Chapter 19: Mix Design – IS Method of Mix Design

Introduction

Concrete mix design is the process of selecting suitable ingredients of concrete and determining their relative proportions with the objective of producing concrete of desired strength, durability, and workability. The Indian Standard (IS) method of mix design provides a systematic approach to achieve the desired quality of concrete economically.

The IS method primarily refers to **IS 10262:2019** titled *"Concrete Mix Proportioning – Guidelines"*, which should be read alongside **IS 456:2000**. These codes specify the basis of proportioning, target strength, and the procedure to be followed for ordinary and special concretes.

This chapter elaborates the IS method in step-by-step detail, covering theoretical background, assumptions, and practical considerations.

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1. Objectives of Mix Design

- To achieve the desired compressive strength at 28 days.
- To ensure workability for ease of placement and compaction.
- To ensure durability under environmental exposure conditions.
- To optimize cost through economical use of materials.
- To maintain consistency in production and quality.

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2. Governing Codes

The IS method of mix design relies on the following standards:

- **IS 10262:2019** – Concrete Mix Proportioning – Guidelines
- **IS 456:2000** – Plain and Reinforced Concrete – Code of Practice
- **IS 383:2016** – Specification for Coarse and Fine Aggregates
- **IS 9103:1999** – Concrete Admixtures
- **IS 1199:1959** – Methods of Sampling and Analysis of Concrete

- **IS 516:1959** – Methods of Tests for Strength of Concrete
- **IS 2386 (Parts I to VIII)** – Methods of Test for Aggregates

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3. Input Parameters Required

The following data is required before proceeding with mix design:

a. **Grade of Concrete**

- E.g., M20, M25, M30, etc.
- Defines the characteristic compressive strength at 28 days.

b. **Type of Cement**

- OPC 43 Grade, OPC 53 Grade, PPC, etc.

c. **Maximum Nominal Size of Aggregate**

- Typically 10 mm, 20 mm, or 40 mm.

d. **Workability**

- Measured in terms of slump (mm). Depends on placing conditions.

e. **Exposure Conditions**

- As per IS 456:2000 (mild, moderate, severe, very severe, extreme).

f. **Water-Cement Ratio**

- Based on durability requirement from IS 456:2000.

g. **Cement Content**

- Minimum content prescribed as per IS 456:2000 for different exposures.

h. **Type of Aggregates**

- Shape (rounded or angular), grading, specific gravity, etc.

i. **Admixtures (if any)**

- Plasticizers, superplasticizers, etc., along with manufacturer's recommendations.

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4. Target Mean Strength

The characteristic compressive strength is enhanced to a **target mean strength** to account for variation.

$$f_{ck'} = f_{ck} + k \times S$$

Where:

- $f_{ck'}$ = Target mean strength (N/mm²)
- f_{ck} = Characteristic strength
- k = Risk factor (1.65 for 5% risk)
- S = Standard deviation

Standard deviation values are provided in IS 10262 for different grades of concrete.

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5. Selection of Water-Cement Ratio

- Determined from durability requirements in **IS 456:2000** (Table 5).
- A trial value can be taken from graphs (compressive strength vs w/c ratio) based on experience.
- Lower of the two values (durability & strength requirement) is selected.

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6. Estimation of Water Content

- Based on workability (slump) and aggregate type.
- Initial values provided in **Table 4 of IS 10262:2019**.
- Adjustments made for use of admixtures or different aggregate shapes:
  - ±3% for every 25 mm slump increase/decrease.
  - ±10% for angular/rounded aggregates.
  - Reduction of 5–10% for use of superplasticizers.

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7. Calculation of Cement Content

$$\text{Cement Content} = \frac{\text{Water Content}}{\text{Water-Cement Ratio}}$$

- Must not be less than the **minimum content** required for durability.
- Must not exceed **maximum cement content** of 450 kg/m³ as per IS 456.

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8. Proportioning of Aggregates

- **Volume method** is used.
- Use **Table 5 of IS 10262:2019** to find the volume of coarse aggregate per unit volume of total aggregate, based on:
  - Maximum size of aggregate
  - Zone of fine aggregate (Zone I–IV)
  - W/C ratio
- The balance is fine aggregate (sand).

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9. Calculation of Mix Proportions (Volume Basis)

The mix design is computed by volume using the absolute volume method:

$$\text{Volume of concrete} = 1\,\text{m}^3 = V_c + V_w + V_{fa} + V_{ca} + V_{adm}$$

Where:

- V_c = Volume of cement
- V_w = Volume of water
- V_{fa} = Volume of fine aggregate
- V_{ca} = Volume of coarse aggregate
- V_{adm} = Volume of admixtures

a. Volume of Cement:

$$V_c = \frac{\text{Cement Content}}{\text{Specific Gravity} \times 1000}$$

b. Volume of Water:

$$V_w = \frac{\text{Water Content}}{\text{Specific Gravity of Water} \times 1000}$$

c. Volume of Admixture (if any):

$$V_{adm} = \frac{\text{Admixture in kg}}{\text{Specific Gravity} \times 1000}$$

d. Volume of Aggregates:

$$V_{fa} + V_{ca} = 1 - \left(V_c + V_w + V_{adm}\right)$$

Then distribute between fine and coarse aggregates using selected ratios.

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10. Conversion to Mass

Convert calculated volumes to mass using:

$$\text{Mass} = \text{Volume} \times \text{Specific Gravity} \times 1000$$

Do this for fine and coarse aggregates.

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11. Moisture Corrections

Adjust water and aggregate content for:

- **Free surface moisture** in aggregates (increases water content).
- **Absorption capacity** (reduces effective water content).

Corrections are vital to ensure accurate w/c ratio and workability.

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12. Trial Mix and Adjustments

A **trial batch** should be prepared using the calculated proportions.

Tests to Perform:

- Slump test (workability)
- Cube compressive strength at 7 and 28 days
- Fresh density
- Air content (if required)

If the results do not match the target:

- Adjust w/c ratio, water content, or admixture dose.
- Maintain cementitious material content as per minimum durability criteria.

Multiple trials may be needed to optimize the mix.

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13. Final Mix Proportion (per m³)

Expressed in the standard format:

$$\text{Cement : Fine Aggregate : Coarse Aggregate :: Water Content :: Admixture (if any)}$$

Example:

$$1:1.82:3.29::0.45\,w/c::0.8$$

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14. Special Considerations

- **Pumping concrete** requires lower coarse aggregate content and higher workability.
- **High-performance concrete** requires precise control over admixtures.
- **Self-compacting concrete (SCC)** needs different guidelines (refer IS 10262:2019 Annex).
- Environmental and sustainability factors like recycled aggregates or supplementary cementitious materials (SCMs) should be accounted for.

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15. Incorporation of Supplementary Cementitious Materials (SCMs)

The use of SCMs like **Fly Ash, Ground Granulated Blast Furnace Slag (GGBS), Silica Fume**, and **Metakaolin** is widely recommended for sustainable and high-performance concrete.

a. **Fly Ash**

- Reacts slowly (pozzolanic reaction).
- Improves workability, long-term strength, and durability.
- Reduces heat of hydration.

Substitution: 15–35% of total cementitious content (Class F or Class C).

b. **GGBS**

- Enhances durability against chloride attack and sulphate attack.
- Slower setting but better long-term strength.

Substitution: 25–70%.

c. **Silica Fume**

- Extremely fine; increases strength and impermeability.
- Increases water demand – superplasticizers required.

Substitution: 5–10%.

> □ **Note:** Adjustments in water, admixture, and mix proportions are necessary when SCMs are used. IS 10262:2019 provides specific guidance for their incorporation.

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16. Mix Design for Special Concrete Types

a. **Self-Compacting Concrete (SCC)**

- Requires high flowability without segregation.
- Lower coarse aggregate content.
- Use of viscosity-modifying agents (VMAs).
- Guidelines in **IS 10262:2019, Annex B**.

b. **High Strength Concrete (HSC)**

- Grade M60 and above.
- Needs optimized aggregate grading, silica fume, and superplasticizers.
- Trial mixes essential to fine-tune setting and early strength gain.

c. **Fibre-Reinforced Concrete**

- Addition of steel, glass, or synthetic fibres.
- Enhances tensile strength, crack control, and ductility.
- Mix proportions must consider volume fraction of fibres and their effects on workability.

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17. Durability Considerations (From IS 456:2000 Table 5)

Durability directly impacts mix design through:

- **Minimum cement content**
- **Maximum water-cement ratio**
- **Cover to reinforcement**

Exposure	Max W/C Ratio	Min Cement (kg/m^3)	Min Grade
Mild	0.60	300	M20
Moderate	0.50	300	M25
Severe	0.45	320	M30
Very Severe	0.45	340	M35
Extreme	0.40	360	M40

> Always choose the **stricter requirement** between strength-based and durability-based criteria for water-cement ratio and cement content.

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18. Quality Control in Mix Design Execution

To ensure consistency and performance in the field:

a. **Batching Accuracy**

- Use of calibrated digital weigh-batching systems.
- Avoid volume batching.

b. **Control Charts**

- Maintain **compressive strength control charts**.
- Monitor standard deviation regularly.

c. **Storage and Handling of Materials**

- Avoid moisture variation in aggregates.
- Store cement in moisture-proof containers.

d. **Trial Batching at Site**

- Small-scale mix verification using **pan mixer or drum mixer** before full-scale use.

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19. Example Mix Design – M25 Grade (Using IS 10262:2019)

Given:

- Grade of concrete: M25
- Max nominal aggregate size: 20 mm
- Workability: 75–100 mm slump
- Exposure: Moderate
- Cement: OPC 43 Grade
- Specific gravities: Cement = 3.15, FA = 2.65, CA = 2.7
- Zone of sand: II
- Superplasticizer: Yes

Step-by-step solution:

- Target mean strength = 25 + 1.65 × 4 = **31.6 MPa**
- Select W/C ratio = **0.45**
- Estimate water = **186 kg/m³**
- Cement = 186 / 0.45 = **413 kg/m³**
- From IS 10262 Table 5: Coarse aggregate volume = 0.62
- Volumes calculated and converted to masses (as per earlier section)

Final Mix:

\text{Cement: 413 kg, Water: 186 kg, FA: 628 kg, CA: 1186 kg, SP: 0.8% of cement}

$$\text{Mix ratio (by weight)} = 1:1.52:2.87::0.45\,w/c$$

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20. Frequently Faced Issues and Corrections

Issue	Likely Cause	Suggested Action
Slump too low	Less water or excessive fines	Add water or use superplasticizer
Segregation	Excessive water, improper grading	Use VMAs, re-check aggregate proportion
Strength too low	Low cement content or high W/C	Reduce W/C, check batching accuracy
Setting too fast	High temperature,	Use retarders or

Issue	Likely Cause	Suggested Action
	fast-reacting cement	chilled water

21. Recent Changes in IS 10262:2019 (vs 2009)

Feature	IS 10262:2009	IS 10262:2019 (Current)
Applicable Grades	Upto M60	Upto M100
SCC Guidelines	Not included	Annex B added
Use of SCMs	Limited reference	Separate clauses for SCMs
High Strength Concrete	Not covered explicitly	Annex for HSC added
Admixture Adjustments	Implicit	Clearly specified procedures