PART B

1.Explain any three test conducted on cement in laboratory. (MAY 2019)

Fineness Test

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster the development of strength, (Fig. 2.5). The fineness of grinding has increased over the years. But now it has got nearly stabilised. Different cements are ground to different fineness. The disadvantages of fine grinding is that it is susceptible to air-set and early deterioration. Maximum number of particles in a sample of cement should have a size less than about 100 microns. The smallest particle may have a size of about 1.5 microns. By and large an average size of the cement particles may be taken as about 10 micron. The particle size fraction below 3 microns has been found to have the predominant effect on the strength at one day while 3-25 micron fraction has a major influence on the 28 days strength. Increase in fineness of cement is also found to increase the drying shrinkage of concrete. In commercial cement it is suggested that there should be about 25-30 per cent of particles of less than 7 micron in size.Fineness of cement is tested in two ways :

(*a*) By seiving.

(*b*) By determination of specific surface (total surface area of all the particles in one gram of cement) by air-premeability appartus. Expressed as cm^2/gm or m^2/kg. Generally Blaine Airpermeability appartus is used.

Sieve Test

Weigh correctly 100 grams of cement and take it on a standard IS Sieve No. 9 (90 microns). Break down the air-set lumps in the sample with fingers. Continuously sieve the sample giving circular and vertical motion for a period of 15 minutes. Mechanical sieving devices may also be used. Weigh the residue left on the sieve. This weight shall not exceed 10% for ordinary cement. Sieve test is rarely used.

Air Permeability Method

This method of test covers the procedure for determining the fineness of cement as represented by specific surface expressed as total surface area in sq. cm/gm. of cement. It is also expressed in m^2/kg. This apparatus can be used for measuring the specific surface of cement. The principle is based on the relation between the flow of air through the cement bed and the surface area of the particles comprising the cement bed. From this the surface area per unit weight of the body material can be related to the permeability of a bed of a given porosity. The cement bed in the permeability cell is 1 cm. high and 2.5 cm. in diameter. Knowing the density of cement the weight required to make a cement bed of porosity of 0.475 can be calculated. This quantity of cement is placed in the permeability cell in a standard manner. Slowly pass on air through the cement bed at a constant velocity. Adjust the rate of air flow until the flowmeter shows a difference in level of 30-50 cm. Read the difference in level (h_1) of the manometer and the difference in level (h_2) of the flowmeter. Repeat these observations to ensure that steady conditions have been obtained as shown by a constant value of h_1/h_2. Specific surface S_w is calculated from the following formula:

$$S_W = K\sqrt{h_1 / h_2} \quad \text{and} \quad K = \frac{14}{d(1-\xi)}\sqrt{\frac{\xi^3 A}{CL}}$$

where, ξ = Porosity, *i.e.*, 0.475

A = Area of the cement bed

L = Length (cm) of the cement bed

d = Density of cement, and

C = Flowmeter constant.

Fineness can also be measured by Blain Air Permeability apprartus. This method is more commonly employed in India.

Standard Consistency Test

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used. It is pertinent at this stage to describe the procedure of conducting standard consistency test. The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the mould shown in Fig. The appartus is called Vicat Appartus. This appartus is used to find out the percentage of water required to produce a cement paste of standard consistency. The standard consistency of the cement paste is some time called normal consistency (CPNC).

The following procedures is adopted to find out standard consistency. Take about 500 gms of cement and prepare a paste with a weighed quantity of water (say 24 per cent by weight of cement) for the first trial. The paste must be prepared in a standard manner and filled into the Vicat mould within 3-5 minutes. After completely filling the mould, shake the mould to expel air. A standard plunger, 10 mm diameter, 50 mm long is attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink into the paste by its own weight. Take the reading by noting the depth of penetration of the plunger. Conduct a 2nd trial (say with 25 per cent of water) and find out the depth of penetration of plunger. Similarly, conduct trials with higher and higher water/cement ratios till such time the plunger penetrates for a depth of 33-35 mm from the top. That particular percentage of water which allows the plunger to penetrate only to a depth of 33-35 mm from the top is known as the percentage of water required to produce a cement paste of standard consistency. This percentage is usually denoted as '*P*'. The test is required to be conducted in a constant temperature (27° $\pm$ 2°C) and constant humidity (90%).

Setting Time Test

An arbitraty division has been made for the setting time of cement as initial setting time and final setting time. It is difficult to draw a rigid line between these two arbitrary divisions.

For convenience, initial setting time is regarded as the time elapsed between the moment that the water is added to the cement, to the time that the paste starts losing its plasticity. The final setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure.

In actual construction dealing with cement paste, mortar or concrete certain time is required for mixing, transporting, placing, compacting and finishing. During this time cement paste, mortar, or concrete should be in plastic condition. The time interval for which the cement products remain in plastic condition is known as the initial setting time. Normally a minimum of 30 minutes is given for mixing and handling operations. The constituents and fineness of cement is maintained in such a way that the concrete remains in plastic condition for certain minimum time. Once the concrete is placed in the final position, compacted and finished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies. This time should not be more than 10 hours which is often referred to as final setting time. Table 2.5 shows the setting time for different cements.

The Vicat Appartus shown in Fig. 2.8 is used for setting time test also. The following procedure is adopted. Take 500 gm. of cement sample and guage it with 0.85 times the water required to produce cement paste of standard consistency (0.85 P). The paste shall be guaged and filled into the Vicat mould in specified manner within 3-5 minutes. Start the stop watch the moment water is added to the cement. The temperature of water and that of the test room, at the time of gauging shall be within 27°C ± 2°C.

Initial Setting Time

Lower the needle (C) gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needly may penetrate only to a depth of 33-35 mm from the top. The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35 mm from the top is taken as initial setting time.

Final Setting Time

Replace the needle (C) of the Vicat appartus by a circular attachment (F).The cement shall be considered as finally set when, upon, lowering the attachment gently cover the surface of the test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm.

Strength Test

The compressive strength of hardened cement is the most important of all the properties. Therefore, it is not surprising that the cement is always tested for its strength at the laboratory before the cement is used in important works. Strength tests are not made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement. Strength of cement is indirectly found on cement sand mortar in specific proportions. The standard sand is used for finding the strength of cement. It shall conform to IS 650-1991. Take 555 gms of standard sand (Ennore sand), 185 gms of cement (*i.e.*, ratio of cement to sand is 1:3) in a non-porous enamel tray and mix them with a trowel for one minute, then add water of quantity P_4 + 3.0 per cent of combined weight of cement and sand and mix the three ingredients thoroughly until the mixture is of uniform colour. The time of mixing should not be less than 3 minutes nor more than 4 minutes. Immediately after mixing, the mortar is filled into a cube mould of size 7.06 cm. The area of the face of the cube will be equal to 50 sq cm. Compact the mortar either by hand compaction in a standard specified manner or on the vibrating equipment (12000 RPM) for 2 minutes.Keep the compacted cube in the mould at a temperature of 27°C ± 2°C and at least 90 per cent relative humidity for 24 hours. Where the facility of standard temperature and humidity room is not available, the cube may be kept under wet gunny bag to simulate 90 per cent relative humidity. After 24 hours the cubes are removed from the mould and immersed in clean fresh water until taken out for testing.

Three cubes are tested for compressive strength at the periods mentioned in Table 2.5. The periods being reckoned from the completion of vibration. The compressive strength shall be the average of the strengths of the three cubes for each period respectively.

Soundness Test

It is very important that the cement after setting shall not undergo any appreciable change of volume. Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious difficulties for the durability of structures when such cement is used. The testing of soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance.

The unsoundness in cement is due to the presence of excess of lime than that could be combined with acidic oxide at the kiln. This is also due to inadequate burning or insufficiency in fineness of grinding or thorough mixing of raw materials. It is also likely that too high a proportion of magnesium content or calcium sulphate content may cause unsoundness in cement. For this reason the magnesia content allowed in cement is limited to 6 per cent. It can be recalled that, to prevent flash set, calcium sulphate is added to the clinker while grinding. The quantity of gypsum added will vary from 3 to 5 per cent depending upon C_3A content. If the addition of gypsum is more than that could be combined with C_3A, excess of gypsum will remain in the cement in free state. This excess of gypsum leads to an expansion and consequent disruption of the set cement paste.

Unsoundness in cement is due to excess of lime, excess of magnesia or excessive proportion of sulphates. Unsoundness in cement does not come to surface for a considarable period of time. Therefore, accelerated tests are required to detect it. There are number of such tests in common use. The appartus is shown in Fig. 2.9. It consists of a small split cylinder of spring brass or other suitable metal. It is 30 mm in diameter and 30 mm high. On either side of the split are attached two indicator arms 165 mm long with pointed ends. Cement is gauged with 0.78 times the water required for standard consistency (0.78 P), in a standard manner and filled into the mould kept on a glass plate. The mould is covered on the top with another glass plate. The whole assembly is immersed in water at a temperature of 27°C – 32°C and kept there for 24 hours. Measure the distance between the indicator points. Submerge the mould again in water. Heat the water and bring to boiling point in about 25-30 minutes and keep it boiling for 3 hours. Remove the mould from the water, allow it to cool and measure the distance between the indicator points. The difference between these two measurements represents the expansion of cement. This must not exceed 10 mm for ordinary, rapid hardening and low heat Portland cements. If in case the expansion is more than 10 mm as tested above, the cement is said to be unsound.

The Le Chatelier test detects unsoundness due to free lime only. This method of testing does not indicate the presence and after effect of the excess of magnesia. Indian Standard Specification stipulates that a cement having a magnesia content of more than 3 per cent shall be tested for soundness by Autoclave test which is sensitive to both free magnesia and free lime. In this test a neat cement specimen 25 × 25 mm is placed in a standard autoclave and the steam pressure inside the autoclave is raised in such a rate as to bring the gauge pressure of the steam to 21 kg/ sq cm in $1 - 1^{1}/_{4}$ hour from the time the heat is turned on. This pressure is maintained for 3 hours. The autoclave is cooled and the length measured again. The expansion permitted for all types of cements is given in Table 2.5. The high steam pressure accelerates the hydration of both magnesia and lime.

No satisfactory test is available for deduction of unsoundness due to an excess of calcium sulphate. But its content can be easily determined by chemical analysis.

2. **Detail about the properties of aggregate (MAY 2019) (MAY 2017)(MAY 2016)**

Concrete is a mixture of cementious material, aggregate, and water. Aggregate is commonly considered inert filler, which accounts for 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete. Although aggregate is considered inert filler, it is a necessary component that defines the concrete's thermal and elastic properties and dimensional stability. Aggregate is classified as two different types, coarse and fine. Coarse aggregate is usually greater than 4.75 mm (retained on a No. 4 sieve), while fine aggregate is less than 4.75 mm (passing the No. 4 sieve). The compressive aggregate strength is an important factor in the selection of aggregate. When determining the strength of normal concrete, most concrete aggregates are several times stronger than the other components in concrete and therefore not a factor in the strength of normal strength concrete. Lightweight aggregate concrete may be more influenced by the compressive strength of the aggregates.

Other physical and mineralogical properties of aggregate must be known before mixing concrete to obtain a desirable mixture.

These properties include

- shape and texture
- size gradation
- moisture content
- specific gravity
- reactivity
- soundness and
- bulk unit weight.

These properties along with the water/cementitious material ratio determine the strength, workability, and durability of concrete.

SIZE

Aggregate size and gradation are the most important factors when selecting aggregate. Aggregate can be large or small, from fist-sized rocks to fine sand. Aggregates larger than ¼ inch are classified as coarse aggregate, while anything smaller than ¼ inch is termed fine aggregate. As a general rule, the largest aggregate should be no greater in diameter than one-third the depth of the slab, or one-fifth the smallest dimension of the form. For example, the largest piece of aggregate allowed for a 1 ½-inch-thick countertop slab is ½ inch. Generally coarse aggregate is blended with finer aggregates (such as sand) to fill in the spaces left between the large pieces and to "lock" the larger pieces together. This reduces the amount of cement paste required and decreases the amount of shrinkage that could occur.

SHAPE

Aggregate shape influences strength, but has more of an immediate impact on the workability of the plastic concrete. Rough, angular particles pack tighter, have more surface area, and have greater interparticle friction than smooth, rounded particles, which reduces workability. Angular particles also require a bit more cement paste to coat them than rounded particles. Therefore, mixes containing them will require a slightly higher cementitious content.

GRADATION

In general, coarse aggregates tend to be about 10 times larger than the fine aggregates in concrete, but the range of sizes could be greater than that in certain circumstances. As shown in the figure, there are three typical range categories:

- Well-graded aggregate has a gradation of particle sizes that fairly evenly spans the size from the finest to the coarsest. A slice of a core of well-graded aggregate concrete shows a packed field of many different particle sizes.
- Poorly graded aggregate is characterized by small variations in size. This means that the particles pack together, leaving relatively large voids in the concrete.
- Gap-graded aggregate consists of coarse aggregate particles that are similar in size but significantly different in size from the fine aggregate. A core slice of gap-graded concrete shows a field of fine aggregate interspersed with slightly isolated, large aggregate pieces embedded in the fine aggregate.

Typical aggregate gradations are shown in the drawing below:

Poorly graded concretes generally require excessive amounts of cement paste to fill the voids, making them uneconomical. Gap-graded concretes fall in between well-graded and poorly graded in terms of performance and economy. Gap-graded concrete is a viable gradation, but not optimal.

Well-graded aggregates are tricky to proportion. The goal of aggregate proportioning and sizing is to maximize the volume of aggregate in the concrete (and thus minimize the volume of cement paste) while preserving strength, workability, and aesthetics. This balances the proportions of each so there are just enough of each size to fill all the voids, while preserving workability and cast-surface quality.

Note that aggregate gradation is particularly important in cast in place concrete countertop mixes. This blog entry explains further about cast in place mixes.

MOISTURE CONTENT

The moisture content of an aggregate is an important factor when developing the proper water/cementitious material ratio. All aggregates contain some moisture based on the porosity of the particles and the moisture condition of the storage area. The moisture content can range from less than one percent in gravel to up to 40 percent in very porous sandstone and expanded shale. Aggregate can be found in four different moisture states that include oven-dry (OD), air-dry (AD), saturated-surface dry (SSD) and wet. Of these four states, only OD and SSD correspond to a specific moisture state and can be used as reference states for calculating moisture content. In order to calculate the quantity of water that aggregate will either add or subtract to the paste, the following three quantities must be calculated: absorption capacity, effective absorption, and surface moisture.

MORTAR CONCRETE

Concrete made with just fine aggregate (or sand) is known as mortar concrete. Like the mortar used for brick and concrete block construction, which is simply made with mortar cement and sand, mortar concrete has no coarse aggregate in it, so a ground finish will have a fine-grained appearance. Mortar concrete is commonly used in concrete countertop mixes, since the surface finish is so important.

Even with an all-sand mix, aggregate gradation is still an important factor to consider and affects strength, workability, and aesthetics. It is always preferable to have some particle size variation rather than absolute uniformity because the interparticle void volume will be lower than with uniform particle sizes. While it is possible to blend different sands of different sizes together in a fashion similar to graded aggregates, generally only one type of sand is used. Most sand, especially bulk or bank-run sand, already has a particle size distribution that has some variation to it.

In order to achieve adequate workability, the cement paste volume must be high enough to encapsulate all of the aggregate particles and to provide some workability while the concrete is fresh. Therefore, mortar concrete tends to have a high cement content.

For mixture proportioning, the bulk unit weight (a.k.a. bulk density) is required. The bulk density measures the volume that the graded aggregate will occupy in concrete, including the solid aggregate particles and the voids between them. Since the weight of the aggregate is dependent on the moisture content of the aggregate, a constant moisture content is required. This is achieved by using OD aggregate. Additionally, the bulk density is required for the volume method of mixture proportioning.

The most common classification of aggregates on the basis of bulk specific gravity is lightweight, normal-weight, and heavyweight aggregates. In normal concrete the aggregate weighs 1,520 – 1,680 kg/m^3, but occasionally designs require either lightweight or heavyweight concrete. Lightweight concrete contains aggregate that is natural or synthetic which weighs less than 1,100 kg/$m^3$and heavyweight concrete contains aggregates that are natural or synthetic which weigh more than 2080 kg/m^3.

CONCLUSION

Aggregate gradation, whether in a mortar concrete or a traditional concrete mix, involves tradeoffs between strength and workability and is always a delicate balance. Understanding the implications of aggregate gradation is especially important when creating a from-scratch mix and will ultimately help you produce a better concrete countertop.

Although aggregates are most commonly known to be inert filler in concrete, the different properties of aggregate have a large impact on the strength, durability, workability, and economy of concrete. These different properties of aggregate allow designers and contractors the most flexibility to meet their design and construction requirements.

3. Describe the importance of the quality of water used for concreting. (May 2019)(NOV 2019)

Water is an important ingredient of concrete as itactively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water isrequired to be looked into very carefully. It has been discussed enough in chapter 1 about the quantity ofmixing water but so far the quality of water has not been discussed. In practice, very often great control on properties of cement and aggregate is exercised, but the control on the quality of water is often neglected. Since quality of water affects the strength, it is necessary for us to go into the purity and quality of water.

Qualities of Water

A popular yard-stick to the suitability of water for mixing concrete is that, if water is fit for drinking it is fit for making concrete. This does not appear to be a true statement for all conditions. Some waters containing a small amount of sugar would be suitable for drinking but not for mixing concrete and conversely water suitable for making concrete may not necessarily be fit for drinking. Some specifications require that if the water is not obtained from source that has proved satisfactory, the strength of concrete or mortar made with questionable water should be compared with similar concrete or mortar made with pure water. Some specification also accept water for making concrete if the pH value of water lies between 6 and 8 and the water is free from organic matter. Instead of depending upon pH value and other chemical composition, the best course to find out whether a particular source of water is suitable for concrete making or not, is to make concrete with this water and compare its 7 days' and 28 days' strength with companion cubes made with distilled water.

If the compressive strength is upto 90 per cent, the source of water may be accepted. This criteria may be safely adopted in places like coastal area of marshy area or in other places where the available water is brackish in nature and of doubtful quality. However, it is logical to know what harm the impurities in water do to the concrete and what degree of impurity is permissible is mixing concrete and curing concrete.

Carbonates and bi-carbonates of sodium and potassium effect the setting time of cement. While sodium carbonate may cause quick setting, the bi-carbonates may either accelerate or retard the setting. The other higher concentrations of these salts will materially reduce the concrete strength. If some of these salts exceeds 1,000 ppm, tests for setting time and 28 days strength should be carried out. In lower concentrations they may be accepted.

Brackish water contains chlorides and sulphates. When chloride does not exceed 10,000 ppm and sulphate does not exceed 3,000 ppm the water is harmless, but water with even higher salt content has been used satisfactorily.

Salts of Manganese, Tin, Zinc, Copper and Lead cause a marked reduction in strength of concrete. Sodium iodate, sodium phosphate, and sodium borate reduce the initial strength of concrete to an extra-ordinarily high degree. Another salt that is detrimental to concrete is sodium sulphide and even a sulphide content of 100 ppm warrants testing.

Silts and suspended particles are undesirable as they interfere with setting, hardening and bond characteristics. A turbidity limit of 2,000 ppm has been suggested. Table 4.1 shows the tolerable concentration of some impurities in mixing water.The following guidelines should also be taken into consideration regarding the quality of water.

(a) To neutralize 100 ml sample of water using phenoplhaline as an indicator, it should not require more than 5 ml of 0.02 normal NaOH.

(b) To neutralise 100 ml of sample of water, using mixed indicator, it should not require
more than 25 ml of 0.02 normal H2So4.

(c) Permissible limits for solids has to be limited

4. Describe the hydration reaction of important Bogue compounds indicating the products of hydration. (MAY/JUNE 2016)(NOV 2019)

Hydration

The setting and hardening of concrete are the result of chemical and physical processes that take place between Portland cement and water, i.e. hydration. To understand the properties and behaviour of cement and concrete some knowledge of the chemistry of hydration is necessary.

Hydration reactions of pure cement compounds The chemical reactions describing the hydration of the cement are complex. One approach is to study the hydration of the individual compounds separately. This assumes that the hydration of each compound takes place independently of the others.

Calcium silicates

Hydration of the two calcium silicates gives similar chemical products, differing only in the amount of calcium hydroxide formed, the heat released, and reaction rate.

$2\ C3S + 7\ H \rightarrow C3S2H4 + 3\ CH\ 2\ C2S + 5\ H \rightarrow C3S2H4 + CH$

The principal hydration product is C3S2H4, calcium silicate hydrate, or C-S-H (non-stoichiometric). This product is not a well-defined compound. The formula C3S2H4 is only an approximate description. It has amorphous structure making up of poorly organized layers and is called glue gel binder. C-S-H is believed to be the material governing concrete strength. Another product is CH - Ca(OH)2, calcium hydroxide. This product is a hexagonal crystal often forming stacks of plates. CH can bring the pH value to over 12 and it is good for corrosion protection of steel.

II. Tricalcium aluminate

Without gypsum, C3A reacts very rapidly with water:

$C3A + 6\ H \rightarrow C3AH6$

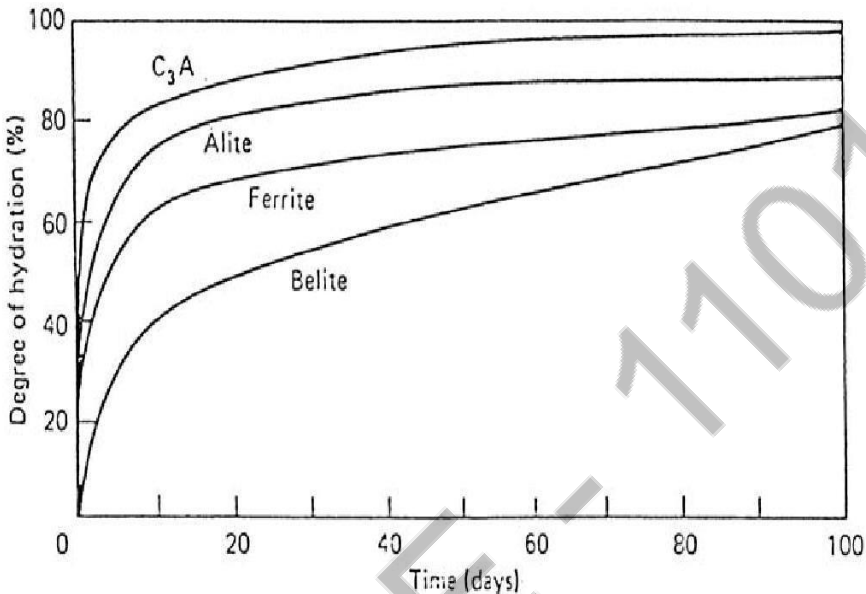
The reaction is so fast that it results in flash set, which is the immediate stiffening after mixing, making proper placing, compacting and finishing impossible. With gypsum, the primary initial reaction of C3A with water is :

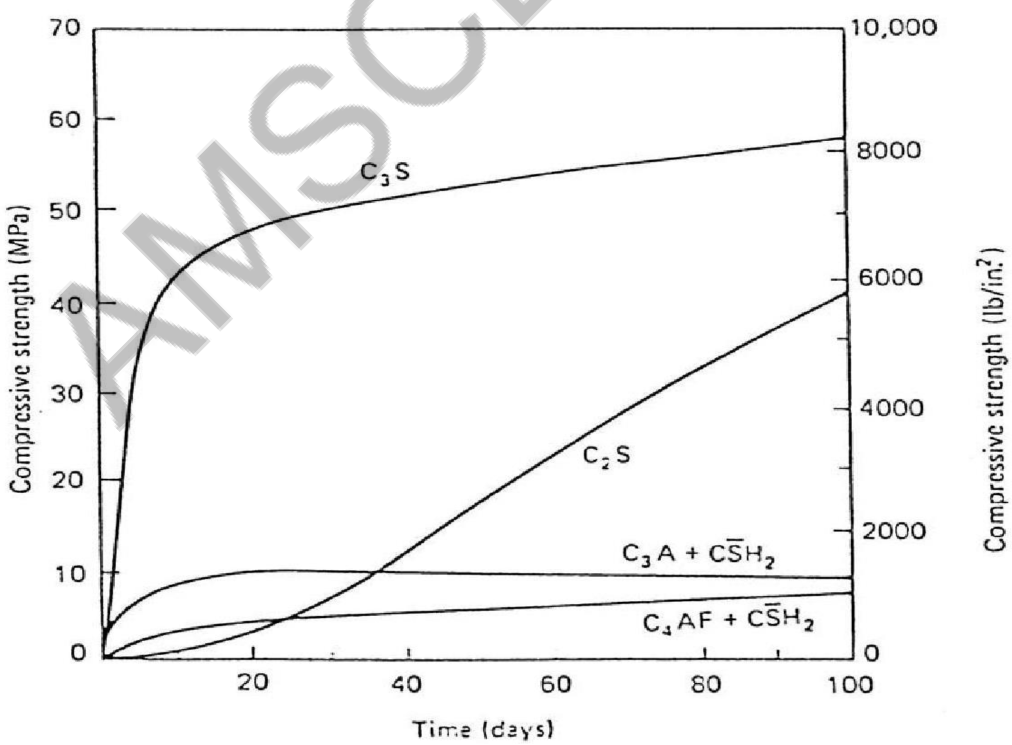
$C3A + 3\ (C\ S\ H2) + 26\ H \rightarrow C6A\ S\ 3H32$

The 6-calcium aluminate trisulfate-32-hydrate is usually called ettringite. The formation of ettringite slows down the hydration of C3A by creating a diffusion barrier around C3A. Flash set is thus avoided. Even with gypsum, the formation of ettringite occurs faster than the hydration of the calcium silicates. It therefore contributes to the initial stiffening, setting and early strength development. In normal cement mixes, the ettringite is not stable and will further react to form monosulphate (*C4A S H18).*

B) Kinetics and Reactivities

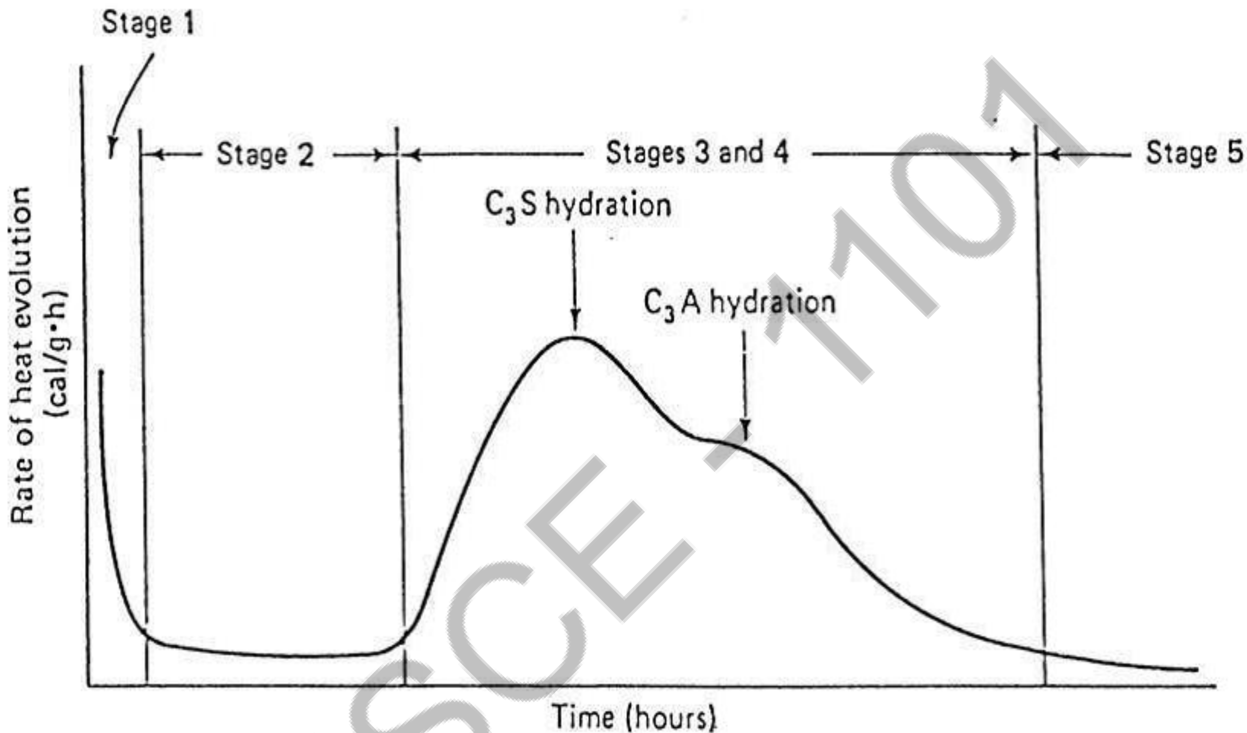
The rate of hydration during the first few days is in the order of C3A > C3S > C4AF >C2S.





C) Calorimetric curve of Portland cement

A typical calorimetric curve of Portland cement is shown in the following figure. The second heat peaks of both C3S and C3A can generally be distinguished, although their order of occurrence can be reversed.



From the figure, five stages can be easily identified. Since C3S is a dominating component in cement, the five stages above can be explained using the reaction process of C3S by the following table.

Reaction Stage	Kinetics of Reaction	Chemical Processes	Relevance to Concrete
1. Initial hydrolysis	Chemical control; rapid	Initial hydrolysis; dissolution of ions	-
2. Induction period	Nucleation control; slow	Continued dissolution of ions	Determines initial set
3. Acceleration	Chemical control: rapid	Initial formation of hydration products	Determines final set and rate of initial hardening
4. Deceleration	Chemical and diffusion control; slow	Continued formation of hydration products	Determines rate of early strength gain
5. Steady State	Diffusion control; slow	Slow formation of hydration products	Determines rate of later strength gain

On first contact with water, calcium ions and hydroxide ions are rapidly released from the surface of each C3S grain; the pH values rises to over 12 within a few minutes. This hydrolysis slows down quickly but continues throughout the induction period. The induction (dormant) period is caused by the need to achieve a certain concentration of ions in solution before crystal nuclei are formed for the hydration products to grow from. At the end of dormant period, CH starts to crystallize from solution with the concomitant formation of C-S-H and the reaction of C3S again proceeds rapidly (the third stage begin). CH crystallizes from solution, while C-S-H develops from the surface of C3S and forms a coating covering the grain. As hydration continues, the thickness of the hydrate layer increases and forms a barrier through which water must flow to reach the unhydrated C3S and through which ions must diffuse to reach the growing crystals. Eventually, movement through the C-S-H layer determines the rate of reaction. The process becomes diffusion controlled.

D) Setting and Hydration

Initial set of cement corresponds closely to the end of the induction period, 2-4 hours after mixing. Initial set indicates the beginning of forming of gel or beginning of solidification. It represents approximately the time at which fresh concrete can no longer be properly mixed, placed or compacted. The final set occurs 5-10 hours after mixing, within the acceleration period. It represents approximately the time after which strength develops at a significant rate. In practice, initial and final set are determined in a rather arbitrary manner with the penetration test. While the determination of initial and the final set has engineering significance, there is no fundamental change in hydration process for these two different set conditions.

The reaction of cement with water is exothermic. The reaction liberates a considerable quantity of heat. This liberation of heat is called heat of hydration. This is clearly seen if freshly mixed cement is put in a vaccum flask and the temperature of the mass is read at intervals. The study and control of the heat of hydration becomes important in the construction of concrete dams and other mass concrete constructions. It has been observed that the temperature in the interior of large mass concrete is 50°C above the original temperature of the concrete mass at the time of placing and this high temperature is found to persist for a prolonged period. Fig 1.2 shows the pattern of liberation of heat from setting cement1.4 and during early hardening period.

On mixing cement with water, a rapid heat evolution, lasting a few minutes, occurs. This heat evolution is probably due to the reaction of solution of aluminates and sulphates (ascending peak A). This initial heat evolution ceases quickly when the solubility of aluminate is depressed by gypsum. (decending peak A). Next heat evolution is on account of formation of ettringite and also may be due to the reaction of C3S (ascending peak B). Refer Fig. 1.2.

Different compounds hydrate at different rates and liberate different quantities of heat. Fig. 1.3 shows the rate of hydration of pure compounds. Since retarders are added to control the flash setting properties of C3A, actually the early heat of hydration is mainly contributed from the hydration of C3S. Fineness of cement also influences the rate of development of heat but not the total heat. The total quantity of heat generated in the complete hydration will depend upon the relative quantities of the major compounds present in a cement.

Normal cement generally produces 89-90 cal/g in 7 days and 90 to 100 cal/g in 28 days.

The hydration process is not an instantaneous one. The reaction is faster in the early period and continues idenfinitely at a decreasing rate. Complete hydration cannot be obtained under a period of one year or more unless the cement is very finely ground and reground with excess of water to expose fresh surfaces at intervals. Otherwise, the product obtained shows unattacked cores of tricalcium silicate surrounded by a layer of hydrated silicate, which being relatively impervious to water, renders further attack slow. It has been observed that after 28 days of curing, cement grains have been found to have hydrated to a depth of only 4μ. It has also been observed that complete hydration under normal condition is possible only for cement particles smaller than 50μ.

A grain of cement may contain many crystals of C3S or others. The largest crystals of C3S or C2S are about 40μ. An average size would be 15-20μ. It is probable that the C2S crystals present in the surface of a cement grain may get hydrated and a more reactive compound like C3S lying in the interior of a cement grain may not get hydrated.

The hydrated product of the cement compound in a grain of cement adheres firmly to the unhydrated core in the grains of cement. That is to say unhydrated cement left in a grain of cement will not reduce the strength of cement mortar or concrete, as long as the products of hydration are well compacted. Abrams obtained strength of the order of 280 MPa using mixes with a water/cement ratio as low as 0.08. Essentially he has applied tremendous pressure to obtain proper compaction of such a mixture. Owing to such a low water/cement ratio, hydration must have been possible only at the surface of cement grains, and a considerable portion of cement grains must have remained in an unhydrated condition.

The present day High Performance concrete is made with water cement ratio in the region of 0.25 in which case it is possible that a considerable portion of cement grain remains unhydrated in the core. Only surface hydration takes place. The unhydrated core of cement grain can be deemed to work as very fine aggregates in the whole system

5. **Explain about testing procedure for aggregate.(MAY 2018)(NOV 2018)**

Aggregatte 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. Different rock samples are found to give different compressive strength varying from a minimum of about 45 MPa to a maximum of 545 MPa. As said earlier, the compressive strength of parent rock does not exactly indicate the strength of aggregate in concrete. For this reason assessment of strength of the aggregate is made by using a sample of bulk aggregate in a standardised manner. This test is known as aggregate crushing value test. 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. The aggregate is placed in a cylindrical mould and a load of 40 ton is applied through a plunger. The material crushed to finer than 2.36 mm is separated and expressed as a percentage of the original weight taken in the mould. This percentage is referred as aggregate crushing value. The crushing value of aggregate is restricted to 30 per cent for concrete used for roads and pavements and 45 per cent may be permitted for other structures.

The crushing value of aggregate is rather insensitive to the variation in strength of weaker aggregate. This is so because having been crushed before the application of the full load of 40 tons, the weaker materials become compacted, so that the amount of crushing during later stages of the test is reduced. For this reason a simple test known as "10 per cent fines value" is introduced. When the aggregate crushing value become 30 or higher, the result is likely to be inaccurate, in which case the aggregate should be subjected to "10 per cent fines value" test which gives a better picture about the strength of such aggregates.

This test is also done on a single sized aggregate as mentioned above. Load required to produce 10 per cent fines (particles finer than 2.36 mm) is found out by observing the penetration of plunger. The 10 per cent fines value test shows a good correlation with the standard crushing value test for strong aggregates while for weaker aggregates this test is more sensitive and gives a truer picture of the differences between more or less weak samples.

It should be noted that in the 10 per cent fines value test unlike the crushing value test, a higher numerical result denotes a higher strength of the aggregate. The detail of this test is given at the end of this chapter under testing of aggregate.

Aggregate Impact Value

With respect to concrete aggregates, toughness is usually considered the resistance of the material to failure by impact. Several attempts to develop a method of test for aggregates impact value have been made. The most successful is the one in which a sample of standard aggregate kept in a mould is subjected to fifteen blows of a metal hammer of weight 14 Kgs. falling from a height of 38 cms. The quantity of finer material (passing through 2.36 mm) resulting from pounding will indicate the toughness of the sample of aggregate. The ratio of the weight of the fines (finer than 2.36 mm size) formed, to the weight of the total sample taken is expressed as a percentage. This is known as aggregate impact value 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

Apart from testing aggregate with respect to its crushing value, impact resistance, 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

Los Angeles Test

Los Angeles test was developed to overcome some of the defects found in Deval test. Los Angeles test is characterised by the quickness with which a sample of aggregate may be tested. The applicability of the method to all types of commonly used aggregate makes this method popular. The test involves taking specified quantity of standard size material along with specified number of abrasive charge in a standard cylinder and revolving if for certain specified revolutions. The particles smaller than 1.7 mm size is separated out. The loss in weight expressed as percentage of the original weight taken gives the abrasion value of the aggregate. The abrasion value should not be more than 30 per cent for wearing surfaces and not more than 50 per cent for concrete other than wearing surface.

6. **What is the effect of water cement ratio on strength and durability of concrete?(MAY 2017)(NOV 2018)(NOV 2016)**

In concrete mix design, the ratio of the amount of water to the amount of cement used (both by weight) is called the water to cement ratio (w/c). These two ingredients are responsible for binding everything together.

The water to cement ratio, or w/c ratio, largely determines the strength and durability of the concrete when it is cured properly. The w/c ratio refers to the ratio of the weights of water and cement used in the concrete mix. A w/c ratio of 0.4 means that for every 100 lbs of cement used in the concrete, 40 lbs of water is added.

For ordinary concrete (sidewalks and driveways), a w/c ratio of 0.6 to 0.7 is considered normal. A lower w/c ratio of 0.4 is generally specified if a higher quality concrete is desired. The practical range of the w/c ratio is from about 0.3 to over 0.8. A ratio of 0.3 is very stiff (unless superplasticizers are used), and a ratio of 0.8 makes a wet and fairly weak concrete. For reference, a 0.4 w/c ratio is generally expected to make a concrete with a compressive strength (its f'c) of about 5600 psi when it is properly cured. On the other hand, a ratio of 0.8 will make a weak concrete of only about 2000 psi.

The simplest way to think about the w/c ratio is to think that the greater the amount of water in a concrete mix, the more dilute the cement paste will be. This not only affects the compressive strength, it also affects the tensile and flexural strengths, the porosity, the shrinkage and the color.

The more the w/c ratio is increased (that is, the more water that is added for a fixed amount of cement), the more the strength of the resulting concrete is reduced. This is mostly because adding more water creates a diluted paste that is weaker and more susceptible to cracking and shrinkage. Shrinkage leads to micro-cracks, which are zones of weakness. Once the fresh concrete is placed, excess water is squeezed out of the paste by the weight of the aggregate and the cement paste itself. When there is a large excess of water, that water bleeds out onto the surface. The micro channels and passages that were created inside the concrete to allow that water to flow become weak zones and micro-cracks.

Using a low w/c ratio is the usual way to achieve a high strength and high quality concrete, but it does not guarantee that the resulting concrete is always appropriate for countertops. Unless the aggregate gradation and proportion are balanced with the correct amount of cement paste, excessive shrinkage, cracking and curling can result. Good concrete results from good mix design, and a low w/c ratio is just one part of a good mix design.

Water-Cement Ratio

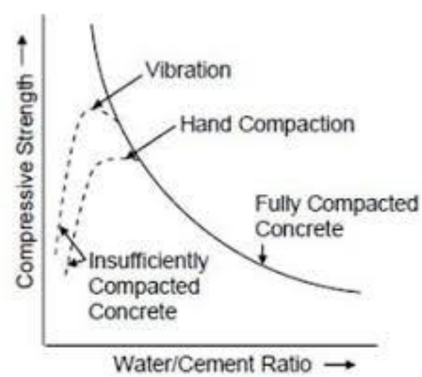
The water-cement ratio is the weight of water provided in a mix divided by the weight of cementitious materials. The total weight of the water includes all the batch water & free water from the surface of aggregates. Cementitious materials includes portland cement, blended cements & supplementary cementitious materials such as fly ash, silica fume & slag. Because of this, the water-cement ratio may be referred to as the water-to-cementitious materials ratio (w/cm).

Strength of Concrete

Water-cement ratio is one of the largest single factor on which the strength of well compacted concrete depends. Cured concrete strength depends on the two main factors i.e.

1. Water-cement ratio
2. Degree of compaction

Air voids in the concrete depends on the water-cement ratio. There is an increase in the air voids with increase in the weight of water. When this situation happens, then strength of the concrete drops down. Hardened concrete contains about 1% of air voids. In the hardened state concrete, strength is inversely proportional to water/cement ratio.



Above figure shows that validity range of the water-cement ratio is very limited. Compressive strength is at peak, when water-cement ratio is low. Beginning of the curve depends on available means of the compaction (i.e. either done with vibrators or manual-hand compaction). If the large size aggregates is used with the low water-cement ratio & high contents of cement then it exhibit retrogression of concrete strength.
A conclusion can be made that if there is a low water-cement ratio in a fresh mix than after hardening, water/cement will not be able to lead higher strength of the concrete. These conditions happen because of the development of the tensile stresses due to shrinkage & creep. This leads to cracking of the cement or to the loss of bonds (that is between cement and aggregates) as if aggregates try to restrain the tensile stresses.

lets consider two cases;

When the water/cement ratio is high.

If the w/c ratio is high, a large amount of water is available per unit weight of cement in the concrete mix. So if a fixed volume of concrete is poured into a cube of form-work, there are a large number of water-filled voids in the cube. So when the hydration reaction starts on the surface of the cement particle, the gel-like products of hydration get precipitated in the water – away from the surface of cement particles.

The gels formed in such a case are termed as Outer Products of Hydration. Now there are two reasons why the strength of concrete is low in this case, namely –

1. Since there is a large space for them to develop, the outer products of hydration are large in size. And we know, from the size effect, that larger sized particles have lower strength compared to particles of smaller size.
2. No matter how high the water consumption rate of the reaction is, due to the large amount of water present in the mix, some water will still be left when the concrete hardens and is ready for use. This trapped water will gradually evaporate, leaving some voids in the concrete block. The presence of voids results in greatly reduced strength.

When the water/cement ratio is low.

In this case, there will be very less amount of water in the block of formwork when the concrete is poured into it, and hence lesser voids. When the hydration reaction proceeds, the gels formed do not have enough space to migrate out and precipitate in the voids. So they get deposited on the surface of the cement particle itself. Such products of hydration are termed as Inner Products of Hydration. The space available for the crystals to grow is limited, so they remain much smaller in size compared to the outer products of hydration.

The strength of concrete is more when the w/c ratio is low, because of the following reasons –

1. As per the law of size effect, the smaller sized gels formed in this case have much greater strength as compared to those formed when the w/c is high.
2. Since the water available for hydration is very less, almost all of it is utilized during the reaction. So no water is left to get evaporated later, and hence the strength-reduction due to subsequent void formation is also much lower when the w/c ratio is low.

7. Explain the mechanical properties of OPC. (MAY 2017)(NOV 2016)

Performance of concrete is evaluated from mechanical properties which include shrinkage and creep, compressive strength, tensile strength, flexural strength, and modulus of elasticity. But compressive strength of concrete is the most important characteristic and it is generally assumed that an improvement in concrete compressive strength will improve its mechanical properties; however, in case of concrete in which cement is partially replaced by mineral admixtures, all mechanical properties are not directly associated with compressive strength and the effects of the same amount of different mineral admixtures on the mechanical properties of hardened concrete are not same. This difference of the effects of different minerals on the mechanical properties is as follows.

Pore Size and Porosity

Mechanical properties of concrete are closely related to its porosity and pore dispersion . It is reported in the literature that the addition of mineral admixture considerably refines the pore configuration by reducing the pore size and porosity. After initial hydration of cement, hydrated limes ($Ca(OH)_2$) form. Due to less or limited solubility, this hydrated lime remains independent in the interstitial spaces. If moisture is available, mineral admixture reacts with lime to form tricalcium silicate which refines the pore configuration of the cement matrix. It is important to mention that the rate and speed of this reaction are very much dependent on the pozzolanic nature of the mineral admixture; therefore to attain good results, silica in mineral admixture should be amorphous, glassy, or reactive. Thus, the parameters representing the pore configuration, that is, pore size and porosity, are significantly different for each partially replaced cement pastes with different mineral admixtures, even if the amount of cement replacement and water binder ratio is the constant.

Drying Shrinkage and Creep

Drying shrinkage property of pastes and/or concrete is usually associated with the loss of adsorbed water from the material. This property is very much significant in porous concrete, especially aerated concrete due to higher total porosity (40–80%) and specific surface of pores (around 30 m^2/g) Decrease in the pore radii results in a higher percentage of pores and results in increased shrinkage however this property is usually related to the aggregate quality and volume; therefore, shrinkage in the paste is higher than concrete. pore radius is an important parameter to determine the magnitude of shrinkage instead of the quantity of moisture loss. Higher temperature and lower humidity significantly influence shrinkage. Size of the capillary pores in the pastes and in the aggregate paste interface zone is reduced; thus capillary pressure increases as mineral admixture refines the pore configuration by reducing the pore diameter; therefore, shrinkage in concrete containing mineral admixtures will be lower due to reduced pore size as compared to OPC.

Compressive Strength

Compressive strength of concrete is an indexing property as concrete is designed to carry compressive loadings. Concrete compressive strength requirements can vary from 2500 psi (17 MPa) for residential concrete to 4000 psi (28 MPa) and higher in commercial structures. Higher strengths up to and exceeding **10,000 psi** (70 MPa) are specified for certain applications.

Splitting Tensile Strength

The **tensile strength of concrete** is one of the basic and important **properties**. **Splitting tensile strength** test on **concrete** cylinder is a method to determine the**tensile strength of concrete**. The **concrete** is very weak in tension due to its brittle nature and is not expected to resist the direct tension.

Splitting tensile strength is the measure of tensile strength of the concrete which is determined by splitting the cylinder across its diameter.

Flexural/Bending Strength

Flexural strength is one measure of the **tensile strength of concrete**. It is a measure of an unreinforced con- crete beam or slab to resist failure in **bending**. It is measured by loading 6 x 6-inch (150 x 150-mm) con- crete beams with a span length at least three times the depth.

Modulus of Elasticity

Modulus of elasticity is an important property to assess the resistance of concrete against freezing and thawing. This property can be determined by static as well as dynamic compression test. The literature reveals that the elastic modulus of FA concrete is generally equal to or slightly better than equivalent grade of concrete

8. **Compare the physical properties of 33,43 and 53 grade of concrete. (MAY 2017)(NOV 2016)**

33 Grade OPC

- This cement is used for general civil construction work under normal environmental conditions.
- The compressive strength of cement after 28 days test as per BIS specification is 33 MPa.
- Due to low compressive strength, this cement is normally not used where high grade of concrete viz, M-20 and above is required.
- The availability of higher grades of OPC in the market impacts the usage of 33 grade OPC as these days 43 grade OPC is normally used for general construction work.
- This grade of cement is more useful for mass concreting and plain cement concreting and can also be used for plastering and single storied individual houses.

Fineness=**300 m2/kg**

Compressive strength after 3 days=**16 N/mm2**

Compressive strength after 7 days=**22 N/mm2**Compressive strength after 28 days=**33N/mm2**

Grade 33 cement has high workability and is mainly used for mortar in masonry work and for plastering.

43 Grade OPC

The 43 grade OPC is the most popular general-purpose cement in the country today. The production of 43 grade OPC is nearly 50% of the total production of cement in the country.

Fineness=**225 m2/kg**

Compressive strength after 3 days=**23 N/mm2**

Compressive strength after 7 days=**33 N/mm2**

Compressive strength after 28 days=**43 N/mm2**

Grade 43 cement is moderately sulphate resisting and has good workability. Grade 43 cement has low chloride content and thus resists corrosion on R.C.C. Grade 43 cement has smooth and better finish.

Grade 43 cement is mainly used in:

Ready mix concrete.(R.M.C)

1. Asbestos products such as sheets and pipes.
2. Reinforced cement concrete work (R.C.C)
3. Pre-cast concrete such Block, tile, Pipes, etc. (Another Example in Delhi Metro pillars)
4. Silos and chimneys.
5. Non-structural works such as plastering, flooring etc.

53 Grade OPC

53 Grade OPC is a higher strength cement to meet the needs of the consumer for higher strength concrete. As per BIS requirements the minimum 28 days compressive strength of 53 Grade OPC should not be less than 53 MPa. For certain specialized works, such as pre-stressed concrete and certain items of precast concrete requiring consistently high strength concrete, 53 grade OPC is found very useful. 53 grades OPC produce higher-grade concrete at very economical cement content. In concrete mix design, for concrete M-20 and above grades a saving of 8 to 10 % of cement may be achieved with the use of 53 grade OPC.

Fineness=**225 m2/kg**

Compressive strength after 3 days=**27 N/mm2**

Compressive strength after 7 days=**37 N/mm2**

Compressive strength after 28 days=**53 N/mm2**

Grade 53 cement has low chloride content and is moderately sulphate resisting. Volume of cement required is less due to high strength and surface area which saves the cost of construction.

Grade 53 cement is used in:

1. RCC works(Preferably where grade of concrete is M-25 and above)
2. Industrial buildings, roads and subways
3. Pre-cast concrete.
4. R.C.C Bridges.
5. Concrete sleeper for railways.

9. What are the raw materials for manufacture of cement and mention its functions.(MAY 2016)

The raw materials required for manufacture of Portland cement are calcareous materials, such as limestone or chalk, and argillaceous material such as shale or clay. Cement factories are established where these raw materials are available in plenty. Cement factories have come up in many regions in India, eliminating the inconvenience of long distance transportation of raw and finished materials.

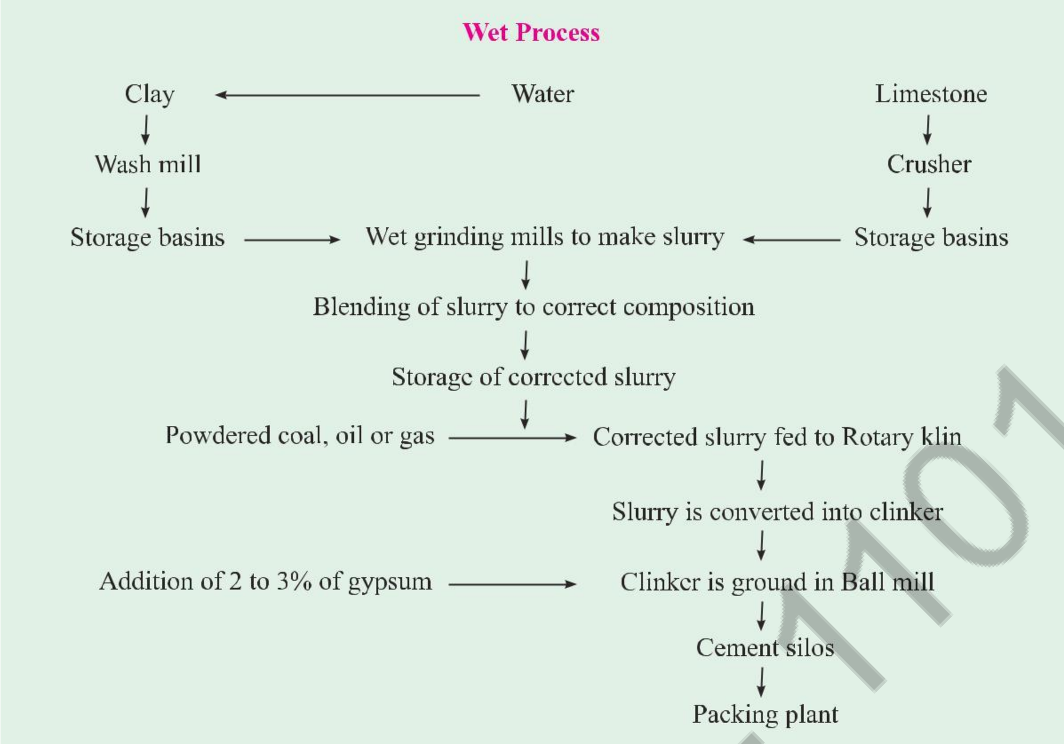
The process of manufacture of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon their purity and composition and burning them in a kiln at a temperature of about 1300 to 1500°C, at which temperature, the material sinters and partially fuses to form nodular shaped clinker. The clinker is cooled and ground to fine powder with addition of about 3 to 5% of gypsum. The product formed by using this procedure is Portland cement

There are two processes known as “wet” and “dry” processes depending upon whether the mixing and grinding of raw materials is done in wet or dry conditions. With a little change in the above process we have the semi-dry process also where the raw materials are ground dry and then mixed with about 10-14 per cent of water and further burnt to clinkering temperature.

For many years the wet process remained popular because of the possibility of more accurate control in the mixing of raw materials. The techniques of intimate mixing of raw materials in powder form was not available then. Later, the dry process gained momentum with the modern development of the technique of dry mixing of powdered materials using compressed air. The dry process requires much less fuel as the materials are already in a dry state, whereas in the wet process the slurry contains about 35 to 50 per cent water. To dry the slurry we thus require more fuel. In India most of the cement factories used the wet process. Recently a number of factories have been commissioned to employ the dry process method. Within next few years most of the cement factories will adopt dry process system.

In the wet process, the limestone brought from the quarries is first crushed to smaller fragments. Then it is taken to a ball or tube mill where it is mixed with clay or shale as the case may be and ground to a fine consistency of slurry with the addition of water. The slurry is a liquid of creamy consistency with water content of about 35 to 50 per cent, wherein particles, crushed to the fineness of Indian Standard Sieve number 9, are held in suspension. The slurry is pumped to slurry tanks or basins where it is kept in an agitated condition by means of rotating arms with chains or blowing compressed air from the bottom to prevent settling of limestone and clay particles. The composition of the slurry is tested to give the required chemical composition and corrected periodically in the tube mill and also in the slurry tank by blending slurry from different storage tanks. Finally, the corrected slurry is stored in the final storage tanks and kept in a homogeneous condition by the agitation of slurry.

The corrected slurry is sprayed on to the upper end of a rotary kiln against hot heavy hanging chains. The rotary kiln is an important component of a cement factory. It is a thick steel cylinder of diameter anything from 3 metres to 8 metres, lined with refractory materials, mounted on roller bearings and capable of rotating about its own axis at a specified speed. The length of the rotary kiln may vary anything from 30 metres to 200 metres. The slurry on being sprayed against a hot surface of flexible chain loses moisture and becomes flakes. These flakes peel off and fall on the floor. The rotation of the rotary kiln causes the flakes to move from the upper end towards the lower end of the kiln subjecting itself to higher and higher temperature. The kiln is fired from the lower end. The fuel is either powered coal, oil or natural gass. By the time the material rolls down to the lower end of the rotary kiln, the dry material



undergoes a series of chemical reactions until finally, in the hottest part of the kiln, where the temperature is in the order of 1500°C, about 20 to 30 per cent of the materials get fused. Lime, silica and alumina get recombined. The fused mass turns into nodular form of size 3 mm to 20 mm known as clinker. The clinker drops into a rotary cooler where it is cooled under controlled conditions The clinker is stored in silos or bins. The clinker weighs about 1100 to 1300 gms per litre. The litre weight of clinker indicates the quality of clinker.

The cooled clinker is then ground in a ball mill with the addition of 3 to 5 per cent of gypsum in order to prevent flash-setting of the cement. A ball mill consists of several compartments charged with progressively smaller hardened steel balls. The particles crushed to the required fineness are separated by currents of air and taken to storage silos from where the cement is bagged or filled into barrels for bulk supply to dams or other large work sites.In the modern process of grinding, the particle size distribution of cement particles are maintained in such a way as to give desirable grading pattern. Just as the good grading of aggregates is essential for making good concrete, it is now recognised that good grading pattern of the cement particles is also important.

1. Explain abrasion test for coarse aggregate (MAY 2016)

Apart from testing aggregate with respect to its crushing value, impact resistance, 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

Los Angeles Test

Los Angeles test was developed to overcome some of the defects found in Deval test. Los Angeles test is characterised by the quickness with which a sample of aggregate may be tested. The applicability of the method to all types of commonly used aggregate makes this method popular. The test involves taking specified quantity of standard size material along with specified number of abrasive charge in a standard cylinder and revolving if for certain specified revolutions. The particles smaller than 1.7 mm size is separated out. The loss in weight expressed as percentage of the original weight taken gives the abrasion value of the aggregate. The abrasion value should not be more than 30 per cent for wearing surfaces and not more than 50 per cent for concrete other than wearing surface. Table 3.4 gives average values of crushing strength of rocks, aggregate crushing value, abrasion value, impact value and attrition value for different rock groups

Dorry abrasion test:

The test measures **resistance of aggregates to surface wear by abrasion.**

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 hardness of the rock sample is expressed in an empirical formula.

Hardness = 20 – (Loss in Grams/3)

Good aggregate should show an abrasion value of not less than 17. A aggregate sample with a value of less than 14 would be considered poor.

2. Describe the classification of aggregate.(NOV 2019)

Aggregates can be classified as

(*i*) Normal weight aggregates,

(*ii*) Light weight aggregates and

(*iii*) Heary weight aggregates.

Light weight aggregate and heavy weight aggregate will be discussed elsewhere under appropriate topics.

Normal weight aggregates can be further classified as natural aggregates and artificial aggregates.

Natural	***Artificial***
Sand, Gravel, Crushed	Broken Brick,
Rock such as Granite,	Air-cooled Slag.
Quartzite, Basalt,	Sintered fly ash
Sandstone	Bloated clay

Aggregates can also be classified on the basis of the size of the aggregates as coarse aggregate and fine aggregate

12. Explain the structure of hydrated cement (NOV 2018)

To understand the behaviour of concrete, it is necessary to acquaint ourselves with the structure of hydrated hardened cement paste. If the concrete is considered as two phase material, namely, the paste phase and the aggregate phase, the understanding of the paste phase becomes more important as it influences the behaviour of concrete to a much greater extent. It will be discussed later that the strength, the permeability, the durability, the drying shrinkage, the elastic properties, the creep and volume change properties of concrete is greatly influenced by the paste structure. The aggregate phase though important, has lesser influence on the properties of concrete than the paste phase. Therefore, in our study to understand concrete, it is important that we have a deep understanding of the structure of the hydrated hardened cement paste at a phenomenological level.

Transition Zone

Concrete is generally considered as two phase material *i.e.*, paste phase and aggregates phase. At macro level it is seen that aggregate particles are dispersed in a matrix of cement paste.

At the microscopic level, the complexities of the concrete begin to show up, particularly in the vicinity of large aggregate particles. This area can be considered as a third phase, the transition zone, which represents the interfacial region between the particles of coarse aggregate and hardened cement paste. Transition zone is generally a plane of weakness and, therefore, has far greater influence on the mechanical behaviour of concrete.

Although transition zone is composed of same bulk cement paste, the quality of paste in the transition zone is of poorer quality. Firstly due to internal bleeding, water accumulate below elongated, flaky and large pieces of aggregates. This reduces the bond between paste

and aggregate in general. If we go into little greater detail, the size and concentration of crystalline compounds such as calcium hydroxide and ettringite are also larger in the transition zone. Such a situation account for the lower strength of transition zone than bulk cement paste in concrete.

Due to drying shrinkage or temperature variation, the transition zone develops microcracks even before a structures is loaded. When structure is loaded and at high stress levels, these microcracks propagate and bigger chracks are formed resulting in failure of bond. Therefore, transition zone, generally the weakest link of the chain, is considered strength limiting phase in concrete. It is because of the presence of transition zone that concrete fails at considerably lower stress level than the strength of bulk paste or aggregate.

Sometimes it may be necessary for us to look into the structure of hardening concrete also. The rate and extent of hydration of cement have been investigated in the past using a variety of techniques. The techniques used to study the structure of cement paste include measurements of setting time, compressive strength, the quantity of heat of hydration evolved, the optical and electron microscope studies coupled with chemical analysis and thermal analysis of hydration products. Continuous monitoring of reactions by X-ray diffractions and conduction calorimetry has also been used for the study.

Measurements of heat evolved during the exothermic reactions also gives valuable insight into the nature of hydration reactions. Since approximately 50% of a total heat.

13. Explain the chemical composition and properties of cement (NOV 2018)

Oxide	*Per cent content*
CaO	60–67
SiO_2	17–25
Al_2O_3	3.0–8.0
Fe_2O_3	0.5–6.0
MgO	0.1–4.0
Alkalies (K_2O, Na_2O)	0.4–1.3
SO_3	1.3–3.0

Fineness:

The uniform size among the particles in the cement is the main reason for their undeterrable strength. The finer the particles the perfect the strength build-up in them. High fineness denotes that there is more area available for water reaction in the cement.

Soundness:

The ability to not change the properties when water is mixed with it is called as soundness. Material which is sound, don't get cracks or structural weakness easily. This is the sole reason for cement being very useful. Concrete and mortar, which are made from cement. have high soundness.

Consistency:

The uniformity in the particle nature is what makes the whole material very consistent. Due to regularity, the whole finished product is very consistent in strength.

Setting Time:

The time at which the cement paste loses its plasticity after the addition of water is known as initial Setting Time. The time consumed by paste to become hard mass is known as final Setting Time. The initial setting time is required for mixing, transporting and placing of the concrete. At the time of initial setting time the temperature rises rapidly and at the final setting time, the temperature reaches the peak value.

Heat of Hydration:

The chemical reaction between cement and water is known as hydration of cement and heat generated in this is known as heat of hydration.

Comprehensive strength:

This is the strength of cement which helps it to resist Compressive stress.

10. What are the initial and final setting time of cement? What is their importance?(NOV 2017)

Cement is widely used material in building construction for making cement mortar and concrete. As we know that cement start hydrates when it is mixed with water. In presence of water, cement has a property to achieve strength and get hardened within a short period. So its mandate to place the cement in position without losing its plasticity. To achieve this, the setting time of cement is calculated.

Setting time of cement:

When cement is mixed with water, it hydrates and makes cement paste. This paste can be moulded into any desired shape due to its plasticity. Within this time cement continues with reacting water and slowly cement starts losing its plasticity and set harden. This complete cycle is called Setting time of cement.

Initial Setting time of Cement:

The time to which cement can be moulded in any desired shape without losing it strength is called Initial setting time of cement Or

The time at which cement starts hardens and completely loses its plasticity is called Initial setting time of cement. Or

The time available for mixing the cement and placing it in position is an Initial setting time of cement. If delayed further, cement loses its strength.

For Ordinary Portland Cement, The initial Setting Time is 30 minutes.

Final setting time of Cement:-

The time at which cement completely loses its plasticity and became hard is a final setting time of cement.Or

The time taken by cement to gain its entire strength is a Final setting time of cement.

For Ordinary Portland Cement, The Final Setting Time is 600 minutes (10hrs).

Significance of calculating Initial and final setting time of cement:-

Well, After mixing cement with water, it takes time to place the cement paste in position, initial setting time possess a primary role in strength & it is mandated that cement paste or concrete is placed in position before it crosses initial setting time. i.e.,30mins. And it shouldn’t be disturbed until it completes Final setting time i.e., 600mins for Ordinary Portland Cement.

Factors that affect initial and final setting time of cement:-

The fineness of cement, the presence of salts in sand, atmospheric conditions. For example, cement requires a temperature of 27°c to complete Hydration, during winters the climate is low which stops the hydration and takes a longer time to set harden.

11. How will you determine the compressive strength of cement? Explain briefly the procedure.(NOV 2017)

CEMENT - DETERMINATION OF STRENGTH

Preparing Samples Compressive, event. flexural strength determinates on prismatic test specimens 40 mm x 40 mm x 160 mm in size. These specimens are cast from a batch of plastic mortar containing one part by mass of cement and three parts by mass of standard sand with a water-cement ratio of 0,50.

The mortar is prepared by mechanical mixing and is compacted in a mould using a standard jolting apparatus. Alternative compaction equipment and techniques may be used provided that they have been shown to give cement strength results which do not differ significantly from those obtained using the standard jolting apparatus. The specimens in the mould are stored in a moist atmosphere for 24 h and then the demoulded specimens are stored under water until strength testing. At the required age, the specimens are taken from their wet storage, broken in flexure into two halves and each half tested for strength in compression.

Cement.

When the cement to be tested is kept for more than 24 h between sampling and testing, it shall be stored in completely filled and air tight containers made from material which does not react with cement.

Water.

Distilled water shall be used for reference testing. For other test, drinking water may be used.

Mixer shall consist from stainless steel bowl with a capacity of about 5 l and stainless blade

APPARATUS

- Vibrating machine confirming to IS: 10080 – 1982.
- Poking rod confirming to IS: 10080-1982.
- Cube moulds shall be of 70.60mm size confirming to IS: 10080-1982.
- Gauging trowel having steel blade 100 to 150mm in length with straight edge weighing 210 + 10gms.

• Balance of capacity 10Kg and sensitivity 1gram.

PROCEDURE

• Unless otherwise specified this test shall be conducted at a temperature 270 + 2 0 C.

• Weigh the material required for each cube separately.

• The quantity of cement, standard sand and water required for each cube are as follows

Cement = 200gms 2mm to 1mm - 200gms

Standard Sand = 600gms 1mm to 500mic - 200gms Conforming to IS: 650 –1991. 500mic to 90mic - 200gms Water =(P/ 4+ 3) Percentage of combined mass of cement and sand.

P is the consistency of cement as per IS: 4031 (Part 4) 1988.

• Place on a nonporous plate, a mixture cement and standard sand. • Mix it dry with a trowel for one minute and then with water until the mixture is of uniform colour.

• The time of mixing shall in any event be not less than 3 minutes and should be the time taken to obtain uniform colour exceeds 4 minutes.

• In assembling the moulds ready for use, cover the joints between the halves of the mould with a thin film of petroleum jelly and apply a similar coating of petroleum jelly between the contact surface of the bottom of the mould and base plate in order to ensure that no water escapes during vibration.

• Place the assembled mould on the table of the vibration machine and hold it firmly in position by means of suitable clamp, attach a hopper of suitable size and shape securely at the top of the mould to facilitate filling and hopper shall not be removed until the completion of vibration period.

• Immediately after fixing the mould in the vibrating machine, place the mortar in the cube mould and prod with the rod.

• Prod the mortar 20 times in about 8 seconds to ensure elimination of entrapped air and honey combing.

• Place the remaining mortar in the cube mould and prod again as specified for the first layer and then compact the mortar by vibration.

• The period of vibration shall be two minutes at the specified speed of 12000 + 400 vibrations per minute.

• Remove the mould from the vibrating machine and cut of the excess mortar with a straight edge.

• Store the test specimens in a place free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27 + 20 C for 24 + 1/2 hours from the addition of water to the dry ingredients

Casting of cement mortar cubes

- After this period, mark the specimens and remove from the moulds and unless required for test within 24 hours.
- Immediately submerge the cubes in a clean, fresh water or saturated lime solution and keep there until taken out just prior to test.
- Renew the water or solution in which the specimens are submerged for every seven days, and the temperature of water is maintained with the specified limits.
- Conduct testing at recognized ages of the specimens, the most usual being 7 and 28 days.
- When it may be necessary to obtain the early strength, tests may be conducted at the age of 72 + 2 hours.
- Calculate the ages from the addition of water to the dry ingredients.
- Test at least three specimens preferably from different batches at each selected age.

CALCULATION

$$\text{Compressive strength} = \frac{\text{Load}}{\text{Cross sectional area of the specimen}} \ N/mm^2$$

12. Discuss the characteristics of good aggregates.(NOV 2017)

Aggregates are used in concrete to provide economy in the cost of concrete. Aggregates act as filler only. These do not react with cement and water.

But there are properties or characteristics of aggregate which influence the properties of resulting concrete mix. These are as follow.

1. Composition
2. Size & Shape
3. Surface Texture
4. Specific Gravity
5. Bulk Density
6. Voids
7. Porosity & Absorption
8. Bulking of Sand
9. Fineness Modulus of Aggregate

10. Surface Index of Aggregate
11. Deleterious Material
12. Crushing Value of Aggregate
13. Impact Value of Aggregate
14. Abrasion Value of Aggregate

1. COMPOSITION

Aggregates consisting of materials that can react with alkalies in cement and cause excessive expansion, cracking and deterioration of concrete mix should never be used. Therefore it is required to test aggregates to know whether there is presence of any such constituents in aggregate or not.

2. SIZE & SHAPE

The size and shape of the aggregate particles greatly influence the quantity of cement required in concrete mix and hence ultimately economy of concrete. For the preparation of economical concrete mix on should use largest coarse aggregates feasible for the structure. IS-456 suggests following recommendation to decide the maximum size of coarse aggregate to be used in P.C.C & R.C.C mix.

Maximum size of aggregate should be less than

- One-fourth of the minimum dimension of the concrete member.
- One-fifth of the minimum dimension of the reinforced concrete member.
- The minimum clear spacing between reinforced bars or 5 mm less than the minimum cover between the reinforced bars and form, whichever is smaller for heavily reinforced concrete members such as the ribs of the main bars.

The size & shape of aggregate particles influence the properties of freshly mixed concrete more as compared to those of hardened concrete.

3. SURFACE TEXTURE

The development of hard bond strength between aggregate particles and cement paste depends upon the surface texture, surface roughness and surface porosity of the aggregate particles.

If the surface is rough but porous, maximum bond strength develops. In porous surface aggregates, the bond strength increases due to setting of cement paste in the pores.

4. SPECIFIC GRAVITY

The ratio of weight of oven dried aggregates maintained for 24 hours at a temperature of 100 to 110^0C, to the weight of equal volume of water displaced by saturated dry surface aggregate is known as specific gravity of aggregates.

Specific gravities are primarily of two types.

- Apparent specific gravity
- Bulk specific gravity

Specific gravity is a mean to decide the suitability of the aggregate. Low specific gravity generally indicates porous, weak and absorptive materials, whereas high specific gravity indicates materials of good quality. Specific gravity of major aggregates falls within the range of 2.6 to 2.9.

Specific gravity values are also used while designing concrete mix.

5. BULK DENSITY

It is defined as the weight of the aggregate required to fill a container of unit volume. It is generally expressed in kg/litre.

Bulk density of aggregates depends upon the following 3 factors.

- Degree of compaction
- Grading of aggregates
- Shape of aggregate particles

6. VOIDS

The empty spaces between the aggregate particles are known as voids. The volume of void equals the difference between the gross volume of the aggregate mass and the volume occupied by the particles alone.

7. POROSITY & ABSORPTION

The minute holes formed in rocks during solidification of the molten magma, due to air bubbles, are known as pores. Rocks containing pores are called porous rocks.

Water absorption may be defined as the difference between the weight of very dry aggregates and the weight of the saturated aggregates with surface dry conditions.

Depending upon the amount of moisture content in aggregates, it can exist in any of the 4 conditions.

- Very dry aggregate (having no moisture)

- Dry aggregate (contain some moisture in its pores)
- Saturated surface dry aggregate (pores completely filled with moisture but no moisture on surface)
- Moist or wet aggregates (pores are filled with moisture and also having moisture on surface)

8. BULKING OF SAND

It can be defined as in increase in the bulk volume of the quantity of sand (i.e. fine aggregate) in a moist condition over the volume of the same quantity of dry or completely saturated sand. The ratio of the volume of moist sand due to the volume of sand when dry, is called bulking factor.

Fine sands bulk more than coarse sand

When water is added to dry and loose sand, a thin film of water is formed around the sand particles. Interlocking of air in between the sand particles and the film of water tends to push the particles apart due to surface tension and thus increase the volume. But in case of fully saturated sand the water films are broken and the volume becomes equal to that of dry sand.

9. FINENESS MODULUS

Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves ranging from 80 mm to 150 micron and dividing this sum by 100.

Fineness modulus is generally used to get an idea of how coarse or fine the aggregate is. More fineness modulus value indicates that the aggregate is coarser and small value of fineness modulus indicates that the aggregate is finer.

10. SPECIFIC SURFACE OF AGGREGATE

The surface area per unit weight of the material is termed as specific surface. This is an indirect measure of the aggregate grading. Specific surface increases with the reduction in the size of aggregate particle. The specific surface area of the fine aggregate is very much more than that of coarse aggregate.

11. DELETERIOUS MATERIALS

Aggregates should not contain any harmful material in such a quantity so as to affect the strength and durability of the concrete. Such harmful materials are called deleterious materials. Deleterious materials may cause one of the following effects

- To interfere hydration of cement
- To prevent development of proper bond

- To reduce strength and durability
- To modify setting times

Deleterious materials generally found in aggregates, may be grouped as under

- Organic impurities
- Clay , silt & dust
- Salt contamination

12. CRUSHING VALUE

The aggregates crushing value gives a relative measure of resistance of an aggregate to crushing under gradually applied compressive load. The aggregate crushing strength value is a useful factor to know the behavior of aggregates when subjected to compressive loads.

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14. ABRASION VALUE OF AGGREGATES

The abrasion value gives a relative measure of resistance of an aggregate to wear when it is rotated in a cylinder along with some abrasive charge.

13. Briefly discuss the following tests on aggregates: specific gravity test, crushing test and impact test.(NOV 2017)

SPECIFIC GRAVITY TEST

OBJECTIVE

For determination of specific gravity & water absorption of aggregates.

EQUIPMENT & APPARATUS

- Wire basket
- Oven (300^{0}c)
- Container for filling water and suspending the basket
- An air tight container
- Balance[0-10 kg]
- Shallow tray & absorbent clothes.

PREPARATION OF SAMPLE

The sample to be tested is separated from the bulk by quartering or by using sample divider.

PROCEDURE

1. About 2kg of the aggregate sample is washed thoroughly to remove fines, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22 to 32^0C with a cover of at least 50 mm of water above the top of the basket
2. Immediately after the immersion the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second. The basket and the aggregate should remain completely immersed in water for a period of 24±0.5 hours afterwards.
3. The basket and the sample are then weighed while suspended in water at a temperature of 22 to 32^0C. The weight is noted while suspended in water (W_1) g.
4. The basket and the aggregate are then removed from water and allowed to drain for a few minutes, after which the aggregates are transferred to one of the dry absorbent clothes.
5. The empty basket is then returned to the tank of water, jolted 25 times and weights in water (W_2) g.
6. The aggregates placed in the dry absorbent clothes are surface dried till no further moisture could be removed by this clothe.
7. Then the aggregate is transferred to the second dry cloth spread in a single layer, covered and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. 10 to 60 minutes drying may be needed. The surface dried aggregate is then weighed W_3 g.
8. The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110^0C for 24 hours. It is then removed from the oven, cooled in air tight container and weighed W_4 g.

CALCULATION

Weight of saturated aggregate suspended in water with basket = W_1 g

Weight of basket suspended in water = W_2 g

Weight of saturated aggregate in water = (W_1-W_2)g = W_s g

Weight of saturated surface dry aggregate in air = W_4 g

Weight of water equal to the volume of the aggregate = (W_3-W_s) g

$$\text{Specific gravity} = \frac{W_4}{W_3 - (W_1 - W_2)}$$

$$\text{Apparent sp.gravity} = \frac{W_4}{(W_4 - (W_1 - W_2))}$$

CRUSHING VALUE TEST

OBJECTIVE

For determination of the aggregate crushing value of coarse aggregate, which passes 12.5 mm. IS sieve and retained on 10 mm. IS sieve.

EQUIPMENT & APPARATUS

- Steel Cylinder
- Sieves (12.5mm,10mm)
- Cylindrical metal measure
- Tamping Rod
- Balance (0-10kg)
- Oven (300^0c)
- Compression testing Machine (2000KN)

PREPARATION OF SAMPLE

Test sample consist of aggregate passing a 12.5mm IS sieve and retained on a 10mm IS sieve. The aggregate to be tested is dried in oven for a period of not less than 4 hours.

PROCEDURE

1. The cylindrical steel cup is filled with 3 equal layers of aggregate and each layer is tamped 25 strokes by the rounded end of tamping rod and the surplus aggregate struck off, using the tamping rod as a straight edge.
2. The net weight of aggregate in the cylindrical steel cup is determined to the nearest gram (W_A) and this weight of aggregate is used for the duplicate test on the same material.
3. The cup is fixed firmly in position on the base of the machine and the whole of the test sample is added in thirds, each third being subjected to 25stokes from tamping rod.
4. The surface is leveled and the plunger is inserted so that it rests horizontally on the surface. The whole assembly is then placed between the platens of testing machine and loaded at a uniform rate so as to reach a load of 40 tones in 10 minutes.

5. The load is then released and all aggregate is removed from the cup and sieved on 2.36 mm. IS sieve until no further significant amount passes in one minute.
6. The fraction passing the sieve is weighed to an accuracy of 0.1 g (W_B)

CALCULATION

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place.

Aggregate crushing Value =$(W_B/W_A) \times 100$

IMPACT VALUE TEST

OBJECTIVE

For determination of the aggregate impact value of coarse aggregate, which passes 12.5 mm. IS sieve and retained on 10 mm. IS sieve.

EQUIPMENT & APPARATUS

Aggregate Impact Test Machine

- Sieves (12.5mm,10mm)
- Cylindrical metal measure
- Tamping Rod
- Balance (0-10kg)
- Oven(300^0c)

PREPARATION OF TEST SAMPLE

Test sample consist of aggregate passing a 12.5mm IS sieve and retained on a 10mm IS sieve. The aggregate to be tested is dried in oven for a period of not less than 4hours.

PROCEDURE

1. The cylindrical steel cup is filled with 3 equal layers of aggregate and each layer is tamped 25 strokes by the rounded end of tamping rod and the surplus aggregate struck off, using the tamping rod as a straight edge.
2. The net weight of aggregate in the cylindrical steel cup is determined to the nearest gram (W_A) and this weight of aggregate is used for the duplicate test on the same material.
3. The cup is fixed firmly in position on the base of the machine and the whole of the test sample is placed in it and compacted by a single tamping of 25 strokes of tamping rod.

4. The hammer is raised until its lower face is 380 mm. above the upper surface of the aggregate in the cup, and allowed to fall freely onto the aggregate 15 times, each being delivered at an interval of not less than one second.
5. The crushed aggregate is removed from the cup and sieved on 2.36 mm. IS sieve until no further significant amount passes in one minute.
6. The fraction passing the sieve is weighed to an accuracy of 0.1 g (W_B)

CALCULATION

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place.

Aggregate impact Value = $(W_B / W_A) \times 100$

14. Explain the water absorption and moisture content text on aggregate (NOV 2019)

Determination of moisture content in aggregate is of vital importance in the control of the quality of concrete particularly with respect to workability and strength. The measurement of the moisture content of aggregates is basically a very simple operation. But it is complicated by several factors. The aggregate will absorb a certain quantity of water depending on its porosity. The water content can be expressed in terms of the weight of the aggregate when absolutely dry, surface dry or when wet. Water content means the free water, or that held on the surface of the aggregate or the total water content which includes the absorbed water plus the free water, or the water held in the interior portion of aggregate particles.

The measurement of the moisture content of aggregate in the field must be quick, reasonably accurate and must require only simple appartus which can be easily handled and used in the field. Some of the methods that are being used for determination of moisture content of aggregate are given below:

- Drying Method
- Displacement Method
- Calcium Carbide Method
- Measurement by electrical meter.
- Automatic measurement
- Drying Method

The application of drying method is fairly simple. Drying is carried out in a oven and the loss in weight before and after drying will give the moisture content of the aggregate. If the drying is done completely at a high temperature for a long time, the loss in weight will include not only the surface water but also some absorbed water. Appropriate corrections may be made for the saturated and surface dry condition. The oven drying method is too slow for field use. A fairly quick result can be obtained by heating the aggregate quickly in an open pan. The process can also be speeded up by pouring inflammable liquid such as methylated spirit or acetone over the aggregate and igniting it.

Displacement Method

In the laboratory the moisture content of aggregate can be determined by means of pycnometer or by using Siphon-Can Method. The principle made use of is that the specific gravity of normal aggregate is higher than that of water and that a given weight of wet aggregate will occupy a greater volume than the same weight of the aggregate when dry. By knowing the specific gravity of the dry aggregate, the specific gravity of the wet aggregate can be calculated. From the difference between the specific gravities of the dry and wet aggregates, the moisture content of the aggregate can be calculated.

Calcium Carbide Method

A quick and reasonably accurate method of determining the moisture content of fine aggregate is to mix it with an excess of calcium carbide in a strong air-tight vessel fitted with pressure gauge. Calcium carbide reacts with surface moisture in the aggregate to produce acetylene gas. The pressure of acetylene gas generated depends upon the moisture content of the aggregates. The pressure gauge is calibrated by taking a measured quantity of aggregate of known moisture content and then such a calibrated pressure gauge could be used to read the moisture content of aggregate directly. This method is ofen used to find out the moisture content of fine aggregate at the site of work. The equipment consists of a small balance, a standard scoop and a container fixed with dial gauge. The procedure is as follows: Weigh 6 grams of representative sample of wet sand and pour it into the container. Take one scoop full of calcium carbide powder and put it into the container. Close the lid of the container and shake it rigorously. Calcium carbide reacts with surface moisture and produces acetylene gas, the pressure of which drives the indicator needle on the pressure gauge. The pressure gauge is so calibrated, that it gives directly percentage of moisture. The whole job takes only less than 5 minutes and as such, this test can be done at very close intervals of time at the site of work.

Electrical Meter Method

Recently electrical meters have been developed to measure instantaneous or continuous reading of the moisture content of the aggregate. The principle that the resistance gets changed with the change in moisture content of the aggregate has been made use of. In some sophisticated batching plant, electrical meters are used to find out the moisture content and also to regulate the quantity of water to be added to the continuous mixer.

Automatic Measurement

In modern batching plants surface moisture in aggregates is automatically recorded by means of some kind of sensor arrangement. The arrangement is made in such a way that the quantity of free water going with aggregate is automatically recorded and simultaneously that much quantity of water is reduced. This sophisticated method results in an accuracy of ± 0.2 to 0.6%.