Resilience-Based Seismic Design: Current Design Approach, Technical Developments, and a Look Into the Future

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[and discussion of project work by many others]

How Do We Design U.S. Buildings Today?

- Building Life Safety:
 - This is the focus (intent of the building code).
 - **Result:** Probably do fairly well here (?).
- Building Closure and Business Disruption:
 - Not considered is design process.
 - **Result:** Not controlled. Likely "months" at design-level, possible demolition ("years") at maximum-level.
- Building Damage and Repair Costs:
 - Not considered is design process.
 - **Result:** Not controlled. Presume 20% loss at designlevel, possible demolition at maximum-level.

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Question #2: Is this how we should design buildings?

Question #1:

Why do we

design this way?

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What If ?

What if we...

- ...had a robust analysis method that could estimate monetary losses, closure time, and fatalities/injuries?
- ...had an analysis method detailed enough so we can clearly see the effects of our design decisions?
- ...had this analysis stream-lined so we can do the initial analysis in hours (rather than days/weeks) and then refine the analysis as needed?
- ...had a building rating system (USRC) that packages this all into an easily communicated result? [Heintz]
- How would this change our thinking?

Overview of FEMA P-58

- P-58 is a performance prediction methodology based on a 10-year FEMA study (enabled by much previous research).
- P-58 is an alternative to other experience-based or judgmentbased methods (e.g. HAZUS, ATC-13, etc.).
- P-58 is tailored to building-specific analysis (cause + effect).
- ATC is currently working on another 5-year effort to further advance the methodology, implementation, ease of use.
- FEMA P-58 Output Results:
 - Losses [\$]
 - Fatalities & injuries [safety]
 - Repair time & red tagging [business disruption]

15th ATC US-Japan Workshop on Structural Engineering and Resiliency



Seismic Performance Assessment of Buildings Volume 1 - Methodology

FEMA P-58-1 / September 2012

🍪 FEMA

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 - Soil and hazard curve
 - Ground motions (if needed)



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A: Substructure			623
A10: Foundations			83
A101: Standard Foundations	Please Select		0
A102: Special Foundations	Please Select	•	
A103: Slab on Grade	Please Select	•	23
A20: Basement Construction			10
A202: Basement Walls	Please Select	-	10
B: Shell			13
B10: Super Structure			10
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B102: Roof Construction	Please Select	-	85
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Structural Engineering and Resiliency

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Dir. 2

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Monte Carlo Simulation used ("roll dice" thousands of times).

Each "dice roll" gives a single observation of losses and other consequences.

Full set of "dice rolls" provides solid statistical information on performance (e.g. 10,000 at 14 levels = 140,000 runs).

FEMA P-58: Output Examples

Sample results (12-story RC frame):



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FEMA P-58: Output Examples

Dig as deep as you like...



FEMA P-58: Benefits

- Objective process based on data and research.
- Quantitative performance information:
 - Solid statistical basis.
 - Sensitive enough to inform design decisions (cause + effect).
 - Tools to communicate with owners.
 - Dig as deep as you like.



FEMA P-58: Perceived "Difficulty"

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I need to hire a geotech to do this...?

I need to do a response-history analysis...?

I need to count and enter every foot of partition wall and other contents...?

- A barrier to widespread FEMA P-58 adoption has been related to software and ease-of-use (high cost of entry).
- ATC/FEMA have created a great methodology but are not in the business of maintaining software (for the long-term).
- Need: For our profession to move forward with FEMA P-58 methods, an enabling software is needed.
- Our Contribution: In February, we decided to fill this role by creating/maintaining a user-friendly software for P-58.
- Our Goal: Help enable adoption of FEMA P-58 in practice.
- ATC Coordination: We have been in coordination with ATC from the start (so all pulling in same direction).

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Seismic Performance Prediction Program by Haselton Baker Risk Group

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Soil and hazard curves embedded.

Simplified method embedded (only need period, mode shape, yield drift).

Structural and nonstructural contents estimates and prepopulated.

Loss Est <u>Two-level structure</u>:

 (1) Simple (prelim. design, basic rating, PML)
 (2) Refine and go as deep as you like (full new PBD).

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- How does this change our thinking?

Discussion: Back to my Initial Question...

Question: Given all these recent technical developments, is this <u>still</u> how we should design buildings?

Current Design:

- Safety: Probably decent.
- **Building Closure:** Not controlled. Likely "months" at design-level, possible demolition ("years") at maximum-level.
- **Repair Costs:** Not controlled. Presume 20% loss at design-level, possible demolition at maximum-level.
- Exciting time of development (FEMA P-58, software, USRC, etc.). How do we leverage this to achieve a more resilient infrastructure?
- What are our policy recommendations for:
 - The design of all buildings?
 - The municipality (or State of CA) worried about widespread building damage and businesses closure affecting the city/region?
 - Owner-elected improved design to protect business or assets?
 - Other?



- Thank you for your attention and feedback!
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