Response of Masonry Infill Walls and Confined Masonry Walls Subjected to Direct Shear

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Introduction

Confined masonry building damage – 2010 8.8 $M_w$ Chile earthquake (Brzev, Astroza et al. 2010)

Increased stiffness + reduced displacement

or

Reduced strength + increased displacement?

Masonry infill building damage – 2015 $M_w$ 7.8 earthquake (www.datacenterhub.org)
Outline

Direct shear test specimens
Experimental results
Analytical modeling
  ◦ Nonlinear pushover analysis
  ◦ 4-story building damaged during 2015 Nepal earthquake
Conclusions
Plane Masonry (PM) Specimen
Masonry Infill (MI) Specimen

4 ft x 4 ft Masonry Infill Panel

Concrete Confining Frame
Confined Masonry (CM) Specimen

4 ft x 4 ft Masonry Infill Panel

Concrete Confining Frame

Shear Keys in Every Other Layer of Masonry
Reinforced Concrete Frame

- Masonry infill
- Confined masonry
## Material Properties

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Average 28-day Compression Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plain Masonry</td>
</tr>
<tr>
<td>2 in. x 2 in. mortar cube</td>
<td>2440</td>
</tr>
<tr>
<td>4 in. x 8 in. concrete cylinder</td>
<td>-</td>
</tr>
<tr>
<td>12 in. x 12 in. masonry prism</td>
<td>130</td>
</tr>
</tbody>
</table>

Shear Strength (psi)
Loading Setup

corner fixture per ASTM E519
## Peak Loads and Displacements at Failure

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Peak Load</th>
<th>Displacement at peak load (in)</th>
<th>Displacement at failure (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain masonry</td>
<td>39.7</td>
<td>0.04</td>
<td>-</td>
</tr>
<tr>
<td>Masonry Infill</td>
<td>53.4</td>
<td>0.41</td>
<td>0.58</td>
</tr>
<tr>
<td>Confined Masonry</td>
<td>69.8</td>
<td>0.10</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Load Displacement Response
Failure Patterns

masonry infill  masonry infill  confined masonry
Modeling (SAP2000)

![Diagram of plastic hinge]

- Measured
- Calculated
4-Story Building Model

Gungabu Bus Park Building
- Damaged during 2015, 7.8 $M_w$ Nepal earthquake
- [www.datacenterhub.org](http://www.datacenterhub.org)

2D Analytical model
- Perform step-by-step nonlinear pushover analyses using plastic hinge properties for MI and CM walls
- Linear load distribution
  - $0.35I_g$ for beams, $0.70I_g$ for columns.
<table>
<thead>
<tr>
<th>Model</th>
<th>Base shear at Failure (k)</th>
<th>CM/MI Ratio</th>
<th>Level 1 Story Drift Ratio (%)</th>
<th>CM/MI Ratio</th>
<th>Roof Drift Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masonry Infill</td>
<td>75.4</td>
<td>0.8</td>
<td>0.46</td>
<td>1.6</td>
<td>0.31</td>
</tr>
<tr>
<td>Confined Masonry</td>
<td>95.5</td>
<td>1.0</td>
<td>0.28</td>
<td>1.0</td>
<td>0.31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specimen</th>
<th>CM/MI ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masonry Infill</td>
<td>0.8 peak load, 2.0 peak displ.</td>
</tr>
<tr>
<td>Confined Masonry</td>
<td>1.0 peak load, 1.0 peak displ.</td>
</tr>
</tbody>
</table>
Observed Damage

first story  second story  third story
Conclusions

Peak displacements of masonry infill and confined masonry wall specimens were 10 and 2.5 times, larger than a plain masonry wall specimen.

The peak load of the confined masonry wall was 30% larger than the masonry infill wall. At failure, the masonry infill specimen deflected twice as much (with more masonry damage).

Strain concentrations of the CM specimen were distributed over a more uniform effective strut width than the masonry infill specimen.
Conclusions

Limiting base shears calculated for a 4-story building model were 27% larger for the confined masonry structure compared to the masonry infill structure.

First story drift ratios were 64% larger for the masonry infill building.

Roof drift ratios were approximately the same (0.31%) for both models at these base shears.
Questions