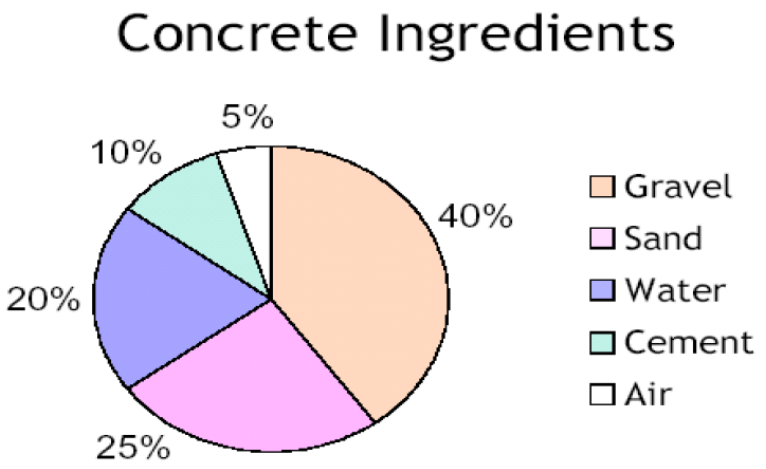
Aggregates: Physical Properties and Mechanical Properties

Lecture No. 3

Aggregates

- Aggregates generally occupy 65- 80% of a concrete's volume. Aggregates are inert fillers floating in the cement paste matrix for concretes of low strength. The strength of aggregates do not contribute to the strength of concrete for low strength concrete. The characteristics of aggregates impact performance of fresh and hardened concrete.



Why use aggregate

- Reduce the cost of the concrete – 1/4 - 1/8 of the cement price
- Reduce thermal cracking – 100 kg of OPC produces about 12oC temperature rise
- Reduces shrinkage – 10% reduction in aggregate volume can double shrinkage
- High aggregate : cement ratio (A/C) desirable
- A/C mainly influenced by cement content
- Imparts unit weight to concrete

Aggregate Classification

- Size:- Coarse Aggregates & Fine Aggregates.
- Specific Gravity:- Light Weight, Normal Weight and Heavy Weight Aggregates.
- Availability:- Natural Gravel and Crushed Aggregates.
- Shape:- Round, Cubical, Angular, Elongated and Flaky Aggregates.
- Texture:- Smooth, Granular, Crystalline, honeycombed and Porous.

Aggregate Classification : Size

- Fine Aggregate
  - Sand and/or crushed stone.
  - < 4.75 mm.
  - F.A. content usually 35% to 45% by mass or volume of total aggregate.
- Coarse Aggregate
  - Gravel and crushed stone.
  - >4.75 mm.
  - Typically between 9.5 and 37.5 mm.

Aggregate Classification : Specific Gravity

- Normal-Weight Aggregate
  - Most common aggregates (Ex: Sand, Gravel, Crushed stone)
  - Produce normal-weight concrete 2200 to 2400 kg/m^3
- Lightweight Aggregate
  - Expanded (Shale, Clay, Slate, Slag)
  - Produce structural lightweight concrete 1350 to 1850 kg/m^3
  - And (Pumice, Scoria, Perlite, Diatomite)
  - Produce lightweight insulating concrete— 250 to 1450 kg/m^3

Aggregate Classification : Specific Gravity

- **Heavyweight Aggregate**
  - Barite, Limonite, Magnetite, Hematite, Iron
  - Produce high-density concrete up to 6400 kg/m^3
  - Used for Radiation Shielding

Aggregate Classification : Availability

- Natural Gravel
  - River or seashore gravels; desert, seashore and windblown sands
  - Rounded in nature
  - Fully water worn or completely shaped by attrition
- Crushed Aggregates.
  - Crushed rocks of all types; talus; screes
  - Angular in nature

Aggregate Classification : Shape

- The shape of aggregates is an important characteristic since it affects the workability of concrete.

Round (spherical) concrete aggregate.

Flaky concrete aggregate.

Crushed concrete aggregate.

Aggregate Classification : Shape

Classification	*Description*	*Examples*
Rounded	Fully water worn or completely shaped by attrition	River or seashore gravels; desert, seashore and wind-blown sands
Irregular or Partly rounded	Naturally irregular or partly shaped by attrition, having rounded edges	Pit sands and gravels; land or dug flints; cuboid rock
Angular	Possessing well-defined edges formed at the intersection of roughly planar faces	Crushed rocks of all types; talus; screes
Flaky	Material, usually angular, of which the thickness is small relative to the width and/or length	Laminated rocks

Aggregate Classification : Texture

- Surface texture is the property, the measure of which depends upon the relative degree to which particle surfaces are polished or dull, smooth or rough.
- Surface texture depends on hardness, grain size, pore structure, structure of the rock.

Per cent of Particles		*Water/Cement Ratio*	*Strength 28 days MPa*	
Smooth	*Rough*		*Flexural*	*Compressive*
100	0	0.54	4.3	34.8
50	50	0.57	4.6	32.1
0	100	0.60	4.8	29.5

Aggregate Classification : Texture

Group	*Surface Texture*	*Examples*
1.	Glassy	Black flint
2.	Smooth	Chert; slate; marble; some rhyolite
3.	Granular	Sandstone; oolites
4.	Crystalline	Fine : Basalt; trachyte; medium : Dolerite; granophyre; granulite; microgranite; some limestones; many dolomites. Coarse : Gabbro; gneiss; granite; granodiorite; syenite
5.	Honeycombed and porous	Scoria; Pumice, trass.

Physical Prosperities of Aggregate : Grading

- Grading is the particle-size distribution of an aggregate as determined by a sieve analysis using wire mesh sieves with square openings.
- As per IS:2386(Part-1)
  - Fine aggregate : 6 standard sieves with openings from 150 µm to 4.75 mm. (150 µm, 300 µm, 600 µm, 1.18mm, 2.36mm, 4.75mm)
  - Coarse aggregate: 5 sieves with openings from 4.75mm to 80 mm. (4.75mm, 10mm, 12.5mm, 20mm, 40mm)

Physical Prosperities of Aggregate : Grading

- Grain size distribution for concrete mixes that will provide a dense strong mixture.
- Ensure that the voids between the larger particles are filled with medium particles. The remaining voids are filled with still smaller particles until the smallest voids are filled with a small amount of fines.

Grading of Fine Aggregate

I.S. Sieve Designation		Percentage passing by weight for		
	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10 mm	100	100	100	100
4.75 mm	90–100	90–100	90–100	95–100
2.36 mm	60–95	75–100	85–100	95–100
1.18 mm	30–70	55–90	75–100	90–100
600 micron	15–34	35–59	60–79	80–100
300 micron	5–20	8–30	12–40	15–50
150 micron	0–10	0–10	0–10	0–15

Grading of Coarse Aggregate

IS Sieve Designation	Percentage passing for single-sized aggregate nominal size (by weight)						Percentage passing for Graded aggregate of nominal size (by weight)			
	63 mm	40 mm	20 mm	16 mm	12.5 mm	10 mm	40 mm	20 mm	16 mm	12.5 mm
80 mm	100	–	–	–	–	–	100	–	–	–
63 mm	85–100	100	–	–	–	–	–	–	–	–
40 mm	0–30	85–100	100	–	–	–	95–100	100	–	–
20 mm	0–5	0–20	85–100	100	–	–	30–70	95–100	100	100
16 mm	–	–	–	85–100	100	–	–	–	90–100	–
12.5 mm	–	–	–	–	85–100	100	–	–	–	90–100
10 mm	–	0–5	0–20	0–30	0–45	85–100	10–35	25–55	30–70	40–85
4.75 mm	–	–	0–5	0–5	0–10	0–20	0–5	0–10	0–10	0–10
2.36 mm	–	–	–	–	–	0–5	–	–	–	–

Grading of All in Aggregate

I.S. Sieve Designation	*Percentage by weights passing for all in-aggragrate of*	
	40 mm Nominal size	*20 mm Nominal size*
80 mm	100	–
40 mm	95–100	100
20 mm	45–75	95–100
4.75 mm	25–45	30–50
600 micron	8–30	10–35
150 micron	0–6	0–6

Fineness Modulus (FM)

- The results of aggregate sieve analysis is expressed by a number called Fineness Modulus. Obtained by adding the sum of the cumulative percentages by mass of a sample aggregate retained on each of a specified series of sieves and dividing the sum by 100.
- The following limits may be taken as guidance:
  - Fine sand : Fineness Modulus : 2.2 - 2.6
  - Medium sand : F.M. : 2.6 - 2.9
  - Coarse sand : F.M. : 2.9 - 3.2
  - A sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete.

$$\text{Finess Modulus, } FM = \left(\frac{\text{Total of Cumulative Percentage of Passing (\%)}}{100} \right)$$

Physical Properties of Aggregate: Flakiness Index

- The flakiness index of aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three-fifths of their mean dimension.
- The test is not applicable to sizes smaller than 6.3 mm.
- The flakiness index is taken as the total weight of the material passing the various thickness gauges expressed as a percentage of the total weight of the sample taken.
- Table 3.18 shows the standard dimensions of thickness and length gauges.

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Physical Properties of Aggregate: Flakiness Index

Table 3.18. Shows Dimensions of Thickness and Length Gauges

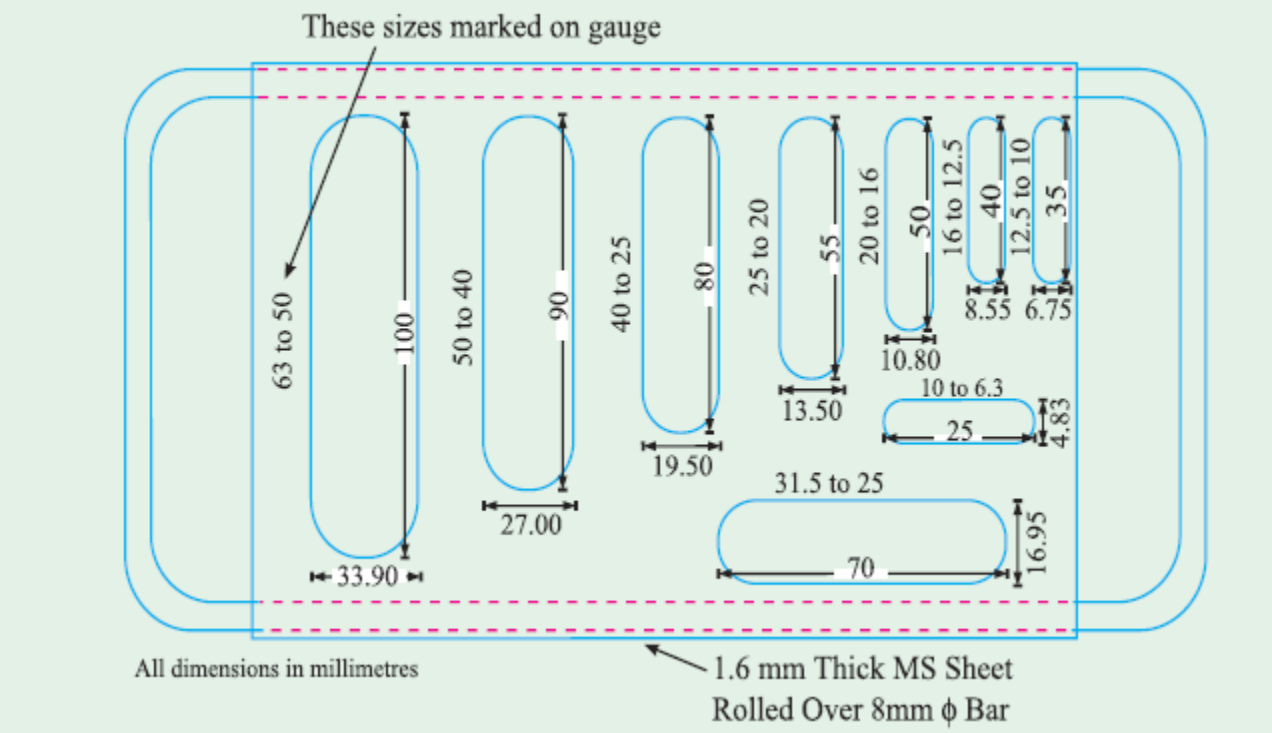
(IS: 2386 (Part I) – 1963)

Size of Aggregate Thickness		*Length of Gauge* mm*	*Gauge† mm*
Passing through IS Sieve	*Retained on IS Sieve*		
63 mm	50 mm	33.90	–
50 mm	40 mm	27.00	81.0
40 mm	25 mm	19.50	58.5
31.5 mm	25 mm	16.95	–
25 mm	20 mm	13.50	40.5
20 mm	16 mm	10.80	32.4
16 mm	12.5 mm	8.55	25.6
12.5 mm	10.0 mm	6.75	20.2
10.0 mm	6.3 mm	4.89	14.7

* This dimension is equal to 0.6 times the mean Sieve size.

† This dimension is equal to 1.8 times the mean Sieve size.

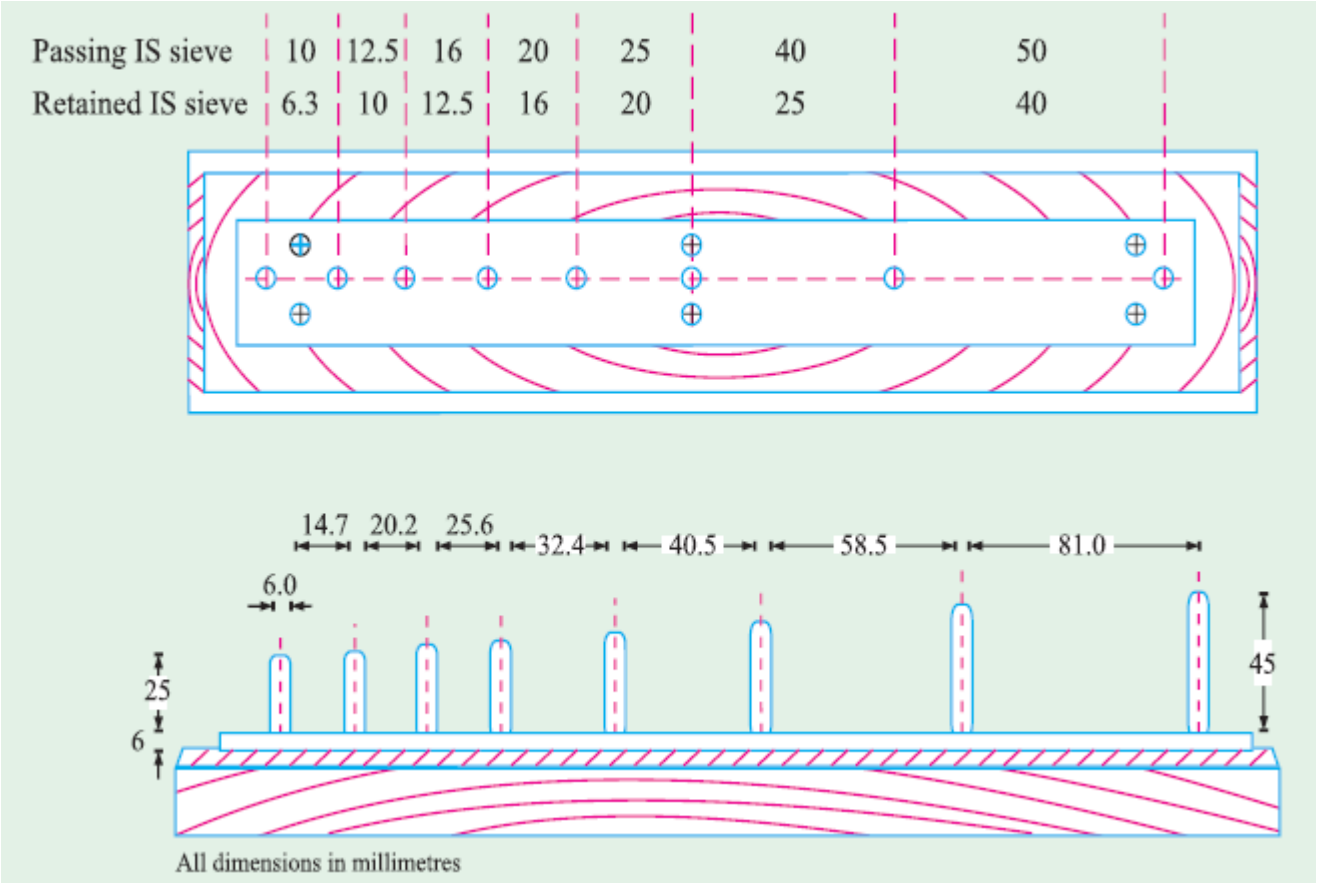
Physical Properties of Aggregate: Flakiness Index



Physical Properties of Aggregate: Elongation Index

- The elongation index on an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than 1.8 times their mean dimension.
- The elongation index is not applicable to sizes smaller than 6.3 mm.
- The elongation index is the total weight of the material retained on the various length gauges expressed as a percentage of the total weight of the sample gauged. The presence of elongated particles in excess of 10 to 15 per cent is generally considered undesirable, but no recognized limits are laid down.

Physical Properties of Aggregate: Elongation Index



Physical Properties of Aggregate: Specific Gravity

- Indian Standard Specification IS : 2386 (Part III) of 1963 gives various procedures to find out the specific gravity of different sizes of aggregates.

$$\text{Specifc Gravity} = \frac{C}{A-B}$$

$$\text{Apparent Specifc Gravity} = \frac{C}{C-B}$$

$$\text{Water Absorption} = \frac{100(B-C)}{C}$$

A = Weight of saturated aggregate in water = $(A_1 - A_2)$

B = Weight of the saturated surface - dry aggregate in air

C = Weight of ovendried aggregate in air.

A_1 = Weight of aggregate and basket in water

A_2 = Weight of empty basket in water

Physical Properties of Aggregate: Bulk Density

- The cylindrical measure is filled about 1/3 each time with thoroughly mixed aggregate and tamped with 25 strokes by a bullet ended tamping rod, 16 mm diameter and 60 cm long.
- The net weight of the aggregate in the measure is determined and the bulk density is calculated in kg/litre.

$$\text{Bulk dinsity} = \frac{\text{net weight of the aggregate in kg}}{\text{capacity of the container in litre}}; \qquad \text{Percentage of voids} = \frac{G_s - \gamma}{G_s} \times 100$$

where, G_s = specific gravity of aggregate and γ = bulk dinsity in kg/litre.