UNIT-IV

1. Causes of Earthquakes

An **earthquake** occurs due to the **sudden release of energy** in the Earth's crust.

1.Tectonic Movements (Major Cause)

- Movement of Earth's plates
- Stress builds up → sudden release → earthquake

2.Volcanic Activity

- Movement of magma inside Earth
- Causes tremors near volcanoes

3. Faulting

- Breaking and slipping of rocks along weak planes

4.Human-Induced Causes

- Mining
- Reservoir-induced seismicity (dams)
- Explosions

2. Causes of Plate Tectonics

Earth's crust is divided into **large plates** called tectonic plates.

Types of Plate Boundaries

(a) Convergent Boundary

- Plates move **towards each other**
- Causes strong earthquakes

(b) Divergent Boundary

- Plates move **away from each other**

(c) Transform Boundary

- Plates slide past each other

Example: Major earthquakes occur along such boundaries

3. Causes of Faults

Definition

A **fault** is a fracture in Earth's crust where movement occurs.

Types of Faults

1.Normal Fault

- Caused by tension
- One block moves downward

2.Reverse Fault

- Caused by compression
- One block moves upward

3.Strike-Slip Fault

- Horizontal movement

4. Causes of Seismic Waves

Energy released during earthquakes travels as **seismic waves**

1.Body Waves

(a) P-Waves (Primary)

- Fastest
- Travel through solids, liquids, gases
- Cause compression and expansion

(b) S-Waves (Secondary)

- Slower than P-waves
- Travel only through solids
- Cause shear motion

2.Surface Waves

(a) Love Waves

- Horizontal motion

(b) Rayleigh Waves

- Rolling motion (like ocean waves)
- Cause **maximum damage**

2.Explain Magnitude, Intensity, Epicenter, Energy Release, and Ground Motions.

1.Magnitude

Definition

Magnitude is a measure of the **total energy released** during an earthquake.

Scales

- Richter Scale
- Moment Magnitude Scale (Mw)

Features

- Single value for an earthquake
- Logarithmic scale (each unit ↑ ≈ 32× more energy)

Example: Magnitude 6 is much stronger than Magnitude 5

2.Intensity

Definition

Intensity measures the **severity of shaking and damage** at a specific location.

Scale

- Modified Mercalli Intensity (MMI) Scale (I to XII)

Features

- Varies from place to place
- Depends on:
    - Distance from epicenter
    - Soil conditions
    - Building quality

3.Epicenter

Definition

The **epicenter** is the point on Earth's surface **directly above the focus (origin)** of an earthquake.

Importance

- Area near epicenter experiences **maximum damage**
- Used to locate earthquake position

4.Energy Release
Concept
Earthquakes release **stored strain energy** from rocks.
Key Points
- Energy spreads in all directions as seismic waves
- Small increase in magnitude → large increase in energy
- Energy causes ground shaking and destruction

5.Ground Motions
Definition
Movement of the ground during an earthquake due to seismic waves.
Types
- Horizontal motion (most dangerous)
- Vertical motion
- Rotational motion

Characteristics
- Amplitude (displacement)
- Frequency (vibration rate)
- Duration (time of shaking)

Effects
- Structural damage
- Foundation failure
- Collapse of weak buildings

3.Earthquake Effects– On Ground, Soil Rupture, Liquefaction, Landslides.

1.Effects on Ground (Ground Shaking)
Definition
Movement of the ground due to seismic waves.
Effects
- Vibrations in buildings
- Cracks in roads and pavements
- Settlement of soil
- Collapse of weak structures

Key Point
Ground shaking is the primary cause of most earthquake damage

2.Soil Rupture (Surface Rupture)
Definition
Breaking and displacement of the Earth's surface along a fault.
Effects
- Formation of cracks and fissures
- Horizontal and vertical displacement
- Damage to:
    - Buildings
    - Roads
    - Pipelines

Example :Structures built over faults are highly vulnerable

3.Liquefaction

Definition

A phenomenon where **water-saturated loose soil behaves like a liquid** during shaking.

Causes

- Sandy soil
- High groundwater level
- Strong shaking

Effects

- Buildings sink or tilt
- Loss of bearing capacity
- Foundation failure
- Uplift of buried structures

Key Point

Common in coastal and river areas

4.Landslides

Definition

Downward movement of soil and rock on slopes triggered by earthquakes.

Causes

- Ground shaking
- Weak soil or rock
- Steep slopes

Effects

- Burial of buildings and roads
- Blockage of rivers → flooding
- Damage in hilly regions

4.Performance of Ground and Buildings in Past Earthquakes

1. Performance of Ground

(a) Ground Shaking

- Strong shaking caused **collapse of poorly designed buildings**
- Soft soils amplified shaking → more damage

Example: Severe amplification observed in Bhuj Earthquake 2001

(b) Liquefaction

- Water-saturated soils behaved like liquid

Effects:

- Buildings tilted/sank
- Roads and pipelines damaged

Observed in Nepal Earthquake 2015

(c) Surface Rupture

- Ground cracks and displacement

Damaged infrastructure directly above faults

(d) Landslides

- Common in hilly regions

Example: Kashmir Earthquake 2005

- Blocked roads and rivers

2. Performance of Buildings

(a) Poorly Designed Buildings

- Non-engineered constructions suffered severe damage

Failures:

- Collapse of masonry buildings
- Shear failure in columns
- Pancake collapse (floor-by-floor collapse)

(b) Soft Storey Failure □

- Open ground floors collapsed

Seen in many Indian earthquakes including Bhuj Earthquake 2001

(c) Irregular Buildings

- L, T-shaped buildings showed **torsional damage**

(d) Heavy Structures

- Buildings with heavy roofs or tanks had higher damage

(e) Poor Construction Quality

- Weak materials and bad workmanship increased failure

(f) Non-Structural Damage

- Falling parapets
- Cracked walls
- Broken glass

3. Performance of Engineered Buildings

Well-designed buildings performed better:

- Structures with **shear walls** survived
- Buildings with **proper reinforcement detailing** showed limited damage
- Ductile design prevented sudden collapse

Modern buildings designed as per seismic codes performed well in recent earthquakes

5.Behavior of Various Types of Buildings and Structures, Collapse Patterns;

1. Masonry Buildings (Brick/Stone)

Behavior

- Heavy and brittle
- Low tensile strength

Performance

- Poor seismic resistance
- Sudden failure without warning

Collapse Patterns

- Diagonal shear cracks (X-shaped)
- Out-of-plane wall failure
- Corner separation

6.Case Studies of Earthquakes

1.Bhuj Earthquake 2001

Details

- Magnitude: 7.7
- Location: Gujarat, India

Ground Performance

- Severe **liquefaction** in some areas
- Ground cracks and settlement

Building Performance

- Collapse of many **masonry buildings**
- Failure of **RC buildings due to poor detailing**
- Soft storey collapse common

Lessons Learned

- Importance of **seismic codes (IS 1893, IS 4326)**
- Need for **ductile detailing**
- Avoid soft storey design

2.Nepal Earthquake 2015

Details

- Magnitude: 7.8
- Location: Nepal

Ground Performance

- Landslides in hilly areas
- Soil instability

Building Performance

- Traditional masonry buildings collapsed
- Heritage structures heavily damaged

Lessons Learned

- Need for **retrofitting old buildings**
- Importance of **lightweight construction**
- Strengthening rural construction practices

3.Kobe Earthquake 1995

Details

- Magnitude: 6.9
- Location: Japan

Ground Performance

- Strong ground shaking
- Infrastructure damage

Building Performance

- Collapse of older structures
- Modern engineered buildings performed better

Lessons Learned

- Importance of **modern seismic design**
- Improvement in **building codes and detailing**

7.Explain Seismic Retrofitting

Seismic Retrofitting
Definition
Seismic retrofitting is the process of **strengthening existing buildings** to improve their performance during earthquakes.
Goal:

- Prevent collapse
- Reduce damage
- Protect life and property

1. Objectives of Retrofitting

- Increase **strength and stiffness**
- Improve **ductility**
- Ensure **load path continuity**
- Reduce seismic forces
- Correct structural deficiencies

2. Need for Retrofitting

- Old buildings not designed for earthquakes
- Poor construction quality
- Change in building use (increased load)
- Located in seismic zones

3.Retrofitting Techniques
(a) Jacketing
Types:

- RC jacketing
- Steel jacketing

Use:

- Strengthening columns and beams

Improves strength and ductility

(b) Adding Shear Walls

- Introduce RC shear walls in building

Increases lateral load resistance

(c) Bracing Systems

- Steel cross-bracing

Improves stiffness and stability

(d) Base Isolation

- Install isolators at foundation level

Reduces transmission of earthquake forces

(e) Fiber Reinforced Polymer (FRP) Wrapping

- Wrapping columns/beams with FRP sheets

Lightweight and effective strengthening

(f) Grouting & Crack Repair

- Filling cracks with cement or epoxy

Restores structural integrity

(g) Mass Reduction

- Removing unnecessary loads

Reduces seismic forces

(h) Foundation Strengthening

- Underpinning
- Adding piles

Improves support system

4. Retrofitting of Masonry Buildings

- Provide **seismic bands** (lintel, roof)
- Add vertical reinforcement
- Strengthen wall connections

5. Advantages

- Cost-effective compared to reconstruction
- Extends life of structure
- Improves safety
- Faster than rebuilding

6. Limitations

- May be expensive for severely damaged buildings
- Requires skilled labor
- Not always feasible for all structures

8.Weakness in Existing Buildings, Aging, Concepts in Repair, Restoration, and Seismic Strengthening.

Weakness in Existing Buildings
Common Causes of Weakness
1.Design Deficiencies

- Not designed for earthquake loads
- Lack of ductile detailing
- Irregular configuration

2.Poor Construction Quality

- Low-quality materials
- Improper reinforcement placement
- Weak connections

3.Structural Irregularities

- Soft storey

- Floating columns
- Discontinuous load path

4. Foundation Issues
- Weak soil
- Differential settlement
- Inadequate foundation design

5. Overloading
- Additional floors or heavy equipment added later

Aging of Buildings
Causes of Deterioration
- Corrosion of steel reinforcement
- Weathering (rain, temperature changes)
- Chemical attack (sulphates, chlorides)
- Creep and shrinkage in concrete

Effects
- Cracks in structural elements
- Reduced strength and stiffness
- Loss of durability

Concepts in Repair, Restoration & Seismic Strengthening

1.Repair
Definition
Repair means fixing **damaged parts** to restore original condition.
Examples
- Crack filling (cement grout, epoxy)
- Replacing damaged plaster
- Minor concrete patchwork

Purpose: Restore **appearance and minor strength**

2. Restoration
Definition
Restoration means bringing the structure back to its **original condition before damage**.
Methods
- Rebuilding damaged portions
- Strengthening weakened elements
- Re-aligning displaced components

Purpose: Restore **structural performance**

3. Seismic Strengthening (Retrofitting)
Definition
Improving building strength to **resist future earthquakes**
Techniques
- RC/steel jacketing

- Adding shear walls
- Steel bracing
- FRP wrapping
- Base isolation

Purpose: Increase **strength, stiffness, and ductility**

ASSIGNMENT QUESTIONS

Long answer questions

1. Explain causes of

A) Earthquakes B)Plata Tectonics C)Faults D)Seismic Waves

2. Explain Earth quake effects of

A)Ground B)Soil Rupture

C) Lique fraction D)Land Slides

3.Explain behaviour of various types of building and structures collapse patterns.

4.Explain any three case studies of Earthquakes.

5.Explain seismic Retrofittings.

Shor Answer questions

1.What are the main causes of earthquakes?

2.Define magnitude and intensity of an earthquake.

3.What is liquefaction, and why is it dangerous?

4.What is a soft storey collapse pattern in buildings?

5.Differentiate between repair, restoration, and seismic strengthening.