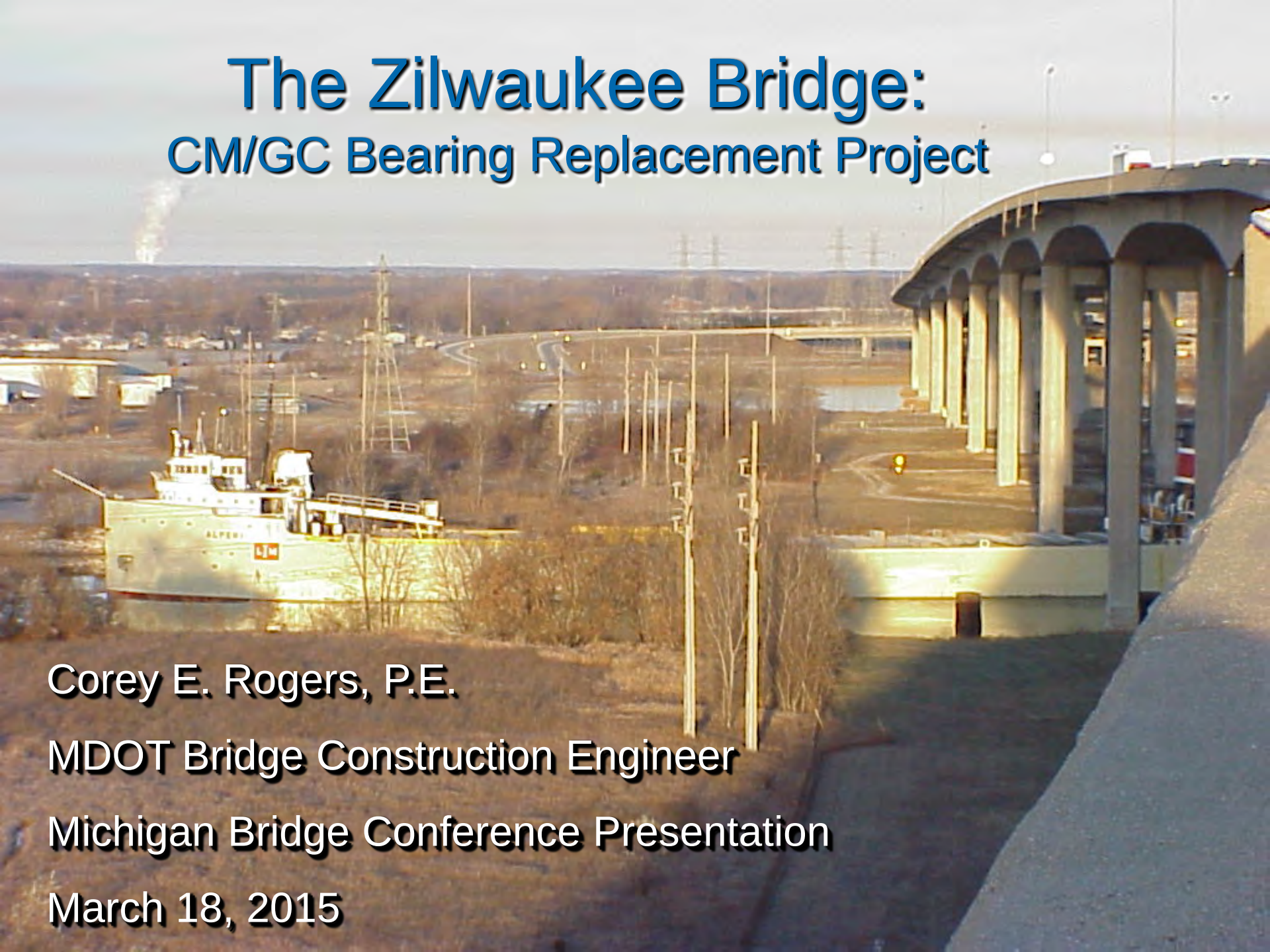
The Zilwaukee Bridge:
CM/GC Bearing Replacement Project



Corey E. Rogers, P.E.

MDOT Bridge Construction Engineer

Michigan Bridge Conference Presentation

March 18, 2015

CM/GC Bearing Replacement

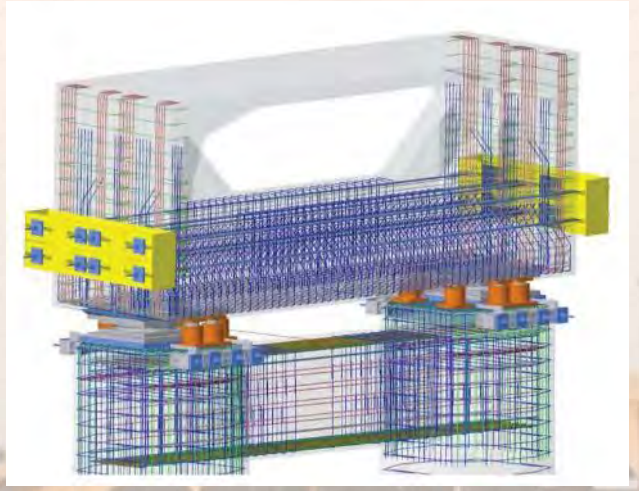
- Design for replacement of all bearings started in the fall of 2010
- MDOT decided to use CM/GC project delivery method to engage contractor with experience in segmental bridges during design phase
- CM/GC pre-construction services contract was executed in early 2013
- Work began in April 2013 with the closure of SB I-75

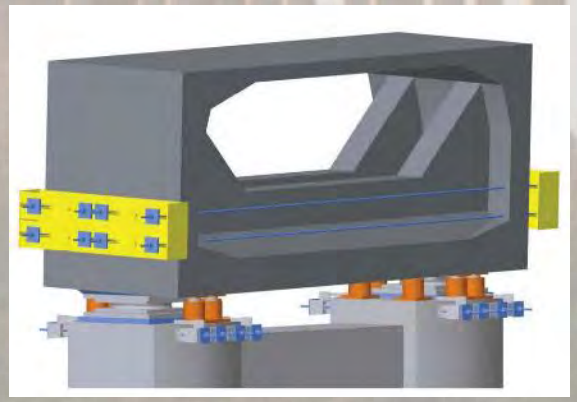
CM/GC Bearing Replacement

Pot Bearing

Disk Bearing

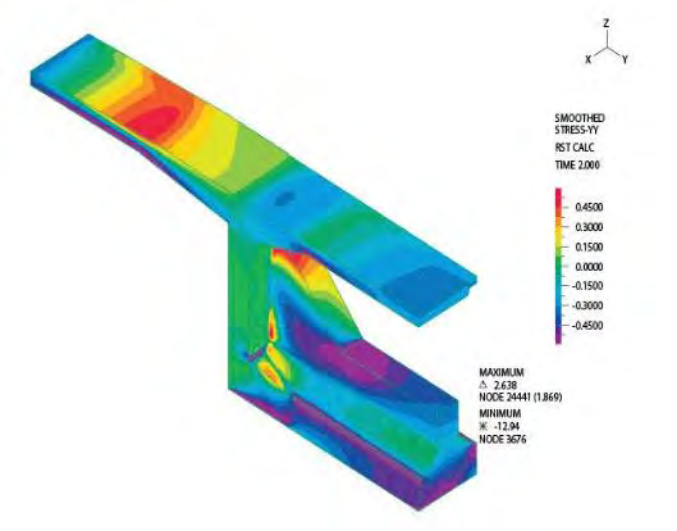
Pier Bearing Replacement

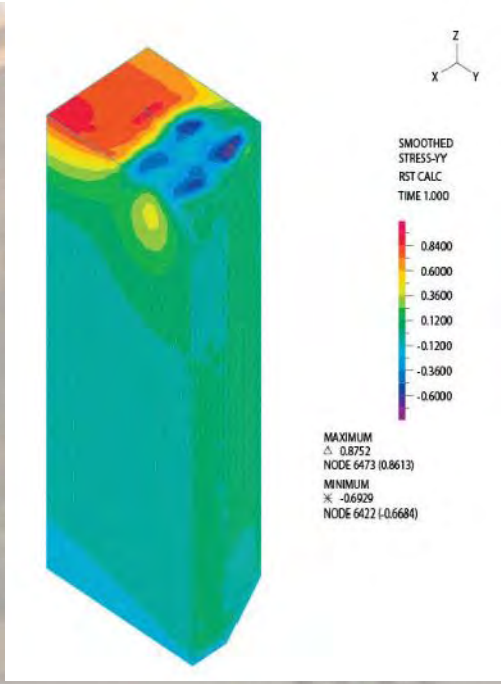




- Jack locations change the bearing location and designed load flow path
- Pier diaphragms are overstressed upon application of jacking
- Finite model analysis was used to determine additional compression needed in segments to not exceed principle tensile stresses during jacking

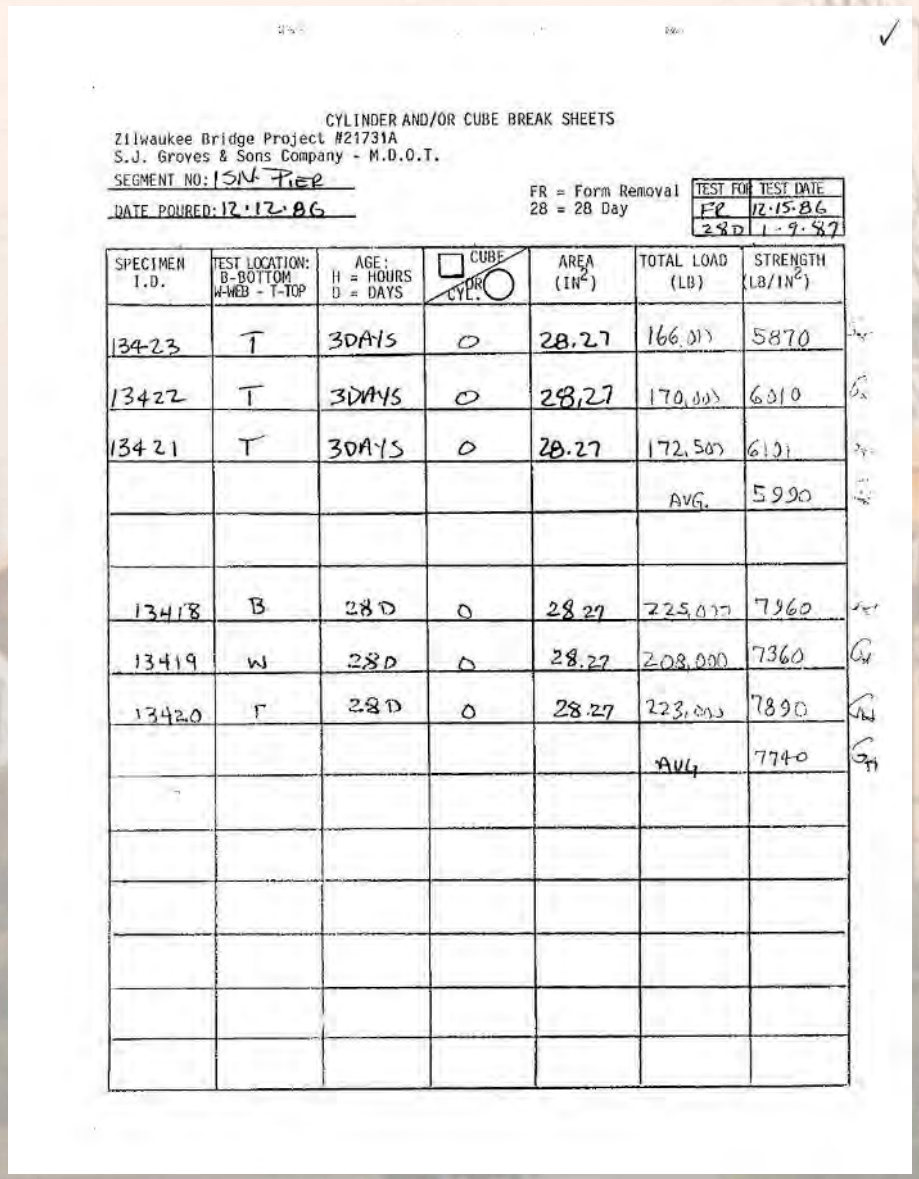
Pier Bearing Replacement





- Additional transverse post tensioning is needed near the centroid of the pier diaphragm
- Additional compression is also required at the top of the pier column to confine the tension tie that develops from the center of the jacking plates to the center of the column

Pier Bearing Replacement



CYLINDER AND/OR CUBE BREAK SHEETS

Zilwaukee Bridge Project #21731A
S.J. Groves & Sons Company - M.D.O.T.

SEGMENT NO: 15N Pier

DATE POURED: 12-12-86

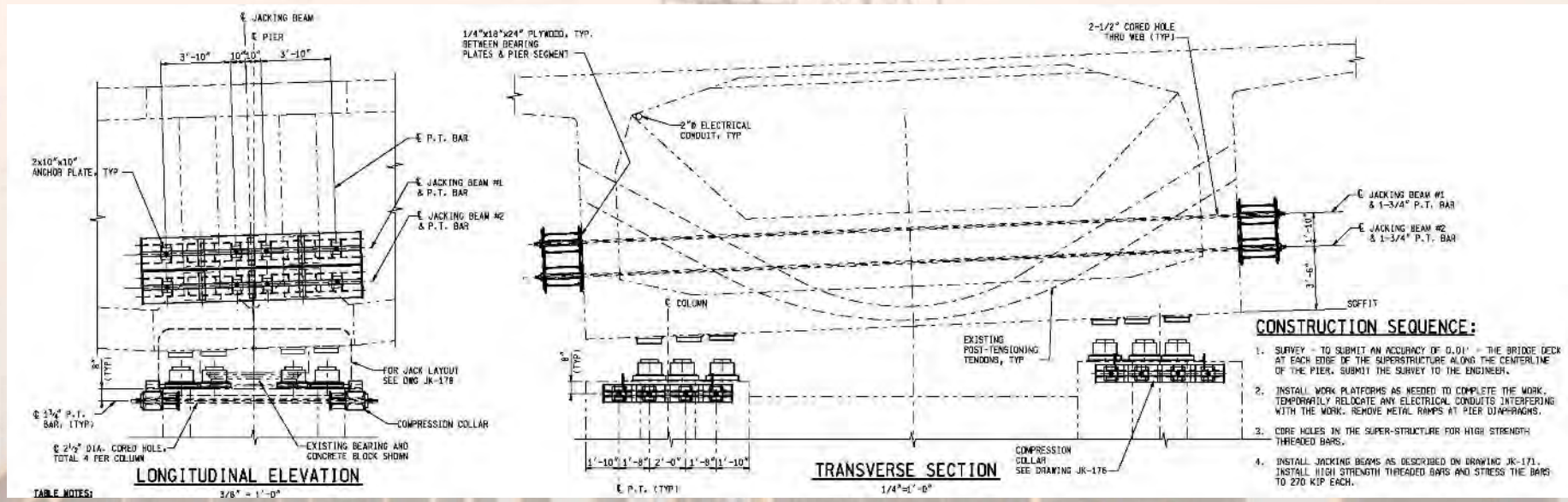
FR = Form Removal
28 = 28 Day

TEST FOR	TEST DATE
FR	12-15-86
28D	1-9-87

SPECIMEN I.D.	TEST LOCATION: B-BOTTOM W-WEB - T-TOP	AGE: H = HOURS D = DAYS	CUBE / CYL.	AREA (IN^2)	TOTAL LOAD (LB)	STRENGTH (LB/IN^2)
13423	T	3DAYS	O	28.27	166,000	5870
13422	T	3DAYS	O	28.27	170,000	6010
13421	T	3DAYS	O	28.27	172,500	6100
					AVG.	5990
13418	B	28D	O	28.27	225,000	7960
13419	W	28D	O	28.27	208,000	7360
13420	T	28D	O	28.27	223,000	7890
					AVG	7740

- Using original concrete break strengths for piers and segments to analyze concrete stresses due to actual compressive strengths plus and age factor

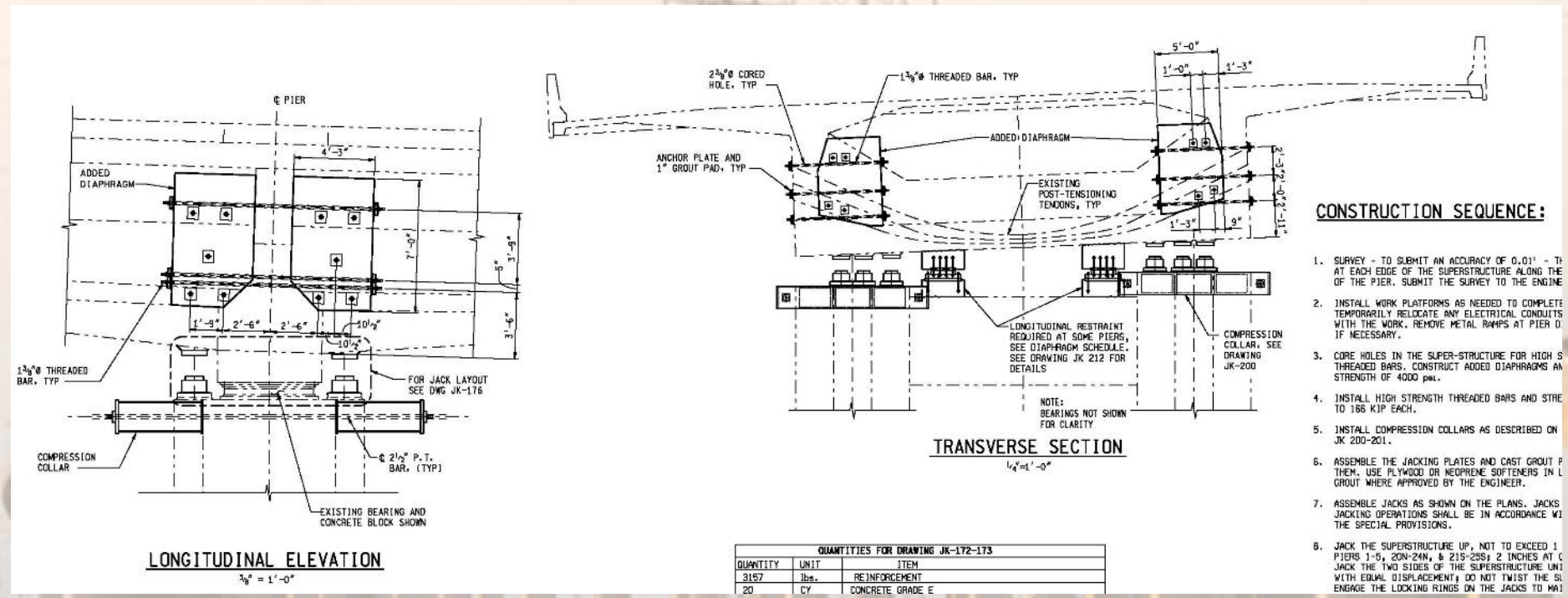
Pier Bearing Replacement



- Twelve 1 ¾” PT bars stressed at 210 kips each are required to properly compress the section

- 12’ long x 25” high box girder walers distribute the PT force into the cross section

Pier Bearing Replacement

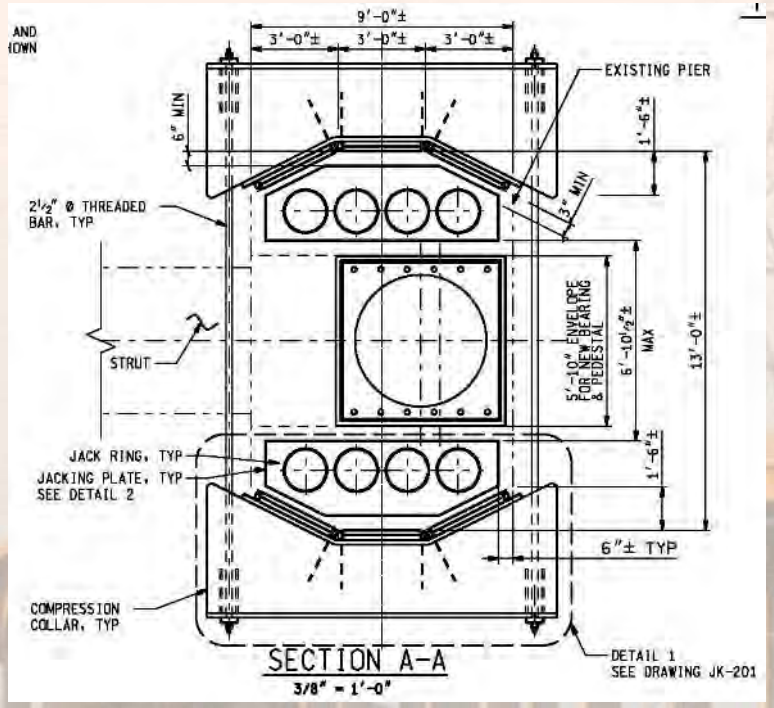


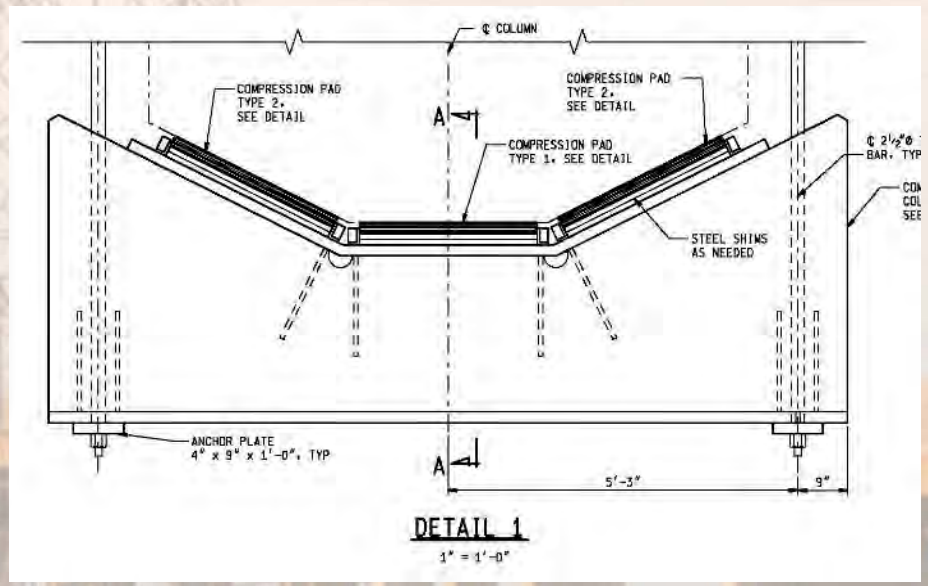
QUANTITIES FOR DRAWING JK-172-173

QUANTITY	UNIT	ITEM
3157	lbs.	REINFORCEMENT
20	CY	CONCRETE GRADE E

- Smaller segmental box sections require additional concrete diaphragms to support jacking loads
- PT bars stressed to 166 kips each

Pier Bearing Replacement

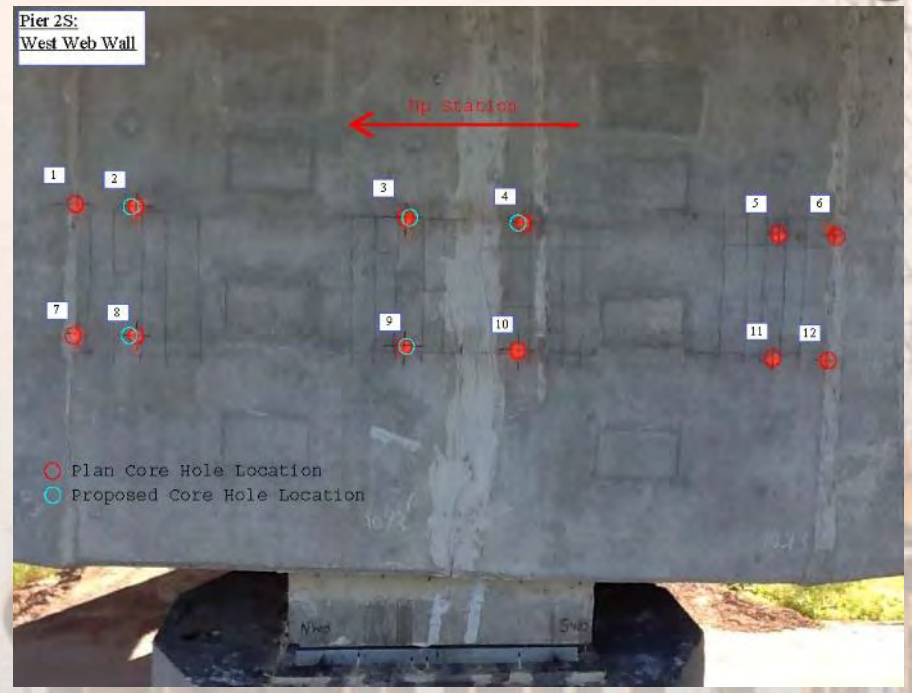


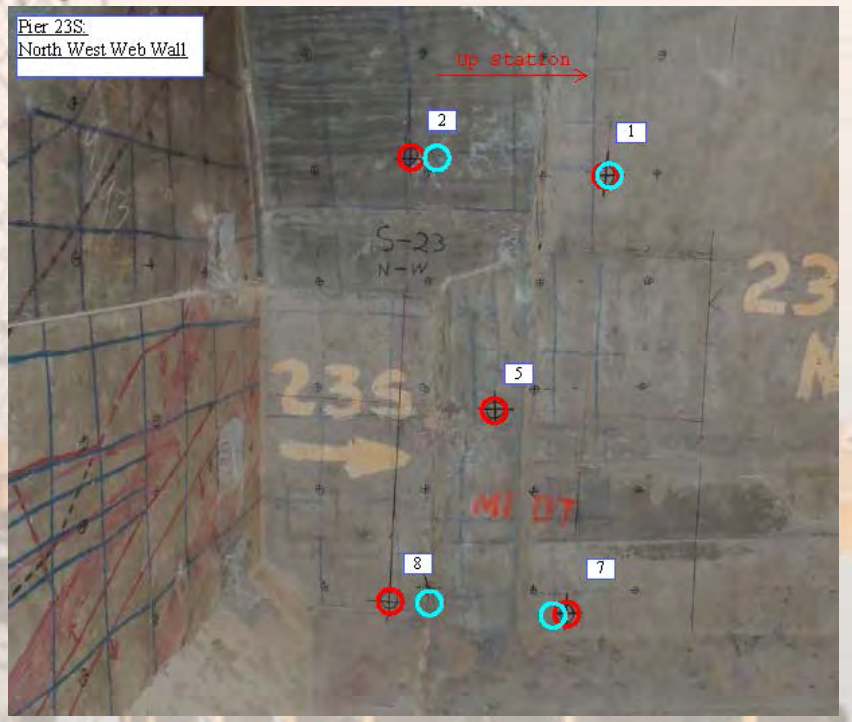


- Two 2 ½” PT bars stressed at 540 kips each apply compression force to top of piers under jacking plates

- Plate girder collar beams comprised of 2 ½” thick plate and bearing plates distribute the PT force

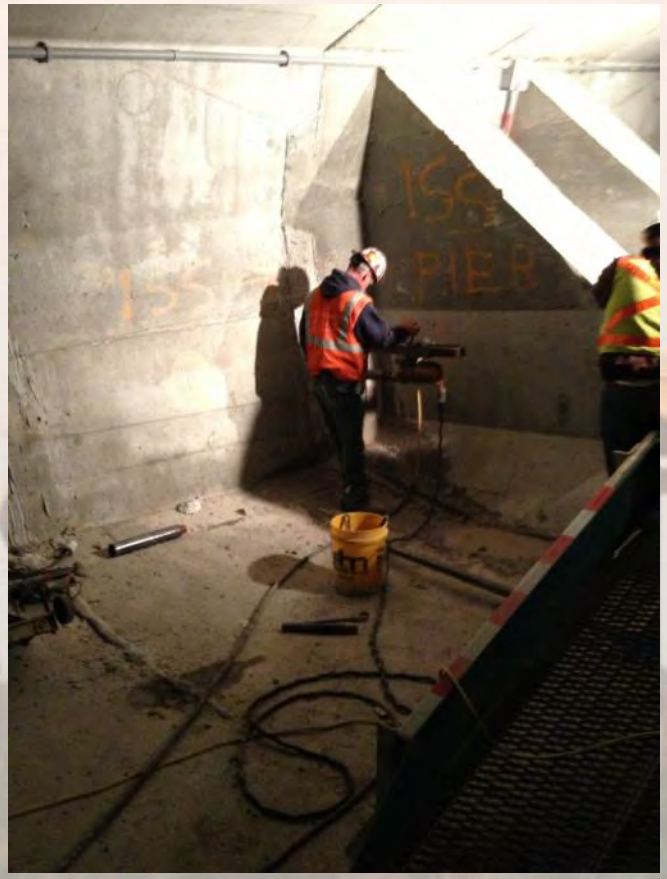
Pier Bearing Replacement





- Coring plans – NDT is performed at everyone proposed core hole location. An RFI is submitted requesting permission to core. RFI's are reviewed and approved by MDOT and the designer. Thus far, 75 RFI's have been submitted.

Pier Bearing Replacement



- Coring and placement of 1 ¾” transverse PT bars

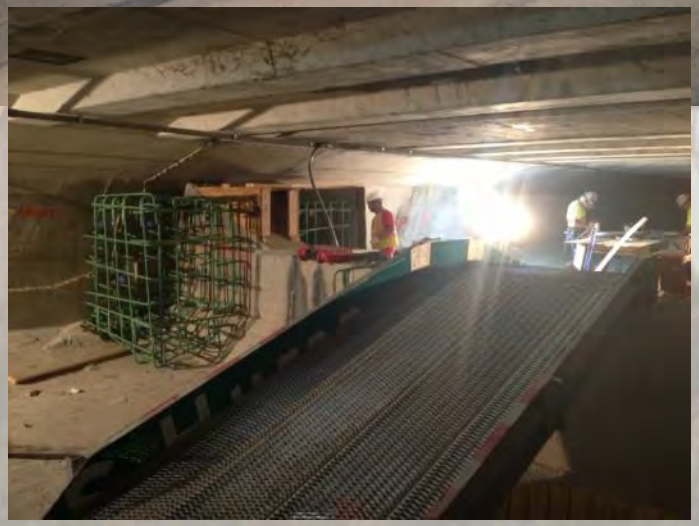
Pier Bearing Replacement

- Longitudinal restraint construction

Pier Bearing Replacement

- Placement of waler beams and stressing

Pier Bearing Replacement



- Some pier diaphragms require strengthening

Pier Bearing Replacement

- Setting and stressing of compression collars

Pier Bearing Replacement

- Setting and stressing of compression collars

Pier Bearing Replacement

- Issues with elastomeric pads, switched to plywood

Pier Bearing Replacement

- 600 ton jacks and custom pump with 8 manifolds

Pier Bearing Replacement

- Jacking layouts

Pier Bearing Replacement

- Jacking layouts

Pier Bearing Replacement

- Jacking operation – the first lift

Pier Bearing Replacement

- Lift complete, lock rings engaged, hydraulics removed

Pier Bearing Replacement

- Existing bearing removal with wire saw rig

Pier Bearing Replacement

- Existing bearing stacked for inspection

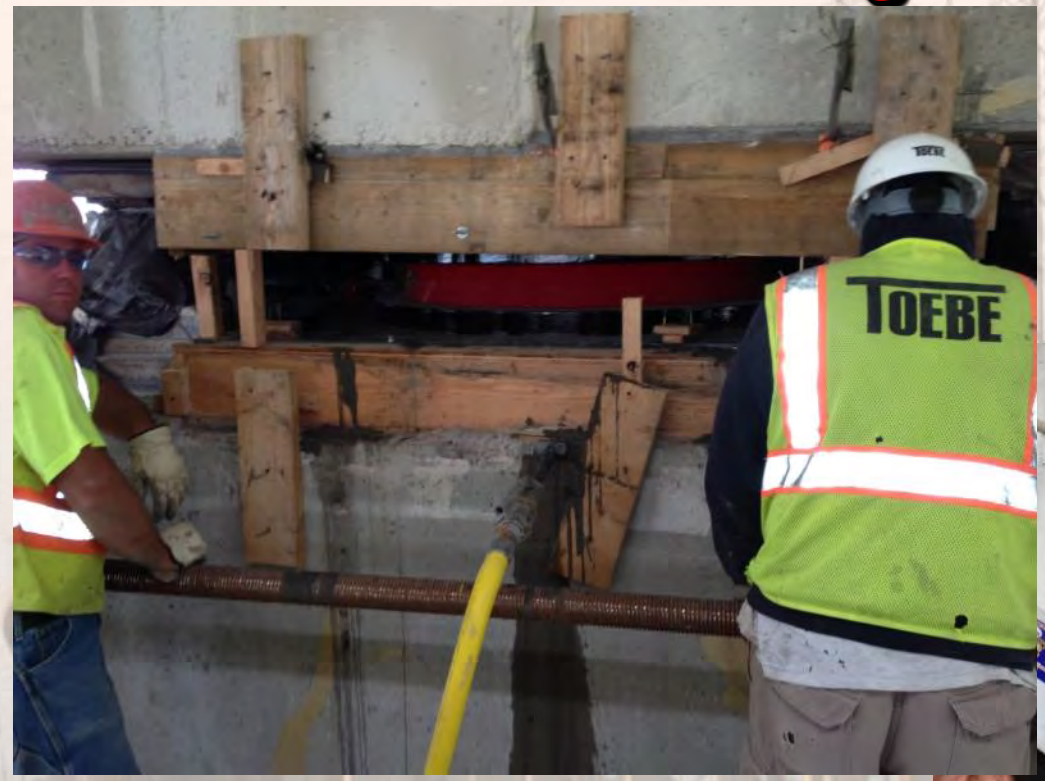
Pier Bearing Replacement

- New disc bearings – max capacity 8100 kips

Pier Bearing Replacement

- Installing rebar and shimming bearings

Pier Bearing Replacement



- Forming and pressure grouting

Pier Bearing Replacement

- Completed bearings

Pier Bearing Replacement

- Completed bearings

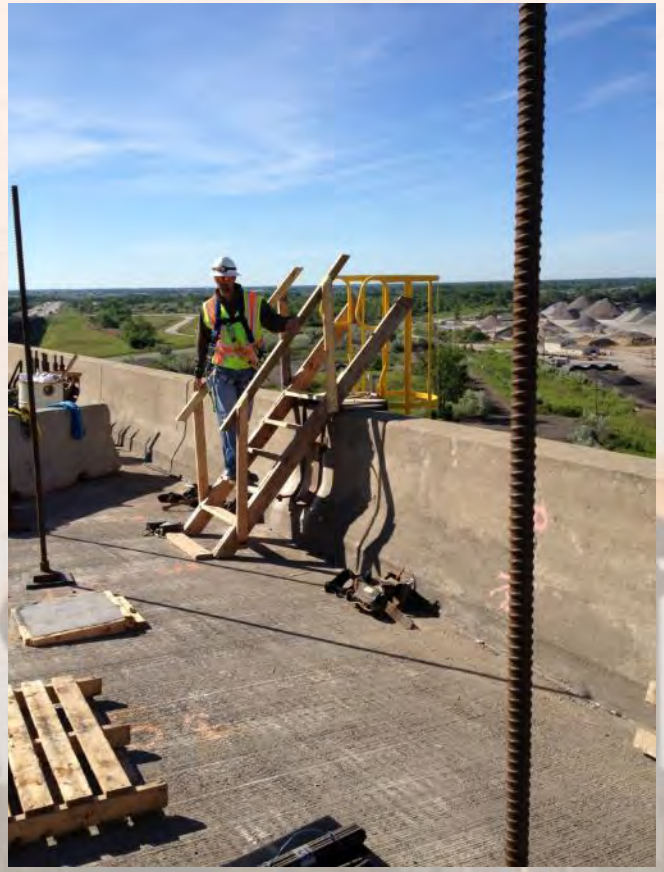
Pier Bearing Replacement

- Grouting and shimming issues addressed early

Work Platforms

- Supported by core holes through segment wings

Work Platforms

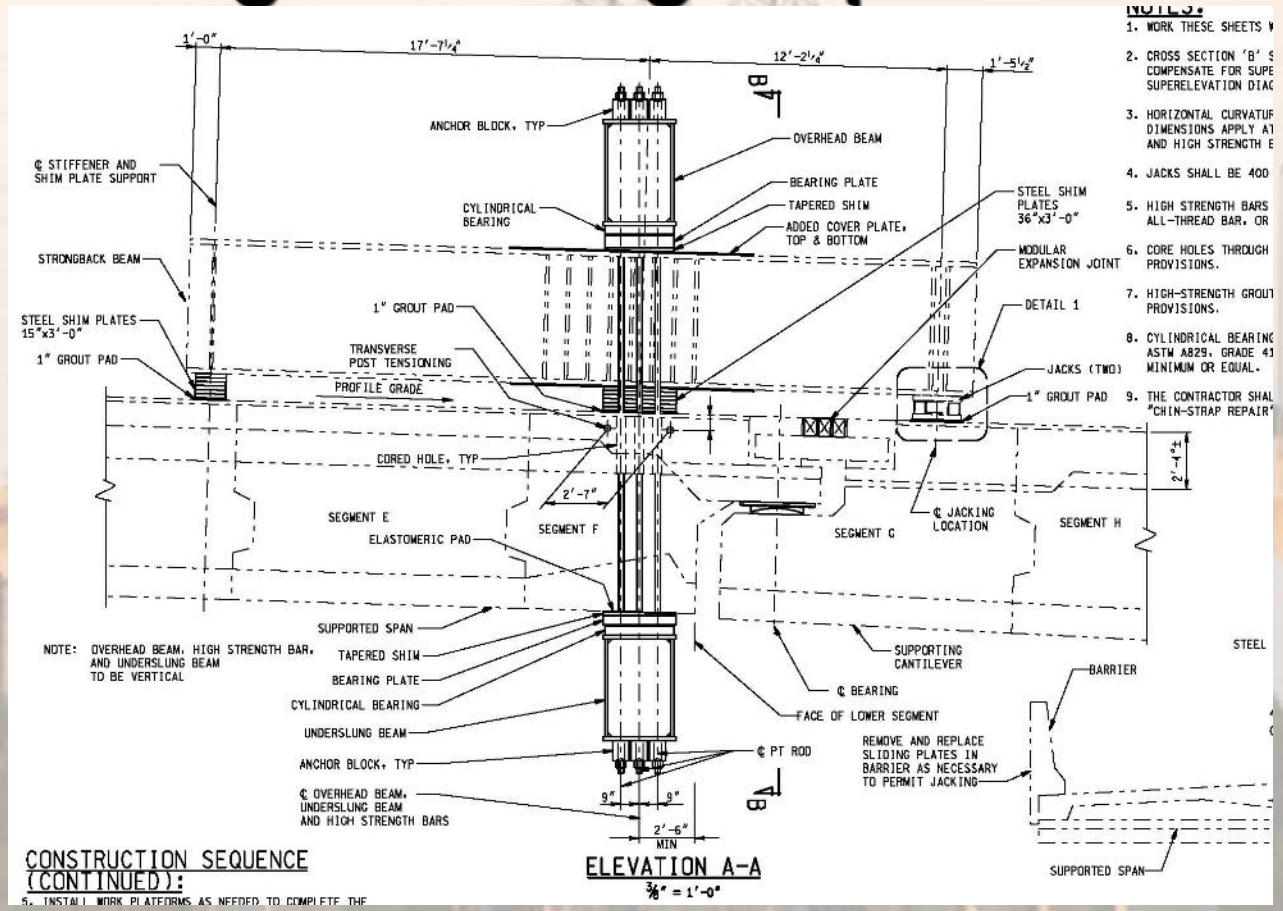


- Designed for weight of equipment and bearings

Work Platforms

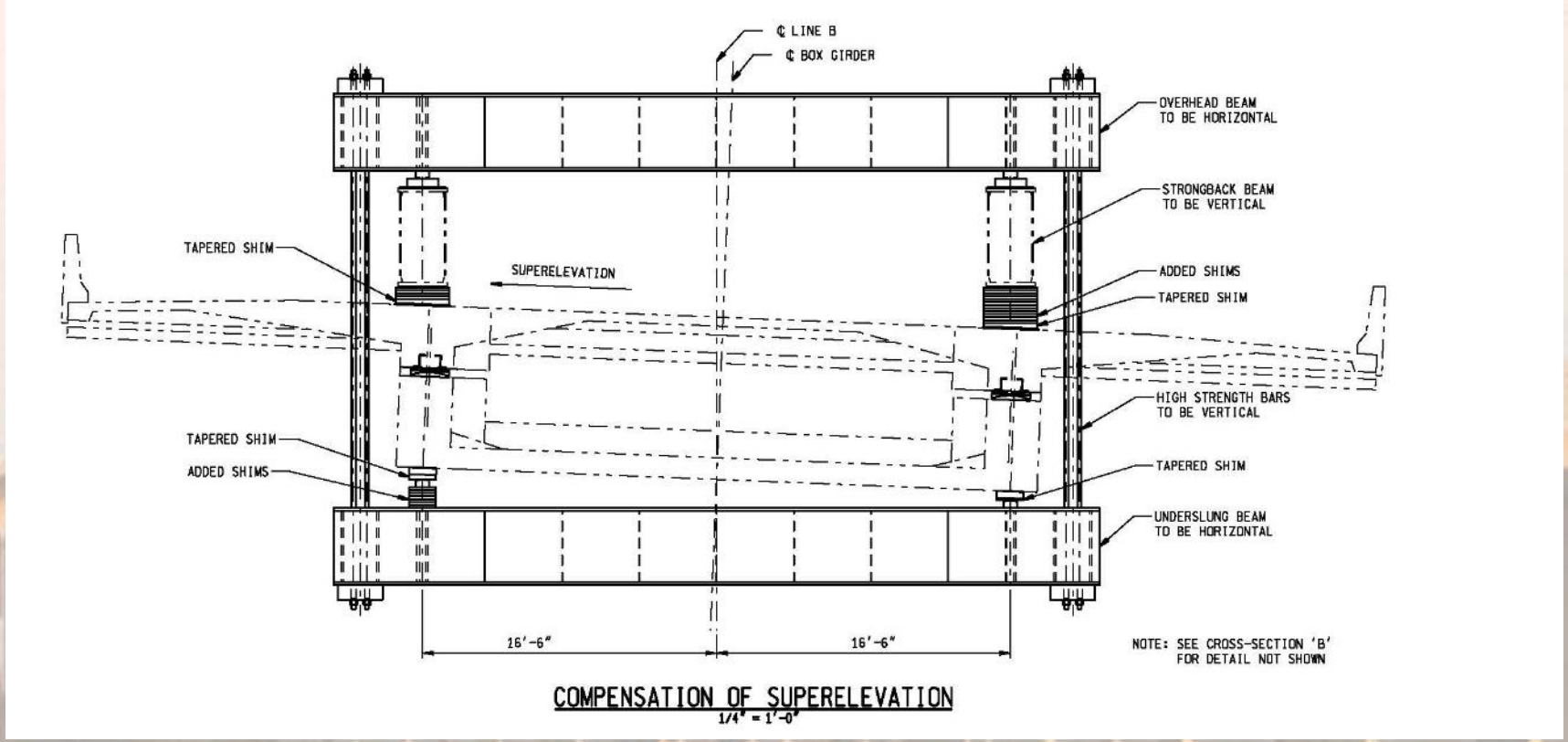
- Amazing views

Hinge Bearing Replacement



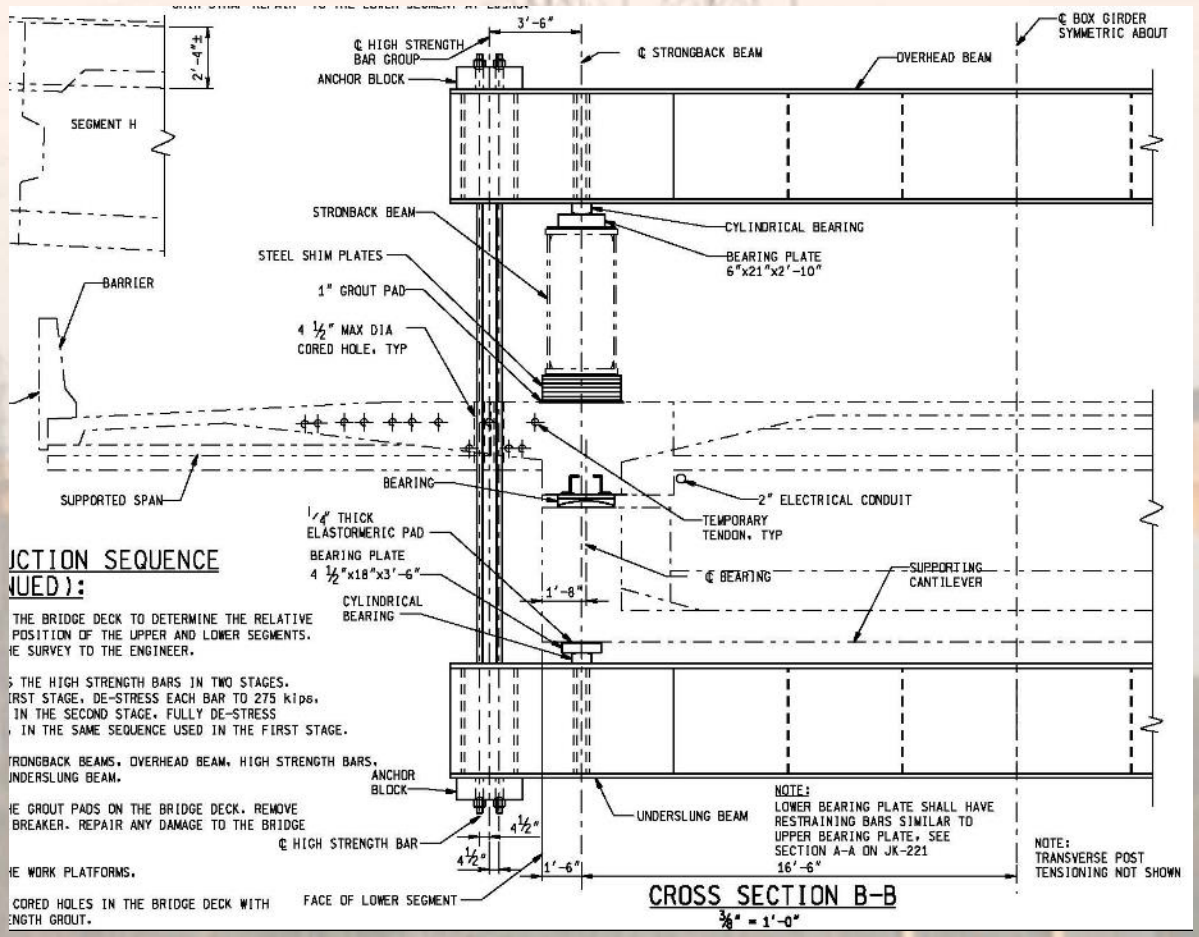
- Quarter point hinges allow for expansion and rotation
- Most complicated and sensitive portions of the structure

Hinge Bearing Replacement



- General scheme to use strong back, overhead and underslung beams to transmit load from upper segment

Hinge Bearing Replacement

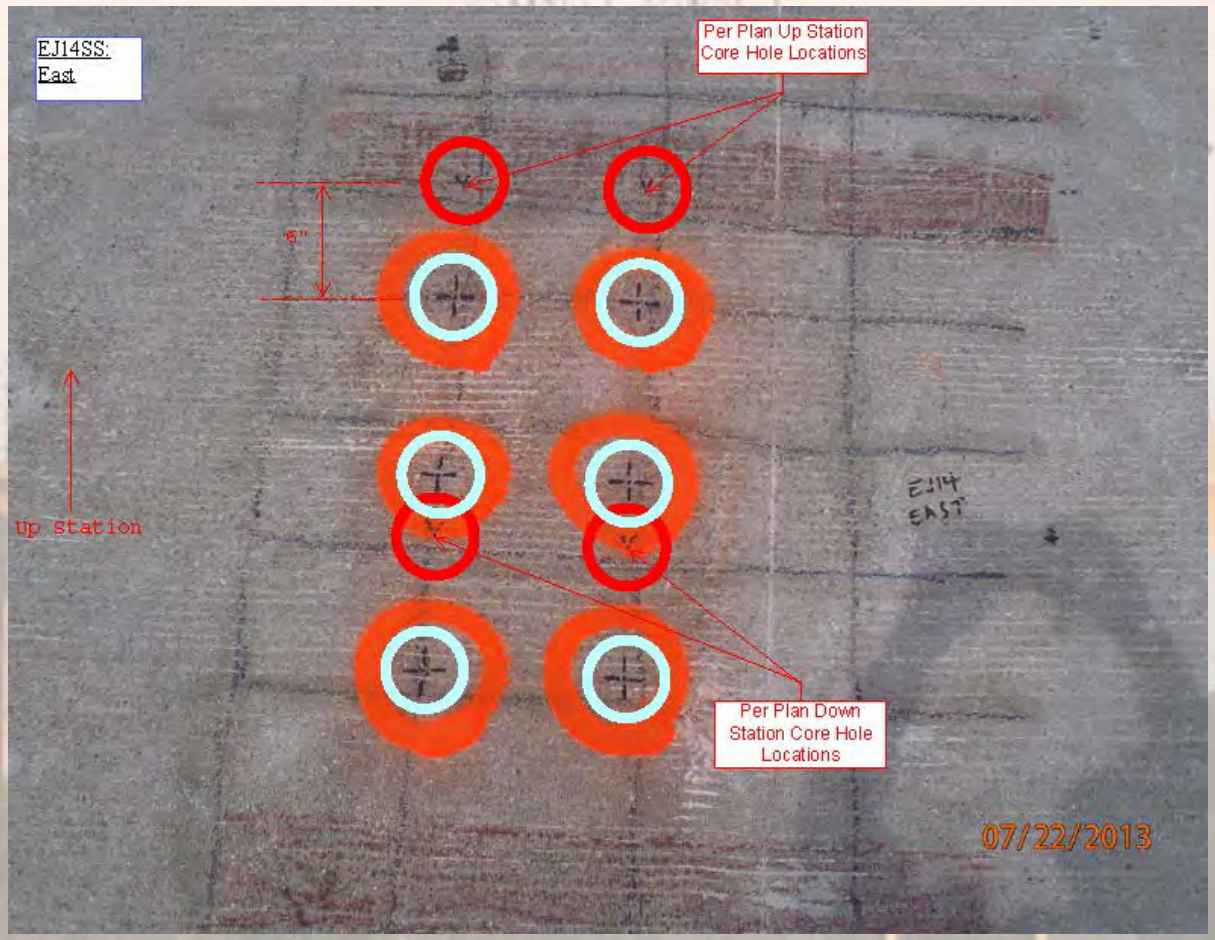


- Uses six 2 ½” PT bars stressed at 460 kips each (each side), cored through wing section near existing PT tendons

Hinge Bearing Replacement

- Use of Ground Penetrating Radar to locate rebar and PT tendon conduits

Hinge Bearing Replacement



- Similar process as pier coring, contractor submits coring plan for approval

Hinge Bearing Replacement

- Coring process slow, chipped down to located transverse PT tendon conduit locations

Hinge Bearing Replacement

- Inserting of 2 ½” diameter PT bars through deck, overhead and underslung beams

Hinge Bearing Replacement

- Raising underslung beam into position

Hinge Bearing Replacement

- Strong back beam assembly and stressing of 2 ½” diameter PT bars

Hinge Bearing Replacement

- Completed assembly, awaiting jacking

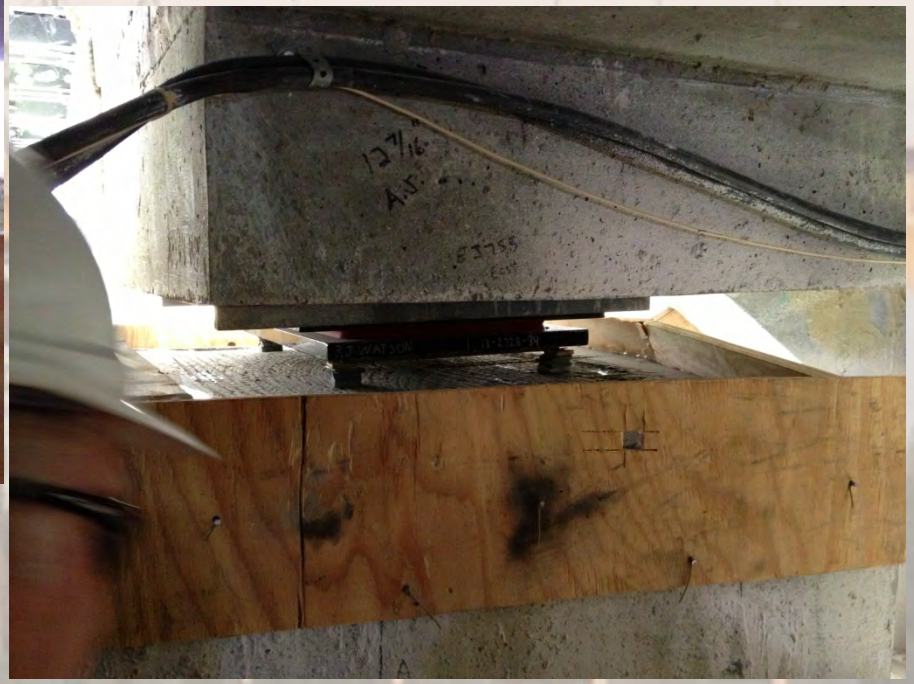
Hinge Bearing Replacement

- 7/16” opening at hinge bearing

Hinge Bearing Replacement

- Existing bearings are removed via wire sawing

Hinge Bearing Replacement



- Shimming of bearing for grout pad placement

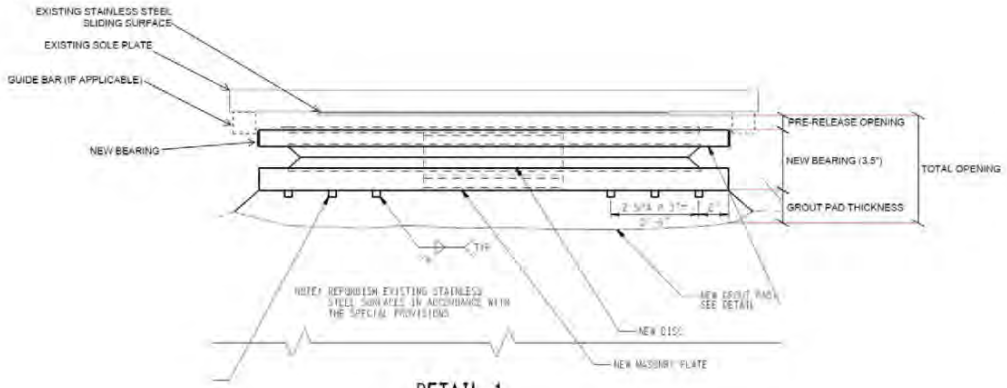
Hinge Bearing Replacement

- Due to complexity of rotations and expansion/contraction due to thermal gradient, all jacking operations, and measurement for grout pad thickness determination is done between 7 a.m. and 9 a.m.
- Contractor required to remove ½” of material on beam seat for shear key
- Grout pad thickness calculations are submitted to MDOT for approval

Hinge Bearing Replacement

EJ7SS Bearing Grout Pad Thickness Survey Rev 1

PCL/Toebe - Zilwaukee Bridge Bearing Replacement
Date: 7/13/13
PCL Contact: Clayton Ringer
Contact Number: (813)-344-7342



DETAIL 1
3" = 1'-0"

BEARING	LOCATION	TYPE	TOTAL OPENING (APPROXIMATE)	ANTICIPATED COMPRESSION	JACKING DISTANCE	NEW BEARING HEIGHT	NEUTRAL PRE-RELEASE OPENING	GROUT PAD THICKNESS (APPROXIMATE)
			A	B	X	Y	Z	-
			FIELD MEASURED	MANUFACTURER	FIELD MEASURED	MANUFACTURER	(X - B)	(A-Y-Z)
EAST	NW	GUIDED	5 14/16 in	1/16 in	7/16 in	3 8/16 in	6/16 in	2 in
EAST	NE	GUIDED	5 12/16 in	1/16 in	7/16 in	3 8/16 in	6/16 in	1 14/16 in
EAST	SW	GUIDED	6 2/16 in	1/16 in	7/16 in	3 8/16 in	6/16 in	2 4/16 in
EAST	SE	GUIDED	6 in	1/16 in	7/16 in	3 8/16 in	6/16 in	2 2/16 in
WEST	NW	FREE	6 2/16 in	1/16 in	7/16 in	3 8/16 in	6/16 in	2 4/16 in
WEST	NE	FREE	5 6/16 in	1/16 in	7/16 in	3 8/16 in	6/16 in	1 8/16 in
WEST	SW	FREE	6 1/16 in	1/16 in	7/16 in	3 8/16 in	6/16 in	2 3/16 in
WEST	SE	FREE	5 6/16 in	1/16 in	7/16 in	3 8/16 in	6/16 in	1 8/16 in

- Submittal for MDOT review and approval

Hinge Bearing Replacement

- New disc bearings set, superstructure lowered

Hinge Bearing Replacement

- Issue with guide bars, 5 out of 11 cap screws sheared, with loss of 72 kips lateral resistance

Abutment Bearing Replacement

- Installation of passive PT under jacking locations

Abutment Bearing Replacement

- Removal of existing bearing, and setting of new bearing

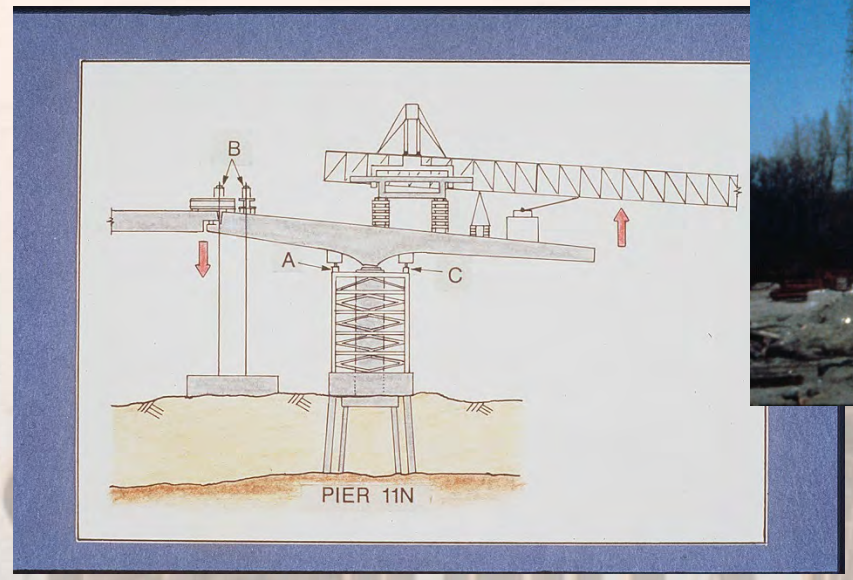
Abutment Bearing Replacement

- Setting, grouting, and finished bearing

Abutment Bearing Replacement

- Abutment bearings are repurposed from 2008 project

Pier 11N

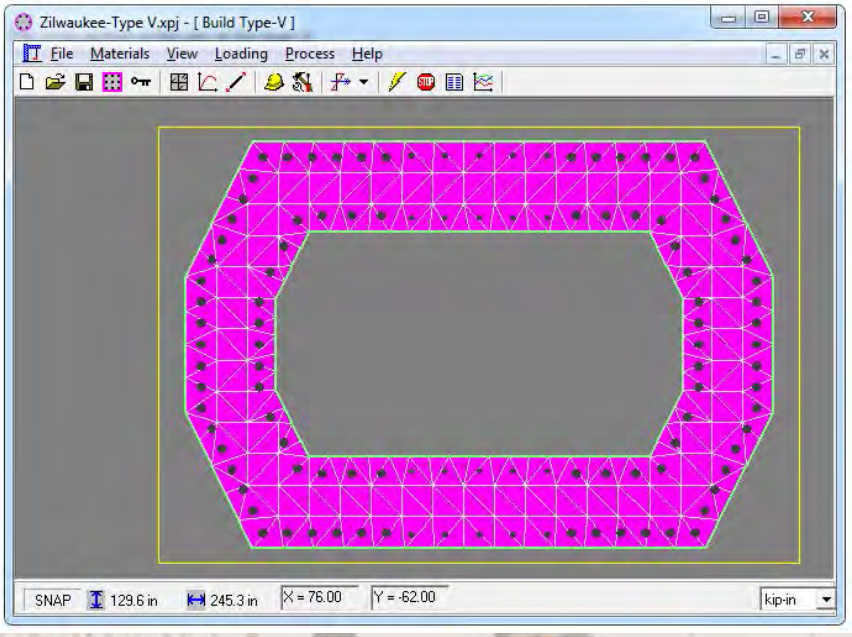


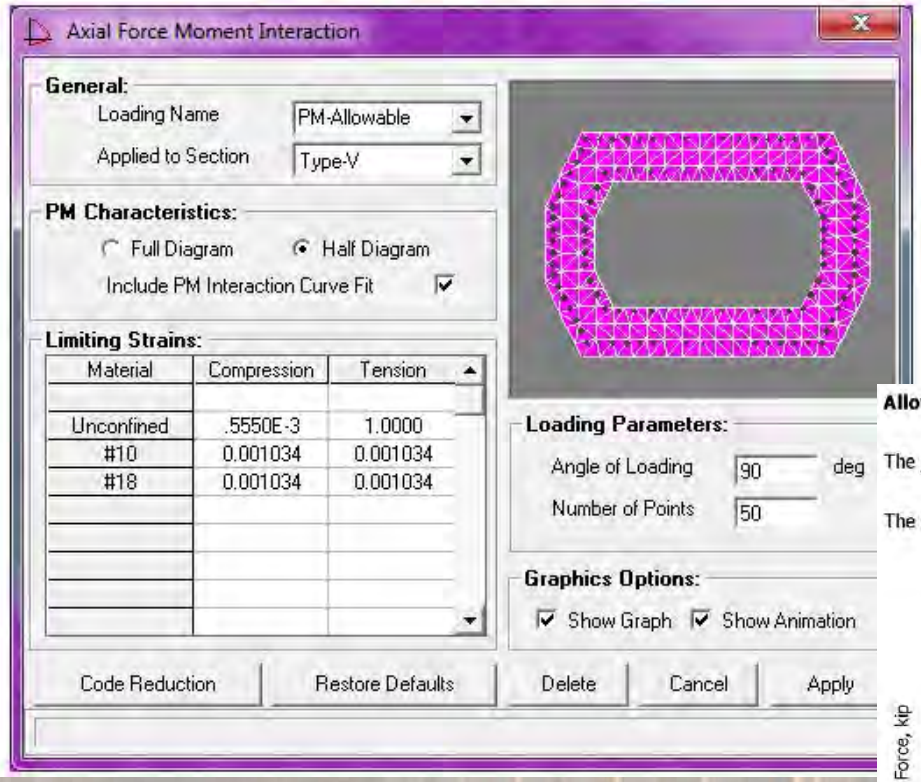
- Existing footing was abandoned in place, and a new footing placed over it, then superstructure was jacked back into position

Pier 11N

- Due to permanent tilt of Pier 11N, pier head did not have as much room as others to place and center the jacks
- Needed to lift 15 million lbs with an offset jack pattern center of gravity while trying to minimize additional stress on the columns and footing due to eccentric load
- Ran numerous iterations of calculations, and determined jacks could be up to 32” away from centerline of pier. Actual placement was 10” from centerline
- Decided to monitor stresses and tilt in pier during jacking, and while supported on jacks for 3 weeks

Pier 11N

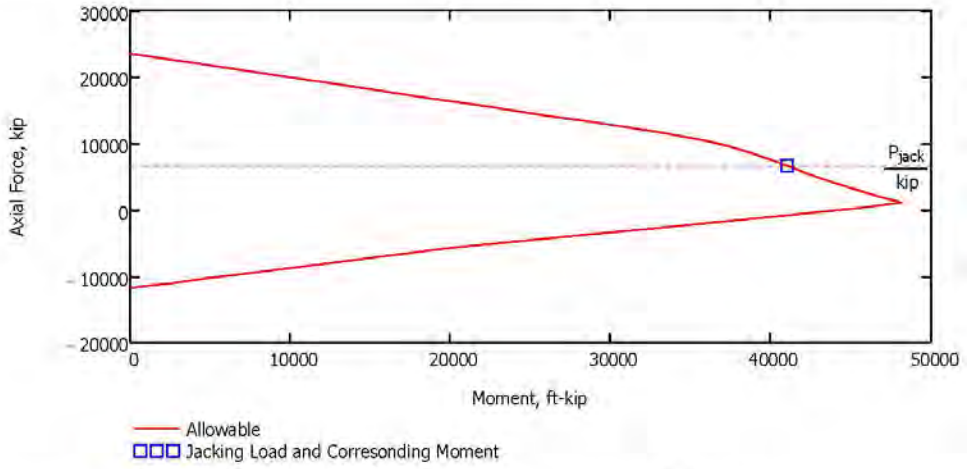




Allowable Moment and Eccentricity

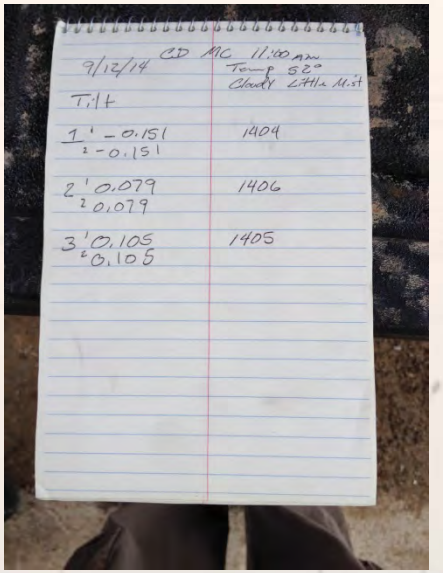
The jacking load at Pier 11N is $P_{jack} := 6640 \cdot kip$

The corresponding moment is $M_{jack} := linterp(reverse(P), reverse(M), P_{jack}) = 41009.95 \cdot ft \cdot kip$



The corresponding allowable eccentricity of the vertical load is $e_{allow} := \frac{M_{jack}}{P_{jack}} = 6.176\,ft$

Pier 11N



- Contractor exposed retrofitted footing for inspection, placed strain gages and tilt sensors for constant monitoring

Pier 11N

- Existing retrofitting bearing showing tilt – the structure was jacked back into place on these bearings in 1984

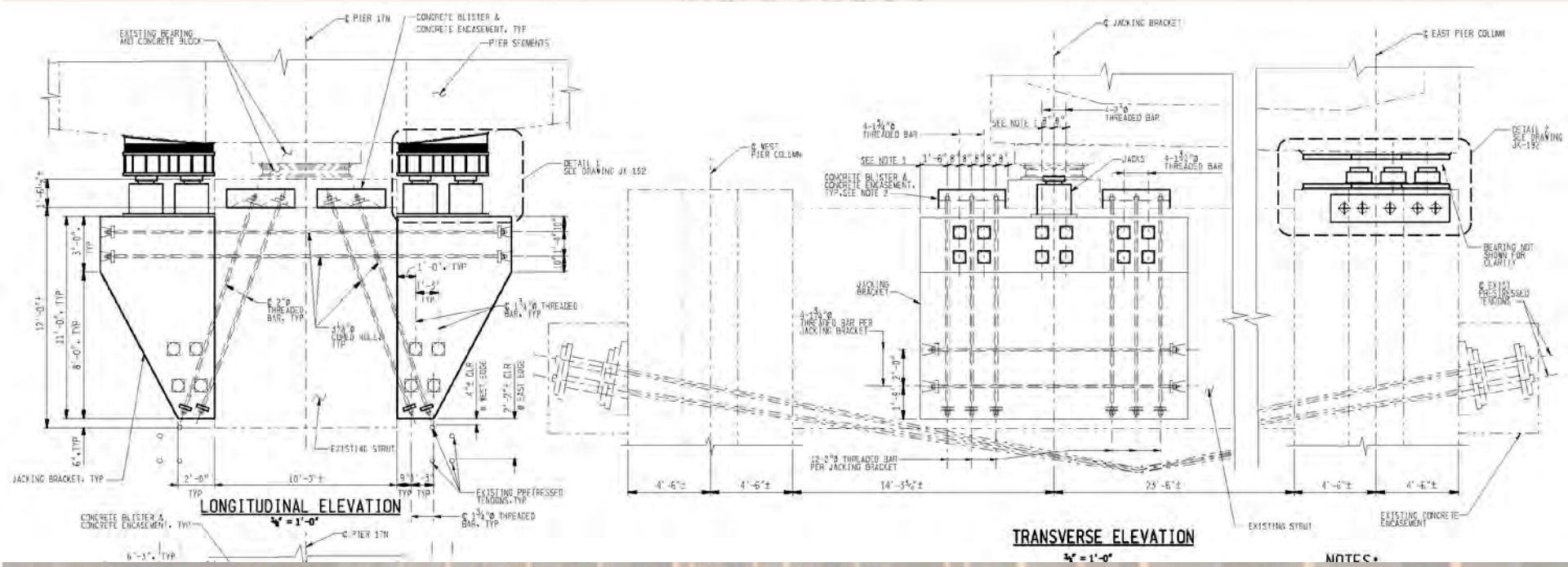
Pier 11N

- Lifted on 9/18/2014 – removal of existing retrofitted bearings – total weight of 18,000 lbs, had to be lifted in 3 pieces

Pier 17N

- Unique design spans the railroad, so one bearing is supported by the strut between columns

Pier 17N

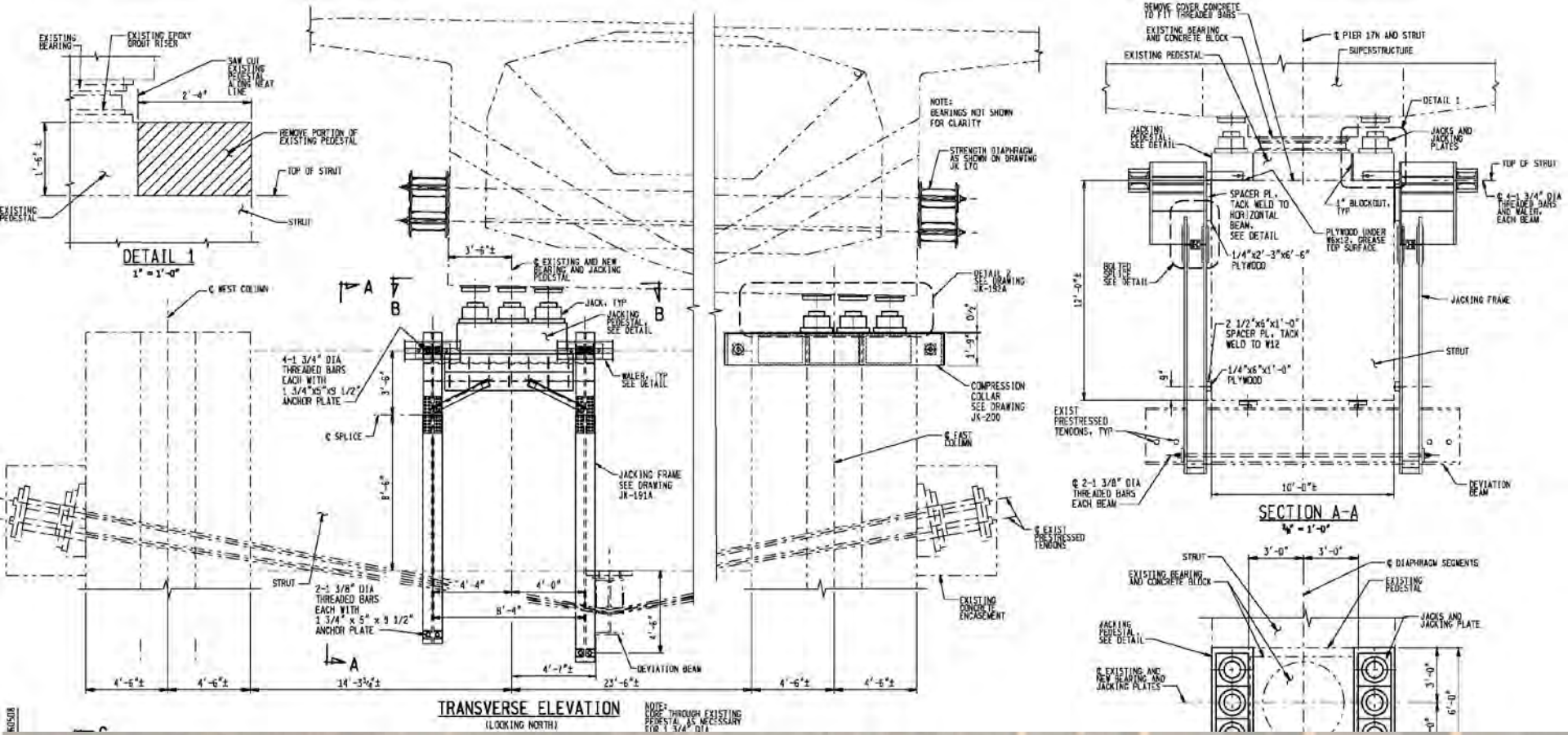


- Original design called for PT strengthening of strut for jacking, which require 20 core holes in strut

Pier 17N

- Chipped down to expose a few of the 60 #18 (2 ¼” diameter) reinforcing bars

Pier 17N



- Developed alternative method of external jacking frame, which carried significantly less risk – no coring required

Pier 17N

- Hoisting work platforms on to pier, with jacking frame attached

Pier 17N

- Heavy duty steel jacking frame post tensioned around pier strut

Project Completion

- Epoxy healer sealer overlay on bridge deck almost complete

Project Completion

- Structural lifting operations complete on October 9, 2014
- Majority of remaining bridge work done second week of November, including de-mobilization

Project Completion

- **Project statistics:**
  - Original negotiated contract cost = $35,974,257
  - Final contract cost = $35,993,783
  - Total net change amount = $19,526
  - Total net change = 0.05%
  - Cored 1464 holes in the NB & SB structures, nicked 1 wire of a 12 strand post tensioning tendon near Pier 22S, which resulted in a 0.21% reduction in capacity at that location – negligible
  - Expansion hinge lifts – 3 million lbs, 16 times
  - Pier lifts – 10 million to 15 million lbs, 49 times
  - 1.2 million lbs of structural steel (plates, PT bars, beams) needed to temporarily reinforce the structure for jacking

Project Completion

- **Project statistics:**
  - Over 200 submittals and RFI's submitted by contractor for approval
  - 3 minor injuries during construction
  - 65% of the work performed by Michigan contractors
  - Z-bridge disc bearings are the second largest bearings ever fabricated by R. J. Watson

Project Completion

- **Recognized efficiencies**
  - Complete elimination of shoring towers for mainline piers 1-9 and 17-25, and H-ramp piers, ***saving over $1 million***
  - Deck and barrier patching quantities were initially increased due to overages in plan quantities in 2013. Final balancing mod reduced these quantities, ***saving $850,000***
  - Modified existing strong back support beams for use on project as opposed to fabricating new ones, ***saving $300,000***
  - Use of thin rectangular disc bearings at hinges (first of their kind), did not require resetting of modular joints, ***saving $1.6 million***
  - New bearings retained existing guide bars, eliminating the need to construct external lateral restraints, ***saving $600,000***

Project Completion

- **Truly a Team Effort**
  - Changes made to temporary works, procedures and contractor payment in the winter of 2013-2014 created no extras on the project
  - Challenges (there were many) were addressed as a group by MDOT/consultant/contractor team
  - Prime contractor PCL noted on several occasions that MDOT was an excellent owner to work for, as we were engaged, and made decisions in a timely manner
  - During discussions with field staff and contractors, everyone was proud to be working on Z-bridge, recognizing their service to the public by prolonging the service life for a bridge that carries 21.6 million vehicles per year and impacts the regional economy

Thank You

Questions?

PCL CONSTRUCTION LEADERS

TOEBE

C.A. HULL CONTRACTORS SINCE 1954

TY LIN INTERNATIONAL

JSE