

Expected Performance of New Code-Compliant Buildings in California

Katherine Wade: Haselton Baker Risk Group, LLC

D. Jared DeBock: CSU, Chico | Haselton Baker Risk Group, LLC

Curt Haselton: CSU, Chico | Haselton Baker Risk Group, LLC

Dustin Cook: University of Colorado, Boulder

Edward Almeter, Haselton Baker Risk Group, LLC

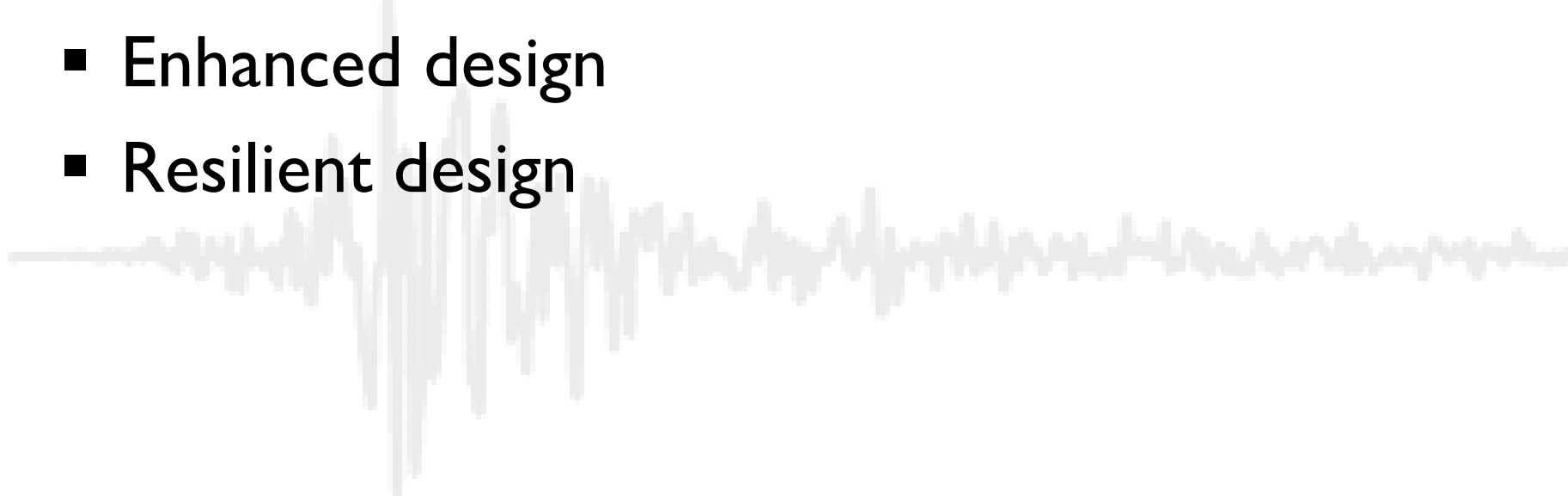
- Life safety
- Limit cost
- Limit recovery time



- Life safety
- Limit cost
- Limit recovery time

Safe but
disposable!



- Methods
 - FEMA P-58
 - REDI
 - 8-story office building example
 - Enhanced design
 - Resilient design
- 

- Probabilistic performance prediction
- Building-specific analysis
- Output results:
 - Repair costs
 - Repair time
 - Safety



Seismic Performance Assessment of Buildings

Volume 1 – Methodology

FEMA P-58-1 / September 2012

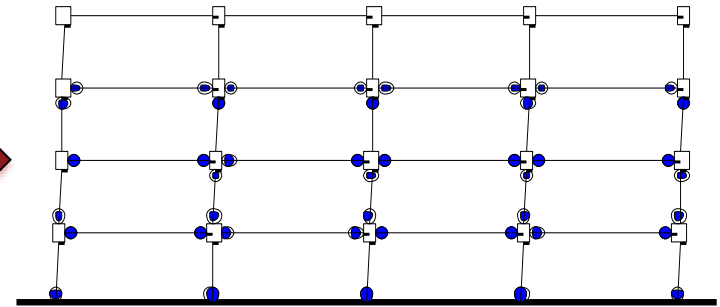


FEMA

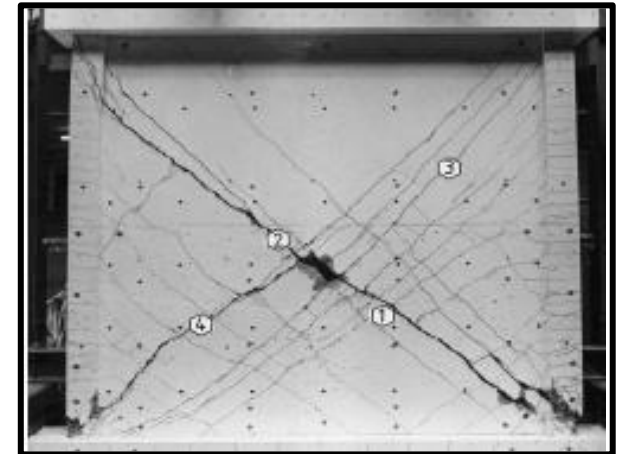




Ground Motion Hazard



Structural Response



Component Damage



Casualties

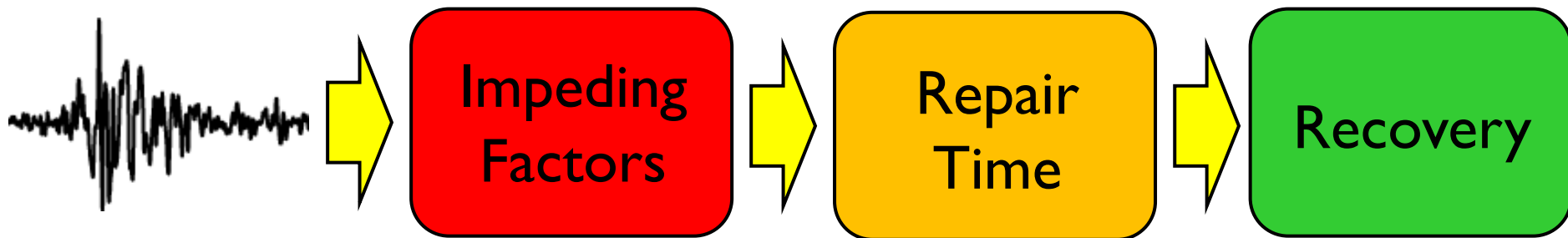


Economic Loss



Repair Time

- Recovery Levels
 - Re-occupancy
 - Functional Recovery
 - Full Recovery



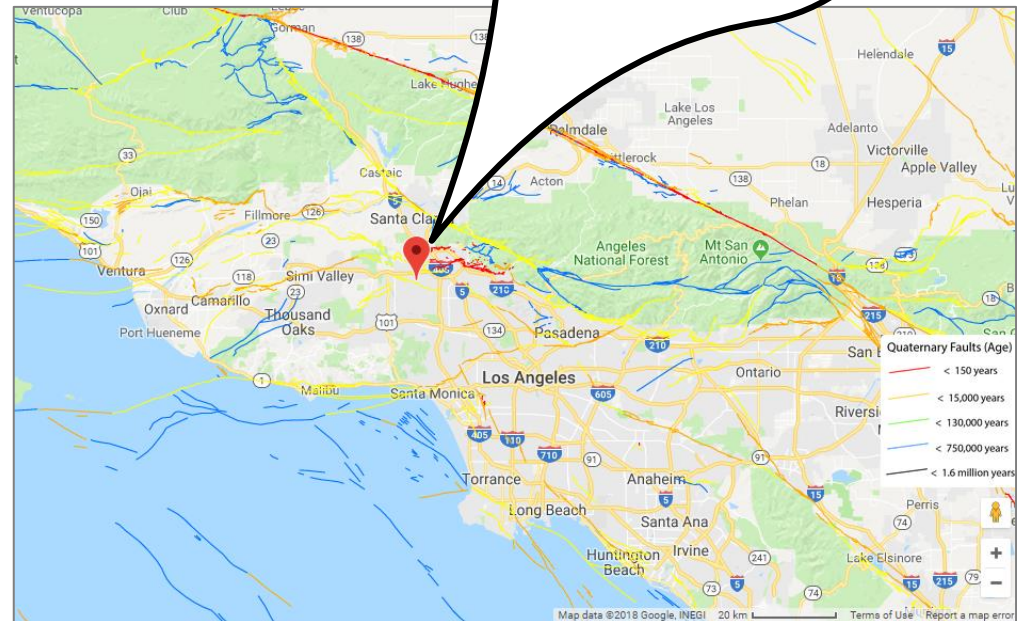
- Methods
 - FEMA P-58
 - REDI
- 8-story office building example
- Enhanced design
- Resilient design

- 8-story office building
 - Northridge, CA
 - New design
 - Steel Special Moment Frame



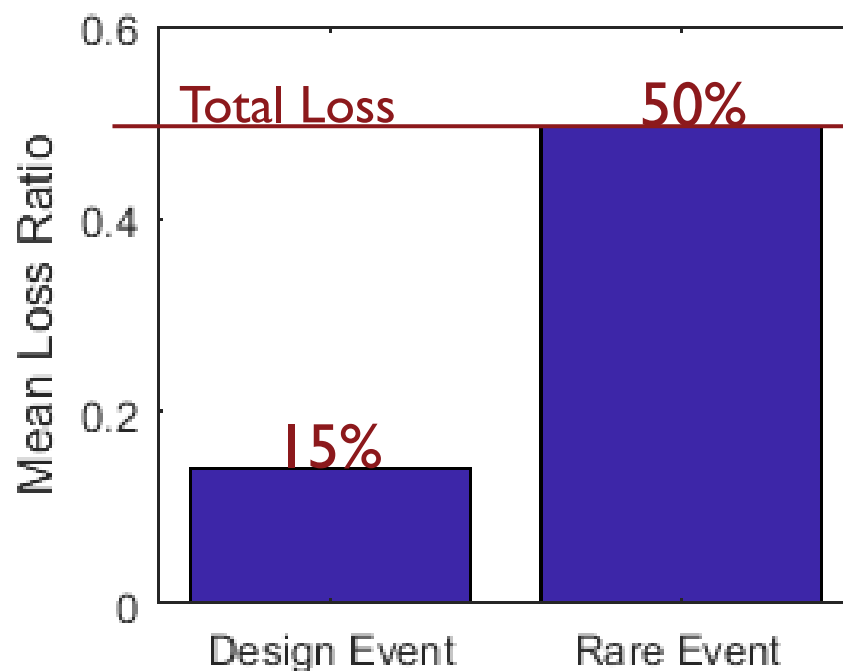
Design Event: 475 yr.
return period

Rare Event: 2475 yr.
return period

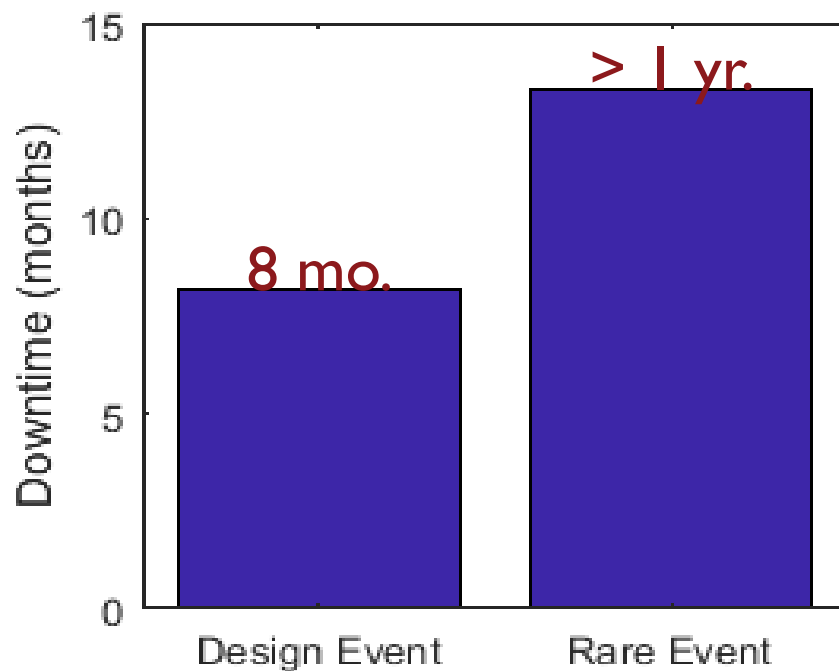
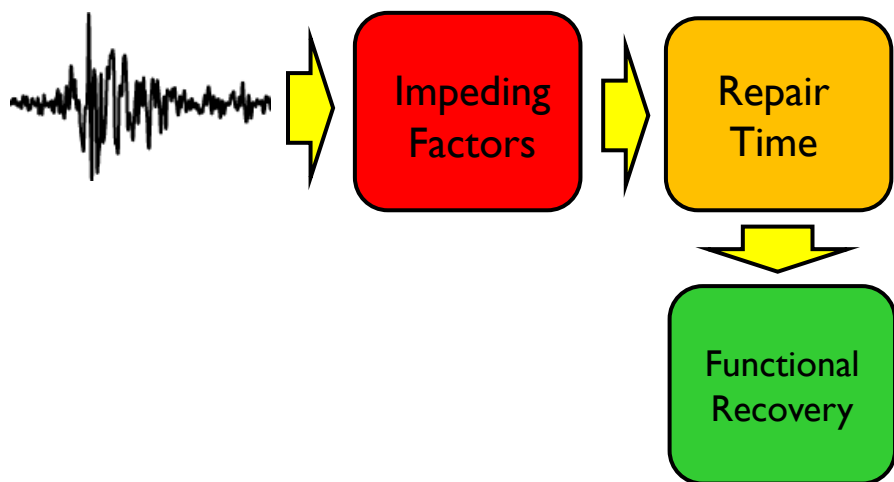


- 8-story office building
 - Northridge, CA
 - New design
 - Steel Special Moment Frame

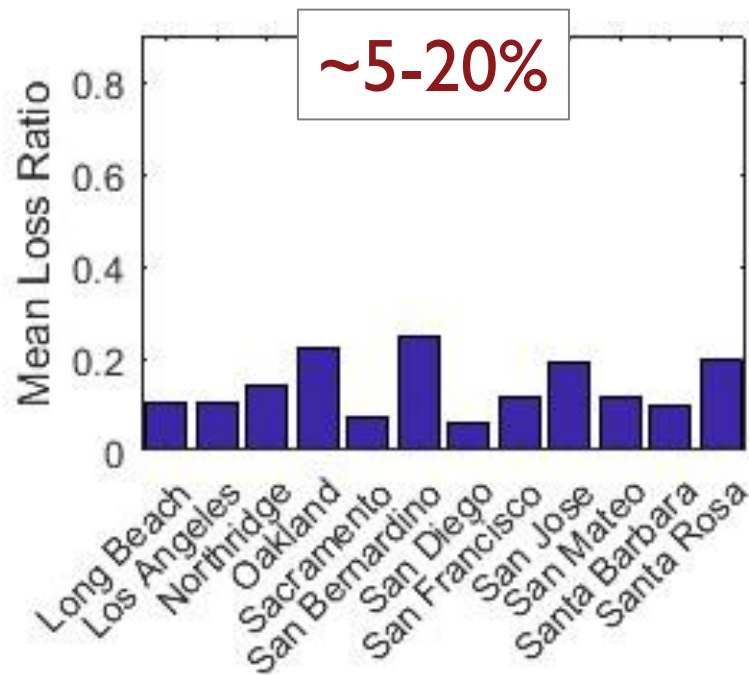
$$\text{Loss Ratio} = \frac{\text{Repair Cost}}{\text{Building Replacement Cost}}$$



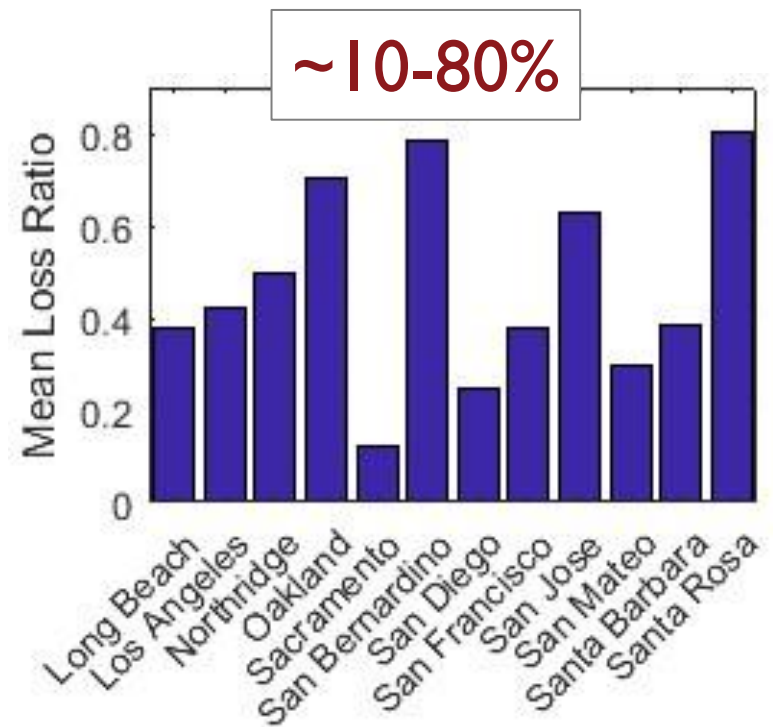
- 8-story office building
 - Northridge, CA
 - New design
 - Steel Special Moment Frame



- 8-story office building
 - 12 CA cities

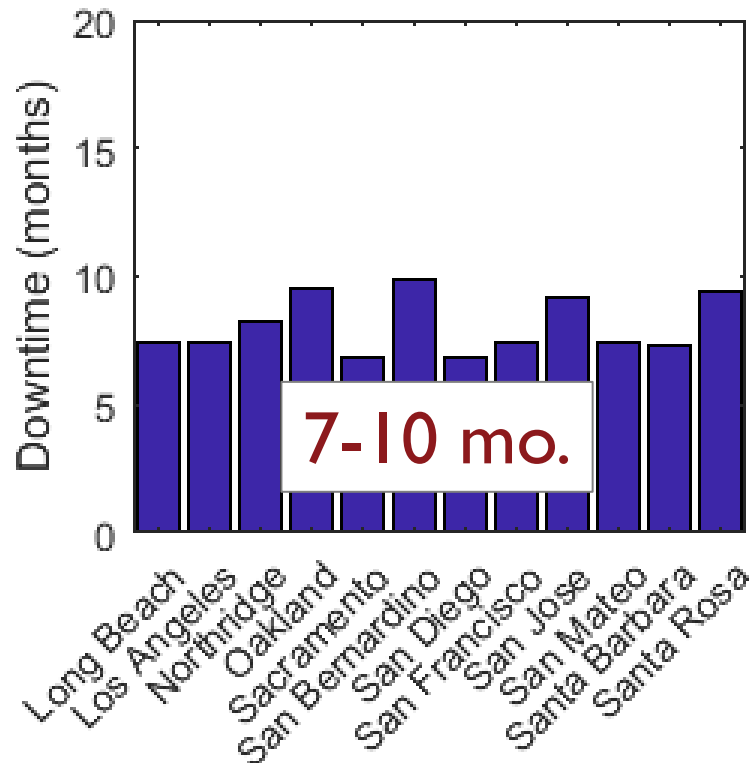


Design Event

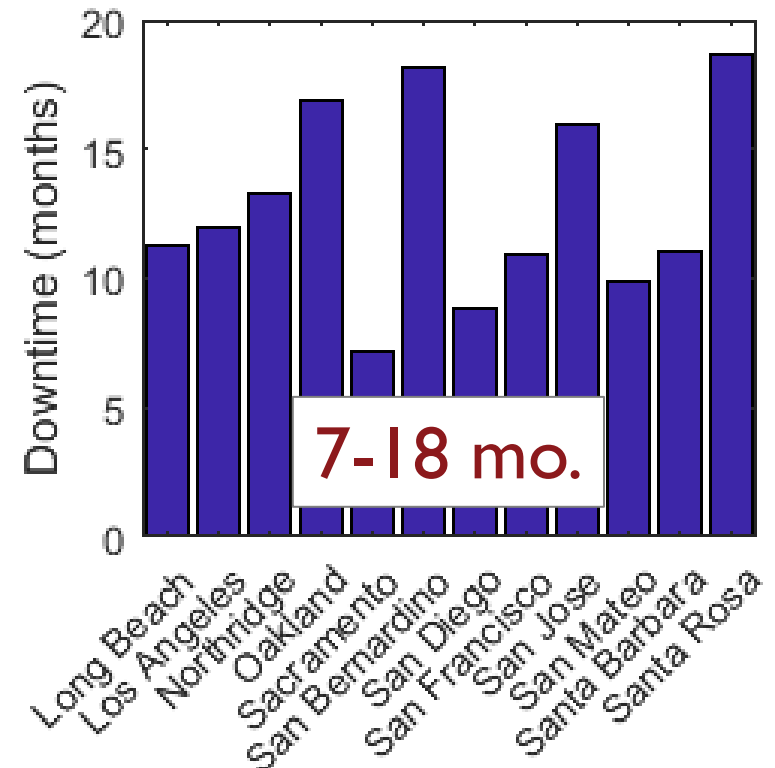


Rare Event

- 8-story office building
 - 12 CA cities



Design Event

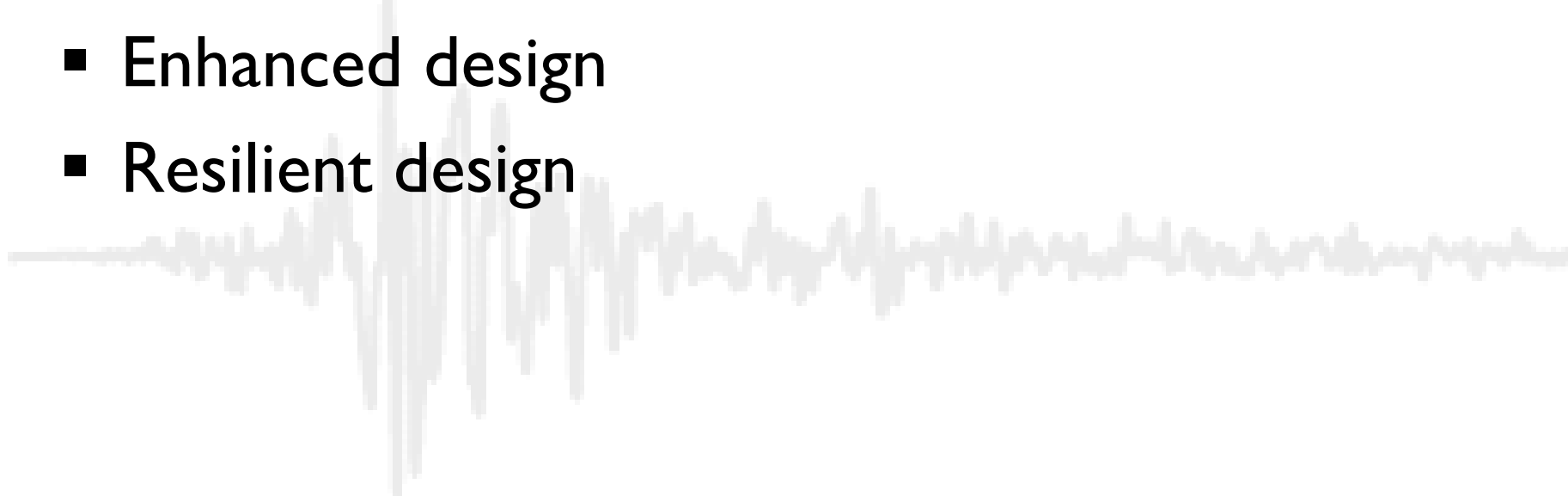


Rare Event

- Wide range of building types
 - Design Event
 - 5-25%
 - 6-12+ mo.
 - Rare Event
 - 10-80%
 - 1.5+ yrs.

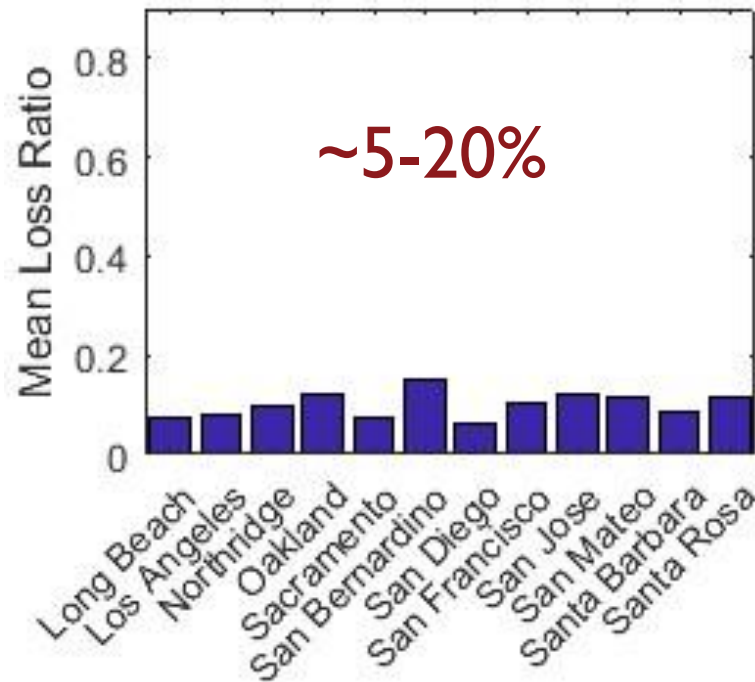
Safe but
disposable!



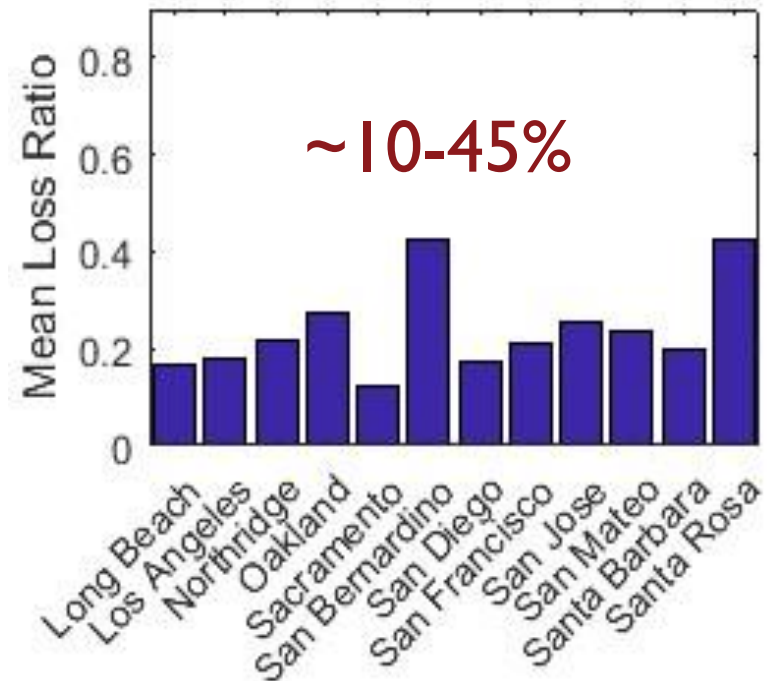
- Methods
 - FEMA P-58
 - REDI
 - 8 Story office building example
 - Enhanced design
 - Resilient design
- 

- Critical Facility - Risk Category IV
 - Seismic Importance Factor, $I_e = 1.5$
 - Component Importance Factor, $I_p = 1.5$
 - Drift Limit = 1%

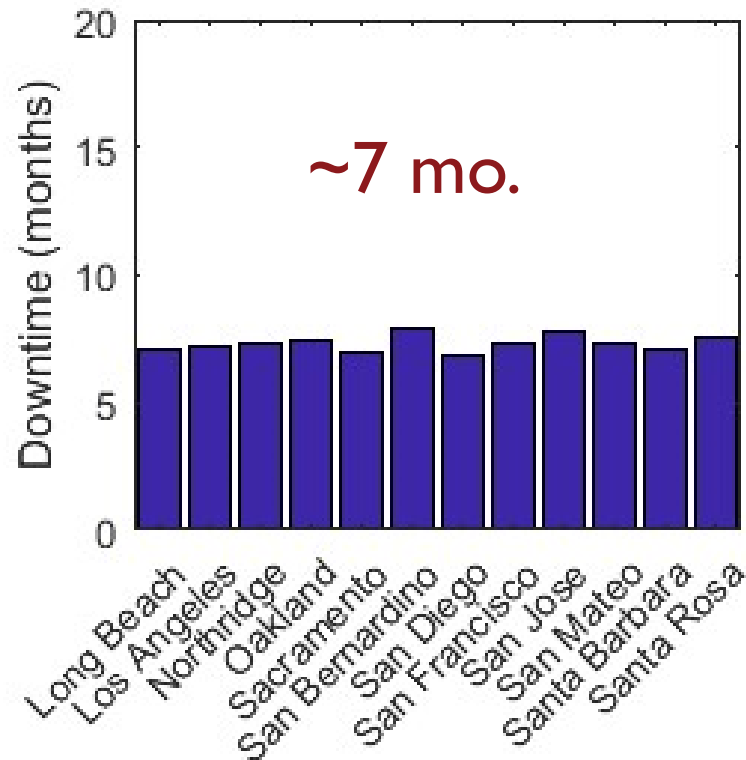
Remember: Building strength
is increased by I_e/R !



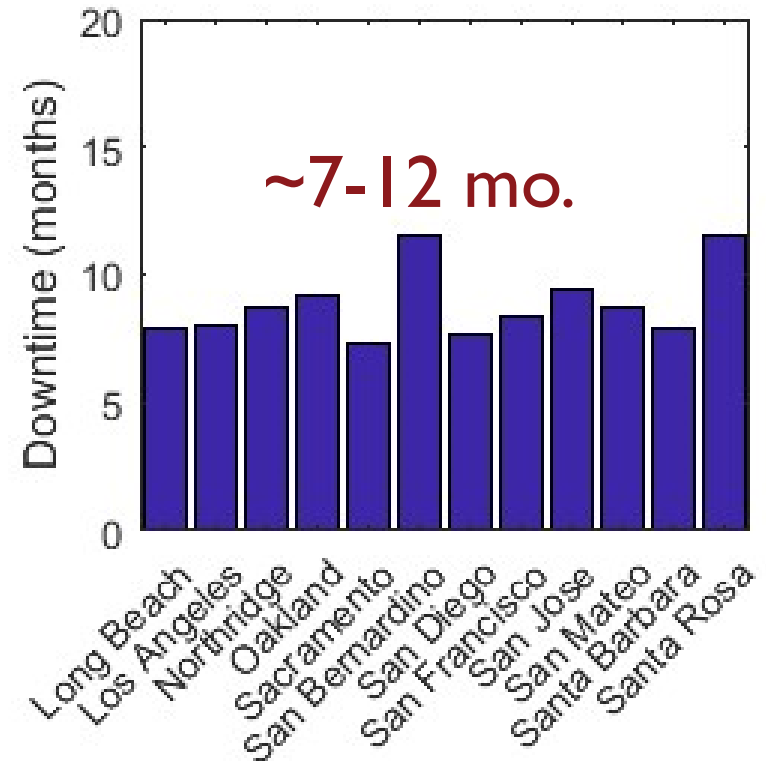
Design Event



Rare Event

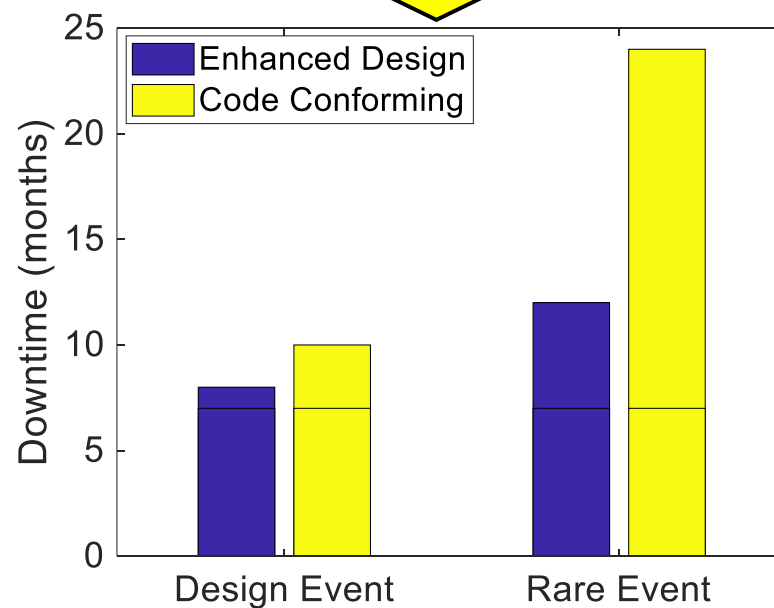
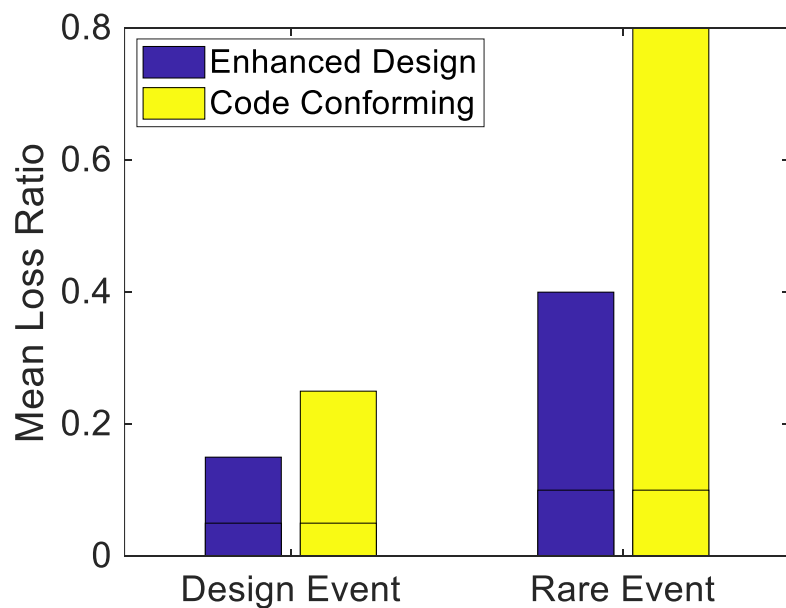
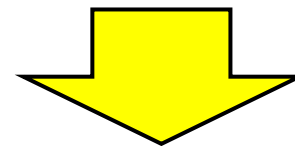


Design Event



Rare Event

Significant Downtime



- Methods
 - FEMA P-58
 - REDI
- 8-story office building example
- Enhanced design
- Resilient design

- Limit repair cost & downtime
 - Set specific performance goals
 - Assess where damage will occur
 - Strengthen/stiffen as needed
 - Iterate

- Project: Municipal office building
- Building: Design a 10-story RC Wall (coupled core), office occupancy
- Site: LA high-seismic, $S_{DS} = 1.1g$, $S_{DI} = 0.6g$.
- 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 assessment*.

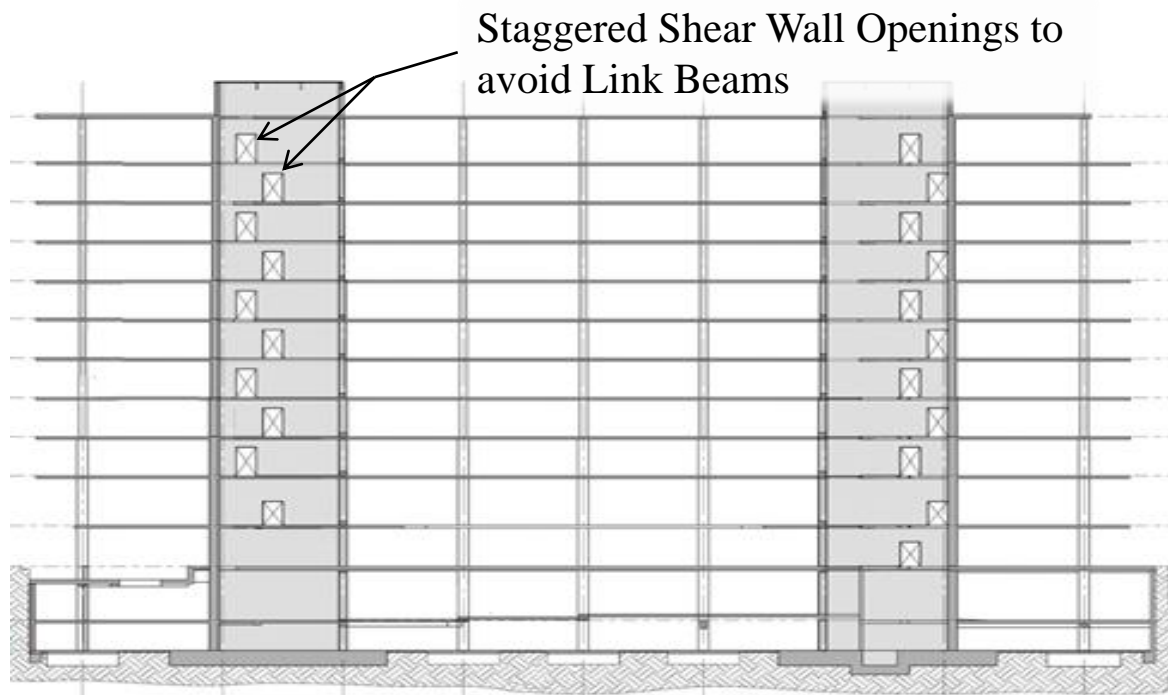
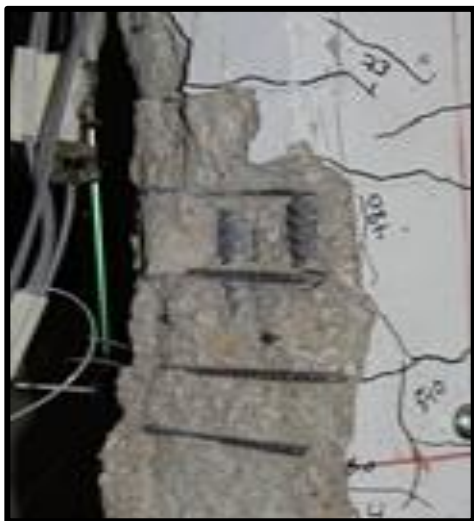


Figure Source: SOM/NYASE 2016 SEAOC presentation

- **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)

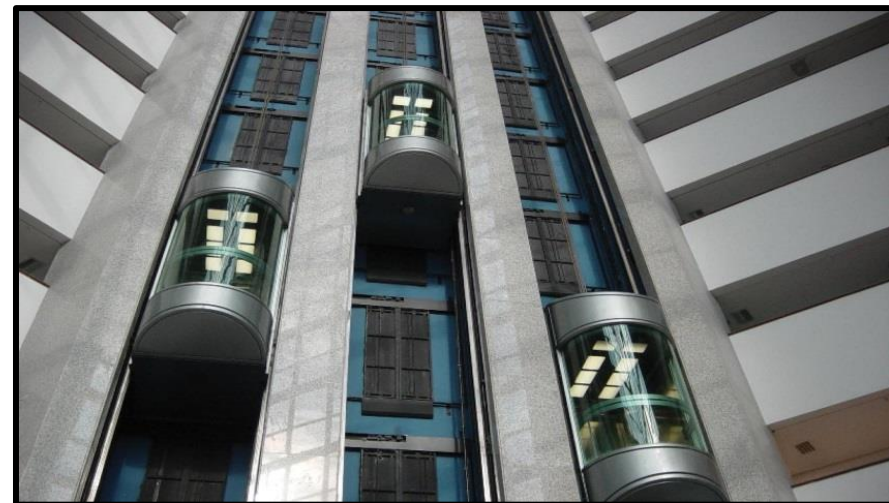


- **Step #2:** Design wall to be “essentially elastic” (very strong) and remove coupling beams (need NO DAMAGE THAT WILL REQUIRE REPAIR).



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

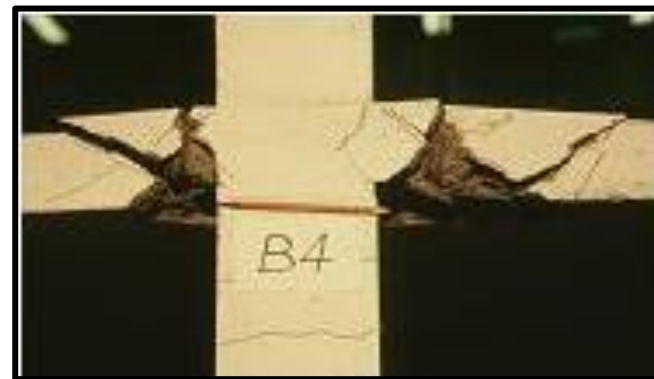
- Result for Steps #2-3:
 - Repair Cost = 5.5% [still 4-star]
 - Recovery Time = 2.5 months [still 3-star]
 - 1.0 month – slab-column connections
 - 1.5 months – partition walls



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



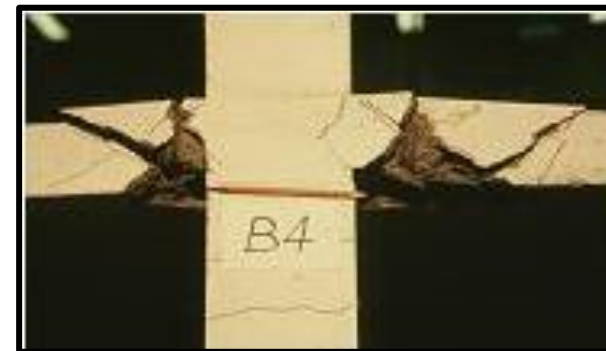
Step #6: Stiffen the building (longer walls, more coupling, etc.). Reduces the maximum drifts from around 1.4% to 1.0%.

- 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]



- **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.**



- **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).



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**.

