

For rigid circular footing on elastic half-space with $\nu = ¼$:

E = 191,000ksf = 1330ksi

E ≈ 100q$_u$ for q_u ≈ 13ksi

Footing Construction

Greenville, MS Bridge

Ref: F.K. Jacoson, 2013. “Construction of the Main Tower Pier Caissons for the Greenville Bridge in Mississippi,” 38th Annual Conference on Deep Foundations, DFI

Open-well Caisson

Caisson Cutting Edge showing Half-cylinder Air Domes

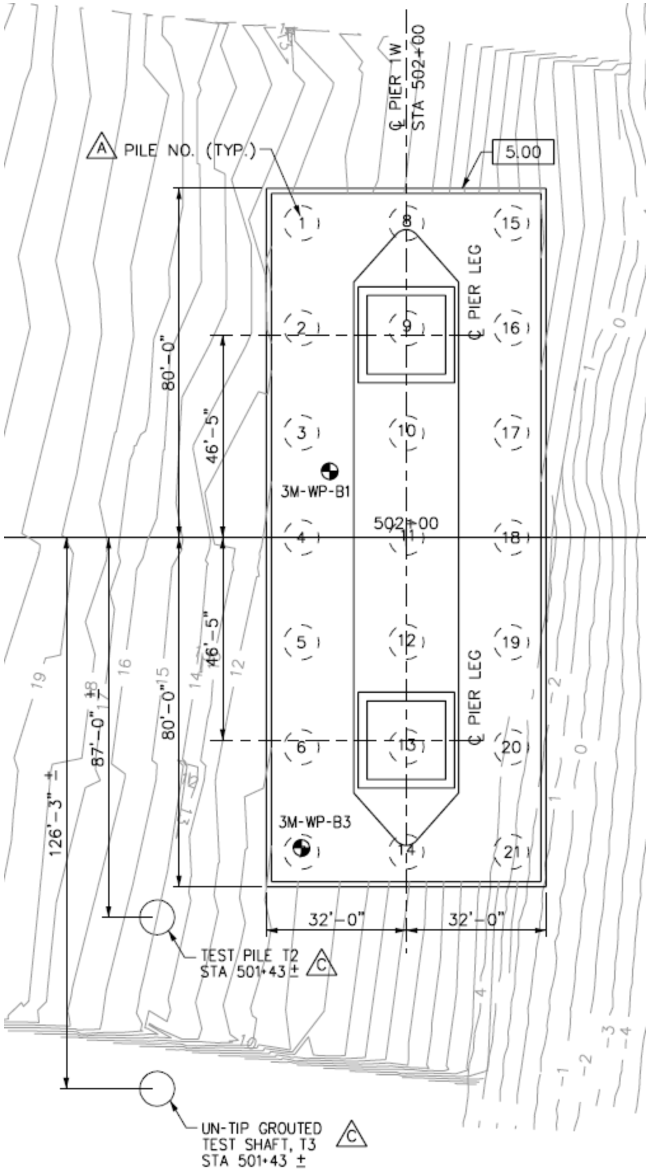
Audubon Bridge

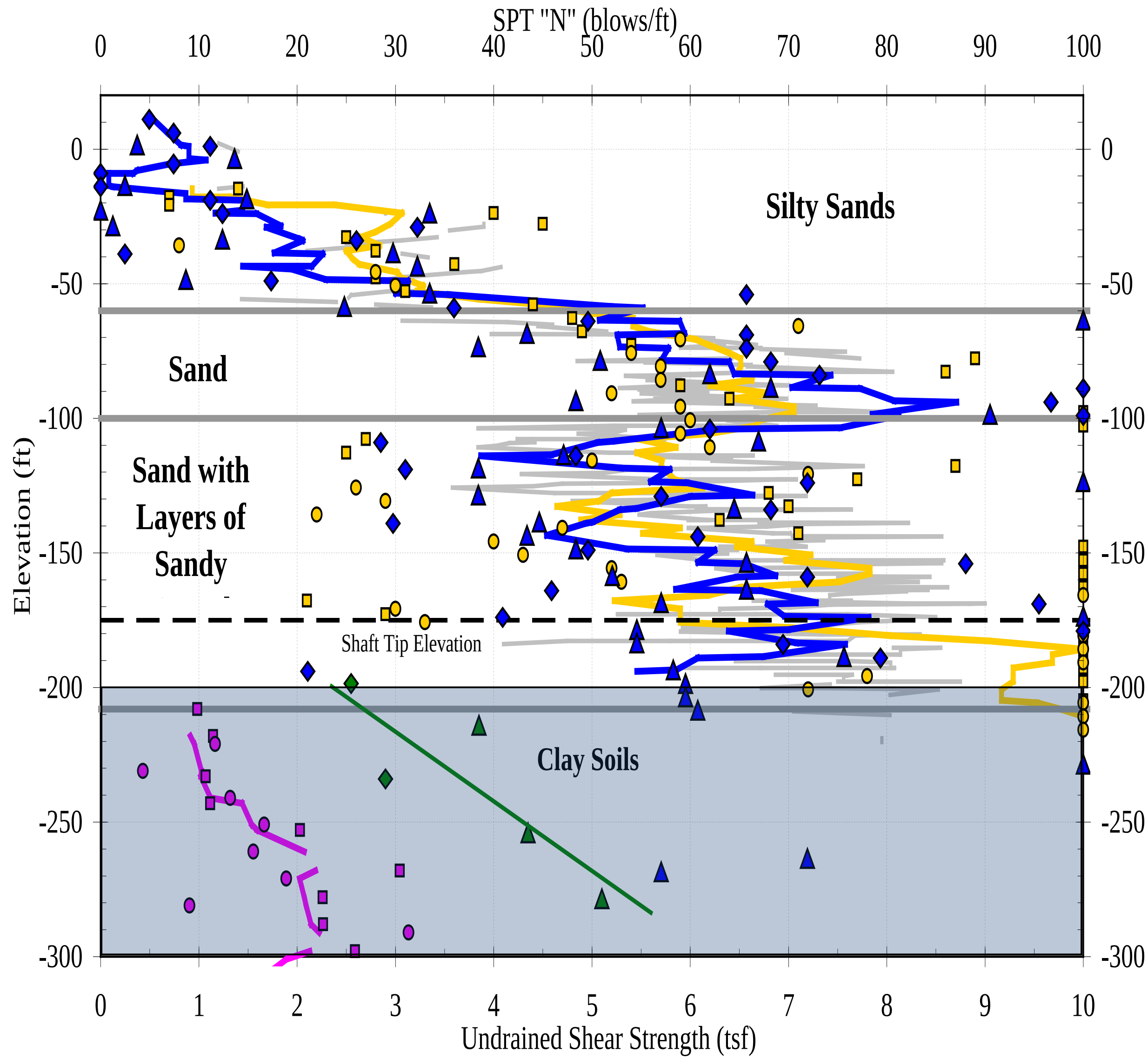
Cable-stayed bridge, 1583’ main span
Two pylons: 3 x 7 group of 7.5’ dia. Shafts
High approach: 2 column piers

Photo courtesy Flatiron Corp.

Audubon BRIDGE CONSTRUCTORS
PARSONS
FLATIRON
GRANITE

Soil Conditions at Pylons





Base Grouting

- Enhance Axial Resistance
- Improve Reliability
- Mitigate Imperfections in Base Conditions

Criteria:

- *Target Pressure*
- *Minimum Net Volume*
- *Limit Upward Shaft Movement*

Base Grouting

Tube á Manchette
(using CSL tubes)

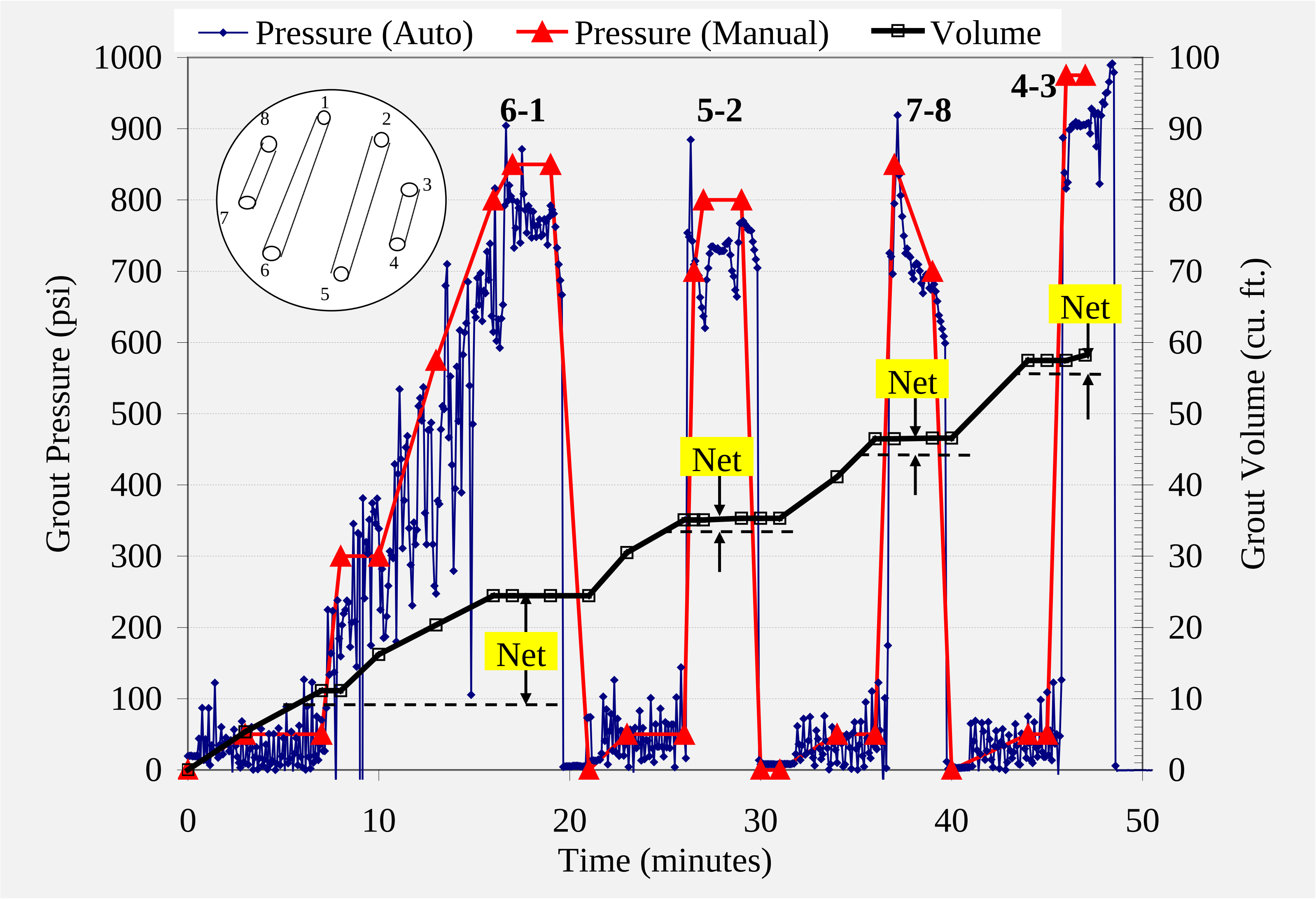
Cover Plate

Casing & Oscillator System

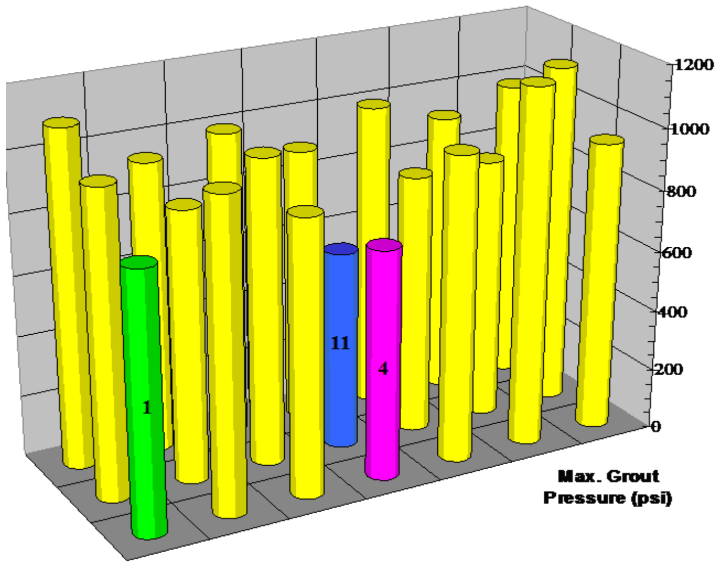

ALL

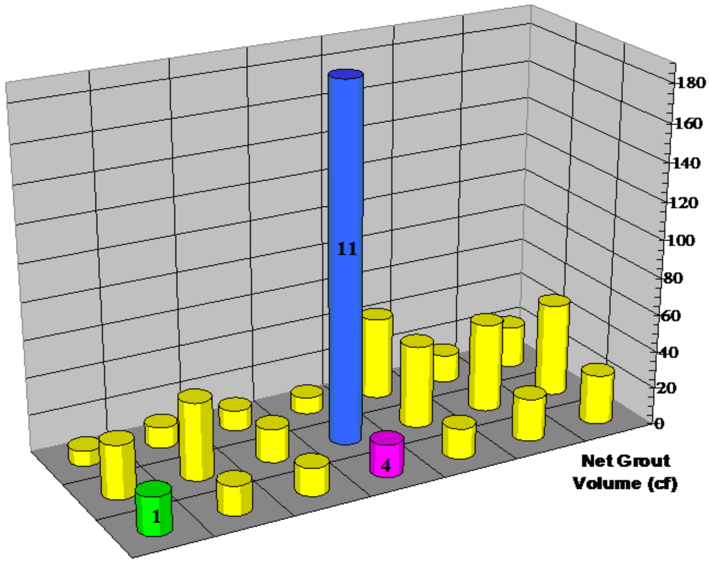
Dan Brown & Associates

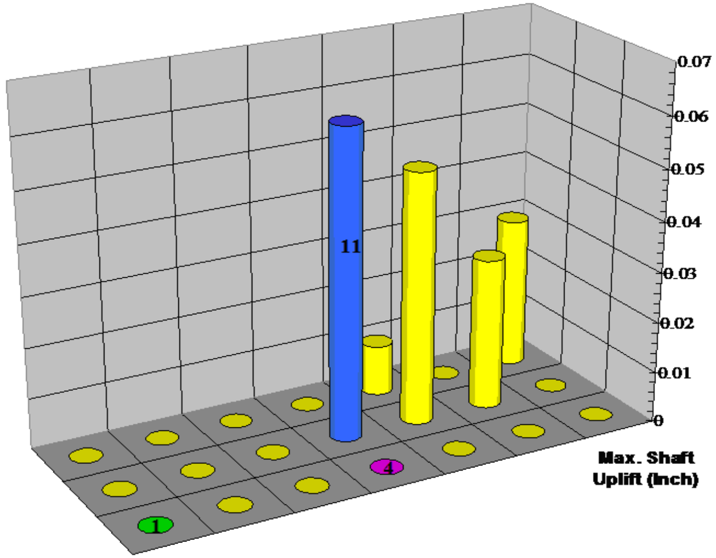
Base Grouting Measurements



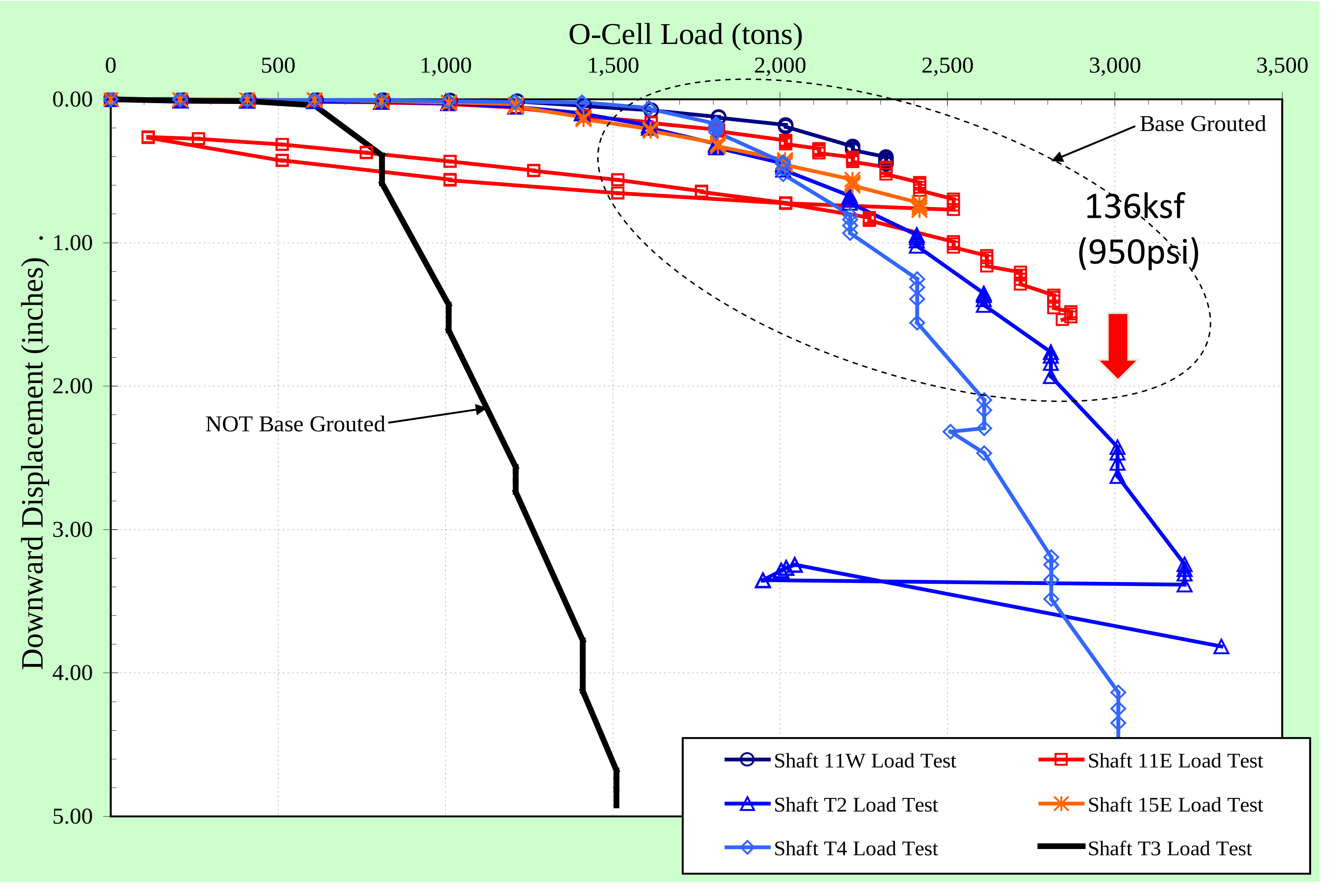
Performance During Grouting







Load Test Results



Huey P. Long Bridge Widening

Owner:

La. DOTD

Structural Engineers:

Modjeski and Masters

Geotechnical Engineers:

Eustis Engineering

General Contractor:

Kiewit/Massman/Traylor

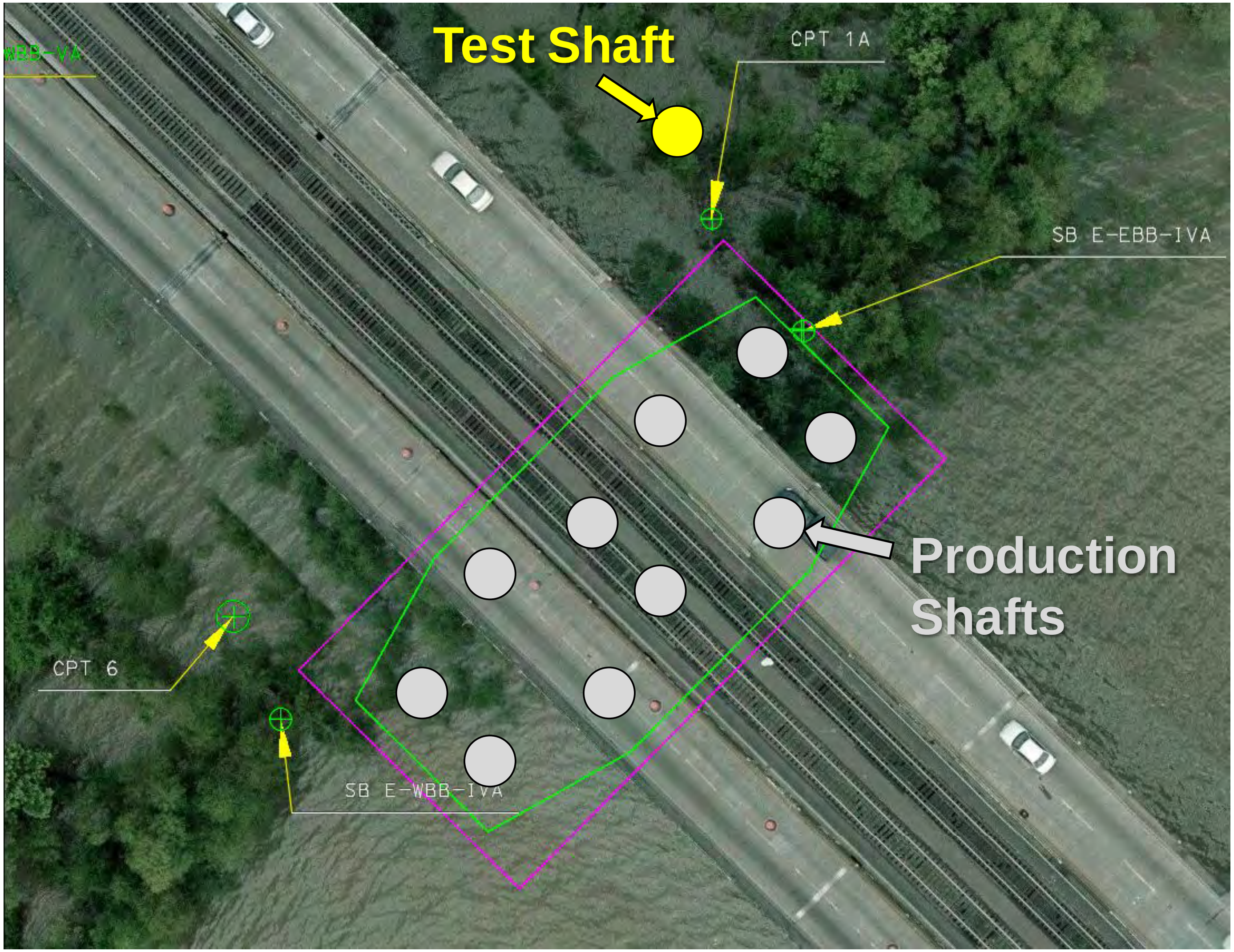
Subcontractor:

Malcolm Drilling Company

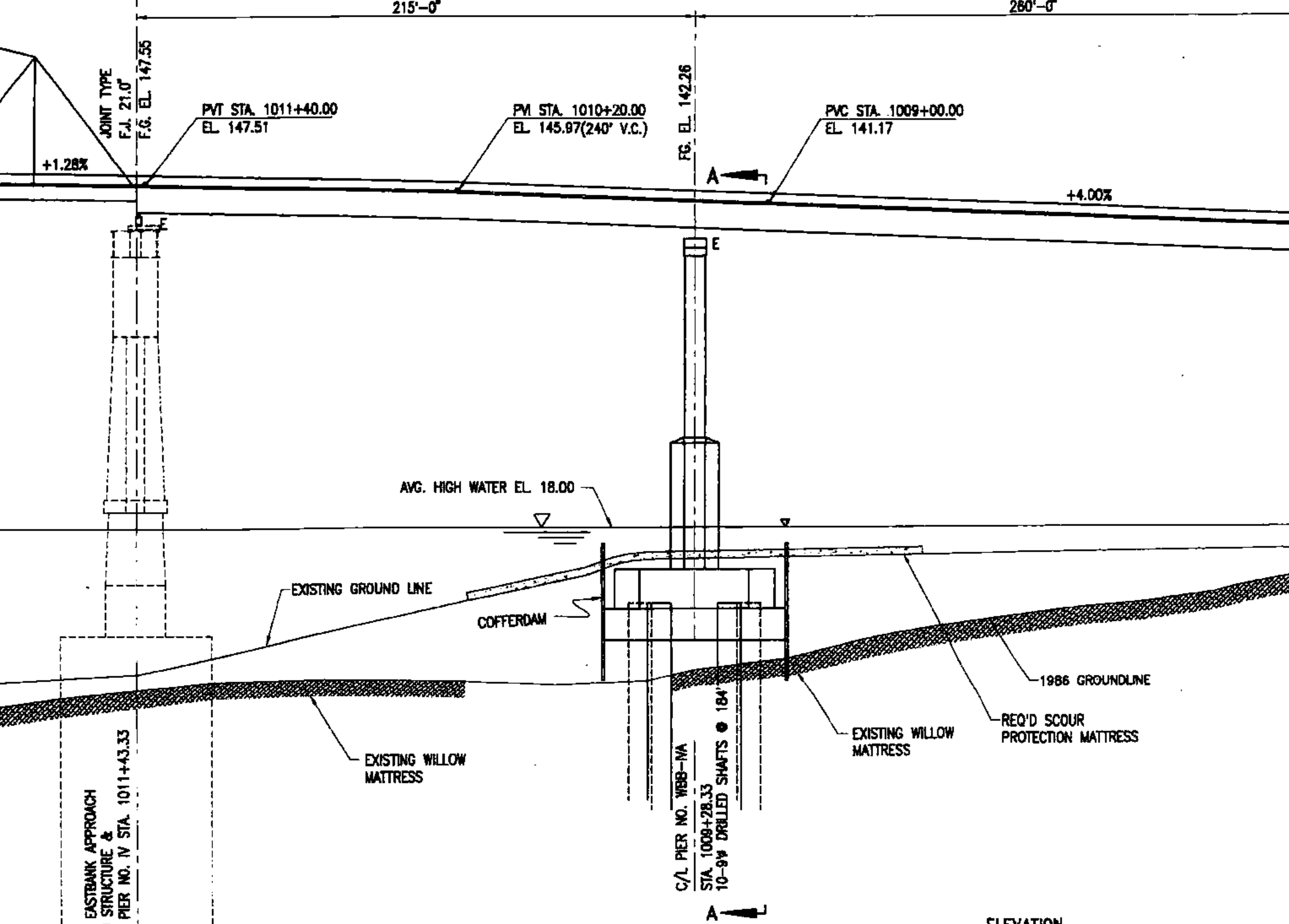
Foundation Consultant:

Dan Brown and Associates

Pier IVA



WBB-VA
Test Shaft
CPT 1A
SB E-EBB-IVA
Production Shafts
CPT 6
SB E-WBB-IVA



ELEVATION
SCALE:1"=30'-0"

Rotator System

Casing

Excavation Using Hammer-grab

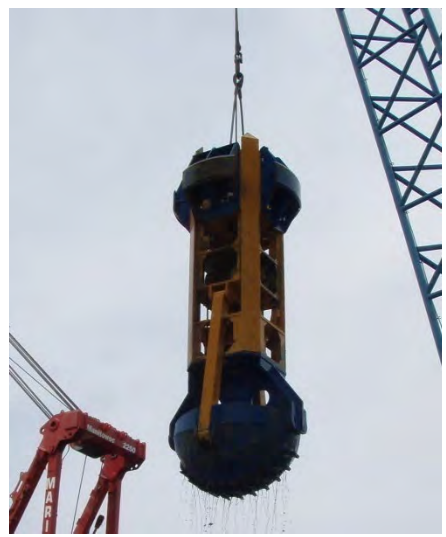
Shaft Cleaning & Inspection

Airlift

SID

'Bottle Brush'

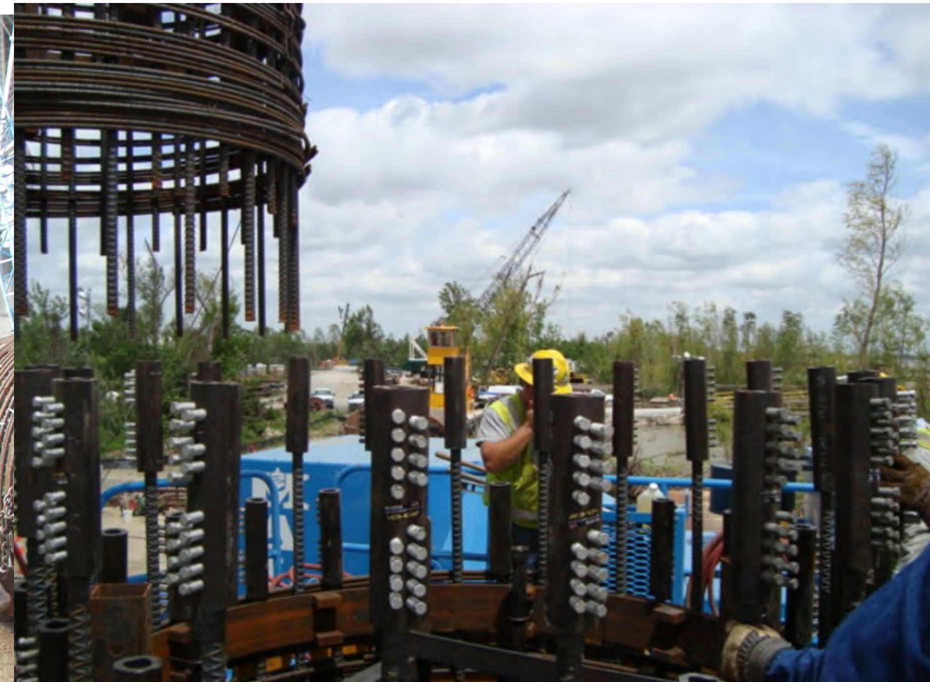
(Hydraulic)
Cleaning Bucket



Place Gravel

Reinforcement

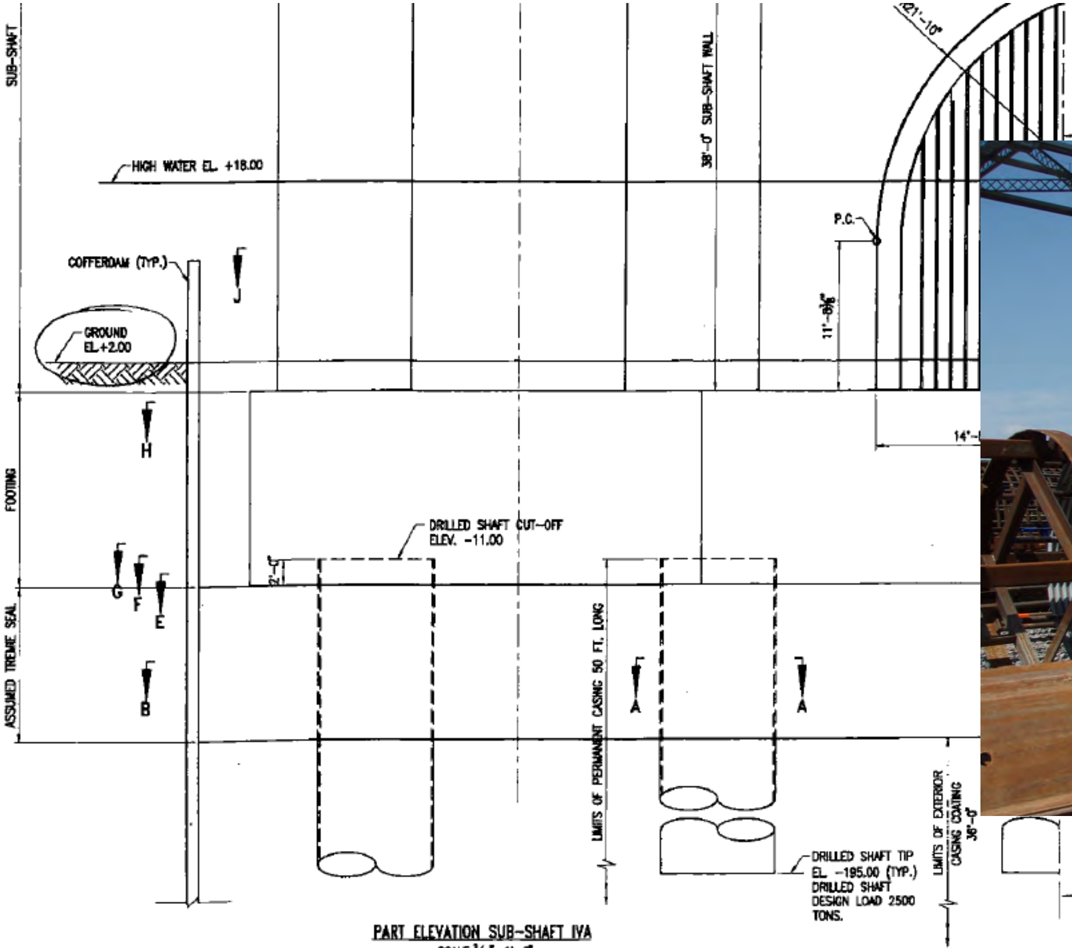
Backbone Frame



Bar Splices

Placement of Reinforcement

Shaft/Cap Connection



Shaft Cutoff at -11

Isolation Casing

Concrete

Mix Proportions For One Cubic Meter (Cubic Yard) of Concrete

Cement	455	kg (lb)	
Fly Ash		kg (lb)	
Slag	245	kg (lb)	
Fine Aggregate (SSD)	1501	kg (lb)	
Coarse Aggregate 1 (SSD)	1481	kg (lb)	
Coarse Aggregate 2 (SSD)		kg (lb)	
Water	35.1	L (gal)	
Water Reducer	14.0	mL (oz)	UNIT
Air Entrainer		mL (oz)	kg, L, mL
Set Accelerator		mL (oz)	(lb, gal, oz)
Superplasticizer	21.0	mL (oz)	
Special Additive A	49.0		
Special Additive B	21.0		
Special Additive C			

Contractor KIEWITT MASSMAN TRAYLOR

Certified Concrete Technician 1208 Code

Date Submitted 04-02-09

Recover (7 oz/cwt)

VMA (3 oz/cwt)

Base Grouting

Base Grouting QC/QA

General Information	
Date:	August 7, 2009
AFT Project No.:	808117
Project Description:	Huey P. Long Bridge Widening, State Project No.: 006-01-0021
Client Name:	Kiewit-Massman-Traylor Constructors (KMTC)
Client Address:	4910 Pontchartrain Avenue Suite T, Jefferson, LA 70123
Client Contact:	Mr. Luis Paiz
Post Grout Date:	July 29, 2009
AFT Grout Specialist:	Jason Frederick
AFT Data Acquisition Specialist:	Mike Muchard, P.E.
AFT Responsible Engineers:	Mike Muchard, P.E., Tom Santee, P.E.

Drilled Shaft Information

Shaft Number	Bent/Pier Number	Diameter (inches)	Length (feet)	Installation Date
Test Shaft	N/A	110	~190	7/21/09

Ground Surface Elevation (feet)	Approximate Top of Concrete Elevation (feet)
~+13.5	
Cut Off Elevation (feet)	Tip
-11.0	

Installation Records provided

Yes [ ] No [X] Attached [ ]

Instrumentation Installed in

Strain Gages Installed:	Yes
Installed By:	Jason Frederick, AFT
Number and Location:	4 gages at 9 feet above grout plate
Other Instrumentation:	Grout Pressure Transducer, LVDT's a

Post Grout Informa

Grout Distribution Apparatus Type:	Tube–a-Manchette with plate (als
Grout Tube Type:	2" steel (also used for CSL testin
Number of Grout Tubes:	8 (4 - U-Tube pairs)
Tube Reference:	Northernmost tube designated #'
Grout Plant Type:	Hany IC 720 (note: had Hany IC
Grout Type:	Type I/II Portland Cement and W as needed in field as shown on fi

Post Grout Criteria	
Minimum Required Grout Pressure:	650 psi (45 bar) (measured at pump)
Maximum Permissible Displacement:	0.25 inch (measured via survey at shaft top)
Minimum Grout Volume:	5 cubic feet (net pumped to the toe of the shaft)

Post Grout Measurements	
Data Acquisition System Used:	MEGADAC
Pressure Transducer Used:	Hewlet Packard
Strain Gages :	AFT Sisterbars Micro-Measurements ¼ Bridge Resistance
Manual Grout Pressure:	Manual Oil Filled Bourdon Gage
Survey Level:	By AFT
Manual Grout Volume:	Holding Tank Level Manual Measurement

SUMMARY OF POST GROUT RESULTS

Maximum Grout Pressure (psi)	Upward Shaft Displacement (inches)	Maximum Gross Volume Placed (cubic feet)	Estimated Net Volume Placed (1) (cubic feet)
800	0.081	188.8	156.8

(1) Net volume calculated as follows:
Net Volume = Gross Volume – Theoretical Volume of Grout Tubes (cu. ft.)
Tube I.D. = 2.0 in., Avg. tube length 210 feet.
Theoretical volume per tube = 4.58 cu. ft. Note tube 6 became blocked approximately 2hrs-40min.
) cu. ft.

ents

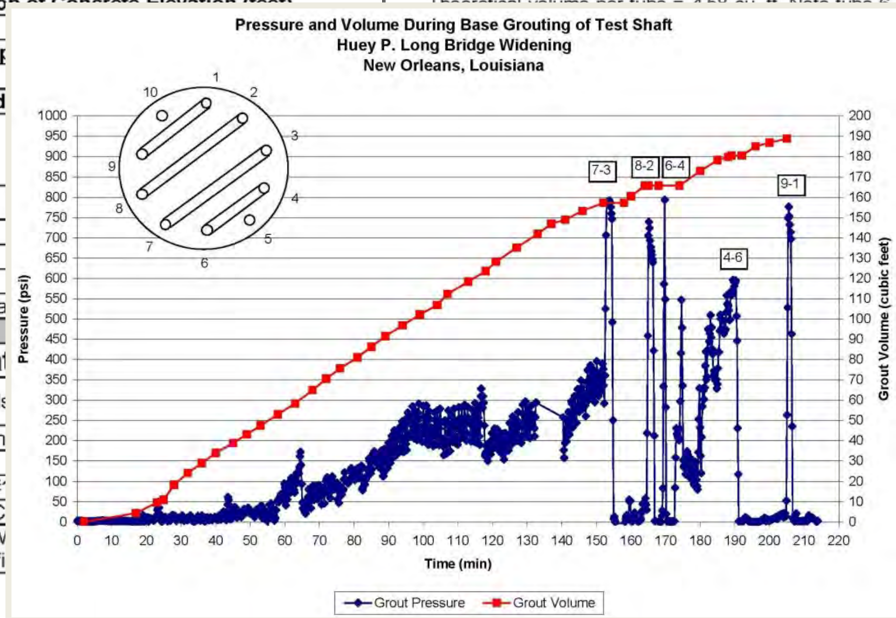
e at Shaft Bottom vs Time [X]

Spread Sheet via email [X]

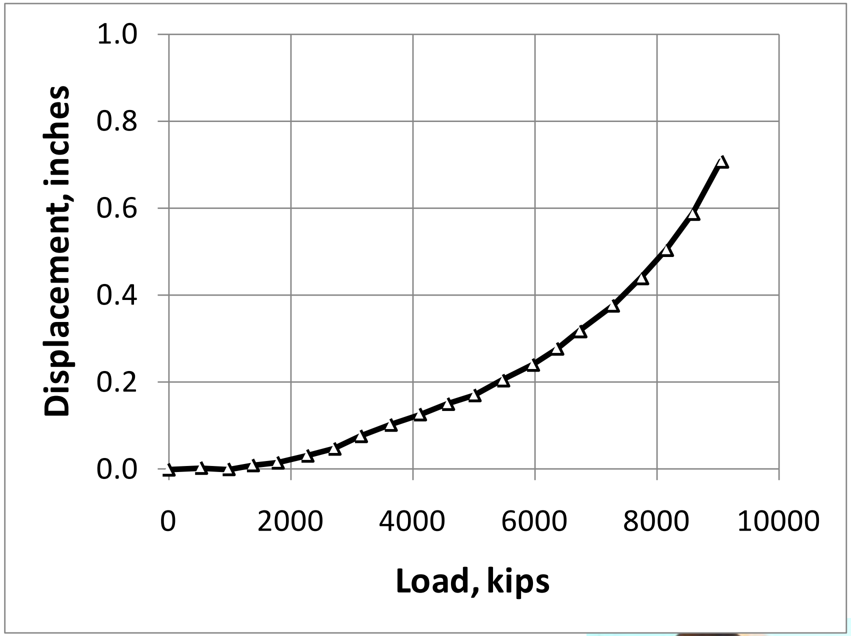
ents

e required minimum grout pressure, nissible displacement. greed well except during grouting of

)2 inch (½ mm) of each other. It is urred 115 to 130 minutes into the wer. out pressure assumed to apply over in gages agreed well for the initial ons beyond that length of time are ortions of the base area. In addition, ocalized portions of the base where act on the full base area. We believe ...that the gravel pack below the base plate may have contributed to a more uniform



Performance of Load Test



Completed Foundation

Summary

Foundations for large bridges present special challenges: key issues

- *Construction plan to minimize risks*
- *Constructability issues of design*
- *Coordinated effort of partners*
- *Performance verification requirements*

Don't get bit!