

There's always a solution in steel.

AISC Live Webinars

Thank you for joining our live webinar today.
We will begin shortly. Please standby.

Thank you.

Need Help?

Call ReadyTalk Support: 800.843.9166



AISC Live Webinars

Today's audio will be broadcast through the internet.

Alternatively, to hear the audio through the phone, dial:

(888) 378-4398

Passcode: 902041



AISC Live Webinars

Today's live webinar will begin shortly. Please stand by.

As a reminder, all lines have been muted. Please type any questions or comments through the Chat feature on the left portion of your screen.

Today's audio will be broadcast through the internet.
Alternatively, to hear the audio through the phone, dial:

(888) 378-4398

Passcode: 902041



AISC Live Webinars

AISC is a Registered Provider with The American Institute of Architects Continuing Education Systems (AIA/CES). Credit(s) earned on completion of this program will be reported to AIA/CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This program is registered with AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.



AISC Live Webinars

Copyright Materials

This presentation is protected by US and International Copyright laws. Reproduction, distribution, display and use of the presentation without written permission of AISC is prohibited.

© The American Institute of Steel Construction 2017

The information presented herein is based on recognized engineering principles and is for general information only. While it is believed to be accurate, this information should not be applied to any specific application without competent professional examination and verification by a licensed professional engineer. Anyone making use of this information assumes all liability arising from such use.



Course Description

Seismic Design for Non-West Coast Engineers – Part 1 August 10, 2017

This introductory, two-part webinar will address basic concepts of seismic design.

Part 1 of the webinar will start with a brief historical perspective of earthquakes and will then discuss the basics of earthquake loading and building dynamic response, and the use of ductility in resisting earthquakes.



Learning Objectives

- Describe the impact of major historical earthquakes
- Define key components of force on buildings caused by earthquakes
- Identify philosophy behind earthquake resistant design
- Describe the roll of ductility in earthquake resistant design



Seismic Design for Non-West Coast Engineers – Part 1



Presented by
Michael D. Engelhardt, PhD, PE
Professor
The University of Texas at Austin

There's always a solution in steel.



Seismic Design for Non-West Coast Engineers

Part 1 (August 10, 2017)

- **Causes, Location, and Impact of Earthquakes**
- **EQ Forces on Buildings**
- **Overall Philosophy and Approach for EQ-Resistant Design**
- **Role of Ductility in EQ-Resistant Design**



9

Seismic Design for Non-West Coast Engineers

Part 2 (August 17, 2017)

- **Steel Structures: Performance in Past EQs**
- **EQ Resistant Design per ASCE 7-10**
- **Structural Steel Seismic Force-Resisting Systems in the AISC *Seismic Provisions***
- **References for Further Learning**



10



Seismic Design for Non-West Coast Engineers

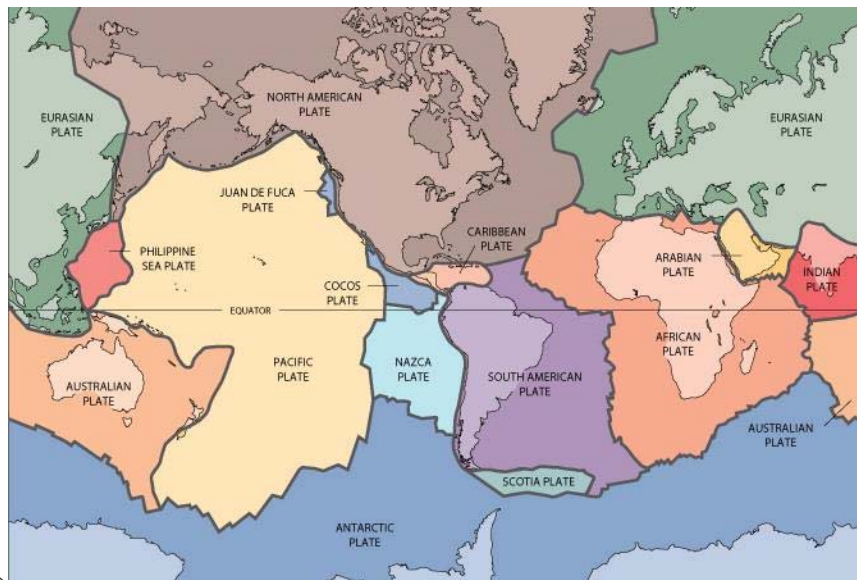
Part 1

- Causes, Location, and Impact of Earthquakes
- EQ Forces on Buildings
- Overall Philosophy and Approach for EQ-Resistant Design
- Role of Ductility in EQ-Resistant Design



11

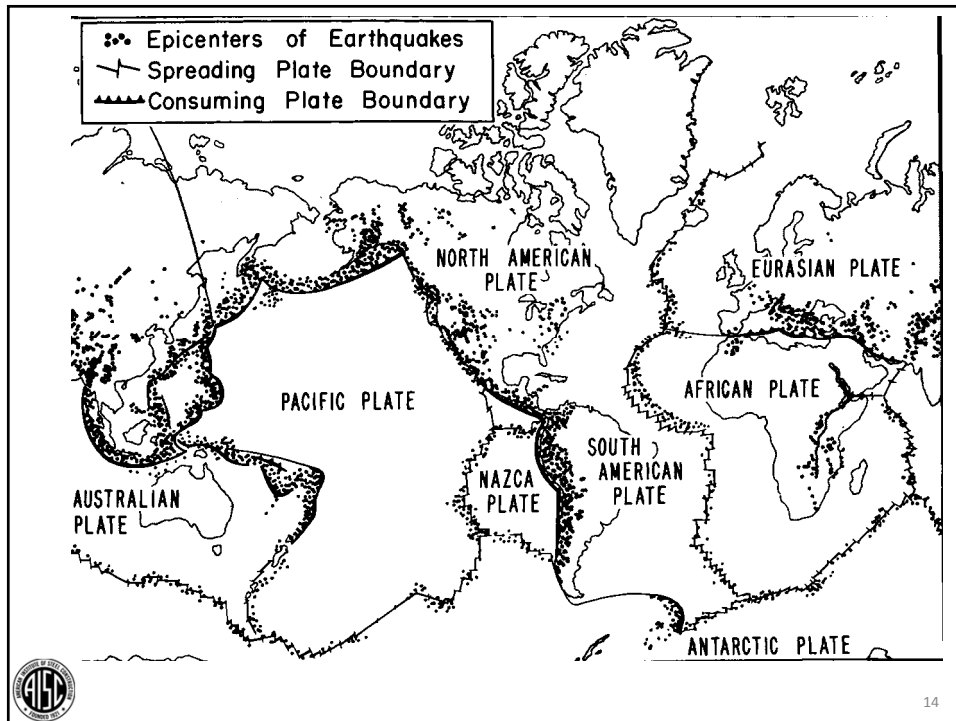
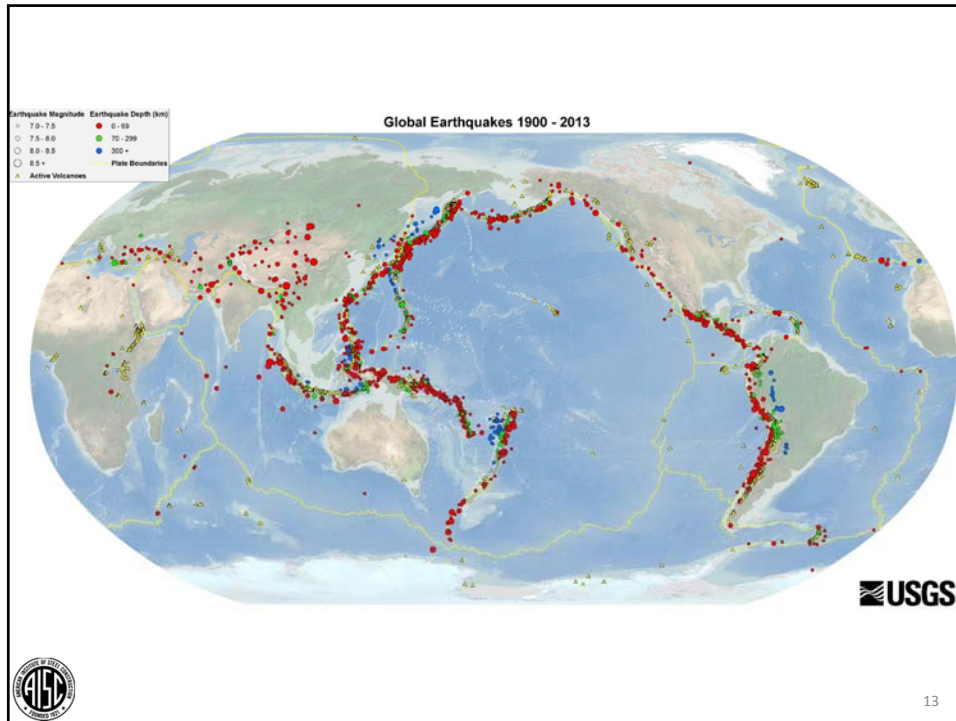
Cause and Location of Earthquakes

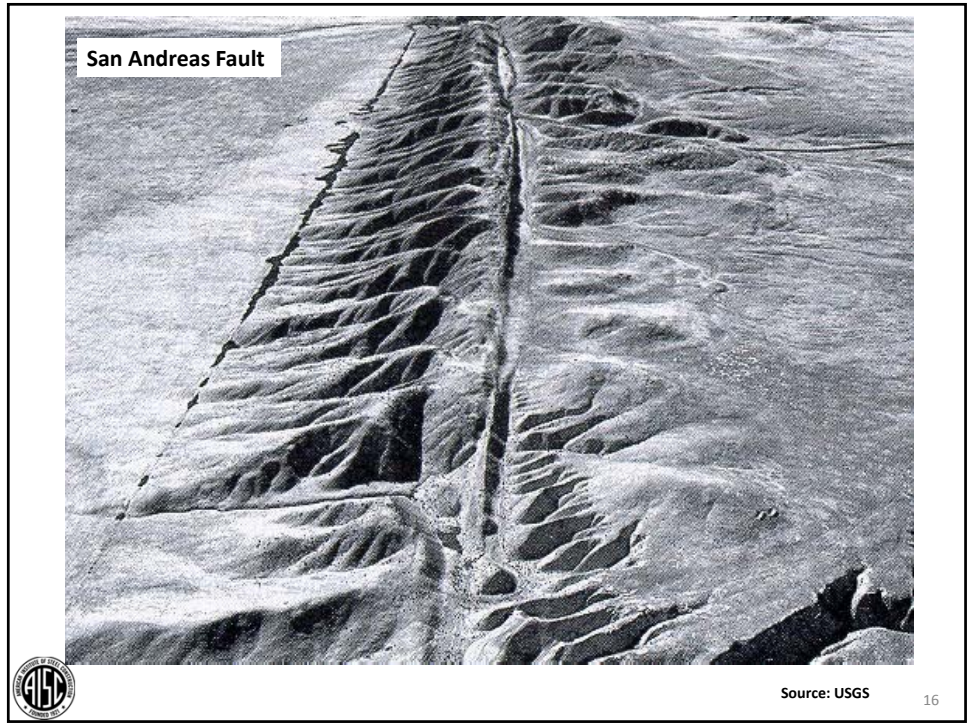
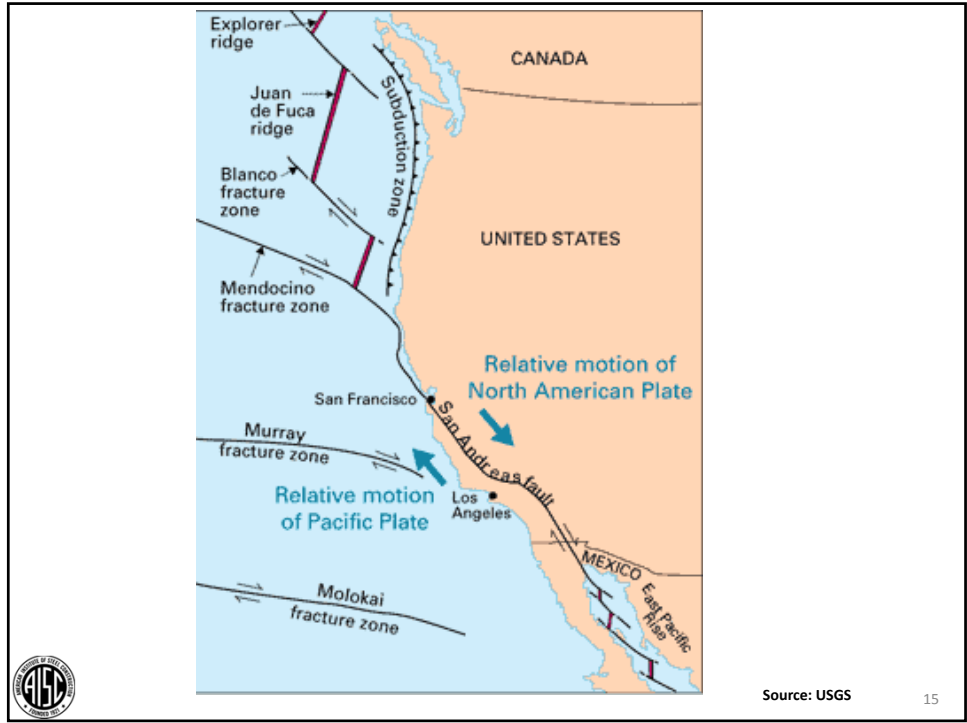


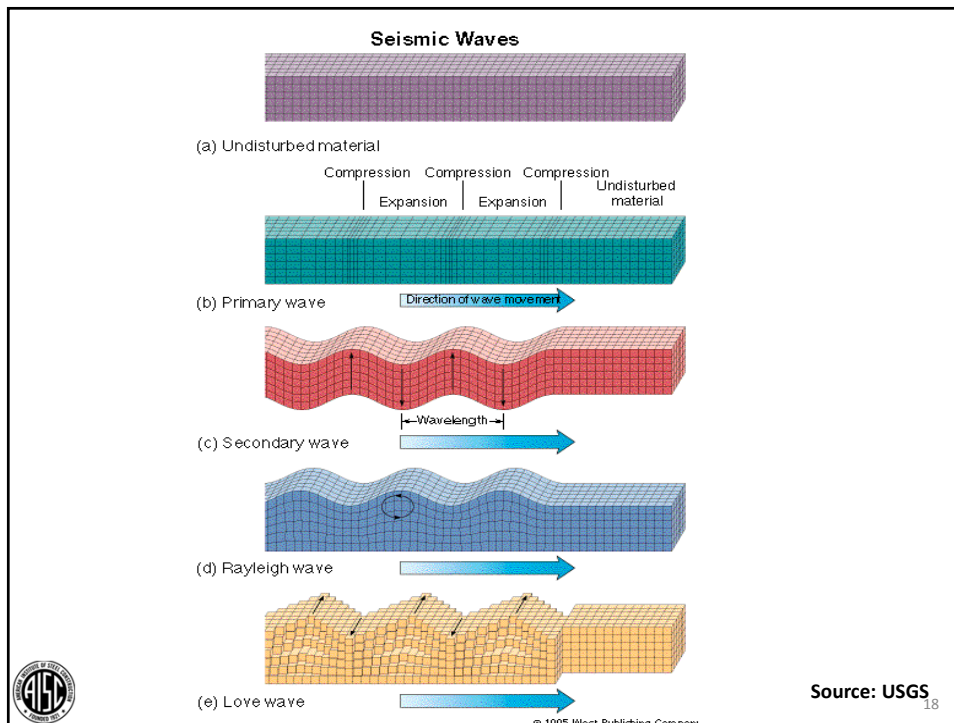
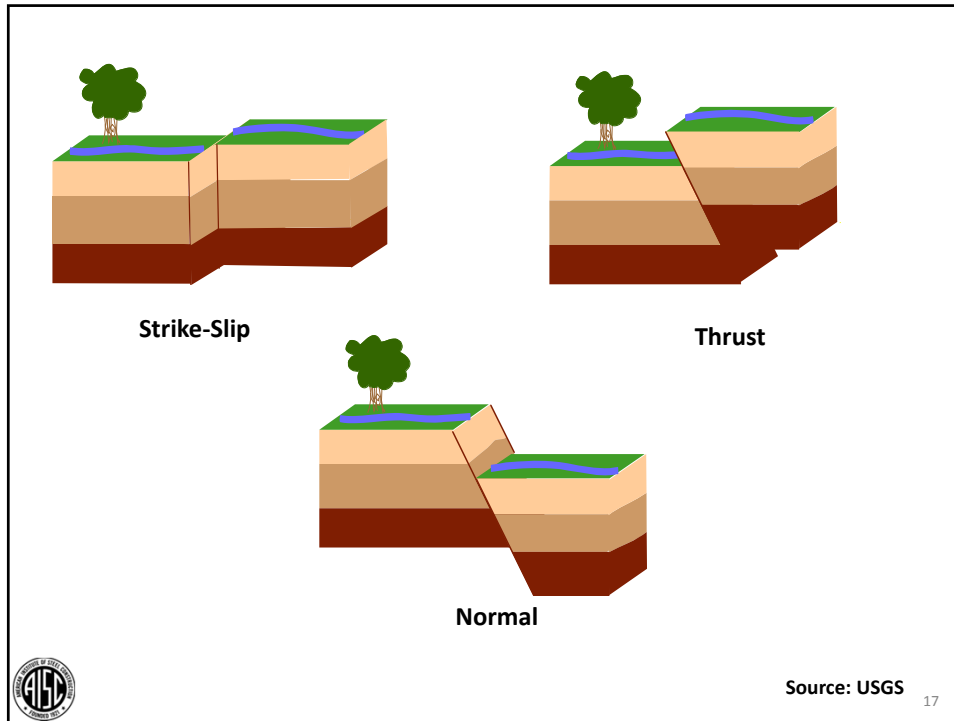
Source: USGS



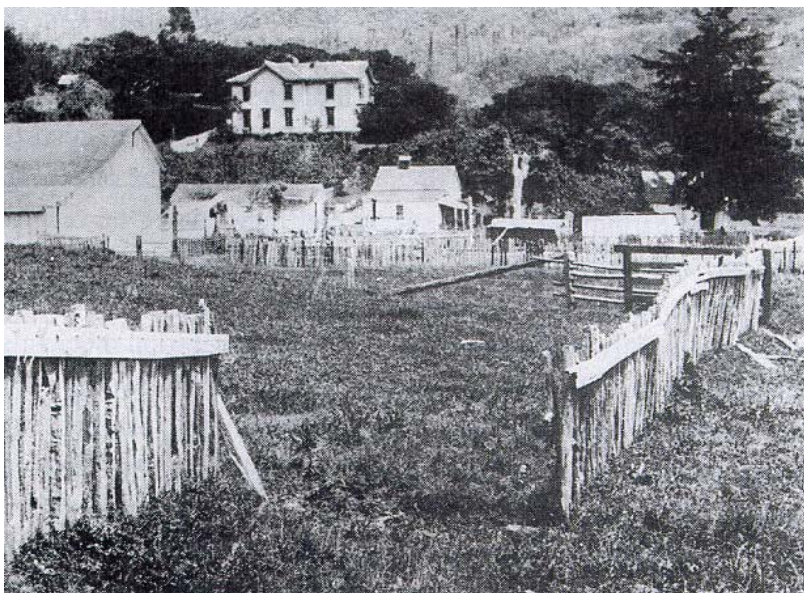
12







1906 San Francisco Earthquake



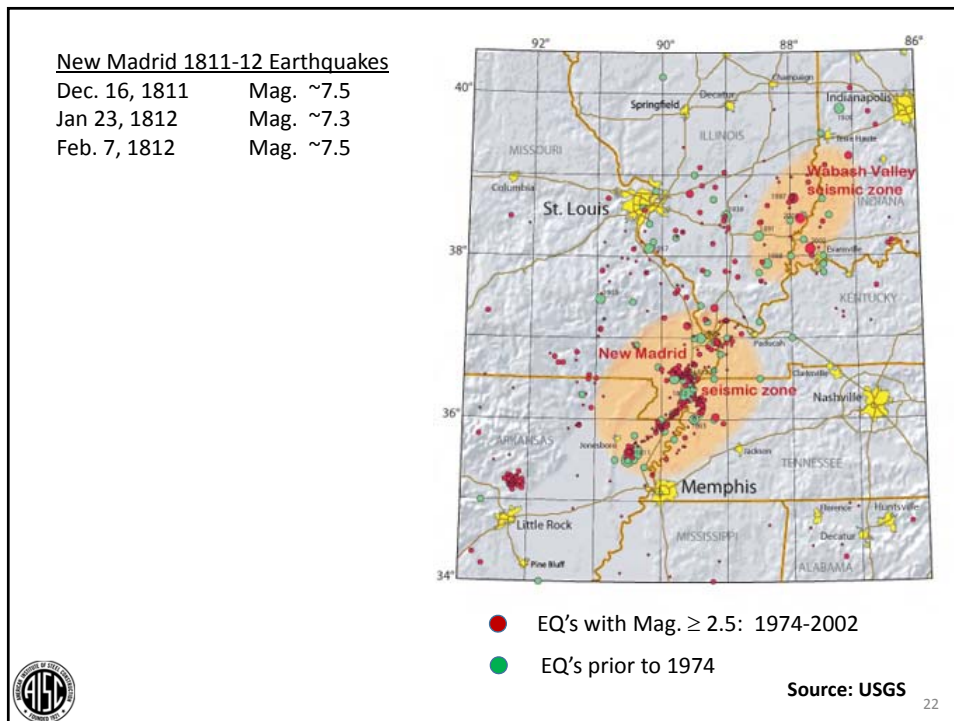
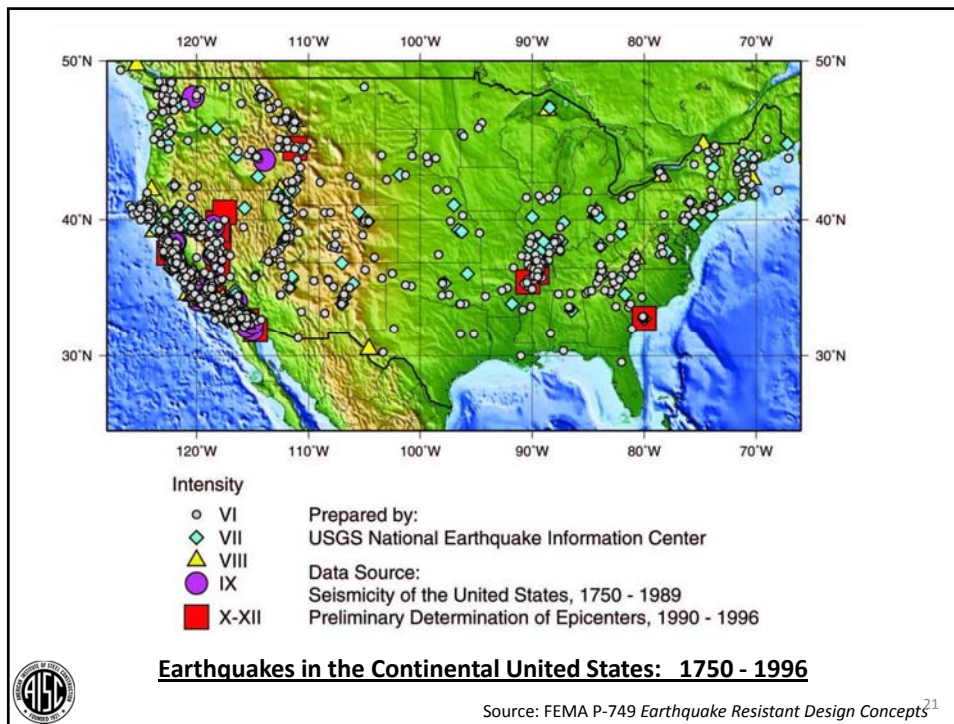
Source: USGS 19

2010 Darfield New Zealand Earthquake

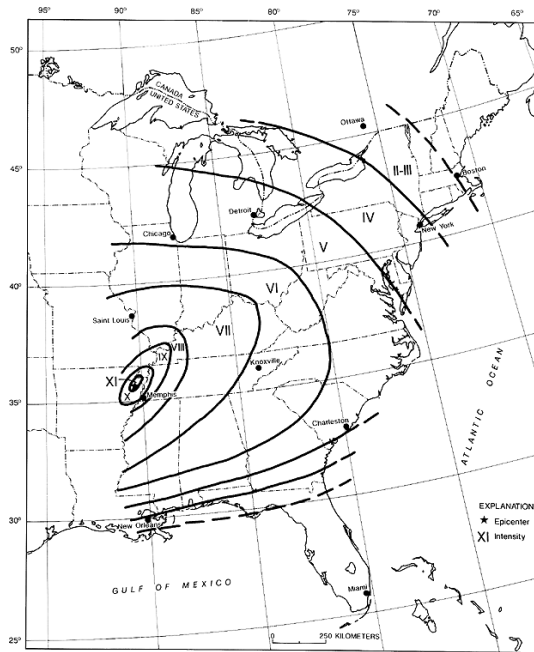


Source: www.gns.cri.nz 20





Dec. 16, 1811 New Madrid EQ:
Estimated Intensities



Source: USGS 23

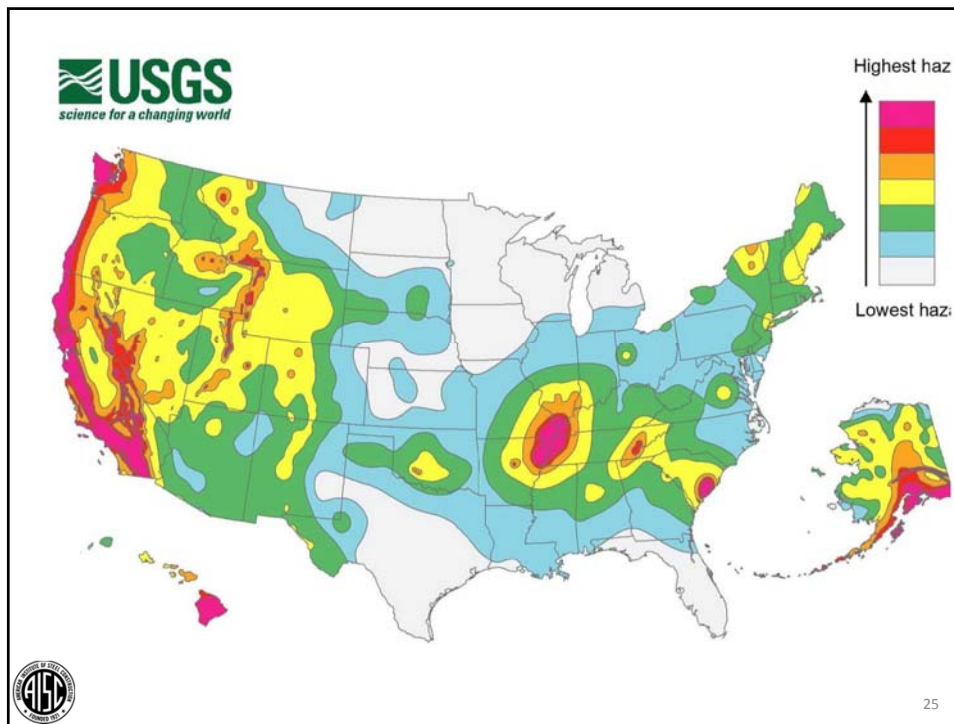


Charleston, South Carolina
EQ Sept 1, 1886
Mag. ~7.3
Approx. 60 fatalities



Source: USGS 24





Earthquake Fatalities....Some of the World's Deadliest Earthquakes

Fatalities	Year	Location
316,000	2010	Haiti
243,000	1976	Tangshan, China
228,000	2004	Sumatra
200,000	1920	Haiyuan, China
143,000	1923	Kanto, Japan
110,000	1948	Turkmeniya, USSR
88,000	2008	Eastern Sichuan, China
86,000	2005	Pakistan
72,000	1908	Messina, Italy
70,000	1970	Chimbote, Peru
40,000	1990	Iran
40,000	1927	Gulang, China
33,000	1939	Erzincan, Turkey
33,000	1915	Avezzano, Italy

Source: USGS

26



Earthquake Fatalities....Some of the World's Deadliest Earthquakes

Fatalities	Year	Location
21,000	2011	Japan
316,000	2010	Haiti
88,000	2008	Eastern Sichuan, China
86,000	2005	Pakistan
228,000	2004	Sumatra
31,000	2003	Southeastern Iran
40,000	1990	Iran
25,000	1988	Spitak, Armenia
243,000	1976	Tangshan, China
23,000	1976	Guatemala
70,000	1970	Chimbote, Peru
110,000	1948	Turkmeniya, USSR
33,000	1939	Erzincan, Turkey
28,000	1939	Chillan, Chile



Source: USGS 27

Earthquake Fatalities....U.S. Earthquakes

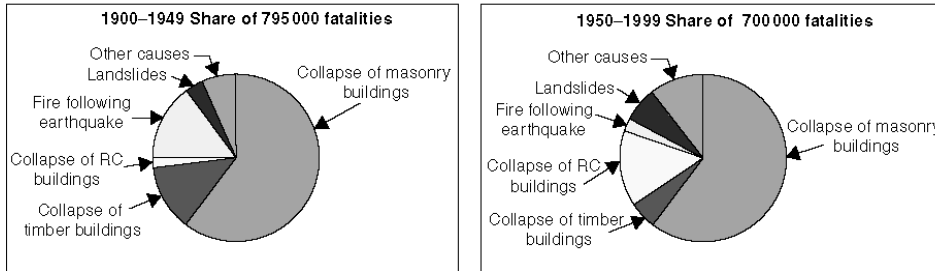
Fatalities	Year	Location
3000	1906	San Francisco
165	1946	Aleutian Islands, Alaska
128	1964	Prince William Sound, Alaska
115	1933	Long Beach, California
77	1868	Hawaii
65	1971	San Fernando, California
63	1989	Loma Prieta, California
60	1994	Northridge, California
60	1886	Charleston, South Carolina



Source: USGS 28



Earthquake Fatalities....Causes



75% of fatalities due to building collapse.



Source: "Earthquake Protection," 2nd Ed.
Andrew Coburn and Robin Spence, Wiley, 2002

29

Major US Earthquakes over Last 50 Years

Year	Location	Fatalities	Property Losses
1964	Prince William Sound, Alaska	125	\$300 Million
1971	San Fernando, California	65	\$500 Million
1989	Loma Prieta, California	63	\$6 Billion
1994	Northridge, California	60	\$20 Billion



30



Northridge Earthquake

- January 17, 1994
- Magnitude = 6.8
- Epicenter at Northridge - San Fernando Valley
- Fatalities: 60
- Estimated Damage: \$20 Billion

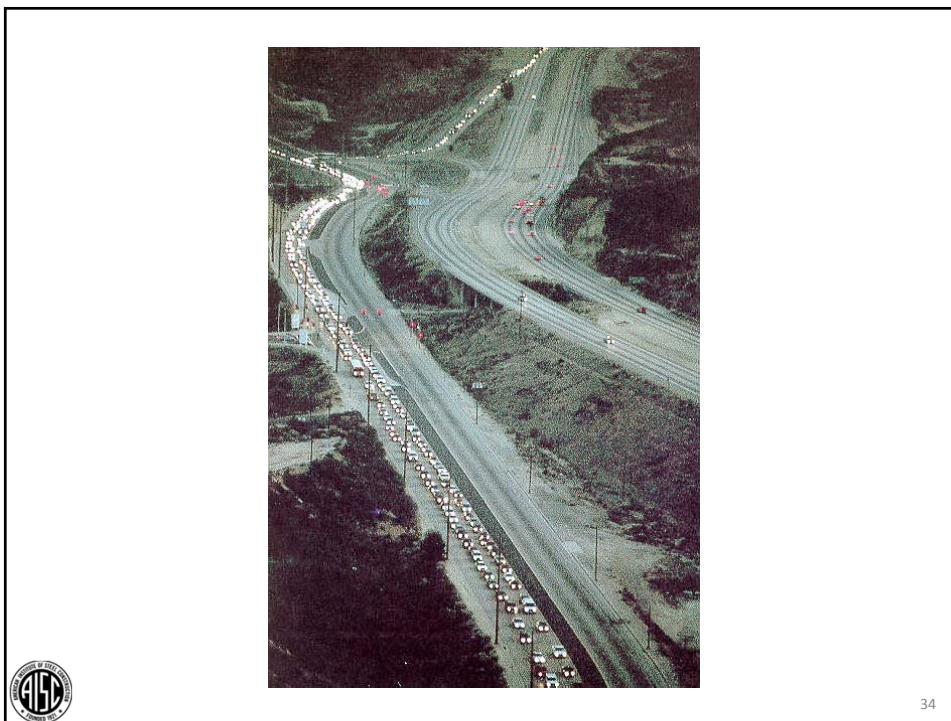


31



Source: FEMA

32









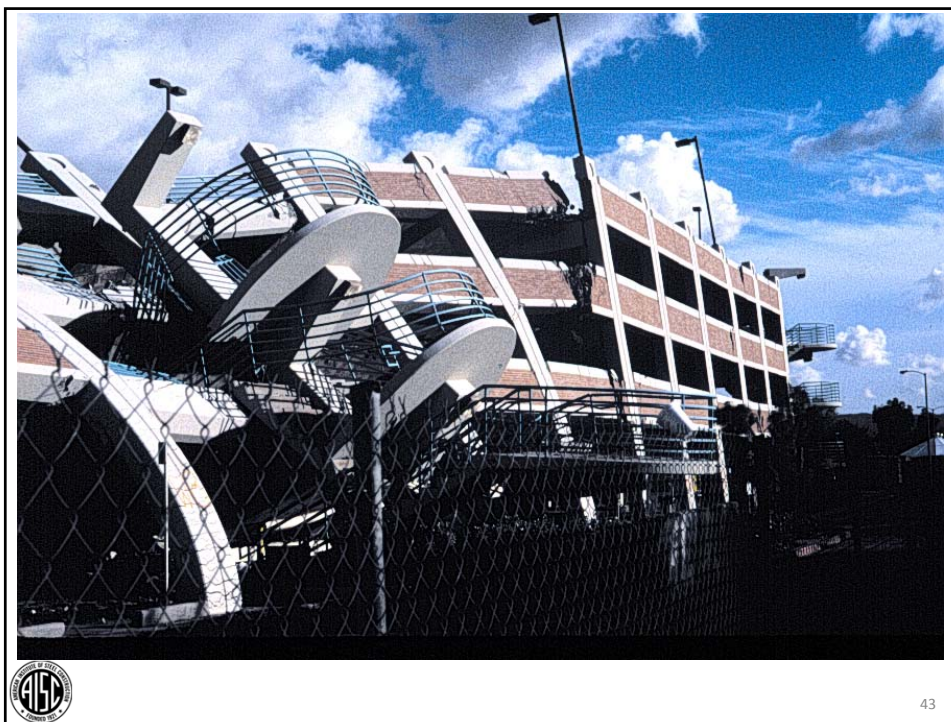


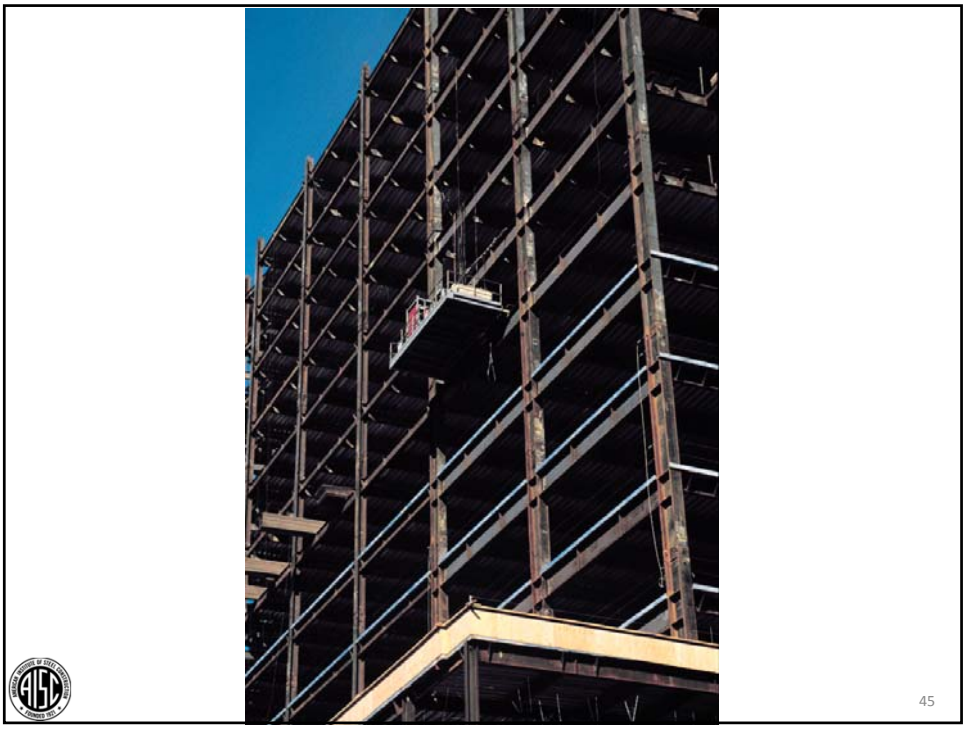
41



42









47

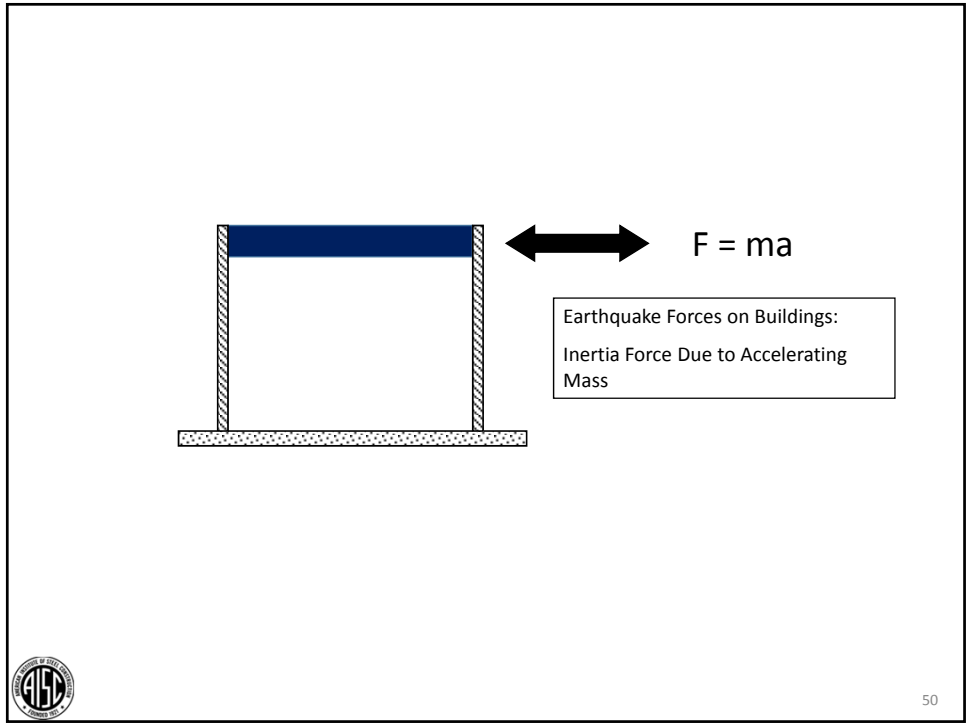
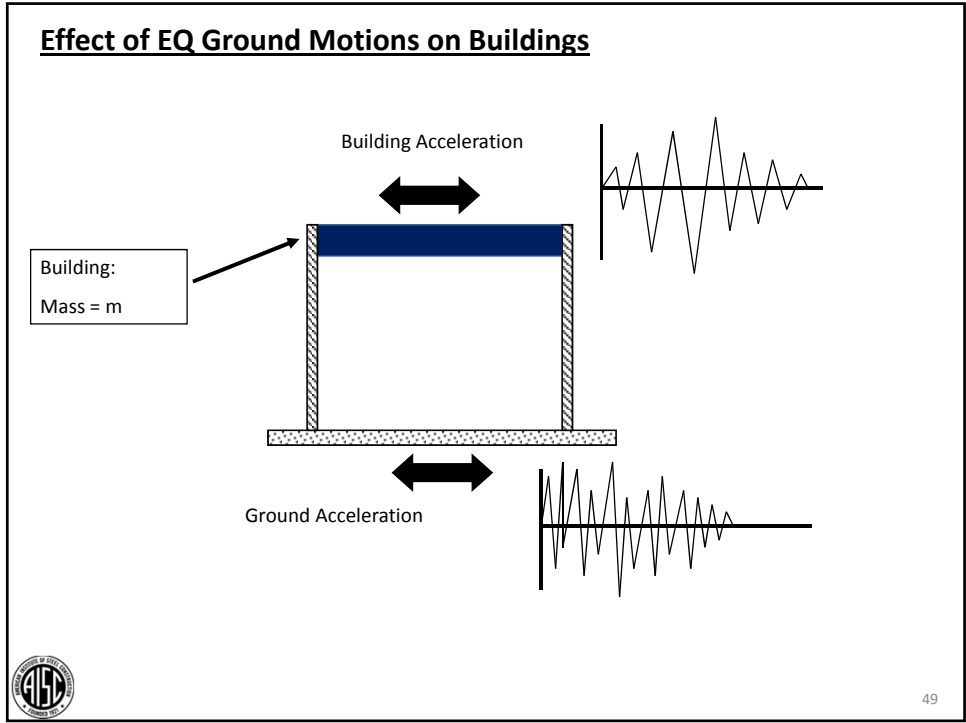
Seismic Design for Non-West Coast Engineers

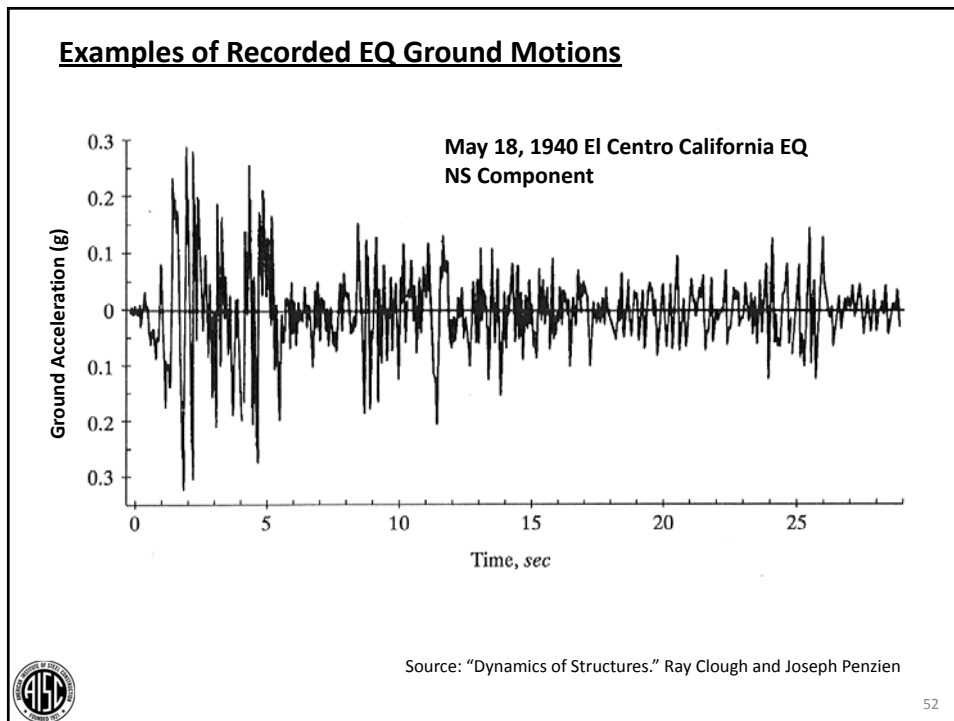
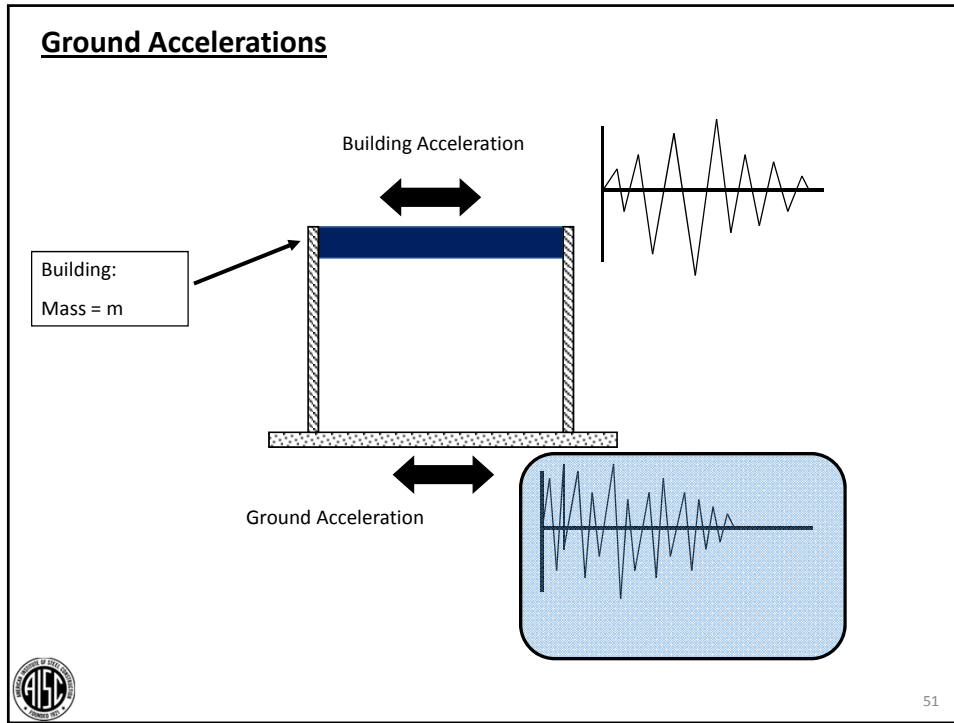
Part 1

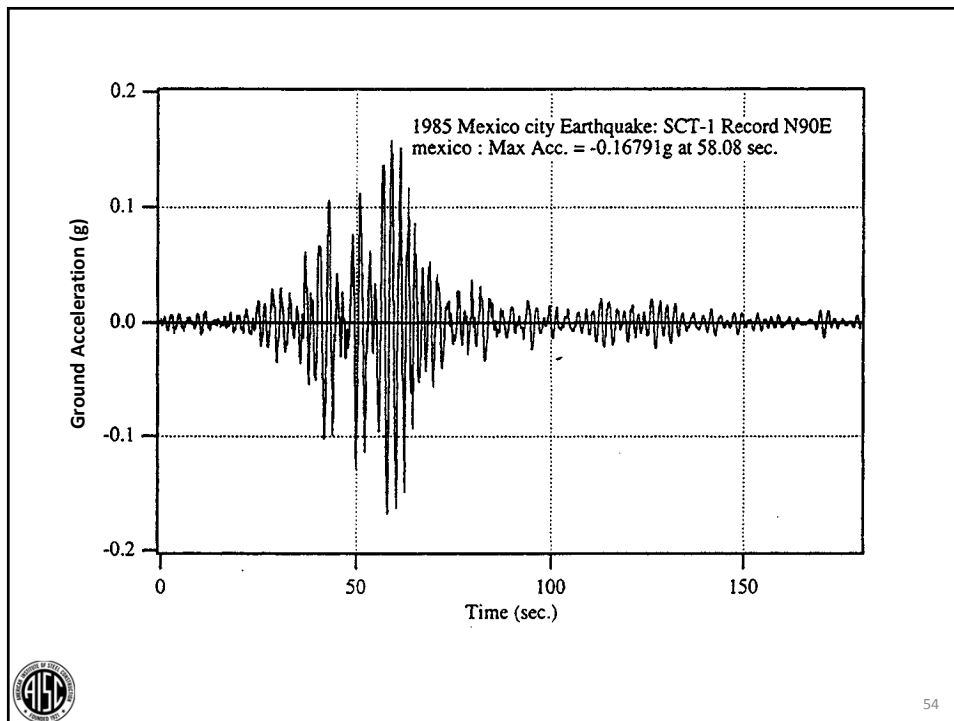
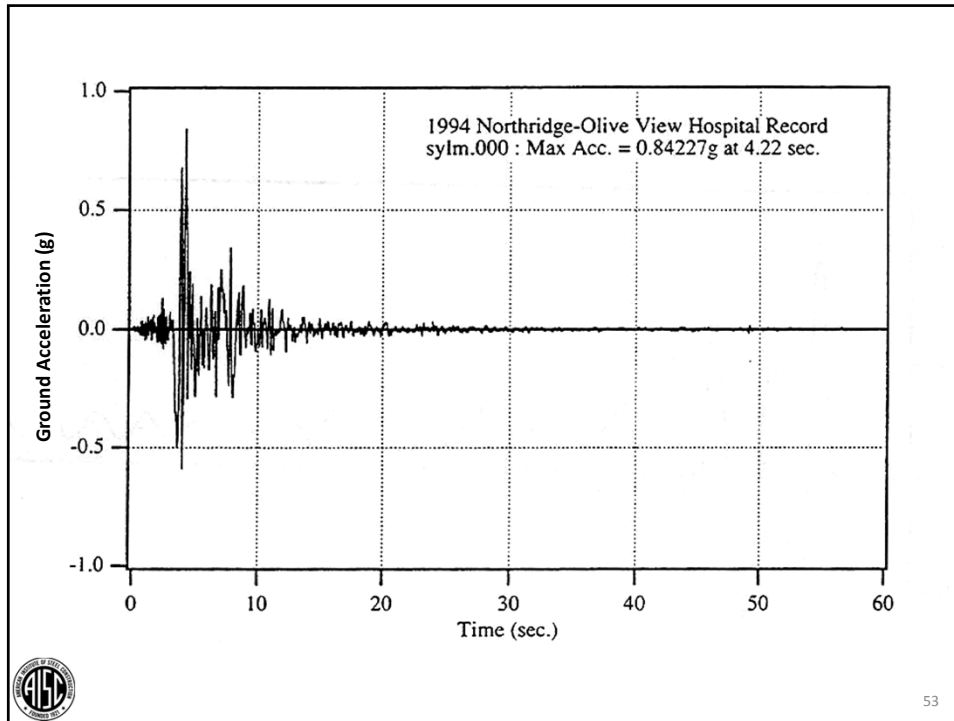
- Causes, Location, and Impact of Earthquakes
- EQ Forces on Buildings
- Overall Philosophy and Approach for EQ-Resistant Design
- Role of Ductility in EQ-Resistant Design

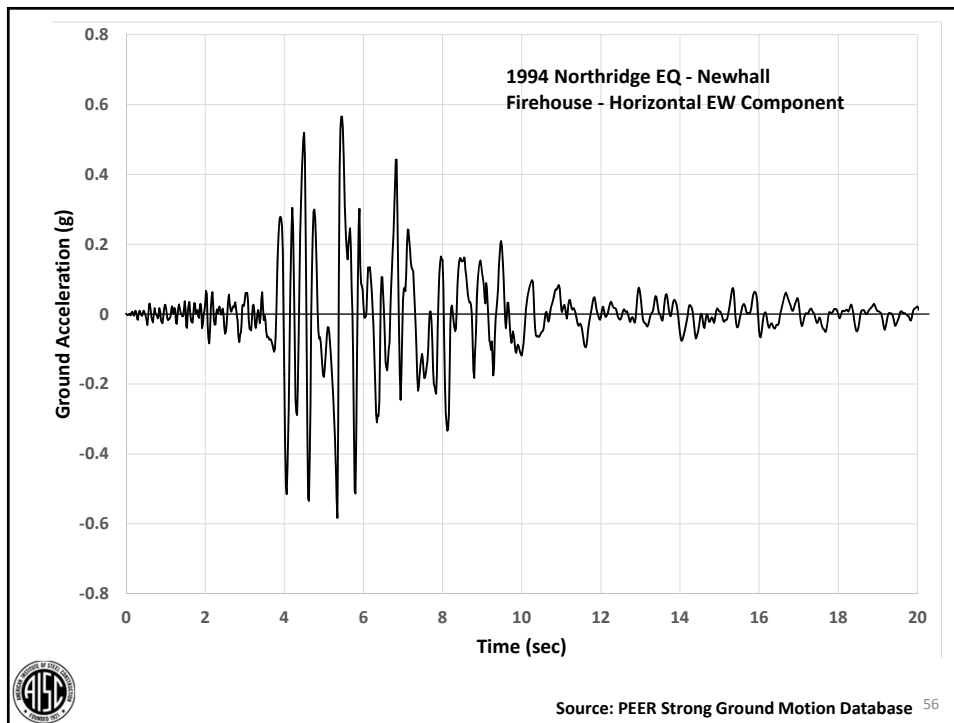
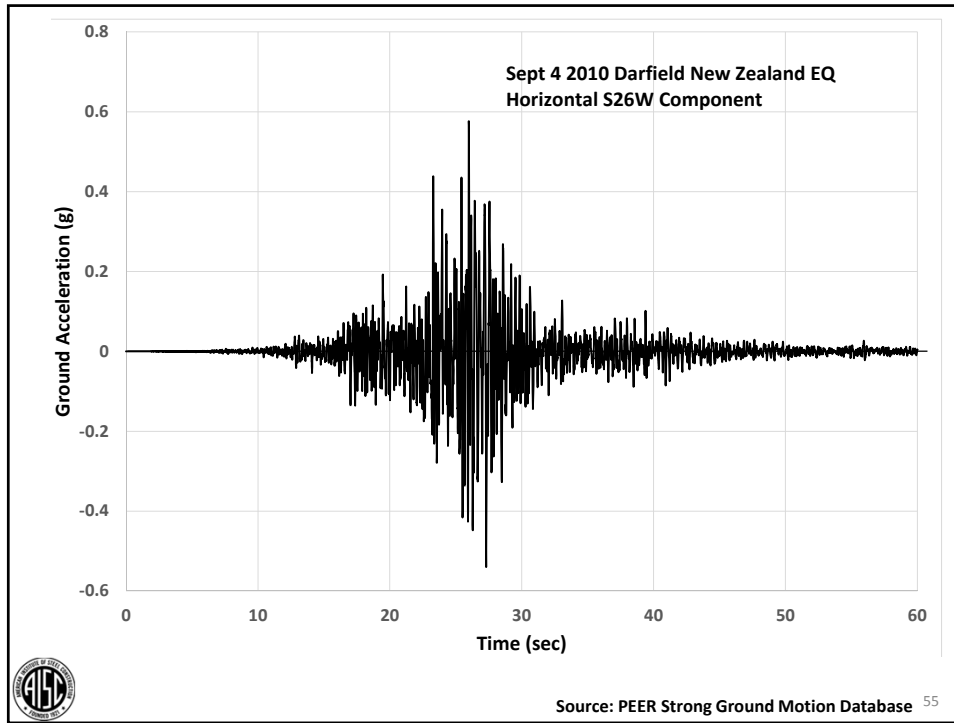


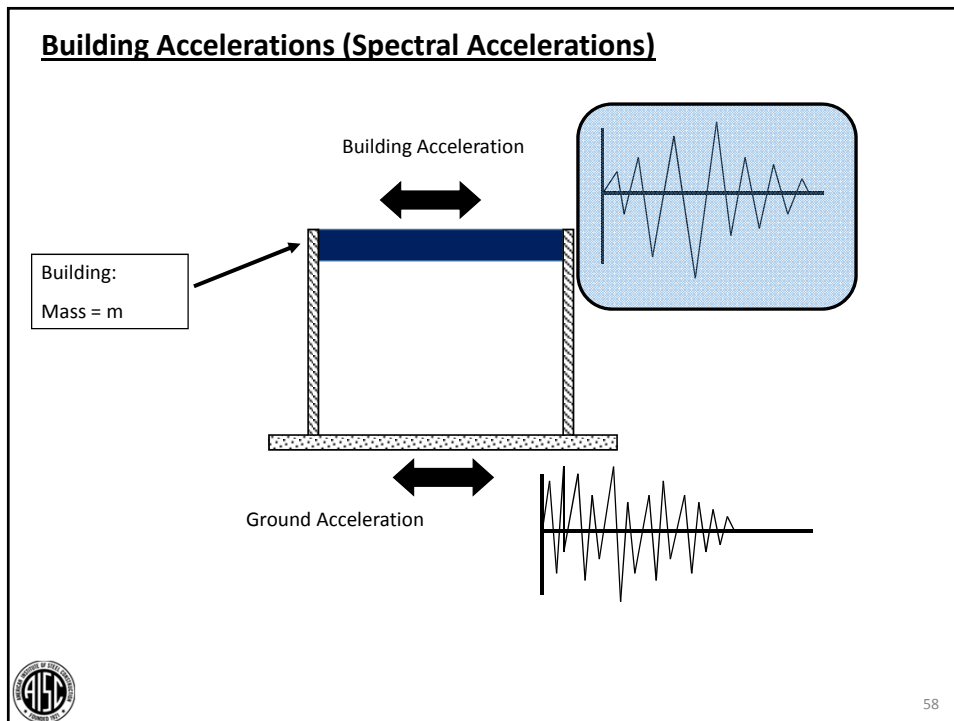
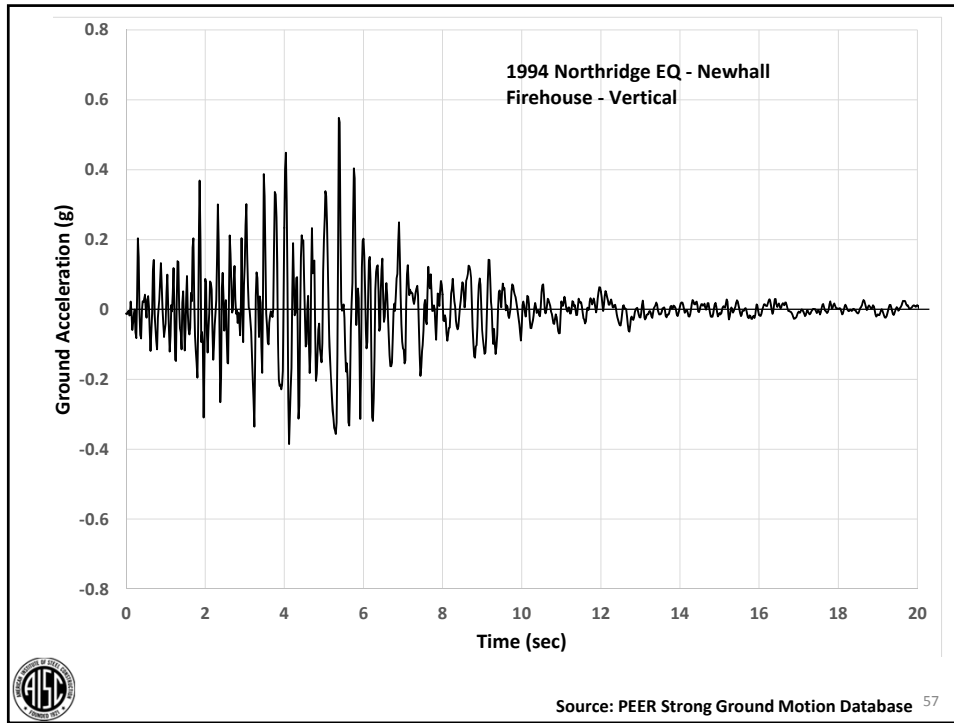
48





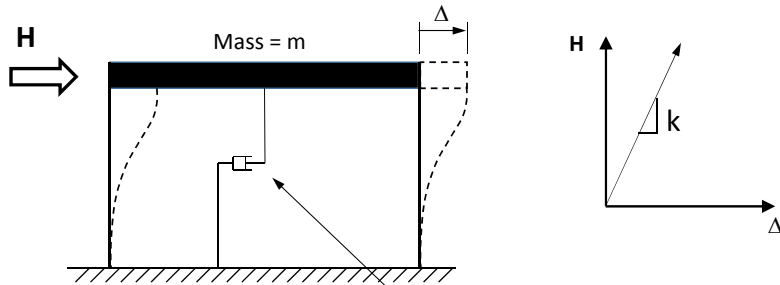






Structural Response to EQ Ground Motions: Elastic Response Spectrum for SDOF Systems

Elastic Single Degree of Freedom (SDOF) System



Characteristics of SDOF System:

Mass = m
Elastic stiffness = k
Damping ratio (0.02, 0.05 etc)

Damping (expressed as a damping ratio)

Natural Period of Vibration:

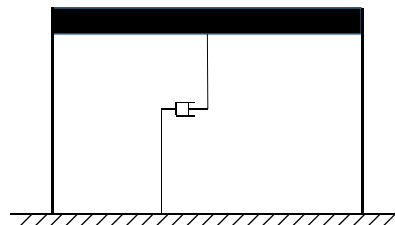
$$T = 2\pi\sqrt{\frac{m}{k}}$$



59

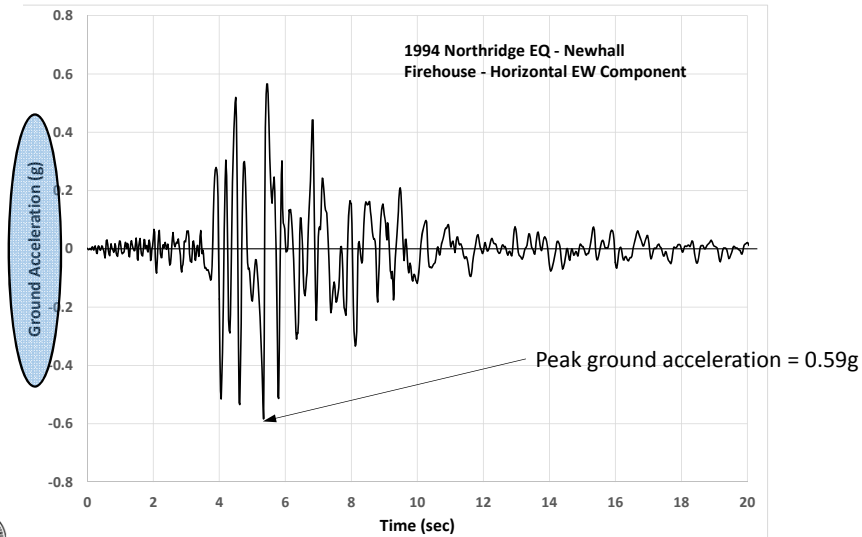
Structural Response to EQ Ground Motions: Elastic Response Spectrum for SDOF Systems

- Choose (SDOF) System with specified period T and specified damping ratio
- Choose ground acceleration record.
- Determine response of SDOF system to ground motion record.
- Peak acceleration of SDOF = **spectral acceleration** for selected period and damping ratio.
- Repeat analysis for different values of SDOF period T .
- Plot results as an **acceleration response spectrum**.



60

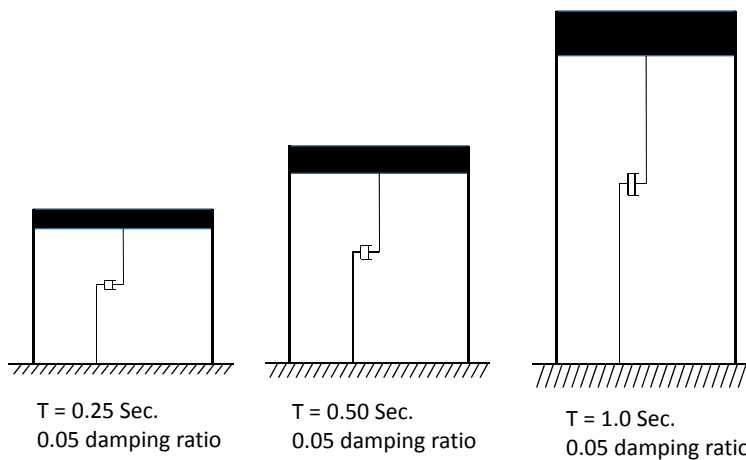
Example SDOF Response
Record: 1994 Northridge EQ Newhall Firehouse EW Record



61

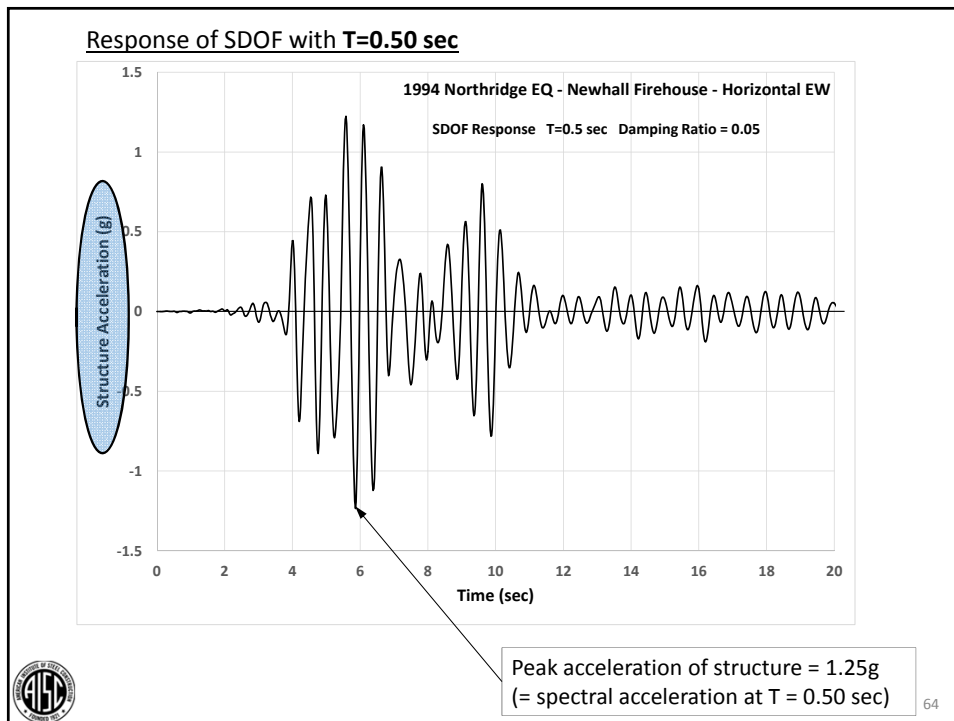
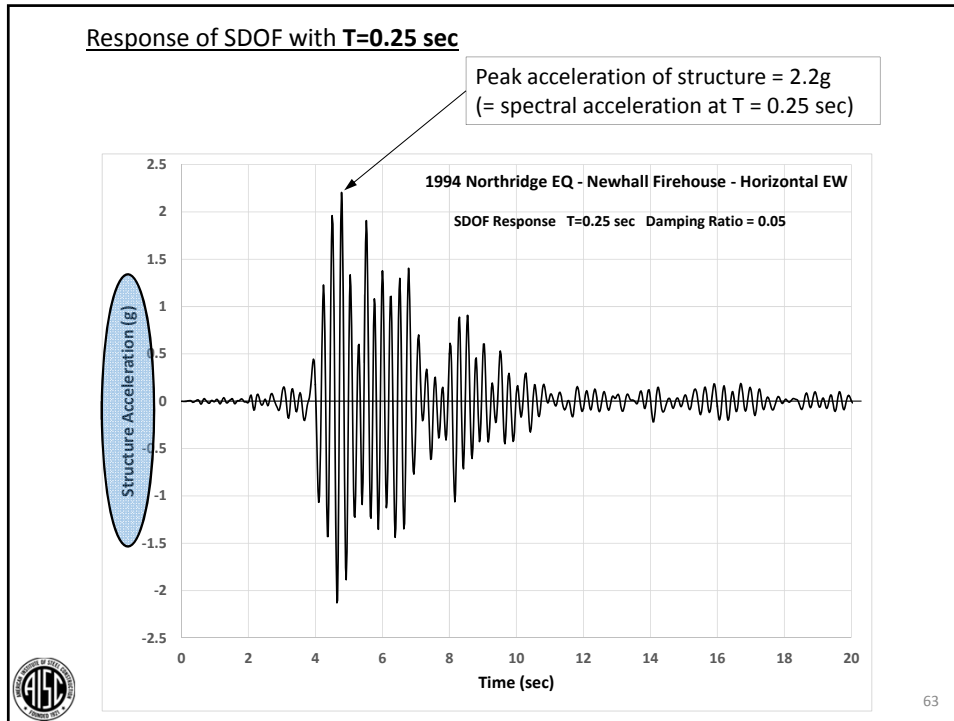
Example SDOF Response
Record: 1994 Northridge EQ Newhall Firehouse EW Record

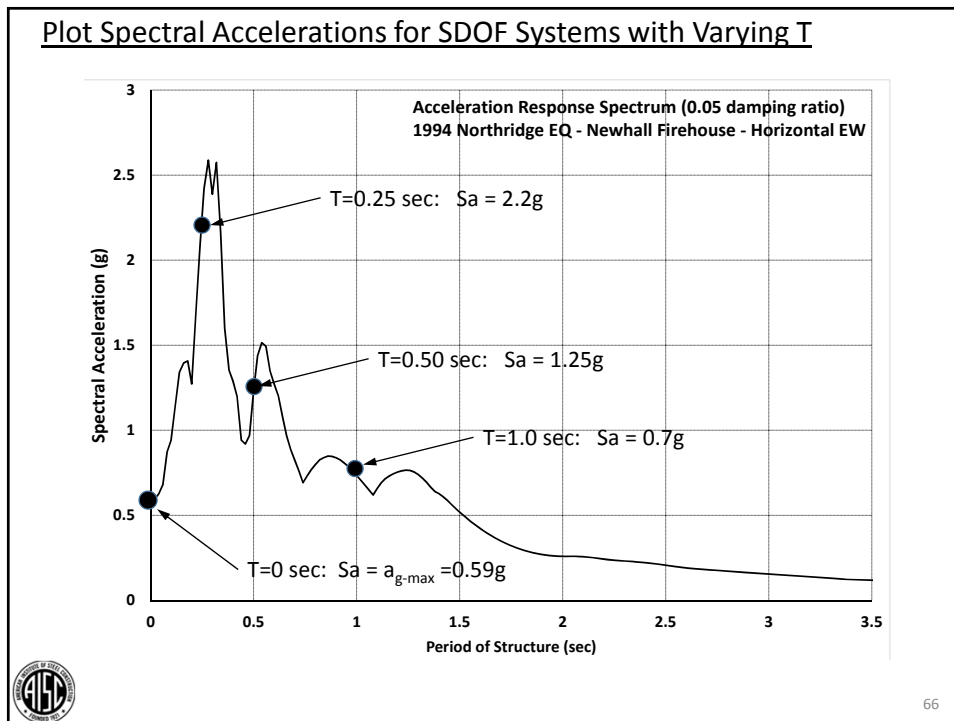
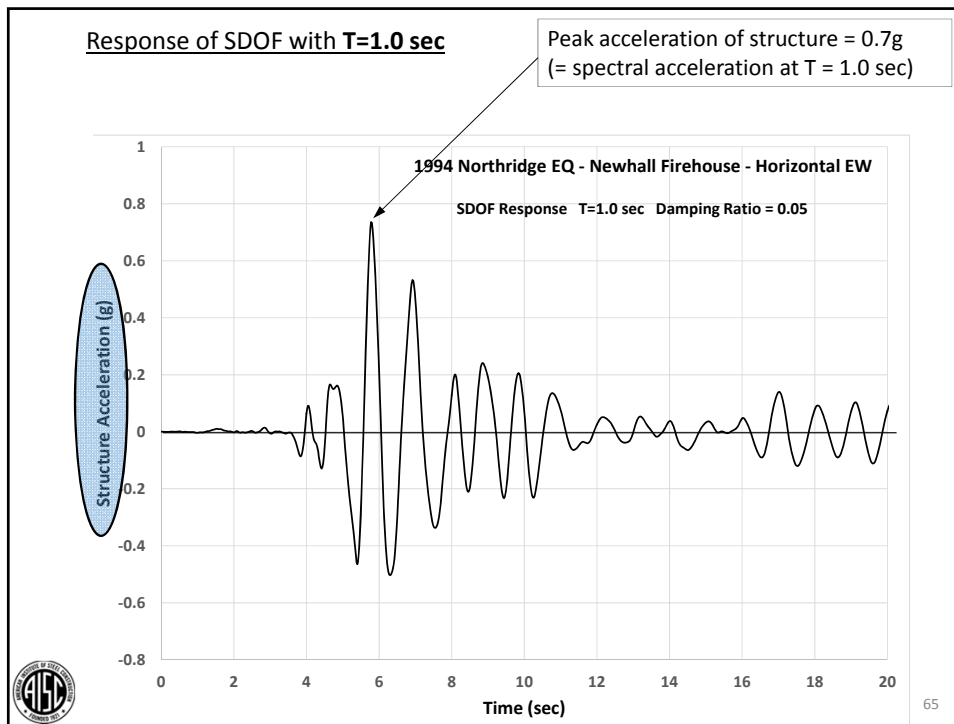
Analysis of Three SDOF Systems:

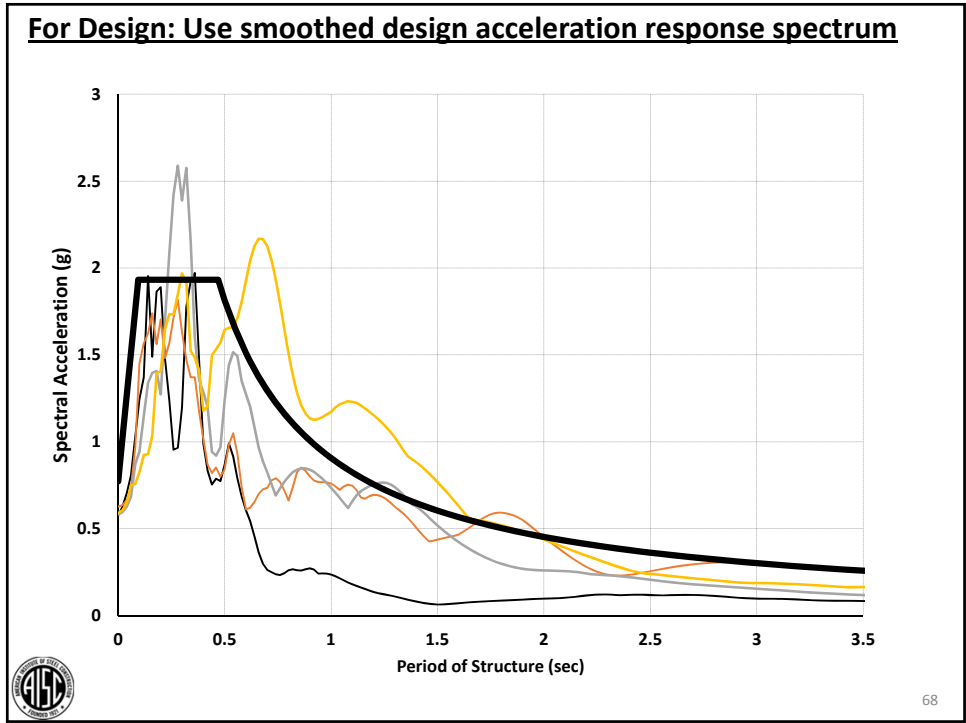
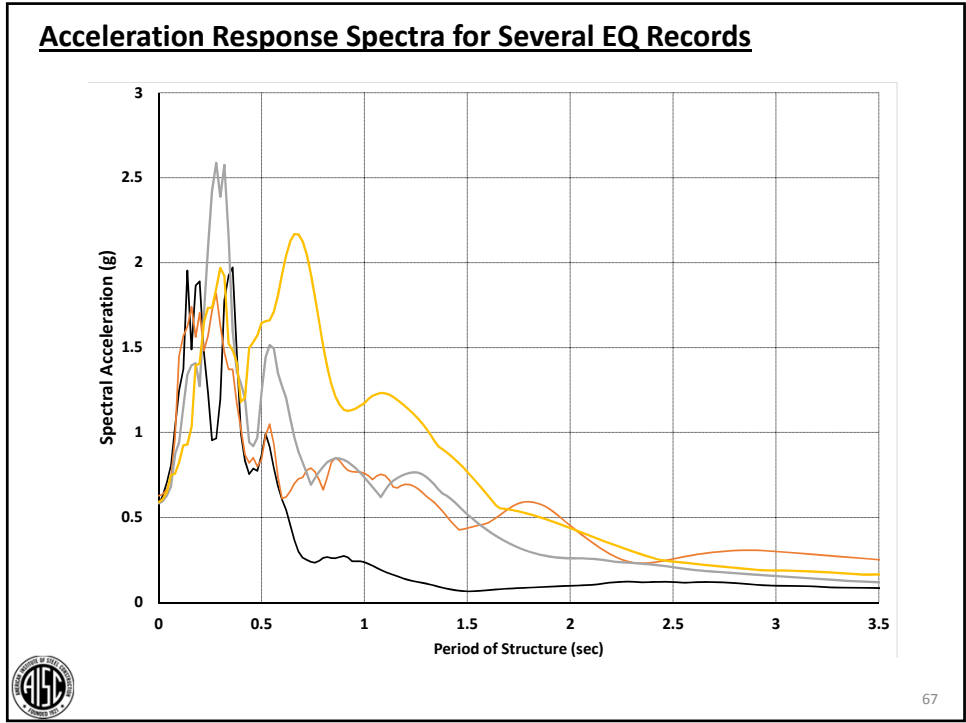


62









Approximate Fundamental Period of a Building Structure

See ASCE 7-10: Section 12.8.2 *Period Determination*

Approximate Fundamental Period = T_a (seconds)

For buildings with moment frames and no more than 12 stories:

$$T_a = \frac{N}{10} \quad N = \text{number of stories}$$

- Examples:
- N = 2 stories: T = 0.2 sec
 - N = 5 stories: T = 0.5 sec
 - N = 10 stories: T = 1.0 sec



Approximate Fundamental Period of a Building Structure

See ASCE 7-10: Section 12.8.2 *Period Determination*

For any system:

$$T_a = C_t h_n^x \quad h_n = \text{structural height (ft.)}$$

Table 12.8-2 Values of Approximate Period Parameters C_t and x

Structure Type	C_t	x
Moment-resisting frame systems in which the frames resist 100% of the required seismic force and are not enclosed or adjoined by components that are more rigid and will prevent the frames from deflecting where subjected to seismic forces:		
Steel moment-resisting frames	0.028 (0.0724) ^a	0.8
Concrete moment-resisting frames	0.016 (0.0466) ^a	0.9
Steel eccentrically braced frames in accordance with Table 12.2-1 lines B1 or D1	0.03 (0.0731) ^a	0.75
Steel buckling-restrained braced frames	0.03 (0.0731) ^a	0.75
All other structural systems	0.02 (0.0488) ^a	0.75

^aMetric equivalents are shown in parentheses.



Examples:

- 5 Story Steel Moment Frame. $h_n = 65 \text{ ft.}$

$$C_t = 0.028 \quad x = 0.8 \quad T_a = 0.028 (65)^{0.8} = 0.8 \text{ sec}$$

- 5 Story Steel Concentrically Braced Frame. $h_n = 65 \text{ ft.}$

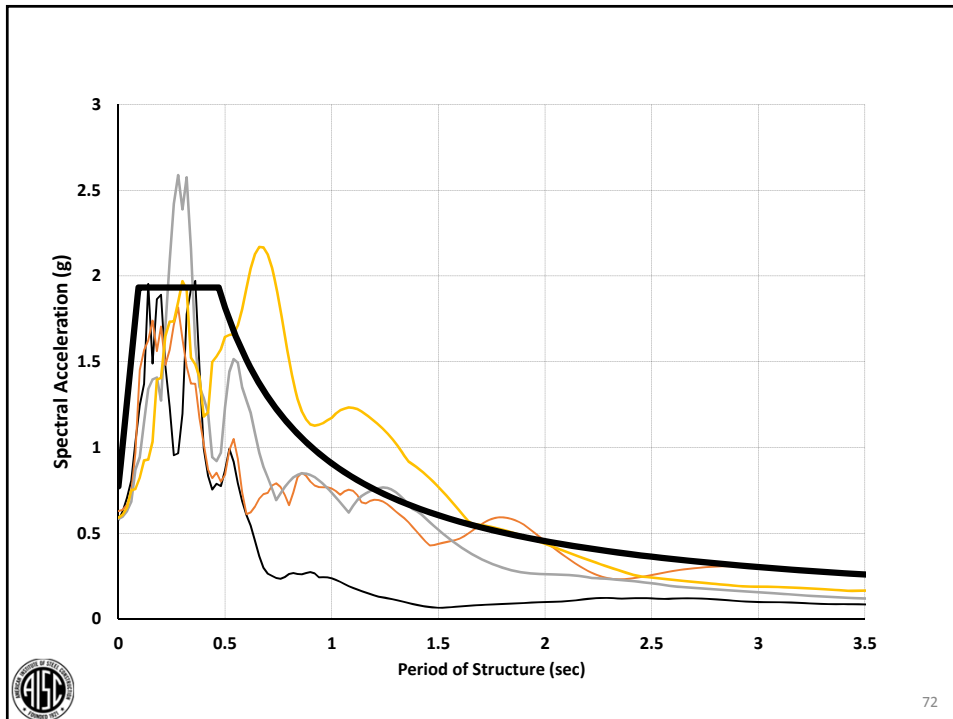
$$C_t = 0.02 \quad x = 0.75 \quad T_a = 0.02 (65)^{0.75} = 0.46 \text{ sec}$$

- 20 Story Steel Moment Frame. $h_n = 250 \text{ ft.}$

$$C_t = 0.028 \quad x = 0.8 \quad T_a = 0.028 (250)^{0.8} = 2.32 \text{ sec}$$

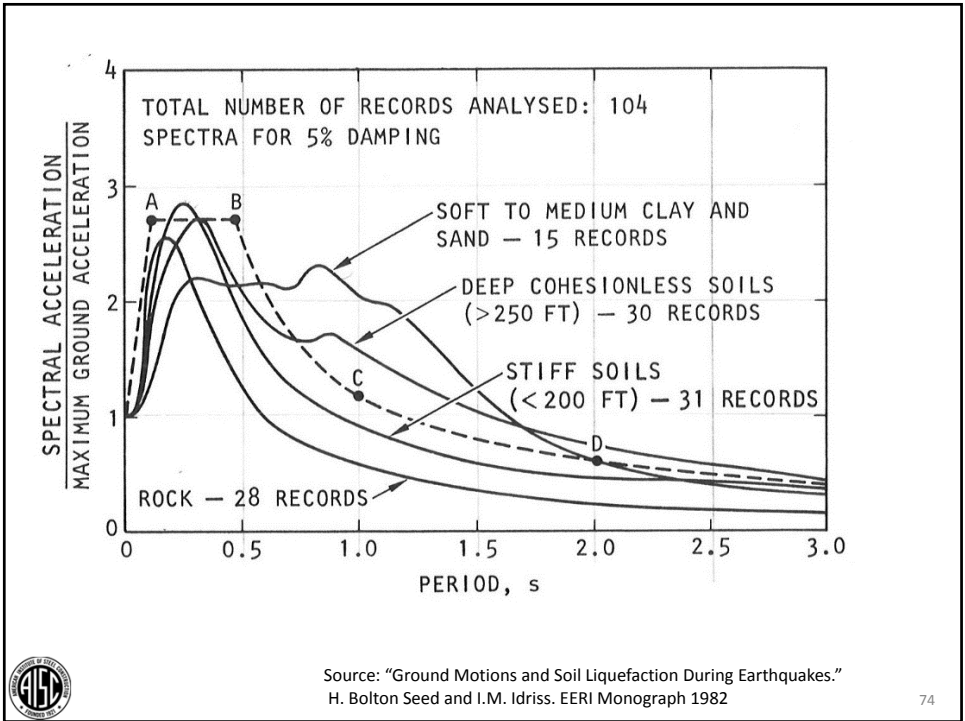
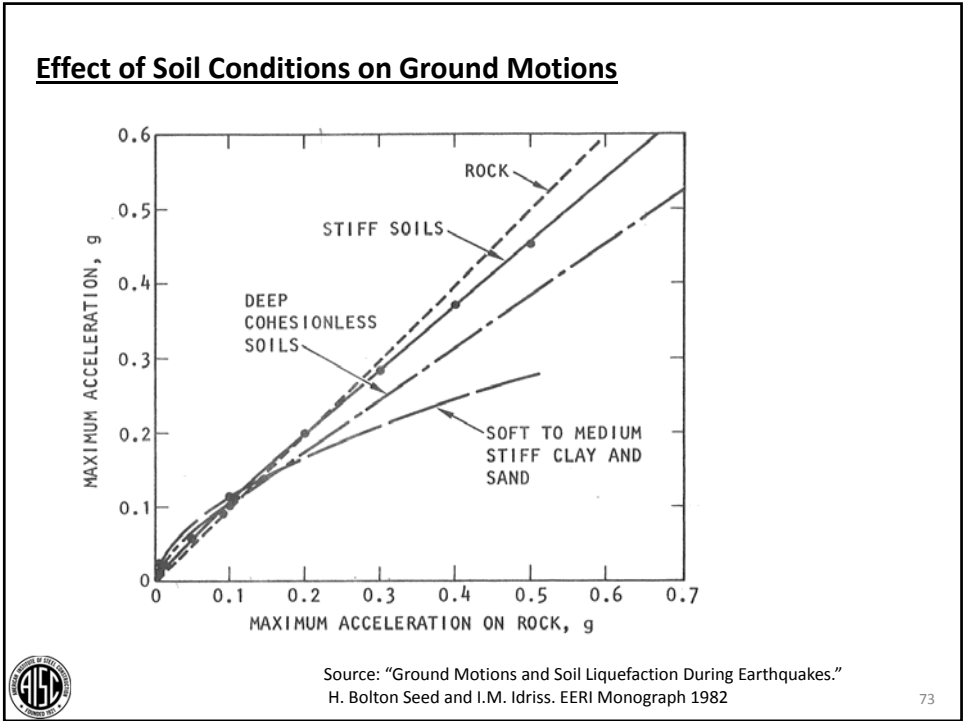


71

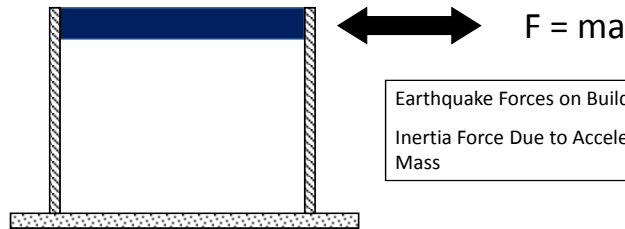


72





Earthquake Forces on Elastic Structure



Earthquake Forces on Buildings:
 Inertia Force Due to Accelerating
 Mass

For a strong earthquake:

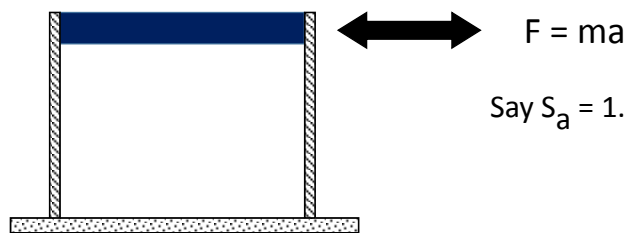
Max ground acceleration = $a_{g-max} \approx 0.2 g$ to $0.8 g$

Max. acceleration of structure ($=S_a$) $\approx 1 g$ to $2.5 g$



75

Earthquake Forces on Elastic Structure



Say $S_a = 1.5 g$

$$F_{max} = m (1.5g)$$

$$m = \frac{W}{g}$$

$$F_{max} = \left(\frac{W}{g} \right) 1.5g$$

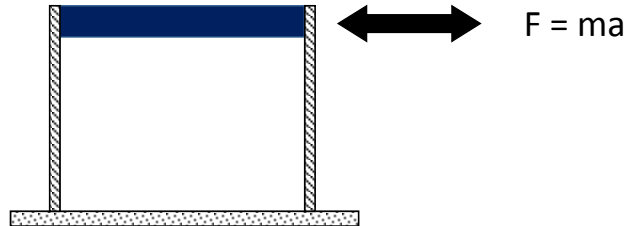
$$F_{max} = 1.5 W$$



76



Earthquake Forces on Elastic Structure



Maximum force experienced by an elastic structure $\approx (1 \text{ to } 2.5) * W$

Typical design lateral force per building code: $F_{max} \approx (0.1 \text{ to } 0.2) * W$

How is this possible ?

We do not design buildings to remain elastic in strong earthquakes



77

Seismic Design for Non-West Coast Engineers

Part 1

- Causes, Location, and Impact of Earthquakes
- EQ Forces on Buildings
- Overall Philosophy and Approach for EQ-Resistant Design
- Role of Ductility in EQ-Resistant Design



78

Conventional Building Code Philosophy for Earthquake-Resistant Design

Objective: Prevent collapse in the extreme earthquake likely to occur at a building site.

Objectives are not to:

- limit damage
- maintain function
- provide for easy repair



79



Earthquake-Resistant Design Concepts

An Introduction to the NEHRP Recommended Seismic Provisions for New Buildings and Other Structures

FEMA P-749 / December 2010



Free download:

<http://www.nibs.org/?page=bssc>

80



FEMA P-749

2.2 Acceptable Risk

Defining acceptable risk is difficult because the risk that is acceptable to one person may be unacceptable to many others. Often a person's perception of an acceptable level of risk depends on whether or not the person believes he or she will be personally affected and how much the person is being asked to personally spend to avoid the risk. The *NEHRP Recommended Seismic Provisions* has adopted the following target risks as the minimum acceptable for buildings and structures constructed in the United States:

A small chance (on the order of 10 percent) that any structure will experience partial or total collapse as a result of the most intense earthquake ground motion considered by the building codes. These very rare and intense earthquake effects are called risk-targeted maximum considered earthquake (MCE_2) ground motions and the probability of their occurrence varies across the nation. This collapse-prevention goal is intended as the primary means of ensuring life safety in that most casualties in past earthquakes occurred as a result of structural collapse. Although protection at this level does not guarantee no lives will be lost, it should prevent the loss of tens of thousands of lives in individual earthquake events such as those that occurred in Armenia, China, Haiti, Turkey, and other nations in recent years.



Earthquake-Resistant Design Concepts

An Introduction to the NEHRP Recommended Seismic Provisions for New Buildings and Other Structures

FEMA P-749 / December 2010



NEHRP Recommended Seismic Provisions

for New Buildings and Other Structures

FEMA P-750 / 2009 Edition



Conventional Building Code Philosophy for Earthquake-Resistant Design

Objective: Prevent collapse in the extreme earthquake likely to occur at a building site.

Objectives are not to:

- limit damage
- maintain function
- provide for easy repair



83

Seismic Design for Non-West Coast Engineers

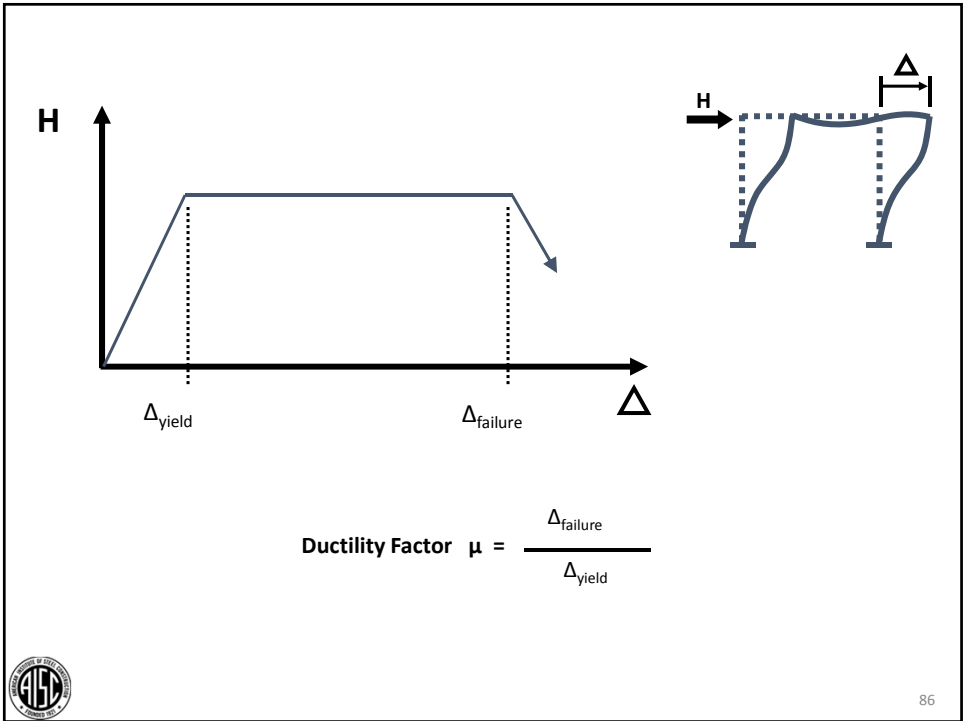
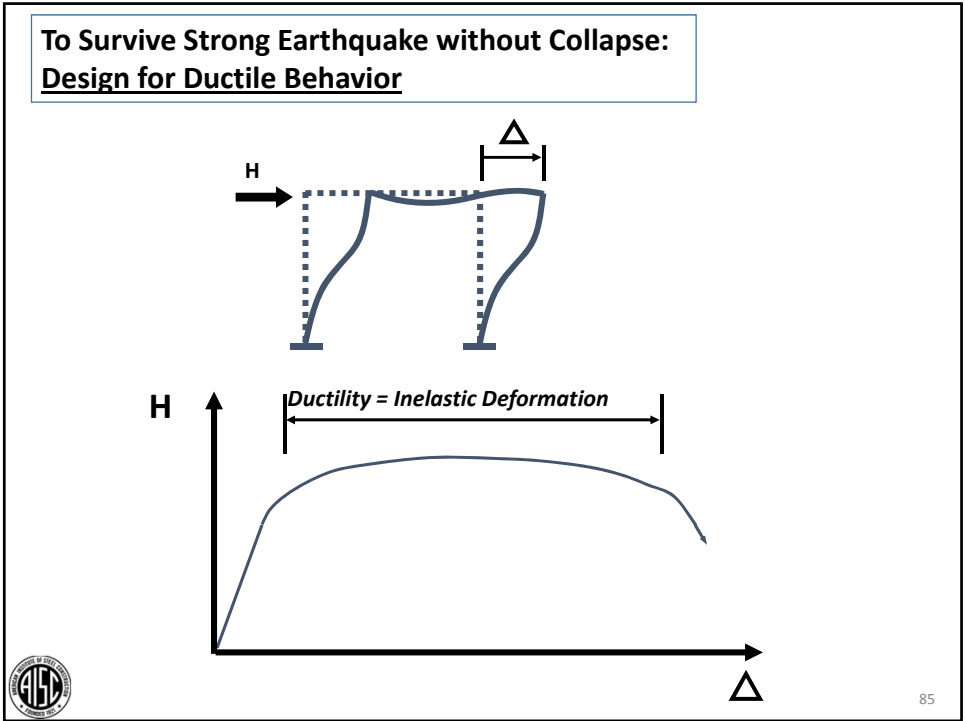
Part 1

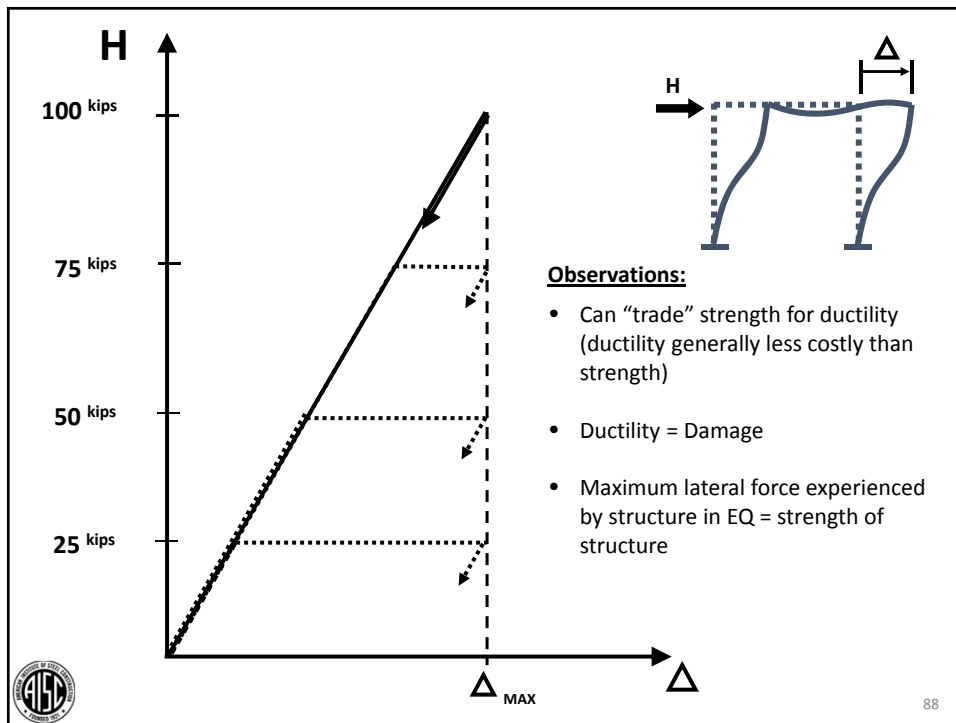
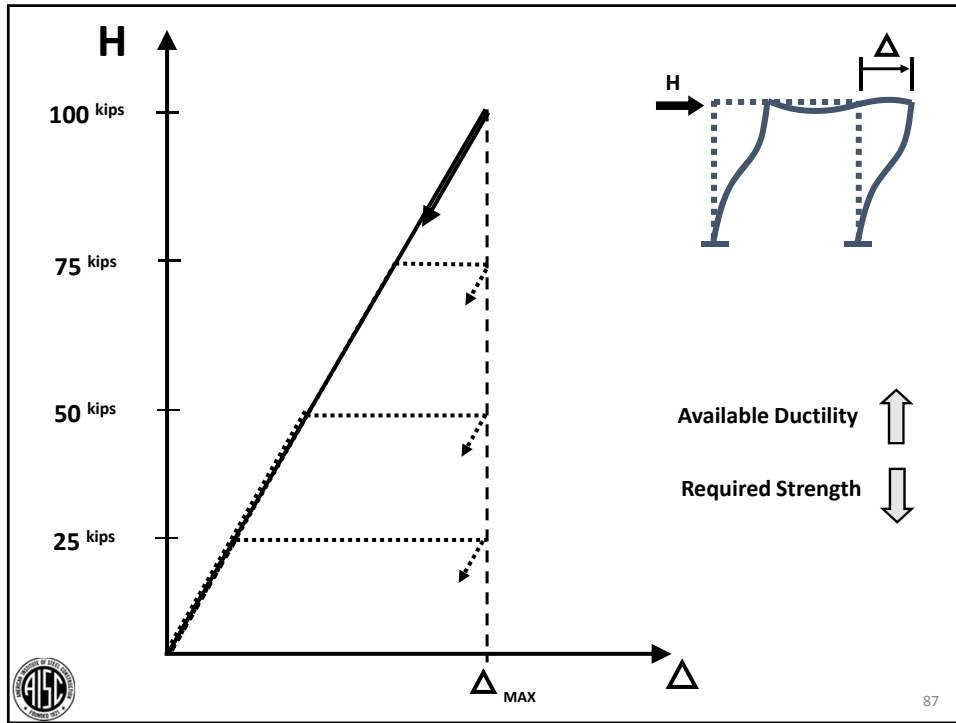
- Causes, Location, and Impact of Earthquakes
- EQ Forces on Buildings
- Overall Philosophy and Approach for EQ-Resistant Design
- Role of Ductility in EQ-Resistant Design



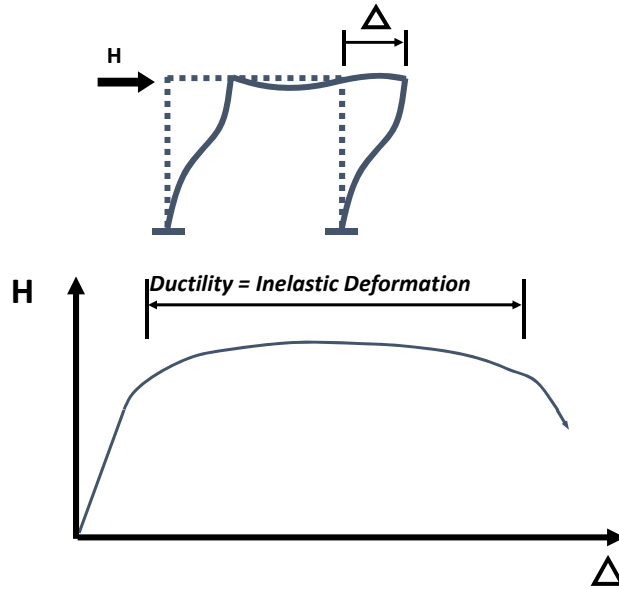
84







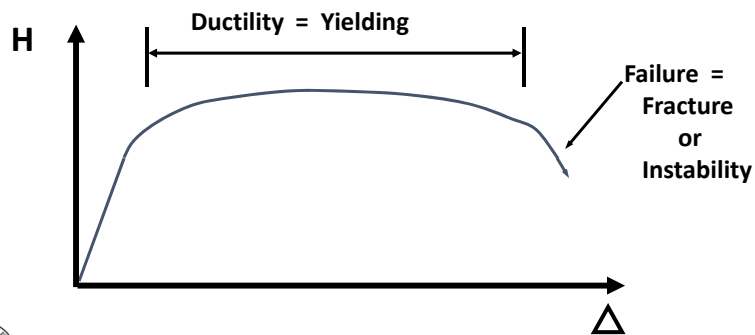
**To Survive Strong Earthquake without Collapse:
Design for Ductile Behavior**



89

Ductility in Steel Structures: *Yielding*

Nonductile Failure Modes: *Fracture or Instability*



90



Seismic Design for Non-West Coast Engineers

Part 1 (August 10, 2017)

- **Causes, Location, and Impact of Earthquakes**
- **EQ Forces on Buildings**
- **Overall Philosophy and Approach for EQ-Resistant Design**
- **Role of Ductility in EQ-Resistant Design**



91

Seismic Design for Non-West Coast Engineers

Part 2 (August 17, 2017)

- **Steel Structures: Performance in Past EQs**
- **EQ Resistant Design per ASCE 7-10**
- **Structural Steel Seismic Force-Resisting Systems in the *AISC Seismic Provisions***
- **References for Further Learning**



92



Question 1

True or False: The term “spectral acceleration” refers to the peak ground acceleration in an earthquake.

- a) True
- b) False



93

Question 2

True or False: Most buildings designed in accordance with the building code would be expected to experience significant structural damage during a major earthquake.

- a) True
- b) False



94

PDH Certificates

Within 2 business days...

- You will receive an email on how to report attendance from: registration@aisc.org.
- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!



PDH Certificates

Within 2 business days...

- Reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.



There's always a solution in steel.

Thank You

Please give us your feedback!
Survey at conclusion of webinar.

