

STRUCTURAL ENGINEERING SUMMIT



FEMA P-58 for Seismic Risk Assessment

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Haselton Baker Research Group

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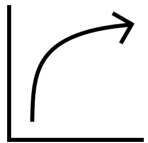
Presentation Outline



Introduction to Haselton Baker Risk Group, LLC



Background on Applications for Seismic Risk Assessment



Seismic Risk Assessment Methodologies



Comparison Study

Haselton Baker Risk Group, LLC



Creators of SP3-RiskModel

SP3 Team Where Research Meets Practice

- Research & Development with the Applied Technology Council (ATC)
- Advocates for Seismic Resilience in the Built Environment (BSSC, ASCE 7, and ASCE 41)
- Creators of Software Solutions for Seismic Risk Assessment
- Professional Consulting to Support Advanced Seismic Research Subjects

Applications for Seismic Risk Assessment

Design & Retrofit

New Construction and Seismic Retrofit Resilient Design

Commercial Real Estate Due Diligence (Buildings & Portfolios)

Seismic Risk Assessment and Property Resilience Assessment

Community Resilience Planning

FEMA Funding Grants (Benefit-Cost Analysis)

Insurance

Underwriting and Reinsurance

General Seismic Risk Assessment Metrics

FIGURE 1. BUILDING DAMAGEABILITY

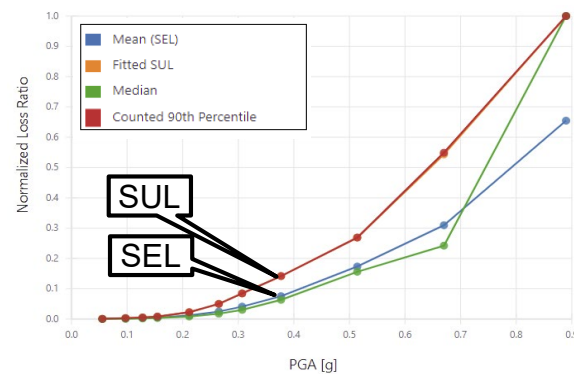


FIGURE 2. RECOVERY TIME

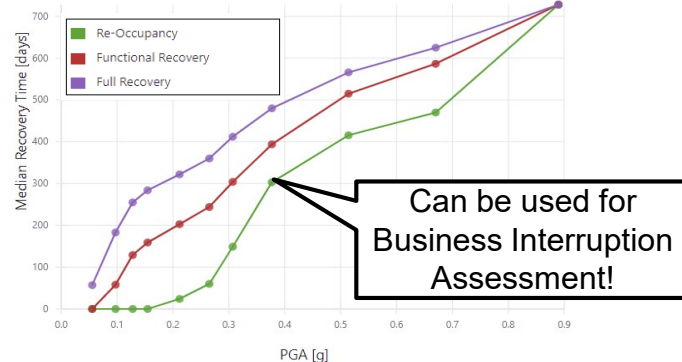


FIGURE 3. COMPONENT GROUP LOSSES

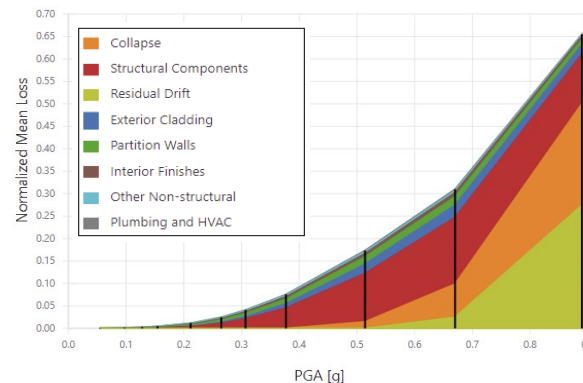


FIGURE 4. ANNUALIZED LOSSES

The expected annual loss for this building is: \$246,515.

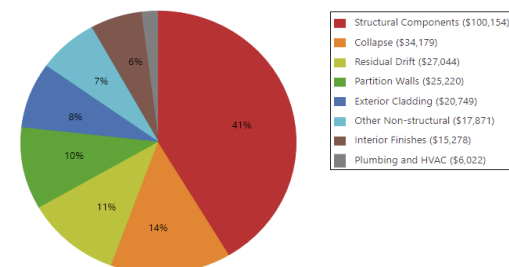


FIGURE 5. PORTFOLIO(REGIONAL) ANALYSIS

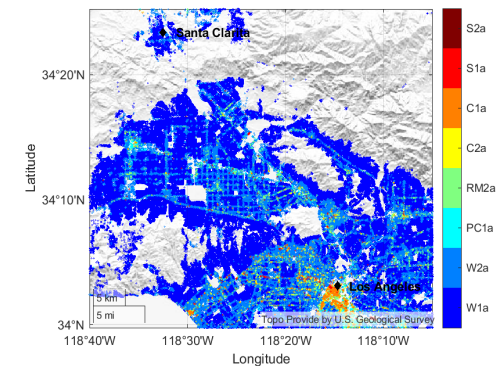
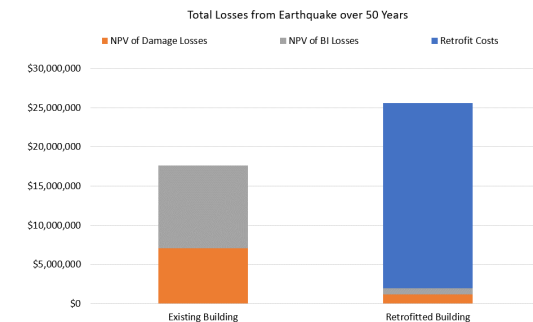


FIGURE 6. NET PRESENT VALUE

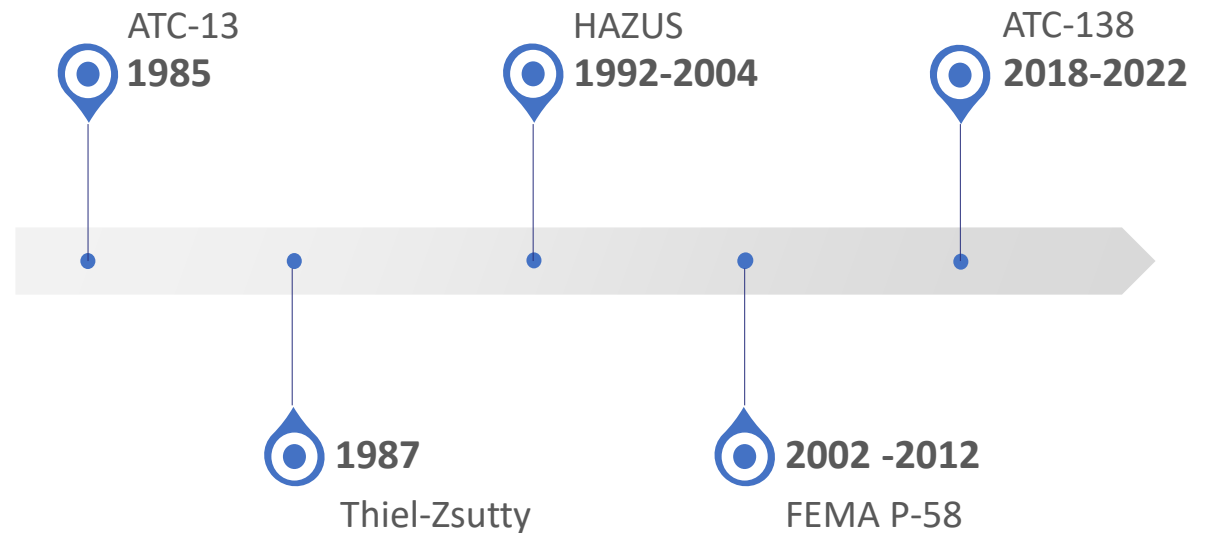


Evolution of Seismic Risk Assessment Methodology Leading to the Development of the FEMA P-58 Methodology

ATC-13 Method: Developed based on judgement of group of experts, based on earthquake experience up to 1985.

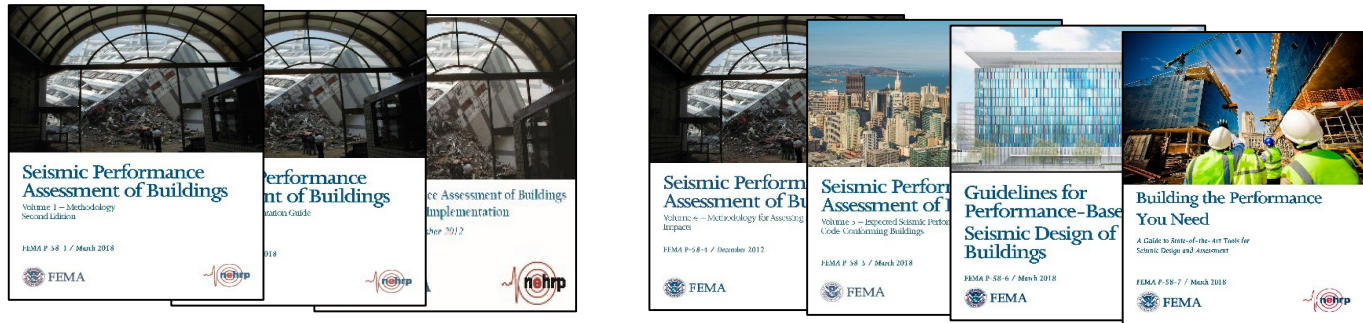
Thiel-Zsutty Method: Developed based on the ATC-13 Method and also a method for building classes and is not inherently building-specific.

HAZUS Method: Developed based on the ATC-13 Method and based a mix of historical data, previous research, and engineering judgment.



The FEMA P-58 Methodology

FEMA P-58 Method: FEMA P-58 was a ~15-year project, \$16M, and released in 2012 (updated in 2018) and provides a standardized method for loss prediction based on building-specific modeling using comprehensive database of structural and non-structural components.



ATC-138 (Functional Recovery) Method: The functional recovery methodology is based on the general methodology and recommended procedures described in the FEMA P-58; the methodology can be used to assess seismic performance in terms of the probable functional recovery time of individual buildings subjected to a damaging earthquake.

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Primary Inputs

*location,
construction year,
structural system,
occupancy, etc.*

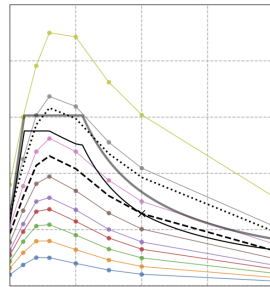
Building Layout

*building
geometric
layout and
square footage,
etc.*

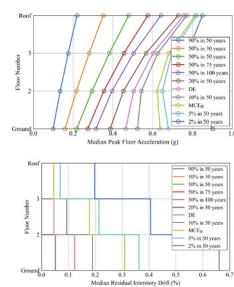
Building Design & Behavior Modifiers

*Level of detailing,
design
requirements,
irregularities,
deficiency
checklist*

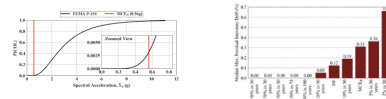
Seismic Hazard Response Spectra



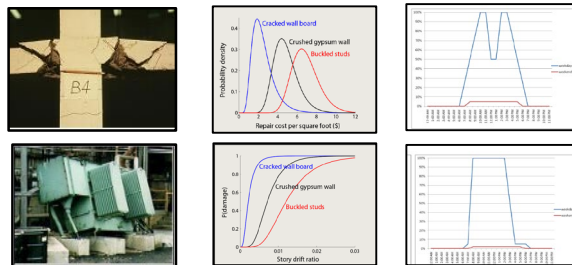
Structural Responses Demand Parameters



Collapse & Residual Drift



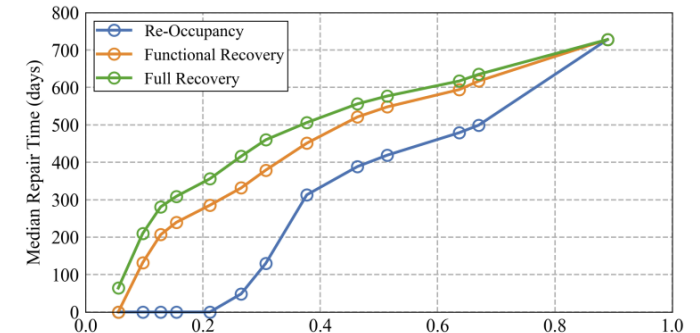
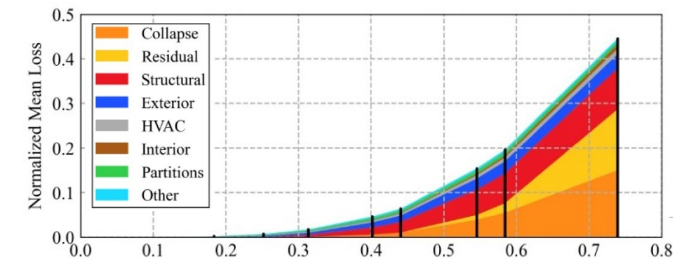
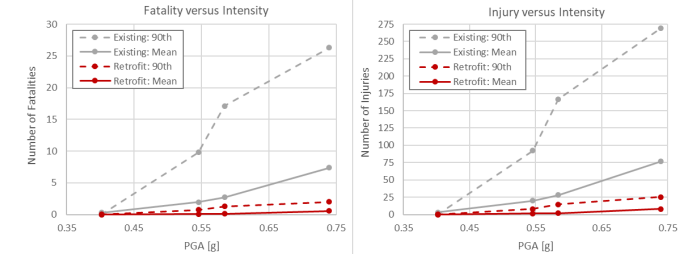
Building Performance Model Population, Fragilities and Cost Functions



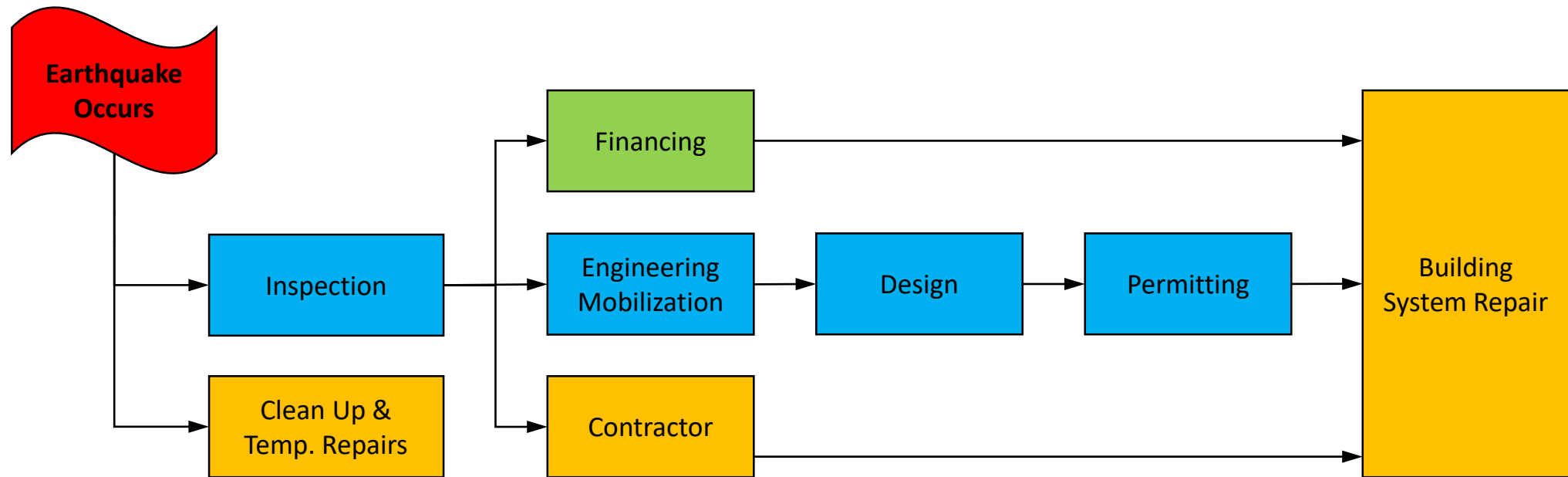
Aggregate Consequences Monte-Carlo Simulation

Recovery
Time Options
Impedance
and
Functional
Recovery
Options

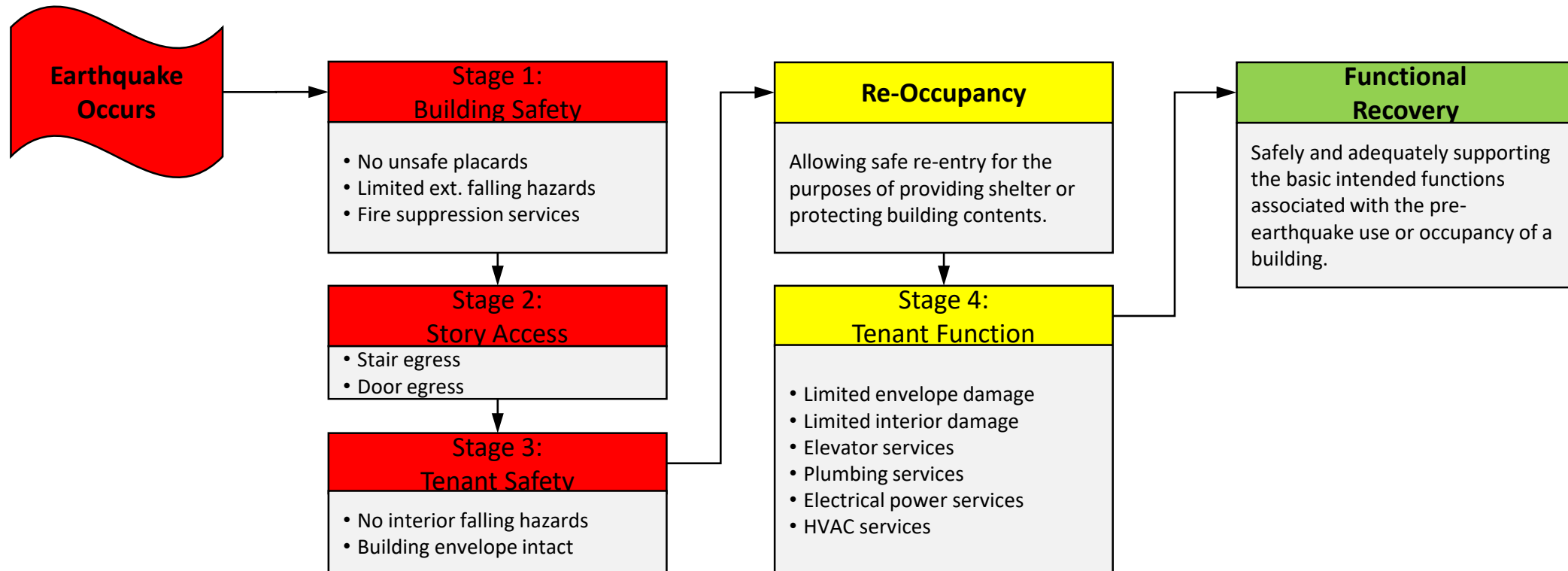
Risk Analysis Results Safety, Damage & Recovery



Recovery Time Modeling

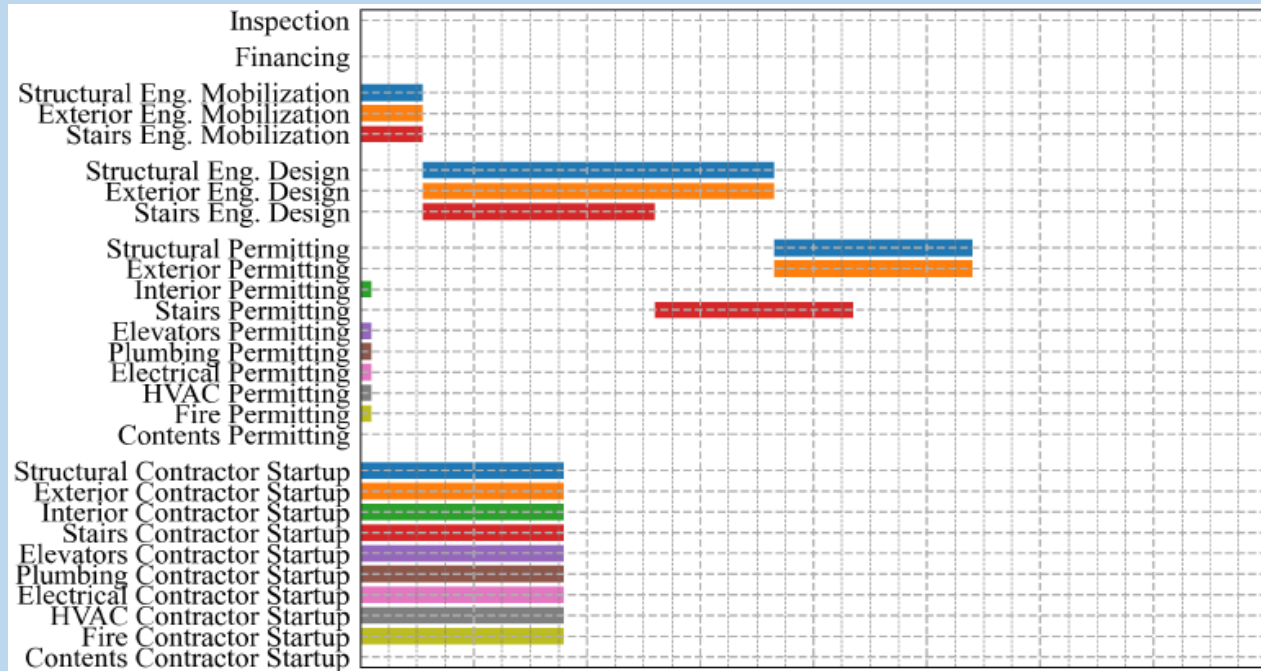


ATC-138 – Reoccupancy and Functional Recovery Assessment

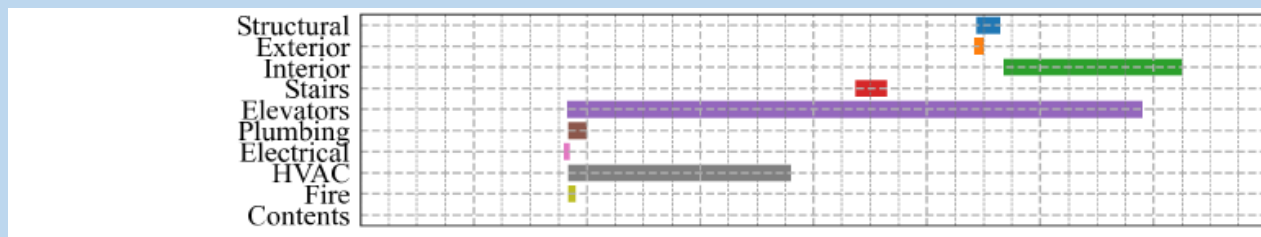


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BUILDING RECOVERY – IMPEDING TIME



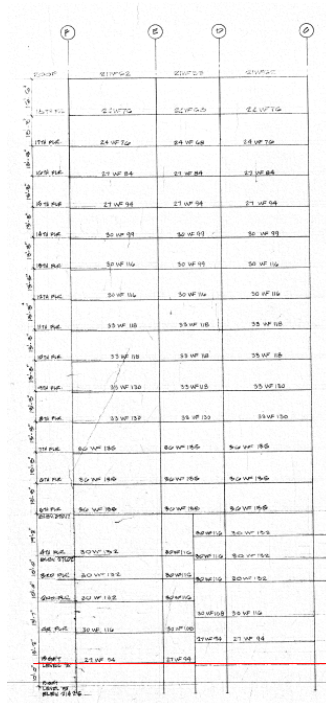
BUILDING RECOVERY – REPAIR TIME



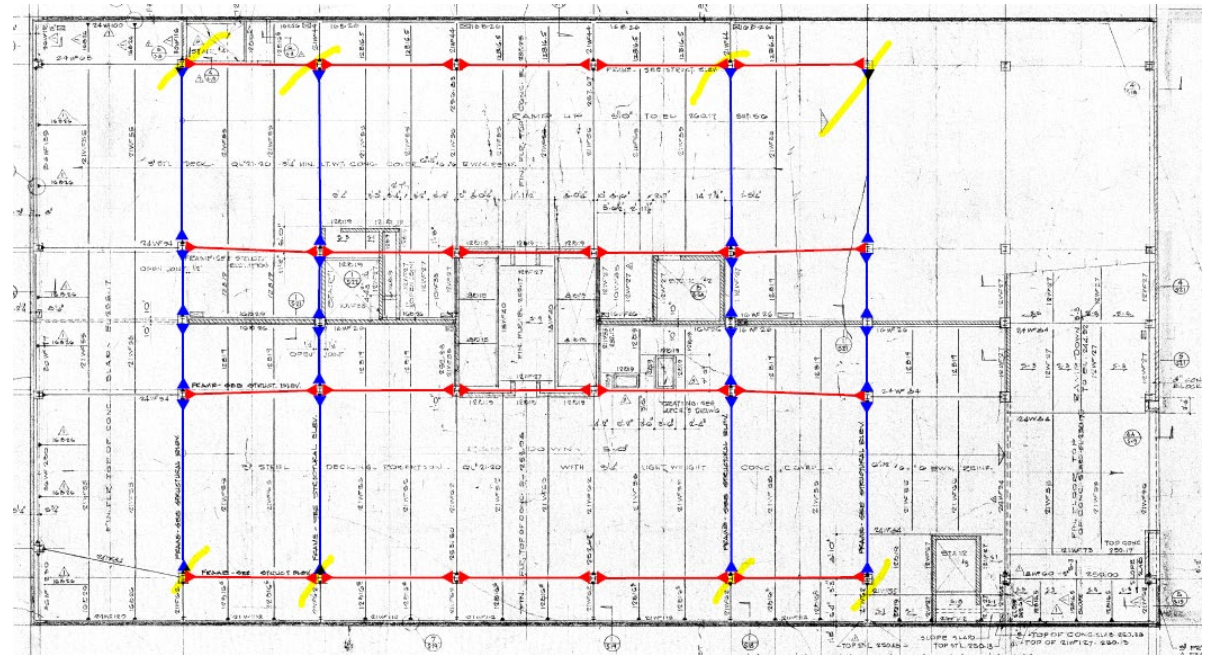
Recovery Time Modeling

- Recovery Time includes both impedance time and repair time
- Fault-tree logic that provides sequencing of impedance and repairs
- Building-specific customization for functional recovery requirements

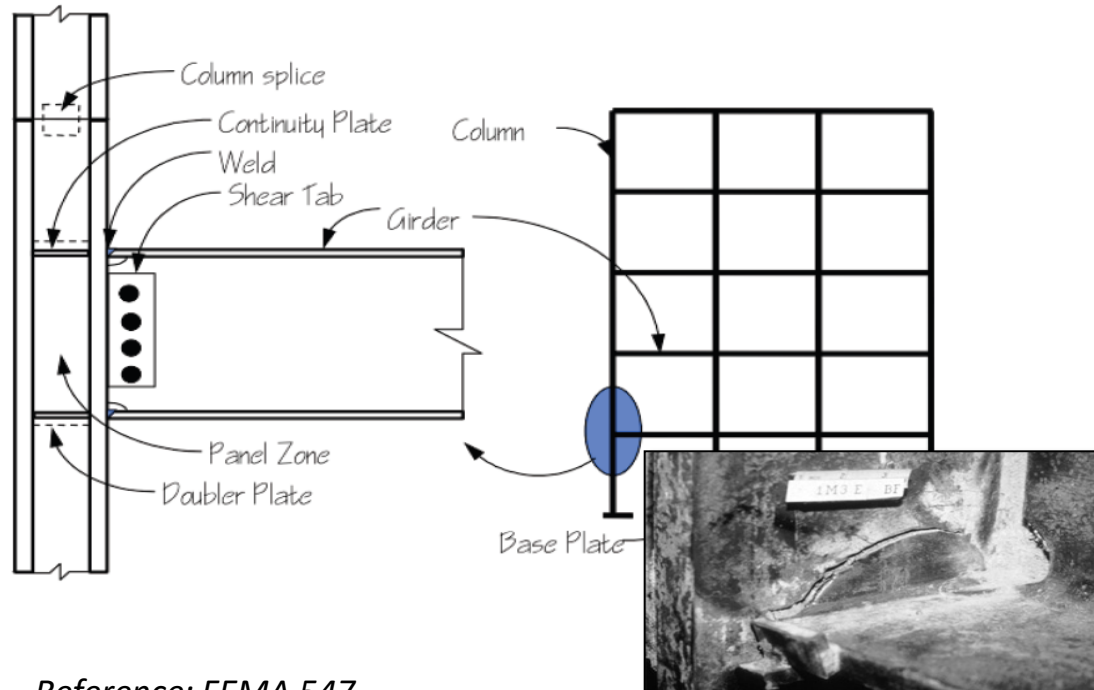
18-story PNMF frame in Los Angeles built in 1973



	P	D	P	D
18th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
17th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
16th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
15th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
14th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
13th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
12th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
11th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
10th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
9th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
8th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
7th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
6th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
5th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
4th FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
3rd FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
2nd FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"
1st FLOOR	21' 0" 00"	21' 0" 00"	21' 0" 00"	21' 0" 00"



18-story PNMF frame in Los Angeles built in 1973



Reference: FEMA 547

PNMF – Thiel Zsutty Methodology



$$\mathbf{PML (SEL) = 0.554 (b \ m \ s) \ a^{0.630}}$$

a = Peak Ground Acceleration (PGA)

s = Site Soil Coefficient

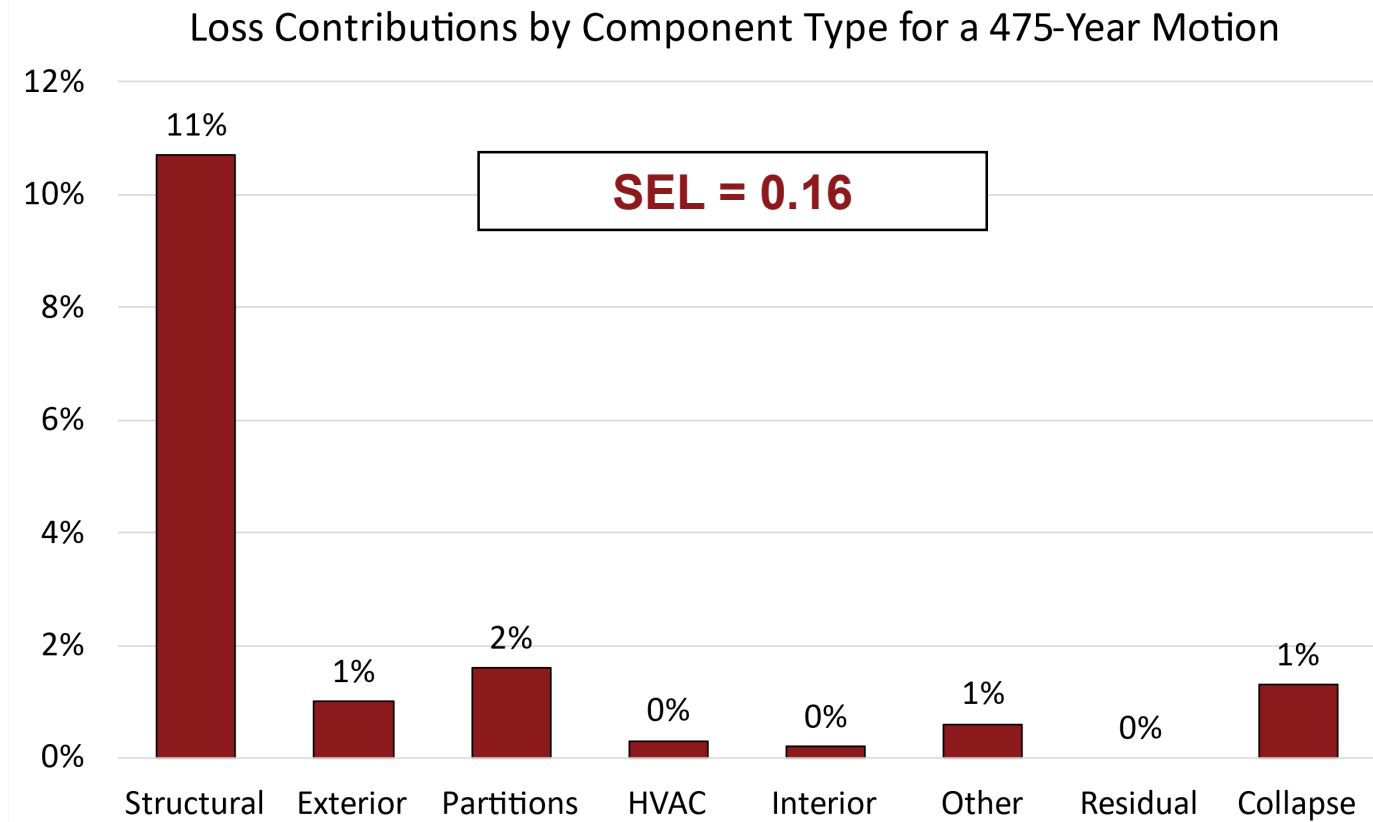
m = Spectral Modification Parameter

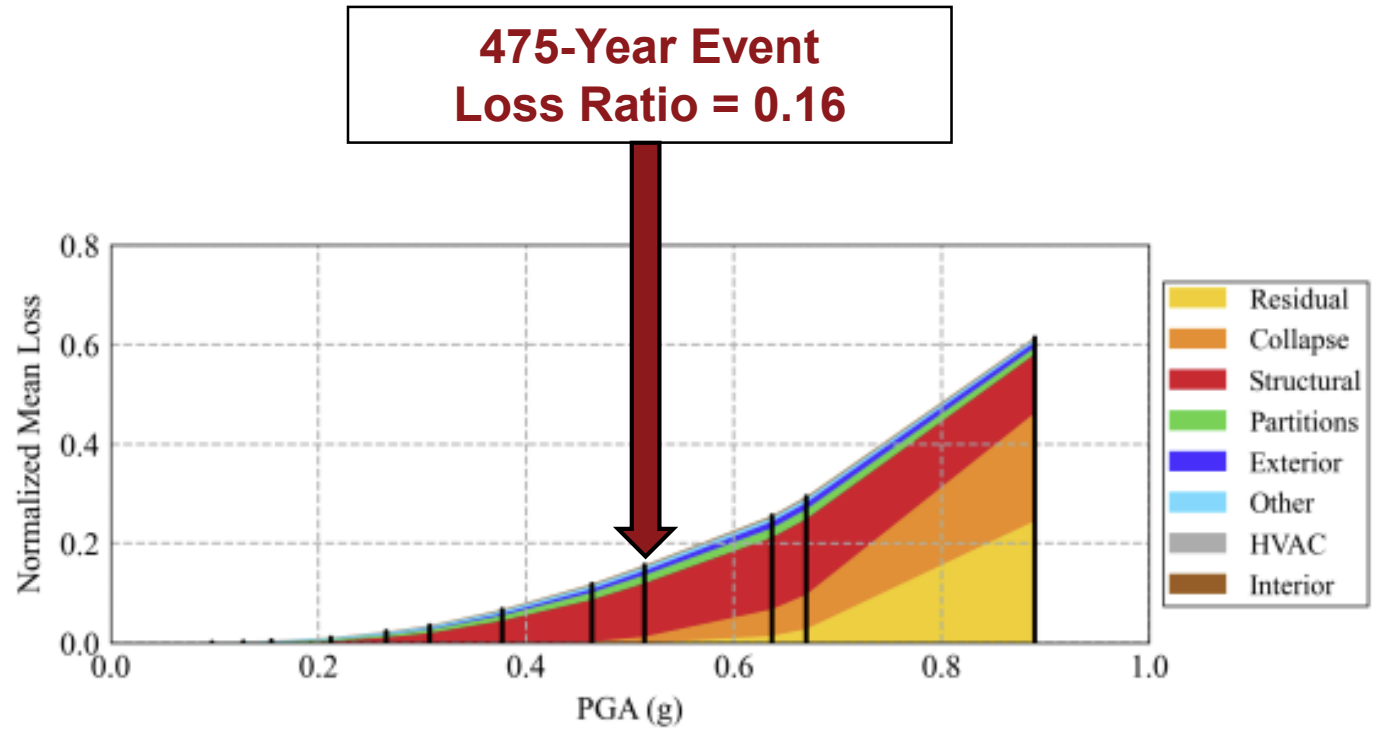
b = Building Vulnerability Parameter (Based on Table of structural system classes)

$$\mathbf{SEL = 0.21 = 0.554 (0.41 * 1.0 * 1.4) \ 0.51^{0.63}}$$

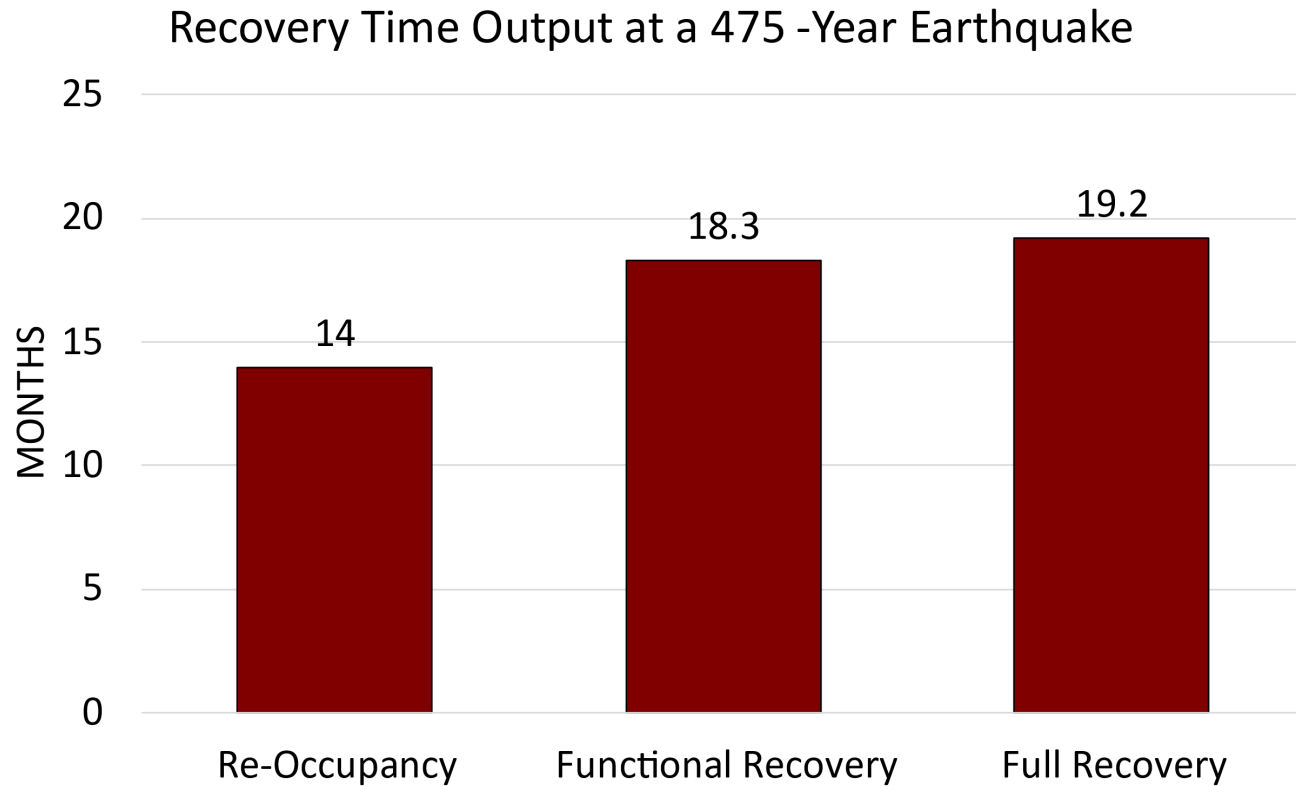
Good back of the napkin check to do!!!

PNMF – Damageability at 475-Year Return Period





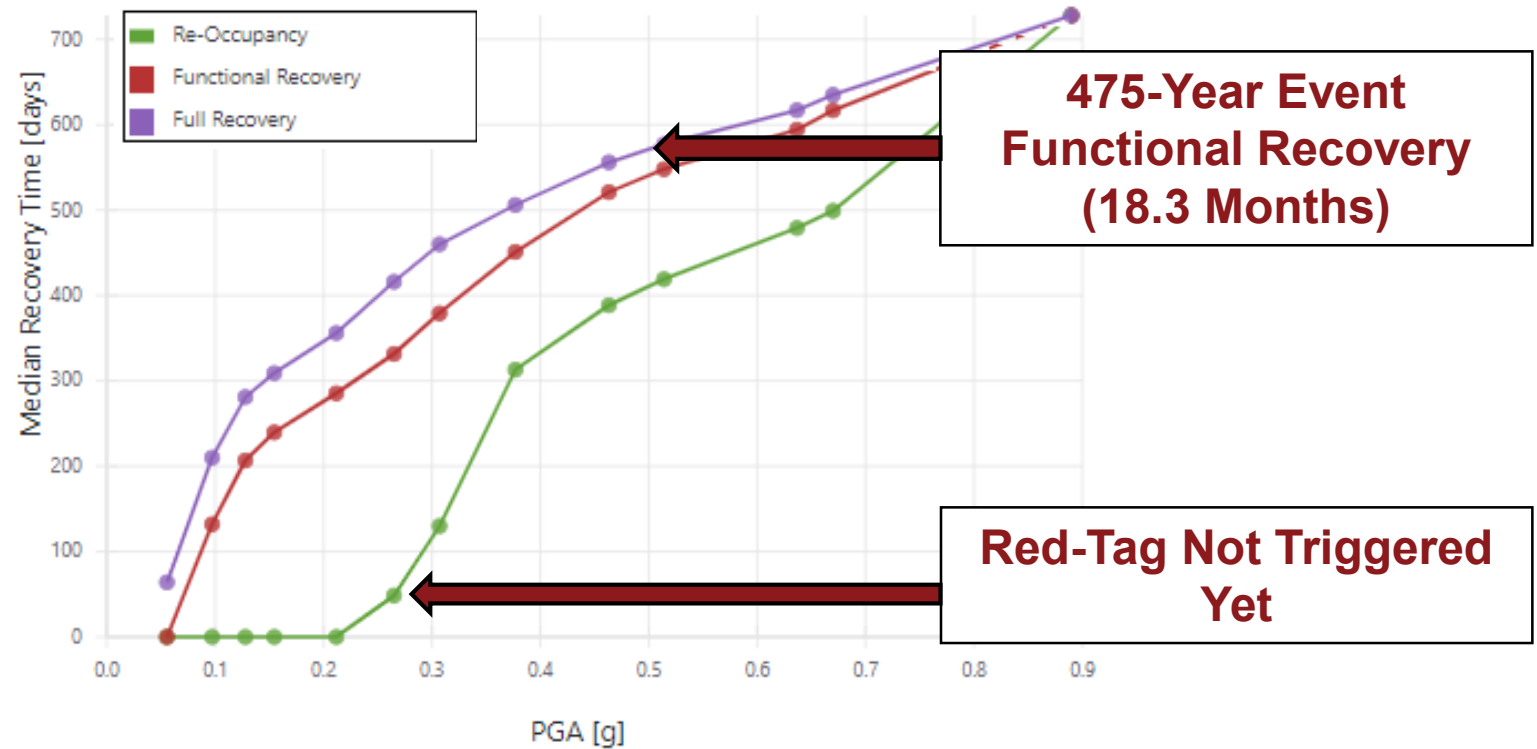
PNMF – Recovery Time at 475-Year Return Period



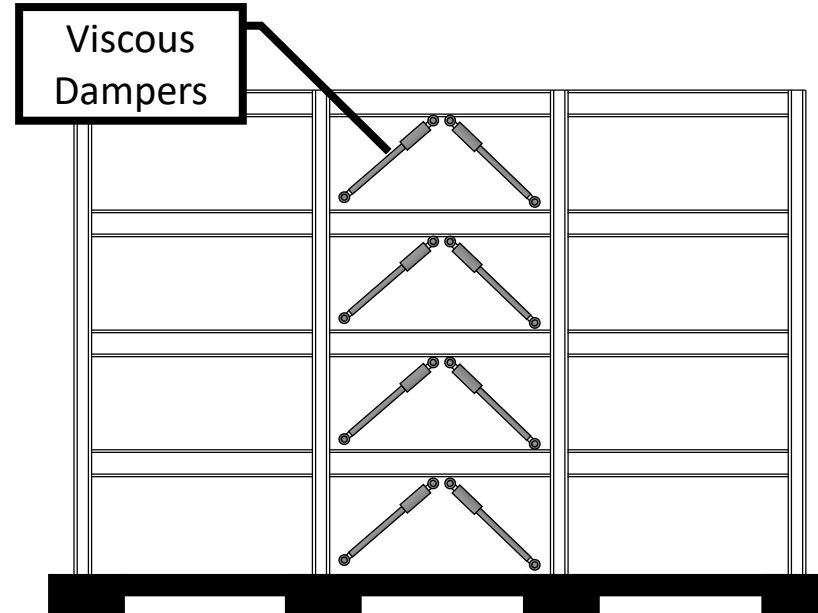
PNMF – Recovery Time Vulnerability



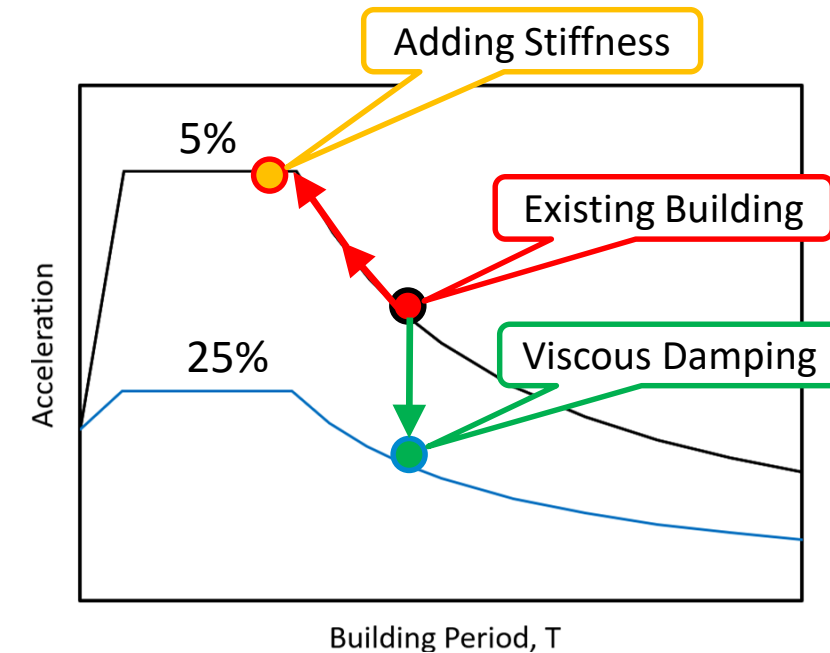
ATC-138 Recovery Time (Beta) (with selected impeding factors) ?



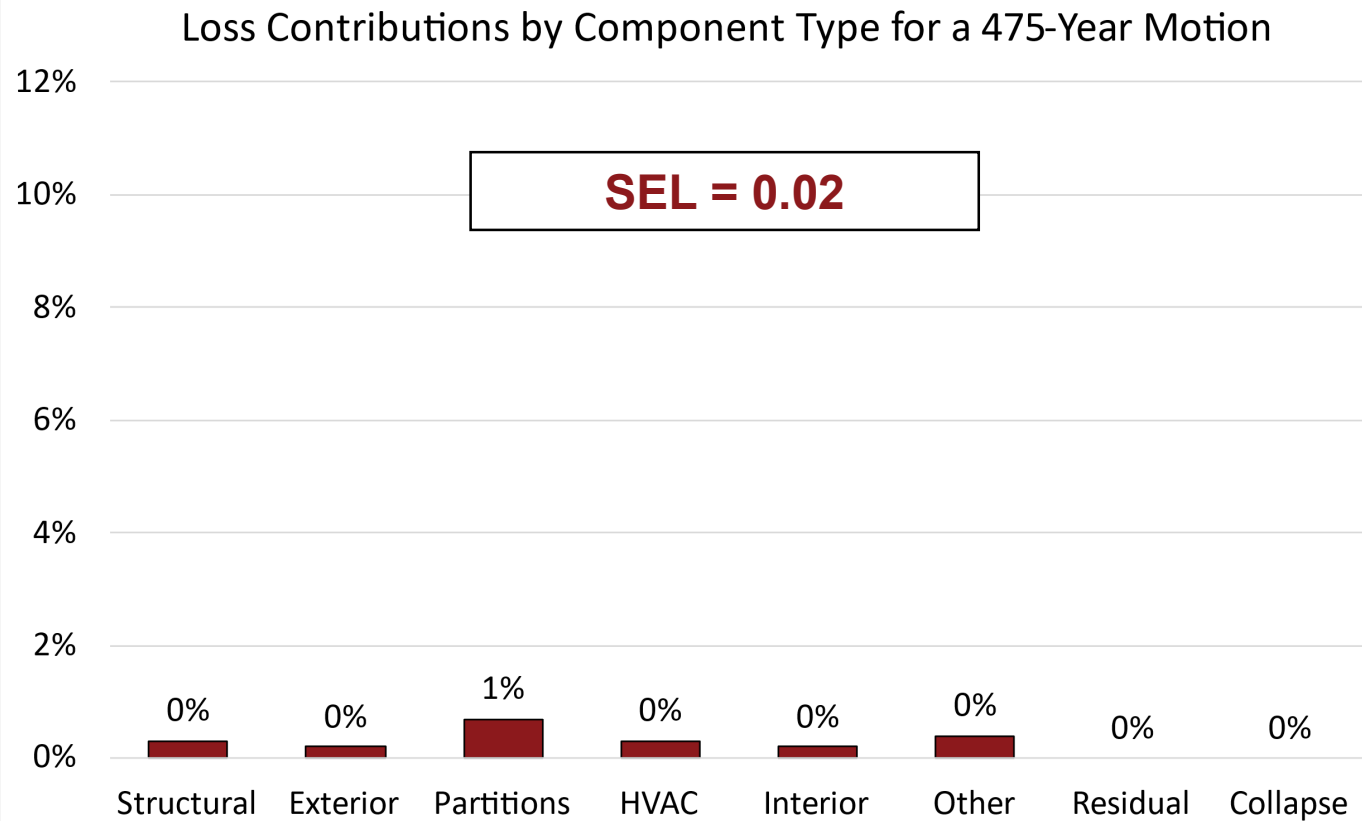
Seismic Retrofit for 18-story PNMF frame in Los Angeles built in 1973

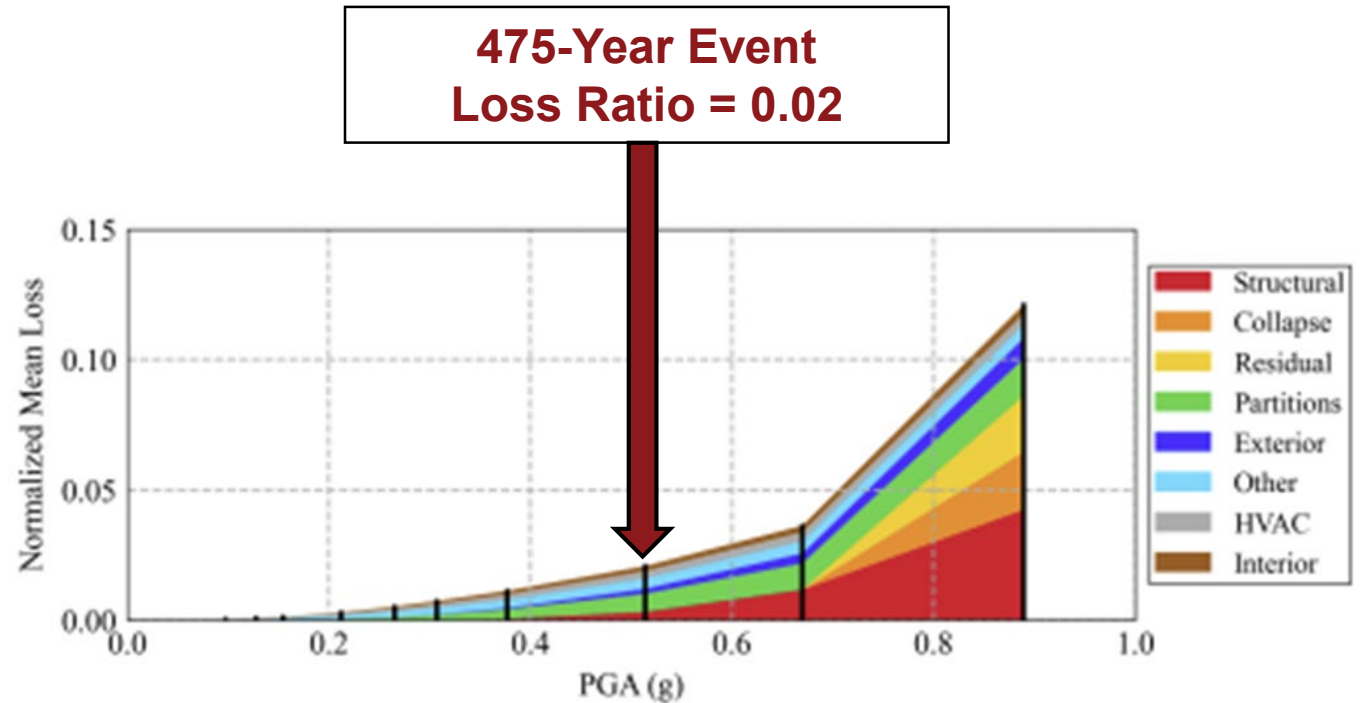


←→
Damper Base Shear Relatively Small in Comparison with Stiff Systems

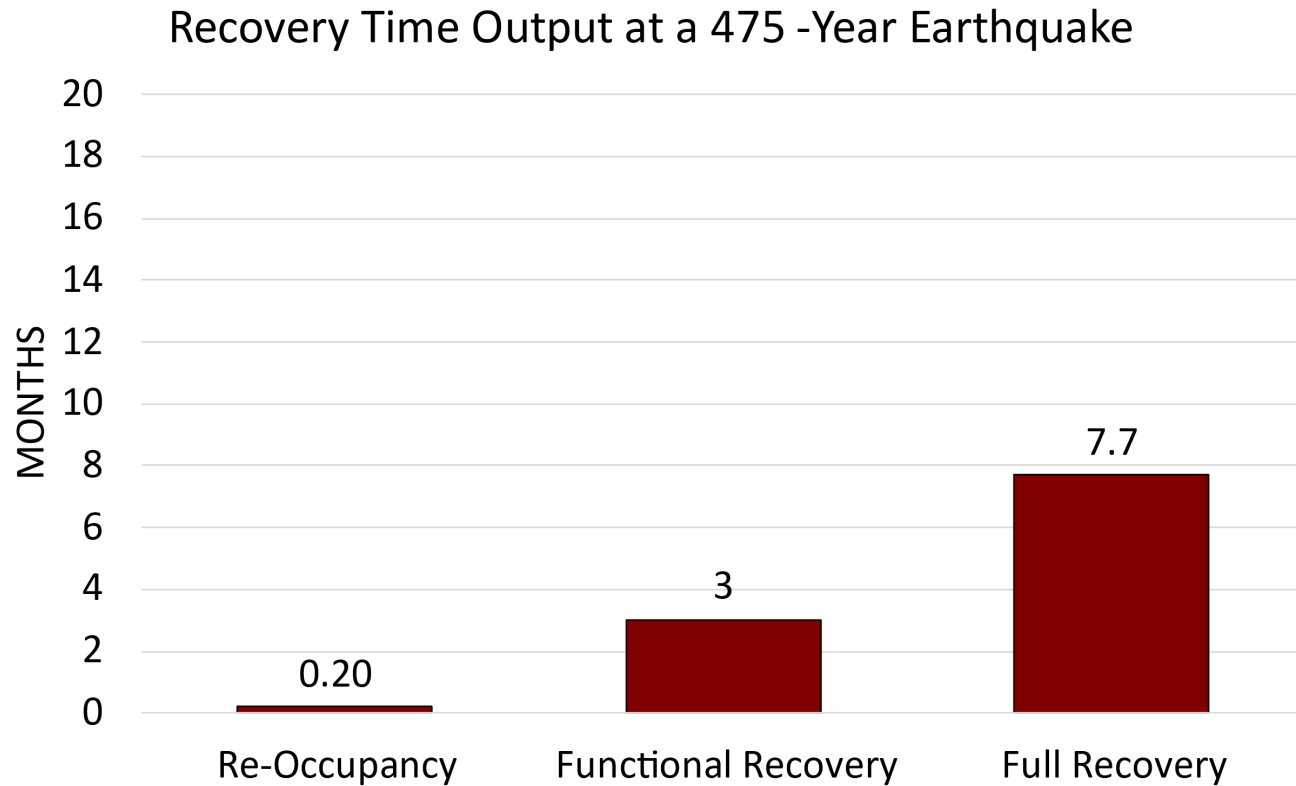


Seismic Retrofit of PNMF – Damageability at 475-Year Return Period

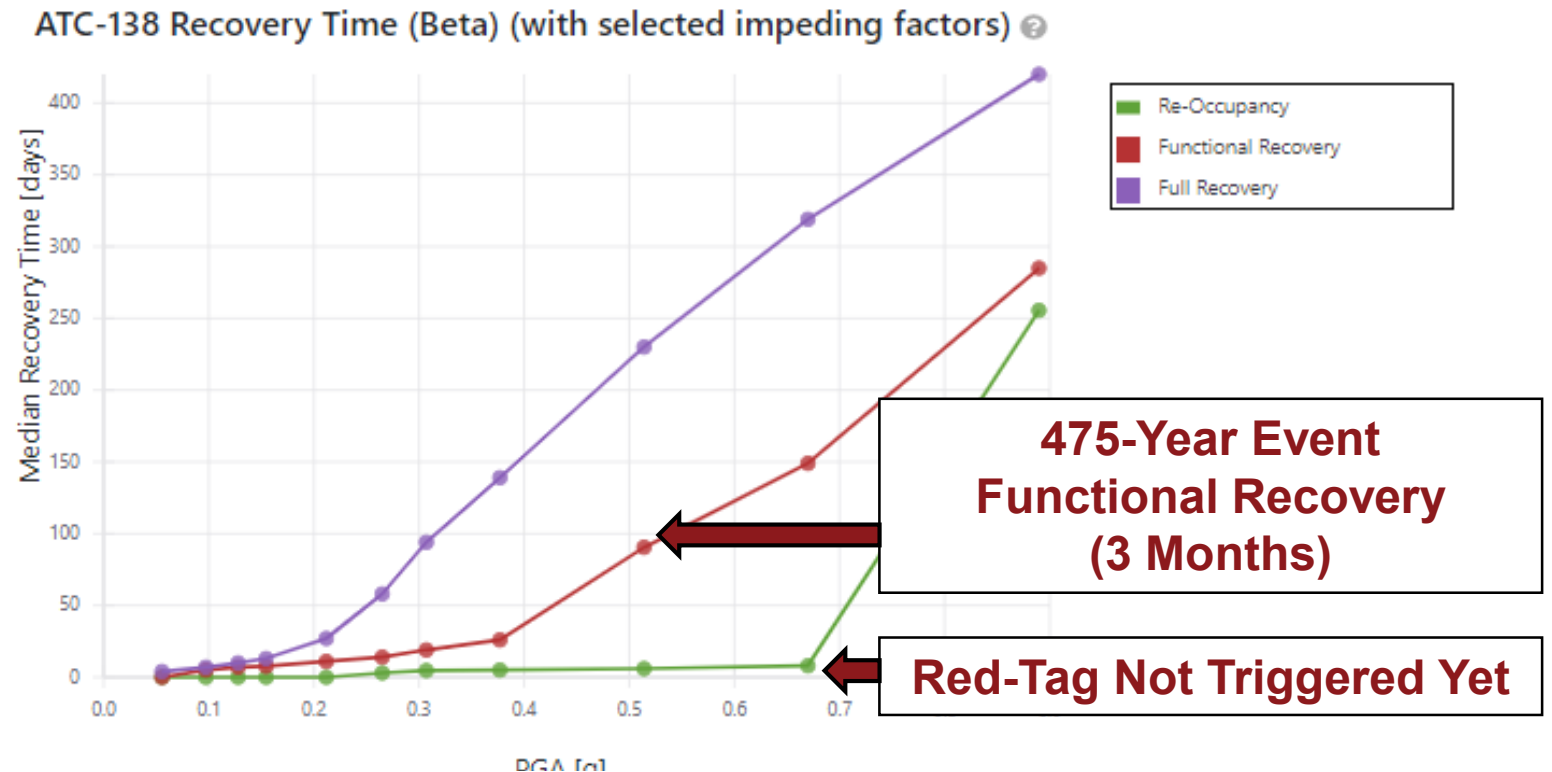




Seismic Retrofit of PNMF – Recovery Time at 475-Year Return Period



Seismic Retrofit of PNMF – Recovery Time Vulnerability



Bin Name	Building Type	Occupancy Type
Wood Light Frame	W2a	Multi-Unit Residential
Wood Light Frame - SS Retrofit	W2a	Multi-Unit Residential
Tilt-Up	PC1a	Warehouse
Tilt-Up - Anchorage Retrofit	PC1a	Warehouse
RC Shear Wall	C2a	Commercial
RC Shear Wall w/ RC Frame	C2b	Commercial
RC Shear Wall w/ Coupling Beams	C2c	Commercial
RC Shear Wall w/ S Frame	S4a	Commercial
RC Moment Frame	C1b	Commercial
NDCMF - FRP Retrofit	C1b	Commercial
BRBF	S2e	Commercial
SCBF	S2a	Commercial
SMF - Post 1994	S1a	Commercial
PNMF - Pre 1995	S1b	Commercial
PNMF - Pre 1995 - Conn. Retrofit	S1b	Commercial

Seismic Risk Assessment Methodology Comparison

- Various building structural systems are compared using Thiel Zsuty and FEMA P-58 Method
- Highlight key differences

Pre-Northridge Moment Frames (PNMF)

- High, Moderate, and Low Seismic –Site Class D and B/C
- Design Code Years: 1968, 1973, 1985
- Number of Stories: 2, 4, 8, 12, 20, 40
- Occupancy: Commercial
- Aspect Ratio: 1, 2

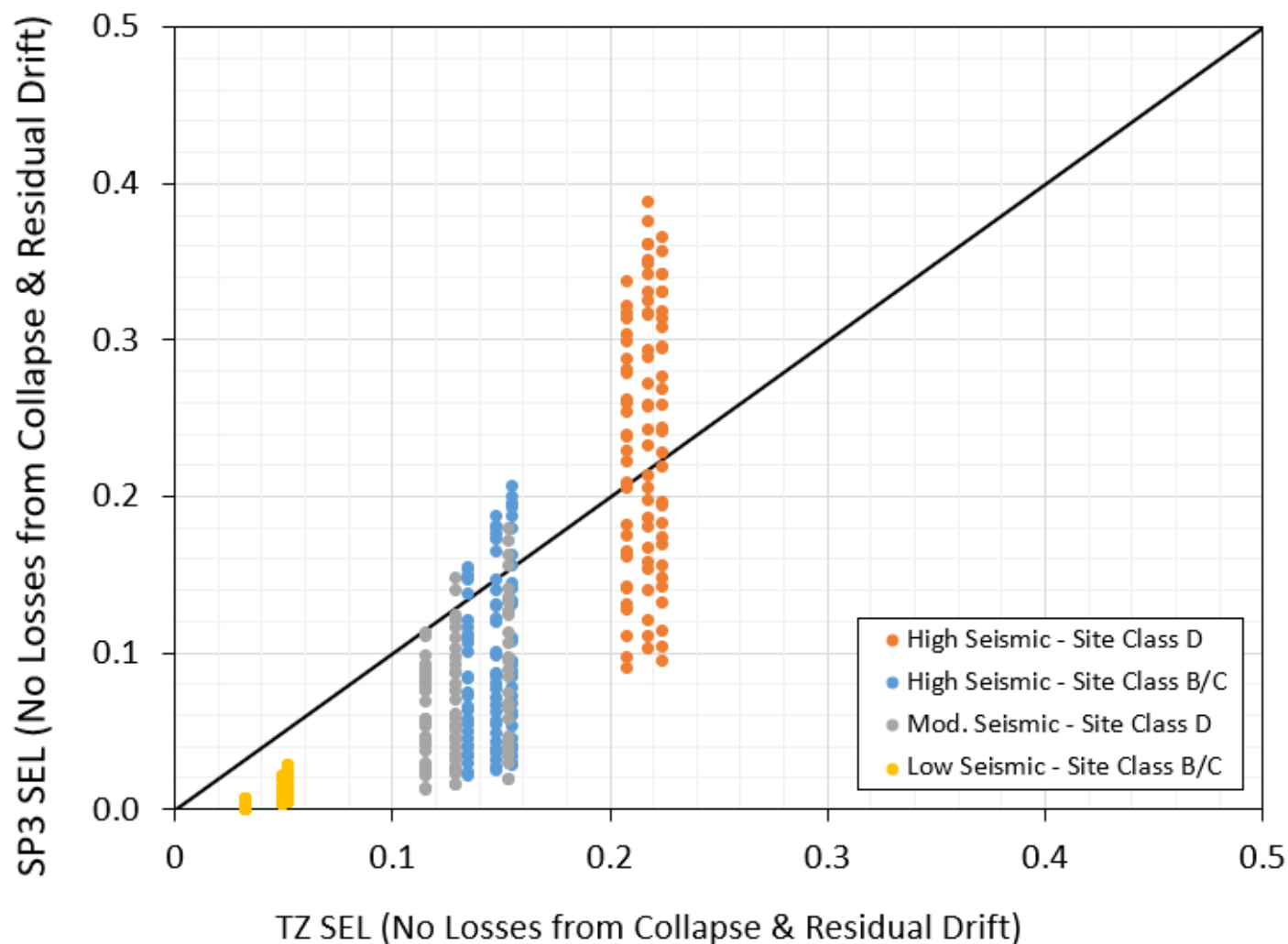
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Pre-Northridge Moment Frames

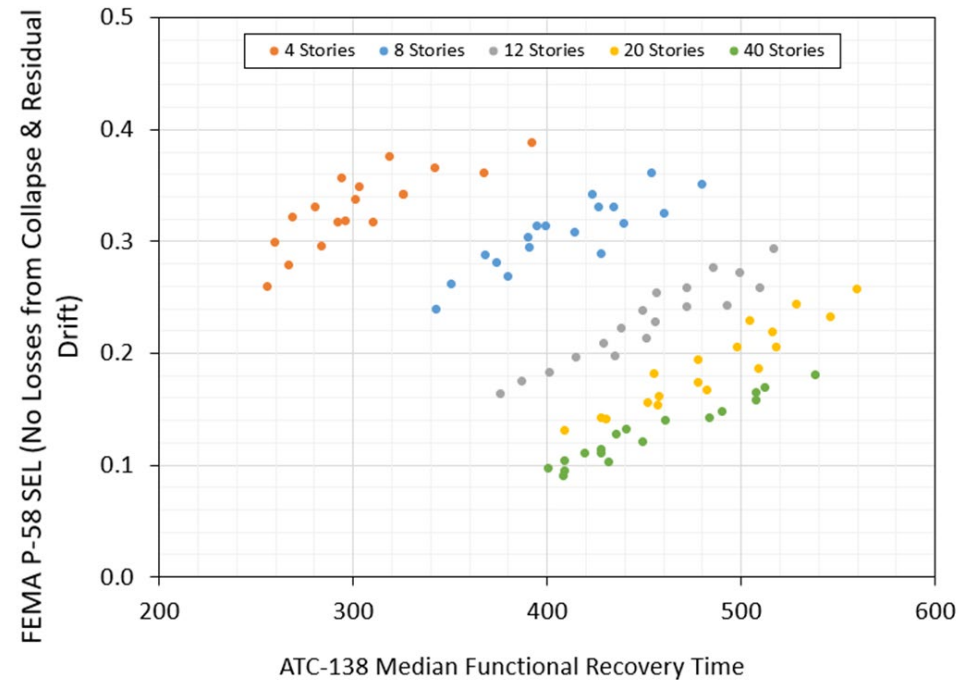
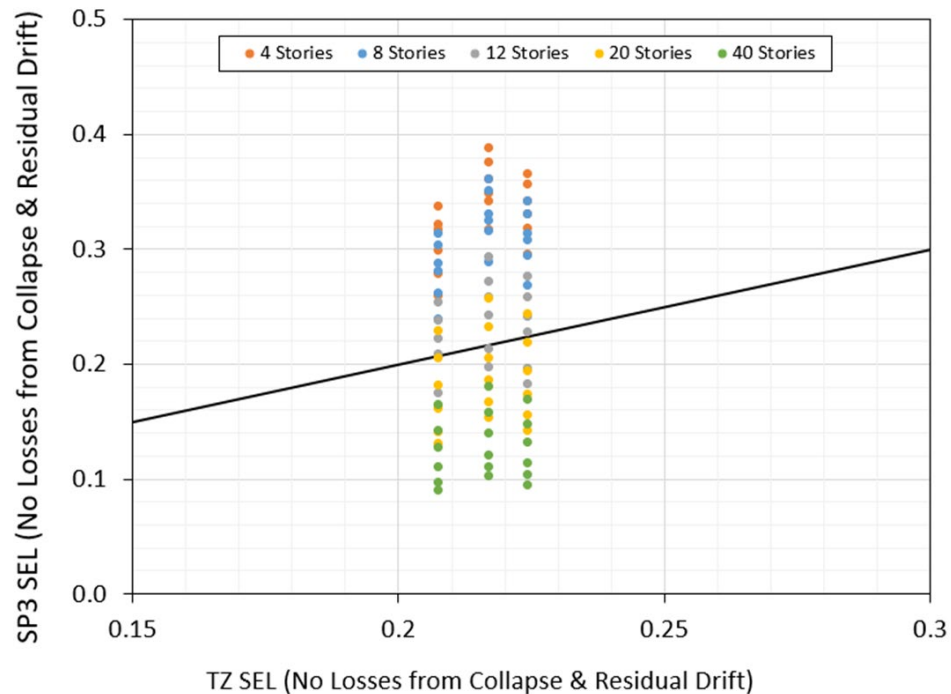
Vertical columns of dots are building classes as at a specific location.

The “spread” of answers from FEMA P-58 is due to the building-specific characteristics that are captured, such as number of stories, building strength, and occupancy type.



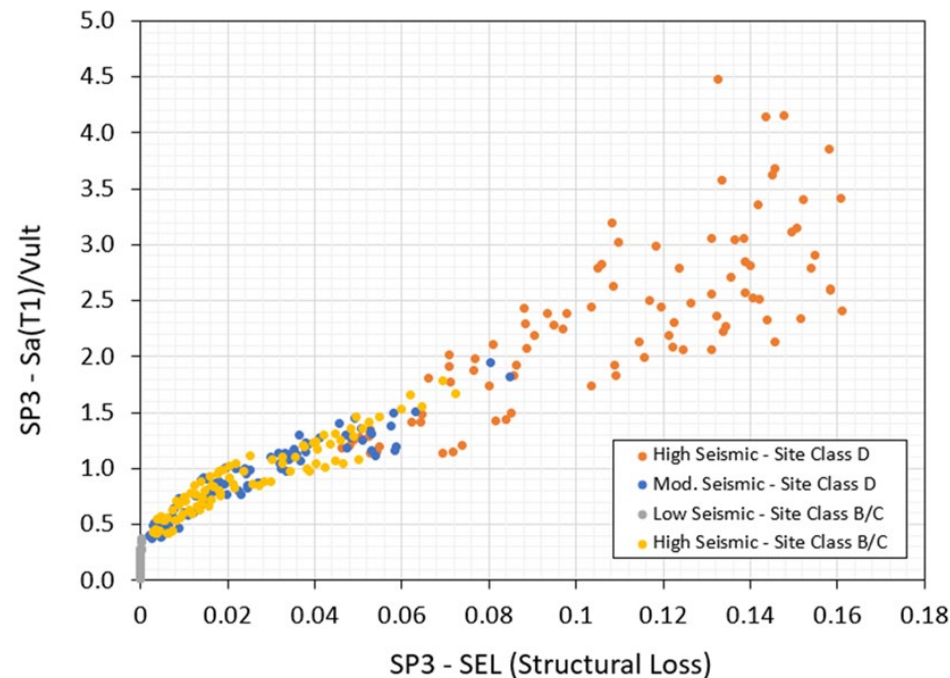
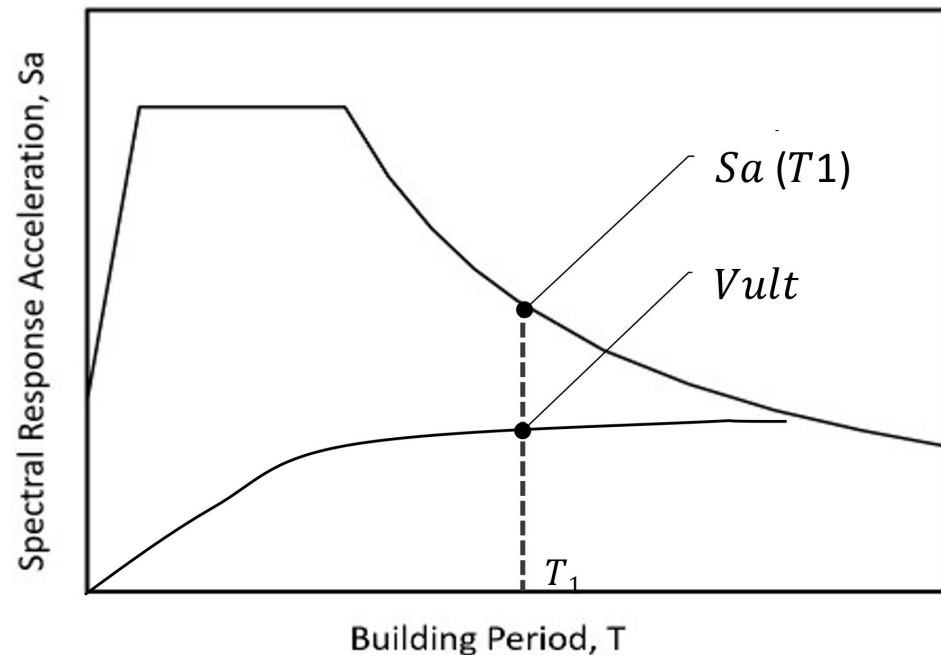
Zoomed in on Site Class D and Segmented by Number of Stories

- Demonstrates building-specific characteristics of story height, also correlates to building strength.



Building-Specific Characteristics

- In this graph you can visualize the trend in which structural strength influences structural loss. $S_a(T_1)/V_{ult}$ can be utilized as an approximation of global ductility demand.

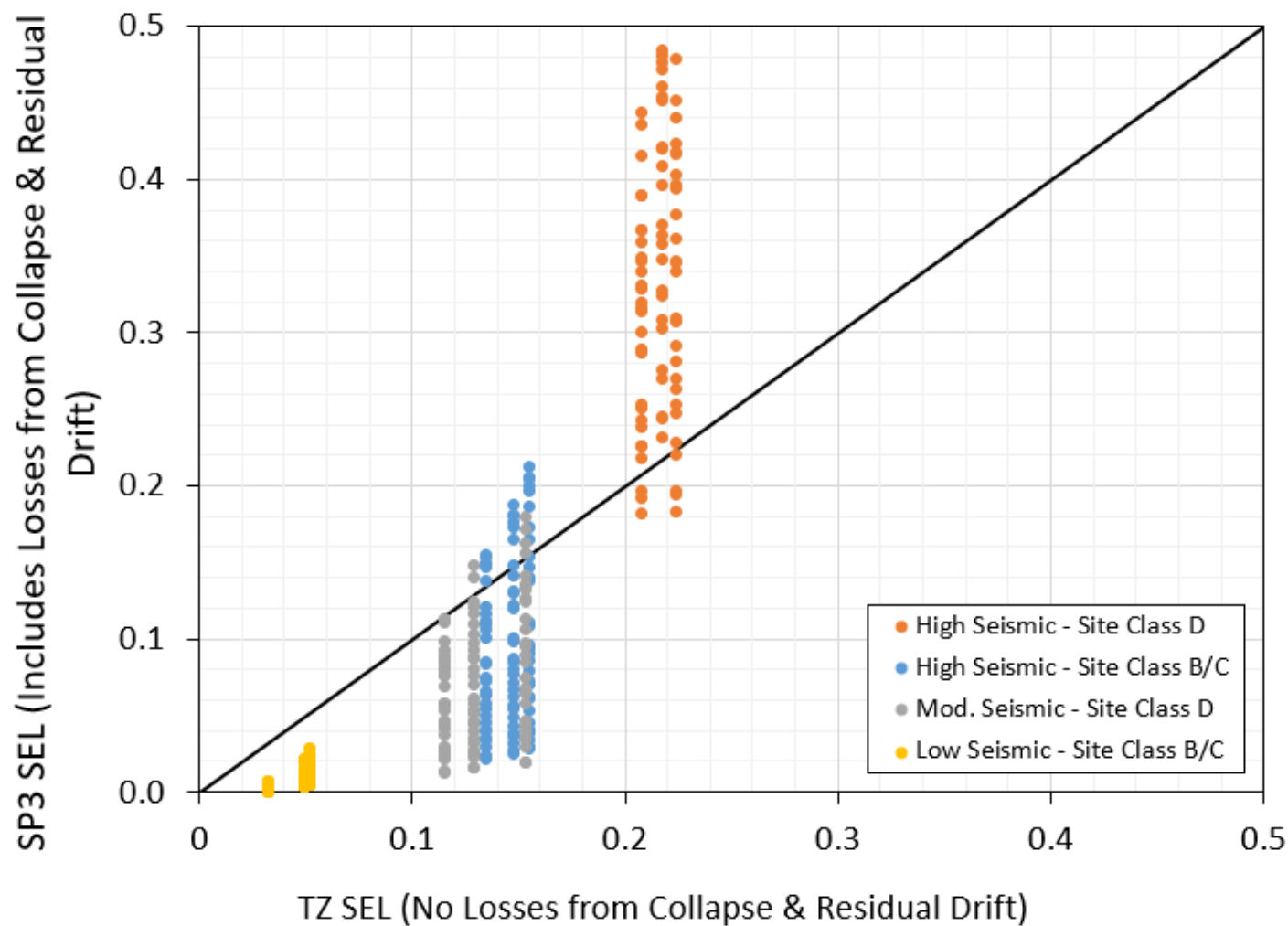


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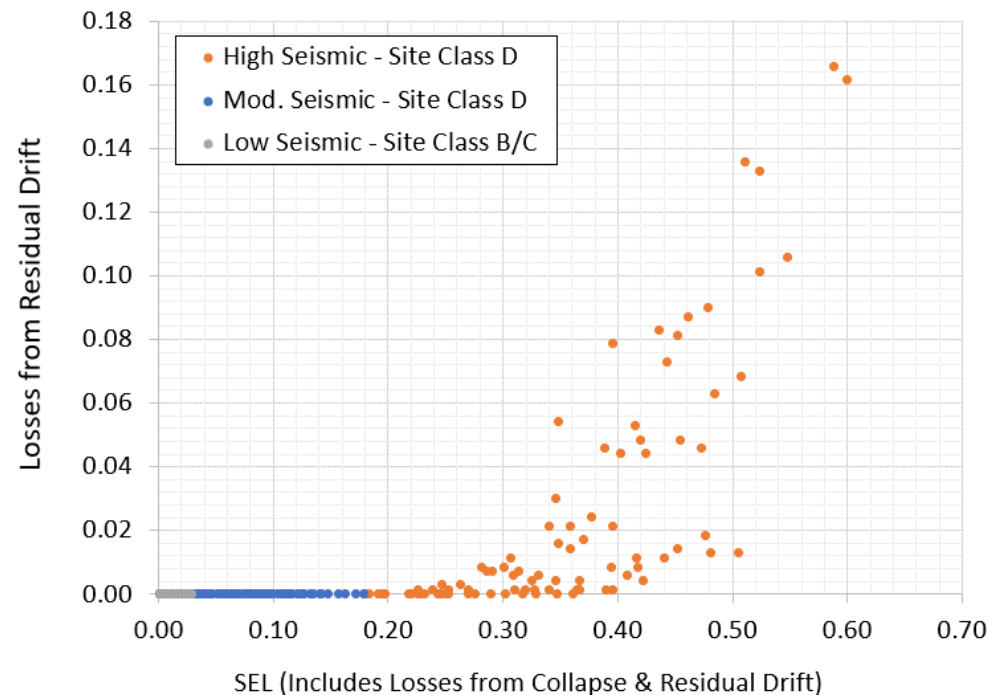
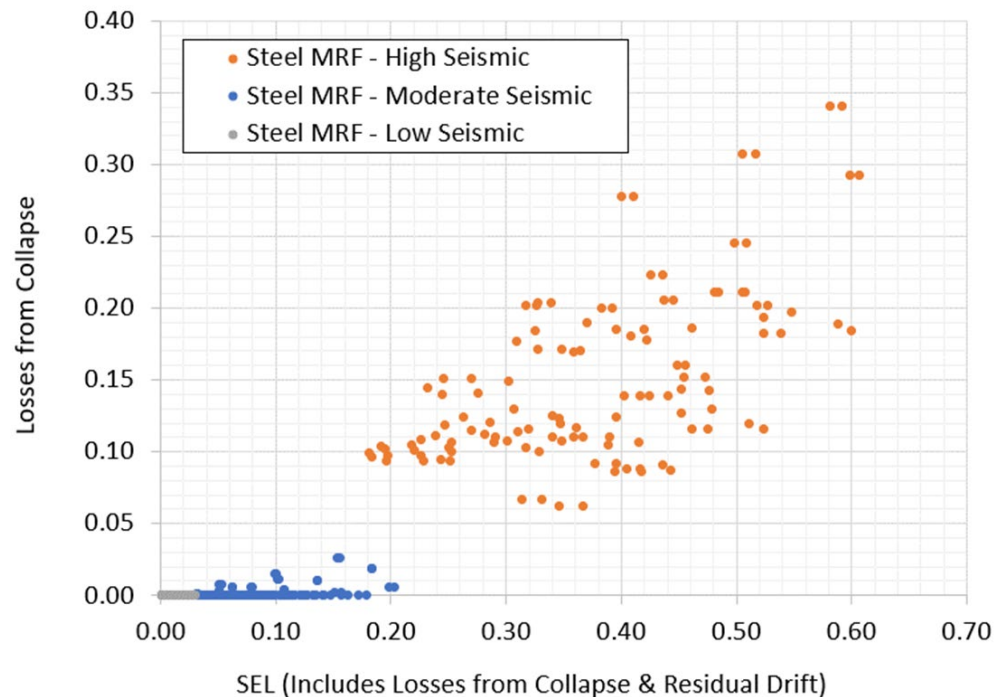
Pre-Northridge Moment Frames

Significant contributions to damage losses in high-seismic zones from building collapse and residual drift.

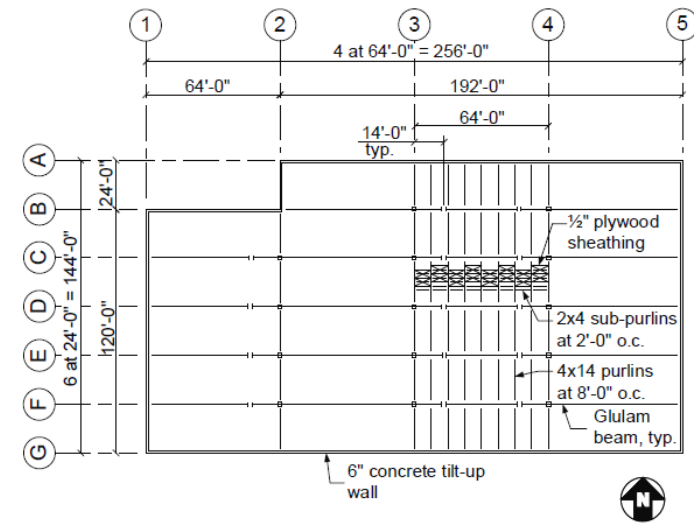


Collapse and Residual Drift in Seismic Risk Assessment Methodology

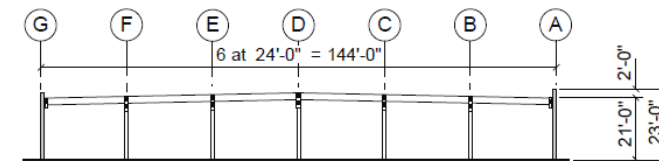
- Inclusion of building collapse and residual drifts may significantly impact building vulnerability in high-seismic zones.



Tilt-Up Warehouses in Different Eras



(b) Roof framing plan of tilt-up building



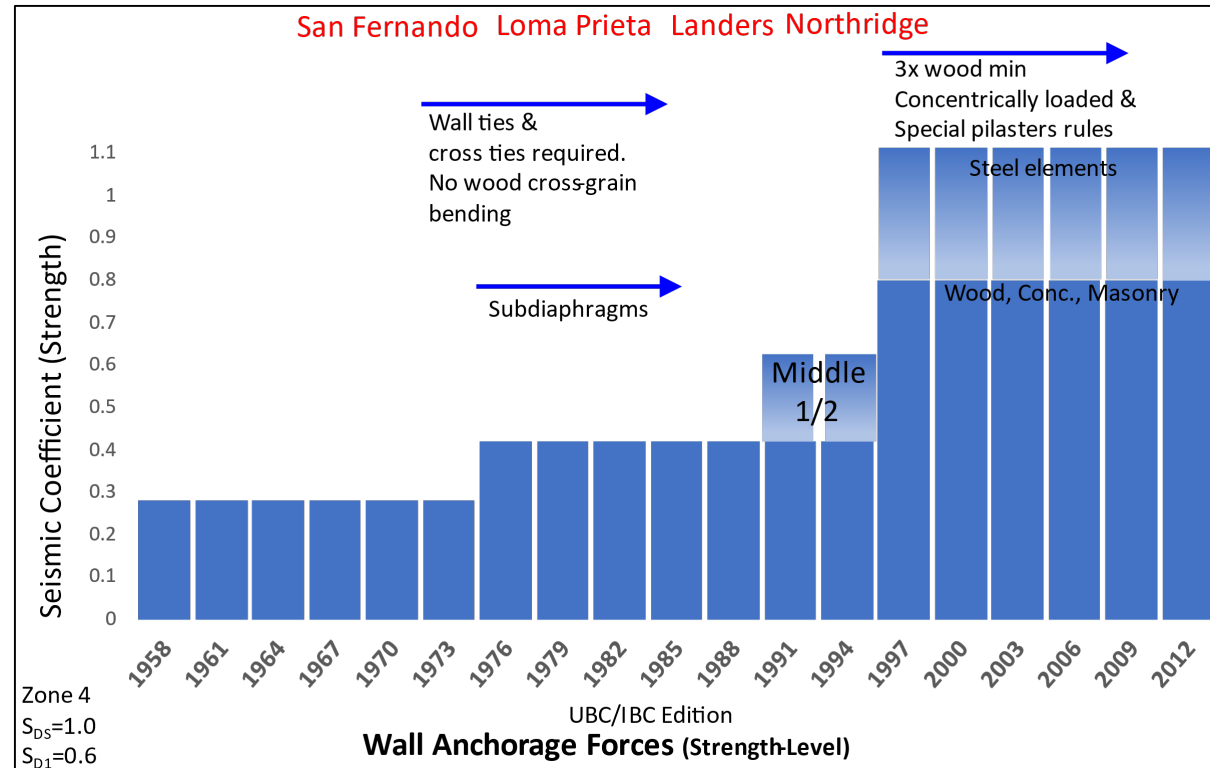
(c) Typical cross-section

Tilt-Up Warehouses in Different Eras

Changes in wall anchorage requirements in different eras.

ATC 13 not capturing these wall anchorage requirements in building classes.

- High, Moderate, and Low Seismic –Site Class D and B/C
- Number of Stories: 1
- Occupancy: Warehouse
- Aspect Ratio: 1, 2, 3, 4, & 5



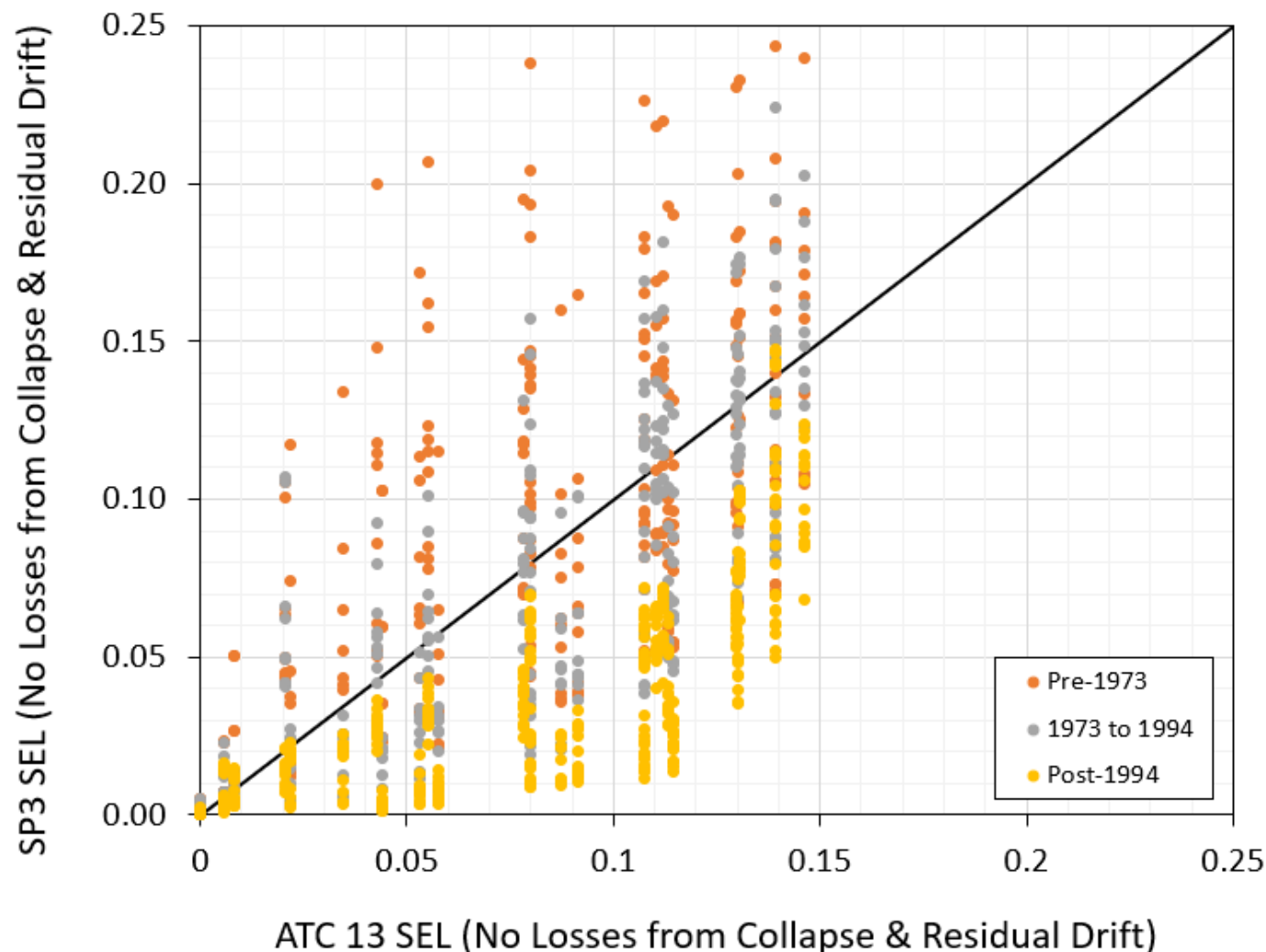
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Tilt-Up Buildings

Vertical columns of dots are building classes as at a specific location.

The “spread” of answers from FEMA P-58 is due to the building-specific characteristics that are captured, such as number of stories, building strength, and occupancy type.



Conclusion

- Historic background on seismic risk assessment methodology and FEMA P-58
- FEMA P-58 method gives similar results to building-classification-based methods in high-seismic zones on average, but lower loss results on average in lower seismic zones
- The FEMA P-58 method results vary more between buildings, since it has the ability to quantify the effects of building-specific (and site-specific) features to provide a more detailed risk assessment for the individual building (in contrast to giving results for a building class and adding modifiers)
- FEMA P-58 also provides additional detailed building-specific risk information such as what specific components are expected to be damaged and contribute most to losses, building repair time estimates, etc.
- More to come with Building Code development for Functional Recovery!

Thank You!

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