Chapter 40: Codal Provisions

Introduction

In earthquake-prone regions, structures must be designed and constructed to withstand seismic forces. In India, the Bureau of Indian Standards (BIS) has laid down codal provisions to guide engineers in the analysis, design, detailing, and construction of earthquake-resistant structures. These codes form the backbone of seismic design in Indian civil engineering practice. This chapter explores the key codal provisions as specified in **IS 1893 (Part 1): 2016** – *Criteria for Earthquake Resistant Design of Structures* and **IS 13920: 2016** – *Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces*, along with references to other related standards such as IS 456, IS 4326, and IS 13828.

40.1 Overview of Relevant Codes and Standards

- **IS 1893 (Part 1): 2016** – General provisions for buildings.
- **IS 13920: 2016** – Ductile detailing of RC structures.
- **IS 4326: 1993** – Earthquake-resistant design and construction of buildings.
- **IS 13828: 1993** – Guidelines for low strength masonry buildings.
- **IS 456: 2000** – Code of practice for plain and reinforced concrete (with seismic provisions in clause 8).

40.2 Seismic Zoning and Seismic Coefficient (IS 1893)

40.2.1 Seismic Zones in India

India is divided into **four seismic zones (II to V)**:

- **Zone II**: Low seismic risk
- **Zone III**: Moderate seismic risk
- **Zone IV**: High seismic risk
- **Zone V**: Very high seismic risk

40.2.2 Zone Factor (Z)

- Represents the severity of ground shaking.
- Values range from **0.10 (Zone II)** to **0.36 (Zone V)**.

40.3 Design Horizontal Seismic Coefficient (Ah)

$$A_h = \frac{Z}{2} \cdot \frac{I}{R} \cdot \frac{S_a}{g}$$

Where:

- Z: Zone factor
- I: Importance factor
- R: Response reduction factor
- S_a/g: Spectral acceleration coefficient
- A_h: Design horizontal acceleration coefficient

40.3.1 Importance Factor (I)

- Depends on the use and occupancy.
- E.g., 1.0 for ordinary buildings, 1.5 for hospitals, emergency buildings.

40.3.2 Response Reduction Factor (R)

- Depends on the structural system and ductility.
- E.g., 3 for ordinary moment resisting frame (OMRF), 5 for special moment resisting frame (SMRF).

40.4 Seismic Weight and Base Shear

40.4.1 Seismic Weight (W)

- Includes dead load and a portion of live load.
- 25% of live load is considered for design, except for storage where 50% may be considered.

40.4.2 Base Shear (V)

$$V = A_h \cdot W$$

- Total lateral force at base due to earthquake effects.

40.5 Distribution of Base Shear along Height

The lateral force at any floor level is given by:

$$F_i = \frac{W_i \cdot h_i^2}{\sum W_j \cdot h_j^2} \cdot V$$

Where:

- F_i: Lateral force at level i
- W_i: Seismic weight at level i
- h_i: Height of level i from base

40.6 Load Combinations (IS 456 & IS 1893)

Typical load combinations considering seismic load are:

- $1.5(DL + LL)$
- $1.2(DL + LL \pm EL)$
- $1.5(DL \pm EL)$
- $0.9DL \pm 1.5EL$

Where:

- DL = Dead Load
- LL = Live Load
- EL = Earthquake Load

40.7 Ductile Detailing Provisions (IS 13920)

40.7.1 General Requirements

- Mandatory for structures in Zone III, IV, and V.
- Applies to RC buildings designed with SMRF systems.

40.7.2 Beam Detailing

- Minimum and maximum reinforcement limits.
- **Lap splices** not permitted in the joint region.
- **Shear reinforcement**: Closely spaced stirrups near beam ends.

40.7.3 Column Detailing

- Axial load carrying capacity limited to 0.4fckAg for ductile columns.
- **Transverse reinforcement**: Closely spaced ties in plastic hinge zones.
- **Strong column-weak beam** design principle.

40.7.4 Joint Detailing

- **Stirrups provided through joints**.
- Ensure full anchorage of longitudinal bars.

40.8 Shear Walls and Dual Systems

- Shear walls must be **well-distributed and symmetric**.
- Design must consider **flexural and shear capacity**.
- Dual systems: Combination of SMRF and shear walls – both must be capable of resisting total base shear independently.

40.9 Foundation Design in Seismic Zones

- Foundations should be **tied with plinth beams**.
- **No differential settlement**.
- Use of **raft or pile foundations** in soft soil regions.
- Check **sliding and overturning stability**.

40.10 Special Considerations for Masonry and Low-Strength Structures

40.10.1 IS 4326 and IS 13828 Guidelines

- For unreinforced and low-strength masonry:
  - Use of **horizontal bands (lintel, roof, plinth)**.
  - **Vertical reinforcement at corners and openings**.
  - Light roof coverings.

40.11 Performance-Based Design Approach (Emerging Concepts)

- Modern codes incorporate **performance objectives**:
  - **Immediate occupancy**
  - **Life safety**
  - **Collapse prevention**

While not fully covered in IS codes yet, these are gradually being introduced in performance-based seismic designs.

40.12 Quality Control and Workmanship Requirements

- **Supervision and quality control** critical in seismic zones.
- Emphasis on:

- Proper **placement of reinforcement**
- **Curing and compaction**
- Avoidance of honeycombing
- **Joint detailing in beams and columns**

40.13 Torsional Irregularities and Code Provisions

Structures with asymmetry in mass or stiffness are prone to **torsional effects** during earthquakes.

40.13.1 Types of Irregularities (IS 1893 Clause 7.1)

- **Plan Irregularities**
  - Torsional irregularity: Difference in lateral displacement between stiff and flexible edges.
  - Re-entrant corners, diaphragm discontinuities.
- **Vertical Irregularities**
  - Stiffness irregularity (soft storey).
  - Mass irregularity.
  - Vertical geometric irregularity.

40.13.2 Torsional Design Provisions

- Additional shear forces are considered on frames located at the edge.
- Eccentricity factor (usually 1.5 times the design eccentricity) used to increase stability.

40.14 Drift and Deflection Limits

40.14.1 Storey Drift Limit

- Defined as the relative lateral displacement between floors divided by storey height.
- As per IS 1893:

$$\text{Drift} \leq \frac{0.004 \times h}{1}$$

- where h is the storey height.

40.14.2 P-Delta Effects

- Considered when **drift is large**.
- Amplifies moments due to secondary effects.

40.15 Pounding Effects and Separation Gaps

40.15.1 Pounding Between Adjacent Structures

- Caused when two buildings with different dynamic characteristics collide during an earthquake.

40.15.2 Codal Provision for Separation Gaps

- IS 4326 and IS 1893 suggest **minimum separation gap**:

$$\text{Gap} = 0.005 \times h$$

- where h is height of building in meters.
- Additional gap if adjacent buildings have differing heights or dynamic responses.

40.16 Soil-Structure Interaction

- IS 1893 allows incorporation of **soil flexibility** in dynamic analysis.
- Soil type affects base shear and natural period.
  - **Type I**: Hard rock
  - **Type II**: Medium soil
  - **Type III**: Soft soil
- For soft soils, amplification of ground motion is considered.

40.17 Provisions for Non-Structural Elements

40.17.1 General Guidelines

- Non-structural components (cladding, partitions, parapets, equipment) must be **securely anchored**.
- Falling hazard must be mitigated.
- IS 1893 recommends:
  - Bracing for water tanks, electrical panels, etc.

    - Flexible connections for piping systems.

40.18 Seismic Design of Water Tanks (IS 1893 Part 2)

40.18.1 Elevated Water Tanks

- Designed using **staging height**, **impulsive** and **convective** modes.
- **Hydrodynamic pressure** is calculated.
- Staging should follow ductile detailing.

40.18.2 Ground Supported Water Tanks

- Consider **sloshing effects**.
- Base shear and overturning moments must be computed for water mass and container.

40.19 Retrofitting and Strengthening Guidelines

40.19.1 Evaluation of Existing Structures

- Rapid Visual Screening (RVS)
- Detailed vulnerability assessment

40.19.2 Retrofitting Techniques

- **Jacketing of columns and beams**
- **Shear wall insertion**
- **FRP wrapping**
- **Base isolation (for critical structures)**

Codes like **IS 15988: 2013** provide retrofitting procedures.

40.20 Base Isolation and Energy Dissipation Devices

40.20.1 Base Isolation

- Reduces seismic forces by introducing **flexibility** at foundation level.
- Types:
    - **Lead rubber bearings (LRB)**
    - **Friction pendulum systems**

40.20.2 Damping Devices

- Absorb earthquake energy:
  - **Viscous dampers**
  - **Tuned mass dampers**
  - **Metallic yield dampers**

Not yet mandatory by code but considered in performance-based design.

40.21 Codal Provisions for Bridges (IS 1893 Part 3)

40.21.1 Dynamic Effects on Bridges

- Modal analysis required for long-span or irregular bridges.
- Bearings and expansion joints must accommodate seismic movements.

40.21.2 Seismic Restraints

- Use of seismic stoppers and dampers.
- Pier and abutment design to resist lateral forces.

40.22 Seismic Design Categories and Importance Classifications

- Categories based on:
  - **Occupancy type**
  - **Structural system**
  - **Seismic zone**
- High-importance structures:
  - Emergency response centers
  - Hospitals
  - Power plants

Design with **higher importance factor (I)** and **enhanced ductility provisions**.
