ATC 143: Earthquake Damage Assessment and Repair Guidelines for Residential Wood-Frame Buildings

Morgan Griffith, Exponent
Motivation

- High demand for assessment of damage following major EQ’s in California
- High percentage of wood-frame houses comprising California’s building stock
- Low emphasis on wood-frame design and performance in most engineering universities
- Guidelines needed for efficient and consistent assessment of EQ damage to wood-frame houses (engineers and non-engineers)
Purpose and Scope

- Provide guidance related to:
  - Structural behavior common to residential wood-frame buildings during earthquakes
  - Earthquake-induced permanent ground deformation mechanisms
  - Efficient and consistent identification of earthquake damage
  - Development of a conceptual scope of repair for earthquake damage
  - Organizing the results of the assessment in a technical report.
Intended Audience

- **General Guidelines:**
  - Building contractors
  - Insurance claim representative
  - Homeowners

- **Engineering Guidelines:**
  - Structural consultants (civil/structural engineers, architects)
  - Geotechnical consultants (civil/geotechnical engineers, engineering geologists)
Earthquake Damage Assessment and Repair Guidelines for Residential Wood-Frame Buildings

Volume 1 | GENERAL GUIDELINES
CEA-EDA-01 2020

Earthquake Damage Assessment and Repair Guidelines for Residential Wood-Frame Buildings

Volume 2 | ENGINEERING GUIDELINES
CEA-EDA-02 2020
Structural Behavior
Permanent Ground Deformation
# Identification of Damage

<table>
<thead>
<tr>
<th>Table 3-3</th>
<th>Indicators of Damage to Concealed Sill Plates and Anchorage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Element being investigated</strong></td>
<td><strong>Indicator</strong></td>
</tr>
<tr>
<td>Wood sill plate</td>
<td>• Permanent movement of wood-frame wall relative to the top of foundation</td>
</tr>
</tbody>
</table>
| Steel cast-in-place anchor bolts | • Permanent movement of wood-frame wall relative to the top of foundation  
  • Fractured or dislocated sill plate |
| Steel post-installed anchor bolts | • Permanent movement of wood-frame wall relative to the top of foundation  
  • Fractured or dislocated sill plate |
| Steel post-installed plate connectors | • Permanent movement of wood-frame wall relative to the top of foundation  
  • Fractured or dislocated sill plate |
| Hillside house: Framing-to-foundation connection | • Leaning or racking of wood-frame side walls of underfloor area  
  • At uphill side, widened gap between exterior flatwork and house structure |

## Investigation Checklist for Sill Plates and Anchorage

<table>
<thead>
<tr>
<th>Check if present</th>
<th>Element type</th>
<th>Earthquake Damage</th>
<th>Non-EQ Damage</th>
<th>Not investigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>Wood sill plate</td>
<td>☐</td>
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### Table 4.4-1 Repair of Wood Sill Plates (1)

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<tr>
<th>Earthquake Damage Pattern</th>
<th>Repair Method (2)</th>
</tr>
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<tbody>
<tr>
<td>4.4-1A Sliding in any horizontal direction up to 1/4 inch with no other distress</td>
<td>No repair</td>
</tr>
<tr>
<td>4.4-1B Local sill plate splitting at individual bolts, not more than one out of ten bolts</td>
<td>Add a replacement bolt or replacement retrofit plate in the vicinity of the fracture location for each affected bolt</td>
</tr>
<tr>
<td>4.4-1C Sliding in any horizontal direction more than 1/4 inch</td>
<td>Move sill plate as close to its original location as possible. Install new anchorage to the foundation, otherwise provide support and anchorage in the displaced location</td>
</tr>
<tr>
<td>4.4-1D Sill plate splitting extending to more than one bolt in a row or at more than one out of ten bolts</td>
<td>Reinforce existing sill plate in place where possible, otherwise replace sill plate</td>
</tr>
<tr>
<td>4.4-1E Local splitting not associated with anchor bolts</td>
<td>Where local splitting interferes with support of framing members above, remove and replace the section of sill. Where local splitting is away from members to be supported, place a 2x block over the split area and nail</td>
</tr>
<tr>
<td>4.4-1F Splitting of blocking on top of foundation sill plate added as part of cripple wall retrofit</td>
<td>Remove sheathing, remove and replace blocks, replace sheathing</td>
</tr>
<tr>
<td>4.4-1G Widespread splitting not associated with anchor bolts</td>
<td>Reinforce existing sill plate in place where possible, otherwise replace sill plate</td>
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<tr>
<td>4.4-1H Crushing of the sill plate of not more than 1/8 inch of the sill plate under studs or posts</td>
<td>Shim at crushed location to regain bearing or provided sister stud alongside</td>
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<tr>
<td>4.4-1I Crushing of the sill plate of more than 1/8 inch of the sill plate under studs or posts</td>
<td>Provide sister studs alongside existing to reestablish bearing</td>
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### Table D-1 Earthquake Damage Relationships Based on Arnold et. al. Walls 1 and 2 (CUREE CDA-03, 2003)

<table>
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<tr>
<th>Damage Appearance</th>
<th>Overall Pattern</th>
<th>Peak Transient Drift When Observed (% of Story Height)</th>
<th>Hysteresis Curve</th>
<th>Damage Description</th>
</tr>
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<td>Wall</td>
<td>Exterior Stucco and Interior Gypsum Wallboard</td>
<td>Wall behavior up to 0.2% drift was characterized by some softening of the wall stiffness, extension of cracks in length and width, development of new cracks, and very slight deterioration of wall response during trailing cycles.</td>
<td>0.2%</td>
<td>Wall 1 stucco cracking at failure (no crack widths provided).</td>
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<td>Wall 2 stucco cracking up to 0.4% drift</td>
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<td>Wall behavior from 0.4% to 0.7% drift was characterized by some softening of the wall stiffness, extension of cracks in length and width, development of new cracks, and very slight deterioration of wall response during trailing cycles.</td>
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Handoff between Volumes 1 and 2

Damage assessment by owner, adjuster, or contractor
- Gather relevant property information
  - Review ShakeMap
  - Complete building occupant questionnaire

Scope – Chapter 1
Background – Chapter 2

Indicators of structurally significant damage?

Damage identification and documentation, house
- Inspect following areas of house for damage:
  - Foundations and slabs-on-grade
  - Walls
  - Floors, ceilings and roofs
  - Fireplaces and chimneys
  - Mechanical, electrical and plumbing systems

Investigation/documentation of damage to house – Chapters 4-8

Indicators of permanent ground deformation?

Damage identification and documentation, geotechnical
- Inspect ground surface and house for signs of:
  - Surface fault rupture
  - Liquefaction
  - Seismic compression
  - Landslide/rockslide
  - Rotating wall deformation

Investigation/documentation of permanent ground deformation – Chapter 3

Scope of repair for structurally insignificant damage
- Identification of relevant damage patterns from repair tables and/or text
- Conceptual recommendations for each damaged building component

Conceptual scope of repair – Chapters 4-8

Yes
- Structural consultant retained

Yes (ultimately, retain structural consultant initially)

Engineering Guidelines

Geotechnical consultant retained
- Technical consultant report(s)

Damage evaluation by technical consultant(s)
Training Materials (ongoing)

- Training for Volume 1 and Volume 2
- Mid-2020
Acknowledgements

- Project funding by CEA: Janiele Maffei, Mitch Ziemer
- Project management by ATC: Justin Moresco, Ayse Hortacsu
- Project Technical Committee: Morgan Griffith, John Osteraas, David Bonowitz, Kelly Cobeen, David Cocke, Dan Dyce
- Project Working Group: Sean Ahdi, Christine Beyzaei, Taylor Funk, Kari Klaboe, Evelyn Mikailian, Jon Wren