

ASSIGNMENT - I

Short Answer Questions

1. Define Natural Disaster give two examples.
2. List the main types of natural disaster
3. Differentiate between hazard and disaster
4. Name any four geological disasters.
5. Why are coastal regions more prone to cyclones?

Long Answer Questions

1. Explain the meaning, causes, characteristics and impacts of natural disasters, why is disaster management important?
2. Describe in detail the different types of natural disasters (Geographical, hydrological, meteorological, climatological and biological) with suitable example.
3. Explain the occurrence of disasters in different climatic and geographical regions.
4. Explain the earthquake and cyclone hazard maps of the world and India, their tones, and their importance in disaster preparedness and planning.
5. Discuss the Regulations for faster disaster risk reduction (DRR) and explain the post-disaster recovery and rehabilitation process.

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Short Answers

1. Natural Disaster

A natural disaster is a sudden and catastrophic event caused by natural processes, leading to significant damage or loss of life.

Ex:- Earthquake, Flood

2. Main types of Natural disasters

- * Geophysical disasters
- * Meteorological disasters
- * Hydrological disasters
- * Climatological disasters
- * Biological disasters

3. Hazard vs Disaster

A hazard is a situation or event with potential to cause harm, while a disaster is an actual event causing significant damage or loss.

4. Four geological disasters

- * Earthquakes
- * Landslides
- * Volcanic eruptions
- * Tsunamis

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5. Coastal regions are more prone to cyclones due to warm ocean waters and atmospheric conditions that facilitate cyclone formation.

Long Answers

1. Meaning of Natural Disasters

Natural disasters are extreme events caused by natural processes that lead to significant damage, loss of life, and disruption of normal life.

Examples include earthquakes, floods, cyclones, and volcanic eruptions.

Causes of Natural Disasters

→ Geological Factors

Tectonic movements causing earthquakes and volcanic eruptions.

→ Meteorological Factors

Weather patterns leading to floods, droughts and storms.

→ Environmental Factors

Climate change and deforestation increasing disaster frequency and intensity.

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Characteristics of Natural Disasters

→ Unpredictability

many disasters are hard to predict accurately.

→ Destructive power

They can cause massive damage to life and property.

→ Impact on ecosystems

Disasters can disrupt ecosystems and biodiversity.

Impacts of Natural Disasters

→ Humanitarian Crisis

loss of life, injuries and displacement.

→ Economic losses

Damage to infrastructure, agriculture and industries

→ Environmental degradation

soil erosion, water pollution, and loss of biodiversity

Why disaster management is important

→ saves lives

prepares communities to respond effectively.

→ Reduces economic losses

protects infrastructure and supports recovery.

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2. Types of Natural Disasters

1. Geological Disasters

* Earthquakes

sudden ground shaking due to tectonic movements

Ex:- 2011 Japan earthquake and tsunami.

* Volcanic Eruptions

Release of magma, ash and gases

Ex:- 2010 Mount Eyjafjallajökull eruption in Iceland.

* Landslides and Vockfalls

movement of rock, soil or debris down a slope

Ex:- 2013 Uttarakhand landslides in India

2. Hydrological Disasters

* Floods

overflow of water into normally dry areas

Ex:- 2010 Pakistan floods.

* Tsunamis

large ocean waves caused by underwater disturbances

Ex:- 2004 Indian Ocean tsunami

* Laval Flows and mudslides

Fast-moving mixtures of water and debris

Ex:- 1985 Colombia mudslide.

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3. Meteorological Disasters

* cyclones and hurricanes

Intense storms with strong winds and heavy rain

Ex!:- 2013 Typhoon Haiyan in Philippines.

* Tornadoes

Rotating columns of air touching the ground

Ex!:- 1999 Oklahoma tornado outbreak, etc

* storm surges

Abnormal sea level rise due to storms

Ex!:- 2005 Hurricane Katrina in US

4. Climatological Disasters

* Droughts

Prolonged lack of rainfall affecting water supply.

Ex!:- 2011 East African drought

* Heatwaves and cold waves

Extreme temperature events

Ex!:- 2003 European heatwave.

* Wild Fires

Uncontrolled fires in forests or grasslands

Ex!:- 2019 Australian bushfires.

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5. Biological Disasters

* Epidemics and pandemics

Disease outbreaks affecting human or animals

Ex!- Covid-19 pandemic

* Locust swarms

large insect groups causing agricultural damage

Ex!- 2020 locust plague in East Africa.

3. Disasters in Different Regions

1. Tropical Regions

* Cyclones and hurricanes

frequent in areas like South East Asia, Caribbean, and Gulf of Mexico.

* Floods and landslides

Heavy rainfall and monsoons cause frequent disasters in places like India and Indonesia.

* Droughts

Some tropical areas face water scarcity, like parts of Africa and Australia.

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2. Temperature Regions

* Earthquakes

Areas like Japan and California experience frequent seismic activity.

* Floods and storms

Europe and North America face river floods and intense storms.

* Wildfires

Countries like Greece and parts of the US are prone to forest fires.

3. Polar and High-altitude Regions

* Avalanches and blizzards

Snow areas like the Himalayas and Alps face these risks.

* Glacial lake outbursts

Melting glaciers can cause sudden floods in places like Nepal.

4. Coastal Regions

* Tsunamis and storm surges

Coastal areas in Asia and the Pacific are at risk.

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* Erosion and sea-level rise

low lying areas like maldives and Bangladesh

face coastal threats.

4. Earthquake and cyclone hazard maps : Understanding

India's Risk

India's geographical location makes it prone to various natural disasters, including earthquakes and cyclones.

To mitigate the impact of these events, hazard maps play a crucial role in disaster preparedness and planning.

Earthquake hazard maps in India

The Bureau of Indian Standards (BIS) has classified India into four seismic zones: zone II, III, IV and V with zone V being the most earthquake-prone. The zones are determined based on historical earthquake data and geological features.

Zone V :-

Covers area with high seismic activity, including parts of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and northeastern states.

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ZONE IV

Includes areas with frequent earthquakes, such as Delhi, parts of Punjab and western Uttar Pradesh.

ZONE III

Encompasses areas with moderate seismic activity, including Kerala, Goa and parts of Maharashtra.

ZONE II

Covers areas with low seismic activity, including parts of Rajasthan and Tamil Nadu.

Cyclone Hazard maps of India

India's coastline is vulnerable to cyclones, with the Bay of Bengal being particularly prone to intense storms. The Indian meteorological department (IMD) issues cyclone alerts and advisories for coastal regions.

Cyclone - prone areas

Eastern coast, including Odisha, Andhra Pradesh, and Tamil Nadu, and Western coast, including Gujarat and Maharashtra.

High Risk zones

Areas with high population density and infrastructure, such as Mumbai, Chennai, and Kolkata.

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Importance of Hazard maps

Hazard maps are essential for

- * Disaster preparedness

Help authorities and communities prepare for potential disasters.

- * Infrastructure planning

Inform urban planning, building codes and infrastructure development.

- * Emergency response

Facilitate effective response and relief efforts during disasters.

- * Risk reduction

Enable targeted mitigation measures and reduce vulnerability.

5. Regulations for Disaster Risk Reduction (DRR)

- * Key Frameworks and Policies

→ Sendai Framework

Global agreement focusing on reducing disaster risk

and losses.

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National disaster management Act (2005, India)
mandates disaster management planning and response.

International Building Codes

Guidelines for constructing disaster-resistant infrastructure

* DRR strategies

→ Risk assessment and mapping

Identifying vulnerable areas.

→ Early warning systems

Alerts for impending disasters

→ public awareness and education

Preparing communities

→ Infrastructure resilience

Building codes and flood defenses.

* post-disaster Recovery and Rehabilitation

→ Search and Rescue - locating and aiding survivors

→ Relief operations

providing food, water, shelter and medical aid.

Recovery phase

→ Damage assessment

Evaluating impact on infrastructure and livelihood.

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→ Restoring basic services

Rebuilding water, electricity and communication network

→ Housing and livelihood support

Temporary shelters and aid for restarting livelihood

* Rehabilitation and Reconstruction

→ Building back better

Rebuilding with improved standards and resilience

→ Economic recovery

Reviving local businesses and agriculture.

→ Psychological support

Counselling for affected communities.

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Short Answer Questions

1. Define tropical cyclone and explain the role of climate change in its intensification.
2. Write short notes on storm surges and their impact on coastal areas.
3. What are the common structural damages observed during cyclones and windstorms?
4. Explain the concept of cyclonic retrofitting and its importance.
5. What are life-line structures? Describe the importance of temporary cyclone shelters.

Long Answer Questions

1. Discuss changes in frequency, intensity, rainfall pattern, and coastal vulnerability due to climate change.
2. Describe the nature of cyclonic winds, velocities and pressure distribution in a cyclone.
3. Explain in detail the major effects of cyclones such as storm surges, floods, and landslides.
4. Explain the concept of cyclonic retrofitting and its importance.
5. What are life-line structures? Describe the importance of temporary cyclone shelters.

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Short answers

1. Tropical cyclones

A tropical cyclone is a rotating low-pressure system formed over warm ocean waters.

Role of climate change

One of the major consequences of climate change is its effect on tropical cyclones.

2. Storm surges

A storm surge is an abnormal rise in sea level along a coastal area caused by strong winds and low atmospheric pressure associated with tropical cyclones, storms or hurricanes.

3. Structural failure observed in cyclones and windstorms

Cyclones and windstorms are severe natural hazards that produce strong winds, heavy rainfall, and storm surges. These forces affect buildings, bridges, and other infrastructure.

4. Cyclonic retrofitting

Cyclonic retrofitting refers to strengthening existing buildings and structures to resist damage caused by cyclones and strong winds.

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Importance

Cyclonic Retrofitting is very important in cyclone-prone coastal regions such as India, especially along the Bay of Bengal coast where severe cyclones frequently occur.

5. Life-line structures

Life-line structures are essential facilities that remain functional during and after disasters.

Importance of cyclone shelters

- Reduce mortality and injuries during cyclones.
- Prevent displacement and homelessness.

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Long Answers

1. Changes in Frequency of extreme events
- * The overall number of cyclones may not increase significantly.
 - * There is a rise in extreme weather events like heatwaves, heavy rainfall, and severe storms.
 - * Some regions experience fewer but more powerful cyclones.
 - * Seasonal patterns and shifting, causing unpredictable occurrence.

Increase in intensity

Rising sea surface temperatures provide more energy to storms.

* Leads to

• stronger cyclones

• Higher wind speeds

* Results in greater destruction and disaster impact

Changes in rainfall pattern

* Warmer atmosphere holds more moisture — heavier rainfall events.

* Rainfall is becoming

* more intense but short-duration

* irregular and unevenly distributed

* Increased risk of:



- Floods
- landslides
- longer dry spells between rains.

Increased Coastal Vulnerability

Sea-level rise leads to

- Coastal flooding
- permanent submergence of low-lying areas.

* stronger cyclones cause

- Higher storm surge
- Drinking water sources.

* coastal ecosystems (mangroves, coral reefs) are degrading, reducing natural protection.

* climate change is not just increasing hazards but also amplifying their impacts, making coastal and vulnerable regions more at risk.

2) Nature of cyclonic winds

Cyclonic winds spiral inward toward a central low-pressure area

* Due to the Coriolis effect

- Rotate anticlockwise in the northern hemisphere.
- Rotate clockwise in the southern hemisphere.

* winds are converging and rising at the center, forming clouds and heavy rain.

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- * The cyclone has three main parts.
- * Eye calm region with light winds.
- * Eyewall: Region of strongest winds and heavy rainfall.
- * Rainbands: spiral bands with intermittent rain and wind.

Wind velocity in a cyclone

- * Wind speed increases from the outer region toward the centre

- * maximum velocity occurs in the eyewall.

- * Typical speeds:

- Depression: $\sim 30 - 60 \text{ km/h}$
- Cyclone: $> 119 \text{ km/h}$
- Severe cyclones: can exceed $200 - 300 \text{ km/h}$

- * Wind velocity decreases again inside the eye (calm zone)

- * strong winds cause

- structural damage

- storm surges

- flying debris.

pressure distribution

- * A cyclone has a very low pressure at the centre (eye)

- * pressure gradually increases outward from the centre.

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- * This creates a steep pressure gradient
 - * The closer the isobars (pressure lines), the stronger the winds.
 - * Lowest central pressure $\rightarrow$ strongest cyclone intensity.
 - * Cyclones are characterized by spiraling winds, high wind velocities near the eyewall, and a strong low-pressure center, which together determine their intensity and destructive power.
3. storm surges.

A storm surge is the abnormal rise in sea level caused by strong cyclone winds pushing seawater towards the coast.

causes

- * strong onshore winds
- * low atmospheric pressure
- * shape of coastline

Effects

- * severe coastal flooding and submergence
- * destruction of houses, roads, ports and infrastructure
- * loss of human and animal life
- * salt water intrusion into soil and groundwater damaging agriculture.
- * erosion of beaches and coastal land.

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Floods

Flooding occurs due to intense and continuous rainfall during and after cyclones

Causes

- * Heavy rainfall over a short period.
- * Overflow of rivers, lakes, and drainage systems.
- * Poor urban drainage

Effects

- * Damage to crops → food shortages
- * Disruption of transportation and communication
- * Economic losses and displacement of people.

Types of floods

- * Flash floods
- * River floods

Land slides

land slides are the downward movement of soil, rocks and debris on slopes due to loss of stability.

Causes

- * Heavy and prolonged rainfall saturates soil.
- * Increased pore water pressure weakens slopes
- * Deforestation and unstable terrain worsen the effect.

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Effects

Burial of houses, roads and people.

* Disruption of transport and communication networks.

* Loss of life and property, especially in hilly regions.

4. Structural Failures

Structural failure occurs when a building or structure cannot withstand cyclone forces such as high wind pressure, flying debris and flooding.

Common types of failures

Roof Failure

Up lift due to strong winds $\rightarrow$ roofs get blown off.

Wall collapse

Weak masonry walls fail under lateral wind pressure.

Failure of doors and windows

Breakage allows wind to enter - increases internal pressure -

Roof collapse.

Foundation failure

Due to soil erosion and flooding.

Connection Failure

Weak joints between roof, walls and columns.

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Lessons learned from past cyclones

* Poor construction practices increase damage.

* Buildings without proper design standards are highly vulnerable.

* Importance of building codes and regulations,

* Need for Quality materials and skilled workmanship.

* Role of early warning systems and evaluation.

* mangroves and natural barriers reduce cyclone impact.

* importance of community awareness and preparedness.

Design improvements (mitigation measures)

Structural improvements

* Use aerodynamic building shapes to reduce wind

* provide strong roof anchoring systems.

* strengthen connections between all structural elements

* Use reinforced concrete or cyclone-resistant materials.

* Install storm shutters for windows and doors.

Engineering measures

* Follow cyclone-resistant building codes

* proper load calculation for wind forces.

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5. **planning measures**
- * Avoid construction in high-risk coastal zones
 - * Develop cyclone shelters
 - * maintain green belts.
- Methods of structural strengthening**
- structural strengthening improves the ability of existing buildings to resist cyclone forces such as high winds, flooding, and debris impact.
- Roof strengthening**
- * Use cyclone-resistant roofing materials
 - * Fix sheets properly to avoid uplift
- Wall strengthening**
- * Add reinforcement in masonry walls
 - * Use cross-bracing to improve stability.
- strengthening connections**
- strengthen joints using bolts, straps, and connections.
- Foundation Improvement**
- * Increase foundation depth.
 - * protect against scouring and erosion.

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opening protection

Install storm shelters for windows and doors.

* Use impact-resistant glass.

Adaptive and sustainable reconstruction

This approach focuses on rebuilding after disasters in a way that is resilient, eco-friendly, and suitable for future risks.

Key Principles

* Build Back better Concept.

* Use locally available and sustainable materials.

Strategies

* Elevated houses in coastal/flood areas

* Use of eco-friendly materials.

* Incorporation of rainwater harvesting and drainage systems.

Benefits

* Reduces future disaster losses

* Cost-effective in the long term

* Environmentally sustainable.

Importance of lifeline structures

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lifeline structures

These are essential facilities required during disasters

- * Hospitals
- * Roads and bridges
- * power supply
- * water supply

Importance

- * provide safe refuge for people in vulnerable areas
- * reduce loss of life during evaluation
- * used as relief centres after disaster.

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ASSIGNMENT - III

1. Long Answer Questions

1. Explain the basic concepts of wind engineering and structural response.
2. Discuss wind characteristics, wind loading mechanism, and dynamic response of structures.
3. Describe the aerodynamics of bluff bodies.
4. Explain how separation, wake formation, drag and lift forces with neat sketches.
5. What is vortex shedding?

Short Answer Questions.

1. Define wind engineering
2. What are bluff bodies? Give examples
3. Define vortex shedding
4. What is structural number?
5. Differentiate flow along-wind and across-wind force.

Long Answer Questions

1. Basic Concept of Wind Engineering and structural Response :-
Wind Engineering is all about understanding how wind interacts with structures and how structures respond that interaction. It combines ideas from fluid mechanics metrology and structural engineering.

Structural Response to Wind

"structural response" refers to how a structure behaves when wind forces act on it. This depends on:

- * Mass of the structure
- * Stiffness (how much it resists deformation)
- * Damping (how quickly it stops moving after being disturbed)

There are two main types of response:

1. Static Response

2. Dynamic Response

1. Static Response

Caused by steady wind loads

* Structure bends or deflects but remains stable

Ex:- a building slightly leaning under constant wind pressure.

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2. Dynamic Response

* caused by fluctuating or gusty winds

* leads to vibration or oscillations.

* Important for all, flexible structures like sky scrapes or long bridges.

Importance phenomena

Vertex shedding

Wind creates alternating swirling forces that can cause oscillations.

Buffering : Random turbulence causing irregular motion.

Resonance

When wind frequency matches the structural, natural frequency, leading to large vibration.

2. Wind Characteristics

Wind is not constant it varies in both time and space

important characteristics include:

* Wind speed :- Increases with height above ground due to reduced friction.

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- * Turbulence :- Irregular fluctuation in wind speed and direction.
- * Gusts :- sudden short-duration increases in wind speed.
- * Terrain effects :- Urban areas forests and open fields affect wind flow differently.
- * Wind direction :- Can change frequently influence load distribution on structures.
→ Engineers often use statistical model to predict extreme wind speeds for safe design.
- * Wind loading mechanism
Wind creates forces when it interacts with a structure.
- * On windward side (facing (pressure) wind)
- * suction on leeward side (away from wind)
- * Drag force : Acts in the direction of wind flow.
- * lift force : Acts perpendicular to wind flow (important for roof and bridges)

Types of wind loads

* static loads :- Due to steady wind

* Dynamic loads :- Due to fluctuating wind (gusts, turbulence),

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load calculation depends on :-

- * Wind speed
- * shape and size of structure
- * exposure conditions (terrain, height)

Dynamic response of structures

When wind is unsteady respond dynamically.

- * Along - Wind Response :- movement in direction of wind.
- * Across - Wind Response :- movement perpendicular to wind (often due to vortex shedding)
- * Torsional response :- Twisting of structure

Key Factors

- * Mass :- Heavier, structure more less
- * Stiffness :- stiffer structure resist deformation
- * Damping :- Reduces vibration overtime.

3. Aerodynamics of Bluff Bodies

Bluff bodies are objects with a broad, non-streamlined shape that causes the airflow to separate early when wind passes around them.

Example Include buildings, chimneys, and bridges decker.

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What makes a Bluff body

- * Sharp edges or abrupt shape changes
- * Flow separates quickly from the surface.
- * Large wake region forms behind the body
- * High pressure drag compared to streamlined bodies

Flow Behaviour Around Bluff bodies

When wind approaches a bluff body:

1. Stagnation point forms on the windward face (maximum pressure)
2. Flow moves around the side.
3. Flow separation occurs at edges

Key Aerodynamics Effects

1. Drag force

* Dominant force for bluff bodies

* Mainly due to pressure difference b/w front and back.

2. Vortex Shedding

* Alternating vortices are formed behind the body

* Creates oscillating forces perpendicular to the wind.

3. Lift Forces

- * Can develop due to asymmetric flow
- * Important install on slender structures.

4. Bluffing

Random turbulence causing irregular vibrations.

Engineering Significance

- * causes structural vibrations and fatigue.
- * Can lead to instability if resonance occurs.

4. Flow Separation

Flow separation occurs when the boundary layer the thin layer of fluid sticking to a surface - detaches from the body.

* causes

When fluid flows against increasing pressure (an adverse pressure gradient) it loses momentum and slows down.

* point of separation

The specific location on the body where the flow reverses direction, characterized by a zero velocity gradient at the wall ($\frac{du}{dy} = 0$).

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* Effect

separation disrupts smooth flow, reducing lift and significantly increasing pressure drag.

Wake Formation

The wake is the turbulent, low-velocity region that forms directly behind a body after the flow separates.

* Structure

It consists of recirculating flow and vortices that are shed downstream.

* pressure

The wake is a region of low pressure (suction) compared to the front of the body.

* Vortex shedding

At higher speeds, vortices can shed alternately, forming a von Karman vortex street.

* Drag Force

Drag is the force acting parallel to the oncoming flow, slowing the object down. It consists of two main parts.

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* skin Friction drag

Caused by the viscosity of the fluid rubbing against the surface.

* sketch: Drag on a sphere / cylinder

* Bluff body (e.g. cylinder) :- early separation, large wake, high pressure drag.

5. Vortex Shedding

Vortex shedding is the alternate formation and release behind a bluff when wind flow past it.

Examples

* Chimneys

* Towers

* Bridge cables

process

1. Wind flows past body
2. Flow separates
3. vortices form alternatively
4. vibrations occurs.

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Effects of vertex shedding

* structural vibration

* Noise

* fatigue failure

* Resonance

Resonance Condition

Shedding frequency equals natural frequency, large

vibration occurs.

Prevention methods

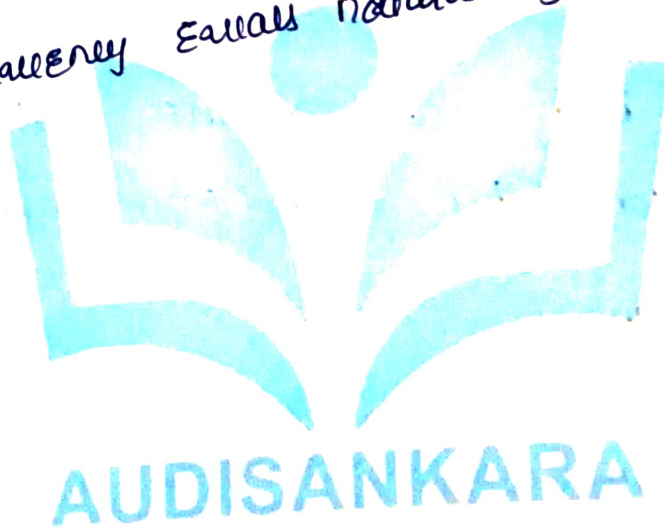
* Helical springs

* Dampers

* Shape modification

* Shape modification

* Increasing stiffness.



ASSIGNMENT - IV

Short Answer Questions

1. What are the main causes of earthquake?
2. Define magnitude and intensity of an earthquake?
3. What is liquefaction, and why is it dangerous?
4. What is a soft story collapse pattern in buildings?
5. Differentiate between repair, restoration, and seismic strengthening.

Long Answer Questions.

1. Explain causes of
A) earthquake B) plate tectonics
C) Faults D) seismic waves
2. Explain Earthquake effect of
A) Ground B) Soil Rupture
C) Liquefaction D) Land slides
3. Explain behaviour of various types of building and structure collapse patterns.
4. Explain any three case studies of earthquake.
5. Explain seismic retrofittings.

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Short Answers

1. Causes of Earthquake

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

- Tectonic movements
- Volcanic activity
- Faulting
- Human-Induced causes.

magnitude

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

Intensity

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

3. Liquefaction

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

Causes

- sandy soil
- high groundwater level
- strong shaking

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4. Soft Storey Collapse Pattern

A soft storey collapse pattern is a type of building failure that happens when one floor of a building is much weaker or less stiff than the floor above. During an earthquake or strong lateral force, that weak floor bends, sways or collapses first.

5. Repair

Repair means fixing damaged parts to restore original condition.

Ex:-

- * Crack filling (Cement grout, epoxy)
- * Replacing damaged plaster
- * monitor concrete patchwork

* Restoration

Restoration means bringing the structure back to its original condition before damage.

* Seismic strengthening

Improving building strength to resist future earthquake.

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Long-Answer Questions

1. Earthquake

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

1. Tectonic movements

- * 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.

b) Causes of plate Tectonics

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

Types of plate

a) Convergent Boundary

- * plates move towards each other
- * causes strong earthquakes

b) Divergent Boundary

Plates move away from each other.

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c) Causes of Faults

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

Types of faults

1. Normal Fault

- * Caused by tension
- * Caused one block move downward

2. Reverse fault

- * caused by compression
- * one block moves upward.

3. Strike-slip fault

- * horizontal fault movement.

d) causes of seismic waves

Energy released during earthquakes travels as seismic waves.

1. Body waves

a) P waves (primary)

- * Fastest
- * Travel through solids, liquid, gases
- * Cause compression and expansion.

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b) waves (secondary)

- * slower than p-waves
- * Travel only through solids
- * Cause shear motion.

2. surface wave :-

a) Love waves

- * horizontal motion

b) Rayleigh waves

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

2. 1. Effects on Ground

Movement of the ground due to seismic waves.

Effects

- * vibration in buildings
- * cracks in roads and pavements
- * settlement of soil
- * Collapse of weak structure

Key point-

Ground shaking is the primary cause of most earthquake damage

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2. Soil Rupture

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

Ex:- structure built over faults are highly vulnerable

3. Liquefaction

→ A phenomenon where water-saturated loose soil behaves like a fluid 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. Land slides

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

Causes

- * Ground Shaking
- * Weak soil or rock
- * Steep slopes

Effects

- * Burial of building and roads
- * Blockage of rivers → flooding
- * Damage in hilly regions.

2

Different buildings and structures fail in different ways during Earthquakes, explosions, poor construction, overloading fire or foundation failure. The failures are called collapse patterns. Understanding them helps Engineers design safer structures and identify weak points.

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Types of Building and Structure Collapse patterns

1. pancake collapse

In this type, floor collapse one over another like a stack of pancakes.

CAUSES:-

- * Weak columns
- * Heavy vertical loads
- * Earthquakes
- * Explosions

Features

- * Floors remain mostly flat
- * Very little empty space between floors.
- * Dangerous for trapped people.

Ex:- Common in reinforced concrete buildings during strong earthquakes.

2. Soft Storey Collapse

A soft storey is a floor with less stiffness or fewer walls than other floors, usually the ground floor used for parking or shops.

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Causes

- * open ground floor
- * weak columns
- * Earthquake forces

Features

- * Ground floor collapse first
- * Upper floor fall onto lower floor.
- * Building tilts or crushes at one level.

Ex:- Apartment building with parking areas at ground level.

3. Lean-To-Collapse

one wall falls while the opposite wall remains standing,

Creating a sloping roof or floor.

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Causes

- * Failure of one side wall
- * Uneven foundation settlement
- * Blast pressure.

Features

- * Triangular empty space formed
- * part of building remains standing.

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4. Cantilever Collapse :-

one side of the structure hinged freely while support fails on the other side.

Causes :-

- * Beam or column failure
- * earthquake shaking
- * structural imbalance

Features

- * one portion project outward
- * sudden breaking possible

4. 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.

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* soft storey collapse common.

lesson learned

* Importance of seismic Code (is 1893, IS 10326)

* Need for ductile detailing

* Avoid soft storey design

2. Nepal Earthquake 2015

Detail

* magnitude : 7.8

* location: Nepal

Ground performance

* landslides in hilly areas

* Soil instability

Buildings performance

* Traditional masonry buildings collapsed.

* Heritage structure heavily damaged.

lesson learned

* Need for retrofitting old buildings

* Importance of lightweight construction.

* Strengthening rural construction practices



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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 building performed better.

5. Seismic Retrofitting

Seismic retrofitting is the process of strengthening existing building 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

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- * 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:-

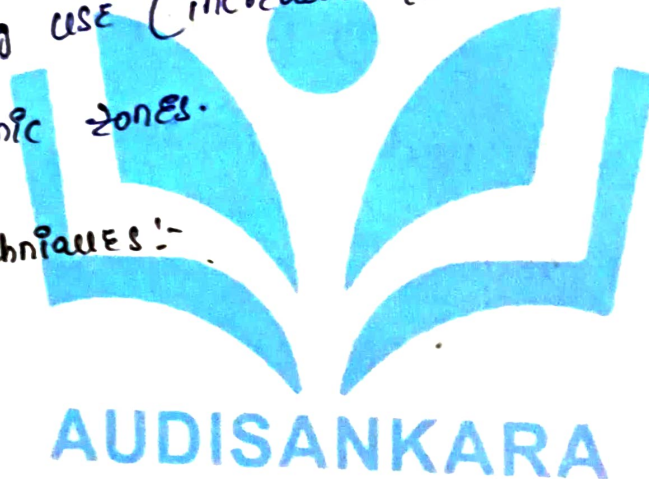
- * RC Jacketing
- * Steel Jacketing

Use:-

Strengthening columns and beams Improves strength and ductility.

b) Adding Shear walls

Introduce RC shear walls in building increase lateral local resistance.



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c) Bracing Systems

Steel cross-bracing Improves stiffness and stability.

d) Base Isolation

Install isolators at foundation level Reduces transmission of earthquake forces.

e) mass Reduction

Removing unnecessary loads Reduces seismic forces.

4. Retrofitting of masonry Building

- * provide seismic bonds (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. limitation

- * may be expensive for severely damaged building
- * Requires skilled labor
- * Not always feasible for all structures.

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Short Answer Questions

1. What is soft storey, and why is it dangerous during earthquakes?
2. Define plan irregularity with one example.
3. What is meant by seismic isolation in structures?
4. Define mass irregularity in a building.
5. What is the finite element method (FEM) used for in structural analysis?

Long Answer Questions.

1. Explain site selection and ground condition for seismic safety.
2. Explain and design consideration for
A) Building forms B) Horizontal and vertical eccentricities
C) mass and stiffness distribution D) soft storey effects
3. Explain seismic effects related to building configuration
4. Explain construction details for
A) Foundation B) soil stabilization
C) Retaining wall D) Under ground and over head tanks.
5. Explain innovative construction materials and Techniques.

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Long answers

1. Site Selection & Ground Conditions

Avoid Fault zones

Buildings should not be placed directly over active faults

Soil type matters

- Hard rock → safer, less shaking amplification
- Soft soil → amplifies vibrations and increases damage

Liquefaction risk

Loose, water-saturated soils can behave like liquid during

Earthquakes.

Topography

Slopes and hills may trigger landslides.

1. Structural Configuration (Planning stage)

* Simple and regular shapes

Rectangular or square plans perform better

* Symmetry

Prevents torsional (twisting) effects

* Uniform mass distribution

Avoid heavy loads concentrated at one level.

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Avoid irregularities
sudden changes in height, stiffness, or geometry leads to
stress concentration.

Continuous load path

Forces should transfer smoothly from roof $\rightarrow$ foundation

2. Structural Design Considerations

Ductility

• structures should deform without collapsing (absorbing energy).

• lateral load resistance systems

• Shear walls

• Braced frames

• moment-resisting frames.

Strong column - weak beam concept

prevents collapse by allowing beams to fail first.

Redundancy

multiple load paths improve safety.

Base isolation (advanced)

Reduces seismic force transmission.

materials & Construction Quality

$\rightarrow$ High-Quality materials

$\rightarrow$ proper detailing

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- Good workmanship
- connections are critical

4. Building Components & Non-structural safety

→ Flexible utilities

Pipes, cables, and ducts should allow movement

→ Secure Non-structural elements:

- * Ceilings

- * Facades

- * Equipment

- lightweight roofing

- Exit planning

5. Foundation Design

- * match foundation to soil conditions

- * avoid differential settlement

- * use deep foundations (piles) in weak soils

- * ensure strong connection between foundation and superstructure.

2. Design Considerations

Building Forms

- * Best practice

Keep the building simple, regular and symmetric.

preferred forms

- * Rectangular / square plans

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- * Uniform height
- * Symmetrical layout in both directions.

problematic forms

- * L-shape, T-shape, U-shape buildings
- * Re-entrant corners

* Setbacks

Why it matters

Irregular shapes cause:

- stress concentration
- uneven force distribution
- torsion

Horizontal eccentricity (plan irregularity)

- Center of mass (cm) $\neq$ Center of Rigidity (CR)

This causes torsional rotation during earthquakes.

Effects

- one side of the building experiences more displacement.
- unequal damage distribution
- possible structural failure.

Control measures

- Symmetrical
- uniform stiffness distribution
- proper placement of shear walls.

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Vertical Eccentricity (Vertical irregularity)

Examples

- Heavy floors at top
- Sudden change in column size
- Discontinuous shear walls.

Effects

- Concentration of forces at certain floors
- Weak levels $\rightarrow$ failure initiation points.

Control measures

- Gradual variation in mass/stiffness.
- Continuous vertical structural elements

mass distribution

principle

- Earthquake force is proportional to mass.
- More mass = more seismic force

Good practices

- uniform mass distribution across floors
- Avoid heavy loads at higher levels.
- use lightweight materials.

Problems

- Heavy top floors $\Rightarrow$ large overturning moments
- Uneven mass $\rightarrow$ torsion.

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Stiffness distribution

* Good practices

- uniform stiffness throughout height
- even distribution in plan
- Balanced placement of structural elements.

Problems

- Sudden stiffness change → stress concentration
- Uneven stiffness → torsional effects.

Soft Storey Effect

Definition

A story with significantly lower stiffness than the storeys above

Can be dangerous

* large lateral deformation at that level.

* columns may fail → collapse mechanism.

Solutions

- Avoid open ground storey OR provide
- shear walls
- Bracing
- Stronger columns.

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3) Seismic effects Related to building Configuration

Vertical Configuration Effects

Examples:

- Setbacks
- Sudden Change in Column Size
- Discontinuous Structural Elements.

Effects

- Concentration of seismic forces at certain levels
- Weak points $\rightarrow$ failure initiation.

b) Soft Storey Effect

A storey with much lower stiffness than adjacent storeys

Ex:- open ground floor

Effects

* large deformation in that storey

* column failure $\rightarrow$ collapse

c) Weak Storey - storey with less strength

Effects

* failure begins at weakest level

* progressive collapse risk.

.max irregularity

Ex:- heavy roof, water tanks on top

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Effects

- * Increased inertia force

- * large bending and overturning

Discontinuity in load path

What it mean - Breaks structural force transfer

Examples

- * Floating columns

- * Sudden failure at discontinuity

Stiffness irregularity

Cause - Uneven distribution of stiffness

Effects

- * Unequal deformation

- * Torsion

- * Stress concentration.

Height and Slenderness effects

Tall buildings

- * Larger sway

- * Higher vibration modes

Short buildings

- * Higher base shear

Both require different design approaches.

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pounding effect - collision b/w adjacent buildings

Cause - Insufficient separation gap

Effects - SEVERE damage at contact points.

Redundancy and structural integrity

Good configuration - multiple load paths.

Types :-

- * soft storey
- * mass irregularity
- * vertical geometric irregularity
- * discontinuity in vertical elements.

4. Construction Details

1. Foundation

Types

- * Isolated footing
- * Combined footing
- * Raft (mat) foundation
- * pile foundation

* Tie all footings using tie beams → prevents differential movement.

* prefer raft or pile foundations in soft/loose soils

* ensure uniform settlement

* provide strong connection with superstructure.

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Soil stabilization

Methods

- * compaction
- * Grouting
- * stone columns
- * Chemical stabilization

Importance

- * Reduces liquefaction risk.
- * Improves bearing capacity
- * minimizes settlement during shaking

3) Retaining walls

Risks in earthquakes

- * Increased lateral earth pressure.
- * sliding and overturning.

Safety measures

- * provide proper drainage
- * Reinforcement for lateral loads.
- * Strong foundation and anchoring

4. underground & overhead Tanks

overhead Tanks

Risks

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- * Heavy mass $\rightarrow$ high seismic forces
- * sloshing of water.

measures

- * proper staging design
- * Bracing system
- * secure anchorage

Underground Tanks

measures:-

- * Strong RCC construction
- * waterproofing
- * Resist uplift pressure.

Slab cases

Issues - can act as rigid elements $\rightarrow$ damage building

Good practice

- * provide separation gap or sliding joints
- * avoid restraining building movement.
- * Ensure independent support if needed.

Isolation of Structures

Concept

Separate different parts of a structure to avoid interaction during earthquakes.

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5. Innovative Construction materials and Techniques

1. Innovative Construction materials

a) High-performance concrete (HPC)

Higher strength, durability, and workability than normal concrete

-Advantages

- * Better resistance to cracking
- * Improved seismic performance (ductility)
- * longer life.

b) Self-compacting concrete (SCC)

- Flows without vibration

-Advantages

- * Fills complex reinforcement areas.
- * Reduces voids → stronger structure
- * Faster construction.

c) Fiber Reinforced Concrete (FRC)

- Contains steel, glass, or synthetic fibers

-Advantages

- * Increased tensile strength
- * Crack resistance
- * Better energy absorption during earthquakes.

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d) Geopolymer Concrete

- uses industrial waste (Fly ash, slag) instead of cement.

Advantages

- * Eco-friendly (low CO₂ emission)
- * Good chemical resistance
- * suitable for sustainable construction

Benefit

2. Innovative Construction Techniques

a) Base Isolation

- Building separated from foundation using isolators.

Effect - Reduces earthquake forces significantly

b) Energy Dissipation Devices (Dampers)

- Absorb seismic energy

Types

* viscous dampers

* Friction dampers

Benefit - Reduces vibration and damage.

c) modular construction / prefabrication

- * Components manufactured off-site

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Advantages

- * Faster Construction
- * Better Quality Control
- * Reduced waste

d) 3D printing in Construction

- Automated layer-by-layer Construction

Advantages

- * Cost Effective
- * Less labor
- * Custom designs

e) Tunnel form Construction

- monolithic walls + slabs cast together.

Benefit

- * High Structural integrity
- * Good seismic resistance

Short Answers

1. Soft story

- A story with significantly lower stiffness than the storeys above.

Ex:- Ground floor used for parking (open columns, no walls)

Why dangerous

- * large lateral deformation at that level
- * columns may fail $\rightarrow$ collapse mechanism

2. Plan irregularity

Plan irregularity is a type of structural irregularity in a building where the shape, size, or stiffness of the structure is not uniform in the horizontal direction.

Ex:- An L-shaped building is a plan irregularity.

3. Isolation of structures

Separate different parts of a structure to avoid interaction during earthquakes

Importance

- * prevent pounding between buildings
- * allows independent movement

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4. Mass irregularity

Mass irregularity in a building occurs when the mass (weight) of one floor is significantly greater than that of the adjacent floors.

5. Finite Element Method (FEM)

In FEM, a large and complex structure is divided into many small elements connected at points called nodes. The behaviour of each element is analysed.