Integral Abutment Connection Details for ABC – Phase II

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Acknowledgements

- ABC-UTC
- IowaDOT
  - Match funding
Project Goal

• Develop Integral Abutment Connection(s) that meet the design and construction demands of an Accelerated Bridge Construction (ABC) project
  – Slide-in Construction Capable
  – Durable
  – Construction Friendly
Objective and Scope

• Analyze strength and durability of three integral abutment connection details for ABC applications

• Scope
  – Revise and retest the two connection details designed for Phase I (ISU 2014-2016)
  – Design and test Ultra-High Performance Concrete (UHPC)-Joint for Iowa DOT
Why Integral Abutment

• Integral Abutments
  – Semi-Integral
  – Expansion Joint

• Benefits of Integral Abutment
  – Eliminate Expansion Joint
  – Decrease Maintenance Costs
  – Increase Service Life
  – Less Expensive to Construct, Simple to Detail
Laboratory Specimens
Design, Construction and Testing
Cast-In-Place (control) Specimen

Figure 1: Cast-In-Place Pile Cap
Cast-In-Place (control) Specimen

Figure 2: Cast-In-Place Integral Diaphragm
Cast-In-Place (control) Specimen

Figure 3: Cast-In-Place Connection prior to concrete casting
Cast-In-Place (control) Specimen

Figure 4: Cast-In-Place Integral Abutment Specimen completed (with reaction blocks)
Specimen Construction

• Three specimens evaluated:
  – Grouted Reinforcing Bar Coupler (GRBC)
    • 8 couplers revised from 17 couplers in Phase I
  – Pile Coupler (PC)
    • 4 couplers revised from 2 couplers in Phase I
  – UHPC-Joint
    • Designed in conjunction with IowaDOT

• Structural Response & Constructability
Grouted Reinforcing Bar Coupler (GRBC)

Figure 5: Plan View of GRBC Specimen (Note: Red dots represent locations of couplers)
Grouted Reinforcing Bar Coupler (GRBC)

Figure 6: Section View through couplers (Note: Red marks represent Grouted Couplers)
Figure 7: Completed GRBC Pile Cap
Grouted Reinforcing Bar Coupler (GRBC)

Figure 8: GRBC Integral Diaphragm Reinforcing Cage (Note: Grout Sleeves on bottom)
Grouted Reinforcing Bar Coupler (GRBC)

Figure 9: Completed GRBC Integral Diaphragm
Grouted Reinforcing Bar Coupler (GRBC)

Figure 10: Completed GRBC Integral Diaphragm Surfaced Grout Ports
Grouted Reinforcing Bar Coupler (GRBC)

Figure 11: GRBC Connection Dry-Fit
Grouted Reinforcing Bar Coupler (GRBC)

Figure 12: GRBC Connection Installation (Note: ¾” Neoprene pad with silicone)
Grouted Reinforcing Bar Coupler (GRBC)

Figure 13: Completed GRBC Connection Installation
Grouted Reinforcing Bar Coupler (GRBC)

Figure 14: Completed GRBC Specimen
GRBC – Construction Issues

• Pile Cap
  – No significant issues

• Integral Diaphragm
  – Reinforcement cage adjustments for grout sleeve ports
  – One grout sleeve port did not fully surface

• Connection
  – No significant issues
Pile Coupler (PC)

Figure 15: Plan View of PC Specimen
Pile Coupler (PC)

Figure 16: Section View through couplers
Figure 17: PC Pile Cap Corrugated Metal Pipe (CMP) plug
Figure 18: PC Pile Cap salvage reinforcing bars holding CMP’s at design location
Pile Coupler (PC)

Figure 19: Completed PC Pile Cap
Pile Coupler (PC)

Figure 20: PC Integral Diaphragm CMP plug
Figure 21: PC Integral Diaphragm reinforcing cage
Figure 22: PC Integral Diaphragm CMP with Ports and “locking” salvage reinforcing bars
Figure 23: Completed PC Integral Diaphragm Surfaced CMP’s and Ports
Figure 24: Completed PC Integral Diaphragm
Figure 25: Steel Section Couplers with Shear Studs suspended within CMP’s
Figure 26: PC Connection Installation – Installation of and Completed SCC
Pile Coupler (PC)

Figure 27: Completed PC Specimen
PC – Construction Issues

• Pile Cap
  – CMP movement during concrete pour
  – One CMP Plug blowout

• Integral Diaphragm
  – One 1 in. vent port did not fully surface

• Connection
  – SCC aggregate settled to bottom of barrel during casting
  – Steel Section Guide locations
Figure 28: Plan View of UHPC-Joint Specimen (Note: Red dots represent locations of couplers)
Figure 29: Section View through “Chimney” (Left) and other sections (Right)
UHPC-Joint

- Flowability Test conducted to investigate the ability of the UHPC material to flow through the designed cross section

Figure 30: Elevation View (Left) Section View through “Chimney” (Right)
Figure 31: UHPC-Joint Flowability Test Completed
Figure 32: UHPC-Joint Pile Cap Threaded Couplers
UHPC-Joint

Figure 33: Completed UHPC-Joint Pile Cap
Figure 34: UHPC-Joint Integral Diaphragm Formwork
Figure 35: UHPC-Joint Integral Diaphragm Reinforcing Cage (Note: Coupler Bars passing through bottom of formwork)
Figure 36: Form Retarder applied to bottom of UHPC-Joint Integral Diaphragm
Figure 37: Completed UHPC-Joint Integral Diaphragm with Exposed Aggregate Finish
Figure 38: UHPC-Joint Connection Installation – (Left to Right) Adequate Clearance for Rear Coupler Bars. Adequate Clearance for Front Coupler Bars. Bottom of Integral Diaphragm with Steel Shoe bearing on Neoprene Pad
Figure 39: UHPC-Joint Rear face of Specimen (Note: “Chimney’s”)
Figure 40: UHPC-Joint Connection Installation – (Left) Chimney System for installing UHPC (Right) Completed UHPC-Joint
Figure 41: Completed UHPC-Joint Specimen
UHPC-Joint – Construction Issues

• Pile Cap
  – Some bars did not have 8 in. protrusion

• Integral Diaphragm
  – Variation of protruding lengths for coupler bars
  – Coupler bars were not easily tied to reinforcement cage

• Connection
  – UHPC layers during casting
Laboratory Test Setup

• Two independent static loads applied to the fixed-base specimens
  – 100-kip Horizontal Load => front face joint opening
  – 400-kip Vertical Load => rear face joint opening

• Instrumentation
  – Displacement Transducers
  – Sacrificial Strain Gauges
  – Displacement Gauges
Laboratory Test Setup

Figure 42: Laboratory Testing Setup

- 100 kip Horizontal Load
- Post-tensioned Tie-Down Bars
- Reaction Blocks
- 400 kip Vertical Load
Laboratory Test Results - GRBC

Figure 43: GRBC Front Face Joint Crack from Horizontal Load
Figure 44: GRBC Front Coupler Bar Stress from Horizontal Load
Figure 45: GRBC Rear Face Joint Crack from Vertical Load
Figure 46: GRBC Rear Coupler Bar Stress from Vertical Load
Figure 47: PC Front Face Joint Crack from Horizontal Load
• Maximum Front Coupler Stress due to Horizontal Load was tabulated to be 3.34-ksi, which is essentially no stress in the coupler steel sections.
Figure 48: PC Rear Face Joint Crack from Vertical Load
Figure 49: PC Rear Coupler Section Stresses from Vertical Load
Figure 50: UHPC-Joint Front Face Joint Crack from Horizontal Load
Laboratory Test Results – UHPC-Joint

Figure 51: UHPC-Joint Front Coupler Bar Stresses from Horizontal Load
Figure 52: UHPC-Joint Rear Face Joint Crack from Vertical Load
Laboratory Test Results – UHPC-Joint

Figure 53: UHPC-Joint Rear Coupler Bar Stresses from Vertical Load

Beam
## Laboratory Test Results

### Table 1: Summary of Laboratory Test Results

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Max. Front Face Joint Crack (in)</th>
<th>Max. Rear Face Joint Crack (in)</th>
<th>Max Coupler Stress (ksi)</th>
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<tr>
<td>Cast-In-Place</td>
<td>0.001</td>
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<td>GRBC – Phase I</td>
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<tr>
<td>GRBC – Phase II</td>
<td>0.020</td>
<td>0.348</td>
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<td>PC – Phase I</td>
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<tr>
<td>PC – Phase II</td>
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<tr>
<td>UHPC-Joint</td>
<td>0.018</td>
<td>0.032</td>
<td>48.1</td>
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Recommended Future Work

Figure 54: Proposed revision to UHPC-Joint Connection Detail
Recommended Future Work

- Add confinement reinforcement surrounding the CMP’s
- Spiral reinforcing cage in lieu of H-pile sections

Figure 55: Proposed spiral reinforcing cages for Pile Coupler
Recommended Future Work

- GRBC grout sleeve size variation
  - Dayton Superior allows for variance of 2 bar sizes between reinforcing bar and grout sleeve (i.e. #8 bar with #10 sleeve)
- Cyclic loading of connection details
- Field monitoring of real-world applications of the connection details
- Finite element simulations of connection details for laboratory testing and field monitoring
Research Implementation
Implementation of Details

• UHPC-Joint Connection Detail to be used by IowaDOT – design phase currently
• Grouted Couplers have been used on numerous pier-pier cap connections
Thank You

Questions and Discussions