A precast Concrete Bridge Bent for Seismic Regions: Achieving both Performance and Constructability

John Stanton
Marc Eberhard

University of Washington

PCI Fall Convention
15 Sept 2009, San Antonio, TX.
Acknowledgments

- FHWA
- WSDOT
- PEER / State of California
- TransNOW
Accelerated Bridge Construction

Goals:
- Reduce traffic delays, and associated costs.
- Reduce fuel wastage.
- Increase worker safety.

Potential difficulties:
- Constructability.
- Seismic performance.
- Cost.
Solution: Precast Concrete

- Precast concrete offers the opportunity to:
  - Shorten time for site operations.
  - Improve quality of components.
  - Increase worker safety.
  - Reduce environmental hazards.

- Use of precast concrete:
  - The material of choice for girders.
  - Opportunities for use in bridge bents.
Constructability vs. Performance

- Linear elements are the easiest to handle and transport.
- Connections occur at the intersections of members.
  - Moments are highest there.
  - Inelastic deformations expected.
Seismic Performance

Maximum moments occur at beam-column intersections.
Constructability vs. Performance

Connections need to:
- be readily constructible.
- have good seismic performance.
Precast Concrete Connections using Bars Grouted into Sleeves.
“Many Ducts” Connection

Emulates typical c.i.p. connection.

Tight tolerance requirements.

Courtesy: BERGER/ABAM Engineers
“Large-Bar” Connection

- **Concept**
  - Larger bars (e.g., #18)
  - Fewer bars (e.g., 6-8)
  - Much larger ducts (e.g., 8-in. dia.)

- **Constructability**
  - More generous tolerances
  - Easier fabrication
  - Faster alignment
“Large-Bar” Connection

- Suitable for beam-column connection.
- Can be used with single-piece or segmental columns.
- Column configuration depends on circumstances:
  - Column weight (crane size).
  - Column height (stability during erection).
  - etc.
Large-Bar Connection

- 4ft Diameter Column
- 5ft x 3.5ft Cap Beam
- 6 # 18 rebar
- 8.5” Corrugated Metal Ducts
- 12 # 9 rebar
- High Strength Grout
- Debond Intentionally?
Seismic Performance
Anchorage of #18 Bars
Full-Scale Anchorage Tests

Corrugated duct
Anchorage Test Results.

- #8, #10, #14, #18 bars.
- Behavior determined by $L_e/d_b$.
  - Low $L_e/d_b$: bond failure.
  - High $L_e/d_b$: bar yield and fracture.
Full-Scale Anchorage Tests

Low $L_e/d_b$ (pullout)

High $L_e/d_b$ (fracture)
Full-Scale Anchorage Tests
Full-Scale Anchorage Tests

Graph showing the relationship between bar nominal stress (in ksi) and le/db with different markers for fibers, no fibers, surface, and scaled conditions. Points are labeled with codes such as 18N14, 18N08, 10N06, etc.
Anchorage Test Results.

- For $f_y$, need $L_e/d_b \geq 6$
- Bond failure at the bar surface: “confined bond failure”.
- Bond stress $= 0.25f_s/(L_e/d_b) = 2500$ psi $= 27\sqrt{f'_g} = 0.31f'_g$.
- Consistent with previous research on smaller bars. (e.g. Raynor, Moustafa).
Seismic Performance of Connection with Concentrated Deformations

Debond Intentionally to reduce strain concentration?
Seismic Performance

- Lab tests at 42% scale.
<table>
<thead>
<tr>
<th>Test Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>REF.</td>
</tr>
<tr>
<td>LB-FB</td>
</tr>
<tr>
<td>LB-D1</td>
</tr>
<tr>
<td>LB-D2</td>
</tr>
</tbody>
</table>
Equivalent Moment vs. Drift

- **LB-FB**
- **LB-D1**
- **LB-D2**
- **REF**
Failure Mechanisms

LB-FB: Bar buckling and spiral fracture at 6.5% drift
Implementation
Highways for Life Program: Team Membership.

- FHWA
- BERGER-ABAM
- University of Washington
- WSDOT
- Tri-State Construction
- Concrete Technology Corporation
Highways for Life Program: Tasks.

- Develop suitable connections (Column to cap-beam and footing)
- Lab tests for seismic performance.
- Build the bridge, monitor constructability:
  - Fabricate columns.
  - Erect bents (note skew).
- Develop specification language.
- Prepare design examples.
The Bridge
(SR12 Over I-5)
Connections to be used

- Top: 8#18 in 48” square column.
- Bottom: Still under development. Watch this space!
- Possible footing connections:
Project-Specific Tests

- **PS-1**: PC column grouted over bars in CIP spread footing

- **PS-2**: Spread footing cast around bars projecting from segmental column.
Increased Versatility

- AD-1a & 1b: Hollow Columns
- AD-2: Connection to Drilled Shaft
Conclusions

- Large-Bar precast systems can be constructed rapidly.
- Many possible variants for footing connection.
- Seismic performance similar to c.i.p.