Unit -1

Aggregate: Deleterious substance in aggregate – Soundness of aggregate – Alkali aggregate reaction – Thermal properties – Sieve analysis – Fineness modulus – Grading curves – Grading of fine, Manufactured sand and coarse Aggregates – Gap graded aggregate – Maximum aggregate size- Properties Recycled aggregate.

Concept-1

Deleterious Substances in Aggregate

Aggregates are a crucial component in concrete and construction materials. However, they may contain deleterious substances that can adversely affect the strength, durability, and performance of the final product. These substances may be present naturally or introduced during processing and transportation. Understanding these harmful impurities is essential to ensure the quality of construction materials.

Ensuring the quality of aggregates by controlling the presence of deleterious substances is vital for producing durable and high-performance concrete. Proper testing, washing, and selecting high-quality materials help in reducing the adverse effects of these impurities, leading to safe and long-lasting construction.

Types of Deleterious Substances

Several deleterious substances can be present in aggregates, including:

- Clay Lumps and Friable Particles
- Silt and Dust
- Organic Impurities
- Coal and Lignite
- Salts and Other Contaminants
- Alkali-Silica Reactive Particles

1. Clay Lumps and Friable Particles

Clay lumps are soft, weak particles that break down under pressure. These particles reduce the bond strength between aggregate and cement paste, leading to lower durability and strength in concrete.

2. Silt and Dust

Fine silt and dust particles coat aggregate surfaces, preventing proper adhesion between cement paste and aggregates. This leads to a reduction in the concrete's compressive strength and workability.

3. Organic Impurities

Organic materials such as decayed vegetation, humus, or other carbonaceous matter can interfere with cement hydration, resulting in weak and non-durable concrete. Excessive organic impurities delay setting time and reduce strength development. A simple colorimetric test can help assess the presence of these impurities.

4. Coal and Lignite

Coal and lignite are lightweight and weak materials that create voids in concrete, reducing its density and load-bearing capacity. They can also cause staining on concrete surfaces.

5. Salts and Other Contaminants

Chlorides and sulfates from contaminated aggregates can lead to corrosion of reinforcement bars and deterioration of concrete. Excess chloride ions promote steel reinforcement corrosion, while sulfates react with cement compounds, causing expansion and cracking in hardened concrete.

6. Alkali-Silica Reactive Particles

Certain silica-rich aggregates react with alkalis in cement, forming an expansive gel that absorbs moisture and causes cracking in concrete structures over time.

Problems Caused by Deleterious Substances

- Reduced strength and durability of concrete
- Increased permeability leading to water ingress and corrosion
- Poor workability and finish ability of concrete
- Volume instability and cracking due to chemical reactions
- Surface staining and aesthetic issues

Permissible Limits as per IS 383:2016

The Indian Standard IS 383:2016 specifies the permissible limits of deleterious substances in aggregates to ensure their quality and suitability for construction. The limits are as follows:

Deleterious Substance	**Permissible Limit (% by weight)**
Clay Lumps & Friable Particles	1.0 (for both fine and coarse aggregate)
Silt & Dust (by sedimentation method)	3.0 (for natural sand), 15.0 (for crushed sand)
Organic Impurities	Should not exceed prescribed limits (to be tested using colorimetric methods)
Coal & Lignite	1.0 (for fine aggregate), 0.5 (for coarse aggregate)
Salts (Chlorides)	0.04 (for reinforced concrete), 0.1 (for plain concrete)
Sulphates (SO3)	0.5 (for fine aggregate), 1.0 (for coarse aggregate)

Concept-2

Soundness of Aggregate

Soundness of aggregate refers to its ability to withstand weathering effects like freezing and thawing, repeated wetting and drying, or chemical exposure without breaking down or changing in size too much. It is an important property that ensures the aggregate remains strong and durable over time, maintaining the stability and integrity of construction materials.

Test for Soundness:

The Soundness Test (IS 2386 Part 5) is conducted using Sodium Sulphate (Na_2SO_4) or Magnesium Sulphate ($MgSO_4$) solutions.

- The aggregate is immersed in a saturated solution of Na_2SO_4 or $MgSO_4$ for 16-18 hours.
- It is then dried in an oven at 105-110°C.
- This cycle is repeated for 5 to 10 times, simulating weathering effects.
- The percentage loss in weight after the test indicates the aggregate's soundness.

Acceptable Limits:

The total weight loss should not exceed 12% for sodium sulphate and 18% for magnesium sulphate for coarse aggregate.

Significance:

- Ensures long-term durability of concrete structures.
- Prevents early failure due to disintegration.
- Important for roads, bridges, and heavy structures exposed to environmental changes.

Concept-3

Alkali-Aggregate Reaction

- Alkali-Aggregate Reaction is a chemical reaction that occurs between the alkalis (Na_2O and K_2O) present in cement and certain reactive minerals in aggregates. This reaction produces an expansive gel, which absorbs moisture, swells, and leads to cracks in concrete over time.
- Preventing Alkali-Aggregate Reaction ensures the durability, safety, and longevity of concrete structures like roads, bridges, and dams, reducing long-term maintenance costs and preventing structural failures.

Types of Alkali-Aggregate Reaction:

1. Alkali-Silica Reaction (ASR): The most common type, occurring when alkalis react with reactive silica in aggregates, forming a gel that expands when it absorbs water.

2. Alkali-Carbonate Reaction (ACR): A less common reaction that occurs between alkalis and certain carbonate rocks, leading to volume changes and cracking.

Effects of Alkali-Aggregate Reaction:

- Formation of cracks and fissures in concrete.
- Reduced strength and durability of the structure.
- Increased maintenance and repair costs.
- Structural instability over time, leading to potential failure.

Prevention Methods:

- Using Low-Alkali Cement: Cement with alkali content below 0.6% helps reduce reactions.
- Incorporating Pozzolanic Materials: Fly ash, silica fume, or slag help neutralize alkalis.
- Selecting Non-Reactive Aggregates: Aggregates tested and proven to be chemically stable should be used.
- Controlling Moisture: Proper drainage and sealing reduce water infiltration, limiting gel expansion.

Concept-4

Thermal Properties of Aggregates

Thermal properties of aggregates refer to how they respond to temperature changes, affecting the expansion, contraction, and heat transfer in concrete. These properties play a crucial role in the durability and performance of concrete structures exposed to varying temperatures.

Important Thermal Properties:

1. Coefficient of Thermal Expansion:

- Measures how much the aggregate expands or contracts with temperature changes.
- Higher Coefficient of Thermal Expansion can lead to cracks in concrete due to differential expansion between cement paste and aggregates.

2. Thermal Conductivity:

- Determines how well aggregates transfer heat.
- High thermal conductivity leads to faster heat transfer, while low conductivity provides better insulation.

3. Specific Heat Capacity:

- The amount of heat required to raise the temperature of the aggregate.

- Higher specific heat capacity helps in temperature stability.

4. Heat Resistance:

- Some aggregates resist high temperatures better than others.
- Siliceous aggregates (e.g., quartz) expand more, whereas calcareous aggregates (e.g., limestone) perform better under heat.

Effects on Concrete:

Uneven expansion and contraction can cause thermal cracks.

- High thermal conductivity can lead to temperature variations, affecting durability.
- Poor heat resistance may weaken concrete in fire-prone areas.

Prevention & Considerations:

- Using Low- Coefficient of Thermal Expansion Aggregates to reduce thermal cracking.
- Selecting Aggregates with Good Heat Resistance for fire-resistant structures.
- Proper Mix Design to balance expansion and shrinkage in different temperatures.

Importance:

Understanding thermal properties helps in designing durable concrete structures that withstand temperature variations, preventing cracks, improving insulation, and ensuring long-term stability in roads, buildings, and bridges.

Concept-5

Sieve Analysis, Fineness Modulus, Grading Curves, and Importance of Aggregate Grading in Concrete Mix Design

Sieve analysis is a fundamental test used to determine the particle size distribution of fine and coarse aggregates. It is conducted as per IS 2386 (Part 1) - 1963 to classify aggregates and assess their suitability for concrete mix design.

Process of Sieve Analysis:

The test is performed using a set of standard sieves with decreasing mesh sizes. The steps involved are:

Sample Preparation:

A representative 500g to 1kg sample of aggregate is taken and dried in an oven at 100-110°C.

Sieving Procedure:

- The sieves are arranged in a stack with the largest sieve on top and the finest sieve at the bottom.
- The sample is placed in the top sieve and shaken manually or mechanically for a set duration.
- Calculation of Percentage Retained and Cumulative Percentage Passing:
- Percentage retained on each sieve = (Weight retained / Total weight) × 100
- Cumulative percentage retained = Sum of the percentage retained on all sieves above a given sieve.
- Percentage passing = 100 - Cumulative percentage retained.

Standard Sieve Sizes and Ranges for Aggregates

As per IS 383:2016, the standard sieve sizes used for fine and coarse aggregates are:

A. Fine Aggregates (Sand) Sieve Sizes:

- 4.75 mm
- 2.36 mm
- 1.18 mm
- 600 µm
- 300 µm
- 150 µm

B. Coarse Aggregates Sieve Sizes:

- 80 mm
- 40 mm

- 20 mm
- 10 mm
- 4.75 mm

Fineness Modulus (FM) is a numerical index that gives an estimate of the average particle size in an aggregate sample.

FM= (Sum of cumulative percentages retained) / 100

FM Ranges as per **IS 383:2016**:

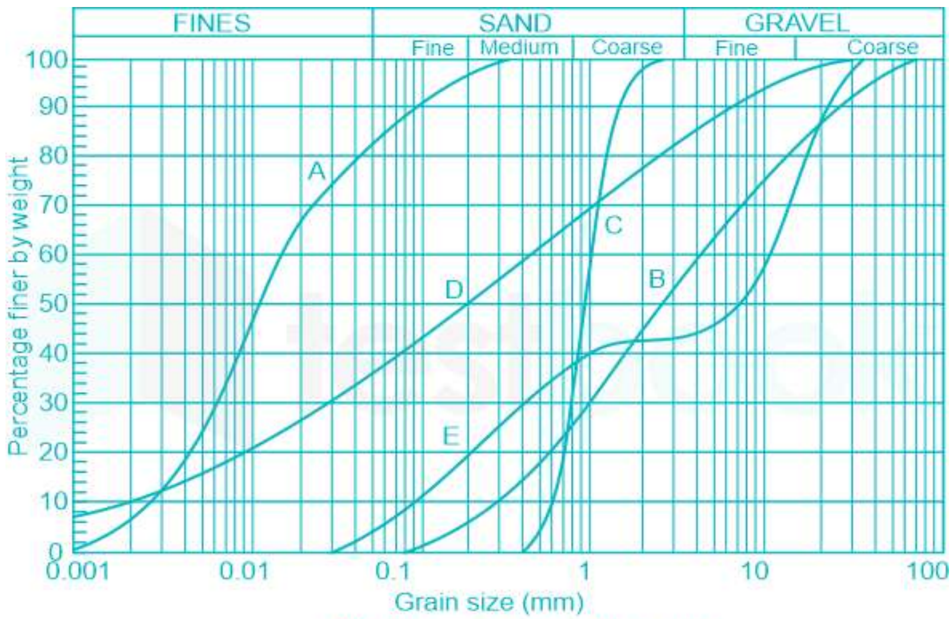
Aggregate Type	**Fineness Modulus (FM) Range**
Fine Aggregates (Sand)	2.2 to 3.2
Coarse Aggregates:	
10 mm aggregate	5.5 to 6.5
20 mm aggregate	6.5 to 7.5
40 mm aggregate	7.5 to 8.5

Significance of FM Range:

- Fine aggregates with FM < 2.2 are too fine, increasing water demand and reducing strength.
- Fine aggregates with FM > 3.2 are too coarse, affecting workability and compaction.
- Coarse aggregates with proper FM ensure better particle interlocking, leading to improved concrete strength.
- Well-graded aggregates reduce voids, minimize cement paste usage, and enhance durability.

Grading Curves and Their Role in Particle Size Distribution:

The particle size distribution curve, also known as the gradation curve, represents the range of particle sizes present in a aggregate or aggregate sample. It is plotted using data from a sieve analysis, where the percentage of material passing through each sieve is recorded. The graph is drawn on semi-logarithmic paper, with the percentage finer (cumulative passing) on the y-axis (arithmetic scale) and the particle size on the x-axis (logarithmic scale).This curve helps in understanding the aggregate's gradation, which affects properties like permeability, strength, and compaction. Well-graded aggregates contain a mix of different particle sizes, leading to better interlocking and stability, while poorly graded aggregates (uniform or gap-graded) may have weaker structures and lower strength. Engineers use this information to classify aggregate and determine its suitability for construction projects.



Particle size distribution curve

- Gap-Graded Aggregate (Aggregate E)
- Uniformly Graded Aggregate (Aggregate C)
- Well-Graded Aggregate (Aggregate D)
- Fine-Grained Aggregate (Aggregate A)
- Coarse-Grained Aggregate (Aggregate B)

Importance of Proper Aggregate Grading in Concrete Mix Design:

Proper grading of aggregates ensures a concrete mix that is workable, durable, and cost-effective.

Sieve analysis is a key test in concrete mix design that helps determine the fineness modulus and particle size distribution of aggregates. The FM range, as per IS 383:2016, ensures that aggregates are neither too fine nor too coarse, optimizing workability, strength, durability, and cost-efficiency. Grading curves provide a visual assessment of aggregate distribution, ensuring that fine and coarse aggregates are well-proportioned for long-lasting and high-performance concrete structures.

Workability:

- Well-graded aggregates improve workability and minimize water demand.
- **Poorly graded aggregates make concrete harsh and unworkable.**

Strength and Durability:

- Proper grading increases compressive strength and reduces permeability.
- Enhances durability by preventing moisture ingress and shrinkage cracks.

Reducing Voids and Cement Requirement:

- A well-graded aggregate system minimizes voids, reducing cement paste demand.
- Lower cement content leads to cost savings and reduced heat generation.

Avoiding Segregation and Bleeding:

- Uniform grading prevents segregation, ensuring a homogeneous mix.
- Reduces bleeding (water rising to the surface), which weakens the concrete.

Economy in Mix Design:

- Proper grading optimizes aggregate proportions, achieving desired performance at a lower cost.

Concept-6

Manufactured Sand (M-Sand)

Manufactured sand (M-Sand) is an artificially produced fine aggregate that is used as a substitute for natural river sand in construction. It is made by crushing hard stones, such as granite, basalt, or limestone, in a controlled environment to achieve the desired particle size and shape.

Production Process of M-Sand

The production of M-Sand involves the following steps:

- Raw Material Selection – Hard rocks like granite or basalt.
- Crushing & Screening – The rocks are crushed into fine particles using a jaw crusher, cone crusher.

- Washing & Grading – The crushed material is washed to remove clay, dust, and impurities.
- Final Screening – The particles are sorted into different sizes according to IS 383:2016 standards.

Properties of M-Sand

Property	Manufactured Sand (M-Sand)
Shape	Angular, cubical
Particle Size	Conforms to IS 383:2016
Fineness Modulus (FM)	2.4 to 3.1
Water Absorption	2–4% (higher than river sand)
Silt & Clay Content	≤ 3% (after washing)
Specific Gravity	2.5–2.9

Advantages of M-Sand

- Sustainable Alternative – Reduces dependence on river sand, preventing riverbed depletion.
- Uniform Particle Size – Provides better gradation and strength in concrete.
- Higher Compressive Strength – Due to angular particles that improve bonding.
- Cost-Effective – Locally available and cheaper than river sand.
- Less Impurities – Contains minimal organic matter and silt.

Disadvantages of M-Sand

- Higher Water Demand – Angular particles increase water requirement in concrete.
- Quality Variations – Poor manufacturing control can lead to excessive fines or impurities.
- More Cement Requirement – Increased surface area may need extra cement paste.

M-Sand vs. River Sand (Comparison)

Factor	**M-Sand**	**River Sand**
Source	Crushed rock	Natural deposits
Shape	Angular	Rounded
Strength	Higher (better bonding)	Moderate
Silt Content	< 3%	May exceed 7%
Water Absorption	2-4%	1.5%
Environmental Impact	Eco-friendly	Depletes riverbeds

Applications of M-Sand

- Concrete Production: Used in RCC, PCC, and plastering.
- Road Construction: As a base layer and sub-grade material.
- Brick & Block Manufacturing: Used in concrete blocks and pavers.

Manufactured sand (M-Sand) is an eco-friendly, high-strength alternative to river sand. It ensures better workability, durability, and cost savings in concrete and masonry construction. However, quality control in production and grading is essential to ensure its effectiveness in construction applications.

Concept-7

Gap-Graded Aggregate

Gap-graded aggregate is missing certain intermediate-sized particles, creating a discontinuous gradation. This leads to higher void content and is often used in decorative concrete, stone matrix asphalt (SMA), and drainage layers where specific properties are required.

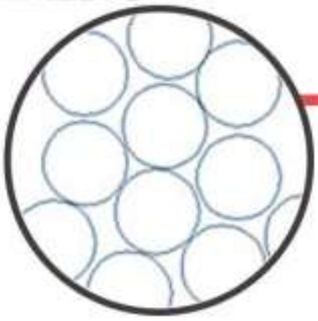
Uniformly Graded Aggregate

Uniformly graded aggregate consists of particles of nearly the same size, resulting in poor packing and high void content. It lacks smaller particles to fill the gaps, making it prone to segregation and requiring more cement paste in concrete mixes.

Well-Graded Aggregate

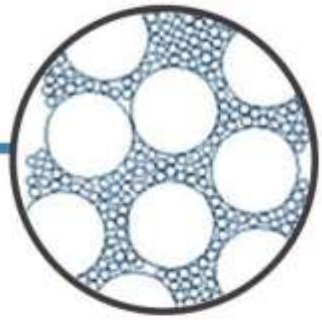
Well-graded aggregate contains a wide range of particle sizes, ensuring good packing, reduced voids, and better interlocking. This improves concrete strength, workability, and durability, making it ideal for high-strength concrete, pavements, and structural applications.

GRADATION OF AGGREGATES IN CONCRETE



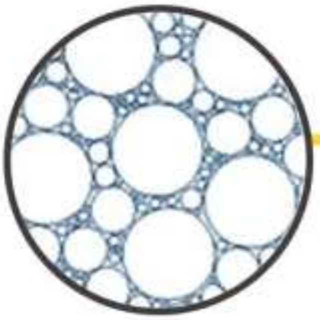
Poorly Graded

Have aggregates with almost of the same size resulting to relatively large voids in the concrete which requires excessive amount of cement paste.



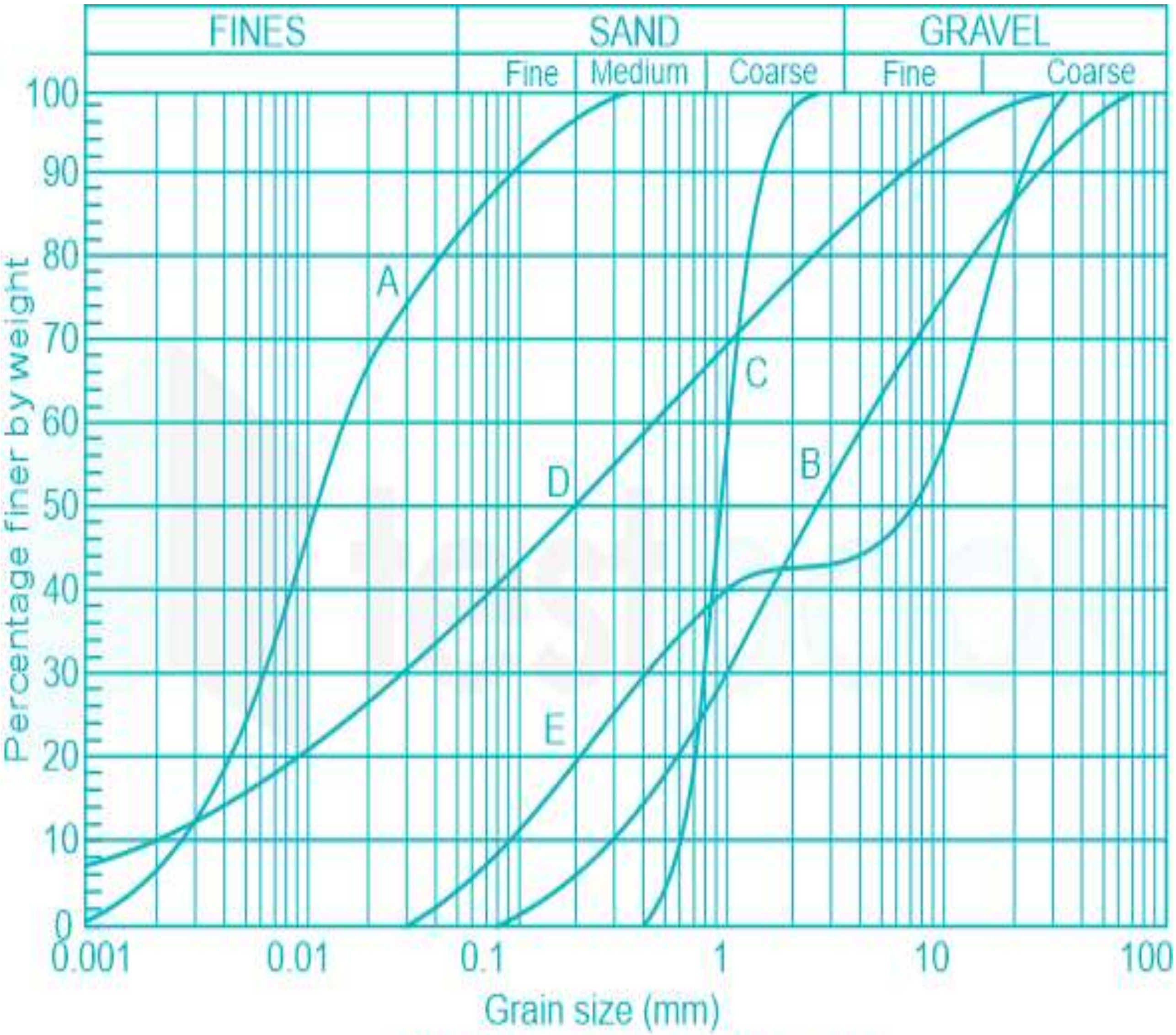
Gap Graded

Have aggregates lacking intermediate sizes.



Well Graded

Have less voids between aggregates which improves concrete's strength and durability.



Particle size distribution curve

Factor	Gap-Graded Aggregate (Aggregate E)	Uniformly Graded Aggregate (Aggregate C)	Well-Graded Aggregate (Aggregate D)
Grading Curve in Image	Curve E – Shows a steep gap in the middle, indicating missing sizes.	Curve C – Steep rise in a narrow range, showing limited particle size variation.	Curve D – Smooth and uniform rise, indicating a well-graded mix.
Voids Content	Moderate to high due to missing sizes.	High due to similar particle sizes preventing proper packing.	Low as particles pack efficiently.
Cement & Paste Demand	Moderate – Some voids need filling with cement paste.	High – More voids increase cement demand.	Low – Well-packed particles reduce cement paste demand.
Workability	Good for decorative finishes but needs proper mix design.	Poor due to high voids and segregation issues.	Excellent – Ensures a dense and strong mix.
Strength & Durability	Moderate strength, dependent on mix design.	Low strength due to excessive voids.	High strength, as particles interlock well.
Segregation Risk	Medium – Needs careful handling.	High – Segregates easily due to uniform particle sizes.	Low – Properly packed particles resist segregation.
Water Demand	Moderate – Less than uniformly graded but more than well-graded.	High – More voids increase water requirement.	Low – Less water needed for proper compaction.
Applications	Decorative concrete (exposed finishes) - Stone Matrix Asphalt (SMA) - Drainage layers	- Railroad ballast - Filter media - Drainage layers	-General concrete mixes - High-strength concrete - Pavements & bridges

Concept-8

Maximum Aggregate Size

The maximum aggregate size refers to the largest particle size present in a given aggregate sample. It plays a crucial role in determining the workability, strength, and durability of concrete and asphalt mixtures. According to IS 383:2016, the maximum aggregate size should be selected based on structural requirements and reinforcement spacing. Larger aggregates reduce the surface area, thereby lowering cement and water demand, improving economy, and reducing shrinkage. However, excessively large aggregates can cause segregation and poor compaction, affecting the overall strength of the mix. Common maximum aggregate sizes used in construction range from 10 mm, 20 mm, to 40 mm, depending on the application, such as pavements, structural concrete, and mass concreting works.

Maximum Aggregate Size and Its Applications

- The maximum aggregate size significantly influences the strength, workability, and durability of concrete and other construction materials. The selection of aggregate size depends on structural requirements, load conditions, and reinforcement spacing.
- 80 mm aggregates are commonly used in railway ballast, as they provide stability, drainage, and load distribution for railway tracks.
- 40 mm aggregates are used in sub-base layers, mass concrete works, and foundation beds, where higher load-bearing capacity and durability are required.
- 20 mm aggregates are widely used in Reinforced Cement Concrete (RCC) structures, such as beams, slabs, and columns, ensuring good workability and strength while preventing segregation.
- 10 mm aggregates are used in plastering, finishing works, and precast concrete products, where a smoother surface and higher cohesion are needed.
- Choosing the right aggregate size enhances structural performance, cost efficiency, and durability in different construction applications.

Concept-9

Recycled Aggregate

Recycled aggregate, obtained from the processing of construction and demolition (C&D) waste, possesses distinct properties that influence its performance in construction applications. As per the **Construction and Demolition Waste Management Rules, 2016**, recycled aggregates should be segregated, processed, and reused to promote sustainability in construction.

Physical Properties:

- Density: Generally lower than natural aggregates due to adhered mortar.
- Porosity & Water Absorption: Higher water absorption due to residual cement paste.
- Particle Shape: More angular and rough-textured, affecting workability.

Mechanical Properties:

- Compressive Strength: Slightly lower than natural aggregates due to weaker adhered mortar.
- Impact & Abrasion Resistance: Reduced resistance compared to virgin aggregates.
- Durability: Recycled aggregates may contain impurities, affecting long-term durability.
- Proper processing and quality control improve performance in non-structural applications like road bases and subgrade layers.

Environmental Benefits:

- Reduces the demand for natural aggregates.
- Minimizes landfill waste and promotes sustainable construction practices.

Applications:

- Non-structural concrete (e.g., paving blocks, kerbstones).
- Road construction (e.g., sub-base and base layers).
- Landfill cover and embankment filling as per C&D waste rules.
- Proper grading and treatment improve the suitability of recycled aggregates for diverse construction applications, supporting sustainable resource management.