

# Post-Earthquake Building Damage Assessment

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

- 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

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

- **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**
- **ATC-43 / FEMA 306, 307, 308 – 1998**
- **CUREE Earthquake Damage Assessment Project 1998-2007?**

- *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 in to 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

- ***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, Appplied 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

- **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,*

- 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

- **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**

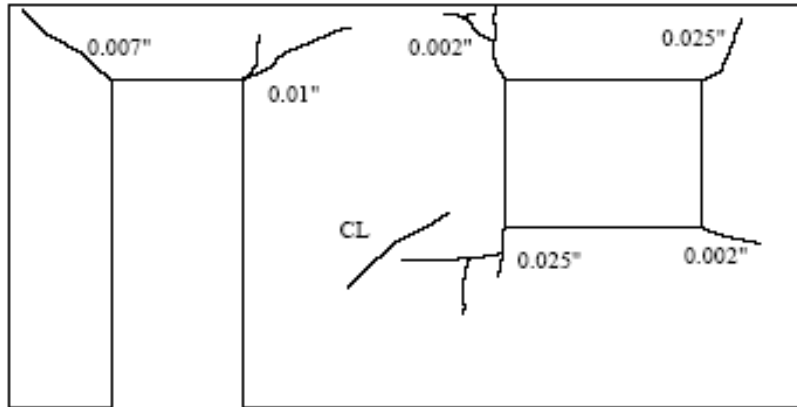
## Research to-date:

- **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**

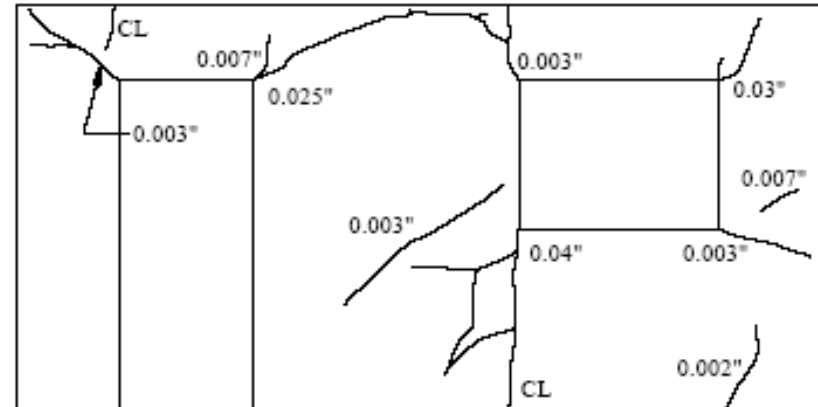
- **Researchers: Chia-Ming Uang, Andre Filiatrault, Andrew Arnold, UCSD**
- **Publications**
  - *EDA-03 - Cyclic Behavior and Repair of Stucco and Gypsum Sheathed Woodframe Walls Phase I*
  - *EDA-07 - Cyclic Behavior and Repair of Stucco and Gypsum Sheathed Woodframe Walls Phase II*

# Stucco & Drywall Shearwalls

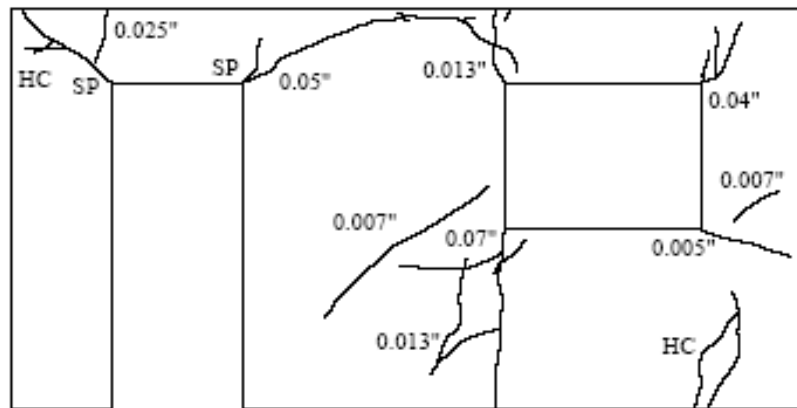




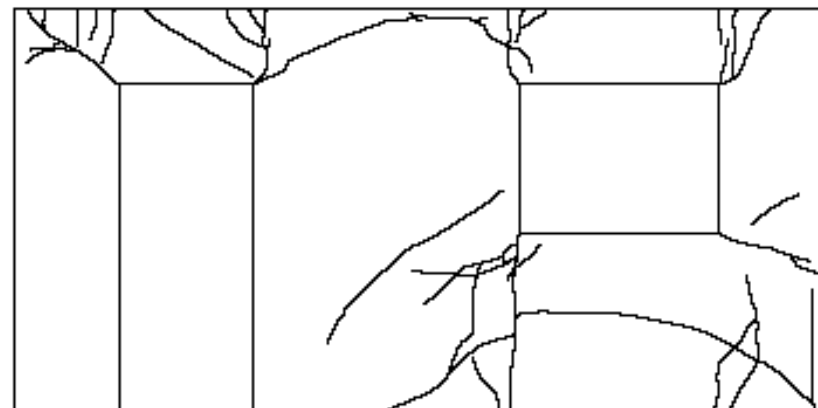
(a) 0.2% Drift



(b) 0.4% Drift



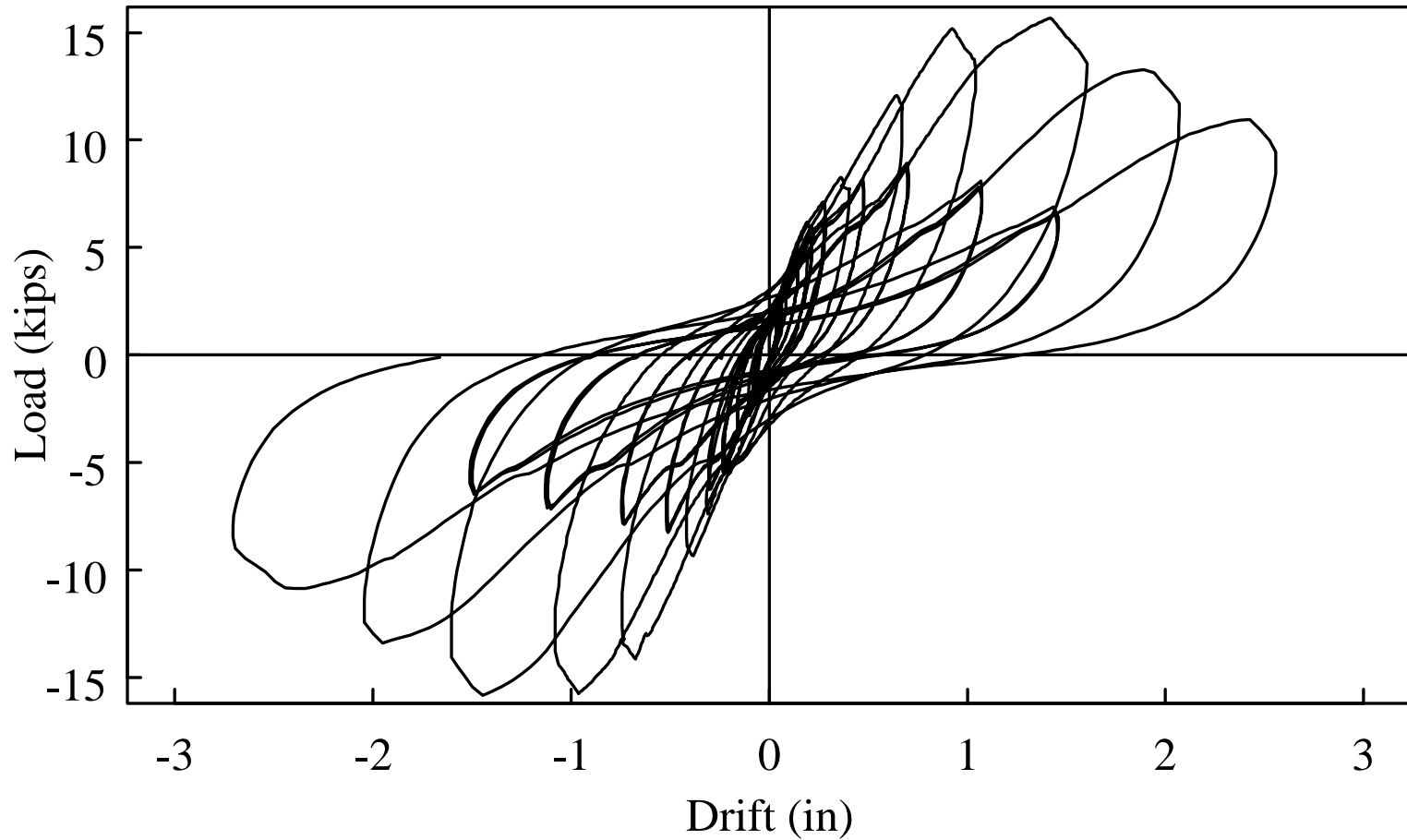
(c) 0.7% Drift



(d) Failure



Photo Credit: CUREE



(a) Wall 3d

- **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.

- 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.

- **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*



Photo Credits: CUREE

- **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)

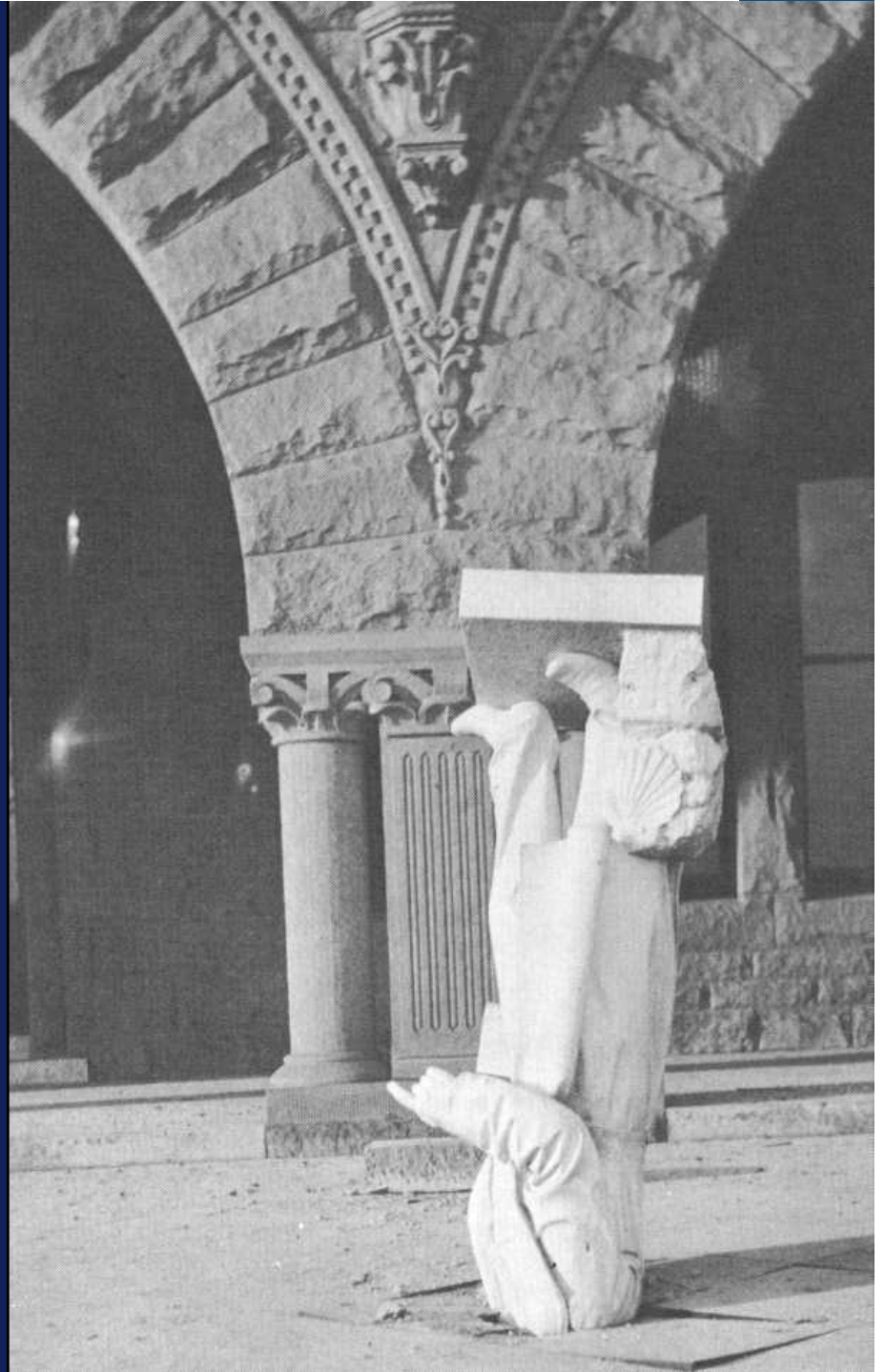
- *EDA-06 - Engineering Guidelines for the Assessment and Repair of Earthquake Damage in Residential Woodframe Buildings*
- Section 1 – Introduction
- Section 2 – Client Interactions & Reporting
- Section 3 – Characterization of Ground Motion Damage Potential and Structural Vulnerabilities
- Section 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

- **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**

- **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

- **Tutorial Friday:**
  - *Evaluation and Repair of Earthquake Damaged Buildings*
- **Publications:**
  - ATC: [www.atccouncil.org](http://www.atccouncil.org)
  - CUREE: [www.curee.org](http://www.curee.org)
- **Presenter:**
  - John Oстераas: [osteras@exponent.com](mailto:osteras@exponent.com)
  - Business card for CUREE EDA Project mailing list

Questions?



## 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
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# Final Questions?

