Chapter 7: Properties and Testing of Aggregates

Introduction

Aggregates form the bulk of materials used in road construction, making up 70–80% of the volume of bituminous and cement concrete pavements. Their properties significantly affect the strength, durability, and performance of pavement structures. Hence, understanding and evaluating the physical and mechanical characteristics of aggregates is vital for ensuring the longevity and serviceability of road infrastructure. This chapter discusses the essential properties of aggregates and the standardized testing methods used to evaluate their suitability in various types of pavements.

7.1 Classification of Aggregates

Aggregates can be classified based on:

a) Source

- **Natural aggregates**: Sand, gravel, crushed stone.
- **Artificial aggregates**: Slag, sintered fly ash.
- **Recycled aggregates**: Derived from construction and demolition waste.

b) Size

- **Coarse aggregates**: Retained on 4.75 mm IS sieve.
- **Fine aggregates**: Pass through 4.75 mm IS sieve and retained on 75 µm sieve.
- **Filler**: Passes 75 µm sieve.

c) Shape

- Rounded
- Angular
- Flaky
- Elongated
- Flaky and elongated

7.2 Desirable Properties of Aggregates

7.2.1 Strength

Ability to withstand crushing under traffic loads. Important for base, sub-base, and surface layers.

7.2.2 Hardness

Resistance to abrasion and wear during service life.

7.2.3 Toughness

Resistance to impact loading and shocks.

7.2.4 Durability

Ability to resist weathering and chemical attack over time.

7.2.5 Shape and Texture

Affects workability, stability, and bonding with binders.

7.2.6 Specific Gravity and Water Absorption

Affects the density and strength of the mix.

7.2.7 Cleanliness

Aggregates must be free from dust, clay, organic matter, and other impurities.

7.3 Standard Tests on Aggregates

The following standardized tests are conducted to evaluate the aforementioned properties:

7.3.1 Crushing Test

- **Purpose**: To determine aggregate crushing value.
- **Standard**: IS: 2386 (Part IV) – 1963.
- **Apparatus**: Compression testing machine, cylindrical measure, tamping rod.
- **Procedure**:
    a. Aggregate sample is filled in three layers in a cylindrical mold.

b. Each layer is tamped.
c. Load is applied at a uniform rate.
d. Measure the fraction passing through 2.36 mm sieve.

- **Result**: Aggregates with crushing value <30% are suitable for pavement layers.

7.3.2 Abrasion Test

- **Purpose**: To assess the hardness by measuring resistance to wear.
- **Methods**:
  - **Los Angeles Abrasion Test** – IS: 2386 (Part IV)
  - **Deval Abrasion Test** – IS: 2386 (Part V)
- **Apparatus**: LA abrasion machine, steel balls.
- **Procedure**:
  a. Sample is rotated with abrasive charge in a drum.
  b. Measure the weight loss after a fixed number of revolutions.
- **Acceptable Limits**:
  - Bituminous mixes: <35%
  - Base courses: <40%

7.3.3 Impact Test

- **Purpose**: To determine toughness of aggregates.
- **Standard**: IS: 2386 (Part IV) – Aggregate Impact Value Test.
- **Apparatus**: Impact testing machine, cylindrical measure, tamping rod.
- **Procedure**:
  a. Sample is placed in a cup.
  b. Hammer is dropped 15 times from a specified height.
  c. Fines passing through 2.36 mm sieve are weighed.
- **Result**: Aggregate impact value <30% for surface courses.

7.3.4 Shape Tests

- **Flakiness Index (FI)** – IS: 2386 (Part I)

  - Measures the percentage of flaky particles (thickness $< 0.6 \times$ mean sieve size).
- **Elongation Index (EI)** – IS: 2386 (Part I)
  - Measures the percentage of elongated particles (length $> 1.8 \times$ mean sieve size).
- **Combined Index**: Should generally be <35% for bituminous mixes.

7.3.5 Specific Gravity and Water Absorption Test

- **Standard**: IS: 2386 (Part III).
- **Purpose**: Determines density-related properties.
- **Types of Specific Gravity**:
  - Apparent specific gravity.
  - Bulk specific gravity (oven-dry or saturated surface dry).
- **Water Absorption**: Affects bitumen adhesion and moisture susceptibility.
- **Acceptable Values**:
  - Specific Gravity: 2.6 – 2.9
  - Water Absorption: <2%

7.3.6 Soundness Test

- **Purpose**: Assess resistance to weathering, particularly freeze-thaw.
- **Standard**: IS: 2386 (Part V).
- **Procedure**:
  a. Samples are subjected to repeated cycles of wetting and drying in sodium or magnesium sulphate solution.
  b. Weight loss is measured.
- **Acceptable Values**:
  - <12% for sodium sulphate
  - <18% for magnesium sulphate

7.3.7 Stripping Value Test

- **Purpose**: Evaluates adhesive property between bitumen and aggregates.

- **Apparatus**: Beaker, hot plate.
- **Procedure**:
  a. Bitumen-coated aggregate samples are boiled in water.
  b. Visual inspection for stripping of bitumen film.
- **Result**: <25% stripping is acceptable.

7.3.8 Alkali-Aggregate Reactivity Test

- **Purpose**: To detect potential chemical reactivity with cement in concrete.
- **Standard**: IS: 2386 (Part VII).
- **Types**:
  - **Alkali-silica reaction (ASR)**
  - **Alkali-carbonate reaction (ACR)**
- **Procedure**: Mortar bars are tested for expansion in NaOH solution.
- **Acceptable Limit**: Expansion <0.1% in 14 days.

7.3.9 Deleterious Material Test

- **Purpose**: Detects the presence of unwanted materials (clay, silt, organic matter).
- **Methods**:
  - Clay Lumps and Friable Particles Test
  - Organic Impurities Test (using NaOH solution)
  - Lightweight Particles Test

7.3.10 Moisture Content Test

- **Purpose**: Determines moisture content for mix design adjustment.
- **Standard**: IS: 2386 (Part III).
- **Method**: Oven-drying or moisture meters.
- **Use**: Essential for volumetric mix design and compaction control.

7.3.11 Bulk Density and Voids

- **Purpose**: Determines the compactness and voids in aggregate mass.
- **Standard**: IS: 2386 (Part III).
- **Significance**: Used in mix design to calculate voids and optimize compaction.

7.4 Field Evaluation of Aggregates

In addition to laboratory testing, field checks include:

- Visual inspection for shape and cleanliness.
- Field compaction behavior.
- Field density measurement using core cutter or sand replacement method.

7.5 Selection Criteria for Aggregates in Pavement Construction

Layer	Strength Requirements	Shape	Max. Abrasion Value
Surface Course	High	Angular	<30–35%
Base Course	Medium–High	Angular	<40%
Sub-Base Course	Moderate	Sub-angular	<50%
Bituminous Layers	High adhesion, low stripping	Clean, dry	<30%
