Effective repair of severely deteriorated prestressed beam ends

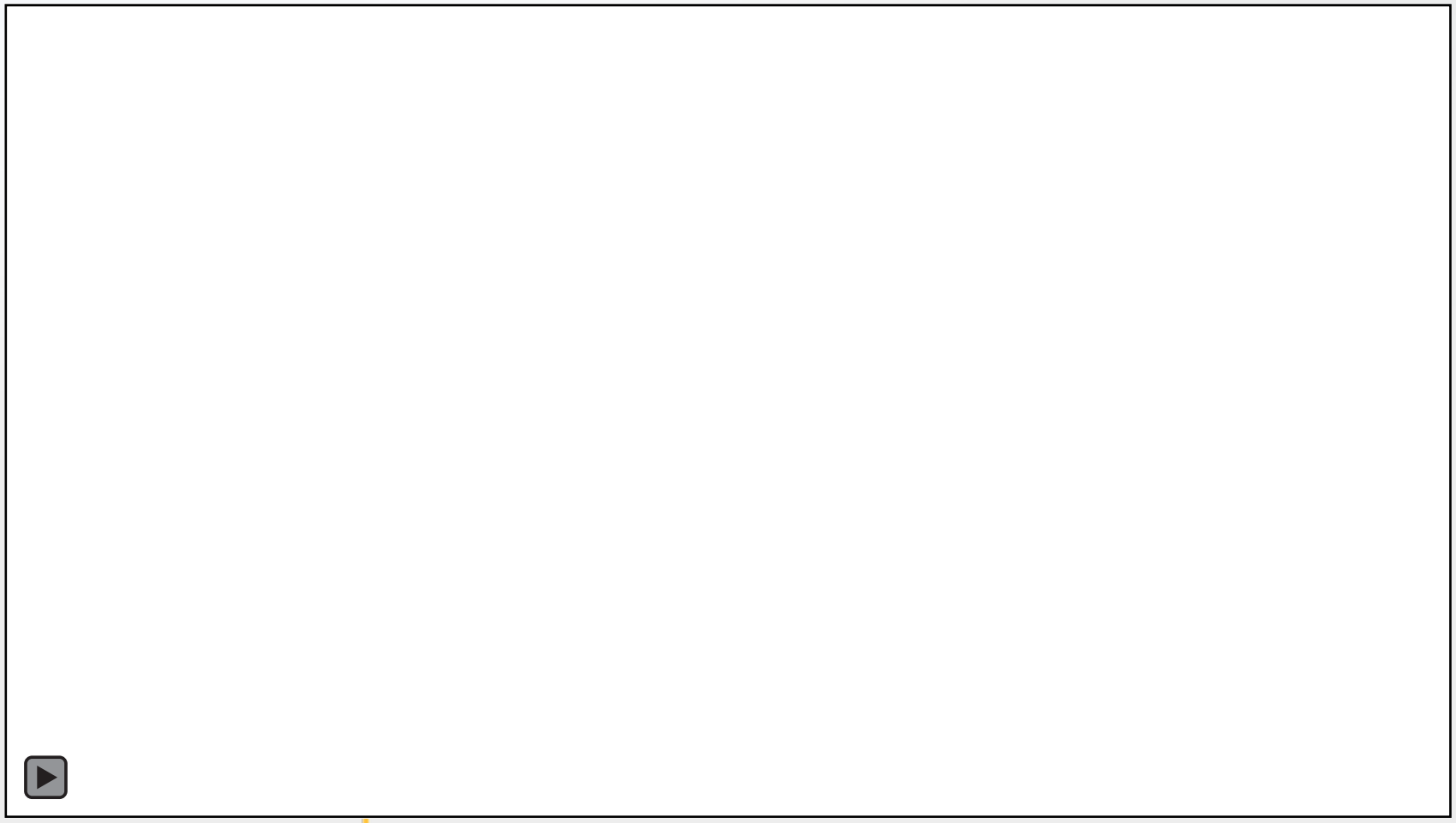
Paul Pilarski, P.E., S.E.
Metro North Region Bridge Construction Engineer

MnDOT Research performed at University of Minnesota
Dr. Carol Shield and Paul Bergson

PS Beam End Repair Research

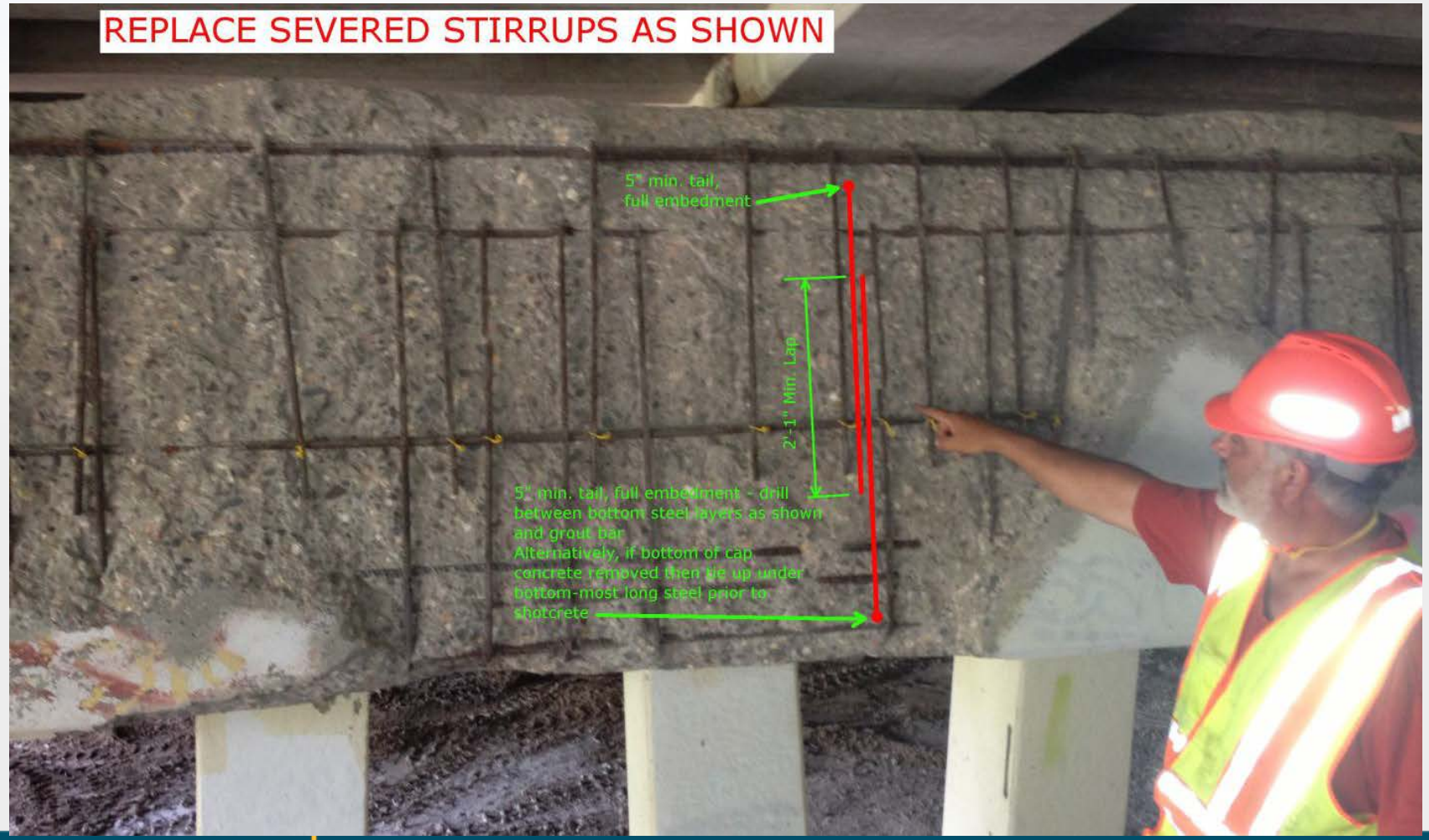
- Typical concrete repair procedures
- Concerns
- Original repair project
- Research

How are concrete repairs to bridges made?



Step 2: Remove delaminated concrete

Step 3: Supplement corroded reinforcement



Step 4: Replace concrete

Shotcrete: dry cement, sand and aggregate wetted at a nozzle and sprayed at high velocity

Step 4: Replace concrete

Shotcrete: dry cement, sand and aggregate wetted at a nozzle and sprayed at high velocity

Common shotcrete map-crack

Shotcrete often performed without load relief or temporary support

BR 27568 – SB Pier 34

Questions:

- Does the shotcrete restore strength? Or just cover up and protect from additional deterioration? Durability?
- How does lack of load relief affect repair?
- Is there an effective means to preserve prestressed beam ends with internal stresses?

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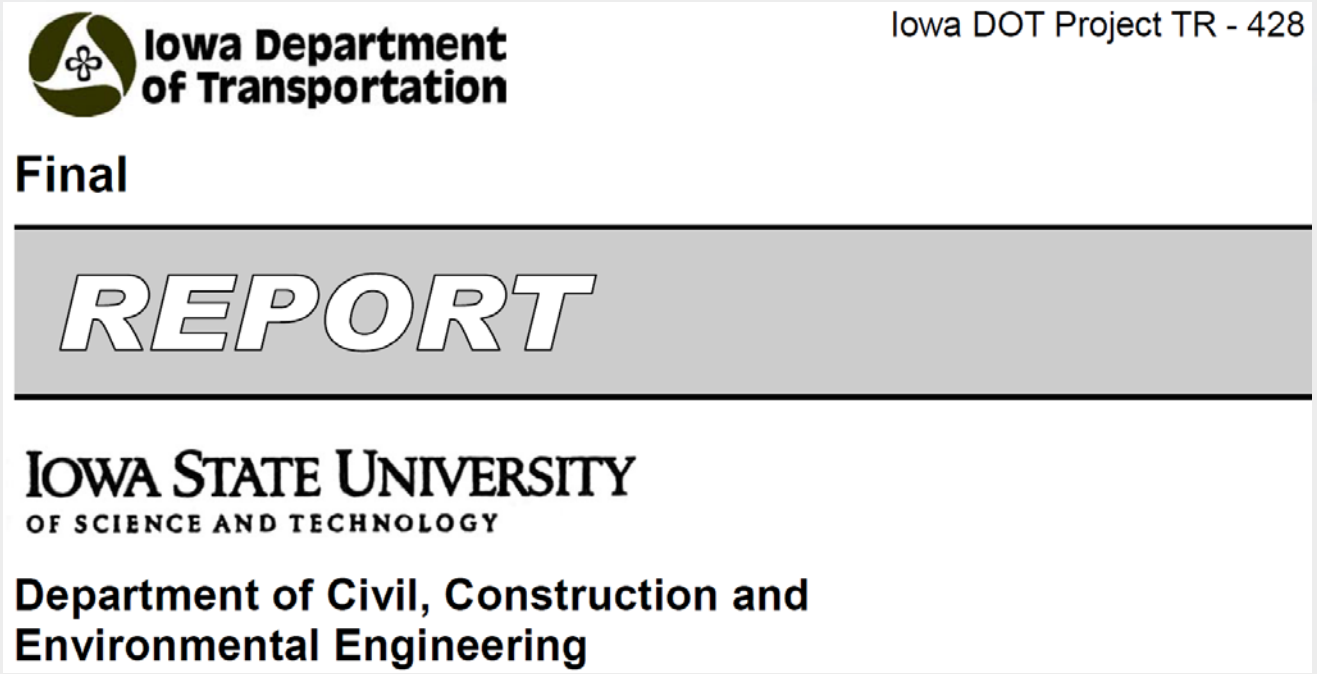
Durability?

"Evaluation of Repair Materials for Use in Patching Damaged Concrete"

Must use compatible patch material

- Match elastic modulus
- High bond strength
- Thermal compatibility
- Compressive strength

➔ Must moist cure


Iowa Department of Transportation

Iowa DOT Project TR - 428

Final

REPORT

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Department of Civil, Construction and Environmental Engineering

Durable Repairs with FRP

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Repair and Strengthening of Bridge Substructures

Steven W. Ainge
Marquette University

Report No.

FWHA/TX-03/1774-2

SP-230—82

Performance of Corrosion-Damaged RC Columns Repaired by CFRP Sheets

by S.-W. Bae, A. Belarbi, and J.J. Myers

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12-1-2014

Investigation of Chloride Induced Corrosion of Bridge Pier and Life-Cycle Repair Cost Analysis Using Fiber Reinforced Polymer Composites

Dinesh Dhakal
University of Nevada, Las Vegas, dhakad1@unlv.nevada.edu

Column repairs (2014 scoping)

unsound removals

shotcrete repair with curing agent

Shrinkage cracks within year old patch

Questions:

- Does the shotcrete restore strength? Or just cover up and protect from additional deterioration? Durability?
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Column repair (ICRI Doc. 310.1R)

- Sustained forces flow through remaining section of concrete and intact vertical reinforcement after removals

- Only LL and other transient forces act on repaired section unless shored during repair

Original Removals

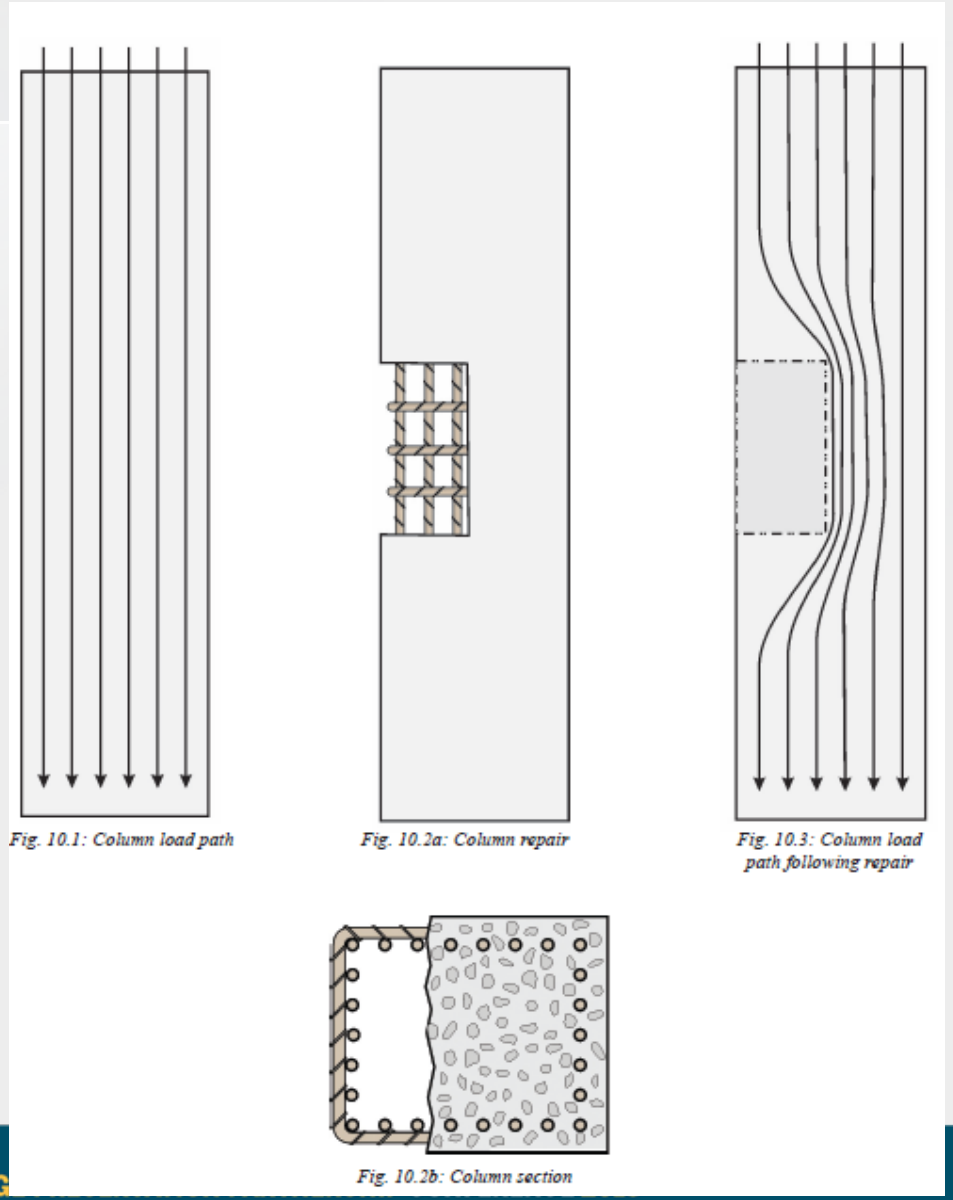


Fig. 10.1: Column load path

Fig. 10.2a: Column repair

Fig. 10.3: Column load path following repair

Fig. 10.2b: Column section

Column repair

- Visualize forces as truss (Strut and tie model)

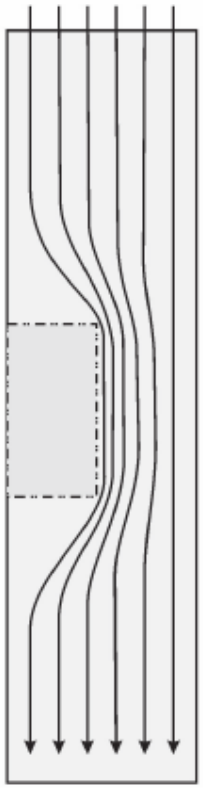


Fig. 10.3: Column load path following repair

Column repair

- Visualize forces as truss (Strut and tie model)

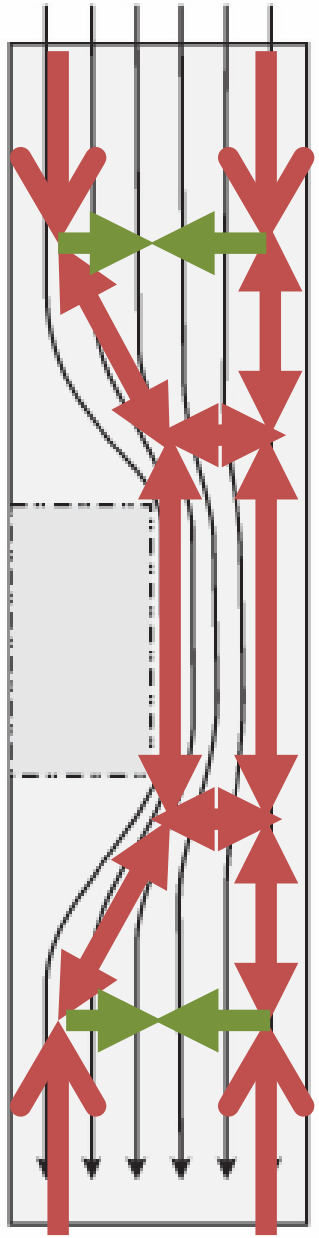


Fig. 10.3: Column load path following repair

Column repair

- Visualize forces as truss (Strut and tie model)
- External confinement maintains patch ability to sustain additional compression

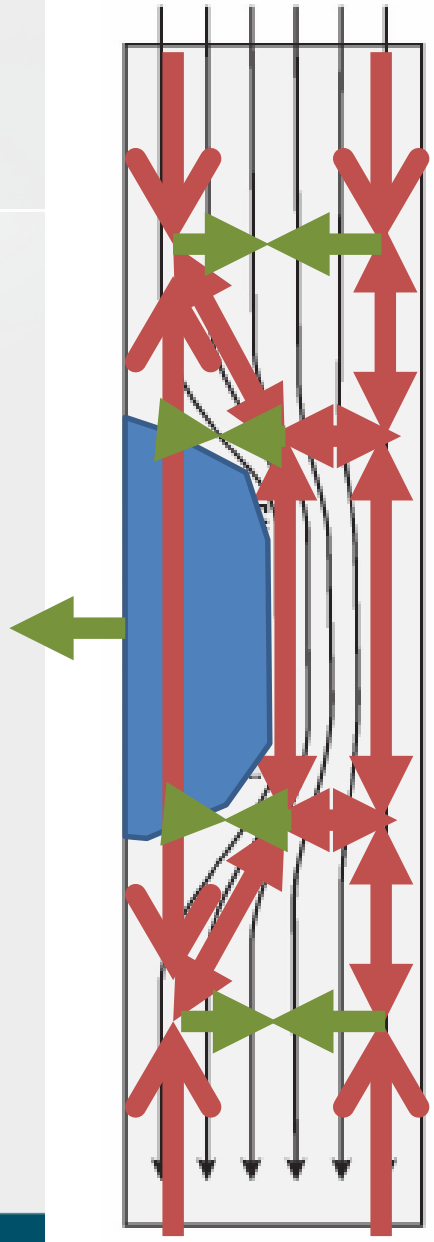
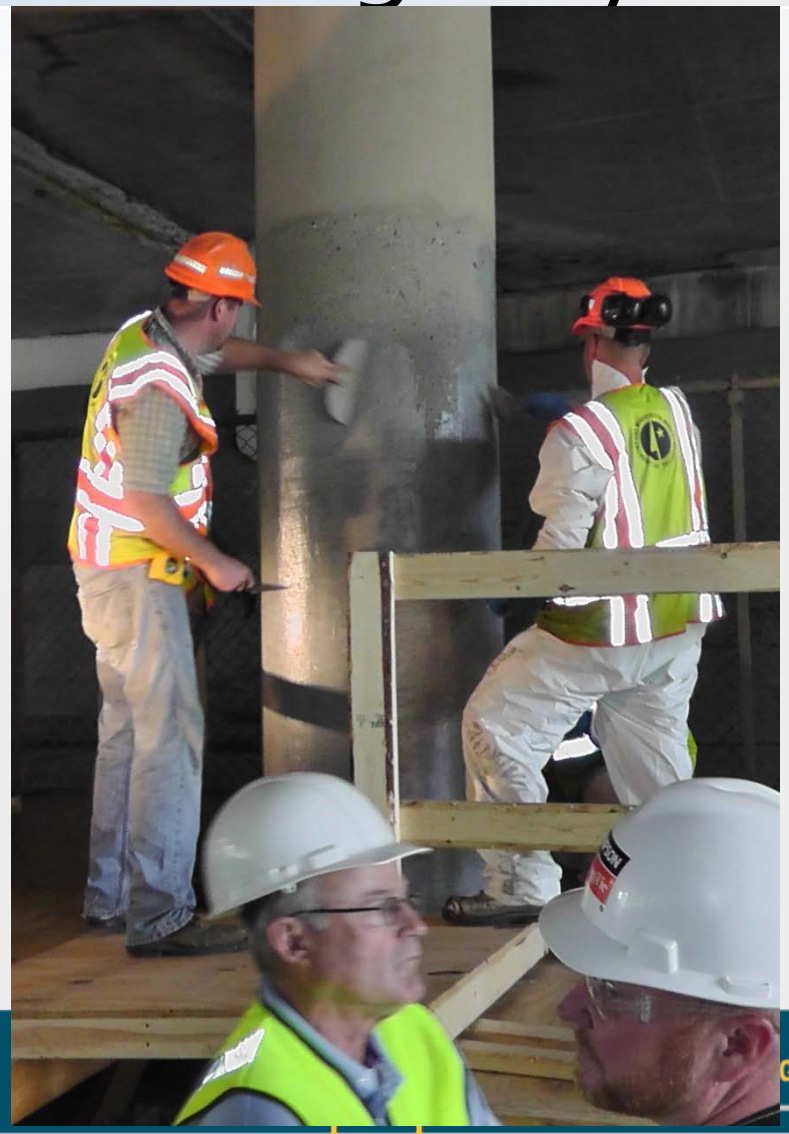


Fig. 10.3: Column load path following repair

FRP wrapping for confinement and patch longevity



Questions:

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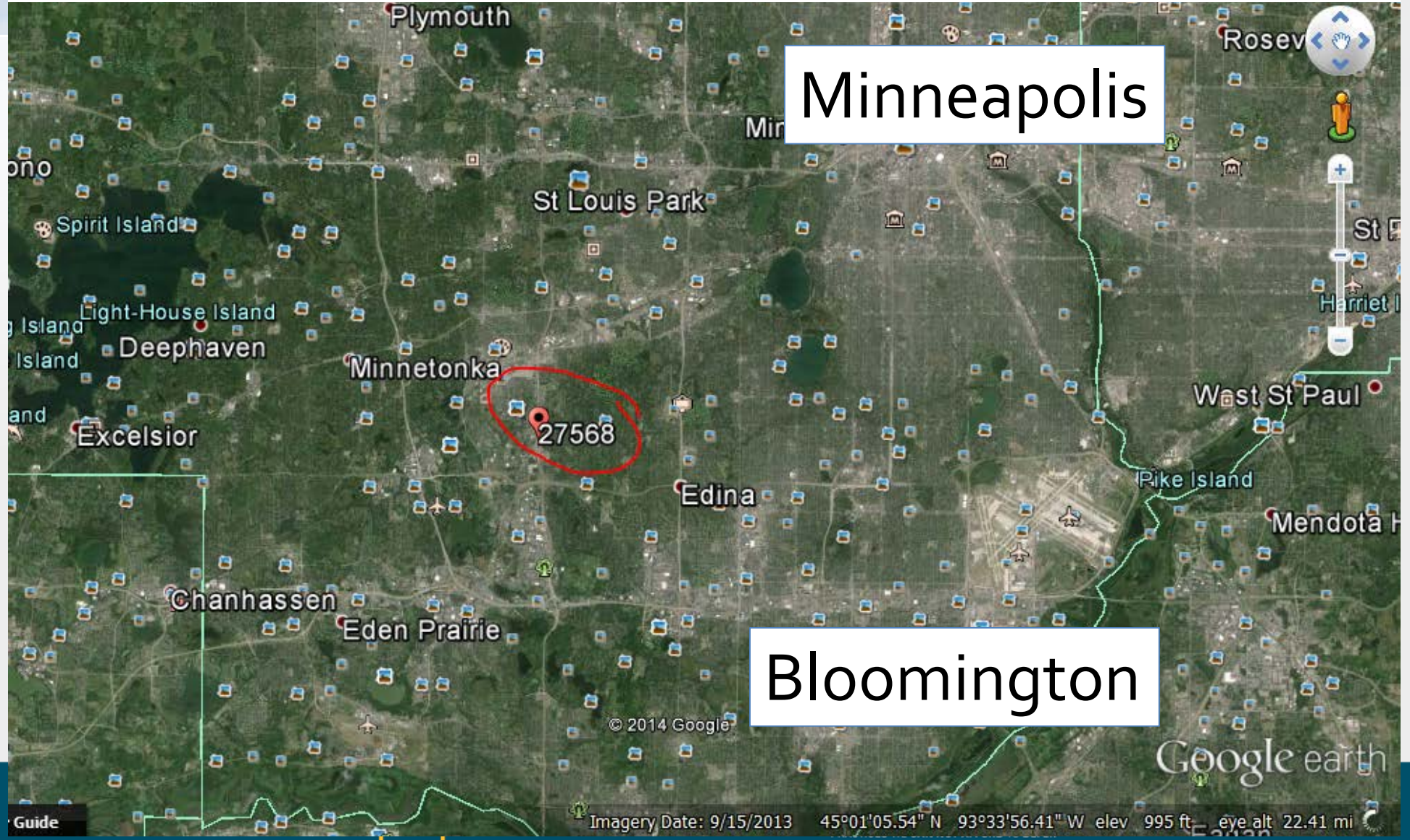
Repair of Bridge 27568

US Route 169 over Nine Mile Creek

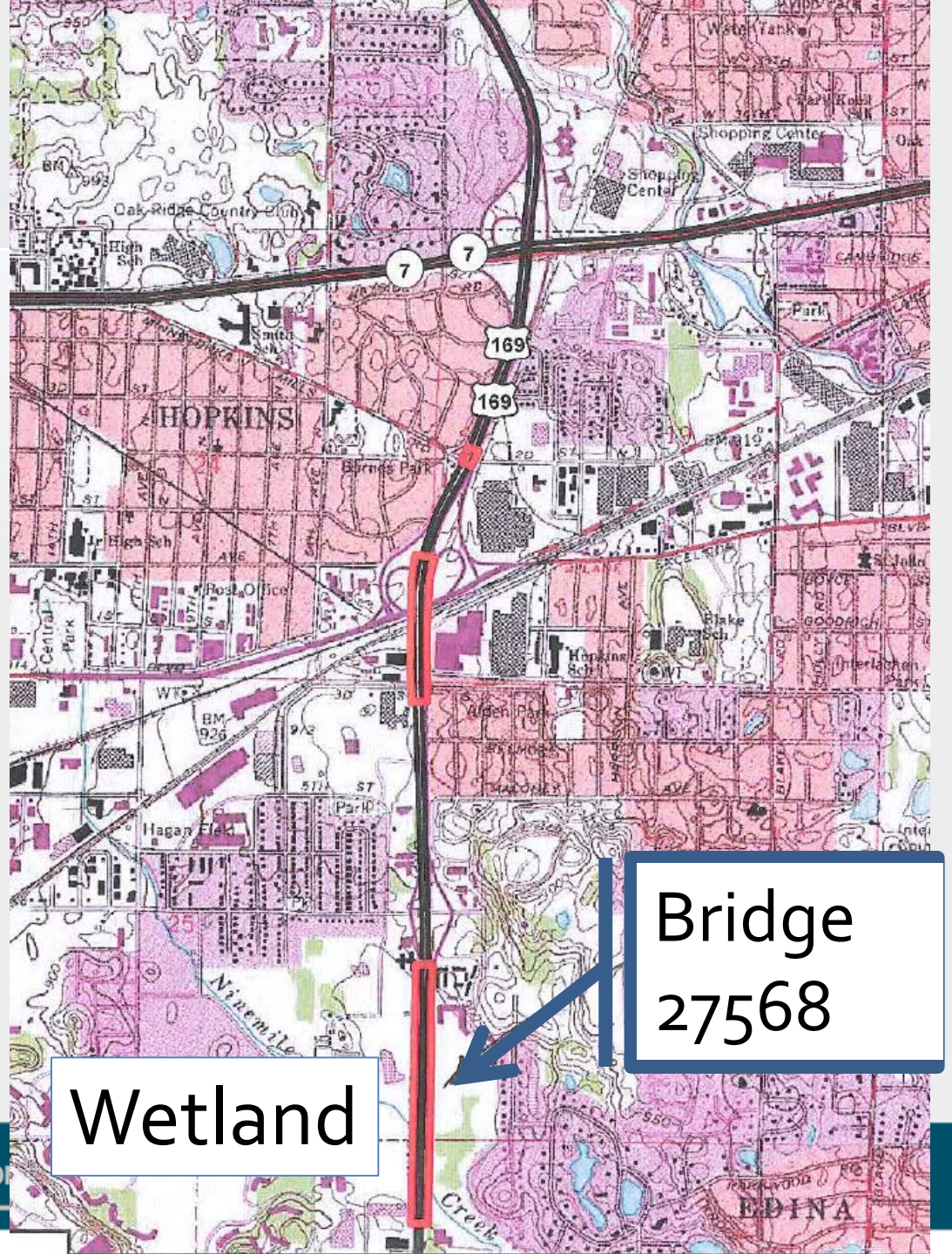
Scoped 2011-12
Contract work 2013

Bridge 27568: Nine Mile Creek Location

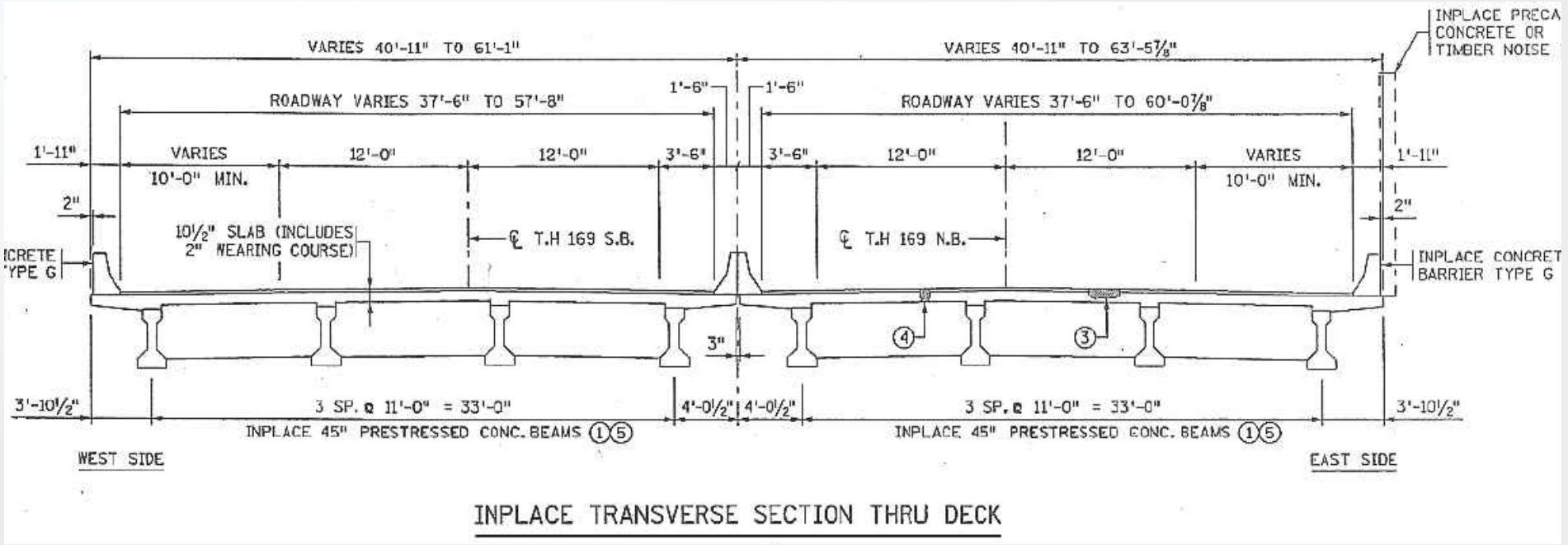


Br. 27568

- TH 169 over Nine Mile Creek in Edina, MN
- Built by Hennepin County in 1974
- Spans over poorly drained wetland above old roadbed(s)



Structure Background



INPLACE TRANSVERSE SECTION THRU DECK

- 60’ spans
- 49 Prestressed beam spans
- Prestressed concrete pile bent piers

Preservation Scoping 2011: Beam ends at joint locations

Variety of deterioration levels

Beam End Repairs - Small

NB Pier 10 Fascia

Beam End Repairs - Small

NB Pier 34 East Fascia

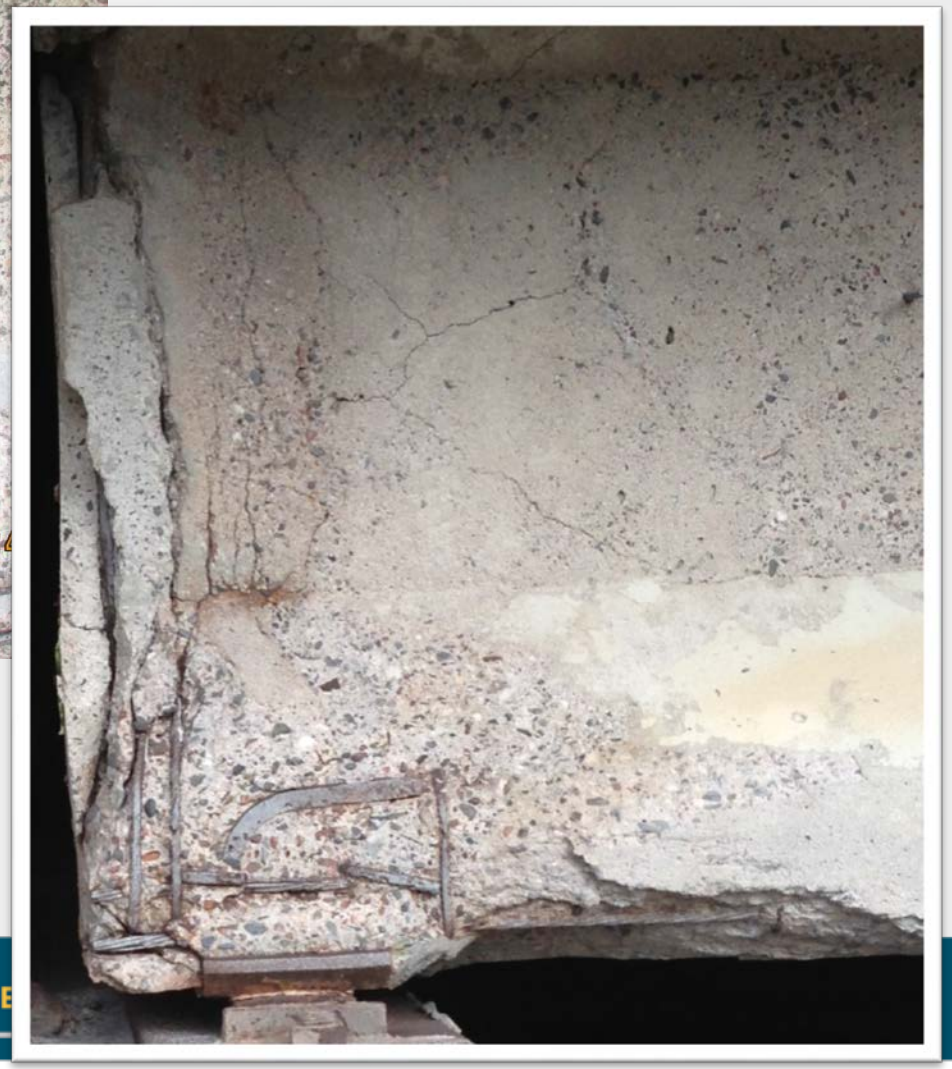
Beam End Repairs - Large

Pier 16: Large repair - Shotcrete repair without support

Beam End Repairs - ~~Large~~ Medium

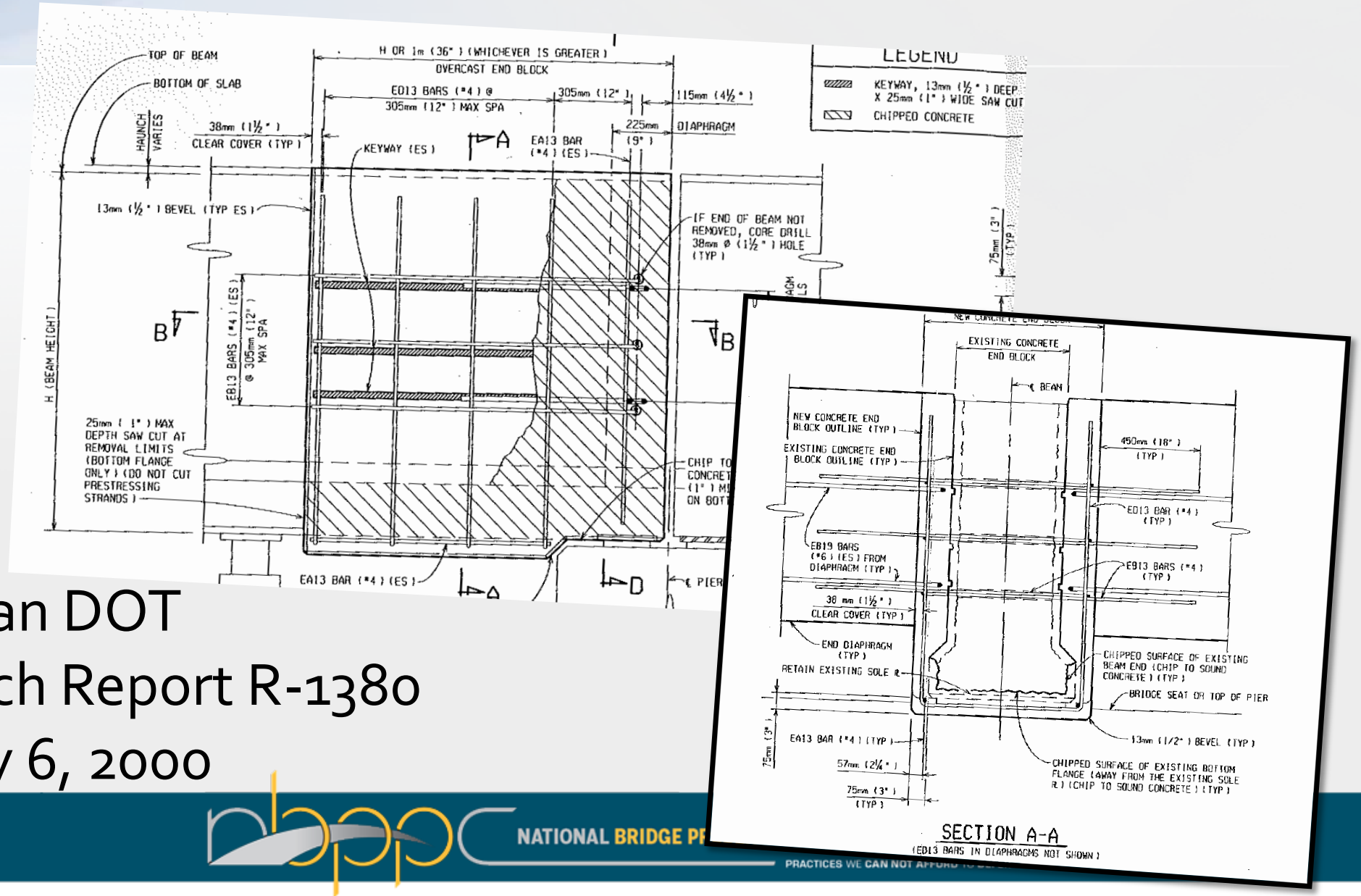
Pier 16: ~~Large~~ Medium repair - Shotcrete repair without support

Change of Plan



Beam End Repair - Large

Michigan DOT Detail for End Repair



Michigan DOT
Research Report R-1380
January 6, 2000

Michigan DOT Detail for End Repair

Michigan DOT Research Report R-1373, Sept 1999

- MDOT and FHWA personnel drafted a 1999 repair procedure
- Repair procedure was performed in our laboratory on a salvaged prestressed I beam.
- Beam was load-tested
- Conclusion: ***Up to 1 stirrup and 12" of strands may be exposed without prestress or shear strength loss***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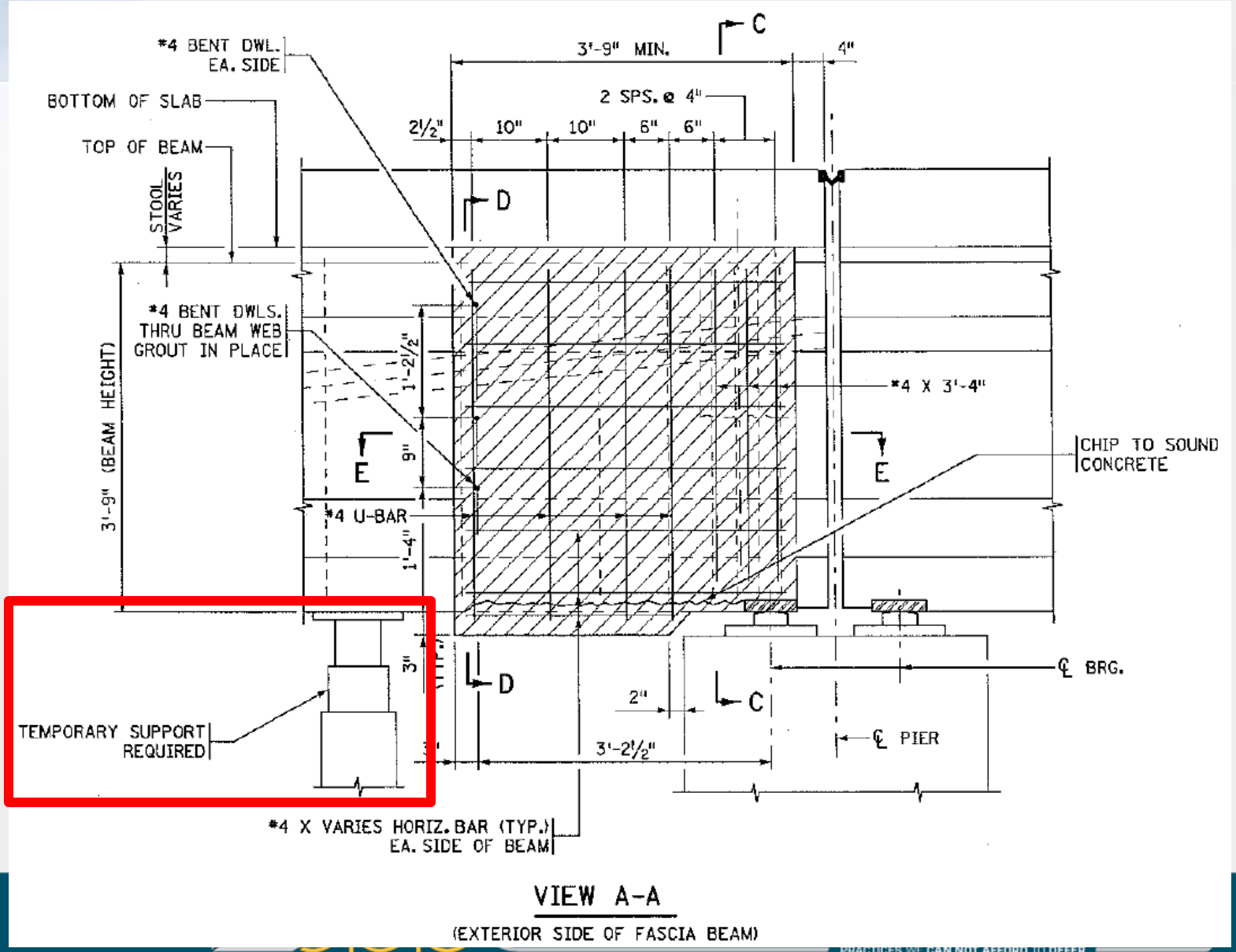
Damage beyond Michigan Conclusions

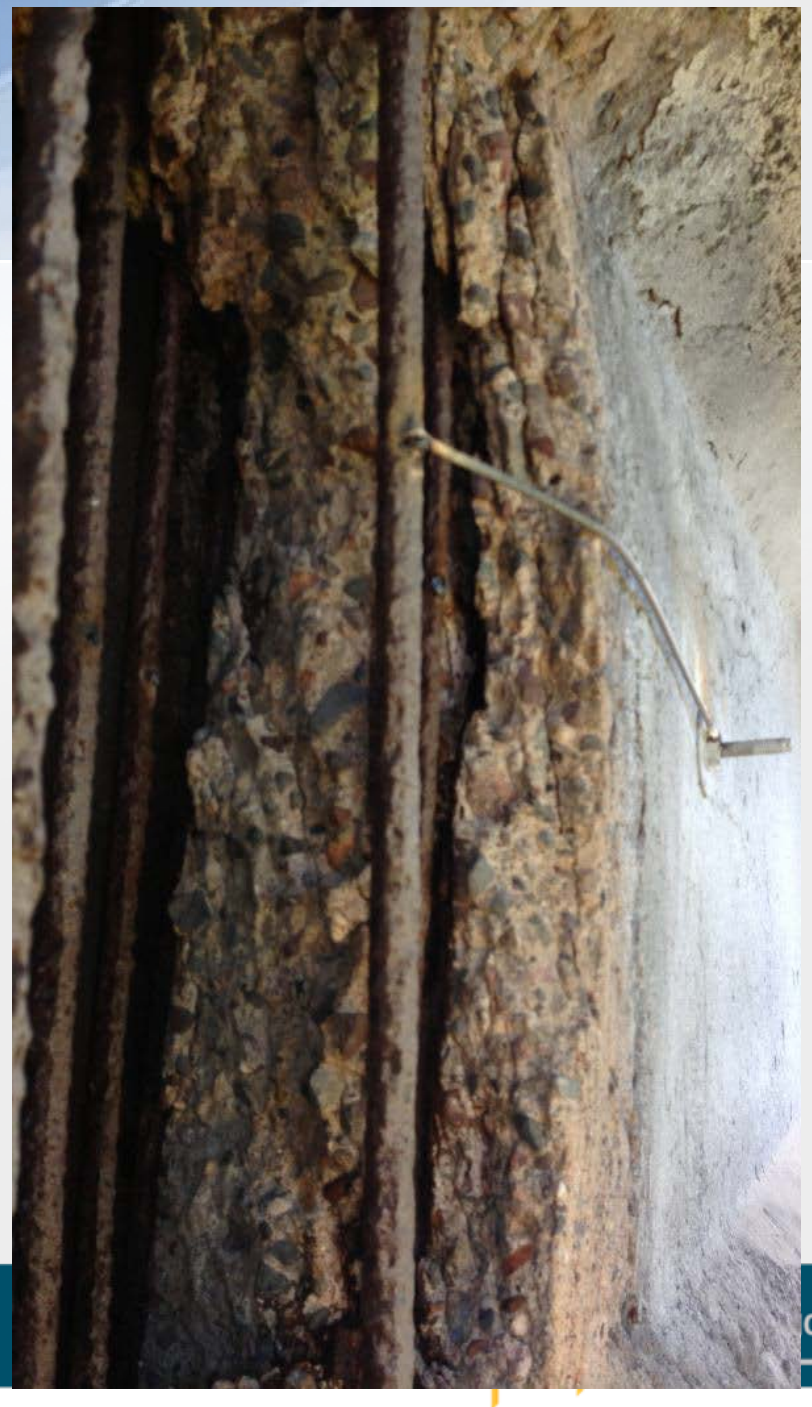
Damage beyond Michigan Conclusions

Box Type Repair (Large Repair)



VIEW A-A

(EXTERIOR SIDE OF FASCIA BEAM)



Full DL relief can be detrimental to internal force balance!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SB2654

Other deteriorated components


07/25/2013

Pile deterioration


07/25/2013


07/25/2013


10"
07/25/2013


07/25/2013


07/25/2013

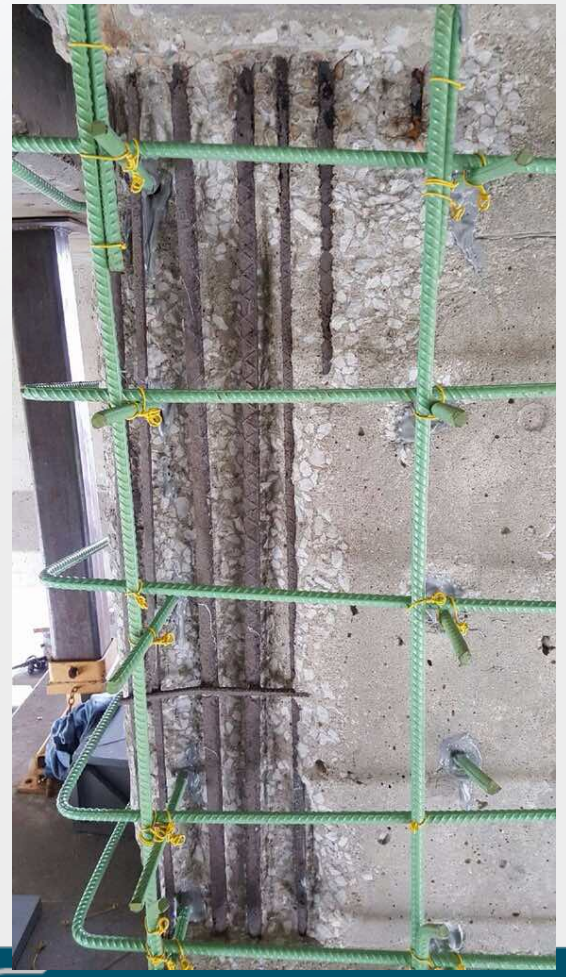

07/26/2013

How do we assess adequacy?

- Small scale testing.
- Industry research on shotcrete bond.
- Observations during destruction.
- Monitoring for cracks and crack growth

Other DOT's and Agencies:2015 WisDOT

Other DOT's and Agencies: USACE



Bridge replaced in 2017 due to high risk deterioration in piling and beams

➔Opportunity!!!

Research money sought and awarded:

Verify beam repair restored strength to original capacity or better

Beam End Research

- Salvage 2 repaired beams
- Salvage 2 unrepaired beams
- Load test all four – record crack patterns and failure progression
- Compare strength

Beam End Research

Hurdles:

- Sawcut to suitable length for U of M Civil Engineering Laboratory
- $35K salvage and transport estimate from contractor of new causeway
- Cast narrow 10,000 psi deck on beams (Required to ensure a failure in the beam end rather than center)

Salvage and Transport

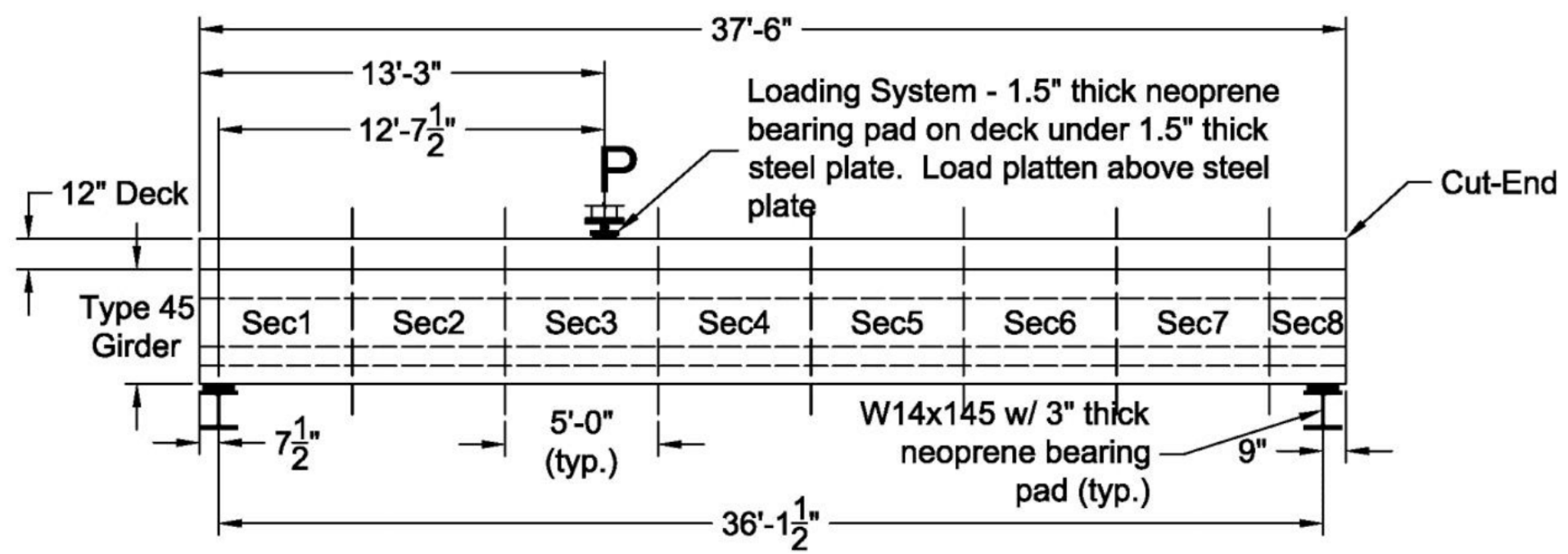
Girders at lab

P4 – End View

Cast 10,000 psi narrow deck in lab

Experimental Setup

- 36’-1.5” span, original bearing pads at original CL bearing
- Load applied at 13’-3” from end



ELEVATION VIEW

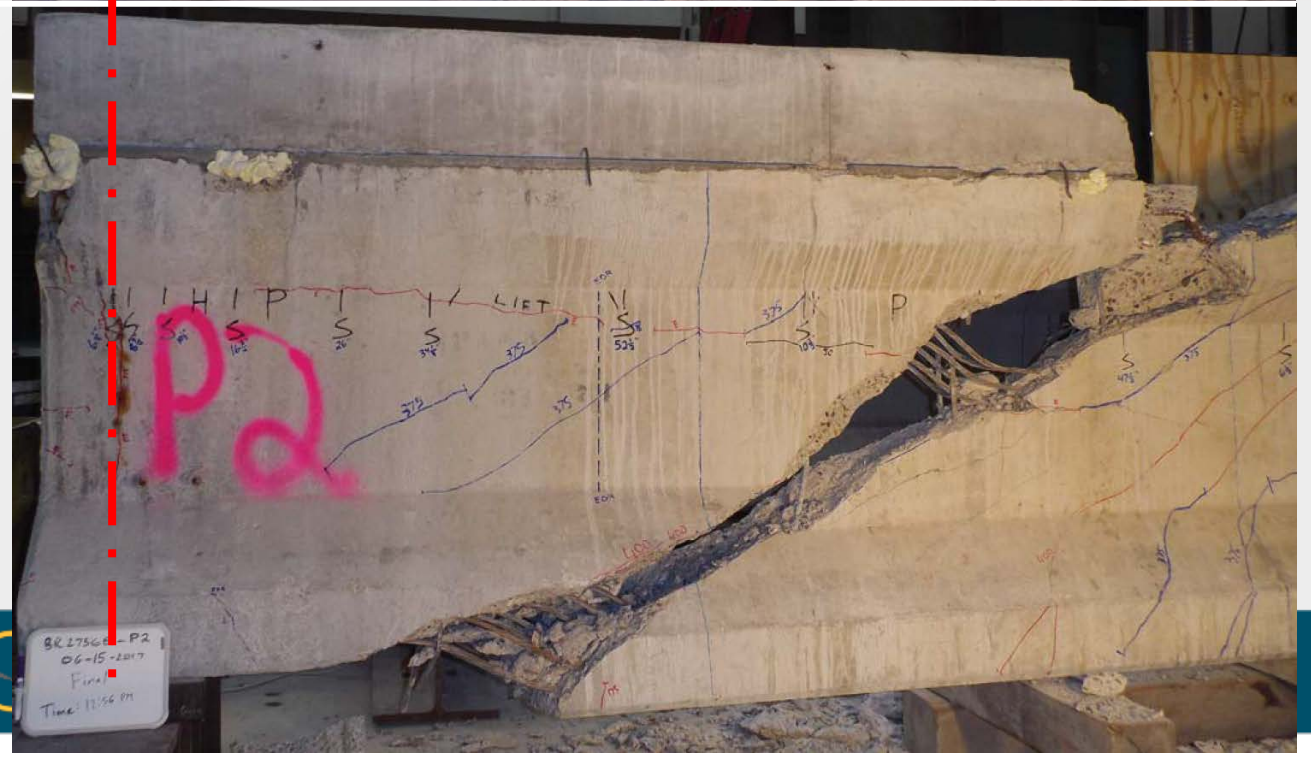
Experimental Setup

- External shear stirrup system to prevent cut end failure
- 50 kips initial load
- Displacement controlled loading (0.06”/minute)
- Stop at 25 kips increments to map cracks

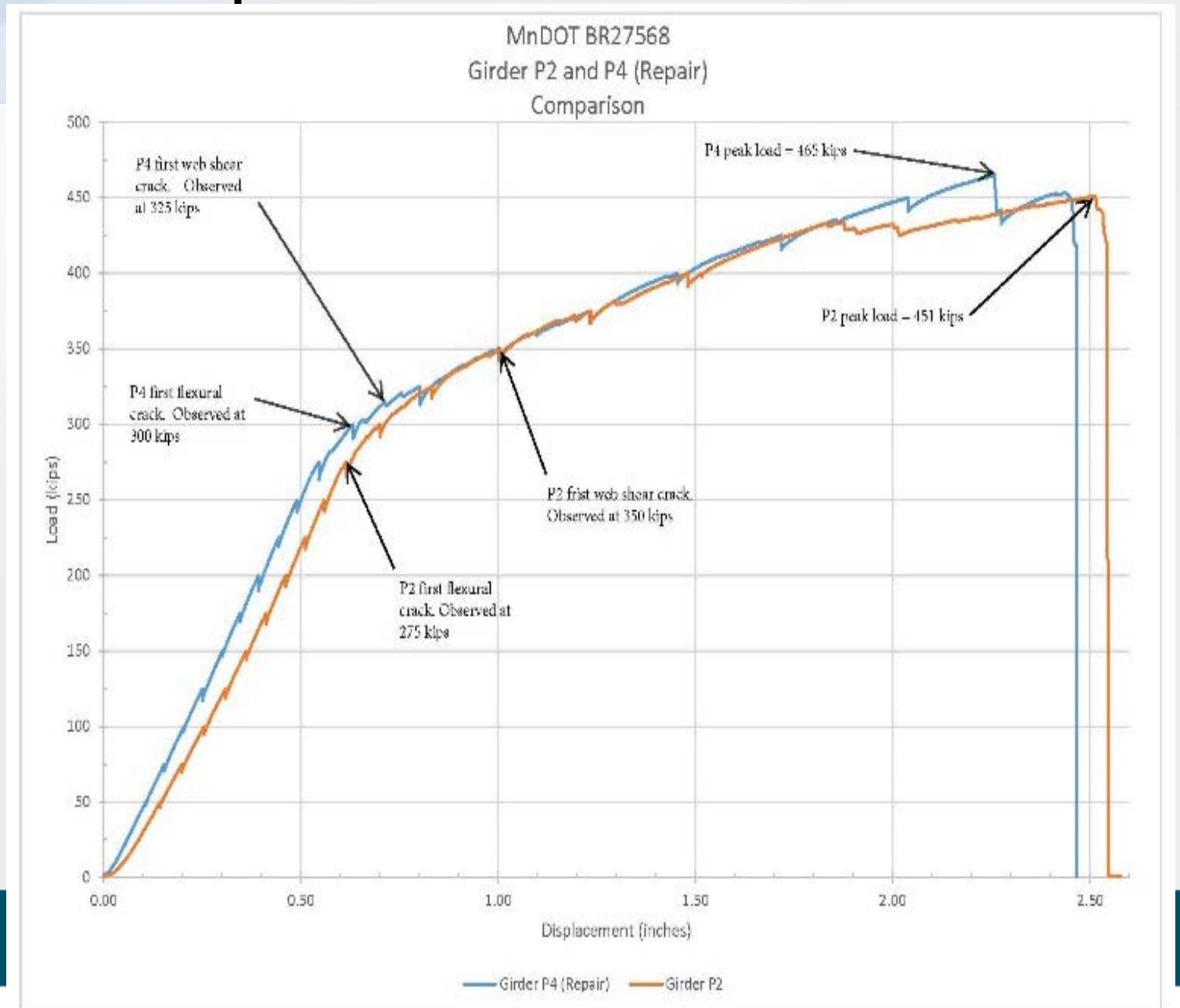

Made by Paul Pilarski, MnDOT Bridge Office
P4

- Peak load = 465 kips
- 1st flexural crack = 300 kips
- 1st web shear crack = 325 kips

- Peak load = 451 kips
- 1st flexural crack = 275 kips
- 1st web shear crack = 350 kips



Girder P4 and Girder P2 Results



AASHTO LRFD predicts V_n=204 kips

Girder P4 (Repaired)

- Vu LL = 302 kips
- Vu DL= 14 kips

(at closest stirrup failure to girder end)

Girder P2 (unrepaired)

- Vu LL= 293 kips
- Vu DL = 12 kips (at closest stirrup failure to girder end)

Girder P26 (repaired)

- Vu LL = 323 kips
- Vu DL= 14 kips

(at closest stirrup failure to girder end)

Girder P24 (unrepaired)

- Vu LL= 320 kips
- Vu DL = 12 kips (at closest stirrup failure to girder end)

Beam End Repair Cost

- 2013 Beam end shotcrete surface repair- EACH beam end, *not* square foot area. Bid cost = $755.
  - ➔Included bearing jacking cost
- 2017 Shotcrete repairs typically $160/SF

Beam End "Reconstruction"

- 2013 by S.A. $5.5K Each (Qty = 2)
- 2016 by S.A. $12.5K Each (Qty = 2)
- 2017 by contract $10,000 Each (Qty=5)

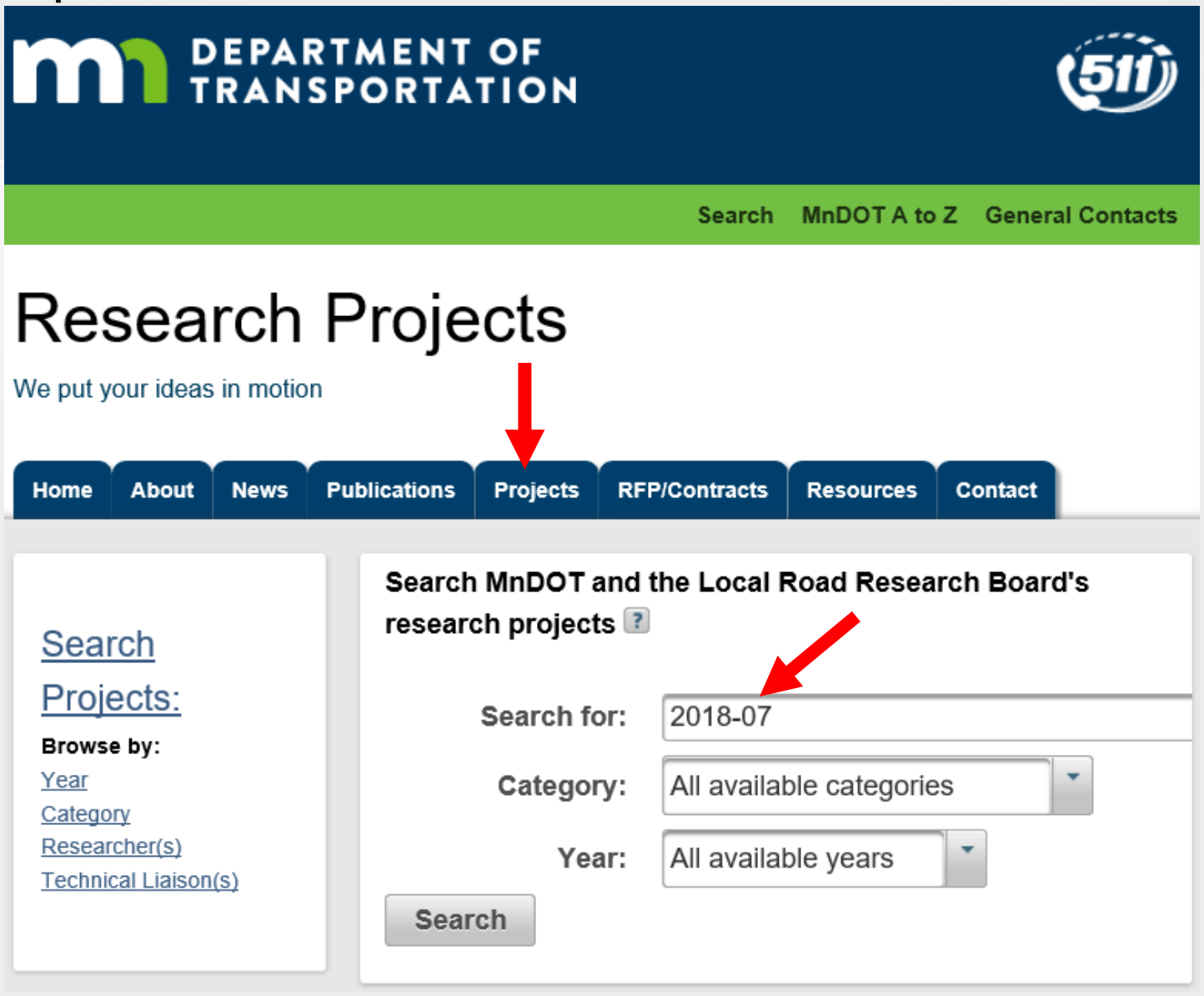
➔Shoring extra

Thanks are due!

- MnDOT Research Services
- Ames Construction
- U of M Civil Engr. Dept.
- Eden Prairie Bridge Maintenance
- David Kogler, GV Bridge inspector
- PCI Roads (Repair Contractor)

PS Beam End Repair Testing

http://www.dot.state.mn.us/research/index.html



Questions?

Full report #2018-07, published 03/12/2018