Post-Earthquake Building Damage Assessment

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Agenda

• Introduction & Background
• Damage Assessment References
• ATC-43 Concrete & Masonry Wall Damage
• The CUREE Woodframe Damage Assessment Project
Assessment Stages

• **Search & Rescue**: focus on safety of buildings for extraction of entombed victims and safety of rescuers

• **Safety**: focus on the safety of a building for continued occupancy, without regard to the extent of non-structural damage
  - ATC-20
  - BORP

• **Damage**: focus on the determination of the nature, extent, and appropriate repair of earthquake damage
Purpose of Post-Eq Damage Assessment

- Confirm safety assessment
- Document damage
- Determine significance of damage
- Provide basis for decision on what to do about damage
Need for Guidelines

• What is damage?

• What constitutes an adequate inspection?
  – What to look for
  – Where to look
  – When to look for concealed damage

• What constitutes appropriate repair
  – Do nothing - accept damage
  – Restore to pre-event condition
  – Upgrade to a better condition
  – Demolish as uneconomical to repair
• ATC-20 – 1989
• SAC Steel Moment Frame Project – 1995-2001
• CUREE - CalTech Woodframe Project 1998-2003
• CUREE Earthquake Damage Assessment Project 1998-2007?
ATC-20

- **ATC-20 Procedures for Post-Earthquake Safety Evaluation of Buildings, 1989**
- Developed for and focused on SAFETY
- Goal to get as many people as possible back into buildings that are no less safe than before the earthquake
- Not concerned with non-safety related damages
- Applies to all building types
- Identification of vulnerabilities provides good starting point for damage assessment
SAC Steel Moment Frame Project

- **FEMA 352 - Recommended Post-earthquake evaluation and repair criteria for Welded Steel Moment-Frame Buildings**
- Developed for and focused on assessment and repair of earthquake damaged buildings
- Applies only to steel moment frames

SAC: Structural Engineers of California, Applied Technology Council, California Universities for Research in Earthquake Engineering
• **Evaluation and Repair of Earthquake-Damaged Concrete and Masonry Wall Buildings, 1998**
• Developed for and focused on assessment and repair of earthquake damaged buildings
• Applies to buildings consisting of concrete or masonry bearing walls and frames with concrete or masonry infill panels
ATC-43 / FEMA 306, 307, 308

- Field investigation techniques & damage evaluation procedures
- Methods for performance loss determination
- Repair guides and recommended repair techniques
- In-depth discussion of policy issues pertaining to the repair and upgrade of earthquake damaged buildings
- Intended audience includes design engineers, building owners, building regulatory officials, and government agencies
• Performance-based damage evaluation uses the actual behavior of a building, as evidenced by the observed damage, to identify specific deficiencies.

• Performance-based damage evaluation provides an opportunity for better allocation of resources.

• Engineering judgment and experience are essential to the successful application of the procedures.

• The new procedures are different from past damage evaluation techniques and will continue to evolve in the future.
Documents:

FEMA 306: *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Basic Procedures Manual*

FEMA 307: *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Technical Resources*

FEMA 308: *The Repair of Earthquake-Damaged Concrete and Masonry Wall Buildings,*
CUREE-CalTech Woodframe Project

• Objective to significantly reduce earthquake losses to both existing and new woodframe construction through improved design, construction, & retrofit

• Applies to woodframe residential (houses, apartment, and condominium buildings) & non-residential (school and commercial)

• 30 Publications
CUREE EDA Project

- **Earthquake Damage Assessment and Repair for Woodframe Residential Construction (EDA)**
- Objective to develop guidelines to be used by engineers, contractors, owners, insurance industry, building officials, and others for post-earthquake damage assessment and repair
- Applies to residential woodframe construction
- In progress
CUREE EDA Project

Research to-date:

• Damage assessment and repair of walls where shear resistance is provided only by stucco and drywall
  – refining understanding of damage mechanisms
  – establishing correlations between visible damage and structural response
  – assessing the efficacy of repair techniques for common types of earthquake damage

• Potential for earthquake-induced cracking of concrete slabs-on-grade and foundations at sites that are geotechnically stable

• Efficacy of epoxy repair of cracks in unreinforced concrete slabs-on-grade and foundations

• Refined understanding of seismic compression of fills
Stucco & Drywall Shearwalls

- Researchers: Chia-Ming Uang, Andre Filiatrault, Andrew Arnold, UCSD

- Publications
  - EDA-03 - Cyclic Behavior and Repair of Stucco and Gypsum Sheathed Woodframe Walls Phase I
  - EDA-07 - Cyclic Behavior and Repair of Stucco and Gypsum Sheathed Woodframe Walls Phase II
Stucco & Drywall Shearwalls

Photo Credits: CUREE
Stucco & Drywall Shearwalls

(a) 0.2% Drift

(b) 0.4% Drift

(c) 0.7% Drift

(d) Failure

Diagram Credit: CUREE
Surface Strains

• Workshop Panel:
  – Bruce Bolt
  – Paul Somerville
  – Norman Abrahamson
  – Aspasia Zerva

• Publication:
  – EDA-04 – *Workshop Proceedings: Effect of Earthquake-Induced Transient Ground Surface Deformations on At-Grade Improvements*, A. Gupta, ed.
Surface Strains

• The magnitude of earthquake-induced transient ground surface strains at an arbitrary site can be reasonably estimated given the current state-of-science.

• The effect of surface strains on at-grade improvements would be inconsequential, except perhaps in the near fault region where large transient peak ground displacements may occur.

• The reported observations of visible waves on the ground surface during strong ground shaking cannot be explained from a seismological perspective. Under special circumstances where the ground is extremely soft, it may be possible to observe the surface waves, however these waves would likely not be damaging to at-grade improvements, as the wavelength of these waves would be much larger than the dimensions of the at-grade improvements.
Epoxy Repair

• **Contractor:**
  – Jay Crandall, National Association of Home Builders Research Center

• **Report:**
  – EDA-01 – *Testing and Assessment of Epoxy Injection Crack Repair for Residential Concrete Stem Walls and Slabs-on-Grade*
Seismic Compression

• Researcher:
  – Jon Stewart, UCLA

• Publication:
  – EDA-05 – *Seismic Compression of As-Compacted Fill Soils with Variable Levels of Fines Content and Fines Plasticity*
EDA-02 - General Guidelines for the Assessment and Repair of Earthquake Damage in Residential Woodframe Buildings

• Section 1 – Introduction
• Section 2 – Working with Engineers
• Section 3 – Characterization of Ground Motion Damage Potential and Structural Vulnerabilities (in progress)
• Section 4 – Geotechnical Aspects (in progress)
• Section 5 – Foundations and Slabs-on-Grade
• Section 6 – Wall Elements
• Section 7 – Floors, Ceilings, and Roofs (in progress)
• Section 8 – Fireplaces and Chimneys (in progress)
• Section 9 – Mechanical Systems (in progress)
• Section 10 – Glossary (in progress)
**EDA-06 - Engineering Guidelines for the Assessment and Repair of Earthquake Damage in Residential Woodframe Buildings**

- Section 1 – Introduction
- Section 2 – Client Interactions & Reporting
- Section 3 – Characterization of Ground Motion Damage Potential and Structural Vulnerabilities
- Section 4 – Geotechnical Aspects (completed)
- Section 5 – Foundations and Slabs-on-Grade
- Section 6 – Wall Elements
- Section 7 – Floors, Ceilings, and Roofs
- Section 8 – Fireplaces and Chimneys
- Section 9 – Mechanical Systems
- Section 10 - Glossary
ATC-43/CUREE EDA Commonalities

- Characterization of ground motions & damage potential
- Investigation methodologies
- Guidelines for distinction between pre-existing conditions and earthquake damage
- Damage documentation guidelines
- Damage classification
- Component performance information
- Correlation between visible damage and structural behavior
- Repair alternatives
ATC-43/CUREE EDA Differences

• Construction type
  – ATC-43 – concrete & masonry walls
  – CUREE EDA – woodframe

• Components
  – ATC-43 – lateral load resisting wall elements
  – CUREE EDA – all building components, structural & non-structural
More Information

• Tutorial Friday:
  – *Evaluation and Repair of Earthquake Damaged Buildings*

• Publications:
  – ATC: [www.atcouncil.org](http://www.atcouncil.org)
  – CUREE: [www.curee.org](http://www.curee.org)

• Presenter:
  – John Osteraas: [osteraas@exponent.com](mailto:osteraas@exponent.com)
  – Business card for CUREE EDA Project mailing list
Questions?
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Final Questions?