WSDOT Highways For Life Project

“Fully Precast Bridge Bents for Use in Seismic Regions”

Bijan Khaleghii
Bridge Substructure Seismic Design:

Max. moments occur at beam-column intersections

- Connections need to:
  - Constructible.
  - Adequate seismic performance.
Earthquake-resisting Systems (ERS) Requirements For SDCs C AND D

The LRFD Seismic Guide Specifications allow three global seismic design strategies:

- **Type 1**—Design a ductile substructure with an essentially elastic superstructure
- **Type 2**—Design an essentially elastic substructure with a ductile superstructure
- **Type 3**—Design an elastic superstructure and substructure with a fusing mechanism
Ductility Limit and Requirements

[Diagram showing the relationship between force and displacement, with critical bridge, essential bridge, and ordinary bridge categories defined by specific displacement limits.]
Capacity-Protected Members

ED – Energy Dissipating
CP – Capacity Protected
Local Member Ductility Demand

- Concrete Modeling – Stress-strain model for confined and unconfined concrete model (Mander’s model is commonly used)

<table>
<thead>
<tr>
<th>Substructure</th>
<th>Member Ductility Demand, $\mu_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Column Bents</td>
<td>$\mu_D \leq 5$</td>
</tr>
<tr>
<td>Multiple Column Bents</td>
<td>$\mu_D \leq 6$</td>
</tr>
<tr>
<td>Pier Walls in Weak Direction</td>
<td>$\mu_D \leq 5$</td>
</tr>
<tr>
<td>Pier Walls in Strong Direction</td>
<td>$\mu_D \leq 1$</td>
</tr>
</tbody>
</table>

\[
\mu_D = 1 + \frac{\Delta_{pl}}{\Delta_{yi}}
\]
Column Failure - Lack of Ductility & Confinement
Grouted Duct – Large-Bar Connection

Seismic Performance of Connection with Concentrated Deformations

Emulates CIP connection
Grouted Duct – Large-Bar Connection

WARD 648.2 Rapidly Constructible Large-Bar Precast Bridge-Bent Seismic Connection
Grouted Duct – Large-Bar Connection

Bar Size - Duct Size - Embedment Length

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Nominal Duct Size, in.</th>
<th>Embedment Length, in.</th>
<th>Embedment / Bar Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>2</td>
<td>12</td>
<td>29</td>
</tr>
<tr>
<td>#4</td>
<td>2.5</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td>#5</td>
<td>3</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>#6</td>
<td>3</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>#7</td>
<td>3</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>#8</td>
<td>3.5</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>#9</td>
<td>3.5</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>#10</td>
<td>3.5</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>#11</td>
<td>4</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>#14</td>
<td>4</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>#18</td>
<td>4.5</td>
<td>40</td>
<td>16</td>
</tr>
</tbody>
</table>
Column-Cap Beam Connection – Seismic test

WARD 648.2 Rapidly Constructible Large-Bar Precast Bridge-Bent Seismic Connection
Column-Cap Beam Connection – Seismic test

Cap beam (upside down)
Precast Bent cap
SR 202 / SR 520

Tolerances - Tack Weld

Duct Template

Spirals
Precast Bent cap
SR 202 / SR 520

$1^{1/2}$ Hours +/-
Bent Cap Erection
WSDOT Research Project: FHWA – HFL
2-span Precast Prestressed Girder Bridge
I-5 Grand Mount to Maytown I/C

I-5, Grand Mound Interchange

New Bridge over I-5

New US 12 Bridge over Railroad

Loop ramps to be closed

Change in US 12 alignment will allow new bridges to be built “off-line”
Shortens construction phase from 20 months to 14 months
Fully Precast Bridge For Seismic Regions
Superstructure-Bent cap and Columns
WSDOT Research Project: FHWA – HFL
Fully Precast Bridge For Seismic Regions
Precast Segmental Columns
Precast Column-to-Footing Connection Seismic Test

- Column-to-footing connection:
  - A precast column embedded in a cast-in-place foundation

- Two 42 %-scale specimens constructed:
  - Specimen A: “Full Guide Spec”
  - Specimen B: Less conservative
1. Pure axial load

2. Axial load plus horizontal load:
   - Constant un-factored dead load
   - Cyclic horizontal displacement.

3. Pure axial load to failure
   - Determine punching capacity
Precast Column-to-Footing Connection
Saw Teeth

Lateral load:
Potential prying failure

Spread Footing Test
Precast Column-to-Footing Connection
Saw Teeth

Lateral load:
Potential prying failure

Spread Footing Test
Precast Column Reinforcement and Placement

TEST SPECIMEN
Precast Column Placement and Grouting

TEST SPECIMEN
Precast Column-to-Footing Connection Seismic Test

Vertical (gravity) load.

Lateral (seismic) load.
Precast Column-to-Footing Connection Seismic Test

Column Splice – During Seismic Test- Only hairline cracks.
Precast Column-to-Footing Connection Seismic Test

Spread Footing Connection – Gravity Load Test

No damage to footing. No sign of punching failure.
Additional Tests: Thinner Footing

- Footing thickness < column diameter.
- Investigate strength and failure mode if footing fails.
- Expected failure mode:
  - Punching shear + moment transfer

Precast Column-to-Footing Connection
Seismic Test
Precast Column-to-Footing Connection Seismic Test

Additional Tests: Drilled Shaft Connection

- P.C column embedded in drilled shaft.
- Investigate potential for failure in transition region

1. Specimen A: per WSDOT BDM and AASHTO Seismic Guide Spec
2. Specimen B: Less conservative design of transition region
Precast Column-to-Footing Connection Seismic Test

- Precast column-Oversized Shaft Connection Test
- Used for conventional, CIP drilled shaft/column systems.
HFL Project: - Precast Column Placement
HFL Project: Precast Column Erection
HFL Project: Precast Columns
HFL Project: Precast Bent Cap
HFL Project: Precast Bent Cap
CITY OF REDMOND
NORTH 36TH STREET BRIDGE

Precast Column
WSDOT ABC Project:
I-5 / SR 16 EB Nalley Valley Bridge Replacement
WSDOT ABC Projects:
I-5 / SR 16 EB Nalley Valley Bridge Replacement

I included this to show what the rest of the piers look like and the size of the other pieces relative to piers 5 and 7.

The crossbeams are not drawn correctly. The columns are.

All 6 columns are constructed of four different pieces, making for excellent repeatability and ease.

All pieces are either exactly the same, or different in length only.

Connection details are coordinated to be much the same everywhere, and the pieces are lighter.
WSDOT Website for ABC

Thank You

Questions?