Chapter 44: Important Points in Mitigating Effects of Earthquake on Structures

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Introduction

Earthquakes pose a significant threat to the built environment, especially in seismically active regions. The destructive energy released during an earthquake can cause massive structural damage and loss of life. However, through thoughtful design, construction practices, and retrofitting techniques, the vulnerability of structures to seismic forces can be reduced substantially. This chapter explores the key principles and practical measures necessary to mitigate the effects of earthquakes on civil engineering structures. It covers architectural considerations, structural design techniques, soil-structure interaction, seismic isolation, damping systems, and retrofitting strategies, all aimed at ensuring safety, serviceability, and resilience during and after an earthquake.

44.1 Selection of Site and Soil Consideration

- **Site Selection**: Avoid construction near active faults, liquefiable soils, steep slopes prone to landslides, and areas with high groundwater tables.
- **Geotechnical Investigation**: Perform a detailed soil investigation to understand soil type, bearing capacity, liquefaction potential, and amplification effects.
- **Seismic Zoning Maps**: Use BIS seismic zoning maps (IS 1893 Part 1) to determine the zone factor and spectral acceleration.

44.2 Architectural Considerations

- **Building Configuration**:
  - Avoid irregular configurations (plan and vertical).
  - Aim for symmetry in mass and stiffness.
- **Separation Joints**:
  - Provide seismic joints between adjacent structures to prevent pounding.
- **Height and Mass Distribution**:
  - Maintain uniform distribution of mass and stiffness.
  - Avoid soft storey formation by ensuring consistent column stiffness throughout.

- **Overhangs and Cantilevers**:
  - Minimize heavy overhangs and cantilevers that can create torsional effects.

44.3 Structural Configuration

- **Redundancy and Continuity**:
  - Ensure alternate load paths.
  - Maintain continuous load transfer paths from superstructure to foundation.
- **Ductility**:
  - Design members to undergo large deformations without loss of strength.
  - Use ductile detailing as per IS 13920 for reinforced concrete structures.
- **Torsional Resistance**:
  - Avoid eccentricities in mass and stiffness distribution to reduce torsional vibrations.

44.4 Seismic Load Considerations in Design

- **Load Calculations**:
  - Follow IS 1893 (Part 1): 2016 for determining design base shear and distribution.
- **Response Spectrum Method**:
  - Use response spectra appropriate to the soil type and seismic zone.
- **Dynamic Analysis**:
  - Use time-history or response spectrum analysis for irregular or tall structures.

44.5 Materials and Construction Quality

- **Material Selection**:
  - Use high-quality materials with proven ductility and strength properties.
  - Use high-grade steel and concrete for critical members.

- **Construction Practices**:
  - Ensure proper compaction, curing, and placement of concrete.
  - Ensure correct placement and anchorage of reinforcement bars.
- **Inspection and Quality Control**:
  - Regular site inspections during construction.
  - Use non-destructive tests for quality verification.

44.6 Foundation Design in Seismic Areas

- **Foundation Types**:
  - Prefer shallow foundations on firm soil.
  - Use pile foundations or raft foundations where soil is poor.
- **Soil-Structure Interaction**:
  - Account for dynamic interaction between soil and structure.
- **Liquefaction Mitigation**:
  - Use soil densification, drainage systems, or replacement with non-liquefiable material.

44.7 Seismic Separation and Expansion Joints

- **Purpose**:
  - To allow independent movement between adjacent structures or structural units.
- **Design Guidelines**:
  - Calculate separation distance based on expected displacement.
  - Use proper detailing to ensure waterproofing and fireproofing of joints.

44.8 Use of Seismic Base Isolation

- **Concept**:
  - Decouples superstructure from ground motion using flexible bearings.
- **Types of Isolators**:
  - Lead Rubber Bearings (LRB), High Damping Rubber Bearings (HDRB), Friction Pendulum Systems.

- **Advantages**:
  - Reduces acceleration and inter-storey drift.
  - Protects contents and reduces post-earthquake downtime.

44.9 Energy Dissipation Devices

- **Supplemental Damping Systems**:
  - Add passive devices to dissipate seismic energy.
- **Types of Dampers**:
  - Viscous dampers, metallic yielding dampers, friction dampers, tuned mass dampers.
- **Placement**:
  - Install dampers at strategic locations to reduce overall structural response.

44.10 Retrofitting and Strengthening of Existing Structures

- **Need for Retrofitting**:
  - Upgrade older buildings not designed for seismic forces.
  - Repair damage and increase safety margin.
- **Retrofitting Techniques**:
  - Jacketing (RC or steel), steel bracings, shotcrete, FRP wrapping.
- **Seismic Evaluation**:
  - Conduct vulnerability assessment using rapid visual screening (RVS) or detailed analysis.

44.11 Non-Structural Components and Architectural Features

- **Securing Contents**:
  - Anchor cabinets, false ceilings, glass panels, HVAC ducts, and pipelines.
- **Fall Prevention**:

  - Use wire restraints, fasteners, and bracings to prevent toppling of equipment.

- **Architectural Safety**:
  - Avoid heavy cladding or parapets without anchorage.

44.12 Building Regulations and Codes

- **Relevant Codes in India**:
  - IS 1893: Criteria for Earthquake Resistant Design of Structures.
  - IS 13920: Ductile Detailing of Reinforced Concrete.
  - IS 4326: Earthquake Resistant Design and Construction of Buildings.
  - IS 13828: Guidelines for Low Strength Masonry.
- **Mandatory Compliance**:
  - Ensure design is reviewed and approved by qualified structural engineers.

44.13 Post-Earthquake Performance Considerations

- **Structural Monitoring**:
  - Use sensors to assess building performance during quakes.
- **Damage Assessment**:
  - Conduct visual and instrumental inspection post-event.
- **Resilience Planning**:
  - Include provisions for emergency evacuation, repair access, and continuity of function.
