

Chapter 4: Earthquakes and Human Activities

Anatolian vs. San Andreas Fault (Figure 1)

The Nature of Earthquakes

- Earthquakes occur along faults, or ruptures/fractures in the lithosphere (where movement takes place along the fracture).

How and when does this fracturing take place?

- Elastic Rebound Theory (Harold Reid, 1906)
 - Stress: force per unit area
 - Strain: deformation
- Stress produces strain

Types of Faults

Two major groups with 2 subtypes each

Group 1: Dip Slip Faults

- 1) Normal
Stress type:

- 2) Reverse
Stress type:

Group 2: Strike Slip Faults

Stress Type:

- 1) Right Lateral

- 2) Left Lateral

Fault Nomenclature

- Movement along the fault blocks produces friction. We know this friction as an Earthquake.

When Earthquakes occur, energy waves are released. These waves can be divided into two major groups, body waves and surface waves.

Body waves- travel through the interior of the Earth

- 1) P Waves (Longitudinal Waves)

- 2) S Waves (Transverse Waves)

Surface waves- travel near the surface

- 1) Love Waves

- 2) Raleigh Waves

Locating the Epicenter

- Seismograph: instrument designed specifically to detect, measure, and record vibrations in the Earth's crust.
- Seismogram: data recorded on paper (typically) from an earthquake event.
- Mapping epicenters has been characteristically done via triangulation.

Earthquake Measurement

- First known earthquake measuring device- Chang Heng, China- 130 A.D.
- Modified Mercalli Scale – measures intensity of an earthquake
 - Utilizes roman numerals
 - Utilizes human perceptions (typically from questionnaires)
 - Isoseismals are generated from perceptions and then plotted on maps these plots can then be used to look for areas of weak soil or rock as well as areas of substandard building construction.
- CIIM: Community Internet Intensity Maps- data is obtained via computer- particularly useful in sparsely populated areas.

Richter Magnitude Scale- The Best Known Scale

- Richter and Gutenberg in 1935 at Caltech
- Scale of energy released by Earthquake
- Measured in microns (10^{-6}), corrected to a standard and the epicentral distance resulting in the Richter Magnitude.
$$\text{Richter Magnitude} = \log_{10} 10,000 \text{ microns} = 4$$
- Thus, a magnitude 7 produces 10 times greater shaking than a magnitude 6, 100 times more than a magnitude 5, 1000 times more than a magnitude 4.

- Total energy, however, varies by an exponent of 30 (a magnitude 7 has 30 times more energy than a magnitude 6, 900 times more than a magnitude 5, and 27,000 times more than a magnitude 4).
- The Richter number is open ended

Moment Magnitude Scale- M_w or M

- Seismologists like this one more
- Richter magnitudes do not accurately portray the energy released by large earthquakes on faults with great rupture lengths.

M_o = Seismic moment

M_o = (Average Displacement) (Rupture Area) (Rigidity of Faulted Rocks)

- Thus, the amount of seismic energy (in ergs) released from the ruptured fault surface is linearly related to seismic movement by a simple factor, whereas Richter Magnitude is logarithmically related to energy.
- Can be compared to other phenomena

$$M_w = (2/3 \text{Log} M_o - 10.7)$$

Fault Creep, the “Non-Earthquake”

- Movement that occurs in short spurts, sometimes not even producing detectable earthquakes.
- Creepers- Hayward and Calaveras faults

Problem Sites:

1) Hollister sidewalks

2) UCB’s Memorial Stadium

(UCB is the institution that installed the first seismometer in the U.S.)

Forensic Use of Seismic Records

Compares seismic energy from earthquakes, explosions, etc.

Seismic Design Considerations

1) Ground Shaking

- Rapid horizontal movement from surface and sheer waves
 - Effects of horizontal acceleration:
 1. Cube to rhombus shape
 2. Knocked off foundation
 3. Story shift
- Base shear- maximum potential ground acceleration expected in a particular region
- Usually expressed as a percentage of gravity.
 - 9.8m/s^2 or 32ft/s^2
 - A fraction of g can cause buildings to separate from their foundations or collapse completely.
(Pulling the carpet analogy)

➤ Prevention:

1. Bolting to foundation

2. Shear walls

3. Diagonal bearing and blocking

4. Seismic joints- accommodate movement

- Wave Period- time interval between annuals of successive wave crests (expressed in seconds, as T).
- Resonance- occurs when a building sways in step with an oscillatory wave
 - Successive “pushes”- such as a swing
 - Low Rise Buildings- Short natural wave periods (0.05-0.1sec)
 - High Rise Buildings- Longer wave periods (1-2sec)

Therefore, high frequency (short period) waves affect single story dwellings, and long periods (low frequency) affect tall buildings.

- 2) Landslides
 - Northridge- 17k
 - Loma Prieta- 10 million
 - Red Mountain near Yellowstone- 26 deaths- 1959- created Quake Lake

- 3) Ground or Foundation failure- sudden loss of strength of water saturated sandy soils resulting from shaking during a quake.
 - Less than 30 feet below- maps have been produced- expensive to pole lots of holes
 - Quick Clays- northern latitudes (Alaska)

- 4) Ground Rupture and Changes in Ground Level

Production of fault scarps

 - Alquist-Priolo Special Study Zones Act (1970)
 - Renamed Earthquake Fault Zone Act in 1995
 - Landers (6-28-92) designated just prior
 - Provides funds for state and private geologists to locate faults
 - Ground Level- 1964 Alaskan- parts moved up to 36 feet

- 5) Fires
 - From ruptured utility lines
 - 1906 San Francisco, California
 - 1995 Kobe, Japan (morning)

- 6) Tsunamis- stay tuned

Four Earthquakes

- 1) Gujarat, India @ 8:46am on 1-26-2001
 - Reverse fault, no ground rupture, $M_w = 7.8$
 - Lots of liquefaction
 - 20,000 lives lost due to poor building construction
 - “Bad earthquake, wrong buildings.”
 - Relatively flat area, void of the usual tectonic landforms(hundreds of miles from the plate boundary)

2) Alaska, 2002

3) Colima, Mexico, 2003

4) Northridge, CA 1994

What we can learn:

Does Earthquake Country Include Idaho, Missouri, and New York?

Pacific Northwest

Forecasts

Statistical Approach

Geological Methods

Survival Methods

Case Studies:

4.1: Earthquakes, Landslides and Disease

4.2: Predictable Future Shocks

4.3: Rx For Failed Freeways