RESEARCH PROJECTS AT UNIVERSITY OF NEVADA, RENO

QUARTERLY REPORT

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Submitted by

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RESEARCH PROJECTS:

1- Behavior and Design of Precast Bridge Cap Beams with Pocket Connections

2- Development of Design Guidelines for Bridge Columns with Couplers

3- Columns with Innovative Materials and Post-tensioning Systems
Behavior and Design of Precast Bridge Cap Beams with Pocket Connections

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ABC-UTC Project Website: http://abc-utc.fiu.edu/index.php/research/project/behavior-and-design-of-precast-bridge-cap-beams-with-pocket-connections

Literature Review: 100% Completed

A comprehensive literature search was carried out to investigate seismic performance of columns connected to adjoining members with pocket connections (Fig. 1) and a summary of all published and unpublished test data was presented (Table 1). The as-built embedment length of bars or precast columns into adjoining members, connection performance, cap beam damage, and the measured yielding of cap beam longitudinal bars were presented.

Figure 1. Pocket Connections
Table 1. Summary of Available Test Data on Pocket Connections

<table>
<thead>
<tr>
<th>Used in</th>
<th>Reference</th>
<th>Emb. Length</th>
<th>Connection Performance</th>
<th>Cap Beam Performance</th>
<th>Yielding in Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column to Cap Beam</td>
<td>Matsumoto et al. (2001)</td>
<td>0.5 column diameter</td>
<td>Plastic hinge formed in column, 27% lower drift capacity compared to cast-in-place, plastic hinge formed in column</td>
<td>Minor concrete damage</td>
<td>Not Available</td>
</tr>
<tr>
<td></td>
<td>Restrepo et al. (2011)</td>
<td>1.2 column diameter</td>
<td>Large drift capacity and large displacement ductility were achieved</td>
<td>Minor radial splitting cracks</td>
<td>Yes, 2.7 times the bar yielding</td>
</tr>
<tr>
<td></td>
<td>Mehrsoroush and Saiidi (2014)</td>
<td>1.2 column diameter</td>
<td>Large drift capacity and large displacement ductility were achieved</td>
<td>No damage of post-tensioned cap beam</td>
<td>No, 40% of the yield strain</td>
</tr>
<tr>
<td></td>
<td>Mehrraein and Saiidi (2014)</td>
<td>1.0 column diameter</td>
<td></td>
<td>Minor damage up 72% of the design level earthquake</td>
<td>No, 70% of the yield strain</td>
</tr>
<tr>
<td>Column to Footing</td>
<td>Motaref et al. (2011)</td>
<td>1.5 column diameter</td>
<td>Large displacement capacity, no connection damage</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td></td>
<td>Haraldsson et al. (2012)</td>
<td>1.1 column diameter</td>
<td>Similar to cast-in-place, plastic hinge formed in column</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td></td>
<td>Kavianipour and Saiidi (2013)</td>
<td>1.5 column diameter</td>
<td>Minimal spalling of concrete in footing</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Pile to Cap Beam</td>
<td>Larosche et al. (2014a)</td>
<td>1.3 column diameter</td>
<td>No damage of pile cap was reported</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td></td>
<td>Cukrov and Sanders, 2012</td>
<td>1.2 column diameter</td>
<td>Plastic hinge formed in piles</td>
<td>no apparent damage of cap</td>
<td>Not Applicable</td>
</tr>
</tbody>
</table>

(a) This was not a “column”. It was a RC stub with 4 bars extended to the cap. Was not subjected to cyclic loads that represent earthquakes.

**Seismic performance and Behavior of Cap Beam Pocket Connections:**

100% completed

Effects of pocket connections were studied in this task using moment-curvature and pushover analyses. First, a full-scale two-column bent was designed based on AASHTO then effects of the pocket were studied on the overall and local behavior of the bent. Second, the cap beam test models from the available literature were evaluated and reasons for meeting or violating the capacity protected limitation were presented.

It was shown through extensive analytical analyses that effects of pocket on the seismic performance of cap beam are negligible for a well-design cap even under the worst-case scenario in which pocket concrete was excluded from cap beam section resulting in an inverted U-shape section. Moment-curvature analyses of the test models with pocket connections revealed that
cap beams will remain elastic if these elements are designed adequately. Fig. 2 shows one sample of the analysis result presented in this task.

![Figure 2. Moment-Curvature Relationships for Bent Tested by Mehraein and Saiidi (2014)](image)

In seismic zones, cap beam must be designed using a legal code such as AASHTO LRFD or AASHTO Guide Specification to determine the controlling design moment. Moment-curvature analyses are recommended to provide insight into the effect of strain hardening and estimate the demand on cap beams realistically.

**Constructability of pocket connections:** 100% Completed

Five practical detailing for cap beam pocket connections were proposed in this chapter (Fig. 3). Constructability of these detailing was discussed and it was mentioned that the size of cap beam incorporating pocket connections will remain the same as conventional cast-in-place cap beam sizes. Material to fill the pockets, constructional tolerance, need for shoring and formwork, and speed of construction were discussed for each alternative. It was found that the best alternative is Alt-5 in which the construction time is only 25% of that of the cast-in-place
bent mainly because there is no need for shoring. In Alt-5, a precast column extends into the pocket and the gap between the steel pipe and the column is filled with fluid grout.

Figure 3. Different Detailing for Pocket Connections
AASHTO Seismic Guide Specification (2014) provides a comprehensive design method and thorough detailing for capacity protected members such as cap beams and joints (Sections 8.9 to 8.13). Furthermore, Restrepo et al. (2011) proposed design and construction guidelines in NCHRP 681 for precast cap beams with pockets to facilitate field deployment. This part of the current project was dedicated to development of design guidelines for cap beam pocket connections reflecting new detailing and experimental findings reported in recent studies. Both the Seismic Guide Specifications and NCHRP 681 were incorporated in the proposed guidelines, which include recommendations and commentary. The proposed pocket connection guidelines address design and construction considerations and will facilitate field deployment of this viable ABC connection.

Design examples are being developed to demonstrate the application of the guidelines.