Aggregates

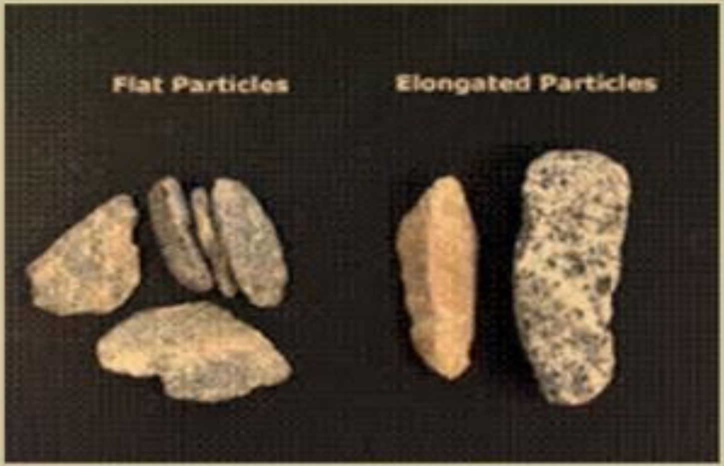
Unit 1

Module 4

Introduction

- Aggregates are inert materials which are mixed with binding material such as cement or lime for manufacturing of mortar or concrete. Aggregates are used as a filler in mortar and concrete and also to reduce their cost


Cubic
Particles
Flat, Elongated, and Flat & Elongated Particles


Flat Particles
Elongated Particles

(1) Fine Aggregates:

Aggregates whose particles pass through 4.75 mm IS sieve are termed as fine aggregates. Most commonly used fine aggregates are sand (pit or quarry sand, river sand and sea sand) and crushed stone in powdered form, how ever some times sukhi and ash or cinder are also used.

(i) Pit or quarry sand:

It is found as deposited in soil and is to be excavated out. Its grains are generally sharp or angular. It should be free from organic matter and clay. It is usually considered to be the best fine aggregate for use in mortar and concrete.

(ii) **River Sand:**

It is obtained from the banks and beds of rivers. It may be fine or coarse. Fine sand obtained from beds and banks of rivers is often found mixed with silt and clay so it should be washed before use. But coarse sand is generally clean and excellent for use especially for plastering.

(iii) **Sea Sand:**

It consists of fine rounded grains of brown colour and it is collected from sea shores or sea beaches. Sea sand usually contains salts and while using that in mortar, etc, causes disintegration of the work in which it is used. In R.C.C work these salts will attack reinforcement if salt content is high. These salts may cause efflorescence. It should be used locally after thorough washing.

(b) Crushed stone:

It is obtained by crushing the waste stones of quarries to the particular size of sand. Sand obtained from by crushing a good quality stone is excellent fine aggregate.

Mortar made with this sand is usually used in ashlar work (good quality of work).

(2) <u>Coarse Aggregates</u>:

Aggregates whose particles do not pass through 4.75 mm IS are termed as coarse aggregates. Most commonly used coarse aggregates are crushed stone, gravel; broken pieces of burnt bricks,etc.

(a) Crushed stone:

It is an excellent coarse aggregate and is obtained by crushing granite, sand stone or grained lime stone and all types of stones. Crushed stones are used for the construction of roads and railway tracks, etc.

(b) Gravel:

It is an other very good coarse aggregate. It is obtained from river beds, quarries and sea shores. The gravel obtained from sea shores should be well washed with fresh water before use in order to remove the impurities which may be clay, salts ,silt,etc. It is commonly used in the preparation of concrete.

- Aggregates are the important constituents in concrete.
- They give body to the concrete, reduce shrinkage and effect economy. Earlier, aggregates were considered as chemically inert materials but now it has been recognized that some of the aggregates are chemically active and also thatcertain aggregates exhibit chemical bond at the interface of aggregate and paste.
- Aggregates occupy 70-80 of volume of concrete.
- The study of aggregates can best be done under the following sub-headings
- **Classification, Size, Shape, Texture, Strength, Specific gravity and bulk density, Cleanliness,**
- **Soundness, Chemical properties, Durability, Sieve analysis, Grading**

(c) **Broken pieces of bricks**:

It is also a good artificial source of coarse aggregates. It is obtained by breaking well burnt bricks. It is generally used in lime concrete at places where aggregates from natural sources are either not available or are expensive. It can be used at places where low strength is required. It should be watered well before using it in the preparation of concrete. It is commonly used for mass concrete in foundations and under floors.

Classification of aggregates

- a) Aggregates can be classified as
- (i) Normal weight aggregates,
- (ii) Light weight aggregates and
- (iii) Heavy weight aggregates.
- In this chapter the properties of normal weight aggregates will only be discussed.
- Normal weight aggregates can be further classified as natural aggregates and artificial aggregates.
- Sand, Gravel, Crushed rock such as Granite, Quartzite, Basalt, sandstone will come under natural aggregates.
- *Broken brick, air cooled slag, sintered fly ash, bloated clay will come under artificial aggregates.*
- *Aggregates can also be classified on the basis of the size of the aggregates as coarse aggregate and fine aggregate*.

- **b) Size:**
- 80 mm size is the maximum size that could be conveniently used for concrete making.
- Using the largest possible maximum size will result in
- (i) reduction of the cement content
- (ii) reduction in water requirement
- (iii) reduction of drying shrinkage.
- However, the maximum size of aggregate that can be used in any given condition may be limited by the following conditions:
- *(i) Thickness of section; (ii) Spacing of reinforcement;*
- *(iii) Clear cover; (iv) Mixing, handling and placing techniques*

- For heavily reinforced concrete member, the nominal maximum size of aggregate should usually be restricted to 5 mm less than the minimum clear distance between the main bars or 5 mm less than the minimum cover to the reinforcement, whichever is smaller.
- But from various other practical considerations, for reinforced concrete work, aggregates having a maximum size of 20 mm are generally considered satisfactory.
- Aggregates are divided into two categories from the consideration of size **(i) Coarse aggregate and (ii) Fine aggregate.**
- The size of aggregate bigger than 4.75 mm is considered as **coarse** aggregate and
- Aggregate whose size is 4.75 mm and less is considered as **fine** aggregate.

c) Shape:

- The shape of aggregates is an important characteristic since it affects the workability of concrete.
- Type of crusher used and parent rock affects shape of aggregates. From the standpoint of economy in cement requirement for a given water/cement ratio, rounded aggregates are preferable to angular aggregates.
- On the other hand, angular aggregates needs more cement due to its high specific surface area. Also angular aggregates create good interlocking between aggregates.
- Flat particles in concrete aggregates will have particularly objectionable influence on the workability, cement requirement, strength and durability. In general, excessively flaky aggregate makes very poor concrete

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

Round (spherical)
concrete aggregate.

Flaky
concrete aggregate.

Crushed
concrete aggregate.

Cubical

How do you determine angularity of aggregates??

- Angularity is based on the percentage voids in the aggregate after compaction in a specified manner. The test gives a value termed the angularity number. The method of determination is described in IS: 2386 (Part I) 1963.
- A quantity of single sized aggregate is filled into metal cylinder of three litre capacity. The
- aggregates are compacted in a standard manner and the percentage of void is found out.
- The void can be found out by knowing the specific gravity of aggregate and bulk density or by pouring water to the cylinder to bring the level of water upto the brim.
- If the void is 33 per cent the angularity of such aggregate is considered zero.
- If the void is 44 per cent the angularity number of such aggregate is considered 11.
- In other words, if the angularity number is zero, the solid
- volume of the aggregate is 67 per cent and if angularity number is 11, the solid volume of the
- aggregate is 56 per cent. The normal aggregates which are suitable for making the concrete may
- have angularity number anything from zero to 11. Angularity number zero represents the most
- practicable rounded aggregates and the angularity number 11 indicates the most angular
- aggregates that could be tolerated for making concrete not so unduly harsh and uneconomical

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- Generally, rounded aggregates are smooth textured and angular aggregates are rough textured.
- Some engineers prohibit the use of rounded aggregate as it yields poor concrete, due to lack of bond between the smooth surface of the aggregate and cement paste.
- Angular aggregates are superior to rounded aggregates from the following two points of view:
- *(a) Angular aggregates exhibit a better interlocking effect in concrete, which property makes it superior in concrete used for roads and pavements.*
- *(b) The total surface area of rough textured angular aggregate is more than smooth rounded aggregate for the given volume. By having greater surface area, the angular aggregate may show higher bond strength than rounded aggregates*.

Discussion

- The higher surface area of angular aggregate with rough texture requires more water for a given workability than rounded aggregates. This means that for a given set of conditions from the point of view of water/cement ratio and the consequent strength, rounded aggregate gives higher strength.
- *Superimposing plus and minus points in favour and against these two kinds of aggregates it can be summed up as follows:*
- For water/cement ratio below 0.4 the use of crushed aggregate has resulted in strength up to 38 per cent **higher** than the rounded aggregate.
- With an increase in water/cement ratio the influence of roughness of surface of the aggregate gets reduced, presumably because the strength of the paste itself becomes paramount,
- and at a water/cement ratio of 0.65, no difference in strength of concrete made with angular aggregate or rounded aggregate has been observed

Texture:

- Surface texture depends on hardness, grain size, pore structure, structure of the rock, and the degree to which forces acting on the particle surface have smoothed or roughend it.
- Hard, dense, fine-grained materials will generally have smooth fracture surfaces.
- As surface smoothness increases, contact area decreases, hence a highly polished particle will have less bonding area with the matrix than a rough particle of the same volume.

Strength:

- Strong aggregates cannot make strong concrete, but to make strong concrete, strong aggregates are an essential requirement.
- In other words, from a weak rock or aggregate strong concrete cannot be made.
- By and large naturally available mineral aggregates are strong enough for making normal strength concrete.
- The test for strength of aggregate is required to be made in the following situations:
- *(i) For production of high strength and ultra-high strength concrete.*
- *(ii) When contemplating to use aggregates manufactured from weathered rocks.*
- *(iii) Aggregate manufactured by industrial process.*

GOOD QUALITYIES OF AN IDEAL AGGREGATE:

An ideal aggregate used for the manufacturing of concrete and mortar, should meet the following requirements.

- (1) It should consist of natural stones, gravels and sand or in various combinations of these materials.
- (2) It should be hard, strong and durable.

Flaky

pure concrete

R.C.C

- (3) It should be dense, clear and free from any coating.
- (4) It should be free from injurious vegetable matters.
- (5) It should not contain flaky (angular) and elongated pieces.
- (6) It should not contain any material liable to attack steel reinforcement in case of reinforced concrete.

Abutments @ the ends of bridge

Type of structure	Max. size of aggregate
1. Mass concrete work i.e. dams, retaining walls, piers and abutments, etc.	40 mm
2. R.C.C work i.e. beams, columns, etc	20 mm
3. Flooring	10 mm

It may be clearly noted that the size and shape of the aggregate particles influence the properties of freshly mixed concrete more as compared to those of hardened concrete.

How to determine mechanical properties of aggregates

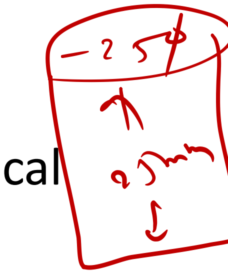
- The mechanical properties of aggregate can be determined by usin gf ollowing
- test
- • Test for determination of aggregate crushing value
- • Test for determination of aggregate impact value
- • Test for determination of aggregate abrasion value

1 Aggregate crushing value

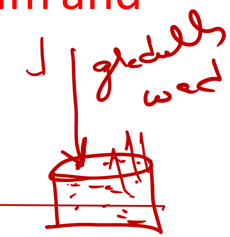
2 " Impact "

" Abrasion value

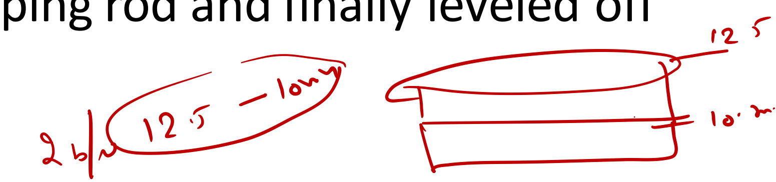
Aggregate crushing value:

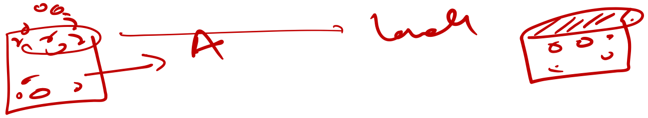


- Strength of rock is found out by making a test specimen of cylindrical shape of size 25 mm diameter and 25 mm height. This cylinder is subjected to compressive stress.
- Aggregate crushing value gives a relative measure of the resistance of an aggregate sample to crushing under gradually applied compressive load. Generally, this test is made on single sized aggregate passing 12.5 mm and retained on 10 mm sieve.

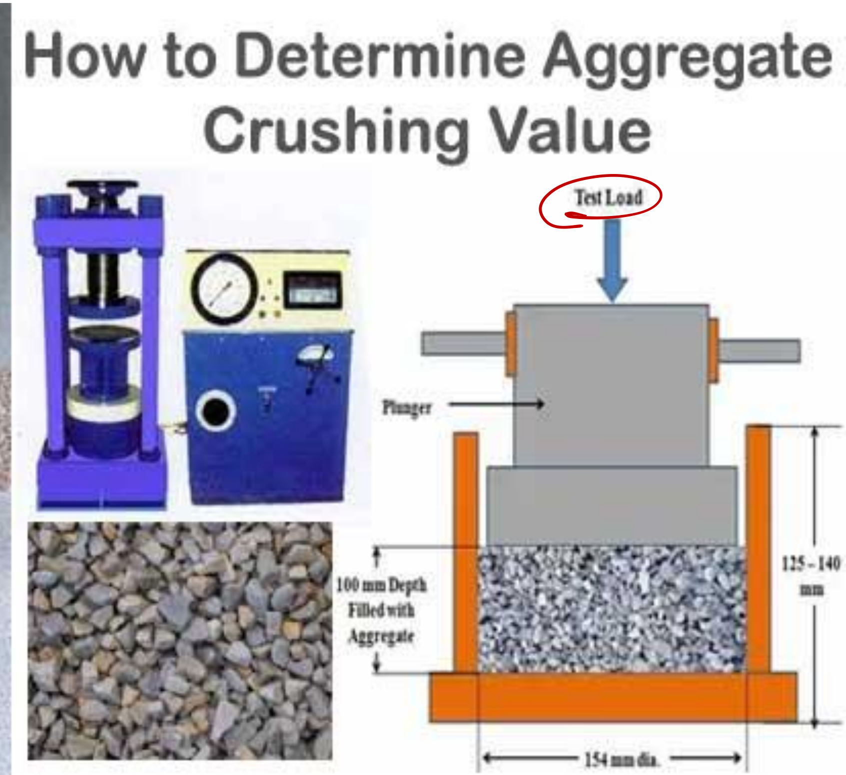


- *Procedure:-*
- To determine crushing value, about 6.5 kg material consisting of aggregates passing 12.5 mm and retained on 10 mm sieve is taken. The aggregate in a surface dry condition is filled into the standard cylindrical measure in three layers approximately of equal depth.
- Each layer is tamped 25 times with the tamping rod and finally leveled off using the tamping rod as straight edge



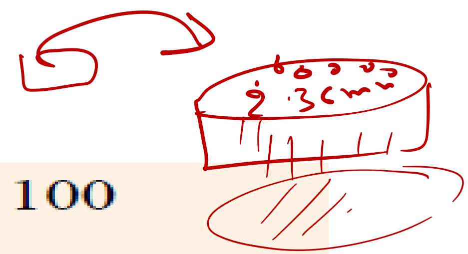


- Weight of the sample contained in the cylinder measure is taken as A.
- The cylinder of the test appartus with aggregate filled in a standard manner is put in position on the base-plate and the aggregate is carefully levelled and the plunger inserted horizontally on this surface. The plunger should not jam in the cylinder.



C.T.M → Compression Testing machine

- The apparatus, with the test sample and plunger in position, is placed on the compression testing machine and is loaded uniformly upto a total load of 40 tons in 10 minutes time.
- The load is then released and the whole of the material removed from the cylinder and sieved on a 2.36 mm I.S. Sieve.
- The fraction passing the sieve is weighed (B).



$$\text{Aggregate crushing value} = \frac{B}{A} * 100$$

- Where B is the weight of fraction passing 2.36 mm sieve, A is the weight of surface dry sample taken in mold.
- This percentage is referred as aggregate crushing value.
- The crushing value of aggregate is restricted to 30 percent for concrete used for roads and pavements and 45 per cent may be permitted for other structures.

30%

45% →

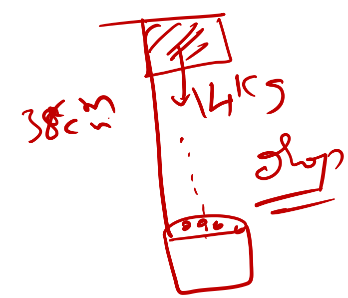
Aggregate impact value:

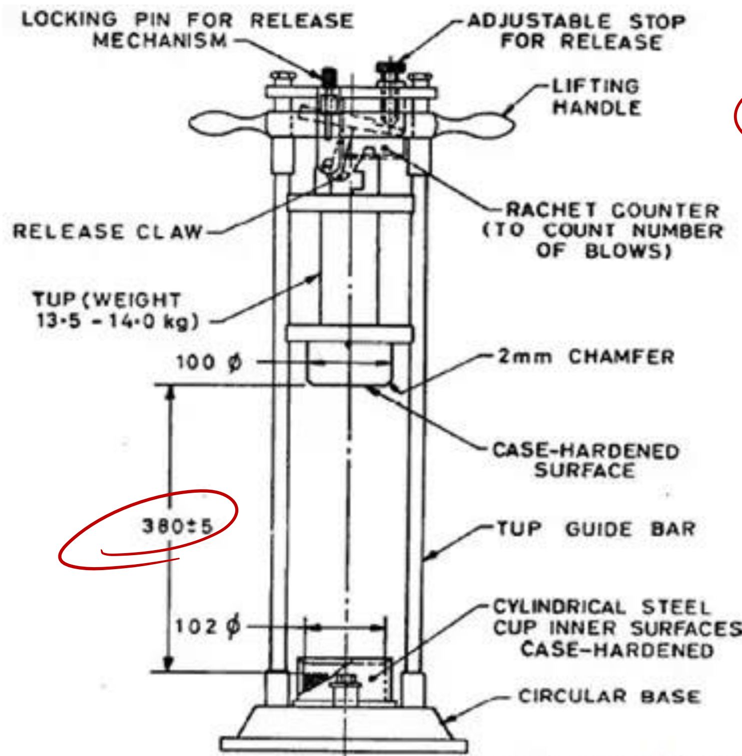
machine

- The aggregate impact value gives relative measure of the resistance of an aggregate to sudden shock or impact.
- ➢ The test sample consists of aggregate passing through 12.5 mm and retained on 10 mm I.S. Sieve. The aggregate shall be dried in an oven for a period of four hours at a temperature of 100°C to 110°C and cooled.
- ➢ The aggregate is filled about one-third full and tamped with 25 strokes by the tamping rod. A further similar quantity of aggregate is added and tamped in the standard manner.
- ➢ The measure is filled to over-flowing and then struck off level. The net weight of the aggregate in the measure is determined (weight A)

- ➢ The mold is fixed to the base of the machine and a metal hammer of weight 14 Kgs falling from a height of 38 cms is dropped on to the aggregate. The test sample is subjected to 15 such blows.
- ➢ The crushed aggregate is removed from the cup and the whole of it is sieved on 2.36 mm I.S.Sieve.

15 times





Impact Testing Machine

- The fraction passing the sieve is weighed to an accuracy of 0.1 gm. (weight B).
- The fraction retained on the sieve is also weighed (weight C). If the total weight (B + C) is less than the initial weight A by more than one gram, the result shall be discarded and a fresh test made.
- Two tests are made. The ratio of the weight of fines formed to the total sample weight in each test is expressed as percentage.

$$\text{Aggregate impact value} = \frac{B}{A} * 100$$

- Where B is the weight of fraction passing 2.36 mm sieve, A is the weight of oven dry sample taken in mold.
- IS 283-1970 specifies that aggregate impact value shall not exceed 45 per cent by weight for aggregate used for concrete other than wearing surface and 30 per cent by weight, for concrete for wearing surfaces, such as run ways, roads and pavements.

Aggregate abrasion value:

- Testing the aggregate with respect to its resistance to wear is an important test for aggregate to be used for road constructions, ware house floors and pavement construction.
- Three tests are in common use to test aggregate for its abrasion resistance.
- (i) Deval attrition test
- (ii) Dorry abrasion test
- (iii) Los Angels test.
- **Deval Attrition Test:**
- In the Deval attrition test, particles of known weight are subjected to wear in an iron cylinder
- rotated 10000 times at certain speed. The proportion of material crushed finer than 1.7 mm size is expressed as a percentage of the original material taken.
- This percentage is taken as the attrition value of the aggregate. This test has been covered by IS 2386 (Part IV) – 1963. It is mentioned that, wherever possible, Los angeles test should be used.

- **Dorry Abrasion Test:**
- This test is not covered by Indian Standard Specification. The test involves in subjecting a cylindrical specimen of 25 cm height and 25 cm diameter to the abrasion against rotating metal disk sprinkled with quartz sand. The loss in weight of the cylinder after 1000 revolutions of the table is determined. The hardeness of the rock sample is expressed in an empirical formula
- Hardness = 20 – (Loss in Grams)/3
- Good rock should show an abrasion value of not less than 17. A rock sample with a value of less than 14 would be considered poor.

poor > aggregate

(not IS specification)

Los Angeles Test

Spheres (or) charge

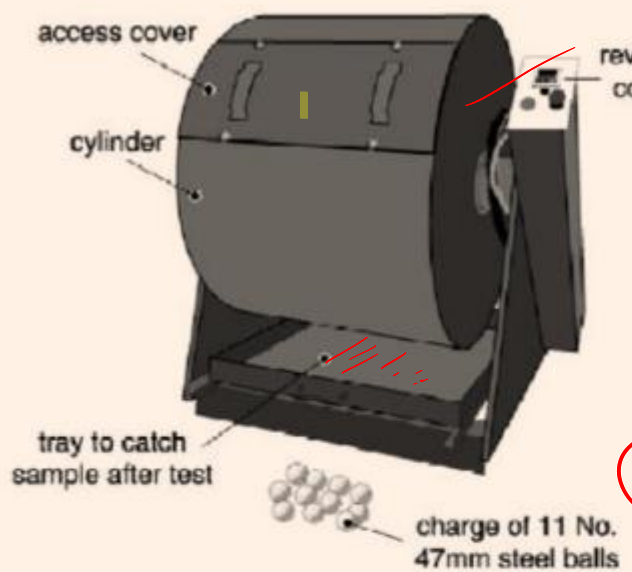
390 — 445 gm

- Indian Standard 2386 (Part IV) of 1963 describes Los Angeles test.
- The applicability of the method to all types of commonly used aggregate makes this method popular.
- The following table gives the details of charge which consists of cast iron spheres or steel spheres approximately 48 mm in diameter and each weighing between 390 to 445 gm.

- Test sample and abrasive charge are placed in the Los Angeles Abrasion testing machine and the machine is rotated at a speed of 20 to 33 revolutions/min.
- For grading A, B, C and D, the machine is rotated for 500 revolutions. For grading E, F and G, it is rotated 1000 revolutions.

LOS-ANGELES ABRASION RESISTANCE

Los Angeles machine



Tests :
Bulk Density
Specific gravity
water absorption
for both C.A & F.A

Toughness & Abrasion Resistance

- Resist load damage
  - During construction
  - Traffic loads
- LA abrasion test

- Prepare sample
- Minimum mass original
- Specified gradation

- Charge drum w/ sample
- Steel spheres
- 500 revolutions

- Sieve

$$Loss = \left(\frac{M_{original} - M_{final}}{M_{original}} \right) \times 100$$

Bulk Density:

- The bulk density or unit weight of an aggregate gives valuable information regarding the shape and grading of the aggregate. For a given specific gravity, the angular aggregates show a lower bulk density.
- The bulk density of aggregate is measured by filling a container of known volume in a standard manner and weighing it. Bulk density shows how densely the aggregate is packed when filled in a standard manner. The bulk density depends on the particle size distribution and shape of the particles.
- The higher the bulk density, the lower is the void content to be filled by sand and cement.
- The sample which gives the minimum voids or the one which gives maximum bulk density is taken as the right sample of aggregate for making economical mix.

- The method of determining bulk density also gives the method for finding out void content in the sample of aggregate. For determination of bulk density, the aggregates are filled in the container and then they are compacted in a standard manner.
- The weight of the aggregate gives the bulk density calculated in kg/litre or kg/m3. Knowing the specific gravity of the aggregate in saturated and surface-dry condition, the void ratio can also be calculated

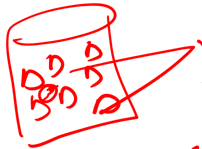
$$\text{Percentage voids} = \frac{G_s - \gamma}{G_s} \times 100$$

- where Gs = specific gravity of the aggregate and
- γ = bulk density in kg/liter.

: ratio of $\dfrac{\text{the mass of solid in given volume of sample}}{\text{mass of an equal volume of water}}$ @ the same temp

- **Specific Gravity:**
- In concrete technology, specific gravity of aggregates is made use of in design calculations of concrete mixes.
- Specific gravity of aggregate is also required in calculating the compacting factor in connection with the workability measurements.

  Slump test:- Compaction factor Test
- Average specific gravity of the rocks vary from 2.6 to 2.8.
- <u>**Absorption and Moisture Content:**</u>
- Some of the aggregates are porous and absorptive. Porosity and absorption of aggregate will affect the water/cement ratio and hence the workability of concrete.
- The porosity of aggregate will also affect the durability of concrete when the concrete is subjected to freezing and thawing and also when the concrete is subjected to chemically aggressive liquids



→ The aggregates generally contain voids

→ Absolute S.G: (Excluding voids)

Def: ratio of mass of solid to the weight of an an equal void-free volume of water

→ If the vol of aggregates includes the voids, the resulting S.G is called as apparent/bulk specific gravity)

→ SG is determined on SSD condition (Saturated Surface Dry)

$2.5 = \frac{\gamma_s}{\gamma_w} = \frac{\gamma_s}{1000\ kg/m^3}$

S.G ↑ → harder and stronger (aggregate)

→ SG is determined by IS : 2386 (part III) 1963

$S.G = \frac{c}{a-b}$ | Apparent SG $= \frac{c}{c-b}$

Water absorption $= \left(\frac{a-c}{c}\right) \times 100\%$

where

a = mass of SSD agg in air

b = " " " " in water

c = mass of ovendry agg in air

Concl: The avg S.G of majority of natural aggregates lies b/w (2.5 and 2.8)

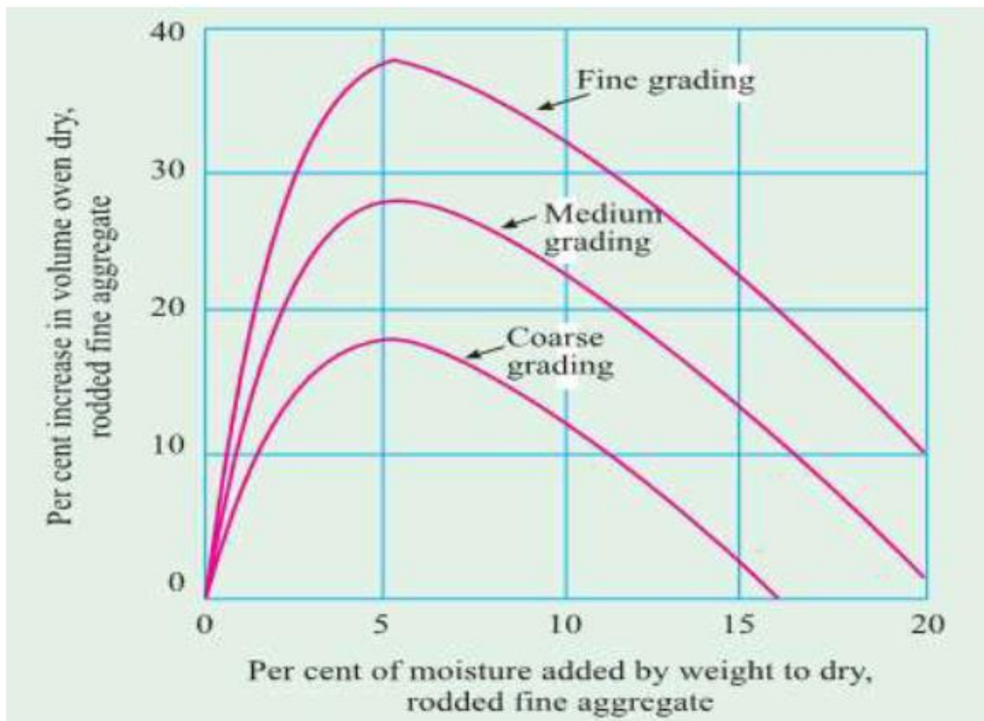
- The water absorption of aggregate is determined by measuring the increase in weight of an oven dry sample when immersed in water for 24 hours.
- The ratio of the increase in weight to the weight of the dry sample expressed as percentage is known as absorption of aggregate.
- Aggregate absorbs water in concrete and thus affects the workability and final volume of concrete.
- The absorption capacity of the coarse aggregate is of the order of about 0.5 to 1 per cent by weight of aggregate.
- The natural fine aggregates often contain free moisture anything from one to ten per cent or more.

Bulking of Aggregates:

- Free moisture content in fine aggregate results in bulking of volume.
- Free moisture forms a film around each particle. This film of moisture exerts what is known as surface tension which keeps the neighboring particles away from it.
- Similarly, the force exerted by surface tension keeps every particle away from each other.
- Therefore, no point contact is possible between the particles. This causes bulking of the volume.
- The extent of surface tension and consequently how far the adjacent particles are kept away will depend upon the percentage of moisture content and the particle size of the fine aggregate.
- Bulking increases with the increase in moisture content upto a certain limit and beyond that the further increase in the moisture content results in the decrease in the volume and at a moisture content representing saturation point, the fine aggregate shows no bulking

C.A neglected Bulking

- Fine sand bulks more and coarse sand bulks less. From this it follows that the coarse aggregate also bulks but the bulking is so little that it is always neglected.
- Extremely fine sand and particularly the manufactured fine aggregate bulks as much as about 40 per cent



- The extent of bulking can be estimated by a simple field test. A sample of moist fine aggregate isfilled into a measuring cylinder in the normal manner. Note down the level, say h1.
- Pour water into the measuring cylinder and completely inundate the sand and shake it. Since the volume of the saturated sand is the same as that of the dry sand, the inundated sand completely offsets the bulking effect.
- Note down the level of the sand say, h2. Then h1 – h2 shows the bulking of the sample of sand under test

$$\text{Percentage of bulking} = \frac{h_1 - h_2}{h_2} \times 100$$

Cleanliness:

- The concrete aggregates should be free from impurities and deleterious substances which are likely to interfere with the process of hydration, prevention of effective bond between the aggregates and matrix.
- The impurities sometimes reduce the durability of the aggregate.
- The organic matters will interfere with the setting action of cement and also interfere with the bond characteristics with the aggregates. The presence of moss or algae will also result in entrainment of air in the concrete which reduces its strength.
- To determine organic matter in sand, the sample of sand is mixed with a liquid containing 3 per cent solution of sodium hydroxide in water. It is kept for 24 hours and the colour developed is compared with a standard colour card. If the colour of the sample is darker than the standard
- Colour card, it is inferred that the content of the organic impurities in the sand is more than the permissible limit. In that case either the sand is rejected or is used after washing.

Soundness of Aggregate:

- Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions. These physical conditions that affect the soundness of aggregate are the freezing the thawing, variation in temperature, alternate wetting and drying under normal conditions and wetting and drying in salt water.
- Aggregates which are porous, weak andcontaining any undesirable extraneous matters undergo excessive volume change when subjected to the above conditions.
- Aggregates which undergo more than the specified amount of volumechange are said to be unsound aggregates.
- If concrete is liable to be exposed to the action of frost, the coarse and fine aggregate which are going to be used should be subjected to soundness test.

Alkali Aggregate Reaction:

- Some of the aggregates contain reactive silica, which reacts with alkalis present in cement i.e., sodium oxide and potassium oxide. The reaction starts with attack on the reactive siliceous minerals in the aggregate by the alkaline hydroxide derived from the alkalies in cement.
- As a result, the alkali silicate gels of unlimited swelling type are formed. It is interesting to note that only such aggregates which contain reactive silica in particular proportion and in particular fineness are found to exhibit tendencies for alkali-aggregates reaction.
- It is possible to reduce its tendency by altering either the proportion of reactive silica or its fineness.
- Factors Promoting the Alkali-Aggreate Reaction are:
- (i) Reactive type of aggregate; (ii) High alkali content in cement;
- (iii) Availability of moisture; (iv) Optimum temperature conditions.

Mortar Bar Expansion Test

- (i) Mortar Bar Expansion Test devised by Stanton has proved to be a very reliable test in assessing the **reactivity or otherwise of the aggregate.**
- **A specimen of size 25 mm x 25 mm and** 250 mm length is cast, cured and stored in a standard manner as specified in IS : 2386 (Part VII1963).
- Measure the length of the specimen periodically, at the ages of 1, 2, 3, 6, 9, and 12 months. Find out the difference in the length of the specimen to the nearest 0.001 per cent and record the expansion of the specimen.
- The aggregate under test is considered harmful if it expands more than 0.05 per cent after 3 months or more than 0.1 per cent after six months.

(ii) High Alkali Content in Cement:

- The high alkali content in cement is one of the most important factors contributing to the alkaliaggregate reaction.
- Many specifications restrict the alkali content expressed as Na_2O equivalent (Na_2O + 0.658 K_2O) to less than 0.6 per cent. Cement meeting this specification is designated as low alkali cement.
- Field experience has never detected serious deterioration of concrete through the process of alkali-aggregate reaction when cement contained alkalies less than 0.6 per cent.

- (iii) Availability of Moisture:
- Progress of chemical reactions involving alkali-aggregate reaction in concrete requires the presence of water.
- It has been seen in the field and laboratory that lack of water greatly reduces this kind of deterioration.
- Therefore, alkali-aggregate reaction will not occur in the interior of mass concrete.
- The deterioration will be more on the surface. It is suggested that reduction in deterioration due to alkali-aggregate reaction can be achieved by the application of waterproofing agents to the surface of the concrete with a view to preventing additional penetration of water into the structure.

- (iv) Temperature Condition:
- The ideal temperature for the promotion of alkali-aggregate reaction is in the range of 10 to 38°C. If the temperatures condition is more than or less than the above, it may not provide an ideal situation for the alkali-aggregate reaction.
- **Control of Alkali-Aggregate Reaction:**
- Alkali-aggregate reaction can be controlled by the following methods:
- (i) Selection of non-reactive aggregates;
- (ii) By the use of low alkali cement;
- (iii) By the use of corrective admixtures such as pozzolanas;
- (iv) By controlling the void space in concrete;
- (v) By controlling moisture condition and temperature.