MARQUETTE INTERCHANGE PIER TS7

QA/QC Lessons Learned, Case Study

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HNTB

ILLINOIS TRANSPORTATION AND HIGHWAY ENGINEERING CONFERENCE

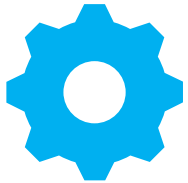
AGENDA

Overview of MQIC, bridge B-40-1231

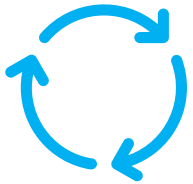
The issues with pier TS7

How did this happen?

HNTB's Response to the Crisis



Potential repair options



Overview of the reconstruction process

Lessons Learned

Questions/Answers/ Discussion

NEW MARQUETTE INTERCHANGE

- Downtown Milwaukee relies on Marquette Interchange
- Wisconsin relies on Marquette Interchange

OVERVIEW OF MQIC, BRIDGE B-40-1231

BIANNUAL INSPECTION: PIER TS7 HAS A PROBLEM

- B-40-1231-001, Wisconsin Ave to I-43 SB over N-E Ramp North Face of Pier TS7

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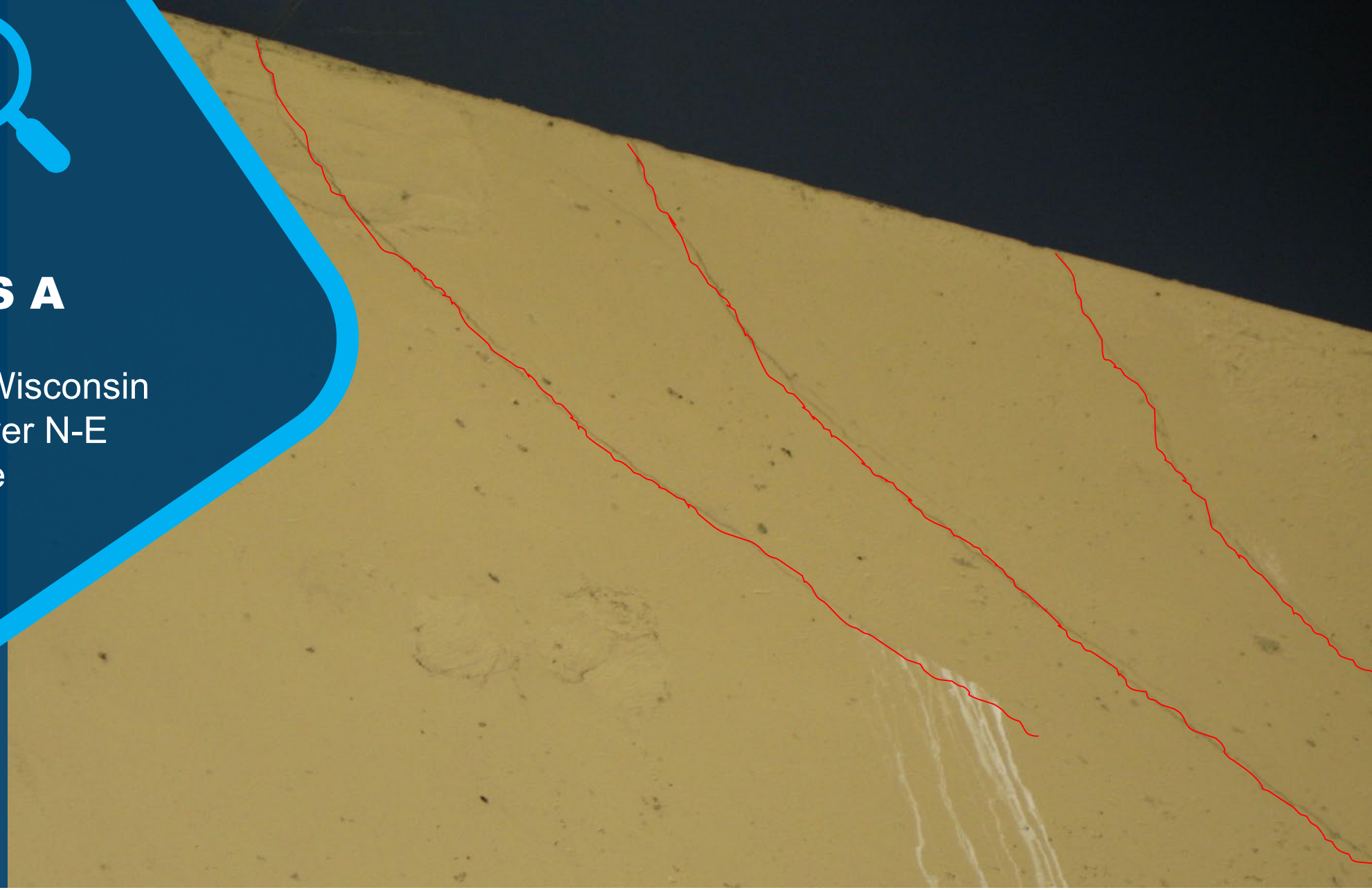

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- B-40-1231-001, Pier TS7 Vertical Crack, East Face (note location of Pot Bearing

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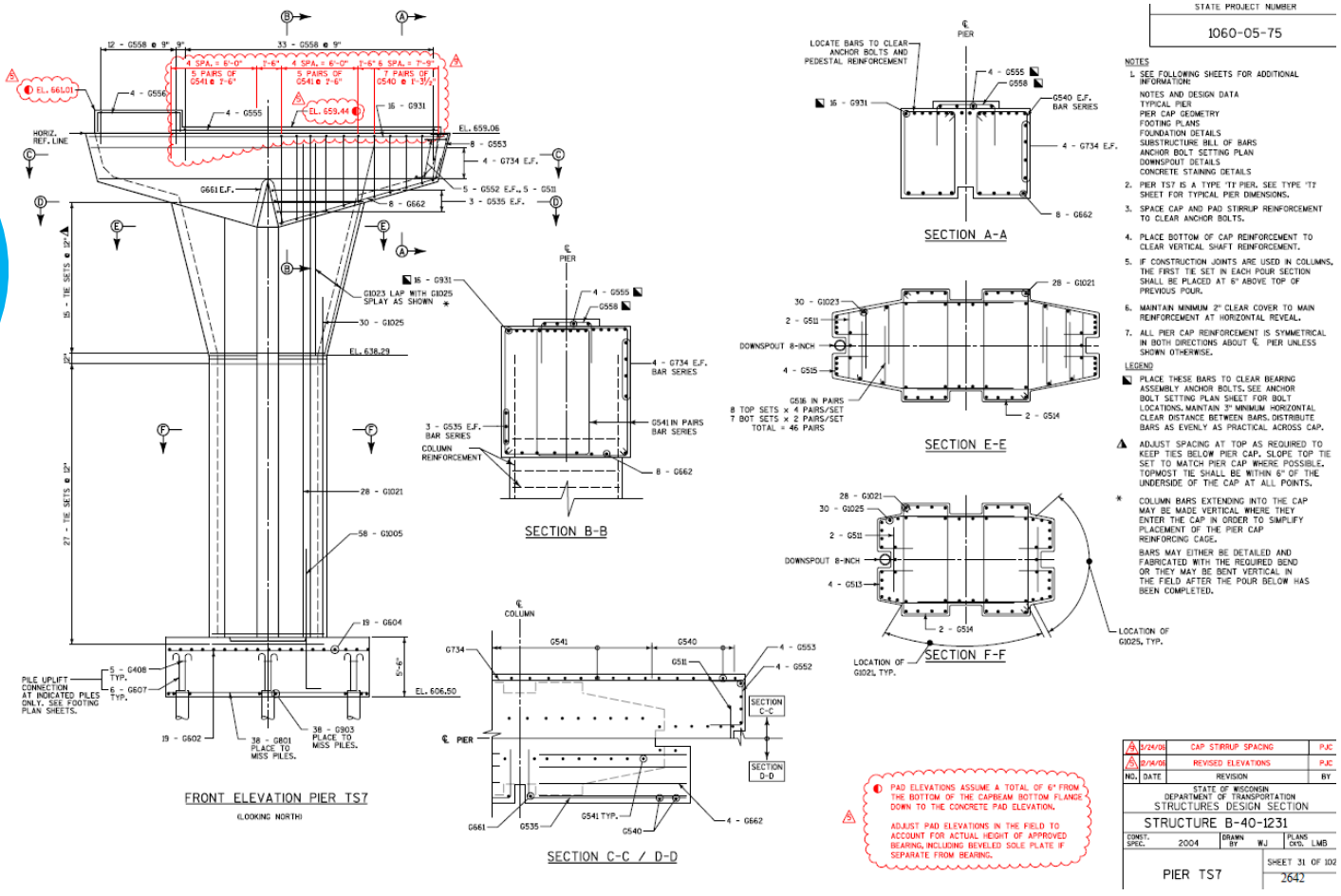
THE ISSUES WITH PIER TS7:

Can One Tell From This?



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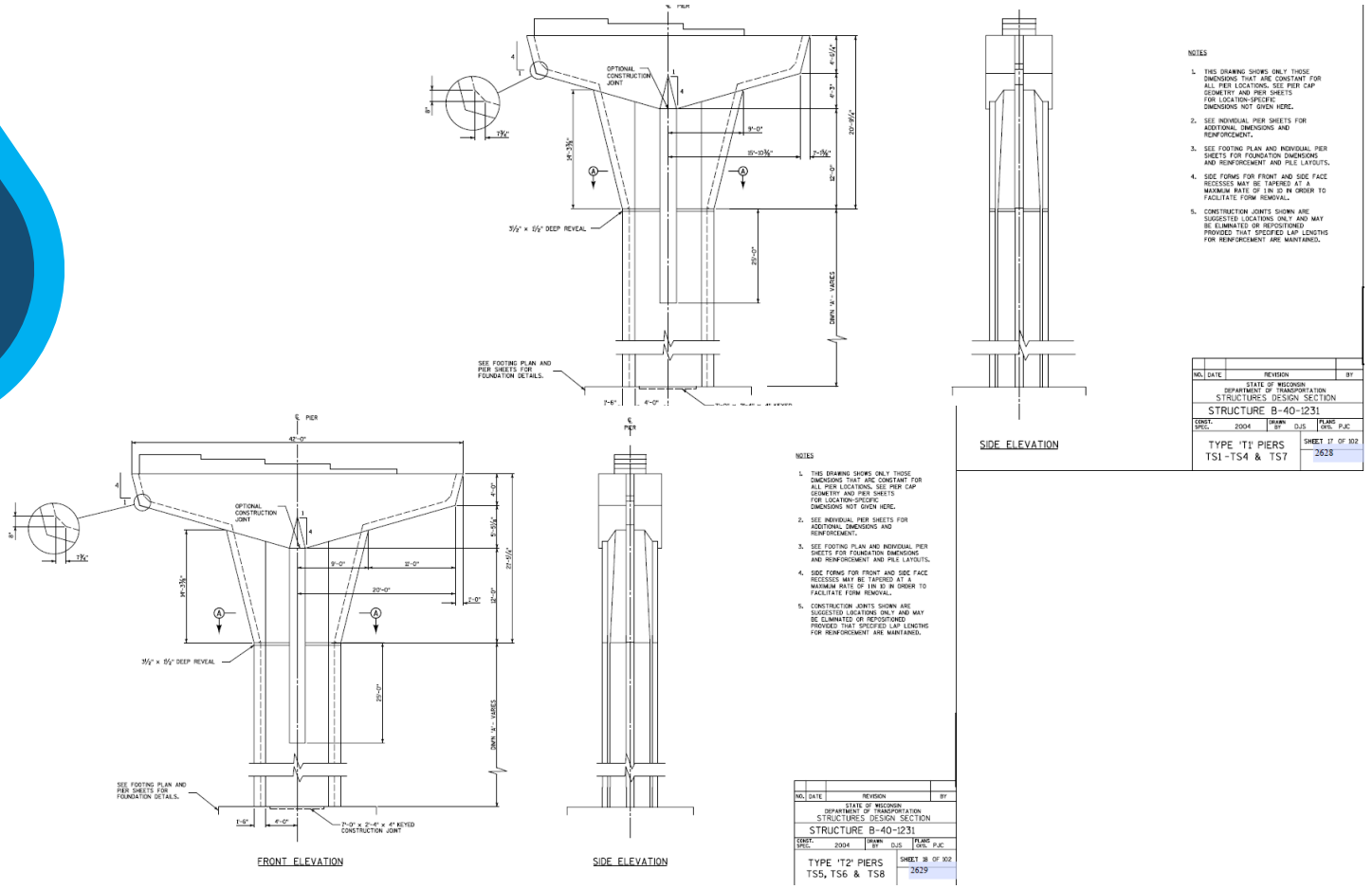
Oooops…maybe, maybe wrong grouping



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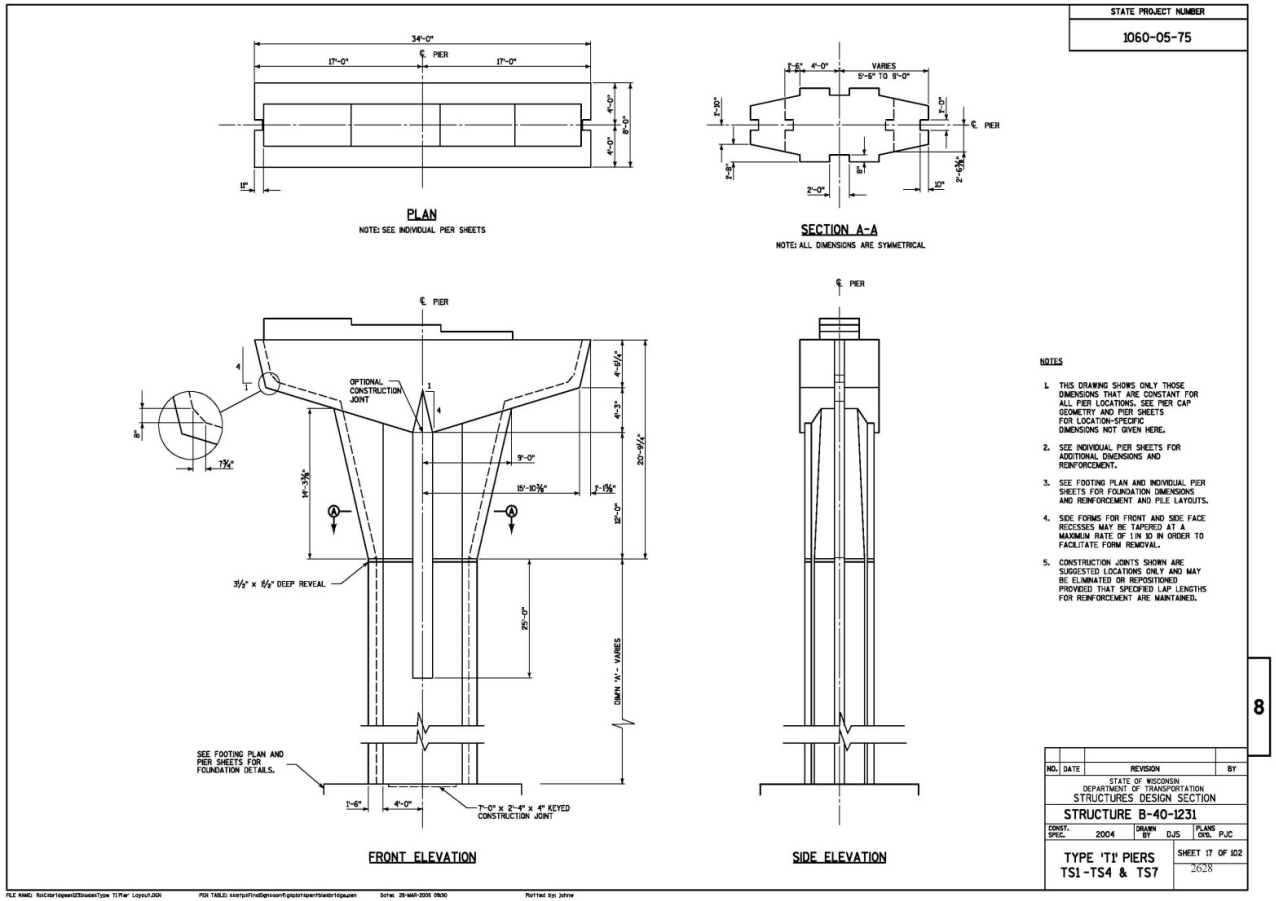

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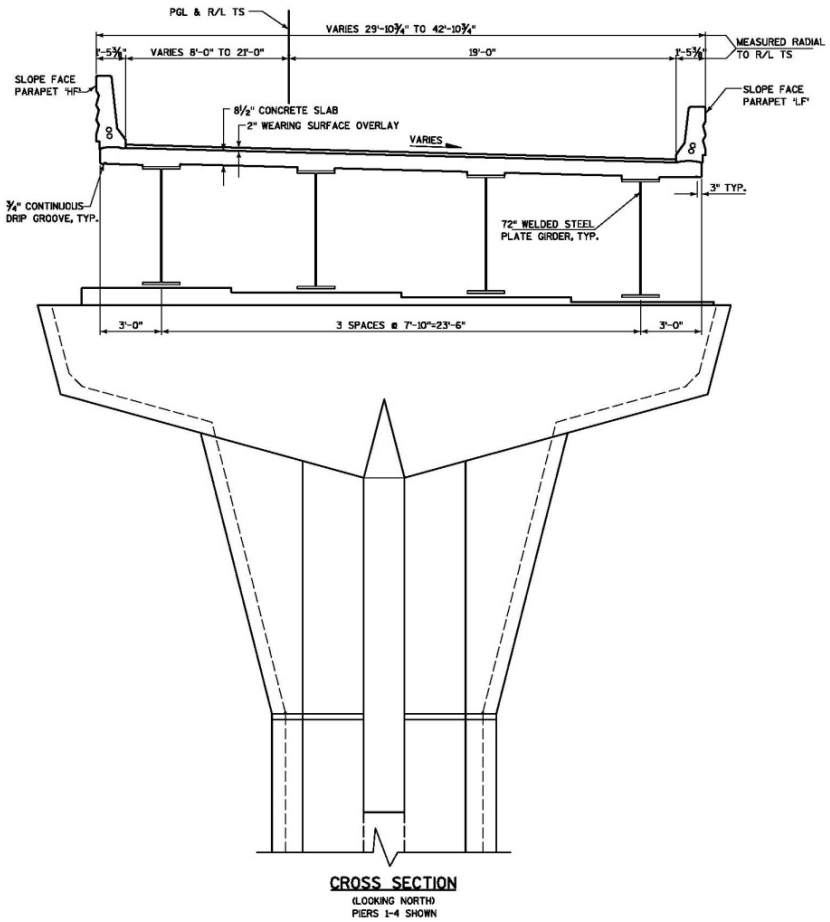
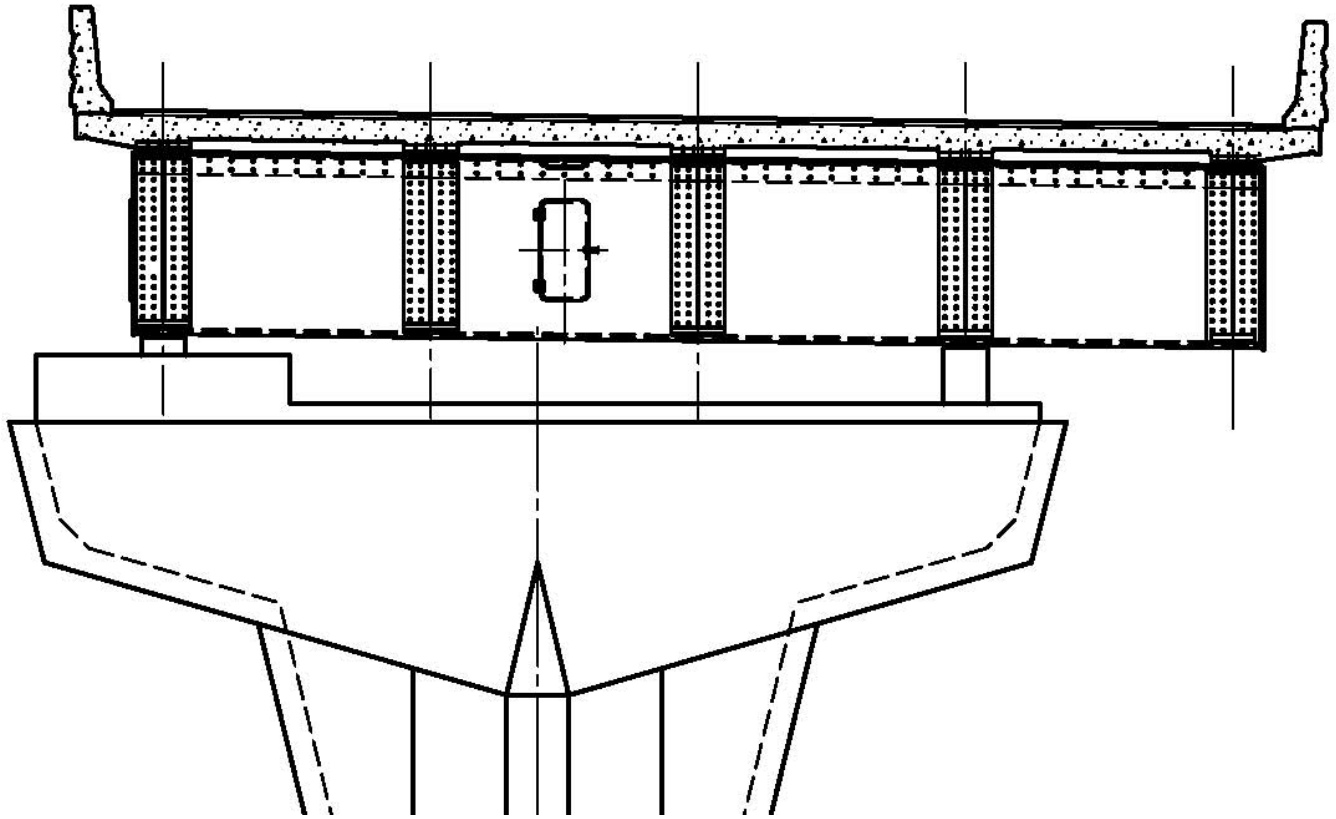
as meant…



THE ISSUES WITH PIER TS7:

as used…



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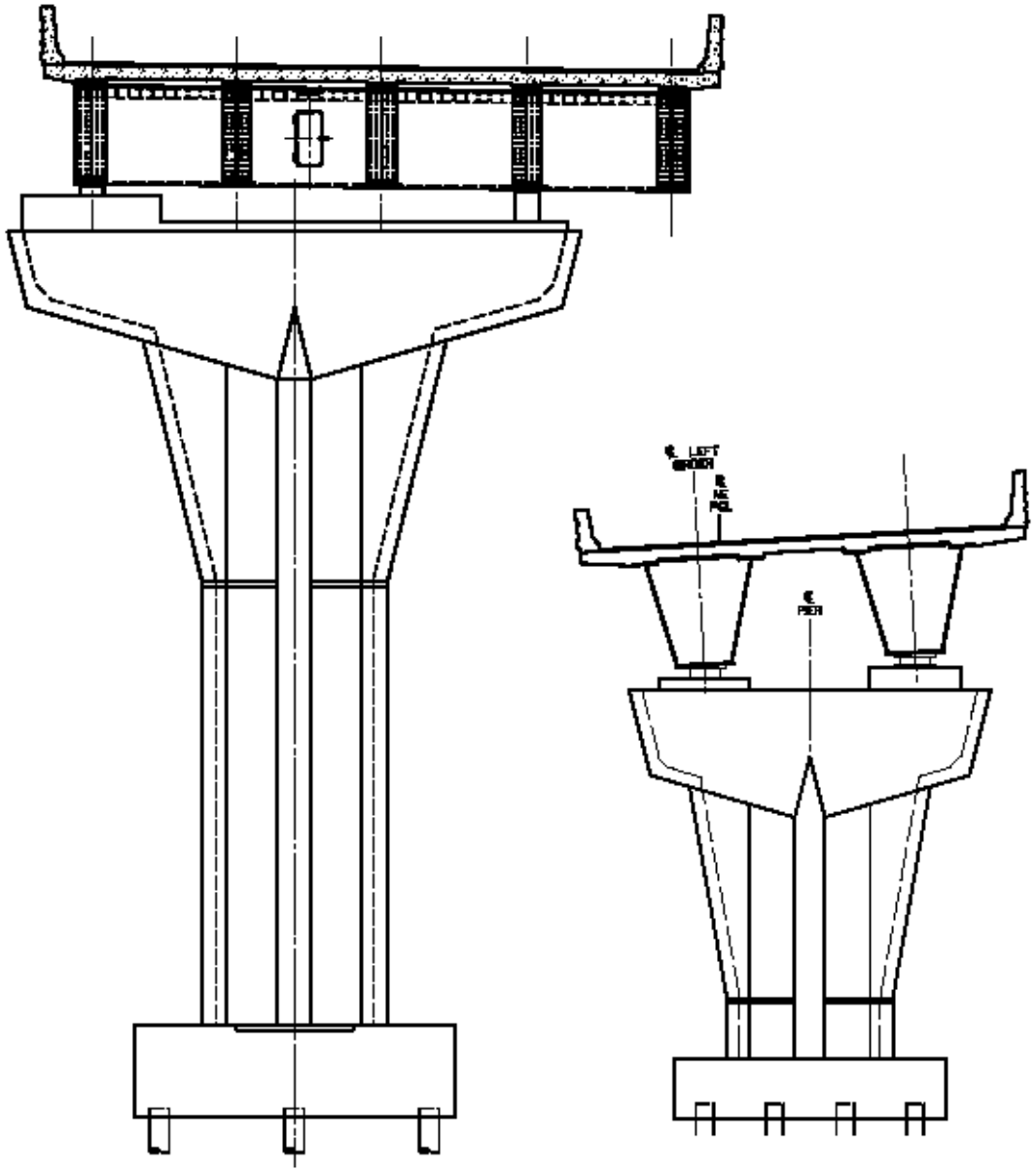

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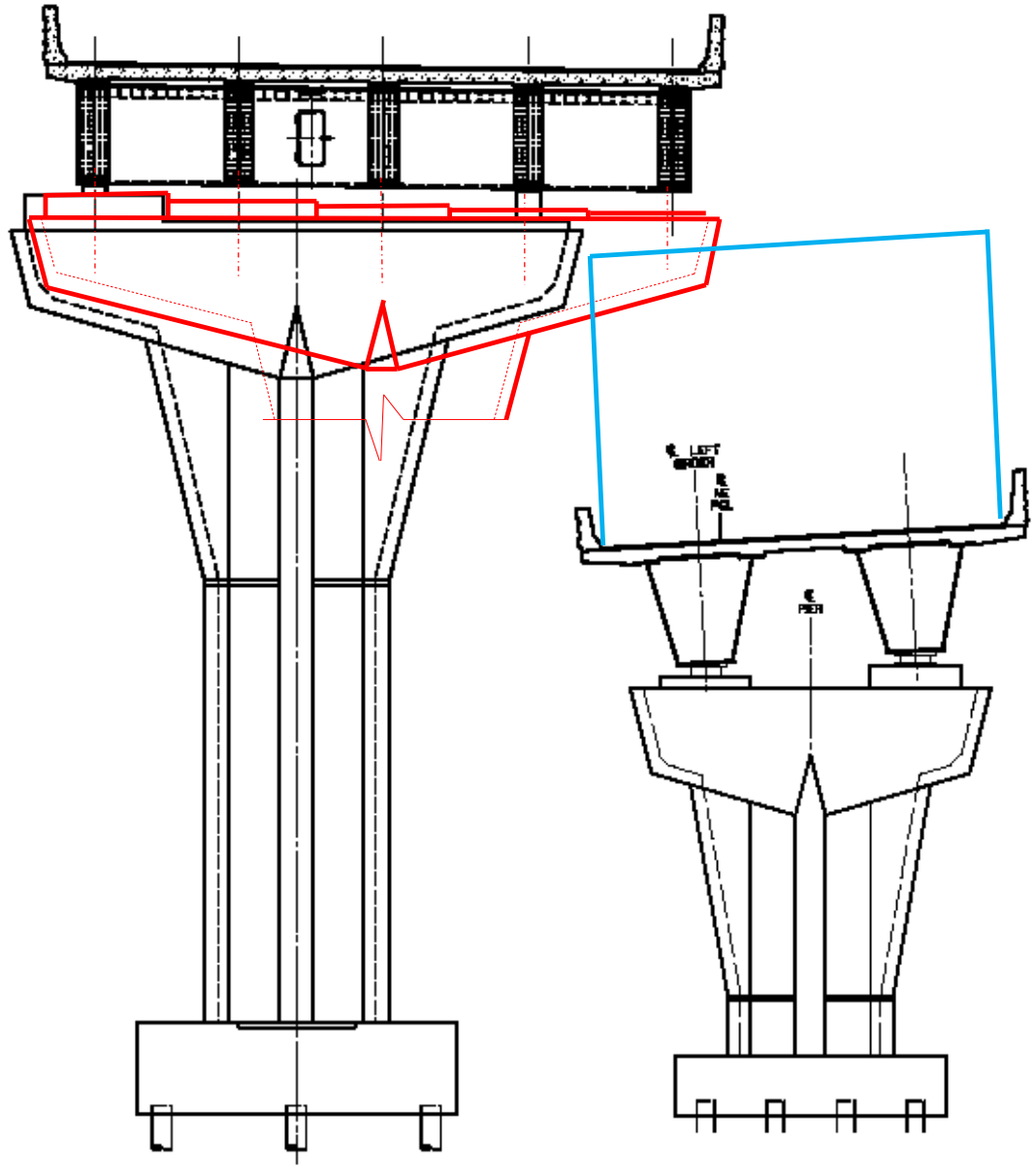

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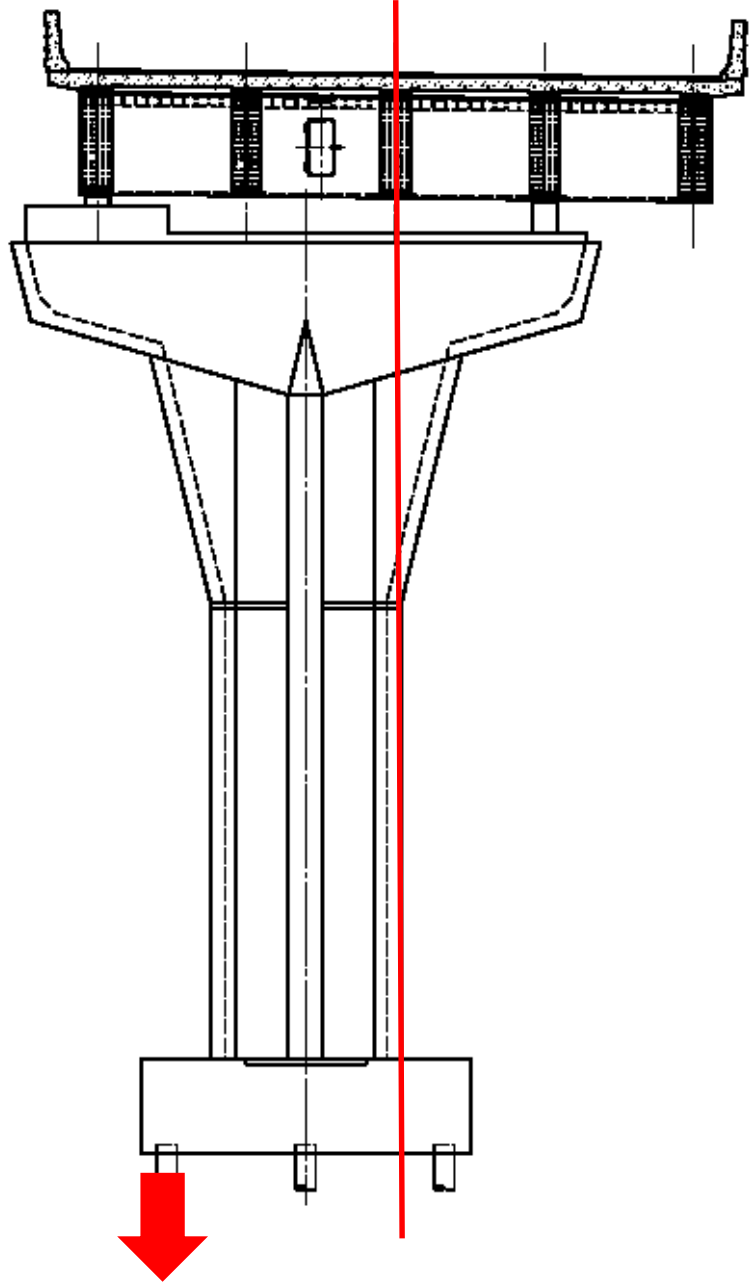
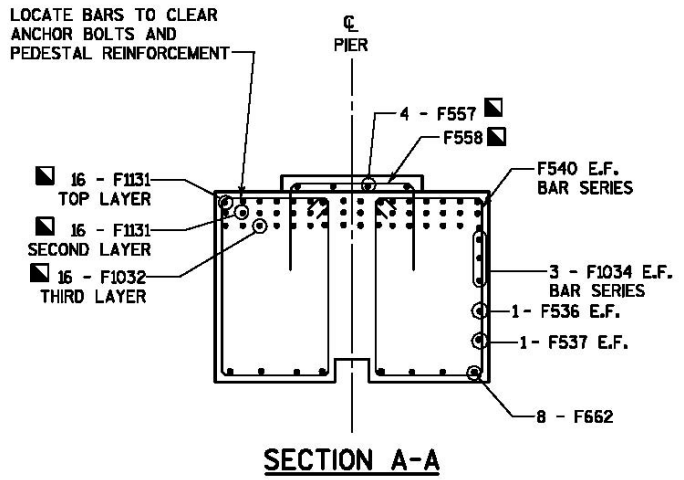


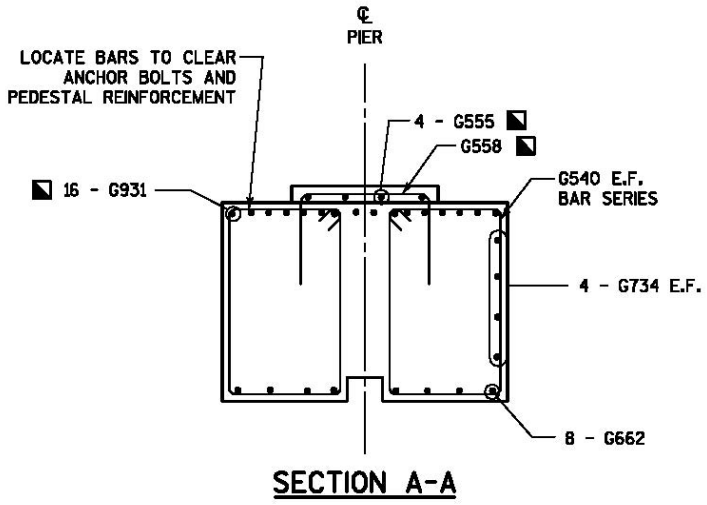
THE ISSUES WITH PIER TS7:

compare…

TS6



TS7



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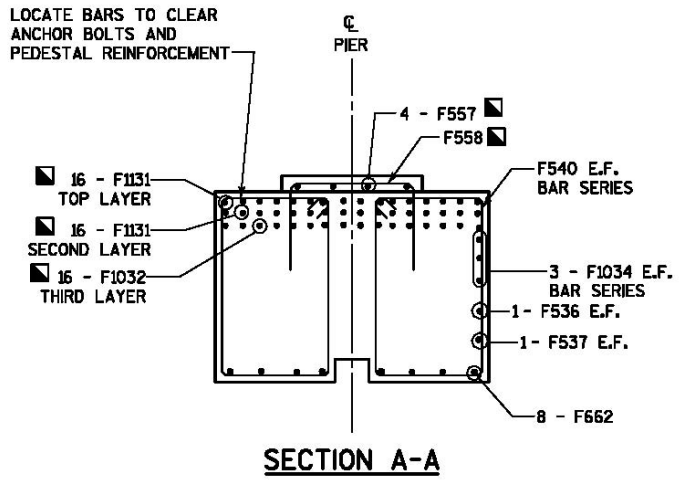
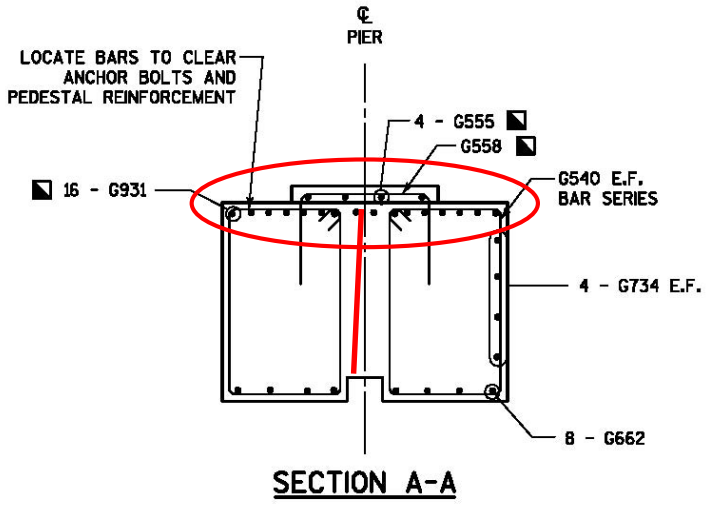


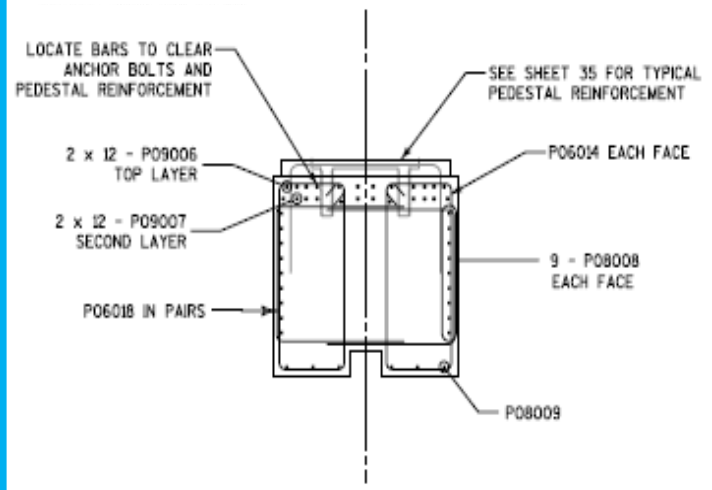
TS7



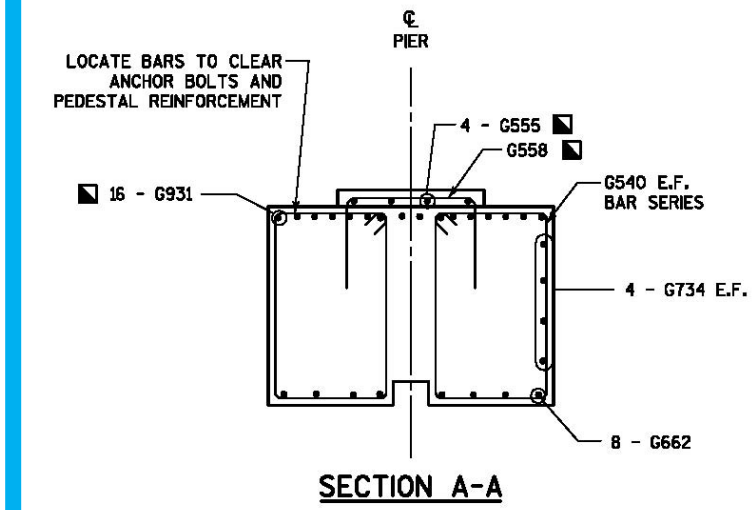
THE ISSUES WITH PIER TS7:

compare…

Tub Girders



TS7



THE ISSUES WITH PIER TS7:
Oooops again…

	CAPACITIES		SERVICE LOAD									
	Shear	Moment	Reaction		Demand				Performance ratios			
			DL	LL	V_{DL}	M_{DL}	V_{TOT}	M_{TOT}	V_{DL}	M_{DL}	V_{TOT}	M_{TOT}
	k	k-ft	k	k	k	k-ft	k	k-ft	%	%	%	%
Pier Cap	1,167	6,300	1,017	421	1,017	6,609	1,438	9,350	114.7	95.3	81.0	67
			Factored Load									
Pier Shaft		19,650						23,500				0.84
Pile Cap	1,711	8,156					589	8,780			2.9	0.93
Pile loads			SERVICE LOAD									
	Axial		Axial						Axial			
	t		t						t			
	200		285						0.7			

HNTB Response to the Crisis

- Any man can make mistakes, but only an idiot persists in his error.

Cicero

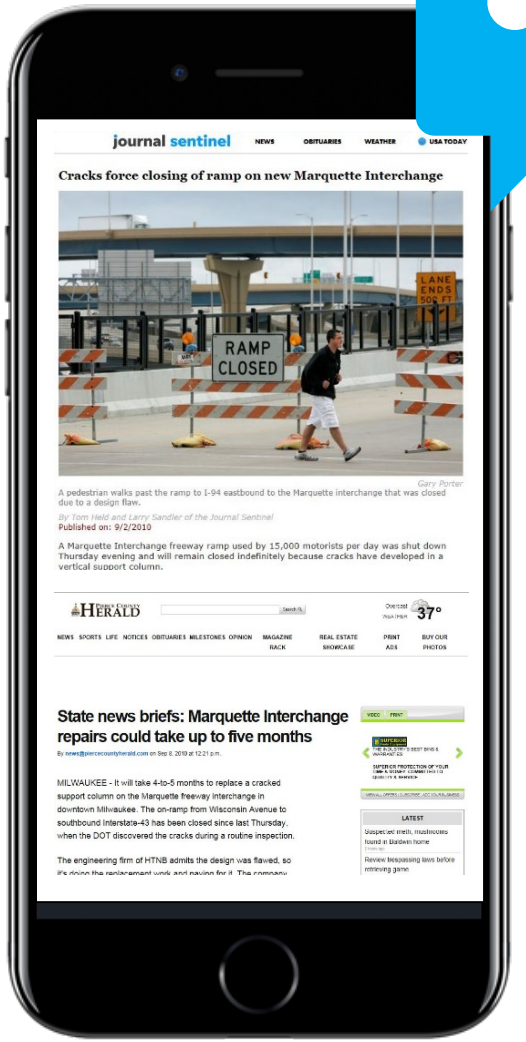
- We all make mistakes at work, it's how you react afterwards that matters

HNTB Response to the Crisis

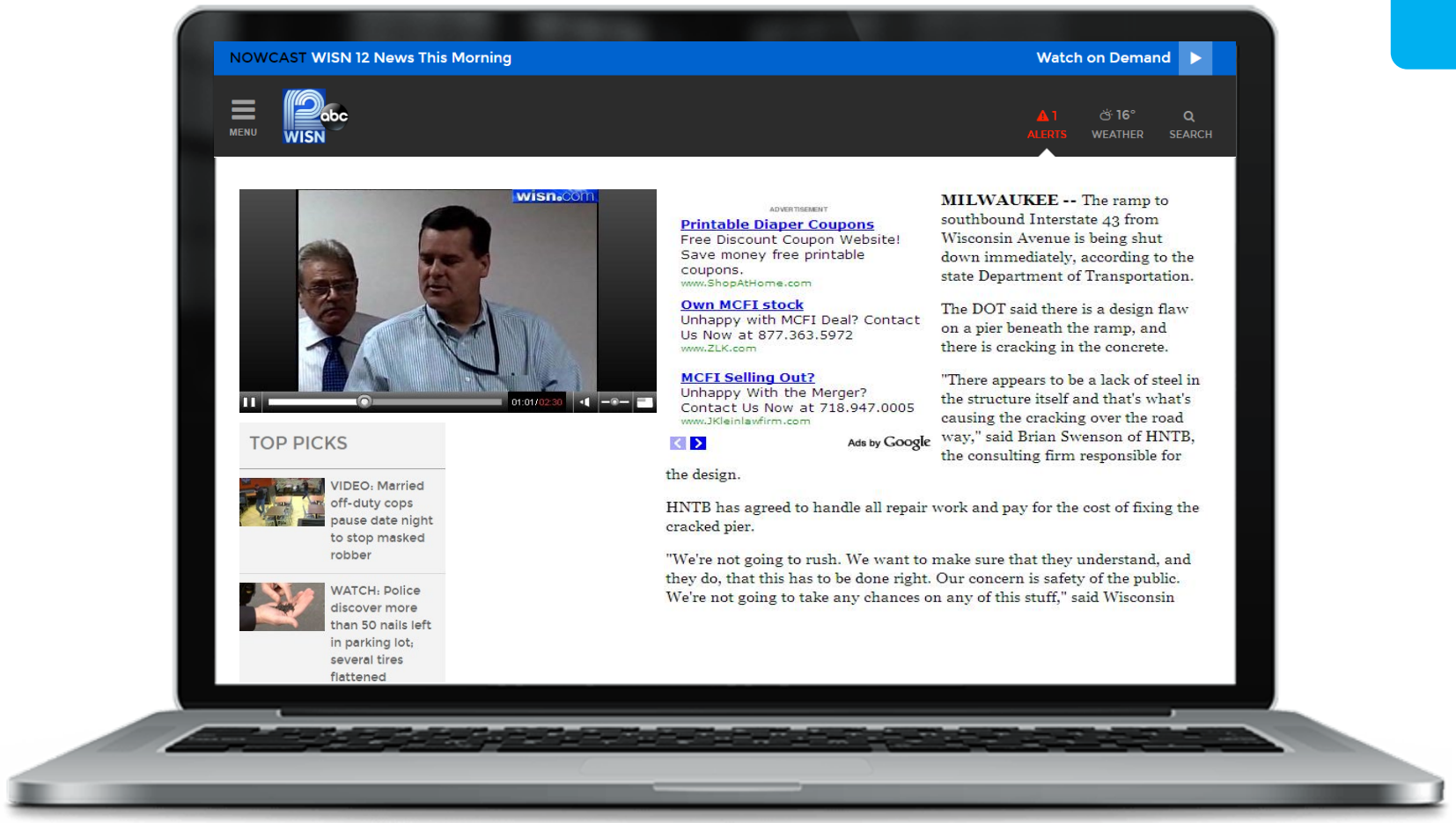
- Immediate, with public safety as first priority
- Accepted fault once it was clear
- Got to work immediately to fix it at no expense to taxpayers

Early Response Activities

- Received call on 9/1
- Close ramp on 9/2
- TV interview on 9/2
- Interviewed contractors 9/4 and 9/5
- Selected contractor 9/5
- Redesign began 9/5
- Initial projections ~ 4 - 5 months
- Reopened ramp in 12 weeks!!!



Early Response Activities



Potential Repair Options

- Post-tensioning and foundation retrofit, various versions $$
- Enhancing the pier shaft underneath the cap and foundation retrofit $
- Replace the pier $$$$

Project Approach

TONY SHKURTI

Technical Design
Lead for Repair

PAT CASHIN

Local Office
Design Support

JIM JANKE

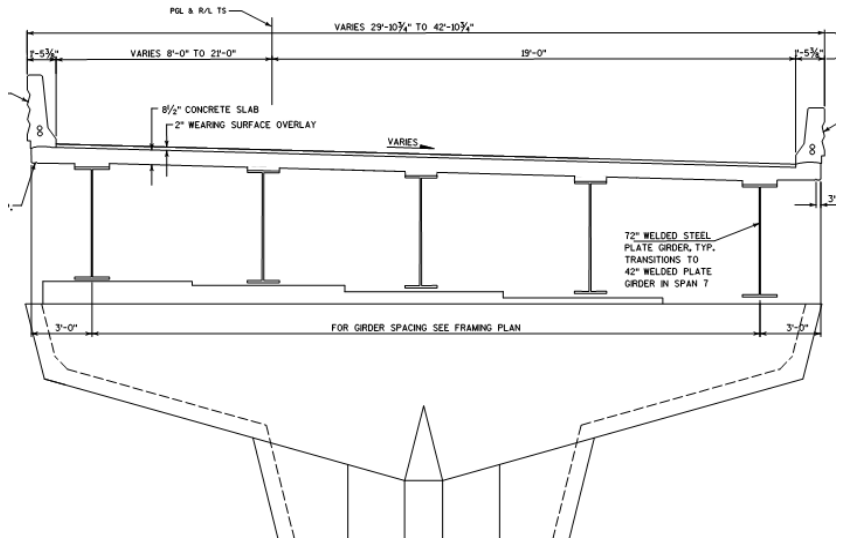
Led Construction
Oversight

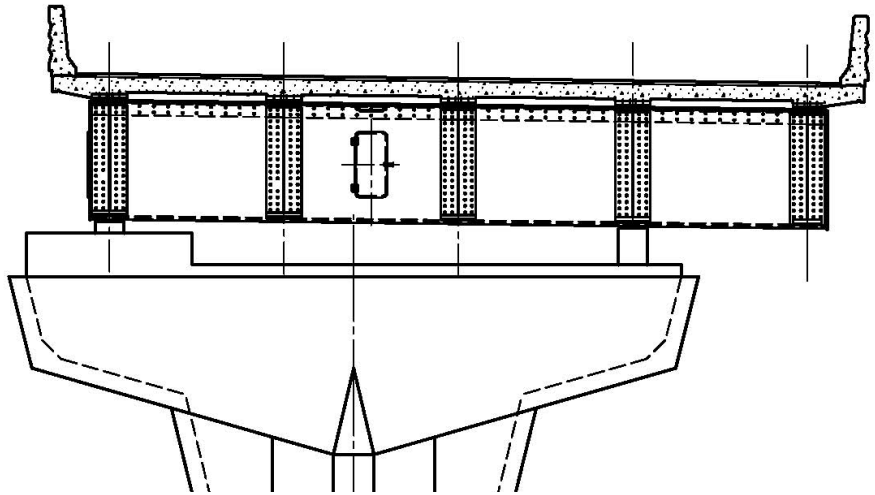
Project Approach

- Weekly call with HNTB Executives
- Weekly call with WisDOT Executives
- Daily meetings with contractor, WisDOT bridge group and local WisDOT SE Region staff
- Once Harvey Hammond said WisDOT is getting a new pier, we were off to the races!
- Work 24/7 to reopen ramp as soon as possible

How Did this Happen?

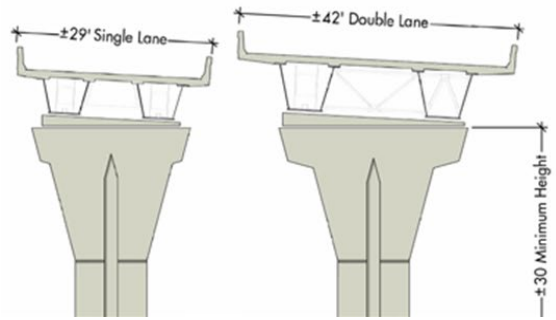
- Final Design Discovery of Clearance Conflict
- Integral Steel Cap Beam Solution was Scrutinized
- Substructure & Superstructure Teams Parallel Path - Missed Big Picture

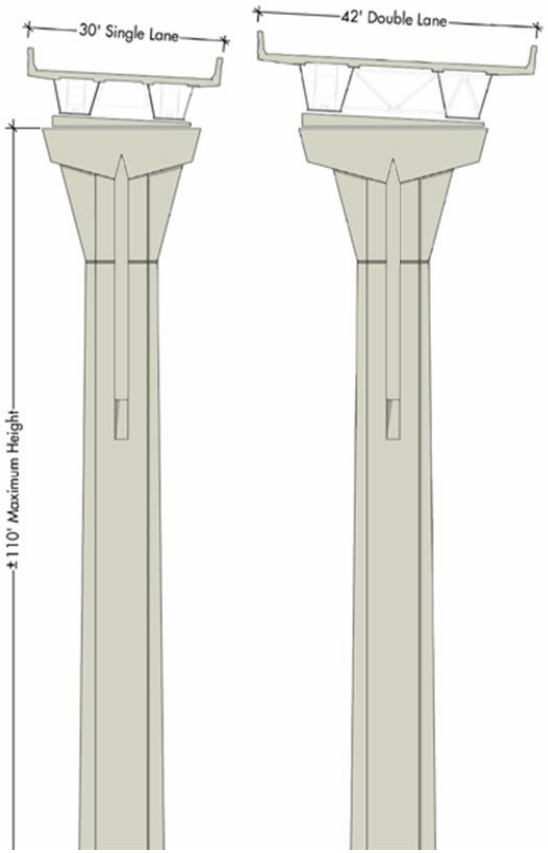


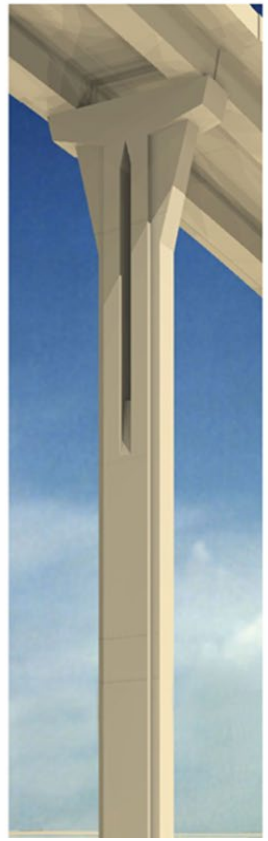


How Did this Happen? Column Grouping

- Column Grouping not Obvious or Transparent
- Individual Pier Designs Fully Checked-No Unique Design for TS7
- Goal: Simplify plans for similar shaped piers-Big miss on Loading







PROVE TO DOT NO OTHER ISSUES

- Report on all 258 Piers in Marquette Interchange

Prove to DOT no other Issues

- Ran Multiple Pier Designs to Support CDR Reports
- Report CDR for Cap, Columns, Footings, Piles
- All other HNTB Piers Checked Out
- KC Team Independent Review of Superstructure

Reporting Table A2-M

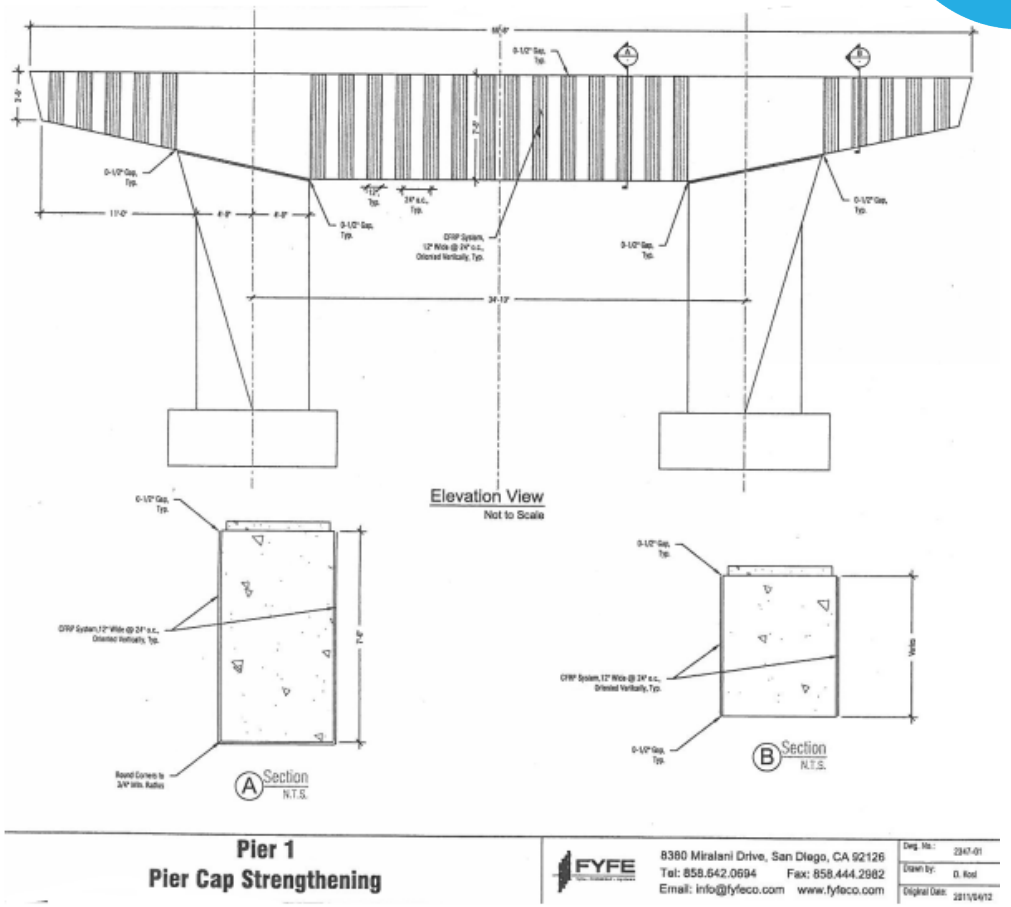
MQIC B-40-1411 Pier Cap Analysis Report:
Moment Analysis

	Negative Moment																		Positive Moment								
	At Cantilever Face of Column								At Inside Face of Column										In Between Columns								
	from RC Pier		from Plans			from Calculation			from RC Pier		from Plans			from Calculation					from RC Pier		from Plans			from Calculation			
	Mu * (k*ft)	Mu ** (k*ft)	Plan Rebar	Plan As (in2)	d (in)	a (in)	φMn (k*ft)	φMn / Mu	φMn / Mu **	Mu * (k*ft)	Mu ** (k*ft)	Plan Rebar	Plan As (in2)	d (in)	a (in)	φMn (k*ft)	φMn / Mu	φMn / Mu **	Mu * (k*ft)	Mu ** (k*ft)	Plan Rebar	Plan As (in2)	d (in)	a (in)	φMn (k*ft)	φMn / Mu	φMn / Mu **
Pier 1	4695.80	4555.68	12-#11 Bars	18.72	62.55	5.51	5839.49	1.11	1.11	5766.48	4557.30	6-#11 Bars	9.36	66.87	2.75	3582.56	0.95	0.82	5375.70	5775.28	10 - #10 Bars	12.70	64.44	3.74	4718.24	0.88	0.82
Pier 2	4752.90		16-#11 Bars	24.96	62.55	7.34	6615.24	1.39		5858.58		6-#11 Bars	12.48	66.87	3.67	4764.32	1.28		3061.80		7 - #10 Bars	8.89	66.74	2.61	3417.73	1.12	
Pier 3	3056.90	3055.08	12-#11 Bars	18.72	62.55	5.51	5839.49	1.27	1.27	2856.78	3046.80	12-#11 Bars	18.72	63.84	5.51	6636.95	2.51	2.24	0.08	355.78	6 - #10 Bars	7.62	66.74	2.24	2855.69	---	8.03
Pier 4	5114.50		14-#11 Bars	21.84	62.55	6.42	5834.51	1.14		5243.28		7-#11 Bars	13.02	66.87	3.21	4180.85	1.28		1087.70		6 - #10 Bars	7.62	66.74	2.24	2855.69	1.47	
Pier 5	4298.80	4298.89	14-#11 Bars	21.84	62.55	6.42	5834.51	1.30	1.30	2855.78	3250.80	7-#11 Bars	13.02	66.87	3.21	4180.85	1.44	1.20	2869.40	3872.48	12 - #10 Bars	15.24	63.67	4.48	5598.18	1.95	1.82
Pier 6	4232.20	4232.28	14-#11 Bars	21.84	62.55	6.42	5834.51	1.35	1.38	2847.08	3186.50	7-#11 Bars	13.02	66.87	3.21	4180.85	1.42	1.26	3089.70	3274.78	12 - #10 Bars	15.24	63.67	4.48	5598.18	1.81	1.71
Pier 7	4138.50	4138.59	14-#11 Bars	21.84	62.55	6.42	5834.51	1.41	1.41	2878.08	3254.80	7-#11 Bars	13.02	66.87	3.21	4180.85	1.45	1.28	3014.20	3222.18	12 - #10 Bars	15.24	63.67	4.48	5598.18	1.86	1.74
Pier 8	3864.30	3864.39	14-#11 Bars	21.84	62.55	6.42	5834.51	1.51	1.51	2857.78	3719.90	7-#11 Bars	13.02	66.87	3.21	4180.85	1.38	1.12	3033.90	4201.68	12 - #10 Bars	15.24	63.67	4.48	5598.18	1.46	1.31
Pier 9	3691.50	3691.59	14-#11 Bars	21.84	62.55	6.42	5834.51	1.62	1.62	2803.38	3581.40	7-#11 Bars	13.02	66.87	3.21	4180.85	1.44	1.14	3575.20	4205.38	12 - #10 Bars	15.24	63.67	4.48	5598.18	1.57	1.33
Pier 10	3378.80	3378.88	14-#11 Bars	21.84	62.55	6.42	5834.51	1.75	1.73	2246.58	3087.80	7-#11 Bars	13.02	66.87	3.21	4180.85	1.56	1.36	2789.80	3624.08	12 - #10 Bars	15.24	63.67	4.48	5598.18	2.07	1.54
Pier 11	3598.90	3598.98	14-#11 Bars	21.84	62.55	6.42	5834.51	1.62	1.62	2827.28	3680.80	7-#11 Bars	13.02	66.87	3.21	4180.85	1.43	1.10	3587.40	4875.98	12 - #10 Bars	15.24	63.67	4.48	5598.18	1.44	1.15
Pier 12	3328.20	3328.29	14-#11 Bars	21.84	62.55	6.42	5834.51	1.75	1.75	2221.18	4146.20	7-#11 Bars	13.02	66.87	3.21	4180.85	1.88	1.81	1334.80	3805.38	8 - #10 Bars	7.62	66.74	2.24	2855.69	2.20	8.58
Pier 13	4047.10	4047.19	14-#11 Bars	21.84	62.55	6.42	5834.51	1.44	1.44	2429.78	3314.10	14-#11 Bars	21.84	63.84	6.42	7023.85	1.26	2.30	39.66	1204.58	8 - #10 Bars	7.62	66.74	2.24	2855.69	66.08	2.44
Pier 13CW	4672.90	4672.08	16-#11 Bars	24.96	66.35	7.34	7265.37	1.55	1.56	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

BMCS Calc Back RC Pier Runs
MTP Current RC Pier Runs
CRITICAL LOCATIONS

Prove to DOT no other Issues

- HNTB Responsible for Subconsultant Designs
- CFRP Wrap Pier Cap Shear



Prove to DOT no other Issues

- Monitor Deck Cracking before and after Jacking

RAW IMAGE FROM SCANNER

IMAGE WITH SCAN DATA

IMAGE, SCAN DATA, AND DRAFTED 3D LINES OF CRACKS

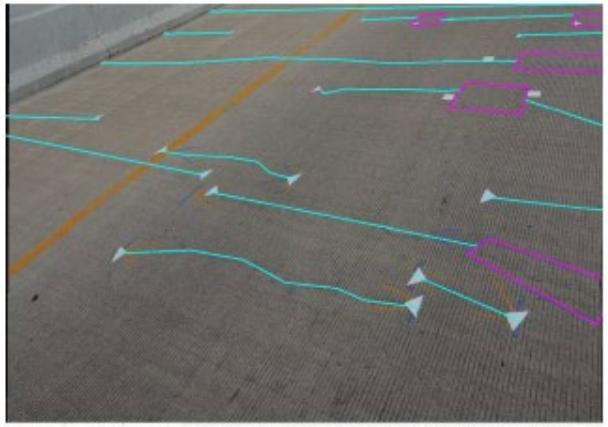
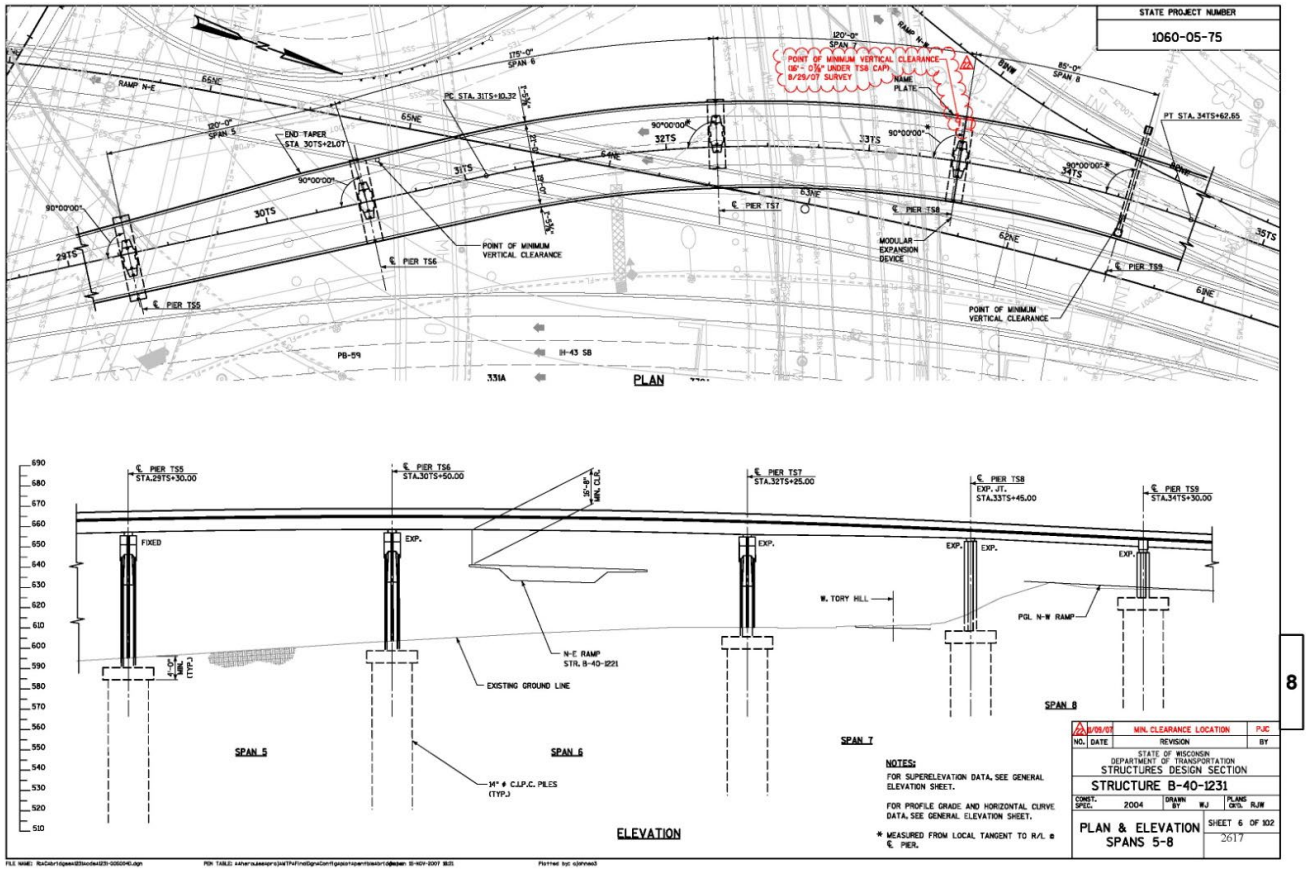


IMAGE WITH DRAFTED 3D LINES OF CRACKS

ANALYSES & DESIGN:
Where do we put the shoring towers?



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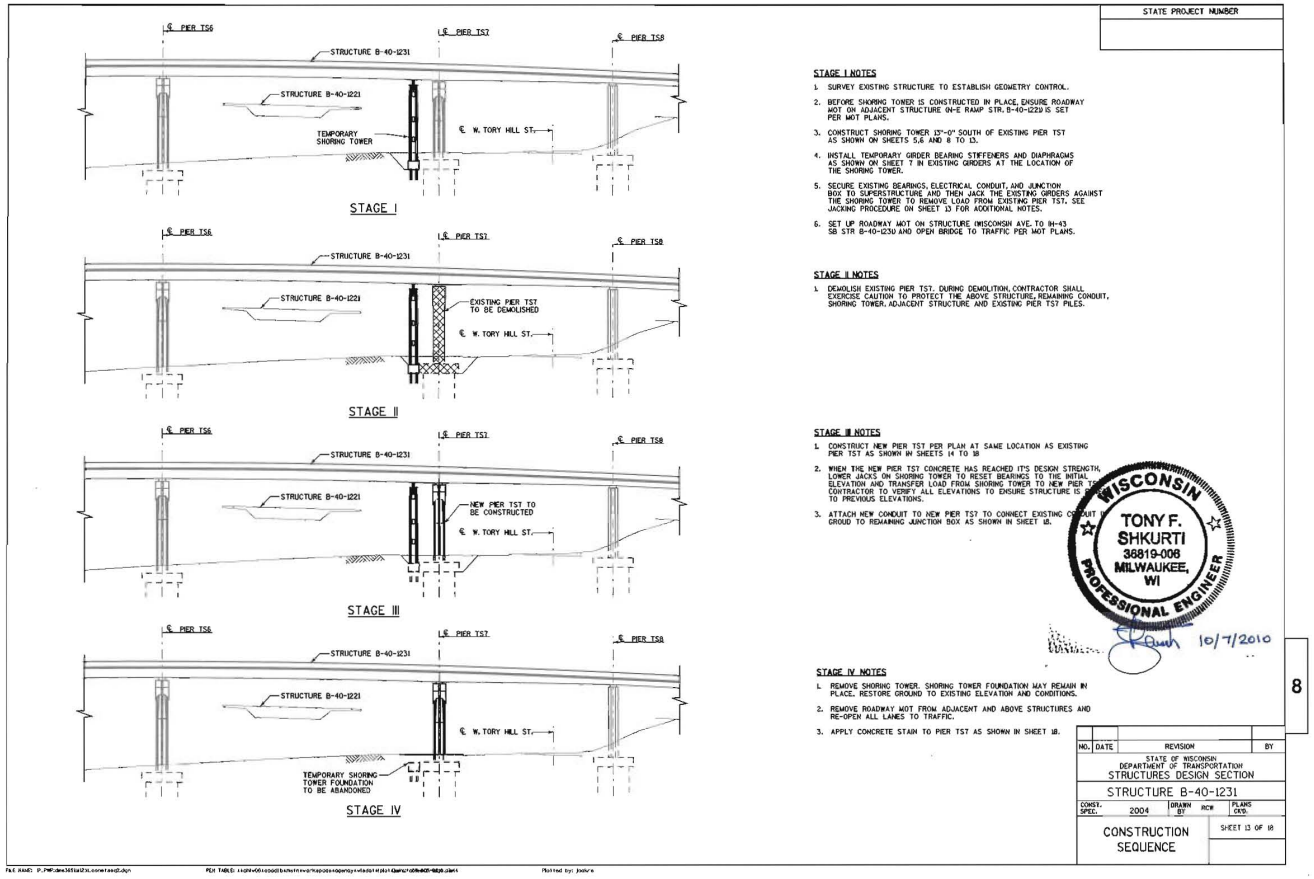
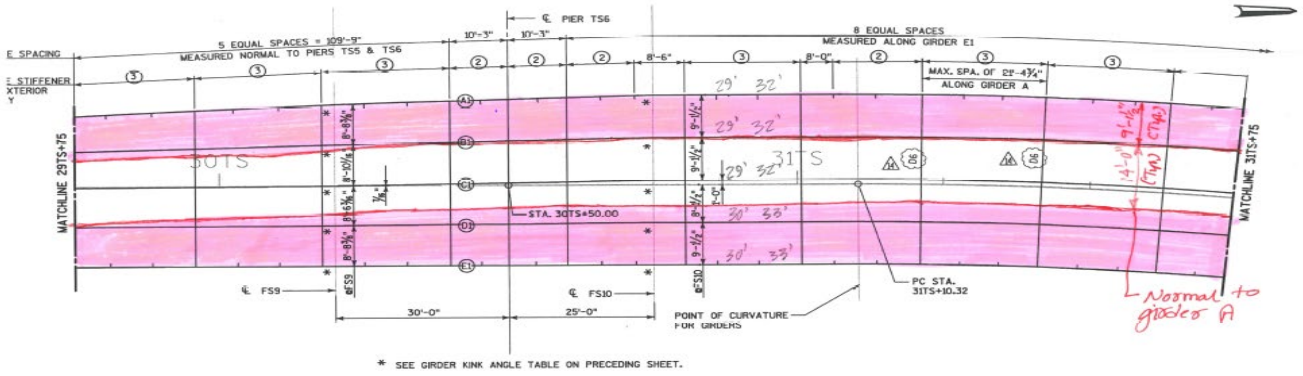
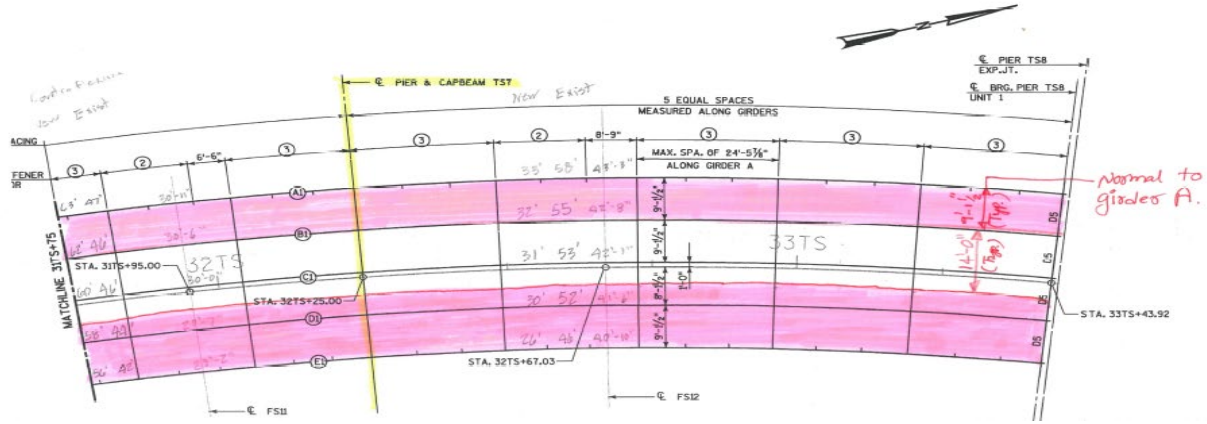


ANALYSES & DESIGN:
Restricted traffic…



FRAMING PLAN



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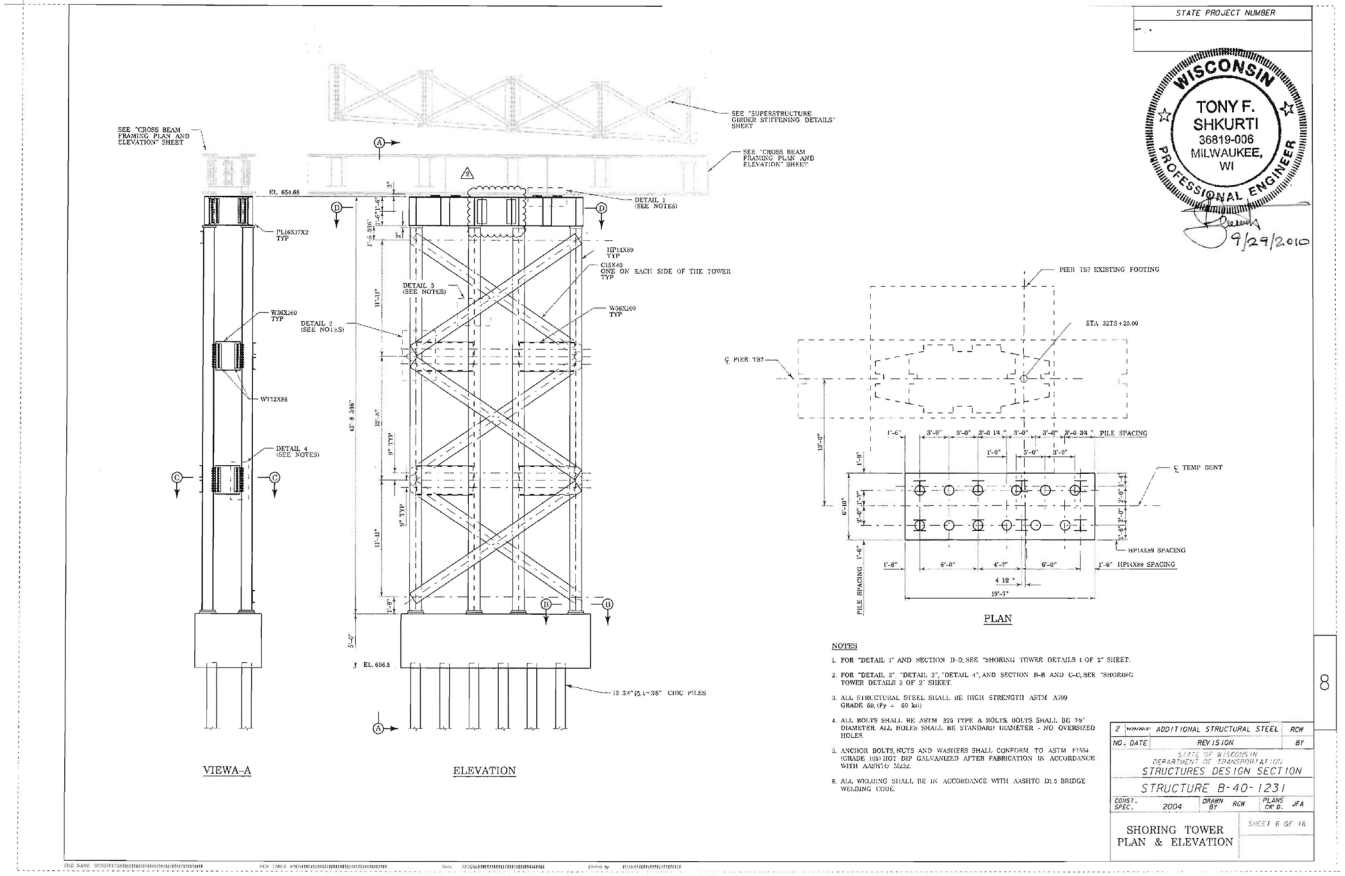
Temporary Pier Design …



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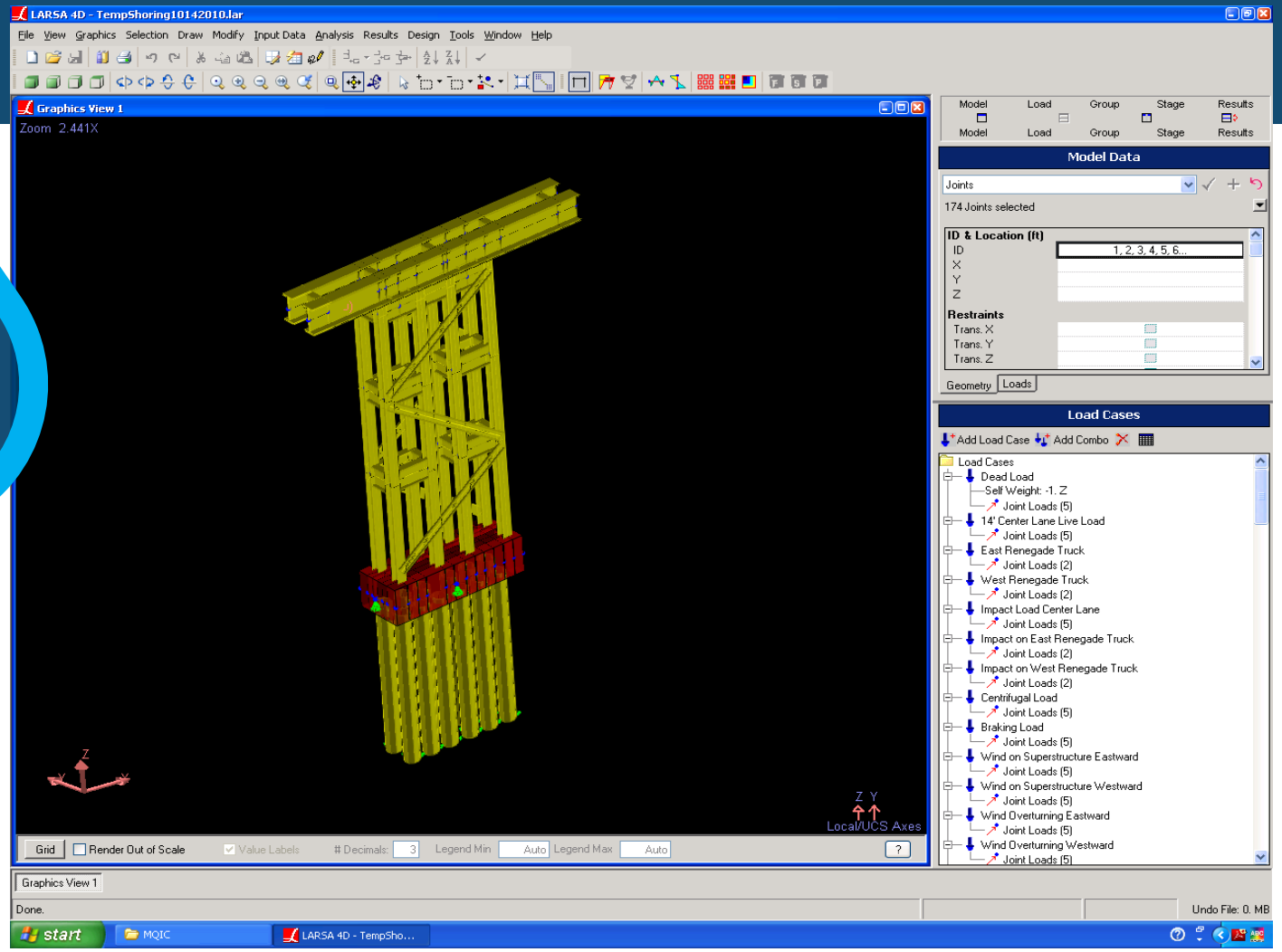

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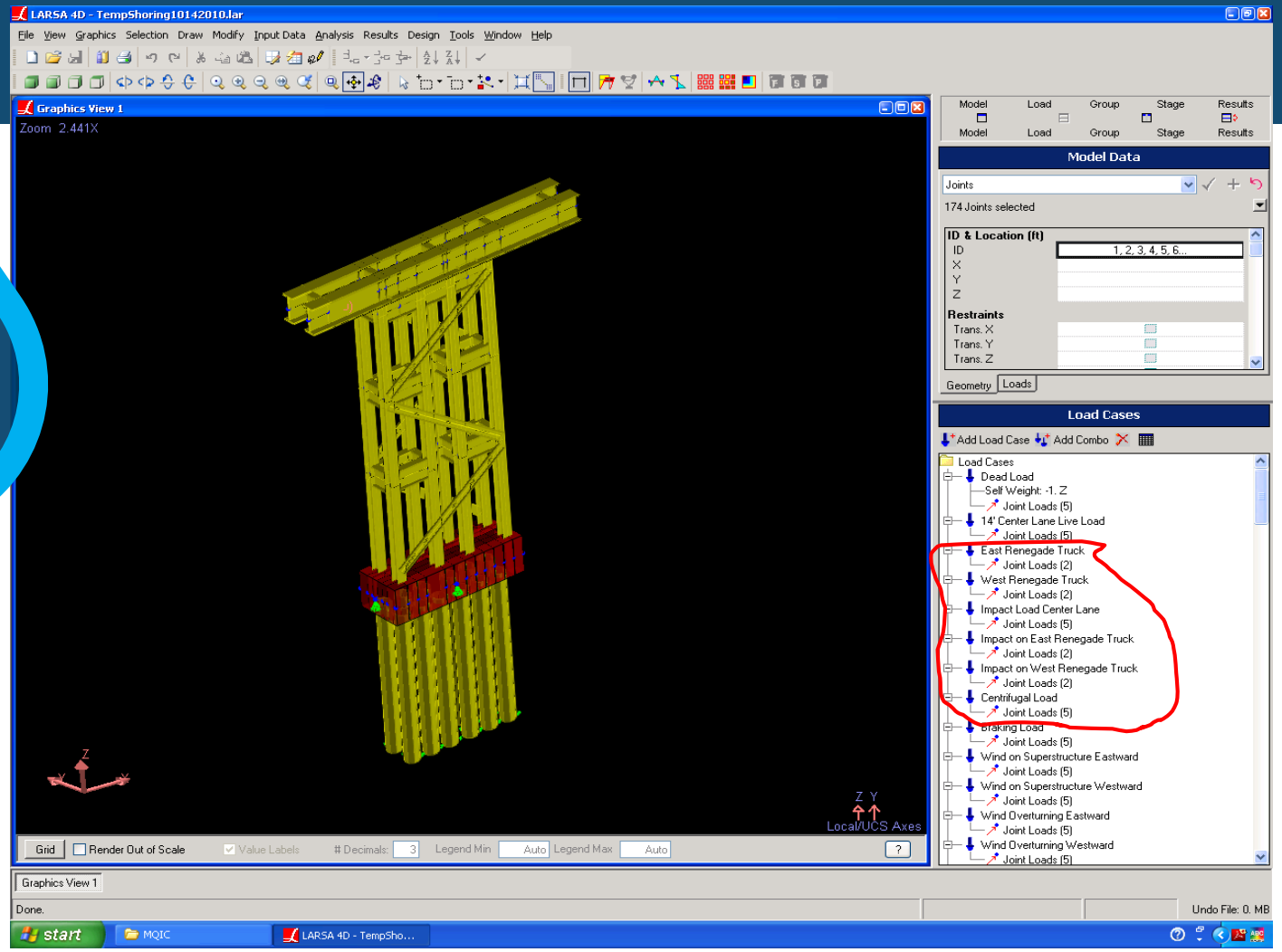
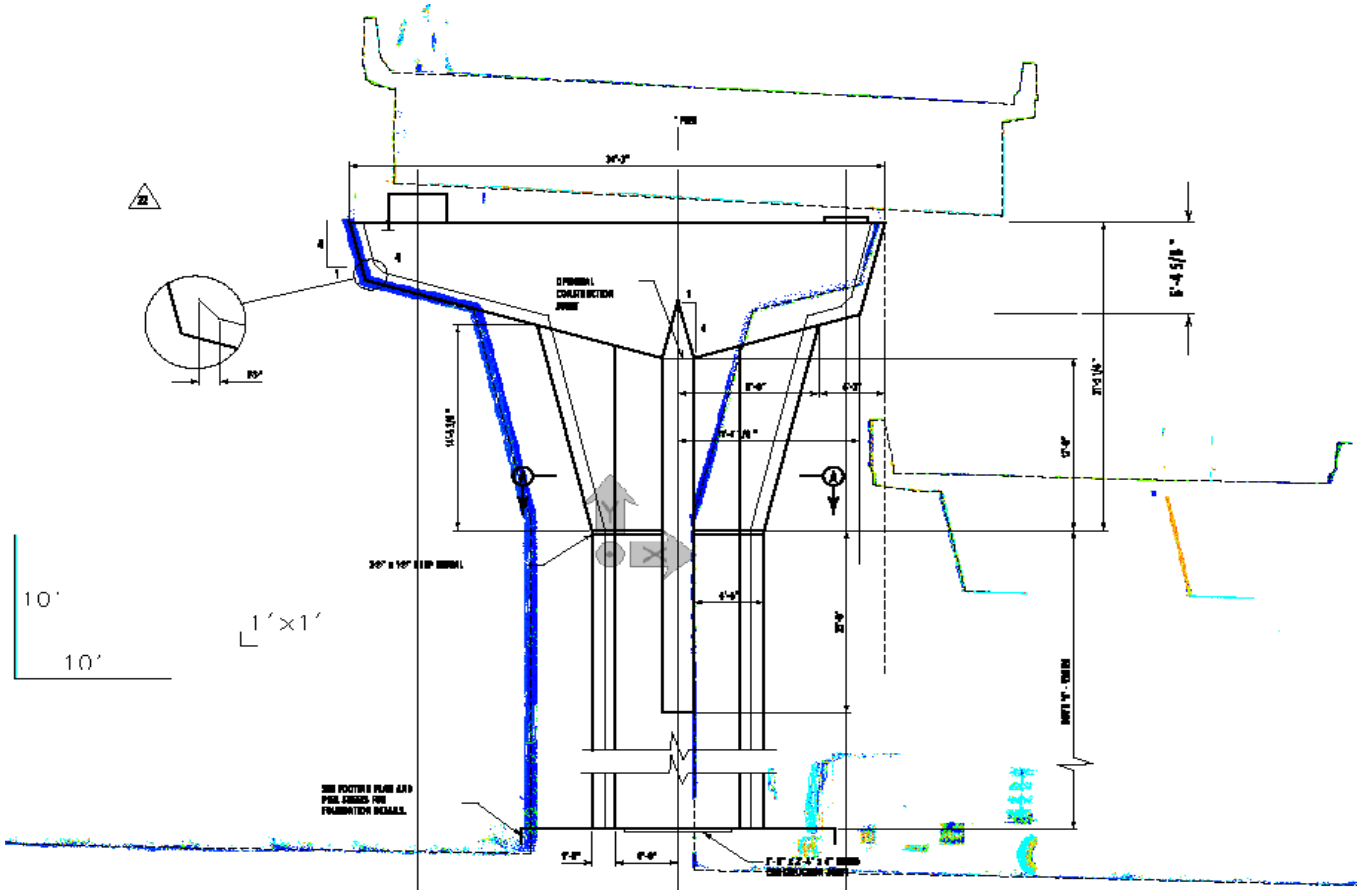


DESIGN OF CHOSEN OPTION:
Erected…

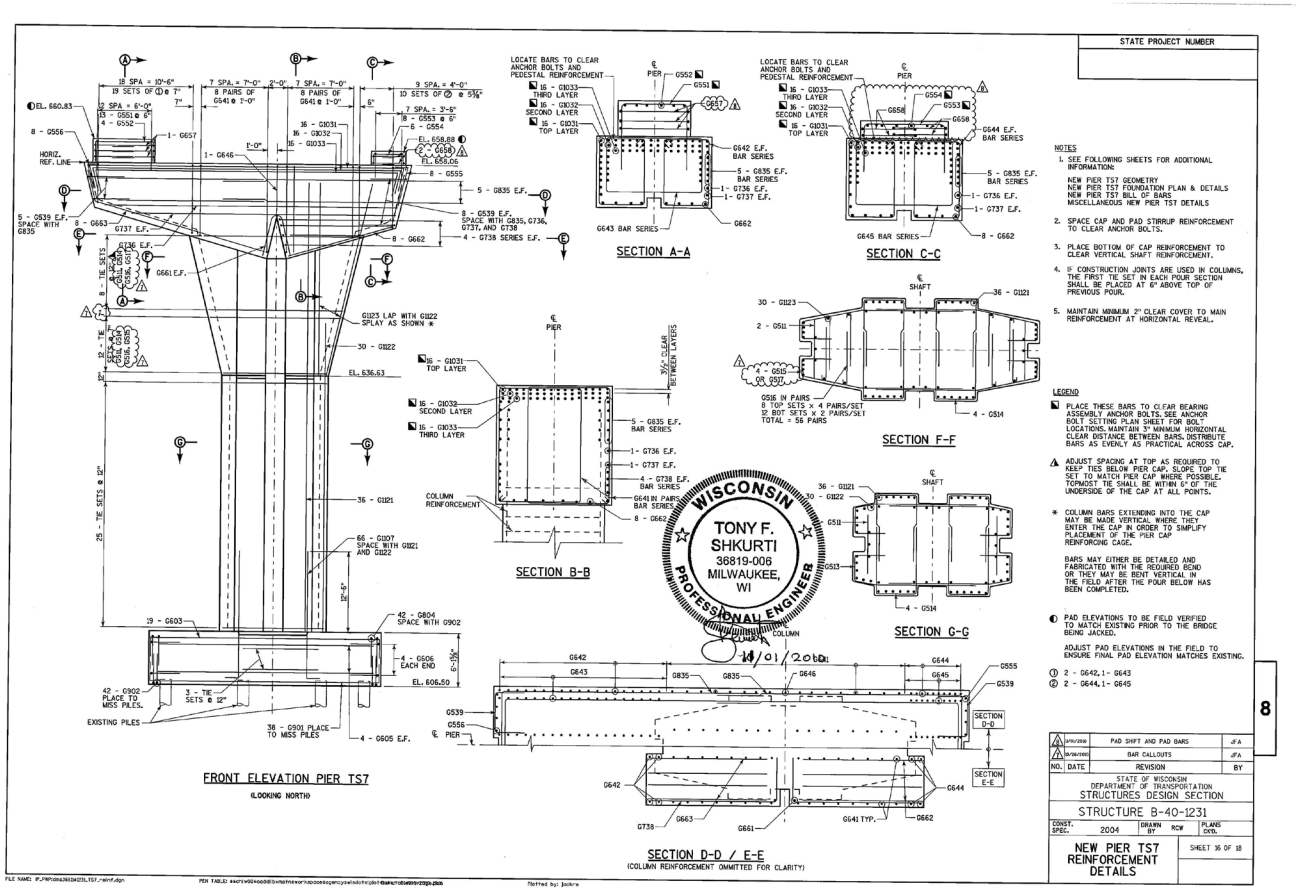
Analyses & Design: Fast & Furious after that…

- Designed one by one on a fast schedule:
  - Foundation
  - Header Beam
  - Shoring Frame
  - Jacking Sequence
- Designed New Pier
- Work continued at the site 24/7

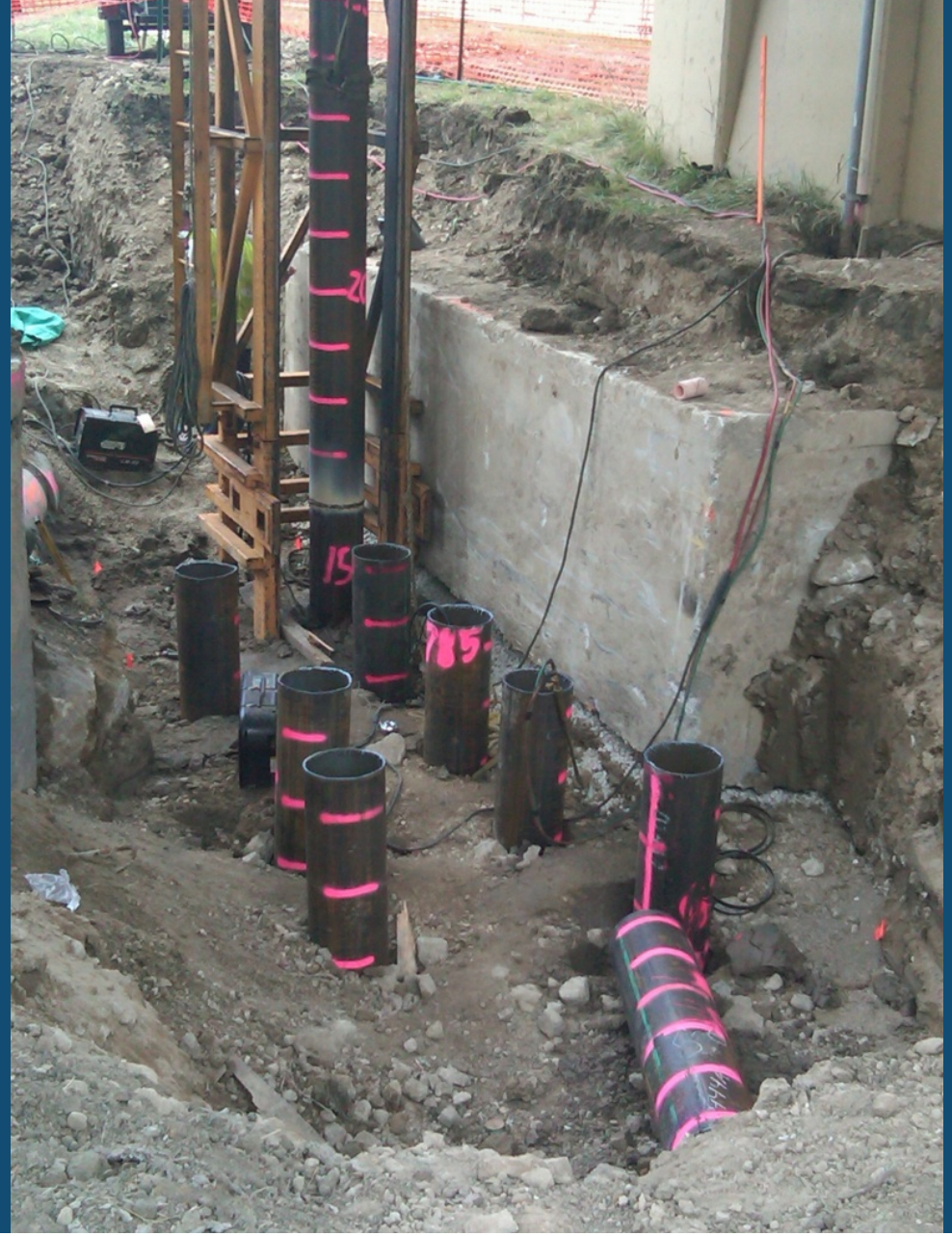
ANALYSES & DESIGN:
New Pier…



ANALYSES & DESIGN:
New Pier…

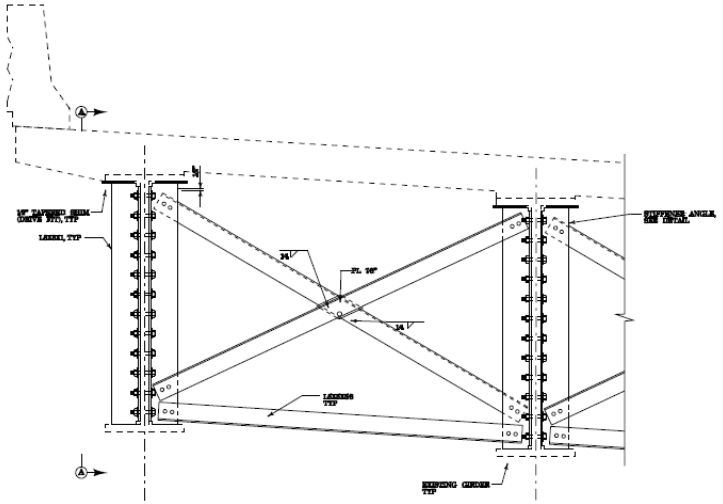


CONSTRUCTION:
Foundation and piles for temporary…

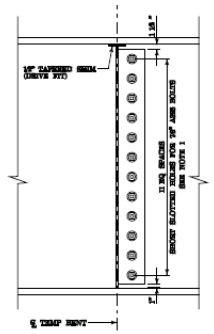


CONSTRUCTION:
Foundation and piles for temporary…

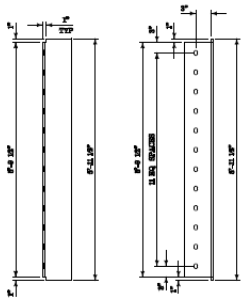
CONSTRUCTION:
Temporary Stiffening Diaphragm…



GIRDER STIFFENING DETAIL



SECTION A-A



STIFFENER ANGLE DETAIL

NOTES

1. SHORT SLOTS VERTICAL IN LEGS USE STANDARD HOLES IN EXISTING GIRDER WEBS. DRILL THROUGH BOTTOM OF SLOTTED HOLES AS TEMPLATE.
2. SET LEGS BOTH SIDES OF WEB AND INSTALL BOLTS WITH NUTS HAND TIGHT.
3. DRIVE TAPERED SHIM BACK SIDES OF WEB AT TOP FLANGE TO BRING OUTSTANDING LEG OF L65 INTO BEARING AT BOTTOM FLANGE OF GIRDER.
4. FULLY TORQUE BOLTS.
5. ALL STEEL SHALL BE ASTM A709 GRADE 50.
6. ALL BOLTS SHALL BE 7/8"ø ASTM A325.
7. SHORT SLOTTED HOLES SHALL BE 15/16" X 1 1/8"

NO.	DATE	REVISION	BY

STATE OF WISCONSIN
DEPARTMENT OF TRANSPORTATION
STRUCTURES DESIGN SECTION

STRUCTURE B-40-1231

CONST. SPEC.	DRAWN BY	RCW	PLANS CK'D.	STH
2004				

SUPERSTRUCTURE
GIRDER STIFFENING
DETAILS

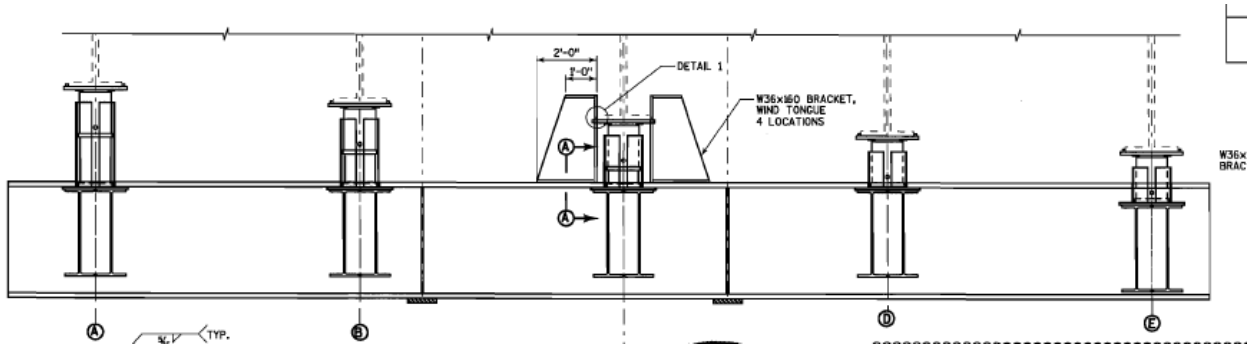
SHEET 5 OF 16

CONSTRUCTION:
Temporary Stiffening Diaphragm…

CONSTRUCTION:
Foundation and piles for temporary…

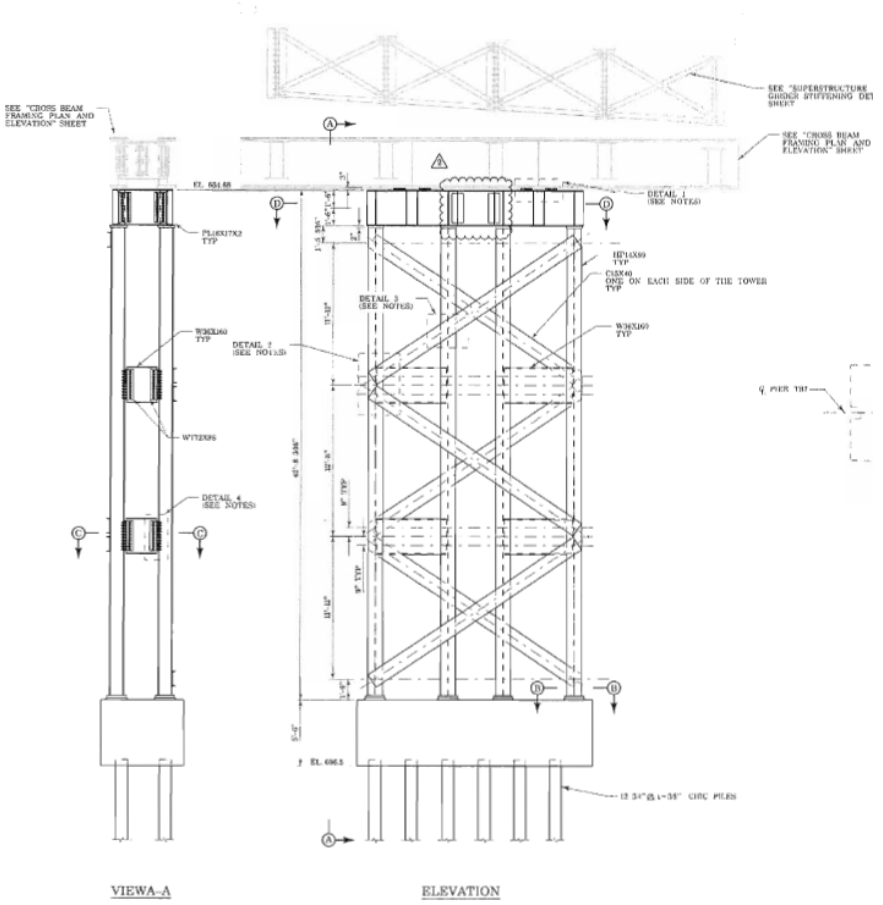
CONSTRUCTION:
Cross Beam Size…

CONSTRUCTION:
Wind Bracing…



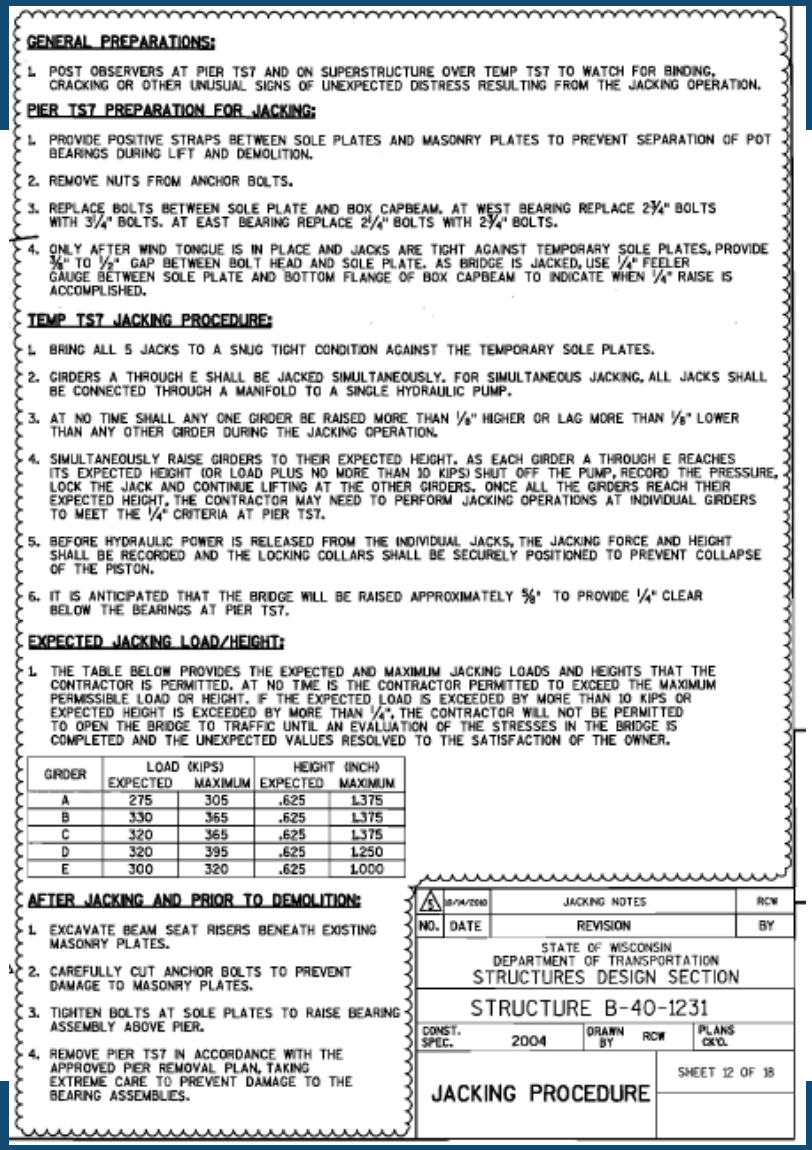
CONSTRUCTION:
Cross Beam Size…

CONSTRUCTION:
Temporary Tower Design
W36, HP…



CONSTRUCTION:
Tower Sliding…

CONSTRUCTION:
Jacking…



GENERAL PREPARATIONS:

1. POST OBSERVERS AT PIER TS7 AND ON SUPERSTRUCTURE OVER TEMP TS7 TO WATCH FOR BINDING, CRACKING OR OTHER UNUSUAL SIGNS OF UNEXPECTED DISTRESS RESULTING FROM THE JACKING OPERATION.

PIER TS7 PREPARATION FOR JACKING:

1. PROVIDE POSITIVE STRAPS BETWEEN SOLE PLATES AND MASONRY PLATES TO PREVENT SEPARATION OF POT BEARINGS DURING LIFT AND DEMOLITION.
2. REMOVE NUTS FROM ANCHOR BOLTS.
3. REPLACE BOLTS BETWEEN SOLE PLATE AND BOX CAPBEAM. AT WEST BEARING REPLACE 2¾" BOLTS WITH 3¼" BOLTS. AT EAST BEARING REPLACE 2¼" BOLTS WITH 2¾" BOLTS.
4. ONLY AFTER WIND TONGUE IS IN PLACE AND JACKS ARE TIGHT AGAINST TEMPORARY SOLE PLATES, PROVIDE ⅜" TO ½" GAP BETWEEN BOLT HEAD AND SOLE PLATE. AS BRIDGE IS JACKED, USE ¼" FEELER GAUGE BETWEEN SOLE PLATE AND BOTTOM FLANGE OF BOX CAPBEAM TO INDICATE WHEN ¼" RAISE IS ACCOMPLISHED.

TEMP TS7 JACKING PROCEDURE:

1. BRING ALL 5 JACKS TO A SNUG TIGHT CONDITION AGAINST THE TEMPORARY SOLE PLATES.
2. GIRDERS A THROUGH E SHALL BE JACKED SIMULTANEOUSLY. FOR SIMULTANEOUS JACKING, ALL JACKS SHALL BE CONNECTED THROUGH A MANIFOLD TO A SINGLE HYDRAULIC PUMP.
3. AT NO TIME SHALL ANY ONE GIRDER BE RAISED MORE THAN ⅛" HIGHER OR LAG MORE THAN ⅛" LOWER THAN ANY OTHER GIRDER DURING THE JACKING OPERATION.
4. SIMULTANEOUSLY RAISE GIRDERS TO THEIR EXPECTED HEIGHT. AS EACH GIRDER A THROUGH E REACHES ITS EXPECTED HEIGHT (OR LOAD PLUS NO MORE THAN 10 KIPS) SHUT OFF THE PUMP, RECORD THE PRESSURE, LOCK THE JACK AND CONTINUE LIFTING AT THE OTHER GIRDERS. ONCE ALL THE GIRDERS REACH THEIR EXPECTED HEIGHT, THE CONTRACTOR MAY NEED TO PERFORM JACKING OPERATIONS AT INDIVIDUAL GIRDERS TO MEET THE ¼" CRITERIA AT PIER TS7.
5. BEFORE HYDRAULIC POWER IS RELEASED FROM THE INDIVIDUAL JACKS, THE JACKING FORCE AND HEIGHT SHALL BE RECORDED AND THE LOCKING COLLARS SHALL BE SECURELY POSITIONED TO PREVENT COLLAPSE OF THE PISTON.
6. IT IS ANTICIPATED THAT THE BRIDGE WILL BE RAISED APPROXIMATELY ⅝" TO PROVIDE ¼" CLEAR BELOW THE BEARINGS AT PIER TS7.

EXPECTED JACKING LOAD/HEIGHT:

1. THE TABLE BELOW PROVIDES THE EXPECTED AND MAXIMUM JACKING LOADS AND HEIGHTS THAT THE CONTRACTOR IS PERMITTED. AT NO TIME IS THE CONTRACTOR PERMITTED TO EXCEED THE MAXIMUM PERMISSIBLE LOAD OR HEIGHT. IF THE EXPECTED LOAD IS EXCEEDED BY MORE THAN 10 KIPS OR EXPECTED HEIGHT IS EXCEEDED BY MORE THAN ¼", THE CONTRACTOR WILL NOT BE PERMITTED TO OPEN THE BRIDGE TO TRAFFIC UNTIL AN EVALUATION OF THE STRESSES IN THE BRIDGE IS COMPLETED AND THE UNEXPECTED VALUES RESOLVED TO THE SATISFACTION OF THE OWNER.

GIRDER	LOAD (KIPS)		HEIGHT (INCH)	
	EXPECTED	MAXIMUM	EXPECTED	MAXIMUM
A	275	305	.625	1.375
B	330	365	.625	1.375
C	320	365	.625	1.375
D	320	395	.625	1.250
E	300	320	.625	1.000

AFTER JACKING AND PRIOR TO DEMOLITION:

1. EXCAVATE BEAM SEAT RISERS BENEATH EXISTING MASONRY PLATES.
2. CAREFULLY CUT ANCHOR BOLTS TO PREVENT DAMAGE TO MASONRY PLATES.
3. TIGHTEN BOLTS AT SOLE PLATES TO RAISE BEARING ASSEMBLY ABOVE PIER.
4. REMOVE PIER TS7 IN ACCORDANCE WITH THE APPROVED PIER REMOVAL PLAN, TAKING EXTREME CARE TO PREVENT DAMAGE TO THE BEARING ASSEMBLIES.

NO.	DATE	REVISION	BY
1	10/24/2006	JACKING NOTES	RCW

STATE OF WISCONSIN
DEPARTMENT OF TRANSPORTATION
STRUCTURES DESIGN SECTION

STRUCTURE B-40-1231

CONST. SPEC.	2004	DRAWN BY	RCW	PLANS CK'D.

JACKING PROCEDURE

SHEET 12 OF 18

CONSTRUCTION:
Jacking…

CONSTRUCTION:
Jacking…

CONSTRUCTION:
Jacking…

CONSTRUCTION:
Tower Protection from debris…

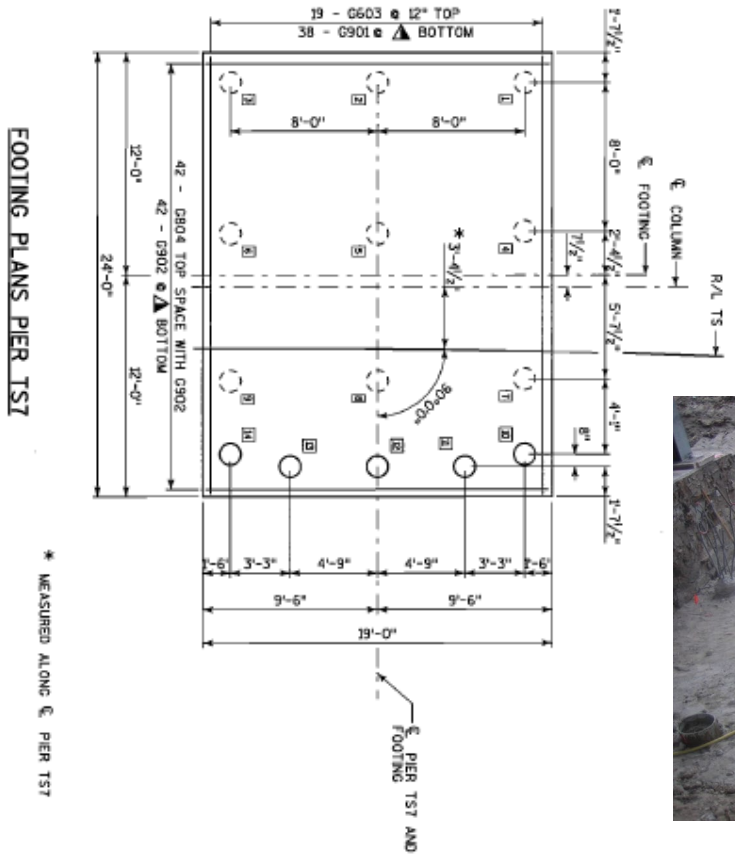
CONSTRUCTION:
Demolition…

CONSTRUCTION:
Demolition…

CONSTRUCTION:
Demolition…

CONSTRUCTION:
Load on Shoring tower…

CONSTRUCTION:
Demolition, Salvaged Piles, New Piles…



CONSTRUCTION:
New foundation…

CONSTRUCTION:
Rebar cage moving in…

CONSTRUCTION:
New Column…

CONSTRUCTION:
Dismantle Temporary Shoring…

CONSTRUCTION:
New Pier…

CONSTRUCTION:
New Pier…

CONSTRUCTION:
New Pier…

Lessons Learned

- Careful grouping design elements
- Clear Design Summaries - Any Doubt, Design
- Perform Early Geometric Clash Detection
- Conventional Bridges can be Complex
- QMS Senior Technical Review (Early Independent)
- PM / Task Lead should do a mandatory Cursory Review before Final
- Makes me proud how the company handled the problem
- Be truthful and fair with your Client and it will pay a dividend
- Raised HNTB's value in the eyes of WisDOT

MARQUETTE INTERCHANGE
PIER TS7

QUESTIONS?