Influence of Irreparability Fragility on Seismic Vulnerability Assessment of Buildings

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Clemson-AIG Collaboration

- Hurricane & Typhoon
  - Hazard Database
    - Wind
    - Storm Surge
    - Rain
  - Vulnerability
- Earthquake
  - Vulnerability
  - Liquefaction
  - Hazard Database
- Technological / Manmade
  - Blast
  - Vulnerability
  - Hazard Database
    - TNT
    - Vapor Cloud
Overview

Motivation

Vulnerability Assessment

Revised Model

Conclusion
Motivation

- Improvement of code seismic provisions over past decades
- ‘Collapse prevention’ and ‘life safety’
- Dramatic increase of financial losses
- Irreparability and loss of functionality
- Example of Christchurch, NZ Earthquake, more than 60% of affected non-collapse reinforced concrete buildings eventually demolished (e.g. Kim, 2015 or Kim et al., 2017)
Vulnerability Assessment
(Based FEMA P-58 w/ Modifications)

1. Earthquake Hazard Level
2. Structural Response Model
   - Collapse?
     - Yes: Repair cost = Replacement cost
     - No: Repairable?
       - Yes: Calculate repair cost
       - No: Vulnerability function

3. Probability of Irreparability
   - Median=0.5%, McCormick, et al. (2008)
   - Median=1.0%, FEMA P-58
   - Median=1.5%, Ramirez CM & Miranda E. (2012)
   - Median=2.5%

Maximum Inter-story Residual Drift (%)
Vulnerability Assessment

4-story
Multifamily
Light Frame Wood

Generally, relatively high predicted loss at MCE level based on AIG engineers’ feedback.

High sensitivity of projected loss to irreparability fragility assumptions.
Vulnerability Assessment
(Based FEMA P-58 w/ Modifications)

- FEMA P-58 links irreparability solely to residual drifts:
  - less confidence on residual drifts predictions
  - lack of consensus on median residual drift threshold

- Kim *et al.* (2017) discussed two types of factors:
  - building features
  - contextual factors
Revised Framework: 1- Irreparability

- Irreparability is treated as a post-loss assessment module.
- If direct and indirect losses exceed replacement cost, the building deems irreparable.
- Indirect loss: downtime, permit fees, site mobilization cost, ...
- Light Frame Wood Example: Indirect loss = 1000 USD/unit.
Revised Framework: Light Frame Wood Example

104.0’  56.0’
Revised Framework: 1- Irreparability

Direct + indirect losses
Direct losses
Depends on building TIV (total insured value)
Revised Framework: 2- Collapse Fragility, Three-Parameter Weibull Distribution

Zero collapse probability region
Revisited Framework: Vulnerability Function

Loss Ratio or Collapse Probability

$S_a (T=0.57 \text{s}) / g$

- Collapse Loss
- Structural and Nonstructural Loss
- Irreparability Loss
- Collapse Fragility
- MCE@ Seattle
Conclusion & Summary

- Limitations of irreparability model in the current version of FEMA P-58 are discussed.
- A collapse fragility adjustment approach suitable for seismic vulnerability characterization of buildings is proposed.
- A new approach to treat irreparability is proposed, in which irreparability module is treated as a post loss assessment decision-making module.
The next presentation:
Seismic Vulnerability Assessment of Buildings using a Statistical Method of Response Prediction (ID 1747)

Thanks a lot
Back-up
The graph plots the loss ratio or collapse probability against $S_a(T=0.57s) / g$. The graph includes four lines:

- Blue line: Vulnerability Function w/o Irreparability
- Red line: Vulnerability Function w/ Irreparability
- Black line: Collapse Fragility
- Dashed line: MCE@ Seattle