The Art of Designing Ductile Concrete in the Past 50 Years: The Impact of the PCA Book and Mete A. Sozen, Part 1

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### DUCTILE DESIGN OF CONCRETE STRUCTURAL WALLS

Sharon L. Wood, University of Texas at Austin

<table>
<thead>
<tr>
<th>Wall Thickness, in.</th>
<th>Horizontal Reinforcement Spacing, in.</th>
<th>Vertical Reinforcement Spacing, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#3</td>
<td>#4</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>10*</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>12*</td>
<td>7</td>
<td>13</td>
</tr>
</tbody>
</table>

* Spacing in each of two curtains.
1964 Earthquake, Anchorage

Mt. McKinley Building
- Constructed in 1952
- 14 Stories
- Exterior Bearing Walls
- Interior Core Walls

Mt. McKinley Building

Mt. McKinley Building

Mt. McKinley Building
**Experimental Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal Reinforcement Ratio</td>
<td>1.1 to 6.0%</td>
</tr>
<tr>
<td>Vertical Web Reinforcement Ratio</td>
<td>0.25 to 0.31%</td>
</tr>
<tr>
<td>Horizontal Web Reinforcement Ratio</td>
<td>0.31 to 1.38%</td>
</tr>
<tr>
<td>Axial Stress ($P/4f_c$)</td>
<td>0.3 to 14.1%</td>
</tr>
<tr>
<td>Aspect Ratio ($H_w/L_w$)</td>
<td>2.4</td>
</tr>
<tr>
<td>Loading History</td>
<td></td>
</tr>
</tbody>
</table>

**Boundary Elements – Rectangular Walls**

**Boundary Elements – Barbell Walls**
Boundary Elements – Flanged Walls

Nominal Capacity

- Flexural Capacity, $V_{nf}$
- Shear Capacity, $V_{nv}$

$$V_{nv} = (2\sqrt{f'_c + \rho_n f_y}) A_{cv}$$

- Nominal Capacity, $V_n = \min (V_{nf}, V_{nv})$

Wall B1

- Flexural Failure
- Top Deflection, in.

Wall B3

- Flexural Failure
- Applied Force, kip
- Top Deflection, in.

Wall B6

- Shear Failure
- Applied Force, kip
- Top Deflection, in.
Shear Failures Occurred after Longitudinal Reinforcement Yielded.

Consequences of Shear Failures

- Web Crushing
- Shear-Compression Failure of Boundary Elements
- Concentration of Distortion near Base of Wall

Shear failures occurred after longitudinal reinforcement yielded.
Slender Walls – Displacement Capacity

- All test specimens were able to sustain multiple cycles to drift ratios exceeding 1%.
- Walls with confined boundary elements were able to sustain larger inelastic deformations.
- Walls that experienced web crushing sustained slightly lower maximum inelastic deformations.
- Maximum inelastic displacement did depend on loading history.

Slender Walls – Shear Capacity

- Average shear stress of \(4\sqrt{f_c}\) represented the boundary between flexural and shear failure mechanisms.
- If \(V_{nf} > 0.6 V_{nv}\) shear failure was observed under cyclic lateral loads.
- Walls with low web reinforcement ratios are susceptible to degradation of shear strength with cycling.

Mt. McKinley Building

CFRP wrap was installed in 2006 and the building has been reoccupied.