RSSB-JE 2020

Rajasthan Staff Selection Board

Combined Junior Engineer Direct Recruitment Examination

Civil Engineering

Building Materials

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY Publications

Building Materials

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CHAPTER 6

Aggregates

6.1 Introduction

- Aggregates are the materials basically used as filler with binding material in the production of mortar and concrete.
- They are derived from igneous, sedimentary and metamorphic rocks or manufactured from blast furnace slag etc.
- They occupy 70-80 percent of the volume and have considerable influence on the properties of the concrete.
- They should be clean, hard, strong, durable and graded in size to achieve almost economy from the paste.
- Earlier aggregates were considered to be chemically inert but latest research has revealed that some of them are chemically active and also that certain type exhibits chemical bond at the interface of aggregates and cement paste.
- To increase the bulk density of concrete aggregates are used in two different sizes: (i) the bigger ones known to be coarse aggregate (grit) and (ii) the smaller ones fine aggregate (sand).
- Coarse aggregate forms the main matrix of concrete and fine aggregate form the filler matrix between the coarse aggregate.

6.2 Classification of Aggregates

(i) On the basis of geological origin

(a) **Natural Aggregates:** These are obtained by crushing from quarries of igneous, sedimentary or metamorphic rocks. Gravels and sand reduced to their present size by the natural agencies also fall in this category. The most widely used aggregates are from igneous origin. Aggregates obtained from pits or dredged from river, creek or sea are most often not clean enough or well graded to suit the quality requirement. They therefore require sieving and washing before they can be used in concrete.

(b) **Artificial Aggregates:** Broken bricks, blast furnace slag and synthetic aggregates are artificial aggregates. Broken bricks known as brick bats are suitable for mass concreting, for example, in foundation bases. They are not used for reinforced concrete works. Blast furnace slag aggregates is obtained from slow cooling of the slag followed by crushing. The dense and strong particles as obtained are used for making precast concrete products. The specific gravity of these range between 2-2.8 and bulk density 1120-1300 kg/m^3. The blast furnace slag aggregate has good fire resisting properties but are responsible for corrosion of reinforcement due to sulphur content of slag. Synthetic aggregates are produced by thermally processed materials such as expanded clay and shale used for making light weight concrete.

(ii) On the basis of size

(a) **Coarse Aggregates :** Aggregate retained on 4.75 mm sieve are identified as coarse. They are obtained by natural disintegration or by artificial crushing of rocks. The maximum size of aggregate can be 80 mm. The size is governed by the thickness of section, spacing of reinforcement, clear cover, mixing, handling and placing methods. For economy the maximum size should be as large as possible but not more than one-fourth of the minimum thickness of the member. For reinforced sections the maximum size should he at least 5 mm less than the clear spacing between the reinforcement and also at least 5 mm less than the clear cover. Aggregate more than 20 mm size are seldom used for reinforced cement concrete structural members.

(b) **Fine Aggregates :** Aggregate passing through 4.75 mm sieve are defined as fine. They may be natural sand - deposited by rivers, crushed stone sand - obtained by crushing stones and crushed gravel sand. Sand is essentially quartz. The smallest size of fine aggregate (sand) is 0.06 mm. Depending upon the particle size, fine aggregate are described as fine, medium and coarse sands. On the basis of particle size distribution, the fine aggregate are classed into four zones i.e. zone I to zone IV; the grading zones being progressively finer from grading zone I to grading zone IV (IS: 383).

(iii) On the basis of shape

(a) **Rounded Aggregates :** These are generally obtained from river or sea shore and produce minimum voids (about 32 percent) in the concrete. They have minimum ratio of surface area to the volume, and the cement paste required is minimum. Poor interlocking bond makes it unsuitable for high strength concrete and pavements.

(b) **Irregular Aggregates :** They have voids about 36 percent and require more cement paste as compared to rounded aggregate. Because or irregularity in shape they develop good bond and are suitable for making ordinary concrete.

(c) **Angular Aggregates :** They have sharp, angular and rough particles having maximum voids (about 40 percent). Angular aggregate provide very good bond than the earlier two, are most suitable for high strength concrete and pavements; the requirement of cement paste is relatively more. Angular aggregate most of whose particles have their three dimensions approximately equal are called cubical aggregate.

(d) **Flaky Aggregates :** These are sometimes wrongly called as elongated aggregate. However, both of these influence the concrete properties adversely. The least lateral dimension of flaky aggregate (thickness) should be less than 0.6 times the mean dimension. For example, the mean sieve size for an aggregate piece passing through 50 mm and retained on 40 mm sieve is (50 + 40)/2 = 45.0 mm. If the least lateral dimension is less than $0.6 \times 45 = 27.0$ mm, the aggregate is classified as flaky. Elongated aggregate are those aggregate whose length is 1.8 times its mean dimension. Flaky aggregate generally orient in one plane with water and air voids underneath. They adversely affect durability and are restricted to maximum of 15 percent.

Important points:

S. No.	Classification Rounded	Examples
1.	Rounded	Rivers or sea shore gravels, desert and wind blown flints
2.	Irregular or partly rounded	Pit sands or gravels, land or dug flints
3.	Angular	Crushed rocks of types
4.	Flaky	Laminated rocks

- From the point of economy in cement requirements a given w/c ratio, rounded are preferred over angular aggregates.
- Angular aggregates have greater durability, interlocking nature, higher surface area and higher bond characteristics, resulting in higher strength.
- Flaky and elongated aggregates make poor concrete.

Example - 6.1 The aggregate which is obtained from the seashore or rivers and produces minimum voids in the concrete is known as________.

(a) angular aggregates (b) flaky aggregates
(c) irregular aggregates (d) rounded aggregates

Solution: (d)

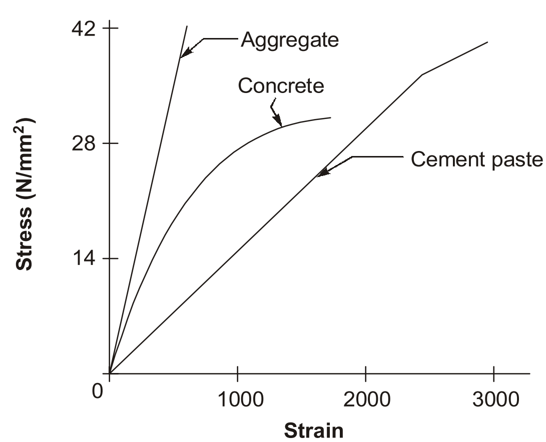
6.3 Characteristics of Aggregate

The properties to be considered while selecting aggregate for concrete are strength, particle shape, specific gravity, bulk density, voids, porosity, moisture content and bulking.

6.3.1 Strength

The strength should be at least equal to that of the concrete. Rocks commonly used as aggregates have a compressive strength much higher than the usual range of concrete strength. A typical stress-strain curve for aggregate is shown in figure below. The test conducted for strength evaluation are crushing test, impact-test and ten per cent fines test. Of these the first one is the most reliable.

The toughness of aggregate is measured by impact test. The impact value should not exceed 30 per cent for wearing surface and 45 per cent for remaining concretes. Hardness of aggregate is tested by abrasion test. The abrasion value is restricted to 30 per cent for wearing surfaces and 5t) per cent for concrete for other purposes.



Stress-Strain Curves for Aggregates, Concrete and Cement Paste

6.3.2 Stiffness

The-modulus of elasticity of concrete is approximately equal to the weighted average ot the moduli of the cement paste and the aggregate, as such the modulus of the coarse aggregate has an important influence on the stiffness of concrete. Further, in general, the modulus of elasticity of concrete increases with increasing aggregate modulus. A high value reduces the dimensional changes due to creep and shrinkage of cement paste, but at the cost Pi higher internal, stresses. In concrete that is to be subjected to wide variations of temperature and humidity; internal cracking is reduced by the use of a more compressible aggregate, but in practice this effect is rarely of sufficient importance to determine the choice of aggregate.

6.3.3 Bond Strength

Due to difference between the coefficients of thermal expansion of paste and aggregate and to the shrinkage of cement paste during hardening, concrete is in a state of internal stress even if no external forces are present. It is reported that the stresses are likely to be greatest at the paste-aggregate interfaces where minute cracks exist, even in concrete that has never been loaded. Under increasing external load, these cracks spread along the interfaces before extending into the paste or aggregate particles. The strength of the bond between aggregate and cement paste thus has an important influence on the strength of concrete. There is no standard test for bond but it is known that the rougher the surface texture of the particles, the better the bond. The role of particle shape is less well understood; the greater specific surface of angular particles should enable greater adhesive force to be developed, but the angular shape probably causes more severe concentrations of internal stress.

6.3.4 Shape and Texture

The shape influences the properties of fresh concrete more than when it has hardened. Rounded aggregate are highly workable but yield low strength concrete. Same is the case with irregular shaped aggregate. Flaky aggregate require more cement paste, produce maximum voids and are not desirable. Angular shape is the best. Crushed and uncrushed aggregates generally give essentially the same strength for the same cement content. The shape and surface texture of fine aggregate govern its void ratio and significantly affect the water requirement.

6.3.5 Specific Gravity

The specific gravity of most of the natural aggregates lies between 2.6-2.7. The specific gravity and porosity of aggregates greatly influence the strength and absorption of concrete. Specific gravity of aggregates generally is indicative of its quality. A low specific gravity may indicate high porosity and therefore poor durability and low strength. The concrete density will greatly dependon_specific gravity.

6.3.6 Bulk Density

The bulk density of aggregate depends upon then packing, the particles shape and size, the grading and the moisture content. For coarse aggregate a higher bulk density is an indication of fewer voids to be filled by sand-arid cement.

6.3.7 Voids

The void ratio is calculated as

$$\text{Void ratio} = 1 - \frac{\text{Bulk density}}{\text{Apparent specific gravity}}$$

If the voids in the concrete are more the strength will be low.

6.3.8 Porosity

It is an important property and affects the behaviour of both green and hardened concrete. The entrapped air bubbles in the rocks during their formation lead to minute holes or cavities known as pores. The porosity of rocks is generally less than 20 per cent; the concrete becomes permeable and ultimately affects the bond between aggregate and cement paste, resistance to freezing and thawing of concrete and resistance to abrasion of aggregate. The porous aggregate absorb more moisture, resulting in loss of workability of concrete at a much faster rate.

6.3.9 Moisture Content

The surface moisture expressed as a percentage of the weight of the saturated surface dry aggregate is known as moisture content. A high moisture content increases the effective water-cement ratio to an appreciable extent and may render the concrete weak.

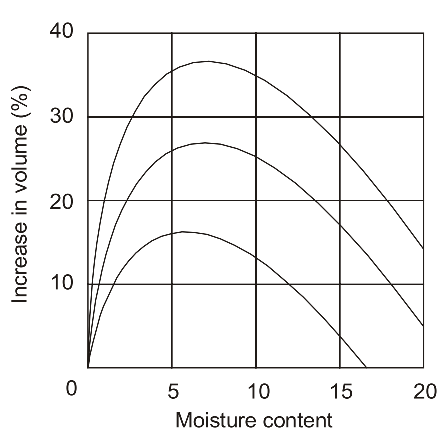
6.3.10 Bulking

The increase in the volume of a given mass of fine aggregate caused by the presence of water is known as bulking. The water forms a film over the fine aggregate particles, exerts force of surface tension and pushes them apart increasing the volume. The extent of bulking depends upon the percentage of moisture present in the sand and its fineness. With ordinary sand bulking varies from 15-30. percent. It increases with moisture content up to a certain point (4-6%), reaches maximum, the film of water on the sand surface breaks, and then it starts decreasing. Figure below shows the bulking of sand with moisture content. In preparing concrete mixes if sand is measured by volume and no allowance is made for bulking, the moist sand will occupy considerably larger volume than that prepared by the dry sand and consequently the mix will be richer. This will cause, less quantity of concrete per bag of cement. For example, if the bulking of sand is 10% and if mix ratio is 1 : 2 : 4, the actual volume of sand used will be 1.1 x 2 = 2.2 instead of 2 per unit volume of cement. If this correction is not applied the actual dry sand in the concrete will be $\frac{1}{1.1} \times 2 = 1.82$, instead of 2 per unit volume of cement. The mix proportion then would be 1 : 1.82 : 4 rather than 1 : 2 : 4. Which indicates lesser production of concrete. Also, there will be chances of segregation, honeycombing and reduced yield of concrete.

Bulking of sand can be determined, in field, by filling a container of known volume, say A, with damp sand in the manner in which the mixer hopper will be filled. The height ot sand in the container is measured. The sand is then taken out of container carefully, ensuring no sand is lost during this transaction. The sand is then either dried and filled back into the gauge box, or the container is filled with water and the damp sand is poured in to displace the water Whichever method is adopted, the new depth of aggregate in the container gives the unbulked volume B.

Then percentage bulking expressed as a percentage of the dry volume = $\frac{A-B}{B} \times 100$

NOTE: The dry and fully saturated (flooded) sand occupy atmost same volume.



Effect of Moisture content on bulking of Sand

Q.21 The fineness modulus of coarse aggregate lies in the range of
(a) 1.2 to 1.9 (b) 2 to 3.5
(c) 3.5 to 6.5 (d) 5.5 to 8

Q.22 For aggregate to be clessed as elongated, its length should be atleast x times its mean dimension, where x is given be
(a) 1.2 (b) 1.5
(c) 1.8 (d) 2.0

Q.23 An aggregate passing through 63 mm sieve and retained on 50 mm sieve is clessed as flaky, if its least lateral dimension is less than about
(a) 63 (b) 50
(c) 34 (d) 25

Q.24 Which of the following aggregate gives maximum bond strength in concrete?
(a) Rounded aggregate
(b) Enlongated aggregate
(c) Flaky aggregate
(d) Angular aggregate

Q.25 The best reflection of strength of coarse aggregate is given by
(a) crushing (b) impact
(c) 10% fines (d) hardness

ANSWER KEY // STUDENT'S ASSIGNMENT

1. (c)	**2.** (c)	**3.** (b)	**4.** (a)	**5.** (c)
6. (c)	**7.** (d)	**8.** (d)	**9.** (b)	**10.** (b)
11. (d)	**12.** (c)	**13.** (d)	**14.** (d)	**15.** (d)
16. (d)	**17.** (a)	**18.** (d)	**19.** (d)	**20.** (a)
21. (d)	**22.** (c)	**23.** (c)	**24.** (d)	**25.** (a)

HINTS & SOLUTIONS // STUDENT'S ASSIGNMENTS

1. (c)

Normal size of aggregate used for ground floor base coarse is 40 mm.

2. (c)

Fineness modulus is a ratio or a number which tells about the grain size of aggregate.

6. (c)

The aggregate is said to be flaky if their dimension is 0.6 times the mean dimension

i.e. $0.6 \times \left(\frac{75+60}{2}\right) = 40.5$ mm

■■■■