Chapter 1 Introduction to the 2020 NEHRP Provisions Design Examples

2020 NEHRP Provisions Training Materials

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Learning Objectives

- Understand the role of the *NEHRP Provisions* in seismic code development
- Gain an awareness of seminal past seismic code changes
- Understand key updates to the 2020 *NEHRP Provisions* and to ASCE/SEI 7-22
- Understand what is contained in the 2020 *Design Examples* and how the document can be used

Acknowledgement: Images are taken from FEMA P-2192-V1 and FEMA P-2192-V2 unless otherwise noted.

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Outline of Presentation

- Overview of the 2020 *NEHRP Provisions*
  - Intent
  - Relationship of the Provisions to ASCE/SEI 7-22
- Summary of notable earthquakes and their impact on seismic design
- History and role of the *NEHRP Provisions* in advancing seismic design
- Highlights of major updates in the *NEHRP Provisions* and seismic provisions of ASCE/SEI 7-22
- Introduction to the organization and content in the new *Design Examples*

Overview of the 2020 *NEHRP Provisions*

The *NEHRP Recommended Seismic Provisions*

- The starting point in the U.S. seismic standards development process
- Major ASCE/SEI 7 seismic analysis and design concepts originate in the *NEHRP Provisions*

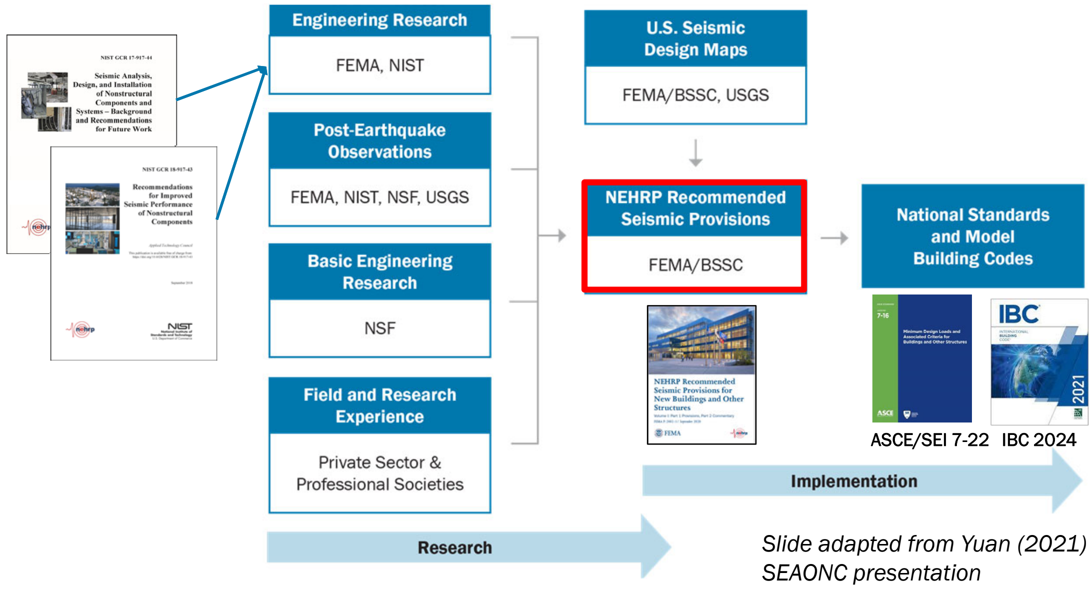
Intent of the 2020 *NEHRP Provisions*

The *Provisions* are the "*minimum recommended requirements for design and construction of new buildings. 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. *Structural 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.*"

From FEMA P-2082-1

From Research to Improved Standards and Seismic Design Practice



Slide adapted from Yuan (2021) SEAONC presentation

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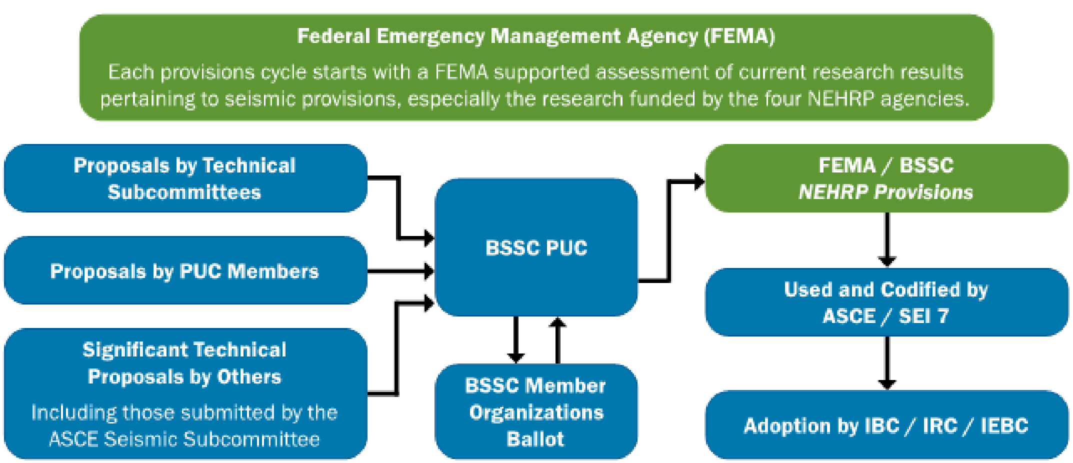
How US Seismic Codes are Developed



From FEMA P-2156

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2020 *NEHRP Provisions* – BSSC Provisions Update Committee

Main Committee

23 voting members

7 non-voting advisors

Issue Teams

IT 1 - Seismic Performance Objectives

IT 2 - Seismic Resisting Systems and Design Coefficients

IT 3 - Modal Response Spectrum Analysis

IT 4 - Shear Wall Design

IT 5 - Nonstructural Components

IT 6 - Nonbuilding Structures

IT 7 - Soil Foundation Interaction

IT 8 - Base Isolation and Energy Dissipation

IT 9 - Diaphragm Issues

IT 10 - Seismic Design Maps (Project '17)

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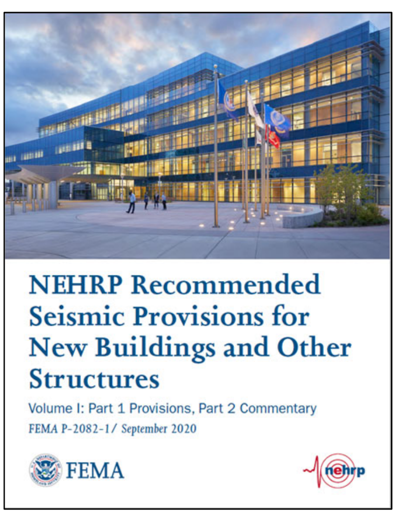
2020 *NEHRP Provisions* Organization



Part 1: Provisions

To introduce new provisions and modifications to improve current requirements in ASCE/SEI 7-16

Part 2: Commentary

A detailed commentary that corresponds to ASCE/SEI 7 and provides useful explanations and guidance on implementation

Part 3: Resource Papers

Introduce new technologies, procedures, and systems for use by design professionals on a provisional basis

Slide adapted from Bonneville and Yuan (2019) SEAOC presentation

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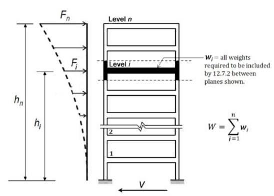
Resources to Support the 2020 *NEHRP Provisions* and ASCE/SEI 7-22

Design Examples

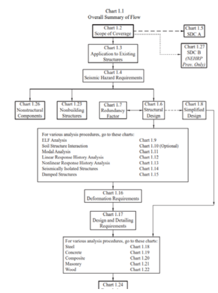


Training Materials

BSSC NEHRP WEBINAR SERIES

www.nibs.org/events/nehrp-webinar-series

Design Flow Charts



Slide adapted from Yuan (2021) SEAONC presentation

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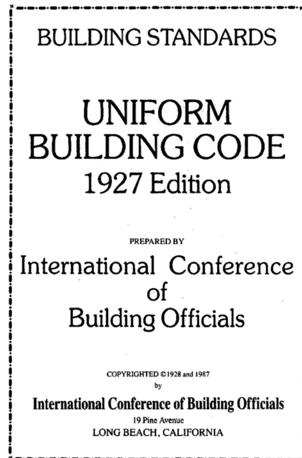
Evolution of Earthquake Engineering

Recent North American Earthquakes and Subsequent Code Changes

1906 San Francisco EQ
- Good steel frame infill performance

1923 Tokyo and 1925 Santa Barbara EQs
- Seismic recording instruments
- Shake tables
- Committees to create seismic code provisions
- 1927 UBC


BUILDING STANDARDS

UNIFORM BUILDING CODE
1927 Edition

PREPARED BY
International Conference of Building Officials

COPYRIGHTED ©1928 and 1987
by
International Conference of Building Officials
19 Pine Avenue
LONG BEACH, CALIFORNIA

Recent North American Earthquakes and Subsequent Code Changes

1933 Long Beach EQ
- Ban on URM
- Field Act for schools

1951:
- Proceedings – Separate No. 66 (ASCE)

1959
- First SEAOC Blue Book

URM Bearing Wall Damage in the 1933 Long Beach EQ
(from FEMA P-2156 and Los Angeles County Library)

Recent North American Earthquakes and Subsequent Code Changes

1964 Anchorage EQ
- Reinforced concrete detailing

1971 San Fernando EQ
- Reinforced concrete detailing
- Anchorage of concrete and masonry walls to diaphragms
- ATC-3-06

Excessive Drift at the Soft Ground Story of the Olive View Hospital in the 1971 San Fernando EQ
(from FEMA P-2156 and William Godden, NISEE-PEER)

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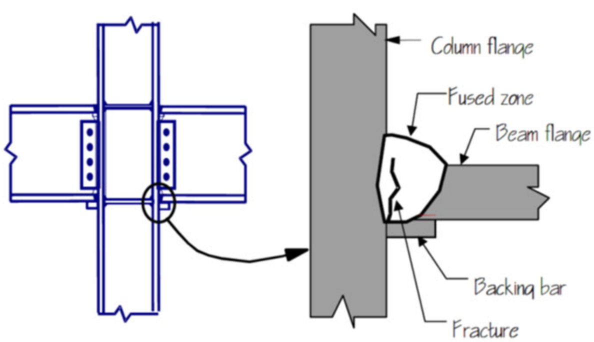
Recent North American Earthquakes and Subsequent Code Changes



Common Location of Fracture Initiation in Pre-Northridge Steel Moment Frame Beam-to-Column Connections
(from FEMA 350)

Earthquake	UBC Edition	Enhancement
1971 San Fernando	1973	▪ Direct positive anchorage of masonry and concrete walls to diaphragms
	1976	▪ Seismic Zone 4, with increased base shear requirements ▪ Occupancy Importance Factor, *I*, for certain buildings ▪ Interconnection of individual column foundations ▪ Special inspection requirements
1979 Imperial Valley	1985	▪ Diaphragm continuity ties
1985 Mexico City	1988	▪ Requirements for columns supporting discontinuous walls ▪ Separation of buildings to avoid pounding ▪ Design of steel columns for maximum axial forces ▪ Restrictions for irregular structures ▪ Ductile detailing of perimeter frames
1987 Whittier Narrows	1991	▪ Revisions to site coefficients ▪ Revisions to spectral shape ▪ Increased wall anchorage forces for flexible diaphragm buildings
1989 Loma Prieta	1991	▪ Increased restrictions on chevron-braced frames ▪ Limitations on *b*/*t* ratios for braced frames
	1995	▪ Ductile detailing of piles
1994 Northridge	1997	▪ Restrictions on use of battered piles ▪ Requirements to consider liquefaction ▪ Near-fault zones and corresponding base shear requirements ▪ Revised base shear equations using 1/*T* spectral shape ▪ Redundancy requirements ▪ Design of collectors for overstrength ▪ Increase in wall anchorage requirements ▪ More realistic evaluation of design drift ▪ Steel moment connection verification by test

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History and Role of the *NEHRP Provisions*

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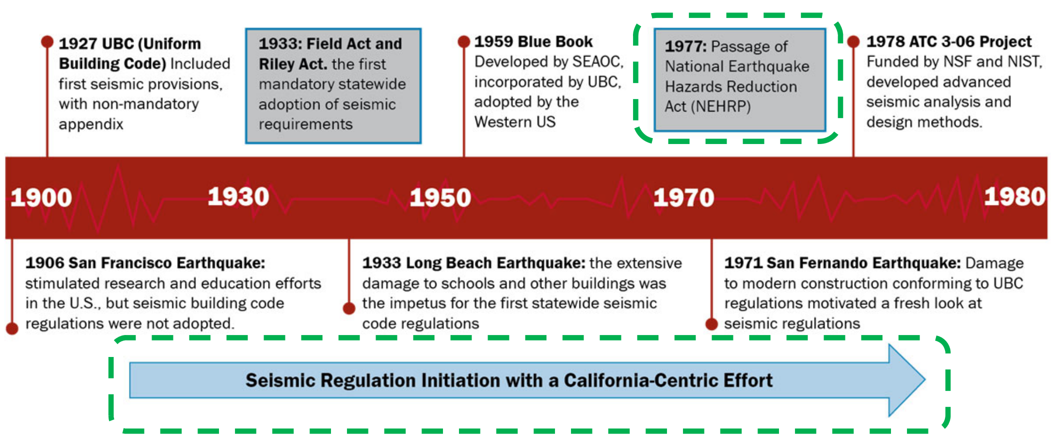
U.S. Seismic Code Development and Role of the *NEHRP Provisions*



From FEMA P-2156

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U.S. Seismic Code Development and Role of the *NEHRP Provisions*

1985 NEHRP Provisions
1st edition, developed based on lessons learned through a FEMA initiative on a national trial design of ATC-3 methods

1988, 1991, 1994 *NEHRP Provisions*
Written in code language for direct adoption by regional model codes and national standards.

1997, 2000, and 2003 *NEHRP Provisions*
Written in code language, adopted into International Building Code via ASCE 7. Improved maps by USGS

2009, 2015, and 2020 *NEHRP Provisions*
No code language but resource documents providing recommend changes. Adopted by ASCE 7 then by IBC.

1985 — **1990** — **2000** — **2020**

1985 Mexico City and 1989 Loma Prieta Earthquakes: illustrated the importance of soil conditions on amplification of earthquake shaking and vulnerability of soft and weak story buildings.

1994 Northridge Earthquake: Generated world-record ground motions. The high repair cost spurred the movement toward Performance-Based Design.

Advancements with *NEHRP Provisions* and National in scope

From FEMA P-2156

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Evolution of the *NEHRP Provisions*

From FEMA P-2156

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Highlights of Major Changes in the 2020 *NEHRP Provisions* and in ASCE/SEI 7-22

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Highlights of Major Changes to 2020 *NEHRP Provisions* and ASCE/SEI 7-22

- Updated earthquake design ground motions, site classes, and determination of spectral acceleration parameters
- Addition of three new shear wall seismic force-resisting systems
- Addition of provisions and alternative procedures for diaphragm design
- Relaxed modal response spectrum analysis requirements
- Revisions in configuration irregularity requirements
- Revisions in displacement requirements
- Changes in the nonbuilding structures provisions
- Addition of quantitative reliability targets for individual members and essential facilities
- A Part 3 paper on how to apply the *NEHRP Provisions* for improved seismic resiliency
- A Part 3 paper on a new approach to seismic lateral earth pressures
- Soil-structure interaction provision definitions for different types of shear wave velocities were clarified
- Significant update of the nonstructural components chapter and the forces used for design

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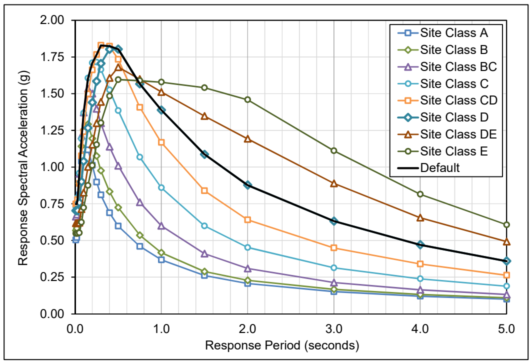
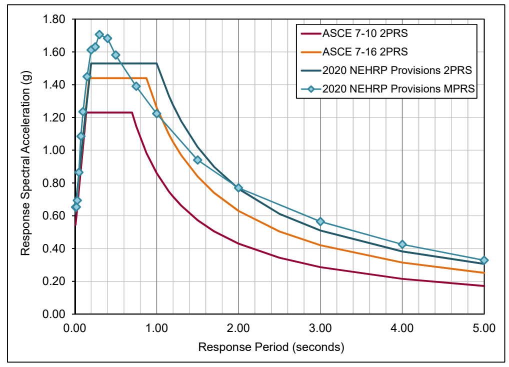
Move from Two-Point Spectra (2PRS) to Multi-Point Spectra (MPRS)



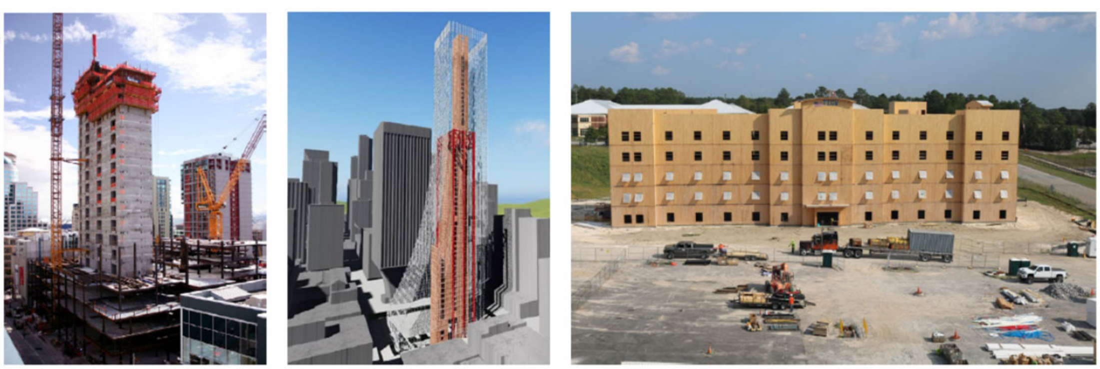


Example MPRS from ASCE/SEI 7-22 Table 21.2-1 (from 2020 NEHRP Training Materials by C. Kircher)

San Mateo, CA for default soil class (from FEMA P-2078, Figure 8.2-2)

Velocity domain of the ASCE 7-16 (2PRS) design spectrum includes the 1.5 multiplier of the applicable Section 11.4.8 exception.

Three New Shear Wall Seismic Force-Resisting Systems



(a) (b) (c)

Figure 6. The three new seismic force-resisting systems that now have detailed requirements in the 2020 *NEHRP Recommended Seismic Provisions*: (a) reinforced concrete ductile coupled walls, (source: MKA); (b) steel and concrete coupled composite plate shear walls (Source: MKA); and (c) cross-laminated timber shear wall (Source: Lendlease).

From FEMA P-2156

Updates to Diaphragm Design Provisions

- ASCE/SEI 7-10
  - Sections 12.10.1 and 12.10.2 - *Traditional Diaphragm Design Method*
- ASCE/SEI 7-16 (2015 *NEHRP Provisions*)
  - Section 12.10.3 - *Alternative Design Provisions* is added
    - Cast-in-place concrete, precast concrete, and wood structural panel diaphragms
- ASCE/SEI 7-22 (2020 *NEHRP Provisions*)
  - Section 12.10.3 – *Alternative Design Provisions* is expanded
    - Bare steel deck, concrete-filled steel deck diaphragms
  - Section 12.10.4 – *Alternative RWFD Provisions* is added

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Relaxation in Requirement for Response Spectrum Analysis

2015 *NEHRP Provisions* and ASCE/SEI 7-16

Table 12.6-1 Permitted Analytical Procedures

Seismic Design Category	Structural Characteristics	Equivalent Lateral Force Analysis, Section 12.8[a]	Modal Response Spectrum Analysis, Section 12.9, and Modal Response History Analysis, Section 12.10[a]	Seismic Response History Procedures, Chapter 16[a]
B, C	All structures	P	P	P
D, E, F	Risk Category I or II buildings not exceeding 2 stories above the base	P	P	P
D, E, F	Structures of light frame construction	P	P	P
D, E, F	Structures with no structural irregularities and not exceeding 160 ft. in structural height	P	P	P
D, E, F	Structures exceeding 160 ft. in structural height with no structural irregularities and with $T < 3.5T_s$	P	P	P
D, E, F	Structures not exceeding 160 ft. in structural height and having only horizontal irregularities of Type 2, 3, 4, or 5 in Table 12.3-1 or vertical irregularities of Type 4, 5a, or 5b in Table 12.3-2	P	P	P
D, E, F	All other structures	NP	P	P

[a]P: Permitted; NP: Not Permitted; $T_s = S_{D1}/S_{DS}$.

2020 *NEHRP Provisions* and ASCE/SEI 7-22

Replace Section 12.6 with the following (delete Table 12.6-1 Permitted Analytical Procedures):

The structural analysis required by Chapter 12 shall be completed in accordance with the requirements of (a) Equivalent Lateral Force Procedure of Section 12. 8, (b) Modal Response Spectrum Analysis of Section 12.9.1, (c) Linear Response History Analysis of Section 12.9.2, or (d) with an analysis approved by the authority having jurisdiction. Nonlinear Response History Procedure requirements are given in Chapter 16.

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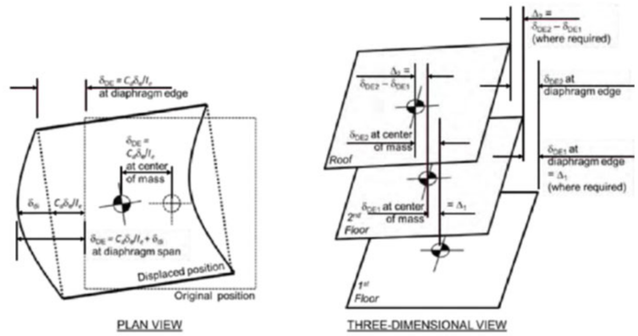
Revisions in Displacement Requirements

- Definitions and graphics developed to include diaphragm deformation in displacements related to deformation compatibility, structural separation, and at members spanning between structures.
- Increase in drift used to check deformation compatibility.
- Part 3 resource paper on issues and available research on whether to amplify drifts by C_d or R.



Design Earthquake displacement and design story drift
(from FEMA P-2082-1, Figure C12-8.1)

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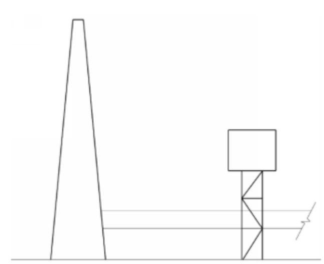
Changes in Nonbuilding Structures Requirements

- New Section 15.2: Addresses coupled systems
- Revised Section 15.3.1: For nonbuilding structures supported by other structures, when the ratio of the nonbuilding structure weight to the nonbuilding structure + supporting structure is below a threshold value, use Chapter 13. When above threshold, use Chapter 15.
  - ASCE/SEI 7-16: Threshold is 25%
  - ASCE/SEI 7-22: Revised to 20%, based on review of research
- New Section 15.7.7.4: Provisions for design of corrugated steel tanks added.



Coupled Analysis Example
Stack connected to a tower by a large duct (Figure C15-2-1 in 2020 *NEHRP Provisions*)

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Addition of Quantitative Reliability Targets for Individual Members and Essential Facilities

- Section 1.1.1 of 2020 *NEHRP Provisions* adds individual member/connection reliability targets to previously available building collapse reliability targets.
- Section 2.1.5 of 2020 *NEHRP Provisions* states:
  "A desired target reliability for Risk Category IV buildings and nonbuilding structures is for there to be a 10% probability of loss of essential function given the Design Earthquake ground motion."

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

Risk Category[1]	Conditional Probability of Failure for Member or Connection: Given DE Shaking	Conditional Probability of Failure for Member or Connection: Given MCE_R Shaking
I	**	**
II	10%	25%
III	5%	15%
IV	2.5%	9%

From FEMA P-2082-1

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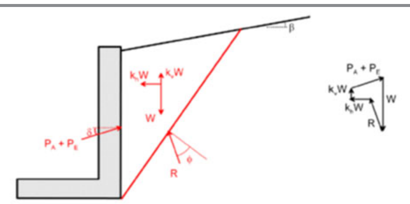
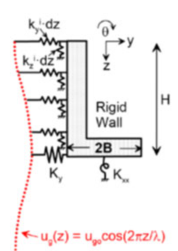
Part 3 Paper on a New Approach to Seismic Lateral Earth Pressures

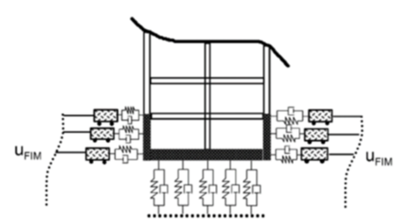
- Classical methods (Mononobe-Okabe) assume the seismic earth pressures are related to acceleration.
- They are actually related to relative displacement between the soil and the wall.
- Soil-structure interaction theory and research can be used to relate kinematic interaction and inertial interaction to wall demands.
- The Part 3 paper provides a simplified method and example.



Classical method free-body diagram



Kinematic interaction



Inertial interaction

Images from FEMA P-2082-2

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New Seismic Design Force Equation

ASCE 7-16

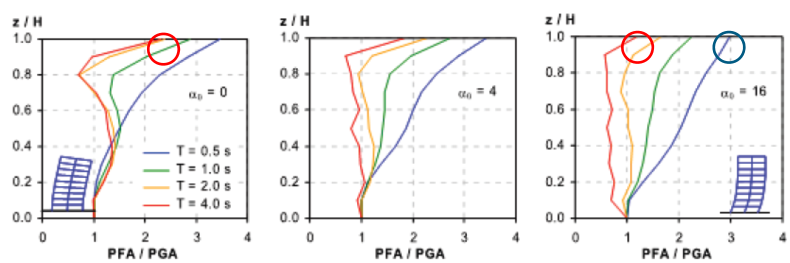
$$\frac{F_p}{W_p} = (0.4S_{DS}) \times \left[1 + 2\left(\frac{z}{h}\right)\right] \times \left[\frac{a_p}{R_p}\right] \times I_p$$

2020 *NEHRP Provisions* and ASCE 7-22

$$\frac{F_p}{W_p} = (0.4S_{DS}) \times \left[\frac{H_f}{R_\mu}\right] \times \left[\frac{C_{AR}}{R_{po}}\right] \times I_p$$

- Ground response
- Peak floor acceleration/PGA
- Resonance and component ductility
- Component strength reserve margin
- Building ductility

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



Effect of period of vibration and lateral system stiffness on PFA/PGA

Key Takeaway

- Longer period means less amplification
- Cantilever systems have more "whipping" action

α_0= Lateral stiffness ratio, defined as $\alpha_0 = H/(GA/EI)^{0.5}$

H = height,
GA = shear rigidity of a shear beam
EI = the flexural stiffness

α_0 = 0 represents a pure flexural model
α_0 approaching infinity represents a pure shear beam
(from Miranda and Taghavi, 2009)

Note: Full reference citations are in NIST GCR 18-917-43.

PFA/PGA (H_f) Amplification Factor

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

or:

$$H_f = 1 + 2.5\left(\frac{z}{h}\right)$$

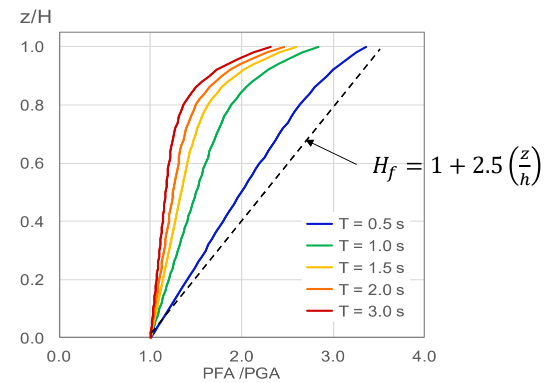
where:

$$a_1 = \frac{1}{T_a} \leq 2.5$$

$$a_2 = [1 - (0.4/T_a)^2] \geq 0$$

$$T_a = C_t h_n^x$$

$$\frac{F_p}{W_p} = (0.4S_{DS}) \times \left[\frac{H_f}{R_\mu}\right] \times \left[\frac{C_{AR}}{R_{po}}\right] \times I_p$$



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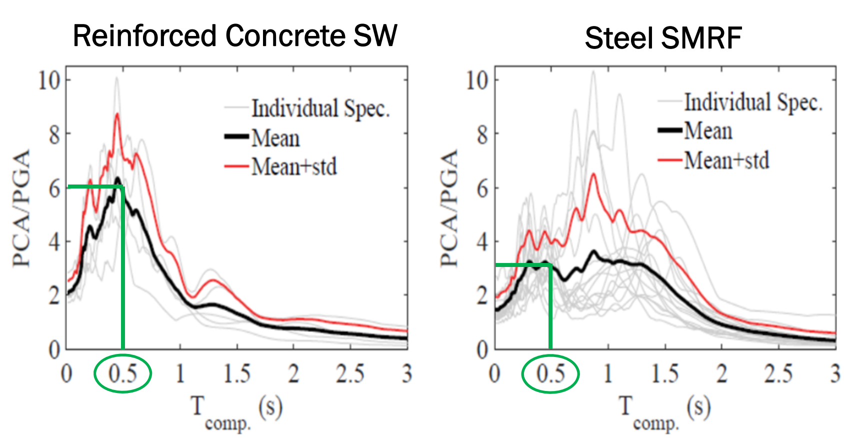
Seismic Force-Resisting System

T_{comp} = 0.5 sec



Effect of building stiffness on PCA/PGA for instrumental recordings
(from NIST GCR 18-917-43, 2018 and
Lizundia paper in 2019 SEAOC Convention Proceedings)

Key Takeaway

- Same component responds very differently in different seismic force-resisting systems

Figure Assumptions

- Elastic component assumed with β_{comp}=5%
- Dataset includes 19 recordings with PGA>0.15g

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Building Ductility, R_μ

$$R_\mu = (1.1\, R/(\, I_e\, \Omega_0))^{1/2} \geq 1.3$$

$$\frac{F_p}{W_p} = (0.4S_{DS}) \times \left[\frac{H_f}{R_\mu}\right] \times \left[\frac{C_{AR}}{R_{po}}\right] \times I_p$$

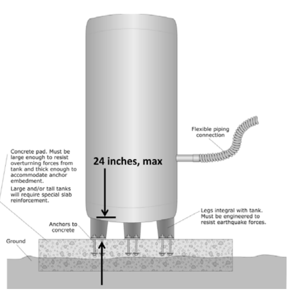
where:

- R = Response modification factor for the building or nonbuilding structure
- I_e = Importance Factor for the building or nonbuilding structure
- Ω_0 = Overstrength factor for the building or nonbuilding structure

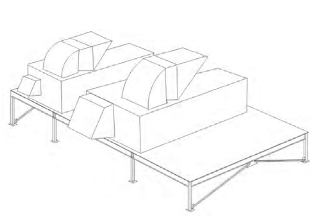
For components at or below grade, R_μ shall be taken as 1.0.

Chapter 13: Other Significant Changes from ASCE/SEI 7-16 to ASCE/SEI 7-22

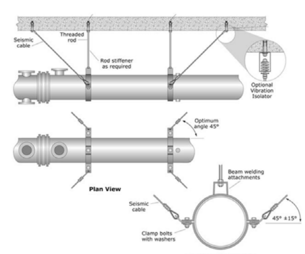
- Three different types of supports defined (Section 11.2) and design of supports depends on their system not components they support (Section 13.5.4.6,7)



Nonstructural component with integral equipment supports



Equipment support platform supporting two mechanical components



Distribution system support for piping

Images from FEMA P-2082-1 (2020) and FEMA E-74

Chapter 13: Other Significant Changes from ASCE/SEI 7-16 to ASCE/SEI 7-22

- Seismic design force provision using nonlinear response history analysis is updated; other dynamic analysis methods are removed (Section 13.3.1.5).
- Ω_{0p} is required to increase the load effects for anchors in concrete or masonry, instead of Ω_0 (Section 13.4.2).
- Architectural component list is expanded, and items account for updated coefficient for seismic design: C_{AR}, R_{po}, and Ω_{0p} (Table 13.5-1).
  Example: Partitions split into short light frame, tall light frame, reinforced masonry and other
- Mechanical and electrical component list is expanded, and items account for updated coefficient for seismic design: C_{AR}, R_{po}, and Ω_{0p} (Table 13.6-1).

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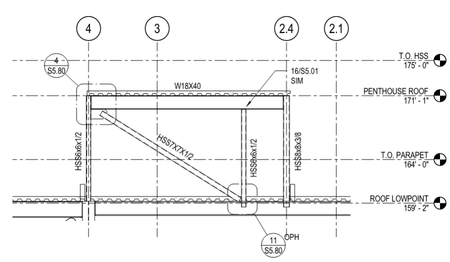
Chapter 13: Other Significant Changes from ASCE/SEI 7-16 to ASCE/SEI 7-22

- Detailed scope of design criteria for nonstructural components (Section 13.1)
- Explicit load combinations for nonstructural components now provided (Section 13.2.2)
- Required analysis for condition where the nonstructural component weight is equal to or greater than 20% the combined effective seismic weight, *W* (Section 13.2.9)
- Penthouse and rooftop structure requirements are added (Section 13.5.11).
  - Seismic force-resisting system to conform to one in Table 12.2-1, Table 15.4-1, or new coefficients in Table 13.5-1



NORTH PENTHOUSE ELEVATION 3

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Questions?

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Overview of Design Example Chapters

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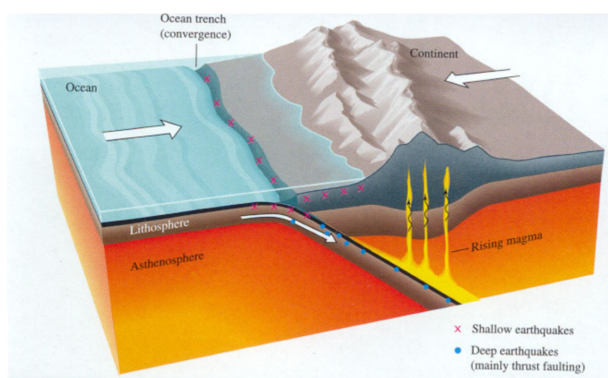
Chapter 2 (Section 2.1 to 2.6) - Fundamentals

Chapter 2 - Fundamentals (Harris): Topics

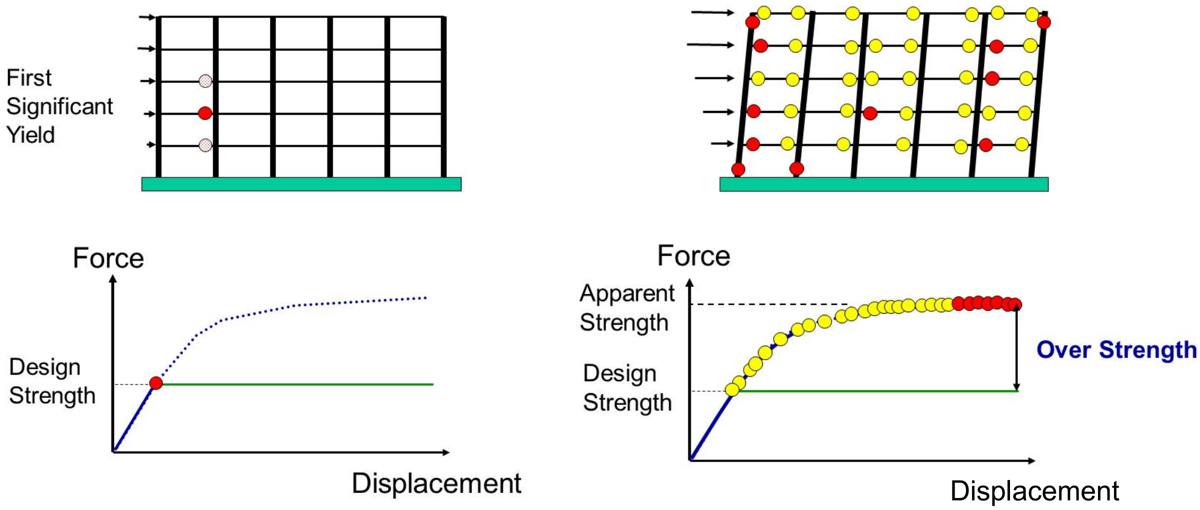
- Fundamental Concepts
- Ground Motions and Their Effects
- Structural Dynamics of Linear SDOF Systems
- Response Spectra
- Structural Dynamics of Simple MDOF Systems
- Inelastic Behavior
- Structural Design



Subduction zone tectonic environment

Image from E.V. Leyendecker, USGS

Chapter 2 – Fundamentals: Yield, Ductility, Overstrength



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Images from Finley Charney

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Section 2.7 – Resilience-Based Design

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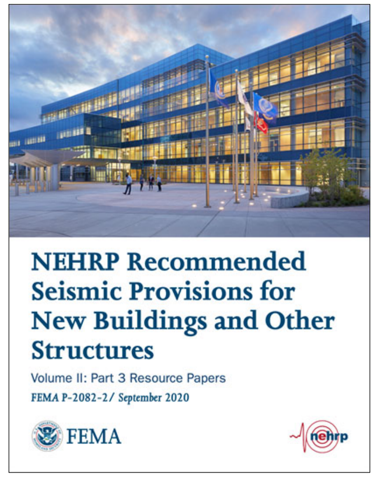
Section 2.7 - Resilience-Based Design (Bonowitz): Topics

- Development of resilience-based earthquake design
  - 2020 *NEHRP Provisions*, Resource Paper 1
- Functional Recovery (FR)
  - Its relation to resilience
  - Its relation to current building code provisions
- Hypothetical application to the CLT Design Example
  - CLT Shear Wall Design Example is in Chapter 6
  - Discussion in terms of resilience-based design is in Section 2.7



Section 2.7 - The "Resilience Field"

Technical

About the physical building
- Structure
- Nonstructural systems

Facility

About one building. Typical context for:
- Engineering
- Building code implementation

Community

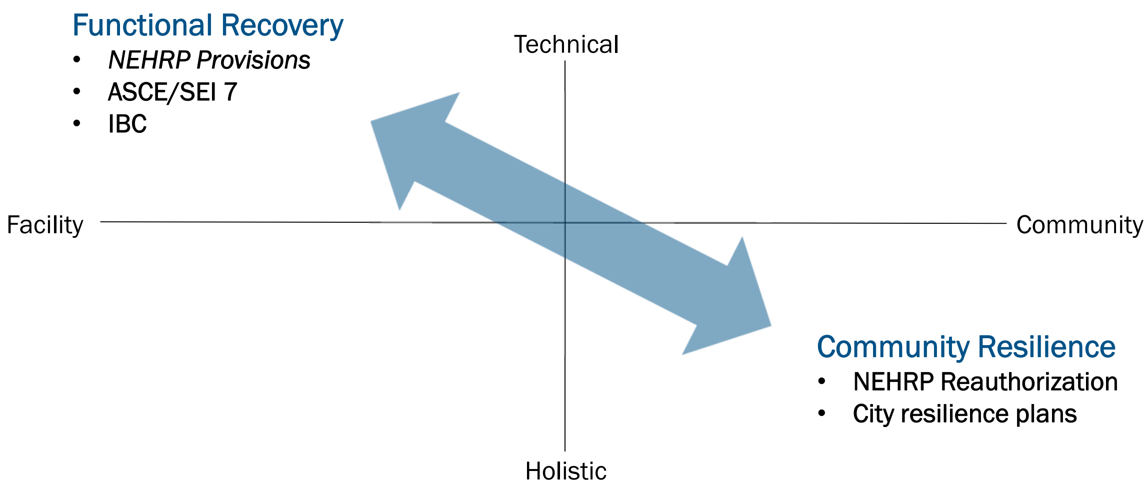
About the group. Typical context for:
- Planning
- Public policy

Holistic

About more than a building
- Contents → Use, Occupancy
- Purpose

From Meister Consultants Group (2017)

Section 2.7 - Functional Recovery vs. Community Resilience



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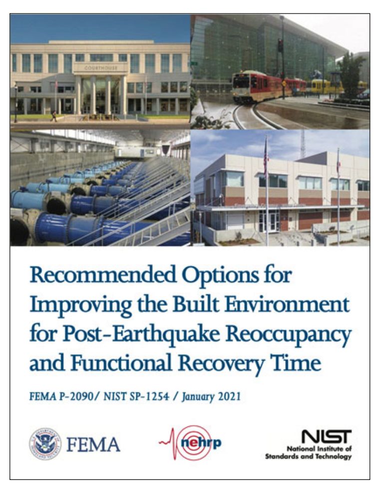
Section 2.7 - FEMA-NIST Definitions* for Functional Recovery

- Functional Recovery (FR) is …
  - A post-earthquake performance state in which a building is maintained, or restored, to support the basic intended functions associated with the pre-earthquake use or occupancy.
- A Functional Recovery objective is …
  - FR achieved within an acceptable time following a specified earthquake, where the acceptable time might differ for various building uses and occupancies.



* The FEMA-NIST definitions consider infrastructure systems as well as buildings. These versions are edited to address only buildings.

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Section 2.7 - Functional Recovery and Performance-Based Engineering

- A structural safety objective may be written as: P(collapse) < X%, given 2/3*MCE_R
- Analogously, a functional recovery objective may be written as:

  $P(T_{FR,\ expected} > T_{FR,\ acceptable}) < Y\%$, given 2/3*$MCE_R$ (or other specified hazard)

- Open policy questions for developers of FR codes:
  - What is the acceptable or desirable FR time, $T_{FR,\ acceptable}$, for a given occupancy?
  - What is the appropriate confidence level, Y?
  - What hazard level should be used for FR?
    - For this example, use 2/3*MCE_R (See Resource Paper 1 and Design Example 2.7 for discussion.)

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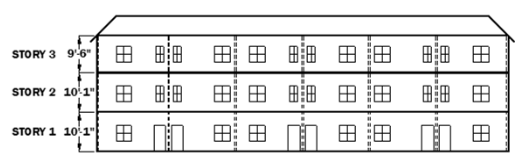
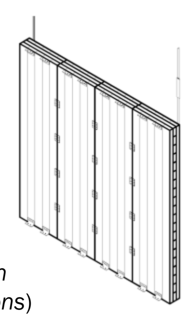
Section 2.7 - Functional Recovery Objective: CLT Design Example

Options for Functional Recovery

- Increase Seismic Importance Factor, I_e
- Reduce *R*-factor (but already low)
- Set a lower value for panel connector capacity
- Account for partitions
- Study expected damage and recovery time in more detail





CLT shear wall
(*Figure C14.5.2.1 in 2020 NEHRP Provisions*)

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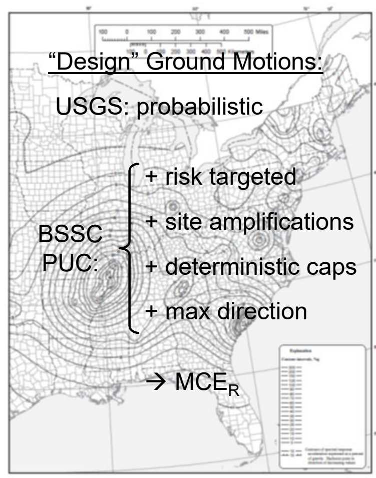
Chapter 3 – Earthquake Ground Motions

Section 3.2 Part 1 – 2018 Update to the USGS National Seismic Hazard Model (Rezaeian): Topics

- Interplay between the USGS hazard models and the BSSC PUC requirements
- The 2018 USGS National Seismic Hazard Model (NSHM) for Conterminous U.S.
  - Ground motion models in CEUS (e.g. NGA-East)
  - Deep basin effects in WUS
- Outside of the Conterminous U.S. (HI, AK, PRVI, GNMI, AMSAM)



Section 3.2: USGS NSHMs and BSSC PUC Requirements

Hazard Model (PSHA) — Site-Specific Procedures of Chapter 21

	USGS NSHM	NEHRP Provisions	ASCE 7 Standards	IBC
PGA, 0.2, 1s 760m/s	1996	1997, 2000	1998,2002	2000, 2003
	2002	2003	2005	2006, 2009
	2008	2009	2010	2012, 2015
	2014	2015	2016	2018
22 Periods 8 Vs30s	**2018**	**2020**	2022*	TBD

Hazard Curves + (RiskTarget, MaxDir, ~~SiteAmpl~~, DetCaps) → "Design" Ground Motions

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Section 3.2 - Updates to 2020 NEHRP Design Ground Motions in Conterminous US

Necessary for MPRS

2018 USGS NSHM

1. New ground motion models (GMMs), including **NGA-East**, & amplification factors in the Central & Eastern US (CEUS)
2. Deep **basin effects** in Los Angeles, Seattle, San Francisco, and Salt Lake City regions
3. Minor modifications of GMMs (crustal & subduction) in the Western US (WUS)
4. Updating **background seismicity** to include 2013-2017 earthquakes

➕

BSSC Project '17

No change to risk-targeted calcs

1. Using **m**ulti-**p**eriod multi-Vs30 **r**esponse **s**pectrum **(MPRS)**
2. Modifying **deterministic caps** based on deaggregation of probabilistic hazard
3. Updating the **max-direction** factors

MPRS issue directly influenced the 2018 update of USGS NSHM (GMMs applicable for all periods and site classes)

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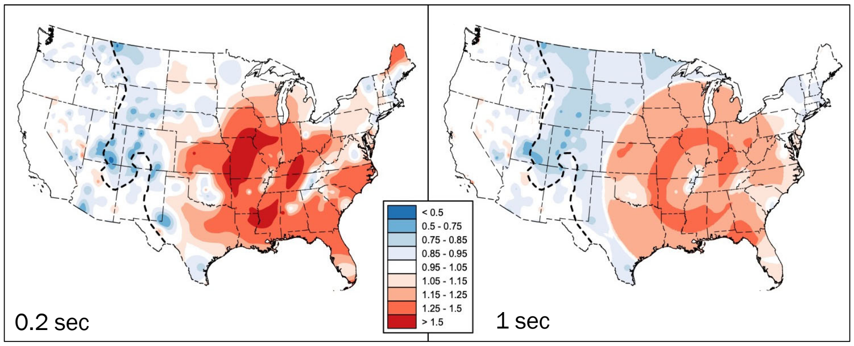
Section 3.2 - Hazard Changes (CEUS)

Ratio Maps (2018/2014):
2% in 50yr uniform hazard, BC site class (760 m/s)



Medians: more significant increases for large M at mid-large distances

Epistemic uncertainty: increased significantly for large M, more around 70-100 km

Aleatory uncertainty: minor changes

Site-effect model: only F_{760} in this figure

Seismicity catalog updates: outside CA, mostly affecting intermountain west region

Figure citation: Petersen et al. (2021). The 2018 update of the US National Seismic Hazard Model: Where, why, and how much probabilistic ground motion maps changed. *Earthquake Spectra*.

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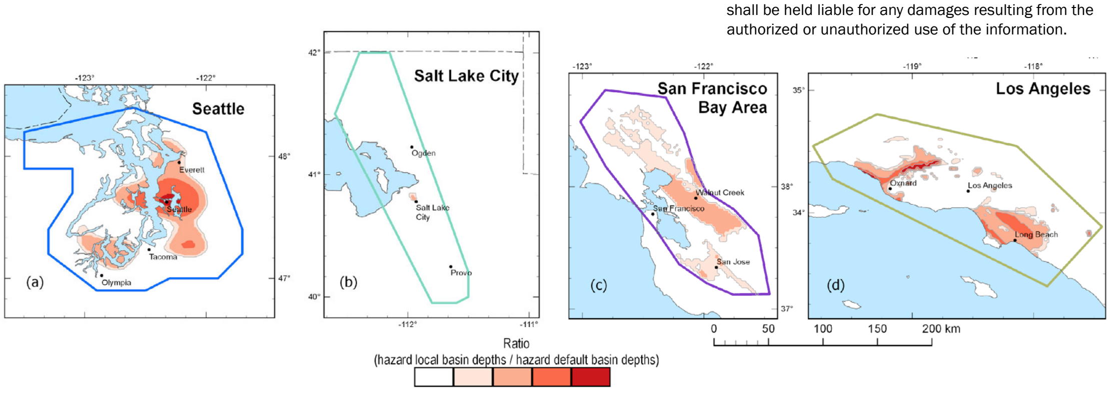
Section 3.2 - Hazard Changes (WUS)

Ratio Maps (2018 local basin depth/2018 default basin depth):
2% in 50-yr uniform hazard, 5 sec, Site Class D (260 m/s)

Disclaimer: This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.



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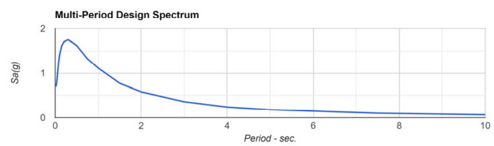
Section 3.2 Part 2 – Dissection of Example Changes to the MCE_R Ground Motion Values (Luco): Topics

- Revisions to deterministic caps
- Examples of changes in MCE_R and MCE_G values
- Risk-targeted maximum considered earthquake (MCE_R) spectral response accelerations
- Maximum considered earthquake geometric mean (MCE_G) peak ground accelerations
- Long-period transition maps (T_L)
- USGS seismic design geodatabase and web service

PGA_M	S_{MS}	S_{M1}	S_{DS}	S_{D1}	T_L	S_S	S_1	SDC	V_{S30} (m/s)
0.94	2.37	1.66	1.58	1.11	8	2.25	0.72	D	260



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Section 3.2 - Deterministic Caps

21.2.2 Deterministic (MCE_R) Ground Motions

The deterministic spectral response acceleration at each period shall be calculated as an 84th-percentile 5% damped spectral response acceleration in the direction of maximum horizontal response computed at that period. The largest such acceleration calculated for ~~the characteristic~~ scenario earthquakes on all known ~~active~~ faults within the region shall be used. The scenario earthquakes shall be determined from deaggregation for the probabilistic spectral response acceleration at each period. Scenario earthquakes contributing less than 10% of the largest contributor at each period shall be ignored.

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Section 3.2 - Examples of Changes in MCE_R Values

Table C22-3 Comparison of short-period MCE_R spectral response acceleration values from these *Provisions*, *ASCE/SEI 7-16*, and *ASCE/SEI 7-10*. The S_{MS} values are for the default site class.

	ASCE/SEI 7-10		*ASCE/SEI 7-16*		*2020 Provisions*	
Location Name	S_S (g)	S_{MS} (g)	S_S (g)	S_{MS} (g)	S_S (g)	S_{MS} (g)
Los Angeles, CA	2.40	2.40	1.97	2.36	2.25	2.37
Century City, CA	2.17	2.17	2.11	2.53	2.37	2.49
Northridge, CA	1.69	1.69	1.74	2.08	2.09	2.26
Long Beach, CA	1.64	1.64	1.68	2.02	1.90	2.03
Irvine, CA	1.55	1.55	1.25	1.50	1.43	1.68
Riverside, CA	1.50	1.50	1.50	1.80	1.50	1.67
San Bernardino, CA	2.37	2.37	2.33	2.79	2.78	2.97
San Luis Obispo, CA	1.12	1.18	1.09	1.31	1.23	1.45
San Diego, CA	1.25	1.25	1.58	1.89	1.74	1.80
Santa Barbara, CA	2.83	2.83	2.12	2.54	2.37	2.44
Ventura, CA	2.38	2.38	2.02	2.42	2.25	2.38

Section 3.2 - Examples of Changes in SDC

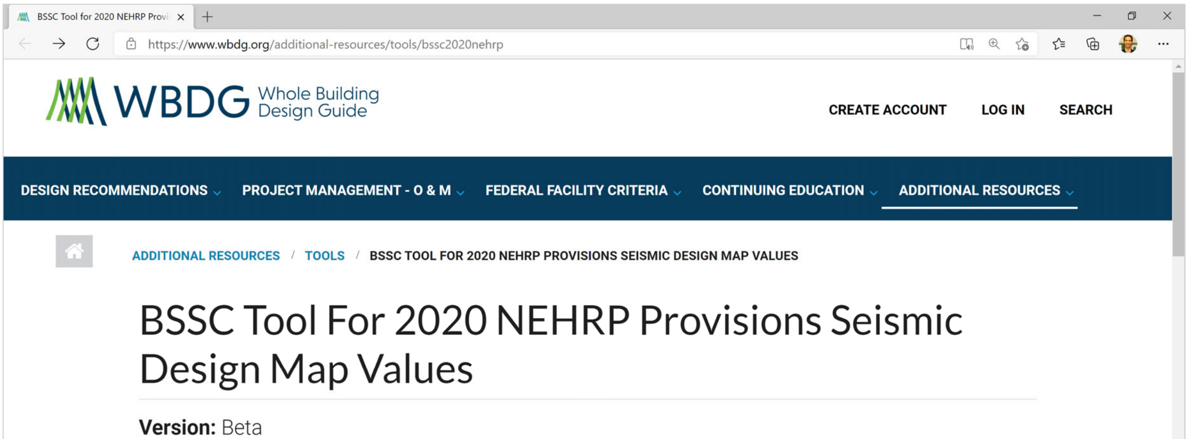
Table C22-6 Comparison of seismic design categories from these *Provisions*, *ASCE/SEI 7-16*, and *ASCE/SEI 7-10*, for the default site class and risk categories I, II, or III. The "SDC_S" categories are determined from Table 11.6-1 ("Seismic Design Category Based on Short-Period Response Acceleration Parameter") alone, but only where S_1<0.75g.

	ASCE/SEI 7-10		*ASCE/SEI 7-16*		*2020 Provisions*	
Location Name	"SDC_S"	SDC	"SDC_S"	SDC	"SDC_S"	SDC
Los Angeles, CA	N/A	E	D	D	D	D
Century City, CA	N/A	E	N/A	E	N/A	E
[illegible]	[illegible]	D	D	D	D	D
[illegible]	[illegible]	D	D	D	N/A	E
[illegible]	[illegible]	D	D	D	D	D
[illegible]	[illegible]	D	D	D	[illegible]	[illegible]
[illegible]	[illegible]	E	N/A	E	[illegible]	[illegible]
[illegible]	[illegible]	D	D	D	[illegible]	[illegible]
San Diego, CA	D	D	D	D	[illegible]	[illegible]
Santa Barbara, CA	N/A	E	N/A	E	[illegible]	[illegible]
Ventura, CA	N/A	E	N/A	E	[illegible]	[illegible]

From ASCE 7-10 to ASCE 7-16, SDC decreases at 2 of 34 locations, from E to D.

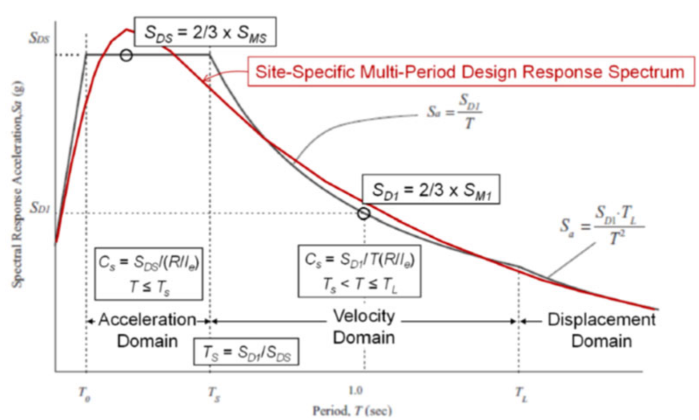
From ASCE 7-16 to 2020 *Provisions*, SDC increases at 4 of 34 locations, from D to E, mostly due to deterministic capping and basin effects.

Section 3.2 - BSSC Tool for Seismic Design Map Values
https://doi.org/10.5066/F7NK3C76



Section 3.3 – Multi-Period Response Spectra (Kircher): Topics

- Design parameters and response spectra of ASCE/SEI 7-16
- Site-specific requirements of ASCE/SEI 7-16
- New ground motion parameters of ASCE/SEI 7-22 Chapter 11
- New site classes of ASCE/SEI 7-22 Chapter 20
- New site-specific analysis requirements of ASCE/SEI 7-22 Chapter 21
- Example comparisons of design response spectra



Section 3.3 - The "Problem" with ASCE 7-10

- For softer sites, in particular those where seismic hazard is governed by large magnitude earthquakes:
  - Frequency content of ground motions (spectrum shape) is not accurately characterized by of the two-period design response spectrum and site coefficients
  - Design ground motions are significantly underestimated (e.g., by as much as a factor of 2 at longer response periods)

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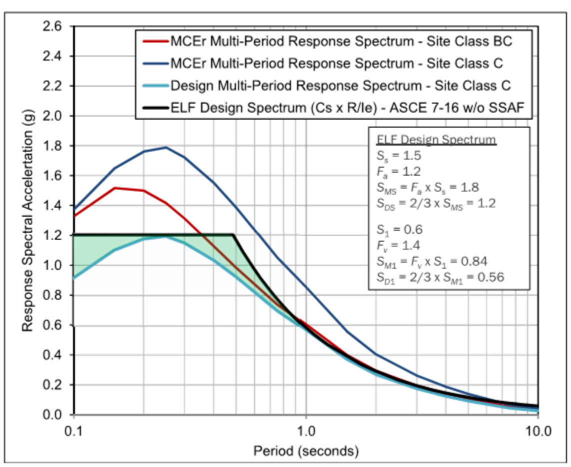
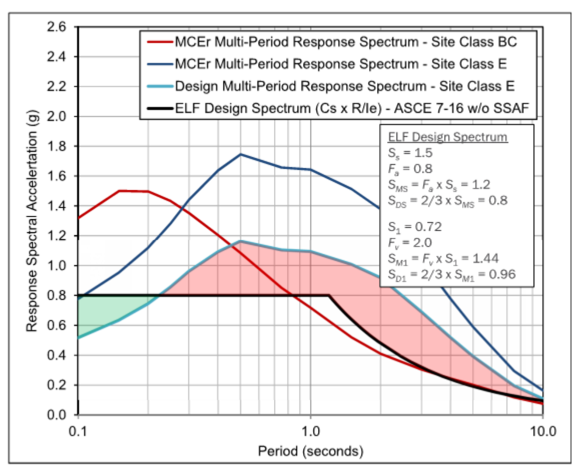
Section 3.3 - Comparison of ASCE/SEI 7-16 Two-Period (ELF) Design Spectrum w/o Spectrum Shape Adjustment with MPRS Design Spectrum



MPRS based on M7.0 earthquake ground motions at 6.8 km – Site Class C



MPRS based on M8.0 earthquake ground motions at 9.9 km – Site Class E

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Section 3.3 - Interim Solution of ASCE/SEI 7-16 (2015 *NEHRP Provisions*)

- Require site-specific analysis to determine design ground motions for softer sites, but provide exceptions to permit design using "conservative" values seismic design parameters
  - Site Class D - Site-specific ground motion procedures are required for structures on Site Class D sites where values of S_1 are greater than or equal to 0.2.
    - An exception permits ELF (and MRSA) design using a "conservative" value of the seismic design coefficient based on a 50 percent increase in the value of the seismic parameter S_{M1} (S_{D1}), effectively extending the acceleration domain to 1.5T_s
  - Site Class E - Site-specific ground motion procedures required for structures on Site Class E sites where values of S_S are greater than or equal to 1.0 (or S_1 greater than 0.2)
    - An exception permits ELF design using a "conservative" value of the seismic design coefficient based on the seismic parameter S_{MS} (S_{DS}) for Site Class C, regardless of the design period, *T*, effectively eliminating the velocity domain

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Section 3.3 - Long-Term Solution - MPRS in 2020 *NEHRP Provisions* and ASCE/SEI 7-22

- Define MCE_R and design ground motions in terms of MPRS (e.g., for MRSA design or as the basis for selecting records for NRHA)
- Derive values of seismic design parameters (e.g., S_{DS} and S_{D1}) from the MPRS of interest (e.g., for ELF design)
- Provide MPRS and associated values of seismic design parameters for User-specified values of:
  - Site Location (latitude, longitude)
  - Site Class
  - From USGS web service at http://doi.org/10.5066/F7NK3C76 (aka USGS Seismic Design Geodatabase for ASCE 7-22) and
  - Other user-friendly providers (e.g., WBDG, ASCE 7 Hazard Tool, etc.)

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Section 3.3 - New Site Classes and Associated Values of Shear Wave Velocities (Table 2.2-1, FEMA P-2078, June 2020)

Site Class		Shear Wave Velocity, V_{s30} (fps)			USGS[2] V_{s30} (mps)
Name	**Description**	**Lower Bound[1]**	**Upper Bound[1]**	**Center**	
A	Hard rock	5,000			1,500
B	Medium hard rock	3,000	5,000	3,536	1,080
BC	**Soft rock**	**2,100**	**3,000**	**2,500**	**760**
C	Very dense soil or hard clay	1,450	2,100	1,732	530
CD	**Dense sand or very stiff clay**	**1,000**	**1,450**	**1,200**	**365**
D	Medium dense sand or stiff clay	700	1,000	849	260
DE	**Loose sand or medium stiff clay**	**500**	**700**	**600**	**185**
E	Very loose sand or soft clay		500		150

1. Upper and lower bounds, Table 20.3-1, ASCE/SEI 7-22.
2. Center of range (rounded) values used by USGS to develop MPRS.

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Section 3.3 - MPRS Format

- Values available for conterminous US regions with ground motion models for all combinations of 22 periods and 8 site classes

Period *T (s)*	5%-Damped Response Spectral Acceleration or PGA by Site Class (g)							
	A	**B**	**BC**	**C**	**CD**	**D**	**DE**	**E**
0.00	0.501	0.565	0.658	0.726	0.741	0.694	0.607	0.547
0.010	0.503	0.568	0.662	0.730	0.748	0.703	0.617	0.547
0.020	0.519	0.583	0.676	0.739	0.749	0.703	0.617	0.547
0.030	0.596	0.662	0.750	0.792	0.778	0.703	0.617	0.547
0.050	0.811	0.888	0.955	0.958	0.888	0.758	0.620	0.551
0.075	1.040	1.142	1.214	1.193	1.076	0.900	0.713	0.624
0.10	1.119	1.252	1.371	1.368	1.241	1.040	0.825	0.724
0.15	1.117	1.291	1.535	1.606	1.497	1.266	1.002	0.875
0.20	1.012	1.194	**1.500**	1.710	1.662	1.440	1.153	1.010
0.25	0.897	1.075	1.397	1.714	1.766	1.584	1.299	1.153
0.30	0.810	0.976	1.299	1.665	1.829	1.705	1.443	1.301
0.40	0.689	0.833	1.138	1.525	1.823	1.802	1.607	1.484
0.50	0.598	0.724	1.009	1.385	1.734	1.803	1.681	1.596
0.75	0.460	0.536	0.760	1.067	1.407	1.566	1.598	1.589
1.0	0.368	0.417	**0.600**	0.859	1.168	1.388	1.512	1.578
1.5	0.261	0.288	0.410	0.600	0.839	1.086	1.348	1.540
2.0	0.207	0.228	0.309	0.452	0.640	0.877	1.192	1.458
3.0	0.152	0.167	0.214	0.314	0.449	0.632	0.889	1.111
4.0	0.120	0.132	0.164	0.238	0.339	0.471	0.655	0.815
5.0	0.100	0.109	0.132	0.188	0.263	0.359	0.492	0.607
7.5	0.063	0.068	0.080	0.110	0.148	0.194	0.256	0.311
10	0.042	0.045	0.052	0.069	0.089	0.113	0.144	0.170
PGA_G	0.373	0.429	**0.500**	0.552	0.563	0.527	0.461	0.416

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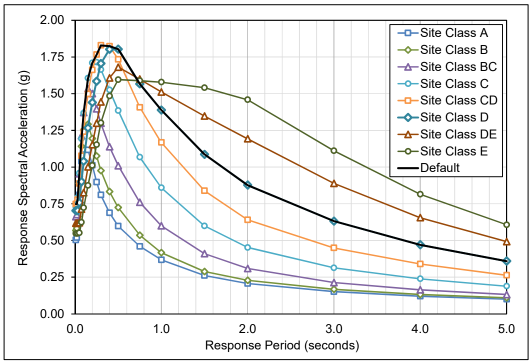
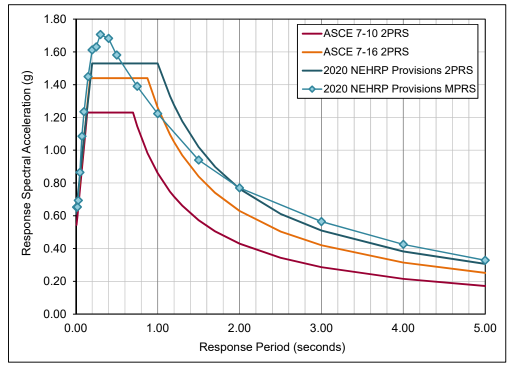
Move from Two-Point Spectra (2PRS) to Multi-Point Spectra (MPRS)



Example MPRS from ASCE/SEI 7-22 Table 21.2-1 (from 2020 NEHRP Training Materials by C. Kircher)



San Mateo, CA for default soil class (from FEMA P-2078, Figure 8.2-2)

Velocity domain of the ASCE 7-16 (2PRS) design spectrum includes the 1.5 multiplier of the applicable Section 11.4.8 exception.

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Section 3.3 - Design (As Usual) Using New MPRS

- Design Ground Motions
  - Ground motion parameters (and MPRS) are available online from a USGS web service [https://doi.org/10.5066/F7NK3C76] for user specified site location (i.e., latitude and longitude) and site conditions (i.e., site class)
  - Site-specific ground motion procedures (Chapter 21) now permit use of MPRS obtained online from the USGS web service (in lieu of a hazard analysis)
- Design Procedures
  - ELF procedures (Chapter 12) are not affected by proposed changes (although values of design parameters, S_{DS} and S_{D1}, would better match the underlying response spectrum of the site of interest)
  - MRSA procedures (Chapter 12) are not affected by proposed changes (although multi-period design spectra would provide a more reliable calculation of dynamic response)

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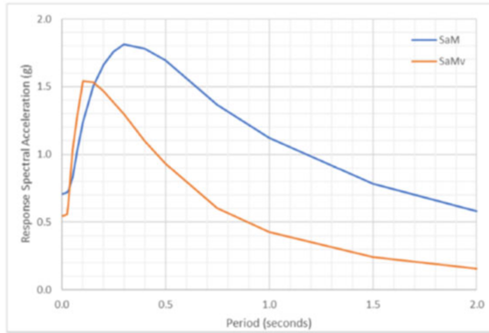
Section 3.4 – Other Changes to Ground Motion Provisions in ASCE/SEI 7-22 (Crouse): Topics

- Maximum Considered Earthquake Geometric Mean (MCE_G) Peak Ground Acceleration (ASCE/SEI 7-22, Section 21.5)
- Vertical Ground Motion for Seismic Design (ASCE/SEI 7-22, Section 11.9)
- Site Class when Shear Wave Velocity Data Unavailable (ASCE/SEI 7-22, Section 20.3)



Comparison of S_{aMv} and S_{aM} for Irvine, CA site and Site Class D

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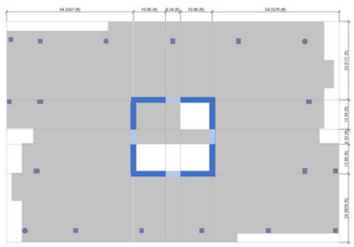
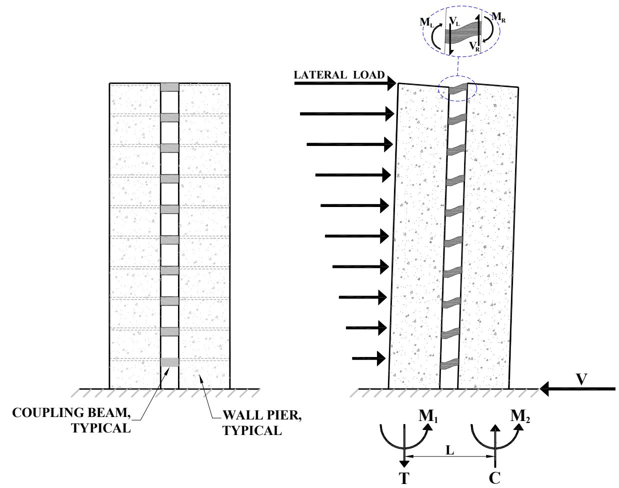
Chapter 4 – Ductile Reinforced Concrete Shear Walls

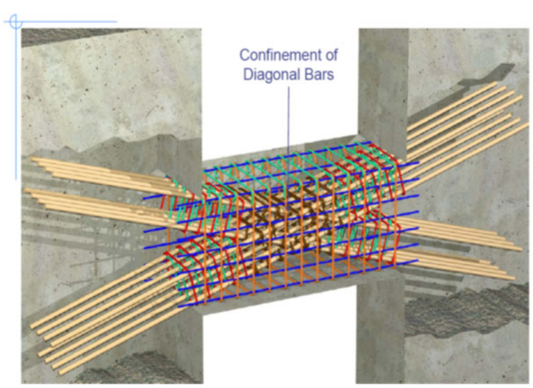
Chapter 4 – Ductile Coupled RC Shear Walls (Ghosh and Dasgupta): Topics

- Ductile coupled shear wall system
- Research justification
- Design example
  - Overall demands
  - Design of shear wall
  - Design of coupling beams

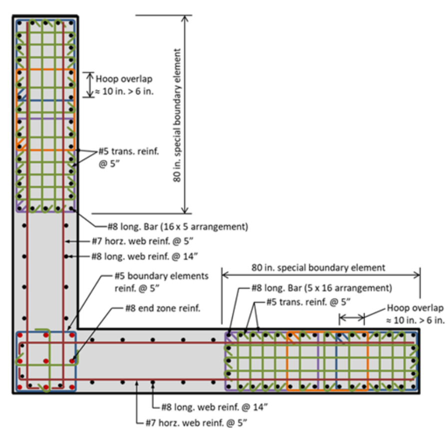




Chapter 2 – Ductile Coupled RC Shear Wall: Details



Source: http://nees.seas.ucla.edu/pankow



Shear wall plan section

Chapter 5 – Coupled Composite Plate Shear Walls/Concrete Filled (C-PSW/CF)

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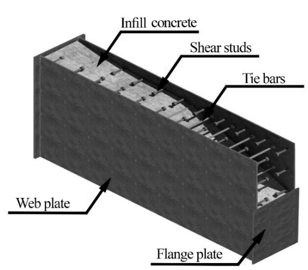
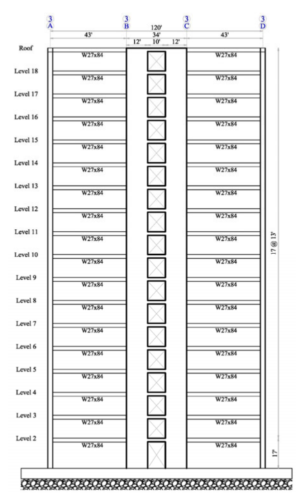
Chapter 5 – Coupled Composite Plate Shear Walls / Concrete Filled (Shafaei and Varma): Topics

- Introduction to Coupled C-PSW/CFs
- Section detailing, limits, and requirements
- Seismic behavior and capacity design
- Design example
  - Overall demands
  - Coupling beams
  - C-PSW/CF
  - Connection of beams to C-PSW/CF





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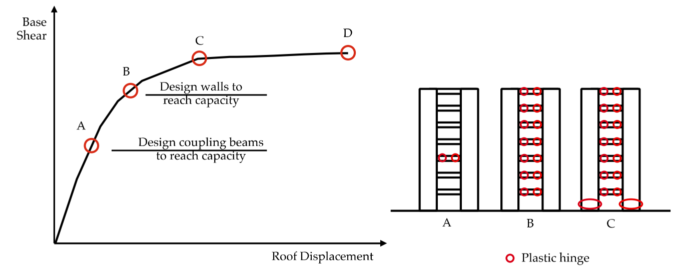
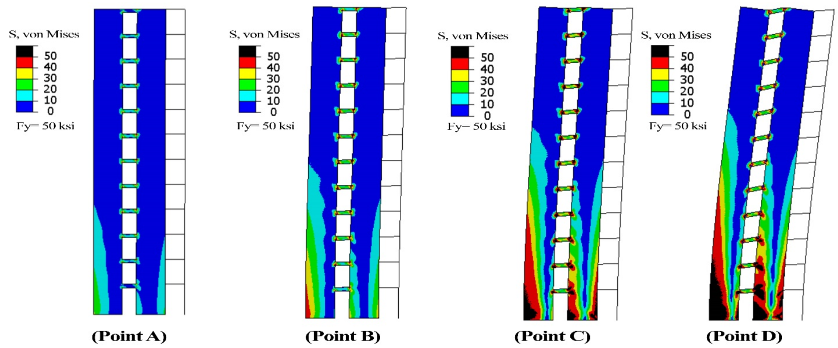
Chapter 5 – C-PSW/CF: Seismic Design Philosophy





From AISC Design Guide 37 (AISC, 2021)

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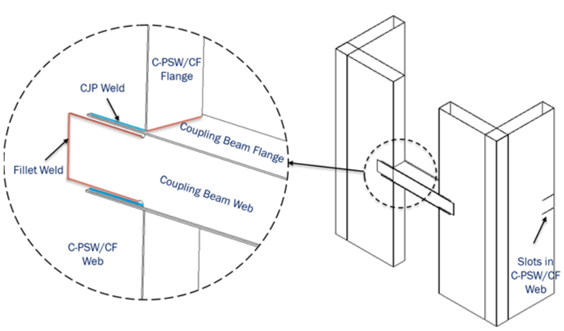
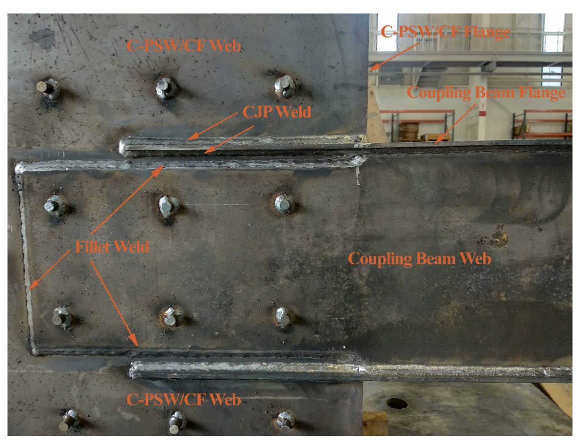
Chapter 5 – C-PSW/CF: Coupling Beam-to-Wall Connection





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Chapter 6 – Cross-Laminated Timber Shear Walls

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Chapter 6 - Cross-Laminated Timber (CLT) Shear Wall (Line and Amini): Topics

- This example features the seismic design of cross-laminated timber shear walls used in a three-story, six-unit townhouse cross-laminated timber building of platform construction
- The CLT shear wall design in this example includes:
  - Check of CLT shear wall shear strength
  - Check of CLT shear wall hold-down size and compression zone length for overturning
  - Check of CLT shear wall deflection for conformance to seismic drift

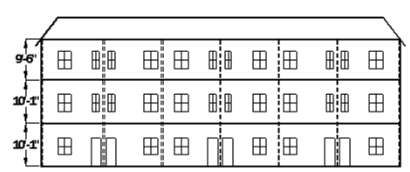

Figure 6-2. Elevation

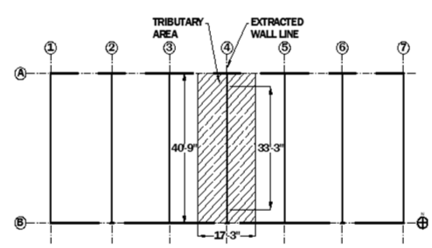

Figure 6-3. Typical Floor Plan (first story openings shown)

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Chapter 6 – CLT Shear Wall: Construction

Photo credits: Will Pryce

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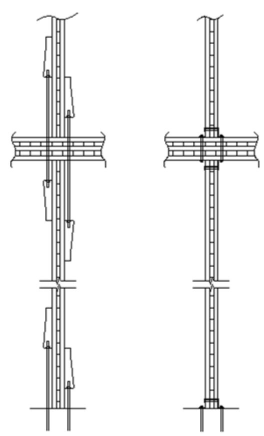
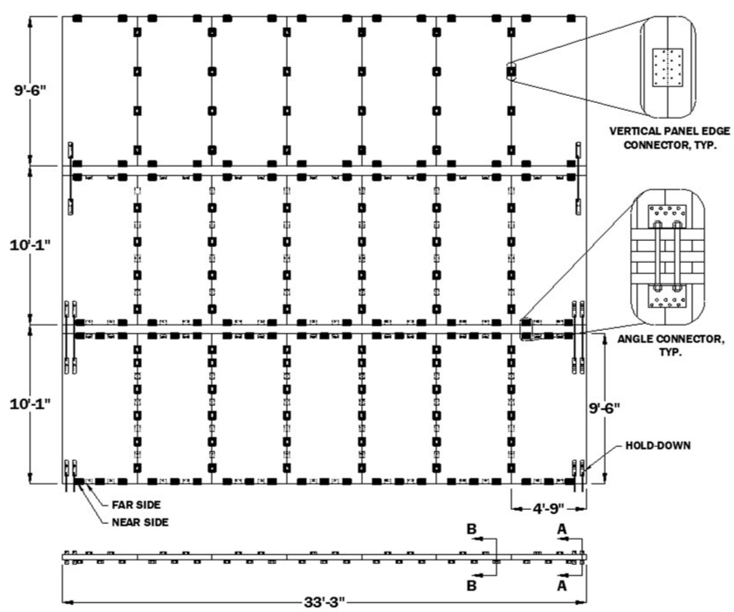
Chapter 6 – CLT: Shear Wall Details



Wall-to-floor intersections



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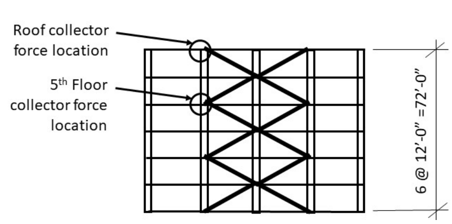
Chapter 7 – Horizontal Diaphragm Design

Chapter 7 – Horizontal Diaphragm Design (Cobeen): Topics

- All diaphragm seismic design methods
  - Sections 12.10.1 and 12.10.2 - *Traditional Diaphragm Design Method* (in ASCE/SEI 7-10)
  - Section 12.10.3 - *Alternative Design Provisions* is added (added in ASCE/SEI 7-16)
    - Cast-in-place concrete, precast concrete, and wood structural panel diaphragms
  - Section 12.10.3 – *Alternative Design Provisions* is expanded (in ASCE/SEI 7-22)
    - Bare steel deck, concrete-filled steel deck diaphragms
  - Section 12.10.4 – *Alternative RWFD Provisions* is added (in ASCE/SEI 7-22)
- Design examples
  - Determination of diaphragm design forces
  - One-story wood assembly hall
  - One-story bare steel deck diaphragm building
  - Multi-story steel building with steel deck diaphragms

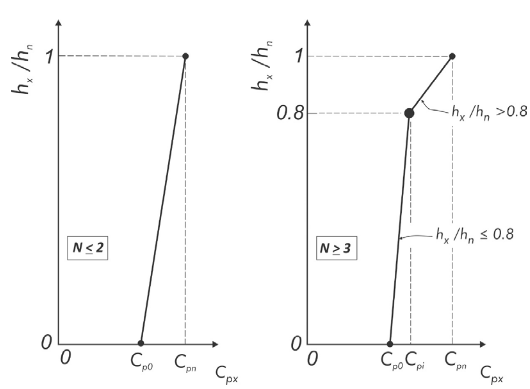


Chapter 7: Diaphragm Seismic Design Method Comparison

- Advantages of using Section 12.10.3 Alternative Design Provisions:
  - Better reflects vertical distribution of diaphragm forces
  - Better reflects effect of diaphragm ductility and displacement capacity
  - May result in lower seismic demands
- Advantages of using Section 12.10.4 Alternative RWFD Method;
  - Better reflects seismic response of RWFD buildings
  - May result in lower seismic demands
  - Is anticipated to result in better performance
- When will the Section 12.10.1 and 12.10.2 Traditional Method result in lower design forces?
  - Bare steel deck diaphragms not meeting the AISI S400 special seismic detailing provisions
  - Other

Chapter 7: Section 12.10.3 Alternative Design Provisions

Part 1: Vertical distribution of seismic forces for near-elastic diaphragm behavior

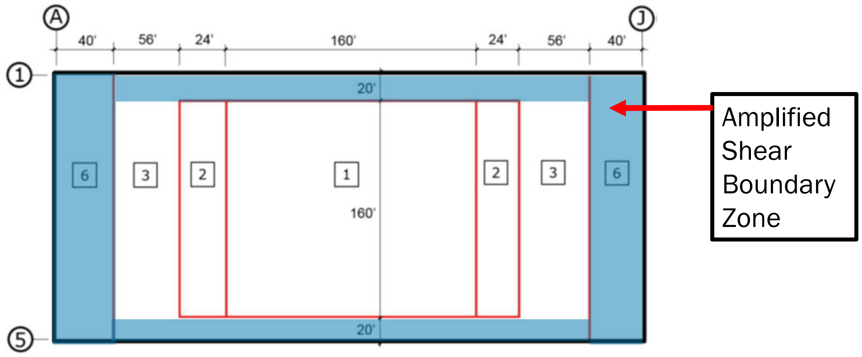


Part 2: Parameter R_s modifies near-elastic forces based on diaphragm ductility and deformation capacity

$$F_{px} = \frac{C_{px}}{R_s} w_{px}$$

Chapter 7: Section 12.10.4 Alternative RWFD Design Method

Design to encourage distributed inelastic behavior for improved seismic performance



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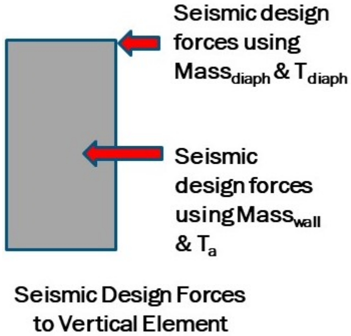
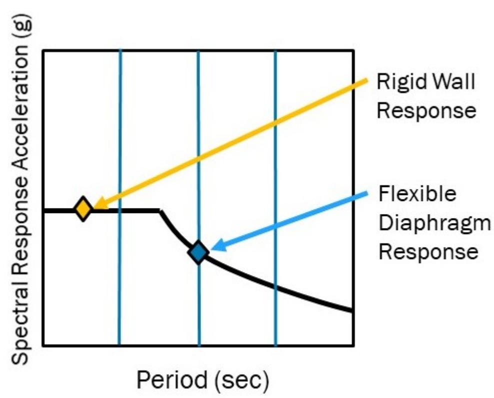
Chapter 7: Section 12.10.4 Alternative RWFD Design Method

Optional incorporation of actual seismic response of RWFD buildings for vertical elements – 2 stage analysis





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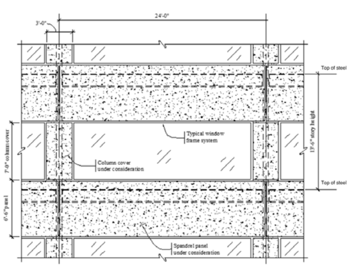
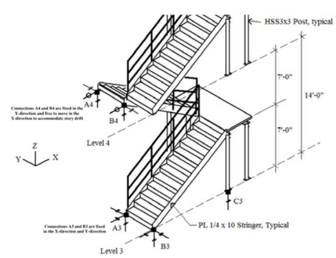
Chapter 8 - Nonstructural Components

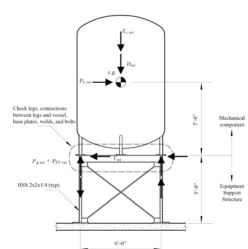
Chapter 8 - Design Examples for Nonstructural Components (Lizundia): Topics



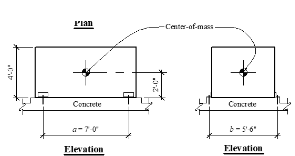
Architectural precast concrete



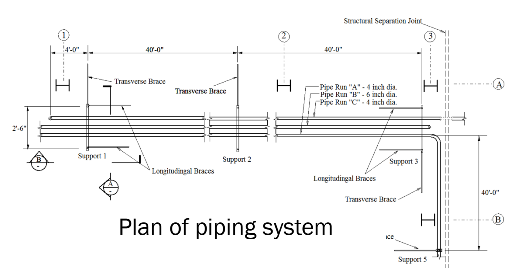
Egress stairs



Pressure vessel



HVAC fan unit



Plan of piping system

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Chapter 8 - Nonstructural Components Example: Architectural Precast Concrete

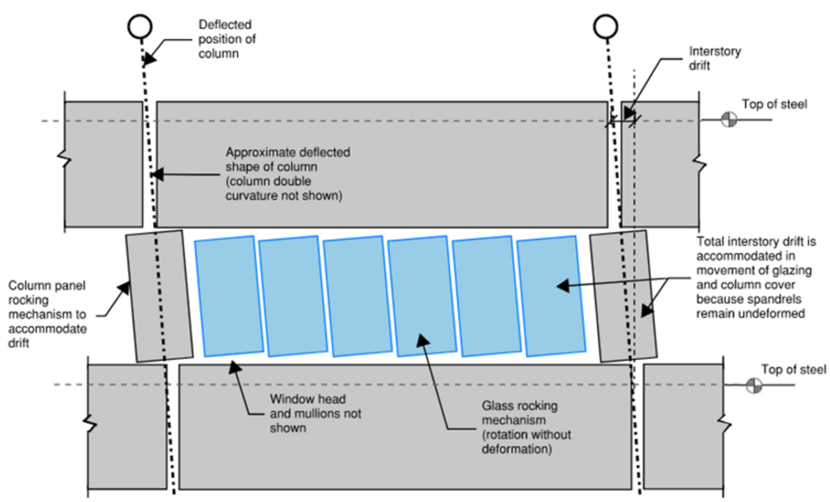
Example Summary

- **Nonstructural component:** Architectural – exterior nonstructural wall elements and connections
- **Building seismic force-resisting system:** Steel special moment frames
- **Equipment support:** Not applicable
- **Occupancy:** Office
- **Risk Category:** II
- **Component Importance Factor:** $I_p = 1.0$
- **Number of stories:** 5
- $S_{DS} = 1.487$

Topics Covered

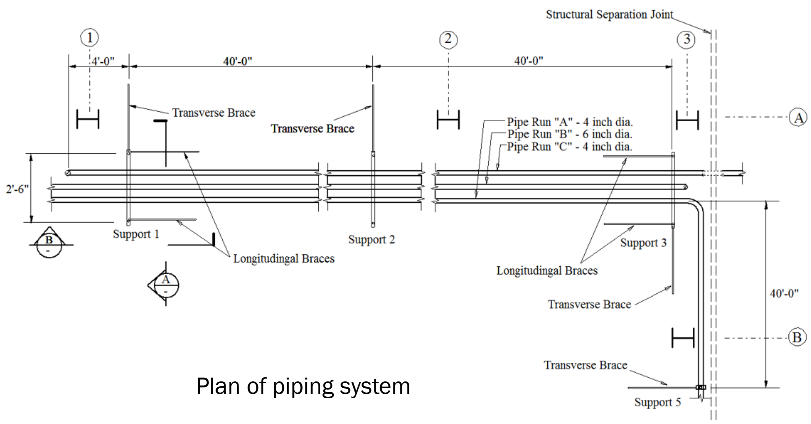
- Providing gravity support and accommodating story drift in cladding
- Spandrel panel
- Column cover
- Prescribed seismic displacements

Chapter 8 - Nonstructural Components Example: Rocking Cladding Mechanism



Deflected position

Chapter 8 - Nonstructural Components Example: Piping System Seismic Design



Plan of piping system

Topics Covered

- Piping system design
- Pipe supports and bracing
- Prescribed seismic displacements

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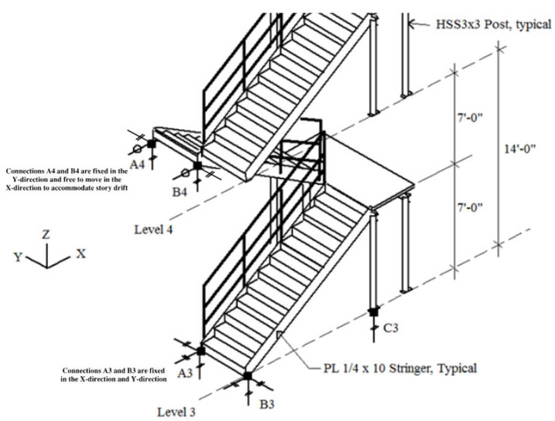
Chapter 8 - Nonstructural Components Example: Egress Stairs



Isometric view of egress stairs

Topics Covered

- Prescribed seismic forces
  - Egress stairways not part of the building seismic force-resisting system
  - Egress stairs and ramp fasteners and attachments
- Prescribed seismic displacements

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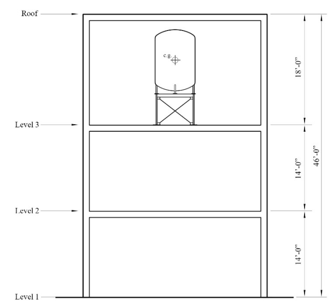
Chapter 8 - Nonstructural Components Example: Elevated Vessel

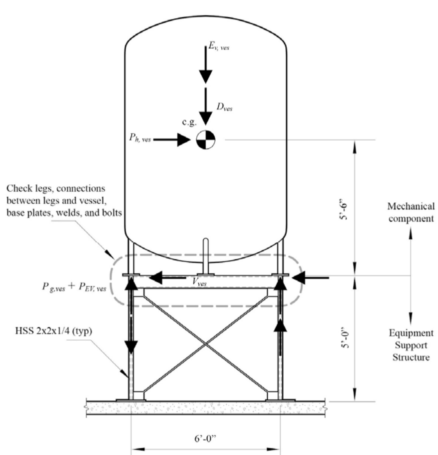
Example Summary

- **Nonstructural components:**
  Mechanical and electrical – pressure vessel not supported on skirts
- **Building seismic force-resisting system:** Special reinforced concrete shear walls
- **Equipment support:** Equipment support structures and platforms – Seismic Force-Resisting Systems with $R > 3$
- **Occupancy:** Storage
- **Risk Category:** II
- **Component Importance Factor:** $I_p = 1.0$
- **Number of stories:** 3
- $S_{DS} = 1.20$
- $S_1 = 0.65$



Elevation

Chapter 8 - Nonstructural Components Example: Elevated Vessel



Changes in ASCE/SEI 7-22

ASCE/SEI 7-16 required the nonstructural components and supporting structure to be designed with the same seismic design forces, F_p, regardless of their interaction, and the force was based on the component properties. A platform supporting a pressure vessel would be designed for pressure vessel forces regardless of whether the platform structure was made of concrete, steel braced frames, or steel moment frames.

In ASCE/SEI 7-22, the concept of an equipment support structure or platform has been introduced and defined. Definitions are given in Section 11.2 and properties have been added to Table 13.6-1. Section 13.6.4.6 has been added to ASCE/SEI 7-22 to require that the support structures and platforms be designed in accordance with those properties. This permits a more accurate determination of forces that more realistically reflect the differences in dynamic properties and ductilities between the component and the support structure or platform.

Chapter 8 - Prescribed Seismic Forces: Vessel Support and Attachments

- Vessel and legs weight, $W_{p,ves} = D_{ves} = 5{,}000 \text{ lb}$
- Seismic design force, F_p

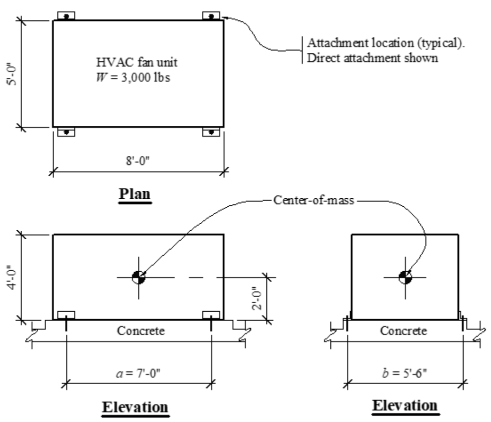
$$F_p = 0.4S_{DS}I_pW_p\left[\frac{H_f}{R_\mu}\right]\left[\frac{C_{AR}}{R_{po}}\right] = 0.4(1.2)(1.0)(W_p)\left[\frac{2.52}{1.48}\right]\left[\frac{1.4}{1.5}\right] = 0.762W_p \quad \text{(controlling equation)}$$

$$F_{p,max} = 1.6S_{DS}I_pW_p = 1.6(1.2)(1.0)(W_p) = 1.92W_p$$

$$F_{p,min} = 0.3S_{DS}I_pW_p = 0.3(1.2)(1.0)(W_p) = 0.360W_p$$

$$F_{p,ves} = 0.762W_p = 0.762(5{,}000 \text{ lb}) = 3{,}808 \text{ lb} \quad \text{(controlling seismic design force)}$$

Chapter 8 - Nonstructural Component Example: HVAC Fan Unit Support



HVAC Fan Unit

Topics Covered

- **Case 1:** Direct attachment to the structure using cast-in place anchors
- **Case 2:** Support on vibration isolation springs that are attached to the slab post-installed expansion anchors.

Organization and Presentation of the Design Example Chapters

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Outline of the 2020 *Design Examples* Chapters

- Chapter 1: Introduction
- Chapter 2: Fundamentals
- Chapter 3: Earthquake Ground Motions
- Chapter 4: Ductile Coupled Reinforced Concrete Shear Walls
- Chapter 5: Coupled Composite Plate Shear Walls/Concrete Filled
- Chapter 6: Three-Story Cross-Laminated Timber (CLT) Shear Wall
- Chapter 7: Horizontal Diaphragm Design
- Chapter 8: Nonstructural Components

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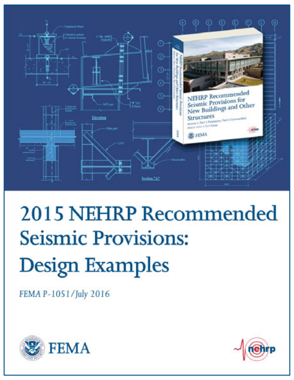
How to Use the 2015 and 2020 *Design Examples* Together

- Both the 2015 and 2020 *Design Examples* are intended to be used together.
- The 2020 *Design Examples* cover major changes and new seismic force-resisting systems, but the 2015 *Design Examples* still apply in many situations.



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How to Use the 2015 and 2020 *Design Examples* Together

Topic	2015 *Design Examples* and ASCE/SEI 7-16	2020 *Design Examples* and ASCE/SEI 7-22
Fundamentals	Chapter 2 – Summary of fundamentals of earthquake engineering	Chapter 2 – Summary of fundamentals of earthquake engineering, updated from 2015 *Design Examples.*
Seismic Resilience	Not covered in 2015 *Design Examples*. Use 2020 *Design Examples.*	Section 2.7 – Summarizes application of resilience design to the *NEHRP Provisions* and includes a CLT case study.
Earthquake Ground Motion	Chapter 3 – Provides basis for Risk Targeted design maps, discusses hazard assessment, site specific spectra, and ground motion selection and scaling. Selection and scaling discussion are still generally applicable with ASCE/SEI 7-22. Use 2020 *Design Examples* otherwise.	Chapter 3 – Summarizes basis for new design maps, addition of more site classes, major update from two-period spectra to multi-period spectra, and update on vertical ground motion.
Linear Analysis	Chapter 4 – Design examples with equivalent lateral force procedure, modal response spectrum analysis, and new linear response history analysis. Applicable with ASCE/SEI 7-22.	Not covered in 2020 *Design Examples*. See Section 1.4 of this Chapter on relaxation of modal response spectrum analysis requirements.
Nonlinear Response History Analysis (NRHA)	Chapter 5 – Design example using NRHA for a tall reinforced concrete shear wall building. Applicable with ASCE/SEI 7-22.	Not covered in 2020 *Design Examples*.
Diaphragm Analysis	Chapter 6 – Design examples comparing traditional and new alternate methods. Use the 2020 *Design Examples*.	Chapter 7 – Design examples showing all diaphragm analysis methods including new methods introduced with the 2020 *NEHRP Provisions*. Diaphragm design for precast diaphragms has been moved out of ASCE/SEI 7-22 to ACI publications, and this is discussed.

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How to Use the 2015 and 2020 *Design Examples* Together

Topic	2015 *Design Examples* and ASCE/SEI 7-16	2020 *Design Examples* and ASCE/SEI 7-22
Foundation and Liquefaction	Chapter 7 – Design examples for shallow and deep foundations and for foundations on liquefiable soil. Applicable with ASCE/SEI 7-22.	Not covered in 2020 *Design Examples*.
Soil-Structure Interaction (SSI)	Chapter 8 – Design example of a four-story reinforced concrete shear wall building with and without SSI. Applicable with ASCE/SEI 7-22.	No examples in 2020 *Design Examples*. See Section 1.4 of this Chapter for discussion on changes to SSI provisions in ASCE/SEI 7-22.
Structural Steel	Chapter 9 – Design examples for a high-bay warehouse with an ordinary concentric braced frame and an intermediate moment frame and for an office building with a special steel moment frame and a special concentric braced frame. Applicable with ASCE/SEI 7-22.	Not covered in 2020 *Design Examples*.
Reinforced Concrete	Chapter 10 – Design examples for an intermediate moment frame, a special moment frame, and special concrete shear walls. Applicable with ASCE/SEI 7-22.	Chapter 4 – Design example for a new reinforced concrete ductile coupled wall.
Precast Concrete	Chapter 11 – Design examples for precast diaphragms, intermediate precast concrete shear walls, tilt-up concrete, and precast special moment frame. Applicable with ASCE/SEI 7-22.	Not covered in 2020 *Design Examples*.
Composite Steel and Concrete	Chapter 12 – Design example of composite partially restrained moment frame. Applicable with ASCE/SEI 7-22.	Chapter 5 – Design example for a new steel and concrete coupled composite plate shear walls.

How to Use the 2015 and 2020 *Design Examples* Together

Topic	2015 *Design Examples* and ASCE/SEI 7-16	2020 *Design Examples* and ASCE/SEI 7-22
Masonry	Chapter 13 – Design examples for two reinforced masonry bearing wall buildings. Applicable with ASCE/SEI 7-22.	Not covered in 2020 *Design Examples*.
Wood	Chapter 14 – Design examples for an apartment, wood roof diaphragm and roof-to-wall anchorage in a masonry building. Use the 2020 *Design Examples* for wood diaphragms.	Chapter 6 – Design example for new cross-laminated timber shear wall system.
Seismic Isolation	Chapter 15 – Design example of an essential facility with lead rubber bearings using the significantly revised isolation provisions. Applicable with ASCE/SEI 7-22.	Not covered in 2020 *Design Examples*.
Damping	Chapter 16 – Design example of fluid viscous dampers in a steel moment frame building. Applicable with ASCE/SEI 7-22.	Not covered in 2020 *Design Examples*.
Nonbuilding Structures	Chapter 17 – Design examples for pipe racks, industrial storage rack, power generating plant, pier, storage tanks, and tall vertical storage vessel. Applicable with ASCE/SEI 7-22.	No examples in 2020 *Design Examples*. See Section 1.4 for discussion on changes to nonbuilding structures in ASCE/SEI 7-22.
Nonstructural Components	Chapter 18 – Design examples for precast cladding, egress stair, roof fan anchorage, piping system, and elevated vessel. Use 2020 *Design Examples*.	Chapter 8 – Background on development of new design equations and other changes, plus design examples for precast cladding, egress stair, roof fan anchorage, piping system, and elevated vessel.

Presentation Techniques in the 2020 *Design Examples*

Reference to ASCE/SEI 7-22

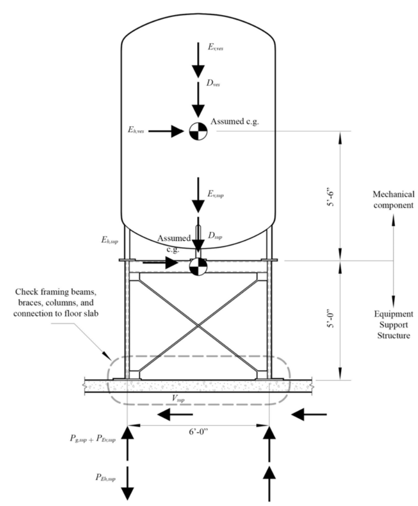
For ease of reader use, the 2020 *Design Examples* typically reference ASCE/SEI 7-22 sections and equations rather than the 2020 *NEHRP Provisions*. However, at the time of completion of writing the 2020 *Design Examples* in the summer of 2021, ASCE/SEI 7-22 had not been finalized or published. Publication was expected in December 2022. The June 17, 2021, draft of ASCE/SEI 7-22 issued for public comment was used as the reference document for ASCE/SEI 7-22. At that time, all major proposals from the ASCE committee responsible for the standard had been incorporated, but public review remained. This may lead to changes in the final published version of ASCE/SEI 7-22. As such, when that published version is available, the reader of this 2020 *Design Examples* should look at the sections in the published version where revisions from ASCE/SEI 7-16 are indicated to determine whether there are meaningful differences.

Presentation Techniques in the 2020 *Design Examples*

- Free-body diagrams are used.
- A worked-out example of the calculations is typically shown in detail only once. Summary tables then show the results for the other similar components.
- The focus is on key selected items in each example to keep the document size manageable. Not all necessary items that would need to be checked or designed are shown. In many cases, a list of these additional items is provided.
- Changes between the NEHRP provisions and ASCE/SEI 7-22 are flagged:

Changes Between the *NEHRP Provisions* and ASCE/SEI 7-22

Equation 13.3-6 in the 2020 *NEHRP Provisions* was modified for ASCE/SEI 7-22, by adding I_e into the denominator to better estimate the structure ductility.



BSSC NEHRP Webinar Training: nibs.org/events/nehrp-webinar-series

- *Introduction to the 2020 NEHRP Provisions Design Examples:* Bret Lizundia and Mai Tong
- *Fundamentals of Earthquake Engineering:* James Harris
- *Diaphragm Seismic Design Part 1 and Part 2:* Kelly Cobeen
- *Ductile Coupled Reinforced Concrete Shear Walls:* S.K. Ghosh
- *Nonstructural Components Part 1 and Part 2:* Bret Lizundia
- *Fundamentals and Evolution of U.S. Seismic Design Values and the 2018 Update of the USGS National Seismic Hazard Model:* Sanaz Rezaeian and Ronald Hamburger
- *Multi-Period Response Spectra Provisions, Other Changes to Ground Motion Provisions, and Dissection of Example Changes to the Ground Motion Values:* Charles Kircher, C.B. Crouse, and Nicolas Luco
- *Cross-Laminated Timber Shear Wall Design and Resilience-Based Design:* M. Omar Amini, David Bonowitz, and Philip Line
- *Coupled Composite Plate Shear Walls / Concrete Filled:* Soheil Shafaei and Amit Varma

Questions?

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