Seismic Performance of Next Generation Bridge Components for Accelerated Bridge Construction (ABC)

TEST MODEL: Grouted Coupler No Pedestal (GCNP)

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Brief Project Description:

The use of prefabricated structural elements is an integral part of many accelerated bridge construction (ABC) efforts. The connection of these prefabricated elements to the rest of the structural system is critical to the performance of the structure under service loads and extreme events. This project investigates the seismic response of rigid connections between precast columns and footing. Five half-scale column models will be tested by reversed cyclic loading. The baseline model used in this study is a conventional cast-in-place reinforced concrete column; this model is denoted in this study as “CIP”. Caltrans Seismic Design Criteria (SDC) was used to determine internal reinforcing steel to achieve a displacement ductility of 5. Furthermore, all detailing used in the CIP model adhered to Caltrans specifications. The four other column models to be tested in this study are composed of hollow precast concrete shells that are rigidly connected to the footing using mechanical rebar couplers located within the plastic hinge zone. After the rigid connection is made, the hollow shells are filled with self consolidating concrete (SCC). Two different mechanical couplers were selected for testing based on an extensive review of available literature. Coupler selection criteria included: mechanical performance under static and dynamic loading, Caltrans pre-qualification, and applicability to rapid construction. The two coupler types selected were the HRC 500 series upset headed coupler and the NMB grout sleeve coupler. Two models incorporate partial pedestals in order to reduced demand on the coupler region. The data compiled will be compared with the performance of the columns with that of similar cast-in-place construction and any necessary refinements will be identified based on the data and analyses. The ultimate objective is to make recommendations to Caltrans regarding precast column connection details, design methodology, and construction techniques.

<table>
<thead>
<tr>
<th>Test Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model ID</strong></td>
</tr>
<tr>
<td>CIP</td>
</tr>
<tr>
<td>HCNP</td>
</tr>
<tr>
<td>HCPP</td>
</tr>
<tr>
<td>GCNP</td>
</tr>
<tr>
<td>GCPP</td>
</tr>
</tbody>
</table>
Column Model Details:

<table>
<thead>
<tr>
<th>Height in (mm)</th>
<th>Diameter in (mm)</th>
<th>Longitudinal Steel Ratio [%]</th>
<th>Transverse Steel Ratio [%]</th>
<th>Aspect Ratio</th>
<th>Axial Load kip (kN)</th>
<th>Axial Load Index [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>108 (2743)</td>
<td>24 (610)</td>
<td>1.92</td>
<td>1.05</td>
<td>4.5</td>
<td>203 (903)</td>
<td>10</td>
</tr>
</tbody>
</table>

Concrete & Grout Properties

<table>
<thead>
<tr>
<th>Component</th>
<th>7 – Day Strength psi (MPa)</th>
<th>28 – Day Strength psi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Footing</strong> (Conventional Concrete)</td>
<td>3350 (23.1)</td>
<td>4695 (32.3)</td>
</tr>
<tr>
<td><strong>Column Shell</strong> (Conventional Concrete)</td>
<td>2974 (20.5)</td>
<td>3826 (26.4)</td>
</tr>
<tr>
<td><strong>Column Core</strong> (SCC)</td>
<td>3612 (24.9)</td>
<td>4303 (29.6)</td>
</tr>
<tr>
<td><strong>NMB Coupler Grout</strong> (SS Mortar)</td>
<td>12,837 (88.4)</td>
<td>15,638 (107.7)</td>
</tr>
</tbody>
</table>

Steel Properties

<table>
<thead>
<tr>
<th>Expected Properties</th>
<th>$f_y$ psi (MPa)</th>
<th>$f_u$ psi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse Bars: #3</td>
<td>68,000 (468)</td>
<td>95,000 (655)</td>
</tr>
<tr>
<td>Longitudinal Bars: #8</td>
<td>68,000 (468)</td>
<td>95,000 (655)</td>
</tr>
</tbody>
</table>
Loading Protocol: Drift vs. Cycle
Calculated Pushover Curve

![Graph showing calculated pushover curve with load (kip) on the y-axis and displacement (in) on the x-axis. The graph compares CIP Test Result and GCNP Calculated Result.](image-url)
Model Reinforcement Details

- **Loading Direction**
  - W (West) to E (East)
  - 3'-9" Overall Length
  - 1'-3" Diameter
  - 2'-8 1/8" Depth
  - 5'-10" Width

- **Section A-A**
  - #3 Spiral
  - 2" Pitch
  - 11 - #8 bars

- **Section B-B**
  - NMB Coupler Sleeve
  - 1'-2" Diameter
  - 1 3/4" Length
  - 2'-2 3/4" Depth
Instrumentation: Strain Gages

Cross-section Orientation

Section 1-1
SG13 / SG20
SG12 / SG19
SG11 / SG18

Section 2-2
SG8
SG7
SG6
SG5
SG1
SG2
SG3

Section 3-3
SG14 / SG21
SG15 / SG22
SG16 / SG23
SG17 / SG24

Section 4-4
SG10 / SG22
SG16 / SG23
SG17 / SG24

Section 5-5
SG40
SG39
SG38
SG41
SG42
SG43
SG45
SG44
SG46

Loading Direction
W  E

1" - 3"  1" - 3"  1" - 3"  1" - 3"

Coupler mid-section
**Instrumentation:** Displacement and Rotation

**Loading Direction:**

- W → E

**String POTs All Corners**

- D01 - D04

**Section A-A**

**Coupler Location**

- BS01
- BS02
- C01
- C02
- C03
- C04
- C05
- C06
- C07
- C08

- 1"
- 7"
Test Set-up

WEST ↔ EAST

MTS - 220 kip Actuator

Hollow-core Jacks

Steel Bearing Plate

High Strength Threaded Rods

Axial Load Spreader Beam

Grout Pad

Strong Floor