Seismic Performance of Reinforced Concrete C-bent Columns

Jun 11, 2005

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C-bent Columns

In urban area, there exist a large number of RC columns with the lateral beam being longer in one side than the other.

C-bent columns have a poor seismic performance!
Current Researches on C-bent Columns

- Cyclic loading and shake table tests in transverse direction, Kawashima and Unjoh, 1994.
- Cyclic loading tests in longitudinal direction, Tuchiya and Maekawa et al, 1999.
- Cyclic loading tests in bilateral direction, Kawasima et al, 2002
Objectives

- To clarify seismic response of RC C-bent columns under bilateral excitation, a series of hybrid loading test were conducted.
- To reproduce the experimental response of RC C-bent columns, a fiber element analysis was conducted.
Test Specimens

RC Columns were designed based on the current Seismic design codes.

- Eccentricity, denoted as $e$, refers to the displacement of the column's center of gravity from its geometric center.
- Width of Columns, denoted as $D$.

<table>
<thead>
<tr>
<th>Eccentricity ($e$)</th>
<th>Axial Reinforcements (%)</th>
<th>Tie Reinforcements (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e=0$</td>
<td>1.27</td>
<td>0.79</td>
</tr>
<tr>
<td>$e=0.5D$</td>
<td>1.35</td>
<td>0.99</td>
</tr>
<tr>
<td>$e=D$</td>
<td>1.9</td>
<td>1.19</td>
</tr>
</tbody>
</table>

- Effective Height: 1350 mm
- Square Section: 400 mm x 400 mm
Hybrid Loading Test on C-bent Columns

Input Ground Motion: JMA Kobe Record

Unilateral Excitation

Bilateral Excitation

Longitudinal

Transverse
Damage after the Unilateral Excitation

Damage of columns at the eccentric completion side

The damage increases as the eccentricity increases.
The residual drift increases as the eccentricity increases.
Hybrid Loading Test under the Bilateral Excitation

Residual Drift
After Loading ———— Before Loading

NS
EW
Effect of Bilateral Excitation

Unilateral Excitation

Bilateral Excitation

Separation of the covering concrete

Bilateral excitation results in more extensive damage
Bilateral Excitation results in larger residual drift. Bilateral Excitation is important in evaluation of a residual drift.
Fiber Model of the RC C-Bent Columns

Torsional Stiffness

\[ T = GJ \phi \]

- \( T \): Torsional Moment
- \( \phi \): Curvature
- \( G \): Shear modulus
- \( J \): Torsional moment of inertia

Fiber Element

Concrete

- Hoshikuma et al. Model
- Sakai Model
- Covering Concrete
- Core Concrete

Reinforcements

Menegotto and Pint Model

Stress (MPa) vs. Strain

Plastic Hinge

Rotational Spring
Fiber Element Analysis  \( e=0 \)

Analysis
Experiment

Longitudinal

Transverse

Displacement (mm)

Drift (%)

Time (Sec)
Fiber Element Analysis $e=0.5D$

Analysis
Experiment

Longitudinal

Transverse

Time (Sec)

Displacement (mm)

Drift (%)

Time (Sec)
The analysis correlates the accumulation of residual drift in the eccentric compression side.
Conclusions

- Extensive failure occurs at the eccentric compression side under both the unilateral and the bilateral excitations. This results in a large residual displacement in the eccentric compression side.

- The failure and the residual displacement under the bilateral excitation are more extensive than those under the unilateral excitation.

- A fiber analysis correlates the accumulation of residual drift in the eccentric compression side. However, the analysis underestimates the residual drift.
Thank you for your attention