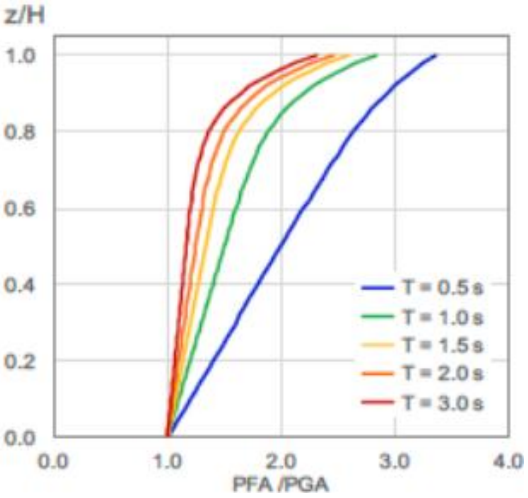
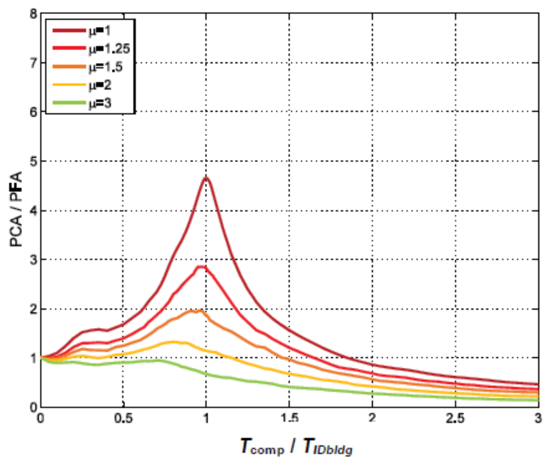
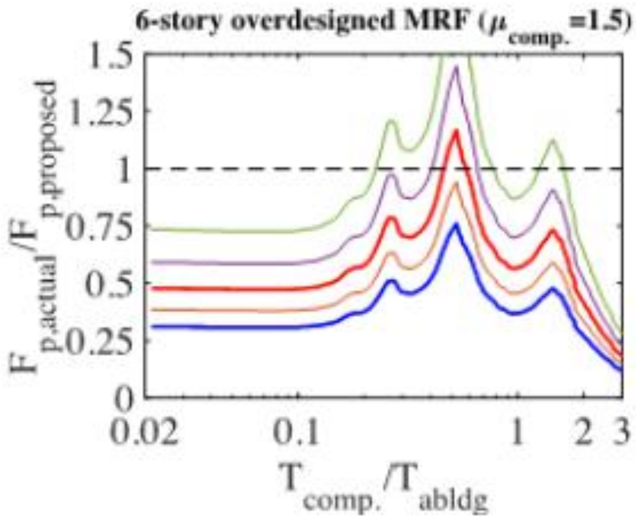
ATC-120 Proposed Nonstructural Design Equations:
What Are They, What is the Basis, and How Do They Compare with Current Practice?







Bret Lizundia
Provisions Update Committee
August 16, 2018

Overview of Presentation

- A little bit about the ATC-120 project
- What are the goals for new equations?
- What are the influences of various parameters?
- The form and development of new equations
- Benchmarking the proposed equations
- Comparisons of results between current and proposed equations
- Illustrative examples
- Recommendations and next steps

ATC-120 Team

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What Are The Goals?

We want equations that are:

- Grounded in science: Based on a comprehensive technical investigation of the parameters that significantly influence component response. Use instrumental records and archetype studies.
- Transparent: The form of the equation is easy to understand and directly relates to the underlying basis.
- Not complicated: Easy to use by practitioners.
- Addresses various situations:
  - Building type and height are not known.
  - Building type and height are known, but no other info.
  - A building analysis is available.

ASCE 7-16 Equations 13.3-1, 13.3-2, and 13.3-3

$$\frac{F_p}{W_p} = \frac{(0.4 S_{DS} a_p)}{(R_p / I_p)}\left(1 + 2\frac{z}{h}\right)$$

$$\frac{F_p}{W_p} = 0.3 S_{DS} I_p$$

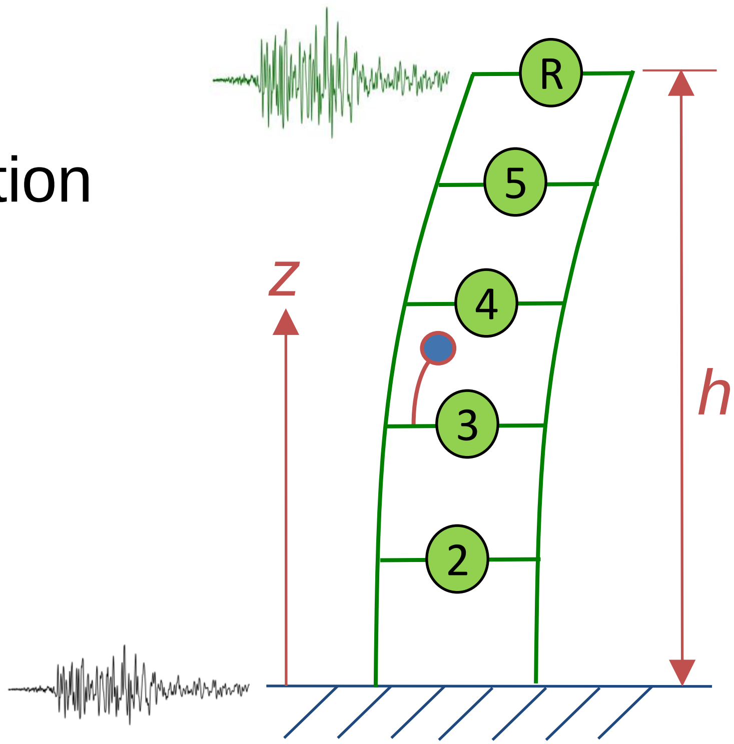
$$\frac{F_p}{W_p} = 1.6 S_{DS} I_p$$

Key Terminology

PCA: Peak Component Acceleration

PFA: Peak Floor Acceleration

PGA: Peak Ground Acceleration



Gillengerten's House of Anchored Components

$$\frac{F_p}{W_p} = \frac{\left(0.4 S_{DS} a_p\right)}{\left(R_p / I_p\right)} \left(1 + 2\frac{z}{h}\right)$$

$0.4S_{DS}$ = Approximation of PGA

$\left(1 + 2\frac{z}{h}\right)$ = Approximation of PFA/PGA

a_p = component amplification factor, PCA/PFA

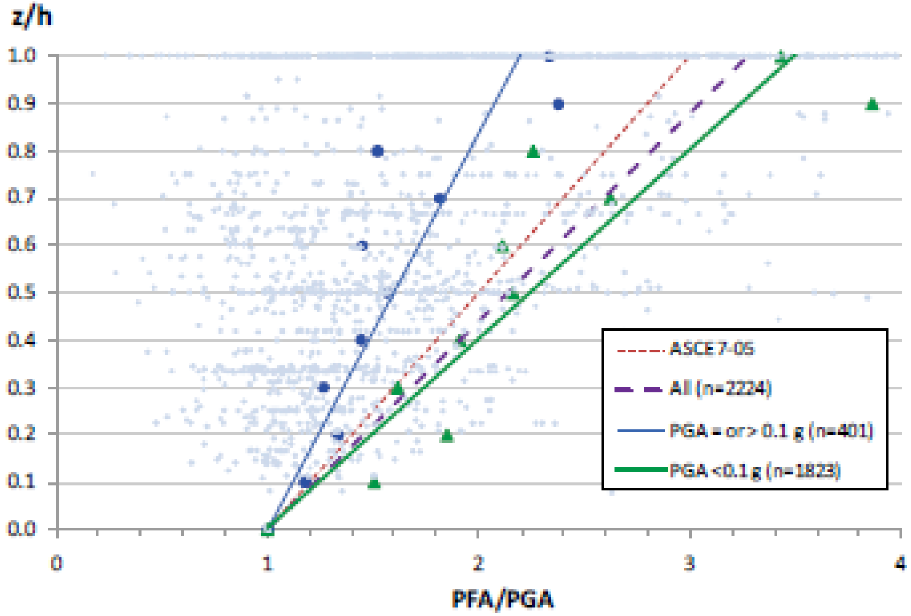
R_p = component response modification factor

I_p = component Importance Factor

$$\frac{F_p}{W_p} = f(PGA, SFRS, T_{n,bldg}, \mu_{bldg}, \beta_{bldg}, IRR, DIA, z/h, T_{comp}, \mu_{comp}, \beta_{comp}, \Omega_{0comp}) \times I_p$$

- Ground shaking intensity, PGA
- Seismic force-resisting system of the building (SFRS)
- The building's modal periods, $T_{n,bldg}$
- Building ductility, μ_{bldg}
- Building damping, β_{bldg}
- Building configuration (such as plan and vertical irregularities), *IRR*
- Floor diaphragm rigidity, *DIA*
- Vertical location of component within the building, z/h
- Component period, T_{comp}
- Component and/or anchorage ductility, μ_{comp}
- Component damping, β_{comp}
- Component reserve strength margin, Ω_{0comp}

PGA

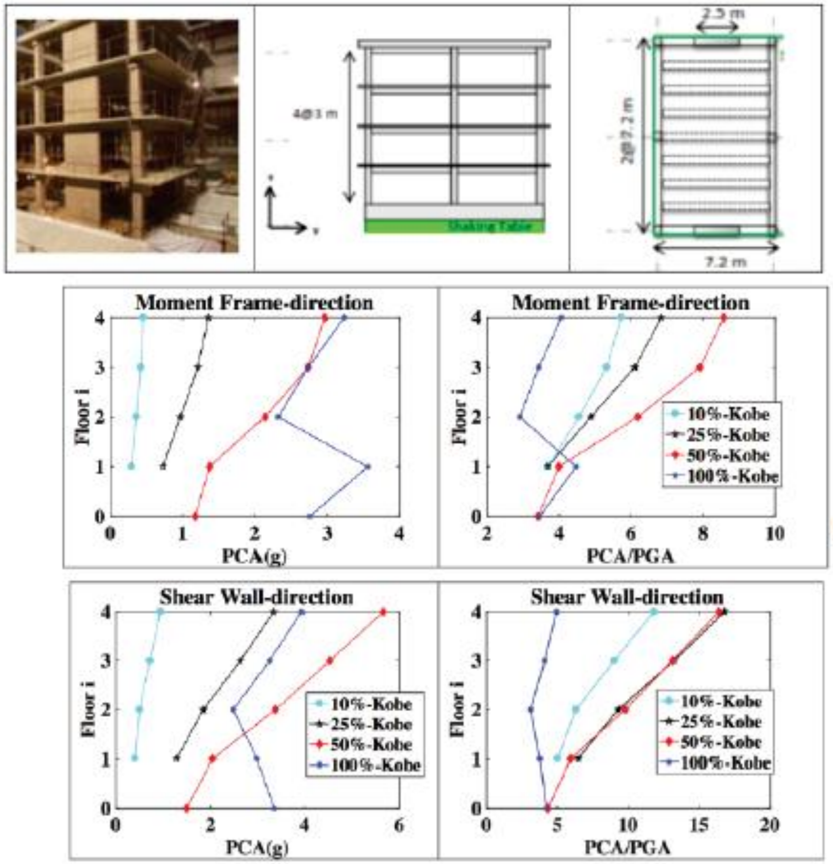


Line Name	Type	Formula
ASCE7-05	Building Code	$\frac{PFA}{PGA} = 1 + 2.00\ (z/h)$
All	Linear regression	$\frac{PFA}{PGA} = 1 + 2.27\ (z/h)$
PGA ≥ 0.1 g	Linear regression	$\frac{PFA}{PGA} = 1 + 1.19\ (z/h)$
PGA < 0.1 g	Linear regression	$\frac{PFA}{PGA} = 1 + 2.49\ (z/h)$

Figure 4-3 The effect of PGA on PFA/PGA from Fathali and Lizundia (2011). The regression lines are for the mean plus one standard deviation values of 2224 data points taken from 151 fixed-base CSMIP building stations.

PGA

NEES #1005; 4-Story, RC Bldg.; 0.43 and 0.31 s in X and Y dir.

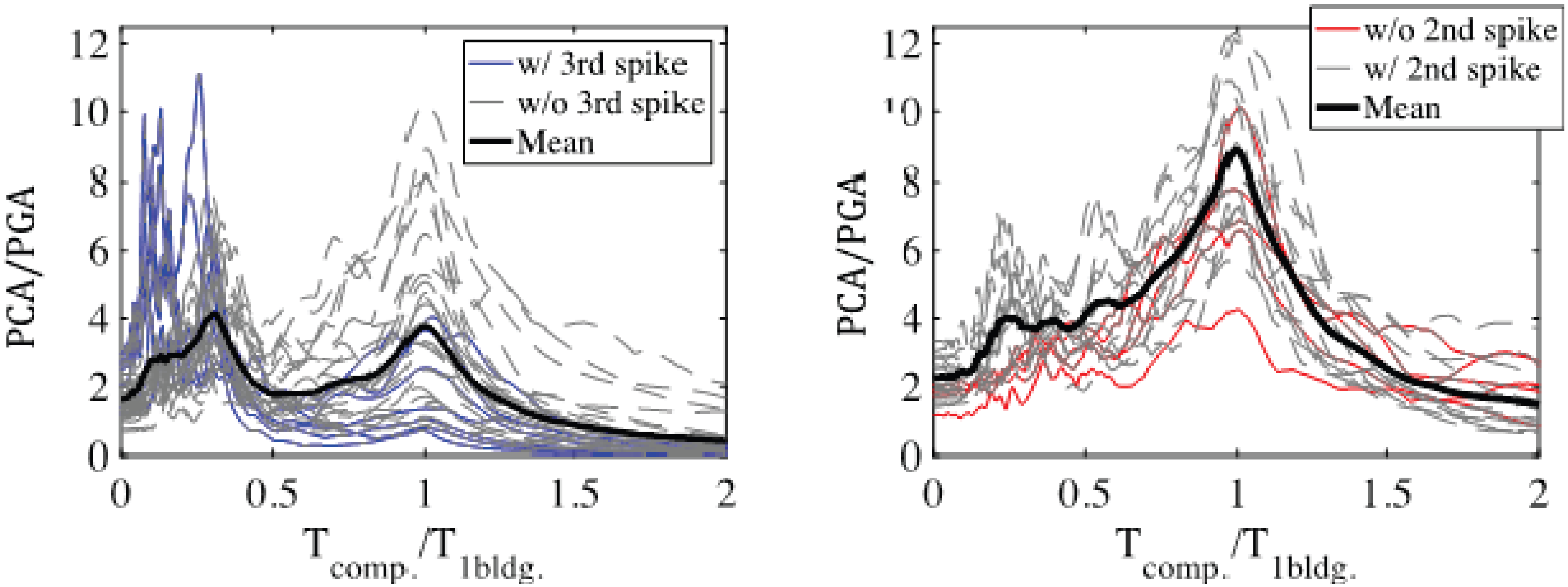


Lateral-load resisting system variation

GM intensity variation

Figure 4-1 The effect of ground shaking intensity on PCA and PCA/PGA in a shake table experiment from Nagae, et al. (2011).

Seismic Force-Resisting System



(a) MRF buildings (33 cases) (b) SW buildings (16 cases)

Figure 4-6 The effect of building stiffness on PCA/PGA for instrumental recordings with a normalized x-axis. Spikes represent higher building modes of vibration where there is increased response. An elastic component is assumed with β_{comp} = 5%. The data set includes 49 recordings with PGA > 0.15g.

Building Modal Periods, $T_{n,bldg}$

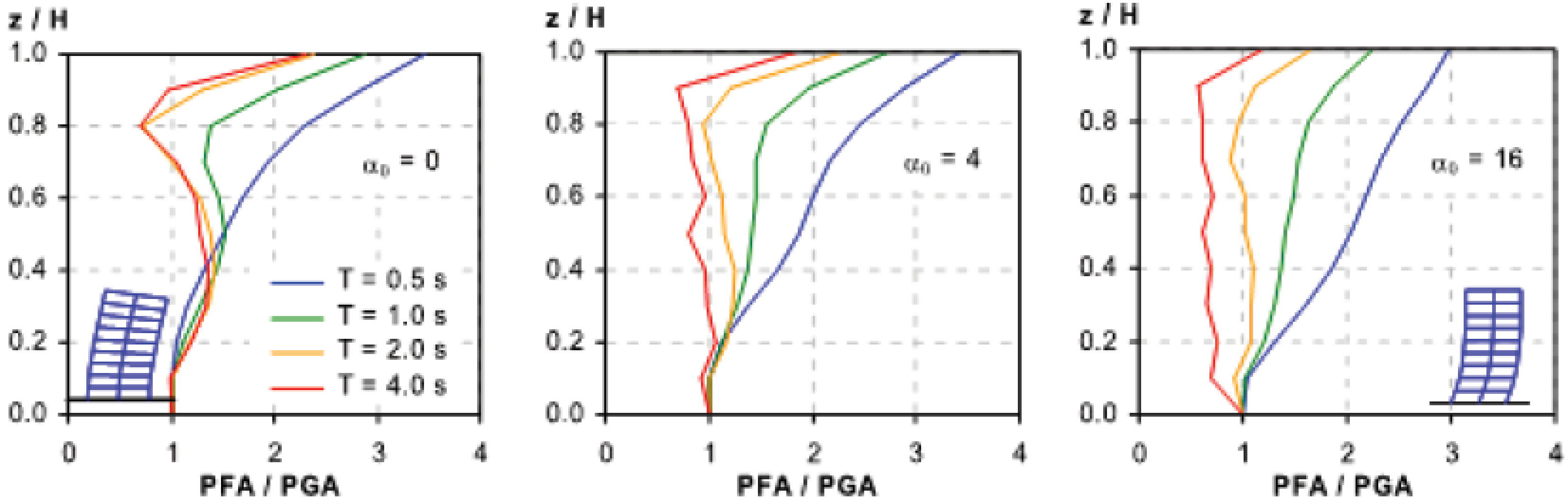


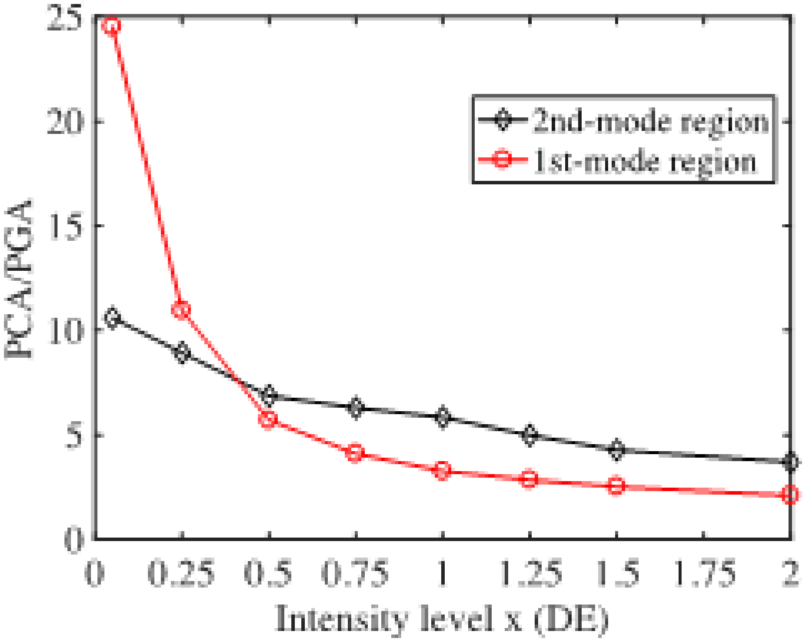
Figure 4-7 The effect of period of vibration and lateral system stiffness on PFA/PGA (from Miranda and Taghavi, 2009). The parameter α is the lateral stiffness ratio defined as $\alpha_0 = H(GA/EI)^{0.5}$, where H is height, GA is the shear rigidity of a shear beam and EI is the flexural stiffness. A value of $\alpha_0 = 0$ represents a pure flexural model; a value of α approaching infinity represents a pure shear beam.

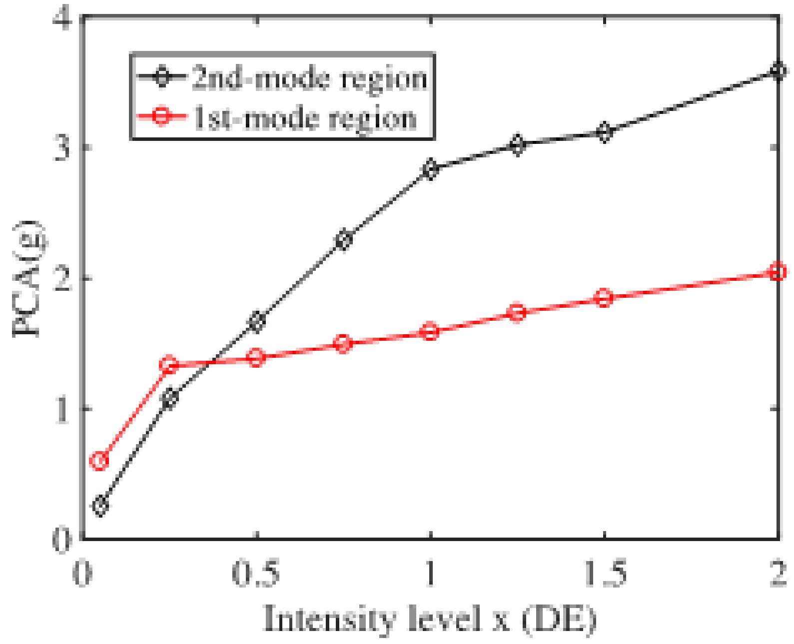
Inherent Building Damping, β_{bldg}

Table 4-1 Reduction in PCA Demands

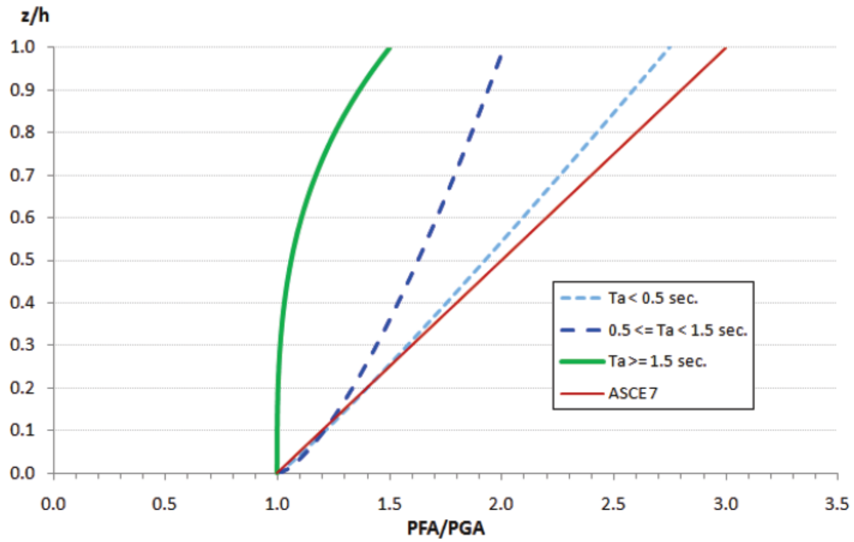
	6-story Moment-Resisting Frame Building			8-story Shear Wall Building.		
	2.5%	*5%*	*Reduction*	*2.5%*	*5%*	*Reduction*
$PCA_{higher\text{-}mode\ region}/PGA$	9.24	7.32	21%	12.1	9.85	19%
$PCA_{1st\text{-}mode\ region}/PGA$	6.10	5.87	4%	5.59	5.47	2%

Building Ductility, μ_{bldg}





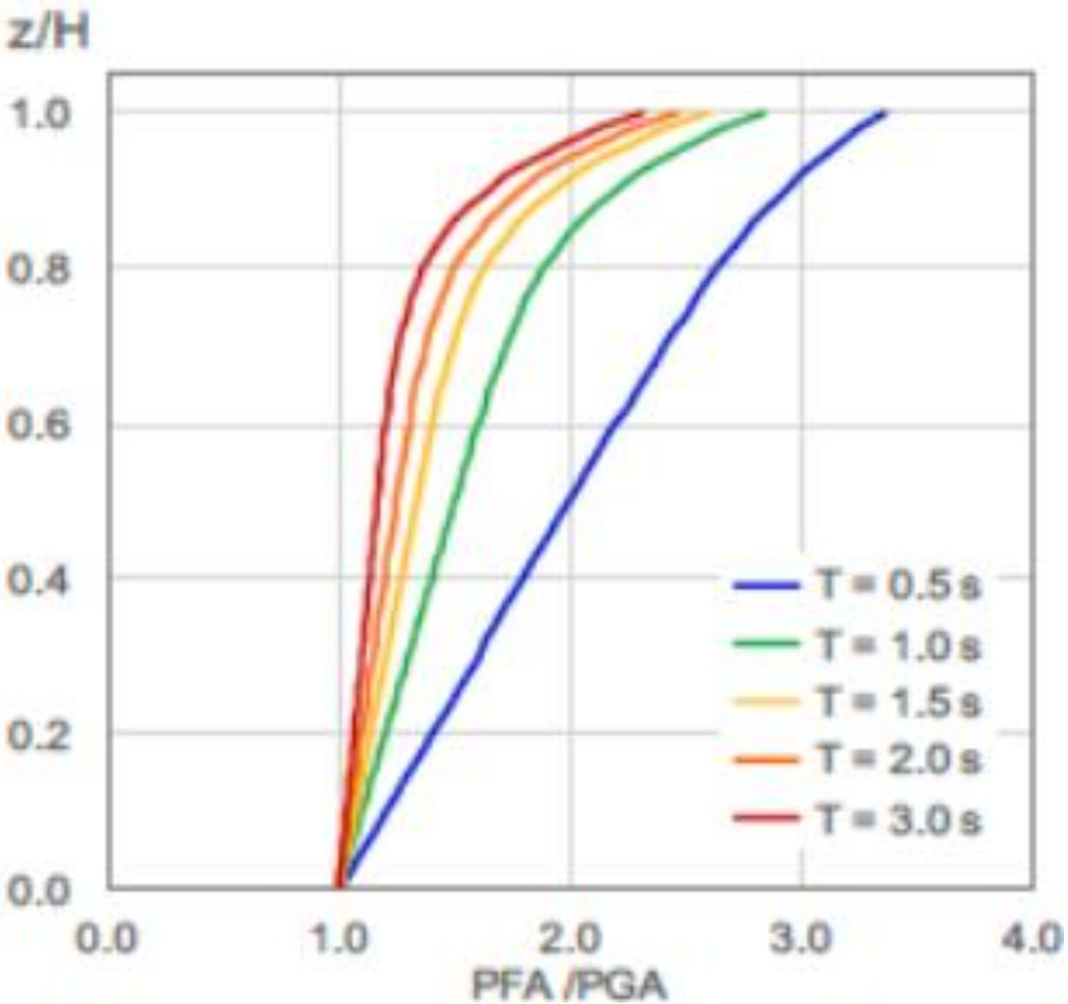
Vertical Location Within the Building, *z/h*



	PGA ≥ 0.20 g (SDC D)
$T_a < 0.5$ sec.	$\frac{PFA}{PGA} = 1 + 1.75\,(z/h)^{0.92}$
$0.5 \le T_a < 1.5$ sec.	$\frac{PFA}{PGA} = 1 + 1.01\,(z/h)^{0.69}$
$T_a \ge 1.5$ sec.	$\frac{PFA}{PGA} = 1 + 0.50\,(z/h)^{3.00}$

Figure 4-13 Sample equation for PFA/PGA for PGA > 0.20g from Fathali and Lizundia (2011).

Vertical Location Within the Building, *z/h*



$$\left(\frac{\text{PFA}}{\text{PGA}}\right) = 1 + a_1\left(\frac{z}{h}\right) + a_2\left(\frac{z}{h}\right)^{10}$$

where:

$a_1 = \dfrac{1}{T_{aBldg}} \leq 2.5$

$a_2 = [1 - (0.4/T_{abldg})^2] > 0$

T_{abldg} = ASCE/SEI 7-16 Equation 12.8-7

Component Period and Building Period Resonance

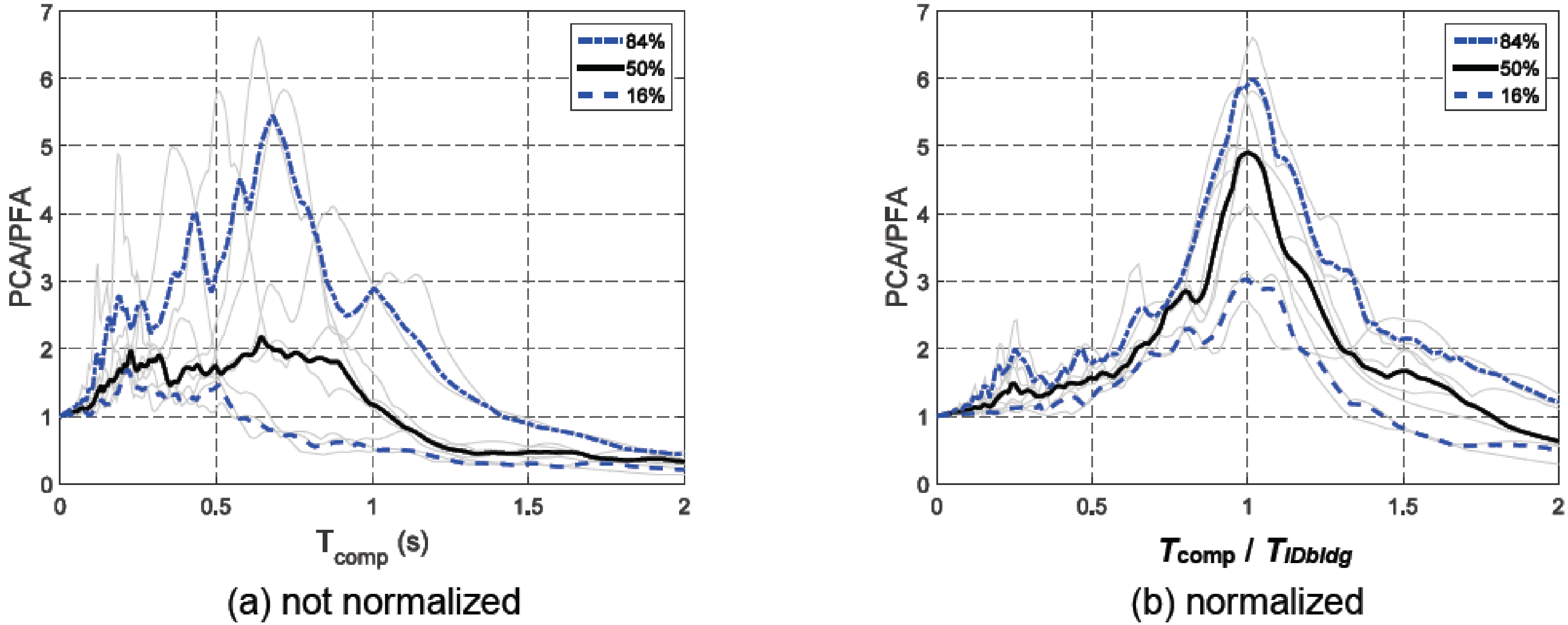


Figure 4-16 Relationship between PCA/PFA comparing spectra without (a) and with (b) normalization by T_{IDbldg}. An elastic component is assumed with β_{comp} = 5%. The data set includes eight recordings with PCA > 0.9g. Figures are from Miranda et al. (2018).

Inherent Component Damping, β_{comp}

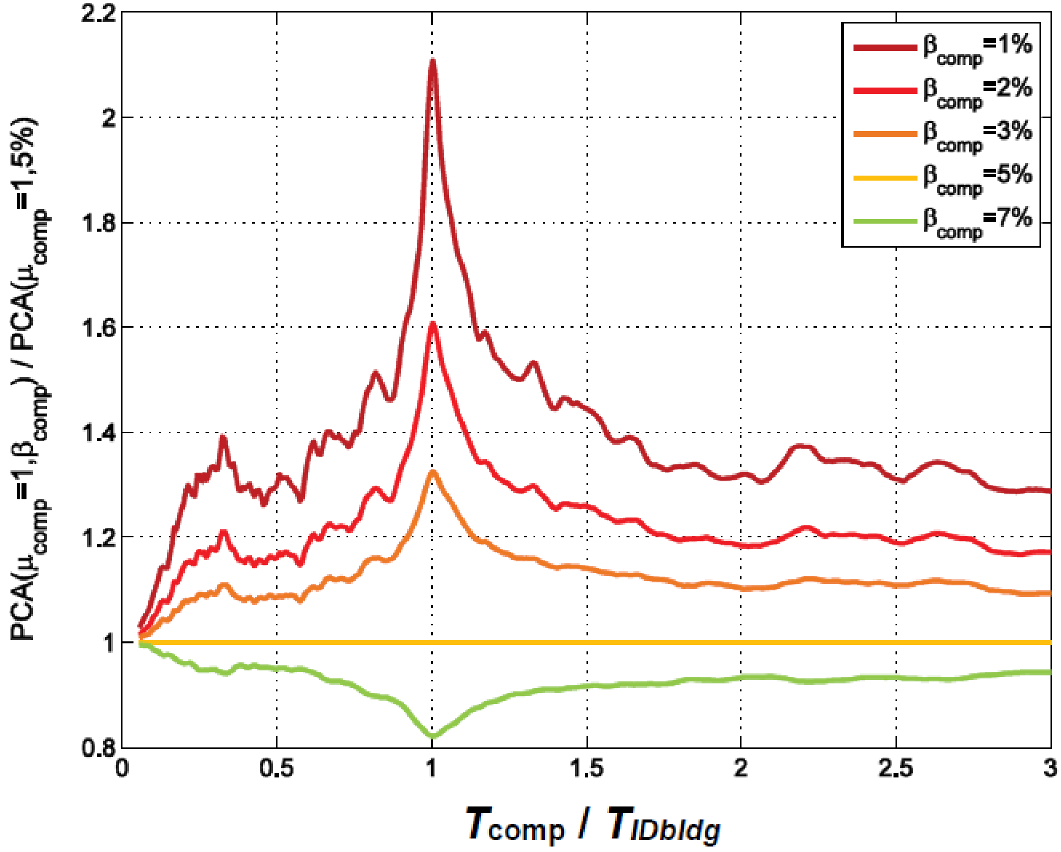
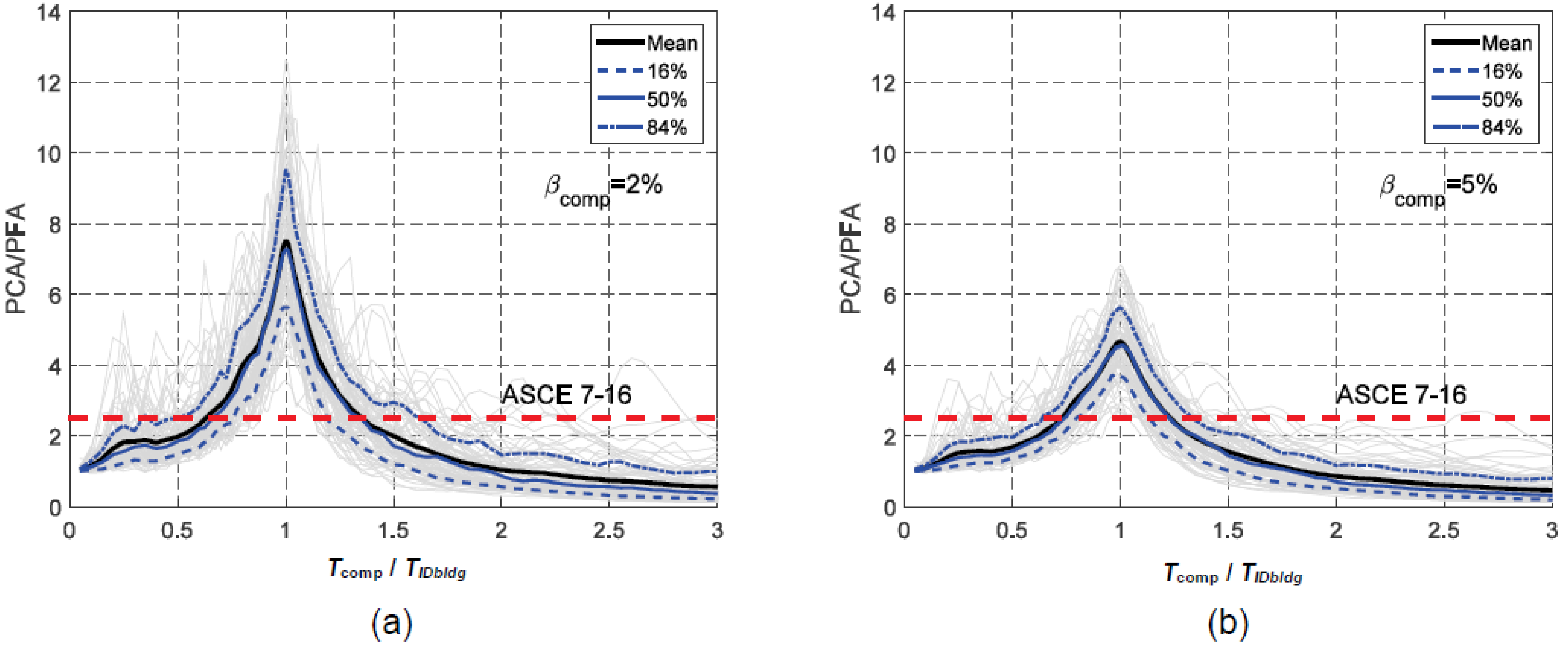
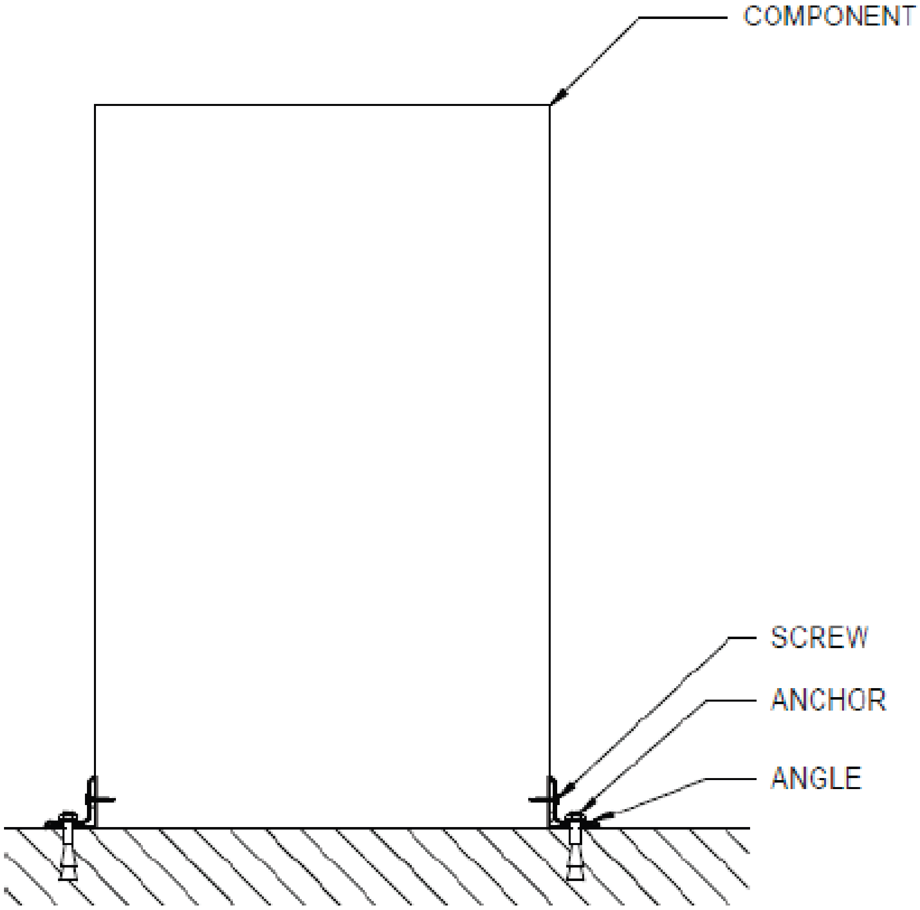


Figure 4-19 Mean elastic PCA ratios between inherent component damping, T_{comp}, of 5% and other damping levels. The data set includes 86 recordings with PCA > 0.9g.

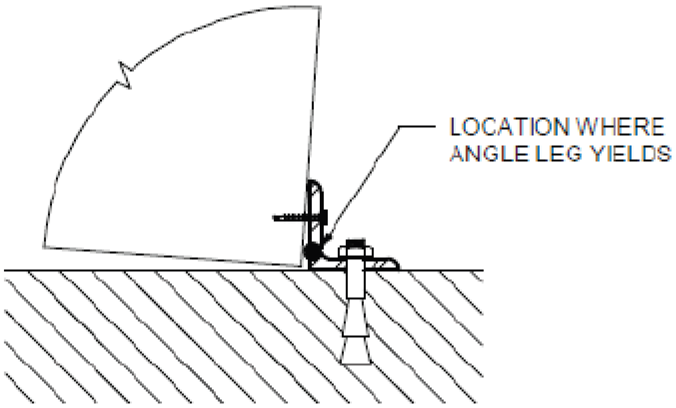
Inherent Component Damping, β_{comp}



Sources of Component and/or Anchorage Ductility, μ_{comp}



- Component
- Connection of component to anchor
- Anchor



Component /Anchorage Ductility, μ_{comp}

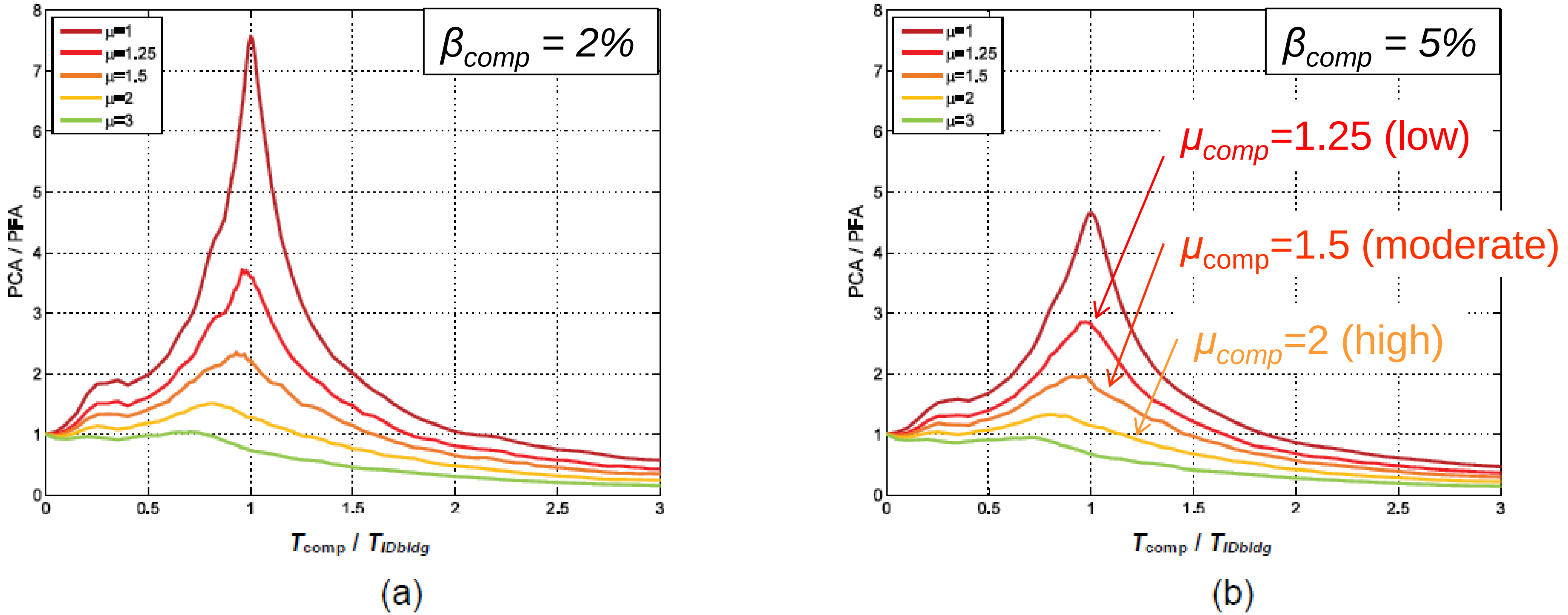
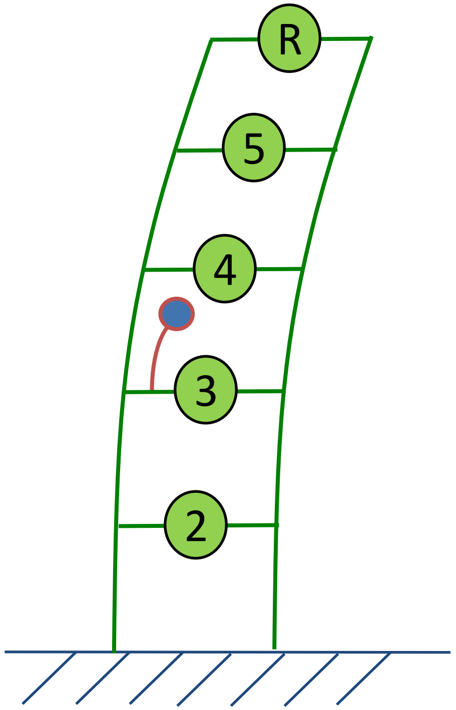


Figure 4-23 Comparison of mean response of PCA/PFA vs T_{comp}/T_{IDbldg} for different levels of component ductility. Figure (a) β_{comp} = 2% inherent component damping; (b) is for β_{comp} = 5%. The data set includes 86 recordings with PCA > 0.9g.

Proposed Equation Framework

$$\frac{F_p}{W_p} = PGA \times \left(\frac{PFA}{PGA}\right) \times \left(\frac{PCA}{PFA}\right) \times I_p$$



Gillengerten's House of Anchored Components

Proposed Equation

$$\frac{F_p}{W_p} = PGA \times \left[\frac{\left(\frac{PFA}{PGA} \right)}{R_{\mu bldg}} \right] \times \left[\frac{\left(\frac{PCA}{PFA} \right)}{R_{pocomp}} \right] \times I_p$$

Reduction factor for building ductility

Reduction factor for component reserve strength

$$\frac{F_p}{W_p} = \mathrm{PGA} \times \left[\frac{\left(\frac{\mathrm{PFA}}{\mathrm{PGA}}\right)}{R_{\mu bldg}}\right] \times \left[\frac{\left(\frac{\mathrm{PCA}}{\mathrm{PFA}}\right)}{R_{pocomp}}\right] \times I_p$$

PGA = Peak Ground Acceleration. Use $0.4S_{DS}$ until this is directly provided in future ASCE/SEI 7 editions.

$$\left(\frac{\mathrm{PFA}}{\mathrm{PGA}}\right) = 1 + a_1\left(\frac{z}{h}\right) + a_2\left(\frac{z}{h}\right)^{10}$$

where:

$a_1 = \frac{1}{T_{aBldg}} \leq 2.5$

$a_2 = [1 - (0.4/T_{abldg})^2] > 0$

T_{abldg} = ASCE/SEI 7-16 Equation 12.8-7

$$\frac{F_p}{W_p} = PGA \times \left[\frac{\left(\frac{PFA}{PGA} \right)}{R_{\mu bldg}} \right] \times \left[\frac{\left(\frac{PCA}{PFA} \right)}{R_{pocomp}} \right] \times I_p$$

$R_{\mu bldg}$ = Reduction factor to account for building global ductility

where:

$R_{\mu bldg} = (R_D)^{1/2} = (1.1R / \Omega_0)^{1/2}$

where R and Ω_o are the Response Modification Coefficient and the Overstrength Factor from ASCE/SEI 7-16 Table 12.2-1. $R_{\mu bldg}$ need not be taken as less than 1.0.

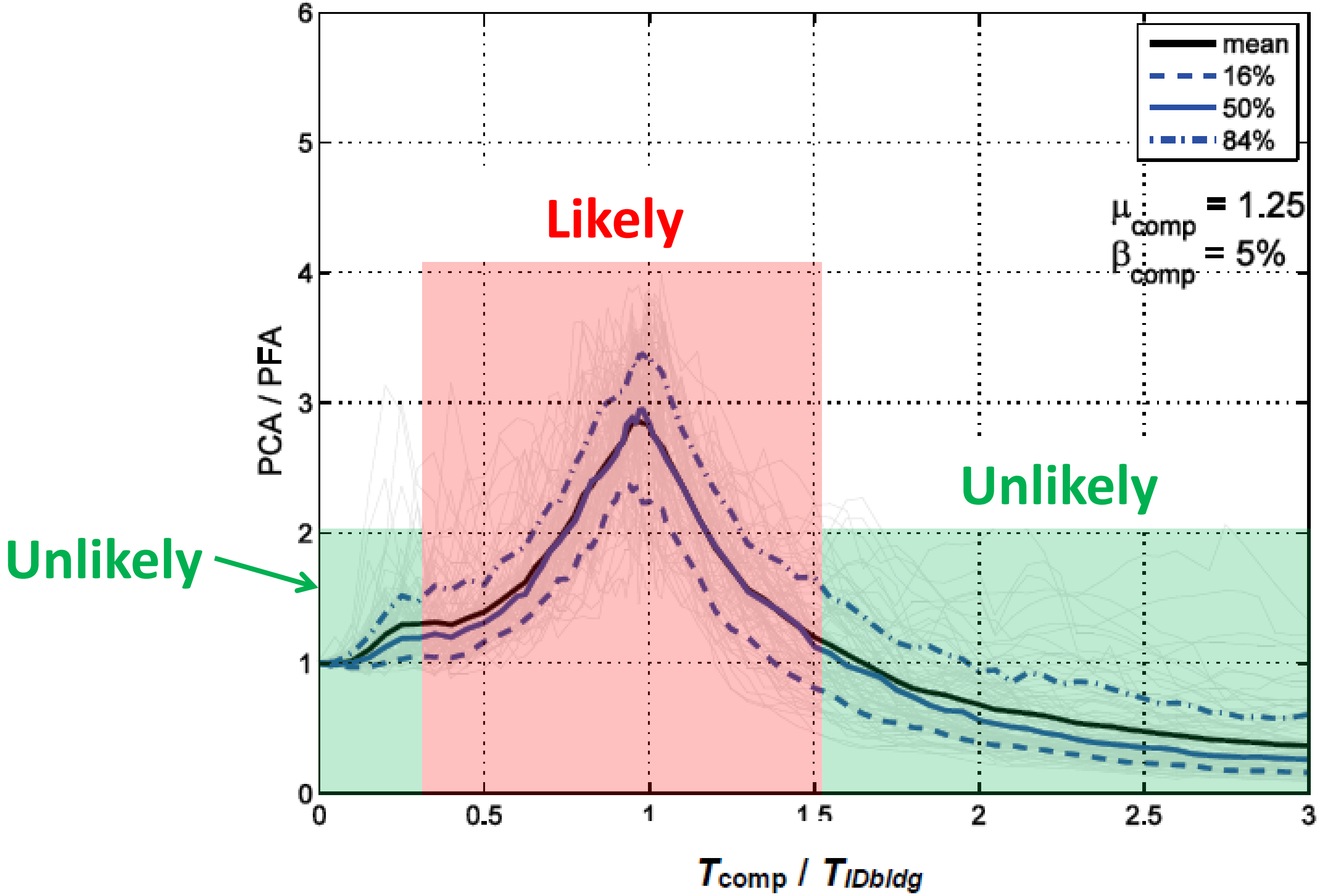
R_{pocomp} = Inherent component overstrength factor. A value of 1.3 is used as a placeholder.

$$\frac{F_p}{W_p} = PGA \times \left[\frac{\left(\frac{PFA}{PGA} \right)}{R_{\mu bldg}} \right] \times \left[\frac{\left(\frac{PCA}{PFA} \right)}{R_{pocomp}} \right] \times I_p$$

Table 4-3 Building Ductility Reduction Factor, $R_{\mu bldg}$

Seismic Force-Resisting System	Response Modification Coefficient, R	Overstrength Factor, Ω_0	Global Ductility Coefficient, R_D	$R_{\mu bldg}$
Steel special moment-resisting frame	8	3	2.93	1.71
Special reinforced concrete moment frame	8	3	2.93	1.71
Special reinforced concrete shear wall (building frame system)	6	2.5	2.64	1.62
Special reinforced concrete shear wall (bearing wall system)	5	2.5	2.20	1.48
Steel eccentrically braced frame	8	2	4.40	2.10
Steel buckling-restrained braced frame	8	2.5	3.52	1.88
Steel special concentrically braced frame	6	2	3.30	1.82
Steel ordinary concentrically braced frame	3.25	2	1.79	1.33
Steel ordinary moment-resisting frame	3.5	3	1.28	1.13

Unlikely vs. Likely in Resonance



$$\frac{F_p}{W_p} = PGA \times \left[\frac{\left(\frac{PFA}{PGA}\right)}{R_{\mu bldg}} \right] \times \left[\frac{\left(\frac{PCA}{PFA}\right)}{R_{pocomp}} \right] \times I_p$$

Location of Component	Possibility of Being in Resonance with Building	Component Ductility		$\left(\frac{PCA}{PFA}\right)$ [1]
		Category[2]	*Assumed Ductility*	
Ground	More Likely	Elastic	$\mu_{comp} = 1$	2.5
		Low	$\mu_{comp} = 1.25$	2.0
		Moderate	$\mu_{comp} = 1.5$	1.8
		High	$\mu_{comp} \geq 2$	1.4
	Less Likely	Any	--	1.0
Roof or Elevated Floor	More Likely	Elastic	$\mu_{comp} = 1$	4.0
		Low	$\mu_{comp} = 1.25$	2.8
		Moderate	$\mu_{comp} = 1.5$	2.2
		High	$\mu_{comp} \geq 2$	1.4
	Less Likely	Any	--	1.0

1 Inherent component damping of 5% is assumed as a default.

2 Categories will be assigned to components similar to ASCE/SEI 7-16 Table 13.5-1. Categories need to be determined.

Component Period vs. Building Period

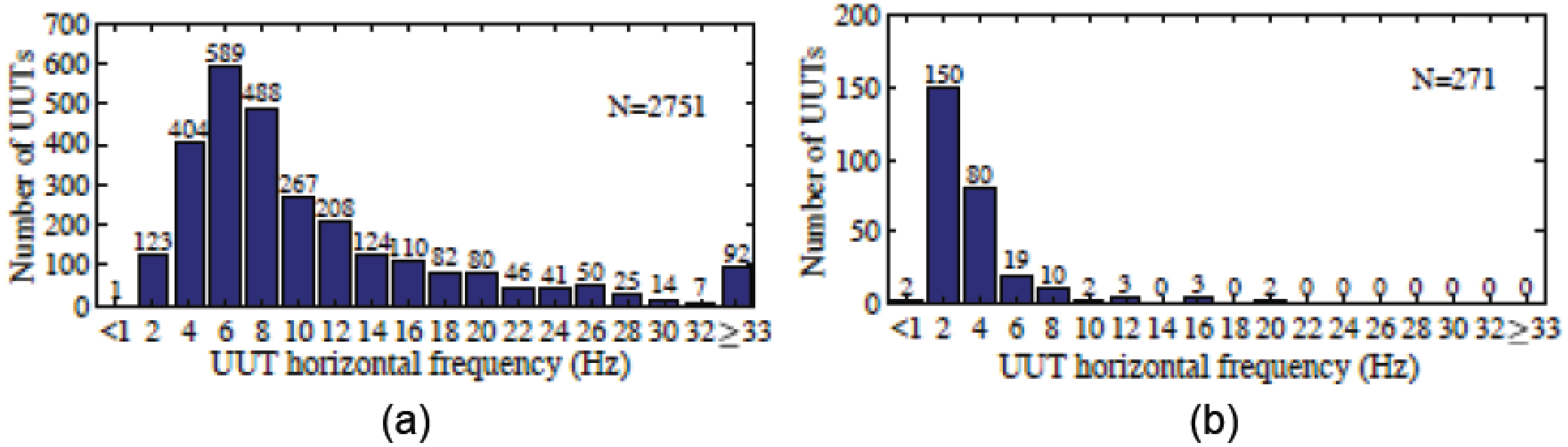


Figure 4-29 Histograms of component frequency for (a) rigid components and (b) vibration-isolated components

Component Period vs. Building Period

Table 4-5 Mean Period and Beta for Buildings and Components

	Mean Period	COV
Building first mode	0.85 s	1.1
Building second mode	0.30 s	1.1
Building third mode	0.15 s	1.1
Rigid components	0.12 s	0.7
Flexible components	0.33 s	0.6

Component Period vs. Building Period

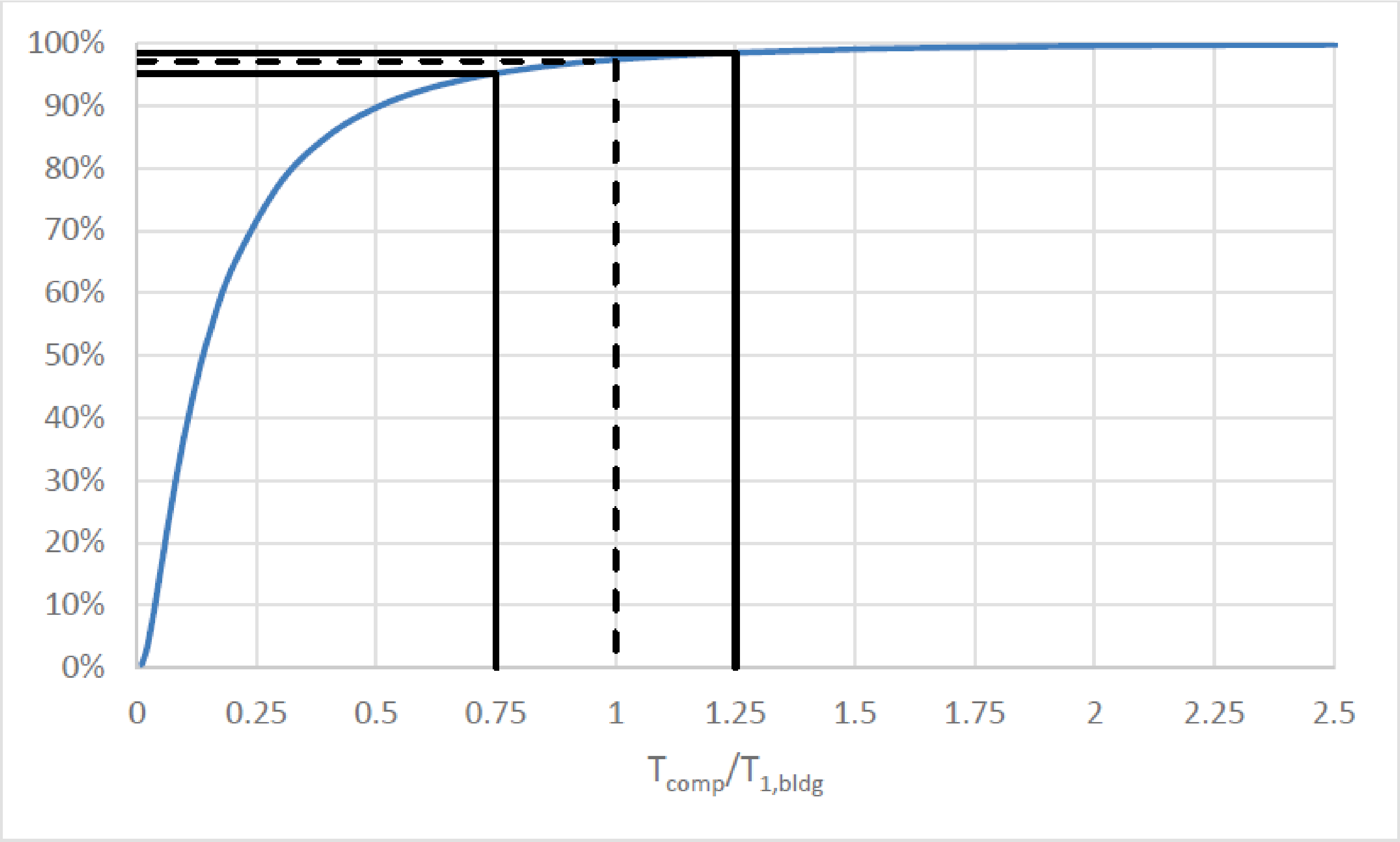


Figure 4-31 Cumulative distribution function for $T_{comp,rigid}/T_{1bldg}$.

PCA/PFA Capping at Resonance

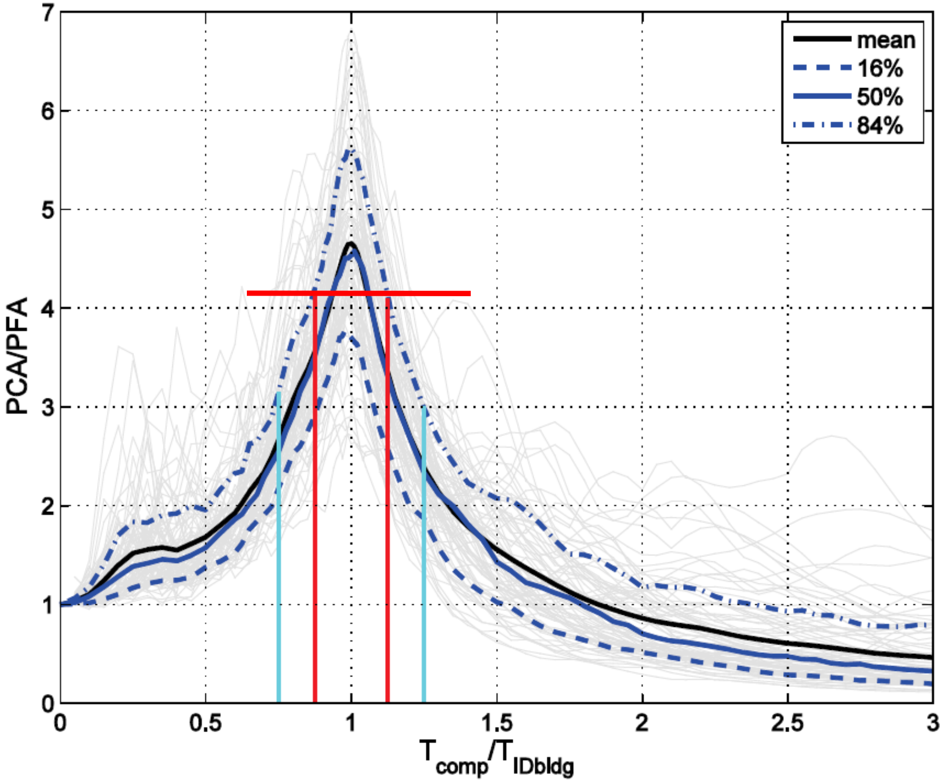


Figure 4-37 Component amplification and capping of PCA/PFA. Values outside the red band capture all cases except those with $0.85 < T_{comp}/T_{n,bldg} < 1.15$. Similarly, values outside the cyan band capture more than 90% of the cases for rigid components all cases except those with $0.75 < T_{comp}/T_{n,bldg} < 1.25$. β_{comp} = 5% inherent component damping is assumed. The data set includes 86 recordings with PCA > 0.9g.

PCA/PFA Capping at Resonance

Table 4-6 Basis for PCA/PFA Values for Flexible Components at Roof and Suspended Floors

Category	Assumed Ductility	Peak Value for PCA/PFA	Reduction from Capping*	PCA/PFA
Elastic	$\mu_{comp} = 1$	5.6 x 1.0 = 5.6	1.4	4.0
Low	$\mu_{comp} = 1.25$	5.6 x 0.6 = 3.4	1.2	2.8
Moderate	$\mu_{comp} = 1.5$	5.6 x 0.4 = 2.2	Not applied	2.2
High	$\mu_{comp} \geq 2$	5.6x 0.25 = 1.4	Not applied	1.4

Note: The narrow band features of PCA/PFA response are more pronounced for an elastic component. The value of 1.4 for an elastic component is taken directly from Figure 4-33. The values for the other categories are from engineering judgment.

$$\frac{F_p}{W_p} = PGA \times \left[\frac{\left(\frac{PFA}{PGA}\right)}{R_{\mu bldg}} \right] \times \left[\frac{\left(\frac{PCA}{PFA}\right)}{R_{pocomp}} \right] \times I_p$$

Selecting Exponent for $R_{\mu bldg} = R_D^{x} = (1.1R/\Omega_0)^{x}$

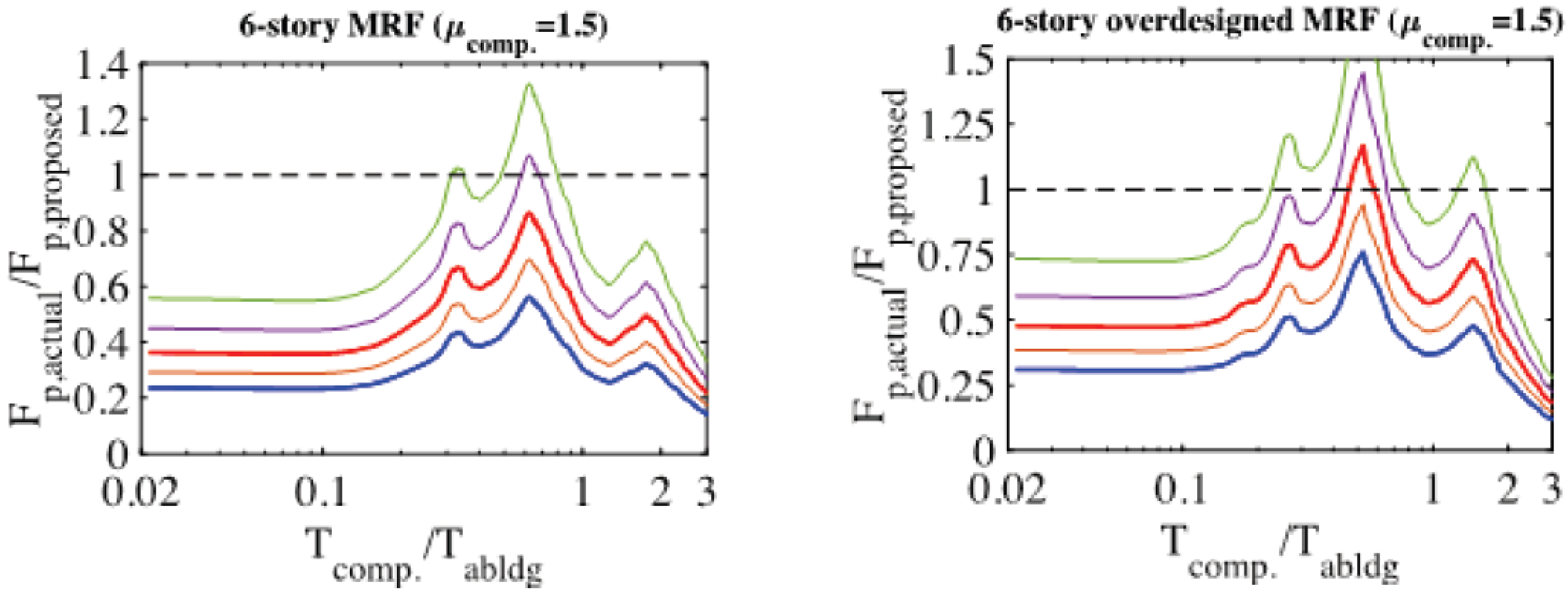


Figure 4-26 Ratio of $F_{p,actual}$ / $F_{p,proposed}$ at the roof for a 6-story steel moment frame archetype T_{abldg} = 0.93 s, assuming μ_{comp} = 1.5 and β_{comp} = 5% inherent component damping, where $F_{p,actual}$ is the mean of 20 spectrum-compatible ground motions. The plots are for different values of "x" in the $R_{\mu bldg} = (R_D)^X$, with the dark blue at the bottom being 0.1, the dark red in middle being 0.5, and the light green at the top being 0.9. The archetype on the right has an additional strength of 1.5 compared to the baseline archetype on the left.

$$\frac{F_p}{W_p} = PGA \times \left[\frac{\left(\frac{PFA}{PGA} \right)}{R_{\mu bldg}} \right] \times \left[\frac{\left(\frac{PCA}{PFA} \right)}{R_{pocomp}} \right] \times I_p$$

Selecting Exponent for $R_{\mu bldg} = R_D^{x} = (1.1R/\Omega_0)^{x}$

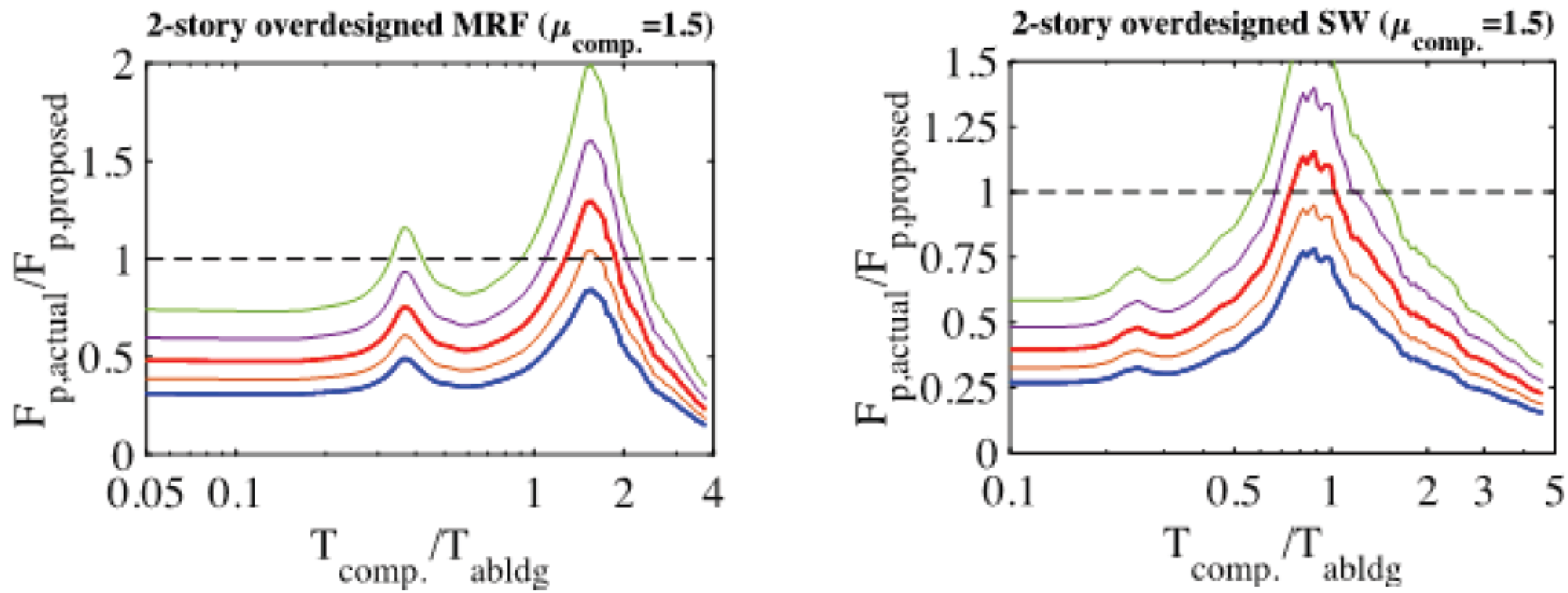


Figure 4-28 Ratio of $F_{p,actual}$ / $F_{p,proposed}$ at the roof for a 2-story moment frame archetype (left, with T_{abldg} = 0.40s) and 2-story concrete shear wall archetype (right, with T_{abldg} = 0.40 s), assuming μ_{comp} = 1.5 and β_{comp} = 5% inherent component damping, where $F_{p,actual}$ is the mean of 20 spectrum-compatible ground motions. The plots are for different values of “x” in the $R_{\mu bldg} =(R_D)^X$, with the dark blue at the bottom being 0.1, the dark red in middle being 0.5, and the light green at the top being 0.9. The moment frame has an overdesign ratio of 2.0, and the shear wall has as an overdesign ratio of 3.0, compared to baseline archetypes.

Likely in Resonance Components: $F_{p,actual}/F_{p,proposed}$

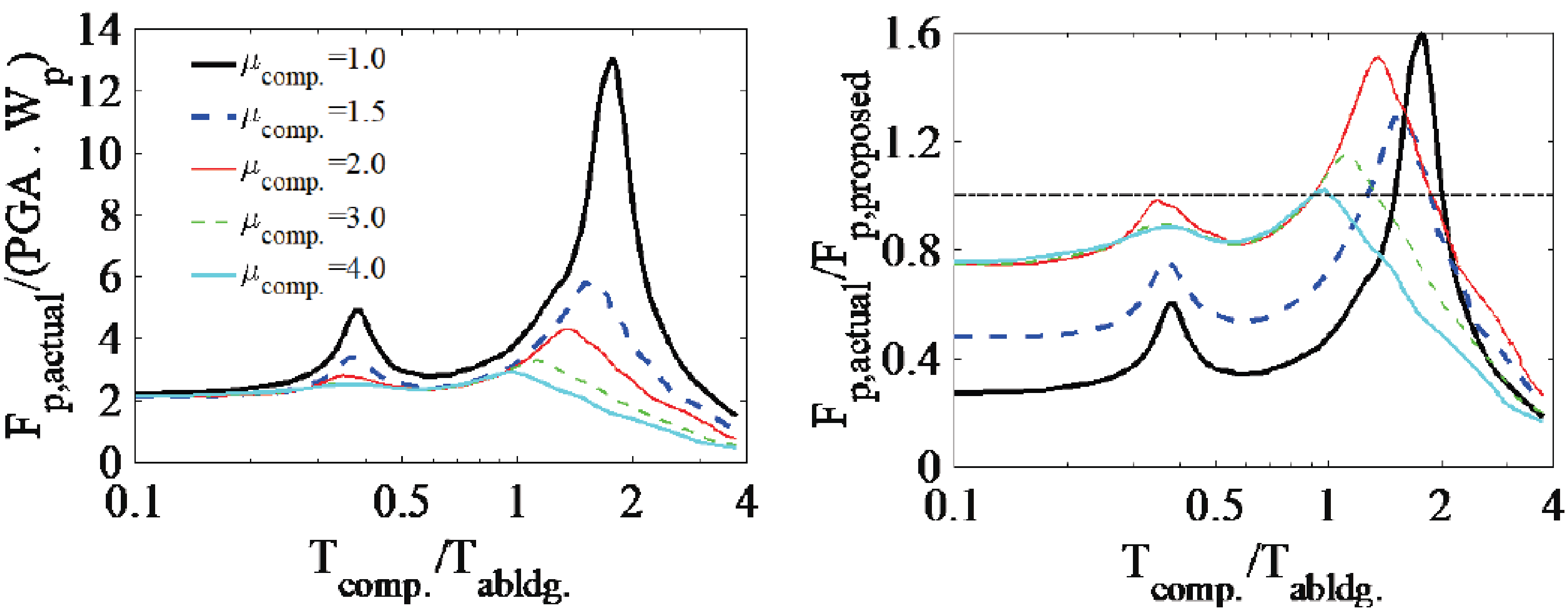


Figure 4-40 (a) Mean of the simulated $F_{p,actual}$ normalized by PGA and (b) normalized of $F_{p,proposed}$ at the roof for a 2-story steel moment-resisting frame archetype assuming an overdesign factor of 2.0, μ_{comp} = 1.0-4.0, and β_{comp} = 5% inherent component damping, where $F_{p,actual}$ is the mean of 20 spectrum-compatible ground motions. $F_{p,proposed}$ is for components likely to be in resonance.

Likely in Resonance Components: $F_{p,actual} / F_{p,proposed}$

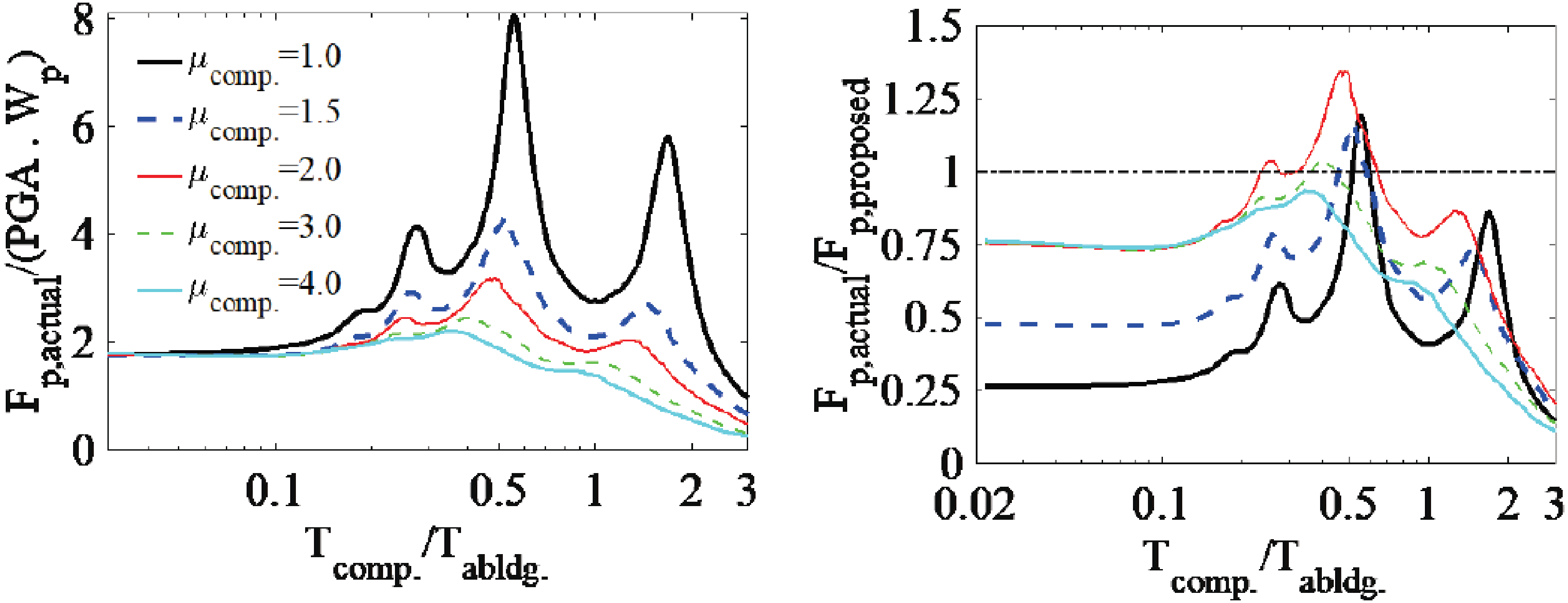


Figure 4-41 (a) Mean of the simulated $F_{p,actual}$ normalized by PGA and (b) normalized of $F_{p,proposed}$ at the roof for a 6-story steel moment-resisting frame archetype assuming an overdesign factor of 1.5, μ_{comp} = 1.0-4.0, and β_{comp} = 5% inherent component damping, where $F_{p,actual}$ is the mean of 20 spectrum-compatible ground motions. $F_{p,proposed}$ is for components likely to be in resonance.

Likely in Resonance Components: $F_{p,actual} / F_{p,proposed}$

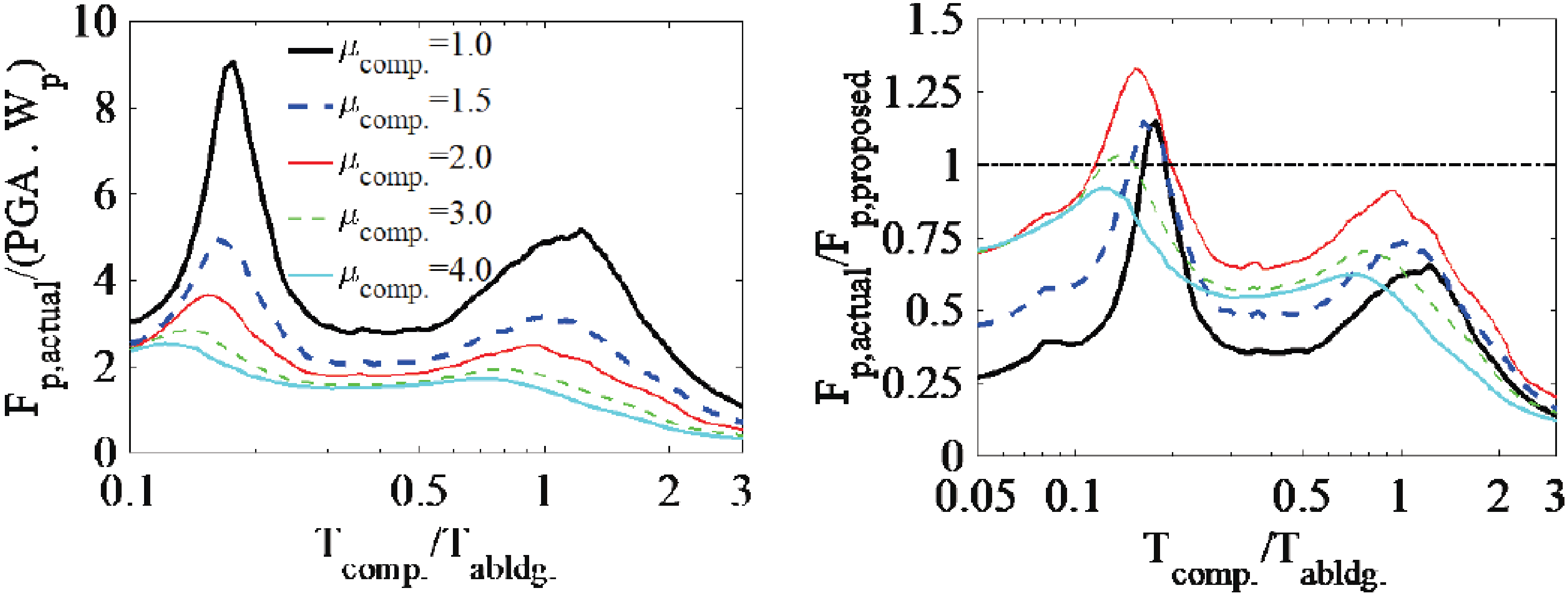


Figure 4-43 (a) Mean of the simulated $F_{p,actual}$ normalized by PGA and (b) normalized of $F_{p,proposed}$ at the roof for an 8-story concrete shear wall archetype assuming an overdesign factor of 1.5, μ_{comp} = 1.0-4.0, and β_{comp} = 5% inherent component damping, where $F_{p,actual}$ is the mean of 20 spectrum-compatible ground motions. $F_{p,proposed}$ is for components likely to be in resonance.

Unlikely in Resonance Components: $F_{p,actual} / F_{p,proposed}$

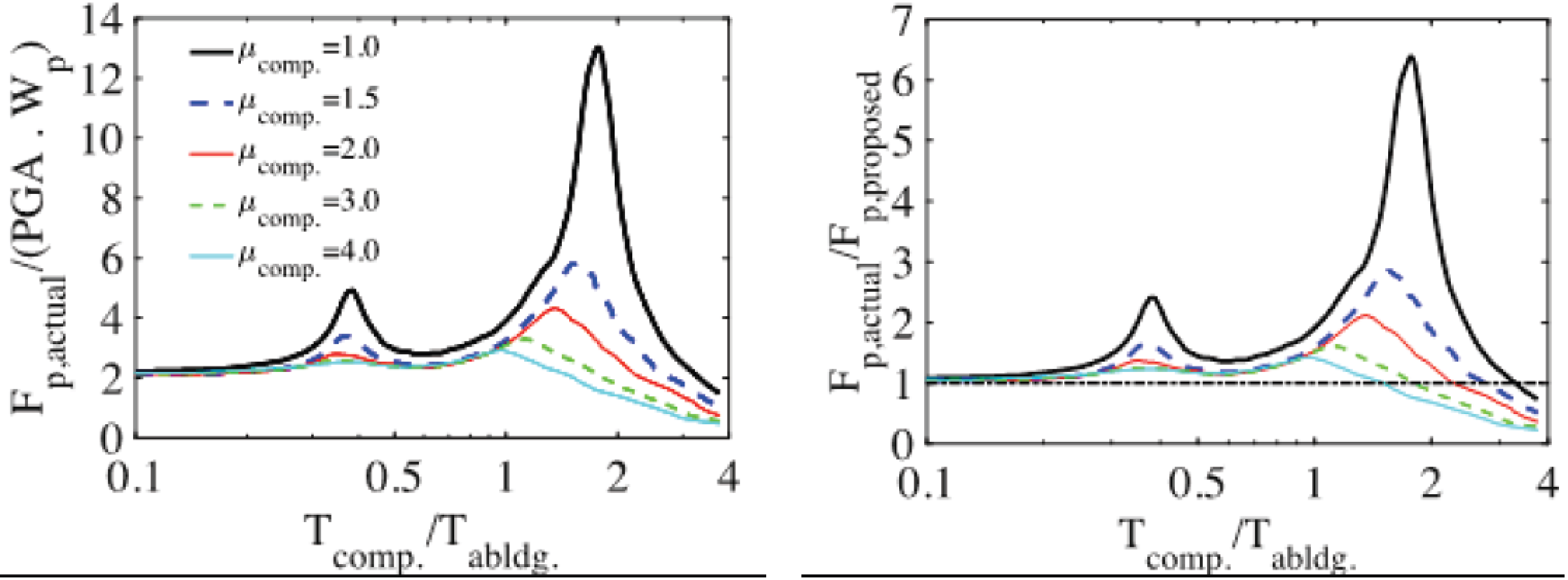


Figure 4-44 (a) Mean of the simulated $F_{p,actual}$ normalized by PGA and (b) normalized of $F_{p,proposed}$ at the roof for a 2-story steel moment frame archetype assuming an overdesign factor of 2.0, μ_{comp} = 1.0-4.0, and β_{comp} = 5% inherent component damping, where $F_{p,actual}$ is the mean of 20 spectrum-compatible ground motions. $F_{p,proposed}$ is for components not likely to be in resonance.

Minimum and Maximum Equations

ASCE 7-16

$$\frac{F_p}{W_p} = 0.3 S_{DS} I_p$$

$$\frac{F_p}{W_p} = 1.6 S_{DS} I_p$$

Proposed

$$\frac{F_p}{W_p} = 0.3 S_{DS} I_p$$

$$\frac{F_p}{W_p} = 2.0 S_{DS} I_p$$

Magnitude of the Minimum

- 1991 UBC (basis of ASCE 7-16 equations)

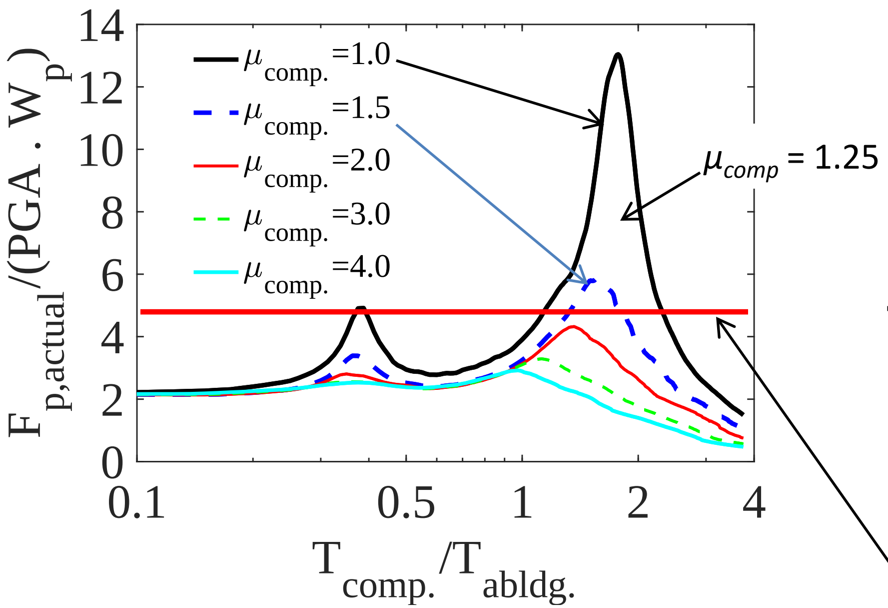
$$F_{p,ASD} = (2/3)ZI_pC_pW_p$$
$$= (2/3)(0.4S_{DS})I_p(0.75)W_p$$
$$= 0.2S_{DS}I_pW_p$$

$$F_{p,LRFD} \approx 1.5F_{p,ASD} = 0.3S_{DS}I_pW_p$$

- Alternate

$$F_{p,LRFD} = 0.4S_{DS}I_pW_p \,/\, R_{pocomp}$$
$$F_{p,LRFD} \approx 0.3S_{DS}I_pW_p$$

Magnitude of the Maximum



2-Story SMRF with
overdesign factor = 2.0

$$\frac{F_p}{W_p} = 2.0 S_{DS} I_p$$

$$\frac{F_p}{W_p} = 2.0(\mathrm{PGA}/0.4)1.0$$

$$\frac{F_p}{(PGA)W_p} = 5.0$$

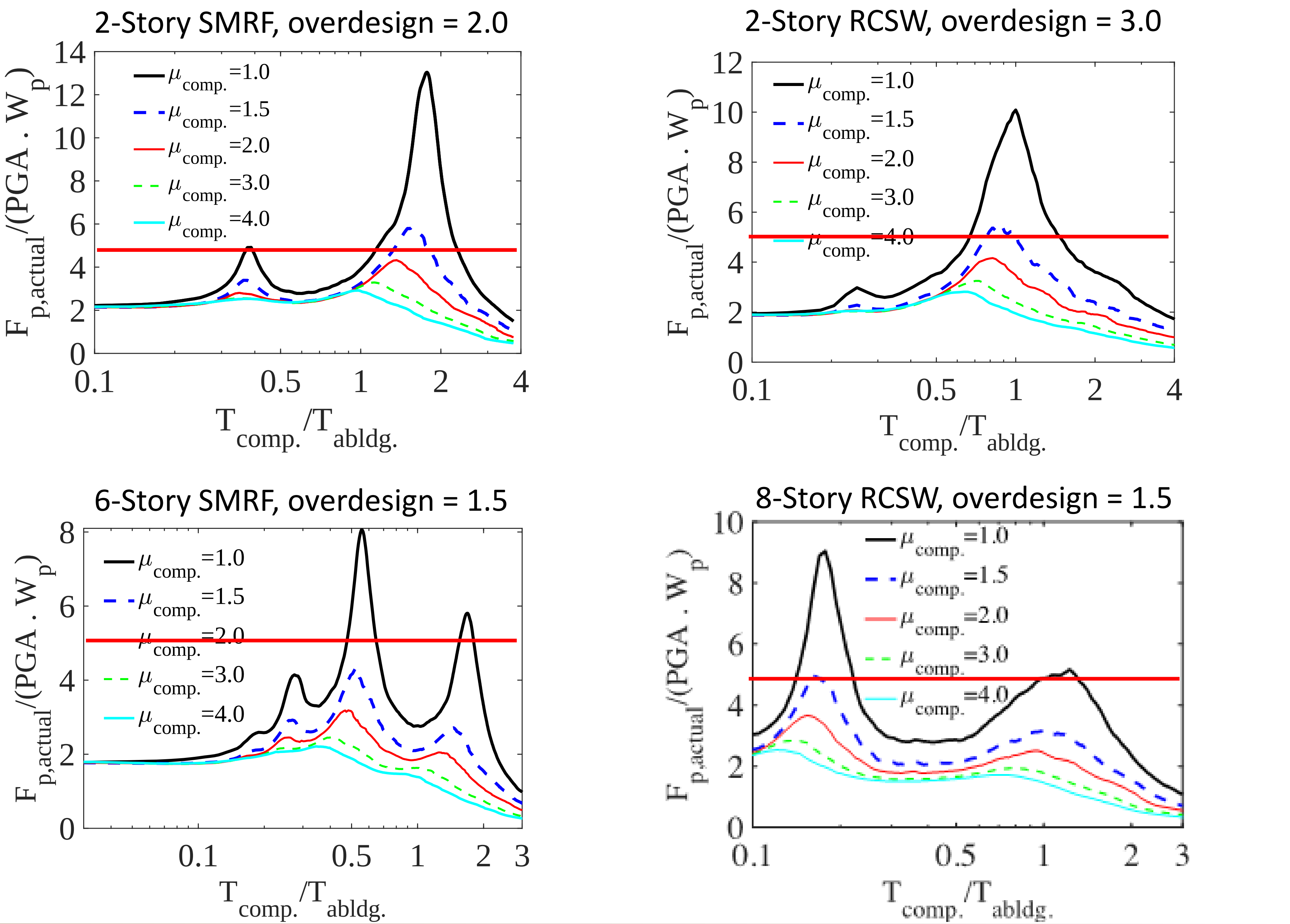

2-Story SMRF, overdesign = 2.0
2-Story RCSW, overdesign = 3.0
6-Story SMRF, overdesign = 1.5
8-Story RCSW, overdesign = 1.5
$F_{p,actual}/(PGA \cdot W_p)$
$T_{comp.}/T_{abldg.}$
$\mu_{comp.}=1.0$
$\mu_{comp.}=1.5$
$\mu_{comp.}=2.0$
$\mu_{comp.}=3.0$
$\mu_{comp.}=4.0$

Table 4-11 F_p/W_p for Proposed Equation

SFRS	z/h	Likely Resonance – Component Ductility – *Elastic*	*Low*	*Moderate*	*High*	Unlikely Resonance	Min 0.3^*S_{DS}	Max 2.0^*S_{DS}
6-story	1.00	2.08	1.45	1.14	0.73	0.52	0.30	2.00
Special	0.75	1.33	0.93	0.73	0.47	0.33	0.30	2.00
SMRF	0.50	1.10	0.77	0.61	0.39	0.28	0.30	2.00
	0.25	0.91	0.64	0.50	0.32	0.23	0.30	2.00
	0	0.45	0.36	0.32	0.25	0.18	0.30	2.00
8-story	1.00	2.42	1.70	1.33	0.85	0.61	0.30	2.00
Special	0.75	1.70	1.19	0.94	0.60	0.43	0.30	2.00
RCSW	0.50	1.37	0.96	0.75	0.48	0.34	0.30	2.00
(Bearing	0.25	1.06	0.74	0.59	0.37	0.27	0.30	2.00
Wall)	0	0.47	0.38	0.34	0.27	0.19	0.30	2.00
4-story	1.00	3.21	2.25	1.77	1.12	0.80	0.30	2.00
Steel	0.75	2.61	1.83	1.44	0.91	0.65	0.30	2.00
OCBF	0.50	2.04	1.43	1.12	0.72	0.51	0.30	2.00
	0.25	1.48	1.04	0.82	0.52	0.37	0.30	2.00
	0	0.58	0.46	0.41	0.32	0.23	0.30	2.00
2-story	1.00	3.80	2.66	2.09	1.33	0.95	0.30	2.00
OMF	0.50	2.44	1.70	1.34	0.85	0.61	0.30	2.00
	0	0.68	0.54	0.49	0.38	0.27	0.30	2.00

Table 4-15 Ratio of F_p/W_p for Proposed Equation versus ASCE/SEI 7-16

			Likely Resonance			Unlikely Resonance		
			Component Ductility			*Component Ductility*		
		Proposed	*Low*	*Moderate*	*High*	*NA*	*NA*	*NA*
SFRS	*z/h*	*ASCE R_p*	*1.50*	*2.50*	*3.50*	*1.50*	*2.50*	*3.50*
6-story	1.00		0.91	0.95	0.85	0.65	1.08	1.51
Special	0.75		0.58	0.73	0.65	0.50	0.83	1.11
SMRF	0.50		0.58	0.76	0.68	0.56	0.94	1.00
	0.25		0.64	0.84	0.74	0.75	1.00	1.00
	0.00		0.54	0.81	1.00	1.00	1.00	1.00
8-story	1.00		1.06	1.11	0.99	0.76	1.26	1.77
Special	0.75		0.74	0.94	0.83	0.64	1.06	1.42
RCSW	0.50		0.72	0.94	0.84	0.64	1.07	1.14
(Bearing	0.25		0.74	0.98	0.87	0.75	1.00	1.00
Wall)	0.00		0.57	0.85	1.00	1.00	1.00	1.00
4-story	1.00		1.25	1.47	1.31	1.00	1.67	2.34
Steel	0.75		1.14	1.44	1.28	0.98	1.63	2.17
OCBF	0.50		1.07	1.41	1.25	0.96	1.60	1.70
	0.25		1.04	1.36	1.21	0.93	1.24	1.24
	0.00		0.69	1.04	1.07	1.00	1.00	1.00
2-story	1.00		1.25	1.67	1.55	1.19	1.98	2.77
OMF	0.50		1.28	1.67	1.49	1.14	1.90	2.03
	0.00		0.81	1.22	1.27	1.00	1.00	1.00

Table 4-16 Ratio of F_p/W_p for Proposed Equation versus ASCE/SEI 7-16 for Anchors

			Likely Resonance			Unlikely Resonance		
			Component Ductility			*Component Ductility*		
		Proposed	*Low*	*Moderate*	*High*	*NA*	*NA*	*NA*
SFRS	*z/h*	*ASCE* R_p	*1.50*	*2.50*	*3.50*	*1.50*	*2.50*	*3.50*
6-story	1.00		0.91	0.95	0.85	0.65	0.81	0.91
Special	0.75		0.58	0.73	0.65	0.50	0.62	0.66
SMRF	0.50		0.58	0.76	0.68	0.56	0.70	0.60
	0.25		0.64	0.84	0.74	0.75	0.75	0.60
	0.00		0.54	0.81	1.00	1.00	0.75	0.60
8-story	1.00		1.06	1.11	0.99	0.76	0.95	1.06
Special	0.75		0.74	0.94	0.83	0.64	0.80	0.85
RCSW	0.50		0.72	0.94	0.84	0.64	0.80	0.69
(Bearing	0.25		0.74	0.98	0.87	0.75	0.75	0.60
Wall)	0.00		0.57	0.85	1.00	1.00	0.75	0.60
4-story	1.00		1.25	1.47	1.31	1.00	1.25	1.40
Steel	0.75		1.14	1.44	1.28	0.98	1.22	1.30
OCBF	0.50		1.07	1.41	1.25	0.96	1.20	1.02
	0.25		1.04	1.36	1.21	0.93	0.93	0.74
	0.00		0.69	1.04	1.07	1.00	0.75	0.60
2-story	1.00		1.25	1.67	1.55	1.19	1.48	1.66
OMF	0.50		1.28	1.67	1.49	1.14	1.43	1.22
	0.00		0.81	1.22	1.27	1.00	0.75	0.60

Example Component Design: Partition, z/h=0.5, 6-story SMRF

- Factors: Rigidity, height, likeliness of resonance with building, damping
- ASCE 7-16: a_p=1, R_p=2.5, F_p/W_p = 0.32g. Issue: Ductility has no effect at T_{comp} = 0.
- Proposed:
  – CMU and short wood/metal stud: Unlikely resonance, F_p/W_p = 0.30g
  – Tall wood/metal stud: Likely resonance, high ductility, F_p/W_p = 0.39g

Example Component Anchor Design: Floor Cabinet, *z/h*=0.75, 4-story OCBF

- Factors: In-plane vs. out-of-plane
- ASCE 7-16: a_p=1, R_p=2.5, Ω_o=2.0, F_p/W_p = 0.80g. Issue: Ductility has no effect at T_{comp}=0
- Proposed:
  - In-plane: Unlikely resonance, F_p/W_p = 0.98g
  - Out-of-plane: Likely resonance, moderate ductility, F_p/W_p = 2.87g
  - But out-of-plane with 6-story SMRF, F_p/W_p = 1.46g

When Building Type/Height Are Unknown

- Use the maximum equation

$$\frac{F_p}{W_p} = 2.0 S_{DS} I_p$$

ATC-120 Recommendations

- Develop code change proposal using report
- Create an industry database on component damping, ductility and periods of vibration
- Study test results to quantify the component reserve strength margin
- Augment archetype studies with low *R*-factor buildings
- Augment archetype studies with more amplitude-scaled response histories
- Increase strong motion instrumentation of components and for more thoughtful vertical response

Next Steps

- PUC IT5 to review and consider adoption of proposed equations.
- IT5 will need to assign components to unlikely/likely in resonance and ductility categories.
- A code change proposal will then be written.

Unlikely in Resonance Potential Criteria

- T_{comp}/T_{abldg} is low, say below ≈ 0.2
- T_{comp} is low, say below 0.06-0.10 seconds
- T_{comp} is relatively low, perhaps above 0.10 seconds, but no or limited history of issues

Architectural Component	a_p[a]
Interior Nonstructural Walls and Partitions[b]	
Plain (unreinforced) masonry walls	1
All other walls and partitions	1
Cantilever Elements (Unbraced or Braced to Structural Frame below Its Center of Mass)	
Parapets and cantilever interior nonstructural walls	2½
Chimneys where laterally braced or supported by the structural frame	2½
Cantilever Elements (Braced to Structural Frame above Its Center of Mass)	
Parapets	1
Chimneys	1
Exterior Nonstructural Walls[b]	1[b]
Exterior Nonstructural Wall Elements and Connections[b]	
Wall element	1
Body of wall panel connections	1
Fasteners of the connecting system	1¼
Veneer	
Limited deformability elements and attachments	1
Low deformability elements and attachments	1
Penthouses (except where framed by an extension of the building frame)	2½
Ceilings	
All	1
Cabinets	
Permanent floor-supported storage cabinets over 6 feet (1829 mm) tall, including contents	1
Permanent floor-supported library shelving, book stacks, and bookshelves over 6 feet (1829 mm) tall, including contents	1
Laboratory equipment	1
Access Floors	
Special access floors (designed in accordance with Section 13.5.7.2)	1
All other	1
Appendages and Ornamentations	2½
Signs and Billboards	2½

Criteria for Assigning Component Ductility

- Test data that shows ductility
- Judgment call on assumed relative level of ductility
- Similar to current R_p
- No ductility when not in resonance in proposed equation

Architectural Component	a_p[a]	R_p
Interior Nonstructural Walls and Partitions[b]		
Plain (unreinforced) masonry walls	1	1½
All other walls and partitions	1	2½
Cantilever Elements (Unbraced or Braced to Structural Frame below Its Center of Mass)		
Parapets and cantilever interior nonstructural walls	2½	2½
Chimneys where laterally braced or supported by the structural frame	2½	2½
Cantilever Elements (Braced to Structural Frame above Its Center of Mass)		
Parapets	1	2½
Chimneys	1	2½
Exterior Nonstructural Walls[b]	1[b]	2½
Exterior Nonstructural Wall Elements and Connections[b]		
Wall element	1	2½
Body of wall panel connections	1	2½
Fasteners of the connecting system	1¼	1
Veneer		
Limited deformability elements and attachments	1	2½
Low deformability elements and attachments	1	1½
Penthouses (except where framed by an extension of the building frame)	2½	3½
Ceilings		
All	1	2½
Cabinets		
Permanent floor-supported storage cabinets over 6 feet (1829 mm) tall, including contents	1	2½
Permanent floor-supported library shelving, book stacks, and bookshelves over 6 feet (1829 mm) tall, including contents	1	2½
Laboratory equipment	1	2½
Access Floors		
Special access floors (designed in accordance with Section 13.5.7.2)	1	2½
All other	1	1½
Appendages and Ornamentations	2½	2½
Signs and Billboards	2½	3

Discussion

Photo from : http://assets2.quakecentre.co.nz/assets/image1_5468_1.png

Likely in Resonance Components: $F_{p,actual} / F_{p,proposed}$

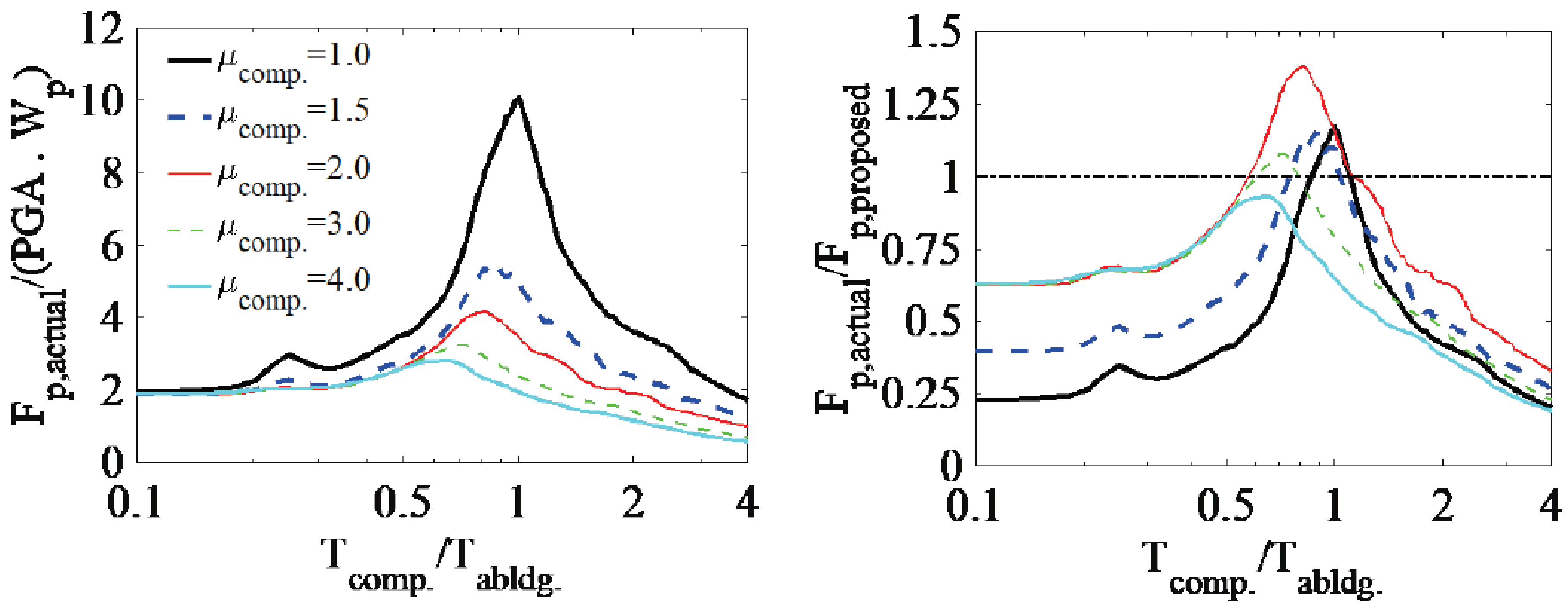


Figure 4-42 (a) Mean of the simulated $F_{p,actual}$ normalized by PGA and (b) normalized of $F_{p,proposed}$ at the roof for a 2-story concrete shear wall archetype assuming an overdesign factor of 3.0, μ_{comp} = 1.0-4.0, and β_{comp} = 5% *inherent* component damping, where $F_{p,actual}$ is the mean of 20 spectrum-compatible ground motions. $F_{p,proposed}$ is for components likely to be in resonance.