Resilience-Based Design & Risk Management using FEMA P-58

FEMA P-58 and SP3: Resilient Design Case Study and SP3 Demo/Training

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Agenda for this Session

- **This Session:**
  - ✓ Resilient design case study
  - ✓ Demo and training: Interactive resilient design using FEMA P-58 and SP3

Quick Resilience-Based Design Example

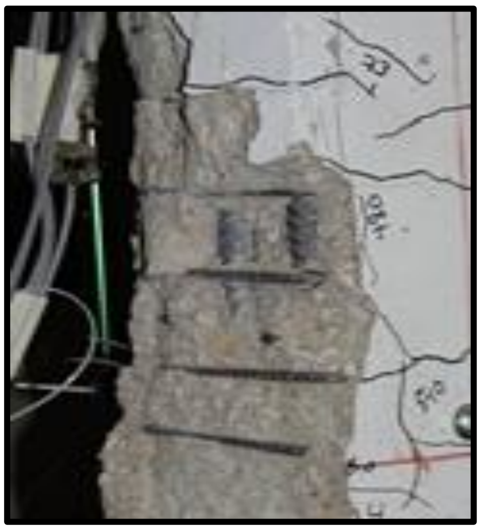
- Project: Municipal office building
- Building: Design a 10-story RC Wall (coupled core), office occupancy
- Site: LA high-seismic, S_{DS} = 1.1g, S_{D1} = 0.6g.
- Design Objectives: USRC five-star performance in all categories
  - Repair Cost < 5%
  - Functional Recovery Time < 5 days
  - Safety – high (low collapse, no/few injuries, good egress)
- Showing example for *design*, but also applicable to *risk*

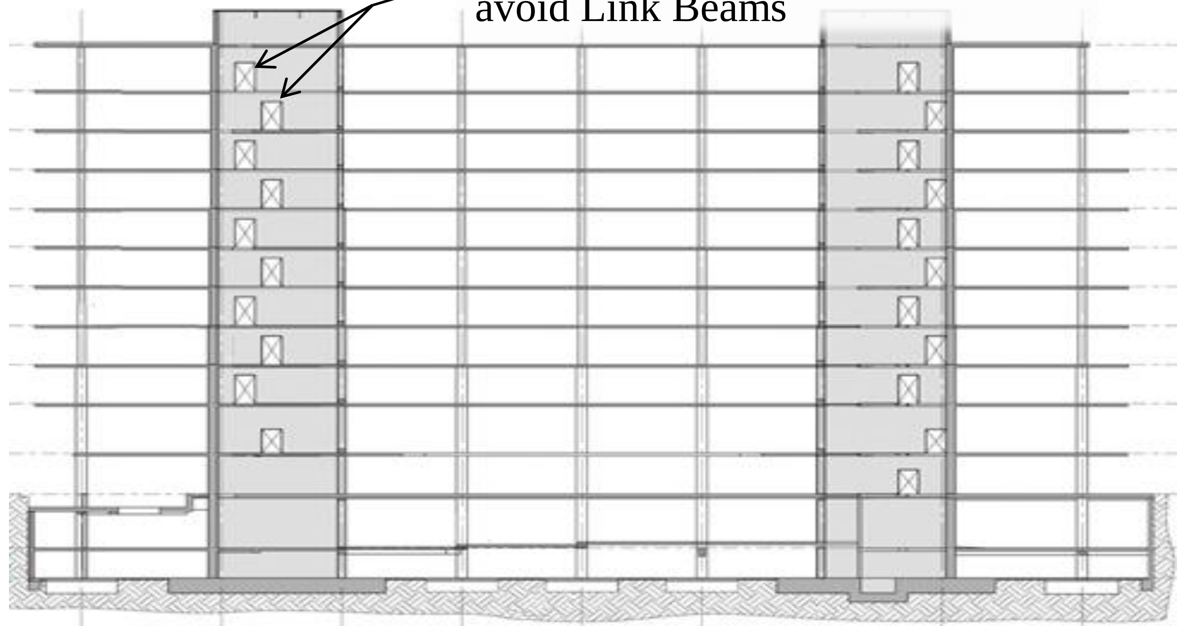
Figure Source: SOM/NYASE 2016 SEAOC presentation

Quick Resilience-Based Design Example

- **Step #1:** Start with code-compliant design to see where that gets us…
  - Repair Cost = 8% [4-star]
  - Recovery Time = 6.5 months [3-star]
    - 3.0 months – mechanical and electrical (HVAC, lighting, switchgear)
    - 2.0 months – structural (mostly walls)
    - 1.5 months – non-structural drift-sensitive (partitions, stairs, piping, fire sprinklers)
  - Safety [3-star]
    (discussed at the end)

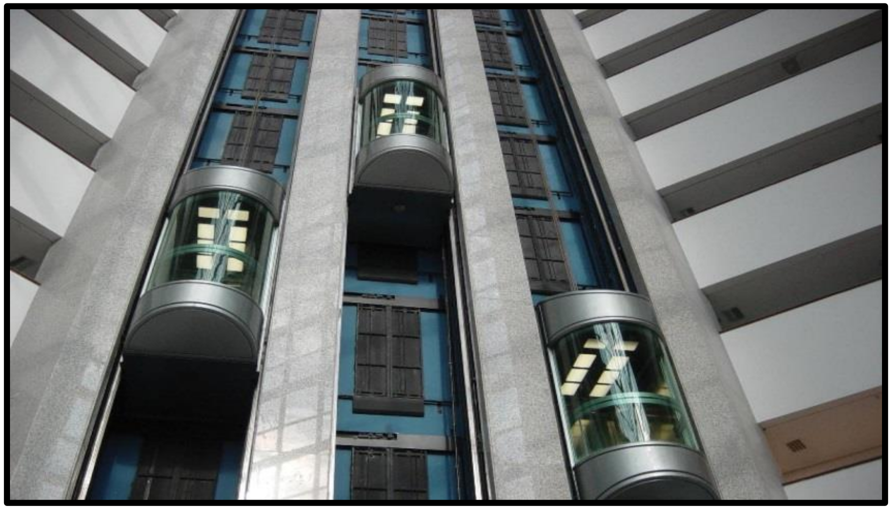
- **Step #2:** Design wall to be "essentially elastic" (very strong) and remove coupling beams.





Step #3: Design mechanical and electrical components to be functional at the 10% in 50 year (anchorage, equipment, lighting, etc.).

- Result for Steps #2-3:
  - Repair Cost = 5.5% [still 4-star]
  - Recovery Time = 2.5 months [still 3-star]
    - 1.0 month – slab-column connections
    - 1.5 months – partition walls

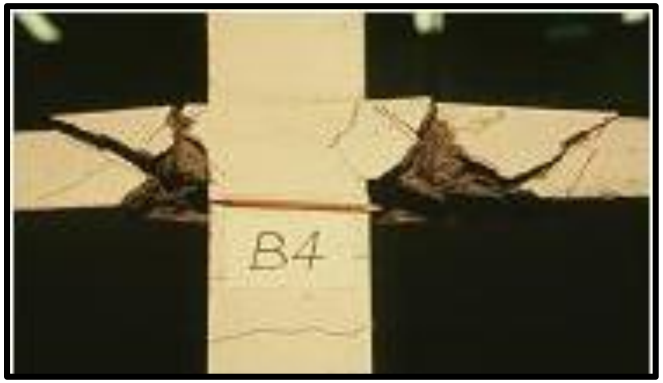


Quick Resilience-Based Design Example

Step #4: Reduce the shear on the slab-column connections.

Step #5: Use less damageable partition walls.

- Result:
  - Repair Cost = 3.5% [now a 5-star]
  - Recovery Time = 6 weeks [still a 3-star]
    - 3 weeks – slab-column connections
    - 3 weeks – partition walls

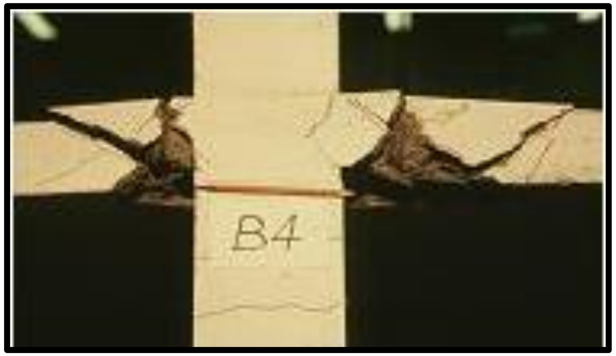


Step #6: Stiffen the building (longer walls, more coupling, etc.). Reduces the maximum drifts from around 1.4% to 1.0%.

- Result:
  - Repair Cost = 2% [5-star]
  - Recovery Time = 2 days [moved from 3-star to 5-star]

Step #7: Now that building has less drift, move back to higher shear slab-column connections.

- Result:
  - Repair Cost = Still 2% [still a 5-star]
  - Recovery Time = Still 2 days [still a 5-star]



Quick Resilience-Based Design Example

- **Step #8:** Now that building has less drift, see if we can move back more damageable partition walls.
- Result:
  - Repair Cost = 2.5% [5-star]
  - Recovery Time = 2 weeks [would moved down to 4-star]

**Move back to less damageable partition walls to keep a 5-star recovery time.

Quick Resilience-Based Design Example

- **Step #9:** Safety checks

- Overview of safety checks:
  - **Fatalities.** Show good collapse safety (limit fatalities).
  - **Injuries.** Check injury prediction from FEMA P-58 (would require additional non-structural bracing to get to 5-star).
  - **Residual Drifts.** Very low (essentially elastic).
  - **Stairs and Egress.** Check probability of non-functionality (direct outputs from the FEMA P-58 detailed results).

Quick Resilience-Based Design Example

Figure Source: SOM/NYASE 2016 SEAOC presentation

- Final Design Outcomes (for 10% in 50 year motion):
  - **Repair Cost: 2%** [5-star] *(Typically 10-20% for new code)*
  - **Recovery Time: ~0 days** [5-star] *(Typically 6-9mo. for new code)*
  - **Safety:** Low fatality+injury risk and good egress [5-star]

- This example was for **new resilient design,** but FEMA P-58 offers this same level of building-specific detail when doing **risk assessments.**

Agenda for this Session

- This Session:
  - ✓ Resilient design case study
  - ✓ **Demo and training: Interactive resilient design using FEMA P-58 and SP3**

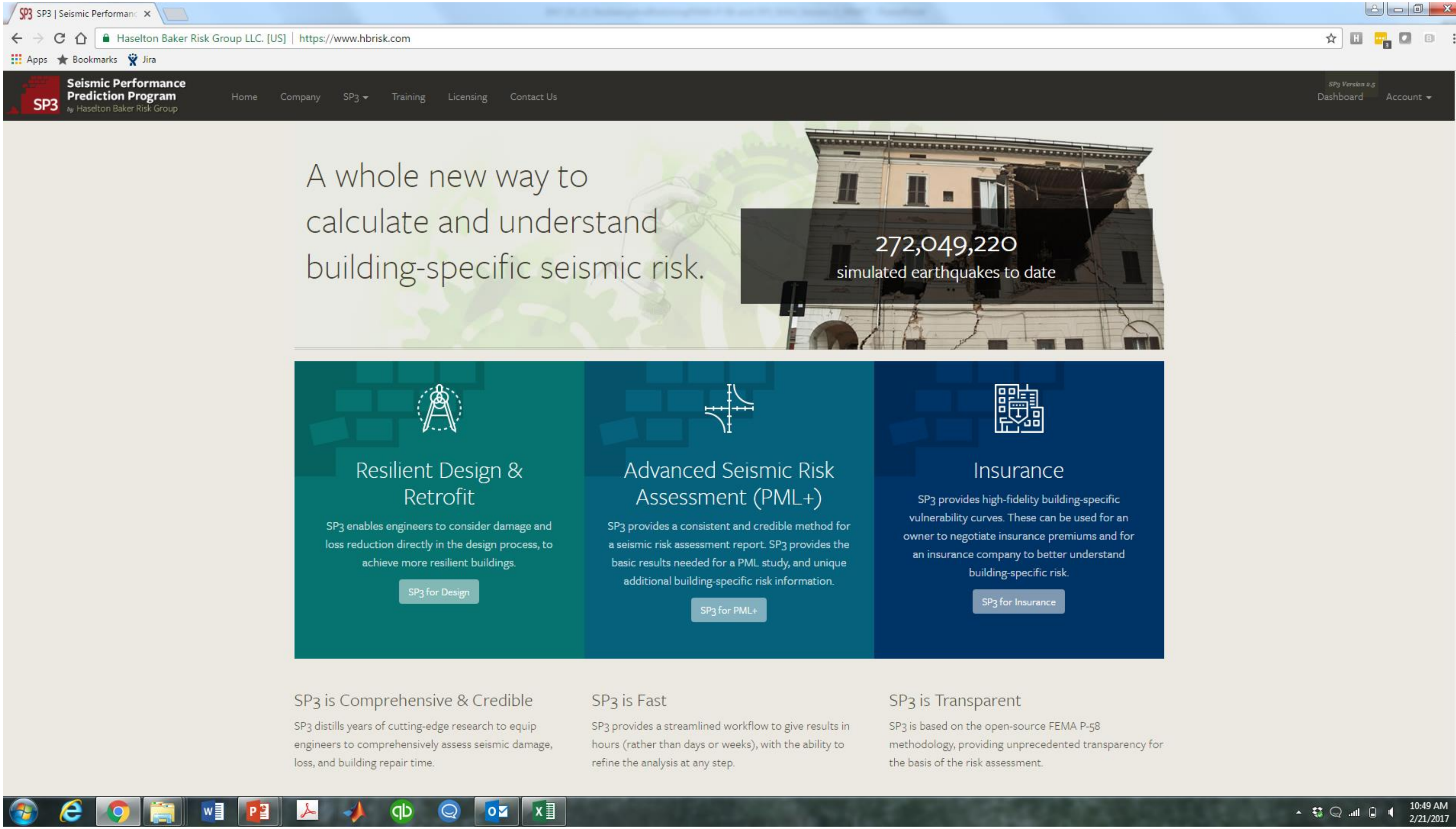
Interactive Resilient Design Example

- Let’s design a building together at this site (approximate design)!
- Let’s do a building as follows:
  - 8-story building
  - Office occupancy
  - Reinforced Concrete Special Moment Frame
  - Perimeter frame with PT slabs for gravity system
  - Footprint of 120’ x 210’ (and do 30’ bays)
- Design targets:
  - “Safe” building (e.g. at least code-compliant)
  - Design motion level: Requirement is > **5%** repair cost, and **2 weeks** of repair time (without impeding factors)
  - 2% in 50 year motion: Requirement is > **20%** repair cost, and **3 months** of repair time (without impeding factors)

Interactive Resilient Design Example

- Some notes for context:
  - For office occupancy, most damage is to drift-sensitive components.
  - To protect drift-sensitive components, we will need to reduce drift (so make building stiffer), even though this will increase floor accelerations.
  - For other occupancies (e.g. medical care), there are more acceleration-sensitive components, so the resilient design strategy would differ.
- Let's jump in!

Interactive Resilient Design Example



What are we going to do about this for design?

- **Performance Results:**
  - Repair cost of ~2-4% rather than ~10-20%.
  - Repair time almost zero rather than ~6-24 months.
  - **With these methods, <u>we can design buildings that are not disposable</u>.
- **Cost:** Recent resilience-based design projects have estimated that resilient seismic performance **costed between 0% and 2%** of the project budget.

The Question for Us All:

With these resilience-based design methods now available, and with costs being reasonable, why wouldn't we do resilience-based design as standard for <u>most new buildings</u>?

Questions and Discussion

- Thank you for your time.
- Our goal is to support adoption of resilience-based design and risk assessment, and we welcome feedback and suggestions.

- Time for questions and discussion!

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