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Mata Kuliah : Dinamika Struktur & Pengantar Rekayasa Kegempaan
Kode : TSP – 302
SKS : 3 SKS

Introduction to Earthquake Engineering

Pertemuan – 9

- TIU :
- Mahasiswa dapat menjelaskan fenomena-fenomena dinamik secara fisik.

- TIK :
  - Mahasiswa dapat menjelaskan tentang teori kegempaan, terjadinya gempa, pengukuran gelombang gempa

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- Sub Pokok Bahasan :
  - Gelombang Gempa
  - Karakteristik pergerakan Tanah
  - Ukuran/Intensitas Gempa
  - Pencatatan Gempa
  - Persamaan Gerak

- Written records of earthquakes in China date as far back as 3000 years, nearly 1600 years in Japan, and 350 years in United States.
- Compared with the millions of years over which earthquakes have been occuring, humankind's experience with earthquakes is very brief
- Earthquakes will occur near densely populated urban areas and subject their inhabitans and the infrastructure they depend on to strong shaking.
- Others will occur in remote, undeveloped areas where damage will be negligible.
- It is impossible to prevent earthquake from occuring, but it is possible to mitigate the effects of strong earthquake shaking; to reduce loss of life, injuries & damage

Seismic Hazard

- Ground Shaking
- Structural Hazards
- Liquefaction
- Landslides
- Retaining Structure Failures
- Tsunami

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Seismic Hazard

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- Historical Earthquake

1971 San Fernando Valley Earthquake

"Soft story" failure of the Olive View Hospital. The column failure caused a collapse that pinned the ambulances under the rubble, rendering them useless.

Damage to the Olive View Hospital was particularly disturbing because the structure was relatively new and was designed according to the "modern" code at the time.

The building was a complete loss and had to be demolished. Note that the ambulance canopy in the foreground is a separate structure, and was also a complete loss.

Also significant is the fact that the ambulances were trapped in the collapsed canopy and were not available for use.

- Historical Earthquake

1989 Earthquake in Loma Prieta, California
Oakland Bay Bridge failure.

Losses of transportation structures are very dramatic and can be among the most costly in terms of loss of life and property and indirect effects. This bridge was out of service for several weeks after the earthquake requiring major rerouting of traffic. The collapse of the Oakland Cyprus Street Viaduct (not shown) was responsible for the loss of 42 lives. There were similar but less catastrophic failures of sections of the Embarcadero Freeway in San Francisco. The Loma Prieta earthquake killed more than 60 people, injured 3,700, and left 12,000 homeless.

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- Historical Earthquake

1994 Northridge Earthquake
Gavin Canyon Undercrossing on I-5

The Northridge earthquake, like the 1971 San Fernando Valley earthquake, was a "wakeup" call to engineers and ultimately resulted in significant changes to building codes.
Much of the current emphasis on performance-based engineering is due to the greater than expected damage that occurred as a result of the Northridge earthquake.

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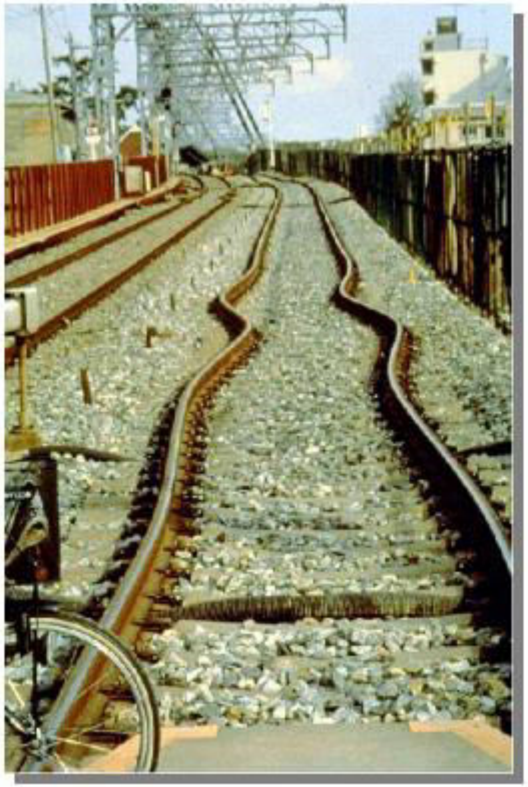
- Historical Earthquake

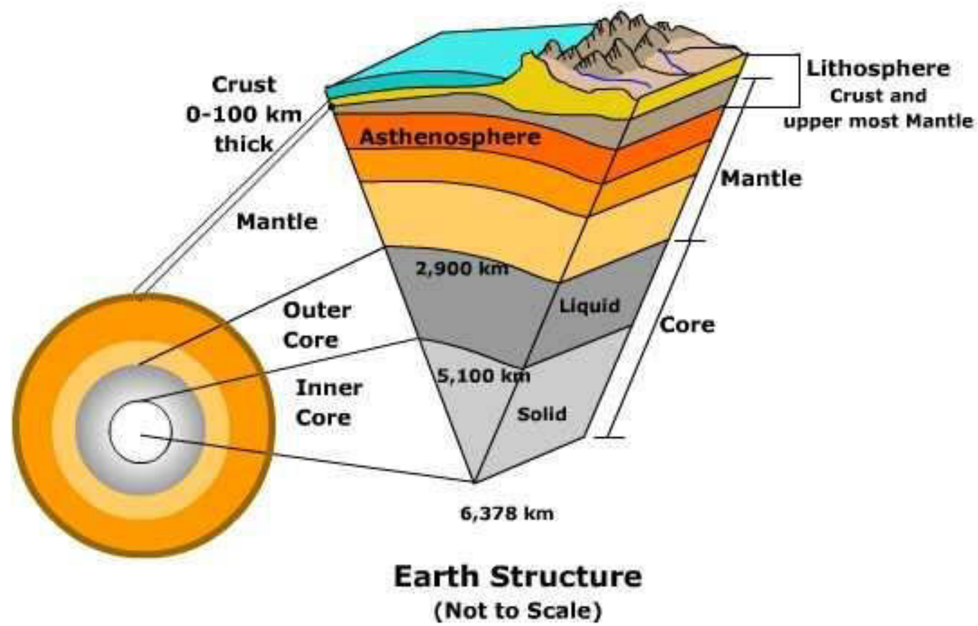


1995 Kobe, Japan, Earthquake

The Kobe earthquake killed more than 5,000 people and injured 26,000 others.
More than 56,000 buildings were destroyed.
Losses were estimated at more than $2 billion.
This is more than 10 times the dollar loss for the Northridge earthquake which occurred exactly one year earlier in southern California.
This slide was selected to emphasize the point that loss to nonbuilding structures and lifelines can have a significant effect on society.
Further, it should be noted that a considerable amount of business and industrial activities that moved from the area after the earthquake never returned.

Seismology & Earthquake

- The term seismology comes from Greek, seismos (earthquake) and logos (science)



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Continental Drift Theory

- Proposed by Wagener (1915).
- Wagener believed that the earth had only one continent called Pangaea 200 million years ago
- Pangaea broke into pieces that slowly drifted into the present configuration of the continent

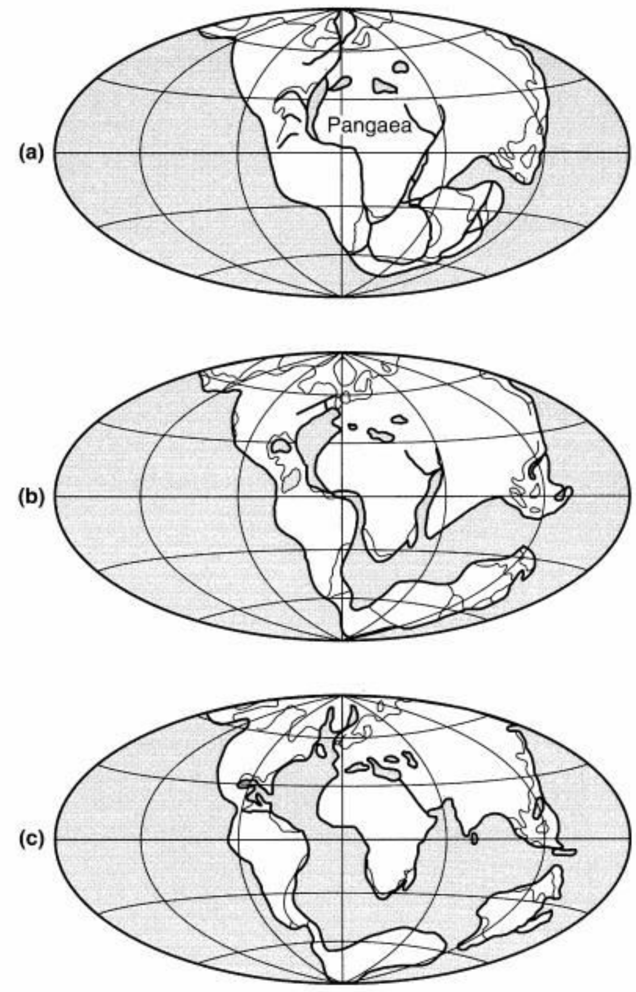
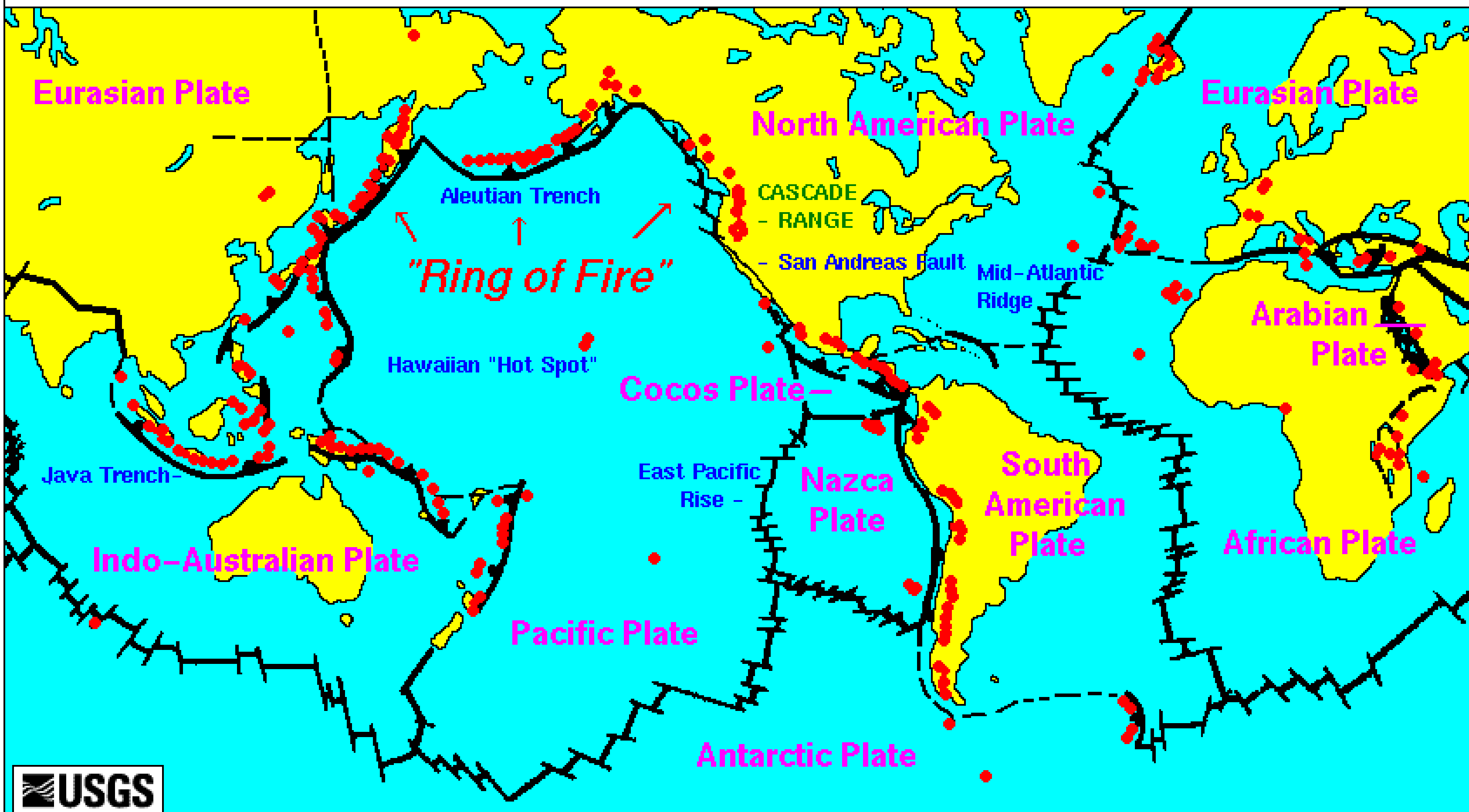


Figure 2.7 Wegener's theory of continental drift: (a) 270 million years ago; (b) 150 million years ago; (c) 1 million years ago. (After Verney, 1979.)

Plate Tectonic Theory

- The basic hypothesis of plate tectonics is that the earth's surface consists of a number of large, intact blocks called plates, and that these plates move with respect to each other.
- The earth's crust is divided into six continental-sized plates (African, American, Antarctic, Australia-Indian, Eurasian and Pacific) and about 14 of sub-continental size (caribbean, Philippine, etc.)
- The relative deformation between plates occurs only in narrow zones near their boundaries.
- This deformation can occur slowly and continuously (aseismic deformation) or can occur spasmodically in the form of earthquakes (seismic deformation)

Active Volcanoes, Plate Tectonics, and the "Ring of Fire"



Topinka, USGS/CVO, 1997, Modifed from: Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

Seismic Waves (Body Waves)

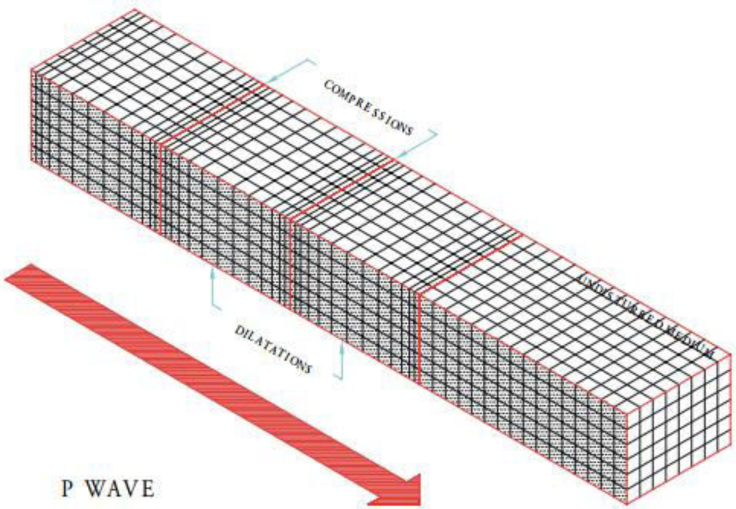
P Wave (primary waves)

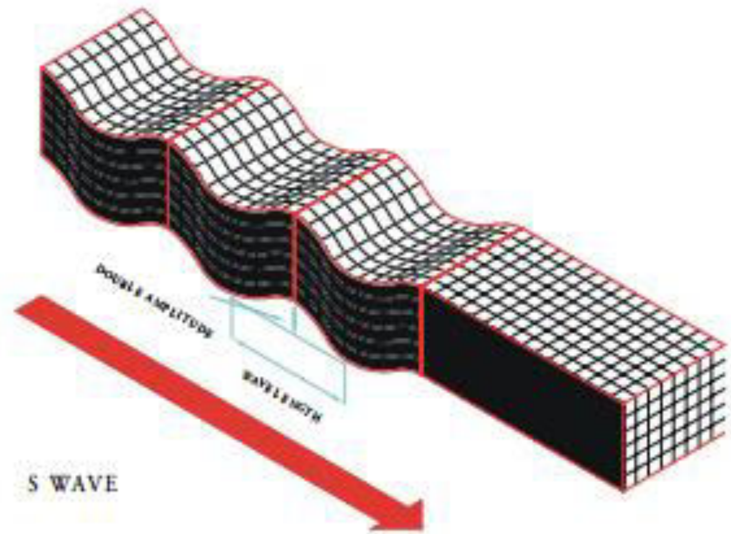
- Its motion is the same as that of a sound wave, in that, as it spreads out, it alternately pushes (compresses) and pulls (dilates) the rock
- Able to travel through both solid rock, such as granite mountains, and liquid material, such as volcanic magma or the water of the oceans.

S Wave (secondary waves)

- It shears the rocks sideways at right angles to the direction of travel
- At the ground surface S waves can produce both vertical and horizontal motions.
- Cannot propagate in the liquid parts of the Earth, such as the oceans and their amplitude is significantly reduced in liquefied soil.

Seismic Waves (Body Waves)





Seismic Waves (Body Waves)

- The actual speed of P and S seismic waves depends on the density and elastic properties of the rocks and soil through which they pass.
- In most earthquakes, the P waves are felt first
- The effect is similar to a sonic boom that bumps and rattles windows.
- Some seconds later the S waves arrive with their significant component of side-to-side motion, so that the ground shaking is both vertical and horizontal.
- This S wave motion is most effective in damaging structures.

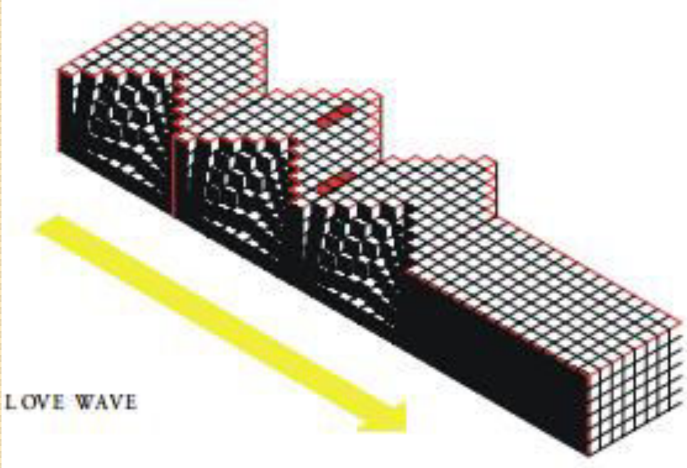
Seismic Waves (Surface Waves)

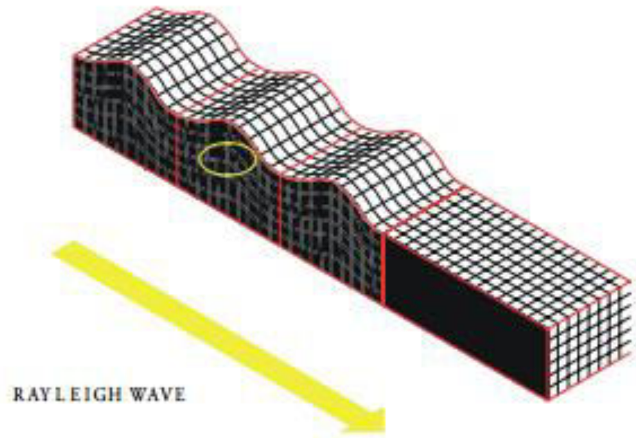
Love Wave

- Its motion is essentially the same as that of S waves that have no vertical displacement; it moves the ground side to side in a horizontal plane parallel to the Earth's surface, but at right angles to the direction of Propagation

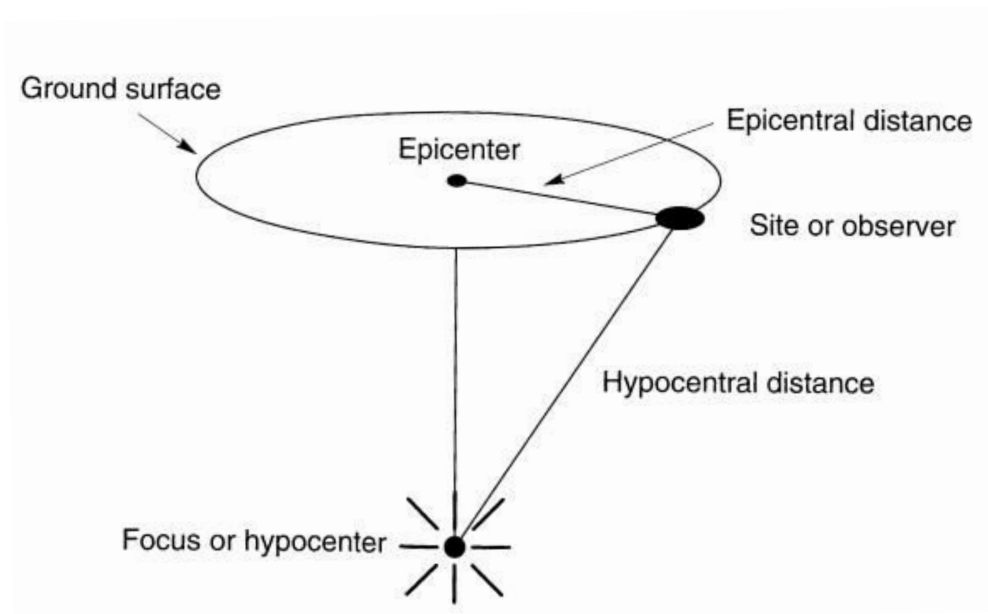
Rayleigh Wave

- Like rolling ocean waves, the pieces of rock disturbed by a Rayleigh wave move both vertically and horizontally in a vertical plane pointed in the direction in which the waves are travelling.

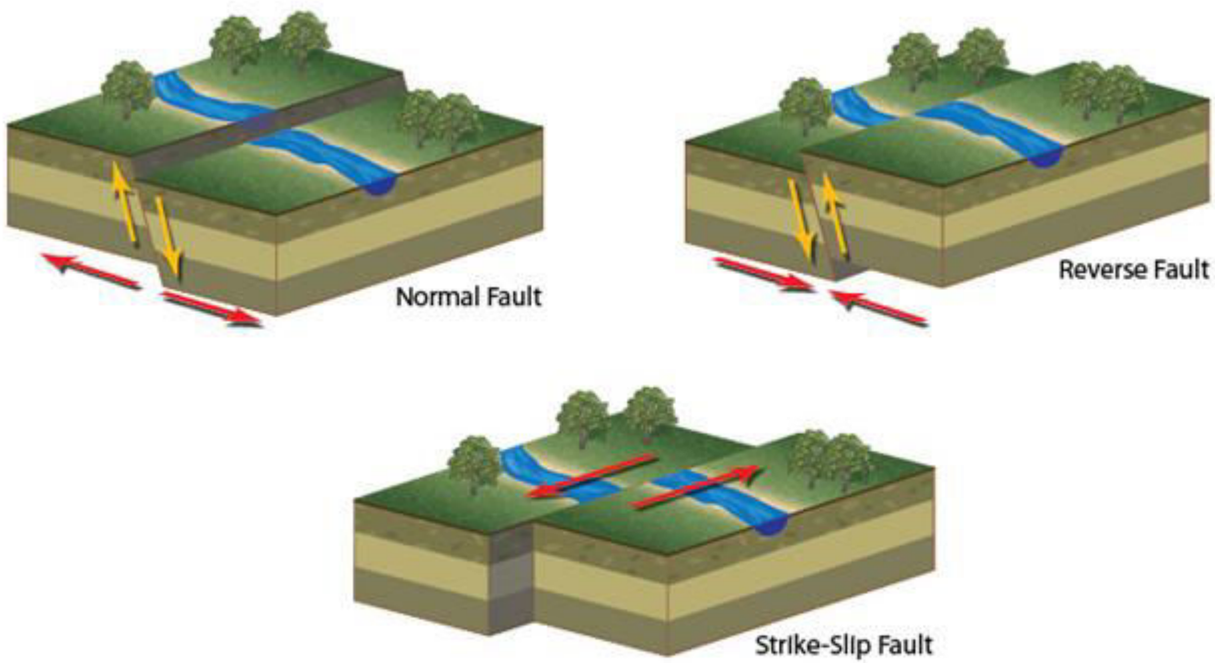

LOVE WAVE


RAYLEIGH WAVE

- Geometric Notation



- Types of Fault



Size of Earthquake

- The oldest measure of earthquake is the earthquake intensity
- The intensity is a qualitative description of the effects of the earthquake at a particular location, as evidenced by observed damage and human reactions at that location
- The Rossi-Forel (RF) scale of intensity, describing intensities with values ranging from I to X, was developed in the 1880s
- RF scale replaced by Modified Mercalli Intensity (MMI) scale, which originally developed by the Italian seismologist Mercalli and modified in 1931 to better represent conditions in California

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Table 13.1 Modified Mercalli Intensity Scale

Intensity Level	Description
I	Not felt.
II	Felt only by a few people at rest. Suspended objects may swing.
III	Felt noticeably indoors. Many people do not recognize it as an earthquake. Parked cars may rock slightly.
IV	Felt indoors by many, outdoors by few. Dishes, windows, doors rattle. Parked cars rock noticeably.
V	Felt by most; many awakened. Some dishes, windows broken. Unstable objects overturned.
VI	Felt by all. Some heavy furniture moves. Damage slight.
VII	Slight to moderate damage in well-built structures; considerable damage in poorly built structures; some chimneys broken.
VIII	Considerable damage in well-built structures. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls.
IX	Damage great in well-built structures, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed. 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.

Table 13-1
Understanding Earth, Fifth Edition

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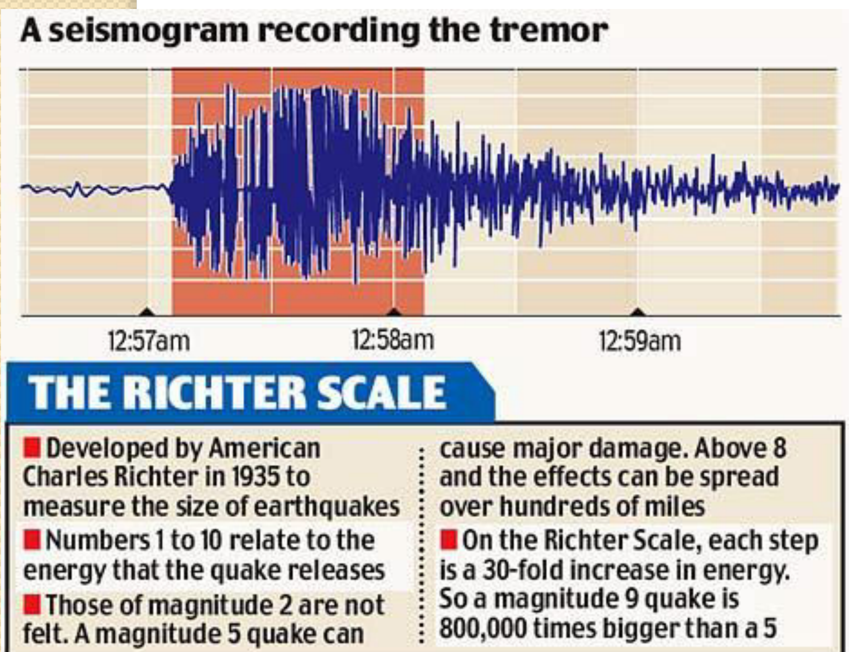
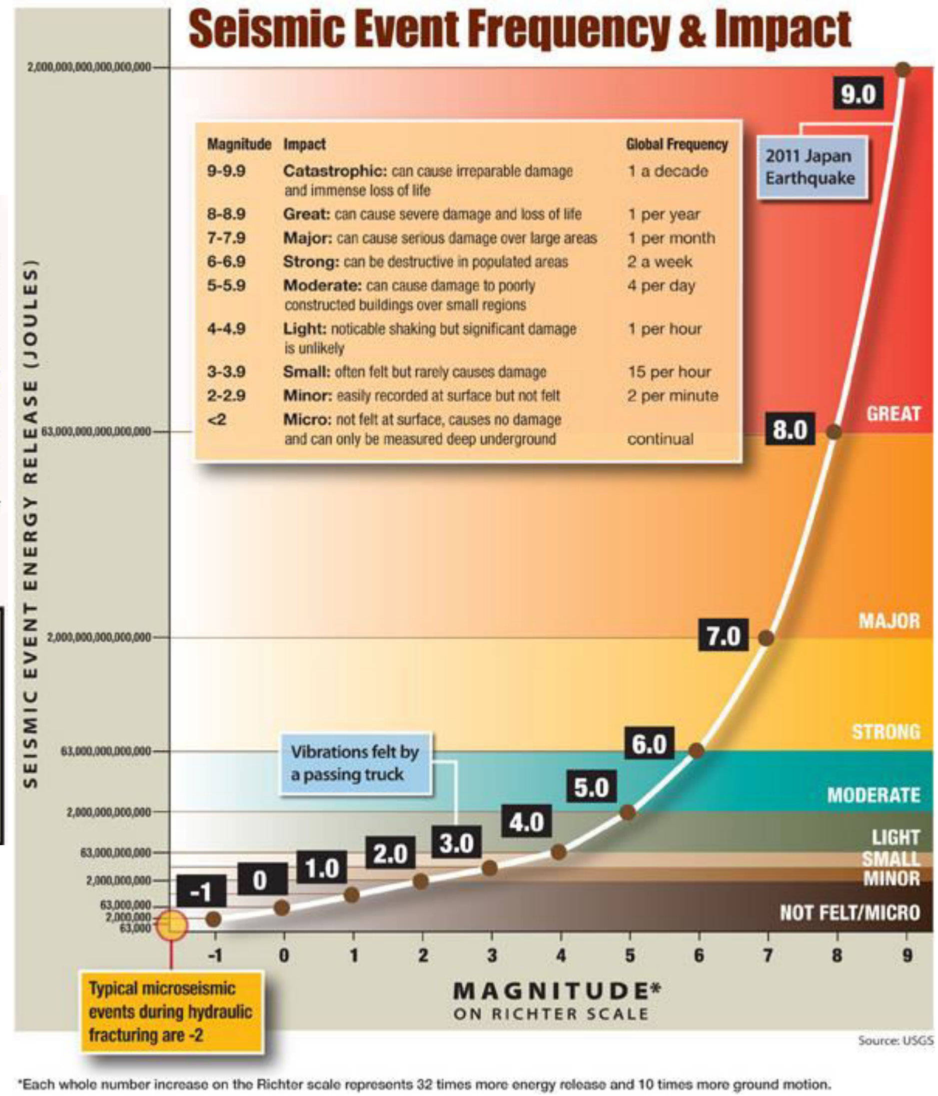
The Richter Scale





Modified Mercalli Scale	
I	Only felt by sensitive instruments
II	Felt by few persons at rest, especially on upper floors, delicate suspended objects may swing
III	Felt indoors, but may not be recognized as earthquake, vibrations like large passing truck
IV	Felt indoors by many, some outdoors, may awaken some sleeping persons; dishes, windows, doors may move, cars rock.
V	Felt by most; some windows, dishes break; tall objects may fall.
VI	Felt by by all, falling plaster and chimneys, light damage but some fear.
VII	Very noticeable, damage to weaker buildings on fill; driving automobiles notice.
VIII	Walls, monuments, chimneys, bookcases fall; liquifaction; driving is difficult
IX	Buildings shifted off foundations, cracked and twisted; ground is cracked and underground pipes are broken.
X	Most structures severely damaged to destroyed; ground is cracked, rails are bent, landslides on steep slopes
XI	Few structures standing; bridges and roads severely damaged or destroyed, large fissures in ground
XII	Total damage; can see the earthquake wave move through the ground; gravity overcome and objects thrown into the air

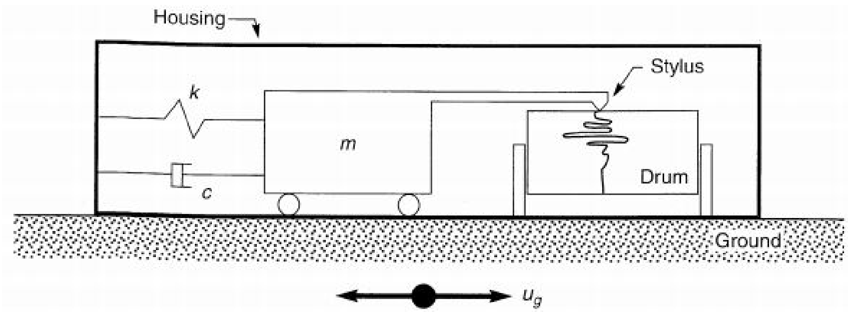
Richter Magnitude Scale
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0

- The first accurate measurements of destructive ground motions were made during the 1933 Long Beach, California Earthquake
- Strong ground motions are usually measured by accelerographs and expressed in the form of accelerograms
- The basic element of an accelerograph is a transducer element, which in its simplest form is an SDF mass-spring-damper system
- Transducer element is characterized by its natural frequency f_n and viscous damping ratio ξ, typically f_n = 25 Hz dan ξ = 60% for modern analog accelerographs; and f_n = 50 Hz , ξ = 70% in modern digital accelerographs.

The K2 Strong Motion Accelerograph

The K2 data logger with force balanced accelerometers, the seismometer, and communications equipment that are typically used:

The K2 as it would be set up at an actual digital site. The metal frame is used to keep things from bumping up against the seismometer while it is in operation. The K2 is crooked in its frame for a specific reason. It must be aligned in a northerly direction so that the North-South and East-West ground motions are indeed what are sensed by the device.



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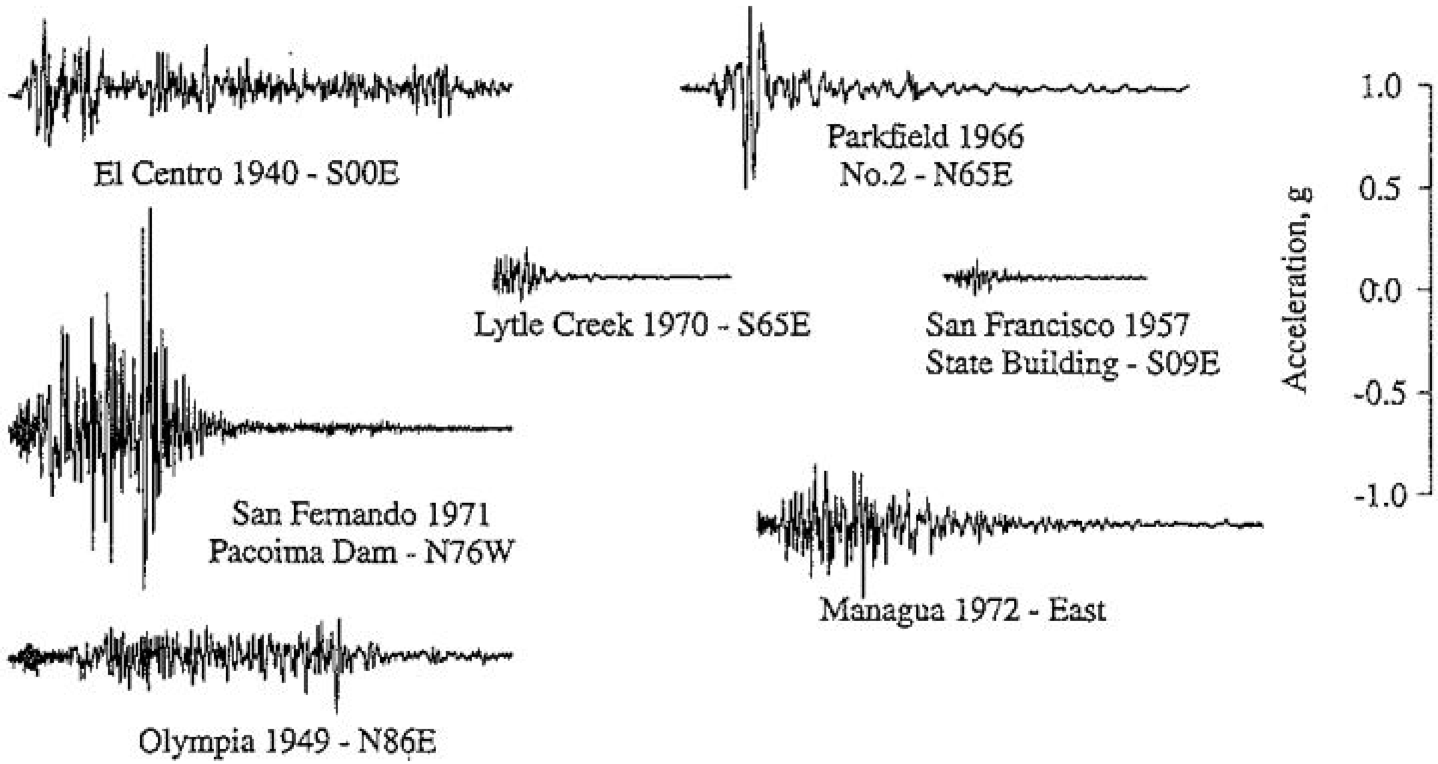
- Ground Motion Record



Equation of Motion

- Differential equation governs the motion of a linear SDoF system subjected to ground acceleration is :

$$m\ddot{u} + c\dot{u} + ku = -m\ddot{u}_g(t) \qquad \textbf{(1)}$$

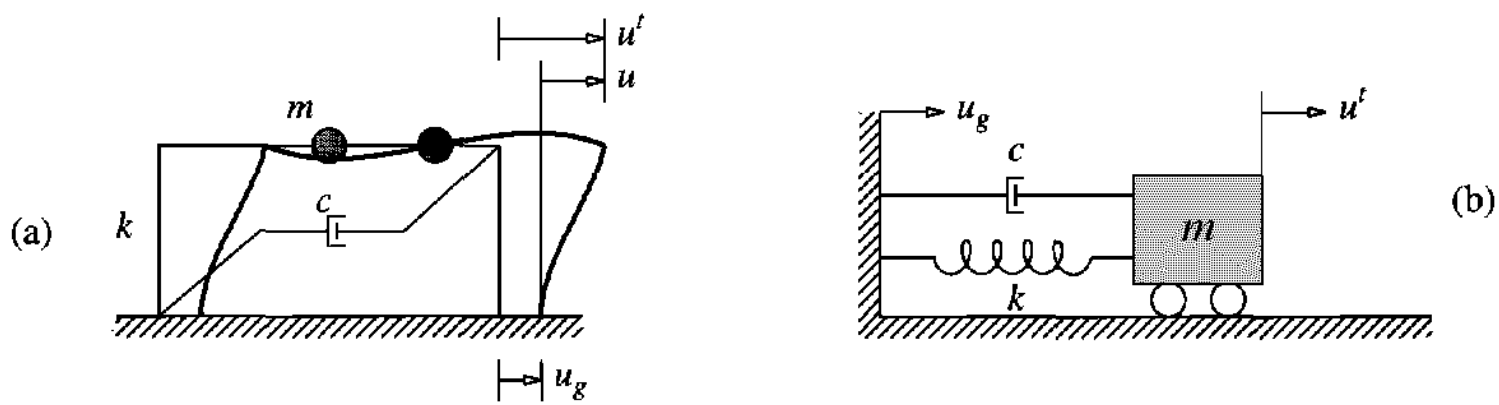
- Dividing this equation by *m* gives :

$$\ddot{u} + 2\xi\omega_n\dot{u} + \omega_n^2 u = -\ddot{u}_g(t) \qquad \textbf{(2)}$$

- The deformation response of the system depends only on the natural frequency ω_n or natural period T_n of the system and its damping ratio, ξ.

Response Quantities

- The greatest interest in structural engineering is the deformation of the system, or displacement u(t) of the mass relative to the moving ground, to which the internal forces are linearly related.
- These internal forces are bending moments and shears in the beams and columns, or the spring force in the system below



Response History

- For a given ground motion, the deformation response u(t) of an SDF system depends only on the natural vibration period of the system and its damping ratio, ξ.

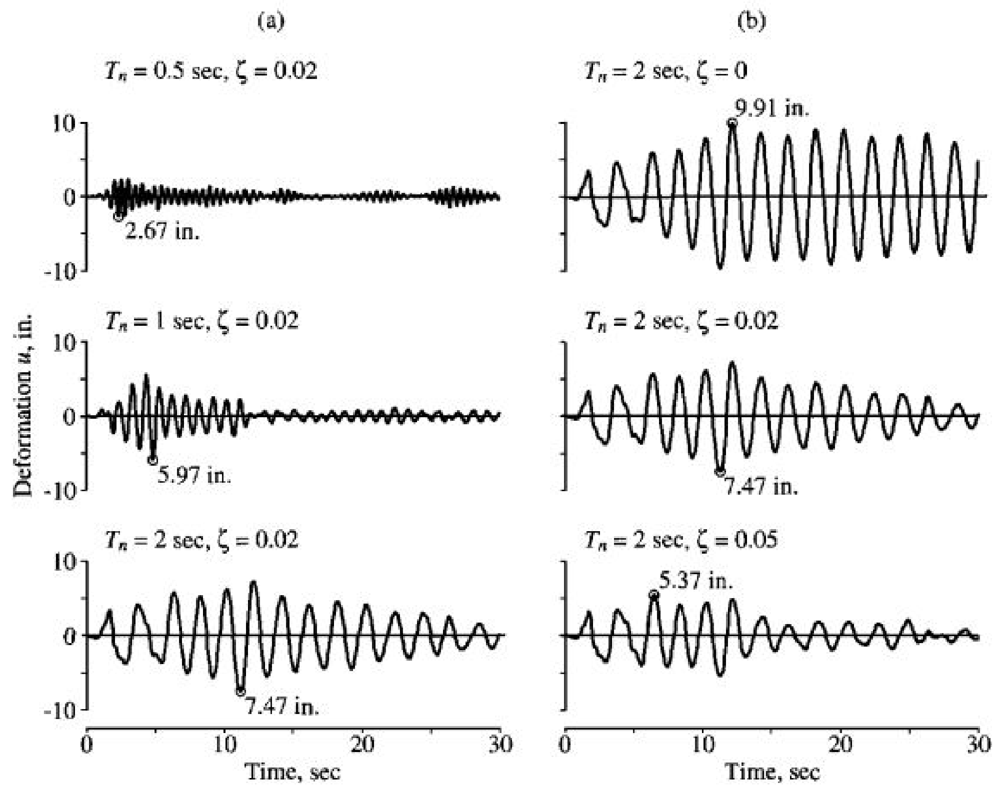


Figure 6.4.1 Deformation response of SDF systems to El Centro ground motion.

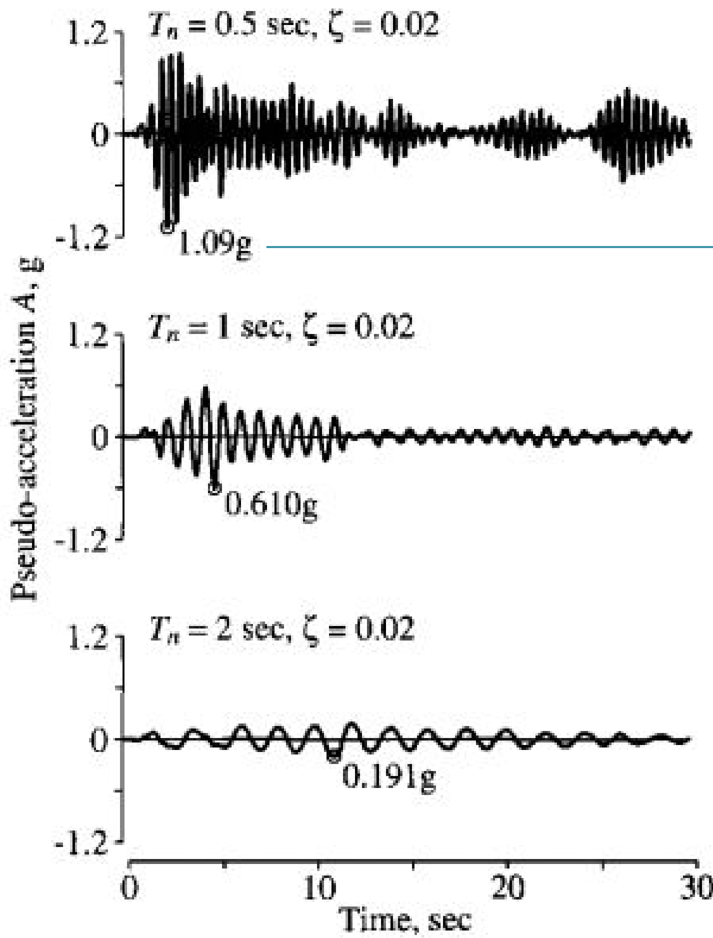
- Once the deformation response history u(t) has been evaluated by dynamic analysis of the structure, *the internal forces can be determined by static analysis of the structure at each time instant*.
- Method to implement such analysis is based on the concept of the equivalent static force f_s :

$$f_s(t) = ku(t) \qquad \textbf{(3)}$$

- Where k is the lateral stiffness of the frame. Expressing k in terms of the mass, m gives :

$$f_s(t) = m\omega_n^2 u(t) = mA(t) \qquad \textbf{(4)}$$

- Where : $A(t) = \omega_n^2 u(t)$, is called pseudo-acceleration response



$$\left(\frac{2\pi}{0,5}\right)^2 \times \frac{2,67\ \text{in}}{386\ \text{in/s}^2} = 1,09\,g$$

Figure 6.4.3 Pseudo-acceleration response of SDF systems to El Centro ground motion.