AISC Night School

Fundamentals of earthquake engineering for building structures

Session 1: Seismology and Earthquake Effects

February 8, 2021 | Rafael Sabelli

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Course Description

Session 1: Seismology and Earthquake Effects

February 8, 2021

This lecture discusses plate tectonics as the source of seismic energy release and addresses earthquake measures and the concepts of magnitude and intensity. As well, local and widespread earthquake effects will be presented. Probability concepts, return periods and risk in addition to issues of related hazards, including tsunamis will be presented.

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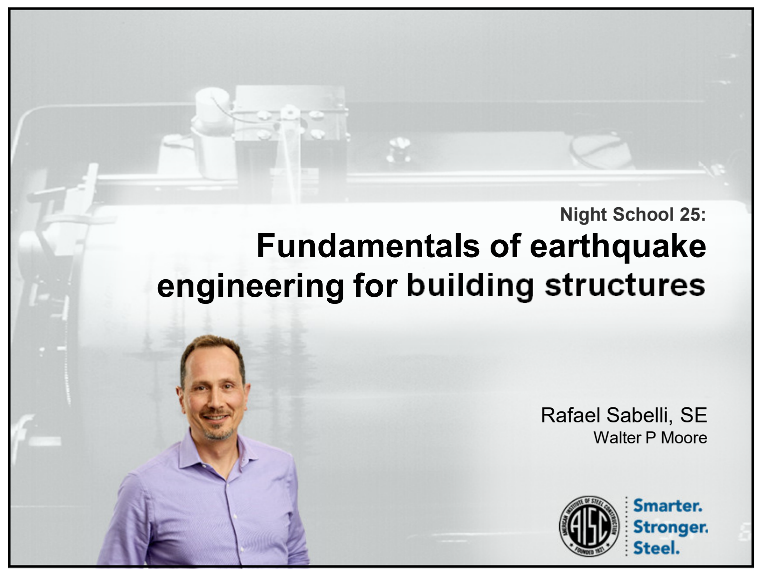
Learning Objectives

- Explain plate tectonics as the source of seismic energy release.
- Explain how earthquake are measured and the concepts of magnitude and intensity.
- List the largest earthquakes and compare to the costliest earthquakes.
- Introduction to probability concepts, return periods and risk, as well as related hazards, including tsunamis.



Course objectives

- Understand the principles of earthquake engineering
- Understand the application of those principles in the fundamental procedures of seismic design
- Understand how the material properties of steel are utilized in seismic design

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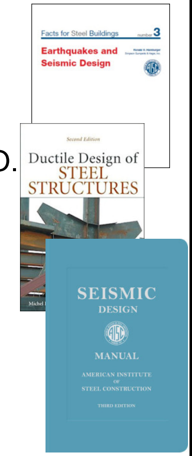
Resources



- *Earthquakes and Seismic Design*, Facts for Steel Buildings #3. Ronald O. Hamburger, AISC.
- *Ductile Design of Steel Structures*, Bruneau, Uang, and Sabelli, McGraw Hill.
- AISC *Seismic Design Manual*
- Other publications suggested in each session

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Resources

- AISC Seismic Design Manual Virtual Seminar
  - Offered as a web-based course in May 2021. www.aisc.org/seminars
    - Consult AISC.org for hosting opportunities.
  - Introduces the *Seismic Design Manual*
  - Introduces the reorganized 2016 AISC *Seismic Provisions*
    - Introduces key technical changes in the *Seismic Provisions*
    - Presents key provisions
    - Explains commonly misapplied provisions
  - Presents selected design examples
- Seismic Night School (this course)
  - Principles
  - Concepts
  - Lays groundwork for Seismic Design Manual Seminar

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Other resources

- AISC Solutions Center
  - 866.ASK.*AISC* (866-275-2472)
  - Solutions@AISC.org
- AISC Night School
  - Nightschool@AISC.org

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Course outline

1. **Seismology and earthquake effects**
2. Dynamics and response
3. Building dynamics and response
4. Steel behavior
5. System ductility and seismic design
6. Steel systems
7. Building configuration
8. Building codes

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Night School 25:

Fundamentals of earthquake engineering for building structures

Session 1: Seismology and earthquake effects
February 8, 2021

Rafael Sabelli, SE
Walter P Moore

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Session topics

- Plate tectonics
- Seismic waves
- Earthquake measures
- Major earthquakes
- Earthquake effects
- Related hazards
- Hazard, risk, and probability

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Plate Tectonics

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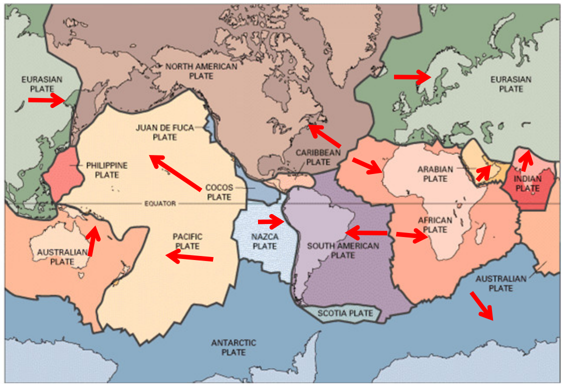
Major Tectonic Plates



Plates move relative to each other continuously. Near plate boundaries strain energy is built up and released as an earthquake.

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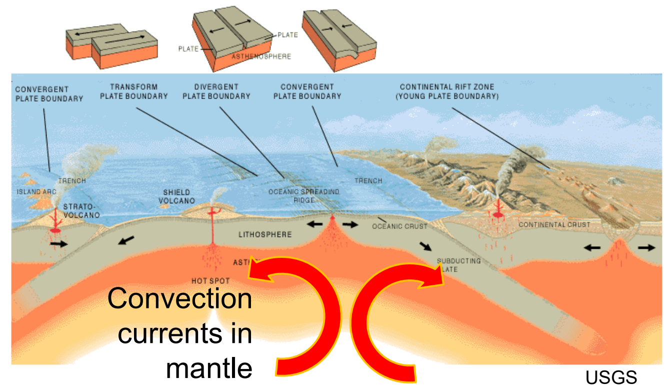
Tectonic plate movement



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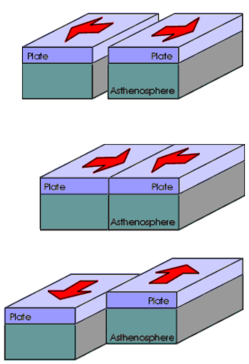
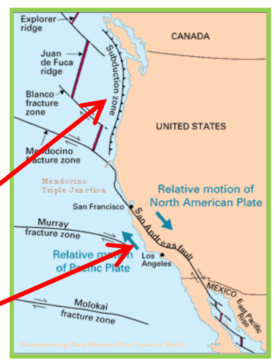
Interactions at plate boundaries



Divergent

Convergent

Transform



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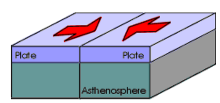
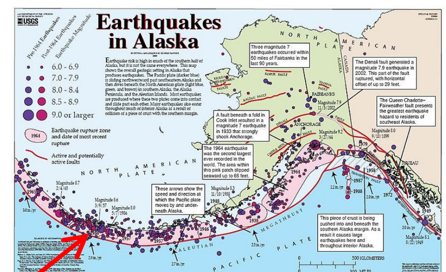
Interactions at plate boundaries





Convergent

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Plate movement

- San Andreas Fault Zone
  - 2 in/year (56 mm/year)
  - Los Angeles and San Francisco are 10 million years apart

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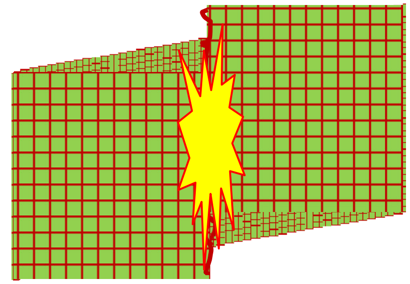
Stored energy



Plates motion is stored as strain energy, and released as an earthquake.

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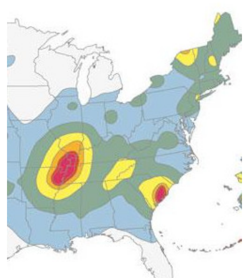
Intraplate earthquakes

- New Madrid
- Charleston
- Indian Ocean
- Underlying mechanisms not clear



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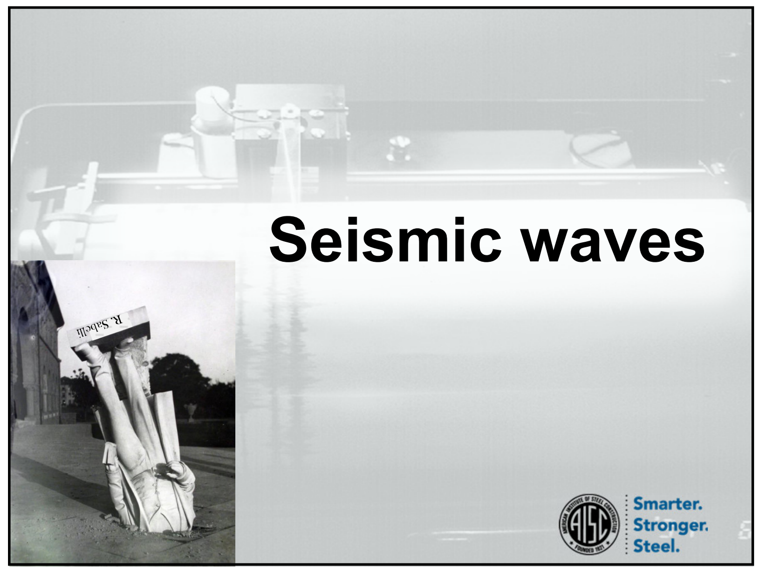

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Seismic waves

- Earthquakes cause sudden release of strain energy
- The release of strain causes high-energy waves to radiate from the hypocenter
- At the surface, the waves change direction and radiate from the epicenter
- Surface waves are high amplitude and cause damage

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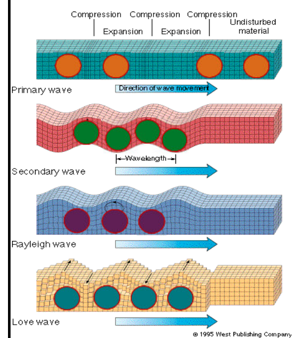
Seismic waves



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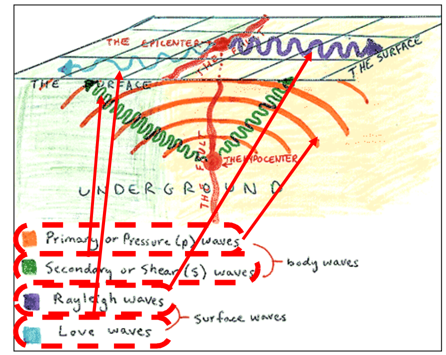

eGFI teacher resources

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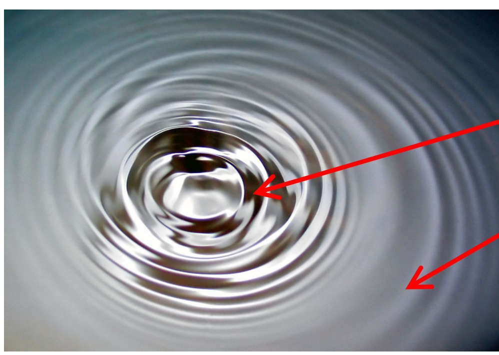
Effect of distance



Highest amplitude

Amplitude diminishes with distance

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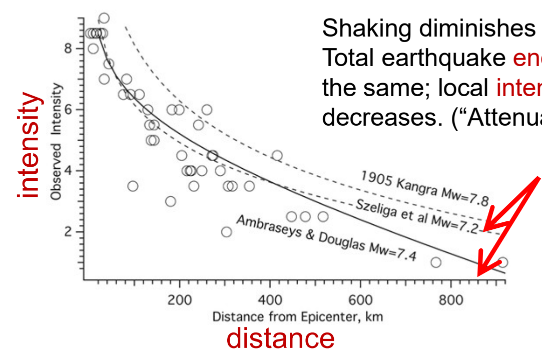
Effect of distance

Shaking diminishes with distance. Total earthquake energy remains the same; local intensity decreases. ("Attenuation")



Attenuation models

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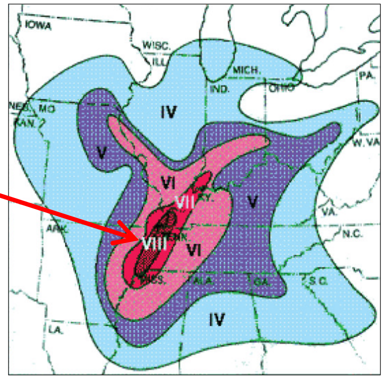
Effect of distance



Highest intensity

The earthquake has a single magnitude, but a range of intensities.

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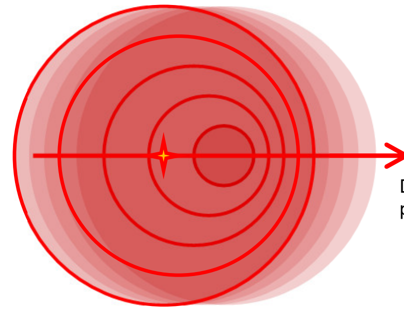
Directivity



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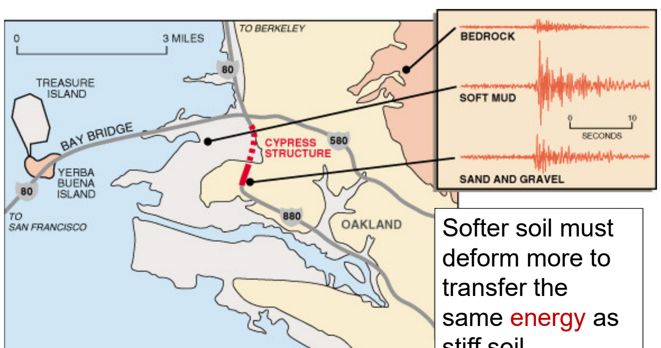
Effect of soil stiffness



Softer soil must deform more to transfer the same energy as stiff soil.

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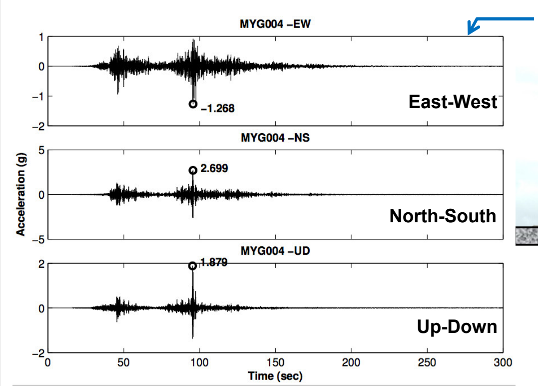
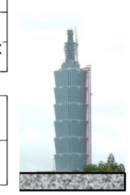
Ground motion





MYG04 station
Tohoku earthquake

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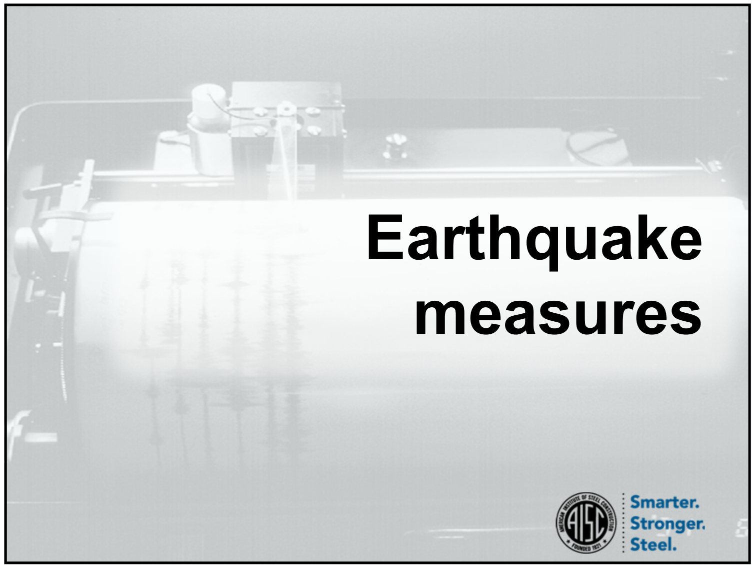
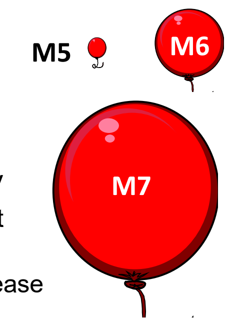


Earthquake measures

- Richter Magnitude
  - Logarithmic
    - M6.0=32*M5.0
  - Energy-based
  - Difficult to establish accurately
    - Based on standard instrument at standard distance
    - Very large earthquakes may release more energy than is recorded



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Earthquake measures

- Moment magnitude
  - Energy-based
  - Based on:
    - Surface area of fault
    - Slip
    - Rock modulus of rigidity
  - Similar to Richter

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Earthquake measures

- Modified Mercalli Intensity (MMI)
  - Based on effects
    - Subjective
    - Based on conventional construction
  - Some correlation to intensity of acceleration

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Modified Mercalli Intensity

I. Not felt except by a very few under especially favorable conditions.

II. Felt only by a few persons at rest, especially on upper floors of buildings.

III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.

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Modified Mercalli Intensity

IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

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Modified Mercalli Intensity

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

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Chimney damage. MMI ~VIII

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Modified Mercalli Intensity

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

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Long Beach, 1933: MMI = IX

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Lisbon, 1755: MMI = XI

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Seward, AK, 1964: MMI = XI

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Modified Mercalli Intensity

Table 1-2 Intensity and Peak Ground Acceleration	
Modified Mercalli Intensity	**Peak Ground Acceleration, *g***
VI	0.05–0.10
VII	0.10–0.20
VIII	0.20–0.30
IX	0.30–0.60
X	> 0.60

Hamburger

Accelerations are used in design

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Magnitude & Intensity

Magnitude	**Typical Maximum Modified Mercalli Intensity**
1.0 - 3.0	**I**
3.0 - 3.9	**II - III**
4.0 - 4.9	**IV - V**
5.0 - 5.9	**VI - VII**
6.0 - 6.9	**VII - IX**
7.0 and higher	**VIII** or higher

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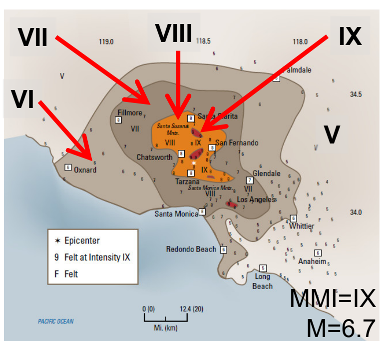
1994 Northridge MMIs



Intensity is useful to describe the local effects.

Magnitude is useful to describe the event as a whole

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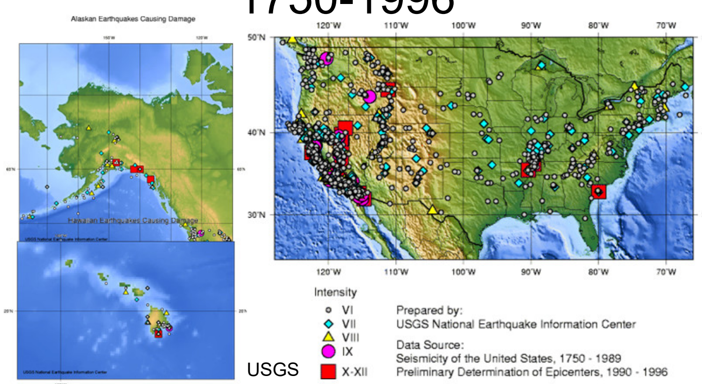
US earthquakes causing damage 1750-1996



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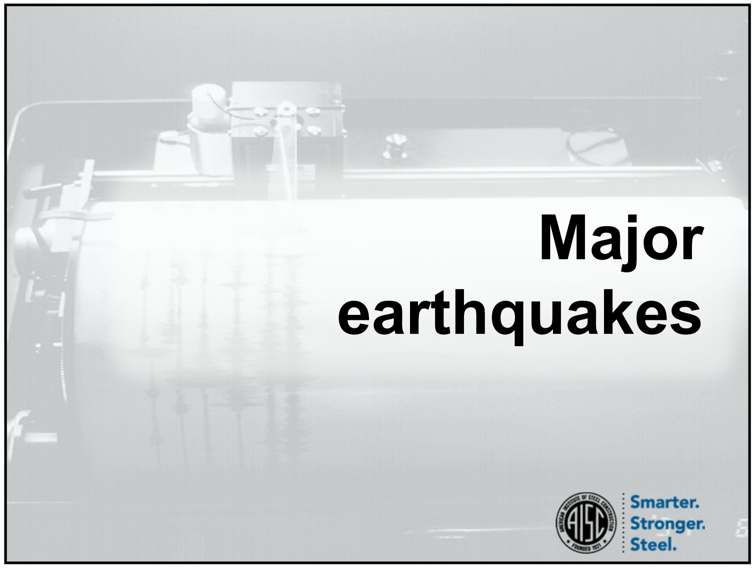

Earthquake frequency

Magnitude	Estimated #/Year
2.5 or less	900,000
2.5 to 5.4	30,000
5.5 to 6.0	500
6.1 to 6.9	100
7.0 to 7.9	20
8.0 or greater	One every 5 to 10 years

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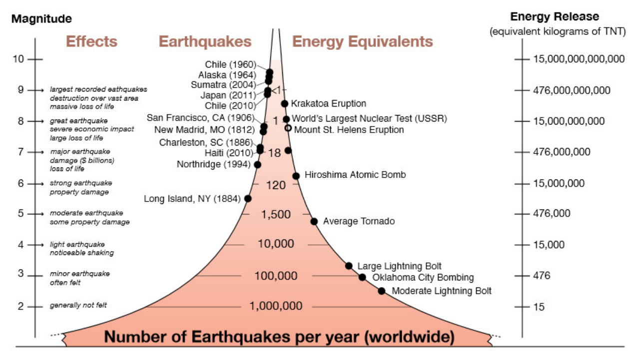
Largest earthquakes

Event	Location	Magnitude
1960 Valdivia earthquake	Chile	9.4–9.6
1964 Alaska earthquake	United States (AK)	9.2
2004 Indian Ocean earthquake	Indonesia	9.1–9.3
2011 Tōhoku earthquake	Japan	9.1
1730 Valparaiso earthquake	Chile	9.1–9.3
1952 Kamchatka earthquakes	Russia	9
1868 Arica earthquake	Chile	8.5–9.0
1700 Cascadia earthquake	US and Canada	8.7–9.2
1762 Arakan earthquake	Bangladesh	8.8
1833 Sumatra earthquake	Indonesia	8.8
1906 Ecuador–Colombia earthquake	Ecuador – Colombia	8.8
2010 Chile earthquake	Chile	8.8
1950 Assam–Tibet earthquake	Assam, India – Tibet, China	8.7
1707 Hōei earthquake	Japan	8.7–9.3
1755 Lisbon earthquake	Portugal	8.5–9.0
1965 Rat Islands earthquake	United States (AK)	8.7
1746 Lima–Callao earthquake	Peru	8.6
1787 Mexico earthquake	Mexico	8.6
1957 Andreanof Islands earthquake	United States (AK)	8.6
2005 Nias–Simeulue earthquake	Indonesia	8.6

Earthquake frequency



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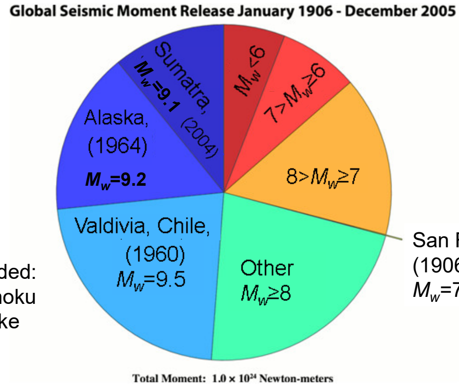
Largest earthquakes



San Francisco, (1906) M_w=7.9

Not included: M9.1 Tōhoku earthquake (2011)

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Valdivia, Chile, 1960 M~9.5

- >2,000 killed
- >3,000 injured
- >2,000,000 homeless
- >$550 million damage
- Tsunamis
  - 61 deaths, $75 million damage in Hawaii
    - $500,000 damage in the United States west coast
  - 138 deaths and $50 million damage in Japan
  - 32 dead or missing in the Philippines

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Valdivia, Chile, 1960 M~9.5

- Earth's day shortened 1.26 microseconds
- Concepción moved 3.0 meters (10 ft)
- Chile may have expanded ~ 1.2 km²

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Costliest earthquakes

Event	Location	Magnitude	Property damage
2011 Tōhoku earthquake and tsunami	Japan	9.1	$235 billion
1995 Great Hanshin earthquake	Japan	6.9	$200 billion
2008 Sichuan earthquake	Sichuan, China	8	$86 billion
2004 Chūetsu earthquake	Japan	6.8	$28 billion
1999 İzmit earthquake	Turkey	7.6	$20 billion
2012 Emilia earthquakes	Italy	6.1	$15.8 billion
2011 Christchurch earthquake	South Island, New Zealand	6.3	$15–40 billion
2010 Chile earthquake	Chile	8.8	$15–30 billion
1980 Irpinia earthquake	Italy	6.9	$15 billion
1994 Northridge earthquake	**Los Angeles**	**6.7**	**$13–44 billion**
1976 Tangshan earthquake	Hebei, China	7.8	$10 billion
1999 Jiji earthquake	Taiwan	7.6	$10 billion
April 2015 Nepal earthquake	Nepal	7.8	$10 billion
1989 Loma Prieta earthquake	California,	6.9	$5.6–6 billion
1923 Great Kantō earthquake	Tokyo, Japan	7.9	$600 million
1906 San Francisco earthquake	San Francisco	7.7 to 7.9	$400 million

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Northridge, CA, 1994, M=6.7

- $20 billion in losses
- 60 people killed
- > 7,000 injured
- 20,000 homeless
- >40,000 buildings damaged
- 1.8g maximum recorded acceleration
  - High local intensities

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Deadliest earthquakes

Event	Location	Magnitude	Fatalities
1556 Shaanxi earthquake	China	8.0	820,000–830,000
1976 Tangshan earthquake	China	7.8	242,769–700,000+
1920 Haiyuan earthquake	China	7.8	273,400
526 Antioch earthquake	Turkey	7.0	250,000
2004 Indian Ocean earthquake	Indonesia	9.1–9.3	227,898
1138 Aleppo earthquake	Syria	7.1	130,000–230,000
2010 Haiti earthquake	**Haiti**	**7.0**	**100,000-316,000**
1303 Hongdong earthquake	China	8.0	200,000
856 Damghan earthquake	Iran	7.9	200,000

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Haiti, 2010, M=7.0

- 200,000-316,000 people killed
- 300,000 injured
- 1.3 million displaced
- Port-au-Prince
  - 97,294 houses destroyed
  - 188,383 houses damaged
- Felt as far as southern Florida, northern Colombia and northwestern Venezuela.

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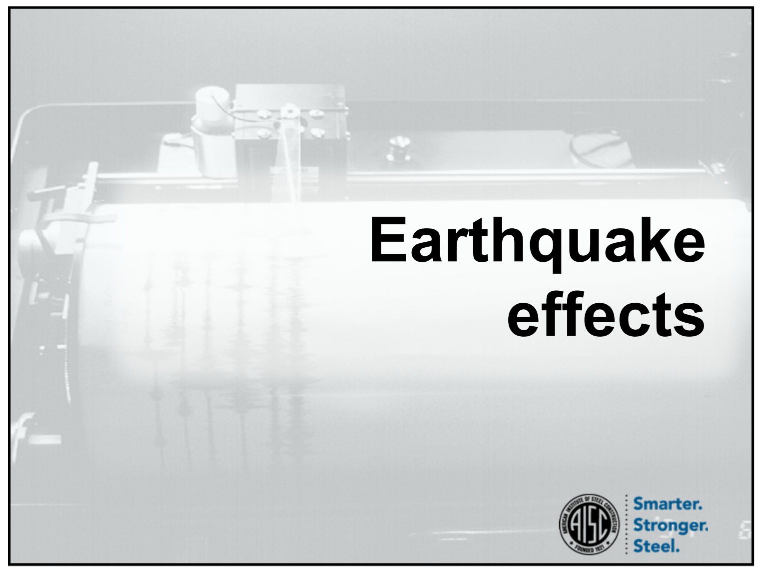

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Earthquake effects

- Local effects
  - Epicenter
    - Fault thrust
    - Sliding/shearing
  - Soil effects
    - Liquefaction
    - Slope instability
- Widespread effects
  - Horizontal shaking
  - Vertical shaking
  - (This is what we typically design for!)

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Surface Faulting

Fig. 1-6. Fault scarp created by the 1954 Dixie Valley earthquake in the Nevada desert. (Photo by K.V. Steinbrugge)

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Surface Faulting

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Surface Faulting

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Surface Faulting

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Codes proscribe construction on sites subject to surface rupture

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Surface Faulting

Manure pile moved 10 feet (along with ground next to barn).

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Landslides

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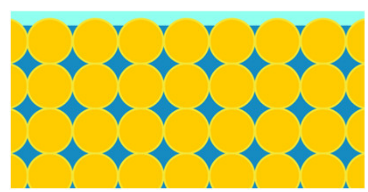
Liquefaction

- Loss of strength
- Ground shaking loosens water-saturated sands
- Soil flows laterally and vertically under pressure



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Liquefaction

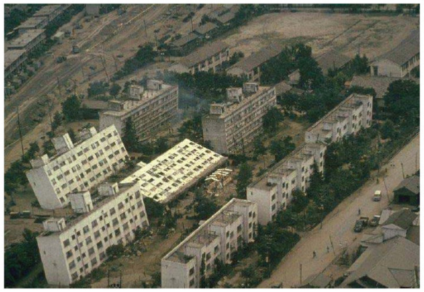

Fig. 1-8. Settlement in apartment buildings due to soil liquefaction, 1964 Nigata, Japan, earthquake. (Photo courtesy of University of Washington)

Codes proscribe construction on unimproved liquefiable sites

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Liquefaction

USGS

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Lateral spreading

Fig. 1-9. Lateral spreading damage to highway pavement near Yellowstone Park, 1959 Hegben Lake earthquake. (Photo courtesy of U.S. Geologic Survey)

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Earthquake effects

- Surface faulting
  - Building is not permitted over known faults
  - Bridges, railways, and roads must have displacement capacity
- Soil effects
  - Soil can be remediated
  - Deep foundations can bypass liquefiable layers

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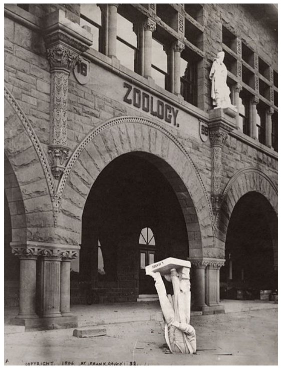
Horizontal shaking



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Horizontal forces

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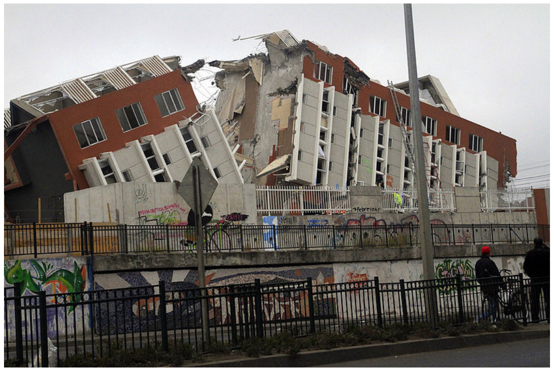
Overturning



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Earthquake effects

- Horizontal shaking
  - Buildings must be designed to resist horizontal shaking, and related overturning
  - Strategies include:
    - Strength
    - Stiffness
    - Displacement capacity
    - Energy absorption

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Tsunami

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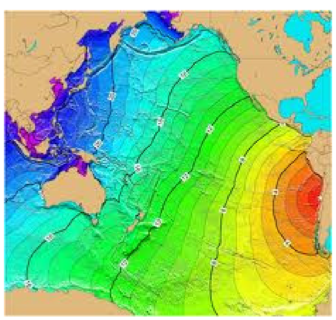
Tsunami



Tsunamis open-sea amplitude gradually attenuates.

Local shoreline effects can be many times open-sea amplitude.

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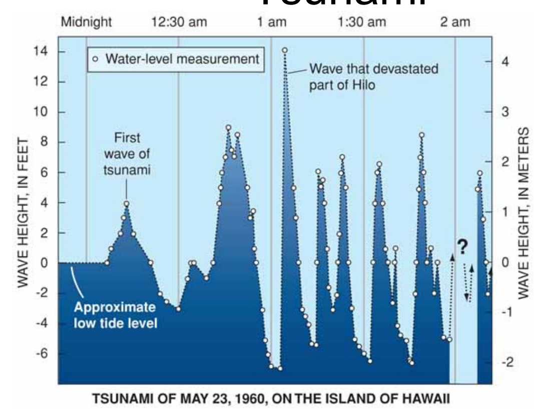
Tsunami



USGS

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Tsunami

Tsunamis are caused by undersea fault movement.

Current design codes do not address tsunamis.

Evacuation and refuge are typical strategies.

Wikimedia commons

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Cascading events

- Fires
  - 1906 San Francisco fire

Wikimedia commons

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Cascading events

- Power loss
  - Critical equipment
  - Elevators
    - How to evacuate 50-story buildings?
- Gas leaks
- Disrupted transportation
- Homelessness

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Hazard, risk, and probability

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Hazard

- "Hazard" is used to correlate probability and intensity
  - The earthquake intensity for which there is a specified probability of exceedance
  - Probability of exceedance can be converted to return period.
    - Similar to 500-year wind, 100-year flood, etc.

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Deterministic approach

- Known seismic source
  - Estimated maximum magnitude
    - Or based on other criteria (return period, historical)
  - Attenuation over distance calculated
- Example:
  - "The earthquake hazard for X site is a peak ground acceleration of 0.65g resulting from an earthquake of magnitude 6.8 on the San Andreas fault at 10 mile distance."

Codes use deterministic methods near well understood faults

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Probabilistic approach

- Known seismic sources:
  - Estimated maximum magnitude
  - Attenuation over distance
- Intensity/return periods for faults combined to form a single intensity at a given return period
- Example:
  - "The earthquake hazard for X site is a peak ground acceleration of 0.35g with 2 % probability of being exceeded in 50 years."

Codes use probabilistic methods where earthquake risk is not dominated by well understood faults

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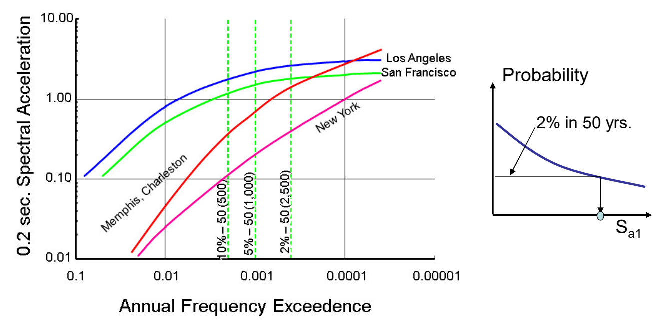
Probability



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Probabilities

P_1 = annual exceedance probability
$1 – P_1$ = annual non-exceedance probability

R = return period
$R = –1/\ln(1 – P_1)$
P_n = exceedance probability for period n
$R = –n/\ln(1 – P_n)$

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Probabilities

$[1−P_1]$ = Probability of non-exceedance in 1yr

$[1−P_1]*[1−P_1]*[1−P_1]$
= Probability of non-exceedance in 3yrs

$P_1*P_1*P_1$
= Probability of exceedance in each of 3 years! (This is not the probability of exceedance in 3 years! Don't do this!)

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Probabilities

$[1−P_1]^n$ = Probability of non-exceedance in n yrs

$P_n = 1−[1−P_1]^n$
= Probability of exceedance in n yrs

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Probabilities

Given: 10% probability of exceedance in 50 yr
→R=475 years
(T=500 years = 9.5% / 50 yr)

Given: 2% probability of exceedance in 50 yr
→R=2475 years
(T=2500 years = 1.98% / 50 yr)

Past codes have used 475 year and 2475 year return periods

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Multiple sources

Probabilities are not additive

- Maintain chance of non-exceedance of acceleration X
- $[1- P_a]^{50} * [1- P_b]^{50} * [1- P_c]^{50}$ …. = 98%
- P_a = probability of acceleration X from source A
- P_b = probability of acceleration X from source B
- P_c = probability of acceleration X from source C

Therefore, a 2% chance in 50 years of exceeding the intensity

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Multiple sources

We are concerned with the probability (return period) of a level of **ground shaking**, not of an earthquake

Small or distant events have very low probability of exceeding the intensity

- Do not reduce the chance of non-exceedance much

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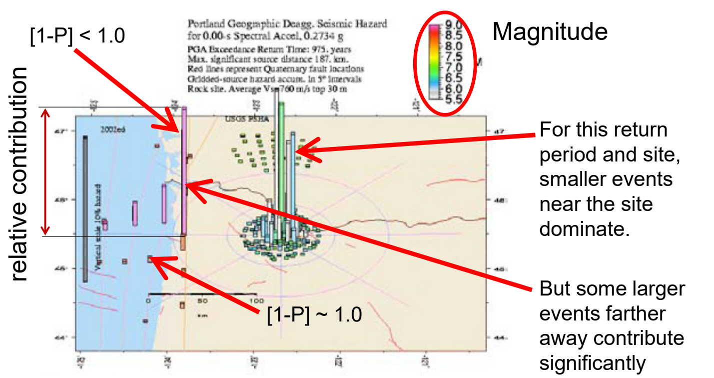
Hazard "de-aggregation"



State of Oregon

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Seismic hazard

- How is the seismic hazard determined?
  - Deterministic method used near major faults
    - Based on characteristic earthquake on known fault
  - Probabilistic methods used elsewhere
    - 2475 year return period
      - Past seismicity
      - Slip rate
      - By USGS
  - Probabilistic methods less relevant near faults with frequent events

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Determining seismic hazard

- Maps examine each location
  - Shaking caused by multiple events
  - Attenuation models used
- Maps created considering:
  - Significant damaging earthquakes
    - Smaller earthquakes
  - Historical intensities
  - Historical seismicity information
  - Geologic (prehistoric) information
  - Geodetic (slip rate) information

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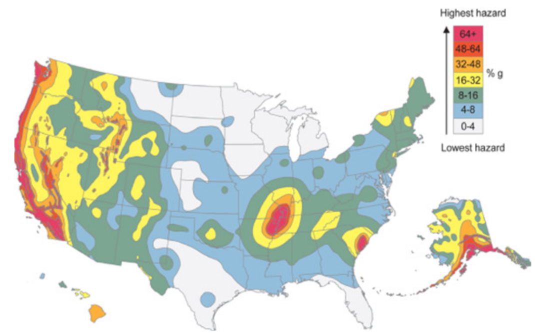
USGS Hazard maps



Periodically reviewed and updated to include:
- new fault data
- new attenuation relations
- new geodetic data
- more seismic data

USGS

USGS acceleration maps are used for design

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Hazard vs risk

Hazard
- Uniform hazard
- "Maximum Considered Earthquake" (MCE)
- 2475 yr return period
  - Given the MCE…
  - 10% chance of collapse

Risk
- Uniform risk
- Risk-targeted MCE = MCE_r
  - Given the MCE_r …
  - 10% chance of collapse
- MCE_r selected
  - 1% chance of collapse in 50 years (maximum risk)
    - Assumed fragility of structures

Current ASCE 7 2016 code uses "uniform risk" concept

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Risk

- Uniform hazard
  - Standard return period considered
- Uniform risk
  - Different return period considered at each location
  - Risk of not meeting performance goal is uniform
  - Assumes similar structural fragility

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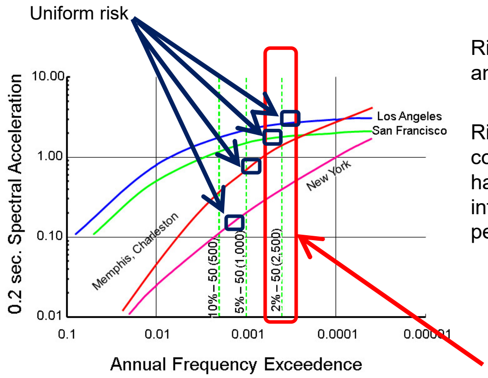
Risk



Risk connects hazard and performance.

Risk includes consideration of all hazard levels that influence the desired performance level.

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Uncertainty

- “Maximum Considered Earthquake” is an arbitrary cut off
- Larger events are possible
- Earthquake demands introduce far more uncertainty than most other loadings
  - Intensity
  - Dynamic characteristics
  - Unmapped faults (e.g., Christchurch)

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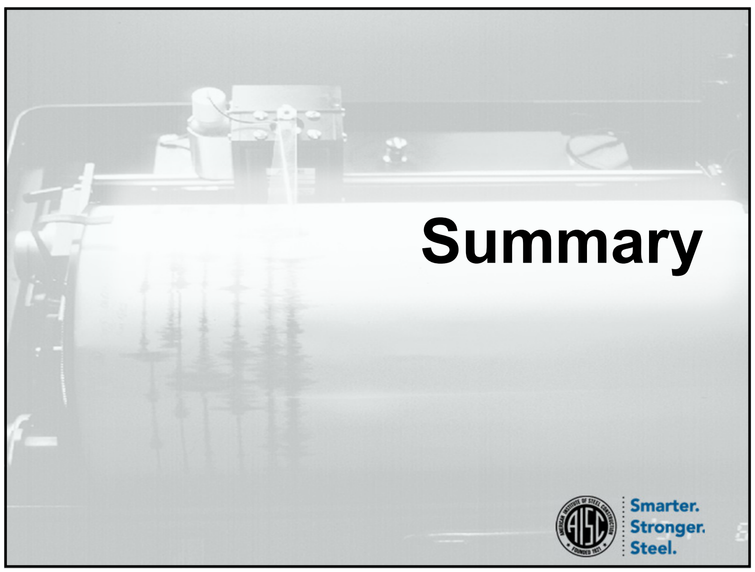

Summary

- Tectonic plate movement results in release of energy
- Seismic waves carry this energy and affect buildings
- Magnitude describes the event
- Intensity describes the local manifestation
- Very large earthquakes are rare but represent a significant risk

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Parting thought

How do structures respond to earthquake-induced shaking?

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Summary

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End of session 1

Next:

Session 2:
Dynamics and response

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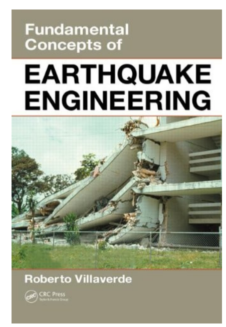
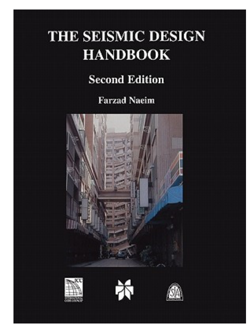
Additional resources





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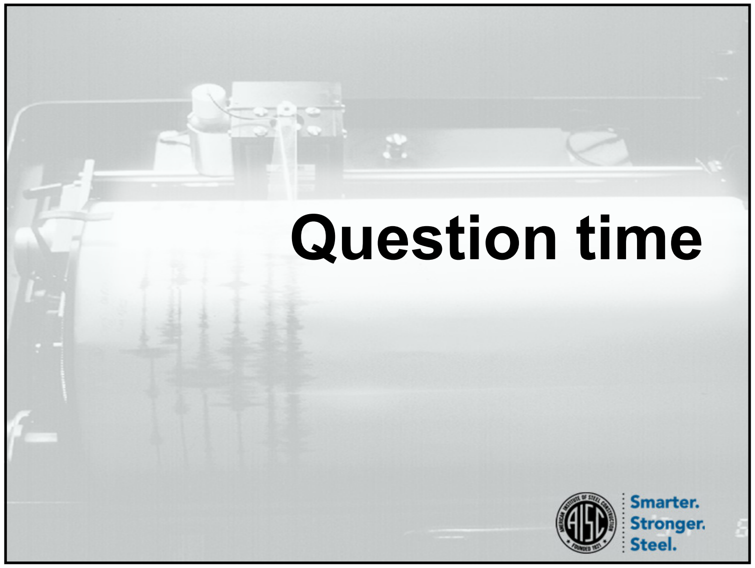

Single-Session Registrants

CEU / PDH Certificates

- 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!

Single-Session Registrants

CEU / PDH Certificates

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

8-Session Registrants

CEU / PDH Certificates

One certificate will be issued at the conclusion of the course.

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8-Session Registrants

Attendance and PDH Certificates

- You have two options to receive credit for a given session.
  - Option 1: Watch the live session. Credit for live attendance will be displayed on the Course Resources table within two days of the session.
  - Option 2: Watch the recording and pass the associated quiz.

Videos and Quizzes

- For each session, find access within two business days after the live air date. (An email will be sent from nightschool@aisc.org.)
- Reasons for quiz:
  - EEU – You must take all quizzes and the final exam to receive EEU.
  - PDHs – If you watch a recorded session, you must pass quiz for PDHs.
  - Reinforce what you learn in the lectures and get more out of the course!

Distribution of Certificates

All certificates will be issued after the course is completed. Only the registrant will receive a certificate for the course.

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8-Session Registrants

Course Resources

Find all your handouts, quizzes and quiz scores, recording access, and attendance information in one place!

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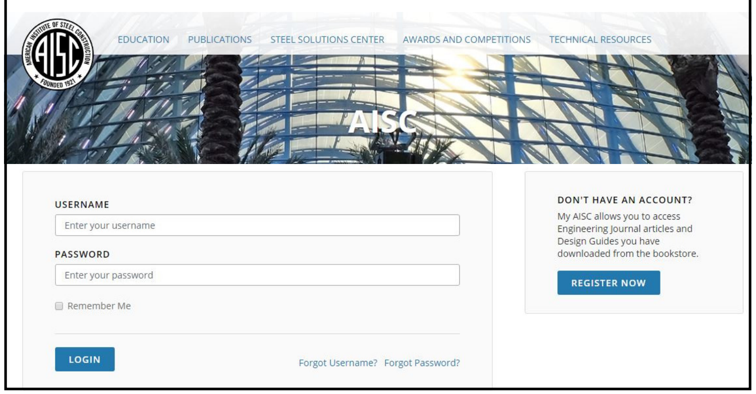
Course Resources

Go to www.aisc.org and sign in.



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Course Resources

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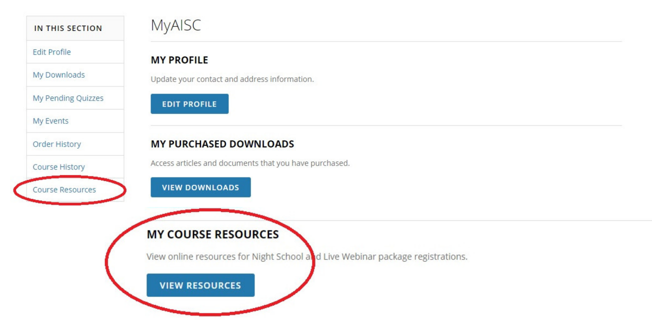

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8-Session Registrants

Course Resources

EDUCATION PUBLICATIONS AWARDS AND COMPETITIONS TECHNICAL RESOURCES STEEL SOLUTIONS CENTER

AISC › MY ACCOUNT › COURSE RESOURCES

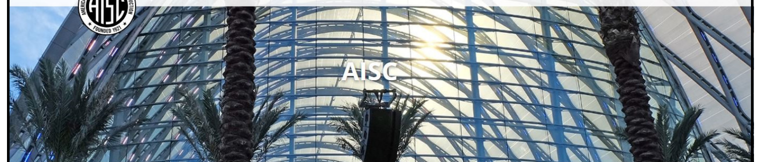
Course Resources

Event	Start Date
Seismic Design in Steel	1/1/1900 12:00:00 AM
4-Session Package-Design of Façade Attachments	5/9/2019 1:30:00 PM
NS 15 8-Session Package-Night School 15 - Fundamentals of Connection Design	10/3/2017 7:00:00 PM
NS 16 8-Session Package-Night School 16 - Seismic Design in Steel	2/5/2018 7:00:00 PM
NS 17 4-Session Package-Night School 17: Design of Façade Attachments	7/16/2018 7:00:00 PM
NS 18 8-Session Package-Night School 18: Steel Construction: Mill To Topping Out	10/15/2018 7:00:00 PM
NS 19 8-Session Package-Night School 19: Connection Design	2/4/2019 7:00:00 PM
NS 20 8-Session Package-Night School 20: Classical Methods of Structural Analysis	6/3/2019 7:00:00 PM
8-Session Package-Seismic Design in Steel - Concepts & Examples	7/16/2018 1:30:00 PM

8-Session Registrants

Course Resources

EDUCATION PUBLICATIONS AWARDS AND COMPETITIONS TECHNICAL RESOURCES STEEL SOLUTIONS CENTER



AISC › MY ACCOUNT › COURSE RESOURCES › NS24 8-SESSION PACKAGE RESOURCES

Night School 24: Modern Methods for Learning Structural Stability

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS24.1 - Compression Members - The Fundamentals	Oct 6 2020 7:00PM EDT	Handouts	Available 10/08/2020 5:00PM EDT	Available 10/08/2020 5:00PM EDT	Pending
NS24.2 - Compression Members - Practical Considerations	Oct 13 2020 7:00PM EDT	Handouts	Available 10/15/2020 5:00PM EDT	Available 10/15/2020 5:00PM EDT	Pending
NS24.3 - Behavior of Flexural Members - The Fundamentals	Oct 20 2020 7:00PM EDT	Handouts	Available 10/22/2020 5:00PM EDT	Available 10/22/2020 5:00PM EDT	Pending
NS24.4 - Flexural Members - Practical Considerations	Oct 27 2020 7:00PM EDT	Handouts	Available 10/29/2020 5:00PM EDT	Available 10/29/2020 5:00PM EDT	Pending
NS24.5 - Stability of Beam-Columns - The Fundamentals	Nov 10 2020 7:00PM EST	Handouts	Available 11/12/2020 5:00PM EST	No longer available	Pending
NS24.6 - Stability of Beam-Columns - Practical Consideration	Nov 17 2020 7:00PM EST	Handouts	Available 11/19/2020 5:00PM EST	No longer available	Pending
NS24.7 - Behavior of Structural Systems - The Fundamentals	Dec 1 2020 7:00PM EST	Handouts	Available 12/03/2020 5:00PM EST	No longer available	Pending
NS24.8 - Structural Systems - Practical Considerations	Dec 8 2020 7:00PM EST	Handouts	Available 12/10/2020 5:00PM EST	No longer available	Pending
NS24 - Final Exam	N/A			No longer available	

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