An Earthquake-resistant Precast Bridge Substructure System Utilizing Socket Connections

Zhao Cheng
Graduate Research Assistant, Iowa State University

Sri Sritharan
Wilkinson Chair Professor, Iowa State University

Jeramy Ashlock
Richard L. Handy Associate Professor, Iowa State University
Precast Bridge Substructure

• Use of precast element is a proven methodology with numerous advantages over traditional CIP bridge construction.

• State DOTs have attempted using precast elements to construct bridge substructure.

U.S. 6 Bridge over Keg Creek  Precast Frame Pier in Georgia
Precast Bridge Substructure

- One challenge is the lack of structurally-sufficient and easy-to-construct connections.
- The formation of plastic hinge at column end make the design of connections in substructure more difficult.
Proposed Precast Bridge Substructure

column socket

pile sockets
Proposed Precast Bridge Substructure

Drive steel H-piles with a template
Proposed Precast Bridge Substructure

Friction collars supporting pile cap
Proposed Precast Bridge Substructure

Plywood sealing the pile sockets
Proposed Precast Bridge Substructure

Place precast pile cap and precast column
Pour grout into column socket and pour SCC into column sockets
Continue superstructure construction after grout reaching specified strength
Proposed Precast Bridge Substructure

Take off the reusable friction collars after SCC reaching specified strength
Proposed Precast Bridge Substructure

Back-fill the trench
Column-to-pile cap Connection Tests

1. Precast pile cap
2. Precast column with roughed surface
3. CSP & grout closure pour

- 1/2 in. fluted fin
- 3/4 in. fluted fin
- Smooth
- Exposed aggregate

Diagram showing the connection tests with labeled components:
- Actuator
- Load cell
- Spacer
- Steel tube
- Column
- Footing
- Base blocks

Department of Civil, Construction, and Environmental Engineering
## Column-to-pile cap Connection Tests

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Column Surface</th>
<th>CSP-to-column Clearance</th>
<th>Loading Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>½” fluted fin</td>
<td>1.5”</td>
<td>monotonic</td>
</tr>
<tr>
<td>2</td>
<td>¾” fluted fin</td>
<td>1.5”</td>
<td>monotonic</td>
</tr>
<tr>
<td>3</td>
<td>exposed aggregate</td>
<td>1.5”</td>
<td>monotonic</td>
</tr>
<tr>
<td>4</td>
<td>¾” fluted fin</td>
<td>3”</td>
<td>monotonic</td>
</tr>
<tr>
<td>5</td>
<td>exposed aggregate</td>
<td>1.5”</td>
<td>cyclic</td>
</tr>
<tr>
<td>6</td>
<td>½” fluted fin</td>
<td>1.5”</td>
<td>cyclic</td>
</tr>
<tr>
<td>7</td>
<td>smooth</td>
<td>1.5”</td>
<td>cyclic</td>
</tr>
<tr>
<td>8</td>
<td>½” fluted fin</td>
<td>3”</td>
<td>cyclic</td>
</tr>
</tbody>
</table>
Column-to-pile cap Connection Tests

All specimens, except the one with smooth column surface, reached the peak strength of more than 75% column axial capacity.
Column-to-pile cap Connection Tests

Impact of column surface roughness

Impact of CSP-to-column clearance

Impact of cyclic loading
### Outdoor System Test

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>test the system at the strength limit states</td>
</tr>
<tr>
<td>Phase II</td>
<td>load the system until forming plastic hinge at column</td>
</tr>
<tr>
<td>Phase III</td>
<td>directly load the pile cap to fully test foundation</td>
</tr>
</tbody>
</table>

![Diagram of the test setup](image-url)
Construction of Test Unit
Construction of Test Unit
Construction of Test Unit
Construction of Reaction System
Summary

• The precast bridge substructure with socket connections provides the potential to significantly reduce the construction time with larger construction tolerances.

• Column socket connection with exposed aggregate on the column surface provides satisfactory strength to sustain vertical loads in routine design practice.

• The ongoing outdoor system test will evaluate the performance of precast substructure system with the effect of soil-structure interaction.
Acknowledgements
Thank You!