IOWA STATE UNIVERSITY
Department of Civil, Construction and Environmental Engineering

Accelerated Repair and Replacement of Expansion Joints

Presenter: Kara Ruble

Mid-Continent Transportation Research Symposium
August 21, 2019

Outline of Presentation

- Introduction
- Replacement of Expansion Joints
  - Cost Analysis
  - Experimental Testing
- Elimination of Expansion Joints
- Conclusions & Future Work

Collaborators

IOWA STATE UNIVERSITY

An Chen, PhD, PE
Charles Jahren, PhD, PE
Brent Phares, PhD, PE
Behrouz Shafei, PhD, PE
Kara Ruble
David Morandeira
Elizabeth Miller

IOWA DOT

James Nelson, PE
Dean Bierwagen, PE
Mike Nop, PE

ABC UTC
ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

Research Focus

Bridge deck expansion joints allow for movement of the bridge deck due to thermal expansion and dynamics loading

Often one of the first components of a bridge deck to fail, repairing or replacing expansion joints are essential to extending the life of any bridge

Develop accelerated options for the replacement or elimination of expansion joints

Introduction

Typical joints used by Iowa DOT

- Sliding plate, strip seal, compression seal, modular, finger, integral abutment
- Strip seals used primarily for Iowa DOT replacements

Common failure modes

- snowplow damage, concrete spalling, tearing, armor detaches, debris build-up, misalignment

Largest bottlenecks in the construction process are demolition and curing of concrete

Demolition Options

Pneumatic breakers

- familiar
- reaches confined areas
- quick set up
- large workforce and time to complete
- risk damage to concrete and rebar

Saw Cutting

- familiar
- easy to remove concrete in blocks
- smooth surface, poor concrete bond
- loss of rebar
- potential overcuts

Hydrodemolition

- newer method
- rough surface, good concrete bond
- quick and small workforce
- high mobilization cost
- creates wastewater slurry

Concrete Header Options

Elastomeric Concrete

- good bond to concrete and steel
- low spalling risk
- ~8 hrs to place and open to traffic
- 25 yrs service life

Magnesium Phosphate

- ~3.5 hrs to place and open to traffic
- can be cast in cold weather
- poor long-term durability

UHPC

- high bond and compression strength
- 12-24 hrs to place and open to traffic
- very long service life
- high material costs

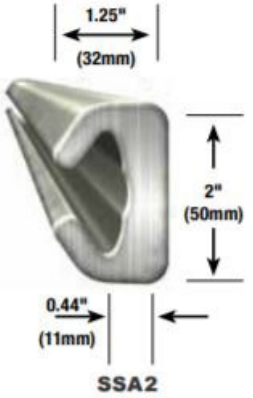
Source: New York State Department of Transportation

Joint Replacement

Hydrodemolition

Ductal JS 1212
UHPC

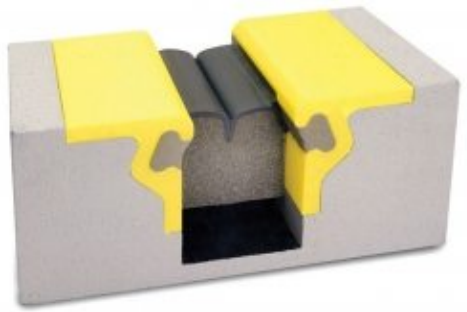
D.S. Brown
Stainless Steel Rails



Cost Analysis

Evaluated four options to determine effectiveness and constructability of the proposed replacement

1. Hydrodemolition, UHPC, Stainless Steel Rail
2. Hydrodemolition, UHPC, A36 Steel Rail, EMSEAL BEJS
3. Pneumatic Hammer, PCC, Stainless Steel Rail
4. Pneumatic Hammer, PCC, A36 Steel Rail



Cost Analysis

Joint Repair Geometry: 30’ x 2’ x 7”

$FV = PV * (1+i)^n$ FV-future value, PV-present value, i-interest rate, n-number of periods

Interest rate determined with 30-year projects in the White House Circular A-94 Appendix C

- Real Interest rate used – accounts for inflation
- 3.80% average

Cost Analysis

The strip seal neoprene gland can be replaced every ~15 years without requiring a full replacement if concrete and rail are in good condition

First replacement 15 years after bridge opening

Avg. Service Lives	
PCC	30
UHPC	100+
A36	25
Stainless	100+
Neo Gland	15
EMSEAL	15

Monte Carlo Simulation

Establish Certain and Uncertain parameters

- Service life
- Material costs
- Mobilization, construction, & traffic control
- Interest rate

Establish statistical distribution of each parameter

Simulation runs iterations with variable costs based on distribution

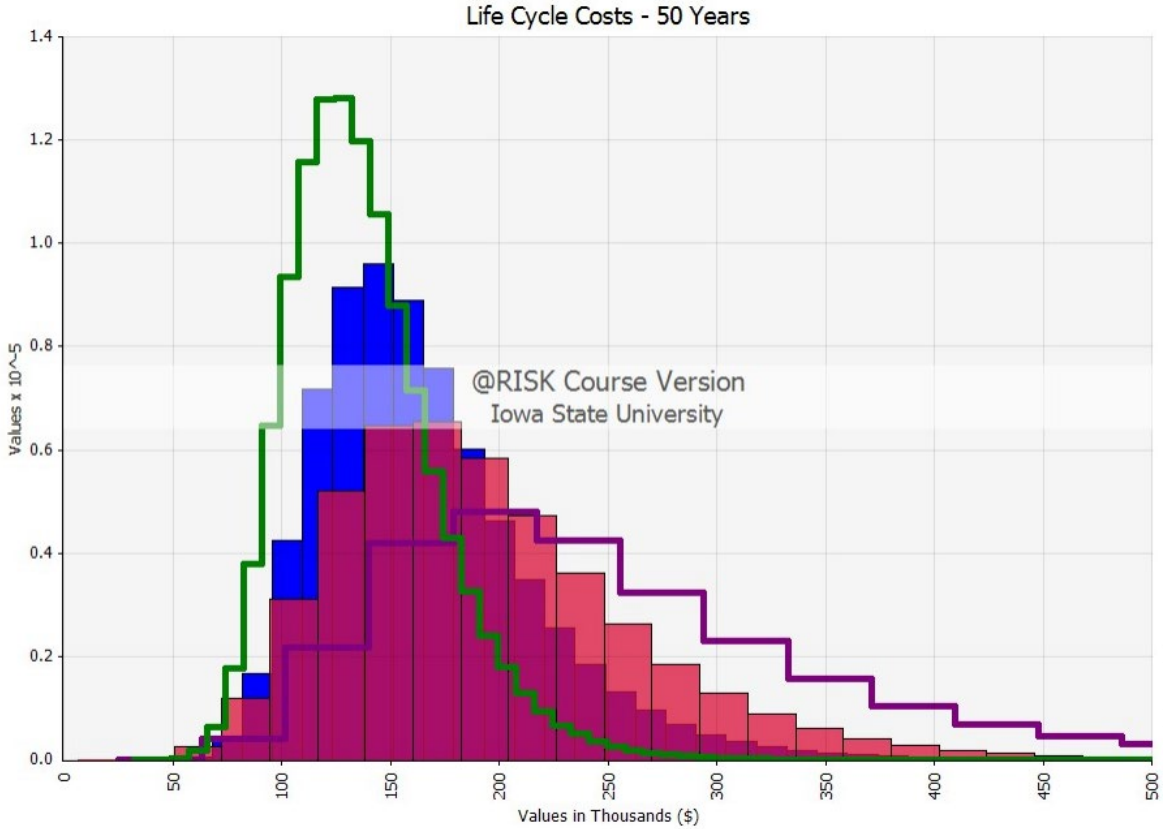
- 1,000,000 iterations

Outputs results in a histogram

Monte Carlo Inputs

		Reference Values				
Uncertain Parameters	Cost	Avg.	High	Low	Distribution	Sta
Mobilization - GR	$ 7,666.67	$ 7,666.67	$ 11,000.00	$ 5,000.00	Normal	$ 63.93
Mobilization	$ 24,840.14	$ 24,840.14	$ 42,000.00	$ 12,148.00	Normal	$ 10,152.39
Steel Extrusion with Neoprene	$ 6,476.70	$ 6,476.70	$ 8,400.00	$ 5,140.50	Normal	$ 882.90
Stainless Steel Extrusion with Neoprene	$ 12,953.40	$ 12,953.40	$ 16,800.00	$ 10,281.00	Normal	$ 1,765.80
Neoprene gland installation and testing	$ 1,465.80	$ 1,465.80	$ 2,250.00	$ 1,020.00	Normal	$ 388.50
Neoprene gland installation and testing - GR	$ 3,725.10	$ 3,725.10	$ 6,000.00	$ 1,800.00	Normal	$ 277.20
Traffic Control	$ 6,312.50	$ 6,312.50	$ 10,600.00	$ 3,000.00	Normal	$ 2,784.55
Traffic Control - GR	$ 6,196.67	$ 6,196.67	$ 14,000.00	$ 980.00	Normal	$ 126.40
Temporary Barrier Rail	$ 296.40	$ 296.40	$ 390.00	$ 255.00	Normal	$ 43.20
Temporary Crash Cushion	$ 1,017.27	$ 1,017.27	$ 1,200.00	$ 915.00	Normal	$ 105.86
Temporary Traffic Signals	$ 4,321.25	$ 4,321.25	$ 4,500.00	$ 3,925.00	Normal	$ 8.31
Flaggers	$ 465.60	$ 465.60	$ 480.00	$ 462.00	Normal	$ 0.75
Painted Pavement Markers	$ 104.59	$ 104.59	$ 407.00	$ 11.00	Normal	$ 118.52
Wet Retroreflective Removal Tape Markings	$ 115.00	$ 115.00	$ 150.00	$ 20.00	Normal	$ 34.39
Pavement Markers Removed	$ 247.27	$ 247.27	$ 1,885.00	$ 26.00	Normal	$ 546.58
UHPC	$ 2,860.00	$ 2,860.00	$ 3,146.00	$ 286.00	Block	
PCC	$ 49.34	$ 49.34			Normal	$ 7.40
Hydrodemolition	$ 324.28	$ 324.28			Normal	$ 48.64
Jackhammer	$ 87.25	$ 87.25			Normal	$ 13.09
EMESEAL BEJS	$ 1,350.00	$ 1,350.00			Normal	$ 202.50
Interest	3.80%				Normal	1.69%

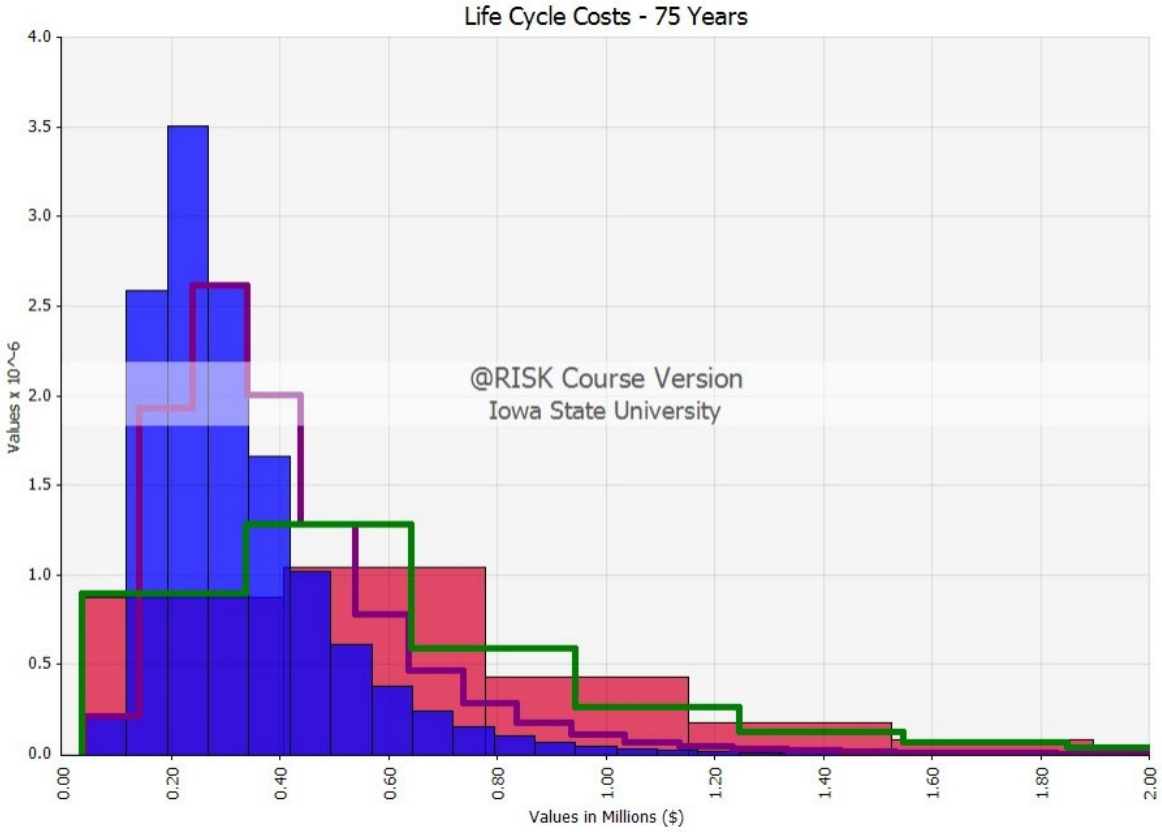
Monte Carlo Results



Option	Avg. Cost
1	$165,960
2	$137,669
3	$250,684
4	$193,974

Blue – Opt 1 (Hydrodemolition, UHPC, Stainless Steel Rail)
Green – Opt 2 (Hydrodemolition, UHPC, A36 Steel Rail)
Purple – Opt 3 (Pneumatic Hammer, PCC, Stainless Steel Rail)
Red – Opt 4 (Pneumatic Hammer, PCC, A36 Steel Rail)

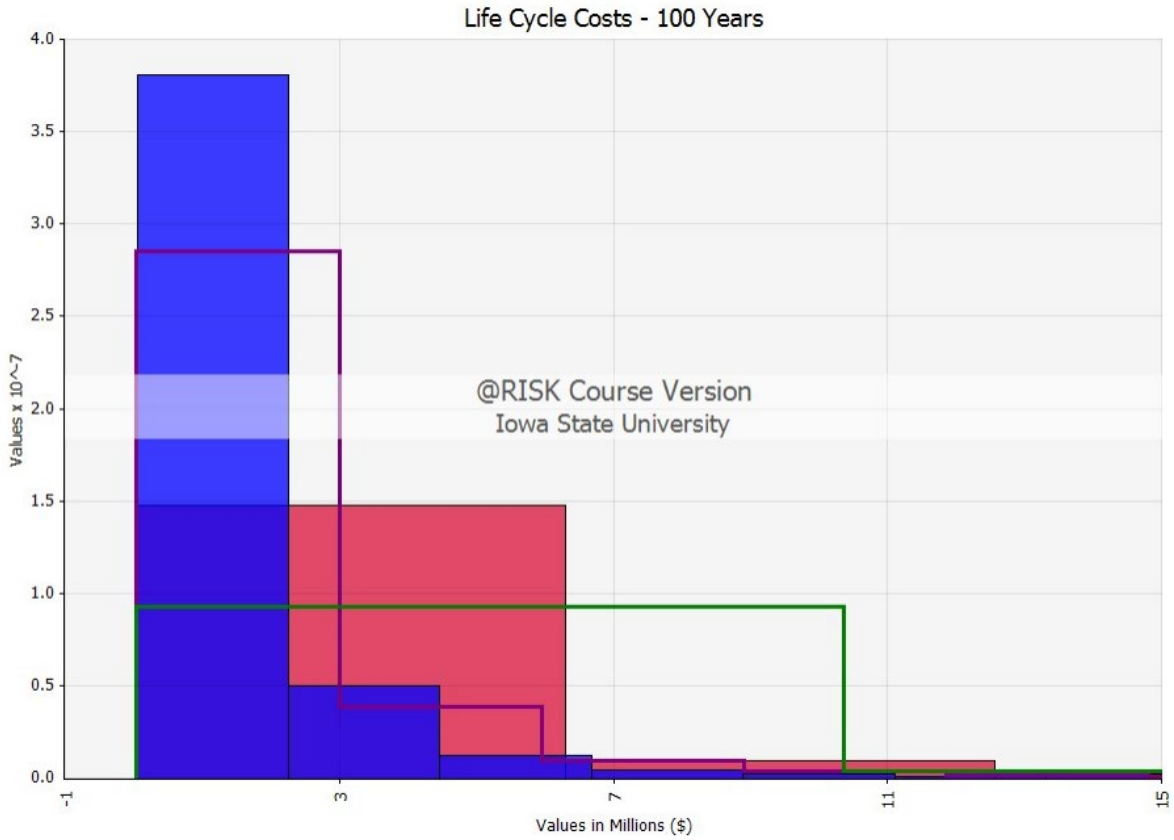
Monte Carlo Results



Option	Avg. Cost
1	$321,315
2	$625,682
3	$406,039
4	$680,699

Blue – Opt 1 (Hydrodemolition, UHPC, Stainless Steel Rail)
Green – Opt 2 (Hydrodemolition, UHPC, A36 Steel Rail)
Purple – Opt 3 (Pneumatic Hammer, PCC, Stainless Steel Rail)
Red – Opt 4 (Pneumatic Hammer, PCC, A36 Steel Rail)

Monte Carlo Results



Option	Avg. Cost
1	$1,409,272
2	$2,919,816
3	$1,867,421
4	$2,499,211

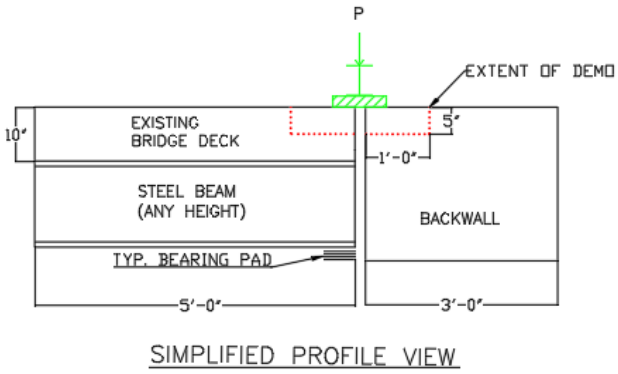
Blue – Opt 1 (Hydrodemolition, UHPC, Stainless Steel Rail)
Green – Opt 2 (Hydrodemolition, UHPC, A36 Steel Rail)
Purple – Opt 3 (Pneumatic Hammer, PCC, Stainless Steel Rail)
Red – Opt 4 (Pneumatic Hammer, PCC, A36 Steel Rail)

Experimental Testing

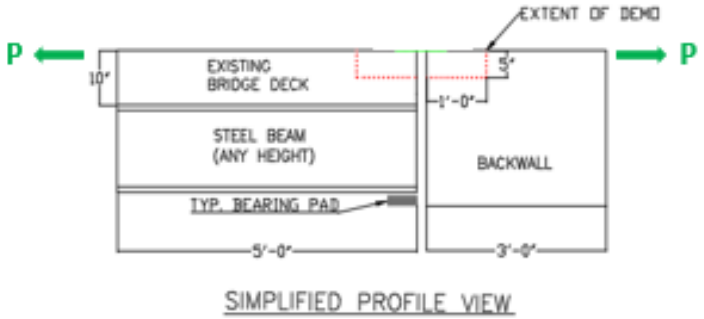
Preliminary Testing is currently underway

Type of tests: vertical load, thermal, bond

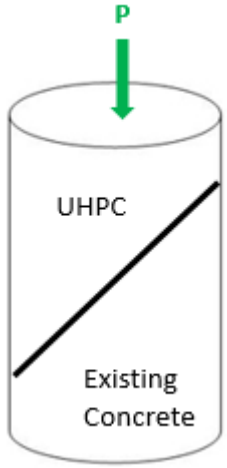
- Beam end rotation will be monitored throughout all tests



SIMPLIFIED PROFILE VIEW



SIMPLIFIED PROFILE VIEW



Experimental Testing

Procedure Outline:

- Pour existing bridge deck and backwall
- Perform testing on a replica of a typical Iowa DOT expansion joint
- Use hydrodemolition and UHPC to replace the joint to evaluate constructability
- Perform testing on proposed joint replacement
- Compare results of the two joints to evaluate effectiveness

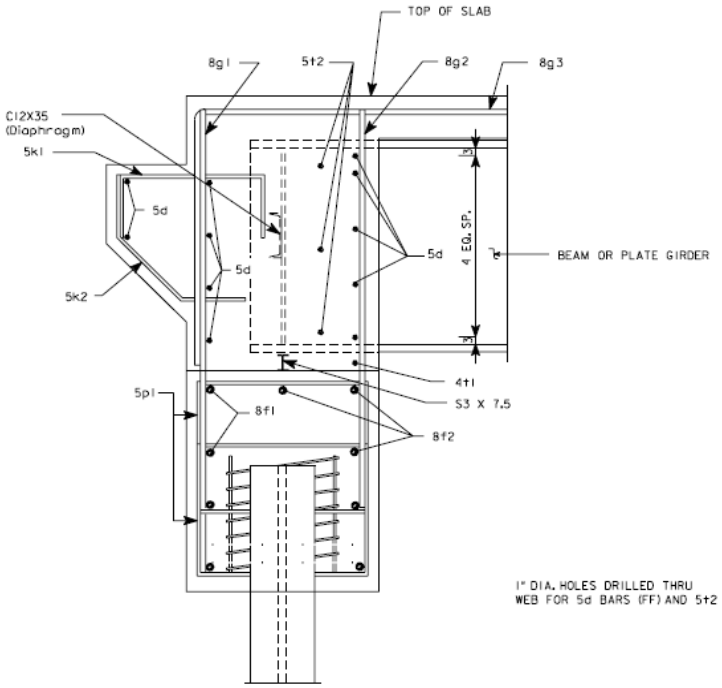
Joint Elimination

When expansion joints are not needed for a bridge, joint elimination can be considered

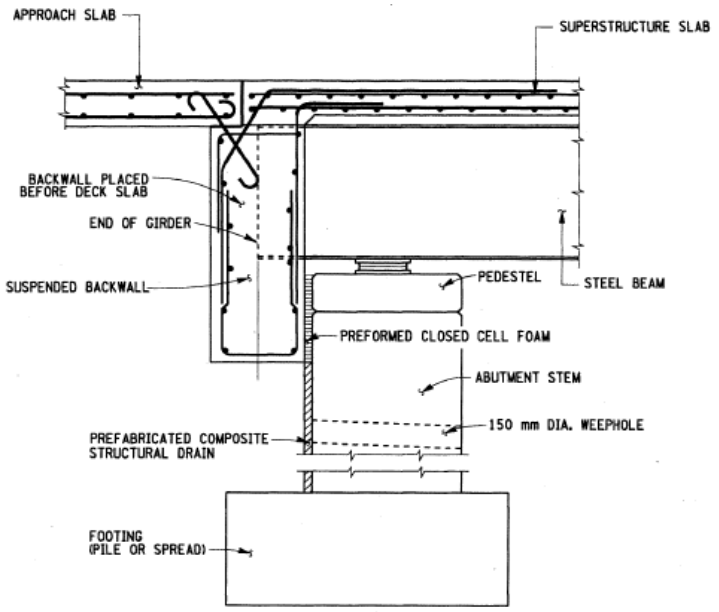
- Integral Abutments
- Semi-integral Abutments
- Deck over Backwall

A combination of precast specimens with cast-in-place UHPC connectors can be utilized for accelerated repair/replacement

Integral & Semi-Integral Abutments



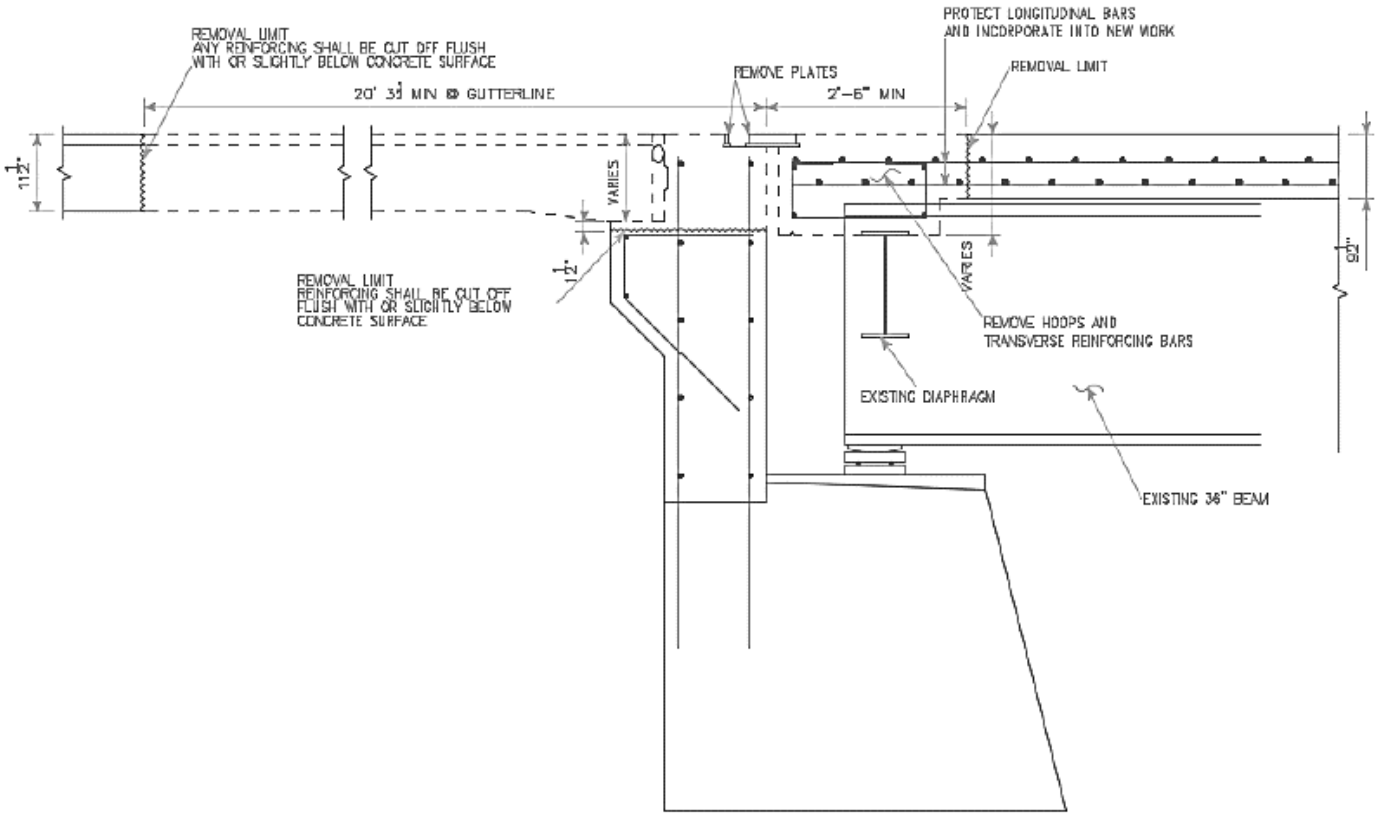
Integral Abutment Cross Section



Integral Abutment Cross Section

Source: Miller and Jahren (2015)

Deck over Backwall Detail



Source: Iowa DOT

Conclusions & Future Work

1. Utilizing hydrodemolition and UHPC can minimize traffic closures for expansion joint replacements
2. UHPC/Stainless steel rail expansion joint system is a viable and cost effective option for bridges with a life of more than 50 years
3. When possible, joint elimination options should be considered with precast sections to protect the substructure and minimize traffic closures
4. Experimental testing should be finished to confirm constructability and that performance meets Iowa DOT standards
5. Conducting and monitoring the accelerated replacement on a full scale bridge should be considered for future work

Questions?

Thank You!