Module – 3
Engineering Seismology
Plate Tectonics
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
Continental drift

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

Alfred Wegener
Evidence for continental drift

- Matching coastlines
- Matching mountains
- Matching rock types and rock ages
- Matching glacier deposits
- Matching fossils
Evidence for continental drift

Matching coastlines
Evidence for continental drift

Matching mountain ranges
Evidence for continental drift

Matching rock types and ages of rocks
Evidence for continental drift

Matching glacier deposits 300 million years ago
Theory of Plate tectonics

• The theory of Plate tectonics was proposed in 1960s based on the theory of continental drift.
• This is the Unifying theory that explains the formation and deformation of the Earth’s surface.
• According to this theory, continents are carried along on huge slabs (plates) on the Earth’s outermost layer (Lithosphere).
• Earth’s outermost layer is divided into 12 major Tectonic Plates (~80 km deep). These plates move relative to each other a few centimeters per year.
Tectonic plates of Earth
Tectonic plates of Earth

- Subduction zone
- Uncertain plate boundary
- Strike-slip (transform)
- Ridge axis faults
Major Earthquakes
Types of plate boundaries

- Divergent plate boundaries: where plates move apart
- Convergent Plate boundaries: where plates come together
- Transform plate boundaries: where plates slide past each other
Types of plate boundaries

Divergent (Tension)

Convergent (Compression)

Transform (shearing)
Types of plate boundaries

- Convergent plate boundary
- Transform plate boundary
- Divergent plate boundary
- Convergent plate boundary (Continental rift zone)

Diagram showing various types of plate boundaries:
- Convergent boundary with trench and volcanic arc
- Transform boundary with horizontal movement
- Divergent boundary with oceanic spreading ridge
- Continental crust and subducting plate
Divergent Plate Boundaries

- Plates move away from each other (tension)
- New lithosphere is formed
- Normal faults
- Causes volcanism
- Not very explosive
Convergent Plate Boundary

- Plates move toward each other (compression)
- Lithosphere is consumed
- Reverse/thrust faults and folds
- Mountain building
- Explosive volcanism
Ocean- Continent convergent margin

- Ocean-continent plates collide
- Ocean plate subducts below continent
- Forms a subduction zone
- Earthquakes and volcanoes
Ocean-ocean convergent margin

- 2 oceanic plates collide
- One plate dives (subducts) beneath other
- Forms subduction zone
- Earthquakes and volcanoes
Continent-continent convergent margin

- 2 continental plates collide
- Neither plate wants to subduct
- Collision zone forms high mountains
- Earthquakes, no volcanoes

example: Himalayas
Plate Tectonics
Transform plate margin

- Two plates slide past each other
- Strike slip faults.
- Lithosphere is neither consumed nor destroyed.
- Earthquakes, no volcanoes
- Responsible for most of the earthquakes
What drives plate movement?

- Ultimately: heat transported from core and mantle to surface
- Heat transported by convection
- Core is \(\sim 5,000°C\) and surface is \(\sim 0°C\)
- Where mantle rises: rifting
- Where mantle dives: subduction zones
Types of Faults

and

Seismic Waves
Elastic Rebound Theory
Sequence of elastic rebound: Stresses
Sequence of elastic rebound: Bending
Sequence of elastic rebound: Rupture
Sequence of elastic rebound: Rebound
Fault

A fracture (crack) in the earth, where the two sides move past each other and the relative motion is parallel to the fracture.

90° dip = vertical fault plane, 0° strike = north parallel fault plane
Surface Trace of a fault
Different Fault Types

Normal fault
(due to extension)

Reverse fault
(due to compression)

Strike-slip fault
(due to regional shear)

Marker bed

Hanging wall down

Hanging wall up

Displacement

No vertical displacement
Normal Dip-slip fault

hanging wall moves down

A Normal dip slip fault
Reverse Dip-slip fault

Hanging wall moves up
This is also called a **Thrust Fault**
Strike-slip fault

Displacement in horizontal direction

A strike-slip fault
Strike-Slip Fault – Left Lateral
Strike-Slip Fault – Right Lateral
Oblique-slip fault

Displacement in both vertical and horizontal directions

An oblique-slip fault
Blind/Hidden faults

Surface trace of known faults

Hidden fault does not intersect ground surface
Sequence of Events

- 1) Tectonic loading of faults
- 2) Earthquakes
- 3) Seismic waves
- 4) Shaking (ground motion)
- 5) Structural failure
Seismic Waves

(Earthquake’s energy is transmitted through the earth as seismic waves)

• Two types of seismic waves
  ◆ Body waves- transmit energy through earth’s interior
    ◆ Primary (P) wave- rocks vibrate parallel to direction of wave
      ◇ Compression and expansion (slinky example)
    ◆ Secondary (S) wave- rocks move perpendicular to wave direction
      ◇ Rock shearing (rope-like or ‘wave’ in a stadium)
  ◆ Surface waves- transmit energy along earth’s surface
    ◆ Rock moves from side to side like snake
    ◆ Rolling pattern like ocean wave
Primary waves

- P-waves, compressional or longitudinal.
- Typical crustal velocity: 6 km/s (~13,500 mph)
- Travel through solids, liquids, or gases
- Material movement is in the same direction as wave movement
- Behavior: Cause dilation and contraction (compression) of the earth material through which they pass.
- Arrival: They arrive first on a seismogram.

Even for P waves (which can travel all the way through) we see some changes in the path at certain points within Earth. This is due to the discontinuities present at different boundaries in earth structure.
Secondary waves

- S waves (secondary)
- Typical crustal velocity: 3 km/s (~6,750 mph)
- Behavior: Cause shearing and stretching of the earth material through which they pass. Generally cause the most severe shaking; very damaging to structures.
- Travel through solids only
- shear waves - move material perpendicular to wave movement
- Arrival: Second on a seismogram.

S-wave velocity drops to zero at the core-mantle boundary or Gutenberg Discontinuity
Shadow Zone - no earthquake waves