Structural and Nonstructural Seismic Design Requirements for Functional Recovery Performance as part of the 2026 NEHRP Provisions

Resilient Design Coalition Webinar Series
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Work In-Progress Disclaimer

Work on the 2026 NEHRP Recommended Seismic Provisions is ongoing.

The final content of the proposals for the 2026 NEHRP Recommended Seismic Provisions will depend on the technical and policy deliberations of the Task Committee and the Provisions Update Committee.

All proposals will be balloted through the consensus review process, and any concepts discussed herein are subject to change depending on further development of proposals and deliberations during balloting.

This work is being done under an ongoing FEMA architect - engineer contract. Final results, conclusions, and recommendations are still pending.

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Outline of Presentation

1. **Setting the stage for functional recovery:**
   - Need, research foundation, definition, categorization and ground motion considerations
2. **Framework for functional recovery design of structural systems:**
   - Scope of Study
   - Methodology: Limiting Safety Critical Structural Damage
   - Illustrative Examples
3. **Framework for functional recovery design of nonstructural systems:**
   - Scope of Study
   - Methodology: Explicit verification of recovery performance with I_{pfr} & Qualification
   - Illustrative Examples

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1. Setting the Stage: Need for Functional Recovery (FR) Design Criteria

- Modern seismic design codes intend to ensure life safety in major earthquakes
- But do not limit damage that impedes functionality (or other recovery states)
- Policymakers are recognizing the importance of going beyond life-safety:
  - US Senate bill 42 USC 7705b (2018)
  - AB-1329 proposed bill in the California Legislative assembly (2021)

Credits: Gillian Needham/Getty Images (Left), Flickr (Right).

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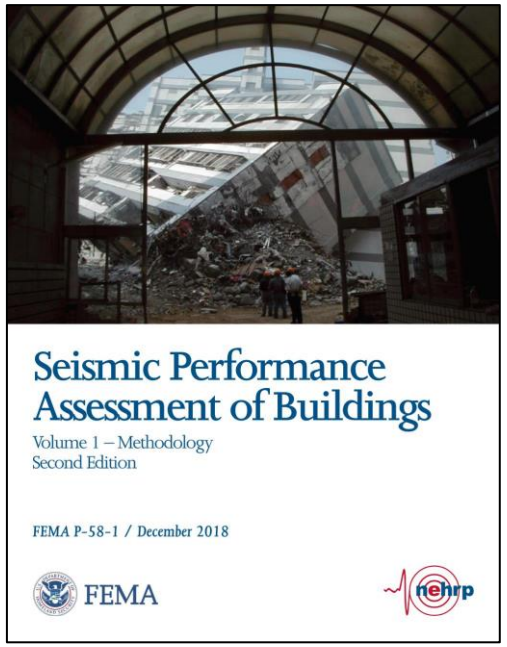
1. Setting the Stage: Foundation for Functional Recovery Codification

- FEMA P-58 Project:

"Next Generation" Performance-based Seismic Design where building performance was reported in understandable metrics:

  - Damage
  - Repair Cost
  - Repair Time

- Recently proposed Recovery Time Estimation Frameworks:
  - Arup → REDi Guidelines
  - Molina Hutt et al. (2022) → TREADS
  - Terzic et al. (2022) → F-REC
  - Cook et al. (2022) → ATC-138



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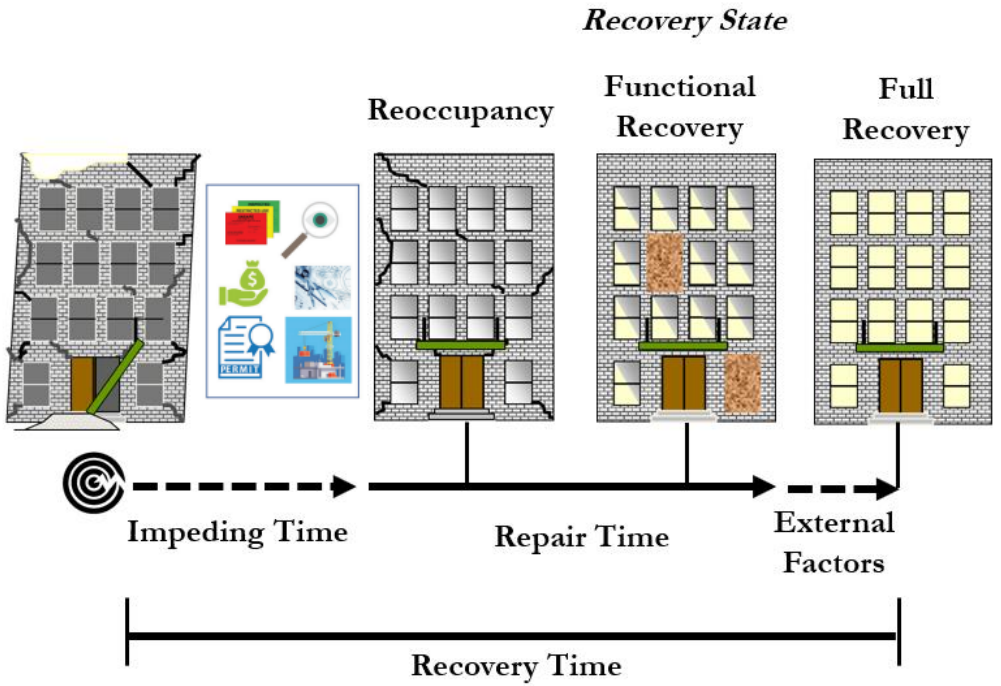
1. Setting the Stage: Functional Recovery Definition

Functional recovery is the post-earthquake recovery state in which a structure is maintained, or restored, to safely and adequately support the basic intended function associated with its pre-earthquake use or occupancy.

A functional recovery objective implies basic intended function **is achieved within an acceptable time following a specified hazard event** (e.g., earthquake), **where the acceptable time might differ for various building uses** and occupancies, or lifeline services.



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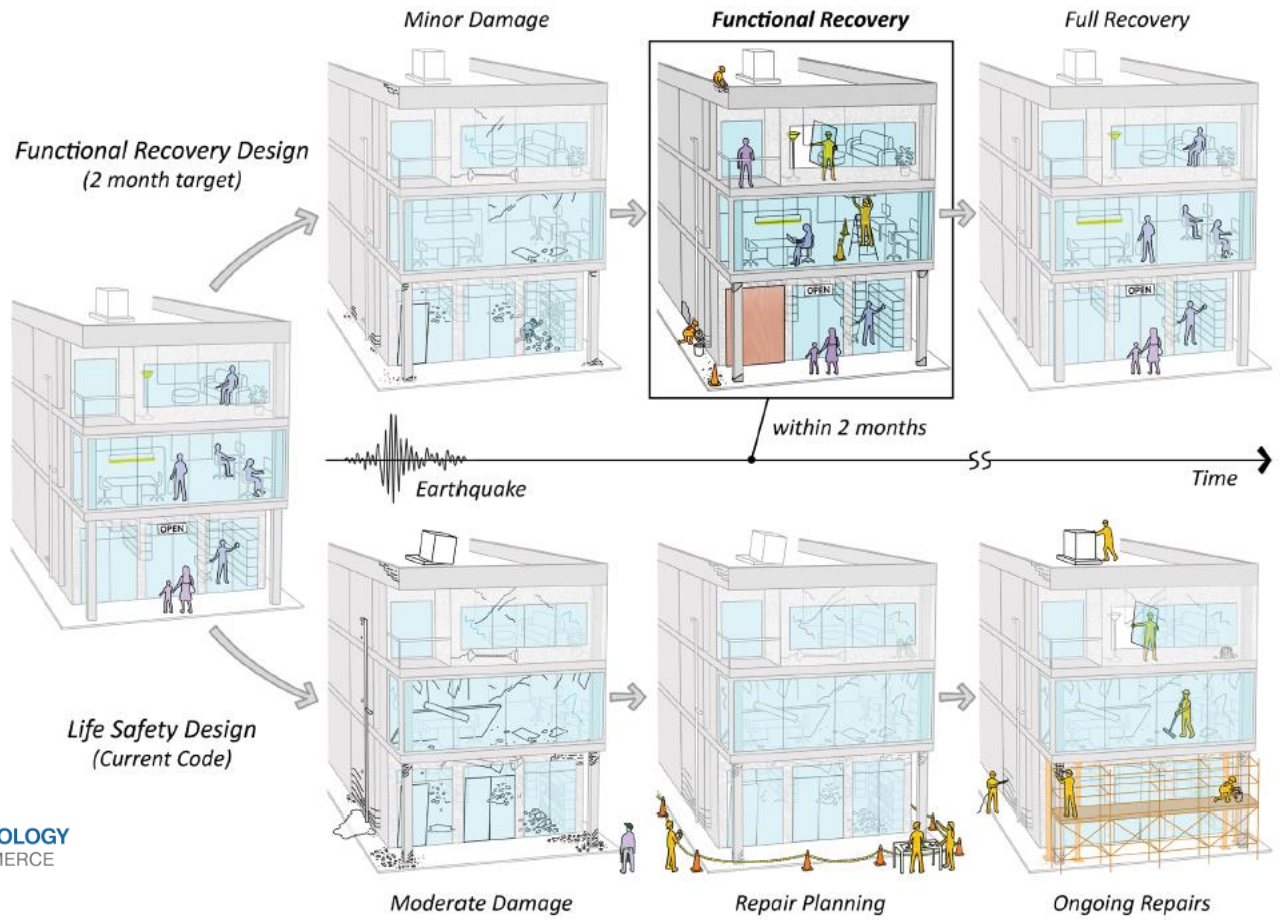

Functional Recovery Design

Life Safety Design

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

Source: https://doi.org/10.6028/NIST.RB.4

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1. Setting the Stage: Functional Recovery Categorization

Buildings are classified based on the function or service they provide to support the timely recovery of a community following an earthquake event.

Where a building supports multiple community functions, it is assigned to the highest Functional Recovery Category for any of the community functions it supports.

Functional Recovery Category	Community Functions Supported by Structures
A (A: Immediate or 0 hours)	Community functions that provide essential and urgent safety and survival needs. Functions in this category include but are not limited to: - Emergency response and communication - Emergency and acute healthcare - Housing of non-ambulatory populations, persons incapable of self-preservation, and persons under custodial care
B (B: within 3 days)	Community functions that provide safety, survival, basic well-being, and essential everyday needs and prevent the escalation of adverse disaster consequences. Functions in this category include but are not limited to: - Emergency services not included in FRC A - Essential food and water services - Healthcare providing regularly scheduled life sustaining treatments - Housing of vulnerable populations - Housing of transient persons for sleeping - Urgent veterinary services - Water and wastewater treatment - Power generation - Telecommunication - Petrochemical - Mining

Functional Recovery Category	Community Functions Supported by Structures
C (C: within 2 months)	Community functions that provide basic human needs, self- and group-preservation, and that sustain short- and long-term economic, educational, and governance activities and services. Functions in this category include but are not limited to: - Essential governance - Custodial care of vulnerable populations - Housing of nontransient populations - Education (PK-12) - Services critical to regional economic stability - Veterinary services
D (D: within 6 months)	Community functions that enhance a community's general well-being and expedite the return to normalcy. Functions in this category include but are not limited to: - Post-secondary education - Non-essential governance - Recreation

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1. Setting the Stage: Ground Motion Considerations for FR

We follow a risk-targeted approach to the selection of ground motions parameters.

- **Life Safety** performance targets:

  Risk Target: 1% chance of collapse in 50 years

  +

  Reliability Target: 10% chance of collapse conditioned on MCE_R ground motions

- **Functional Recovery** performance targets:

  Risk Target: 10% chance of exceeding recovery time target (# of hours, days, etc.) in 50 years

  +

  Reliability Target: 25% chance of exceeding recovery time target (# of hours, days, etc.) conditioned on FRE_R ground motions

	Objective	
	Life Safety	**Functional Recovery**
Risk Target	1%	10%
Lifespan	50 years	50 years
Fragility Uncertainty	$\beta = 0.6$	$\beta = 0.6$
Reliability	10% probability of exceedance	25% probability of exceedance
Design Ground Motion	DE = 2/3x MCE_R	$FRE_R \leq$ 2/3x MCE_R

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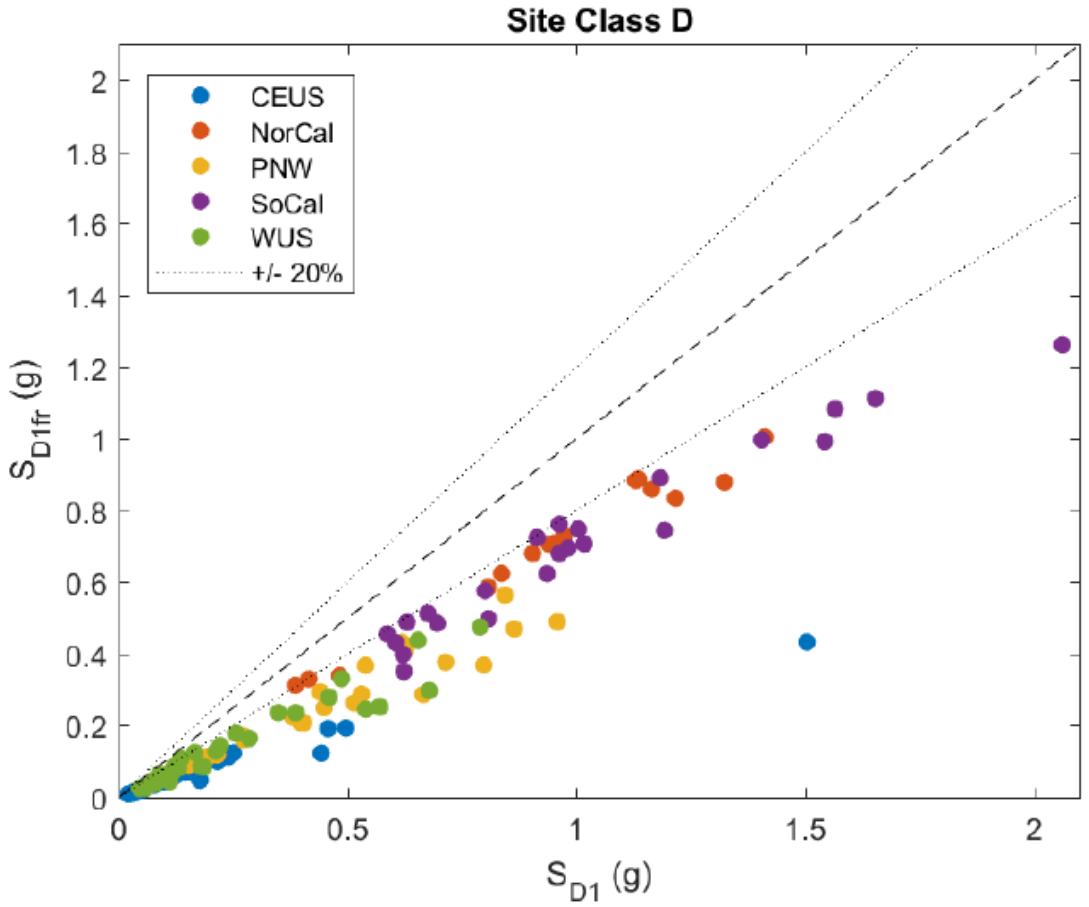

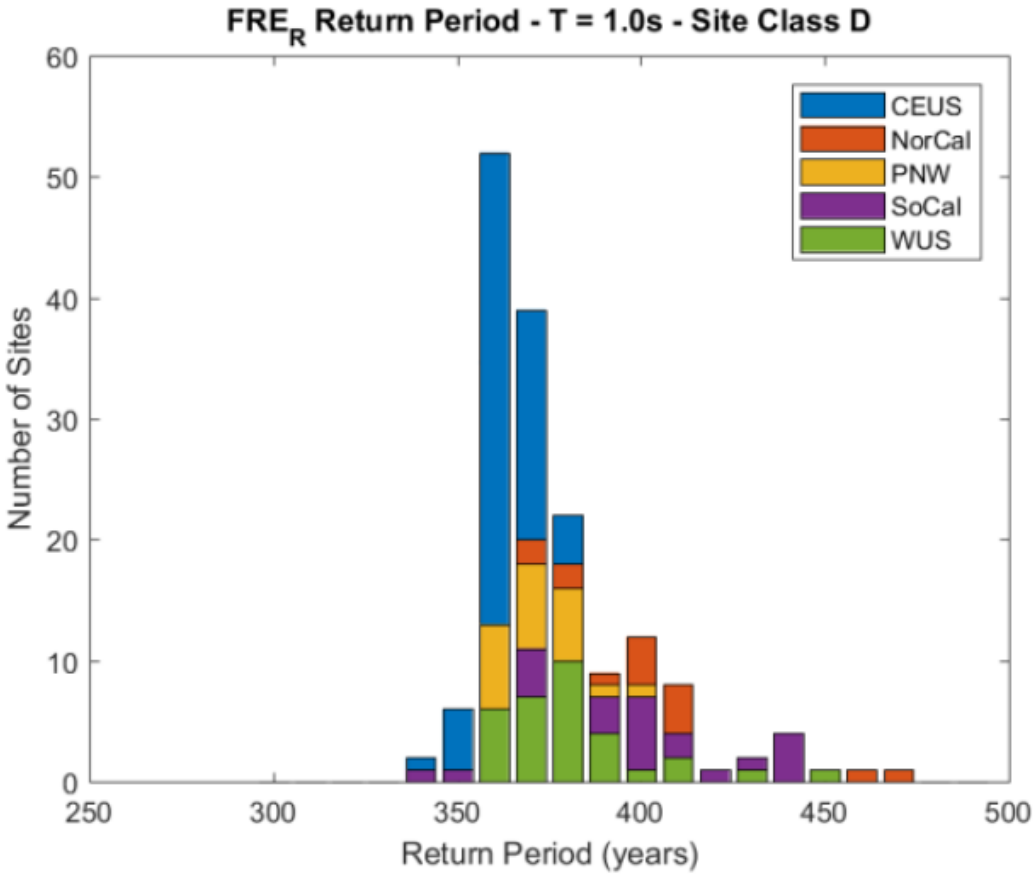

Figures by Dustin Cook (NIST)

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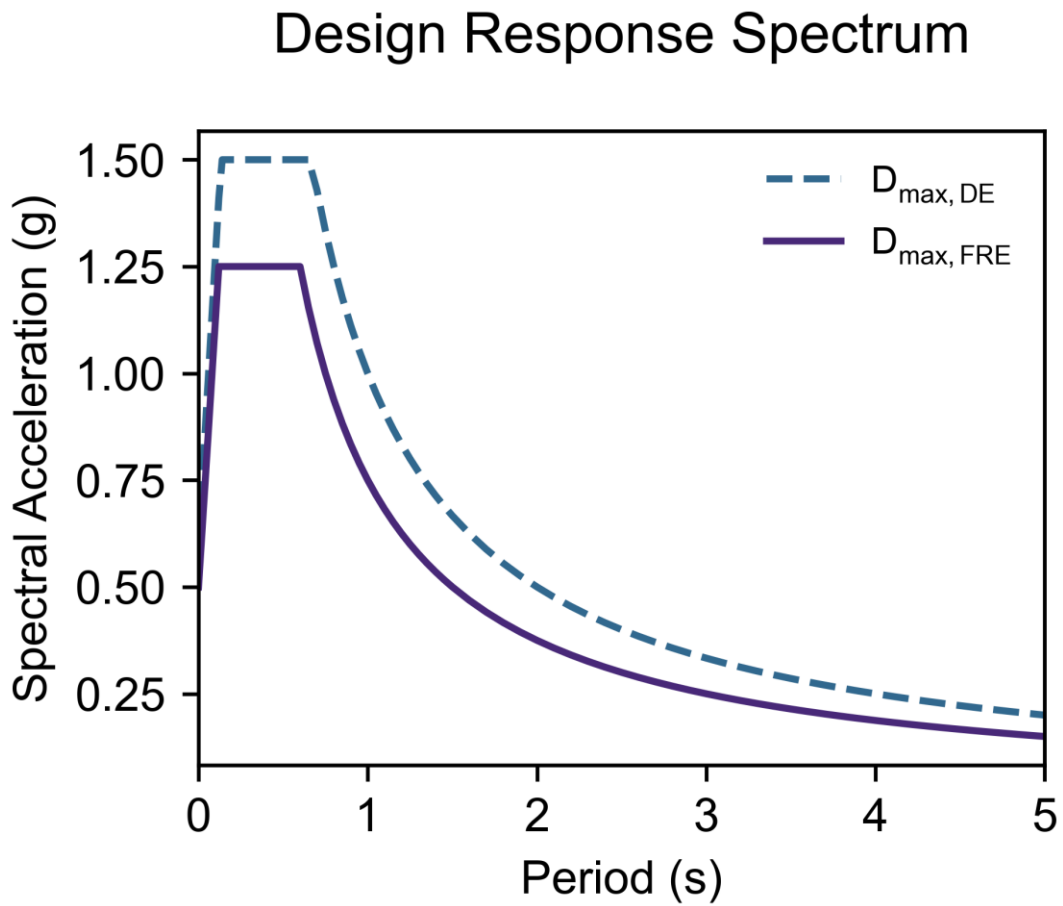
1. Setting the Stage: Functional Recovery Earthquake (FRE_R)

$D_{max,FRE}$ Spectrum:

- Analogous to the FEMA P-695 D_{max} spectrum (used in Life Safety)
- A single spectrum representative of the most critical site conditions a system designed with prescriptive code provisions is expected to experience
- Does not capture soft soil (Site Class E or F)



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2. FR Design of Structural Systems: Scope of Study

Structural systems and building heights evaluated.

Lateral Force-Resisting System	R	Heights (Stories)				Gravity System Considered		
		3	8	16	24	PT Slab	RC Slab	Steel Frame
REINFORCED CONCRETE SHEAR WALL SYSTEMS								
Special RC shear walls (Shear-governed, Bearing)	5	X				X	X	X
Special RC shear walls (Shear-governed, Frame)	6	X				X	X	X
Special RC shear walls (Flexure-governed, Bearing)	5		X	X	X	X	X	X
Special RC shear walls (Flexure-governed, Frame)	6		X	X	X	X	X	X
RC ductile coupled walls (Flexure-governed, Bearing)	8		X	X	X	X	X	X
RC ductile coupled walls (Flexure-governed, Frame)	8		X	X	X	X	X	X
STEEL BRACED FRAME SYSTEMS								
Steel buckling-restrained braced frames (no backup frame)	8	X	X	X	NP			X
Steel buckling-restrained braced frames (backup frame)	8	X	X	X	NP			X
MOMENT-RESISTING FRAME SYSTEMS								
Steel special moment frames	8	X	X	X	X			X
Special RC moment frames	8	X	X	X	X	X	X	

*NP = Not permitted in ASCE 7-22 (ASCE/SEI, 2022a)

PT Slab = post-tensioned reinforced concrete flat slab; RC Slab = conventionally reinforced concrete flat slab; Steel Frame = steel gravity beam-column frame.

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2. FR Design of Structural Systems: Framework

Key considerations:

1. The lateral force-resisting system is designed to have reduced ductility demand by means of a reduced response modification coefficient, R_{fr}, dependent on Functional Recovery Category and structural system.
2. Allowable story drift limits, Δ_{afr}, which range from 0.75% to 1.5%, are also dependent upon system and Functional Recovery Category.

Seismic Force-Resisting System	R_{fr} and Δ_{afr} by Functional Recovery Category	
	A, B and C	D
BEARING WALL SYSTEMS		
Special reinforced concrete shear walls	3.5 $0.01h_{sx}$	4 $0.0125h_{sx}$
Reinforced concrete ductile coupled walls	4 $0.01h_{sx}$	5 $0.0125h_{sx}$
Light-frame (wood) walls sheathed with wood structural panels rated for shear resistance	3 $0.01h_{sx}$	3.5 $0.0125h_{sx}$

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2. FR Design of Structural Systems: Framework

Analytical Studies to identify appropriate R_{fr} and Δ_{afr} for Functional Recovery design:

- Lateral force-resisting systems from ASCE 7 Ch. 12 (w/ typical gravity systems)
- Heights ranging from 3 to 24 stories
- Evaluate lateral systems with combinations of R_{fr} and Δ_{afr} ranging from:
  - R_{fr} =1.0 to R
  - Δ_{afr} = 0.5% to 2%

Design Space

- Initially, we consider damage to structural system components only and we use **safety-critical structural damage** (i.e., structural damage that must be repaired before a building can be safely reoccupied) as our performance metric .
- We select R_{fr} and Δ_{afr} for each system to minimize the probability of safety-critical structural damage under the FRE_R.

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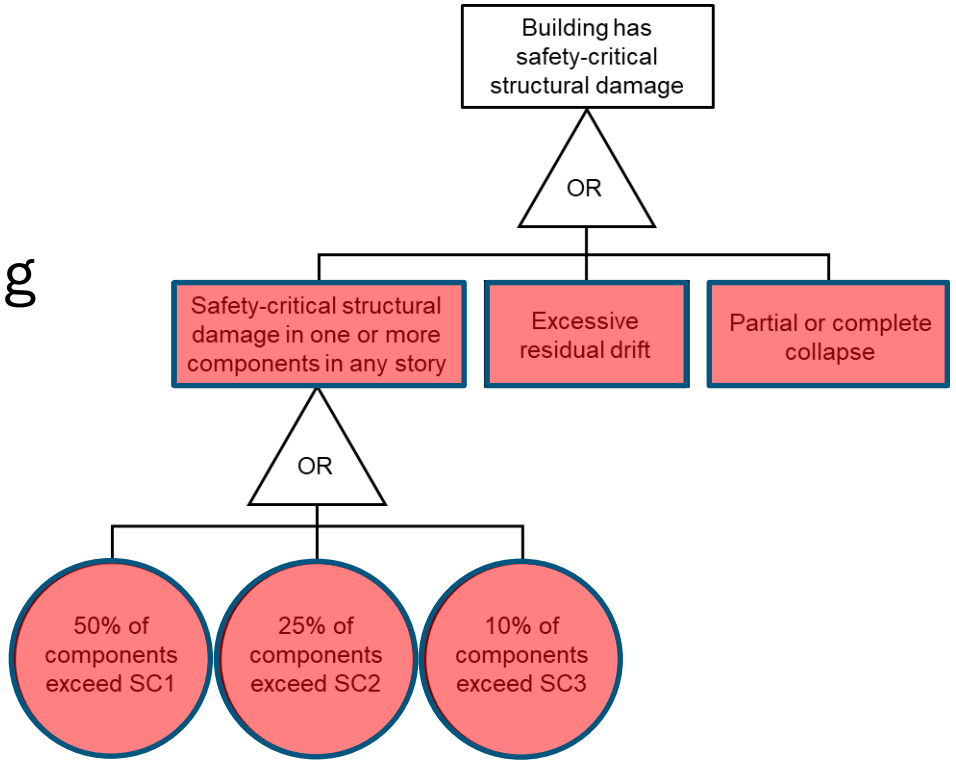
2. FR Design of Structural Systems: Framework

- Safety-critical structural damage **aggregates component level damage to a building-level performance metric** that captures whether a substantial loss of vertical or lateral load-carrying capacity has occurred.
- This building-level metric considers the **distribution and severity of damage** throughout the structure.
- We aim to predict the occurrence of safety-critical damage in the structure, not to replicate the decision of a field evaluator to assign an unsafe placard in a real post-earthquake setting.



Fault tree to used to determine whether the building experiences safety-critical structural damage [SC Denotes Safety Class]. Modified at Cook et al. (2022)

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2. FR Design of Structural Systems: Framework

Step 1: Define Model Parameters

↓

Step 2: Simplified MDOF Models ⇄ **Δ_{afr} = 0.5% to 2.0%**
R_{fr} = 1.0 to R

↓

Step 3: Predict Nonlinear Response

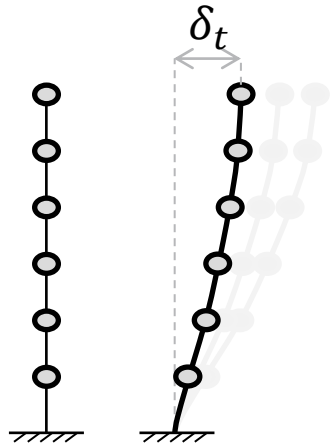
↓

Step 4: Component Damage Assessment using FEMA P-58

↓

Step 5: Assess Probability of Safety Critical Structural Damage

SP3 Seismic Performance Prediction Program by Haselton Baker Risk Group



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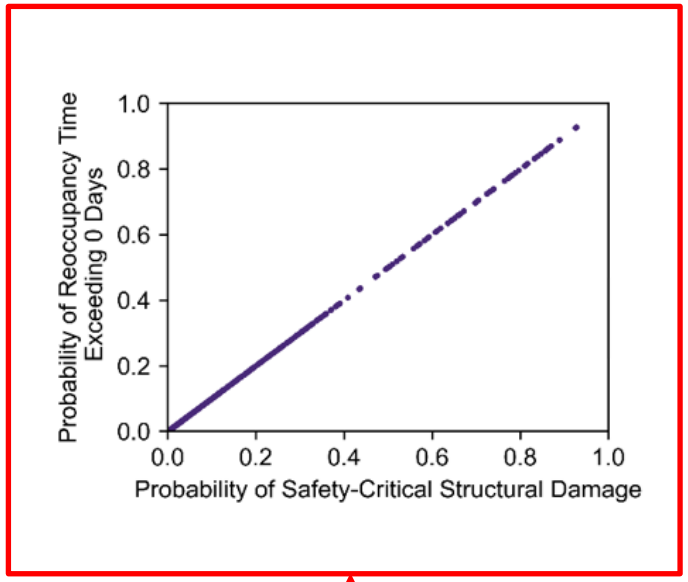

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Δ_{afr} = 0.5% to 2.0%
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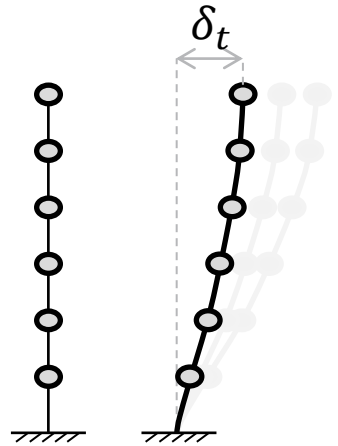

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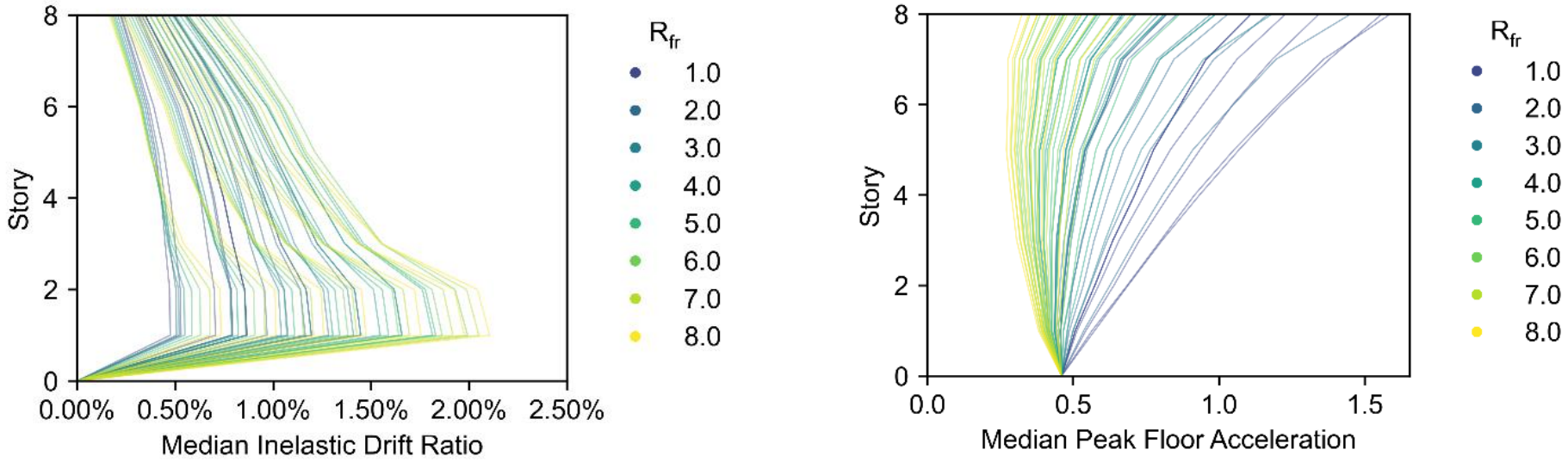
2. FR Design of Structural Systems: Framework Illustration

56 design variations of an 8-story special reinforced concrete moment frame (RCMF):

- as the design drift limit decreases, the realized drifts also decrease
- peak floor accelerations increase as stricter drift limits are imposed



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2. FR Design of Structural Systems: Framework Illustration

Structural components within the example 8-story special RCMF model:

- beam-column joints part of the moment resisting frame
- slab-column joints as part of the gravity system

Component List, Damage State (DS) Definitions and Safety Class (SC) Mapping

Component ID	Component Description	EDP	DS1		DS2		DS3-1		DS3-2	
			θ, β	SC	θ, β	SC	θ, β	SC	θ, β	SC
B1041.002a	ACI 318 SMF , Conc Col & Bm = 24" x 36", Beam one side	Peak Story Drift Ratio	0.02 0.4	0	0.0275 0.3	1	0.05 0.3	2	0.05 0.3	1
B1041.002b	ACI 318 SMF , Conc Col & Bm = 24" x 36", Beam both sides	Peak Story Drift Ratio	0.02 0.4	0	0.0275 0.3	1	0.05 0.3	2	0.05 0.3	1
B1049.031	Post-tensioned concrete flat slabs-columns with shear reinforcing 0<Vg/Vo<.0.4	Peak Story Drift Ratio	0.028 0.5	0	0.04 0.5	2				

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Damage states of each component are mapped to a safety class

Component List, Damage State (DS) Definitions and Safety Class (SC) Mapping

Component ID	Description (DS1)	Safety Class	Description (DS2)	Safety Class	Description (DS3-1)	Safety Class	Description (DS3-2)	Safety Class
B1041.002a	Beams or joints exhibit residual crack widths > 0.06 in. No significant spalling. No fracture or buckling of reinforcing.	0	Beams or joints exhibit residual crack widths > 0.06 in. Spalling of cover concrete exposes beam and joint transverse reinforcement but not longitudinal reinforcement. No fracture or buckling of reinforcing.	1	Beams or joints exhibit residual crack widths > 0.06 in. Spalling of cover concrete exposes a significant length of beam longitudinal reinforcement. Crushing of core concrete may occur. Fracture or buckling of reinforcing requiring replacement may occur.	2	Beams or joints exhibit residual crack widths > 0.06 in. Spalling of cover concrete exposes beam and joint transverse reinforcement but not longitudinal reinforcement. No fracture or buckling of reinforcing.	1
B1041.002b	Beams or joints exhibit residual crack widths > 0.06 in. No significant spalling. No fracture or buckling of reinforcing.	0	Beams or joints exhibit residual crack widths > 0.06 in. Spalling of cover concrete exposes beam and joint transverse reinforcement but not longitudinal reinforcement. No fracture or buckling of reinforcing.	1	Beams or joints exhibit residual crack widths > 0.06 in. Spalling of cover concrete exposes a significant length of beam longitudinal reinforcement. Crushing of core concrete may occur. Fracture or buckling of reinforcing requiring replacement may occur.	2	Beams or joints exhibit residual crack widths > 0.06 in. Spalling of cover concrete exposes beam and joint transverse reinforcement but not longitudinal reinforcement. No fracture or buckling of reinforcing.	1
B1049.031	Yield strain of the slab flexural reinforcement has been exceeded. Spalling of concrete may or may not occur. Slab exhibits large enough crack widths to allow epoxy injection.	0	Punching occurs, causing significant spalling of concrete. Epoxy injection is no longer expected to be sufficient to restore the required strength and stiffness to the slab and the slab-column connection.	2				

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2. FR Design of Structural Systems: Framework Illustr

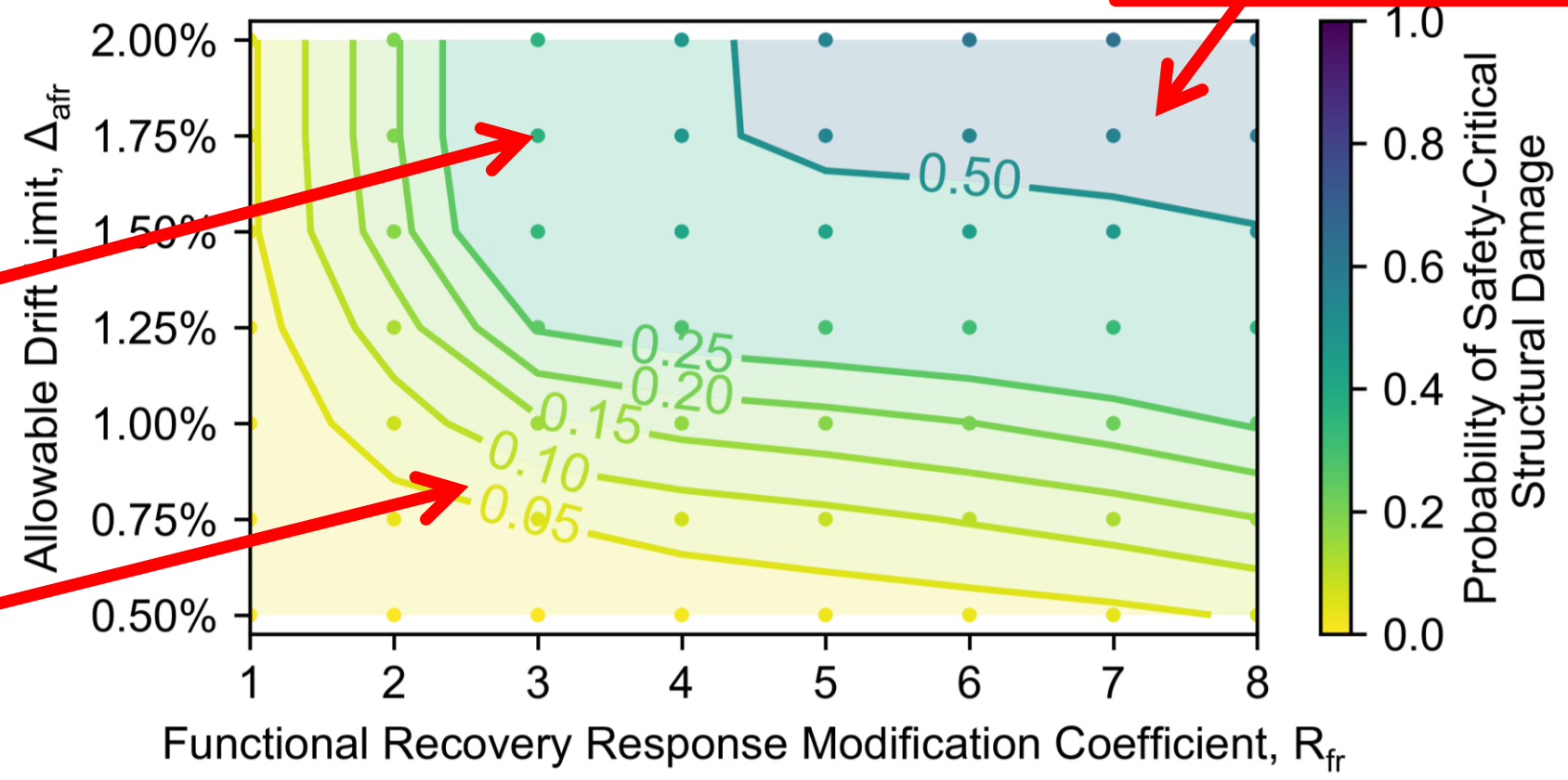
Results for the 8-story special RCMFs at the $D_{max,FRE}$ spectrum

Designs parameters consistent with Life Safety Provisions (Rfr=8 and 2% drift limit) have higher probabilities of safety critical structural damage.

Each dot represents the safety-critical structural damage probability at the FRE_R for the archetype designed to the design drift limit and response modification coefficient.

Lower R_{fr} values and drift limits enable achieving low probabilities, i.e., ≤10%, of safety critical structural damage.

Probabilities are based on 'yes/no' flags from 2500 realizations.



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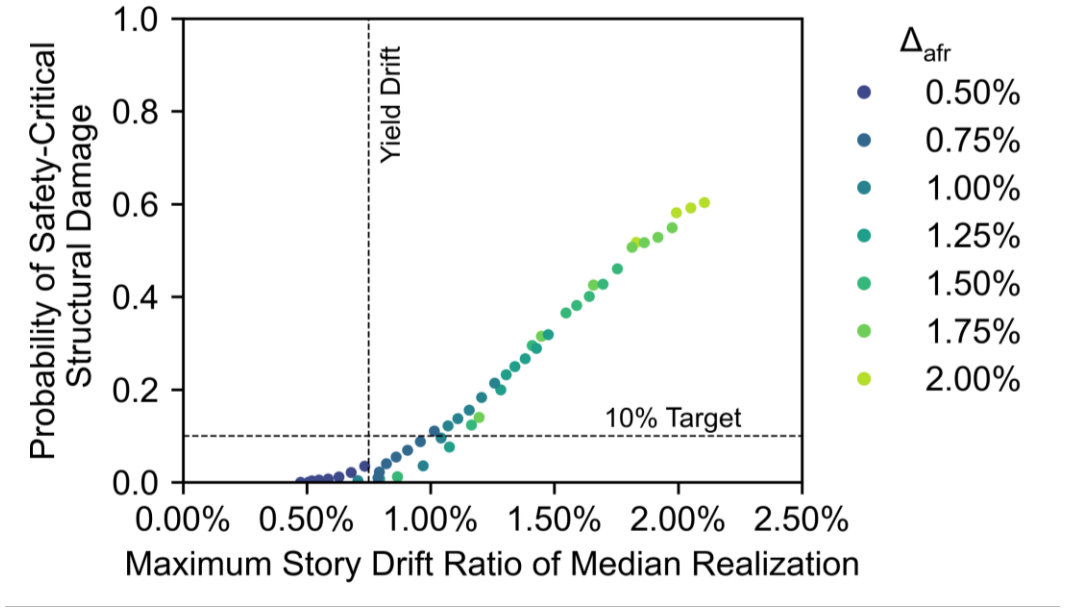
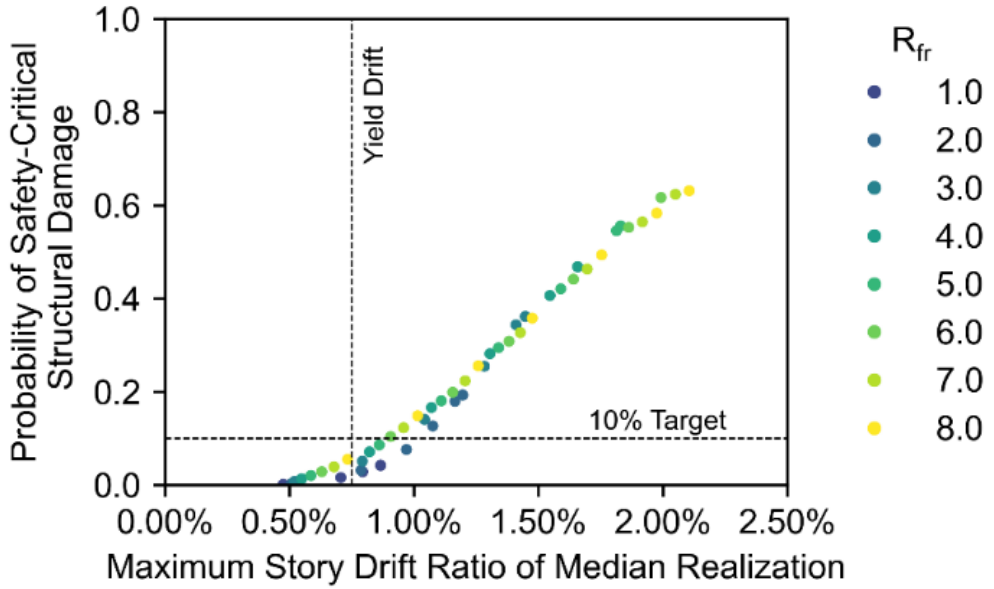
2. FR Design of Structural Systems: Framework Illustration

Results for the 8-story special RCMFs at the $D_{max,FRE}$ spectrum





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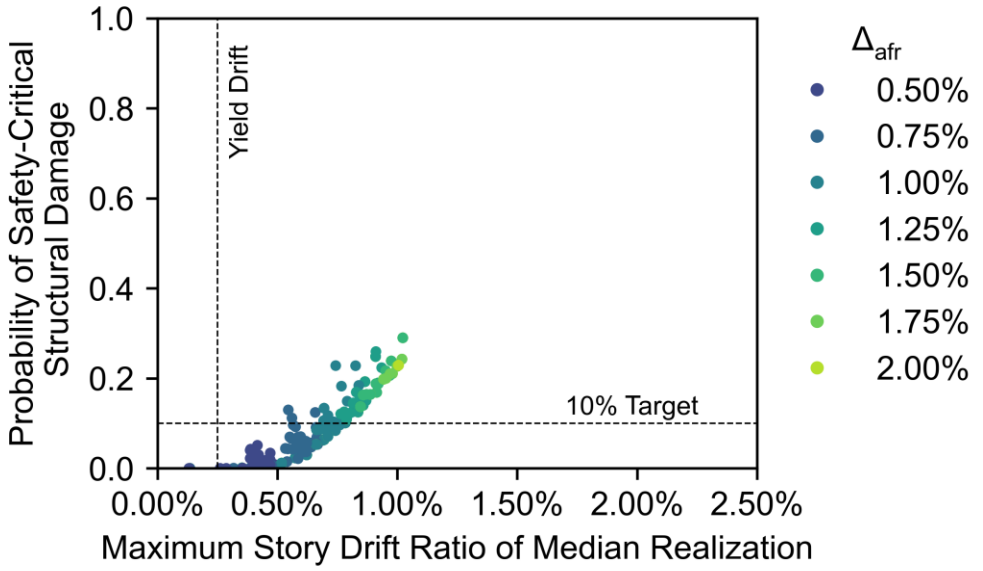
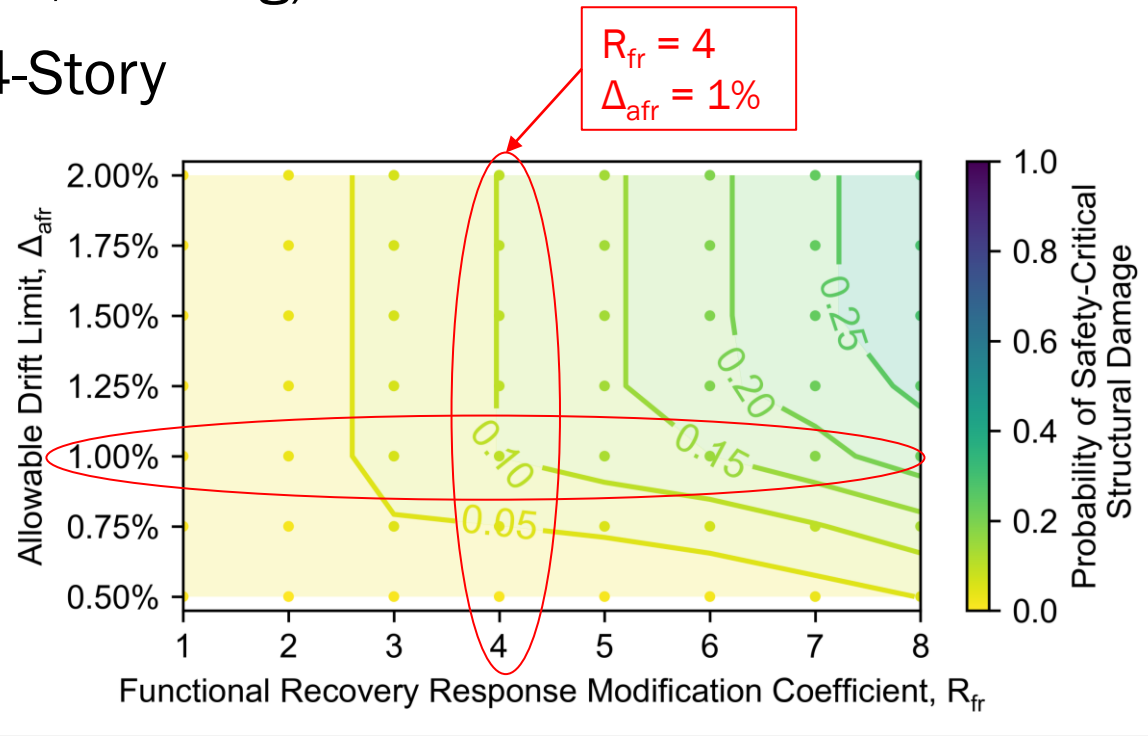
2. FR Design of Structural Systems: RC Shear Wall Systems

RC Ductile Coupled Walls (Flexure-governed, Bearing)

Gravity System: PT Slab; Height: 24-Story





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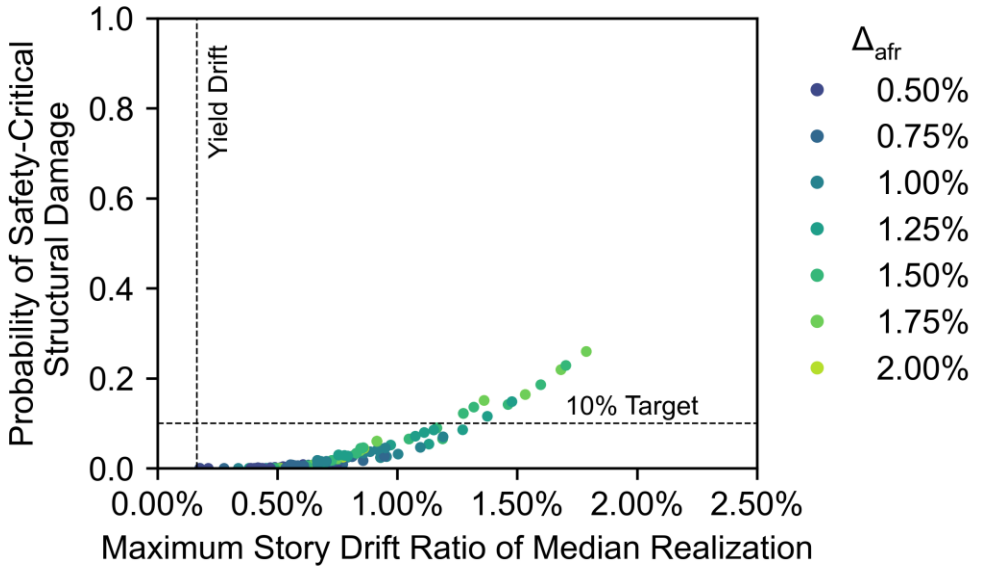
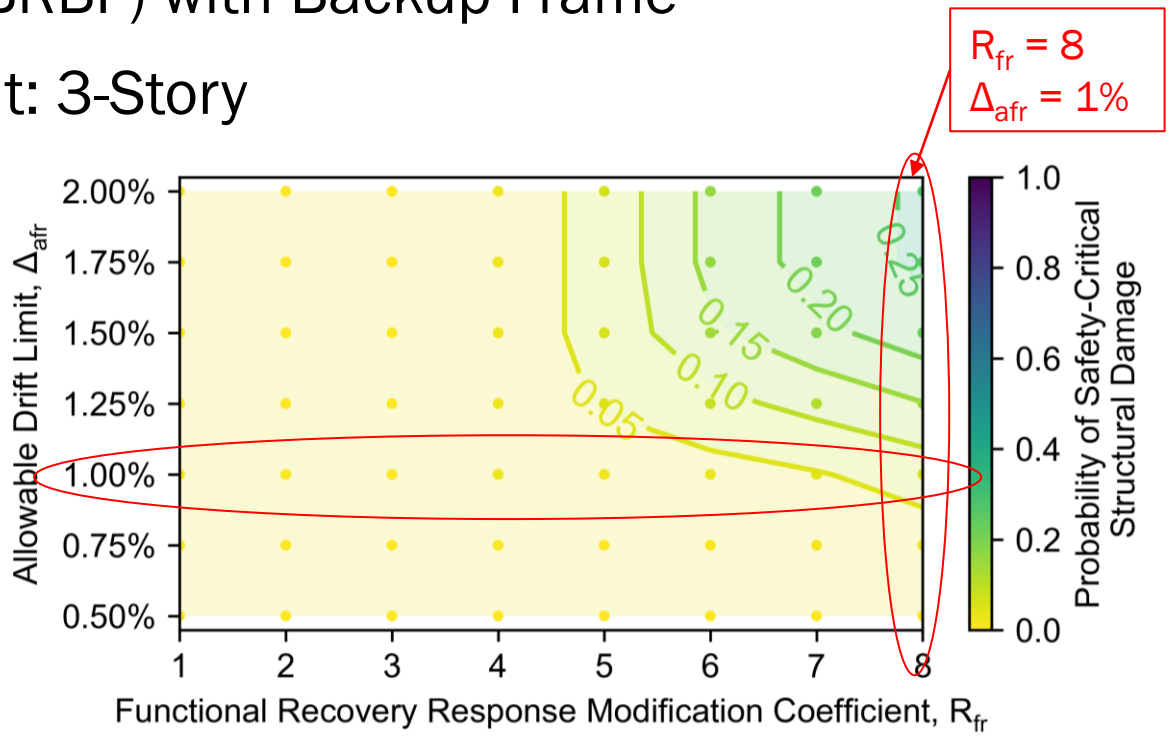
2. FR Design of Structural Systems: Steel BRBF Systems

Steel Bucking-Restrained Braced Frame (BRBF) with Backup Frame

Gravity System: Steel Frame; Height: 3-Story





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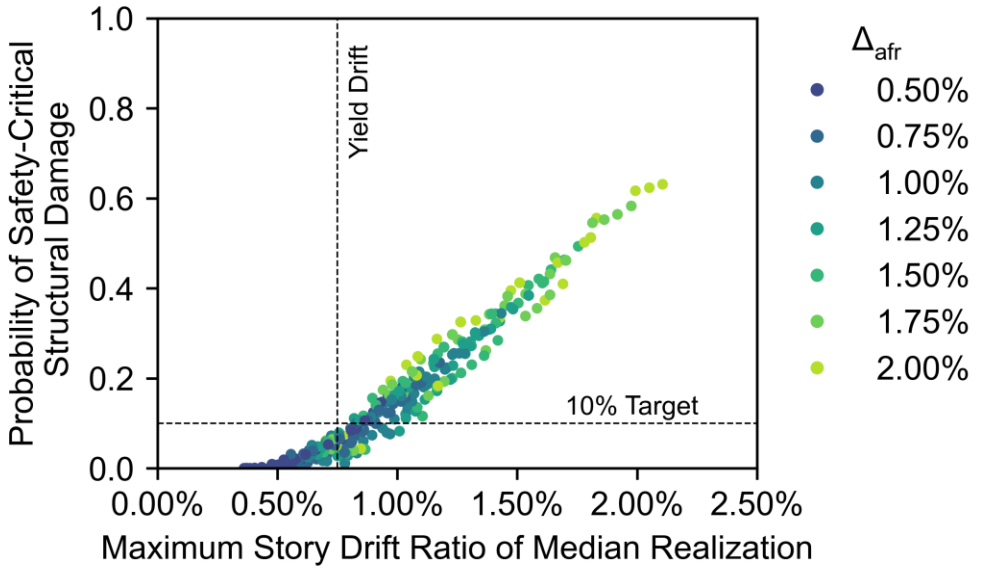
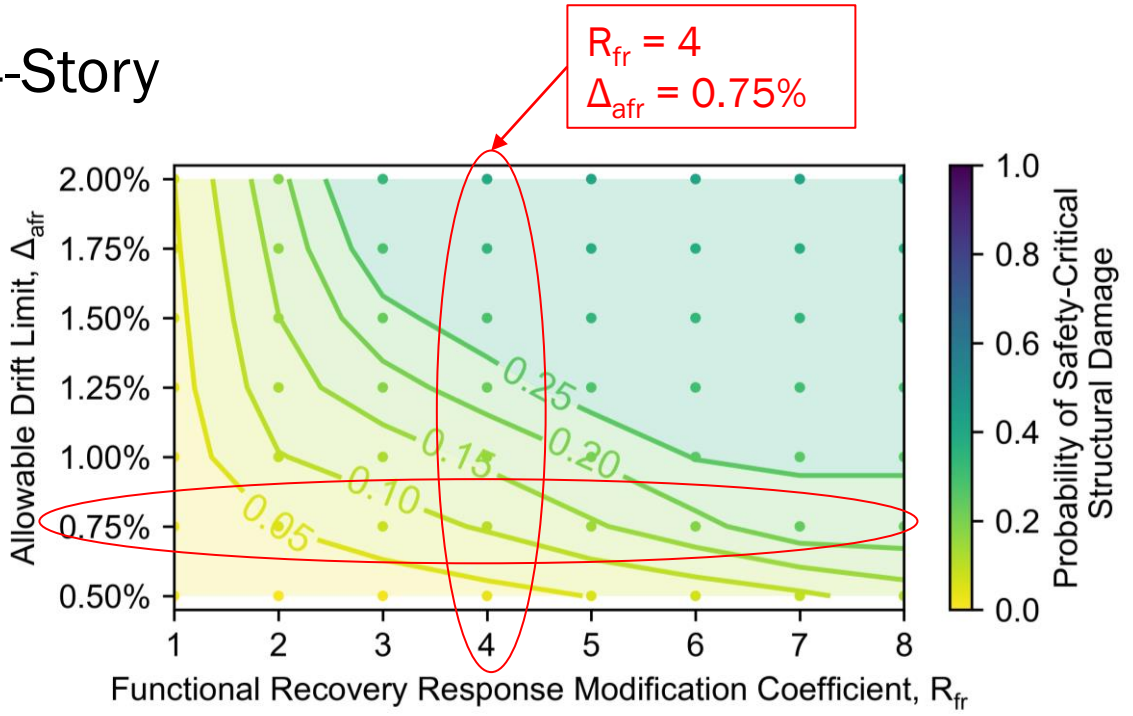
2. FR Design of Structural Systems: Moment Frame Systems

Special RC Moment Frames

Gravity System: PT Slab; Height: 24-Story





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2. FR Design of Structural Systems: Summary of R_{fr} and Δ_{afr}

Seismic Force-Resisting System	R_{fr} and Δ_{afr} by Functional Recovery Category	
	A, B and C	D
BEARING WALL SYSTEMS		
Special reinforced concrete shear walls	3.5 $0.01h_{sx}$	4 $0.0125h_{sx}$
Reinforced concrete ductile coupled walls	4 $0.01h_{sx}$	5 $0.0125h_{sx}$
BUILDING FRAME SYSTEMS		
Special reinforced concrete shear walls	4 $0.01h_{sx}$	5 $0.0125h_{sx}$
Reinforced concrete ductile coupled walls	4 $0.01h_{sx}$	5 $0.0125h_{sx}$
Steel buckling-restrained braced frames, non-moment-resisting beam-column connections	5 $0.01h_{sx}$	5 $0.01h_{sx}$
Steel buckling-restrained braced frames, moment-resisting beam-column connections	5.5 $0.01h_{sx}$	6.5 $0.0125h_{sx}$
MOMENT-RESISTING FRAME SYSTEMS		
Steel special moment frames	5.5 $0.01h_{sx}$	6.5 $0.015h_{sx}$
Special reinforced concrete moment frames	4 $0.0075h_{sx}$	5 $0.0075h_{sx}$

In addition to our analyses, we also use “judgment-based” filters, i.e., R and drift limit for current Risk Category IV (i.e., R/1.5 and 1% drift limit).

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3. FR Design of Nonstructural Systems: Scope of Study

Seismic Force-Resisting System	R_{fr} and Δ_{afr} by Functional Recovery Category	
	A, B and C	D
BEARING WALL SYSTEMS		
Special reinforced concrete shear walls	3.5 $0.01h_{sx}$	4 $0.0125h_{sx}$
Reinforced concrete ductile coupled walls	4 $0.01h_{sx}$	5 $0.0125h_{sx}$
BUILDING FRAME SYSTEMS		
Special reinforced concrete shear walls	4 $0.01h_{sx}$	5 $0.0125h_{sx}$
Reinforced concrete ductile coupled walls	4 $0.01h_{sx}$	5 $0.0125h_{sx}$
Steel buckling-restrained braced frames, non-moment-resisting beam-column connections	5 $0.01h_{sx}$	5 $0.01h_{sx}$
Steel buckling-restrained braced frames, moment-resisting beam-column connections	5.5 $0.01h_{sx}$	6.5 $0.0125h_{sx}$
MOMENT-RESISTING FRAME SYSTEMS		
Steel special moment frames	5.5 $0.01h_{sx}$	6.5 $0.015h_{sx}$
Special reinforced concrete moment frames	4 $0.0075h_{sx}$	5 $0.0075h_{sx}$

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3. FR Design of Nonstructural Systems: Framework

Key considerations:

1. We introduce the seismic functional recovery component importance factor, I_{pfr}.
2. We establish the seismic floor acceleration demand using $F_{p\text{-}fr}$ (similar to ASCE 7 Chapter 13) as a best-estimate of floor acceleration.
3. Where floor accelerations are low enough, we provide exceptions to:

   - Seismic qualification of equipment required to support building's basic intended function.

   - Design requirements for distribution systems (such as pipes) to span between points of support/bracing.

Table A.10-1. Functional Recovery Nonstructural Component Importance Factors by Functional Recovery Category for Earthquake Loads

Functional Recovery Category	Seismic Functional Recovery Component Importance Factor, I_{pfr}
A and B	1.75
C	1.5
D	1.25

Table A.10-2. Seismic Floor Acceleration Threshold

Component or Distribution System	Seismic Floor Acceleration Threshold (g) by Functional Recovery Category		
	B	C	D
MECHANICAL AND PLUMBING			
HVAC Ducting (cross sectional area < 6 ft²)	0.5	0.6	0.65
HVAC Ducting (cross sectional area ≥ 6 ft²)	1.2	1.5	1.6
HVAC Drops/Diffusers	0.5	0.6	0.65

Table A.11-1. Seismic Certification Floor Acceleration Threshold

Equipment or Component	Seismic Certification Floor Acceleration Threshold (g) by Functional Recovery Category	
	C	D
MECHANICAL		
Chillers, including associated evaporators and condensers	0.35	0.4
Cooling Towers	0.6	0.65
Compressors	0.55	0.65

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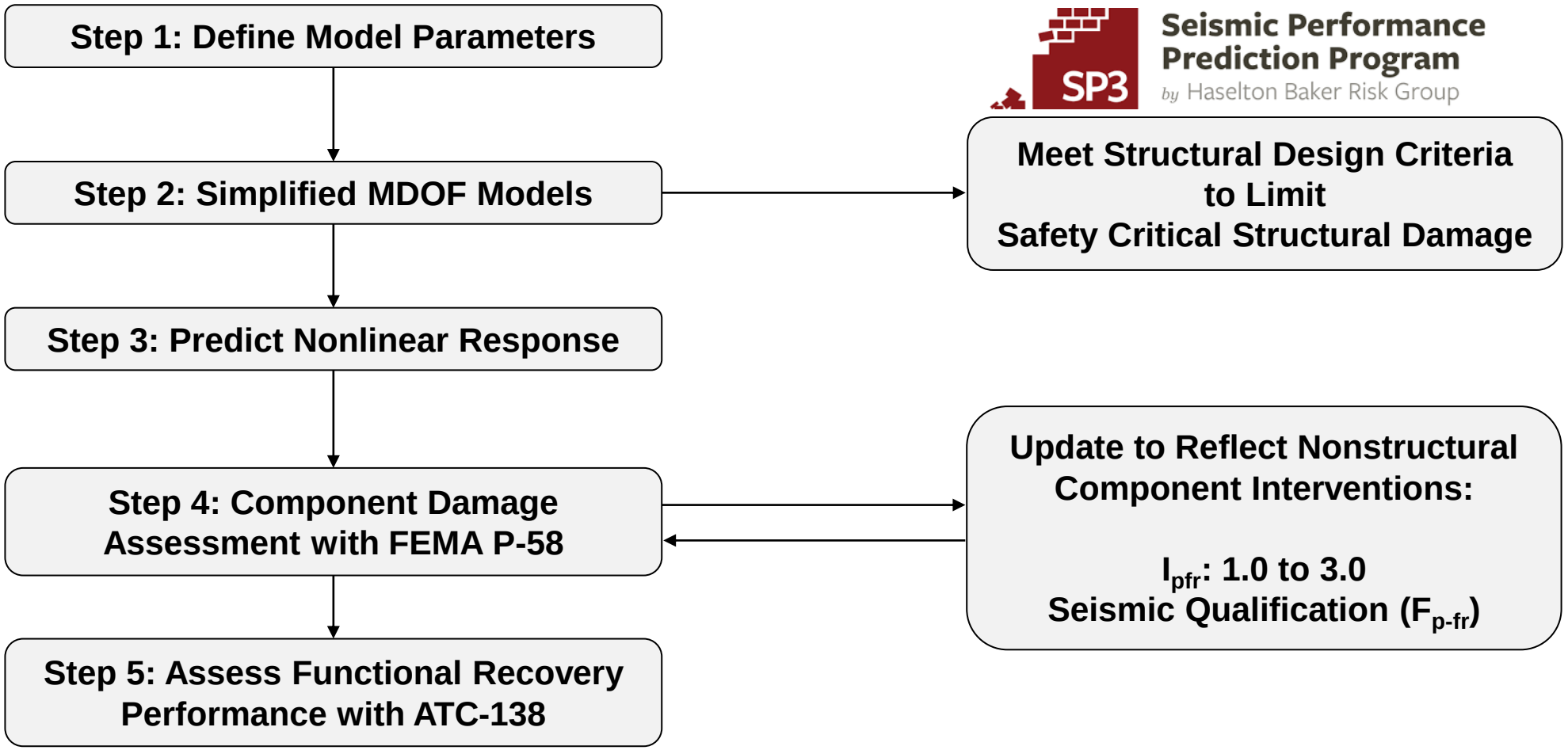
3. FR Design of Nonstructural Systems: Framework



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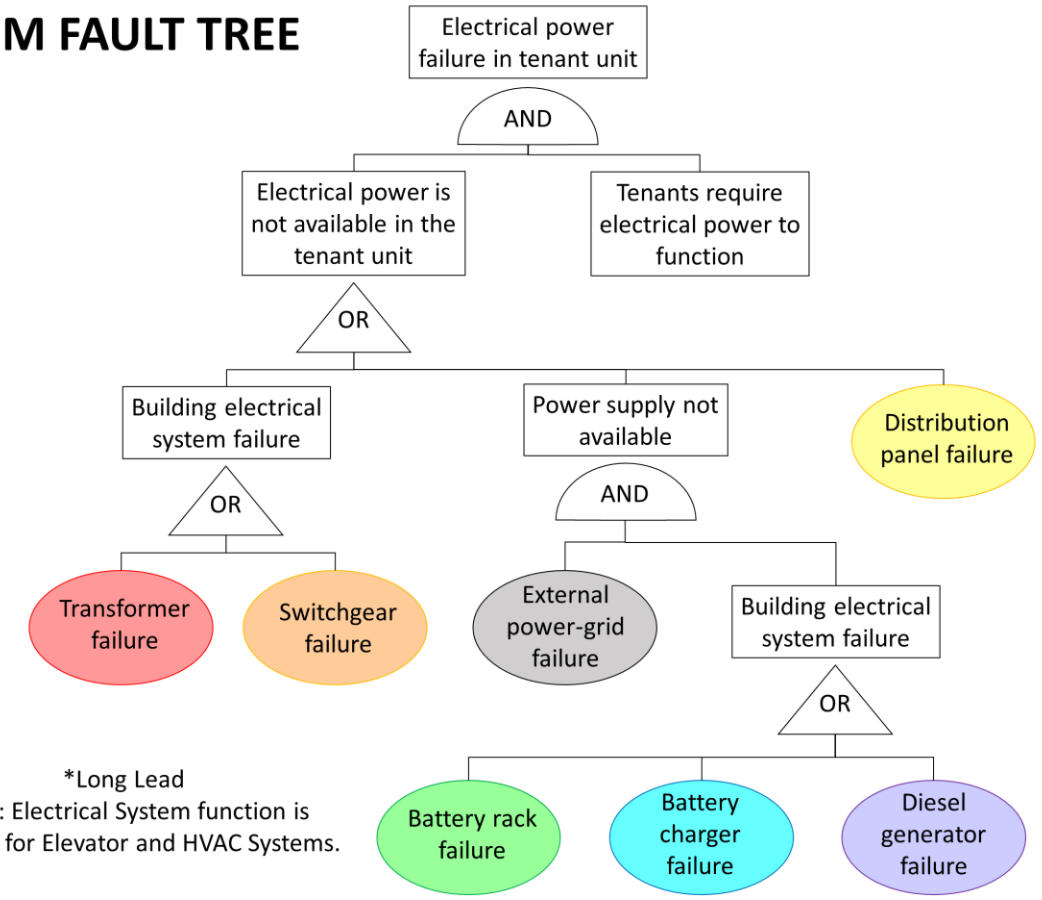
3. FR Design of Nonstructural Systems: System Level Analysis

ELECTRICAL SYSTEM FAULT TREE



Transformer

D5011.013b
Equipment
D5011.013a
Anchorage*

Switchgear

D5012.023b
Equipment*
D5012.023a
Anchorage*

Distribution Panel

D5012.033b
Equipment*
D5012.033a
Anchorage*

*Long Lead
NOTE: Electrical System function is required for Elevator and HVAC Systems.

Battery Rack

D5092.013b
Equipment*
D5092.013a
Anchorage*

Battery Charger

D5092.023b
Equipment*
D5092.023a
Anchorage*

Diesel Generator

D5092.033b
Equipment
D5092.033a
Anchorage*

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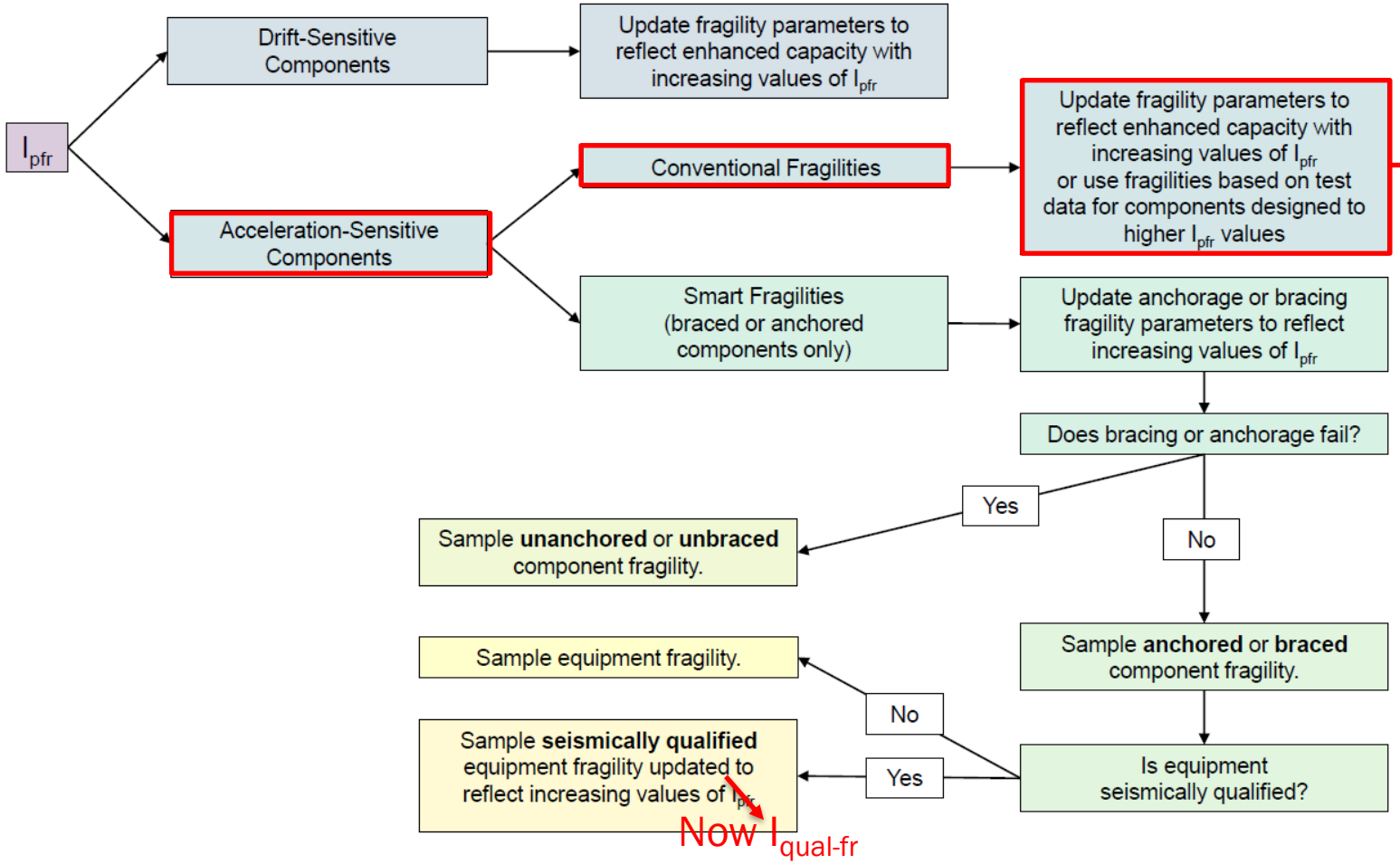
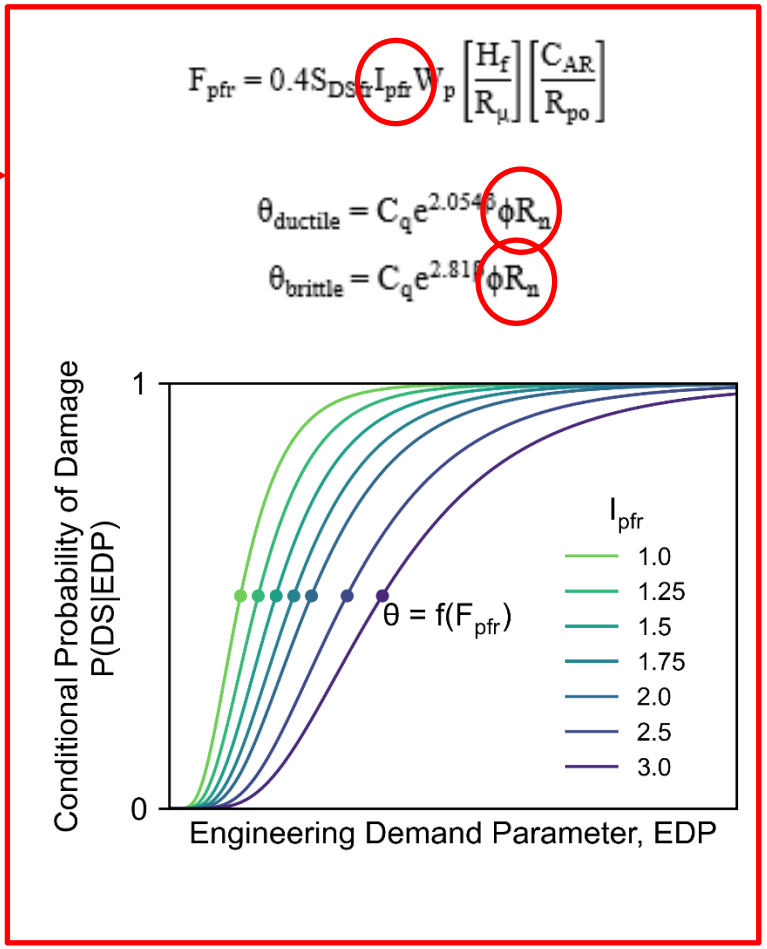
3. FR Design of Nonstructural Systems: Impacts of I_{pfr}





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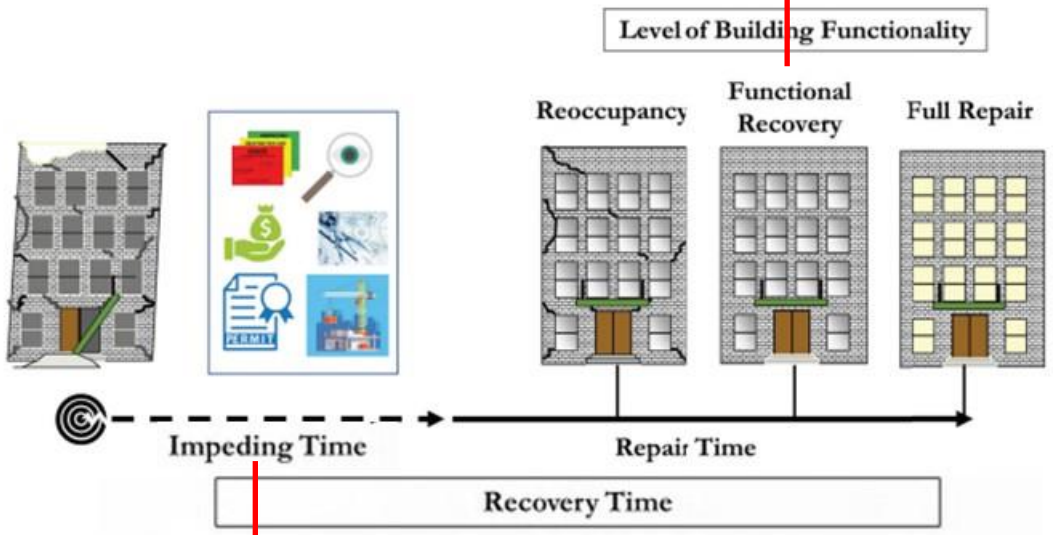
3. FR design of nonstructural systems: FR Definition & Modeling



Requirements for Function Recovery.

Description	Requirements for Functional Recovery
HVAC	Required
Plumbing	Required
Electrical	Required
Elevators	No
Temporary Repairs	Allowed
Fire Watch	Allowed*
Egress	50% of Exits, 2 Minimum
Flooding	Consequences Included
Surge Demand	Not Considered
Percentage of Functional Floor Area	80%

Description	Recovery Category B	Recovery Category C & D
FACTORS THAT DELAY START OF REPAIRS		
Inspection	Required	Required
Financing	Required	Required
Permitting	Required	Required
Engineering Mobilization and Design	Required	Required
Contractor Mobilization	Required	Required
Long Lead Time	On	On
MITIGATION STRATEGIES		
Inspector on Retainer	Yes	No
Engineer on Retainer	Yes	No
Contractor Relationship	Yes	No
Funding Source	Private financing	Private financing
Cash on Hand	5% cash on hand	5% cash on hand

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3. FR Design of Nonstructural Systems: Framework Illustration

Studying the impact on recovery of the different design variables considered:

- R_{fr} (to limit safety-critical damage)
- Δ_{afr} (to limit safety-critical damage)
- I_{pfr}
- Seismic qualification

Functional Recovery Category	Target Functional Recovery Time	
	General Expectation	Acceptance Criteria
A	Immediate	0 hours
B	Within a few days	72 hours
C	Within a couple of months	2 months
D	Within half a year	6 months

with 25% conditional probability of exceedance

Functional Recovery Reliability Target:

- 25% chance of exceeding recovery time target (# of hours, days, etc.) conditioned on FRE_R ground motions
- 10% attributed to the structure (i.e., safety-critical structural damage)

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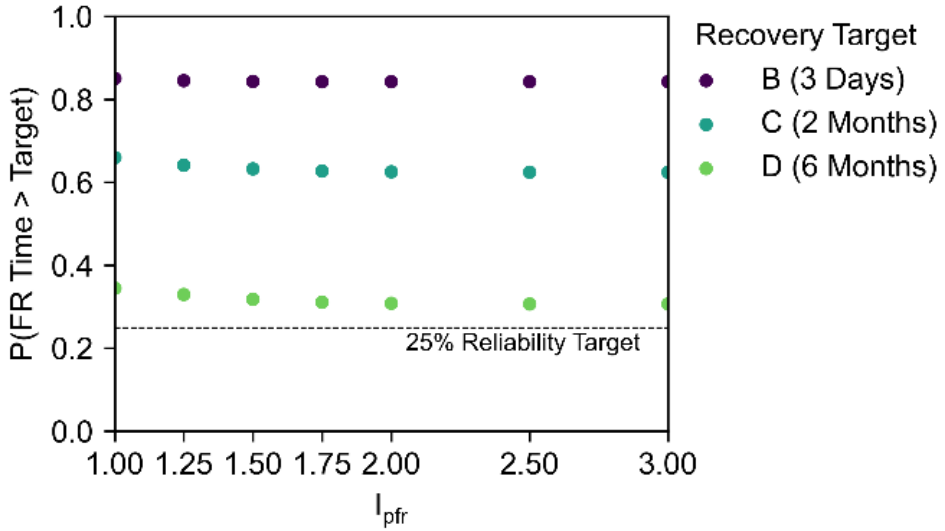
3. FR Design of Nonstructural Systems: Framework Illustration

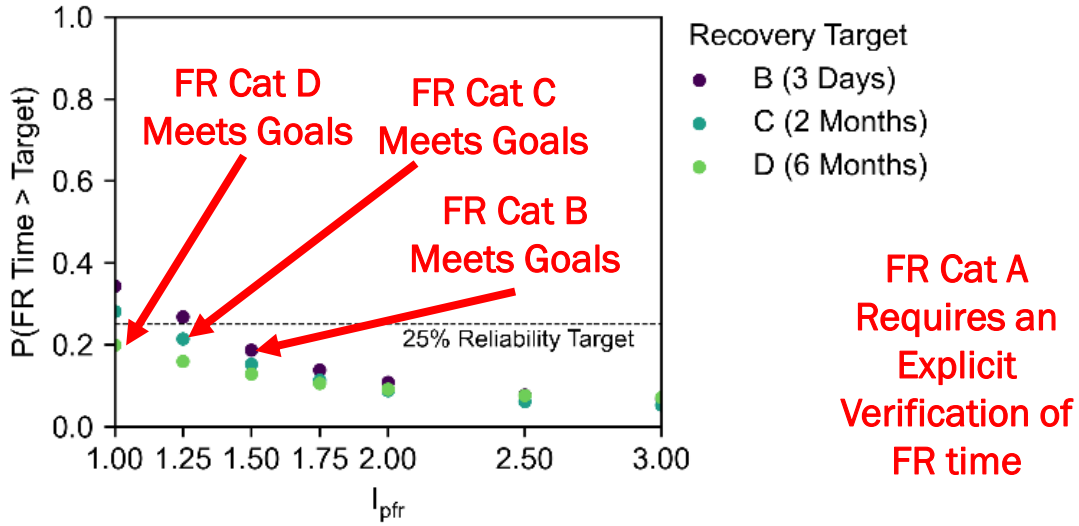
Illustrative Example: 8-story RCMF with PT Slabs ($D_{max,FRE}$ spectrum)

- FR Cat A/B/C: R_{fr} = 4 and Δ_{afr} = 0.75%
- FR Cat D: R_{fr} = 5 and Δ_{afr} = 0.75%

Reliability target: P(FR Time > Target) ≤ 25%



Without Seismic Qualification



FR Cat A Requires an Explicit Verification of FR time

With Seismic Qualification

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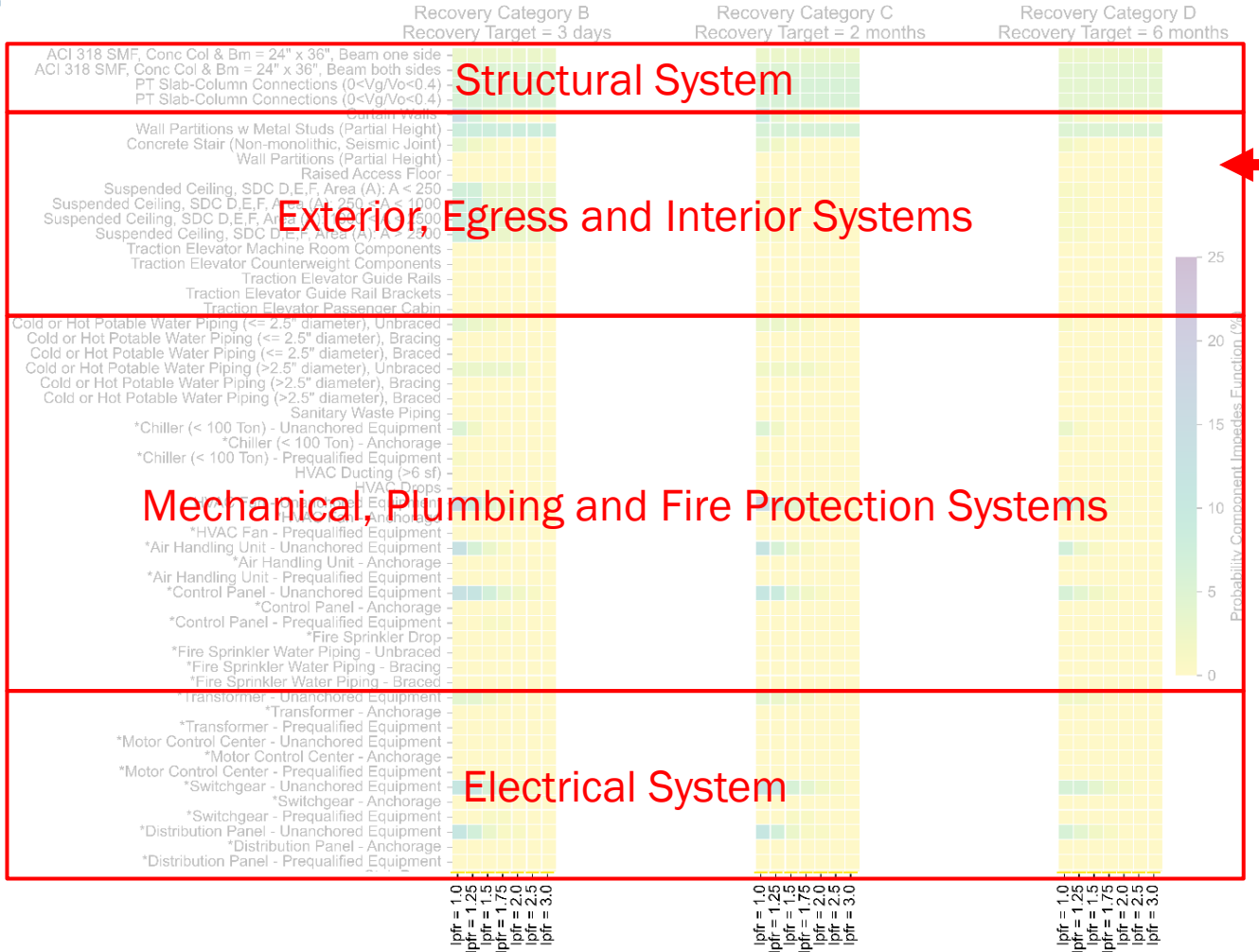
3. FR Design of Nonstructural Systems: Framework Illustration



Disaggregations to identify which components impede function for increasing values of Ipfr at different recovery time targets.

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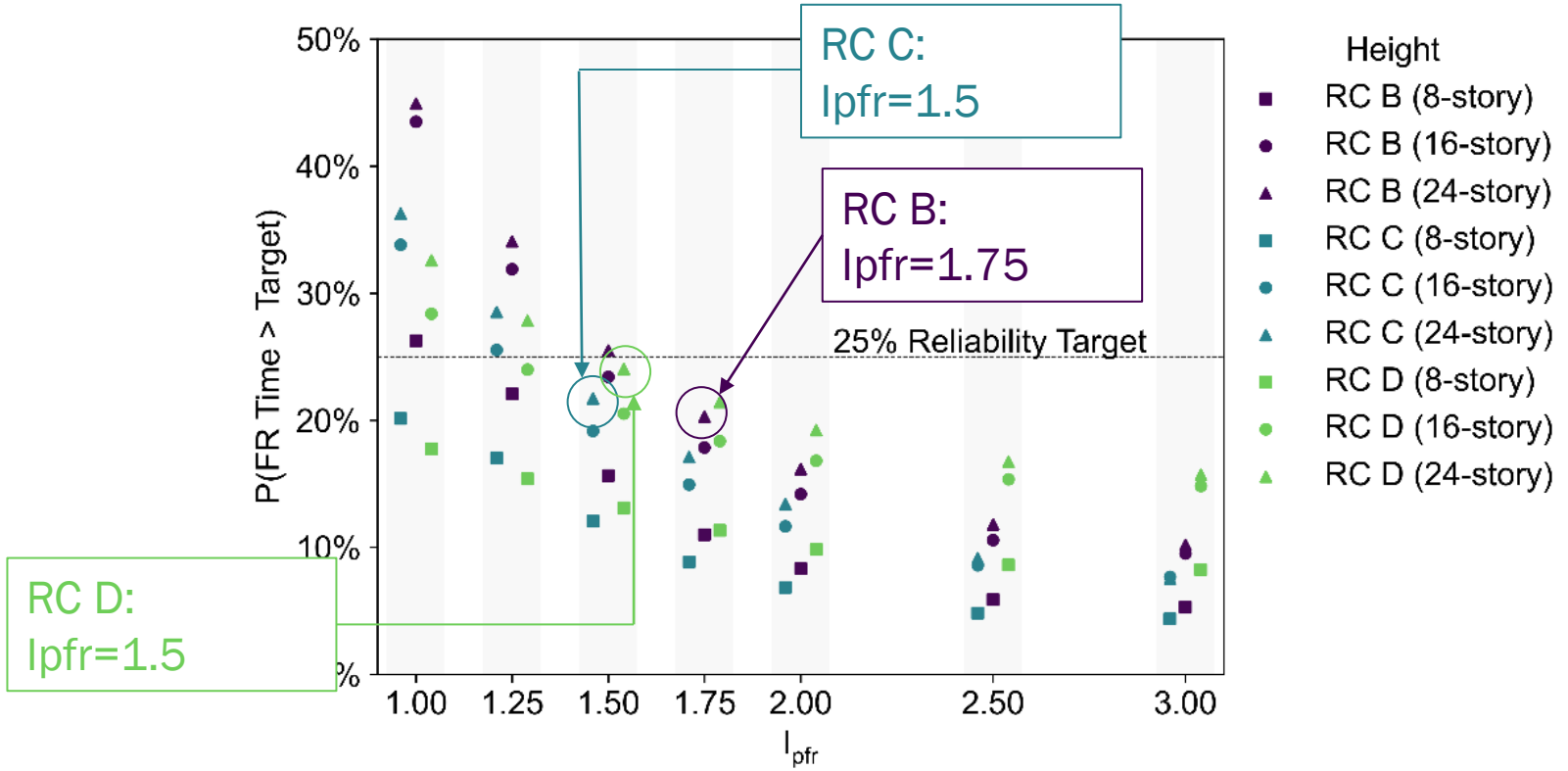
3. FR Design of Nonstructural Systems: RC Shear Wall Systems

RC Ductile coupled walls (Flexure-governed, Bearing), PT Slab



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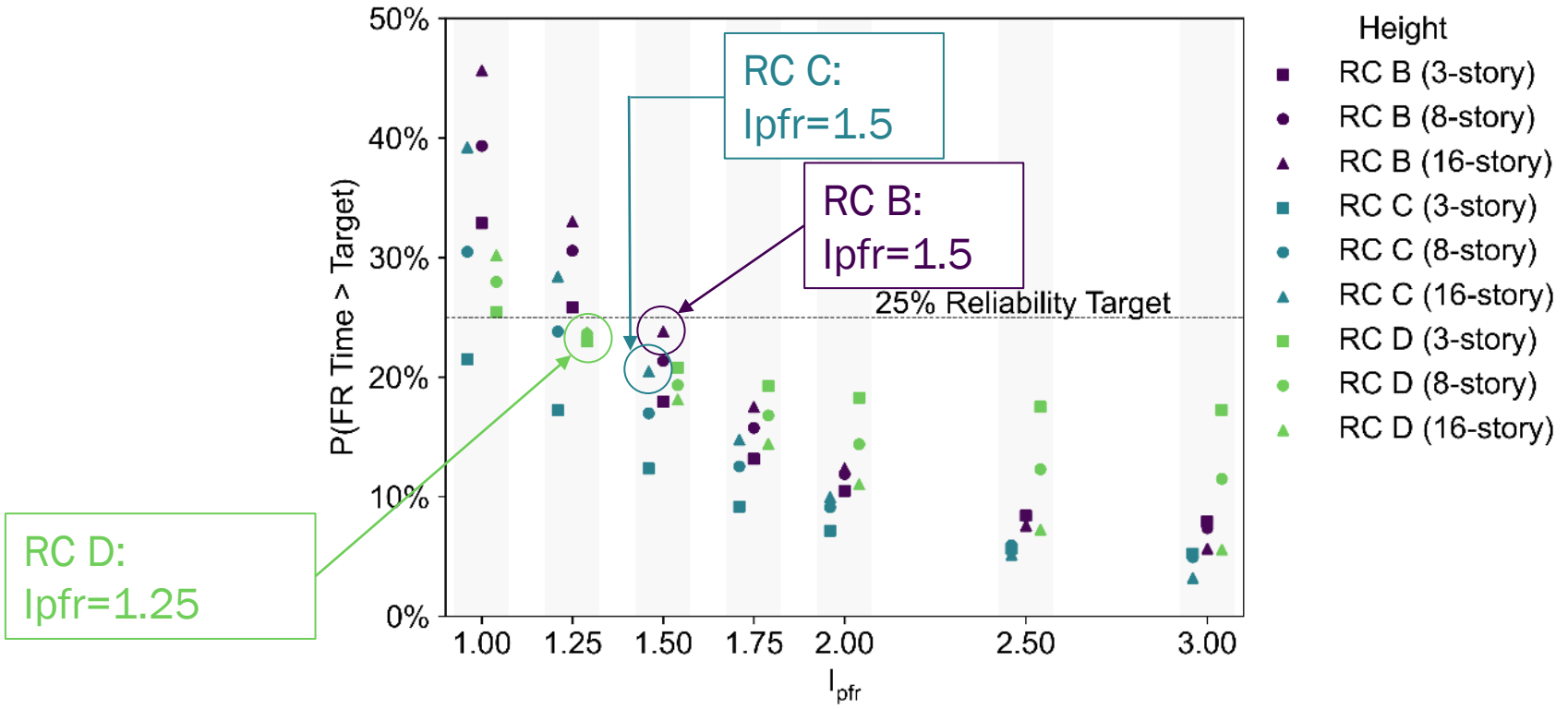
3. FR Design of Nonstructural Systems: Steel BRBF Systems

Steel BRBF with Backup Frame, Steel Gravity System



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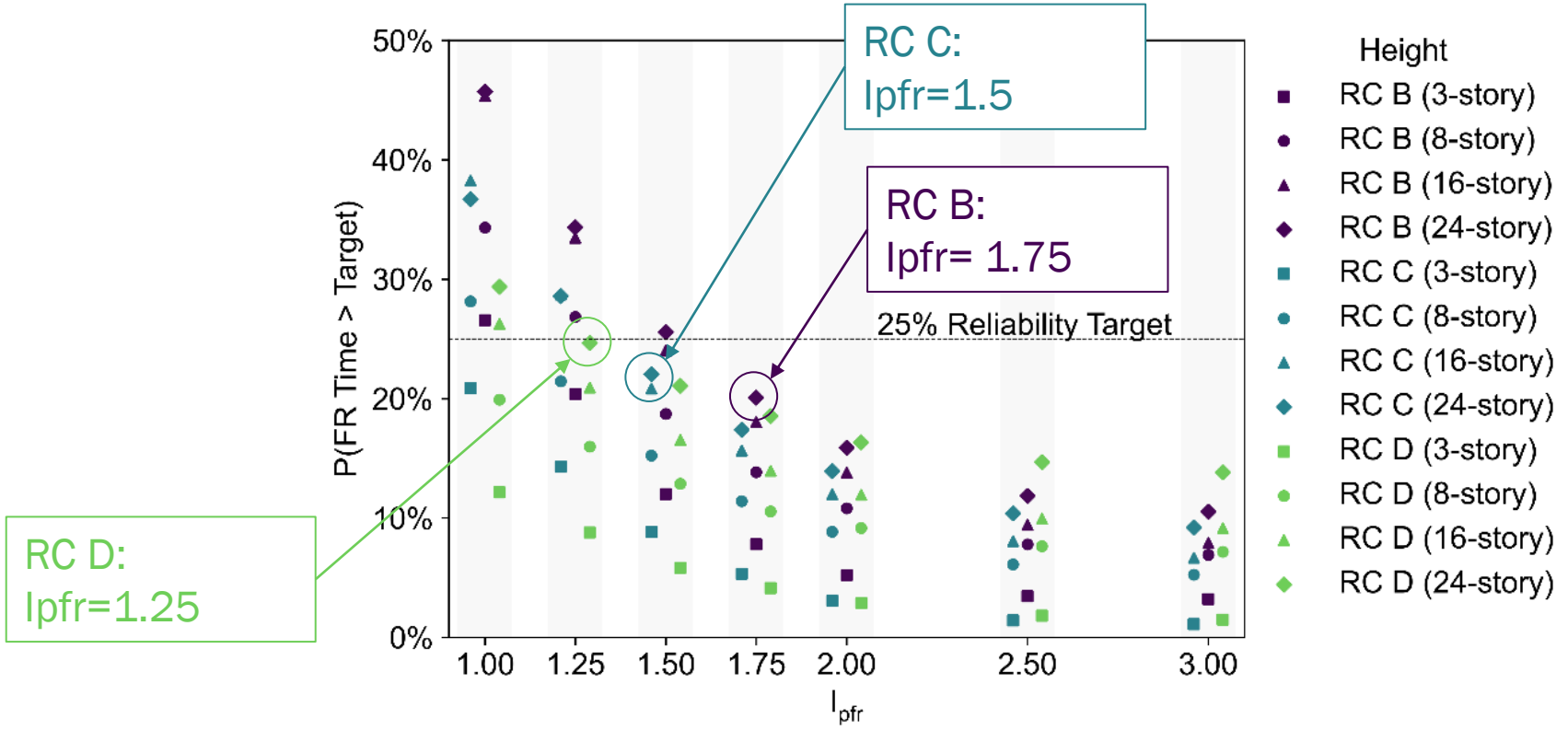
3. FR Design of Nonstructural Systems: Moment Frame Systems

Special RC Moment Frames, PT Slab



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3. FR Design of Nonstructural Systems: Ipfr Summary

Seismic Force-Resisting System	Number of Stories	P(RT > Target) Recovery Category B (I_{pfr} = 1.75)	C (I_{pfr} = 1.5)	D (I_{pfr} = 1.25)	P(RT > Target) Recovery Category B (I_{pfr} = 1.75)	C (I_{pfr} = 1.5)	D (I_{pfr} = 1.25)
BEARING WALL SYSTEMS							
Special reinforced concrete shear walls where the shear capacity is not designed for the shear demand corresponding to the expected flexural capacity	3	15%	16%	15%	15%	16%	15%
Special reinforced concrete shear walls where the shear capacity is designed for the shear demand corresponding to the expected flexural capacity	8	9%	10%	11%	15%	17%	18%
	16	16%	18%	19%			
	24	22%	23%	24%			
Reinforced concrete ductile coupled walls	8	11%	12%	15%	16%	18%	22%
	16	18%	19%	24%			
	24	20%	22%	28%			
BUILDING FRAME SYSTEMS							
Special reinforced concrete shear walls where the shear capacity is not designed for the shear demand corresponding to the expected flexural capacity	3	13%	14%	20%	13%	14%	20%
Special reinforced concrete shear walls where the shear capacity is designed for the shear demand corresponding to the expected flexural capacity	8	11%	12%	14%	16%	17%	21%
	16	18%	19%	22%			
	24	20%	21%	27%			
Reinforced concrete ductile coupled walls	8	11%	12%	15%	16%	18%	22%
	16	18%	19%	24%			
	24	20%	22%	28%			
Steel buckling-restrained braced frames, non-moment-resisting beam-column connections	3	29%	27%	28%	25%	25%	26%
	8	27%	27%	28%			
	16	19%	22%	23%			
Steel buckling-restrained braced frames, moment-resisting beam-column connections	3	13%	12%	23%	15%	17%	23%
	8	16%	17%	24%			
	16	18%	20%	24%			
MOMENT-RESISTING FRAME SYSTEMS							
Steel special moment frames	3	11%	11%	19%	15%	16%	21%
	8	17%	17%	28%			
	16	16%	17%	20%			
	24	16%	18%	18%			
Special reinforced concrete moment frames	3	8%	9%	9%	15%	17%	18%
	8	14%	15%	16%			
	16	18%	21%	21%			
	24	20%	22%	25%			

Table A.10-1. Functional Recovery Nonstructural Component Importance Factors by Functional Recovery Category for Earthquake Loads

Functional Recovery Category	Seismic Functional Recovery Component Importance Factor, I_{pfr}
A and B	1.75
C	1.5
D	1.25

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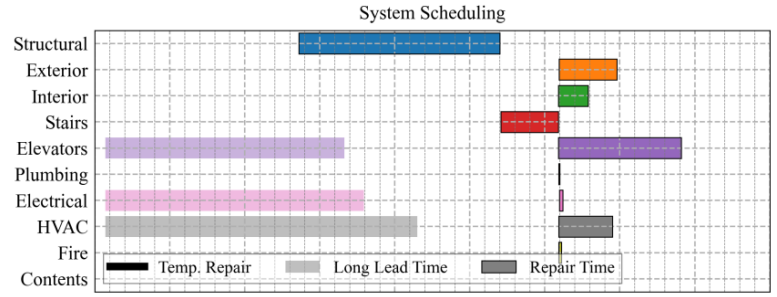
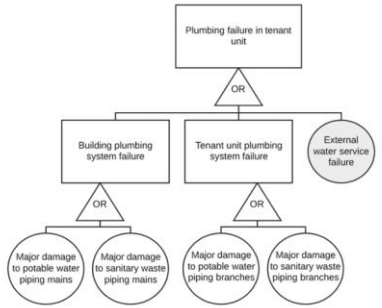
Overall Approach for Functional Recovery Design

<25% building-level probability of functional recovery time exceeding 2 months



<10% system-level probability of functional recovery time exceeding 2 months



<5% component-level probability of damage which triggers function loss

Building Level

System Level

Component Level

Building-Level Analysis

Using ATC-138, “deaggregate” or “partition up” allowable probability of exceedance at building level into allowable probability at system level.

System-Level Analysis

Using ATC-138, “aggregate” probabilities of component damage which trigger function loss to probability at system level.

Component-Level Analysis

Using reliability statistics, determine acceptable margin between demand and component function loss capacity.

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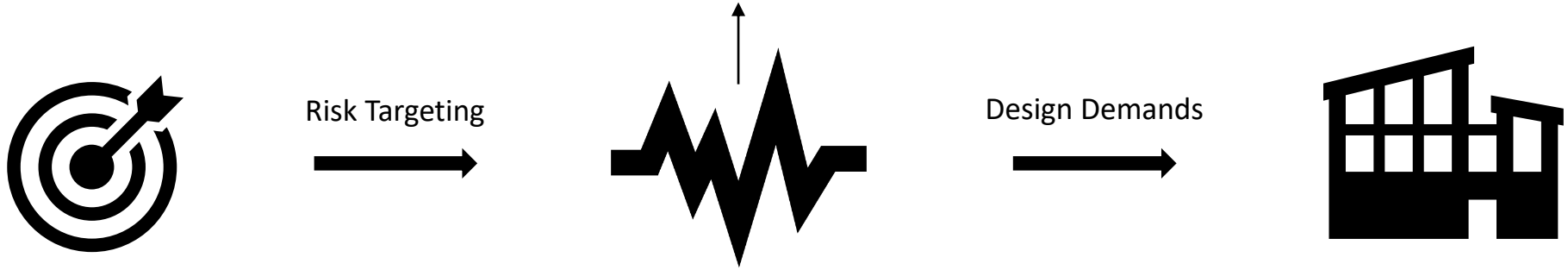
Overall Summary

The Functional Recovery Earthquake (FRE_R) is a risk-based characterization of the earthquake hazard that relies on both a specified risk target and a specified reliability target.



Performance Target

Ground Motion Hazard

Building Design

Functional Recovery Category	Target Functional Recovery Time
A	0 hours
B	72 hours
C	2 months
D	6 months

Prescriptive Design Provisions:

1. Structural System Design (R_{fr}, Δ_{afr})
2. Nonstructural System Design (I_{pfr}, Qualification)
3. Other Requirements (FR Coordinator, etc.)

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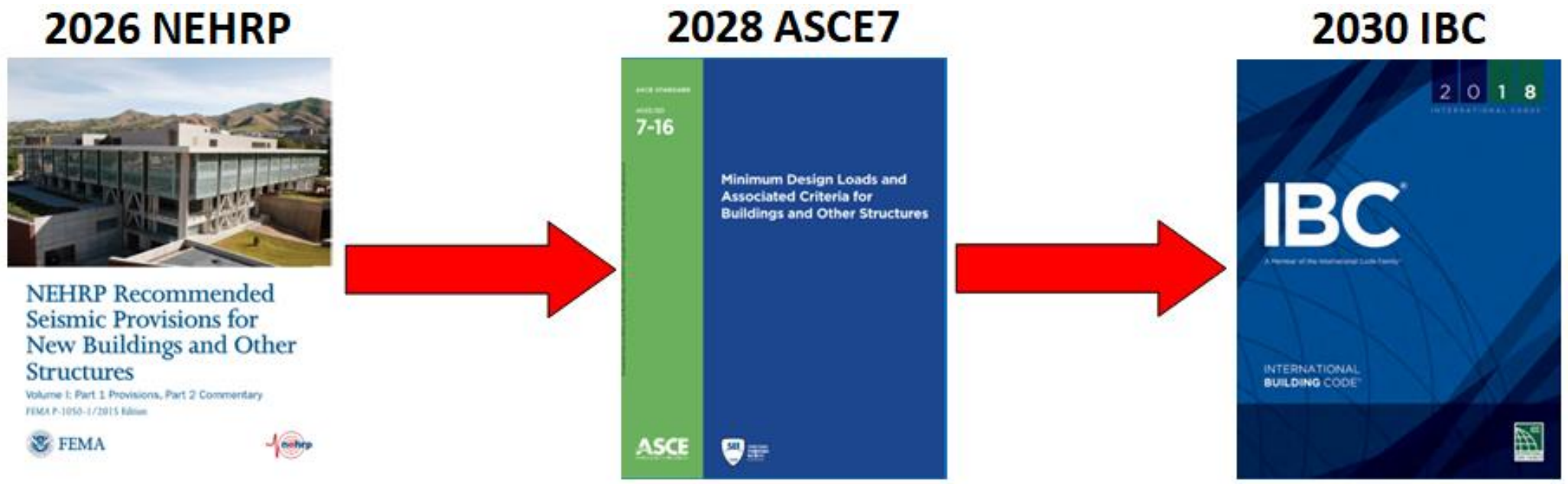
Next Steps of the NEHRP and ASCE 7 Effort

Development of Provisions for Building Code Adoption:
2026 NEHRP Recommended Seismic Provisions



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Additional Resources

- NEHRP PUC Functional Recovery Planning Committee Report
  https://www.nibs.org/reports/functional-recovery-planning-committee-report

- FEMA-NIST Functional Recovery Report
  https://www.fema.gov/sites/default/files/documents/fema_p-2090_nist_sp-1254_functional-recovery_01-01-2021.pdf

- ATC 138-3 Report
  http://femap58.atcouncil.org/documents/fema-p-58/34-atc-138-3-volume-8-methodology-for-assessment-of-functional-recovery-time/file

- FEMA-ATC Functional Recovery Workshop Report
  https://www.atcouncil.org/doclink/atc-58-7-fr-workshop-report-2022-2/eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.eyJzdWIiOiJhdGMtNTgtNy1mci13b3Jrc2hvcC1yZXBvcnQtMjAyMi0yIiwiaWF0IjoxNjc3NjE4NjUwLCJleHAiOjE2Nzc3MDUwNTB9.LqdNzmgp5ySLs0uw4epR6eiQhYLJjK2rRKtJ1sx9OGk

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Reference Material

LIMITING SAFETY-CRITICAL STRUCTURAL DAMAGE IN RECOVERY-BASED SEISMIC DESIGN PROVISIONS

Kristen Blowes, M.EERI[1], Carlos Molina Hutt, M.EERI[1], Reid B. Zimmerman, M.EERI[2], Dustin T. Cook, M.EERI[3], Ed Almeter, M.EERI[4], Curt Haselton, M.EERI[4,5]

NONSTRUCTURAL DESIGN REQUIREMENTS FOR FUNCTIONAL RECOVERY PERFORMANCE

Kristen Blowes, M.EERI[1], Carlos Molina Hutt, M.EERI[1*], Reid B. Zimmerman, M.EERI[2], Dustin T. Cook, M.EERI[3], Ed Almeter, M.EERI[4], Curt Haselton, M.EERI[4,5]

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Other Relevant ESR Lab Journal Papers

- Molina Hutt, C., Vahanvaty, T. and Kourehpaz, P. (2022). "An analytical framework to assess earthquake induced downtime and model recovery of buildings." *Earthquake Spectra,* 38(2) 1283–1320.
https://doi.org/10.1177/87552930211060856

- Molina Hutt, C., Hulsey, A. M., Kakoty, P., Deierlein, G. G., Eksir Monfared, A., Yen, W. Y. and Hooper, J. D. (2022). "Towards functional recovery performance in the seismic design of modern tall buildings." *Earthquake Spectra,* 38(1) 283–309.
https://doi.org/10.1177/87552930211033620

- Blowes, K., Kourehpaz, P. and Molina Hutt, C. (2023) "Risk-targeted seismic evaluation of functional recovery performance in buildings." *Earthquake Engineering and Structural Dynamics, 52: 4245-4264.*
https://doi.org/10.1002/eqe.3984

- Palomino Romani, G., Blowes, K. and Molina Hutt, C. (2023) "Evaluating post-earthquake functionality and surge capacity of hospital emergency departments using discrete event simulation." *Earthquake Spectra, 39(1) 402–433.*
https://doi.org/10.1177/87552930221128607

- Li, L., Chang-Richards, A., Boston, M., Elwood, K., Molina Hutt, C. (2023) "A systematic review of post-disaster functional recovery studies: Directions for future research." *International Journal of Disaster Risk Reduction, 95: 103899.*
https://doi.org/10.1016/j.ijdrr.2023.103899

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- **Abbie Liel* (Vice Chair), Univ. of Colorado**
- **Anna Lang, Zylient**
- Bob Pekelnicky* (PUC Liaison), Degenkolb
- Bret Lizundia*, Rutherford+Chekene
- **Carlos Molina Hutt, Univ. of Brit. Columbia**
- Christina Aronson*, FEMA
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- **Dustin Cook, NIST**
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- Jeff Soulages*, Intel
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- **Jon Heintz*, Applied Technology Council**
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* Indicates member of prior FR Planning Comm.

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Thank you!
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