PERFORMANCE OF A NONDUCTILE RC BUILDING FOR THE FEMA P695 FAR-FAULT GROUND MOTION DATA SET

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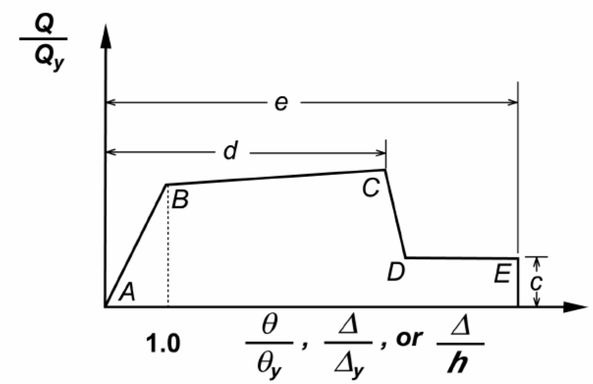
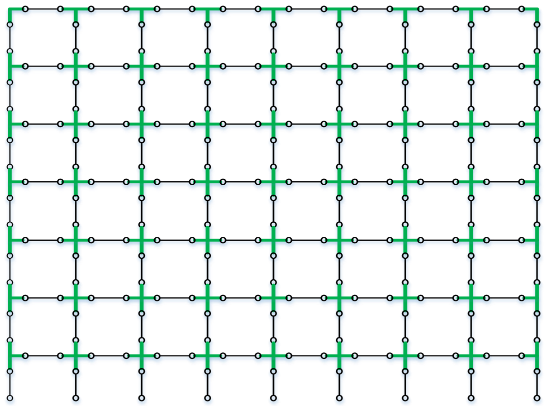
ASCE-41 Standard

Modeling Parameters



(b) Deformation ratio

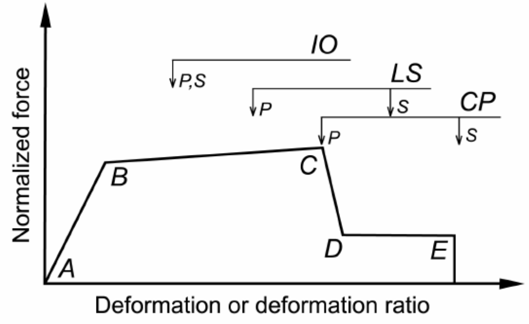


Rehabilitation Objective

Earthquake Hazard Level		Target Building Performance Levels: Operational Performance Level (1-A)	Immediate Occupancy Performance Level (1-B)	Life Safety Performance Level (3-C)	Collapse Prevention Performance Level (5-E)
	50%/50 year 72 yrs	a	b	c	d
	20%/50 year 225 yrs	e	f	g	h
	BSE-1 474 yrs (~10%/50 year)	i	j	k	l
	BSE-2 2475 yrs (~2%/50 year)	m	n	o	p

Maximum **C**onsidered **E**arthquake

Acceptance Criteria



(c) Component or element deformation acceptance criteria

FEMA P695 Methodology

Equivalent safety against collapse for buildings with different seismic force resisting systems

Collapse Safety Margin → Design Criteria for Building Codes (i.e. R, C_d, and Ω_0 seismic performance factors)

Median Collapse: One-half of the structures have some form of collapse

Local Instability

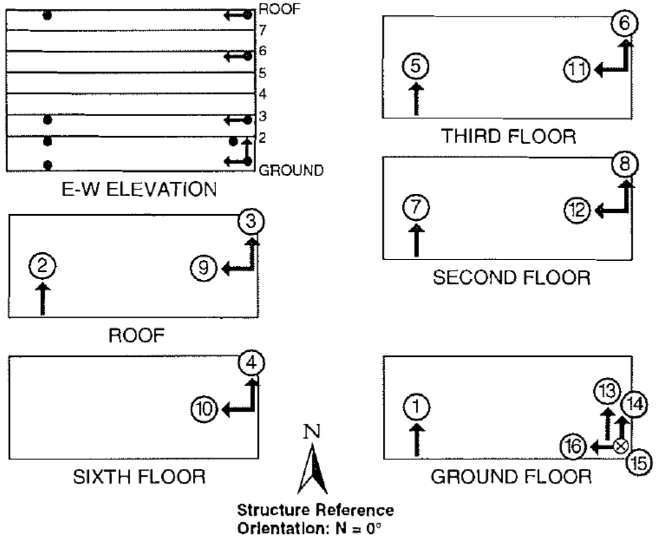
Global Instability

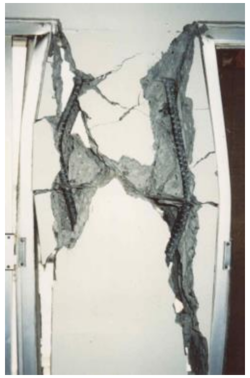
$$\text{Collapse Margin Ratio, } CMR = \frac{SA \text{ Median collapse-level ground motions}}{SA \text{ of } MCE \text{ ground motions}}$$

NEHRP: Structure should have a low probability of collapse for *MCE* (1.5 times the design level earthquake)

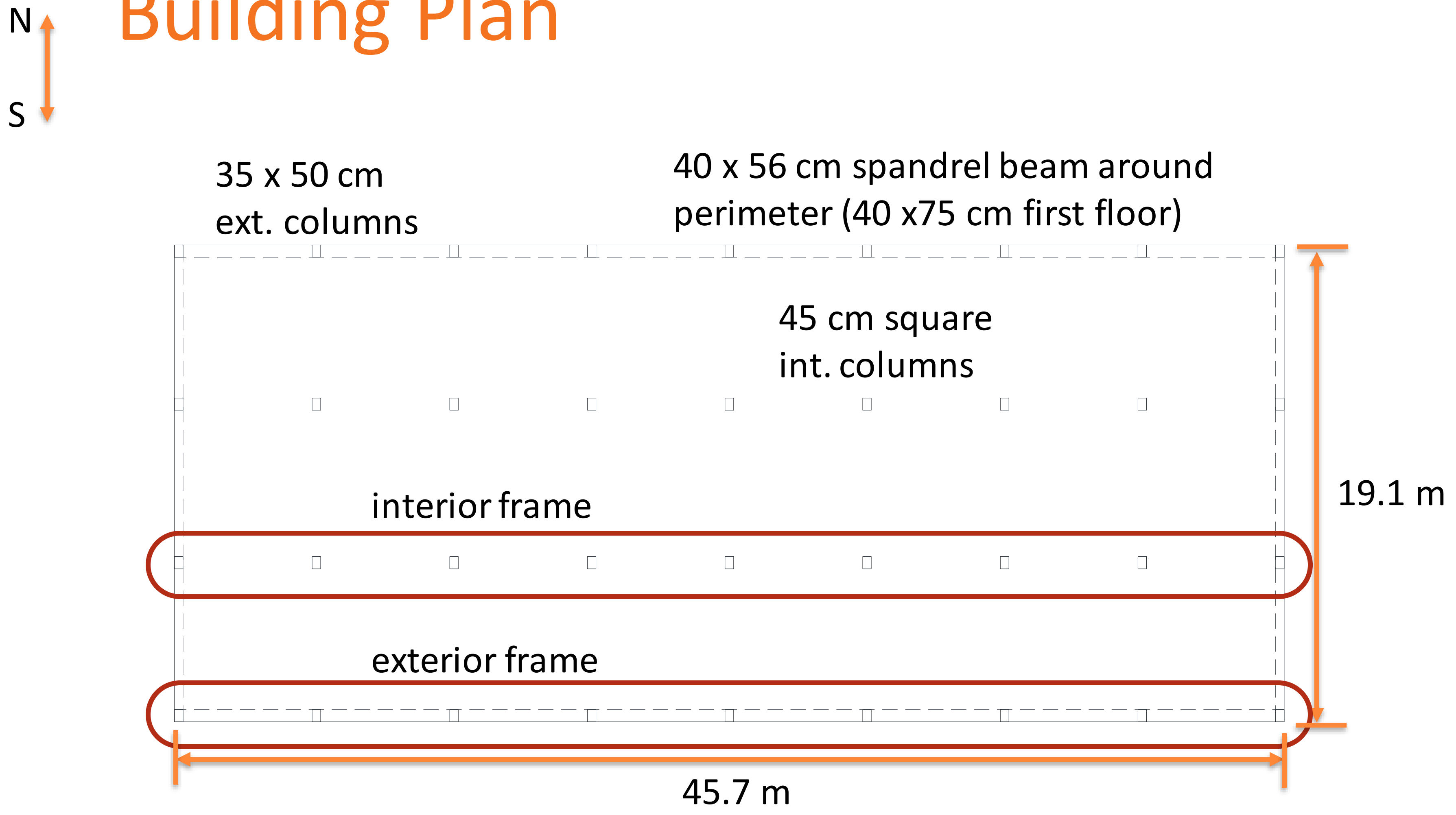
Building Description

- Seven-story RC Building in Van Nuys, CA
- Designed in 1965 and constructed in 1966
- Exterior moment-resisting frames
- Interior gravity load flat slab system
- Strong motion records from:
  - 1971 San Fernando
  - 1987 Whittier
  - 1990 Upland
  - 1992 Sierra Madre
  - 1994 Northridge
- Light structural damage during the 1971 San Fernando Earthquake, severe column damage during the 1995 Northridge earthquake.

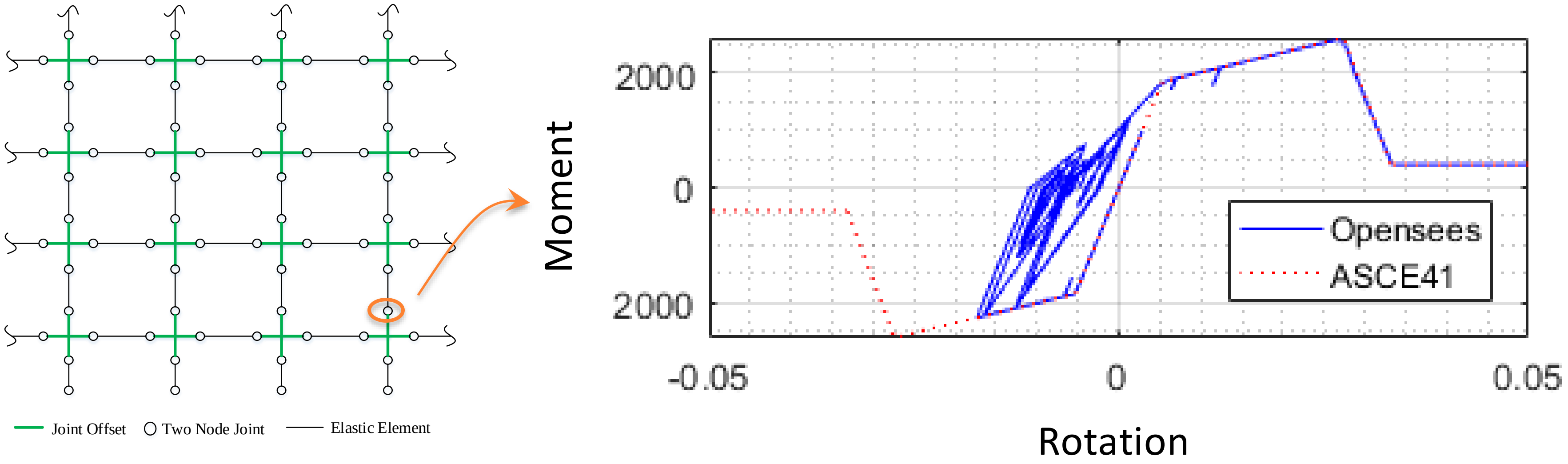




Building Plan

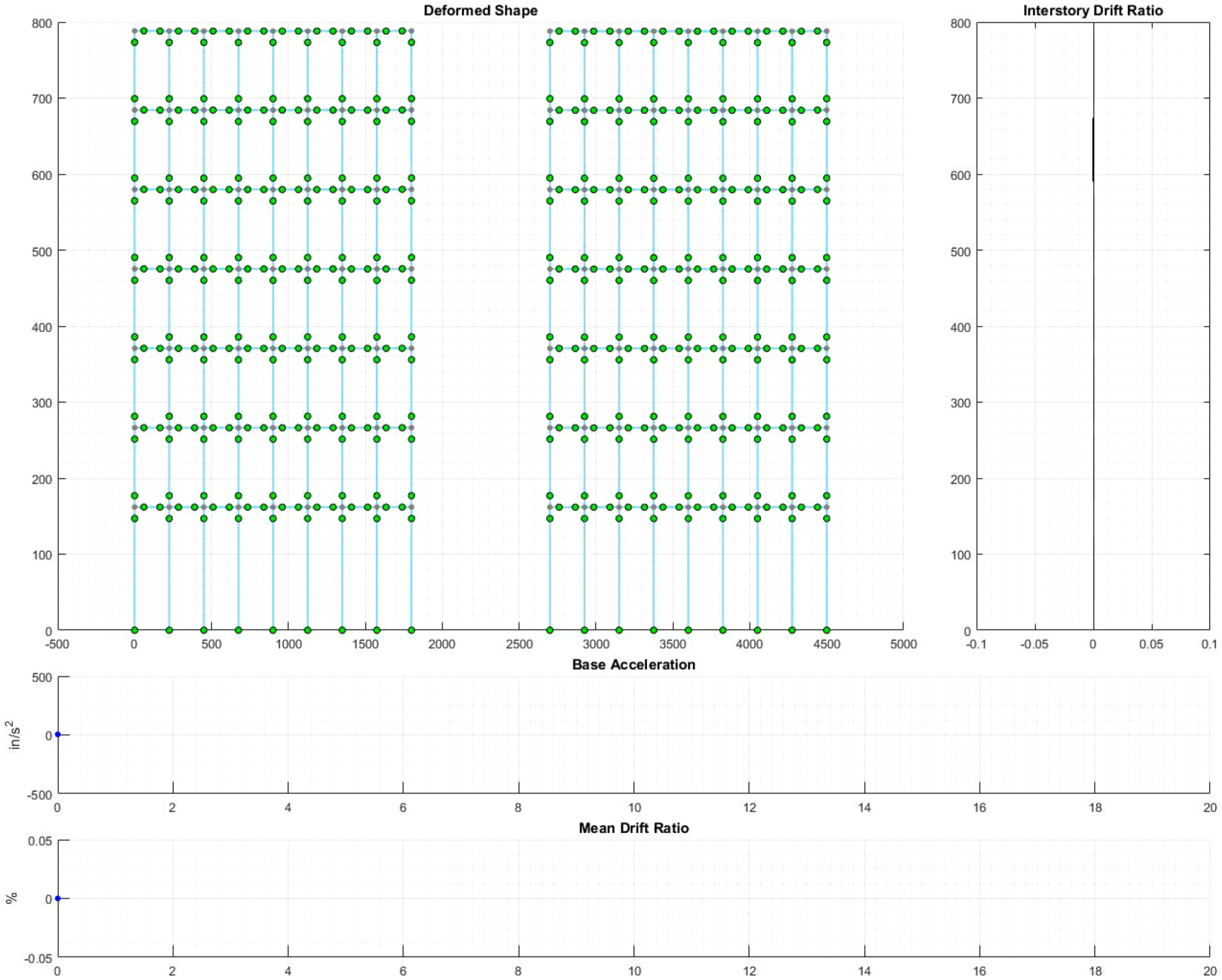


Lumped Plasticity Model for Frame Structure



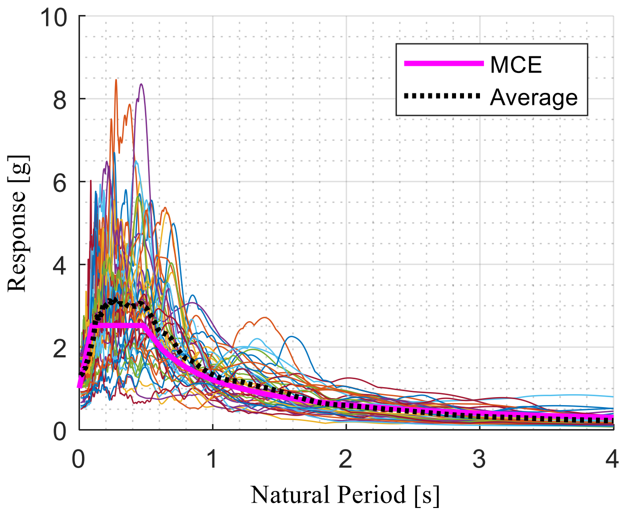
Moment rotation relationship for nonlinear rotational spring of second story column of RC Building

Collapse Simulation

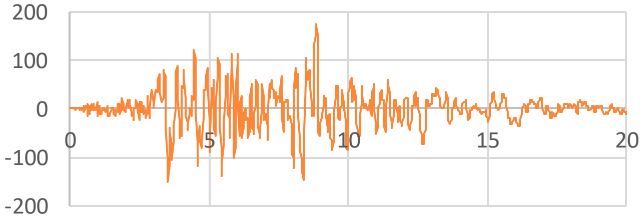


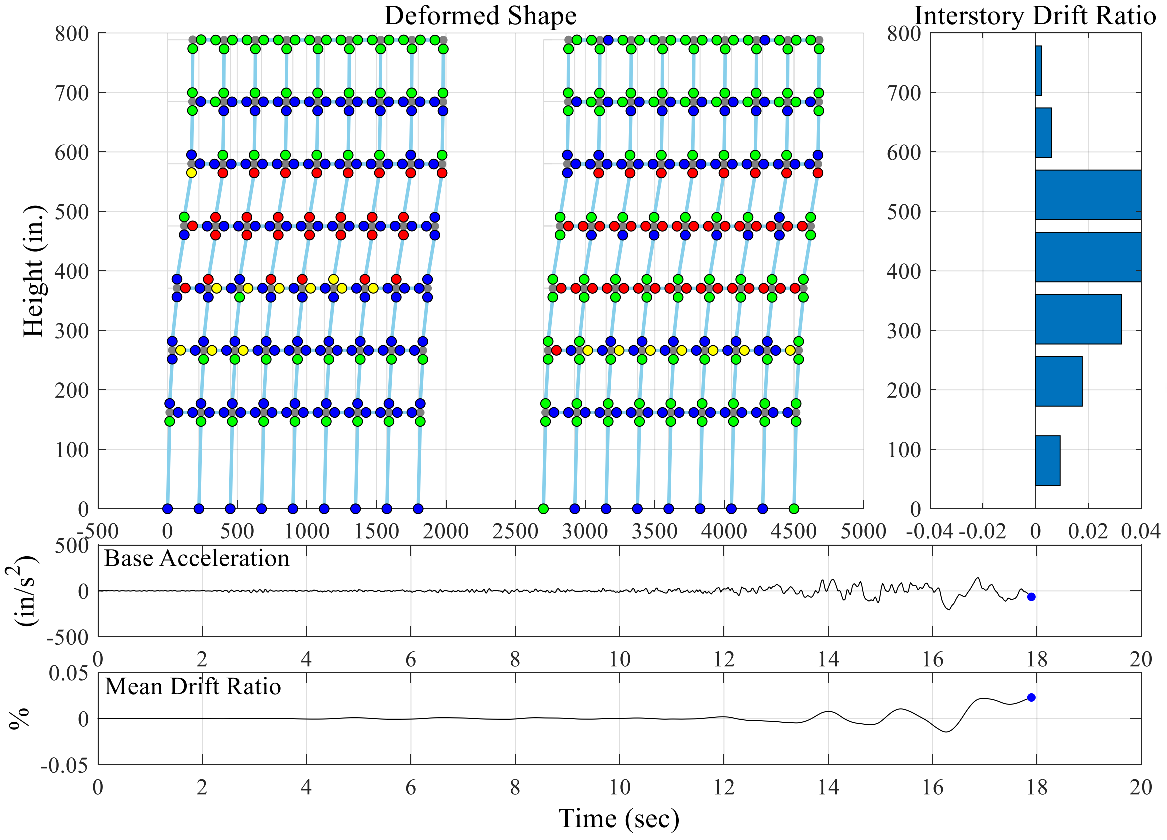
CMR is established through Incremental Dynamic Analysis

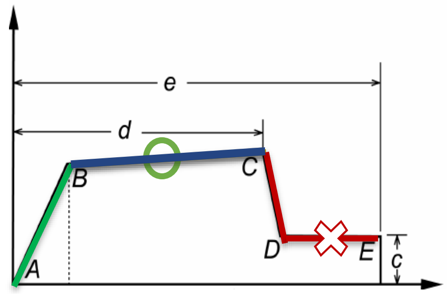
Ground motion set scaled to MCE

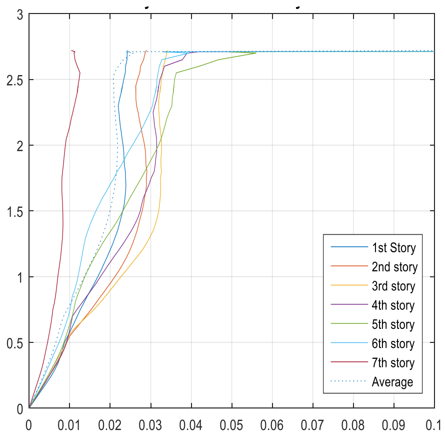


Ground motion records

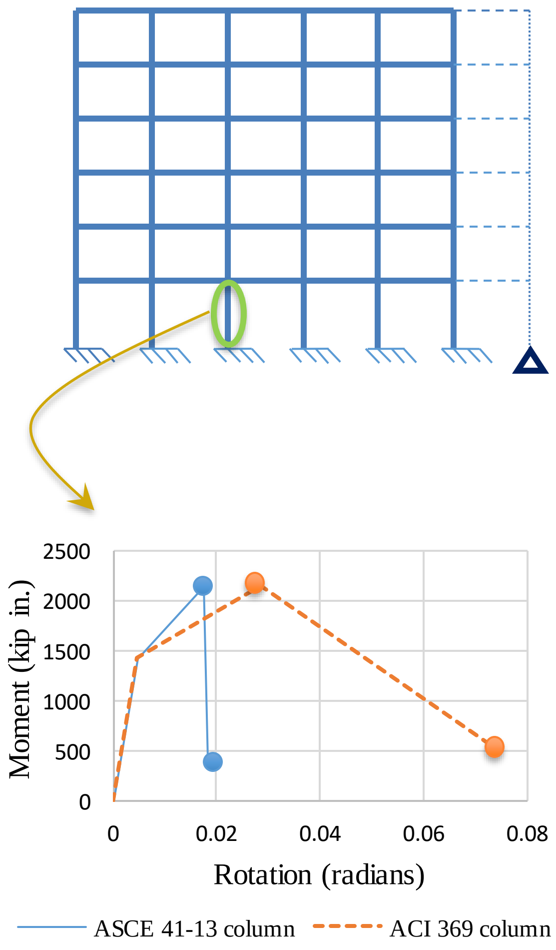


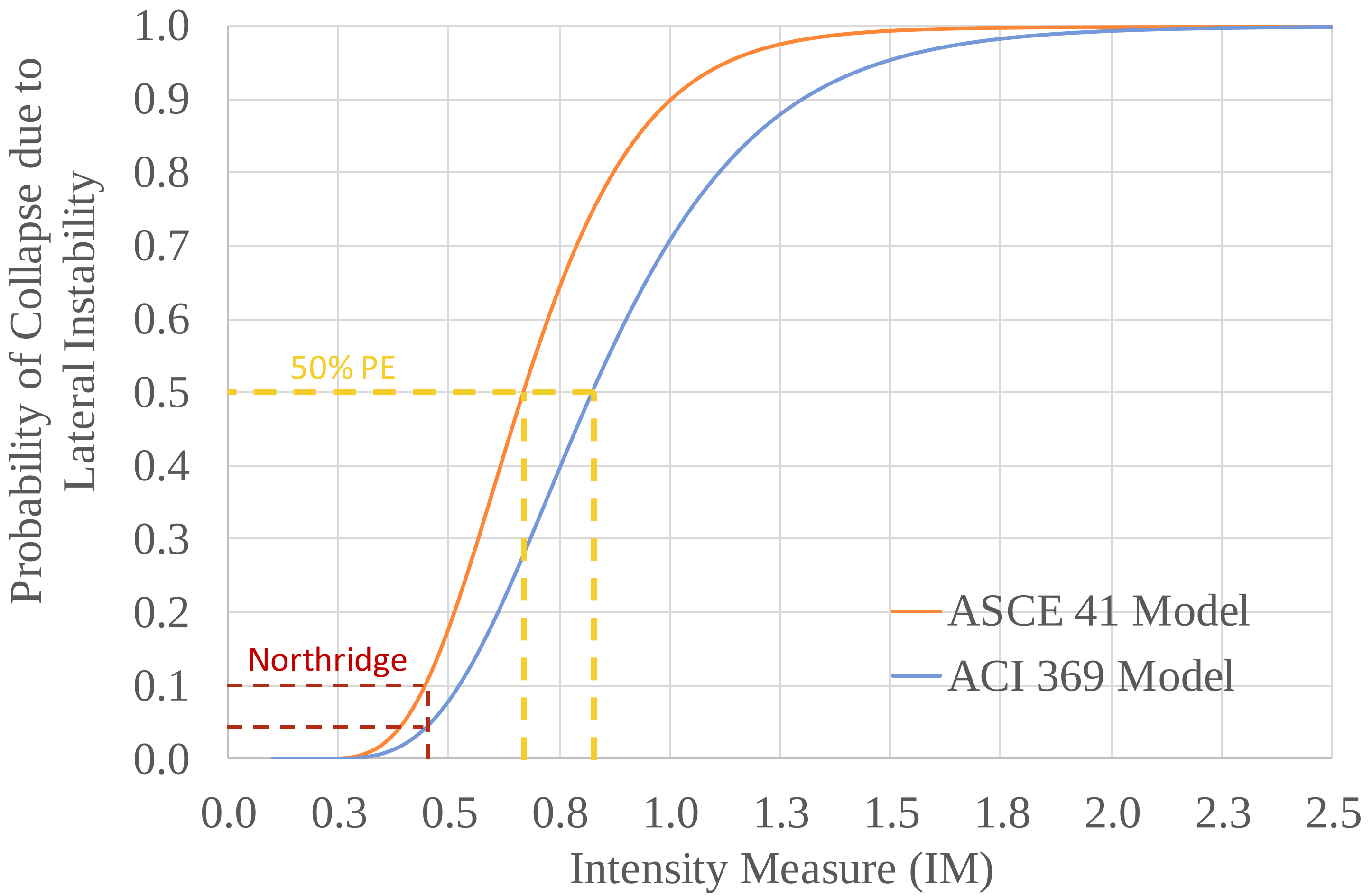


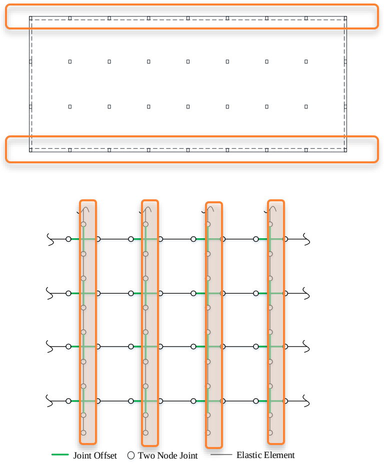




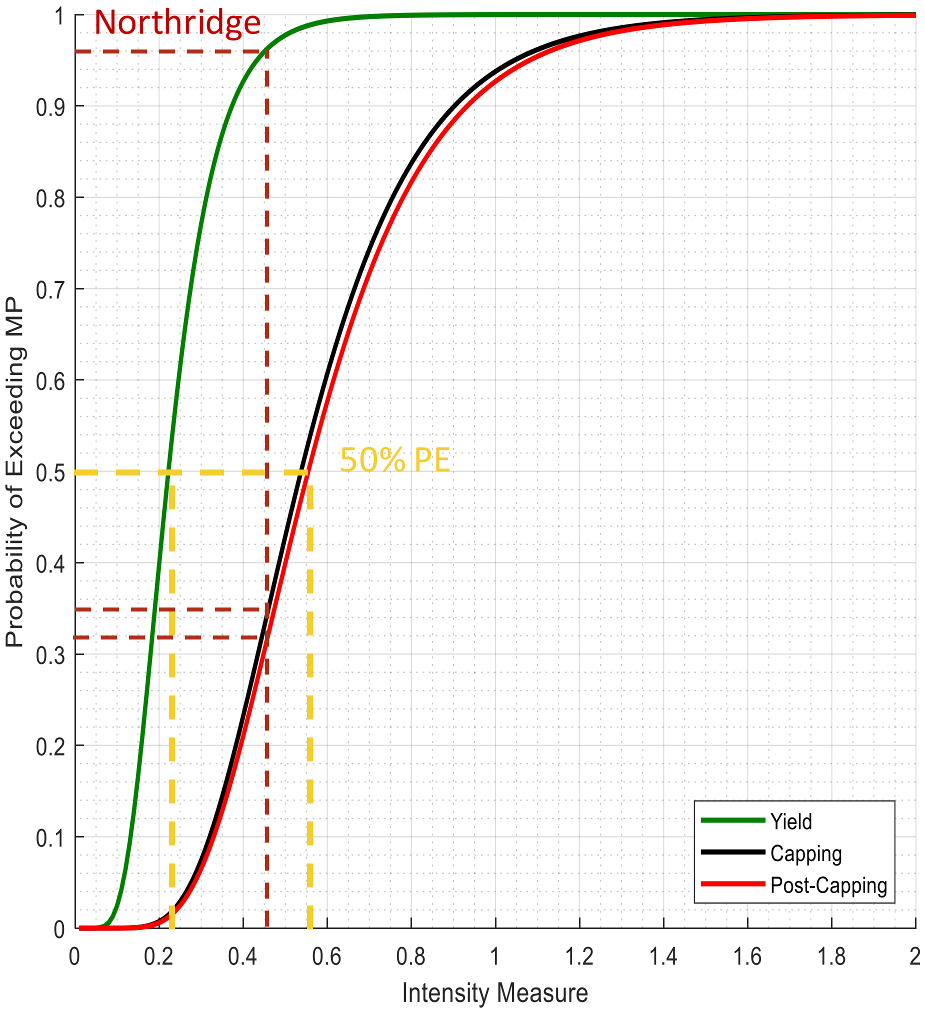
Collapse Simulation Results EW Direction



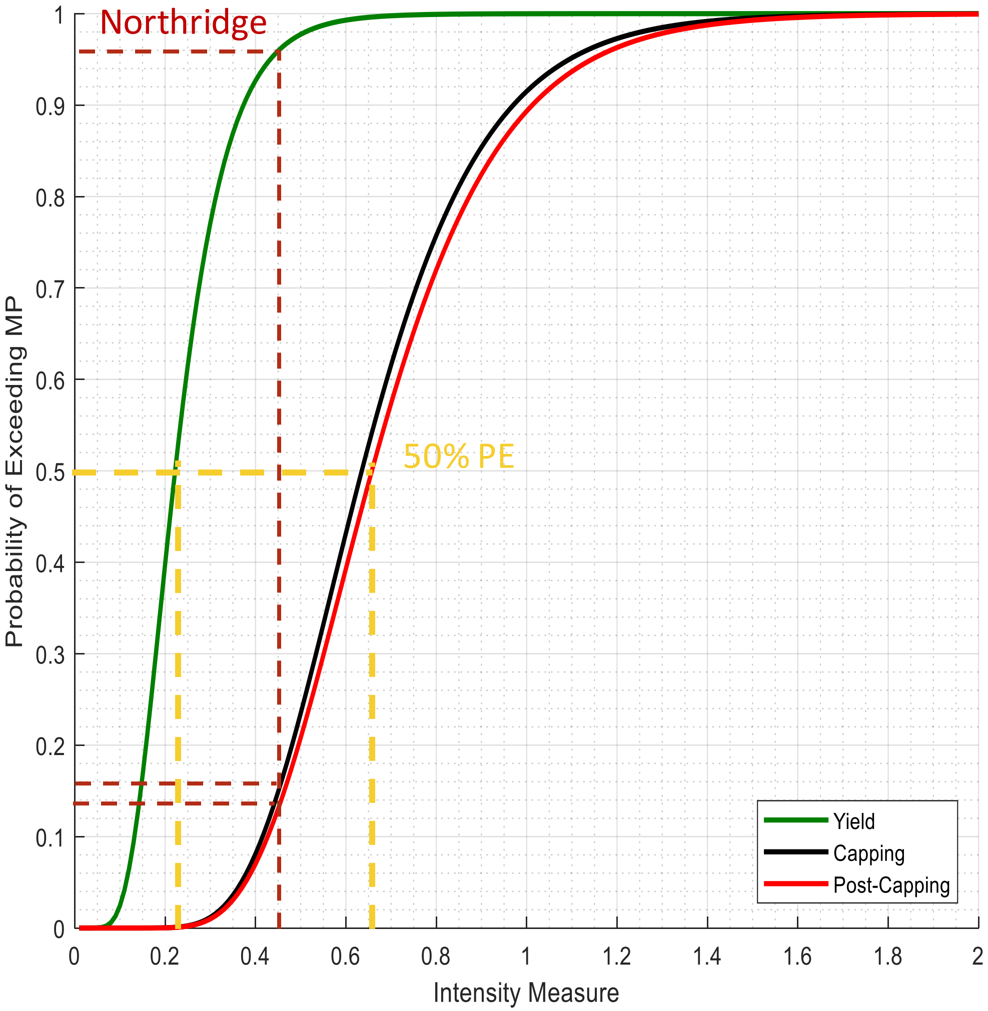




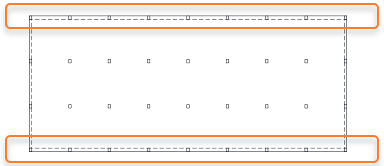
Probability of Exceeding Column Modeling Parameters

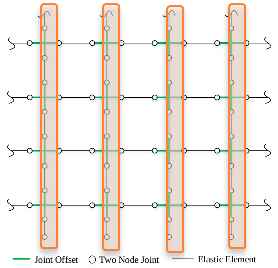


ASCE 41-13

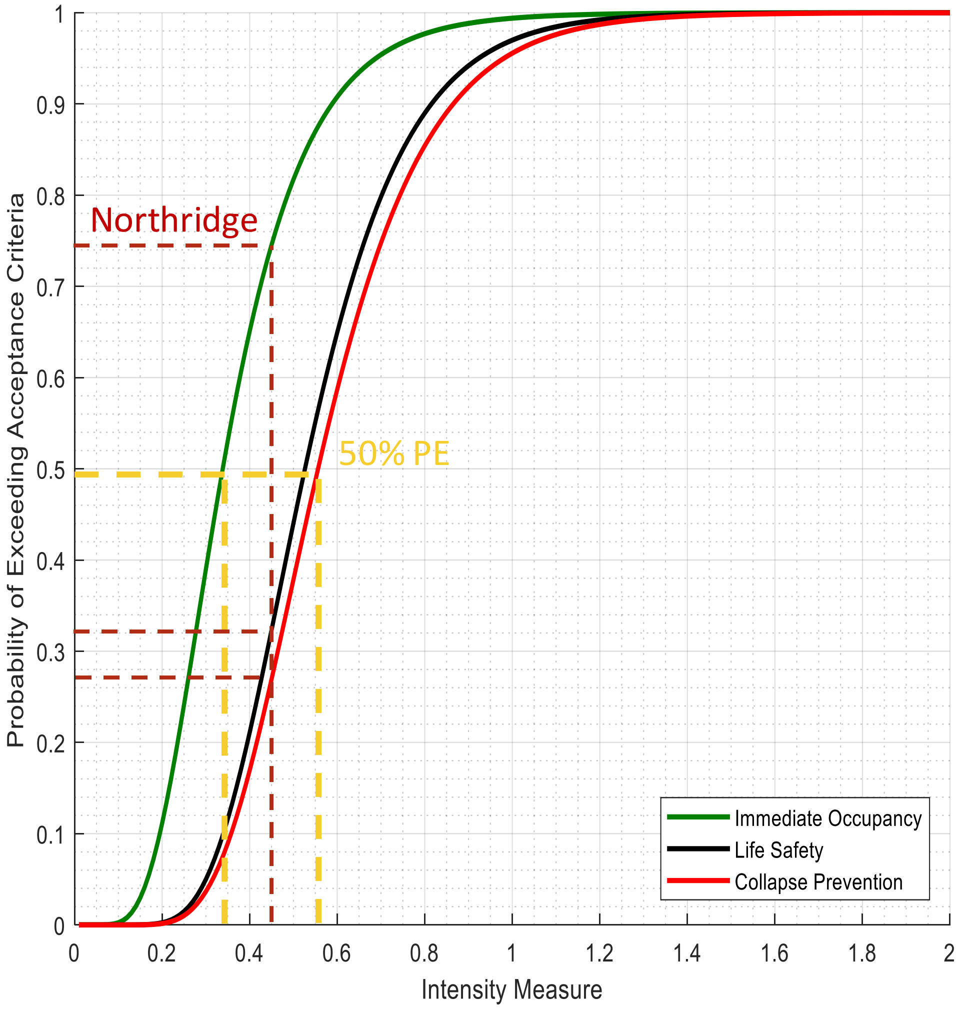


ASCE 41-17

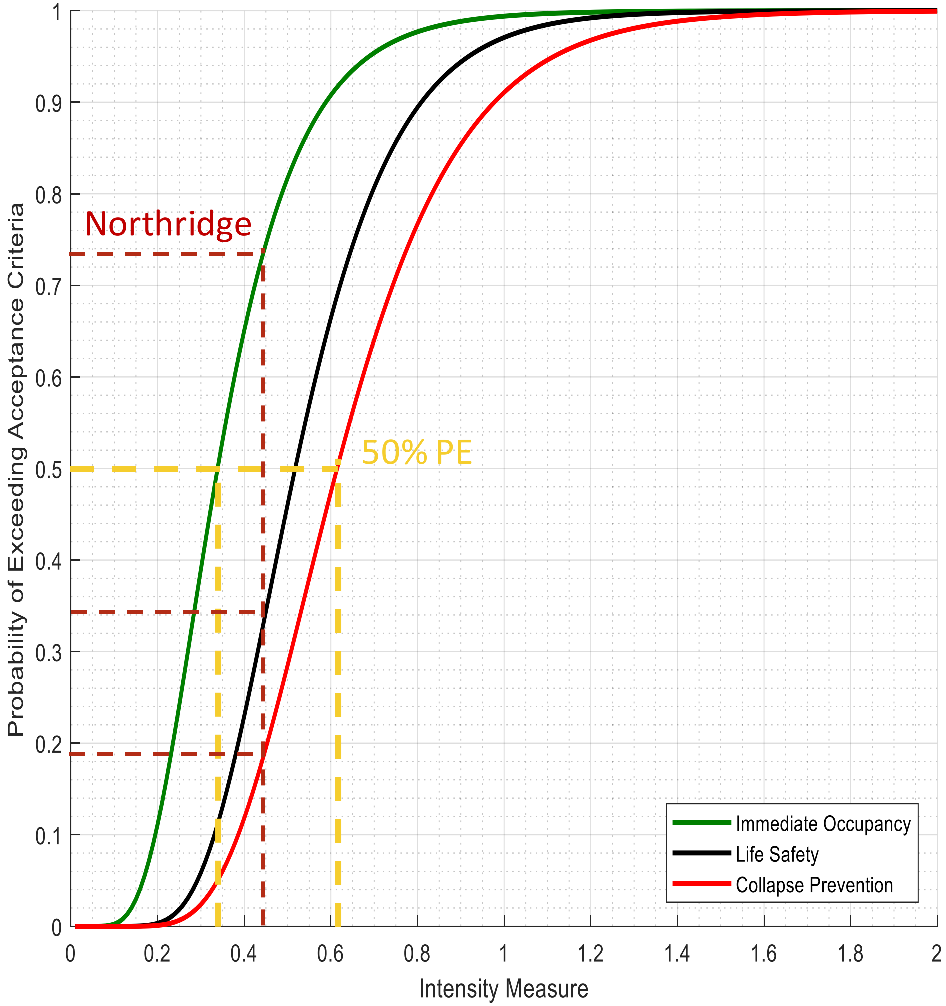




Probability of Exceeding Column Acceptance Criteria

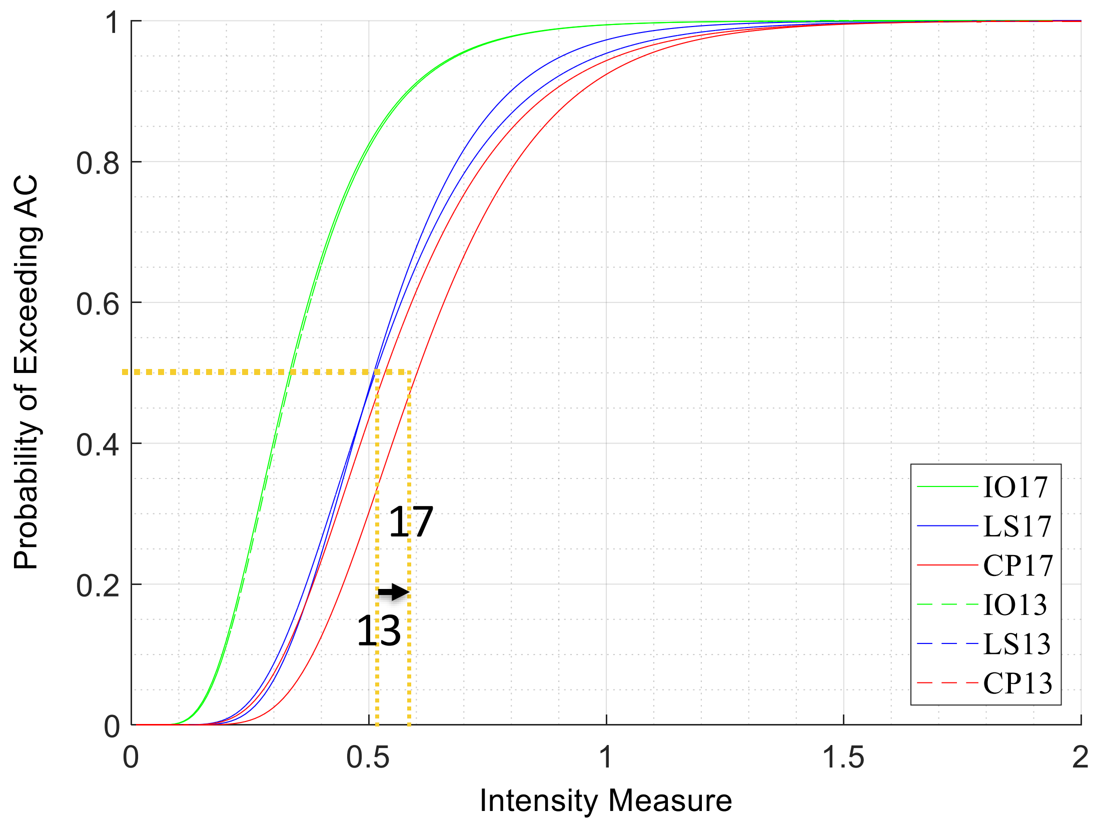


ASCE 41-13

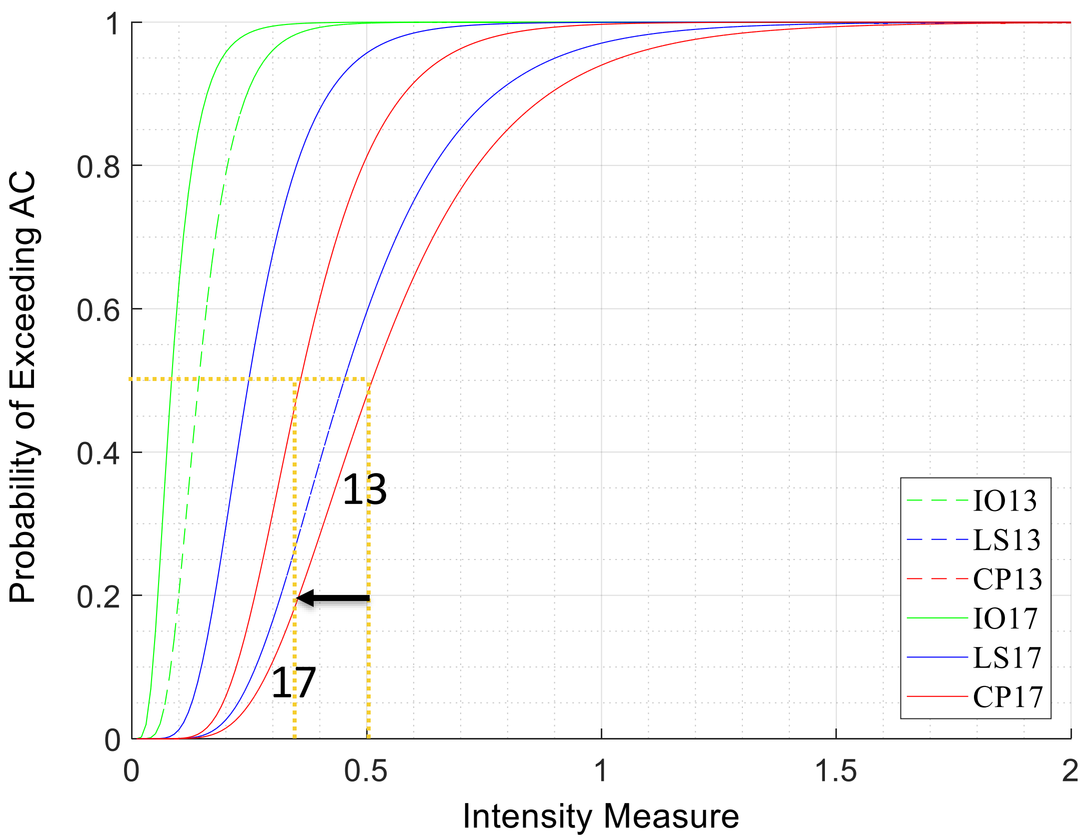


ASCE 41-17

Fragility Relationships for AC in ASCE 41-13 and ASCE 41-17



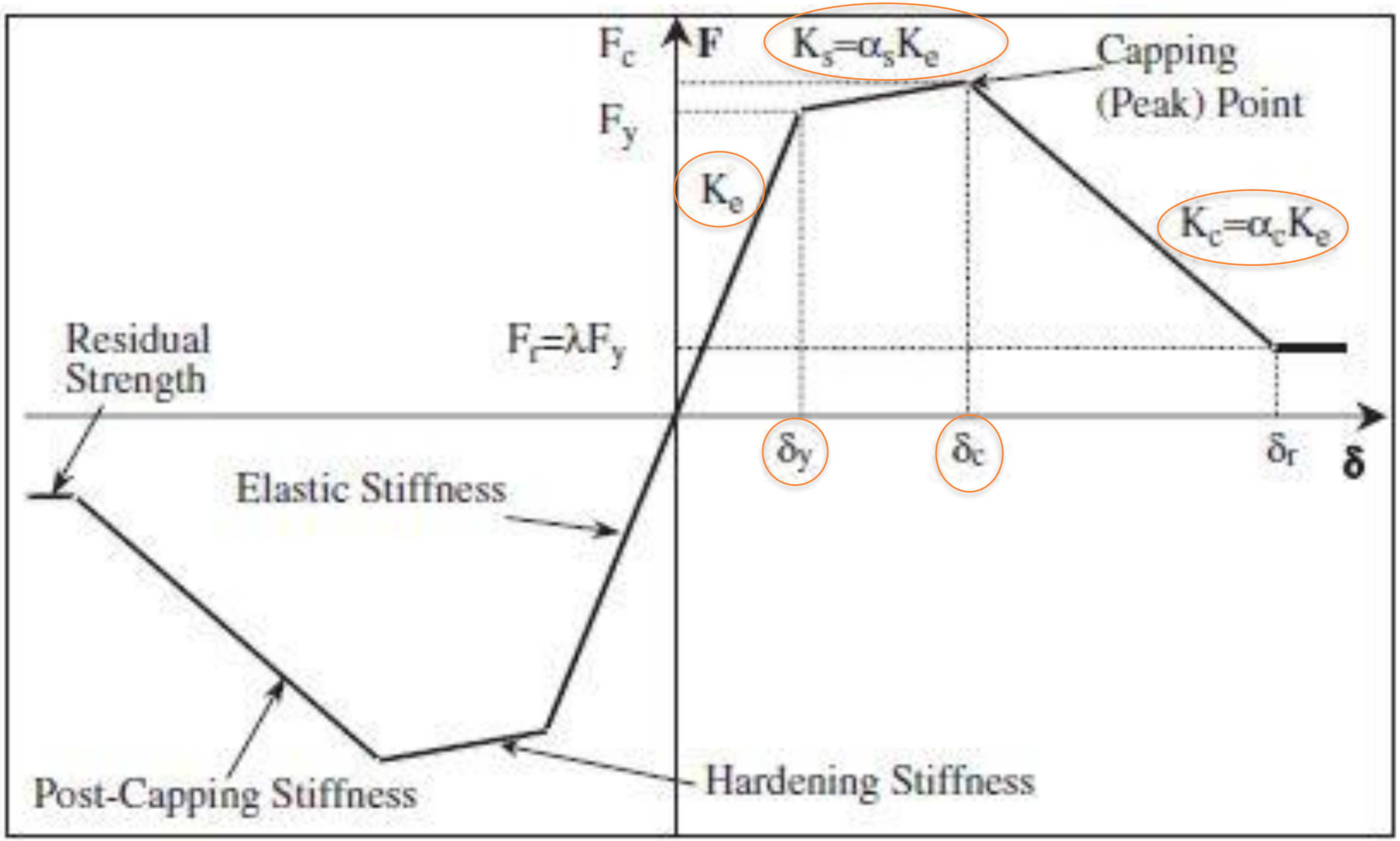
Columns



Beams

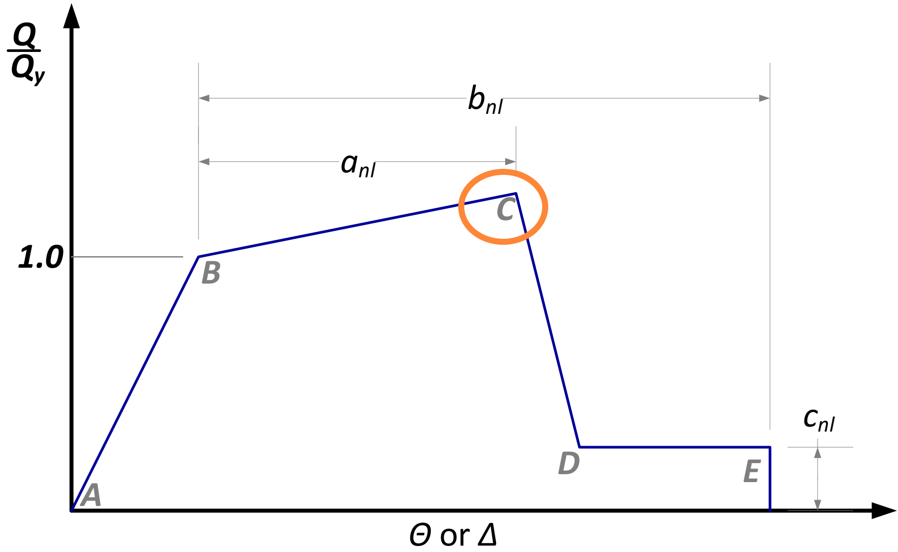
Backbone curve parameters

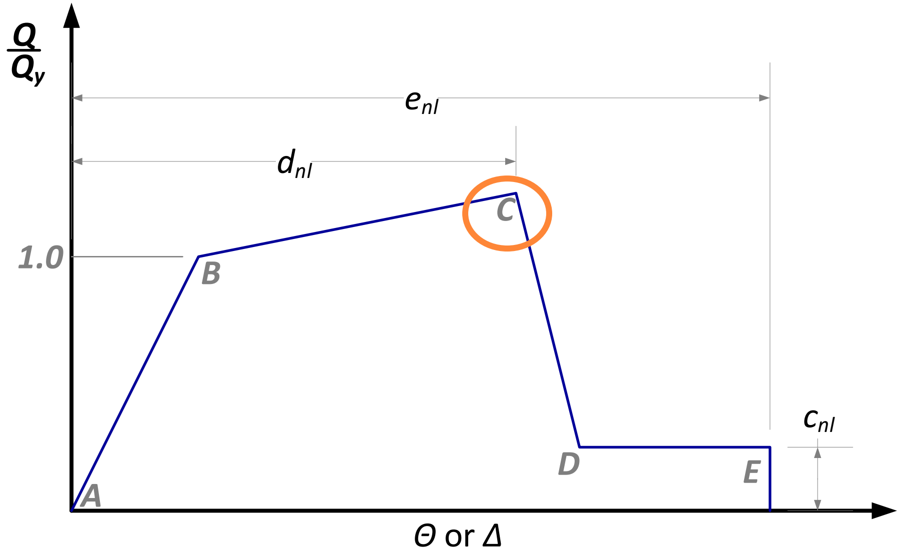
- Yield strength – F_y
- Initial or Elastic stiffness – K_e
- Strain-Hardening stiffness – K_s
- Post-Capping stiffness – K_c
- Residual strength F_r



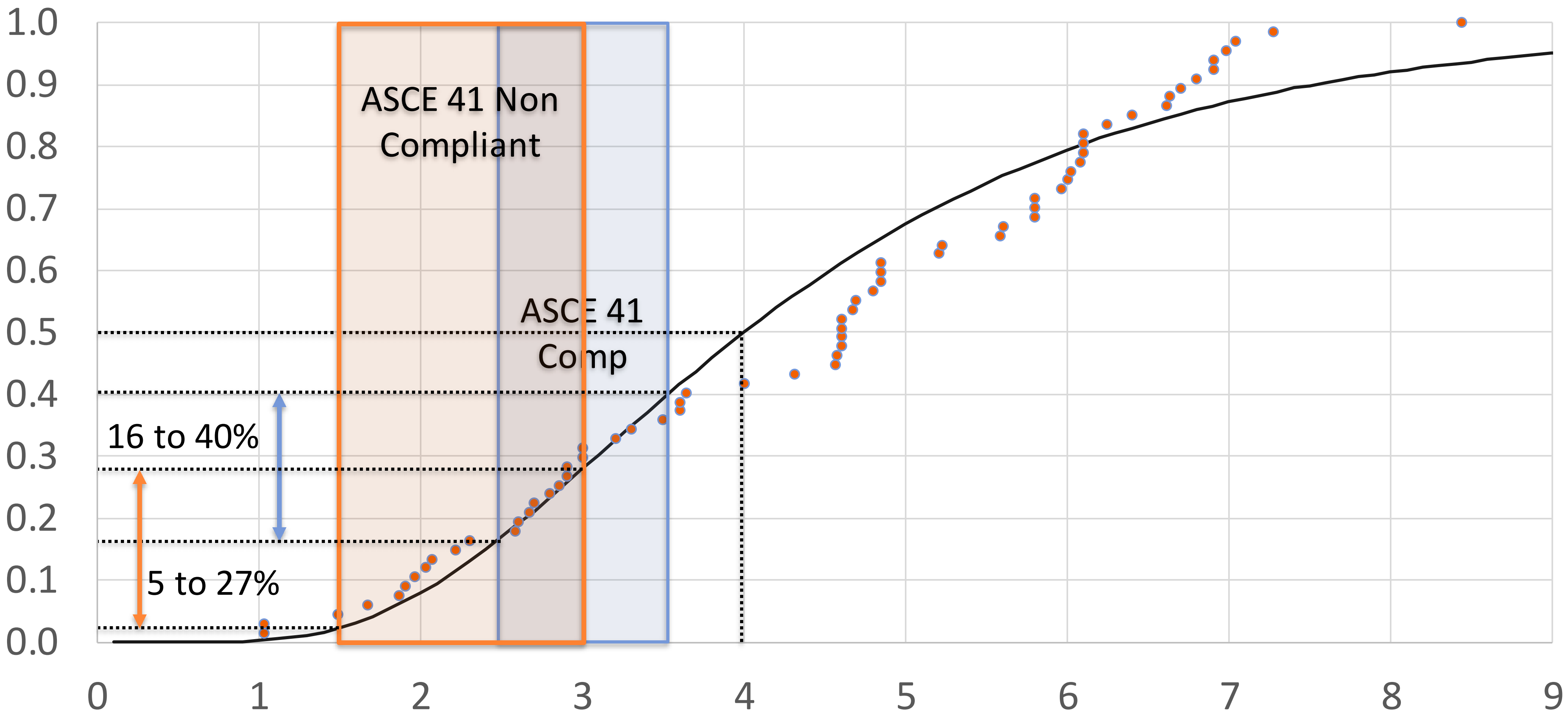
ACI 369 Section 3.1.2.2 Nonlinear Procedures

Point C shall have an ordinate equal to the strength of the component and an ***abscissa equal to the deformation at which significant strength degradation begins***.



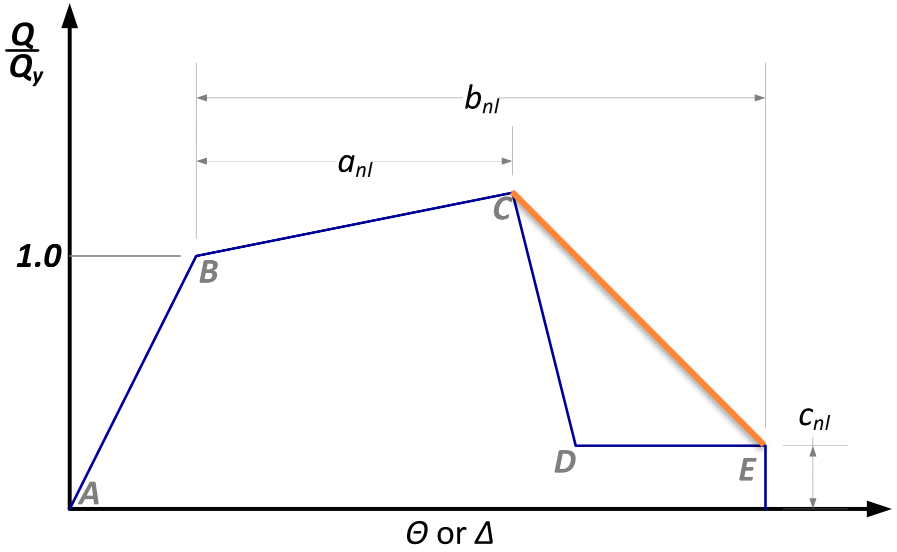


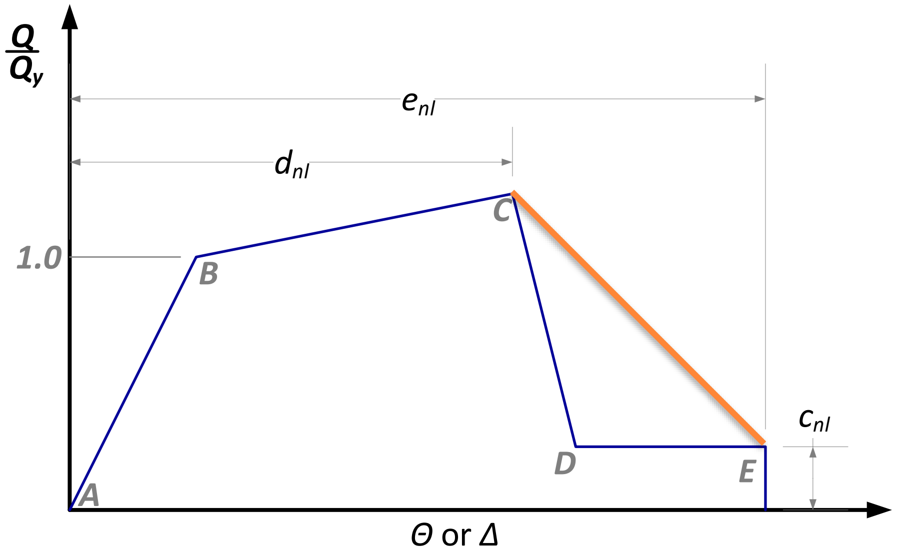
Drift ratio at loss of lateral strength



Effective stiffness coefficient for descending branch α_d

ASCE 41-17 Model	
Compliant low shear	32Mc
Compliant high shear	40Mc
Non-compliant low shear	80Mc
Non-compliant high shear	160Mc
PARAMETERS FROM STATISTICAL ANALYSIS	
Test Data	25Mc





Conclusions

- Due to the lack of ductile detailing, the case-study building will reach local collapse at much lower earthquake intensities (50% at IM 0.65) than would cause dynamic instabilities (50% at IM 0.85).

- Comparison of fragility relationships based on ASCE 41-13 and -17 standards show that acceptance criteria for IO were similar, and that changes in acceptance criteria were noticeable for the LS and CP limit states.

- The greater gap between the curves corresponding to LS and CP observed for the ACI 369 acceptance criteria is a better representation of performance objectives defined in Chapter 2 of ASCE 41 where, for example, the Enhanced Objective corresponds both to seismic hazard level BSE-1 (10% probability of exceedance in 50 yrs) with performance level LS and seismic hazard level BSE-2 (2% probability of exceedance in 50 years) with performance objective CP.

Conclusions

- The performance level of the case study building was controlled by the exterior beams, which are the elements of least concern to the gravity load system. The effect of element damage on the probability of collapse should be considered when formulating Acceptance Criteria.

- Comparisons between models with ASCE 41-13 MP and AC and ASCE 41-17 MP and AC show that that the difference in MP of columns between the two provisions led to significant changes in the distribution of nonlinear deformation in the components of the system

- Analysis results show that plastic rotation demands in columns were much lower than plastic rotation demands in beams. This is attributed to the fact that in the 2017 provisions columns can reach deformations at loss of lateral load capacity as high as twice than those of beams

- It is very important to simulate system behavior accurately that MP and AC for beams and slab column connections be adjusted to have similar probabilities of exceedance than columns.

Acknowledgments

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