Lateral Loads on Structures

Load Types

- Wind
- Earthquake

ASCE – 7 Chapter 3 Wind Loads

- Ch. 3 - Dead Loads
- Ch. 4 - Live Loads
- Ch. 5 - Flood Loads
- Ch. 6 - Tsunami Loads
- Ch. 7 - Snow Loads
- Ch. 8 - Rain Loads
- Ch. 10 - Ice Loads
- Ch. 11-23 Seismic Loads
- **Ch. 26-31 Wind Loads**

CHAPTER 26
WIND LOADS: GENERAL REQUIREMENTS

26.1 PROCEDURES

26.1.1 Scope. Buildings and other structures, including the main wind force resisting system (MWFRS) and all components and cladding (C&C) thereof, shall be designed and constructed to resist the wind loads determined in accordance with Chapters 26 through 31. The provisions of this chapter define basic wind parameters for use with other provisions contained in this standard.

26.1.2 Permitted Procedures. The design wind loads for buildings and other structures, including the MWFRS and C&C elements thereof, shall be determined using one of the procedures as specified in this section. An outline of the overall process for the determination of the wind loads, including section references, is provided in Fig. 26.1-1.

26.1.2.1 Main Wind Force Resisting System. Wind loads for the MWFRS shall be determined using one of the following procedures:

1. Directional Procedure for buildings of all heights as specified in Chapter 27 for buildings meeting the requirements specified therein;
2. Envelope Procedure for low-rise buildings as specified in Chapter 28 for buildings meeting the requirements specified therein;
3. Directional Procedure for Building Appurtenances (rooftop structures and rooftop equipment) and Other Structures (such as solid freestanding walls and solid freestanding signs, chimneys, tanks, open signs, single-plane open frames, and trussed towers) as specified in Chapter 29; or
4. Wind Tunnel Procedure for all buildings and all other structures as specified in Chapter 31.

26.1.2.2 Components and Cladding. Wind loads on C&C on all buildings and other structures shall be designed using one of the following procedures:

1. Analytical Procedures provided in Parts 1 through 6, as appropriate, of Chapter 30; or
2. Wind Tunnel Procedure as specified in Chapter 31.

26.2 DEFINITIONS

The following definitions apply to the provisions of Chapters 26 through 31:

APPROVED: Acceptable to the Authority Having Jurisdiction.

ATTACHED CANOPY: A horizontal (maximum slope of 2%) patio cover attached to the building wall at any height; it is different from an overhang, which is an extension of the roof surface.

BASIC WIND SPEED, *V*: Three-second gust speed at 33 ft (10 m) above the ground in Exposure C (see Section 26.7.3) as determined in accordance with Section 26.5.1.

BUILDING, ENCLOSED: A building that has the total area of openings in each wall, that receives positive external pressure, less than or equal to 4 sq ft (0.37 m^2) or 1% of the area of that wall, whichever is smaller. This condition is expressed for each wall by the following equation:

$$A_o < 0.01A_g, \text{ or } 4 \text{ sq ft } (0.37 \text{ m}^2), \text{ whichever is smaller,}$$

where A_o and A_g are as defined for Open Buildings.

BUILDING, LOW-RISE: Enclosed or partially enclosed building that complies with the following conditions:

1. Mean roof height h less than or equal to 60 ft (18 m).
2. Mean roof height h does not exceed least horizontal dimension.

BUILDING, OPEN: A building that has each wall at least 80% open. This condition is expressed for each wall by the equation $A_o \geq 0.8A_g$, where

A_o = total area of openings in a wall that receives positive external pressure, in ft^2 (m^2); and
A_g = the gross area of that wall in which A_o is identified, in ft^2 (m^2).

BUILDING, PARTIALLY ENCLOSED: A building that complies with both of the following conditions:

1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10%.
2. The total area of openings in a wall that receives positive external pressure exceeds 4 ft^2 (0.37 m^2) or 1% of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20%.

These conditions are expressed by the following equations:

$$A_o > 1.10A_{oi}$$

$$A_o > 4 \text{ ft}^2 (0.37 \text{ m}^2) \text{ or}$$

$$> 0.01A_g, \text{ whichever is smaller, and } A_{oi}/A_{gi} \leq 0.20$$

where A_o and A_g are as defined for Open Building;

A_{oi} = sum of the areas of openings in the building envelope (walls and roof) not including A_o, in ft^2 (m^2); and
A_{gi} = sum of the gross surface areas of the building envelope (walls and roof) not including A_g, in ft^2 (m^2).

Minimum Design Loads and Associated Criteria for Buildings and Other Structures 245

Wind Load

Minimum force

10 psf (ASCE-7 6.1.4.1)

Basic pressure equation

$$q = \frac{1}{2} \times \gamma \times v^2$$

ASCE equation

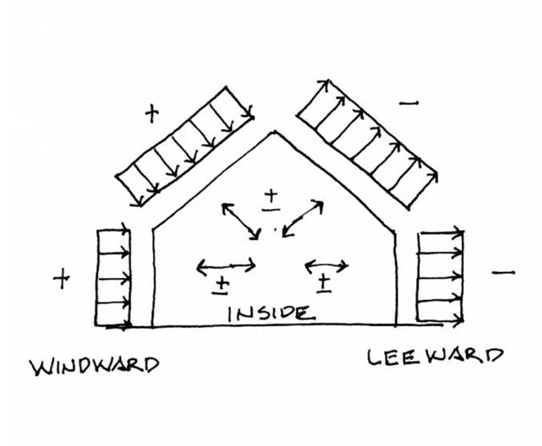
Sec. 6.5.10 eq.6-15

$$q_z = 0.00256 \times \mathrm{K_z K_{zt} K_d} \times v^2 \times \mathrm{I}$$

Velocity v is in MPH

0.00256 accounts for air density/2 and conversions

Safety factor for wind: γ = 1.0



Wind Load (normal to surface)

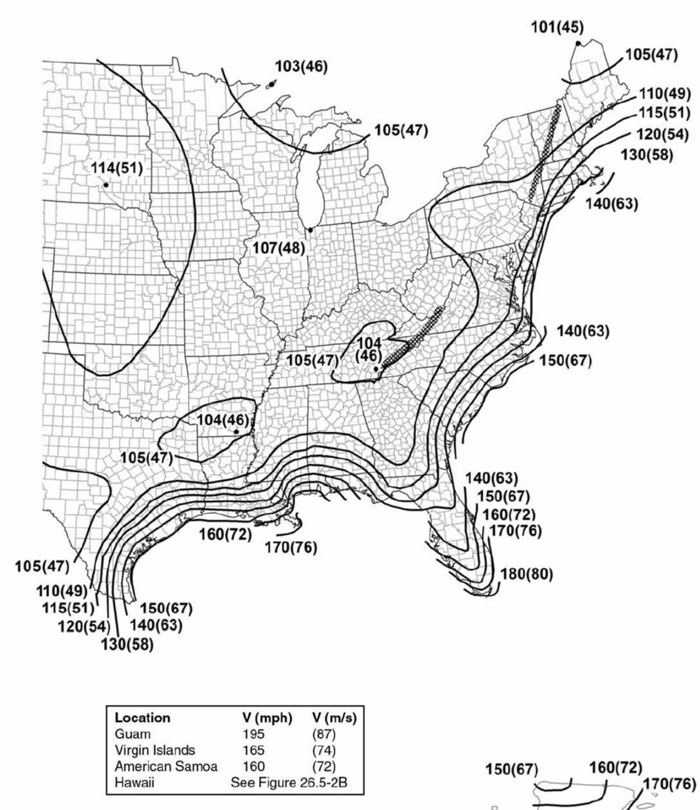
Pressure load

+ pressing load

- suction load

Wind Load

Wind speed map for category II

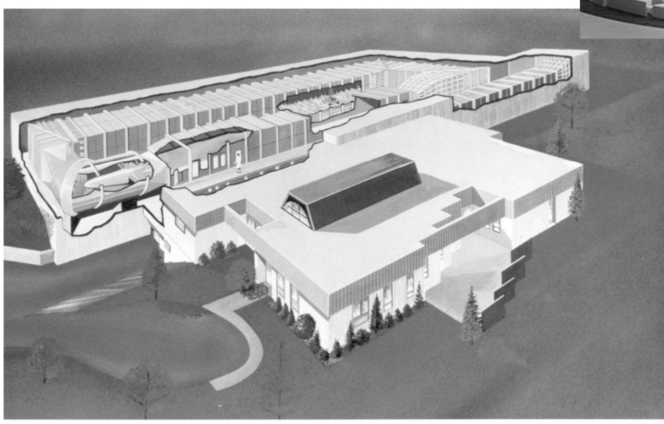


Location	V (mph)	V (m/s)
Guam	195	(87)
Virgin Islands	165	(74)
American Samoa	160	(72)
Hawaii	See Figure 26.5-2B	

FIGURE 26.5-1B (*Continued*). Basic Wind Speeds for Risk Category II Buildings and Other Structures

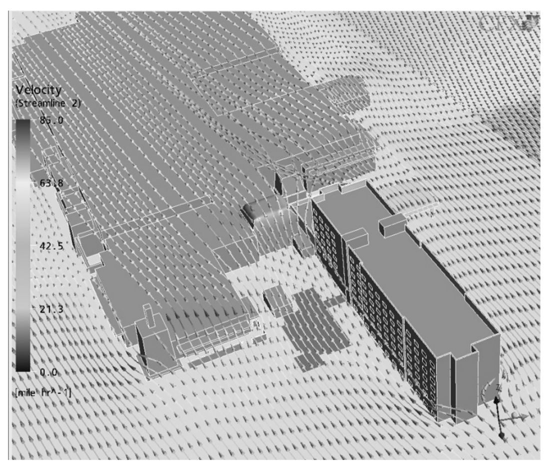
Wind – wind tunnel testing

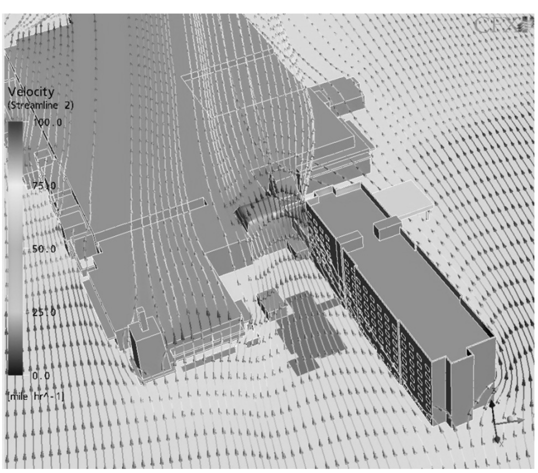
Boundary Layer Wind Tunnel



Wind – CFD

Computational Fluid Dynamics
(not used for structural calculations)





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Ch. 11-23 Seismic Loads

Ch. 26-31 Wind Loads

CHAPTER 12

SEISMIC DESIGN REQUIREMENTS FOR BUILDING STRUCTURES

12.1 STRUCTURAL DESIGN BASIS

12.1.1 Basic Requirements. The seismic analysis and design procedures to be used in the design of building structures and their members shall be as prescribed in this section. The building structure shall include complete lateral and vertical force-resisting systems capable of providing adequate strength, stiffness, and energy dissipation capacity to withstand the design ground motions within the prescribed limits of deformation and strength demand. The design ground motions shall be assumed to occur along any horizontal direction of a building structure. The adequacy of the structural systems shall be demonstrated through the construction of a mathematical model and evaluation of this model for the effects of design ground motions. The design seismic forces and their distribution over the height of the building structure shall be established in accordance with one of the applicable procedures indicated in Section 12.6, and the corresponding internal forces and deformations in the members of the structure shall be determined. An approved alternative procedure shall not be used to establish the seismic forces and their distribution unless the corresponding internal forces and deformations in the members are determined using a model consistent with the procedure adopted.

EXCEPTION: As an alternative, the simplified design procedures of Section 12.14 are permitted to be used in lieu of the requirements of Sections 12.1 through 12.12, subject to all of the limitations contained in Section 12.14.

12.1.2 Member Design, Connection Design, and Deformation Limit. Individual members, including those not part of the seismic force-resisting system, shall be provided with adequate strength to resist the shears, axial forces, and moments determined in accordance with this standard, and connections shall develop the strength of the connected members or the forces indicated in Section 12.1.1. The deformation of the structure shall not exceed the prescribed limits where the structure is subjected to the design seismic forces.

12.1.3 Continuous Load Path and Interconnection. A continuous load path, or paths, with adequate strength and stiffness shall be provided to transfer all forces from the point of application to the final point of resistance. All parts of the structure between separation joints shall be interconnected to form a continuous path to the seismic force-resisting system, and the connections shall be capable of transmitting the seismic force (F_p) induced by the parts being connected. Any smaller portion of the structure shall be tied to the remainder of the structure with elements that have a design strength capable of transmitting a seismic force of 0.133 times the short-period design spectral response acceleration parameter, S_{DS}, times the weight of the smaller portion or 5% of the portion's weight, whichever is greater. This connection force does not apply to the overall design of the seismic force-resisting system. Connection design forces need not exceed the maximum forces that the structural system can deliver to the connection.

12.1.4 Connection to Supports. A positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder, or truss, either directly to its supporting elements or to slabs designed to act as diaphragms. Where the connection is through a diaphragm, then the member's supporting element must also be connected to the diaphragm. The connection shall have a minimum design strength of 5% of the dead plus live load reaction.

12.1.5 Foundation Design. The foundation shall be designed to resist the forces developed and to accommodate the movements imparted to the structure and foundation by the design ground motions. The dynamic nature of the forces, the expected ground motion, the design basis for strength and energy dissipation capacity of the structure, and the dynamic properties of the soil shall be included in the determination of the foundation design criteria. The design and construction of foundations shall comply with Section 12.13.

When calculating load combinations using either the load combinations specified in Sections 2.3 or 2.4, the weights of foundations shall be considered dead loads in accordance with Section 3.1.2. The dead loads are permitted to include overlying fill and paving materials.

12.1.6 Material Design and Detailing Requirements. Structural elements, including foundation elements, shall conform to the material design and detailing requirements set forth in Chapter 14.

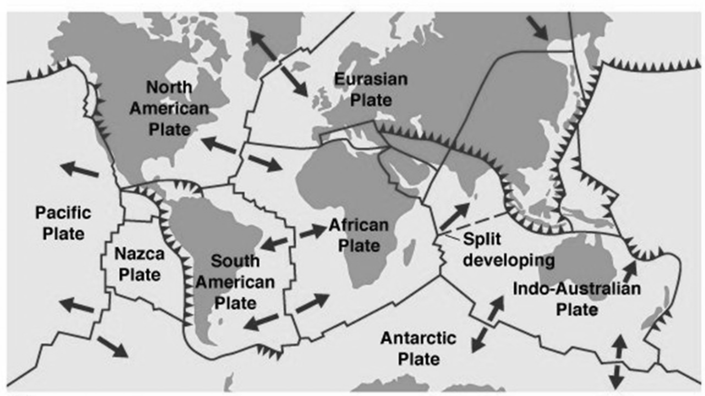
12.2 STRUCTURAL SYSTEM SELECTION

12.2.1 Selection and Limitations. Except as noted in Section 12.2.1.1, the basic lateral and vertical seismic force-resisting system shall conform to one of the types indicated in Table 12.2-1 or a combination of systems as permitted in Sections 12.2.2, 12.2.3, and 12.2.4. Each system is subdivided by the types of vertical elements used to resist lateral seismic forces. The structural systems used shall be in accordance with the structural system limitations and the limits on structural height, h_n, contained in Table 12.2-1. The appropriate response modification coefficient, R; overstrength factor, Ω_0; and deflection amplification factor, C_d, indicated in Table 12.2-1 shall be used in determining the base shear, element design forces, and design story drift.

Each selected seismic force-resisting system shall be designed and detailed in accordance with the specific requirements for the

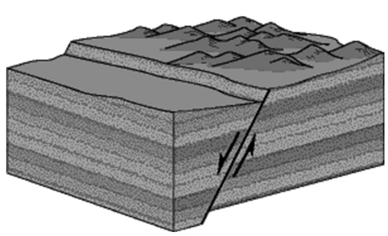
Geologic Background

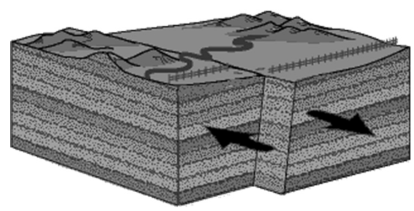
Plate Tectonics



(a) ©1999 Addison Wesley Longman, Inc.

Geologic Faults

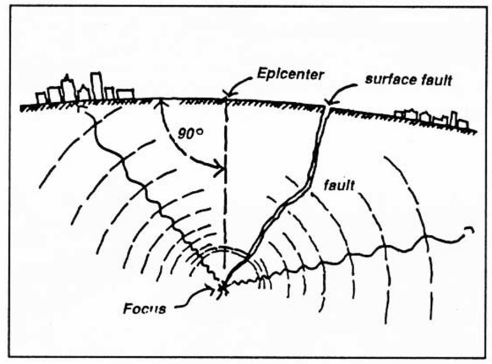




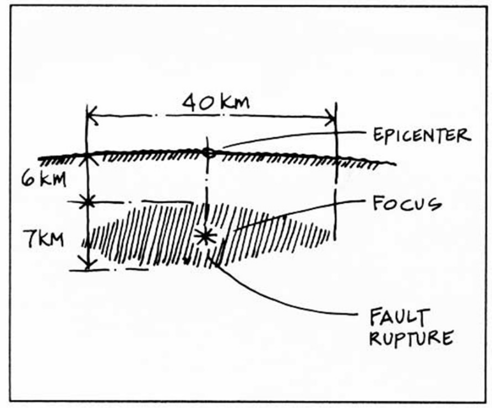
Geologic Background

Fault Location

- Focus (hypocenter)
- Epicenter



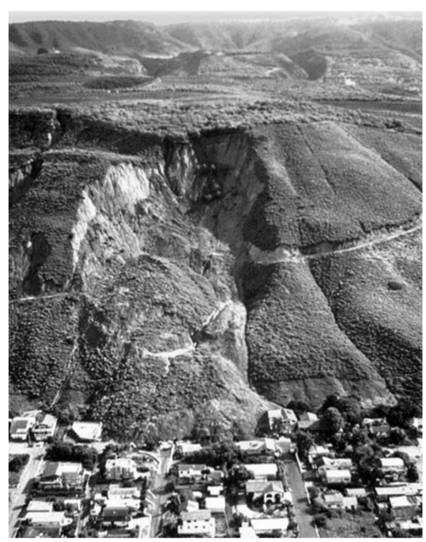
Earthquake location



The Loma Prieta fault rupture, 1989

Ground Failure

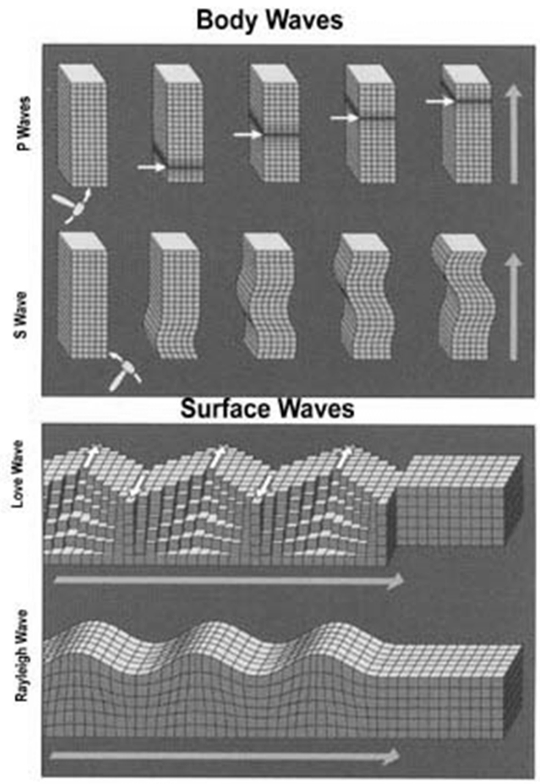
- Landslides
- Liquefaction
- Subsidence



Ground Motion

Primary
- P wave
- hits first
- pressure hammer

Secondary (Shear)
- S wave
- back and forth
- adds to P wave



Ground Motion

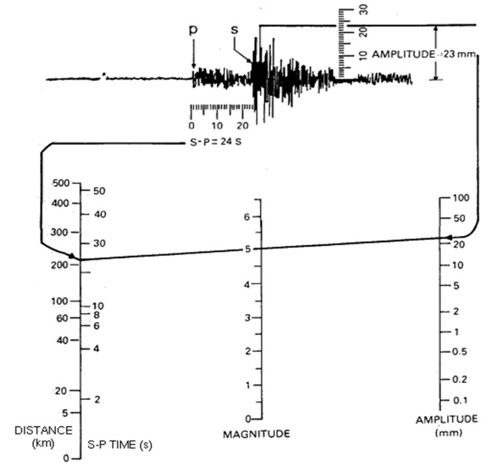
Acceleration
- Measured in g's (1 g = 32 ft/sec^2)
- 0.001 g limit of perception
- 0.1 g weak construction fails
- 0.2 g hard to stand up
- 0.5 g very sever for earthquake

San Francisco, 1906 approximately 0.7g

Measurement

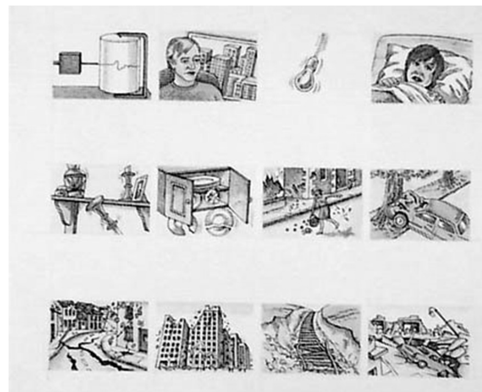
Magnitude

- Richter scale
- Size of the wave
- Accounts for attenuation
- Logarithmic (base 10)



Intensity

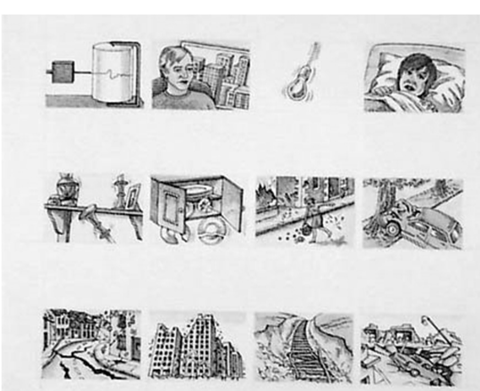
- Modified Mercalli scale
- Relates to effects
- Includes duration
- Differs with location



Measurement

Intensity

- Modified Mercalli scale I to XII
- Relates to effects
- Includes duration
- Differs with location

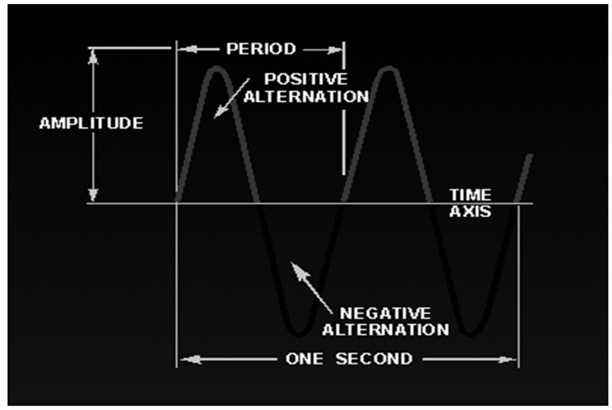


Modified Mercalli Scale

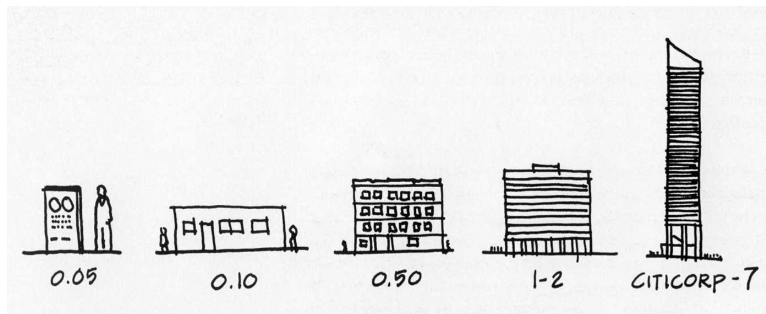
I. Instrumental	Generally not felt by people unless in favorable conditions.
II. Weak	Felt only by a few people at rest, especially on the upper floors of buildings. Delicately suspended objects may swing.
III. Slight	Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV. Moderate	Felt indoors by many people, outdoors by few people during the day. At night, some awaken. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably. Dishes and windows rattle alarmingly.
V. Rather Strong	Felt inside by most, may not be felt by some outside in non-favorable conditions. Dishes and windows may break and large bells will ring. Vibrations like large train passing close to house.
VI. Strong	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books fall off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
VII. Very Strong	Difficult to stand; furniture broken; damage negligible in building 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. Noticed by people driving motor cars.
VIII. Destructive	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture moved.
IX. Violent	General panic; 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. Intense	Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Rails bent slightly. Large landslides.
XI. Extreme	Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly. Numerous landslides, cracks and deformation of the ground.
XII. Catastrophic	Total destruction – Everything is destroyed. Lines of sight and level distorted. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock move position. Landscape altered, or levelled by several meters. In some cases, even the routes of rivers are changed.

Characteristics of Period

- Frequency
  Cycles / second (Hz)
- Period
  Inverse of frequency

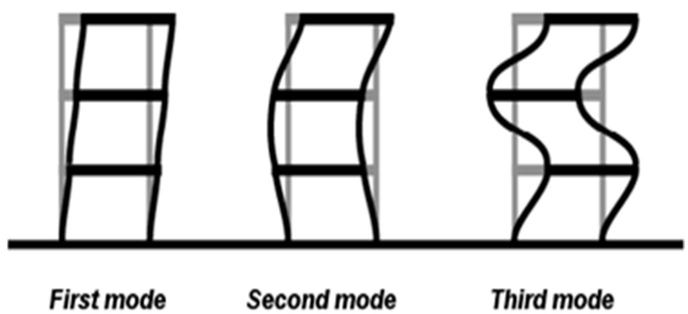


- Fundamental Period
  measure in seconds
  approx. = stories of 18
- Soil approx. 0.5 ~ 2.0

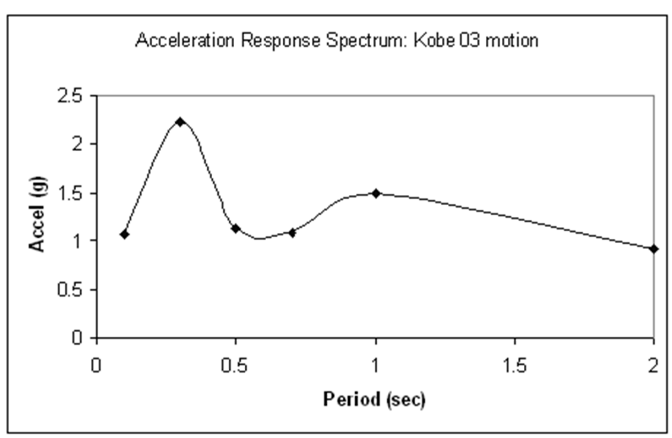


Amplification

- Fundamental Period
  Modes
  Modal shapes
  Modal frequency

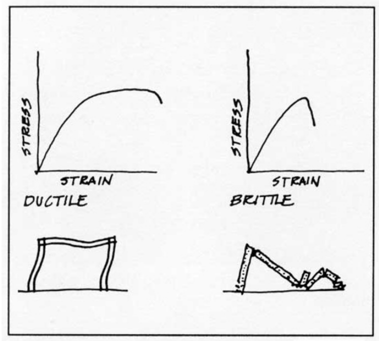


- Resonance
- Response Spectrum
  Fundamental period of soil
  0.4 to 1.5 (or 2.0)
  Harder is shorter (rock)
  Softer is longer (soil)

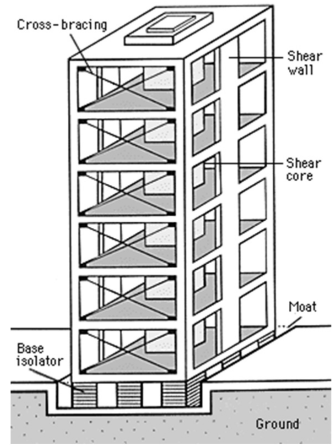


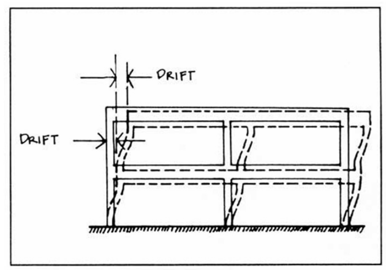
Building Resistance

- Damping
  - Material
  - Partitions
- Ductility
  - connections
- Strength and stiffness
  - drift
- Resistance
  - Shear walls
  - Cross bracing
  - Base isolation
  - Damping

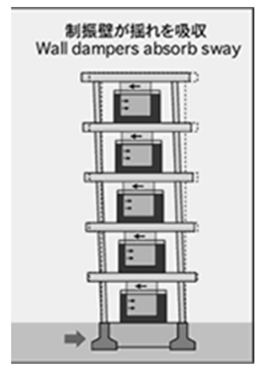


Ductile materials undergo considerable permanent deformation before failure.





Story-to-story drift



Provisions and Codes

National Earthquake Hazards Reduction Program (NEHRP)

not a code but "provisions"

ASCE 7 Section 9

code based on NEHRP