

UNIT-II AGGREGATE

Text book
Ref: Mr. S. Shetty.

Introduction :- Aggregates are the important constituents in concrete. They give body to the concrete. Reduce shrinkage & effect economy. * Earlier, agg were considered as chemically inert materials, but now it has been recognised that some of the aggregates are chemically active and also that certain agg. exhibit chemically bond at the interface of agg. and paste.

* The more fact that the agg. occupy 70-80% of the volume of concrete, their impact on various characteristics and properties of concrete. Is undoubtedly considerable.

* To know more fact that the agg. about the concrete it is very essential that one should know more about the aggregates which constitute major volume in concrete.

Classification :- Agg. can be classified as

(i) Normal weight aggregate.

(a) Natural agg. → sand, Gravel, crushed rock such as Granite, Quartzite, Basalt, Sand stone

(b) Artificial agg. → Broken Brick, Air-cooled slay, Sintered fly ash, Bloated clay.

ii) Light weight Aggregate.

iii) Heavy weight Aggregate.

Aggregate can also be classified on the basis of the size of the aggregates as coarse agg. and fine aggregate.

Size :- The largest maximum size of aggregate practicable to handle under a given set of condn should be used. 30mm size is the maximum size that could be conveniently used for concrete making.

* for heavily reinforced concrete members the normal max. size of agg. should usually be restricted to 5mm less than the minimum clear distance between the main bars are 5mm less than the minimum cover to the reinforcement, which every is smaller.

* But from various other practical considerations for reinforced concrete, aggregates having a max. size of 20mm are generally considered satisfactory.

* Aggregates are divided into two categories

(1) coarse aggregate

(2) fine aggregate.

* The size of aggregate bigger than 4.75mm is

considered as coarse aggregate and aggregate whose size is 4.75mm & less is considered as fine agg.

Shape :-

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

* The shape of the aggregate is very much influenced by the type of crushed and the reduction ratio i.e. the ratio of size of material fed into crusher to the size of the finished product.

Classification of particles on the basis of shape of the aggregate as shown below

Classification	Description	Examples
Rounded	fully water worn or completely shaped by attrition.	River or seashore gravels, desert, seashore, & wind blown sands.
Irrregular (or) Partly rounded.	Naturally irregular or partly shaped by attrition having rounded edges	Pit sands and gravels and of dug flints, cuboid rock.

Angular

Possessing well-defined edges formed at the intersection of roughly planar faces

Crushed rocks of all types, talus scree

Flaky

Material, usually angular of which the thickness is small relative to the width & length.

Laminated rocks

The 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 & 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.

TEXTURE:-

Surface texture is the property, the measure of which depends upon the relative degree to which particle surface are polished or dull, smooth or rough.

* Surface texture depends on hardness, grain size, poro structure, structure of the rock, and the degree to which forces acting on the particle surface have smoothed or roughened it.

* 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.

Surface characteristics of Aggregate.

Group	Surface Texture	Examples.
1	Glossy	Black flint
2.	Smooth,	Chalcocite, slate, marble.
3	Granular	Some, orthopyroxite. Sand stone, oolites
4	Crystalline	Fine:- Basalt, talachyte Medium:- Dolomite, granophyre, granulite microgranite, sometimes stones, many dolomites Coarse:- Gabbro, gneiss granite, granodiorite syenite
5.	Honeycombed & porous	Scoria, pumice, trass

* It has been also shown by experiments that rough textured aggregate develops higher bond strength in tension than smooth textured aggregate.

STRENGTH:-

* we do not imply the strength of the parent rock from which the aggregate are produced, because the strength of the rock does not exactly represent the strength of the aggregate in concrete.

* concrete is an assemblage of individual pieces of agg. bound together by cementing material, its properties are based primarily on the quality of the cement paste.

* The strength is dependant also on the bond b/w the cement paste & the aggregate.

* If the strength of the paste of the bond b/w the paste and aggregate is low, a concrete of poor quality will be obtained irrespective of the strength of the rock or aggregate.

* When cement paste of good quality is provided and its bond with the agg. is satisfactory, then the mechanical properties of the rock or aggregate will influence the strength of concrete.

* The test for strength of agg. is required to be made in the following,

(i) For production of high strength & ultra strength concrete.

ii) when contemplating to use agg. manufactured from weathered rocks.

iii) Aggregate manufactured by industrial process

Mechanical Properties of Aggregate :-

(IS: 2386 part IV-1963)

1. Test for determination of aggregate crushing value.
2. Test for determination of ten percent fine value.
3. Test for determination of aggregate impact value.
4. Test for determination of aggregate abrasion value.

CRUSHING VALUE :-

* The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load.

* with aggregate of aggregate crushing value so high, the result may be anomalous & in such cases the "ten percent fine value" should be determined.

and used instead.

- * The standard agg. crushing test is made on agg. Passing 12.5 mm is sieve and retained on 10 mm ps sieve
- * If required or if the standard size is not available, other sizes upto 25 mm may be tested.
- * About 6.5 kg material consisting of agg. passing 12.5 mm and retained on 10 mm sieve is taken.
- * The agg. in a surface dry condⁿ is filled into the standard cylindrical measure in three layers approximately of equal depth.
- * Each layer is tamped 25 times with the tamper rod as straight edge.
- * The weight of the sample contained in the cylinder measure is taken (A) The load is taken, then released and the whole of the material removed from the cylinder and sieved on a 2.36 mm sieve. The fraction passing the sieve is weighed (B)

The aggregate crushing value: $\frac{B}{A} \times 100$

where

B = wt. of fraction passing 2.36 mm sieve

A = wt. of surface dry sample taken in mould. ~~but not~~

- * It should not be more than 45% for agg. used for concrete other than for wearing surfaces
- * 30% for concrete used for wearing surfaces such as runways, roads and air field pavements.

Ten Percent fines value:-

Aggregate sample is same as that of the sample of crushing value test.

15.50 mm for ground or partially agg.

20.00 mm for normal crushed agg.

4

24.00 mm. foy. honey combed aggregate.

Range of % of fines is 7.5 to 12.5

$$\text{load required for } 10\% \text{ fines} = \frac{14 \times X}{Y+4}$$

where

X = load in tons, causing 7.5 to 12.5%.

Y = mean percentage fines from two tests at X -ton load.

Aggregate Impact Value :-

* It gives relative measure of the resistance of an agg. to sudden shock or impact. which is same agg. differs from its resistance to a slow compressive loads.

* The sample filled into a cylinder (cup) fixed on the base of machine. A hammer wt. about 14 kgs is raised to a height of 380 mm above the upper surface in the agg in the cup.

* It subjected to a total 15 such blows each being delivered at one second interval. Then remove the sample and sieve it in 2.36 mm is sieve

* The fraction passing the sieve is weighed to an accuracy of 0.1 gm (B).

* The fraction retained on the sieve is also weighed (C)

(c) If the total weight (B+C) is less than the initial wt (A) by more than one gm. the result shall be discarded and a fresh test made.

* The ratio of the wt. of fines formed to the total sample weight in each test is expressed as %

$$\text{Agg. Impact value} = \frac{B}{A} \times 100$$

B = weight of fractⁿ passing 2.36 mm is sieve

A = weight of oven dried sample

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 agg. show a lower bulk density.
- * The bulk density of agg. is measured by filling a container of known volume. in a standard manner and weighing it.
- * Bulk density shows how densely the aggregate is placed when filled in a std. manner. The bulk density depends on the particle size distribution and shape of the particles.
- * For determination of bulk density the agg. are filled in the container and then they are compacted in a standard manner.
- * The wt. of the agg. gives the bulk density calculated in kg/litre (or) kg/m³.

Knowing the specific gravity of the agg. in saturated and surface dry condⁿ, the void ratio can also be calculated

$$\% \text{ voidr} = \frac{G_s - 1}{G_s} \times 100$$

G_s = Specific gravity of agg.

γ = Bulk density in kg/lit.

Specific Gravity:- In CT specific gravity of agg. is made use of in design calculations of concrete mixes with the specific gravity of each constituent known, its weight can be converted into solid volume. and hence a theoretical yield of concrete per unit volume can be calculated.

* SP. gravity of agg. is also required in calculating the compacting factor in connection with the workability measurements.

* similarly specific gravity of agg. is required to be considered when we deal with light wt. and heavy weight concrete.

Average sp. gravity of the rocks vary from 2.6 to 2.8.

Absorption & Moisture Content %:-

* some of the agg. are porous and adsorptive

* porosity and adsorption of agg. will affect the w/c ratio. and hence. the workability of concrete.

* The porosity of agg. will also affect the durability of concrete. when the concrete is subjected to freezing and thawing and also when increased the concrete is subjected to chemically. aggressive liquids.

* The water absorption of agg. is determined by measuring the increase in wt. of an oven dry sample when immersed in water for 84 hrs.

* But when we deal with agg. in concrete the 84 hrs. absorption may not be of much significance, on the other hand the % of water absorption during the time interval equal to final set of cement may be of more significance.

* The agg. absorbs water in concrete and this affects the workability and final volume of concrete the rate and amount of absorption within a time interval equal to the final set of the cement will only be a significant factor rather than the 84 hrs. absorption of the agg.

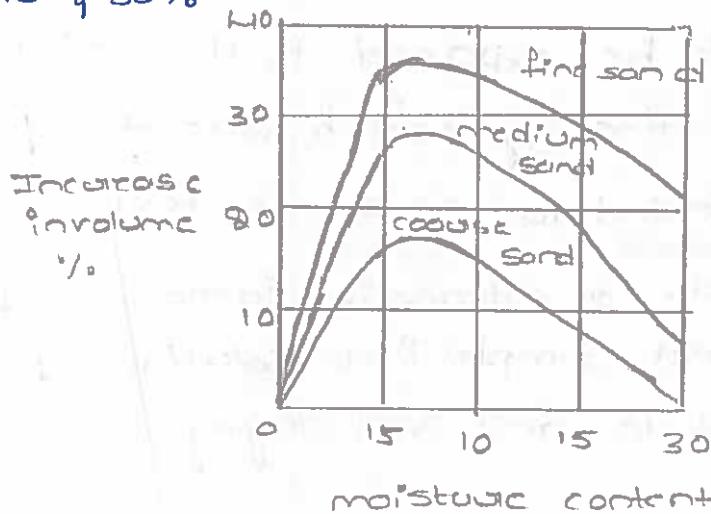
Moisture content of Aggregate :-

- * The surface moisture expressed as a % of the weight of the saturated surface dry agg. is termed as moisture content.
- * Since the absorption represents the water contained in the agg. in the saturated-surface dry condition and the moisture content is the water in excess of that, the total water content of a moist agg. is equal to the sum of absorption and moisture content.
- * The first method namely, the displacement method, gives the moisture content as a % by mass of the saturated surface dry sample whereas the second method namely the drying method, gives the moisture content as a % by mass of the dried sample.
- * The moisture content given by the drying method will normally be the total moisture content due to free plus absorbed water.
- * The accuracy of the displacement method depends upon the accurate information of the sp. gravity of the material in a saturated-surface dry condition.

Bulking of fine aggregate :-

- * The increase in the volume of a given mass of fine agg. caused by presence of water is called bulking.
- * The bulking of the fine agg. is caused by the films of water which push the particles apart. The extent of bulking depends upon the % of moisture present in the sand and its fineness.
- * It is seen that bulking increases gradually with moisture content up to a certain point and then begins to decrease with further addition of water due to the merging of films until when, the sand is inundated.

* In ordinary sands the bulking usually varies bet' 15 & 30%.



* The extent of bulking can be estimated by a simple field test. A sample of moist fine agg. is filled into a measuring cylinder in the normal manner.

* note down the level, say h_1 , 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 offset the bulking effect. Note down the level of the sand say h_2 . then $h_1 - h_2$ shows the bulking of the sample of sand under test.

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

soundness of aggregate:-

* It 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 temp. alternate wetting and drying under normal cond's and wetting and drying in salt water.

* Aggregates which are porous, weak and containing any undesirable extraneous materials undergo excessive volume change when subjected to the above conditions.

- * Agg., which undergo more than the specified amount of volume change is said. to be unsound agg.
- * If concrete is liable to be exposed. to the action. of frost, the coarse and. fine agg. which are going to be used should be subjected to soundness test.
- * The soundness test consists of alternative. immersion of carefully graded and wt. test sample. in a solution of Sodium or magnesium sulphate. and oven drying it under specified condⁿ.
- * The accumulation and growth of salt crystals in the pores of the particles is thought to produce disruptive internal forces. similar to the action. of freezing of water or crystallisation. of salt.
- * loss Ps wt. is measured for a specified number of cycles as a general, It can be taken that the average loss of weight after 10 cycles should not exceed 1% and 18%. weight when tested with sodium. sulphate and magnesium sulphate respectively.

* Alkali Aggregate Reaction:-

- * For a long time agg. have been considered as inert materials but lately on particularly, after laho's Pt was clearly brought out that the agg. are not fully. Inert Some of the agg. contain reactive silica, which reacts with alkalies present in cement & sodium. oxide & potassium oxide.
- * In the USA it was found for the first time that many failures of concrete structures like. pavement pavers and sea walls could be attributed to the alkali- agg. reaction
- * The types of rocks which contain reactive ~~com~~ constituents include traps, andesites, ortholites, siliceous limestones and certain types of sandstones. the reactive constituent may be in the form of opals. cherts.

chalcedony, volcanic glass, zeolites etc.

* The reaction starts with attack on the reactive siliceous minerals in the agg. by alkaline hydroxide derived from the diiss alkalies in cement.

* As a result, the alkali-silicate gets of unlimited swelling type are formed. When the conditions are congenial progressive manifestation by swelling takes place, which results in disruption of concrete with the spreading of pattern cracks and eventual failure of concrete structures.

* The rate of deterioration may be slow or fast depending upon the conditions. There are cases where concrete has become unserviceable in about a year's time.

In India, the basalt rocks occurring in the Deccan plateau, Madhya Pradesh, Kathiawar, Hyderabad, Panchal Hill (Jammu & Kashmir), Bengal and Bihar should be viewed with caution.

Factors Promoting the Alkali-Agg. Reaction:-

1) Reactive type of Aggregate.

2. High alkali content in cement.

3. Availability of moisture.

4. optimum temperature conditions (10-38°C).

Control of Alkali-Aggregate Reaction:-

It can be controlled by the following methods

(i) Selection of non-reactive aggregates.

2. By the use of low alkali cement.

3. By the use of reactive admixtures, such as.

Pozzolans.

4. By controlling moisture condition & temperature.

* Potentially reactive aggregate can be identify by Petrographic examination, mortar bag test or by chemical method.

* Avoiding use of the reactive agg. is one of the sure methods to inhibit the alkali agg. reaction. In concrete.

Thermal Properties :-

* Thermal properties of agg. affect the durability of other qualities of concrete.

* The principal thermal properties of the agg. are.

(i) coefficient of thermal expansion.

(ii) specific heat

(iii) Thermal conductivity.

* The coefficient of thermal expansion of the concrete increase, with the coefficient the thermal expansion of agg.

[In India, the basalt rocks occurring in the Deccan plateau, Madhya Pradesh, Kathiawar, Hyderabad etc]

* If the coefficients of the two materials differ by more than 5.4×10^{-6} per °C. the durability of concrete subjected to freezing and thawing may be affected.

* The coefficient of expansion of the agg. depends on the parent rock.

* For majority of agg. the coefficient of thermal expansion lies between approximately 5.4×10^{-6} and 19.6×10^{-6} per °C.

* For hydrated portland cement the coefficient varies between 10.8×10^{-6} & 16.2×10^{-6} per °C.

* This thermal incompatibility at lower range cause severe stress affecting durability and integrity of concrete structure.

* The specific heat of the agg. is a measure of it's heat capacity, whereas the thermal conductivity is the ability of the agg. to conduct the heat.

* These properties of the agg. influence the sp. heat and thermal conductivity of the concrete, and are important in the case of mass concrete and cohesive insulation is required.

Fineness Modulus:-

* The fineness modulus is a numerical index of fineness giving some idea of the mean size of the particles present in the entire body of the agg.

* The determination of the fineness modulus consists in dividing a sample of agg. into fractions of different sizes by sieving through a set of standard test sieves taken in size 4.75mm, 4mm, 2mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm, 90μm & 45μm.

* The material retained on each sieve after sieving represents the fraction of agg. coarser than the sieve in question but finer than the sieve above.

* The sum of the cumulative % retained on the sieve divided by 100 give the fineness modulus.

* The value of fineness modulus is high for coarse agg. for the agg. commonly used, the fineness modulus of fine agg. varies between 2.0 & 3.5, for coarse agg. it varies between 5.5 & 8.0. and from 3.5 to 6.5 for all-in agg.

Deleterious substances in Aggregates:-

* The materials whose presence may adversely affect the strength, workability and long term performance of concrete are termed deleterious materials. These are considered undesirable as constituent because of their intrinsic weakness, softness, fineness or other physical or chemical characteristics harmful to the concrete behaviour.

* Depending upon their action, the deleterious substances found in the agg. can be divided into three broad categories.

(i) Impurities interfering with the process of hydration of cements.

(ii) coatings preventing the development of good bond between agg and the cement paste

(iii) unsound particles which are weak or bring about chemical reaction bet' the agg and cement Paste

* The coating of impurities affects good bonds, strength and durability of concrete. The soft or loosely adherent coatings can be removed by washing.

* If salt is not removed, it absorbs moisture from air and may cause efflorescence; and slight corrosion of reinforcement may also occur.

* Iron pyrites and magnetite are the most common expansive inclusions in the agg. These sulfides react with water and oxygen in the air resulting in, the surface staining of concr and pop-outs

* The effects is more under warm and humid conditions.

Gap Graded Aggregate :-

* Gap graded is defined as a grading in which one or more intermediate size fractions are absent

* The term continuously graded is used to distinguish the conventional grading from gap grading.

* on a grading curve, gap-grading is represented by by a horizontal line over the range of the size omitted.

- * Some important features of gap-graded agg. are as follows
1. For the given agg.-cement and water-cement ratios the highest workability is obtained with lower sand content in the case of gap-graded agg. rather than when continuously graded agg. is used.
 2. In the more workable range of mixes, gap graded agg. show a greater tendency to segregation. Hence, gap-grading is recommended mainly for mixes of relatively low workability that are to be compacted by vibration.
 3. Gap graded agg. does not affect compressive or tensile strengths.
 4. Specific surface area of gap graded agg. is lower because of higher percentage of coarse agg.
 5. Gap-graded agg. requires lesser cement and lower water-cement ratio.
 6. The drying-shrinkage is reduced in the concrete for the use of gap-graded agg.
- Maximum size of Aggregate :-
- In general, larger the maximum size of the agg, smaller is the cement requirement for a particular w/c ratio.
- * This is due to the fact that workability of conc. increases with the increase in the maximum size of agg.
- * Lesser consumption of cement in concrete will reduce the heat of hydration and corresponding thermal stresses and shrinkage cracks.

- * Due to the smaller surface area of influences the comp. strength of concrete. In that, for a particular volume of agg. the comp. strength tends to increase with the decrease in the size of the coarse agg.
- * This is due to the fact that smaller size agg. provide larger surface area for bonding with the matrix material.
- * For high strength concrete a 10 mm size of agg. is preferable.
- * For strength to 20 MPa agg. upto 40mm may be used.
- * For strengths above 30 MPa agg. upto 80mm may be used.
- * According to IS: 456-2000 the max. nominal size of c. agg. should not be greater than one fourth. the minimum thickness of the member & should be restricted to 5mm less than the min. cover -10-reinforcement distances & 5mm less than the spacing bet. the cables, strands or sheathing in case of prestressed concrete.

Grading of fine and coarse aggregate :-

In grading of aggregates, well graded sand from coarse to fine has less voids than fine sand. Mixes having a large coarse aggregate require less water and less cement. For concrete works to be coated good a dense mix should be aimed at with small size of aggregate.