Providing a Safer Transportation System Through Earthquake Engineering Research

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Overview

• Brief History

• Focus for the Future
The Challenge

Significant California Earthquakes

- 1971  San Fernando
- 1987  Whittier
- 1989  Loma Prieta
- 1994  Northridge
1989 LOMA PRIETA
1994 NORTHRIDGE
Seismic Research - Focus for the Future

- Research must focus on solving problems that designers face in their work.
Recent Seismic Research Problem Statements

- Assessing Live Load Capacity After a Major Event
- Response of Highly-Skewed Structures
- Low Cycle Fatigue of Large Diameter Rebar and Couplers
- Plastic Hinge Ductility of Single Columns Subjected to Torsional Loading
- Evaluation of Accessible Hinge Details
Problem Focused Research
Problem Focused Research

Typical Cross Section – Main Tower

- Tower Legs
- Steel Link Beams

Tower Cross
Tower Strut
“W” Line
“E” Line
Tower Skirt
Tower Anchorage
Top of Footing — Elev 3.000 m

Elev 160.000 m
9000 — Tower Head
3500 — Tower Saddle
4500
6 @ 4000 = 24000
3 @ 10000 = 30000
3 @ 12000 = 36000
7 @ 5000 = 35000
5000
10000 — Tower Base
Tower Shear Link Tests
Seismic Research – Focus for the Future

- Continued Focus on Performance of Retrofit Strategies (old and new)
- Focus on Proof-Testing Special Designs
- Focus on Application to Other Extreme Events
- Improving Understanding of Structure and Member Performance by Designers
- Improving Understanding of Ground Motions and other “input motions” or “demands”
Seismic Research – Focus for the Future

- Implementable results (solve a problem)
- Eliminate ultra-conservatism (reduce costs)
- Reduce design/analysis time
- Articulate the application to other extreme events

- Emphasize the need to continue to work toward a safer transportation system.
Providing a Safer Transportation System Through Earthquake Engineering Research

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1994 Northridge Earthquake

Summary of PEQIT Findings:
- Column flares did not perform as modeled
Flared Column Details

Table 1

<table>
<thead>
<tr>
<th>COLUMN DIAMETER</th>
<th>UPPER FLARE REINFORCEMENT</th>
<th>LOWER FLARE REINFORCEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Top 1/3 FLARE HEIGHT)</td>
<td>(Lower 2/3 FLARE HEIGHT)</td>
</tr>
<tr>
<td>1.22</td>
<td>19 @ 100</td>
<td>13 @ 200</td>
</tr>
<tr>
<td>1.68</td>
<td>22 @ 100</td>
<td>13 @ 200</td>
</tr>
<tr>
<td>2.13</td>
<td>25 @ 100</td>
<td>16 @ 200</td>
</tr>
</tbody>
</table>

Notes to Designers:
1. The thickness of the flare gap shall be 50 mm. However, if significant relative rotation between the gap and the column is expected, then the required gap thickness to accommodate this rotation should be calculated and provided.

2. The longitudinal flare reinforcement is nominal. The maximum spacing between longitudinal flare reinforcement shall not exceed 450 mm and the spacing shall not be less than 150 mm. (E.g., #19 at a maximum of 450 mm minimum 150)

3. The transverse flare reinforcement ratio in the upper 1/3 of the flare height is 0.452, while that ratio for the lower 2/3 of the flare height is 0.25. See Table 1 for typical transverse reinforcement in the flare region. This reinforcement is in addition to the required plastic core confinement/shear reinforcement. The column flare details have been developed after reviewing the results of laboratory tests.

4. Minimum size bars shall conform to requirements of BS 5402.

5. While laboratory tests were conducted with the transverse flare reinforcement having a lap of approximately 40 times bar diameter, the use of mechanical couplers is recommended (particularly in the upper 1/3 of the flare region). The spacing between the bars is to be equal to 10 times the diameter of the bar. As a column is subjected to axial compression, the reinforcement may not be reliable when flare concrete spalls. To prevent spalling during construction, the location of mechanical couplers shall be staggered.
Flared Column Testing

- Shake table testing for Caltrans details
Shake Table Testing For Flared Columns
Ductile Flared Column Details

- Ductility
- Confinement
- Continuity
- Flare isolation