PCMAC Workshop
Sacramento, California
November, 2011

Disclaimer: The opinions presented here are those of the presenter and do not necessarily reflect Caltrans’ official policy.
<table>
<thead>
<tr>
<th></th>
<th>Next Generation Bridge</th>
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Caltrans Research
Seismic Connections in Prefabricated Substructures
Next Generation Bridges

Initial Focus: Precast elements - *columns*

Plastic Hinge Zone
NOTES:
1. Match mark main PC column Rebar and
   Main Column Reinforcement in footing.
2. Rebar size required for placement of
   Main Column Reinforcement in footing.
3. Field fabricate Column Reinforcement as required.
4. Roughen surface to 1/4" amplitude during casting.
5. All hoops are "Ultimate" bolt splice continuity.
6. Plumb and support PC Columns and provide grout weep.

LEGEND:
- Deformed Reinforcement (Rebar) with SCC in column void.
- Deformed Hoop Injection.

SECTION A-A

STAGE 1
ELEVATION - PRECAST COLUMN PLACEMENT

STAGE 2
ELEVATION - COLUMN BASE CONNECTION

STAGE 3
ELEVATION - COLUMN BASE POUR

NOTE:
THE CONTRACTOR SHALL VERIFY ALL
CONTROLLING FIELD DIMENSIONS
BEFORE CASTING OR FABRICATING
ANY MATERIAL.
NOTES:
1. Paint work on main PC column rebar and
   Main Column Reinforcement in footing.
2. Rebar details required for placement of
   Main Column Reinforcement in footing.
3. Field fabricate Column Point Vents as required.
   Test Protocol 1

<table>
<thead>
<tr>
<th>Text Order</th>
<th>Link Type</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>1</td>
<td>A 176 Steel Standard Production</td>
<td>Purpose</td>
</tr>
<tr>
<td>2</td>
<td>NII 285</td>
<td>Failure Use</td>
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</tbody>
</table>

4. Roughen surface to 1/2" amplitude during casting.
5. All hoops are "ULTIMATE" butt spiles continuous.
6. Hrds and support PC Column and provide great seal.

LEGEND:
- Debeads infill with SCC in column void.
- Debeads grout injection.

SECTION A-A
1" = 1'-0"
Next Generation Bridges
Proposed Construction Concepts

NOTES:
1. Match work main PC column filler and main column reinforcement in footing.
2. Require reinforcement for placement of main column reinforcement in footing.
3. Field fabricate column point links as required.
4. Roughen surface to 1/4" amplitude during casting.
5. All hoops are "Ultimate" butt splice continuous.
6. Punch and support PC columns and provide grout seal.

LEGEND:
- Beaded infill with SCC in column void,
- Debond grout injection,

SECTION A-A
1" = 1'-0"

STAGE 1
ELEVATION - PRECAST COLUMN PLACEMENT
1" = 1'-0"

STAGE 2
ELEVATION - COLUMN BASE CONNECTION
1" = 1'-0"

STAGE 3
ELEVATION - COLUMN BASE POUR
1" = 1'-0"

NOTE:
The contractor shall verify all controlling field dimensions before casting or fabricating any material.
Next Generation Bridges
Alternative Configurations
Next Generation Bridges
Alternative Configurations
Seismic Performance of Precast Column to Foundation Connections for Accelerated Bridge Construction

Zachary B. Haber – PhD Student
M. Saiid Saiidi, PhD, P.E. – Professor
David Sanders, PhD – Professor
Department of Civil and Environmental Engineering
University of Nevada, Reno

Research Sponsor: California Department of Transportation

ACI Fall 2011 Meeting – Research in Progress – October 17th 2011
Objective & Scope

• Develop an Innovative Precast Column Element
  – Emulative Design, Light weight, Moment connections using mechanical bar couplers

• 5 Half-scale Column Models Designed/Constructed
  – 1 Conventional Column Model
  – 4 Precast Models
Half-scale Column Models

- Caltrans Seismic Design Criteria (Disp. Ductility ≥ 5)
- Design Details
  - 9ft Tall & 2ft Diameter
  - 11 #8 Longitudinal Steel (1.9%)
  - #3 Spiral @ 2in Pitch
  - Axial Load = 226kip (0.1f’c Ag)
- Precast Hollow Shell Design
- Use of Partial Pedestal
Connection Details – HC Models

- Footing
- Connection
- Dowels
- Grout Layer
- Closure Form
Connection Details – GC Models

Connection
Dowels

Footing
Experimental Testing

Drift (%)

Cycle

0  5  10  15  20  25

0  2  4  6  8  10  12  14

-2  -4  -6  -8  -10  -12  -14
Observations – Accumulated Damage at Failure

CIP (2nd Cycle -10% Drift)  
HCNP (2nd Cycle -10% Drift)  
HCPP (1st Cycle -10% Drift)
Observations – Accumulated Damage at Failure

GCNP
(2\textsuperscript{nd} Cycle -6\% Drift)

GCPP
(1\textsuperscript{st} Cycle -6\% Drift)
Next Generation Bridges

Alternative Configurations
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Caltrans Research  
Seismic Connections in Prefabricated Substructures
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Caltrans Research
Seismic Connections in Prefabricated Substructures
Concurrent Research

University of Washington
CFT connection tests
Rapid Construction of Bridge Piers with Concrete Filled Tubes

Dawn Lehman and Charles Roeder
University of Washington
## Collaborative Research Program

<table>
<thead>
<tr>
<th>COMPONENT TESTS</th>
<th>COLUMN FOUNDATION</th>
<th>DESIGN MODELS</th>
<th>COLUMN CAP BEAM</th>
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<tbody>
<tr>
<td>Engineering Properties</td>
<td>Embedment</td>
<td>Flexural Strength</td>
<td>Future Work: Connection Type</td>
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<tr>
<td>Influence of Bond</td>
<td>Connection Type</td>
<td>Slenderness</td>
<td>Geometry</td>
</tr>
<tr>
<td>Impact of Weld Properties</td>
<td>Material Strengths</td>
<td>Stiffness</td>
<td>Embedment</td>
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<tr>
<td>Axial Load</td>
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**ARMY/Caltrans**

**ARMY Caltrans**

**Caltrans WashDOT**

**Proposed Caltrans**
# Test Matrix

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Diameter/Thickness</th>
<th>Type of Connection</th>
<th>Type of Tube Seam</th>
<th>Embedment/Diameter</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>20/0.25</td>
<td>Monolithic</td>
<td>Straight</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>20/0.25</td>
<td>Isolated</td>
<td>Straight</td>
<td>0.78</td>
</tr>
<tr>
<td>3</td>
<td>20/0.25</td>
<td>Isolated</td>
<td>Spiral</td>
<td>0.78</td>
</tr>
<tr>
<td>4</td>
<td>20/0.25</td>
<td>Monolithic</td>
<td>Spiral</td>
<td>0.8</td>
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<tr>
<td>5</td>
<td>20/0.25</td>
<td>Isolated</td>
<td>Spiral</td>
<td>0.7</td>
</tr>
<tr>
<td>6</td>
<td>20/0.25</td>
<td>Isolated</td>
<td>Spiral</td>
<td>0.6</td>
</tr>
<tr>
<td>7</td>
<td>30/0.375</td>
<td>Isolated</td>
<td>Spiral</td>
<td>0.62</td>
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Large-Scale Specimens: Monolithic Connection

20 or 30 in. diameter

0.25 in. thick

72 in. or 109 in.

CFT column

Annular ring at base of tube. Embedded in foundation for anchorage.

Note: Vertical Reinforcement not shown
Design of Isolated Connection

Isolation of Structural and Reinforcing Steel Trades

1. Build foundation cage
2. Install corrugated metal pipe
3. Cast foundation
4. Install and grout tube
5. Cast column
Test Configuration

Test Specimen

Cyclic Lateral Load

Constant axial load (10%P₀)
Behavior if Embedment is Too Small

- Bisecting cracks: 0.75% drift
- Interface gap: 2.5% drift
- Footing uplift: 4% drift
- Final state: 8% drift
Behavior of Specimen with Sufficient Embedment
Finite Element Study

Nonlinear FE Analysis Study to Extend Testing.

• Capable of simulating global response and local deformations.
• Gap elements to model interface and confinement.
• Solid elements for concrete fill. Shell element used to simulate tube.
• Validated using Caltrans and other large-scale test results.

Graph showing base moment vs. drift with curves for different analyses.
Design Methods
Required Embedment Depth

\[ \tau := \frac{r \cdot F_u \cdot t}{\frac{L_e^2}{2} + r_o \cdot L_e} = \frac{D \cdot F_u \cdot t}{L_e^2 + D \cdot r_o \cdot L_e} \]

Footing Damage for \( \tau > 7 \) to \( 8 \sqrt{f_c} \)
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Caltrans Research
Seismic Connections in Prefabricated Substructures
Isolated Precast
Ordinary Standard Bridge Study
Isolated Precast
Ordinary Standard Bridge Study
Isolated Precast
Ordinary Standard Bridge Study
Isolated Precast
Ordinary Standard Bridge Study

UC Berkely
Professor Marios Panagiotou
Isolated Precast
Ordinary Standard Bridge Study
Isolated Precast
Ordinary Standard Bridge Study

LRFD Service Load Considerations
Isolated Precast
Ordinary Standard Bridge Study

LRFD Service Load Considerations
Isolated Precast
Ordinary Standard Bridge Study
“A scientific theory should be as simple as possible, but no simpler.”

A. Einstein
Caltrans Research

[Images of various construction and research materials, including diagrams and field work.]