Alternative ABC Connections Using UHPC

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Major Categories of UHPC Investigations

1- UHPC based connections to connect prefabricated elements
2- UHPC based solutions for repairing and upgrading bridge columns
3- UHPC based solutions for repairing and upgrading beams and deck
4- ABC made conventional
Major Categories of UHPC Investigations

UHPC Based Technologies for Upgrading and Retrofitting Existing Bridges- Columns
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UHPC Based Technologies for Upgrading and Retrofitting Existing Bridges - Columns
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UHPC Based Technologies for Upgrading and Retrofitting Existing Bridges - Columns

Amir Sadeghjejad  Ph.D Candidate
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Major Categories of UHPC Investigations

UHPC Based Technologies for Upgrading and Retrofitting Existing Bridges - Beams and deck
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UHPC Based Technologies for Upgrading and Retrofitting Existing Bridges- Beams and deck
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UHPC Based Technologies for Upgrading and Retrofitting Existing Bridges- Beams and deck

Alireza Valikhani
Ph.D Candidate
ABC Made Conventional Through UHPC Shell
This major research activity involves cluster of research studies consisting of constructing outside profile of every member of the bridge, using UHPC, transporting them to final bridge site, connecting them together and filling them with concrete
PIER BENT BASE
Investigation includes

Beams
Columns
Foundation
Connections
Seismic and Non-seismic
Advantages

1- Eliminates the need for form work
2- Eliminates the need for removal of formwork
3- UHPC protects the concrete inside- Maintenance free
4- Light weight concrete could be used to fill the cavity
5- Use of light weight concrete reduces foundation sizes
6- It increases the member capacity using same dimension
7- Allows using smaller cross section
8- Reinforcement could be incorporated into the shell, reducing field operations
9- Uses conventional methods of construction
ABC Made Conventional

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UHPC Based ABC Connections for connecting precast columns to precast cap beam

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Problem Statement

Currently all ABC Connections used in practice, to connect cap beam, to columns, uses types of connections where steel reinforcement penetrates into the cap beam, creating a very congested and challenging detailing Requirements within the cap beam.
Background - Common Connections

Bar Couplers

- Grout Bed
- Bar Coupler
- Threaded sleeve
- Headed bars with mating sleeves
- External clamping screws
- Grouted splice sleeve
Background Common Connections

Grouted Ducts

Pics Ref: NCHRP report 681
Background Common Connections
Pocket Connections

Pics Ref: NCHRP report 681
Proposed Connection Detail

Prefabricate Element

Splice Region

Prefabricate Column

UHPC

Detail 1
Proposed Connection Detail

Cap Beam

Splice Region

Prefabricate Column

UHPC

Detail 2
Proposed Connection Details

Detail 1

- UHPC
- Splice region using UHPC
- Plastic Hinge (NC)
- Column

Detail 2

- UHPC
- Splice region using UHPC
- Column

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Advantages

✓ Large Tolerances

✓ Developing the reinforcement over short length

Splice region using UHPC
Advantages

✓ Eliminating the potential interferences with reinforcement in the cap beam
✓ Eliminating need for stirrups
Overview of Experimental Investigation

Feasibility study – Large scale column test
20 by 20 inch square cross section

First test series– Four circular columns
12 inch in diameter

Second test series– Six circular columns
12 inch in diameter
Feasibility Study – Tested a large scale specimen

- Cap Beam (Normal Strength Concrete)
- Plastic Hinge (Normal Strength Concrete)
- Splice region using UHPC
- Column
- UHPC
Construction of the Specimen Segment Representing Prefabricated segment
Construction of the Specimen

Connecting precast column to precast cap beam
Construction of the Specimen - Completed

- Regular Concrete (Support)
- UHPC (Connection)
- Regular Concrete (Plastic Hinge)
- Regular Concrete (Column)
Test Setup and Testing procedures
Loading and Supports (Axial Load=200 Kip (10% Pu)
Specimen at test conclusion

$5 \Delta y$

Column (R.C)
Splice Region UHPC
Plastic Hinge (R.C)
UHPC
Cap Beam (R.C)
Specimen at test conclusion

Bottom

Top
Results - Moment-Displacement

Push Down

Push Up

Push Down

Push Up
Results of Numerical Analysis
Results of Numerical Analysis
Yielding and Crack Formation
Results of Numerical Analysis
Moment-Displacement
Second test specimens series (total of 4)
Dimension (Parametric Study)

Detail 1

Detail 2
Details of the Specimens

- Longitudinal Rebar Size: #5
- Transverse Rebar Size: #3
- Rebar Cover: 1.5 in.

- Reinforcement Ratio: 2.1%
- Column Length/Diameter: 5
Second test series – Two details tested
Construction of second test specimen series

During casting of second test specimen series, because of using more superplasticizers than needed, steel fibers in the UHPC regions did not achieve uniform distribution. However, as it will be discussed, the test outcome was not significantly affected. Also because of the shifting the rebar cage, concrete cover was not the same for all side of the specimens and some of them were not perfectly symmetric.
Test Setup and Testing Procedures
Constant axial load and cyclic lateral loads

Axial Load

Lateral Load

Loading Protocol

- Displacement Ductility Level (μ)
- Displacement Cycles

0 5 10 15
Specimen 1
Stirrups spacing in plastic region 2.5 inches
Stirrups spacing in splice region 2.5 inches
Axial load level - 10% (56 Kips)
Specimen 1
Stirrups spacing in plastic region 2.5 inches
Stirrups spacing in splice region 2.5 inches
Axial load level- 10% (56 Kips)

<table>
<thead>
<tr>
<th>Specimen ID</th>
<th>Maximum drift</th>
<th>Displacement ductility</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-2.5-2.5-10</td>
<td>8.5 %</td>
<td>7</td>
</tr>
</tbody>
</table>
Specimen 2
Stirrups spacing in plastic region 4 inches
No stirrups spacing in splice region
Axial load level- 10% (56 Kips)
Specimen 2
Stirrups spacing in plastic region 4 inches
No stirrups spacing in splice region
Axial load level- 10% (56 Kips)

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>S-4-0-10</td>
<td>5.3 %</td>
<td>5</td>
</tr>
</tbody>
</table>

![Graph showing moment-displacement relationship for Specimen 2]
Specimen 3
Stirrups spacing in plastic region 2.5 inches
Stirrups spacing in splice region 4 inches
Axial load level - 20% (112 Kips)
Specimen 3
Stirrups spacing in plastic region 2.5 inches
Stirrups spacing in splice region 4 inches
Axial load level- 20% (112 Kips)
Specimen 4
Stirrups spacing in plastic region 2.5 inches
No stirrups spacing in splice region
Axial load level- 10% (56 Kips)
Specimen 4
Stirrups spacing in plastic region 2.5 inches
No stirrups spacing in splice region
Axial load level- 10% (56 Kips)

<table>
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<tr>
<th>Specimen ID</th>
<th>Maximum drift</th>
<th>Displacement ductility</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS-2.5-0-10</td>
<td>6.5%</td>
<td>5</td>
</tr>
</tbody>
</table>
Results

Specimen 1

Specimen 2

Specimen 3

Specimen 4
Numerical Analysis

a) S-2.5-2.5-10

b) S-4-0-10

c) S-2.5-4-20

d) NS-2.5-0-10
Conclusion

• Both Details 1 and 2 demonstrated ductile behavior and plastic hinge formed at the desired locations
• Both details could be used in seismic regions
• Detail 1 allows to precisely define the location of plastic hinge in the seismic application
Tests Specimens Ready for Testing (6 more Specimens)

2 Reference specimens + 4 Detail 2 Specimens
Rebar Size #5 & #6
Splice length: 8 $d_b$ & 12 $d_b$  
Rebar Cover $\approx 2$ $d_b$
Tests Specimens Ready for Testing (6 more Specimens)

No stirrup at splice region
Stirrups space in the column: 2.5 in.
Tests Specimens Ready for Testing (6 more Specimens)

No stirrup at splice region
Stirrups space in the column: 2.5 in.
Specimens Ready for Testing (6 More Specimens)
- Major research studies are being conducted to develop UHPC based solution to facilitate use of ABC

- ABC made conventional is an overarching cluster of research studies that allows contractors to use conventional construction techniques and reduce onsite construction activities

- We are interested in working with contractors who are interested in “ABC Made Conventional” products and technologies. Please contact us as aazizina@fiu.edu
Summary

- This presentation focused on a new approach to connect precast cap beams to precast columns.
- Two details were shown. Both could be used in seismic regions.
- Detail 2 is the most economical.
- The complete design provisions for detail 1 and 2 is expected to become available by Dec 2018.
Summary

Please send an email to aazizina@fiu.edu if you need more information or would like to collaborate with us.