Effects of Earthquakes

Fire resulting from Northridge earthquake, 1994

Tsunami aftermath. Banda Aceh, Sumatra, December 26, 2004
Effects of Earthquakes

- Ways in which earthquakes cause damage
  - Shaking
  - Fault Rupture
  - Uplift and Subsidence
Effects of Earthquakes

• Ways in which earthquakes cause damage
  • Shaking
  • Fault Rupture
  • Uplift and Subsidence
Shaking

- Shaking results in...
  - Damage to buildings
  - Damage to contents of buildings
  - Damage to lifelines
  - Fire
  - Landslides
  - Liquefaction
Shaking

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Damage to Buildings

- “Earthquakes don’t kill people, poorly-built structures do!”
- Amount of structural damage from shaking depends on…
  - Strength of the vibrations
  - Duration of the vibrations
  - Nature of the material upon which the structure rests
  - Design of the structure
Example: 1964 Alaskan Earthquake

• M9.2
• Shaking lasted 3-4 minutes.
• Most multistory structures in Anchorage were damaged by the vibrations.
• Wood-frame residential buildings least damaged. (Note: unreinforced masonry buildings are least safe.)
“Poorly designed” five-story J.C. Penney Co. building, Anchorage, Alaska. Very little damage to the steel-framed building on the left.
Example: 1964 Alaskan EQ

• Anchorage built on unconsolidated sediments; heavy structural damage

• Whittier was closer to the epicenter, but built on granite; much less damage.
  • However, Whittier was hit by the resulting tsunami…
1994 Northridge earthquake, M6.7

During the earthquake:
Drop, cover and hold
Do NOT run outside (or inside)

Photo: G. Davis
1994 Northridge earthquake, M6.7
1994 Northridge earthquake, M6.7
1994 Northridge earthquake, M6.7

Photo: G. Davis
The Northridge earthquake hit Los Angeles in California at 4:31 a.m. on the 17th January, 1994. The Magnitude 6.8 (Ms) earthquake was caused by the rupture of a thrust fault buried deep below the earth's surface.
This home was destroyed when an earthquake struck Northridge, California in January 1994.
1994 Northridge earthquake, M6.7

Photo: G. Davis
Major earthquake damage was inflicted upon north-west Turkey on August 17, 1999.

http://www.geog.ucsb.edu/~dylan/mtpe/geosphere/wh/eq(eq1).html
Collapsed 5-story apartment building, with fault in foreground (Photo: Tim Dawson).
Temporary Homelessness

Izmit, Turkey earthquake August, 1999

Photo 2. Heavy damage from the Kocaeli, Turkey earthquake to residences drove people into tent cities for temporary shelter. Photo by Thomas L. Holzer.

Izmit, Turkey earthquake August, 1999
According to official estimates, 222,570 people killed, 300,000 injured, 1.3 million displaced, 97,294 houses destroyed and 188,383 damaged in the Port-au-Prince area and in much of southern Haiti.
FEMA trailers such as these were used for survivors of Hurricane Katrina in 2005.
Harrell Stadium in New Orleans was turned into a trailer park after Hurricane Katrina in 2005.
Shaking

• Shaking results in...
  • Damage to buildings
  • **Damage to contents of buildings**
  • Damage to lifelines
  • Fire
  • Landslides
  • Liquefaction
Northridge earthquake
January 17, 1994

Photo: S. Goldfarb
Shaking

- Shaking results in…
  - Damage to buildings
  - Damage to contents of buildings
  - **Damage to lifelines**
  - Fire
  - Landslides
  - Liquefaction
Lifelines

- Power lines
- Gas lines
- Water lines
- Roads/freeways
- Bridges
- Railways
- Communication (phone lines, fiber optics lines, cell phone towers, etc.)
- Etc.
Damage to Lifelines

1992 Landers earthquake, M7.3

1994 Northridge earthquake, M6.7
- Northridge 1994 $M_w = 6.7$
Japanese earthquake (2002) damage

(source: http://www.asee.org/prism/april02/briefings.cfm, AMP, April 2002)
To be continued…
Effect of soil conditions on earthquake shaking

- Bedrock
- Well-consolidated sediment
- Loose sediment
- Water-saturated, loose sediment
- Artificial landfill

- Best (shaking less severe)
- Worst (shaking more severe)
1989 Loma Prieta M6.9

Fig. 2. 3-component accelerograms at selected rock-soil pairs (the two horizontal axes are orthogonal, this is an example of a 3-component accelerogram: the vertical component is not shown).
Example: 1989 Loma Prieta EQ

- Parts of the Cypress Freeway, interstate 880, in Oakland, CA failed.
  - collapsed on areas built on mud (dashed red line)
  - damaged on areas built on sand and gravel (solid red line).
Example: 1989 Loma Prieta EQ

M6.9

• “World Series Earthquake”
  • Between Oakland Athletics and San Francisco Giants
• Collapse of Cypress/Nimitz Freeway
• Most damage in Marina District (built on artificial fill)
1851 Coast Guard survey map of the cove that eventually became the Marina District (USGS).
Geologic map of San Francisco’s Marina District, adapted from US Geological Survey Professional Paper 1551-F

http://www.seismogenic.net/2012/10/17/marinafill/
The part of the Cypress freeway structure in Oakland, California, that stood on soft mud (dashed red line) collapsed in the 1989 magnitude-6.9 Loma Prieta earthquake, whose epicenter was 55 miles to the south. Adjacent parts of the structure (solid red) that were built on firmer ground remained standing. Seismograms (upper right) show that the shaking was especially severe in the soft mud. Photo, Lloyd S. Cluff.
1989 Loma Prieta earthquake M6.9 to 7.1 (65 killed)
1989 Loma Prieta earthquake M6.9 to 7.1 (65 killed)
Earthquake in Turkey
Damaged bridge from Northridge earthquake.
Taiwan
Shaking

- Shaking results in...
  - Damage to buildings
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  - Fire
  - Landslides
  - Liquefaction
Fires

• Power and gas lines are often ruptured, causing fires
• Chemicals spill and mix
• Electrical appliances shaken into dangerous positions
• Fires quickly become uncontrollable when broken water mains leave firefighters with little water.
Fires

• How fires spread after an earthquake
  • Telephones are unusable, so fires go unreported
  • Fire departments are overwhelmed
  • Roads are blocked with debris and abandoned cars
  • Many fires are not discovered right away
  • Inadequate water pressure
Example: 1906 San Francisco EQ

- Much of the damage was caused by fires in 500 city blocks that were out of control for 3 days.
Northridge, CA 1994
Broken gas line, Balboa Boulevard, Los Angeles, California, 1994 Northridge earthquake (photograph by M. Rymer)
Shaking

• Shaking results in…
  • Damage to buildings
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  • Liquefaction
February 28, 2001, Nisqually, Washington, Earthquake
Landslide at Pacific Palisades after the Northridge earthquake.
(Picture credit: Western States Seismic Policy Council)
Landslides and ground subsidence

• **Ex: 1964 Alaskan EQ:**
  • In Valdez, Alaska, 31 people on a dock died when it slid into the sea.

• In Anchorage, (Turnagain Heights AKA “Earthquake Park”) 200 acres slid as a layer of clay lost its strength.
Shaking

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Liquefaction

- The process by which unconsolidated materials that are saturated with water act like a liquid.
- Grains settle down, becoming more packed, while the water between the pore spaces is forced upward.
- Objects left unsupported topple over or sink.
- Underground objects (storage tanks and sewer line) float to the surface.
Example: 1989 Loma Prieta EQ

- In the Marina District, geysers of sand and water even shot from the ground, making “mud volcanoes.”
Photo 7. Building in Adapazari that partially overturned because soil liquefied and weakened the foundation. *Photo by Richard S. Olsen, Engineer Research and Development Center, U.S. Army Corps of Engineers.*
Photo 6. Building in Adapazari that sank 1.5 m uniformly into the ground when the sandy soil beneath it liquefied and was pushed outward and upward from beneath the building. Magnitudes of sinking were proportional to weight of building. *Photo by Thomas L. Holzer.*
1985 Mexico City Earthquake
An aerial view of apartment houses in Niigata, Japan shows the devastation caused by a 1964 earthquake. The magnitude 7.4 quake killed 26 people and destroyed more than 3,000 houses.
• Liquefaction occurs in areas with high ground water
Effects of Earthquakes

- Ways in which earthquakes cause damage
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Damage to a school in Anchorage, Alaska, caused by the 1964 Prince William Sound earthquake. The earthquake, which killed 131 people and caused $538 million of property damage, registered an 9.2 on the Richter Scale.
Taiwan 1999

CHELUNGPU FAULT
Effects of Earthquakes

• Ways in which earthquakes cause damage
  • Shaking
  • Fault Rupture
  • Uplift and Subsidence
    • Tsunamis
Tsunami
Northern Sumatra-- before and after the tsunami of Dec. 26, 2004
Over 283,000 killed in 11 countries
Tsunami striking Hawaii

Generated by M8.0 earthquake in Aleutian Islands, 1946

6.1 m (20 feet)
Tsunami striking Hawaii in 1957 (part 1)

Generated by M8.6 earthquake in the Aleutian Islands
Tsunami striking Hawaii in 1957 (part 2)
26 December 2004 N. Sumatra-Andaman earthquake, M9.0

Death toll: 283,000
Tsunamis, or seismic sea waves

- Tsunamis, or seismic sea waves
- Destructive waves that are often inappropriately called “tidal waves”
- Result from vertical displacement along a fault located on the ocean floor
  - or a large undersea landslide, meteorite impact, etc.
• FAST!!! 500-950 km/hour (311-590 mph)
• In the open ocean height is usually < 1 meter, and wavelength is 100-700 km (62-435 miles) between waves
• In shallower coastal waters the wave “feels bottom” and the water piles up to great heights.
• Warnings of a tsunami:
  • Feel an earthquake
  • Withdrawal of water from the beaches.
    • Have 5-30 minutes before the first wave hits.
    • Do NOT go out to see the exposed shelf, like many people (especially children) do. A tsunami is coming!
• Don’t go right back to the beach! Multiple waves!
1964 Alaskan Earthquake

- Nine people died from vibrations, 107 died from the tsunami.
- Hit most of the west coast of North America
- Even though they had a one-hour warning, 12 people in Crescent City, CA died due to the fifth wave.
- 1\textsuperscript{st} wave: 13 feet high
- 2\textsuperscript{nd} – 4\textsuperscript{th} waves: progressively smaller
- 5\textsuperscript{th} wave: 20 feet high
2004 Indonesian Earthquake

- December 26, 2004
- M9.0
- Six waves, up to 33 feet high.
- Had no warning system in the Indian Ocean (Pacific Ocean does; Tsunami Warning Center in Honolulu)
- Near Sumatra (worst along Sri Lanka’s coast and Phuket, Thailand)
- More than 283,000 people died.
- Damage as far as Somalia, Africa
Banda Aceh, Indonesia, 10 days after.
Tsunami
Northern Sumatra-- before and after the tsunami of Dec. 26, 2004
Over 283,000 killed in 11 countries

http://earthobservatory.nasa.gov/Newsroom/NewImages/Images/IK_Aceh_zoom_in_old_d.jpg
http://earthobservatory.nasa.gov/Newsroom/NewImages/Images/IK_Aceh_zoom_in_new_d.jpg
26 December 2004 N. Sumatra-Andaman earthquake, M9.0

Death toll now at 283,000
Tsunami
TSUNAMI INFORMATION

IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND
Tsunami

- Asiantsunamivideos.com
  - Thailand wave (Phuket, Thailand)
  - Patong beach (Thailand)
  - Many other videos available at above website
Tohoku Earthquake and Tsunami

- March 11, 2011
- M9.0
- Show news clip-10 min
- Show Liquefaction video (Japan_Earth_Moving)-3 min
Tsunami striking Hawaii

Generated by M8.0 earthquake in Aleutian Islands, 1946

6.1 m (20 feet)
Tsunami striking Hawaii in 1957 (part 1)

Generated by M8.6 earthquake in the Aleutian Islands
Tsunami striking Hawaii in 1957 (part 2)