Issue Team 1
Seismic Design Category Consolidation

Robert Pekelnicky, PE, SE
Chair 2020 PUC IT-01

Topics

- Seismic Design Category Consolodation
- Reliability of Structural and Nonstructural Components for Safety
- Function of RC IV Reliability
- Egress

Issue Team 1

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Purpose

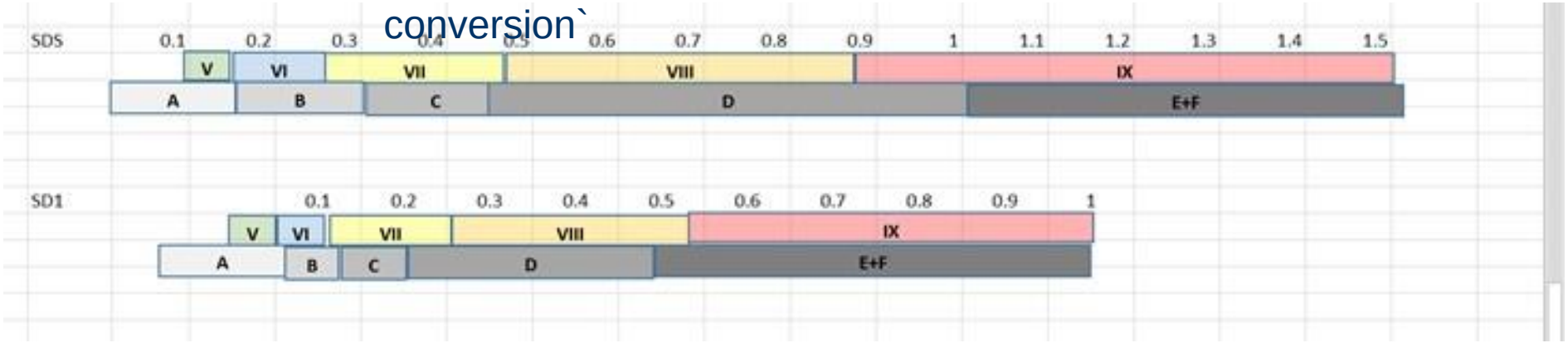
- Simplify the standard, by consolidating 6 SDCs to 4
  - A, B/C, D, E/F
  - Note these could be called-
    - Low seismic
    - Moderate Seismic
    - High Seismic
    - Near Fault
- By combining several B and C eliminate some of the instability in SDC determination as ground motion values change.
- Separate structural and nonstructural requirements. They should not be triggered by the same motions.

Background

- Seismic Design Categories as presently used in ASCE 7 were developed under the 1997 NEHRP Provisions

SDC	S_{DS}	S_{MS}	MCE MMI	S_{D1}	S_{M1}	MCE MMI	Requirements
A	<.167	<.25	VI	<.067	<.1	VI	Structural Integrity
B	<.33	<.5	VII	<.133	<.2	VII	Structure design, parapets, few system limits
C	<.5	<.75	VIII	<.2	<.3	VII	Structure design, multi-direction, nonstructural, few more
D	.5≤	.75≤	VIII+	.2≤	.3<	VIII	Restrictions on analysis method and systems
E			IX	.75<	1.1≤	IX	Irregularity restrictions
F			IX			IX	Irregularity restrictions and height limits

16th percentile MMI to Sa conversion`



EQ Damage Study Conclusions

- Current SDC boundaries map reasonably well to high confidence of having:
  - SDC A – MMI V - maximum
  - SDC B – MMI VI - maximum
  - SDC C – MMI VII - Maximum
  - SDC D – having MMI VIII or higher
- Recent evidence suggests that MMI VI and lower, there is no need to provide seismic protection
- For MMI VII – probably need to protect against cantilevered parapets, chimneys and nonstructural falling hazards
- MMI VIII and above design for earthquake like you mean it!

Proposal

- Separate structural and nonstructural SDCs
- Establish Structural SDCs as follows:

  A – No seismic design required (structural Integrity)
  - Assign this to all structures with MCE MMI <VI at the 16th percentile

  BC – Seismic design required, little regulation of analysis procedure, or systems
  - Assign this to all structures with MMI VII at the 16th percentile

  DEF – High seismic design required. Analysis and system limitations. No extreme weak story irregularity.
  - Assign this to all structures with MMI VIII or greater

Proposed conversion of Sa to MMI

	Upper Bounds	
MMI	S-0.3	S-1
V	0.10	0.02
VI	0.15	0.05
VIII	0.25	0.1
VIII	0.50	0.25
IX	0.90	0.6

Worden C.B., Gertenberger, M.C., Rhoades, D.A. and Wald, D.J. *Probabilistic Relationships between Ground Motion Parameters and Modified Mercalli Intensity in California*, Bulletin of Seismological Society of America, Vol 102, No.1 pp 204-221, Feb, 2012.

- SDC – A: MMI VI and lower S_{DS}<0.15g, S_{D1}< 0.05g (presently 0.167/0.067) "A shrinks"
- SDC – BC: VI < MMI < VIII S_{DS}<0.5g, S_{D1}<0.25g (presently .5/.2) "BC grows at lower end"
- SDC – DEF: S_{DS}>0.5g, S_{D1}>0.25g (presently 0.5/0.2) "D grows to encompass E & F"

SDC BC Criteria

- ELF allowed for any structure
- Direction combination required
- Adopt following System limits
  - Not permitted (all are currently permitted in SDC B)
    - Plain concrete, Plain masonry, Plain AAC
    - Ordinary composite frames
    - Ordinary concrete frames (?)
  - Height Limits – adopt present SDC “C”
    - Ordinary reinforced masonry limited to 160
    - Ordinary reinforced AAC limited to 35 feet

SDC DEF

- Preserve present SDC D criteria
- Add prohibition of extreme weak story irregularity
- The only SDC E & F difference than SDC D are height limits and some system exclusions:
  - SDC E/F – 160’ limit reduced to 100’
  - SDC D/E -160 feet reduced to SDC F 100 feet for bearing wall systems
  - SDC F prohibits Special Truss Moment frames
  - SDC F prohibits Composite Special Concentric Braced Frames
  - SDC F prohibits OCBF under 35’
  - Really there is no basis for these extra limits, other than a desire to be “more conservative” Recent ATC 58 studies suggest bearing wall systems are among the best performing in SDC IV – so why limit?

Nonstructural

- Desire to align with structural SDCs
- SDC A – No nonstructural design requirements (including Risk Category IV)
  - No Change
- SDC B/C – Nonstructural design requirements for items that could hurt/kill.
  - Different from current requirements. More items will be braced in B and C.
  - Use FEMA E74 and ASCE 41 Nonstructural Life Safety as basis.
- SDC DEF – Current SDC D requirements
  - Anchor or brace almost everything
  - Require equipment qualification for Risk Category IV facilities.

Issue Team 1
Performance Objectives
Reliability

Robert Pekelnicky, PE, SE
Chair 2020 PUC IT-01

2015 NEHRP Provisions

1.1 INTENT

The *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures* presents the minimum recommended requirements necessary for the design and construction of new buildings and other structures to resist earthquake ground motions throughout the United States. The objectives of these provisions are to provide reasonable assurance of seismic performance that will:

1. Avoid serious injury and life loss due to
    a. Structure collapse
    b. Failure of nonstructural components or systems
    c. Release of hazardous materials
2. Preserve means of egress
3. Avoid loss of function in critical facilities, and
4. Reduce structural and nonstructural repair costs where practicable.

These performance objectives do not all have the same likelihood of being achieved. Additional detail on the objectives is provided in section 1.1.1 through 1.1.6.

The degree to which these objectives can be achieved depends on a number of factors including structural framing type, building configuration, structural and nonstructural materials and details, and overall quality of design and construction. In addition, large uncertainties as to the intensity and duration of shaking and the possibility of unfavorable response of a small subset of buildings or other structures may prevent full realization of these objectives.

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2015 NEHRP Provisions

Risk Category[1]	Probability of Collapse	
	Given MCE_R Shaking	In 50 years*
I	**	**
II	10%	1%
III	5%	less than 1%
IV	2.5%	less than 1%

*The probability of collapse in 50 years is larger in areas where the MCE_R ground motion is computed from a deterministic assumption of earthquake occurrence.

**Most Risk Category I structures are designed for the same requirement as Risk Category II, while some are exempted from any seismic design requirement.

ASCE 7-16

Table 1.3-2 Target Reliability (Conditional Probability of Failure) for Structural Stability Caused by Earthquake

Risk Category	Conditional Probability of Failure Caused by the MCE_R Shaking Hazard (%)
I & II	10
III	5
IV	2.5

Table 1.3-3 Target Reliability (Conditional Probability of Failure) for Ordinary Noncritical Structural Members Caused by Earthquake

Risk Category	Conditional Probability of Component or Anchorage Failure Caused by the MCE_R Shaking Hazard (%)
I & II	25
III	15
IV	9

ASCE 7-16

Table 1.3-3 Target Reliability (Conditional Probability of Failure) for Ordinary Noncritical Structural Members Caused by Earthquake

Risk Category	Conditional Probability of Component or Anchorage Failure Caused by the MCE_R Shaking Hazard (%)
I & II	25
III	15
IV	9

The standard also seeks to protect against local failure that does not result in global collapse but could result in injury risk to a few persons. Chapter 16 of the standard defines structural elements according to their criticality as critical, ordinary and noncritical, where critical elements can lead to global collapse; ordinary elements to endangerment of a limited number of lives; and noncritical elements do not have safety consequences. For ordinary elements in risk category II structures, the standard accepts a 25% probability of failure given MCE_R shaking (approximately 10% probability of failure for DE shaking). Failure probabilities for ordinary elements in Risk Category III and IV structures are respectively 15% and 9% for MCE_R shaking and 4% and 2% for DE shaking.

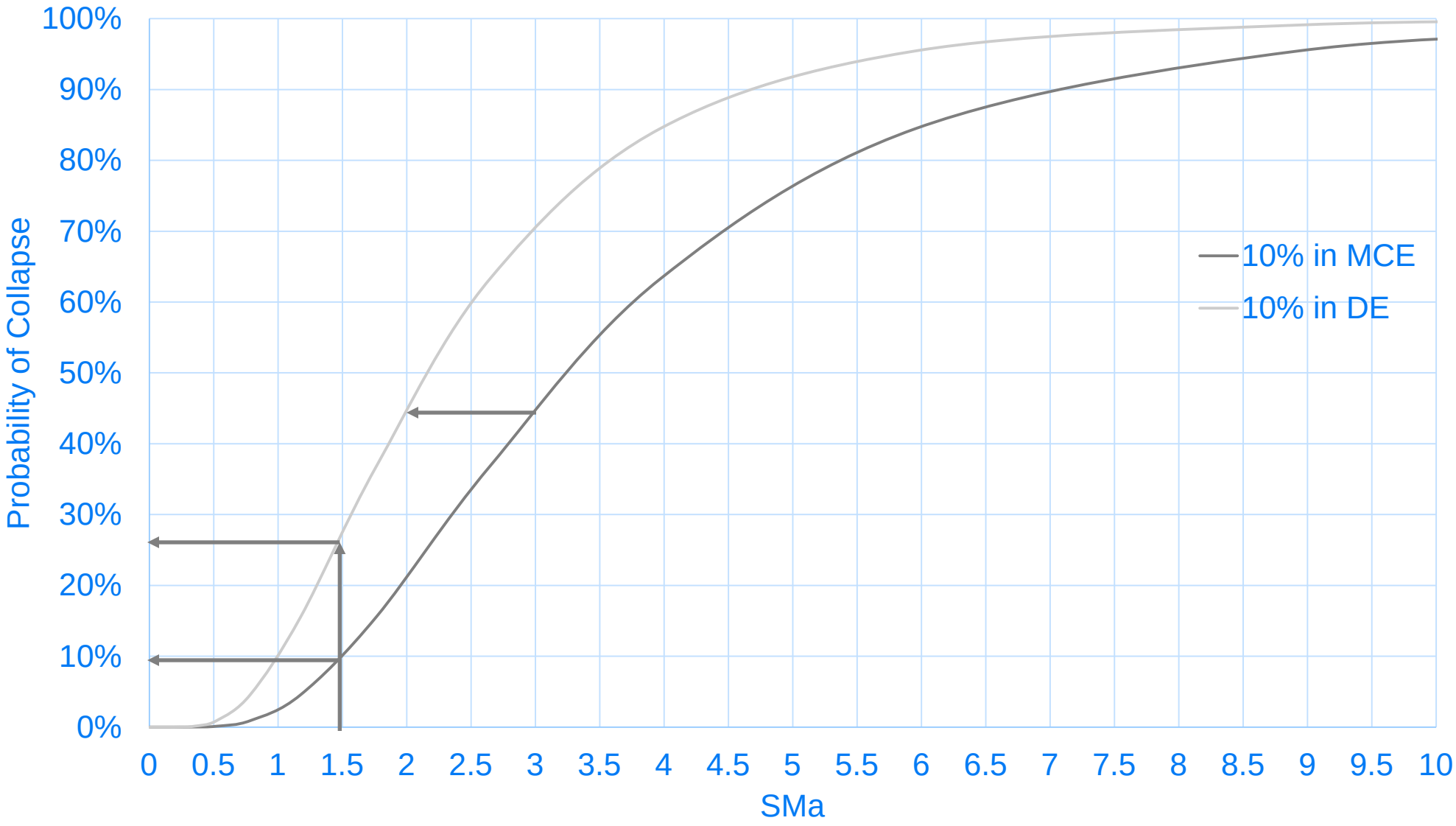
ASCE 7-10

Table C.1.3.1b Anticipated Reliability (Maximum Probability of Failure) for Earthquake[1]

Risk Category I and II	
Total or partial structural collapse	10% conditioned on the occurrence of maximum considered earthquake shaking
Failure that could result in endangerment of individual lives	25% conditioned on the occurrence of maximum considered effects
Risk Category III	
Total or partial structural collapse	6% conditioned on the occurrence of maximum considered earthquake shaking
Failure that could result in endangerment of individual lives	15% conditioned on the occurrence of maximum considered earthquake shaking
Risk Category IV	
Total or partial structural collapse	3% conditioned on the occurrence of maximum considered earthquake shaking
Failure that could result in endangerment of individual lives	10% conditioned on the occurrence of maximum considered earthquake shaking

[1]Refer to the NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Strucures, FEMA (1997), for discussion of the basis of seismic reliabilities.

ASCE 7-10 Basis for 25% in MCE



Individual Elements Proposed for 2020 NEHRP

Risk Category[1]	Probability of Failure for Component or Anchorage	
	Given DE Shaking	Given MCE_R Shaking
I	**	**
II	10%	25%
III	5%	15%
IV	2.5%	10%

This would align with the targeted reliability for ordinary force-controlled actions per Chapter 16.

Individual Elements Proposed for 2020 NEHRP

Risk Category[1]	Failure That Could Result In Individual Lives	
	Given DE Shaking	Given MCE_R Shaking
I	**	**
II	10%	25%
III	5%	15%
IV	2.5%	10%

This would align with the targeted reliability for ordinary force-controlled actions per Chapter 16.

Nonstructural Reliability

Should we extend the individual element reliability in the Design Earthquake to Nonstructural Components?

Risk Category[1]	Probability of Failure for Component or Anchorage	
	Given DE Shaking	Given MCE_R Shaking
I	**	**
II	10%	25%
III	5%	15%
IV	2.5%	10%

Nonstructural Reliability

ATC 120 project had strong consensus that nonstructural components should not have any explicity MCE performance target.

Risk Category[1]	Probability of Failure for Component or Anchorage	
	Given DE Shaking	Given MCE_R Shaking
I	**	**
II	10%	25%
III	5%	15%
IV	2.5%	10%

Nonstructural Reliability

Since there are only two nonstructural performance categories, we would be left with

Risk Category / Nonstructural Importance Factor	Probability of Failure for Component or Anchorage Given DE Shaking
II / Ip = 1.0	10%
IV / Ip = 1.5	2.5%

Hazardous Material Reliability

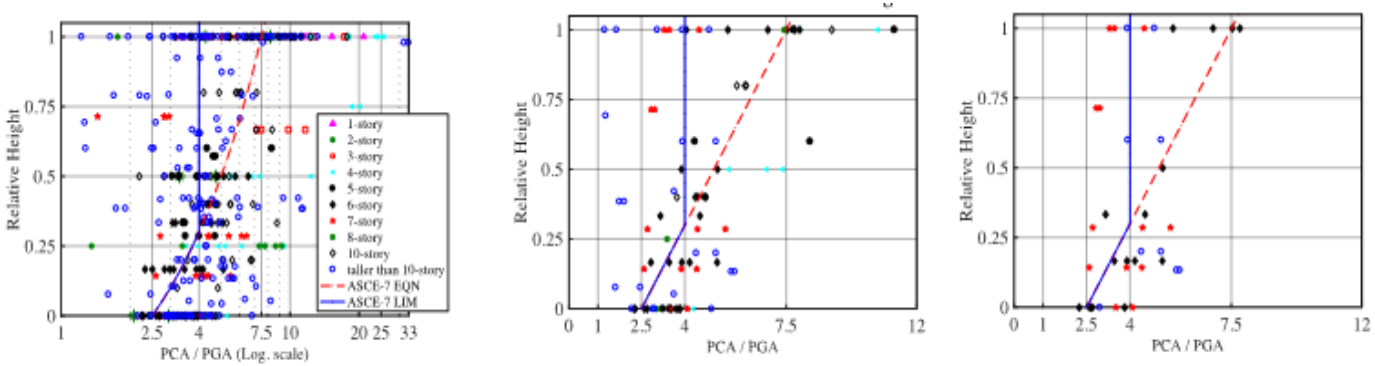
ASCE 7-16 currently requires Ip = 1.5 for a component that “conveys, supports, or otherwise contains toxic, highly toxic, or explosive substances … sufficient to pose a threat to the public if released.”

Provisions currently identify release of hazardous materials is “very low at the DE ground motion and thus low at the MCE_R ground motion.”

Risk Category/ Nonstructural Importance Factor	Probability of Failure for Component or Anchorage	
	Given DE Shaking	Given MCE_R Shaking
IV / Ip = 1.5	2.5%	10%

Impacts / Changes

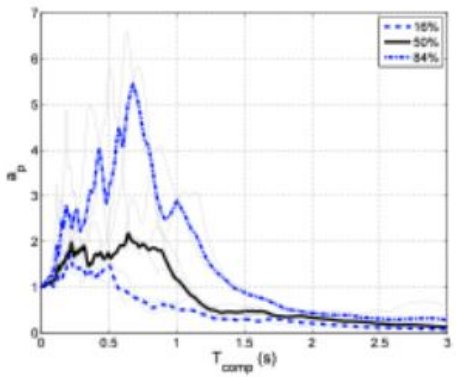
- Provides guidelines for ATC 120 and IT-5 to set equation for nonstructural design forces.



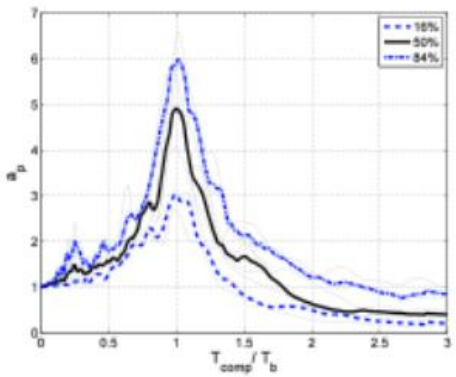
(i) All PGA/PGA_{design} (ii) $PGA/PGA_{design} \geq 0.50$ (iii) $PGA/PGA_{design} \geq 0.75$

Figure A2. Normalized PCA of the instrumented buildings and ASCE-7 F_p equations (unless otherwise noted, an elastic component with a 5% damping ratio is considered)

NOT NORMALIZED



NORMALIZED



Impacts / Changes

- Would require further study of hazardous materials containment systems to validate reliabilities.

Proposal Status

- Task group discussing should probabilities for “ordinary” component failure or for endangerment to individual life.
- Task group discussing should probabilities at the Design Earthquake be extended to Nonstructural components.
- Task group discussing should probabilities at the Design Earthquake and MCE_R be set for hazardous material release.

Issue Team 1
Function Performance Objectives

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ASCE 7-16 Section 1.3.3 Functionality

Structural systems and members and connections thereof assigned to Risk Category IV shall be designed with reasonable probability to have adequate structural strength and stiffness to limit deflections, lateral drift, or other deformations such that their behavior **would not prevent function of the facility immediately following any of the design level environmental hazard events** specified in this standard. Designated nonstructural systems and their attachment to the structure shall be designed with sufficient strength and stiffness such that their behavior would not prevent function immediately following any of the design level environmental hazard events specified in this standard. Components of designated nonstructural systems shall be designed, qualified or otherwise protected such that **they shall be demonstrated capable of performing their critical function after the facility is subjected to any of the design level environmental hazards** specified in this standard.

Proposal

Define the reliability of Risk Category IV buildings and nonbuilding structures as having only a 10% probability of losing function in the Design Earthquake ground motion.

Remove reference to “some” Risk Category III nonbuilding structures having a function preservation goal.

Need to define what constitues “loss of function”

Risk Category IV Requirements

In SDC A, B, C, and E, the SDC is increased by one increment.

Design forces are increased by 50%.

Drift limits are reduced by a factor of 2.

Liquefaction limits are reduced by a factor of 3 to 4.

Freeboard requirement for tanks and buckling prohibition for elevated tanks.

Added requirements for boilers and pressure vessels.

Ip = 1.5 increases SDC requirements again (2 SDC jump for Nonstructural).

Ip = 1.5 requires certified equipment.

Ip = 1.5 adds requirement to evaluate component attachment point.

Ip = 1.5 requires joints for electrical distribution systems.

Note: No explicit DE check in Chapter 16

Risk Category III Requirements

In SDC A, B, C, and E, the SDC is increased by one increment.

Design forces are increased by *25%*.

Drift limits are reduced by a factor of *1.5*.

Liquefaction limits are reduced by a factor of *1.5*.

Freeboard requirement for tanks and buckling prohibition for elevated tanks.

Added requirements for boilers and pressure vessels.

Ip = 1.5 increases SDC requirements again (2 SDC jump for Nonstr.).

Ip = 1.5 requires certified equipment.

Ip = 1.5 adds requirement to evaluate component attachment point.

Ip = 1.5 requires joints for electrical distribution systems.

Note: No explicit DE check in Chapter 16

Supporting Data

ATC 120 report identifies performance objective of nonstructural components required for postearthquake function as being able to function following the Design Earthquake.

Table 3-3 Proposed Framework of Performance Objectives for Nonstructural Components

Framework of Performance Objectives for Nonstructural Components[1,2]							
		Components Not Required for Postearthquake Function			*Components Required for Postearthquake Function*		
Issue/Performance		Frequent Earthquake	Design Earthquake	MCE_R	Frequent Earthquake	Design Earthquake	MCE_R
Safety	Prevent minor falling/overturning hazard with limited safety consequence	×			×	×	
	Prevent significant falling/overturning hazard that causes a casualty to an individual or several individuals	×	×		×	×	
	Prevent significant falling/overturning hazards that cause casualties to a significant number of people	×	×		×	×	
	Maintain egress	×	×		×	×	
	Prevent hazardous material release	×	×		×	×	
	Prevent fire	×	×		×	×	
	Prevent falling hazard that causes casualties outside building footprint	×	×		×	×	
Property	Limit local nonstructural damage/repair	×			×	×	
	Limit extensive nonstructural damage/repair	×			×	×	
	Prevent nonstructural damage that causes damage to structural system	×	×		×	×	
Function	Maintain intended building function	×			×	×	
	Enable reoccupancy/habitation	×			×	×	

1 Performance objectives are targets; there is no guarantee that damage more severe than the target will not occur.

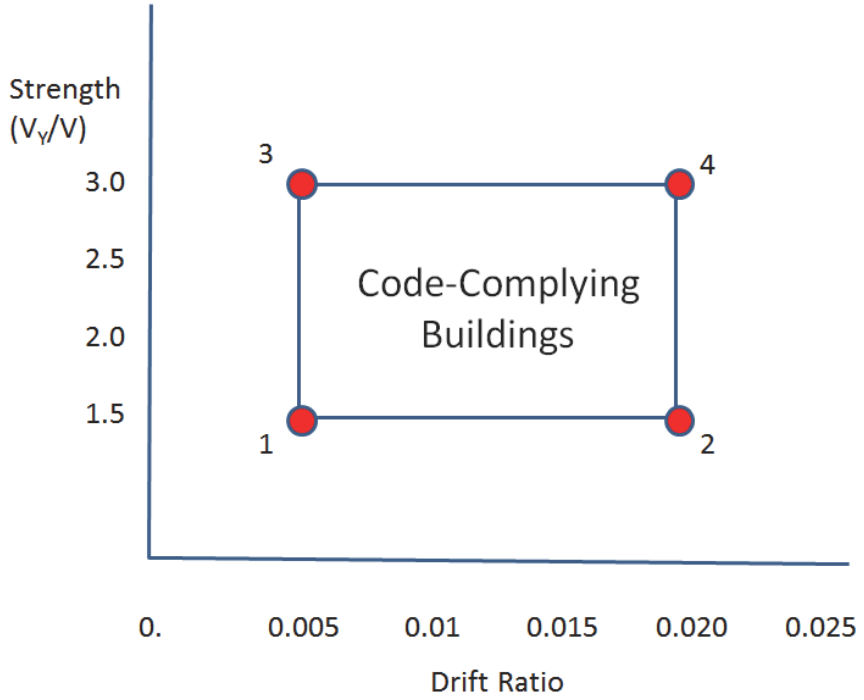
2 Design requirements are intended to apply at the Design Earthquake level only. It is assumed that targets at other levels are likely to be achieved by design at the Design Earthquake Level.

Supporting Data

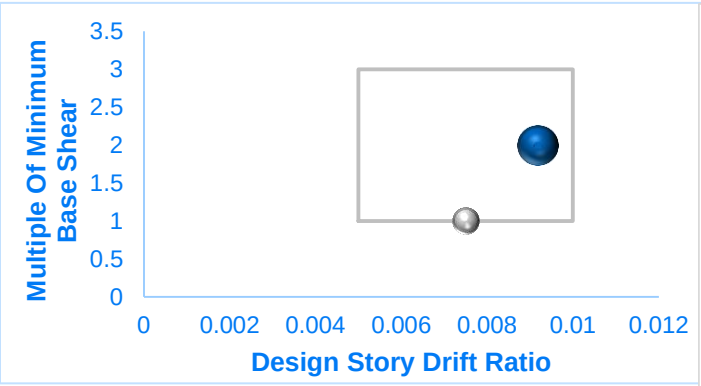
Use the ATC 58-2 studies on probability of an unsafe placard and 90th percentile repair time

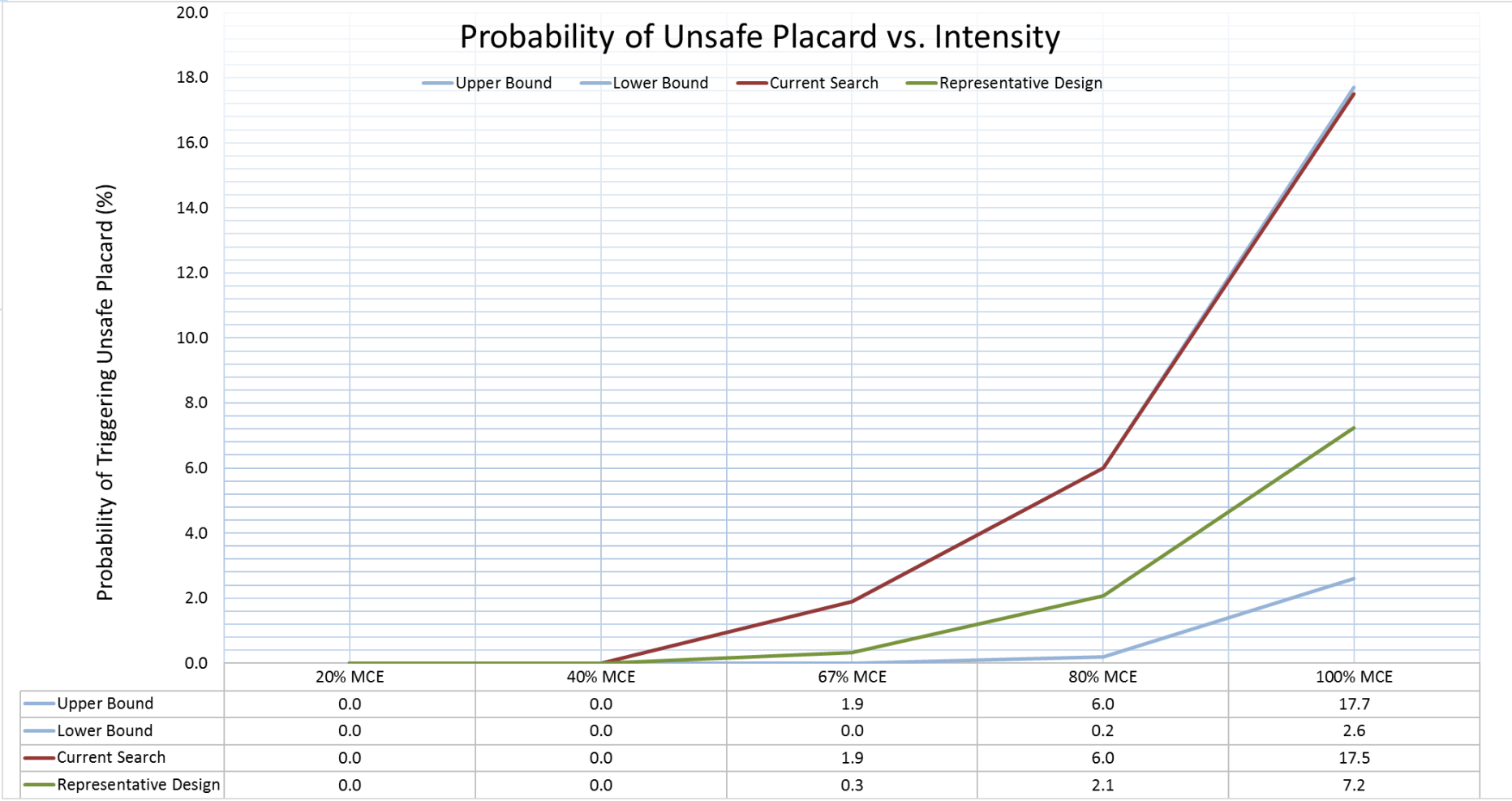
Look at bounds of the “design space” and “representative design”

Use buildings designed to Risk Category IV requirements



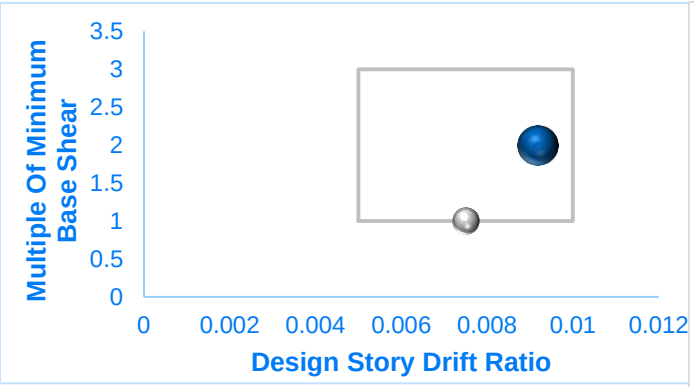
Steel Special Moment Frame

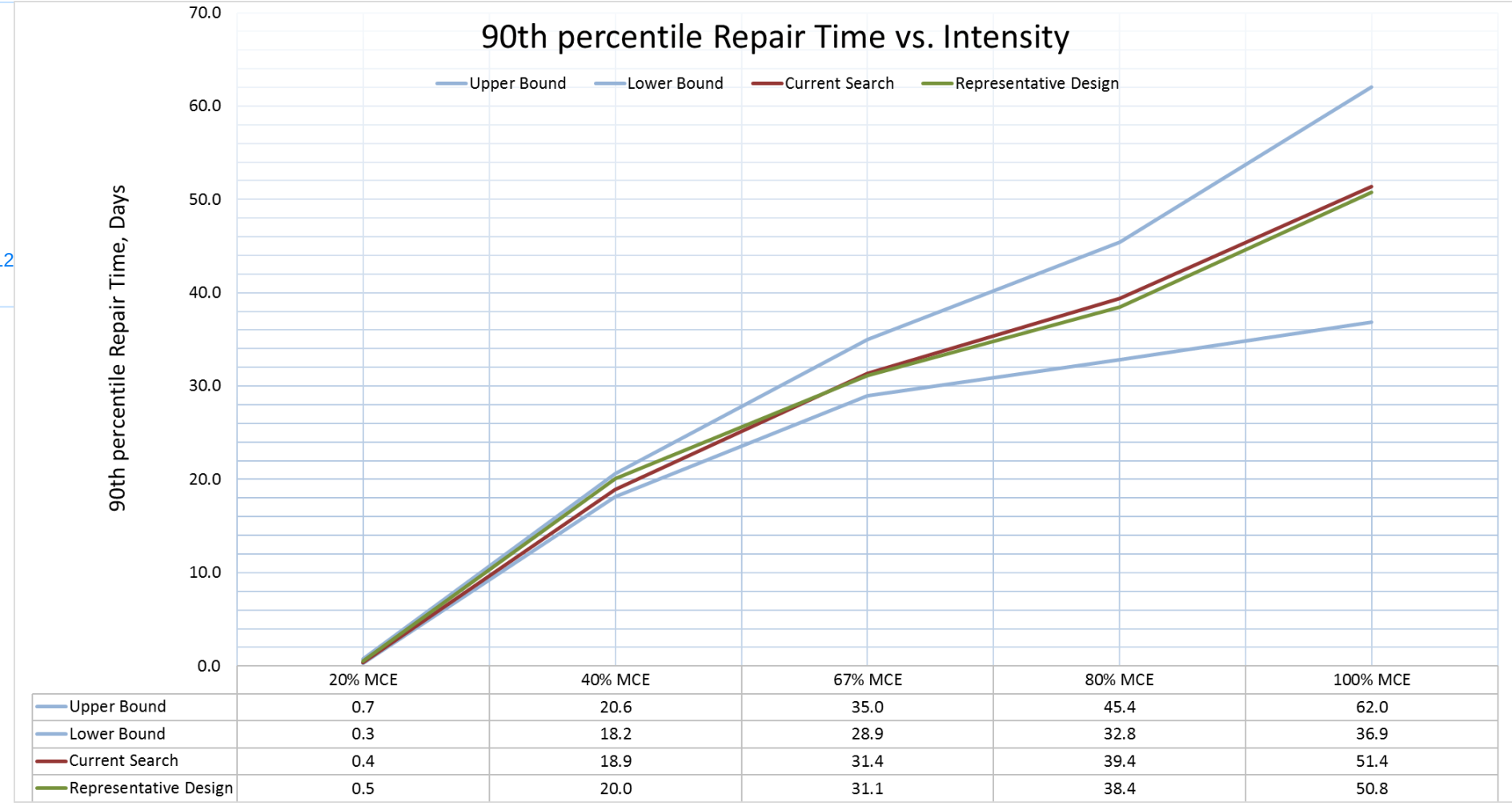




	20% MCE	40% MCE	67% MCE	80% MCE	100% MCE
Upper Bound	0.0	0.0	1.9	6.0	17.7
Lower Bound	0.0	0.0	0.0	0.2	2.6
Current Search	0.0	0.0	1.9	6.0	17.5
Representative Design	0.0	0.0	0.3	2.1	7.2

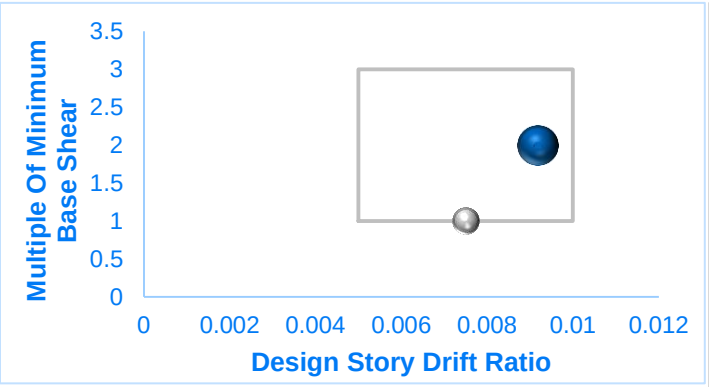
Steel Special Moment Frame

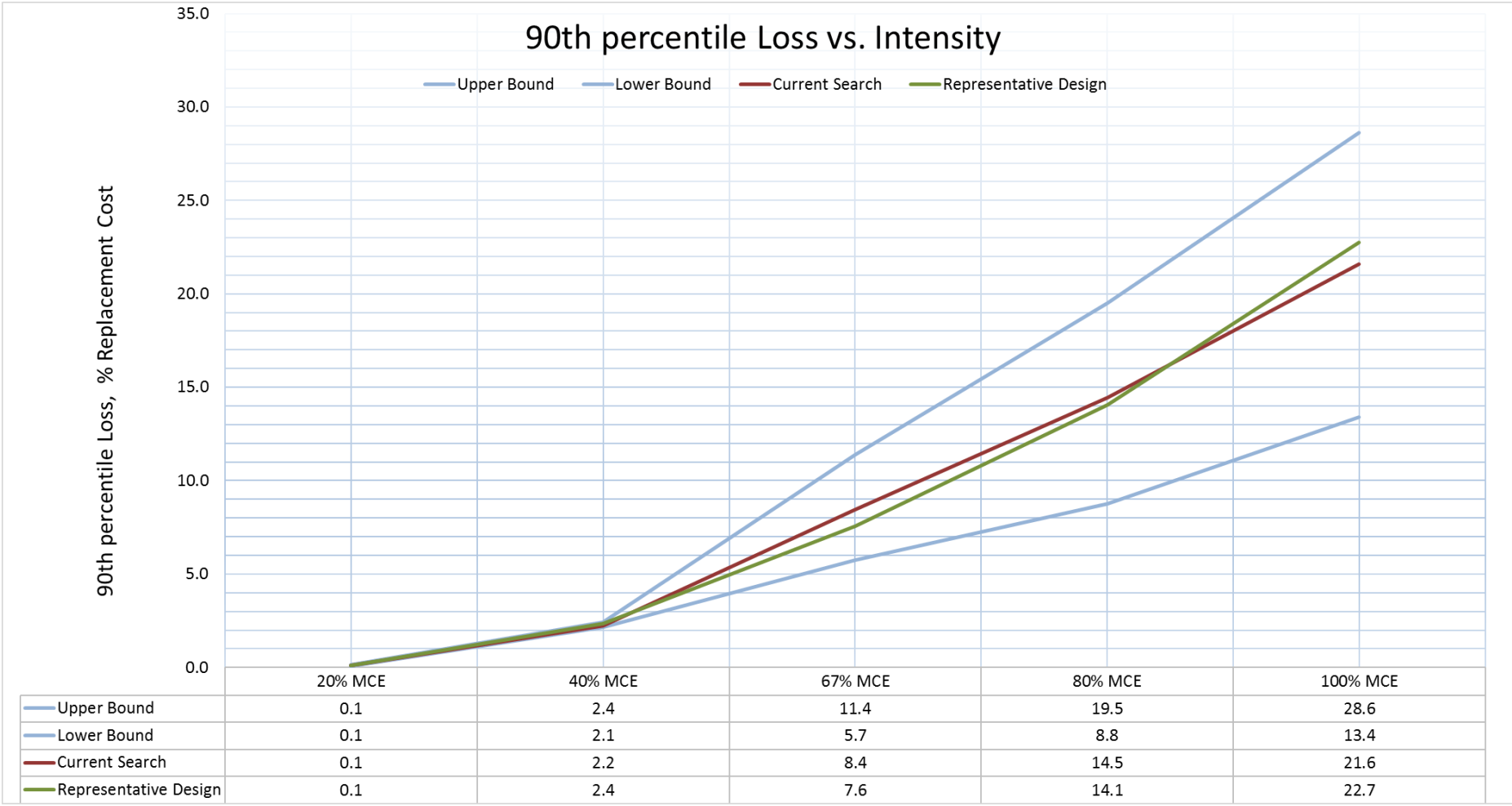




	20% MCE	40% MCE	67% MCE	80% MCE	100% MCE
Upper Bound	0.7	20.6	35.0	45.4	62.0
Lower Bound	0.3	18.2	28.9	32.8	36.9
Current Search	0.4	18.9	31.4	39.4	51.4
Representative Design	0.5	20.0	31.1	38.4	50.8

Steel Special Moment Frame





	20% MCE	40% MCE	67% MCE	80% MCE	100% MCE
Upper Bound	0.1	2.4	11.4	19.5	28.6
Lower Bound	0.1	2.1	5.7	8.8	13.4
Current Search	0.1	2.2	8.4	14.5	21.6
Representative Design	0.1	2.4	7.6	14.1	22.7

		90th Percentile Loss			90th Percentile Repair Time			Probability of Unsafe Placard		
		Best	Represent	Worst	Best	Represent	Worst	Best	Represent	Worst
Steel SMF	Low-Rise	8%	12%	15%	28	34	40	0.1%	2.8%	5.7%
Steel SMF	Mid-Rise	6%	8%	11%	29	31	35	0.0%	0.3%	1.9%
Steel SCBF	Low-Rise	18%	21%	23%	46	54	59	3.3%	42.0%	66.6%
Steel SCBF	Mid-Rise	15%	19%	21%	45	56	61	3.3%	41.5%	80.1%
Steel BRBF	Low-Rise	15%	100%	100%	36	720	720	2.9%	36.7%	65.1%
Steel BRBF	Mid-Rise	11%	16%	100%	34	44.3	720	10.0%	3.3%	11.1%
Conc SMF	Low-Rise	6%	11%	17%	27	38	50.6	0.0%	1.7%	6.1%
Conc SMF	Mid-Rise	5%	6%	7%	28	30	32	0.0%	10.0%	0.5%
Conc SSW	Low-Rise	9%	9%	13%	28	30	38	0.0%	0.1%	6.2%
Conc SSW	Mid-Rise	7%	7%	9%	31	32	34	0.0%	0.0%	10.0%

Impacts / Changes

- Need to define what “loss of function” means. Are there different “loss of function” targets?
- Would require further study of hazardous materials containment systems to validate reliabilities.
- Review nonstructural certification to confirm that current procedures produce 90% reliability.
- Drift limits for BRBF structures may need to be tightened.
- SCBF structural systems would not meet these targets without significant changes in design rules.
- Would need to validate other structural systems or prohibit in RC IV in SDC D and higher without additional validation.

Questions

- Do we support eliminating reference to Risk Category III for function protection?
- Do we support 10% probability of loss of function?
- Is a 30-day 90% upper-bound repair time an acceptable limit?

Issue Team 1
Additional Topics

Robert Pekelnicky, PE, SE
Chair 2020 PUC IT-01

Egress

1.1.4 Preservation of Egress

For Objective 2 the *Provisions* intend that stairs be designed and built to be functional following the DE ground motion. The component importance factor is intended to provide a low likelihood that stairs lose support due to seismic displacements.

- ATC 120 identified preservation of egress in the DE as a performance objective.
- Do we need to edit this statement to extend it beyond just stairs losing support?

Chapter 16 for Risk Category IV

- Currently Chapter 16 only requires nonlinear evaluation at MCE_R shaking intensity.
- There is no explicit DE evaluation. DE performance is based on Chapter 12 evaluation.
- Should we require explicit DE evaluation of Risk Category IV structures in lieu of Chapter 12 evaluation?

16.1.2 Linear Analysis. In addition to nonlinear response history analysis, a linear analysis in accordance with one of the applicable procedures of Chapter 12 shall also be performed. The structure's design shall meet all applicable criteria of Chapter 12. Where soil–structure interaction in accordance with Chapter 19 is used in the nonlinear analysis, it shall be permitted to also use the corresponding spectral adjustment in the linear analysis.

EXCEPTIONS:

1. For Risk Category I, II, and III structures, Sections 12.12.1 and 12.12.5 do not apply to the linear analysis. Where mean computed drifts from the nonlinear analyses exceed 150% of the permissible story drifts per Section 12.12.1, deformation-sensitive nonstructural components shall be designed for 2/3 of these mean drifts.
2. The overstrength factor, Ω_0, is permitted to be taken as 1.0 for the seismic load effects of Section 12.4.3.
3. The redundancy factor, ρ, is permitted to be taken as 1.0.
4. Where accidental torsion is explicitly modeled in the nonlinear analysis, it shall be permitted to take the value of A_x as unity in the Chapter 12 analysis.