BRAUN
INTERTEC

History of Seismic Design and Building Codes

Michael Laney, PE, GE, BC.GE
Principal Engineer, REI Group

11-12-2026

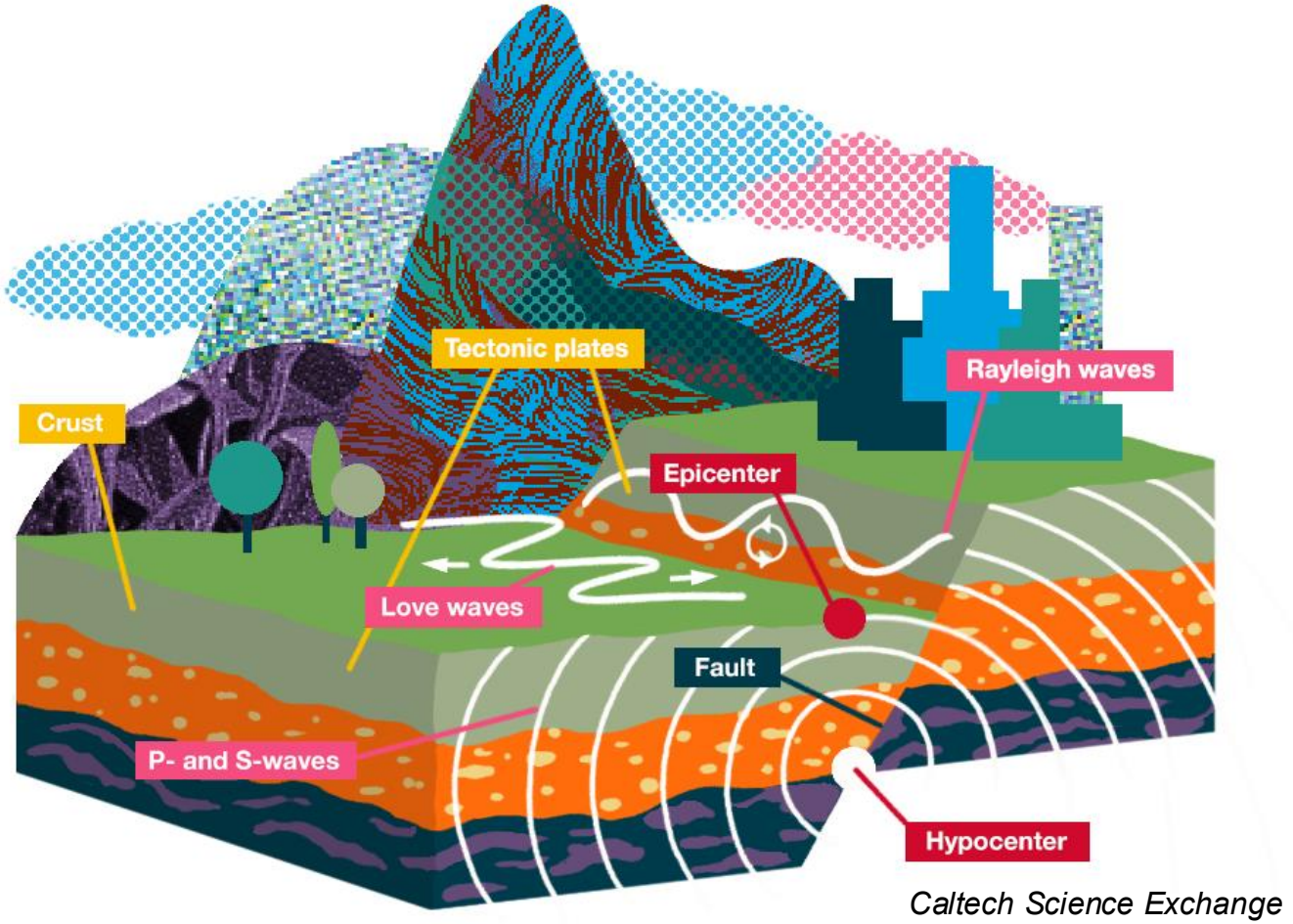


Introduction

- Basic understanding of earthquake engineering terms.
- Why is this important to us in the Midwest?
- How have seismic codes and practice evolved in the United States.
- Current state of Chapter 16 of the International Building Code (2024 IBC) and the ASCE 7-22.

Introduction- Basic Seismic Terms

- Epicenter
- Magnitude
- Intensity
- Fault vs. Subjection
- Tsunami/Seiches
- Liquefaction
- Lateral Spread
- Response Spectra

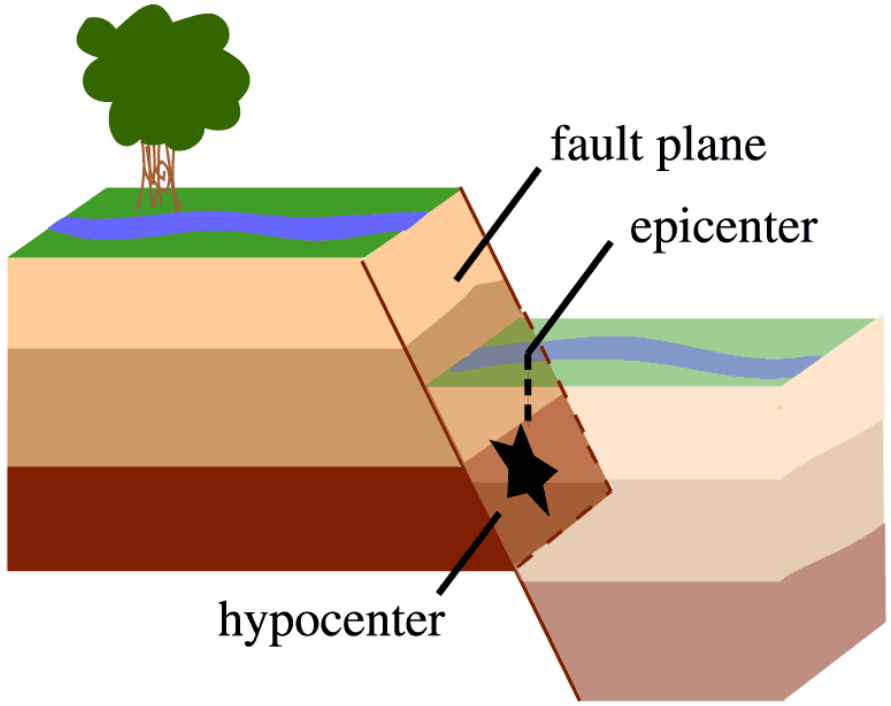


Caltech Science Exchange

Introduction- Basic Seismic Terms

Epicenter

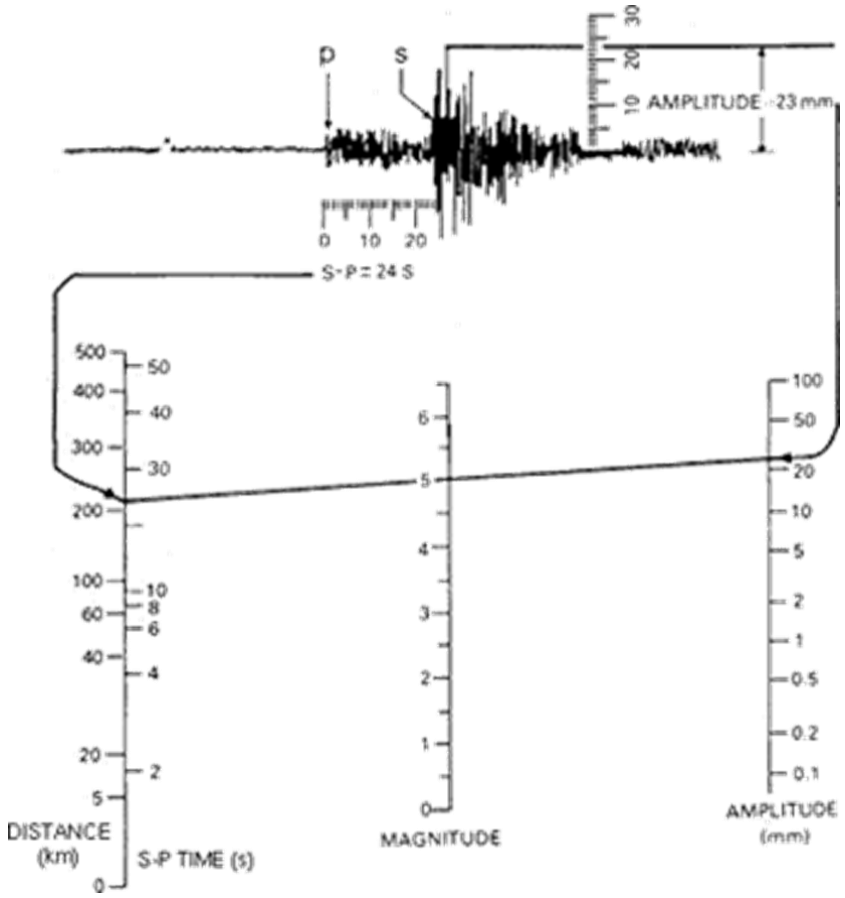
- The location below the earth's surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface of the earth is called the epicenter.



Introduction- Basic Seismic Terms

Magnitude

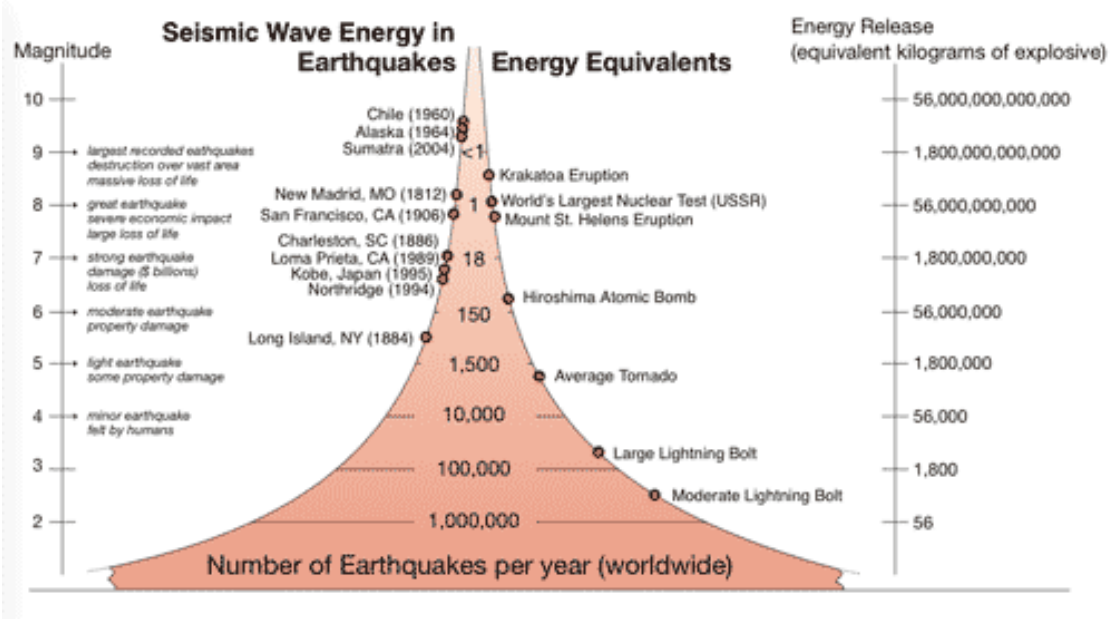
- Moment Magnitude, M_W- This is the current moment scale in use today. The moment magnitude scale is based on the total moment release of the earthquake. M_W is a product of the distance a fault moved, and the force required to move it. It is derived from modeling recordings of the earthquake at multiple stations.
- Richter Magnitude, M_L -The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. Adjustments are included for the variation in the distance between the various seismographs and the epicenter of the earthquakes.



Introduction- Basic Seismic Terms

Magnitude

- The Richter Scale uses common logarithms (i.e. M_L = 3 factors 103, M_L=5 factors 105, and is 100 larger than M_L=3).
- Moment magnitude is also logarithmic but uses a more complicated scale. Each Magnitude is about 31.1 times greater then the previous.



Introduction- Basic Seismic Terms

Intensity

- The effect of an earthquake on the Earth's surface is called the intensity. The intensity scale consists of a series of certain key responses such as people awakening, movement of furniture, damage to chimneys, and finally - total destruction.
- The Modified Mercalli Intensity value assigned to a specific site after an earthquake has a more meaningful measure of severity to the nonscientist than the magnitude because intensity refers to the effects experienced at that place.
- The lower numbers of the intensity scale generally deal with the way the earthquake is felt by people. The higher numbers of the scale are based on observed structural damage. Structural engineers usually contribute information for assigning intensity values of VIII or above.

Introduction- Basic Seismic Terms

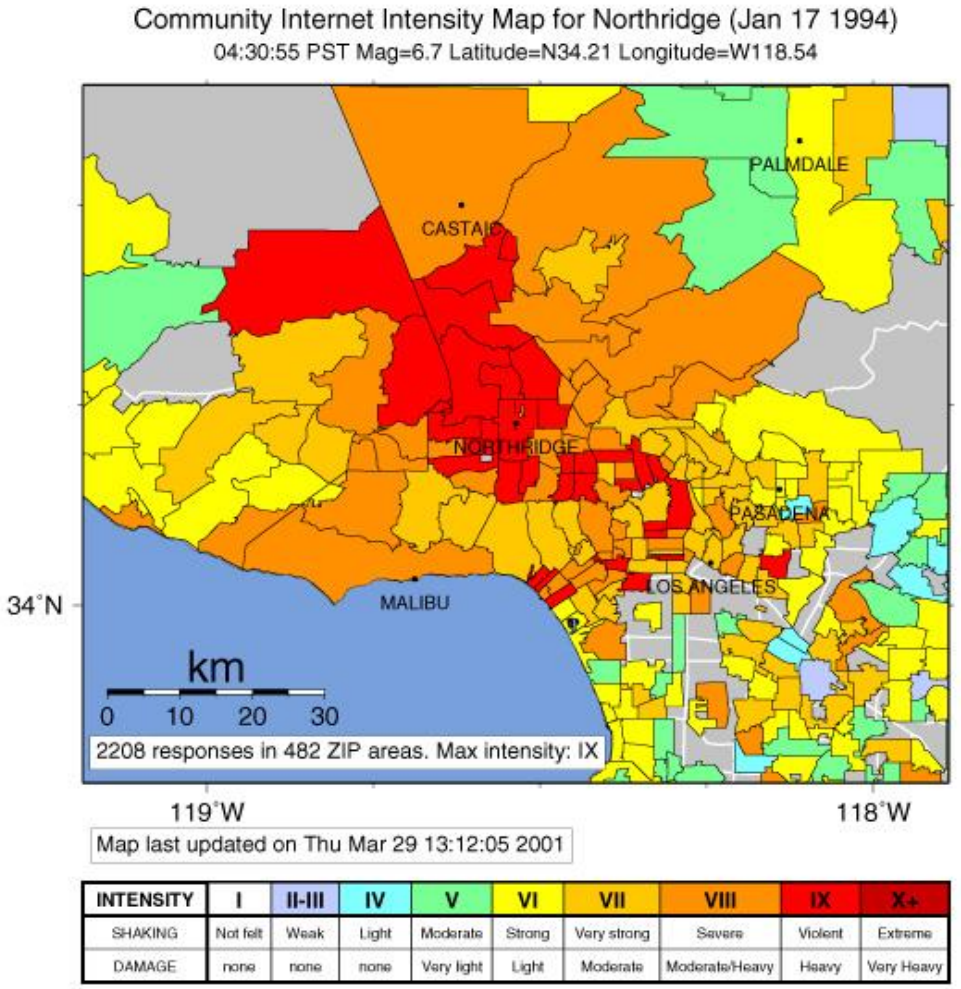
Intensity

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
III	Weak	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.
IV	Light	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	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	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	Severe	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.
IX	Violent	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	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Introduction- Basic Seismic Terms

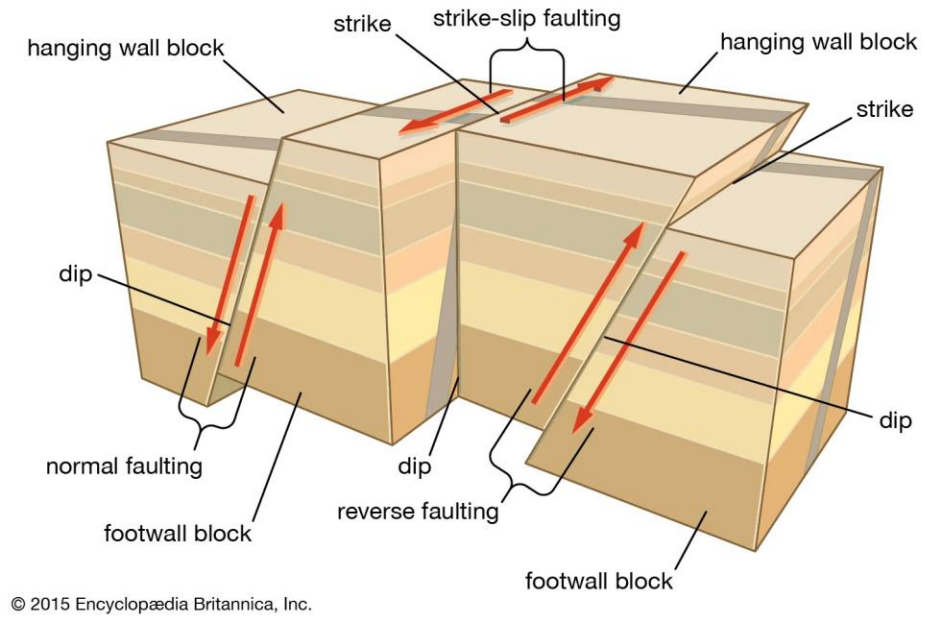
Intensity

The USGS has a website (https://earthquake.usgs.gov/data/dyfi/) and phone application called “Did you feel it” where you can upload your experience during an earthquake, allowi for more accurate intensity maps.

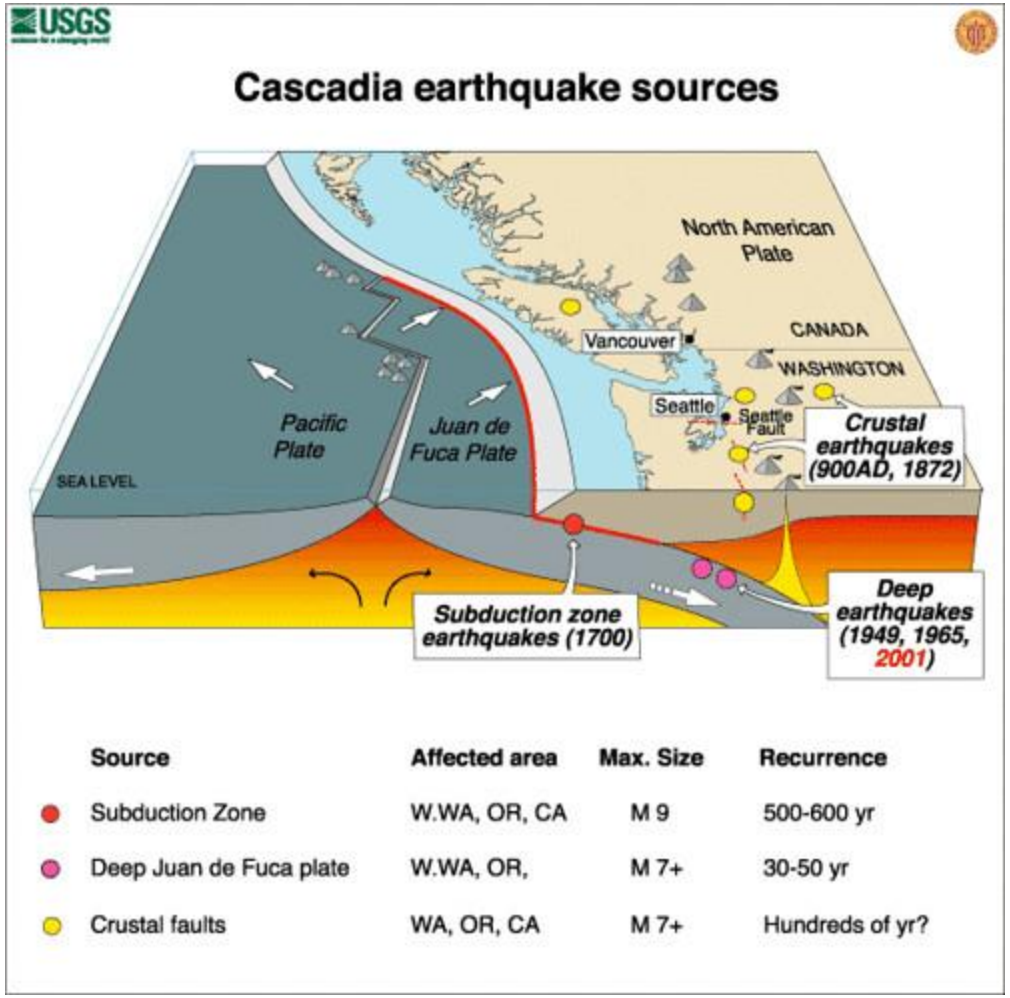


Introduction- Basic Seismic Terms

Faulting or Subduction



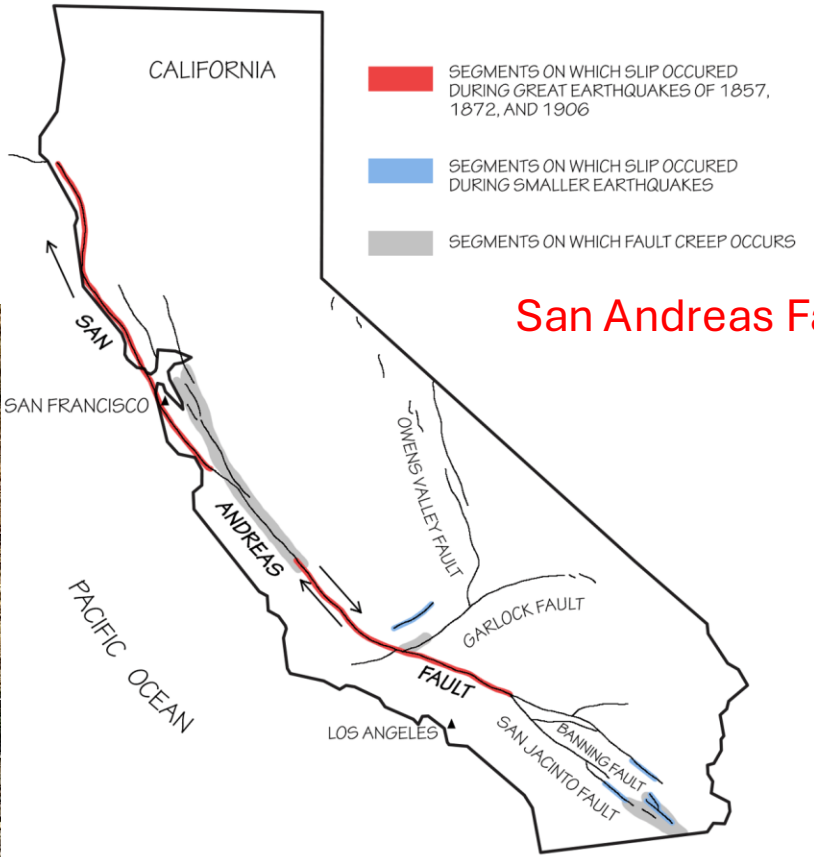
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Introduction- Basic Seismic Terms

Creeping Fault

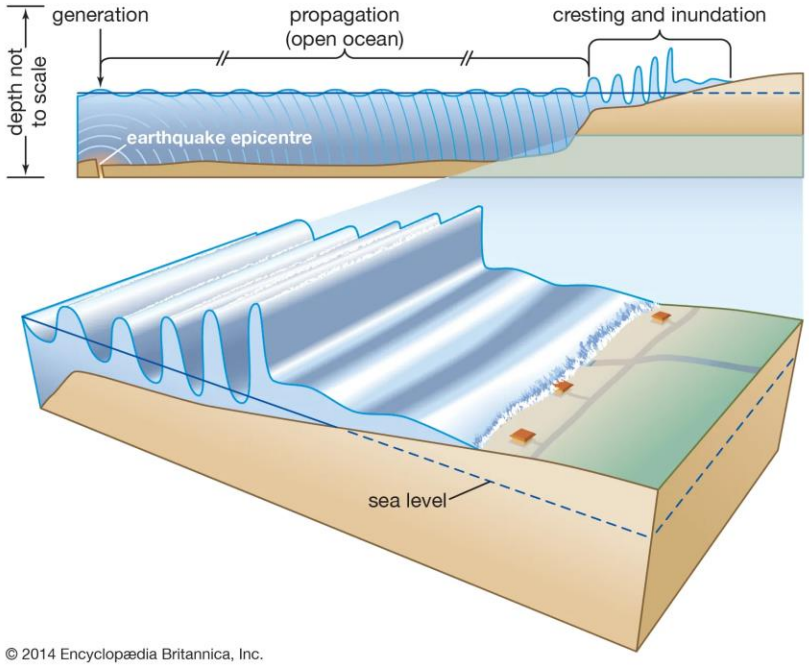




San Andreas Fault ~3cm/year

Introduction- Basic Seismic Terms

Tsunami and Seiches

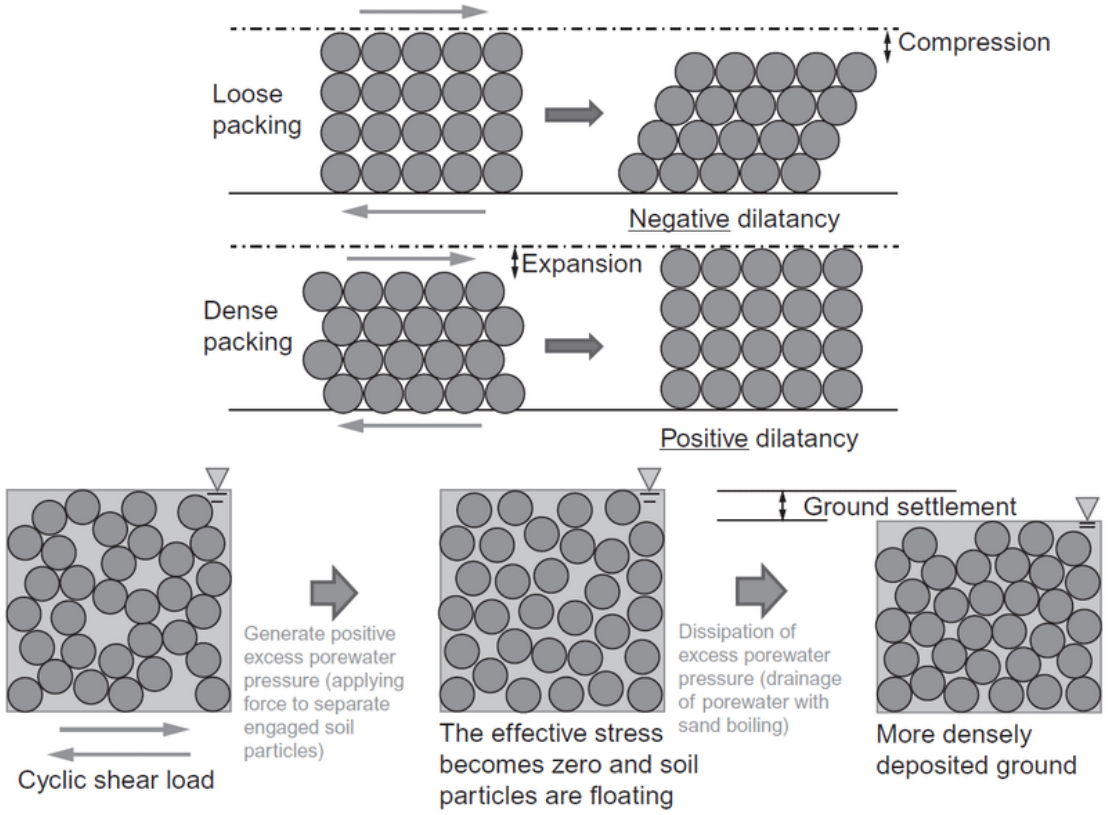


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Introduction- Basic Seismic Terms

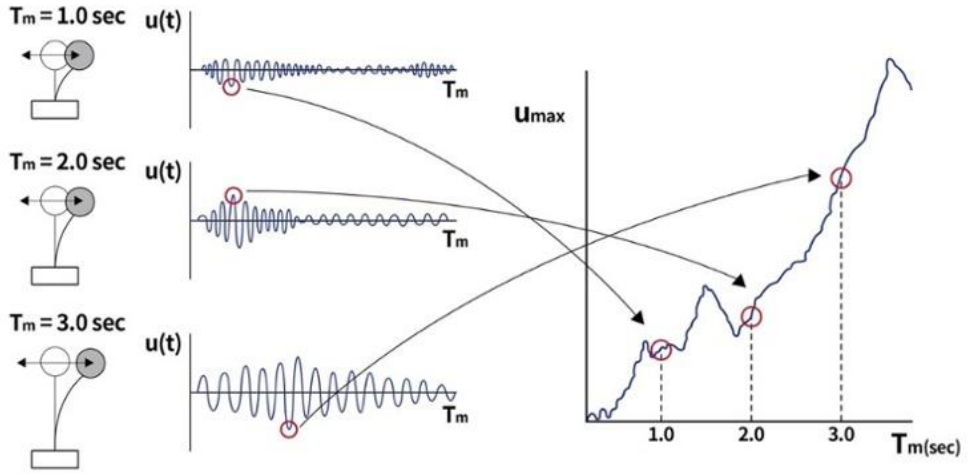
Liquefaction

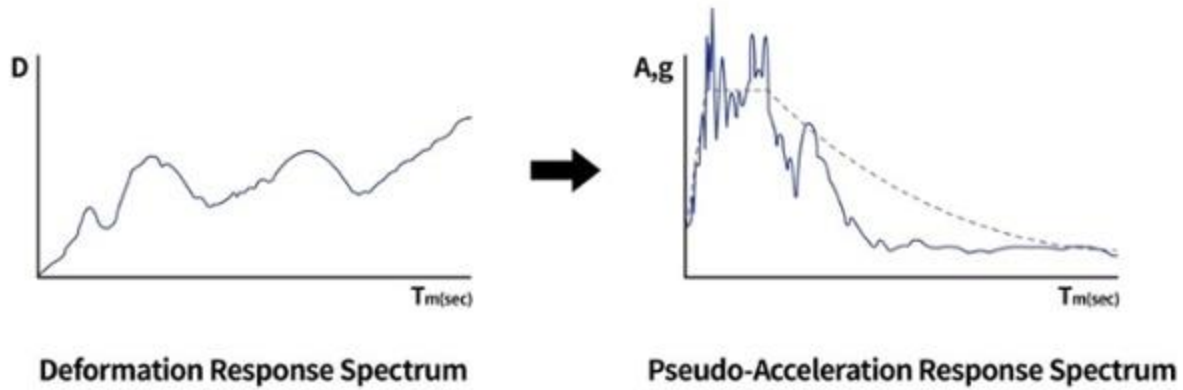




Introduction- Basic Seismic Terms

Response Spectra





Deformation Response Spectrum

Pseudo-Acceleration Response Spectrum

Why do we care? This is the Midwest!

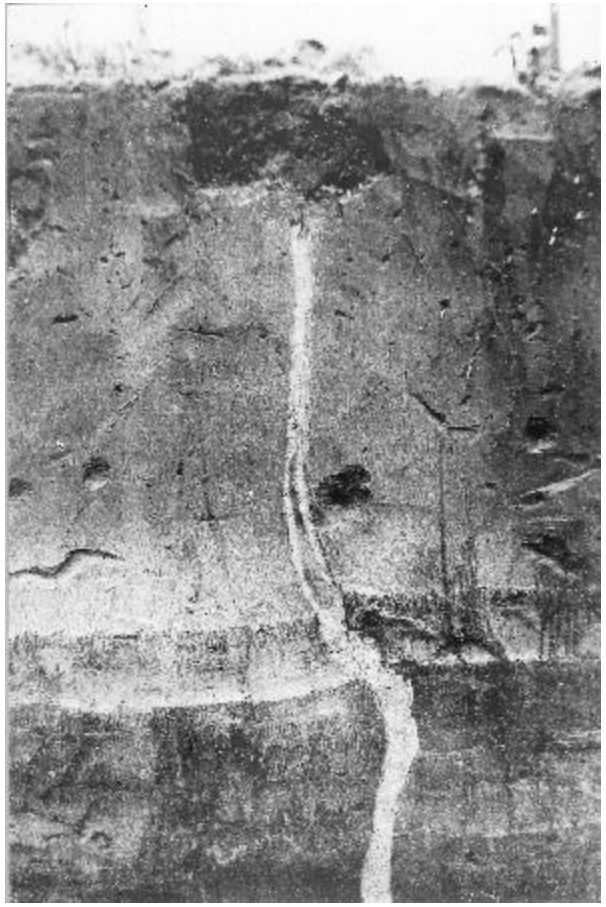
New Madrid EQ Zone

- Most powerful EQs in the contiguous US east of the Rockies.
- December 16, 1811- M7.2 to 8.2, northeast AR. M7.4 aftershock felt 6 hours later.
- Mercalli Intensity of IX felt where Memphis TN is today.
- River Seiche propagated up the Mississippi River.
- Fort San Fernando (today Caruthersville, MO) experienced heavy liquefaction damage.



The Great Earthquake at New Madrid, a 19th-century woodcut from Devens' *Our First Century* (1877)

Why do we care? This is the Midwest!



USGS- Earthquake fissure filled with intruded sand, formed at the time of the New Madrid earthquake. Mississippi County, Arkansas, (1904)

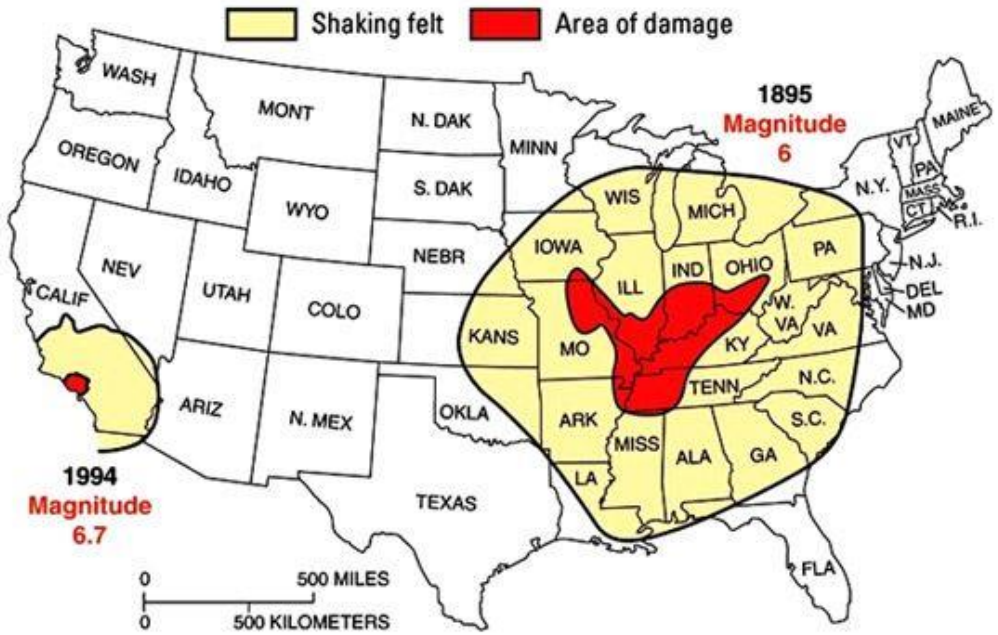
New Madrid EQ Zone

- January 23, 1812- M7.0 to 8.0, Epicenter MO bootheel.
  - Ground subsidence
  - Severe landsliding
  - Caving of stream banks
- February 7, 1812- M7.4 to 8.6, Epicenter Madrid MO.
  - Town of New Madrid destroyed
  - St. Louis MO experienced toppled chimneys and damaged structures
  - Uplift of Reelfoot Fault created waterfalls along the Mississippi at Kentucky Bend
  - Created Reelfoot Lake in Lake County, TN.

Why do we care? This is the Midwest!

New Madrid EQ Zone

- October 31, 1895 – M5.8 to 6.6, Epicenter Charleston, MO.
  - No foreshock felt
  - Building damage and liquefaction observed from Bertrand MO to Cairo IL (chimneys and windows at most buildings destroyed).
  - Charleston experienced severe damage: including broken windows and plaster, collapsed chimneys.
  - Two deaths, one in Bardwell, KY (suspected heart attack) and one in Avery IA (killed by falling slate at mine).
  - Explosion of gas line in Cincinnati OH injured seven.



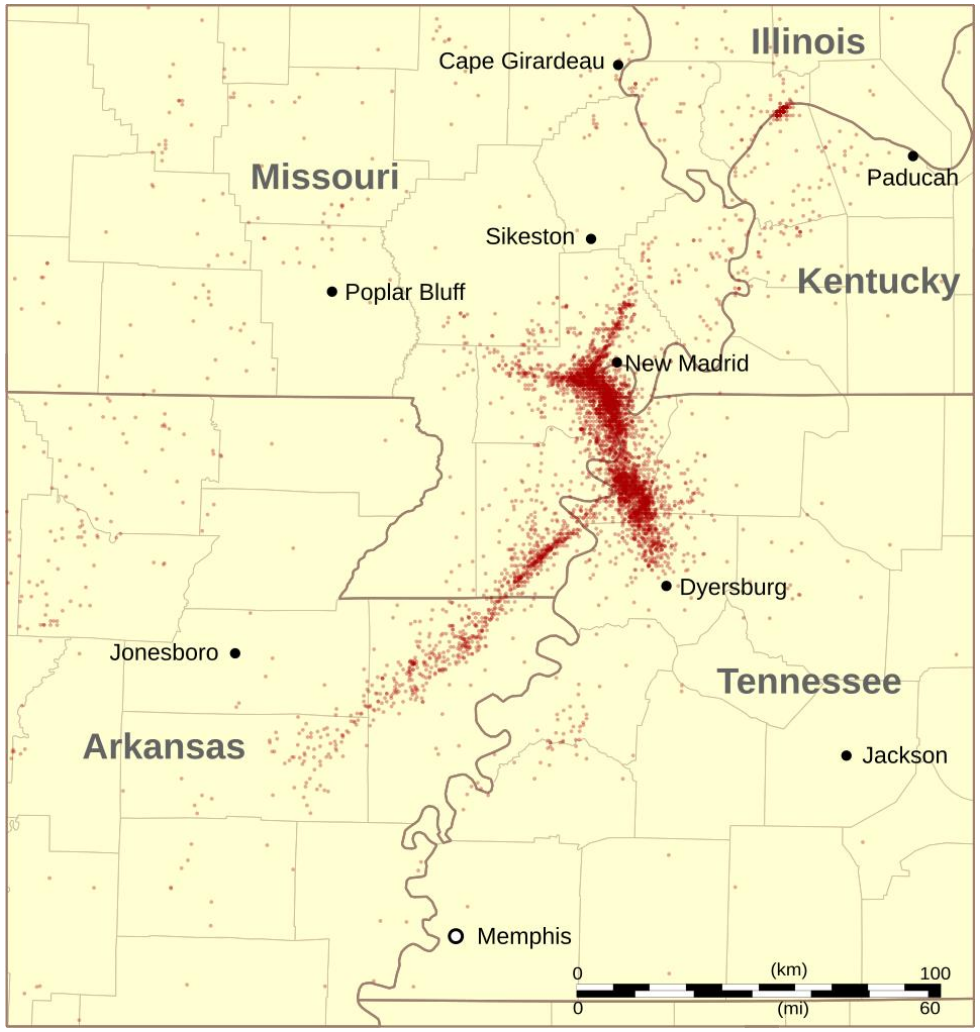
Jackson County, MO Earthquake Threat Website.

Why do we care? This is the Midwest!

New Madrid EQ Zone

- Still a whole lotta shaking going on!
- USGS expects a damaging EQ of MW 6.0 or greater every 80 years. (It has been 129 years).

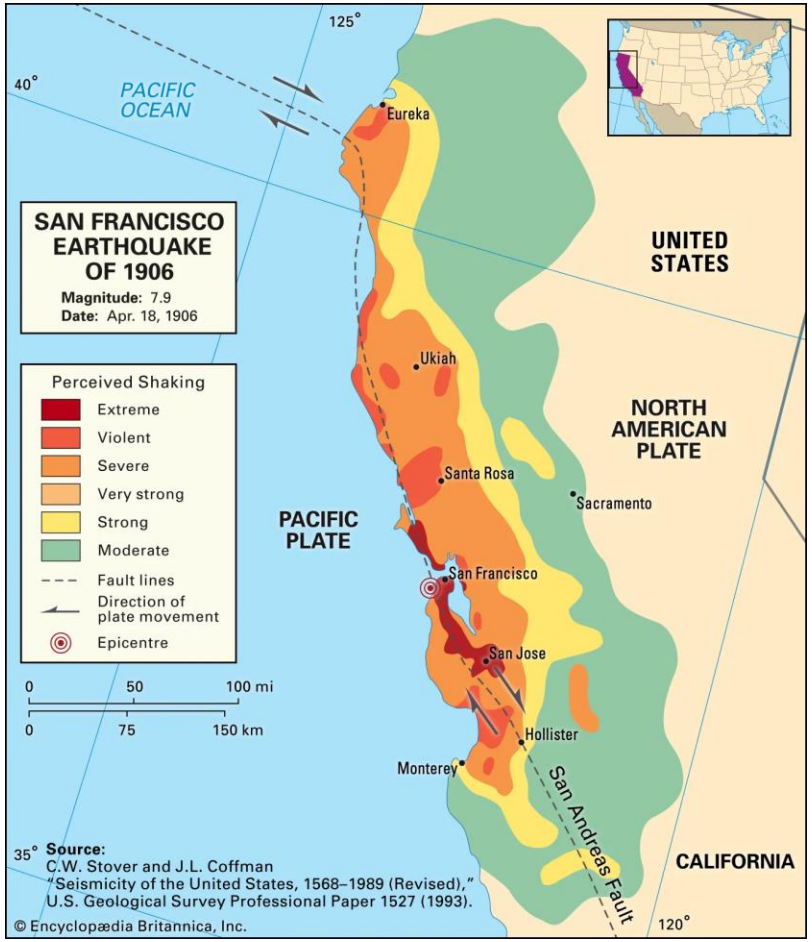




The Evolution of Seismic Building Codes

1906 San Fransico CA EQ

- Struck at 5:12 AM on April 18 and was a M7.9 EQ.
- Still considered one of the most significant EQs in the United States, due to:
  - First Major EQ in a densely populated city center (and major trade hub).
  - Ruptured 196 miles of the San Andreas Fault.
  - In addition to building and infrastructure damage, there was a 4-day firestorm. In all about 3,000 lost their lives.
- This event resulted in:
  - A significant effort to research and understand EQs and buildings, the birth of Seismic Engineering.
  - Civil Engineers were forced to rethink municipal water networks (redundancy in the system).
  - The benefits of reinforced concrete and steel framed buildings over unreinforced masonry was realized.
  - The need for understanding the geology and soils in foundation design was taken to a new level.



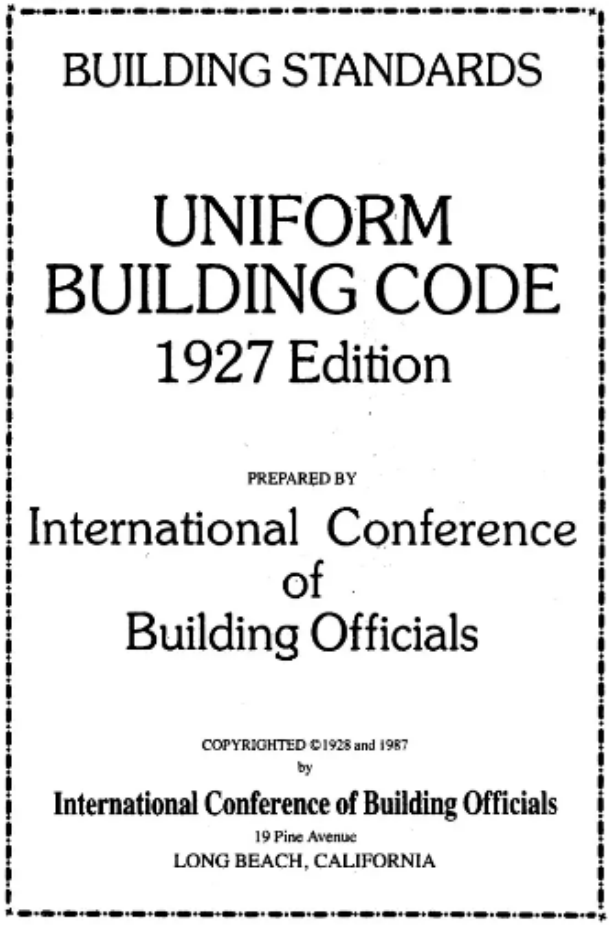
The Evolution of Seismic Building Codes



The Evolution of Seismic Building Codes

So, what was the response of engineers?

- Building codes were a new thing at the turn of the 20th century.
  - 1925, City of Santa Barbara and 1926, City of Palo Alto, CA added building code requirements, in response to the M6.3 1925 Santa Barbara EQ) requiring structures be designed to withstand lateral forces.
  - First Uniform Building Code (UBC) in 1927
    - Provided a non-mandatory appendix (Lateral Bracing Appendix) based on the recent Japanese seismic laws (Kanto EQ 1923) (which used a 0.1g seismic coefficient).
    - §2311: Recommended a minimum lateral design force for earthquake resistance:
      - V = 0.075W for buildings on foundations with allowable bearing pressures of 4,000 psf or more.
      - V = 0.10W for all other buildings (including those on pile foundations)
      - W=DL+LL


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

The Evolution of Seismic Building Codes

1933 Long Beach CA EQ

- M 6.4 EQ caused severe damage across Los Angeles basin. Poor fill material, high groundwater in soils combined with EQ ground motions was identified as the primary reason for this damage.





The Evolution of Seismic Building Codes

1933 Long Beach CA EQ

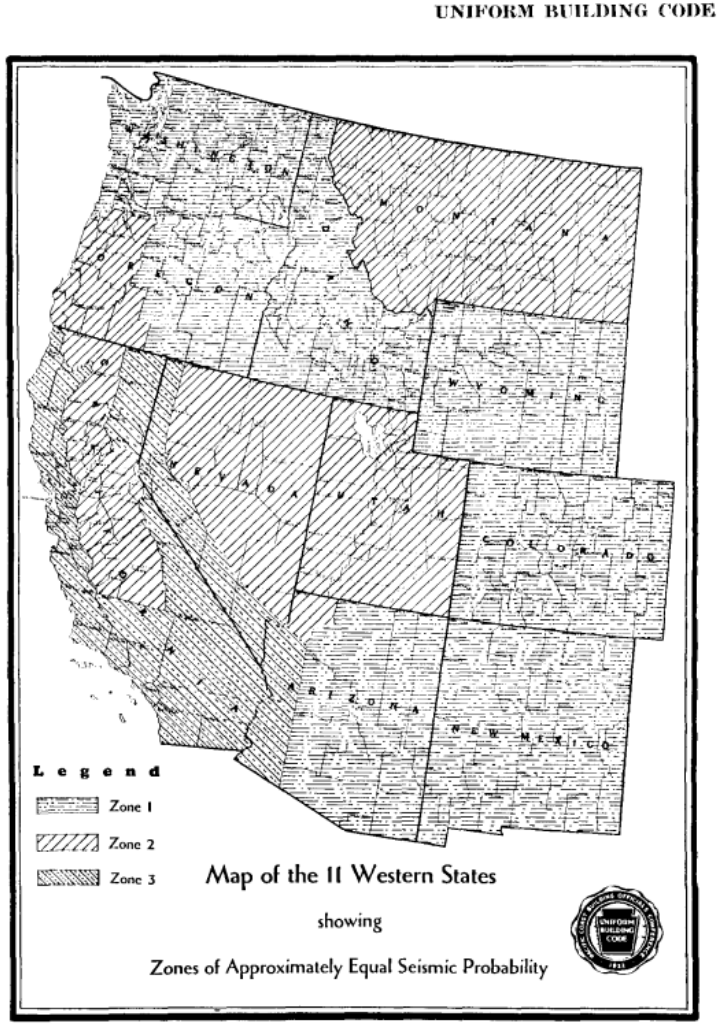
- The first mandatory seismic code was published in Long Beach requiring masonry buildings be designed for a lateral load equal to 10% of the dead load.
- The state of California passed the Field Act in 1933. This act was specifically to address safety for school buildings
  - 230 school buildings destroyed or red-tagged
  - Unreinforced masonry construction identified as a problem this act banned them for schools
  - Required a base shear of 3% of the total building deadload.



The Evolution of Seismic Building Codes

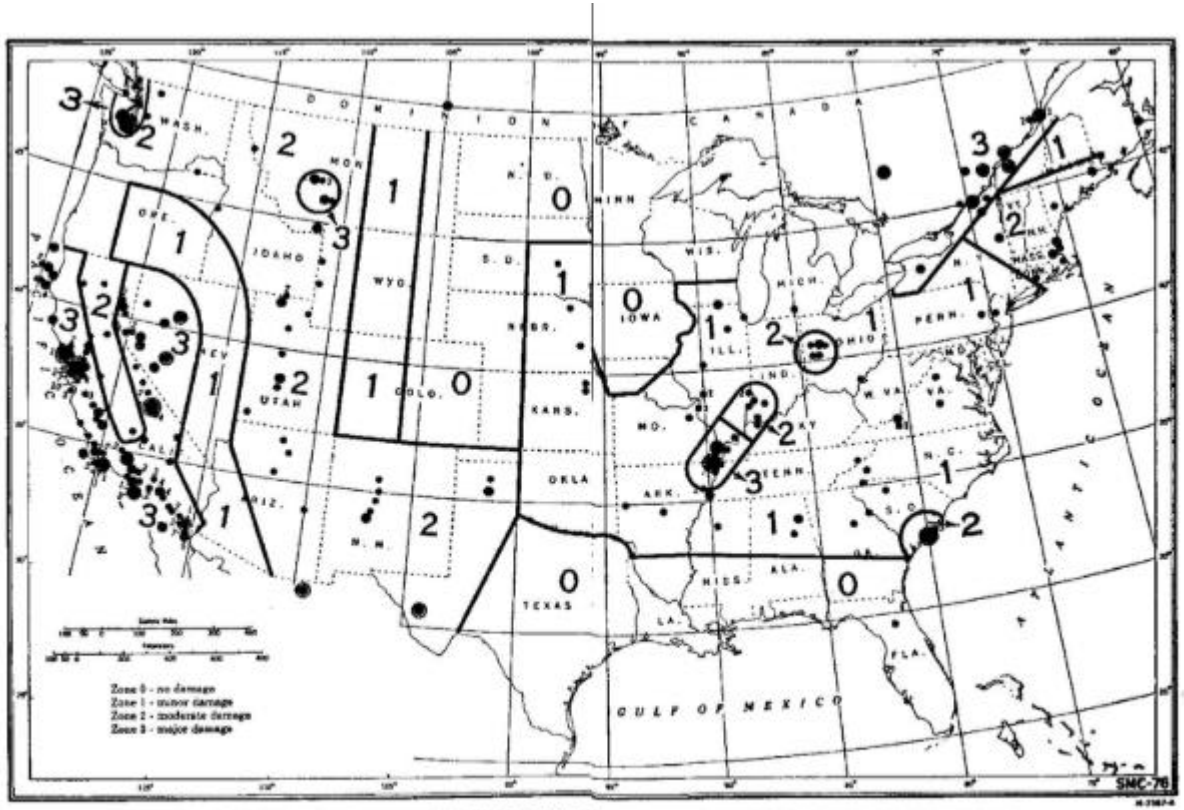
With great earthquakes comes great change.

- 1946 UBC included first seismic national hazard map.
  - This Map provided for 3 seismic zones (western US only) that provided multipliers for the C factor in the following equation:
    - $F = C \cdot W$.
      - F = Lateral Force
      - W = DL+LL/2.
  - Zone 3 multiply C by 4; Zone 2 multiply C by 2; and Zone 1 no factor.



The Evolution of Seismic Building Codes

- The Uniform Building Code Seismic Section was completely rewritten in the 1961 edition.
  - For the first time the fundamental period of a structure is being considered in the EQ lateral forces, as well as building importance and type.
  - 1959 SEAOC Recommended Lateral Force Requirements (aka “The Blue Book”) were considered
  - The entire US is also mapped and zoned.
- Base Shear Calculated as:
  - $V = Z \cdot K \cdot C \cdot W$
  - Z=Seismic Zone Factor (e.g. 1 for Zone 3)
  - K=Horizontal Force Factor (e.g. 0,67 for moment-resisting frame)
  - $C=0.05/T^{0.33}$, T= building period = $0.05H/D^{0.5}$.
  - W=DL



MAP OF THE UNITED STATES SHOWING ZONES OF APPROXIMATELY EQUAL SEISMIC PROBABILITY
As approved by the International Conference of Building Officials in Twenty-Eighth Annual Meeting for inclusion in the 1961 Edition of the Uniform Building Code. This map of seismic probability is legally a part of this Code.

The Evolution of Seismic Building Codes

1964 Alaska Earthquake.

- March 27, 1964, M 9.2 megathrust EQ. Shaking lasted over 4 minutes. It is estimated that 600 miles of fault movement occurred at once, with 60 feet of movement and 500 years of stress buildup released.
- Second most powerful earthquake recorded in the world (Most powerful since 1900 when recording EQs began).
- Severe damage from ground uplift, rupture, landsides, liquefaction and lateral spreading.
- Most buildings were not designed for EQs.
- Areas around Kodiak raised 30 feet, and near Girdwood and Portage dropped 8 feet.
- Port Valdez experienced a collapse of it harbor and docks due to a major underwater landslide. This resulted in a Tsunami that killed 32 people in the village of Chenega AK (an Inuit fishing village).

The Evolution of Seismic Building Codes

1964 Alaska Earthquake.





The Evolution of Seismic Building Codes

1964 Alaska Earthquake.





The Evolution of Seismic Building Codes

1971 San Fernando Earthquake.

- February 9, 1971, also known as the Sylmar EQ.
- Mw of 6.6, with a maximum Intensity of XI.
  - Surface Faulting and ground uplift damaged buildings
  - Several hospitals had severe damage
  - Roads and bridges collapsed
  - The Van Norman Dam almost failed due to liquefaction, resulting in tens of thousands of residents downstream being evacuated.



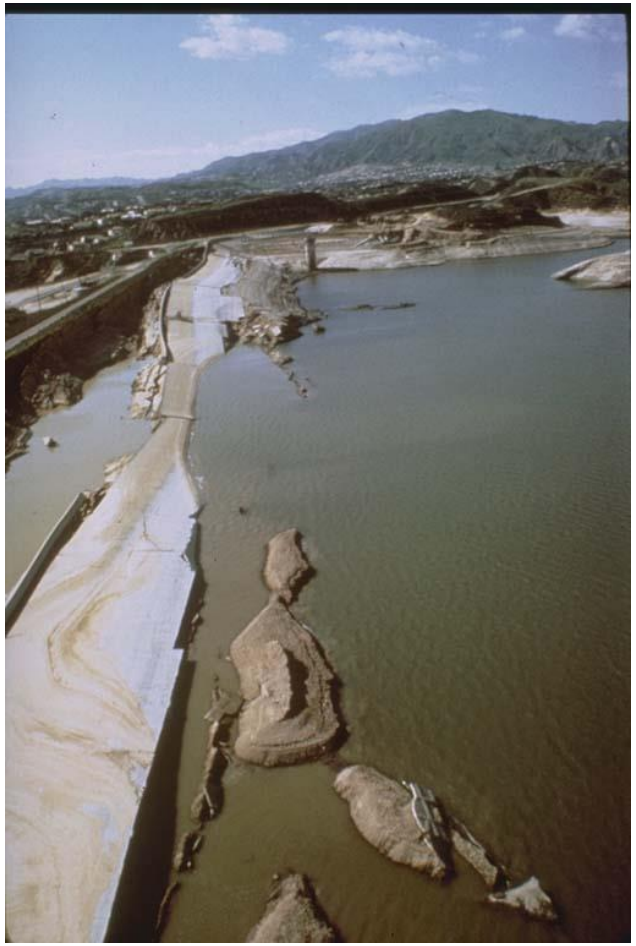
Los Angeles Times

The Evolution of Seismic Building Codes

1971 San Fernando Earthquake.



UC Berkley



Los Angeles Times

The Evolution of Seismic Building Codes

1971 San Fernando Earthquake.



USGS

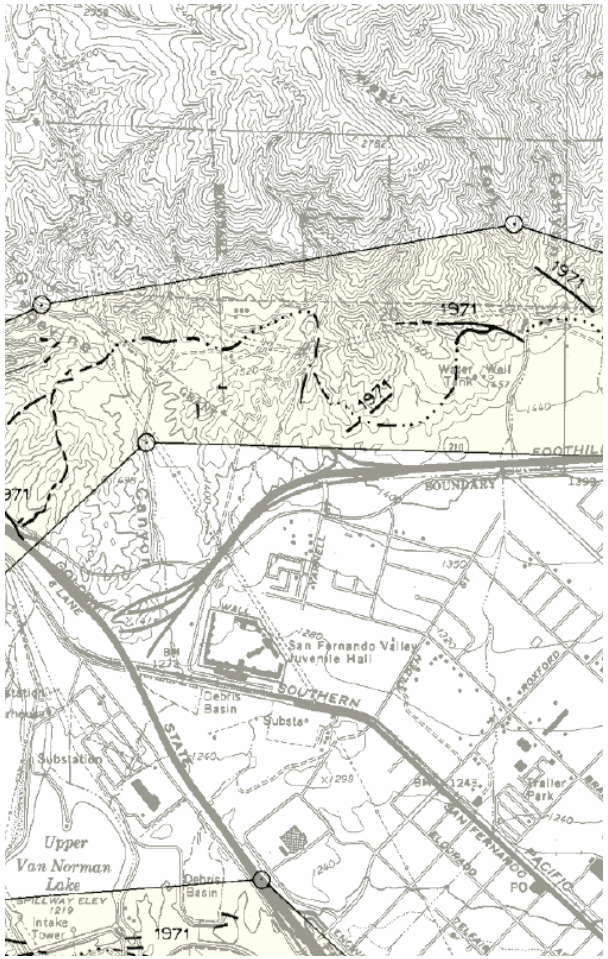


SC/EC

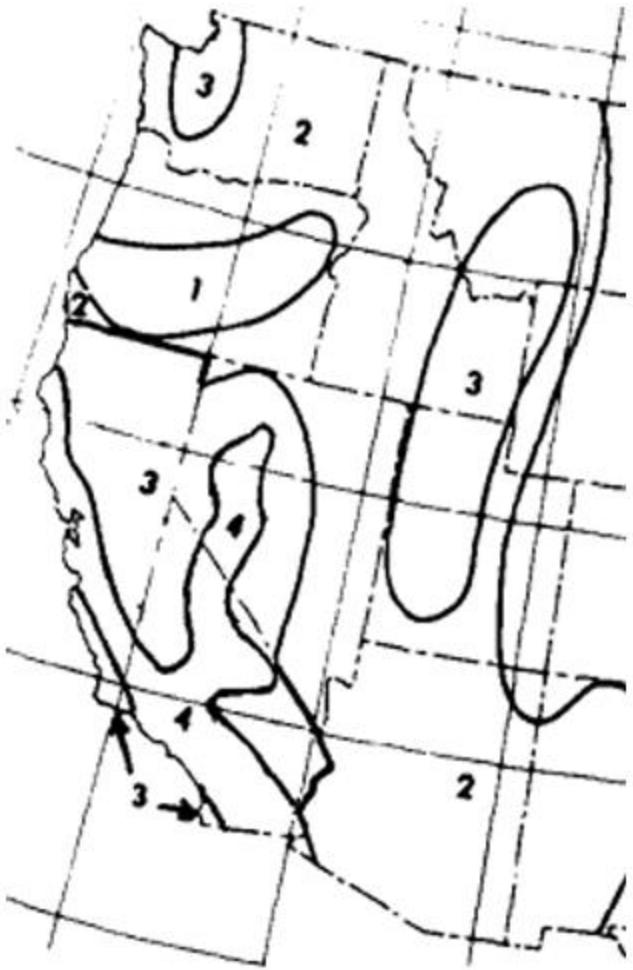
The Evolution of Seismic Building Codes

1971 San Fernando Earthquake.

- The state of California passed the Alquist-Priolo Earthquake Faulting Act in 1972.
  - Required the state geology survey to map all known quaternary faults and 660-foot setback zone that required fault investigation before a structure could be built in that zone.
- The state of California the Alfred E. Alquist Hospital Seismic Safety ACT in 1973.
  - Created code requirements for seismic design of hospitals presented in the California Building Code. Managed by the Office of Statewide Health Planning (OSHPD).



The Evolution of Seismic Building Codes



1971 San Fernando Earthquake.

- The Uniform Building Code Seismic Section was updated in the 1976 edition.
  - Fourth Seismic Zone added to the map
- Base Shear Calculated as:
- $V = Z \bullet I \bullet K \bullet C \bullet S \bullet W$
  - I=Building Importance Factor
  - S=Soil-structure interaction/resonance coefficient ($1.0 \leq S \leq 1.5$), defaulted at 1.5 if the site soil period T_s is unknown.
- First Edition of ASCE 7 was produced (ASCE 7-88). The Structural Engineering Institute (SEI) of ASCE owns this document.

The Evolution of Seismic Building Codes

1971 San Fernando Earthquake.

- The Uniform Building Code Seismic Section was again updated in the 1982 edition.
  - Soil Site Coefficients, S, were based on rock/soil characteristics
  - S_1 through S_3.
- The Uniform Building Code Seismic Section was again updated in the 1988 edition.
  - Soil Site Coefficients S_4 added.
- First Edition of ASCE 7 was produced (ASCE 7-88). The Structural Engineering Institute (SEI) of ASCE owns this document.

TABLE NO. 23-J
SITE COEFFICIENTS[1]

TYPE	DESCRIPTION	*S* FACTOR
S_1	A soil profile with either: (a) A rock-like material characterized by a shear-wave velocity greater than 2,500 feet per second or by other suitable means of classification, or (b) Stiff or dense soil condition where the soil depth is less than 200 feet.	1.0
S_2	A soil profile with dense or stiff soil conditions, where the soil depth exceeds 200 feet.	1.2
S_3	A soil profile 40 feet or more in depth and containing more than 20 feet of soft to medium stiff clay but not more than 40 feet of soft clay.	1.5
S_4	A soil profile containing more than 40 feet of soft clay.	2.0

[1]The site factor shall be established from properly substantiated geotechnical data. In locations where the soil properties are not known in sufficient detail to determine the soil profile type soil profile S_3 shall be used. Soil profile S_4 need not be assumed unless the building official determines that soil profile S_4 may be present at the site, or in the event that soil profile S_4 is established by geotechnical data.

The Evolution of Seismic Building Codes

1989 Loma Prieta Earthquake.

- October 17, 1989, San Francisco Bay area, Mw of 6.9. Damage included
  - Liquefaction of old fill (from the landfill following the 1906 EQ) in the Marina District resulted in severe building damage and fires due to gas line breaks.
  - Collapse of infrastructure including the Cypress Street Viaduct and a portion of the Bay Bridge occurred.
  - 57 deaths due to EQ, 6 related to EQ and almost 3,800 injuries occurred.
  - Interrupted the MLB World Series at Candlestick Park.



The Evolution of Seismic Building Codes

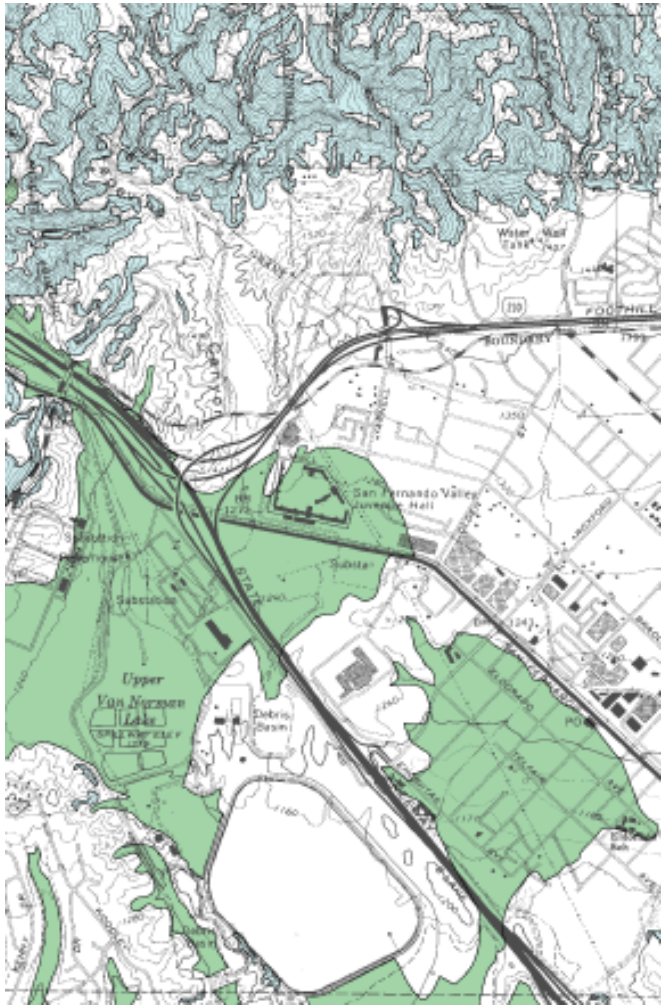




The Evolution of Seismic Building Codes

1989 Loma Prieta Earthquake.

- 1989 Loma Prieta Earthquake.
- 1990 the Seismic Hazards Mapping Act (SHMA) passed, requiring mapping of Liquefaction and Seismic Slope Stability and Ground Acceleration hazards.



The Evolution of Seismic Building Codes

1994 Northridge Earthquake.

- January 17, 1994, Mw of 6.7, same area as 1971 Sylmar EQ.
- Recorded the largest recorded PGA of 1.7g.
- 57 deaths and more than 9,000 injuries.
- Santa Susanna Mountains thrusted up about 16-inches.
- Over 11,000 landslide recorded.
- Older, unreinforced masonry building still a problem.
- Most building collapses were apartment buildings over parking areas.
- Several overhead freeways collapsed due to inadequate confinement of vertical column rebar.
- It was found that the UBC and ACI building codes for design of Braced Moment Frames and concrete Diaphragm Walls were inadequate and needed to be revisited.



The Evolution of Seismic Building Codes

1994 Northridge Earthquake.





The Evolution of Seismic Building Codes

1994 Northridge Earthquake.





The Evolution of Seismic Building Codes

Transition to the International Building Code.

- The 1991 UBC was the next rewrite of seismic section, taking in lessons learned primarily from the 1989 EQ. 1994 UBC was published in 2 volumes.
- Base shear Calculated:

$$V = \frac{Z \cdot I \cdot C}{R} W$$

  - Z=Seismic Zone Factor
  - I=Building Importance Factor
  - C=Seismic Coefficient

$$C = \frac{1.25S}{T^{2/3}} \leq 2.75$$

  - R=Response Modification Factor (ductility and energy dissipation of structure)
  - W=Total Seismic DL

The Evolution of Seismic Building Codes

Transition to the International Building Code.

- The 1997 UBC added the following:
  - Maximum Base Shear Limit
  - Minimum Base Shear Limit
  - Near-source Minimum for Seismic Zone 4.
- Base shear calculated:
  - C_v=Seismic Coefficient for velocity-related acceleration
  - C_a=Seismic Coefficient for acceleration-related seismic coefficient
  - N_v=Near source velocity-related seismic coefficient
  - W=Total Seismic DL

Base shear

$$V = \frac{C_v \cdot I}{R \cdot T} W$$

Maximum Base Shear Limit

$$V \leq \frac{2.5 C_a \cdot I}{R} W$$

Minimum Base Shear Limit

$$V \geq 0.11 C_a \cdot I \cdot W$$

Near-source Minimum for Seismic Zone 4

$$V = \frac{0.8 Z \cdot N_v \cdot I}{R} W$$

The Evolution of Seismic Building Codes

1997 UNIFORM BUILDING CODE

FIGURE 16-2

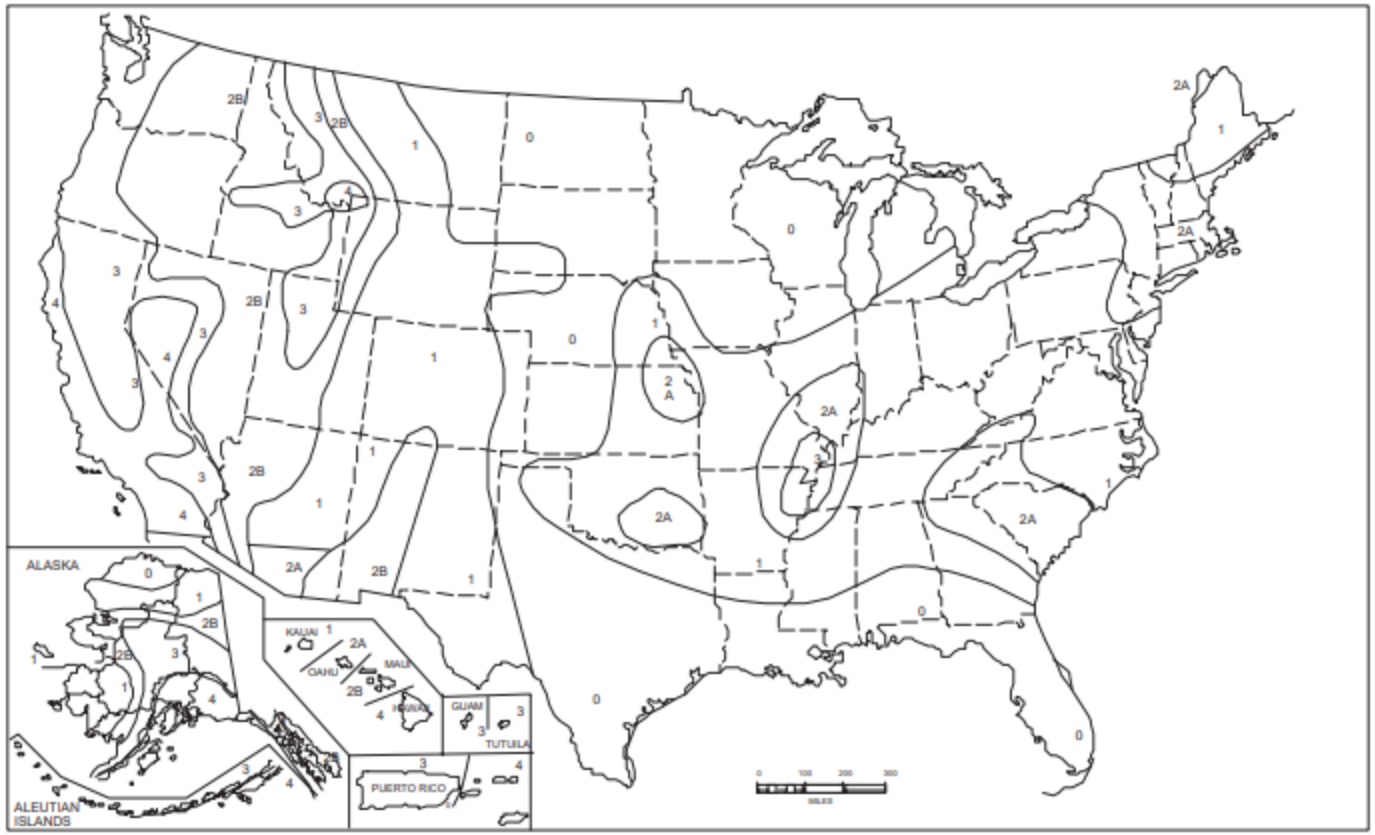


FIGURE 16-2—SEISMIC ZONE MAP OF THE UNITED STATES
For areas outside of the United States, see Appendix Chapter 16.

FIGURE 16-3

1997 UNIFORM BUILDING CODE

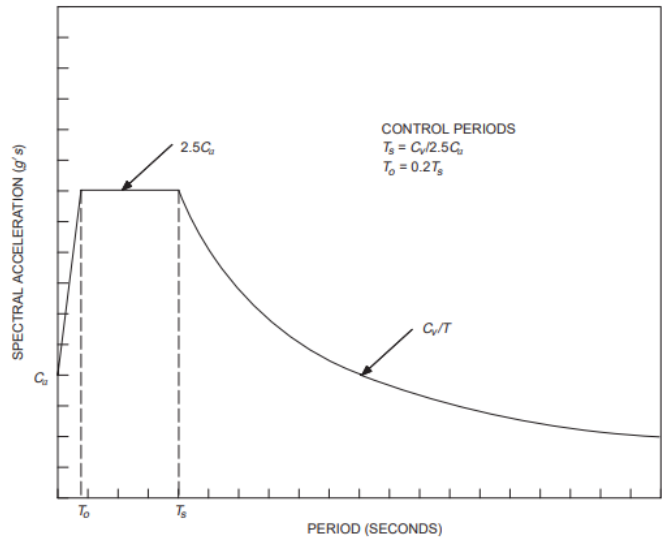
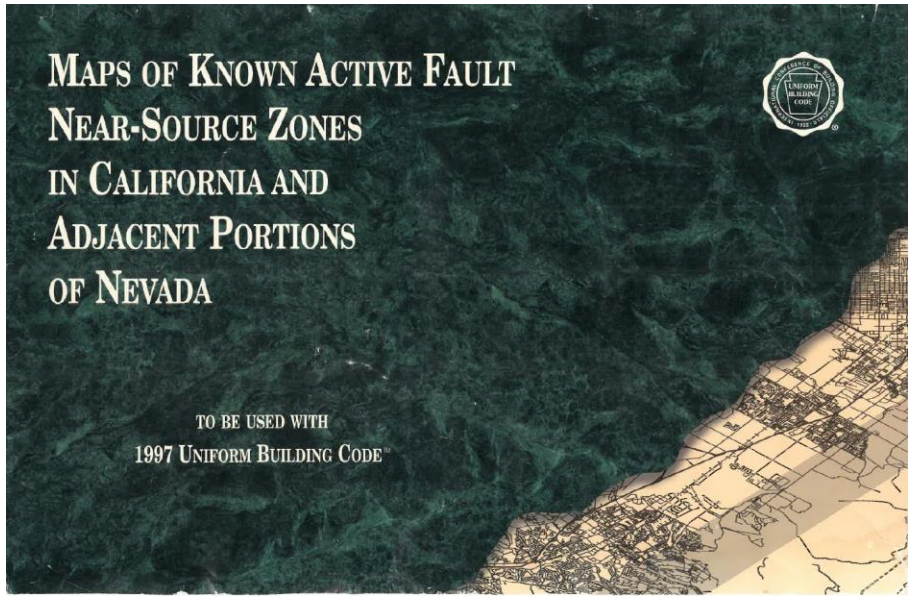
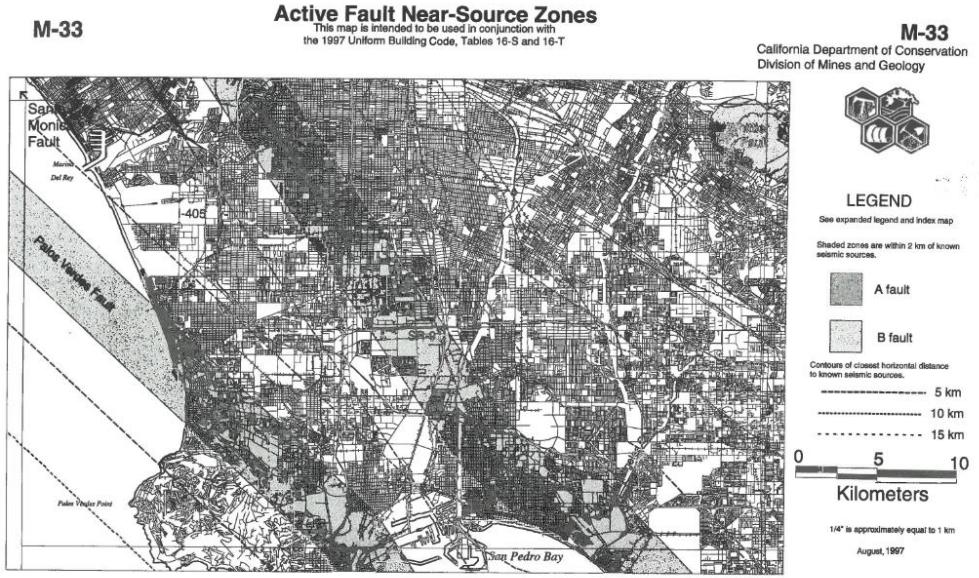


FIGURE 16-3—DESIGN RESPONSE SPECTRA

The Evolution of Seismic Building Codes

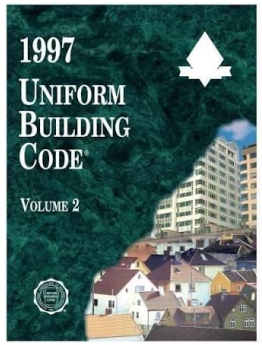




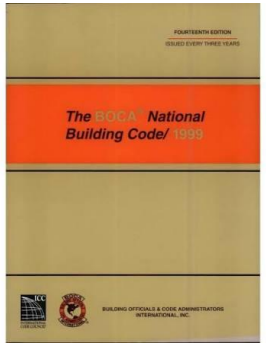
The Evolution of Seismic Building Codes

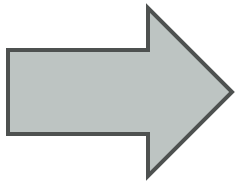
Transition to the International Building Code.

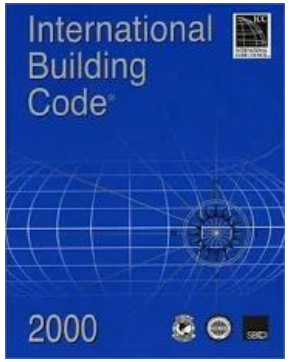
- International Building Code replaced UBC and other codes.
- 1994 the Building Officials and Code Administrators (BOCA) merged with the International Conference of Building Officials (ICBO) and Southern Building Code International, Inc. (SBCCI) to form the Internation Code Council (ICC) to provide one building code for the United States.
- The last UBC was published in 1997. This included the first use of a calculated response spectra and had a supplement for near fault effects for sites in California.











The Evolution of Seismic Building Codes

Transition to the International Building Code.

- In 2000, the first edition of the IBC was published and adopted, and kept 1997 UBC Seismic provisions
- The 2003 IBC was a complete rewrite of the 2000 IBC/1997 UBC.
  - The Seismic Zone maps were replaced with spectral acceleration maps based on the NEHRP ground acceleration models, and spectral accelerations for short (T=0.2-sec) and long (T=1-sec) periods, Ss and S1, were now to be used as inputs for the design response spectra.
  - Introduced the use of the Maximum Considered Earthquake (MCE) which was the 2% in 50-year event with a return period of 2,500 years.
  - Design ground motions set at 2/3 of the MCE.
  - Introduced Site Classes (A through F), Table 1615.1.1.
  - Introduced use of Long-period translation period (T_L), Figure 22-16 ASCE 7



The Evolution of Seismic Building Codes

2003 International Building Code.

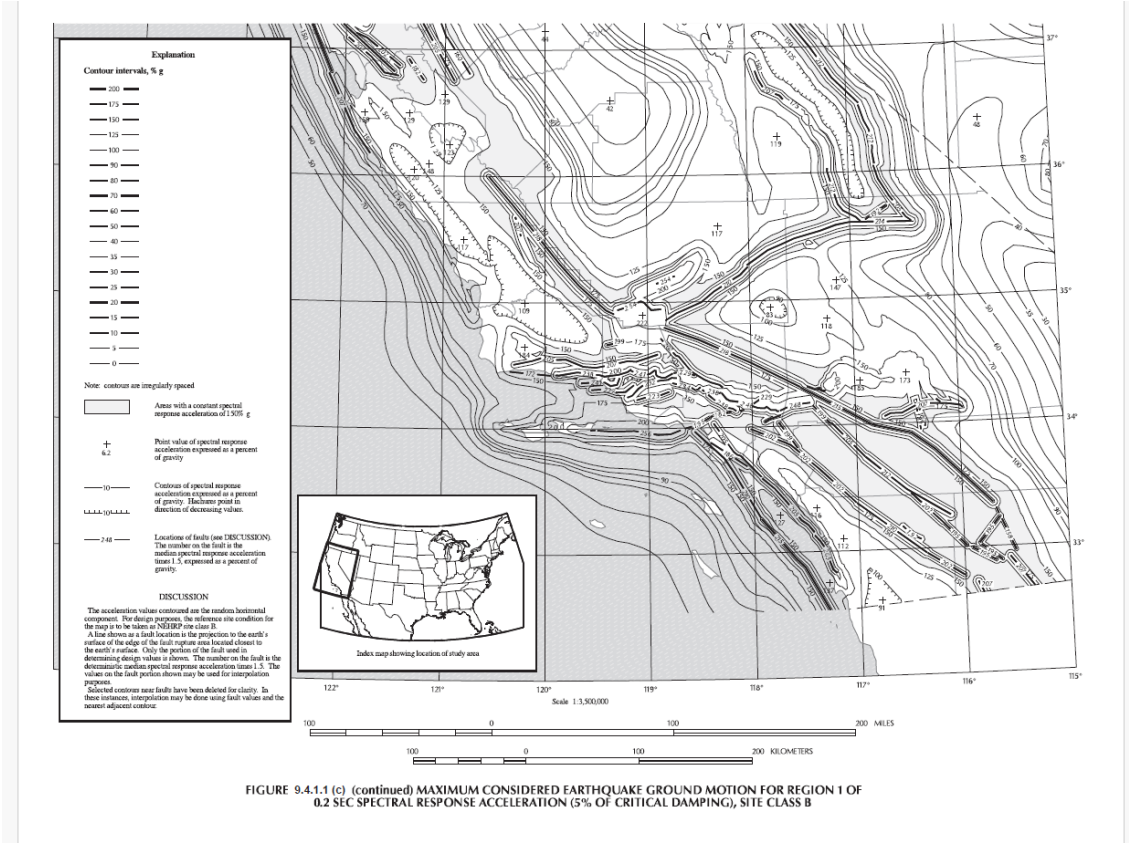
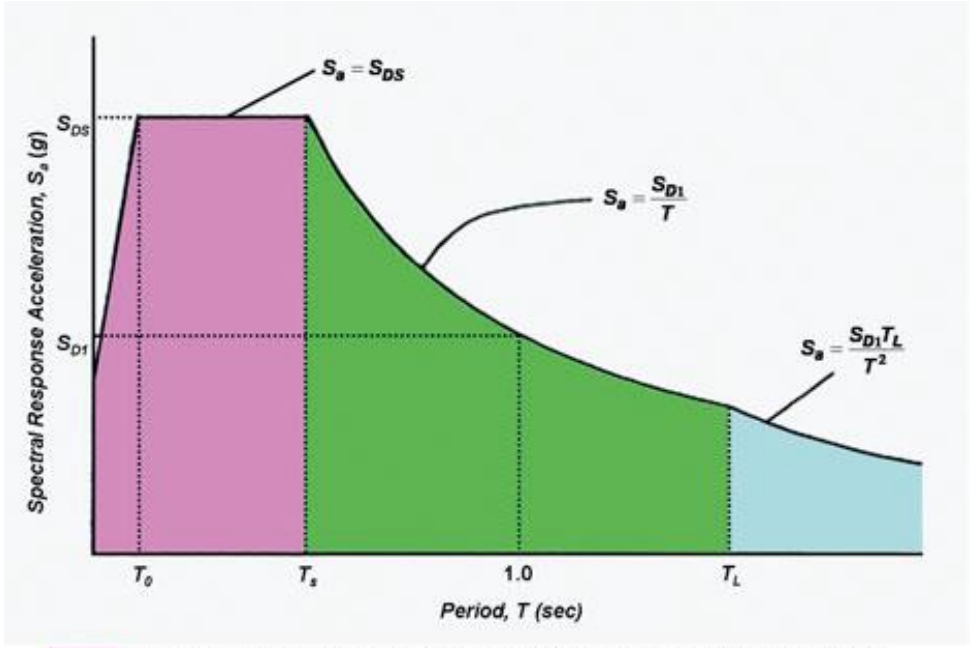


FIGURE 9.4.1.1 (c) (continued) MAXIMUM CONSIDERED EARTHQUAKE GROUND MOTION FOR REGION 1 OF 0.2 SEC SPECTRAL RESPONSE ACCELERATION (5% OF CRITICAL DAMPING), SITE CLASS B

The Evolution of Seismic Building Codes

2000 to 2012 International Building Code.



The Evolution of Seismic Building Codes

2012 International Building Code.

- The seismic section is essentially what is in use through the current 2021 IBC (ASCE 7-16).
- Introduced on-line application to determine response spectra based on Site Class, Structure Type and site location. https://ascehazardtool.org/
- The main difference between codes was the USGS ground motion models used.

Base shear

$$V = C_s \cdot W$$

Seismic Response Coefficient

$$C_s = \frac{S_{DS}}{R/I_e}$$

Upper Limits on C_s

$$T \le T_L: \quad C_s = \frac{S_{D1}}{T\left(R/I_e\right)} \qquad T > T_L: \quad C_s = \frac{S_{D1} \cdot T_L}{T^2\left(R/I_e\right)}$$

Lower Limits on C_s, must satisfy

$$C_s \ge 0.44 \cdot S_{DS} \cdot I_e \ge 0.01$$

The Evolution of Seismic Building Codes

2012 to 2021 International Building Code.

REPORT SUMMARY

ASCE 7-10

Seismic

S_S	1.619
S_1	0.566
F_a	1
F_v	1.5
S_{MS}	1.619
S_{M1}	0.849
S_{DS}	1.079
S_{D1}	0.566
T_L	12
PGA	0.934
PGA_M	0.934
F_{PGA}	1
I_e	1.5
Seismic Design Category	D

REPORT SUMMARY

ASCE 7-16

Seismic

S_S	1.53
S_1	0.522
F_a	1
F_v	N/A
S_{MS}	1.53
S_{M1}	N/A
S_{DS}	1.02
S_{D1}	N/A
T_L	12
PGA	0.941
PGA_M	1.035
F_{PGA}	1.1
I_e	1.5
C_v	1.406
NO SEISMIC SPECTRUM	Design and MCE_R spectrum data not available for this location
Note	Ground motion hazard analysis may be required. See ASCE/SEI 7-16 Section 11.4.8.

The Evolution of Seismic Building Codes

2021International Building Code.

- The 2021 edition of the IBC (ASCE 7-16).
  - Step 1- Determine Building Risk Category (Table 1604.5)
  - Most buildings will fall under Risk Category II
  - Risk Category III is for large occupancy structures that represent substantial hazard to human life.
  - Risk Category IV is for essential facilities (i.e. power generation, emergency care, etc.)

accordance with Section 6.4 of ASCE 7.

TABLE 1604.5
RISK CATEGORY OF BUILDINGS AND OTHER STRUCTURES

RISK CATEGORY	NATURE OF OCCUPANCY
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to: • Agricultural facilities. • Certain temporary facilities. • Minor storage facilities.
II	Buildings and other structures except those listed in Risk Categories I, III and IV.
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to: • Buildings and other structures whose primary occupancy is public assembly with an occupant load greater than 300. • Buildings and other structures containing Group E occupancies with an occupant load greater than 250. • Buildings and other structures containing educational occupancies for students above the 12th grade with an occupant load greater than 500. • Group I-2, Condition 1 occupancies with 50 or more care recipients. • Group I-2, Condition 2 occupancies not having emergency surgery or emergency treatment facilities. • Group I-3 occupancies. • Any other occupancy with an occupant load greater than 5,000.[a] • Power-generating stations, water treatment facilities for potable water, wastewater treatment facilities and other public utility facilities not included in Risk Category IV. • Buildings and other structures not included in Risk Category IV containing quantities of toxic or explosive materials that: Exceed maximum allowable quantities per control area as given in Table 307.1(1) or 307.1(2) or per outdoor control area in accordance with the *International Fire Code*; and Are sufficient to pose a threat to the public if released.[b]
IV	Buildings and other structures designated as essential facilities, including but not limited to: • Group I-2, Condition 2 occupancies having emergency surgery or emergency treatment facilities. • Ambulatory care facilities having emergency surgery or emergency treatment facilities. • Fire, rescue, ambulance and police stations and emergency vehicle garages. • Designated earthquake, hurricane or other emergency shelters. • Designated emergency preparedness, communications and operations centers and other facilities required for emergency response. • Power-generating stations and other public utility facilities required as emergency backup facilities for Risk Category IV structures. • Buildings and other structures containing quantities of highly toxic materials that: Exceed maximum allowable quantities per control area as given in Table 307.1(2) or per outdoor control area in accordance with the *International Fire Code*; and Are sufficient to pose a threat to the public if released.[b] • Aviation control towers, air traffic control centers and emergency aircraft hangars. • Buildings and other structures having critical national defense functions. • Water storage facilities and pump structures required to maintain water pressure for fire suppression.

a. For purposes of occupant load calculation, occupancies required by Table 1004.5 to use gross floor area calculations shall be permitted to use net floor areas to determine the total occupant load.
b. Where approved by the building official, the classification of buildings and other structures as Risk Category III or IV based on their quantities of toxic, highly toxic or explosive materials is permitted to be reduced to Risk Category II, provided that it can be demonstrated by a hazard assessment in accordance with Section 1.5.3 of ASCE 7 that a release of the toxic, highly toxic or explosive materials is not sufficient to pose a threat to the public.

The Evolution of Seismic Building Codes

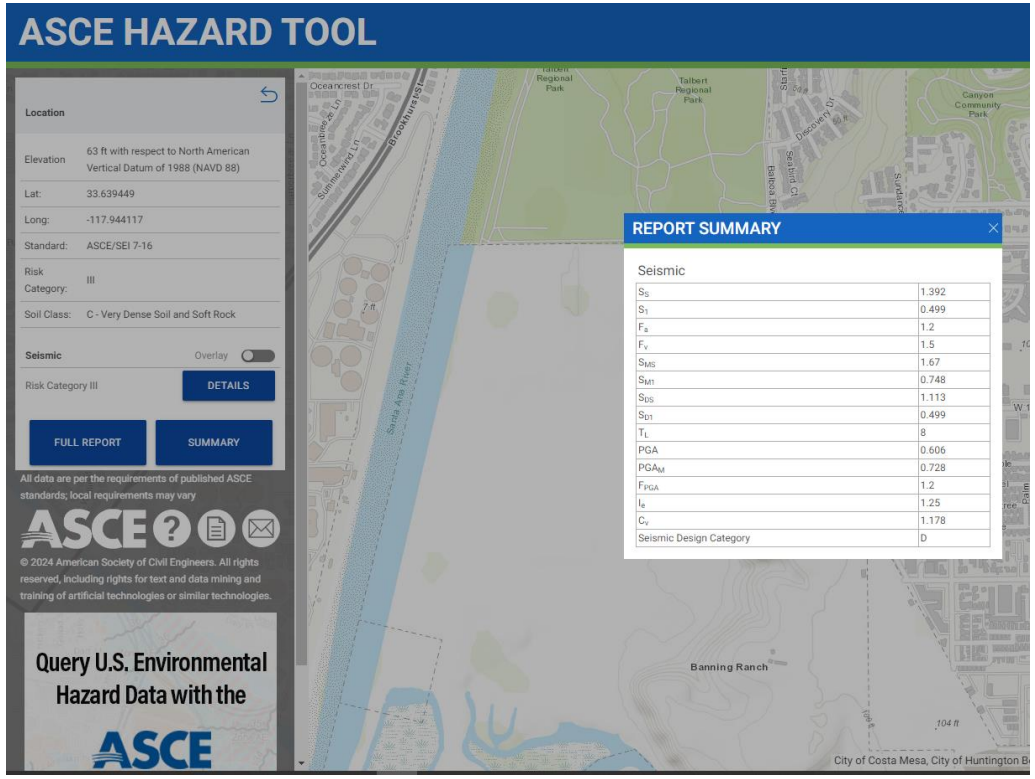
2021International Building Code.

- The 2021 edition of the IBC (ASCE 7-16).
  - Step 2- Determine Site Class (Table 20.3-1 ASCE 7)
  - This allows for the use of corrected N60 blow-counts, undrained shear strength (s_u) or seismic velocities (V_s) in the upper 100 feet of the site soils.
  - This is taken as a weighted average of the measurements.
  - Site Class F requires a Site-specific Evaluation for response spectra.

The Evolution of Seismic Building Codes

2021International Building Code.

- The 2021 edition of the IBC (ASCE 7-16).
  - Step 3- Use ASCE Hazard Tool to look up seismic coefficients and peak ground acceleration.



The Evolution of Seismic Building Codes

2021International Building Code.

- The 2021 edition of the IBC (ASCE 7-16).
  - Step 4- Report values in geotechnical report for the Structural Engineer to use.
  - At a minimum we report the Site Class for sites with expected low eq ground motions.
  - For areas with expected moderate to severe eq ground motions we should report Site Class, Spectral Acceleration for Short Periods (Ss) Spectral Acceleration for 1-second Period (S1) and design modified peak ground acceleration (PGAM)

REPORT SUMMARY

Seismic

S_S	1.53
S_1	0.522
F_a	1
F_v	N/A
S_{MS}	1.53
S_{M1}	N/A
S_{DS}	1.02
S_{D1}	N/A
T_L	12
PGA	0.941
PGA_M	1.035
F_{PGA}	1.1
I_e	1.5
C_v	1.406
NO SEISMIC SPECTRUM	Design and MCE_R spectrum data not available for this location
Note	Ground motion hazard analysis may be required. See ASCE/SEI 7-16 Section 11.4.8.

The Evolution of Seismic Building Codes

International Building Code 2024 (ASCE 7-22)

- Substantial Changes include:
  - Updated Seismic Ground Motion Maps
  - Intermediate Site Classes (BC, CD, DE).
  - The use of Seismic Shear Wave Velocities is encouraged.
  - You can still use correlations of N_{60} and Su to Vs, but with a 33% decrease in the V_s for determining Site Class

The Evolution of Seismic Building Codes

Table 20.3-1 Site Classification

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard rock	>5,000 ft/s	NA	NA
B. Rock	2,500 to 5,000 ft/s	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50 blows/ft	>2,000 lb/ft^2
D. Stiff soil	600 to 1,200 ft/s	15 to 50 blows/ft	1,000 to 2,000 lb/ft^2
E. Soft clay soil	<600 ft/s	<15 blows/ft	<1,000 lb/ft^2
	Any profile with more than 10 ft of soil that has the following characteristics: — Plasticity index $PI > 20$, — Moisture content $w \geq 40\%$, — Undrained shear strength $\bar{s}_u < 500$ lb/ft^2		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

Note: For SI: 1 ft = 0.3048 m; 1 ft/s = 0.3048 m/s; 1 lb/ft^2 = 0.0479 kN/m^2.

ASCE7-16

Table 20.2-1. Site Classification.

Site Class	$\bar{v}_s$ Calculated Using Measured or Estimated Shear Wave Velocity Profile (ft/s)
A. Hard rock	>5,000
B. Medium hard rock	>3,000 to 5,000
BC. Soft rock	>2,100 to 3,000
C. Very dense sand or hard clay	>1,450 to 2,100
CD. Dense sand or very stiff clay	>1,000 to 1,450
D. Medium dense sand or stiff clay	>700 to 1,000
DE. Loose sand or medium stiff clay	>500 to 700
E. Very loose sand or soft clay	≥500
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.2.1

Note: For SI: 1 ft = 0.3048 m; 1 ft/s = 0.3048 m/s.

ASCE7-22

The Evolution of Seismic Building Codes

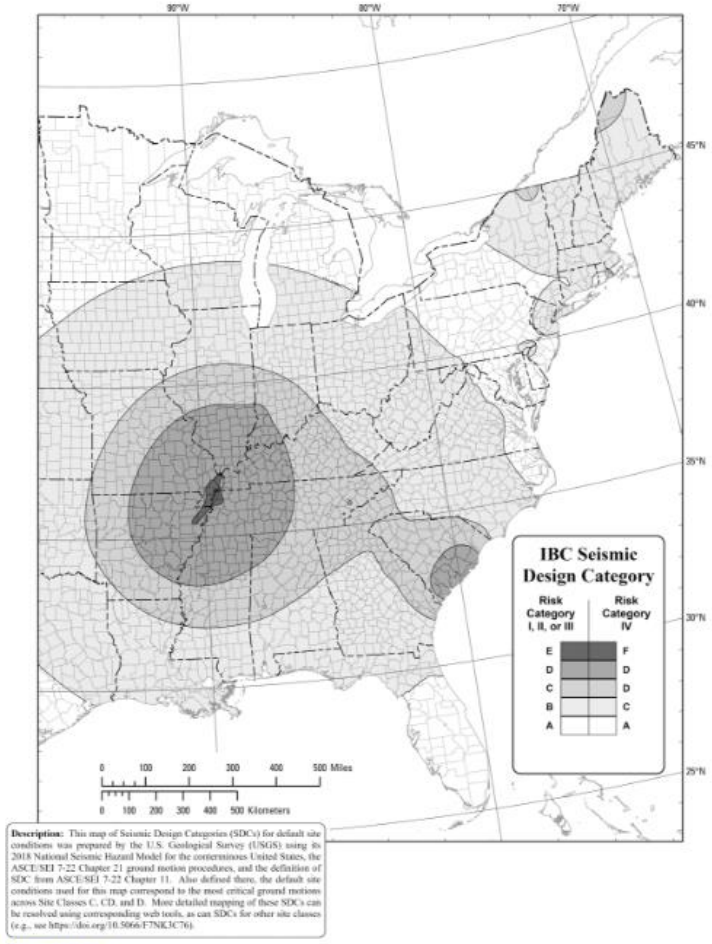


FIGURE 1613.2(2)
SEISMIC DESIGN CATEGORIES FOR DEFAULT SITE CONDITIONS FOR THE CONTERMINOUS UNITED STATES (EASTERN)

International Building Code 2024 (ASCE 7-22)

- Substantial Changes include:
  - Inclusion of the Seismic Design Category (SDC) Maps. The ASCE 7-22 option in the ASCE Hazard Tool can also be used to determine.
  - This eliminates the need to use F_a and F_v to determine the response spectra values.
  - Only set up for Site Classes C, DC, and D.
  - Not for use with Site Classes DE, E, or F. For these site classes refer to ASCE 7-22.

The Evolution of Seismic Building Codes

Key Provisions of Section 20.3

- **Estimation Requirements:** Where measured v_s data is unavailable, v_s must be estimated for the top 100 ft ($30\ \mathrm{m}$) using correlations with:
  - Standard penetration test (SPT) blow counts (N-values).
  - Cone penetration test (CPT) tip resistance.
  - Shear strength.
  - Overburden pressure or void ratio.
- **Sensitivity Evaluation (The 1.3 Factor):** When using correlation models, the site class must be derived using $\bar{v}_s$, $\frac{\bar{v}_s}{1.3}$, and $1.3 \times \bar{v}_s$. If these result in different site classes, the most critical (weaker soil) must be used.
- **Alternative Regional Data:** If established regional correlations exist that demonstrate higher accuracy than the standard 1.3 factor, a lower factor can be used, provided it is approved by the Authority Having Jurisdiction (AHJ).
- **Application in 7-22:** This section is part of the revised site classification procedures in Chapter 20 that aim to provide better accuracy in estimating site impacts on seismic ground motion. Froehling & Robertson +2

Note: In ASCE 7-22, this is a new section that was renumbered from previous editions. ASCE Amplify

Conclusions

- The seismic guidelines in Building Codes and other design guidelines will keep evolving as our understanding of earthquakes and their effects are better understood.
- The ASCE 7/IBC consider the risks for the entire United States, not just the west coast.
- The use of geophysical methods to directly measure seismic shear wave velocity is now the encouraged method.

Thank You

