Ultra-High Performance Concrete for Steel Beam End Repairs

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Outline

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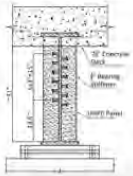
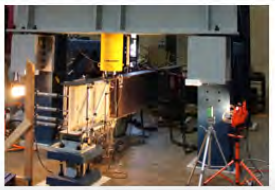
Introduction to the Problem

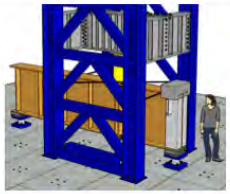
Overview of Proposed Repair Method



Phase 1: Large Scale Girder Tests



Phase 2: Development of Design Guide



Repair Design Example

Summary and Conclusions

Introduction to the Problem

America's Crumbling Infrastructure

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ASCE Report Card

C+

60,000
of the nation's bridges were
STRUCTURALLY DEFICIENT in 2016

$123 billion
to catch up with the
BACKLOG
of rehabilitation projects

Problem – *Corrosion Damage*

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- 15% of structurally deficient bridges experience heavy corrosion damage
- $8.3 billion is spent annually to repair or replace highway bridges with corrosion
- Girder bridges mainly suffer from corrosion at the girder ends
- The main cause of corrosion damage is deicing chemicals

Impact on the Structural Capacity

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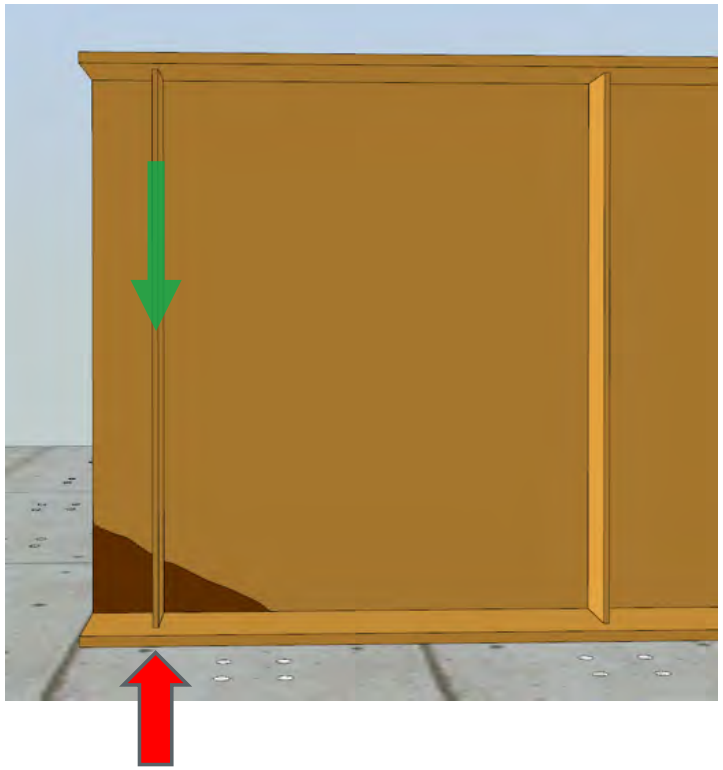

Current Repair Method

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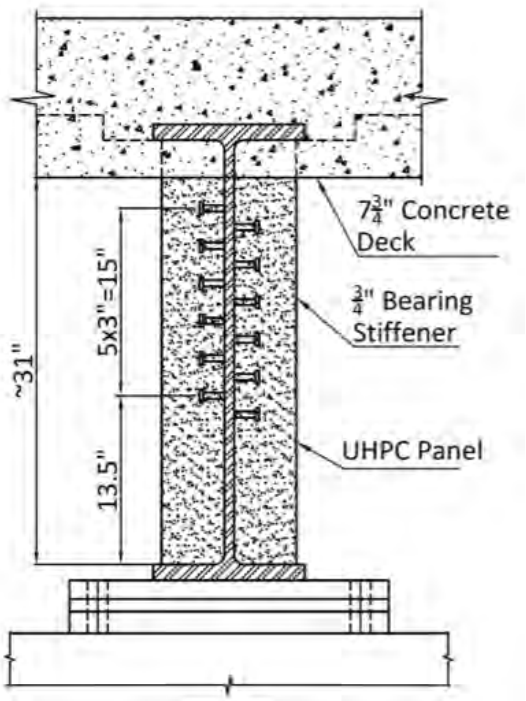
Overview of Proposed Repair Method



Repair Concept

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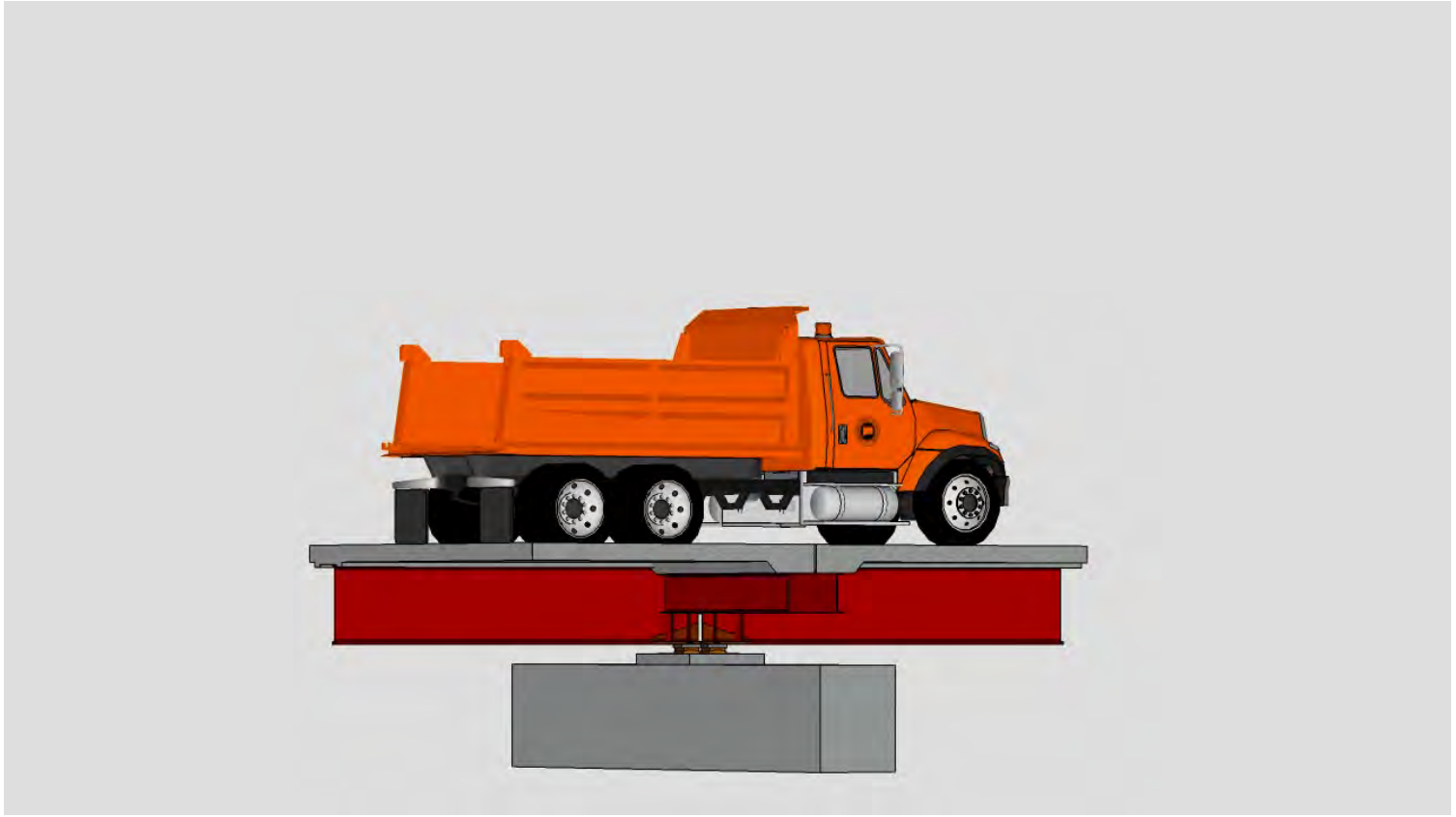

Load Transfer Mechanism

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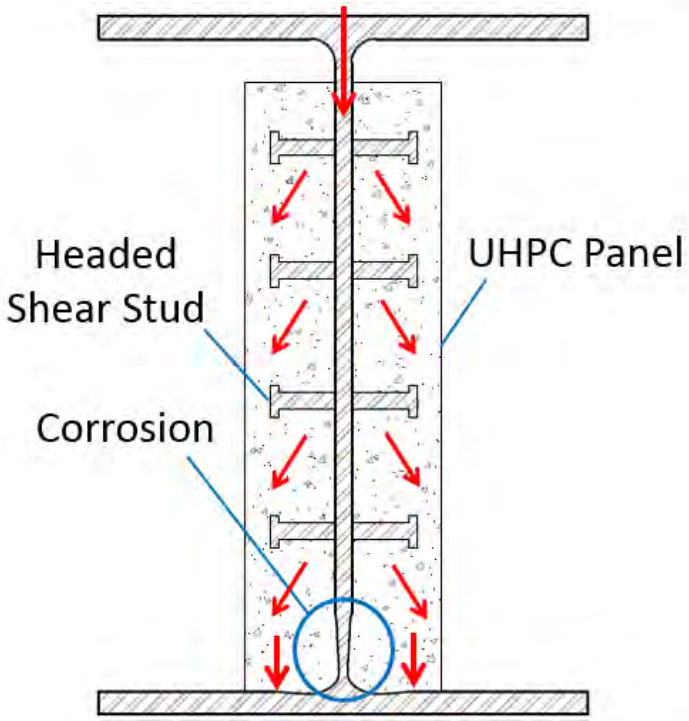

Ultra High Performance Concrete

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- Definition of UHPC (FHWA 2011)
  - Material consisting of optimized granular constituents
  - Maximum W/C ratio of 0.25
  - Compressive strength of larger than 22 ksi
  - Enhanced durability via discontinuous pore structure
- Self consolidating without vibration
- Constituents: cement, silica fume, silica powder, sand, water, admixtures, steel fibers

Component	Mass Fraction (%)
Premix Powder	86.6
Water	5.1
Premia 150 (HRWR 1)	0.7
Optima 100 (HRWR 2)	0.5
Turbocast (Accelerator)	0.9
Steel Fibers	6.2

Ultra High Performance Concrete

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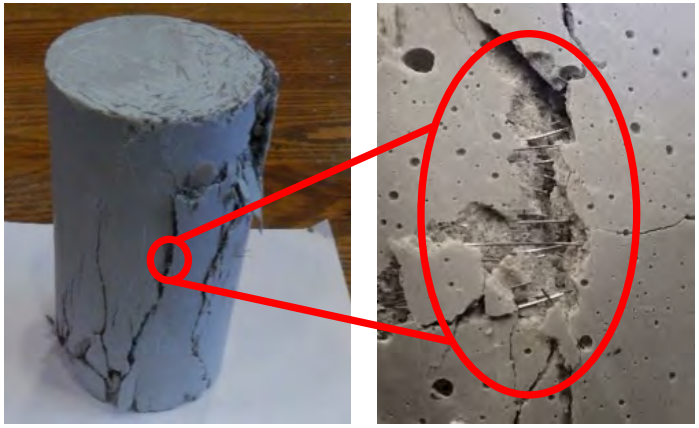

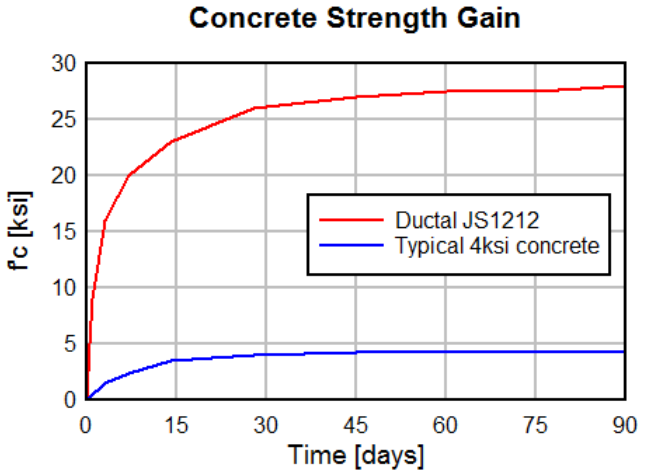

Ultra High Performance Concrete

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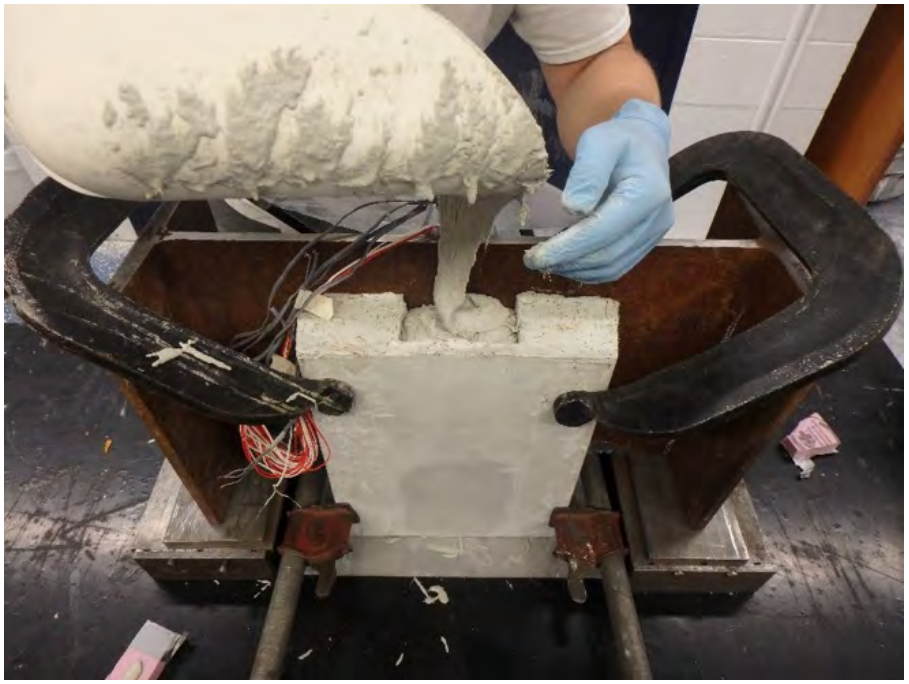
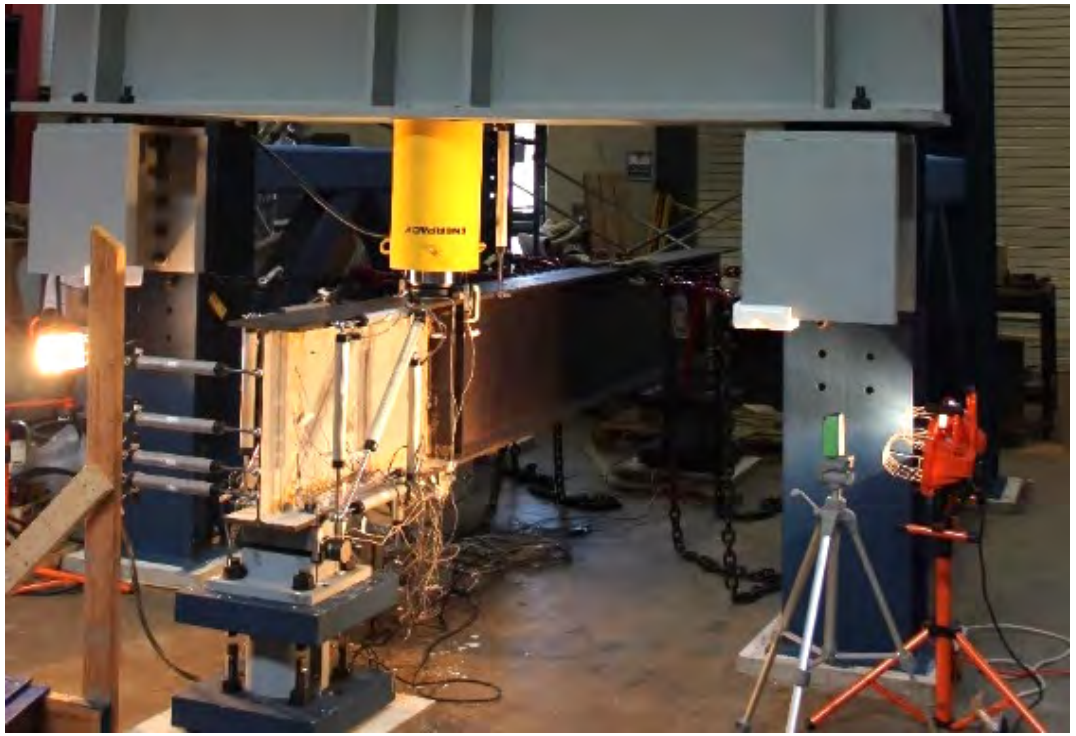


Phase 1: Large Scale Girder Tests



Phase 1: Large-Scale Girder Tests

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Tested three W21x55 Girders

1. **Undamaged:** Baseline to measure capacity.
2. **Damaged:** Web and flange reduction to simulate corrosion damage.
3. **Repaired:** Same section reduction as Damaged, but with UHPC repair.

Phase 1: Large-Scale Girder Tests

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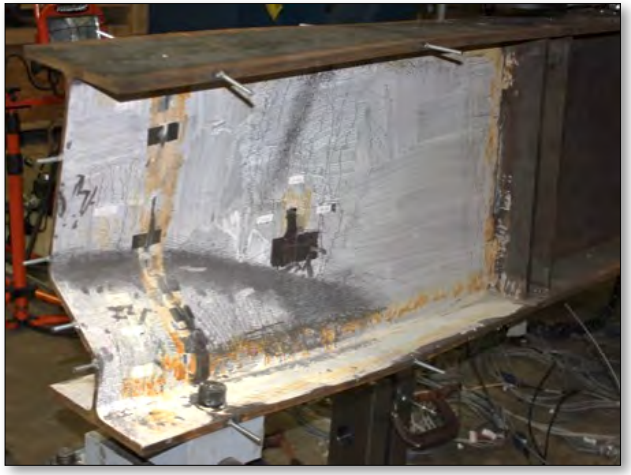
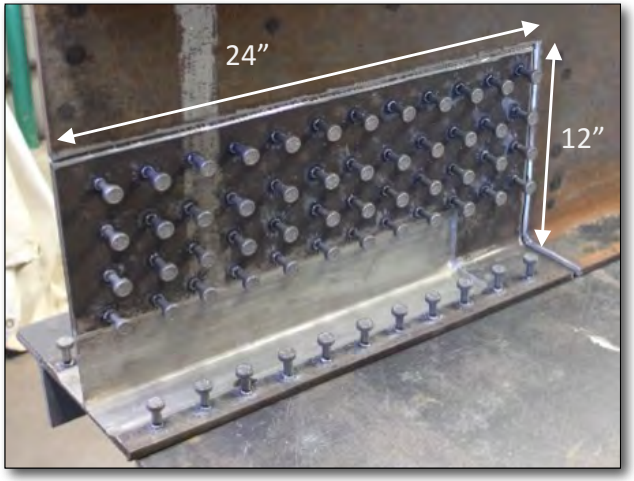
Undamaged
Global Web Buckling



Damaged
Localized Web Buckling

Repaired
Flexural Yielding



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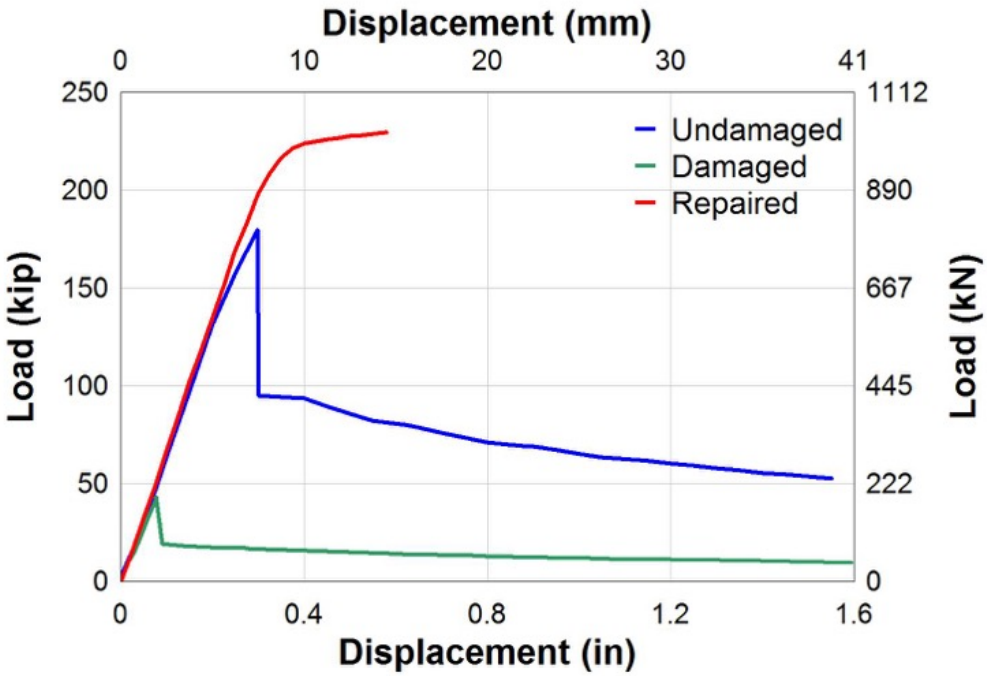

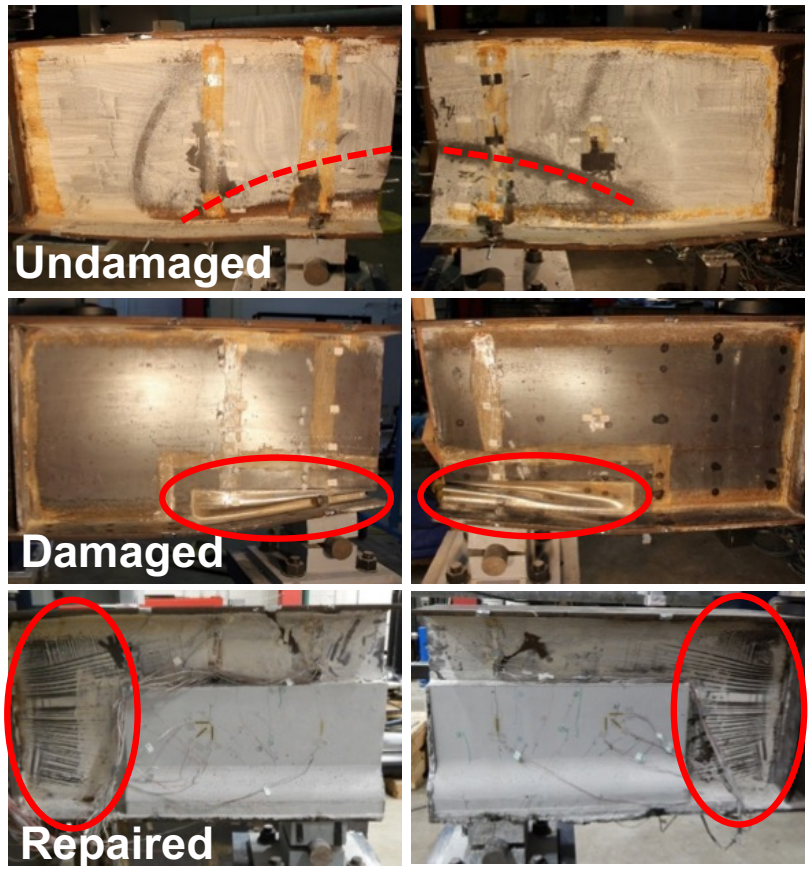

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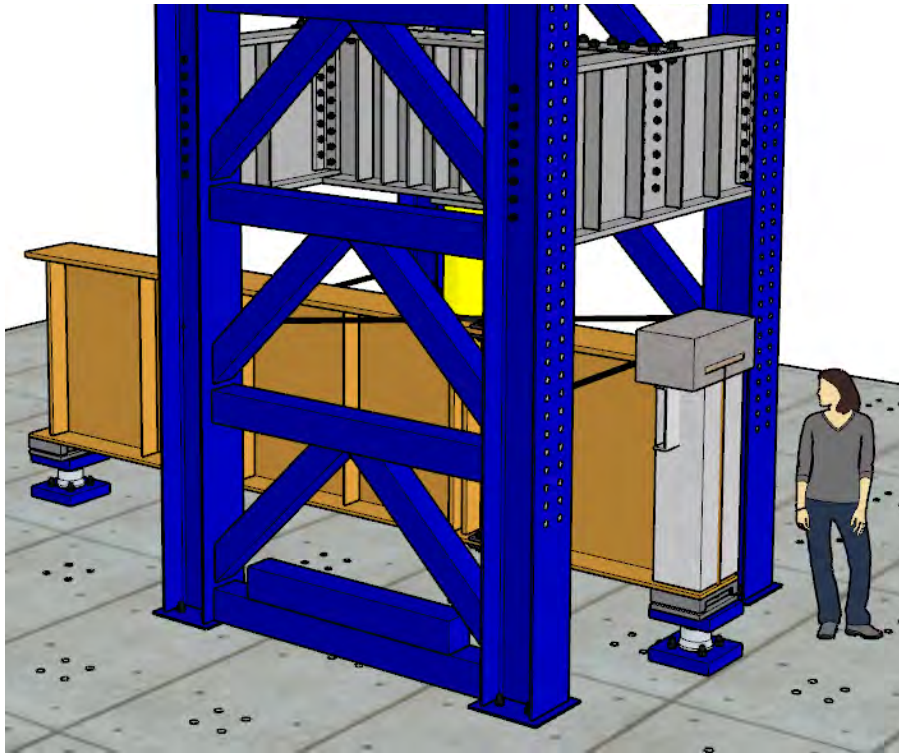

Phase 2: Project Overview

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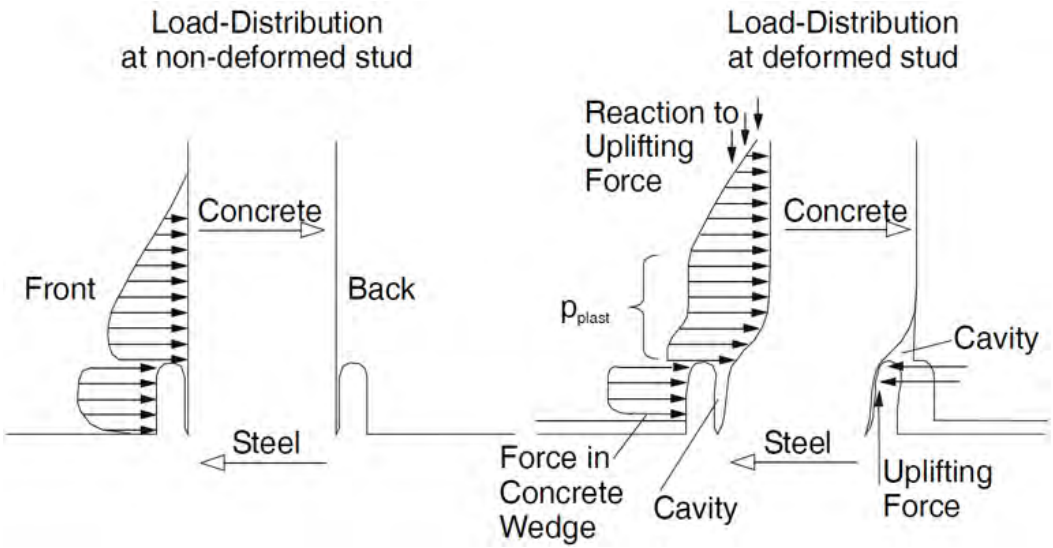
- Investigation of stud capacity in UHPC
- Experimental study of full-scale plate girders
- High fidelity finite element modeling and parametric studies
- Development of design guide and standard details for field application

Phase 2: Stud Capacity

Behavior of shear studs in UHPC is different than in regular concrete.



Phase 2: Stud Capacity

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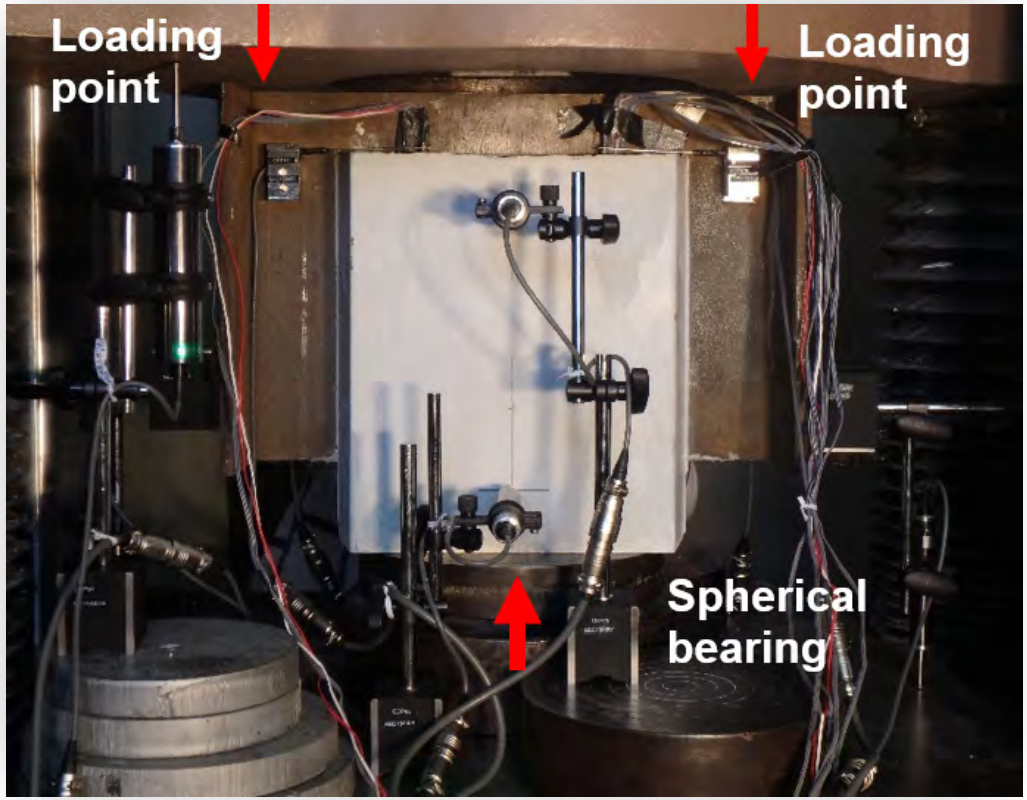

Phase 2: Stud Capacity

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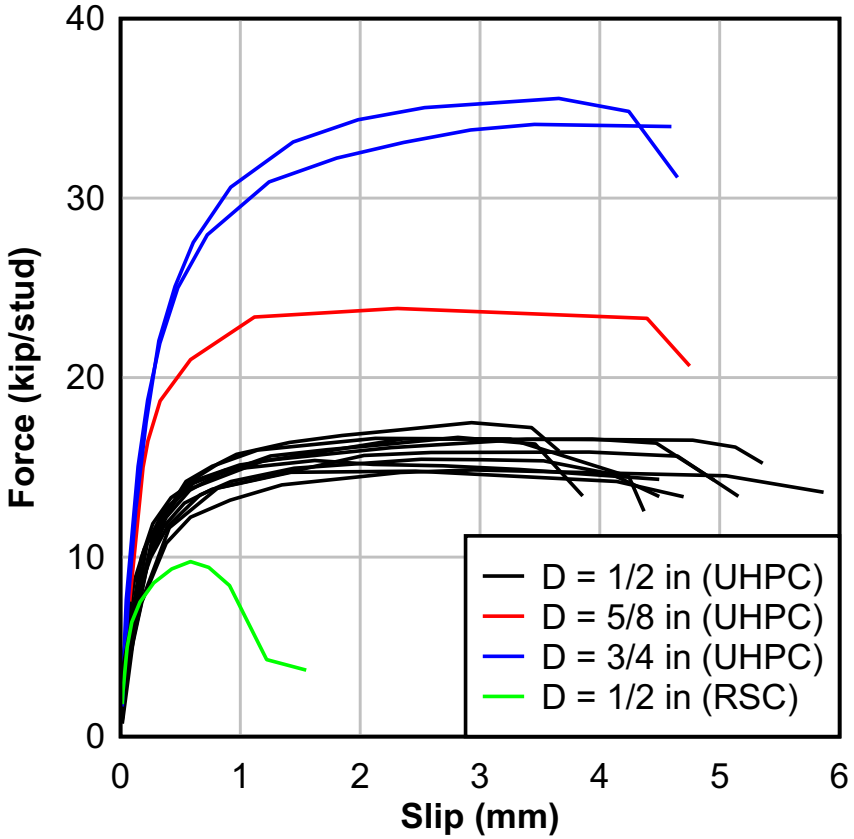
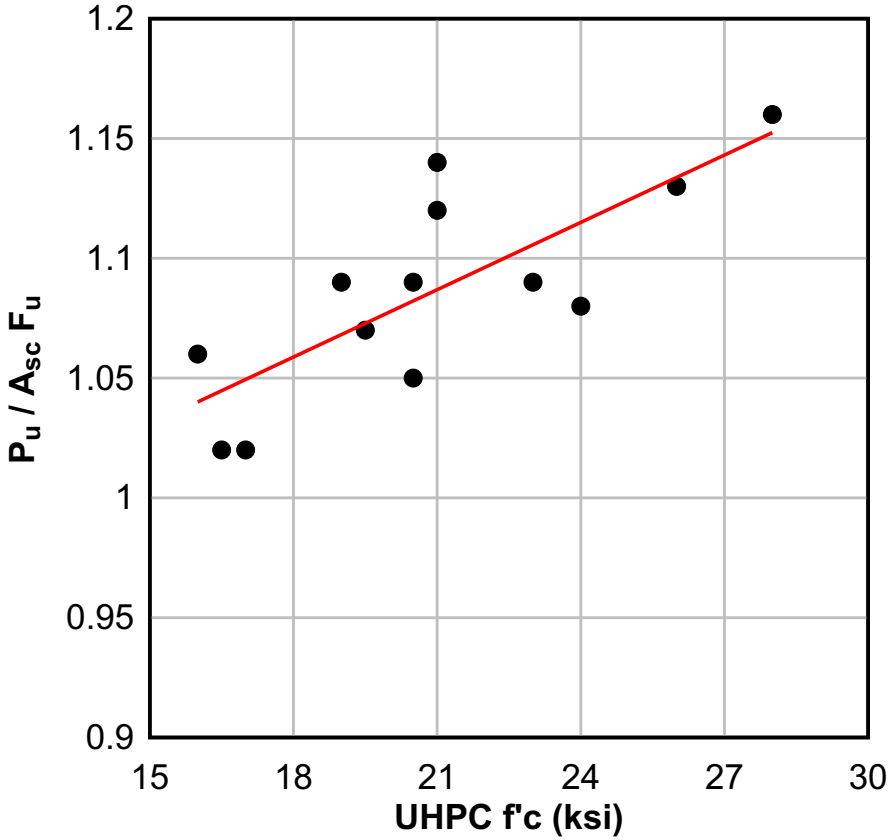
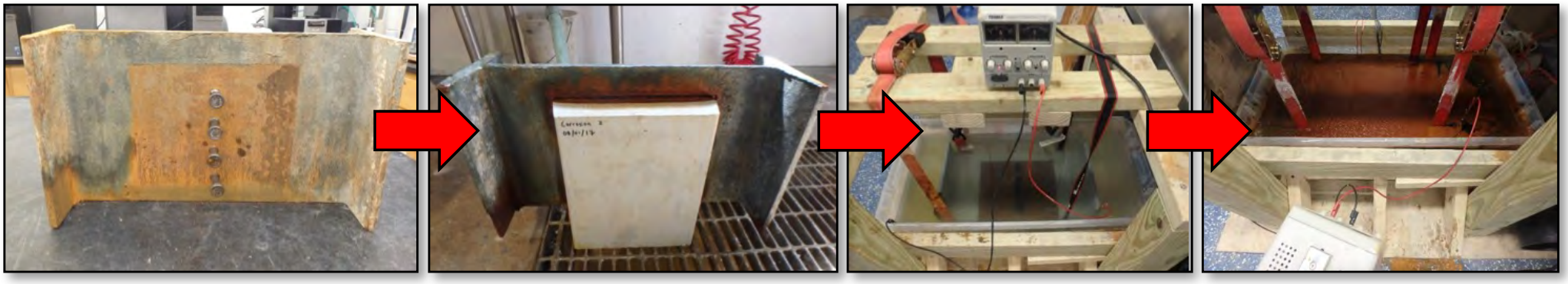
Typical failure of push-out Specimens

Phase 2: Stud Capacity





Phase 2: Durability Testing



Prior to casting UHPC, the web of the steel section was submerged for 60 hours to achieve surface rust.

Phase 2: Durability Testing

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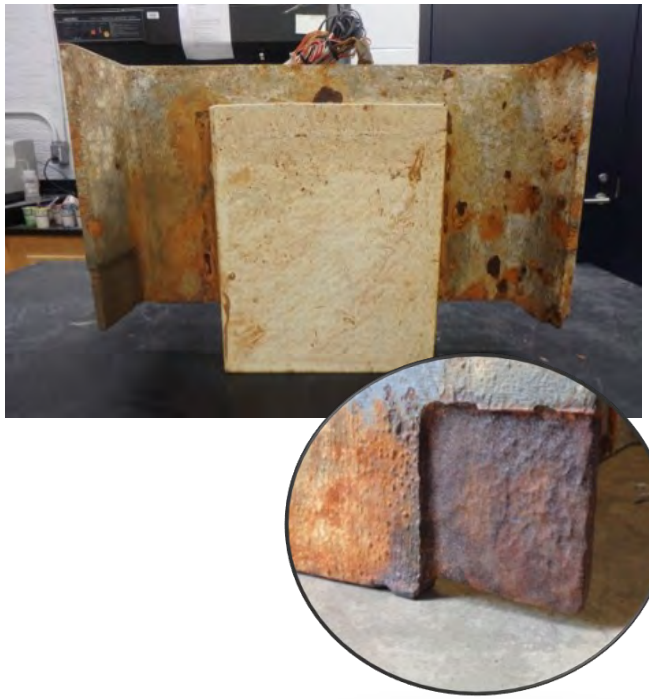

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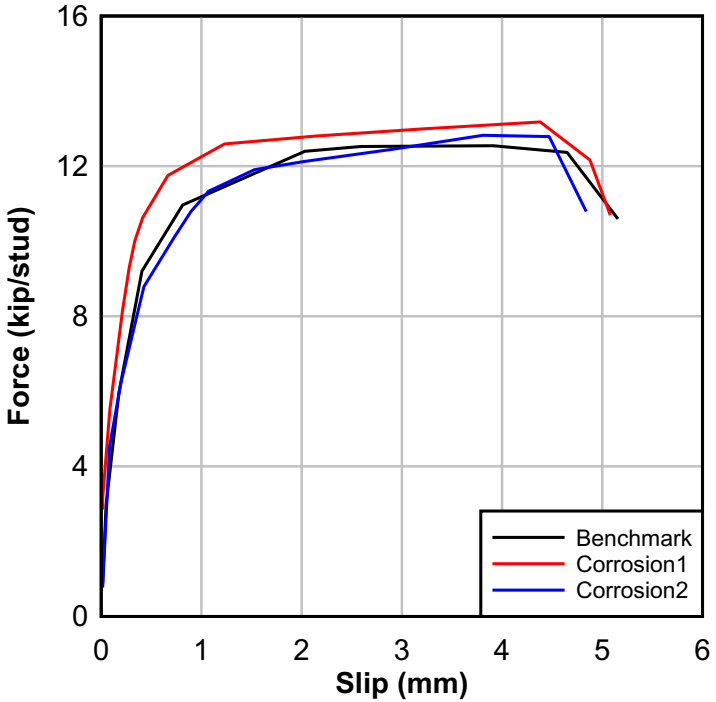

Phase 2: Large Scale Testing

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- 54”-Deep plate girders
- Test different repair geometries:
  - Full Height
  - Half Height
- Simulate Live Load

Phase 2: Large Scale Testing

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Damaged Girder

Half-Height Repair

Full-Height Repair

Phase 2: Large Scale Testing

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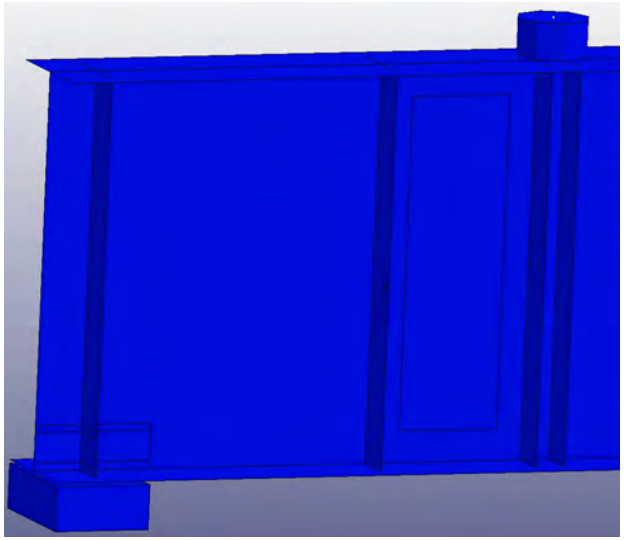
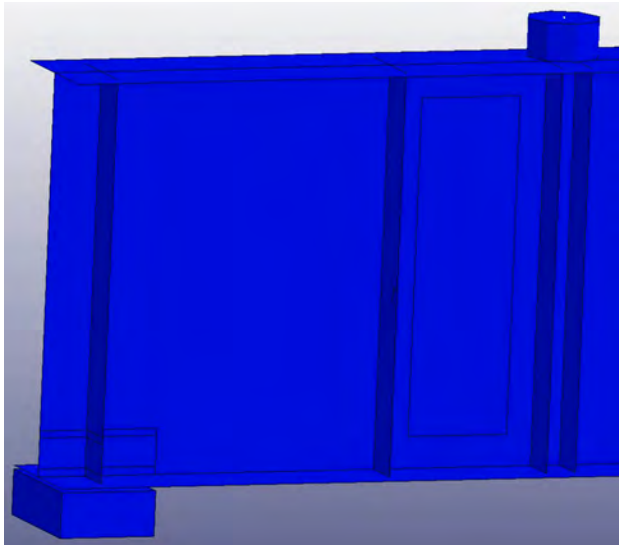
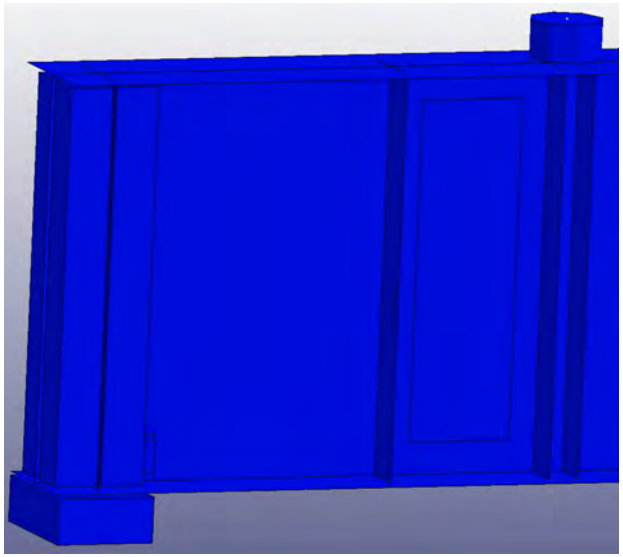


Intact Girder



Damaged Girder



Full-Height Repair

Phase 2: Large Scale Testing

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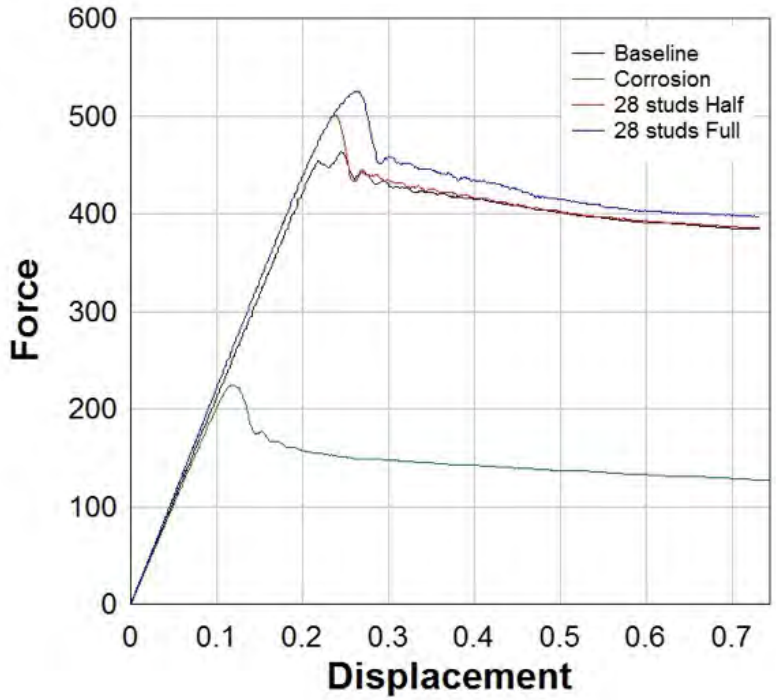
Finite Element Results

Force vs. Displacement



Repair Design Example

Pilot Bridge Repair Design

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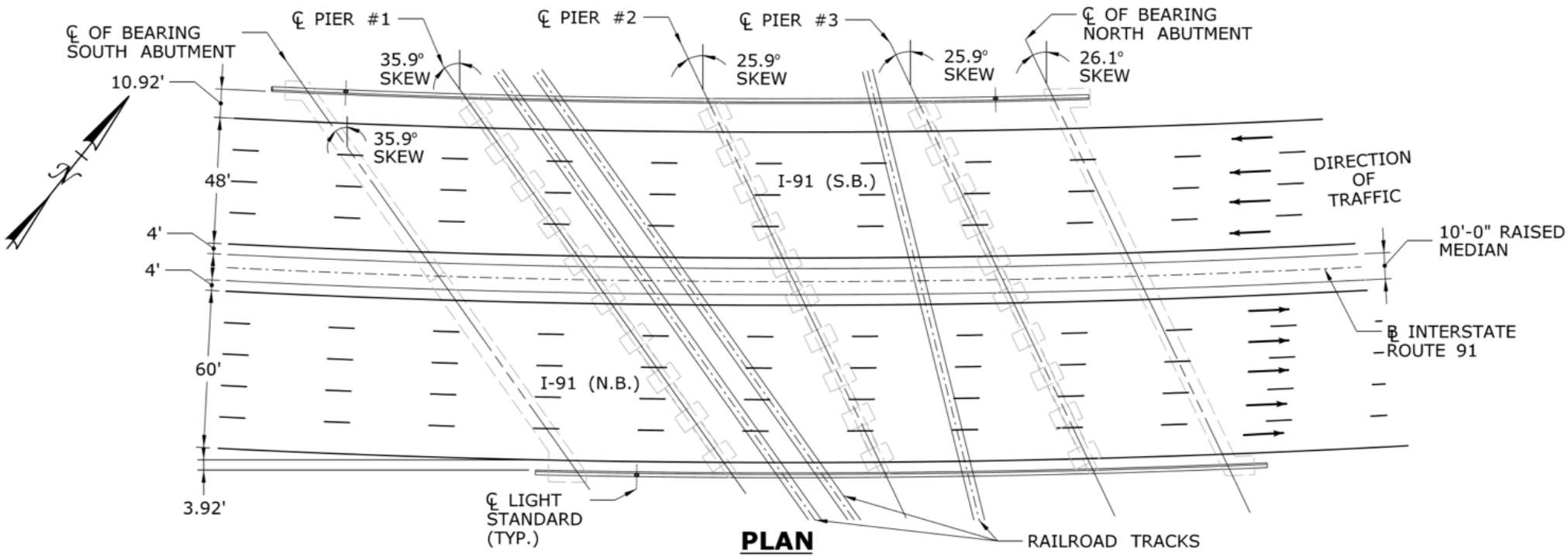
- Constructed in 1965
- Four simply supported spans
- Rolled steel multi-girder superstructure

Pilot Bridge Repair Design



Current Condition

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Design Number of Shear Studs

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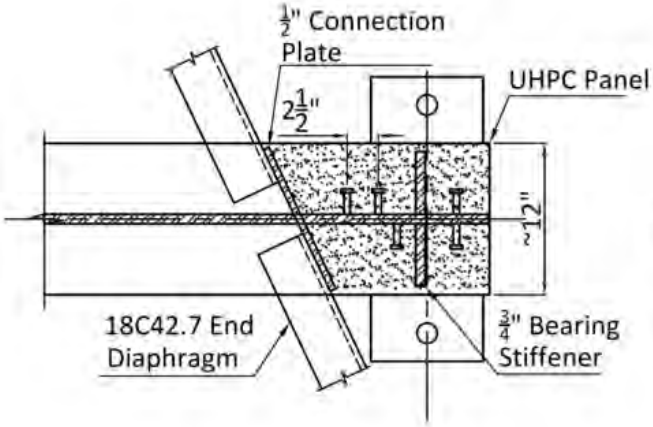
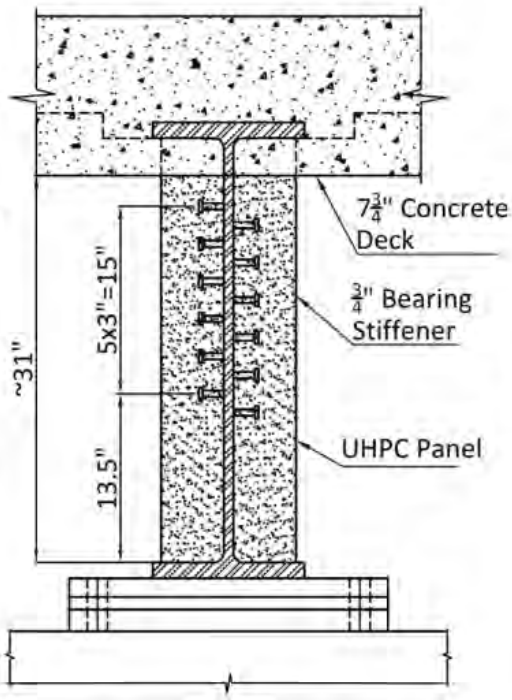
		Demand (kip)	# of ½" Studs	# of ⅝" Studs
Load Design	Live Load Only	116	9	6
	Strength I (AASHTO)	301	22	15
Capacity Design	Bearing	640	48	32
	Shear	568	42	28

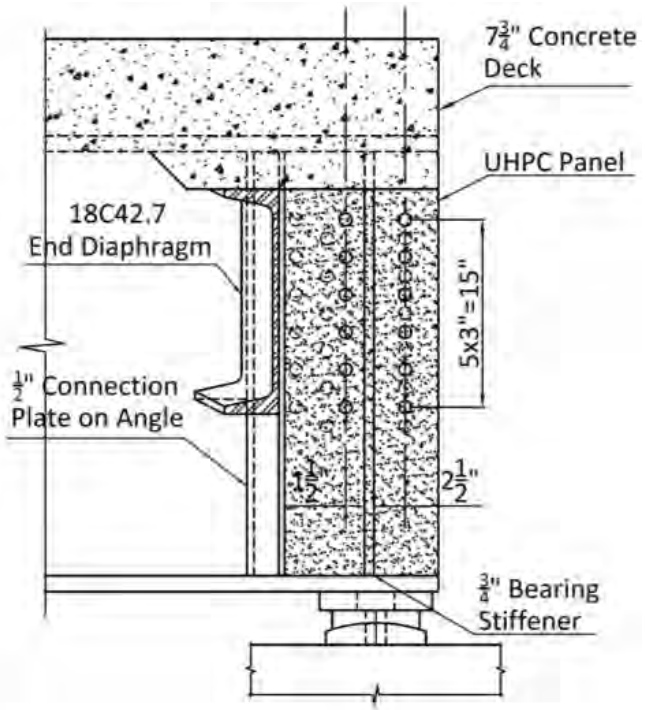
Sample Repair Design



Plan View



Cross Section



Elevation View

Fatigue Control

For studs embedded in UHPC (Cao 2017)

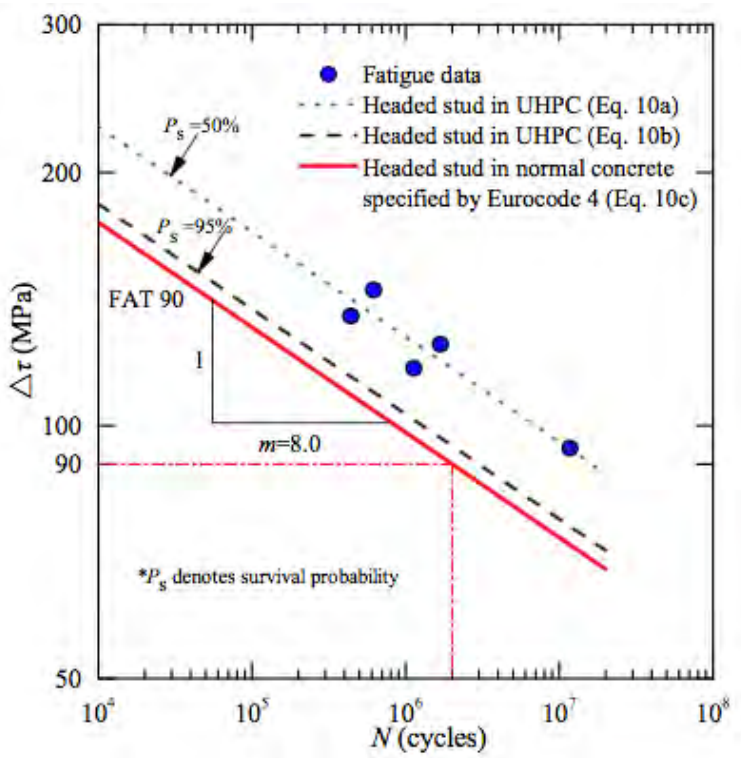
$$8 \log \Delta\tau + \log N = 22.1131$$

ADT = 67,000 vehicles per day

N = 147 million cycles (50 year design life)

Allowable stress range (based on fatigue)= 7.9 ksi

Stress range demand under fatigue truck= 7.0 ksi



Summary and Conclusions

Summary and Conclusion

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- A novel method has been developed to rehabilitate girders with corrosion damage by attaching UHPC panels to the girder using shear studs.
- The composite action of the UHPC repair introduced a secondary load path through the shear studs to transfer bearing and shear forces.
- The UHPC repair demonstrated the ability to restore bearing capacity lost due to corrosion over 5 times that of a damaged girder.
- This repair offers flexibility regarding location and number of studs to tackle complex geometries under various limit states

Acknowledgements

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  - Rabih Barakat
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Repair for Steel Bridge Girders with Corrosion Damage Utilizing UHPC

Thank you!

Ultra High Performance Concrete Workshop
June 28, 2017 | Albany, New York

PDH Questions

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What is the current common method for repairing deteriorated steel girder end regions? (single answer)

a) Apply post-tensioning along length of girder tension flange,

b) Weld or bolt new steel plates over deteriorated steel,

c) Encase the end 10’ of each deteriorated girder in conventional concrete,

d) Selectively apply steel studs and UHPC in and near deteriorated regions.

PDH Questions

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What are some advantages of using UHPC to repair deteriorated steel girder end regions? (multiple answer)

a) UHPC can easily flow into tight spaces,

b) UHPC can carry higher tensile and compressive stresses than conventional concrete,

c) UHPC costs less than conventional concrete,

d) UHPC is far more durable than conventional concrete.

PDH Questions

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The UHPC girder end repair offers flexibility regarding location and number of studs to tackle complex geometries under various limit states? (True/False)

PDH Questions

The full scale structural testing of the UHPC repair solution demonstrated that the lost bearing and shear capacity can often be recovered in a properly detailed UHPC repair? (True/False)