Chapter 17: Design of Concrete Mix for Pavements

Introduction

Concrete pavements play a crucial role in modern highway infrastructure, offering durability, low maintenance, and good riding quality. One of the most vital aspects in ensuring the performance and longevity of concrete pavements is the **design of the concrete mix**. A properly designed concrete mix ensures the required strength, workability, durability, and economy while meeting the specific demands of pavement applications such as resistance to environmental conditions, heavy loads, and volume changes due to temperature and moisture.

This chapter focuses on the principles, guidelines, and methods of concrete mix design tailored specifically for pavements. It emphasizes the parameters influencing mix proportioning, design procedures, testing methods, and relevant standards.

17.1 Requirements of Concrete for Pavement Applications

Concrete used for pavements must meet several performance criteria. Key requirements include:

- **Compressive Strength**: Typically ranging from 30 MPa to 40 MPa for highways.
- **Flexural Strength**: Usually between 4 MPa to 5 MPa as pavement design is flexure-based.
- **Workability**: Sufficient for proper placement and compaction (slump value of 25–75 mm).
- **Durability**: Resistance to freeze-thaw cycles, sulfate attack, abrasion, and chemical exposure.
- **Economy**: Optimized use of materials for cost-effectiveness.
- **Shrinkage and Creep Resistance**: Important to minimize cracks and long-term deformation.

17.2 Factors Affecting Mix Design for Pavements

17.2.1 Environmental Conditions

- Freeze-thaw exposure.
- Sulfate presence in soils or groundwater.
- Temperature variations.

17.2.2 Traffic Loading

- Axle load intensity.
- Repetition of loads.
- Load transfer characteristics.

17.2.3 Subgrade and Sub-base Conditions

- Strength and stiffness of underlying layers.
- Drainage quality.

17.2.4 Type of Pavement

- Jointed Plain Concrete Pavement (JPCP)
- Continuously Reinforced Concrete Pavement (CRCP)
- Roller Compacted Concrete Pavement (RCCP)

17.3 Constituents of Concrete for Pavements

17.3.1 Cement

- **Type**: Ordinary Portland Cement (OPC) – 43 or 53 grade, or blended cement like PPC or PSC.
- **Properties**: Consistency, setting time, fineness, strength development.

17.3.2 Aggregates

- **Coarse Aggregates**: Angular, hard, and clean crushed stone.
- **Fine Aggregates**: Clean river sand or manufactured sand conforming to grading limits.
- **Grading**: Must ensure a well-graded mix for strength and workability.

17.3.3 Water

- Potable water with pH between 6 and 8.
- Free from chlorides and sulfates.

17.3.4 Admixtures

- Water-reducing agents (Plasticizers).
- Superplasticizers for high strength or low w/c ratio.
- Air-entraining agents for freeze-thaw resistance.
- Retarders or accelerators depending on climatic conditions.

17.4 Concrete Mix Design Methods

17.4.1 IRC:44 Method (Recommended by Indian Roads Congress)

- Tailored for pavement concrete.
- Focuses on flexural strength (modulus of rupture) instead of compressive strength.
- Incorporates durability and workability factors.

17.4.2 IS 10262 Method

- General mix design standard in India.
- Recently revised to include provisions for different exposure conditions.
- Modified for pavement use by targeting flexural strength indirectly through compressive strength.

17.4.3 ACI Method (American Concrete Institute)

- Widely used globally.
- Empirical and based on statistical relationships.
- Applicable to high-performance pavement design.

17.5 Design Procedure (IRC:44-2017 Method)

Step 1: Target Mean Flexural Strength

- Determine characteristic flexural strength f_{ck}.
- Add margin to account for variation.

$$f_{target} = f_{ck} + k \times s$$

Where:

- k = statistical constant (usually 1.65)
- s = standard deviation

Step 2: Selection of Water-Cement Ratio

- Based on target strength and durability.
- Check from graphs or tables in IRC/IS standards.

Step 3: Estimation of Water Content

- Based on required workability (slump) and aggregate type.

Step 4: Calculation of Cement Content

$$\text{Cement Content} = \frac{\text{Water Content}}{\text{w/c ratio}}$$

- Must meet minimum content for durability as per IS 456.

Step 5: Selection of Aggregate Ratio and Grading

- Decide proportion of coarse to fine aggregate.
- Confirm compatibility with grading limits (Zone II sand preferred).

Step 6: Mix Calculations (Trial Mixes)

- Compute mix proportions by weight.
- Make adjustments based on field conditions and test results.

Step 7: Trial Mixes and Adjustments

- Prepare trial batches.
- Test for:
    - Flexural strength at 28 days.
    - Workability (slump).
    - Air content.
    - Durability indicators (sulfate resistance, abrasion).

17.6 Flexural Strength Testing

- **Beam Specimen**: 150 mm × 150 mm × 700 mm (per IS 516).
- **Third-point loading** method to calculate modulus of rupture (MOR).
- Acceptance based on average of three specimens.

17.7 Quality Control in Pavement Concrete

- **Batching Accuracy**: Use weigh-batchers or batching plants.
- **Mixing**: Pan mixers or transit mixers with adequate mixing time.
- **Transporting and Placing**: Avoid segregation and delays.
- **Compaction**: Use vibrators or slip-form pavers.
- **Curing**: Continuous wet curing for 14 days or equivalent.
- **Strength Monitoring**: Regular cube or beam testing.

17.8 Ready Mixed Concrete (RMC) in Pavement Construction

- Increasingly used for large highway projects.
- Ensures consistency, quality, and speed.
- Requires control over mix temperature, transport time, and placement.

17.9 Special Considerations for Concrete Pavement Mix

17.9.1 Use of Supplementary Cementitious Materials

- Fly ash, GGBS, Silica fume for improved durability and sustainability.

17.9.2 High-Early-Strength Concrete

- Useful for fast-track pavement repairs.

17.9.3 Use of Fibers

- Steel or synthetic fibers to improve crack resistance and toughness.

17.10 Case Example: Design of M40 Concrete for Highway Pavement

Given:

- Target flexural strength: 4.5 MPa
- Max. aggregate size: 20 mm
- Slump: 50 mm
- Exposure: Moderate

- Admixture: Superplasticizer

Design Steps:

1. Target strength calculated: $4.5 + 1.65 \times 0.6 = 5.49$ MPa
2. From tables, w/c ratio ≈ 0.38
3. Water content: 170 kg/m^3 (adjusted for admixture)
4. Cement content = 170 / 0.38 = 447.4 kg/m^3
5. Coarse aggregate: 1140 kg/m^3
6. Fine aggregate: 650 kg/m^3
7. Superplasticizer: 1% by weight of cement
