

UNIT – I

CONSTITUENT MATERIALS

1. Define Aggregate.

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids. Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement or asphalt cement) to form composite materials or concrete.

2. What are the Various test which are to be done on aggregates ?

Various test which are done on aggregates are listed below

- Sieve Analysis
- Water Absorption
- Aggregate Impact Value
- Aggregate Abrasion Value
- Aggregate Crushing Value

3. What is grade of cement? List any three grades of cement with their strengths.

Grade of cement represents the specific 28 days compressive strength. The following three grades are given along with their compressive strengths

33 Grade OPC – 33 MPa

43 Grade OPC – 43 MPa

53 Grade OPC – 53 MPa

4. What is meant by hydration of cement?

Cements used for making concrete have the property of reacting chemically with water in an exothermic process called hydration that results in water treatment products.

5. What is false set in cement? write reasons for it

False set in cement occurs when the gypsum dehydrates as a result of contacting hot clinker at high temperatures in a grinding mill. This creates plaster to form gypsum and stiffen the concrete.

6. Define Abram's water cement law.

According to Abram's water cement law, the strength of concrete depends on the water cement ratio used.

7. What are the properties of Aggregate?

Moisture conditions

The moisture condition of aggregates refers to the presence of water in the pores and on the surface of aggregates.

Density and specific gravity

Density (D): weight per unit volume (excluding the pores inside a single aggregate)

Solid Weight / Bulk Volume = Bulk density: the volume includes the pores inside a single aggregate.

8. What are the types of cement?

Ordinary Portland cement, rapid hardening cement, low heat cement, blast furnace slag cement, sulphate resistant cement, air entraining cement, white and coloured cement, high alumina cement, pozzolanic cement, super sulphate cement, expansive cement, quick setting cement, water repellant cement, water proofing cement.

9. What is the function of gypsum in the manufacture of cement?

In order to delay the setting action of cement, when mixed with water, a little percentage of gypsum is added in the clinker before grinding them to fine powder.

10. What are bogue's compounds?

- | | | |
|-------------------------------|--|-----------------------|
| • Tricalcium silicate | $\text{CaO} \cdot \text{SiO}_2$ | C_3S |
| • Dicalcium silicate | $\text{CaO} \cdot \text{SiO}_2$ | C_2S |
| • Tricalcium aluminate | $\text{CaO} \cdot \text{Al}_2\text{O}_3$ | C_3A |
| • Tetracalcium aluminoferrite | $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ | C_4AF |

11.. What are the Chemical Composition of cement?

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($\text{K}_2\text{O}, \text{Na}_2\text{O}$)	0.4–1.3
SO_3	1.3–3.0

12. Mention the test adopted to test the properties of cement in laboratories?

- Fineness
- Consistency test
- Setting time
- Soundness
- Compressive strength

13. Mention the test adopted to test the properties of cement in field?

- Open the bag and take a good look at the cement, there should not be any visible lumps
- Thrust your hand into the cement bag should feel cool feeling
- Take a pinch of cement and feel between the fingers. It should give a smooth feeling not a gritty feeling
- Take a hand full of cement and throw it on a bucket full of water, the particle should float for some time before they sink.

14. What is sulphate attack? What are its effects?

Ordinary Portland cement is susceptible to the attack of sulphates, in particular to the action of magnesium sulphate. Sulphates react both with the free calcium hydroxide in set-cement to form calcium sulphate and with hydrate of calcium aluminate to form calcium sulfo aluminate, the volume of which is approximately 227% of the volume of the original aluminates. Their expansion within the frame work of hardened cement paste results in cracks and subsequent disruption. Solid sulphate do not attack the cement compound. Sulphates in solution permeate into hardened concrete and attack calcium hydroxide, hydrated calcium aluminate and even hydrated silicates. The above is known as sulphate attack. Sulphate attack is greatly accelerated by alternate wetting and drying which normally takes place in marine structures in the zone of tidal variations.

15. What are the qualities of water?

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 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.

PART - B

1. Explain in detail about the various types of cement.

1. Ordinary Portland Cement
 - (i) Ordinary Portland Cement 33 Grade
 - (ii) Ordinary Portland Cement 43 Grade
 - (iii) Ordinary Portland Cement 53 Grade
2. Rapid Hardening Cement
3. Extra Rapid Hardening Cement
4. Sulphate Resisting Cement
5. Portland Slag Cement
6. Quick Setting Cement
7. Super Sulphated Cement
8. Low Heat Cement
9. Portland Pozzolana Cement
10. Air Entraining Cement
11. Coloured Cement: White Cement
12. Hydrophobic Cement
13. Masonry Cement
14. Expansive Cement
15. High Alumina Cement

Ordinary Portland Cement

The OPC was classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS 4031-1988.

- If the 28 days strength is not less than 33N/mm^2 , it is called 33 grade cement, If the strength is not less than 43N/mm^2 , it is called 43 grade cement, and If the strength is not less than 53N/mm^2 , it is called 53 grade cement. But the actual strength obtained are much higher than the BIS specifications.
- To upgrade the qualities of cement by using high quality limestone, modern equipments, closer on line control of constituents, maintaining better particle size distribution, finer grinding and better packing. Generally use of high grade cements offer many advantages for

making stronger concrete. Although they are little costlier than low grade cement, they offer 10-20% savings in cement consumption and also they offer many other hidden benefits. One of the most important benefits is the faster rate of development of strength.

Rapid Hardening Cement

- This cement is similar to ordinary Portland cement. Rapid hardening cement which develops higher rate of development of strength should not be confused with quick-setting cement which only sets quickly. Rapid hardening cement develops at the age of three days, the same strength as that is expected of ordinary Portland cement at seven days.
- The rapid rate of development of strength is attributed to the higher fineness of grinding (specific surface not less than 3250 sq. cm per gram) and higher C_3S and lower C_2S content.
- A higher fineness of cement particles expose greater surface area for action of water and also higher proportion of C_3S results in quicker hydration. Consequently, Rapid hardening cement gives out much greater heat of hydration during the early period. Therefore, rapid hardening cement should not be used in mass concrete construction.

Uses :

- (a) In pre-fabricated concrete construction.
- (b) Where formwork is required to be removed early for re-use elsewhere,
- (c) Road repair works,
- (d) In cold weather concrete where the rapid rate of development of strength reduces the vulnerability of concrete to the frost damage.

Sulphate Resisting Cement

- Ordinary Portland cement is susceptible to the attack of sulphates, in particular to the action of magnesium sulphate. Sulphates react both with the free calcium hydroxide in set-cement to form calcium sulphate and with hydrate of calcium aluminate to form calcium sulpho aluminate, the volume of which is approximately 227% of the volume of the original aluminates. Their expansion within the frame work of hardened cement paste results in cracks and subsequent disruption.
- Solid sulphate do not attack the cement compound. Sulphates in solution permeate into hardened concrete and attack calcium hydroxide, hydrated calcium aluminate and even hydrated silicates. The above is known as sulphate attack. Sulphate attack is greatly

accelerated if accompanied by alternate wetting and drying which normally takes place in marine structures in the zone of tidal variations.

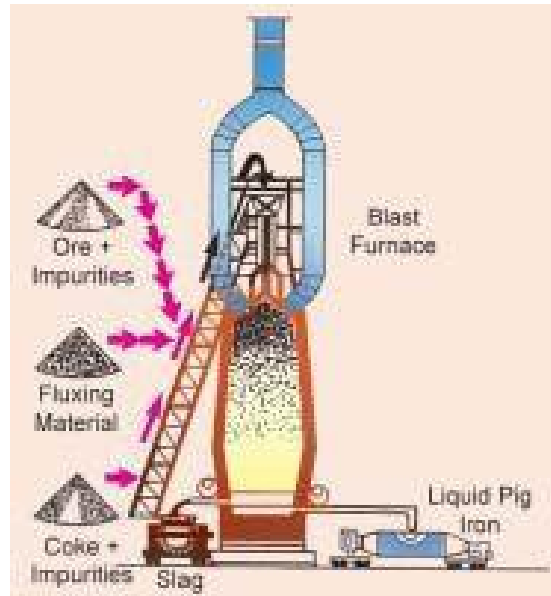
- To remedy the sulphate attack, the use of cement with low C_3A content is found to be effective. Such cement with low C_3A and comparatively low C_4AF content is known as Sulphate Resisting Cement. In other words, this cement has a high silicate content. The specification generally limits the C_3A content to 5 per cent

Uses :

- (a) Concrete to be used in marine condition;
- (b) Concrete to be used in foundation and basement, where soil is infested with sulphates;
- (c) Concrete used for fabrication of pipes which are likely to be buried in marshy region or sulphate bearing soils;
- (d) Concrete to be used in the construction of sewage treatment works.

Portland Slag Cement

- Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag in suitable proportions and grinding the mixture to get a thorough and mixture between the constituents.
- It may also be manufactured by separately grinding Portland cement clinker, gypsum and ground granulated blast furnace slag and later mixing them intimately.
- The resultant product is a cement which has physical properties similar to those of ordinary Portland cement. In addition, it has low heat of hydration and is relatively better resistant to chlorides, soils and water containing excessive amount of sulphates or alkali metals, alumina and iron, as well as, to acidic waters, and therefore, this can be used for marine works with advantage.
- The manufacture of blast furnace slag cement has been developed primarily



to utilize blast furnace slag, a waste product from blast furnaces. The development of this type of cement has considerably increased the total output of cement production in India .

- The quantity of granulated slag mixed with portland clinker will range from 25-65 percent. Early strength is mainly due to the cement clinker fraction and later strength is that due to the slag fraction. Separate grinding is used as an easy means of varying the slag clinker proportion in the finished cement Portland blast furnace cement is similar to ordinary Portland cement with respect to fineness, setting time, soundness and strength.
- It is generally recognised that the rate of hardening of Portland blast furnace slag cement in mortar or concrete is somewhat slower than that of ordinary Portland cement during the first 28 days, but thereafter increases, so that at 12 months the strength becomes close to or even exceeds those of Portland cement.
- The heat of hydration of Portland blast furnace cement is lower than that of ordinary Portland cement. So this cement can be used in mass concrete structures with advantage. However, in cold weather the low heat of hydration of Portland blast furnace cement coupled with moderately low rate of strength development, can lead to frost damage.

- Extensive research shows that the presence of GGBS leads to the enhancement of the intrinsic properties of the concrete both in fresh and hardened states.

Advantages:

- (a) Reduced heat of hydration
 - (b) Refinement of pore structure
 - (c) Increased resistance to chemical attack.
- The slag which is used in the manufacture of various slag cement is chilled very rapidly either by pouring it into a large body of water or by subjecting the slag stream to jets of water, or of air and water.
 - The purpose is to cool the slag quickly so that crystallisation is prevented and it solidifies as glass. The product is called granulated slag. Portland slag cement exhibits very low diffusivity to chloride ions and such slag cement gives better resistance to corrosion of steel reinforcement.

Application of GGBS Concrete

In recent years the use of GGBS concrete is also recommended for use in water retaining structures. Aggressive water can affect concrete foundations. In such conditions GGBS concrete can perform better.

Quick Setting Cement

- This cement as the name indicates sets very early. The early setting property is brought out by reducing the gypsum content at the time of clinker grinding.
- This cement is required to be mixed, placed and compacted very early. It is used mostly in under water construction where pumping is involved. Use of quick setting cement in such conditions reduces the pumping time and makes it economical. Quick setting cement may also find its use in some typical grouting operations.

Low Heat Cement

It is well known that hydration of cement is an exothermic action which produces large quantity of heat during hydration. Formation of cracks in large body of concrete due to heat of hydration has focussed the attention of the concrete technologists to produce a kind of

cement which produces less heat or the same amount of heat, at a low rate during the hydration process.

- Cement having this property was developed in U.S.A. during 1930 for use in mass concrete construction, such as dams, where temperature rise by the heat of hydration can become excessively large.
- A low-heat evolution is achieved by reducing the contents of C_3S and C_3A which are the compounds evolving the maximum heat of hydration and increasing C_2S .
- A reduction of temperature will retard the chemical action of hardening and so further restrict the rate of evolution of heat. The rate of evolution of heat will, therefore, be less and evolution of heat will extend over a longer period.

Therefore, the feature of low-heat cement is a slow rate of gain of strength. But the ultimate strength of low-heat cement is the same as that of ordinary Portland cement. As per the Indian Standard Specification the heat of hydration of low-heat Portland cement shall be as follows:

7 days — not more than 65 calories per gm.

28 days — not more than 75 calories per gm.

- The specific surface of low heat cement as found out by air-permeability method is not less than 3200 sq. cm/gm. The 7 days strength of low heat cement is not less than 16 MPa in contrast to 22 MPa in the case of ordinary Portland cement. Other properties, such as setting time and soundness are same as that of ordinary Portland cement.

2. Explain in detail the tests for cement.

Testing of cement can be brought under two categories:

- (a) Field testing
- (b) Laboratory testing.

Field Testing

It is sufficient to subject the cement to field tests when it is used for minor works.

The following are the field tests:

- (a) Open the bag and take a good look at the cement. There should not be any visible lumps. The colour of the cement should normally be greenish grey.
- (b) Thrust your hand into the cement bag. It must give you a cool feeling. There should not be

any lump inside.

(c) Take a pinch of cement and feel-between the fingers. It should give a smooth and not a gritty feel

(d) Take a handful of cement and throw it on a bucket full of water, the particles should float for some time before they sink.

(e) Take about 100 grams of cement and a small quantity of water and make a stiff paste. From the stiff paste, pat a cake with sharp edges. Put it on a glass plate and slowly take it under water in a bucket. See that the shape of the cake is not disturbed while taking it down to the bottom of the bucket. After 24 hours the cake should retain its original shape and at the same time it should also set and attain some strength.

Laboratory testing :

The following tests are usually conducted in the laboratory.

- | | |
|-----------------------------|--------------------------------|
| (a) Fineness test. | (b) Setting time test. |
| (c) Strength test. | (d) Soundness test. |
| (e) Heat of hydration test. | (f) Chemical composition test. |

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,

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 Air permeability appartus is used

Sieve Test

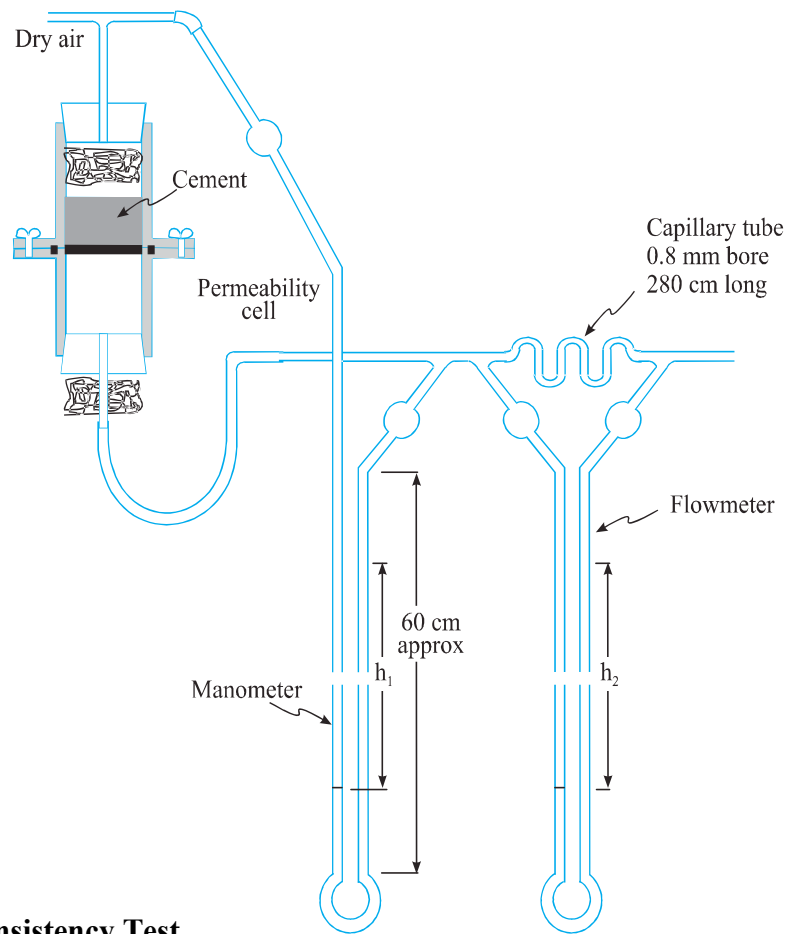
- Weigh correctly 100 grams of cement and take it on a standard IS Sieve No. 9 (90 microns).Break down the air-set lumps in the sample with fingers. Continuously sieve the sample giving circular and vertical motion for a period of 15 minutes.

- 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.

1. **Air Permeability Method**

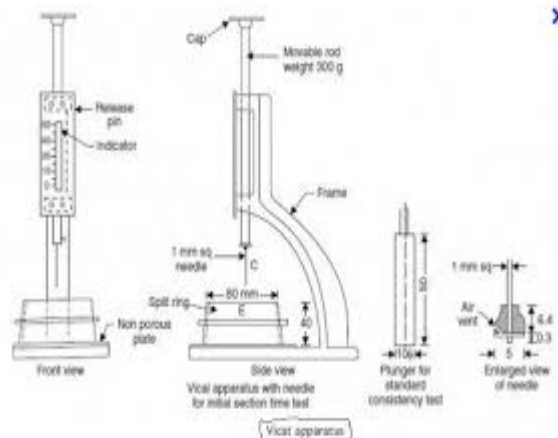
This method of test covers the procedure for determining the fineness of cement as represented by specific surface expressed as total surface area in sq. cm/gm. of cement. It is also expressed in m^2/kg . Lea and Nurse Air Permeability Apparatus is shown in Fig. 2.6. This apparatus can be used for measuring 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.
- 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. Fineness can also be measured by Blain Air Permeability apparatus. 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.
- 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. The apparatus is called Vicat Apparatus. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency or normal consistency.



Procedure :

1. 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.
2. The paste must be 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.
3. 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.
4. 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' .
5. The test is required to be conducted in a constant temperature ($27^{\circ} \pm 2^{\circ}\text{C}$) and constant humidity (90%).

Setting Time Test

- Initial Setting Time is 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.
 - . 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.

Preparation of specimen

- Take 500 gm. of cement sample and gauge it with 0.85 times the water required to produce cement paste of standard consistency (0.85 P). The paste shall be gauged 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 at the time of gauging shall be within $27^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

Procedure

a) 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 and the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needle 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.

b) FINAL SETTING TIME

Replace the needle (C) of the Vicat apparatus by a circular attachment (F) The cement shall be considered as finally set when, upon, lowering the attachment gently over 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 the hardness and 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. 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 + 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 on the vibrating equipment (12000 RPM) for 2 minutes. Keep the compacted cube in the mould at a temperature of $27^{\circ}\text{C} \pm 2^{\circ}\text{C}$ 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. 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 considerable period of time. Therefore, accelerated tests are required to detect it.
- There are number of such tests in common use. 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 – 1¼ 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 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.

3. Explain in detail about mechanical properties of aggregate .

The mechanical properties of aggregate can be determined by using following test

- Test for determination of aggregate crushing value
- Test for determination of ‘ten per cent fines value’
- Test for determination of aggregate impact value
- Test for determination of aggregate abrasion value

1. Test For Determination of Aggregate Crushing Value :

- Strength of rock is found out by making a test specimen of cylindrical shape of size 25 mm diameter and 25 mm height. This cylinder is subjected to compressive stress. 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 standardized 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.

2) Test for determination of ‘ten per cent fines value’ :

- The sample of aggregate for this test is the same as that of the sample used for aggregate crushing value test. The test sample is prepared in the same way as described earlier. The cylinder of the test apparatus is placed in position on the base plate and the test sample added in thirds, each third being subjected to 25 strokes by tamping rod. The surface of the aggregate is carefully levelled and the plunger inserted so that it rests horizontally on this surface.
- The apparatus, with the test sample and plunger in position is placed in the compression testing machine. The load is applied at a uniform rate so as to cause a total penetration of the plunger in 10 minutes of about: 15.00 mm for rounded or partially rounded

aggregates (for example uncrushed gravels) 20.0 mm for normal crushed aggregates, and

24.0 mm for honeycombed aggregates (for example, expanded shales and slags).

- After reaching the required maximum penetration, the load is released and the whole of

the material removed from the cylinder and sieved on a 2.36 mm I.S. Sieve. The fines

passing the sieve is weighed and the weight is expressed as a percentage of the weight of

the test sample. This percentage would fall within the range 7.5 to 12.6, but if it does not,

a further test shall be made at a load adjusted as seems appropriate to bring the

percentage fines with the range of 7.5 to 12.5 per cent. Repeat test is made and the load is

found out which gives a percentage of fines within the range of 7.5 to 12.5.

$$\text{Load required for 10 per cent fines} = \frac{14 \times X}{Y + 4}$$

where, X = load in tons, causing 7.5 to 12.5 percent fines.

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

3. Test for determination of Aggregate Impact Value

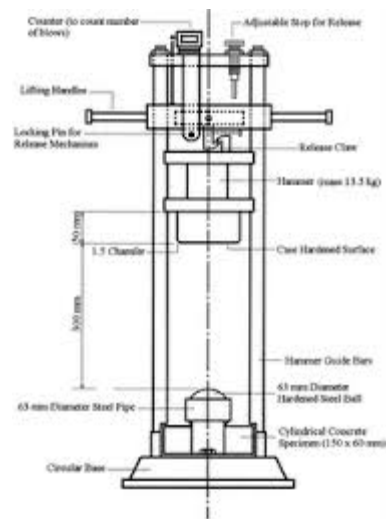
- With respect to concrete aggregates, toughness is usually considered the resistance of the

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.

4. Test for determination of 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 Angeles test.

Deval Attrition Test

In the Deval attrition test, particles of known weight are subjected to wear in an iron cylinder rotated 10000 times at certain speed. The proportion of material crushed finer than 1.7 mm size is expressed as a percentage of the original material taken. This percentage is taken as the attrition value of the aggregate. This test has been covered by IS 2386 (Part IV) – 1963. But it is pointed out that wherever possible Los Angeles test should be used.

Dorry Abrasion Test

This test is not covered by Indian Standard Specification. The test involves in subjecting a cylindrical specimen of 25 cm height and 25 cm diameter to the

abrasion against rotating metal disk sprinkled with quartz sand. The loss in weight of the cylinder after 1000 revolutions of the table is determined

4. Explain in detail about the test carried in aggregate.

The various test carried out in aggregate are

- Sieve analysis test
- Test for determination of flakiness index
- Test for determination of elongation index
- Test for determination of clay, fine silt and fine dust
- Test for determination of organic impurities

1) Sieve Analysis Test :

- The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. A convenient system of expressing the gradation of aggregate is one which the consecutive sieve openings are constantly doubled, such as 10 mm, 20 mm, 40 mm etc. Under such a system, employing a logarithmic scale, lines can be spaced at equal intervals to represent the successive sizes.

- The aggregates used for making concrete are normally of the maximum size 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 600 micron, 300 micron and 150 micron. The aggregate fraction from 80 mm to 4.75 mm are termed as coarse aggregate and those fraction from 4.75 mm to 150 micron are termed as fine aggregate. The size 4.75 mm is a common fraction appearing both in coarse aggregate and fine aggregate (C.A. and F.A.).

- Grading pattern of a sample of C.A. or F.A. is assessed by sieving a sample successively through all the sieves mounted one over the other in order of size, with larger sieve on the top. The material retained on each sieve after shaking, represents the fraction of aggregate coarser than the sieve in question and finer than the sieve above.

- Sieving can be done either manually or mechanically. In the manual operation the sieve is shaken giving movements in all possible direction to give chance to all particles for passing through the sieve. Operation should be continued till such time that almost no particle is passing through. Mechanical devices are actually designed to give motion in all

possible direction, and as such, it is more systematic and efficient than hand sieving.

- 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 an arbitrary number 100. The larger the figure, the coarser is the material.

The following limits may be taken as guidance:

Fine sand : Fineness Modulus : 2.2 - 2.6

Medium sand : F.M. : 2.6 - 2.9

Coarse sand : F.M. : 2.9 - 3.2

A sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete.

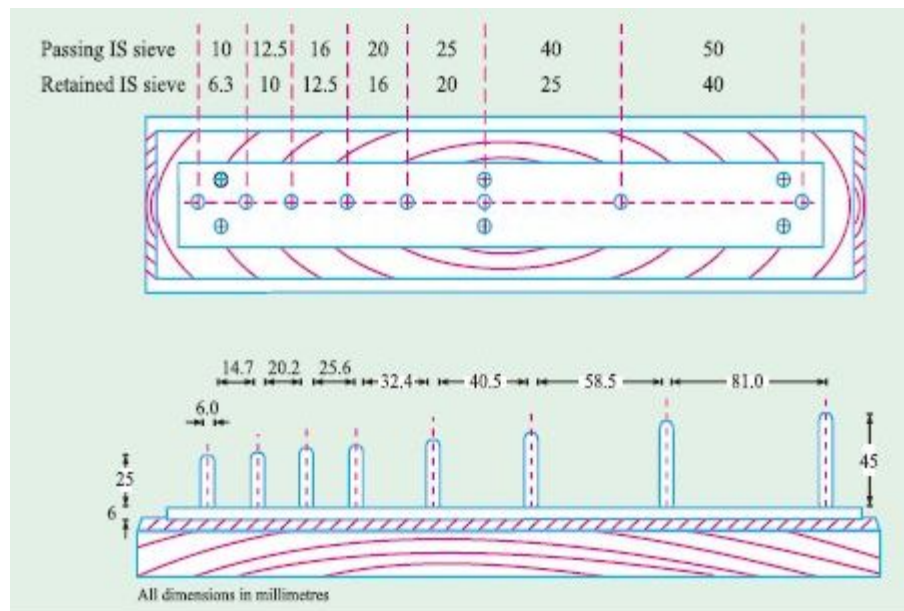
2) Test for Determination of Flakiness Index :

- The flakiness index of aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three-fifths of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.
- This test is conducted by using a metal thickness gauge, of the description shown in Fig. A sufficient quantity of aggregate is taken such that a minimum number of 200 pieces of any fraction can be tested. Each fraction is gauged in turn for thickness on the metal gauge. The total amount passing in the gauge is weighed to an accuracy of 0.1 per cent of the weight of the samples taken. The flakiness index is taken as the total weight of the material passing the various thickness gauges expressed as a percentage of the total weight of the sample taken. Table shows the standard dimensions of thickness and length gauges. **Shows Dimensions of Thickness and Length Gauges (IS: 2386 (Part I) – 1963**

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

3) Test for Determination of Elongation Index :

- The elongation index on an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than 1.8 times their mean dimension. The elongation index is not applicable to sizes smaller than 6.3 mm.
- This test is conducted by using metal length guage of the description shown in Fig.A sufficient quantity of aggregate is taken to provide a minimum number of 200 pieces of any fraction to be tested.
- Each fraction shall be gauged individually for length on the metal guage. The guage length used shall be that specified in column of 4 of Table for the appropriate size of material. The total amount retained by the guage length shall be weighed to an accuracy of at least 0.1 per cent of the weight of the test samples taken.
- The elongation index is the total weight of the material retained on the various length gauges expressed as a percentage of the total weight of the sample gauged. The presence of elongated particles in excess of 10 to 15 per cent is generally considered undesirable, but no recognized limits are laid down.



4) Test for Determination of clay, fine silt and fine dust :

This is a gravimetric method for determining the clay, fine silt and fine dust which includes particles upto 20 microns.

The sample for test is prepared from the main sample, taking particular care that the test sample contains a correct proportion of the finer material. The amount of sample taken for the test is in accordance with Table

Weight of Sample for Determination of Clay, Fine Silt and Fine Dust

<i>Maximum size present in substantial proportions mm</i>	<i>Approximate weight of sample for Test kg</i>
63 to 25	6
20 to 12.5	1
10 to 6.3	0.5
4.75 or smaller	0.3

- Sedimentation pipette of the description shown in Fig. 3.11 is used for determination of clay and silt content. In the case of fine aggregate, approximately 300 gm. of samples in the air-dry condition, passing the 4.75 mm IS Sieve, is weighed and placed in the screw topped glass jar, together with 300 ml of diluted sodium oxalate solution. The rubber washer and cap are fixed. Care is taken to ensure water tightness.
- The jar is then rotated about its long axis with this axis horizontal, at a speed of 80 ± 20 revolutions per minute for a period of 15 minutes. At the end of 15 minutes the suspension is poured into 1000 ml measuring cylinder and the residue washed by gentle swirling and decantation of successive 150 ml portions of sodium oxalate solution, the washings being added to the cylinder until the volume is made upto 1000 ml.
- In the case of coarse aggregate the weighed sample is placed in a suitable container,
- covered with a measured volume of sodium oxalate solution (0.8 gm per litre), agitated
- vigorously to remove all fine material adhered and the liquid suspension transferred to the 1000 ml measuring cylinder. This process is repeated till all clay material has been

transfere to the cylinder. The volume is made upto 1000 ml with sodium oxalate solution.

- The suspension in the measuring cylinder is thoroughly mixed. The pipette A is then gently lowered until the pipette touches the surface of the liquid, and then lowered a further 10 cm into the liquid. Three minutes after placing the tube in position, the pipette A and the bore of tap B is filled by opening B and applying gentle suction at C.

A small surplus may be drawn up into the bulb between tap B and tube C, but this is allowed to run away and any solid matter is washed out with distilled water from E.

The pipette is then removed from the measuring cylinder and its contents run into a weighed container. The contents of the container is dried at 100°C to 110°C to constant weight, cooled and weighed.

The percentage of the fine slit and clay or fine dust is calculated from the formula.

$$\frac{100}{W_1} \left(\frac{1000 W_2}{V} - 0.8 \right)$$

where W1 = weight in gm of the original sample.

W2 = weight in gm of the dried residue

V = volume in ml of the pipette and

0.8 = weight in gm of sodium oxalate in one litre of diluted solution

5) Test for Determination of Organic Impurities :

- This test is an approximate method for estimating whether organic compounds are present in the natural sand in an objectionable quantity or within the permissible limit.
- The sand from the natural source is tested as delivered and without drying. A 350 ml graduated clear glass bottle is filled to the 75 ml mark with 3 per cent solution of sodium hydroxide in water
- The sand is added gradually until the volume measured by the sand layer is 125 ml.
- The volume is then made up to 200 ml by adding more solution. The bottle is then Stoppard and shaken vigorously. Roding also may be permitted to dislodge any organic matter adhering to the natural sand by using glass rod. The liquid is then allowed to stand

for 24 hours. The colour of this liquid after 24 hours is compared with a standard solution freshly prepared, as follows: Add 2.5 ml of 2 per cent solution of tannic acid in 10 per cent alcohol, to 97.5 ml of a 3 per cent sodium hydroxide solution.

- Place in a 350 ml. bottle, stopper, shake vigorously and allow to stand for 24 hours before comparison with the solution above and described in the preceding paragraph. Alternatively, an instrument or coloured acetate sheets for making the comparison can be obtained, but it is desirable that these should be verified on receipt by comparison with the standard solution.

6) Test for Determination of Specific Gravity :

Indian Standard Specification IS : 2386 (Part III) of 1963 gives various procedures to find out the specific gravity of different sizes of aggregates. The following procedure is applicable to aggregate size larger than 10 mm.



A sample of aggregate not less than 2 kg is taken. It is thoroughly washed to remove the finer particles and dust adhering to the aggregate. It is then placed in a wire basket and immersed in distilled water at a temperature between 22° to 32°C. Immediately after 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 sec.

During the operation, care is taken that the basket and aggregate remain completely immersed in water. They are kept in water for a period of $24 \pm 1/2$ hours afterwards. The basket and aggregate are then jolted and weighed (weight A1) in water at a temperature 22° to 32° C.

The basket and the aggregate are then removed from water and allowed to drain for a few

minutes and then the aggregate is taken out from the basket and placed on dry cloth and the surface is gently dried with the cloth. The aggregate is transferred to the second dry cloth and further dried. The empty basket is again immersed in water, jolted 25 times and weighed in water (weight A2).

The aggregate is exposed to atmosphere away from direct sunlight for not less than 10 minutes until it appears completely surface dry. Then the aggregate is weighed in air (weight B). Then the aggregate is kept in the oven at a temperature of 100 to 110°C and maintained at this temperature for $24 \pm 1/2$ hours. It is then cooled in the air-tight container, and weighed (weight C).

$$\text{Specific Gravity} = \frac{C}{B-A}; \quad \text{Apparent Sp. Gravity} = \frac{C}{C-A}$$

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

Where, A= the weight in gm of the saturated aggregate in water (A1 – A2),

B = the weight in gm of the saturated surface-dry aggregate in air, and

C = the weight in gm of oven-dried aggregate in air.

Test for Determination of Bulk Density and Voids

Bulk density is the weight of material in a given volume. It is normally expressed in kg per litre. A cylindrical measure preferably machined to accurate internal dimensions is used for measuring bulk density. The size of the container for measuring bulk density is shown in Table

Size of Container for Bulk Density Test

<i>Size of Largest Particles</i>	<i>Nominal Capacity</i>	<i>Inside Diameter</i>	<i>Inside Height</i>	<i>Thickness of Metal</i>
4.75 mm and under	litre 3	cm 15	cm 17	mm 3.15
Over 4.75 mm to 40 mm	15	25	30	4.00
Over 40 mm	30	35	31	5.00

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

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

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

5. Describe in detail about the importance of the quality of water used for concreting.

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement.

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.

The initial setting time of the test block made with a cement and the water proposed to be used shall not differ by ± 30 minutes from the initial setting time of the test block made with same cement and distilled water.

Tolerable Concentrations of Some Impurities in Mixing Water

Impurity		Tolerable Concentration
Sodium and potassium carbonates and bi-carbonates	:	1,000 ppm (total). If this is exceeded, it is advisable to make tests both for setting time and 28 days strength
Chlorides	:	10,000 ppm.
Sulphuric anhydride	:	3,000 ppm
Calcium chloride	:	2 per cent by weight of cement in non-pre-stressed concrete
Sodium iodate, sodium sulphate, sodium arsenate, sodium borate	:	very low
Sodium sulphide	:	Even 100 ppm warrants testing
Sodium hydroxide	:	0.5 per cent by weight of cement, provided quick set is not induced.
Salt and suspended particles	:	2,000 ppm. Mixing water with a high content of suspended solids should be allowed to stand in a settling basin before use.
Total dissolved salts	:	15,000 ppm.
Organic material	:	3,000 ppm. Water containing humic acid or such organic acids may adversely affect the hardening of concrete; 780 ppm. of humic acid are reported to have seriously impaired the strength of concrete. In the case of such waters therefore, further testing is necessary.
pH	:	shall not be less than 6

The following guidelines should also be taken into consideration regarding the quality of water.

- (a) To neutralize 100 ml sample of water using phenolphthaleine 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.

Permissible limit for solids as per IS 456 of 2000

Material	Tested as per	Permissible limit Max.
Organic	IS 3025 (pt 18)	200 mg/l
Inorganic	IS 3025 (pt 18)	3000 mg/l
Sulphates (as SO_3)	IS 3025 (pt 24)	400 mg/l
Chlorides (as Cl)	IS 3025 (pt 32)	2000 mg/l for concrete work not containing embedded steel and 500 mg/l for reinforced concrete work
Suspended	IS 3025 (pt 17)	2000 mg/l

Algae in mixing water may cause a marked reduction in strength of concrete either by combining with cement to reduce the bond or by causing large amount of air entrainment in concrete. Algae which are present on the surface of the aggregate have the same effect as in that of mixing water.