1.4 AGGREGATES

- The aggregate is a relatively inert material and it imparts volume stability.
- The aggregate provide about 75% of the body of the concrete and hence its influence is extremely important.
- An aggregate should be of proper shape and size, clean, hard and well graded.
- It must possess chemical stability and it must exhibit abrasion resistance.

Physical Properties of Aggregates

The physical properties of aggregates are;

1. Shape
2. Size
3. Color
4. Texture
5. Gradation
6. Fineness modulus

Particle Size, Grading and Dust Content

Well-graded aggregate tend to have lower water requirements than single-sized aggregate and increasing dust contents tend to increase the water requirement of aggregate.

Particle Shape

It is fact that aggregates with well-rounded particles will be less water and make more workable concrete than sands with flaky, elongated particles. However, the strength is undesirable. Aggregate with angular shape, will give moderate water and high strength to concrete by good interlocking characteristics.

Particle Surface Texture

In general, aggregate with a rough surface texture will have a higher water requirement than aggregate with smooth particle surfaces.

Water Absorption

All aggregates absorb water to a greater or lesser degree. The higher the water absorption the higher the water requirement will be, but the water absorbed into the aggregate will not affect the effective water: binder ratio or the strength. It will however lead to rapid slump loss if absorption is excessive, say >1% by mass. In general it is preferable to avoid concrete aggregate properties with water absorptions of more than 1 or 1.5% by mass

Fineness Modulus (FM)

To characterize the overall coarseness or fineness of an aggregate, a concept of fineness modulus is developed. To calculate the fineness modulus, the sum of the cumulative percentages retained on a definitely specified set of sieves needs to be determined, and the result is then divided by 100

The fineness modulus (FM) is a numerical index of fineness, giving some idea of the mean size of the particles present in the entire body of the aggregate.

$$\text{Fineness modulus} = \frac{\text{Sum of cumulative \% retained}}{100}$$

According to IS 2386-1963, the sieves that are to be used for the sieve analysis of the aggregate for concrete are 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 600m, 300m and 150m. For example, a fineness modulus of 6 can be interpreted to mean that the sixth sieve, i.e. 4.75 mm is the average size.

The value of fineness modulus is higher for coarser aggregate and lower for fine aggregate.

Limitations:

The FM for fine sand = 2 - 3.5

The FM for coarse aggregate = 5.5 – 8

[Note: higher FM, the mix will be harsh and if on the other hand gives a lower FM, it produces an uneconomical mix]

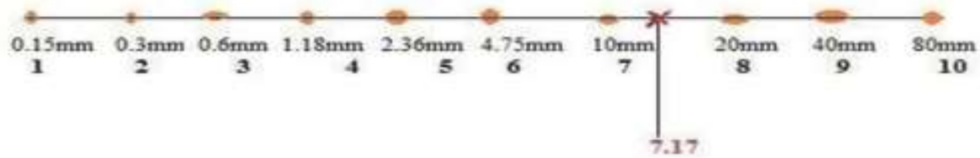
FINENESS MODULUS

Worked Example: (Take 5000 g sample)

Aggregates	Sieve size	Weight retained(g)	Cumulative weight retained (g)	Cumulative % retained (g)
Coarse aggregates	80mm	0	0	0
	40mm	250	250	5
	20mm	1750	2000	40
	10mm	1600	3600	72
Fine aggregates	4.75mm	1400	5000	100
	2.36mm	0	5000	100
	1.18mm	0	5000	100
	0.6mm	0	5000	100
	0.3mm	0	5000	100
	0.15mm	0	5000	100
		Sum	=	717

Therefore, fineness modulus of coarse aggregates = sum (cumulative % retained) / 100 = (717/100) = 7.17

Fineness modulus of 7.17 means, the average size of particle of given coarse aggregate sample is in between 7th and 8th sieves, that is between 10mm to 20mm.



Classification Based on Size

Fine aggregates:

It is the aggregate, which is passes through a 4.75mm IS sieve and retained on 0.7 mm. The fine aggregate may be natural sand, crushed stone sand or crushed gravel sand. According to IS 383-1970, there are four grading zones of the fine sand, Zone I, Zone II, Zone III and Zone IV.

Coarse aggregates:

The aggregates, most of which are retained on 4.75mm IS sieve are termed as coarse aggregates. The coarse aggregates may be Crushed stone, uncrushed gravel and partially crushed stone or gravel.

[*Sometimes combined aggregates are available in nature consisting of different fractions of fine and coarse aggregates, which are known as all in aggregate.]

Classification Based on Shape

Rounded aggregate:

- The aggregate with rounded particles (river or sea shore gravel) has minimum voids ranging from 32 to 33%.
- It gives minimum ratio of surface area to the volume, thus requiring minimum cement paste to make good concrete.

- The only disadvantage is that the interlocking between its particles is less, and hence the development of the bond is poor, making it unsuitable for high strength concrete and pavement.

Irregular aggregates:

- The aggregate having partly round particles (pit sand and gravel) has higher percentage of voids ranging from 35 to 38 %.
- It requires more paste for a given workability.
- The interlocking between particles, though better than that obtained with the rounded aggregate, is inadequate for high strength concrete.

Angular aggregates:

- The aggregate with sharp angular and rough particles (crushed rock) has a maximum percentage of voids ranging from 38 to 40%.
- The interlocking between particles is good, providing a good bond.
- The aggregate requires more paste to make workable concrete of high strength.

- The angular aggregate is suitable for high strength concrete and pavements subjected to tension.

Flaky and elongated aggregates:

- An aggregate is termed flaky when the ratio of least dimension (thickness) to the mean dimension is less than three-fifth (0.6).
- The particle is said to be elongated when the ratio of greatest dimension (length) to the mean dimension is more than nine-fifth (1.8 times).

Classification based on unit weight

Normal weight aggregates:

- The commonly used aggregates i.e. sand, gravel, crushed rocks such as granite, basalt, sandstone (sedimentary) and limestone.

- It has specific gravities between 2.5 and 2.7 produce concrete with unit weight ranging from 23 to 26 kN/m^3
- The compressive strength at 28 days between 15 to 40 mpa are termed Normal weight aggregate.

Heavy weight aggregates:

- Heavy weight concrete is produced from heavy weight aggregate, which is more effective as a radiation shield.
- The unit weight of concrete varies from 30 to 57 kN/m^3.
- The specific gravity is varies from 4 – 6.8
- Example: Baryte (G_s = 4 to 4.6), Ferro phosphorus (G_s = 5.8 to 6.8), Haematite (G_s = 4.9 to 5.3) and Magnetite (G_s= 4.2 to 5.2)

Light weight aggregates:

- The light weight aggregates have unit weight up to 12 kN/m^3.
- These aggregates are obtained from pumice, volcanic cinder, Diatomite, blast furnace slag, fly ash etc.
- The weight of concrete (structure) is reduced to a great extent and it provides better thermal insulation and improved fire resistance.

1.2 CHEMICAL COMPOSITION AND PROPERTIES

Chemical short hand

Because of the complex chemical nature of cement, a shorthand form is used to denote the chemical compounds. The shorthand for the basic compounds is:

Compound	Formula
Calcium oxide (lime)	Ca0
Silicon dioxide (silica)	SiO_2
Aluminum oxide (alumina)	Al_2O_3
Iron oxide	Fe_2O_3
Water	H_2O
Sulfate	SO_3

Chemical composition of clinker

The cement clinker formed has the following typical composition:

Compound	Formula
Tricalcium aluminate	$Ca_3Al_2O_6$
Tetracalcium aluminoferrite	$Ca_4Al_2Fe_2O_{10}$
Belite or dicalcium silicate	Ca_2SiO_5
Alite or tricalcium silicate	Ca_3SiO_4
Sodium oxide	Na_2O
Potassium oxide	K_2O
Gypsum	$CaSO_4.{}_2H_2O$

Bogue's compounds

- Tricalcium silicate $CaO.SiO_2$ C_3S
- Dicalcium silicate $CaO.Sio_2$ C_2S
- Tricalcium aluminate $Cao.Al2O_3$ C_3A
- Tetra calcium aluminoferrite $CaO.Al2O_3.Fe_2O_3$ C_4AF

Properties of cement compounds

These compounds contribute to the properties of cement in different ways

❖ **Tricalcium aluminate, C_3A:-**

It liberates a lot of heat during the early stages of hydration, but has little strength contribution. Gypsum slows down the hydration rate of C_3A. Cement low in C_3A is sulfate resistant.

❖ **Tricalcium silicate, C_3S:-**

This compound hydrates and hardens rapidly. It is largely responsible for Portland cement's initial set and early strength gain.

❖ **Dicalcium silicate, C_2S:**

C_2S hydrates and hardens slowly. It is largely responsible for strength gain after one week.

❖ **Ferrite, C_4AF:**

This is a fluxing agent which reduces the melting temperature of the raw materials in the kiln (from 3,000o F t o 2,600o F). It hydrates rapidly, but does not contribute much to strength of the cement paste.

By mixing these compounds appropriately, manufacturers can produce different types of cement o suit several construction environments.

Ingredients of Cement

- ✓ Lime
- ✓ Silica
- ✓ Alumina
- ✓ Iron oxide
- ✓ Magnesium oxide
- ✓ Sulphur trioxide
- ✓ Alkalies
- ✓ Calcium sulphate

Lime

- ➢ Lime in excess makes the cement unsound and causes the cement to expand and disintegrate.
- ➢ If it is in deficiency, the strength of cement is decreased and cement sets quickly.

Therefore it should be in right proportion to produce the cement sound and strong.

Silica

- Silica imports strength to cement.
- In excess provides greater strength to the cement but at the same time prolongs cement setting time.

Alumina

- It imports quick setting quality to the cement, lowers the clinkering temperature.
- In excess reduces the strength of cement.

Iron oxide

- Provides color, hardness and strength to cement.

Magnesium oxide

- Imparts hardness and color to cement.
- In excess makes the cement unsound.

Sulphur trioxide

- It makes the cement sound.
- In excess it causes the cement unsound.

Alkalies

- In excess will cause efflorescence.

Calcium sulphate

- Control the initial setting time of cement

Oxide	Percent content
Lime CaO	60-67
Silica SiO_2	17-25
Alumina Al_2O_3	3.0-8.0

Iron Oxide Fe_2O_3	0.5-0.6
Magnesia MgO	0.1-4.0
Alkalies(k_2O, Na_2O)	0.4-1.3
Sulphur SO_3	1.3-3.0

Grade of Cement

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

Physical properties	**Grade of cement**		
	33	**43**	**53**
Minimum compressive strength at 28 days (N/mm^2)	33	43	53
Fineness-minimum specific surface area (m^2/kg)	225	225	225
Initial setting time (minimum)	30 min.	30 min.	30 min.
Final setting time (maximum)	600 min.	600 min.	600 min.
Soundness (expansion) in mm	10	10	10
Autoclave test for MgO, percent, maximum	0.8	0.8	0.8
Chemical Properties			
Loss on ignition (%)	5	5	4
Insoluble residue (%), maximum	4	2	2
Magnesia MgO (%), maximum	6	6	6
SO_3 (%) , maximum for C_3A > 5 percent	2.5	2.5	2.5
Lime saturation factor (LSF)	0.66-1.02	0.66-1.02	0.8-1.02
Ratio A F minimum	0.66	0.66	0.66

Hydration of Cement

- When water is added to cement, ingredients of the cement react chemically with water and form various complicated chemical compounds, this is called hydration of cement.

- During hydration process, cement produces calcium hydrate silicate (C-H-S) and calcium hydrate aluminate (C-H-A). These products are thick and sticky and it is called C-H-S / C-H-A gel. This gel has adhesion properties and bind the aggregates together, also fill the voids between sand and coarse aggregates.

Heat of hydration:

- The reaction of cement with water is exothermic. The reaction liberates a considerable amount of heat is called heat of hydration.

Abram's water cement law

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

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.

UNIT – I

CONSTITUENT MATERIALS

SYLLABUS

Cement - Different types - Chemical composition and Properties – Hydration of cement - Tests on cement - IS Specifications - Aggregates – Classification - Mechanical properties and tests as per BIS - Grading requirements – Water - Quality of water for use in concrete

1.1 CEMENT

Cement is the binding material, obtained by burning and crushing of clay stones containing Calcium Carbonate and Magnesium Carbonate.

- Silica, SiO_2: from sand, old bottles, clay or argillaceous rock
- Alumina, Al_2O_3: from bauxite, recycled aluminum, clay
- Iron, Fe_2O_3: from clay, iron ore, scrap iron and fly ash

Manufacture of cement

The main raw material for the production of cement is clinker. Clinker is an artificial rock made by heating limestone and other raw materials in specific quantities to a very high temperature in a specially made klin.

Portland cement gets its strength from chemical reactions between the cement and water. The process is known as hydration. This is a complex process that is best understood by first understanding the chemical composition of cement.

Portland cement is manufactured by crushing, milling and proportioning the following materials:

- Lime or calcium oxide, CaO: from limestone, chalk, shells, shale or calcareous rock
- Gypsum, $CaSO_4.2H_20$: found together with limestone

The materials, without the gypsum, are proportioned to produce a mixture with the desired chemical composition and then ground and blended by one of two processes - dry process or wet process. The materials are then fed through a kiln at 2,600º F to produce grayish-black pellets known as clinker. The alumina and iron act as fluxing agents which lower the melting point of silica from 3,000 to 2600º F. After this stage, the clinker is cooled, pulverized and gypsum added to regulate setting time. It is then ground extremely fine to produce cement.

1.1.1 TYPES OF CEMENT

By altering the chemical compositions of the ordinary Portland cement (OPC), many types of cement can be obtained as follows;

- Ordinary Portland cement (OPC)
- Sulphate resistance cement
- Low heat cement
- Quick setting cement
- Portland Pozzolana cement (PPC)
- High alumina cement
- Colored cement
- White cement
- Air entraining cement
- Hydrophobic cement
- Expansion cement
- Rapid hardening Portland cement

Ordinary Portland cement:

This is the most commonly used cement for all types of engineering works. Ordinary

Portland cement (OPC) is manufactured in different grades; the most common grades in India are 33, 43 and 53 grade. OPC is manufactured by burning lime stone and clay at very high temperature range of 1400^{o} C to1700^{o}C and thereafter grinding (or) pulverizing it with gypsum to retard the setting time.

Uses / Advantages:

- Normally used for all kind of construction works
- Widely used in residential construction where special type of cement properties is not required

Sulphate resistance cement

Sulphate resisting cement is a type of Portland cement in which the amount of tri-calcium aluminates (C_3A) is restricted to 5 %. The use of sulphate resistance cement is particularly beneficial in such conditions where the concrete is exposed to the risk of deterioration due to sulphate attack or directly exposure to the soil.

Uses / Advantages:

- ✓ It is used in the construction of foundations and piles.
- ✓ Basements and underground structures.
- ✓ Sewage and Water treatment plants.
- ✓ Chemical, Fertilizers and Sugar factories.
- ✓ Food processing industries and Petrochemical projects.
- ✓ Coastal works.
- ✓ Also for normal construction works where OPC is used.

- ✓ Construction of building along the coastal area within 50 km from sea.

Low heat cement

Low heat cement is produced by reducing the amount of tri-calcium aluminates (C_3A) & di-calcium silicate (C_2S). This type of cement is used in mass constructions (like dams) and in high wear resistance required area. In general, this type of cement is producing very minimum amount of CO_2 emission than OPC.

Uses / Advantages:

- It is very much used in the mass Construction of dams,
- Mass construction of marine structures
- Hydraulic Engineering Concrete
- Retaining wall construction

Quick setting cement

This type of cement is manufactured by reducing the amount of gypsum and adding small amount of aluminium sulphate to accelerate setting time of cement. As the name suggests, it is used where the works needs to be done quickly and when mixed with water starts to set in five minutes and become hard like stone in just 30 minutes.

Uses / Advantages:

- It is used in under water construction.
- It is also used in rainy & cold weather conditions.
- Where, quick strength is needed in short span of time.

Portland Pozzolana cement (PPC)

PPC is manufactured by adding pozzolanic materials such as fly ash, shales, clays etc. It gains high compressive strength with age and it is affordable than other type of concrete.

Uses / Advantages:

- ✓ Used in the hydraulic structures such as dam, canals, lining etc.
- ✓ Mass concreting works such as foundation, tall building etc.
- ✓ Construction of marine structures.
- ✓ This cement has higher resistance to chemical attacks. Hence it can be used in construction of industrial buildings
- ✓ Used in the construction of water tightened structures (Water tank, retaining wall etc.)

High alumina cement

High-alumina cement is rapid hardening cement made by fusing at 1500 to 1600 °C a mixture of bauxite and limestone in an electric furnace or in a rotary kiln. It also can be made by sintering at about 1250 °C.

[*Sintering: Process of compacting and forming a solid mass of material by heat or pressure without melting it to the point of liquification]

Uses / Advantages:

- ➢ This cement is used in construction of refineries, factory or other workshop type structure
- ➢ Used in Sewage structures
- ➢ Used where acid resistance structures are needed

Colored cement

Colored cement is manufactured by mixing color pigments (5 - 10%) with OPC. As the name suggests, it is used where colored cements required for any aesthetic purpose. Chromium Oxide gives Green color. Cobalt gives blue color. Iron oxide gives brown color.

Uses / Advantages:

- These are wildly used for finishing of floor, external surface, plastering wall, colored tiles.
- Used in construction of swimming pool, garden path, tennis courts etc.
- Used in the construction of artificial marble

White cement

This cement is white in color. This cement is free from coloring ingredients such as iron oxide, magnesium oxide, chromium oxide. This cement in burned by oil, and is very costlier than other type of cements.

Uses / Advantages:

- It is used for floor finishes, plaster works, pointing of brick and stone works
- Used in the manufacturing of precast stone and tiles, aerodromes marking, traffic kerb and bridge rails.
- Used as a base coat before painting
- Used to cover the hairline cracks on concrete surface to give smooth finish

Air Entrained Cement

Air Entrained cement produced by mixing small amount of air entraining agent (Polymer based chemicals). Generally, this air entraining agents are used to introduce a tiny bubbles in the concrete. It is used to fill up the gap in concrete which are produced by excessive amount of water during casting.

Uses / Advantages:

- Used in frost resistance concrete (resistance to freezing and thawing)
- Air entrained concrete has less tendency to bleed, it is considerably more plastic than ordinary concrete, and it generally shows less segregation.

Hydrophobic cement

This type of cement is manufactured by mixing admixtures like petrolatum, naphthalene soap which forms layer and act as water repellent. It is useful in wet climatic conditions and Useful when cement is stored for longer duration in wet climatic conditions.

Expansion cement

Expansive Cement is formed from the reaction of tri calcium aluminate (C_3A) with Calcium Sulphate (C_2SO_4). As the name suggests, it expands and increases in volume while settled. Used to avoid the shrinkage of concrete.

Uses / Advantages:

- ✓ Used in repair works (to create a bond with old concrete surface)
- ✓ Used in Hydraulic Structures

Rapid hardening Portland cement (RHPC)

RHPC manufactured by combining lime stone (finely ground) and shale at high temperature. This type of cement is used where high strength is needed to be achieved quickly.

Uses / Advantages:

- ❖ It is used where formwork has to be removed as early as possible in order to reuse it.
- ❖ It is used where high early strength is required.

- It is generally used for constructing road pavements, where it is important to open the road to traffic quickly.
- It is used in industries which manufacture concrete products like slabs, posts, electric poles, block fence, etc.
- It is used for cold weather concreting

  [The main disadvantage of the rapid hardening cement is costlier than other type of cement]

1.6 GRADING REQUIREMENTS

Grading of aggregate means particle size distribution of the aggregate. If all the particle of an aggregate were of one size, more voids will be left on the aggregate mass.

Properly graded aggregate produces dense concrete and needs smaller quantities of fine aggregate and cement.

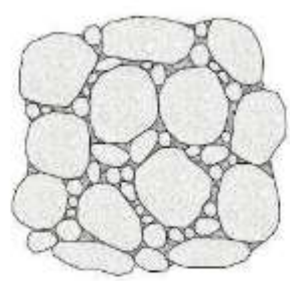
Grading determines the workability of the mix, which controls segregation, bleeding, w/c ratio, handling, placing and other characteristics of the mix.

Types of gradation of aggregate.

a) Well graded
b) Poor / Uniform graded
c) Gap graded

Well graded

Incorporates a combination of particles of many sizes. Hence, it has Low void content, Low permeability and High stability but increases the particle surface area. This is the preferred gradation for making a good concrete.

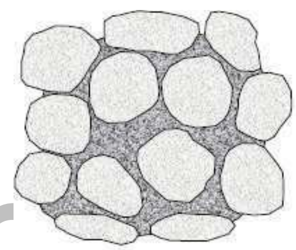


Poor / Uniform graded

All particles are of same size. It produces a large volume of voids irrespective of particle size. Hence the paste requirement for this concrete is high.

Gap graded

This involves grading in which one or more sizes are omitted. It has low stability, moderate voids content and permeability than well graded aggregate. This type of concrete is generally used for architectural or aesthetic purposes.



Factors affecting particle size distribution

- Workability
- Mix proportioning
- Freeze-thaw resistance
- Flow ability
- Pumpability
- Carbonation
- Durability
- Rigidity
- Permeability
- Compressive strength

1.5 MECHANICAL PROPERTIES AND TESTS AS PER BIS

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 t o 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.

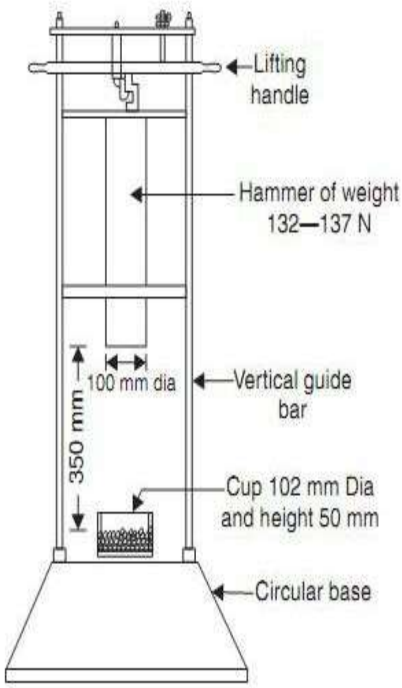
Load required f or 10 per cent fines = $\frac{14 \times X}{Y+4}$

Where, X = load in tons, causing 7. 5t o 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

Tests on aggregates

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 course 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.

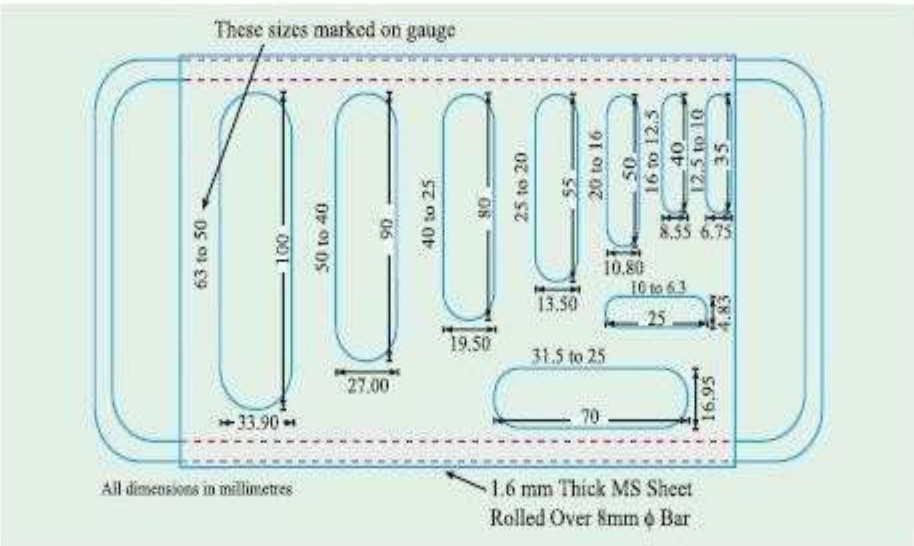
2. Test for Determination of Flakiness Index:

- ✓ 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. 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 guage 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.

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
10.0 mm	6.3 mm	4.89	14.7

* This dimension is equal to 0.6 times the mean Sieve size.

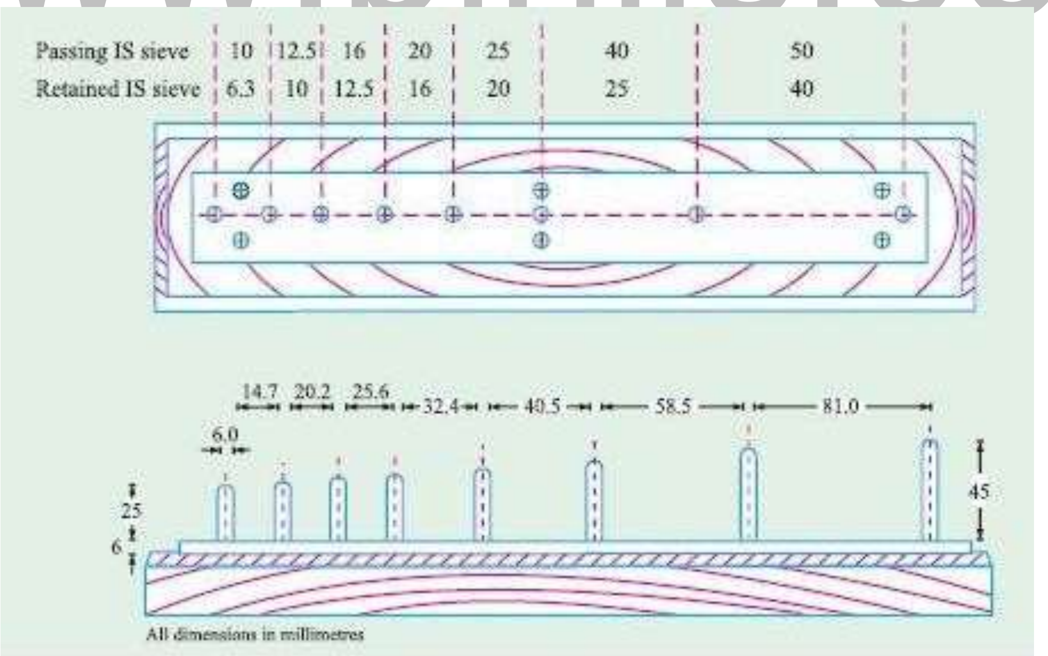
† This dimension is equal to 1.8 times the mean Sieve size.



Dimensions of Thickness and Length Gauges (IS: 2386 (Part I) – 1963

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. 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 atleast 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 f or 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

Maximum size present in substantial proportions mm	*Approximate weight of sample for Test kg*
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. 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 transfered 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 an dt he 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 i n 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 with in 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 percent 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: 238 6(Par It II) 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 of drop 25 times a 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 ± 1/2 hours afterwards.

The basket and aggregate are then jolted and weighed (weight A 1i) n 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).

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

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

Then the aggregate is kept in the oven at a temperature of 100 to 110°C and maintained at this temperature for 24 ± 1/2 hours. It is then cooled in the air-tight container, and weighed (weight C).

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

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

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 I. it's normally expressed in kg per litre. A cylindrical measure preferably machine dot accurate internal dimensions is used for measuring bulk density. The size of the container for measuring bulk density is shown in Table

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

Size of Container for Bulk Density Test

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 of 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.

1.8 QUALITY OF WATER FOR USE IN CONCRETE

Water used for mixing and curing should be free from oil, acid and alkali, salts and organic material. It should be potable and concreting generally requires a value purer than that of drinking. Whenever there is uncertainty in quality, water should be tested before use. Even chlorine added for city water supply will affect concrete if used carelessly without proper testing and treatment. If well water is used for construction, it must be tested for impurities.

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 bicarbonates 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.

- **Chlorides:** They can cause corrosion of steel reinforcement, can accelerate setting. The water used may be contaminated with chlorides because of seawater, some admixtures, salts or deliberate chlorination for disinfections.
- **Sulphates:** They reduce long-term strength levels.

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 s ettling 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 there- fore, further testing is necessary.
pH	:	shall not be less than 6

Tolerable Concentrations of Some Impurities in Mixing Water

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

- To neutralize 100 ml sample of water using phenopthaline as an indicator, it should not require more than 5 ml of 0.02 normal NaOH.
- To neutralise 100 ml of sample of water, using mixed indicator, it should not require more than 25 ml of 0.02 normal H_2SO_4

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.

1.3 TESTS ON CEMENT

Testing of cement can be brought under two categories:

- Field testing
- 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:

- 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.
- Thrust your hand into the cement bag. It must give you a cool feeling. There should not be lump inside.
- Take a pinch of cement and feel-between the fingers. It should give a smooth and not a gritty feel
- Take a handful of cement and throw it on a bucket full of water, the particles should float for some time before they sink.
- 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.

- Fineness test.
- Setting time test.
- Strength test.
- Soundness test.

- Heat of hydration test.
- 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:

- By sieving.
- By determination of specific surface (total surface area of all the particles in one gram of cement) by air-permeability appartus. Expressed as cm2/gm or m2/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% f or 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 Appartus is shown in Fig. This appartus 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 flow meter shows a difference in level of 30-50 cm. Read the difference in level (h1) of the manometer and the difference in level (h2) of the flow meter.
- Repeat these observations to ensure that steady conditions have been obtained as shown by a constant value of h1/h2. Specific surface. Fineness can also be measured by Blain Air Permeability apparatus. This method is more commonly employed in India.

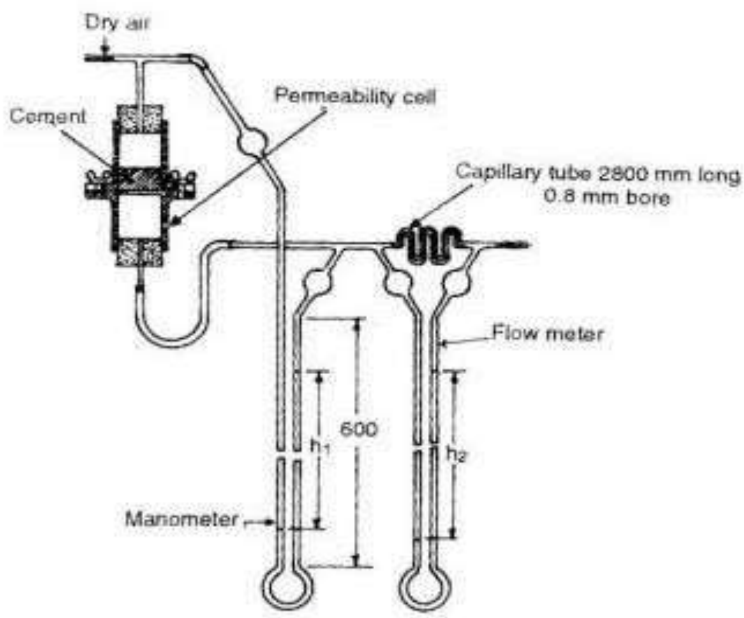
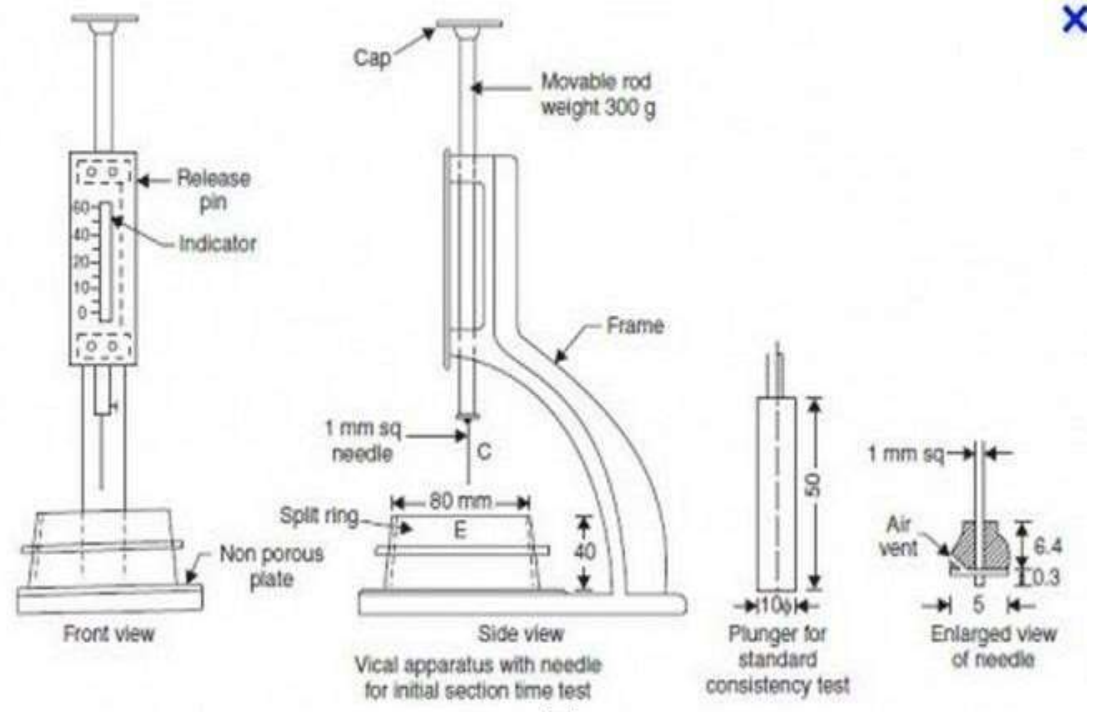


Fig. 28 Permeability Apparatus

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

Appartus. This appartus is used to find out the percentage of water required to produce a cement paste of standard consistency or normal consistency.



Vicat apparatus

Procedure:

- ✓ Take about 500 gm 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 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° + 2°C) and constant humidity (90%).

Setting Time Test

- Initial Setting Time is the time elapsed between the moments 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

o Take 500 gm. of cement sample and guage it with 0.8 5 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°C ± 2°C.

Procedure

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 times 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 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.

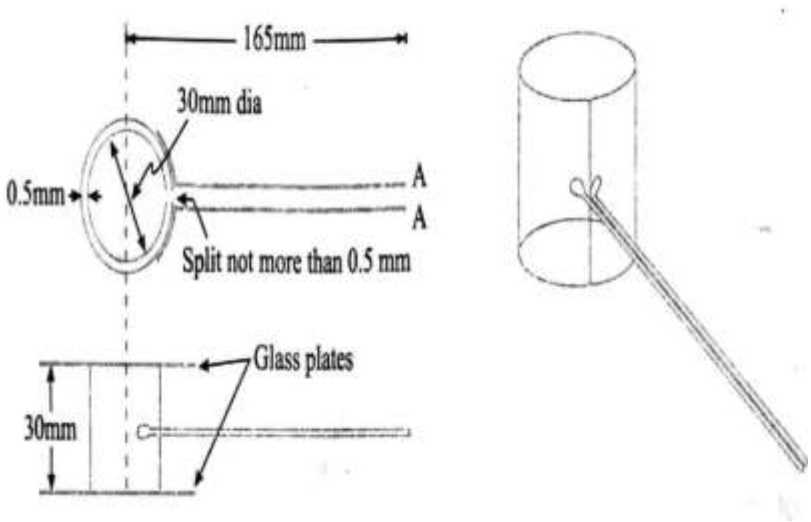
- The standard sand is used for finding the strength of cement. It shall conform to IS 650-1991. Take 555 gm of standard sand (Ennore sand), 185 gm of cement (i.e., ratio of cement to sand is 1:3) in a non-porous enamel tray and mix them with a trowel for one minute, then add water of quantity + 3.0 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 t, he 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°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. 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 (0.78P), 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 – 11/4 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 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.

1.3.1 IS SPECIFICATIONS

CEMENT

Specifications	Minimum Requirements for OPC as per IS:8112-1989
Specific Gravity	3.15
Fineness (m^2/kg) specific surface	225
Setting Time (Initial)	30 min
Setting Time (Final)	600 min
Compressive strength (N/mm^2)	
3 Days	23
7 Days	33
28 Days	43

Physical properties	**Grade of cement**		
	33	43	53
Minimum compressive strength at 28 days (N/mm^2)	33	43	53
Fineness-minimum specific surface area (m^2/kg)	225	225	225
Initial setting time (minimum)	30 min.	30 min.	30 min.
Final setting time (maximum)	600 min.	600 min.	600 min.
Soundness (expansion) in mm	10	10	10
Autoclave test for MgO, percent, maximum	0.8	0.8	0.8

Chemical Properties			
Loss on ignition (%)	5	5	4
Insoluble residue (%), maximum	4	2	2
Magnesia MgO (%), maximum	6	6	6
SO_3 (%) , maximum for C_3A > 5 percent	2.5	2.5	2.5
Lime saturation factor (LSF)	0.66-1.02	0.66-1.02	0.8-1.02
Ratio A F minimum	0.66	0.66	0.66

1.7 WATER

Water is the most important material for construction, especially for making concrete.

The purpose of water in concrete are

- It distributes the cement evenly.
- It reacts with cement chemically and produces calcium silicate hydrate (C-S-H) gel which gives the strength to concrete.
- It provides for workability, i.e., it lubricates the mix.

Hence, for construction, quantity and quality of water is as important as cement.

Effects of water in concrete

As water quantity goes up in a mix (ill effect), the following are the effects:

- Strength decreases
- Durability decreases
- Workability increases
- Cohesion decreases
- Economy may increase at the expense of quality and reliability.

Sources of water in concrete

- Intentionally added water, known as mix water
- Aggregate moisture, which can either add water to the mixture or absorb water from the mixture.

Importance of quality water in concrete

The quality of water used must be checked for ensuring good quality concrete. Water used for mixing and curing should be free from oil, acid and alkali, salts and organic material. It should be of potable quality and generally purer than that required for drinking.