Geotechnical Earthquake Engineering

by

Dr. Deepankar Choudhury

Professor

Department of Civil Engineering

IIT Bombay, Powai, Mumbai 400 076, India.

Email: dc@civil.iitb.ac.in

URL: http://www.civil.iitb.ac.in/~dc/

Lecture - 6
Module – 3

Engineering Seismology
Foreshocks and aftershocks

- Adjustments that follow a major earthquake often generate smaller earthquakes called aftershocks.

- Small earthquakes, called foreshocks, often precede a major earthquake by days or, in some cases, by as much as several years.
How Are Earthquakes Measured?

- Device used to measure an earthquake is called ‘seismograph’
- The seismograph has three main devices, the Richter Magnitude Scale, the Modified Mercalli Intensity Scale, and the Moment-Magnitude Scale.
- First invented in 132 AD, the Dragon Jar was the first instrument for determining the direction of an earthquake.
- Chang Heng, a Chinese scientist, developed the Dragon Jar.
Earthquake Waves

- The energy released during the earthquake travels as waves.
- Modern Seismograph can measure the intensity and duration of these waves in different directions.
- Seismogram is visual record of arrival time and magnitude of shaking associated with seismic wave, generated by a seismograph.
Modern Seismograph (Horizontal)

- Weight hinged to allow movement
- Support moves with Earth
- Mass does not move with ground motion due to inertia
- Rotating drum records motion
- Bedrock
- Earth moves
Modern Seismograph (Vertical) (courtesy: NICCE, IITK)
Seismogram
Earthquakes usually occur at some depth below the ground Surface. The depth can also be calculated from seismograph records

Earthquake foci are described as:

- Shallow: less than 70 km depth
- Intermediate: 70 - 300 km depth
- Deep: 300 - 700 km depth

90% of earthquake foci are less than 100 km deep

Large earthquakes are mostly at < 60 km depth

No earthquakes occur deeper than 700 km
Predicting Earthquakes

Strange Animal Behavior
stress in the rocks causes tiny hairline fractures to form, the cracking of the rocks evidently emits high pitched sounds and minute vibrations imperceptible to humans but noticeable by many animals.

Foreshocks
unusual increase in the frequency of small earthquakes before the main shock

Changes in water level
porosity increases or decreases with changes in strain

Seismic Gaps
based of the chronological distribution of major earthquakes
Seismic Waves

Arrival of seismic waves at a surface (courtesy: NICEE, IITK)
Can earthquakes be predicated?

Successful prediction includes Location, Magnitude, Duration

This still eludes Scientists and Engineers. However, some feel that earthquakes may be predicted with fair accuracy with following approaches:

- **Non-Engineered approach:**
  - Short-term Earthquake Prediction is possible, based on anomalous animal behaviour. For example, In 1975, in Haicheng, China, many people spotted snakes emerging from their burrows a month before the city was hit by a large earthquake. (http://www.bbc.co.uk/nature/15945014)
Can earthquakes be predicted?

- **Engineered Approach:**
  - Can be predicted by using GIS, by studying faults around the area, preparing seismic risk maps etc.
  - By studying and applying methods like PSHA, DSHA etc. through determination of earthquake return period.
Preparing house for earthquake

- FEMA outlines some key preventative steps one can take to protect house interior
  - Repair defective electrical wiring, leaky gas lines, and inflexible utility connections. Get appropriate professional help. Do not work with gas / electrical lines yourself unless you are an expert.
  - Bolt down and secure to the wall studs your water heater, refrigerator, furnace, and gas appliances. If recommended by your gas company, have an automatic gas shut-off valve installed that is triggered by strong vibrations.
  - Place large or heavy objects on lower shelves. Fasten shelves, mirrors, and large picture frames to walls. Brace high and top-heavy objects.
Preparing house for earthquake

• Store bottled foods, glass, china, and other breakables on low shelves or in cabinets that fasten shut.
• Anchor overhead lighting fixtures
• Install flexible pipe fittings to avoid gas or water leaks. Flexible fittings are more resistant to breakage.
• Locate safe spots in each room under a sturdy table or against an inside wall. Reinforce this information by moving to these places during each drill.
• Hold earthquake drills with your family members: Drop, cover, and hold on!
How to behave during an earthquake?

• Remain calm. Do not panic. Do not jump out of the window or from the balcony.

If you are in train
If you are near water body
Run away to open space
How to behave after an earthquake?

- Check yourself for injuries.
- Administer first aid or try to get help from others nearby if necessary.
- Once you've tended to yourself, check others in your immediate area for injury and administer first aid.

open a window or door to secure your exit.

Check for first aid or rescue equipment if needed

Help others..
How to behave after an earthquake?

• Falling items. The contents of high shelves and cabinets can shift during earthquakes. Be careful when opening cabinet doors or pulling items off high shelves.

• Listen to an emergency radio or use a battery-powered television to receive the latest emergency information any instructions available.

• beware of chimneys, damaged walls, balconies and high placed signage or items hanging from the building that might fall on you.

• Pay attention to **aftershocks** !!!!!
PROTECTING AGAINST EARTHQUAKE DAMAGE

Prepare a **Seismic Risk Map** for the globe which identifies rock types, liquefaction potential, landslide potential.

Extensive geologic surveying has to be done to identify all active faults, including hidden faults.
PROTECTING AGAINST EARTHQUAKE DAMAGE

Earthquake Resistant Design of Sub and Super Structures
Enact building codes to design and build earthquake-resistant structures in high seismic risk areas. Wood, steel and reinforced concrete are preferred as they tend to move with the shaking ground (unreinforced concrete and heavy masonry tend to move independently and in opposition to the shaking, battering one another until the structure collapses).

Critical facilities such as nuclear power plants and dams should be built on stable ground and as far as possible from active faults.
Plate Tectonics
Origin of Universe

- **Big Bang model** - The universe began with an explosive expansion of matter, which later became what we know as stars, planets, moons, etc. This event is thought to have occurred 10 - 15 billion yrs ago.

- **Nebular Hypothesis** - Earth and the other bodies of our solar system (Sun, moons, etc.) formed from a “vast cloud of dust and gases” called a nebula.
Nebular Hypothesis

• According to this hypothesis, the nebular cloud consisted of H and He, and a small percentage of the heavier elements we find in the solar system (a).

• Within the rotating disk, the rocky material and gases began to nucleate and accrete into protoplanets (c).
Formation of Earth’s Interior

• As Earth was formed, it was extremely hot from the bombardment of space debris, radioactive decay, and high internal pressures.

• These processes caused Earth’s interior to melt, and then to differentiate into regions of chemical and physical differences as it cooled.
Layers of the Earth

- **Crust:**
  - Continental crust (25-40 km*)
  - Oceanic crust (~6 km)

- **Mantle**
  - Upper mantle (650 km)
  - Lower mantle (2235 km)

- **Core**
  - Outer core: liquid (2270 km)
  - Inner core: solid (1216 km)

* Values in brackets represent the approximate thickness of each layer
Layers of the Earth

The earth is divided into four main layers: **Inner core, outer core, mantle and crust**.

The core is composed mostly of iron (Fe) and is so hot that the outer core is **molten**, with about 10% sulphur (S). The inner core is under such extreme **pressure** that it remains solid.

Most of the Earth's mass is in the mantle, which is composed of iron (Fe), magnesium (Mg), aluminum (Al), silicon (Si), and oxygen (O) **silicate** compounds. At over 1000 degrees C, the mantle is solid but can deform slowly in a **plastic** manner.

The crust is much thinner than any of the other layers, and is composed of the least dense calcium (Ca) and sodium (Na) aluminum-silicate minerals. Being relatively cold, the crust is rocky and **brittle**, so it can fracture in **earthquakes**.
Continental drift

- Theory that continents and plates move on the surface of the Earth proposed by Alfred Wegener in 1915.

Alfred Wegener