CONCRETE TECHNOLOGY

CEMENT CONCRETE

The cement concrete is a mixture of cement, sand, pebbles or crushed rock and water, which when placed in the skeleton of forms and allowed to cure, becomes hard like a stone.

Properties of Cement Concrete :

1. It has high compressive strength.
2. It is free from corrosion and there is no appreciable effect of atmospheric agents on it.
3. It hardens with age and the process of hardening continues for a long time after the concrete has attained sufficient strength.
4. It is proved to be more economical than steel.
5. It binds rapidly with steel and as it is weak in tension, the steel reinforcement is placed in cement concrete at suitable places to take up the tensile stresses. This is termed as the R.C.C.
6. Under the following two conditions, it has a tendency to shrink
   (*i*) There is initial shrinkage of cement concrete which is mainly due to loss of water through forms, absorption by surface of forms, etc.
   (*ii*) The shrinkage of cement concrete occurs as it hardens, the tendency of cement concrete can be minimised by proper caring of concrete.
7. It forms a hard surface, capable of resisting abrasion.
8. Its final strength and quality depends entirely on local conditions and persons handling it.

MATERIALS USED FOR R.C.C. WORK

1. Cement
2. Aggregates
3. Steel
4. Water

- The material which is passed through BIS test sieve no. 480 is termed as fine aggregate. Usually, the natural river sand is used as a fine aggregate.
- The material which is retained on BIS test sieve no. 480 is termed as a coarse aggregate. The broken stone is generally used as a coarse aggregate.
- For thin slabs and walls, the maximum size of coarse aggregate should be limited to one-third the thickness of concerete section.
- It may be noted that sometimes ingredients other than above are added in concrete to give it certain improved qualities or for changing different physical properties in its fresh and hardened stages. These ingredients or substances are known as the admixtures. The addition of an admixture may improve the concrete with respect to its strength, hardness, workability, water resisting power etc.

Commonly used Admixtures:

Alum, Al_2 $(SO_4)_3$, BaO, bitumen, $CaCl_2$, Coal ash, common salt, iron oxide, lime, mineral oil, organic oils, KCl, silicate of soda, tar products, volcanic ashes, $ZnCl_2$ etc.

For instance, when calcium chloride ($CaCl_2$) is added as admixture, it absorbs water from the concrete and w/c ratio falls down and can even be brought down upto the limit of 0.25. Thus it gives quick setting concrete. However the use of calcium chloride is not suitable for concrete with reinforcing bars.

Depending upon their respective activities in the concrete mix, the admixtures can be classified in the following five categories :

1. Accelerators
2. Air entraining admixtures
3. High range of water reducers or super plasticisers
4. Normal range of water reducers or plasticisers, and
5. Retarders.

Advantages are available from their (i.e. admixtures) use :

1. Adjusting the final setting times of concrete.
2. Higher early and ultimate strength.
3. Higher slump and self-travelling concrete.
4. Increasing durability of concrete.
5. Lesser water cement ratios.
6. Reducing quantity of cement.
7. Reducing permeability of the concrete etc.

Sea Water for making Concrete :

All chlorides tend to accelerate the setting of cement and to improve the strength of concrete in early stages. On the other hand, the sulphates tend to retard the setting of cement and to discourage the strength of concrete in early stages.

The sea water tends to develop dampness and efflorescence. Hence, it can be adopted for concrete structures where finishing characteristics are not important or where persistant dampness of surface is permissible.

It is found that the sea water does not lead to corrosion of reinforcement, provided the concrete is dense and there is enough cover to the reinforcement. The minimum cover over the reinforcement should be 75 mm. The sea water should not be used for making prestressed concrete.

Proportioning Concrete:

The process of selection of relative proportions of cement, sand, coarse aggregate and water, so as to obtain a concrete of desired quality is known as the proportioning of concrete.

The proportions of coarse aggregate, fine aggregate, cement and water should be such that the resulting concrete has the following properties :

1. When concrete is fresh, it should have enough workability so that it can be placed in the formwork economically.
2. The concrete must possess maximum density or in other words, it should be the strongest and most water-tight.
3. The cost of materials and labour required to form concrete, should be minimum.

Differential methods of proportioning concrete:

1. Arbitrary method
2. Fineness modulus method
3. Minimum void method
4. Maximum density method
5. Water-cement ratio method

1. **Arbitrary Method :** The general expression for the proportions of cement, sand and coarse aggregate is 1 : n : 2n by volume.

   The recommended proportions are :

   1 : 1 : 2 and 1 : 1.2 : 2.4 for very high strength concrete.

   1: $1\frac{1}{2}$: 3 and 1 : 2 : 4 for normal works.

   1 : 3 : 6 and 1 : 4 : 8 for foundations and mass concrete work.

Recommended Mixes of Concrete

Proportion of Concrete mix.	Maximum size of aggregate	Nature of work
1 : 1 : 2	12 to 20 mm	Heavy loaded R.C.C. columns and R.C.C. arches of long span.
1 : 2 : 2	12 to 20 mm	Small pre-cast members of concrete such as poles for fencing telegraphs etc. long piles, watertight const, and heavily stressed members of the structures.
1 : $1\frac{1}{2}$: 3	20 mm	Water retaining structures, piles, pre-cast products, etc.
1 : 2 : 3 or 1 : $1\frac{2}{3}$: $3\frac{1}{2}$	20 mm	Water tank, concrete deposited bridge construction and sewers.
1 : $2\frac{1}{2}$: $3\frac{1}{2}$	25 mm	Footpaths and road work.
1 : 2 : 4	40 mm	For all general R.C.C. works
1 : 3 : 6	50 mm	Mass concrete work in culverts, retaining walls, etc.
1 : 4 : 8 or 1 : 5 : 10 or 1 : 6 : 12	60 mm	Mass concrete work for heavy walls, foundation footings, etc.

The concrete as per BIS : 456 - 1978 is designated in seven grades, namely, M10, M15, M20, M25, M30, M35 and M40. For lean concrete bases and simple foundations for masonry walls, M5 and M7.5. grades of concrete may be used. These mix need not be designated. The grades of concrete lower than M15 are not to be used in R.C.C. work. For general guidance, the nominal mixes corresponds

M5	—	1 : 5 : 10
M7.5	—	1 : 4 : 8
M10	—	1 : 3 : 6
M15	—	1 : 2 : 4
M20	—	1 : $1\frac{1}{2}$: 3
M25	—	1 : 1

2. **Fineness Modulus Method :** The term fineness modulus is used to indicate an index number which is roughly proportional to the average size of the particle in the entire quantity of aggregates.
   - The fineness modulus is obtained by adding the percentage of the weight of material retained on the following is sieve and divided it by 100.
   - The coarser the aggregates, the higher the fineness modulus.
   - **The sieve adopted for :**

     All aggregates : 80 mm, 40 mm, 20 mm, 10 mm, nos. 480, 240, 120, 60, 30 and 15

     Coarse aggregates : 80 mm, 40 mm, 20 mm, 10 mm and no. 480.

     Fine aggregates : Nos. 480, 240, 120, 60, 30 and 15.
   - Proportion of fine aggregate to the combined aggregate by weight

     $$R = \frac{P_2 - P}{P - P_1} \times 100$$

     where P = desired fineness modulus for a concrete mix of fine and coarse aggregates.

     P_1 = fineness modulus of fine aggregate

     P_2 = fineness modulus of coarse aggregate
3. **Minimum Void Method** (not give satisfactory result) **:** An actual practice, the quantity of fine aggregate used in the mix is about 10% more than the voids in the coarse aggregate and the quantity of cement is kept as about 15% more than the voids in the fine aggregate.
4. **Maximum Density Method** (*not very popular*) **:** A box is filled with varying proportions of fine and coarse aggregates. The proportion which gives heaviest weight is then adopted.
5. **Water-Cement Ratio Method :** According to the w/c-ratio law given by Abram as a result of many experiments, the strength of well compacted concrete with good workability is dependent only on the ratio.
   - The lower water content produces stiff paste having greater binding property and hence the lowering the water-cement ratio within certain limits results in the increased strength.
   - Similarly the higher water content increases the workability, but lower the strength of concrete.
   - The optimum water-cement ratio for the concrete of required compressive strength is decided from graphs and expressions developed from various experiments.
   - Amount of water less than the optimum water decreases the strong and about 10% less may be insufficient to ensure complete setting of cement. An increase in 10% above the optimum may decrease the strength approximately by 15% while an increase in 50% may decrease the strength to one half.
     - According to Abram's water-cement ratio law, lesser the water-cement ratio in a workable mix greater will be its strength.
     - If water cement ratio is less than 0.4 to 0.5, complete hydration will not be secured.

   Some practical values of water cement ratio for structural reinforced concrete are:

   0.45 for 1 : 1 : 2 concrete;

   0.50 for $1 : 1\frac{1}{2} : 3$ concrete; and

   0.50 to 0.60 for 1:2:4 concrete.
     - Concrete vibrated by efficient mechanical vibrators require less water cement ratio, and hence have more strength.

GRADING OF AGGREGATES

Water Cement Ratio:

The ratio of the amount of water to the amount of cement by weight is termed as the water-cement ratio and the strength and quality of concrete primarily depend upon this ratio.

The important points regarding the water-cement ratio are :

1. The minimum quantity of water should be used to have reasonable degree of workability. The strength of concrete is inversely proportional to the water-cement ratio.
2. The w/c ratio for structures which are exposed to weather should be carefully decided.
   - For structure which are regularly wetting and drying, the w/c ratio of weight should be 0.45 and 0.55 for thin sections and mass concrete respectively.
   - For structure which are continuously under water, the w/c ratio by weight should be 0.55 and 0.65 for thin sections and mass concrete respectively.
3. Some thumb rules developed for deciding the quantity of water in concrete are.

   (*i*) Weight of water = 28% of weight of the cement + 4% of the weight of total aggregate

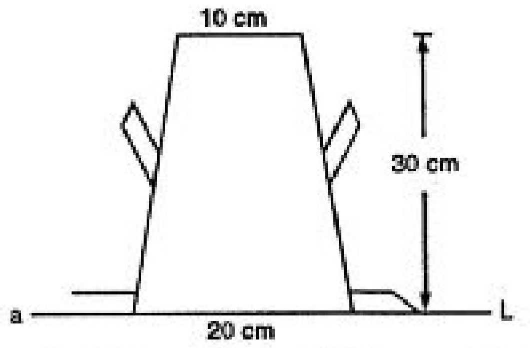
   (*ii*) Weight of water = 30% of the weight of the cement + 5% of the weight of total aggregate

Workability :

The term workability may be defined as the case with which concrete may be mixed, handled, transported, placed in position and comparted.

According to Indian standard, workability of concrete is that property of concrete which determines the amount of internal work necessary to produce full compaction. Several tests which have been developed to measure the workability of concrete are :

1. Slump test
2. Compaction factor test
3. Vee-Bee test, and
4. Vibro-workability test.



Slump Test: Diameter of the rod is 16 mm. and its length is 60 mm. The strokes are given for ramming vary from 20 to 30. The cone is then gradually raised vertically and removed. Then the concrete is allowed to subside and then, height of concrete is measured. The slump of concrete is obtained by deducting height of concrete after subsidence from 30 cm.

Recommend slumps of concrete

No.	Type of Concrete	Slump
1.	Concrete for road construction	20 to 40 mm
2.	Concrete for tops of curbs, parapets, piers, slabs and walls that are horizontal	40 to 50 mm
3.	Concrete for canal linings	70 to 80 mm
4.	Concrete for arch and side walls of tunnels	90 to 150 mm
5.	Normal R.C.C. work	80 to 150 mm
6.	Mass concrete	25 to 50 mm
7.	Concrete to be vibrated	10 to 25 mm

Classification of Concrete Mixes :

Slump	Nature of concrete mix
No slump	Stiff and extra stiff mix
From 10 mm to 30 mm	Poorly mobile mix.
From 40 mm to 150 mm	Mobile mix
Over 150 mm	Last mix

- There is no direct relationship between the workability and the value of slump.

The important facts regarding workability:

1. If more water is added to attain the required degree of workmanship, it results into concrete of low strength and poor durability.
2. It the strength of concrete is not to be affected, the degree of workability can be obtained :
   (*i*) by slightly changing the proportions of fine and coarse aggregates, in case the concrete mixture is too wet; and
   (*ii*) by adding a small quantity of water-cement paste in the proportion of original mix, in case concrete mixture is too dry.
3. A concrete mixture for one work may be prove to be too stiff or too wet for another work. For instance, the stiff concrete mixture will be required in case of vibrated concrete work while wet concrete mixture will be required for thin section containing reinforcing bar.
4. The workability of concrete is affected mainly by water content, water-cement ratio and aggregate-cement ratio.
5. The workability of concrete is also affected by the grading, shape, texture and maximum size of the coarse aggregates to be used in the mixture.

ESTIMATING YIELD OF CONCRETE

By Thumb Rule : If the proportion of concrete is $a : b : c$, i.e. if a parts of cement, b parts of sand and c parts of coarse aggregates are mixed by volume, the resulting concrete will have a volume of

$$\frac{2}{3}(a + b + c)$$

By Absolute Method :

Volume of concrete = Weight of cement + Weight of sand + Volume of coarse aggregate + Absolute weight of water

Cement	– Specific gravity 3.15
Sand	– Specific gravity 2.65 and $y = 16\ \text{kN/m}^3$ when dry
Coarse aggregate	– Specific gravity 2.80 and $y = 15\ \text{kN/m}^3$ when dry
w/c ratio	– 0.60

Importance of Bulking of Sand :

- One of the reasons of adopting proportioning by weight is the bulking of sand as proportioning by weight avoids the difficulty due to the bulking of sand.
- Bulking of sand should be taken into account when volumetric proportioning of the aggregates is adopted.

Transporting and Placing of Concrete :

The two important precautions necessary in transportation of concrete are :

(*i*) The concrete should be transported in such a way that there is no segregation of the aggregates.

(*ii*) Under no circumstances, the water should be added to the concrete during its passage from mixer to the form work.

The precaution to be taken during the placing of concrete are :

1. The formwork or the surface which is to receive fresh concrete, should be properly cleaned, prepared and well watered.
2. The large quantities of concrete should not be deposited at a time.
3. The concrete should be dropped vertically from a reasonable height for vertical laying concrete, care should be taken to use stiff mix. Otherwise bleeding of concrete through cracks in forms will take place. The term bleeding is used to mean the diffusion or running of concrete through formwork.
4. The concrete should be deposited in horizontal layers of about 15 cm height. For mass concrete, the layers may be of 40 cm to 50 cm height. The accumulation of excess water in the uper layers is known as the ***leitance*** and it should be prevented by using shallow layers with stiff mix or by putting dry batches of concrete to absorb the excess water.
5. As far as possible, the concrete should be placed in single thickness. In case of deep sections, the concrete should be placed in successive horizontal layers and proper care should be taken to develop enough void between successive layers.

Consolidation of Concrete:

The term consolidation of concrete is used to mean the compaction between aggregate to aggregate; between aggreate and reinforcement; and between aggregate and forms.

- The voids are the gaps between two individual particles.
- The pores represent the opening within the individual particles.
- The process of consolidation of concrete can be carried out either with hand or with the help of vibrators.

Following are the four types of vibrators :

1. Internal or immersion vibrators
2. Surface vibrators : used to finish concrete surfaces, such as bridge floors, road slabs, station platform
3. Form or shulter vibrators
4. Vibrating tables

The two parameters of vibrations are frequency and time and they are related as follows:

$$\text{Frequency} \propto \frac{1}{\text{Time}}$$

If frequency is more, the consolidation of concrete will be achieved in less time and vice-versa.

Curing of Concrete :

The concrete surface are kept wet for a certain period after placing of concrete so as to promote the hardening of cement. It consists of a control of temperature and of the moisture movement from and into the concrete.

Purposes :

1. The curing protects the concrete surfaces from sun and wind.
2. The strength of concrete gradually increases with age, if curing is efficient. This increase instrength is sudden and rapid in early stages and it continues slowly for an indefinite period.
3. By proper curing, the durability and impermeability of concrete are increased and shrinkage is reduced.
4. The resistance of concrete to abrasion is considerably increased by proper curing.

Period of Curing :

This depends on the type of cement and nature of work. An ordinary portland cement, the curing period is about 7 to 14 days.

Factors affecting evaporation of water from concrete:

1. Air temperature
2. Fresh concrete temperature
3. Relative humidity; and
4. Wind velocity

Factors for selecting mode or method of curing :

1. The tempreture should be kept minimum for dissipation of heat of hydration.
2. The water loss should be prevented.

Most commonly employed methods of curing :

1. Ponding with water (best method) water depth 50 mm
2. Covering concrete with wet jute bags
3. Covering concrete with wet sand, saw dust etc.
4. Covering concrete with water-proof paper or polythene sheets and holding it in position.
5. Intermittent spraying with water and continuous sprinkling of water.
6. Applying curing compounds.

- The basic principle of water curing is to ensure continuous supply of water to concrete surface. It is, however, observed that the intermittent spraying of water takes place after the surface water has dried out.
- Curing compounds is a simple operation and it can be brought about by spraying while the concrete is wet.
- Curing compounds are available on different basis like acrylates, chlorinated rubbers, bitumens, sodium silicates, linseed oils, wax and other items.

Water Proofing Cement Concrete :

Following are the four methods adopted for water proofing of R.C.C. flat roofs:

1. Finishing
2. Bedding concrete and flooring
3. Mastic asphalt and jute cloth
4. Use of water proofing compounds

1. **Finishing :** The finishing of roof surface is done at the time of laying cement concrete by cement mortar (1 : 4) by weight.
2. **Bedding Concrete and Flooring :** The surface of R.C.C. slab is kept rough and on this surface, a layer of concrete is laid, (lime concrete 1 : 2 : 4 or cement concrete 1 : 8 : 14).
3. **Use of Water-proofing Compounds :** Like Pudlo, Impermo etc. is added to the cement during construction, it prevents sewage, leakage, and damp caused by the capillary absorption of the moisture in cement, mortar and concrete.

Light weight Concrete:

- The concrete having bulk density between 5 to 18 KN/m^3.
- The sound absorption coefficient of lightweight concrete is nearly twice than that of the ordinary concrete.
- The only drawback of lightweight concrete is that the depth of carbonation i.e. the depth within which corrosion can occur under suitable condition is nearly twice than that of normalconcrete.

No. fines Concrete :

It consists of cement, coarse aggregate and water.

Joints in Concrete Structures:

1. Construction joints
2. Expansion and contraction joints

1. **Construction Joints :** The construction joints are provided at locations where the construction is stopped either at the end of day or for any other region. The provision of a construction joint becomes necessary to ensure proper bond between the old work and the new one.

   If the construction activity is arranged in such a way that the work is stopped at expansion or contraction joint, the necessity of construction joint will not arise. The construction joint may be horizontal or vertical. For an inclined or curved member, the joint should be at right angle to the axis of the member.

   Following points should be kept in view, in case of the construction joints :

   (*i*) The construction joints should be located along on near the planes of the least bending moment and shear force.

   (*ii*) In case of T-beams or L-beams, the rib of the beam can be connected up to 25 mm below the level of soffit of the slab and the construction joint should be located at that level.

   (*iii*) For slab supported on two sides, the construction joints should be vertical and parallel to the main reinforcement. Alternatively, the construction joint can also be provided at the middle of span at right angles to the main reinforcement. For two-way slabs, the construction joint can be provided near the middle of the either span.

2. **Expansion and Contraction Joints :** These joints are provided in all concrete structures of length exceeding 12 metres, mainly for two purposes :

   (*i*) to allow changes in volume of concrete due to temperature and

   (*ii*) to preserve the appearance and the original shape of the concrete structures

Guniting :

The guniting is the most effective process of repairing concrete work which has been damaged due to inferior work or other reasons. It is also used for providing an impervous layer.

Setting time of cement.

Setting time may be divided into three phases :

1. **Initial set** - 30 to 60 minutes

   During this phase mixed concrete decrease its plasticity and develops pronounced resistance to flow.

2. **Final set** - 5 to 6 hours

   During this phase, concrete appears to be relatively soft solid without surface hardening.

3. The third phase consists of progressive hardening and increase in strength.

   - Concrete has enough strength in compression, but has little strength in tension. Due to this, concrete as such is weak in bending, shear and torsion.

TYPES OF CEMENT

1. **Composition of portland cement.**

   The principal raw materials used in the manufacture of cement are :

   (*a*) Argillaceous or silicates of alumina in the form of clays and shales.

   (*b*) Calcareous or calcium carbonate in the form of lime, stone, chalk and marl. Mixed two part of calcareous material to one part of argillaceous material.

   - The chief constituents of portland cement are :

Lime	(CaO)	—	62%
Silica	(SiO_2)	—	22%
Alumina	($A1_2O_3$)	—	5%
Calcium sulphate	($CaSO_4$)	—	4%
Iron oxide	(Fe_2O_3)	—	3%
Magnesia	(MgO)	—	2%
Sulphur	(S)	—	1%
Alkalies		—	1%
		Total	100%

The above constituents forming the raw materials undergo chemical reactions during burning and fusion, and combine to form the following compounds (called Bogue, compounds) in the finished products :

1. Tricalcium Silicate ($3\,CaO.\,SiO_2$) — C_3S about 70 to 80% of cement is contributed
2. Dicalcium Silicate ($2\,CaO.\,SiO_2$) — C_2 S by and C_2 S which is responsible for the strength of cement.
3. Tricalcium aluminate ($3\,CaO\,.\,Al_2\,O_3$) — C_3A
4. Tetracalcium alumino-ferrite ($4\,CaO.Al_2O_2.FeO_3$) — $C_4\,AF$

- C_3S and C_2S contribute most of the eventual strength.
- Initial setting of portland cement is due to the tricalcium aluminate. This compound is susceptible to be attacked by alkalies and salt. Tetracalcium alumino-ferrite is comparatively inactive.
- All the four compounds generate heat when mixed with water. The aluminate generating the maximum heat and the dicalcium silicate generating the minimum. Due to this C_3A is responsible for most of the undesirable properties of concrete cement having less C_3A will have higher ultimate strength less generation of heat and less cracking.

   (*i*) Ordinary portland cement is manufactured in larger quantities of all the others. It is admirably suited for use in general concrete construction where there is no exposure to sulphates in the soil or in ground water.

   (*ii*) *Rapid Hardeningportland cement (IS-269):*

   It possesses more C_3S and less C_2S than ordinary portland cement. The main advantage of a rapid hardening cement is that shuttering may be removed much earlier, thus saving considerable time and expenses.

   (*iii*) *Extra rapid hardening cement:*

   Extra rapid hardening cement is obtained by inter-grinding with rapid hardening cement. The addition of $CaCl_2$ also imparts quick setting properties.

   (*iv*) *Low heat porlland cement: (IS-269):*

   It has low percentage of C_3A and relatively more C_2S and less C_3S than ordinary portland cement.

(*v*) *Portland blast furnace cement (IS-455):*

- Gypsum regulate the setting time of cement.
- The proportion of slag may vary from 25% to 65% by weight of cement.

(*vi*) *Portland pozzolana cement (IS-1489):*

The proportion of pozzolana may vary from 10 to 25% by weight of cement pozzolana has no cementing value themselves.

(*vii*) *Sulphate resisting cement:*

In sulphate resisting cement the quantity of $C_3A$is strictly limited.

(*viii*) *White and coloured portland cements:*

- The greyish colour of portland cements is due to the presence of iron-rxide.
- White portland cement is manufactured in such a way that the percentage of iron-oxide is limited to less than 1% . To achieve this, superior raw materials, such as chalk and lime stone having low % of iron and white clay (China clay) are used.
- Oil fuel is used in place of coal fuel, to avoid contamination by coal ash.
- Colour portland cements are usually obtained by adding strong pigments upto 10% to the ordinary or white cement, during grinding of clinker.

2. **High alumina cement.**

It is manufactured entirely in different way from that of portland cements. The raw materials used for its manufacture are chalk and bauxite which is a special clay of extremely high alumina content. It has many advantages over other types of cements. High alumina cement is characterised by dark colour, high early strength, high heat of hydration and resistance to chemical attack. It thus produces concrete of far greater strength and is considerably less time even than Rapid-hardening portland cement.

3. **Super Sulphated Cement (IS-6909).**

Super sulphated cement is made from well granulated blast furnace slag (80 to 85%), calcium sulphate (10 to 15%) and portland cement (1 to 2%) and is ground finer than the portland cement. One of its most important properties is its low total heat of hydration. It is therefore very suitable for construction of dams, and mass concreting work.

- Concrete made from super sulphated cement may expand if cured in water and may shrink if the concrete is cured in air. It has high resistance to chemical attack.

4. **Natural Cement.** It is manufactured from naturally occuring cement rock.
5. **Special Cement.**
6. **Masonary Cement.**

SPECIFICATIONS FOR PORTLAND CEMENT.

ISI has recommended the following specifications and tests :

1. Chemical composition
2. Fineness
3. Soundness
4. Setting time
5. Compressive strength; and
6. Heat of hydration.

1. **Chemical Composition :** The various tests are carried out to determine the chemical composition of cement.

(*i*) Ratio of percentage of lime to % of Silica, alumina and iron-oxide, when calculated by the formula.

$$\frac{CaO - 0.7SO_3}{2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3}$$

— [Not greater than 1.02 and not less than 0.66]

(*ii*) Ratio of % of Al_2O_3 to that of Fe_2O_3

— Not less than 0.66%

(*iii*) Weight of insoluble residue

— Not more than 2%

(*iv*) Weight of magnesia

— Not more than 6%

(*v*) Sulphuric anhydride (SO_3)

— Not more than 2.75 %

(*vi*) Total loss on ignition

— Not more than 4%

2. **Fineness :** To check proper grinding of cement.
3. **Soundness :** The purpose of this test is to detect the presence of uncombined lime in cement. This test is performed with the help of Le-Chatelier apparatus. The difference between the two readings indicates the expansion of cement and it should not exceed 10 mm.
4. **Setting Time :** (Vicat apparatus)

The intial setting time is the interval between the addition of water to cement and the stage when needle (square needle 1 mm × 1 mm) ceases to penetrate completely. (The needle should penetrate upto about 5 mm measured from bottom). This time should be about 30 minutes for ordinary portland cement. The final setting time is the difference between the time at which water was added to cement and the time at which the needle (annular collar) makes an impression on test block. This time should be about 10 hours for ordinary portland cement.

5. Compressive strength :

T : B mix by weight, and $\left(\frac{P}{4}+3.5\right)\%$ (of combine weight of cement + sand) water,

where, P is the consistency of water.

The compressive strength at the end of 3 days should not be less than 11.5 N/mm^2 and that at the end of 7 days should not be less than 17.5 N/mm^2.

6. **Tensile strength :** $\frac{P}{4} + 2.5$

at 3 days not be less than 2 N/mm^2

at 7 days not be less than 2.5 N/mm^2.

- High early strength of cement is obtained as a result of fine grinding
- Burning at higher temperature.
- Manganese steel is used in the manufacture of rails.

AGGREGATES :

(*i*) Coarse aggregates and : Aggregates, more than 4.75 mm in size.

(*ii*) Fine aggregates : Aggregates less than 4.75 mm.

Strength quality of an aggregate is usually specified in terns of

(*i*) Crushing strength : for good concrete aggregate, minimum crushing strength,

(*ii*) Aggregate crushing value,

(*iii*) Impact value.

- Aggregate crushing value = $100\,\frac{W_2}{W_1}$

where, W_1 = weight of surface dry sample of aggregate passing 12.5 mm. sieve and retained on 10 mm sieve.

W_2 = weight of the material passing through 2.36 mm. IS sieve after a specified load is appliled

- Aggregate crushing value
- For plane cement concrete < 45
- For R.C.C. for building < 40
- For Prestressed concrete < 30
- Higher aggregate crushing value indicates a weak aggregates.
- Aggregate impact value = $100\,\frac{W_2}{W_1}$

where, W_1 = weight of over dry sample of aggregate passing 12.5 mm IS sieve but retained on 10 mm IS sieve

W_2 = weight of fracture aggregate finer than 2.36 mm formed after 15 impacts of a special hammer through 300 mm.

- For good quality aggregate, impact value lies between 30 to 45.
- A higher aggregate impact value indicates weaker concrete.
- For R.C.C. work, the maximum size of aggregate is limited to 20 mm to 25 mm.
- The aggregates from brick should not be used for reinforced concrete work, since it is porous and may corrode the reinforcement.
- Angular grained sand produces good and strong concrete, because it has good interlocking property.
- **FINENESS MODULUS.**

The fineness modulus of an aggregate is an index number which is roughly proportional to the average size of the particles in the aggregate.

- The fineness modulus is obtained by adding the percentage of the weight of material retained on the following IS sieve and dividing it by 100.

or Fineness modulus

$$= \frac{\text{sum of cumulative \% retained}}{100}$$

WATER :

- Potable waters are generally considered satisfactory for mixing and curing of concrete.
- The pH value of water should not be less than 6.

MEASUREMENTS OF MATERIALS.

1. **Cement :** It is preferable to measured cement in terms of its weight, and not in terms of volume. The volume of cement changes with the conditions of measurement.

Each bag weighing 50 kg. Under normal conditions, the volume of cement in the bag is considered equivalent to 34.5 litres ≈ 35 lit.

2. **Fine aggregate :**
   - The increase in volume due to moisture in sand is known as **bulking of sand.**
   - The bulking increases with fineness.
   - The increase in volume depends on the gradation of sands, but may be taken to be maximum at a moisture content of about 4% by weight of dry sand.
   - $$\% \text{ Bulking} = \frac{\text{Increase in volume}}{\text{Original volume}}$$
     $$= \frac{W_1 - W_2}{W_2} \times 100$$
     $$\text{Bulking factor} = \frac{W_1}{W_2}$$

   where W_1 = weight of one cubic metre of compacted dry sand (i.e. unit weight of dry compacted sand)

   W_2 = weight of dry sand contained in one cubic metre of wet loose sand.

3. **Coarse aggregate :** For accurate and large scale works, measurement should be done by weight.

   For determination of unit weight of coarse aggregate, The Indian Standard specify the following container for carrying out the test :

   (*i*) Maximum size of aggregate 5 mm to 40 mm : 15 litre capacity cylinder of 25 cm diameter.

   (*ii*) Maximum size of aggregate over 40 mm : 40 litre capacity cylinder of 35 cm diameter.

4. **Water :** Water is normally measured in volume.

PROPERTIES AND TESTS ON CONCRETE.

The important properties of concrete, which govern the design of a concrete mix are :

1. Strength
2. Durability
3. Workability; and
4. Economy.

- Durability is the property of concrete by virtue of which it is capable of resisting its disintegration and decay.

Type of work	Slump (mm)
1. Concrete for road work	20 to 30
2. Ordinary R.C.C. work for beams and slabs etc.	50 to 100
3. Columns, retaining wall and thin vertical sections	75 to 150
4. Vibrated concrete	12 to 25
5. Mass concrete	25 to 50

- Compacting factor

$$= \frac{\text{Observed weight of concrete in the mould}}{\text{Theoretical weight}}$$

Compaction factor for a concrete of

low workability ≈ 0.85

medium workability ≈ 0.92

good workability ≈ 0.95

- Factors affecting the workability of concrete are :
  1. Water in the mix
  2. Maximum size of particles
  3. Ratio of coarse and fine aggregates
  4. Particles interference
  5. Particle interlocking; and
  6. Admixtures
- As size of the coarse aggregate decreases, workability of concrete decrease.

METHODS OF PROPORTIONING CONCRETE MIXES :

1. **Arbitrary Method :** The ratio of coarse aggregate to fine is found to lie between $1\frac{1}{2}$ to $2\frac{1}{2}$ for a dense mix of aggregates. In general fine and coarse aggregate in the proportion of 1 : 2, and hence to express the quantities of cement, sand and coarse aggregate in the proportions of 1 : n : 2n by volume.
   - The amount of water to be used in the above mixed is decided on the basis of workability of the mix. The workability depend upon the type of work and the method .of compaction.
2. **Minimum void-ratio method :** The quantity of sand used should be such that it completely fills the voids of coarse aggregate. Similarly, the quantity of cement used shown such that it fills the voids of sand, so that a dense mix the minimum voids is obtained.

- In actual practice, the quantity of sand used in the mix is kept 10% more than the voids in the coarse aggregate and the quantity of cement is taken 25% more than the voids in the sands.

3. Maximum Density Method:

$$P = 100\left(\frac{d}{D}\right)^{1/2}$$

where, D = maximum size of aggregate (i.e. coarse aggregate)

P = percentage of material finer than diameter d (by weight)

d = maximum size of fine aggregate

FINENESS MODULUS AND WATER CEMENT RATIO METHOD.

Abram's' water cement ratio law follows that provided the concrete is fully compacted, the strength is not affected by aggregate shape, type or surface texture, or the aggregate grading, the workability and the richness of mix.

- According to Abram's law, the strength of mix increases with the decrease in the water cement ratio.

  After 7 days curing crushing strength,

$$P_7 = \frac{984}{7^x} \text{ (kg/cm}^2\text{)}$$

  where x = water cement ratio by volume.

  After 28 days curing crushing strength,

$$P_{28} = \frac{984}{4^x} \text{ (kg/cm}^2\text{)}$$

GRADING OF CONCRETE AND CHARACTERISTIC. (IS: 456-2000)

- M10 = M indicates mix and the number to the specified characteristic compressive strength (f_{ck}) of 15 cm cube at 28 days, expressed in N/mm².
- The characteristic strength is defined as the strength of the material below which not more than 5% of the test results are expected to fall.
- M15 grade of concrete of IS : 456-1978 corresponds to

$$f_{ck} = 15 \text{ N/mm}^2$$

- Grade of concrete lower than M20 shall not be used in reinforced concrete.

  Flexural tensile strength,

$$f_{cr} = 0.7\sqrt{f_{ck}} \text{ N/mm}^2$$

- In the absence of test data, the modulus of elasticity for structural concrete may be assumed as follows : *short term modulus of elasticity,*

$$E_c = 5000\sqrt{f_{ck}} \text{ N/mm}^2$$

$$E_{c\theta} = \frac{E_c}{1+\theta}$$

where, θ = creep coefficient

DESIGN MIX CONCRETE.

Grade of Concerte	Nominal mix	Quantity of water Per 50 kg of concrete in litre
M 5	1 : 5 : 10	60
M 7.5	1 : 4 : 8	45
M 10	1 : 3 : 6	34
M 15	1 : 2 : 4	32
M 20	$1 : 1\frac{1}{2} : 3$	30

PERMISSIBLE STRESS IN CONCRETE (IS : 456-2000).

$$\text{Direct tensile stress} = \frac{P}{A_c + mA_{st}}$$

- **Permissible direct tensile stress :**

Grade of concrete	M10	M15	M20	M25	M30	M35	M40
Tensile stress in N/mm²	1.2	2.0	2.8	3.2	3.6	4.0	4.4

- **Permissible compressive stress and Bend stress :**

Grade of concrete	Permissible stress in compression N/mm²		Permissible stress in beond forplain bars in tension τ_{bd}
	Bending σ_{cbc}	Direct σ_{cl}	
M10	3	2.5	—
M15	5	4.0	0.6
M20	7	5.0	0.8
M25	8.5	6.0	0.9
M30	10.0	8.00	1.0
M36	11.5	9.0	1.1
M40	13.0	10.0	1.2

Note: A_s is the area of longitudinal tension reinforcement which continues at least one effective depth beyond the section being considered, except at supports where the full area of tension reinforcement may be used.

- **Modulator ratio :** $m = \dfrac{280}{3\sigma_{cbc}}$

  where, σ_{cbc} is the permissible compressive stress due to bending in concrete in N/ mm².