CTEP – UNIT 1 – CONCRETE TECHNOLOGY

THE CONSTITUENTS, CHEMICAL COMPOSITION, PROPERTIES AND QUALITY REQUIREMENTS OF CEMENT:

Joseph Aspdin who invented the cement and patented as Portland cement. This fancy name of Portland was Christianized as the hardened cement resembled that of the natural stone available at Portland in England.

CEMENT

Hydraulic cement, more commonly known as cement (also referred to as Portland Cement or Ordinary Portland Cement, O.P.C), is one of the most extensively used basic material in almost all civil engineering constructions.

It is a finely ground material which on addition of requisite quantity of water is capable of hardening both under water and in air by the chemical interaction of its constituents with water, and is also capable of building together with appropriate materials.

It consists of two main constituents, viz., argillaceous materials-main ingredient is clay and calcareous materials-main ingredients calcium carbonate.

Constituents of Ordinary Portland Cement

Various constituents (ingredients) of an Ordinary Portland Cement are: Lime (62%), Silica (22%), Alumina (5%), Calcium Sulphate (4%), Iron Oxide (3%), Magnesium Oxide (2%), Sulphur Trioxide (1%) and Alkalies (1%). The functions of these components are given in Table 1.1.

CONSTITUENTS	CHEMICAL COMPOSITION	FUNCTION
Lime	CaO	Major ingredient contributing for the strength of cement. Excess lime makes the cement to expand whereas less lime content leads to quick selling.
Silica	SiO_2	Formation of dicalcium and tricalcium silicates add to the strength. Excess quantity increases the setting time
Alumina	Al_2O_3	Gives quick setting quality to cement. Further acts as a flux in reducing the clinkering temperature. Excess quantity reduces the strength.
Calcium Sulphate	$CaSO_4$	Presents in the form of gypsum and helps in increasing the initial setting time.
Iron Oxide	Fe_2O_3	Provides colour, hardness and strength to cement and also assists in fusion of raw materials during the manufacture of cement.
Magnesium Oxide	MgO	Imparts hardness and colour. Excess quantity affects the soundness of cement.
Sulphur Trioxide	SO_3	Makes the cement sound.
Alkali Oxides	K_2O and Na_2O	Excess quantity causes efflorescence and failure.

Chemical Composition of Cement

The raw materials used for the formation of cement consist mainly of lime, silica, alumina and iron oxide. In the kiln at high temperature the constituents of cement interact with one another. The oxides of these materials in proper quantities are responsible for influencing the various properties of cement including the rate of cooling and fineness of grinding.

The raw materials at high temperature combine with each other and form complex compounds. The four compounds usually regarded as major compounds are Tricalcium silicate (3 $CaOSiO_2$ or C_3S), Dicalcium silicate (2 $CaOSiO_2$ or C_2S),Tricalcium aluminate (3 $CaOAl_2O_3$ or C_3A) and Tetra-calcium aluminoferrite ($4CaOAl_20_3Fe_20_3$ or C_4AF). In addition to the above four compounds, minor compounds(K_2O and N_2O) are also formed which are not significant.

Tricalcium silicate and dicalcium silicate are the most important compounds which contribute for the strength. Presence of free lime in the clinker will cause unsoundness in the cement. High total alumina ferric oxide produce high early strength.

Properties of Cement

1. It is one of the best binding materials used in civil engineering constructions.
2. It has high plastic properties.
3. It offers high strength to masonry.
4. It hardens in short time.
5. It has high resistance to water and other atmospheric effects.

Quality Requirements of Cement

1. It should be homogeneous and be uniform in colour.
2. It should be free from lumps and should sink in water if a small quantity is placed on the surface of water.
3. The ratio of percentage of alumina to that of iron oxide should not be less than 0.66.
4. The weight of magnesia should not exceed 5 %.
5. The total sulphur content of cement should not be greater than 2.75 %.
6. The insoluble residue should not be greater than 1.5 % by weight.
7. Loss of weight by ignition should-not be more than 4 % by weight.
8. The specific surface should not be less than 2250 mm^2/ gm.
9. The expansion of cement, found by soundness test, should not be greater than 10 mm.
10. The initial setting time should not be less than 30 minutes and the final setting time should be around 10 hours.

MANUFACTURING OF CEMENT

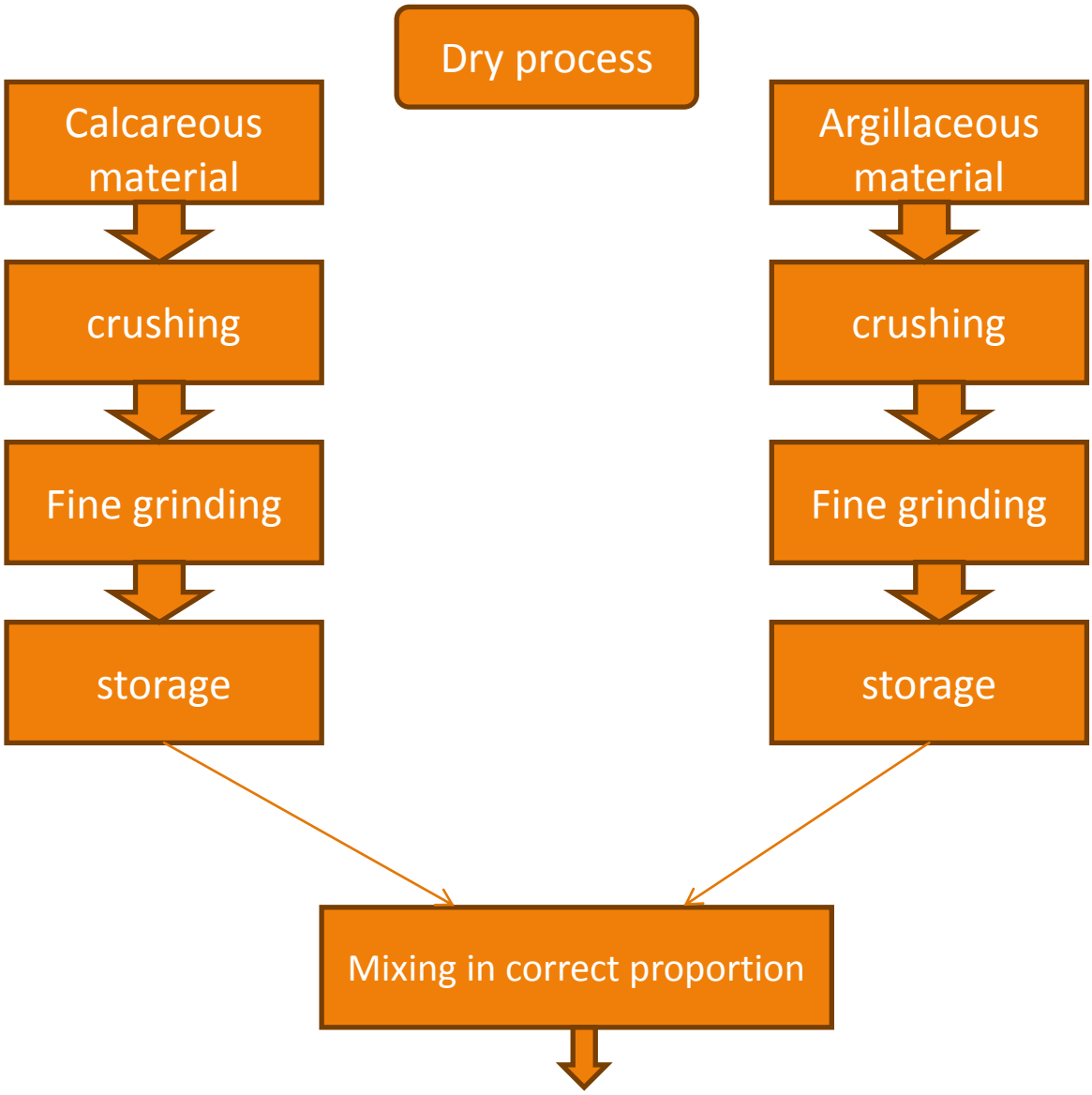
There are three operations involved in manufacture of portland cement:

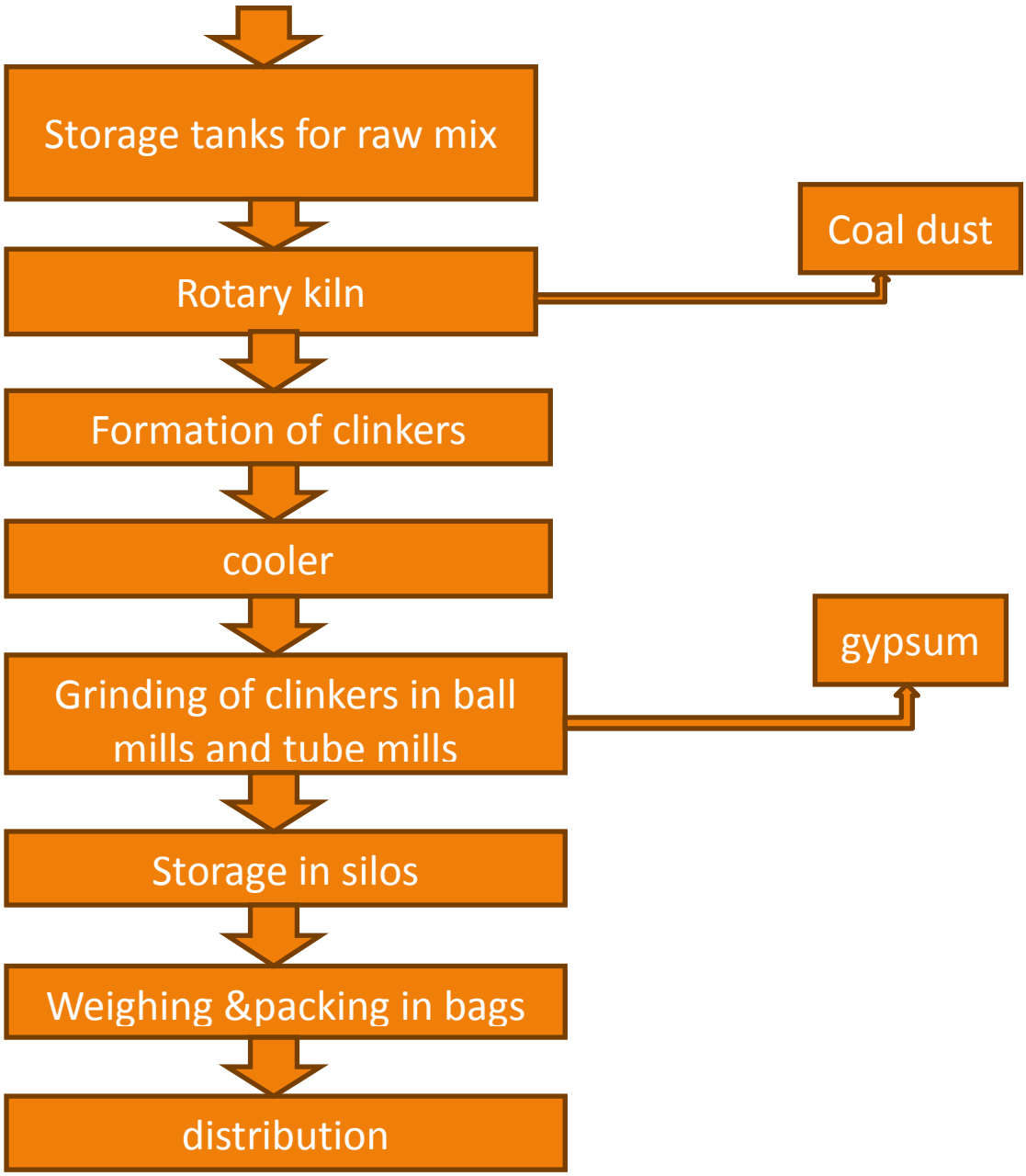
- Mixing of raw materials
- Burning
- Grinding

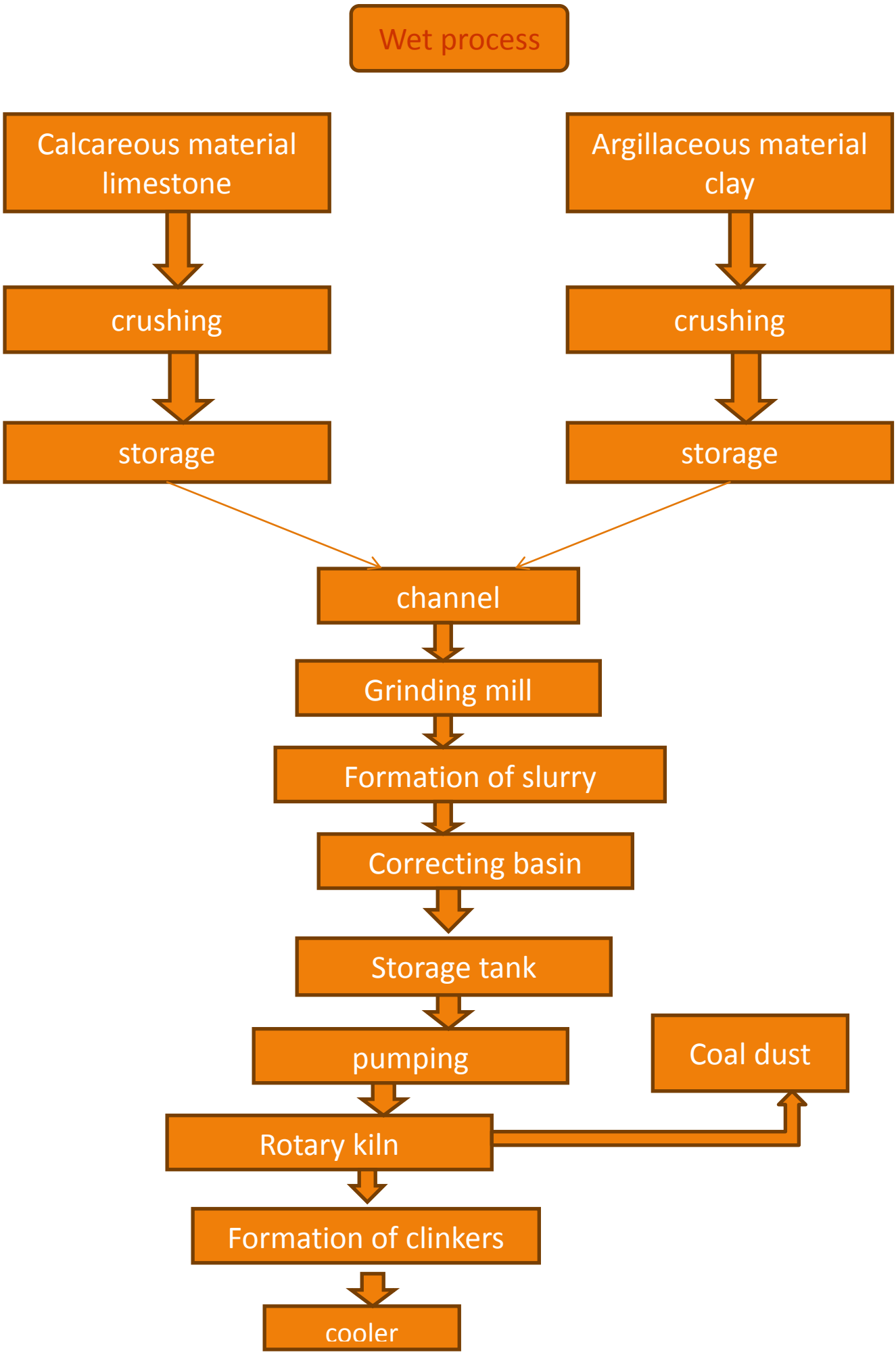
❑ Mixing of raw materials

There are two methods in mixing of raw materials of cement:

- Dry process
- Wet process.


Dry process
Calcareous material
crushing
Fine grinding
storage
Argillaceous material
crushing
Fine grinding
storage
Mixing in correct proportion


Storage tanks for raw mix
Rotary kiln
Coal dust
Formation of clinkers
cooler
gypsum
Grinding of clinkers in ball mills and tube mills
Storage in silos
Weighing &packing in bags
distribution


Wet process
Calcareous material limestone
Argillaceous material clay
crushing
crushing
storage
storage
channel
Grinding mill
Formation of slurry
Correcting basin
Storage tank
pumping
Coal dust
Rotary kiln
Formation of clinkers
cooler

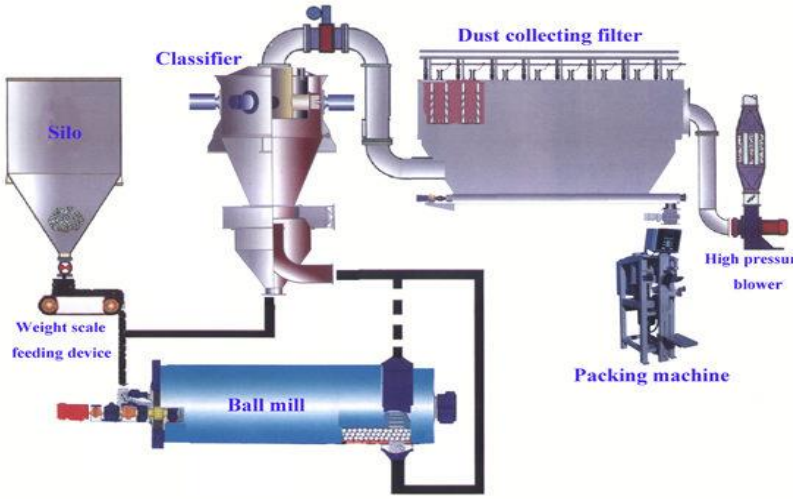
BURNING

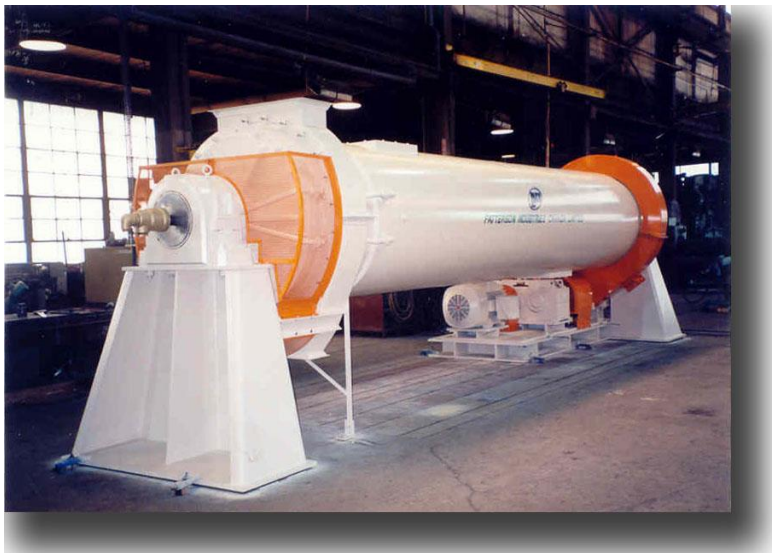
- Burning is carried out in rotary kiln.
- Diameter of kiln is 250-300 cm, length is 90-120 m and inclined about 1 in 20 to 30.
- It is supported on rollers.
- Refractory lining is provided on the inner surface.
- Slurry is injected at upper end and it descends to burning zone carbon-dioxide gets evaporated and forms nodules.
- Temperature is about 1500-1700 c.
- In burning zone the lime and clay in the slurry get chemically fused to form hard balls of portland cement known as clinkers (Size 5 to 10mm).

GRINDING

- Grinding is done in ball mills and tube mills.
- Gypsum is added about 3 to 4 percent during grinding.
- Gypsum controls initial setting time of cement.
- Finely ground cement is stored in silos.
- It is weighed and packed in bags.

- Each bag contains 50Kg of cement.
- The bags are stored in dry places.





USES OF CEMENT

- ❖ It is used for constructing engineering structures such as dams, bridges, storage reservoirs.
- ❖ Used for making joints for pipes, drains.
- ❖ Used for preparation of foundations, footpath.
- ❖ Used for manufacture of precast pipes, fencing posts.
- ❖ Used for masonry work, plastering, pointing.
- ❖ Used for laying floors, roofs and constructing lintels.
- ❖ Used for protecting the structures from weather.

THE VARIOUS TYPES OF CEMENT, GRADES AND THEIR CHARACTERISTICS:

Different types of cements are manufactured, by changing the chemical composition and using different raw materials and additives to suit the specific need.

1.**Ordinary Portland Cement**

This is the common type of cement which is used for construction of many structures in the form of mortar and concrete, viz., multistoreyed buildings, dams, bridges, storage reservoirs, residential buildings, roads, runways, etc. They are also used for making joints for pipes, manufacture of precast pipes, piles, hollow block bricks, etc. 2. **High Alumina Cement**

It is the cement obtained by grinding high alumina clinker. This has long initial setting time, high ultimate strength, high resistance to action of acids and high temperature. This cement is used for furnace insulation, refractory concrete and for special structures which require imperviousness and corrosion resistance.

3. Portland-Pozzolana Cement

It is an intimately inter ground mixture of Portland clinker and pozzolana with the possible addition of gypsum or an intimate and uniform blend of Portland cement and fine pozzolana. The cement takes more time for initial setting which helps in works which involve delayed construction.

4. Masonry Cement

It is a product obtained by intergrinding a mixture of Portland cement clinker with inert materials (non-pozzolanic) and gypsum and air entraining plasticiser. This type of cement is characterised by certain physical properties, such as slow-hardening, high workability and high water retentivity which makes concrete technology it especially suitable for masonry work

5. Hydrophobic Cement

It is the cement obtained by grinding Ordinary Portland Cement clink with an additive which will impart, a water repelling property which shall 1 destroyed only by wet attrition, such as in concrete mix. The hydrophobic quality of cement would facilitate its storage for longer periods in extremely wet climatic conditions.

6. Oil-well Cement

This is hydraulic cement which contains retarders in addition to coarse grinding and/or reduced tricalcium aluminate content of clinker. This is suitable for use in high pressure and temperature in sealing water and gas pockets setting causing during the drilling and repair of oil-wells.

7. Quick-setting Cement

This cement is produced by adding a certain quantity of aluminium sulphate and reducing the quantity of gypsum and a fine grinding is made. This cement used for under-water concreting.

8. Low-heat Cement

It contains low quantity of tricalcium aluminate and high quantity dicalcium silicate. It is used for mass concreting of dams.

9. Expanding Cement

This is obtained by adding an expanding medium like sulpho-alumina and a stabilising agent to ordinary cement. Unlike the conventional cement shrinking, it expands during curing. This cement is used for repairing concrete surfaces.

10. Rapid Hardening Cement

This is produced by burning the raw materials at high temperature a] by increasing lime content. It has the quality of attaining high strength in the period. Thus it is used in the works wherein speed of construction is needed.

11. Acid-resistant Cement

Materials like quartz, sodium silicate and sodium fluosilicate are added to the cement to attain the acid-resistant quality. It is used in chemical industry.

12. Sulphate-resistant Cement

This type of cement has higher silicate content which is effective in fighting back the attacks of sulphates. Further in this cement the tricalcium content is restricted to 5 % only. This has high resistant to sulphate. This is used for construction of sewage treatment works, marine structures and foundation in soil with high sulphate.

13. White Cement

This type of cement does not contain colouring ingredients such as iron oxide, manganese oxide or chromium oxide and the cement is burnt by oil. It is used for floor finish, plastering, pointing of masonry, manufacture of precast stones, tiles and colour cement and runway markings.

14. Coloured Cement

The required colour for the cement, can be obtained by initially mixing, colouring materials with the cement. It is used for external finishing of walls and floors, manufacturing of tiles and precast stones and also used for paths, swimming pools and tennis courts.

GRADES OF CEMENT:

Among different types of cement Ordinary Portland Cement (OPC) is by far the most important type of cement. The OPC has been classified into three grades, namely 33 grade, 43 grade and 53 grade based upon the strength of the cement. If the 28 days strength is not less than 33 N/mm^2 it is called 33 grade cement. Accordingly, if the strength is not less than 43 N/mm^2 it is called 43 grade cement and if the strength is not less than 53 N/mm^2 it is called 53 grade cement. The physical properties of 33, 43 and 53 grade OPC are shown in Table

Physical properties of OPC

Type of cement	**Fineness(m^2/ kg)**	**Soundness(mm)**	**Setting time**		**28 days Compressive strength MPa**
			Initial min	**Final min**	
33Grade OPC	225	10	30	600	33
43 Grade OPC	225	10	30	600	43
53 Grade OPC	225	10	30	600	53

TESTING OF CEMENT

Testing of cement can be brought under two categories:

- Field testing
- Laboratory testing

❖ **Field testing** – sufficient to subject the cement to field tests when it is used for minor works.

- ➢ Open the bag and take a 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.
- ➢ Take a pinch of cement and feel between the fingers. It should give a smooth and gritty feelings.
- ➢ 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 (cake should not disturb when take into the water)

❖ **Laboratory testing** - for using cement in major works, the laboratory test are carried out.

The following are carried out in laboratory:

- ✓ Fineness test (sieve analysis)
- ✓ Setting time test(standard consistency)
- ✓ Strength test(compressive strength)
- ✓ Soundness test(le chatelier)
- ✓ Heat of hydration test(vacuum flask method)
- ✓ Chemical composition test

❑ **Strength test:**

- ✓ Compressive strength is most important.
- ✓ The standard sand is used for finding the strength of cement.

❑ **Fineness test**

- ❖ Fineness of cement is important bearing on the rate of hydration and on rate of gain of strength.
- ❖ Finer cement offers a greater surface area and hence faster and greater the development of strength.
- ❖ Fineness of cement is tested in two ways:
- ✓ By sieving.
- ✓ By determination of specific surface by air- permeability.

SETTING TIME OF CEMENT

- ❖ An arbitrary division has been made for the setting time of cement as initial setting and final setting time.
- ❖ **Initial setting time**- is the time elapsed between the moment that the water is added to the cement to the time that the paste starts losing its plasticity.
- ❖ **Final setting ti**me – 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 sufficient firmness to resist pressure.
- ❖ The test is carried out in vicat apparatus.

CONCRETE CHEMICALS AND APPLICATIONS

Admixtures and construction chemicals are the chemicals added along with the ingredients of concrete or afterwards to get the required mix to fit in for the desired strength and durability.

Admixtures

Now-a-days concrete is used for varied purposes to make suitable for different occasions and in environments. Ordinary concrete does not fit in for varied purposes. Thus admixtures or chemicals are added along with the ingredients of concrete. On the other hand additives are the materials which are added at the time of grinding cement clinker in the cement factories.

The effect of admixtures depends on the brand of cement, grading of aggregate, mix proportion and richness of mix. Thus it is with caution the admixtures should be selected in correctly predicting the behaviour of concrete.

Important Admixtures

There are several admixtures available, some important of them are discussed below.

1. Plasticizers and Superplasticizers.

High degree of workability is needed in different situations. Addition of excess water will only help the fluidity and not the workability of concrete. But addition of plasticizers will improve the desirable qualifies demanded for plastic concrete.

Plasticizers are based on the following constituents:

1. Anionic surfactants such as lignosulphonates and their modifications
2. Nonionic suractants , such as polyglycol acid of hydroxylated carboxylic acids and their modifications
3. Others such as carbohydrates, etc.

Among the plasticizers, calcium, sodium and ammonium lingo sulphonates are mostly used. The quantity used are 0.1 to 0.4 % by weight of cement.

Super plasticizers constitute relatively a new and improved form of plasticizers. These are chemically different from conventional plasticizers. The special quality of super plasticizers are the powerful action as dispersing agents and they are high range water reducers. They are chemically different from plasticizers.
Super plasticizers permit reduction of water up to 30 % without reduction in workability. Super plasticizers are used for production of flowing, self leveling, self compacting and for production of high strength and high performance concrete.

2. Retarders

A retarder is an admixture which slows the process of hydration because of that the concrete remains plastic and workable. If concreting is done in hot weather, retarders overcome the accelerating effect of high temperature. The retarders are used in consolidating large number of pours without the formation of cold joints and in grouting oil wells.
Calcium sulphate is the commonly used retarder. Other admixtures used as retarders are lingo sulphonic acids and their salts, hydroxylates carboxylic acid and their salts. These admixtures which increase the compressive strength by 10 to 20 %. Retarding plasticizers are available in market. These are important type of admixtures often used in the ready mixed concrete industry, for the purposes of retaining the slump loss, during high temperature, long transportation and to avoid construction cold joints.

3. Accelerators

Accelerators are another very useful type of admixture which are added to get the early strength. Such situations may occur under the following conditions:
1. When early removal of formwork is needed.
2. When reduction of period of curing is needed.
3. When to put the structure early to use.
4. When accelerating the setting time in cold weather.
5. For emergency repair work.

The commonly used accelerator was calcium chloride.But it is not in use now but soluble carbonates, silicates, fluosilicate and some of the organic compounds an used. Fluosilicates and organic compound like trietheuolamine are comparatively expensive. Some of the accelerators available now can make the cement set into stone hard in a matter of five minutes. Availability of such accelerators for underwater concreting has become easy. Further waterfront structures which need repair in short time may be done using accelerators. These materials could be used in cold environment up to 60°C. Accelerating plasticizers are also available.

4. Air-entraining Admixture

Air-entrained concrete is made using an air-entrained cement or addition of air-entraining agent. Air-entraining agents produce a large quantity of air bubbles which act as flexible ball bearings and modify the properties of concrete regarding workability, segregation, bleeding and finishing quality of concrete. Further the hardened concrete gains resistance to frost action and permeability.
Natural wood resins, animal and vegetable fats, various wetting agent: (such as alkali salts), water soluble soaps of resin acids, etc., are the air-entrained agents used.
Different air entraining agents behave differently depending on the elasticity of the film of the bubble formed and the extent to which the surface tension is reduced.

5. Pozzolanic Admixtures

Pozzolanic or mineral admixtures have been in use since advent of concrete.Application of pozzolanic modify certain properties of fresh and hardened concretes .Proper addition of pozzolanic admixtures to cement improves many qualities of concrete, such as, lower the heat of hydration, increase the water tightness, reduce the alkali-aggregation reaction, resist sulphate attack, improve workability, etc.

Siliceous materials and aluminous materials, do not possess any cementitious materials. But on reacting with cement and moisture, chemically react with calcium hydroxide liberated on hydration and form compounds possessing cementitious properties. This reaction is called pozzolanic reaction .

Naturally available pozzolanic materials are, clay and shales, diatomaceous earth, volcanic tuffs and pumicites. Artificially available pozzolanic materials are fly ash, blast furnace slag, silica fume, rice husk ash, metalkaoline and surki. Other mineral admixtures are finely ground marble, quartz and granite powder.

6. Damp-proofing Admixtures

Two important properties of concrete should possess with reference to water are,

1. To resist when subjected to presence of water and
2. To protect the absorption of surface water by capillary action.

In general a properly designed and constructed concrete should be impermeable. But it has been accepted that addition of some damp-proofing admixture may prove to be of some advantage in reducing the permeability.

Damp-proofing admixtures are available in powder or liquid form. They have the properties of pore filling or water repellant materials. The chief material in pore filling admixtures are silicate of soda, aluminium and zinc sulphates and aluminium and calcium chloride. They are also more active material which renders the concrete more impervious and also accelerate the setting time. Hence mineral oil free from fatty or vegetable oil are also used. The production of low permeability concrete depends on the uniform spreading of the admixture.

CONSTRUCTION CHEMICALS

The discussion made so far is centered on the modification of the properties of concrete using admixtures. Other chemicals which are used to enhance the performance are discussed in this section. Such chemicals are referred to as construction chemicals or building chemicals.

1. Concrete Curing Compounds

In order to prevent the loss of water, from the surface due to evaporation or otherwise, it has to be retained for which certain measures are taken which is called curing. Surface loss of water from concrete depends upon air temperature, relative humidity, fresh concrete temperature and wind velocity.

Liquid membrane forming curing compounds are used. Curing compounds are used with the following bases, viz, synthetic resin, wax, acrylic and chlorinated rubber.

Resin and wax based compounds effectively seal the concrete from surface evaporation. After 28 days of curing these compounds peel off.

Acrylic based membrane compounds have the additional advantage of better adhesion of subsequent plaster. The membrane need not be removed but the plastering can be done over it. Because of the acrylic emulsion the bonding for the plaster is better.

Chlorinated rubber curing compounds form a thin film on the surface of the concrete which protects drying at the same time they fill the pores on the surface of the concrete. The surface film will wear out.

2. Polymer Bonding Agents

Many a times new concrete is required to be placed over an old concrete surface. In such cases a perfect bond is required. By providing a bond coat between the new and old surfaces of concrete a bond can be achieved. A mixing of a bonding agent with the new concrete helps to provide a better bond. Such mixtures also improve the workability and reduce shrinkage. Many types of commercial products such as Roof Bond ERB, Nitobond PYA, etc., are available.

Polymer modified repair materials are available for repair of concrete work. Such repair works may be ceiling of concrete roof, hydraulic structures, prefabricated members, pipes, poles, etc.

3. Water-proofing Chemicals

Many of the admixtures discussed in the previous section directly or indirectly reduce the permeability of concrete and thereby making the material water-proof. However water-proofing of roofs, walls, bathrooms, toilets, kitchens, basements, swimming pools, and water tanks, etc. still pose some problem.

Different materials are available to make the concrete perfectly waterproof.

They are integral water-proofing compounds, acrylic based polymer, mineral based polymer, chemical DPC, water-proofing adhesive for tiles, silicon based water repellent materials, injection grout, joint sealants and protective and decorative coatings.

GRADES OF CEMENT CONCRETE

Graders of cement concrete mixes-and designated based on the proportions of the ingredients to be used for the concrete or the characteristic compressive strength of the concrete obtained by testing 28 days aged concrete cubes of 15 cm side. Different Grades used are given in Table

Grades of cement concrete (Source: IS:456 - 2000, Table 2)

Sl.No	Group	Grade Designation	Specified Characteristic Compressive Strength of 150 mm cube at 28 days in N/mm^2
1	Ordinary Concrete	M10	10
2		M15	15
3		M20	20
4	Standard Concrete	M25	25
5		M30	30
6		M35	35
7		M40	40
8		M45	45
9		M50	50
10		M55	55
11	High Strength Concrete	M60	60
12		M65	65
13		M70	70
14		M75	75
15		M80	80

Note:

l. In the designation of concrete mix M refers to the mix and number to the specified compressive strength of 150 mm size cube at 28 days, expressed in N/mm^2.

2. For concrete of compressive strength greater than M55 design parameters given in the standard may not be applicable and the values may be obtained from specialized literatures and experimental results.

The characters tic strength is defined as the strength of material below which not more than 5% of the results are expected to fall.

The mix proportion should be selected to ensure that the workability of fresh concrete is suitable for conditions of handling and placing. Further after compaction it should surround all reinforcement and completely fill the fork work when concrete is hardened, it should have the required strength, durability and surface finish.

The proportion of cement, aggregates and water is called the mix which has to be decided to get the desired strength. There are two approaches, viz,

1. By designing the concrete mix called the designed mix
2. By adopting nominal concrete mix called the nominal mix.

The concrete obtained by the process of selecting the required ingredients of concrete and finding their relative proportions with the aim of producing an economical concrete of certain strength and durability is called designed mix.

Nominal mix is one which adopts certain properties of ingredients based on experience and does not consider the properties of ingredients. Design mix should be preferred. The nominal mix properties is given in Table 1.5

Table 1.5: Proportion for nominal concrete mix(Source: Syal and Goel, 2010)

Grade of Concrete	Total quantity of dry aggregates by mass per 50 kg of cement to be taken as the sum of the individual masses of fine and coarse aggregates Max(kg)	Proportion of fine aggregate to Coarse aggregate (By mass)	Quantity of water per 50 kg of cement Max.(Litres)
M5.0	800	Generally 1:2 but subject to an upper limit of 1:1 ½ and lower limit of 1: 2 ½	60
M7.5	625		45
M10	480		34
M15	350		32
M20	250		30

STEPS INVOLVED IN MANUFACTURING OF CONCRETE

1. Proportioning of concrete
2. Batching of materials
3. Mixing of concrete
4. Conveyance of concrete
5. Placing of concrete
6. Compaction of concrete
7. Curing of concrete

(I) PROPORTIONING OF CONCRETE

Selection of proper quantity of cement, coarse aggregate, sand and water to obtain the desired quality is known as proportioning of concrete. Concrete is formed by successive filling of voids in aggregate by sand, the voids in sand by cement and by water filling the voids in cement and under-going a chemical reaction.

The concrete formed by proper proportioning of ingredients should satisfy the following properties:

1. The fresh concrete should have adequate workability for uniform placement.
2. The hardened concrete after setting should have the desired strength and durability.
3. The concrete should be cheap considering both the materials and labour.

There are two approaches in proportioning concrete. In the **first method** no preliminary tests are conducted. But based on experience arbitrary ratios such as 1:2:4;1:11/2:3; 1:1:2, etc. are used. This method of proportioning by adopting arbitrary ratio is called mix-method and the concrete formed by this method is called ordinary concrete. This type of concrete is used for ordinary or common works such as columns and members subjected to medium loads, all general building, RCC works, mass concrete work in culverts, retaining walls, compound walls, and ordinary machine bases. Ordinary concrete can also be used for long span arches with a mix. of 1:1:2 and for heavy stressed members with a mix, of 1:2:2.

In the second method, preliminary tests are conducted, the mix being designed by anyone of the mix design methods, to get the desired strength and durability. The concrete formed by this method is called controlled concrete.

This type of concrete is used for all plain and reinforced concrete structures The concrete mixes for controlled concrete are designed to have an average strength in preliminary test.

(II) BATCHING OF MATERIALS

After fixing the desired proportion the quantity of required ingredients, viz cement, coarse-aggregate, fine-aggregate, have to be measured out in batches for mixing. This process of measuring out ingredients is called batching.

Batching may be done by weight or by volume. Volume batching is inferior to weight batching as the former one is liable for change of volume in sand in bulking or aggregate constant void feasibility.

1. Weight Batching

In this batching method all the ingredients of concrete are directly weighed in kilogram. As the weight of cement bag is 50 kg, 20 bags are needed for 1 tonne of cement. For all important works this batching method should be used. This is a slow process.

2. Volume Batching

In this batching method, two units of measurement, viz., liquids are measured in litres and solid materials in cubic metres. That is all ingredients, viz.,water,cement, sand and coarse aggregates are measured in litres, the end product concrete is measured in cubic metres.

In volume-batching taking cement as the base other quantities are measured.

Considering l litre of cement equal to 1.44 kg, 50 kg bag of cement has a volume of 3.5 liters. Hence for measuring aggregates wooden boxes with inner volume of 3.5litres has to be used. A size of box of 40 cm x 35 cm x 25cm satisfies this 3.5 liters volume requirement. Handles are to be provide on" re sides for handling.

As density of water is 1 gm/cc, it can be measured by weight or by volume.

The quantity of water required depends on the water-cement ratio. Thus for a water-cement ratio of 0.50 the quantity of water required is 25 litres (0.50x50 =25 litres).

In order to have accurate batching the moisture content and absorption of aggregates and bulking of sand have to be ascertained.

(III)MIXING

Thorough mixing of the materials is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. There are two methods adopted for mixing concrete:

- Hand mixing
- Machine mixing

Hand Mixing:

Hand mixing is practiced for smaller volume works portable concrete mixers are often used so that the concrete can be made at the construction site, giving the workers ample time to use the concrete before it hardens.

- Mixing of concrete may be done by hand or by machine.
- Mixing should be done thoroughly so as to have a uniform distribution of ingredients which can be judged by uniform colour and consistency of concrete.
- Then aggregates are added and thoroughly mixed using shovel until the ingredients are uniformly mixed. Based on the water-cement ratio , the quantity of water required is calculated and added to the dry-mix.
- Hand mixing can be used for small quantity of concrete due to non-availability of machine or where noise of machine is to be avoided. In general a quantity of 10 % extra-cement is used to compensate the possible inadequacy.

Machine Mixing:

Mixing of concrete is almost invariably carried out by machine, for reinforced concrete work and for medium or large scale mass concrete work. Machine mixing is not only efficient, but also economical, when the quantity of concrete to be produced is large.

Many types of mixers are available for mixing concrete. They can be classified as

- Batch-mixers
- Continuous mixers.
- Mixing by machine is always preferred. Concrete mixers are used for mixing concrete and are of two types, viz., continuous mixers or batch mixers.
- Continuous mixers are used in works where large quantity of concrete is needed such as dams, bridges ,etc.
- In batch mixer, all required materials in correct quantity are fed into the hopper of the revolving drum. When the mix has attained adequate consistency, the mix is discharged from the drum and conveyed to the concreting yard.

Batch mixers produce concrete, batch by batch with time interval, whereas continuous mixers produce concrete continuously without stoppage till such time the plant is working. In this, materials are fed continuously by screw feeders and the materials are continuously mixed and continuously discharged. This type of mixers is used in large works such as dams. In normal concrete work, it is the batch mixers that are used.Batch mixer may be of pan type or drum type. The drum type may be further classified as tilting, non-tilting, reversing or forced action type.

(iv)TRANSPORTING

Concrete can be transported by a variety of methods and equipments. The precaution to be taken while transporting concrete is that the homogeneity obtained at the time of mixing should be maintained while being transported to the final place of deposition. The methods adopted for transportation of concrete are:

(a) Mortar Pan (b) Wheel Barrow, Hand Cart (c) Crane, Bucket and Rope way (d) Truck Mixer and Dumpers(e) Belt Conveyors (f) Chute (g) Skip and Hoist (h) Transit Mixer (i) Pump and Pipe Line (j) Helicopter.

Mortar pan

- ✓ This case concrete is carried out in small quantities
- ✓ This method exposes greater surface area of concrete for drying conditions
- ✓ This results a great loss of water particularly in hot weather
- ✓ Mortar pan must be wetted to start with and must be kept clean

Wheel barrow

- ✓ Used for transporting concrete in ground level.
- ✓ This method is employed for hauling concrete in longer distance in case of concrete road construction.
- ✓ If the distance is long or ground is rough it is likely that the concrete get segregated due to vibration
- ✓ To avoid this, wheel barrows are provided with pneumatic wheel.

Crane bucket and rope way

- ✓ This is one of the right way for transporting concrete above the ground level
- ✓ Crane can handle concrete in high rise construction project and are becoming familiar sites in big cities
- ✓ Rope way buckets of various sizes are used
- ✓ Rope way method is adopted for
    1. Concrete works in valley
    2. Construction work of the pier in the river
    3. For dam construction

Truck mixer and dumpers

- ✓ For large concrete works particularly for concrete to be placed at ground level
- ✓ These are ordinary open steel tipping lorries
- ✓ Dumpers having 2-3 cubic meter capacity

Chutes

- ✓ Provided for transporting concrete from ground to lower level

- ✓ The surface should have same slope not flatter than 1 vertical to 2 and a1/2 horizontal

Skip and hoist

- ✓ Adopted method for transporting concrete vertically for 3 to 4 floors
- ✓ Mortar pan with staging and human ladder is used for transporting concrete

Transit mixer

- ✓ Transit mixer is one of the most popular equipments for transporting concrete over a long distance particularly in Ready Mixed Concrete plant (RMC).
- ✓ The truck mixer the speed of rotating of drum is between 4–16 revolutions per minute.
- ✓ A limit of 300 revolutions for both agitating and mixing is laid down by ASTM C 94 or alternatively, the concretes must be placed within 112 of mixing.
- ✓ In case of transit mixing, water need not be added till such time the mixing is commenced. BS 5328 – 1991, restrict the time of 2 hours during which, cement and moist sand are allowed to remain in contact. But the above restrictions are to be on the safe side.
- ✓ Exceeding these limit is not going to be harmful if the mix remains sufficiently workable for full compaction.

Pumps and pipe lines

- ➢ Universally accepted method
- ➢ Starts with the suction stroke for suck the concrete inside the pipe
- ➢ It has a piston which moves forward and backward to have suction and delivery of concrete

Choosing a correct pump involves

- Length of horizontal pipe
- Length of vertical pipe
- Number of bends
- Diameter of pipe line
- Length of flexible hose
- Change in line diameter
- Slump of concrete

Points to be noted during conveyance of concrete

1. During transition care should be taken not to allow segregation of aggregates.
2. During transit the containers of the drum should be tight such that there is a minimum loss of water.
3. During transit the mixed concrete should be brought to tile site before the setting in of initial setting to time of the cement.

- ➢ For ordinary simple works, a temporary ladder is formed to convey the concrete using baskets or pans from hand to hand, i.e., by means of manual labour.
- ➢ For larger and important works, various mechanical devices such as vertical hoists, lift-wells for tall structures, wheel barrows, etc are used.

(V) PLACING OF CONCRETE

Placing of concrete is the process of depositing the concrete in its required position. Concrete should be placed in position in a proper manner as early as possible within the initial setting time of cement. Concrete must be placed in a systematic manner to yield optimum results. Placing can be done in the following ways:

- ✓ Placing concrete within earth mould
- ✓ Placing concrete with large earth mould or timber plank form work
- ✓ Placing concrete in layers with in timber or steel shutter
- ✓ Placing concrete with in usual form work
- ✓ Placing concrete under water

(a) Placing concrete within earth mould

- ✓ Concrete is invariably as foundation bed below the walls and columns
- ✓ Before placing concrete

- All loose earth must be removed
- Roots of trees must be cut
- If surface is dry must be made just damp
- If it is too wet or rain soaked the water slush must be removed

(b) **Placing concrete with large earth mould or timber plank form work**

✓ For construction of road slabs, air field slabs and ground floor slabs in building concrete is placed in this method
✓ The ground surface must be free from loose earth pool of water ,grass or roots or leaves
✓ The earth must be compacted well
✓ Poly ethylene film is used in between concrete ground to avoid absorption of moisture
✓ Concrete is laid alternative layers to give enough scope for shrinkage

(c) Placing concrete in layers with in timber or steel shutter

This can be used in the following cases

✓ Dam construction
✓ Construction of concrete abutments
✓ Raft for a high rise building

The thickness of layers depend on

Method of compaction
Size of vibrator
Frequency of vibrator used

✓ It is good for laying 15 to 30 cm thick layer of concrete ,for mass concrete it may varied from 35 to 45 cm
✓ It's better to leave the top of the layer rough so that succeeding layer can have the good bond

(d) Placing concrete with in usual form work

This can be adopt for Column, beam and floors

Rules that should be followed while placing the concrete

- Check the reinforcements are correctly tied and placed
- Check the reinforcement is having appropriate cover
- The joints between plywood's or sheets properly plugged
- Mould releasing agent should be applied

The concrete must be placed very carefully a small quantity at a time so that they will not block the entry of subsequent concrete

(e) Placing concrete under water

✓ Concrete is often required to be placed under water or In a trench filled with slurry
✓ In such a cases use of bottom slurry buckets or termic pipes are used
✓ In the bottom bucket concrete is taken through water in a water tight box or bucket reaching final place of deposition
✓ The bottom is made to open by some mechanism and the whole concrete is dumped slowly.

(V) COMPACTION OF CONCRETE

Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In the process of mixing, transporting and placing of concrete air is likely to get entrapped in the concrete. **The lower the workability, higher is the amount of air entrapped.** In other words, stiff concrete mix has high percentage of entrapped air and, therefore, would need higher compacting efforts than high workable mixes. If this air is not removed fully, the concrete loses strength considerably. The relationship between loss of strength and air voids left due to lack of compaction. It can be seen from the figure that 5 per cent voids reduce the strength of concrete by about 30 per cent and 10 per cent voids reduce the strength by over 50 per cent. Therefore, it is imperative that 100 per cent compaction of concrete is one of the most important aim to be kept in mind in good concrete-making practices.

It must be borne in mind that 100 per cent compaction is important not only from the point of view of strength, but also from the point of durability. In recent time, durability becomes more important than strength. Insufficient compaction increases the permeability of concrete resulting in easy entry for aggressive chemicals in solution, which attack concrete and reinforcement to reduce the durability of concrete. Therefore, 100 per cent compaction of concrete is of paramount importance.

The following methods are adopted for compacting the concrete:

(a) Hand Compaction

(i) Rodding (ii) Ramming (iii) Tamping

(b) Compaction by Vibration

(i) Internal vibrator (Needle vibrator)
(ii) Formwork vibrator (External vibrator)
(iii) Table vibrator
(iv) Platform vibrator
(v) Surface vibrator (Screed vibrator)
(vi) Vibratory Roller.

(c) Compaction by Pressure and

Vibration:

To compact concrete you apply energy to it so that the mix becomes more fluid. Air trapped in it can then rise to the top and escape. As a result, the concrete becomes consolidated, and you are left with a good dense material that will, after proper curing, develop its full strength and durability.

Vibration is the next and quickest method of supplying the energy. Manual techniques such as rodding are only suitable for smaller projects. Various types of vibrator are available for use on site.

Poker Vibrators

The poker, or immersion, vibrator is the most popular of the appliances used for compacting concrete. This is because it works directly in the concrete and can be moved around easily.Pokers with diameters ranging from 25 to 75mm are readily available, and these are suitable for most reinforced concrete work. Larger pokers are available - with diameters up to 150mm - but these are for mass concrete in heavy civil engineering.

- The purpose of compaction is to expel air and bring the particles closer so as to reduce the void and make the concrete denser.
- Wooden or steel hammers are used for **ramming** massive plain concrete works.
- **Tamping** is adopted for compacting slabs or other horizontal surfaces.
- **Roding** is followed for compacting vertical sections.

Advantages of Compaction

- The concrete produced is dense and relatively impermeable.
- A better bond between steel and concrete.
- It is feasible to fill small openings because of good consistency of concrete.
- It is relatively speed in placing concrete.

(VI) CURING OF CONCRETE

The following methods of curing are adopted depending on the type of work:

1. Direct Curing

In this method water is directly applied on the surface for curing. In this process the surface is continuously cured by stagnating water, or using moist gunny bags, straws, etc. These methods are used for horizontal surfaces. Vertical surfaces can be cured by covering moist gunny bags or straws.

2. Membrane Curing

In this method steps are taken to prevent water evaporation from finished concrete surfaces. This is done by covering the surfaces with water-proof papers, polythene papers or by

spraying with patented compounds or bituminous layer to form an impervious film on the concrete surface.

3. Steam Curing

This approach is widely used in precast concrete units. Here the precast units are kept under warm and damp atmosphere of a steam chamber.

4.Direct Electric Curing

Dut to higher productivity, cost effectiveness and more stringent customer requirements, the popularity of accelerated curing of concrete has been greatly enhanced during the last three decades. Direct Electric Curing (DEC) is being used in many advanced countries in the production of precast components such as channel units, railway sleepers, battery cast large panels, PCC poles, etc. Keeping in view large scale in situ concrete construction prevailing in country, DEC process has been developed for such type of construction.

The DEC process consists essentially of passing a current through the concrete, between two immersed electrodes (Fig.1.1). Since he freshly mixed concrete is an electrical conductor possessing high resistivity, the passing of current through the fresh concrete results in the generation of heat responsible for its accelerated curing.

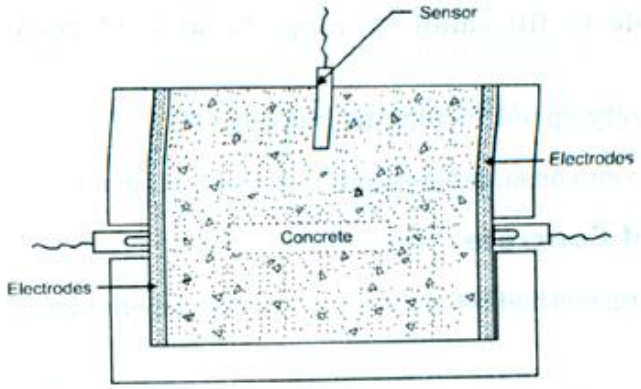


Fig. 1.1· Basic configuration of electrodes

5. Surface Application by Chemicals

Chemicals such as calcium chloride is spread as a layer on the finished concrete. The chemical absorbs moisture from the atmosphere and prevents evaporation of moisture from the concrete surface.

(VII) FINISHING

Finishing is the last stage in concrete construction. After casting of a concrete, the concrete does not offer a pleasant architectural appearance. In some cases like beams a finishing may not be needed. For a residential building, airport or road pavement and culvert and bridges, the finishing is a must. Nowadays the centering materials are so made such that the concrete exhibit a pleasant surface finish. Many of the prefabricated concrete units are made in such a way to give an attractive architectural effect. Different types of finishes have been in use now a days. Surface finishes may be grouped as under

1. Formwork Finishes
3. Applied Finishes
2. Surface Treatment

Formwork Finishes

Concrete maintains the shape of formwork, i.e., centering work. Thus keeping the required shape through formwork, viz., undulated fashionable shapes, V-shaped finishes, plain surfaces or any pleasing surface can be obtained. The imaginative ideas of architects may be implemented by a careful look of concrete surface.

A properly made oat formwork can give a very smooth surface using right proportioning of materials better than that made by a best mason. Because of increasing cost of labour, self finishing concrete surfaces are preferred.

Surface Treatment

This is a commonly used method of surface finishing. A residential floor is to be smooth. In order to get a smooth finish, first the proportioning of mix should be appropriate. The finishing of surface should be at the same rate as that of placing of concrete. Adequate care has to be taken to the extent and time of trowelling. Careful attention should be paid for non-formation of laitance, no excess mortar left and no excess water accumulation on the surface. A poor surface is formed due to hurried completion.

Rough finishes are required in concrete pavement slab, air-field pavements, in roads, e c. In such cases, the concrete is brought to the plane level surface, and then lightly raked, or broomed, or textured or scratched to make the surface rough. Other finishes to give good look like exposed aggregate finish may also be made.

Applied finish

Exterior application of rendering made on concrete structures is denoted As applied finish. In this case the concrete surface is finished and kept wet, then a mortar(1:3) is applied. Any required pleasant finish is given to the mortar.

Sometimes the rendering applied on wall is pressed with sponge. By repeating this process the sand is exposed and the surface gets a finish which is known as Sand Facing. Another type of finish known as rough cast finish is done.

In this type a wet plastic mix (three parts of cement, one part of lime, six parts of sand and four parts of about 5 mm size peagravel aggregate) is dashed on the wall surface by means of a scoop or plasterer's trowel.

Other finishes under this category are non-slip finish, coloured finish, wear resistant floor finish, craziness finish, etc.

TESTS ON FRESH CONCRETE

The following tests are commonly employed to measure workability of fresh concrete:

1. Slump test
2. Compaction factor test
3. Flow test
4. Kelly Ball test
5. Vee Bee consistometer test

Slump Test

- It is the most commonly used method of measuring consistency of concrete.
- This test can be conducted in the field or in laboratory. However, this test is not suitable for very wet or very dry concrete.
- The apparatus for conducting the slump test consists of a metallic mould in the form of a frustum of a cone wit 20 cm bottom diameter, 10 cm top diameter and 30 cm height.
- A steel tamping rod of 16 mm dia, 0.6 m long with a bullet end is used for tamping.
- The internal surface of the mould is thoroughly cleaned and placed on a smooth non-absorbent horizontal surface.
- The mould is filled in four layers of equal height. Each layer is compacted by giving 25 blows with the tamping rod uniformly.
- After filling the mould and Roding, the excess concrete is stuck off and leveled.
- The mould is lifted upwards from the concrete immediately by raising it slowly.
- This allows the concrete to subside. This subsidence is referred to as slump of concrete. The difference in height of the mould and that of the subsided concrete is measured and reported in mm which is taken as the slump of concrete.
- The pattern of slump also represents the characteristics of concrete. If the slump of the concrete is even it is called true slump.
- If one-half of the cone slides down is called as shear slump. In this case the average value of the slump is considered.

- Shear slump also indicates that the concrete is not cohesive and reflects segregation (Fig. 1.2). Concrete mixes are classified based on the **slump as given in Table 1.7.**

Table 1.7: Slump and nature of concrete

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

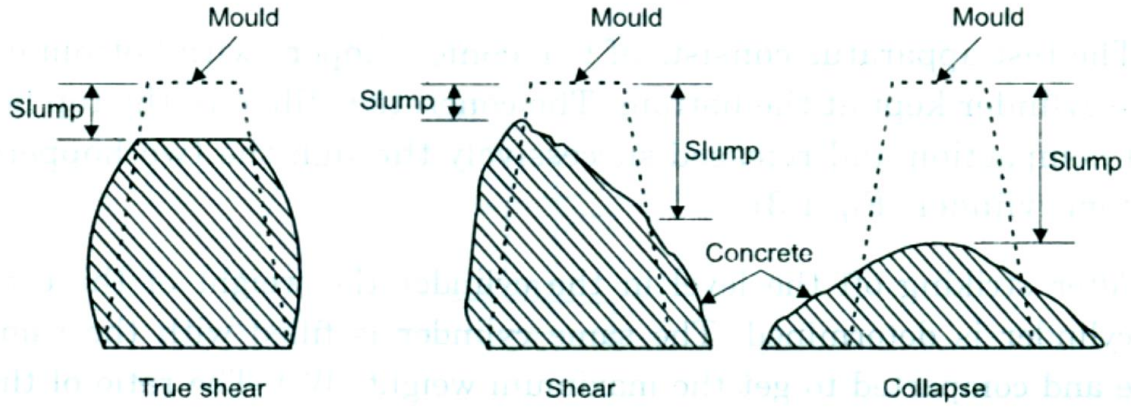


Figure 1.2: Types of slumps

- The slump test can be conducted both in the laboratory and in work site.
- The slump test results grant the facility to early detect the difference in water content of successive batches of the identical mix

Compacting Factor Test

This is a more refined test than the slump test. This test measures the degree of compaction obtained by using certain energy in overcoming the internal friction of the concrete. This property is a measure of workability.

The test apparatus consists of two conical hopers with bottom doors and a separate cylinder kept at the bottom.

The concrete is filled in the top hopper fully without compaction and released successively through the two hoppers and into the bottom cylinder (Fig.1.3).

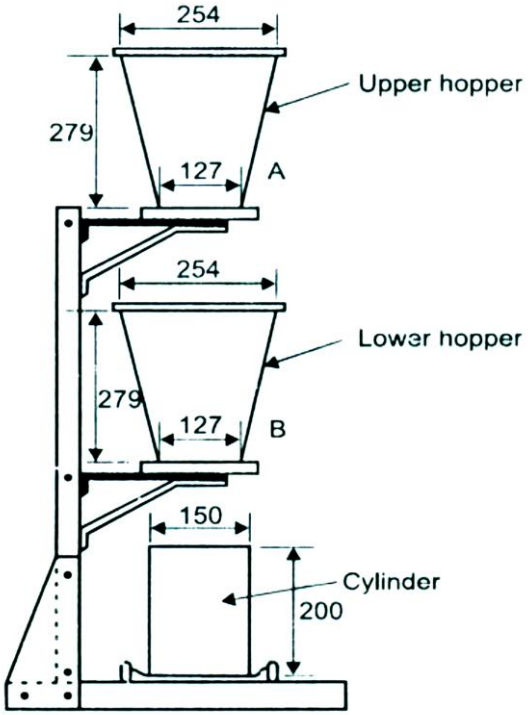
After striking off the level in the cylinder the weight of the concrete (W_1) in the cylinder is determined.

The same cylinder is filled with the same batch of concrete and compacted to get the maximum weight (W_2). The ratio of the observed weight (W_1), to the theoretical weight, (W_2), i.e., W_1/W_2 is the compacting [actor. The workability, compacting factor and the corresponding slump are given in Table 1.9.

Table 1.9: Workability and compacting factor

Workability	Compacting factor	Corresponding slump
Very low	0.80	0 to 25 mm
Low	0.85	25 to 50 mm
Medium	0.92	50 to 100 mm
High	0.95	100 to 180 mm

The compacting factor test measures the quality of concrete which relates very close to the workability. This test clearly depicts the workability of concrete.



Flow Test

- This test gives an indication of the quality of concrete with respect to consistency, cohesiveness and non-segregation.
- In this test a mass of concrete is subjected to jolting and the flow or spread of the concrete is measured. The flow is related to workability.
- The test apparatus consists of a flow table of 76 mm dia on which concentric circles are marked. A mould similar to the one used in slump test with base diameter as 25 cm and upper diameter as 17 cm with a height of 12 cm is used (Fig. 1.4).
- The mould is kept on the clean table and concrete is filled in two layers with each layer being rodded 25 times with a tamping rod of 1.6 cm diameter and 61 cm long with rounded ends. The excess concrete on the top of the mould is leveled.
- The mould is lifted vertically upwards completely. The concrete stands on its own without support.
- The table is raised and dropped 12.5 mm with a earn arrangement, times in about 15 seconds.
- The diameter of the spread-concrete is measured in directions and the average value is taken.
- The flow of the concrete is defined the percentage increase in the average diameter of the spread-concrete to the diameter of the mould, i.e.

$$\text{Flow (\%)} = \frac{\text{Average spread in diameter in cm - 25}}{25} \text{x} 100$$

- The value varies from 0 to 150 %.
- The spread pattern of the concrete also reflects the tendency of the segregation. The flow test is a laboratory test

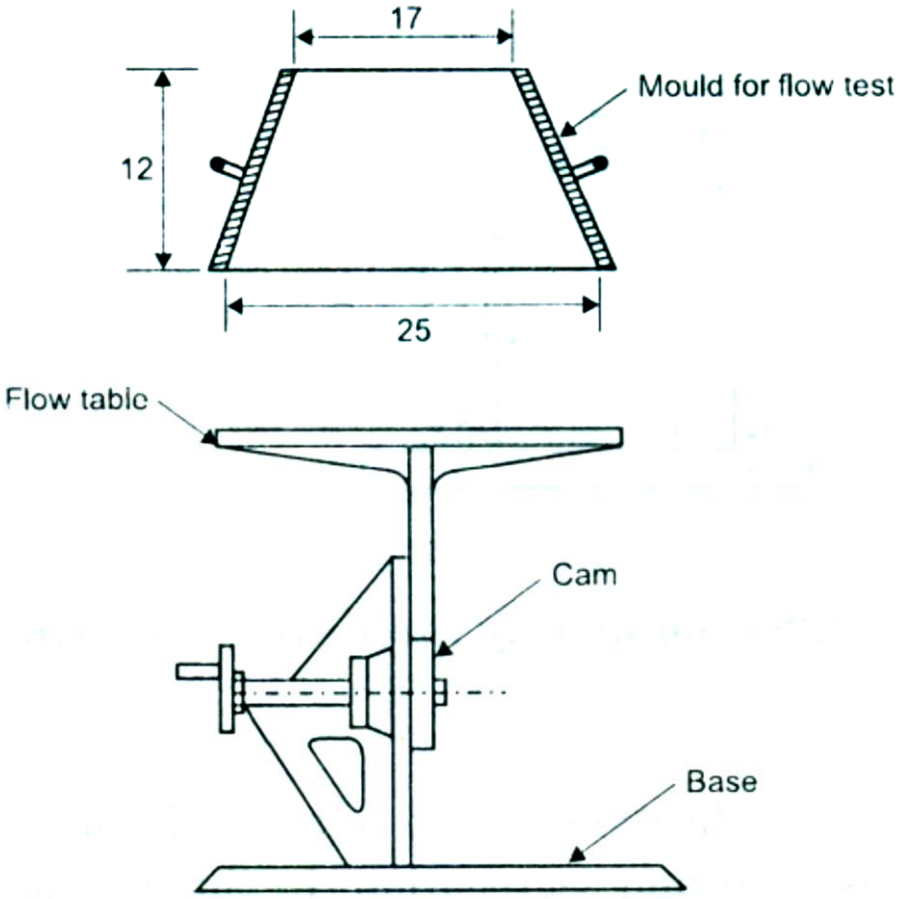


Table 1.4: Flow table apparatus

Kelly-Ball Test

- It consists of a metal hemisphere of 5 cm diameter weighing 13.6 kg.
- The concrete base should be 20 cm depth and the minimum distance from the centre of the ball to nearest edge of the concrete is 23 cm.
- The ball is lowered gradually on the surface of the concrete. The depth of penetration is read immediately on the stem to the nearest 5 mm.
- The test can be done in a shorter periods of about 15 secs. This test gives more consistent results than slump tests (Fig 1.5).
- The test can be performed in the field and it can be performed on the concrete placed on site.

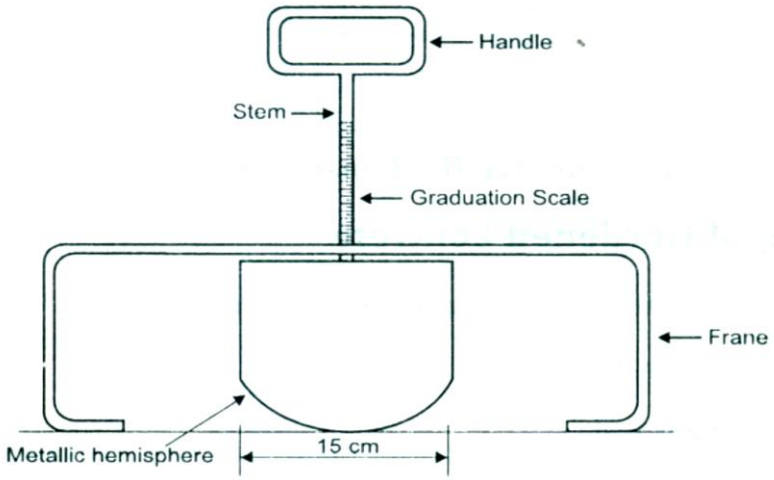


Table 1.5: Kelly ball

Vee-Bee Consistometer Test

- This test consists of a vibrating table, a metal pot, a sheet metal cone and a standard iron rod (Fig 1.6).
- A slump cone with concrete is placed inside the sheet metal cylindrical pot of the conistometer.
- The glass disc is turned and placed on the top of the concrete in the pot. The vibrator is switched on and the stop watch is started simultaneously.
- The vibrator is kept on till the concrete in the cone assumes a cylindrical shape. The time is noted.
- The time required in seconds for the concrete to change from the shape of cone to the shape of a cylinder is known as Vee Bee Degree.
- This is a good laboratory method and more suitable for very dry concrete. This test measures the workability indirectly.

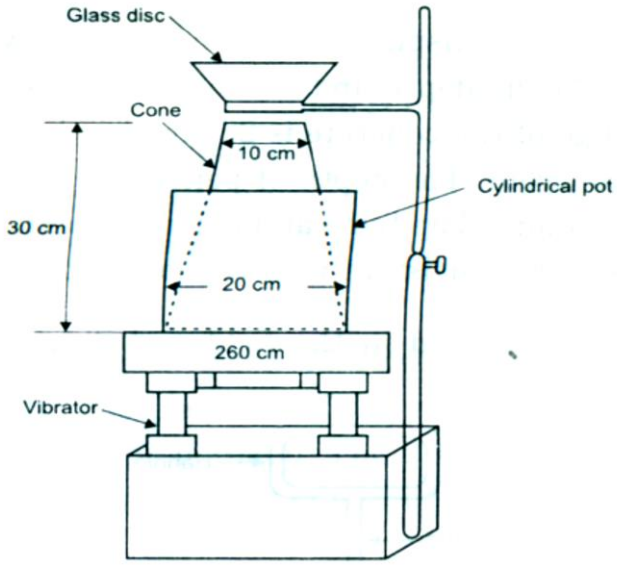


Table 1.6: Vee-Bee Consistometer Test

TESTS ON HARDENED CONCRETE

- Concrete is relatively strong in compression and weak in tension. In reinforced concrete construction the strength of the concrete in compression is only taken into consideration. The tensile strength of concrete is generally not taken into consideration.
- A concrete road slab is called upon to resist tensile stresses from two principal sources - wheel loads and volume change in the concrete.

Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete works. Systematic testing of raw materials, fresh concrete and hardened concrete are inseparable part of any quality control programmed for concrete, which helps to achieve higher efficiency of the material used and greater assurance of the performance of the concrete with regard to both strength and durability.

The test methods should be simple, direct and convenient to apply.

Tests which are conducted for hardened concrete are:

- Compressive strength test
- Flexural strength test
- Split tensile strength test

TESTING PROCEDURE OF COMPRESSIVE STRENGTH TEST OF CONCRETE.

Apparatus

Moulds for the Test Cubes, Tamping rods of 16 mm diameter and 650 mm in length and bullet pointed at the lower end.

Cube beam and cylinder moulding

Procedure:

- Calculate the materials required for preparing the concrete of given proportions.
- Mix those thoroughly in mechanical mixer until uniform colour of concrete is obtained.
- Pour concrete in the oiled with a medium viscosity oil.
- Fill concrete in cube moulds in two layers each of approximately 75 mm and ramming each layer with 35 blows evenly distributed over the surface of layer.
- Fill the moulds in 2 layers each of approximately 50 mm deep and ramming each layer heavily.
- Struck off concrete flush with the top of the moulds.
- Immediately after being made, they should be covered with wet mats.
- Specimens are removed from the moulds after 24 hrs and cured in water 28 days.
- After 24 hrs of casting, cylinder specimens are capped by neat cement paste 35 percent water content on capping apparatus. After another 24 hours the specimens are immersed into water for final curing.
- Compression tests of cube and cylinder specimens are made as soon as practicable after removal from curing pit.
- Test-specimens during the period of their removal from the curing pit and till testing are kept moist by a wet blanket covering and tested in a moist condition.
- Place the specimen centrally on the location marks of the compression testing machine and load is applied continuously, uniformly and without shock.
- Also note the type of failure and appearance of cracks.

Calculation:

Compressive strength (N/mm^2) = W_f / A_p

W_f = Maximum applied load just before failure (N)

A_p = Plan area of mould, (mm^2)

TEST PROCEDURE FLEXURAL STRENGTH OF CONCRETE

Flexural strength test of-concrete

- Wheel loads may cause high tensile stresses due to bending, when there is an inadequate sub grade support. Volume changes, resulting from changes in temperature and moisture, may produce tensile stresses, due to warping and due to the movement of the slab along the sub grade.
- Stresses due to volume changes alone may be high. The longitudinal tensile stress in the bottom of the pavement caused by restraint and temperature warping frequently amounts to as much as 2.5 N/mm^2 at certain periods of the year and the corresponding stress in the .transverse direction is approximately 0.9 N/rnm^2.

- The flexural strength of concrete was found to be 8 to 11 per cent of the compressive strength of the concrete for higher ranges of concrete strength (greater than 25 N/rnm^2) and 9 to 13 per cent for lower ranges of concrete strength (less than 25 N/rnm^2) approximately.
- The flexural to compressive strength ratio was higher with aggregate of 40 mm maximum size than with those of 20 mm maximum size.

Tensile Strength = K (Compressive Strength) x n

- Where, value of K varies from 6.2 for gravels to 10.4 for crushed rock (average value is 8.3) and value of 'n' may vary from 0.5 to 0.75.
- The Indian Standard IS: 456 of2000 give the following relationship between the compressive strength and flexural strength

Flexural strength = 0.7 √fck

Where, fck is the characteristic compressive strength of concrete in N/mm^2

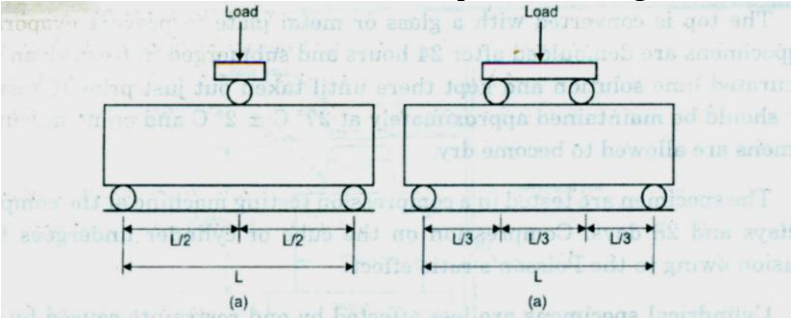


Figure 1.7: Loading arrangement in Flexural beam test

Procedure

- Test specimens are stored in water at a temperature of 24 ° to 30°C for 48 hours before testing.
- They are tested immediately on removal from the water whilst they are still in a wet condition. The dimensions of each specimen should be noted before testing.
- No preparation of the surfaces is required.
- The bearing surfaces of the supporting and loading rollers are wiped clean and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers.
- The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 200 or 133 mm apart.
- The axis of the specimen is carefully aligned with the axis of the loading device.
- No packing is used between the bearing surfaces of the specimen and the rollers. .•
- The load is applied without shock and increasing continuously at a rate such that the extreme fiber stress increases at approximately 0.7 kg/cm-/min that is, at a rate of loading of 400 kg/min for the 150 mm specimens and at a rate of 180 kg/min for the 100 mm specimens .
- The load is increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure is noted.

Calculation

The flexural strength of the specimen is expressed as the modulus of rupture f_b which if' a' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in mm, is calculated to the nearest 0.05 N/mm- as follows:

$f_b = \frac{PL}{bd2}$

when 'a' is greater than 200 mm for 150 mm specimen or greater than 133 mm for a 100 mm specimen, or

$f_b = \frac{3PA}{bd2}$

When 'a' is less than 200 mm but greater than 170 mm for 150 mm specimen or less than 133 mm but greater than 110 mm for a 100 mm specimen,

Where

b = measured width in mm of the specimen.

d = measured depth in mm of the specimen at the point of failure,

L = length in mm of the span on which the specimen was supported, and

P = maximum load in Newton applied to the specimen.

TESTING PROCEDURE OF SPLIT TENSILE STRENGTH OF CONCRETE

Apparatus:

- A compression Testing Machine of adequate capacity and with an arrangement for applying the load at the specified rate. Cylinder moulds of 150mm diameter and 300 mm height, weighting machine, mixer and tamping rod.

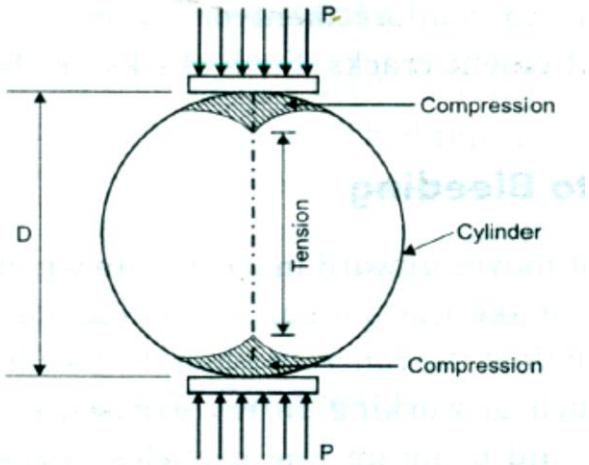


Figure 1.8: Split-tension test

Procedure

- Take the mix proportions as per requirement and mix them thoroughly until uniform colour of concrete is obtained.
- In mixing by hand the cement and fine aggregate shall be first mixed dry to uniform colour and then coarse aggregate is added and mixed until coarse aggregate is uniformly distributed throughout the batch.
- Pour concrete in moulds oiled with medium viscosity oil. Fill the cylinder mould in four layers each of approximately 75 mm and ram each layer more than 35 times with evenly distributed strokes.
- Remove the surplus concrete from the top of the moulds with the help of a trowel.
- Cover the moulds with wet mats and put the identifications marks after about 3 to 4 hours.
- Remove the specimens from the moulds after 24 hrs and immerse them in water for final curing.
- Tests at least three specimens for each age of test are tested.
- Apply the load without shock and increase it continuously at a rate to produce a' split tensile stress of approximately 1.4 to 2.1 N/mm ^{2}/ Min, until no greater load can be sustained.
- Record the maximum load applied to the specimen. Note the appearance of concrete and any unusual feature in the type of failure
- Compute the split tensile strength of the specimen to nearest 0.05 N/ mm^2

EXTREME WEATHER CONCRETING

According to specifications the concrete should be placed between 15°C to 25° C. Hot weather (more than 50°C) would accelerate the rate of hardening and result in pre-matured

gain of strength although the ultimate strength remains the same. On the other hand cold weather retards the rate of hardening concrete although the ultimate strength remains the same.

Concreting in Hot Weather

Concreting in hot weather leads to the following effects

1. The amount of water needed for obtaining a certain workability increases, requiring a high water - cement ratio and / or a higher cement content.
2. The workability of fresh concrete deceases more rapidly. This may result in poor Workability and therefore poorer compaction or it may necessitate the addition of water and therefore an increase in water - cement content ratio. Both these consequences adversely affect the durability of the concrete.
3. The probability of cracking of the concrete, from surface down, is due to plastic shrinkage. This risk is greatly increased if concreting is done in hot and windy conditions. The temperature of the concrete mix and of the ambient atmosphere, the relative humidity and the wind velocity are of major importance in connection with this.
4. Accentuation of thermal gradients due to additional heat released from hydration of cement. This will increase the temperature gradient in the young concrete, with high risk of cracking in consequence.
5.The formation of a porous soft top layer due to rapid evaporation of water increased differential shrinkage across the depth and consequent increase in deflections.

Measures required to counter act the above-mentioned effects are:

1.Using water-reducing admixtures. A complicating feature is that their – action, particularly in the case of super-plasticisers, is confined to a rather limited period of time. This problem can be somewhat eased by the use of retarders as well. It is advisable, however, to add these admixtures only a short time before placing the concrete in the form work.
2.Keeping the temperature of fresh concrete as low as possible. Many specifications for works to be carried .out in hot' countries state that the temperature of the fresh concrete should not exceed about 30° C. Quite often this means that artificial cooling will be necessary. This can be most effective achieved by adding crushed ice to the water for mixing and fog spraying the

coarse aggregates, forms and reinforcement (which then cool down quickly)

3. Protection from direct solar radiation and from wind,' e.g., by covering the concrete, installing screens ,wind breakers, etc.
4.Fromwork to receive concrete should be wetted so as to prevent the loss of water from concrete due to absorption.

Concreting in Cold Weather

The 28 days-strength will be of 50% if cured at 0°C and of 30% if curer at 10^0C. This delay in setting of concrete results in increase of labour cost, material cost, waiting time, etc. It is the condition that freshly laid concrete under no condition should be below 4°C. In practical the freshly placed concrete should be maintained at a temperature of not less than 21°C for 3 days or 10°C for 5 days after it is placed.

If the work has to be done below 4^0c and the materials are not frozen, the heat of hydration may be increased b the use of 20 to 25% extra cement use of rapid hardening or high alumina cement is usually recommended.

READY MIXED CONCRETE.

Ready-mix concrete (RMC) is the concrete which is made at a plant away from the construction site and conveyed in special vehicles.

Ready mixed concrete is a type of concrete that is manufactured in a factory or batching plant, according to a set recipe, and then delivered to a work site by truck mounted transit mixers. The inside of a transit mixer uses a simple Archimedes screw to mix and to lift the concrete to the delivery chute.

This results in a precise mixture, allowing specialty concrete mixtures to be developed and implemented on construction sites. The first ready-mix factory was built in the 1930, but the industry did not begin to expand significantly until 1960 and its has continued to grow since then.

Ready-mixed concrete is sometimes preferred over on-site concrete mixing because of the precision of the mixture and reduced work site confusion. However, using a pre-determined concrete mixture reduce flexibility, both in the supply chain and in the actual components of the concrete.

Ready-mixed concrete is popularly called RMC, refers to concrete that is specifically manufactured for delivery to the customer's construction site in a freshly mixed and plastic or unhardened state.

Concrete itself is a mixture of portland cement, water and aggregates comprising sand and gravel. In traditional work sites, each of these materials is procured separately and mixed in specified proportions at site to make concrete. Ready-mixed concrete is bought and sold by volume, usually expressed in cubic meters. RMC can be custom-made to suit different applications. It is manufactured under computer controlled operations and transported and placed at site using sophisticated equipments and methods.

On some jobs, such as large danger of falling highway Jobs, it is possible to use a batch plant that contains its own mixer. A plant of this type discharges ready-mixed concrete into transit mixers, which haul it to the construction site. The truck carries the mix in a revolving chamber much like the concrete mixer. Keeping the mix agitated in route prevents segregation of aggregate particles. A ready-mix plant

is usually portables so that it can follow the job along. It must be certain, of course, that a truck will be able to deliver the mix at the site before it starts to set. Discharge of the concrete from the drum should be completed within one and half to two hours.

Ready-mix concrete plants use transit mixers. This is a popular equipment for transporting concrete over a long distance. Transit mixers are truck mounted having a capacity of 4 to 7 m^3.

There are two variations in the ready mix concrete. In one type the mixed concrete is transported to the site by keeping it agitated all along at a speed varying between 2 and 6 revolutions per minute. In the other type the concrete is batched at the central batching plant and mixing is done in the truck mixer either in transit or immediately prior to discharging the concrete at site.

Transit mixing permits larger haul and is less vulnerable in case of delay. The speed of the rotating drums in the truck mixer is between 4 and 16 revolution per minute. Here, the water need not to be added till the mixing is commenced. With the development of twin fin process mixer, the transit mixers have become very efficient in mixing.

Advantages

1.As the RMC companies have laboratory facility with sufficient equipment, only quality raw materials are used to produce concrete.

2. Uniform and consistent quality of concrete is assured as it is produced by automated batching plant.

3. Control on water-cement ratio is maintained as it is monitored and operated by automated batching plant.

4. Due to high workable and cohesive mix, less chance of segregation, lumping and consequent absence of honey- comb in the concrete.

5. Better finishing is feasible due to pumpable concrete mix.

6. Les construction time because of continuous mechanical operation.

7. Greatly eliminates need for ordering, storing and wastage of raw materials.

8. Addition of mineral/chemical admixtures is easy.

9. Effectively helpful in crowded cities and sensitive localities.

10. Better in safety aspects compared with site-mix concrete

11. Less noise and dust pollution at the construction site.

Disadvantages

1.Time and rate of pouring of concrete depends on the traffic condition at the site.

2.Requirement of proper approach road in sites is essential to transport the huge weight carrying transit mixture.

3. Concrete produced for a stipulated work cannot be used during unexpected situations like traffic, rain, machine problem, etc.

4. Better planning is required as the concrete cannot be taken as and when required .

5. There is a possibility of change of water-cement ratio by the workmen.

6. Quite expensive.

NON-DESTRUCTIVE TESTING

Non-destructive testing is done on hardened concrete. In non-destructive testing methods some properties of concrete are used to estimate strength, durability, elastic parameters, crack depth, micro-cracks, and progressive deterioration of concrete.

Such properties of concrete are hardness, resistance to penetration, rebound number, resonant frequency ability to allow ultrasonic pulse velocity, ability to scatter and transmit X-rays and Gamma rays, its response to nuclear activation and acoustic emission. Using one or more of the above properties various nondestructive methods have been developed. Some of the important methods in use are explained below.

Rebound Hammer Test

This is commonly adopted equipment for measuring the surface hardness. This type of hammer consists of a spring controlled hammer mass that slides on a guide within a tubular housing (Fig. 1.9). When the plunger at the tip of the hammer mass is pressed against the surface of concrete, it retracts against the force of the tip of the hammer mass is pressed against the surface of concrete, it retracts against the force of the spring. When completely retracted the spring controlled mass rebounds, taking a rider with it along the guide. By pushing a button, the rider can be held in position to allow readings to be taken. The readings on the scale are termed as the rebound number.

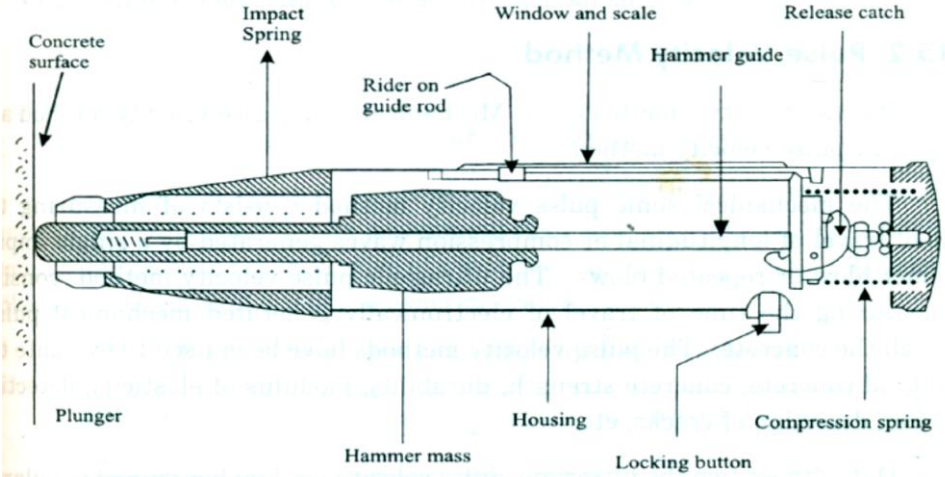


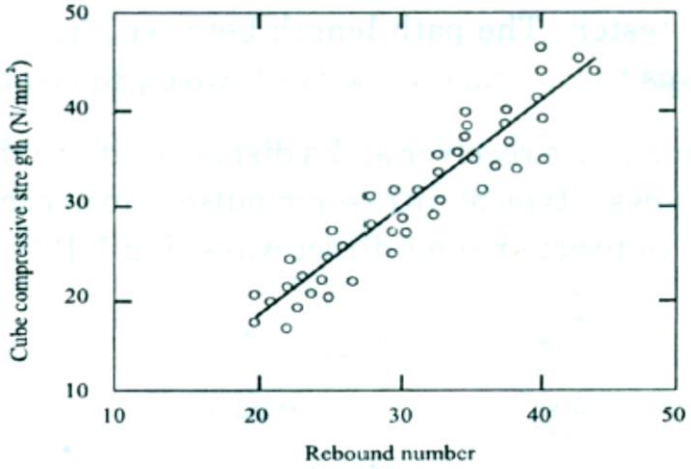
Fig. 1.9: Rebound hammer

Calibration chart developed correlating the rebound number and compressive strength of concrete serves as a ready reference to assess the strength of in-situ concrete in members by this method.

This method provides an inexpensive, simple and quick method for nondestructive testing of

1. Concrete in the laboratory
2. In -situ concrete in precast member in precast industry
3. Concrete in members where strength is doubtful

The test results are affected by smoothness of surface, moisture condition of test specimen, type of aggregates and the carbonation of concrete. Estimation of strength of concrete by this method will be with an accuracy of only ± 25%



Eg.1.10: Typical rebound number and cube strength

Pulse Velocity Method

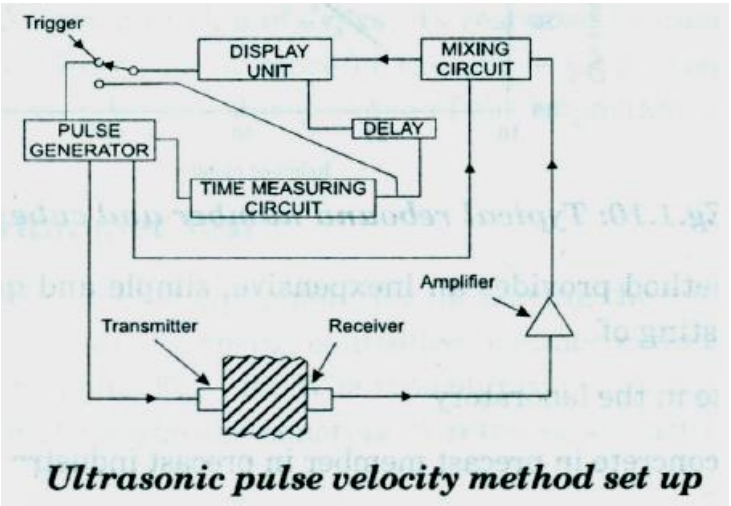
It consists of two methods, viz mechanical sonic pulse velocity method and Ultrasonic pulse velocity method.

The mechanical sonic pulse velocity method consists of measuring the time of travel of longitudinal or compression waves generated by a single impact hammer blow or repeated blows. The ultrasonic pulse velocity method consists of measuring the time of travel of electronically generated mechanical pulses through the concrete. The pulse velocity methods have been used to evaluate the quality of concrete, concrete strength, durability, modulus of elasticity, detection of water, detection of cracks etc.

Out of these two the ultrasonic pulse velocity method has gained popularity all over the world which is explained below.

The ultrasonic pulse velocity method consists of measuring the time travel of an ultrasonic pulse wave passing through the concrete to be tested. The time of travel between the initial onset and reception of the pulse is measure electronically by the tester. The path length between the transducers divided by the time of travel gives the average velocity of wave propagation.

Pulse generator, pulse receiver and a display unit are the major units in the tester. Figure l.ll shows a typical ultrasonic pulse velocity method. Tests may be carried out in direct, indirect or semi-direct ways (Fig. 1.12)



Ultrasonic pulse velocity method set up

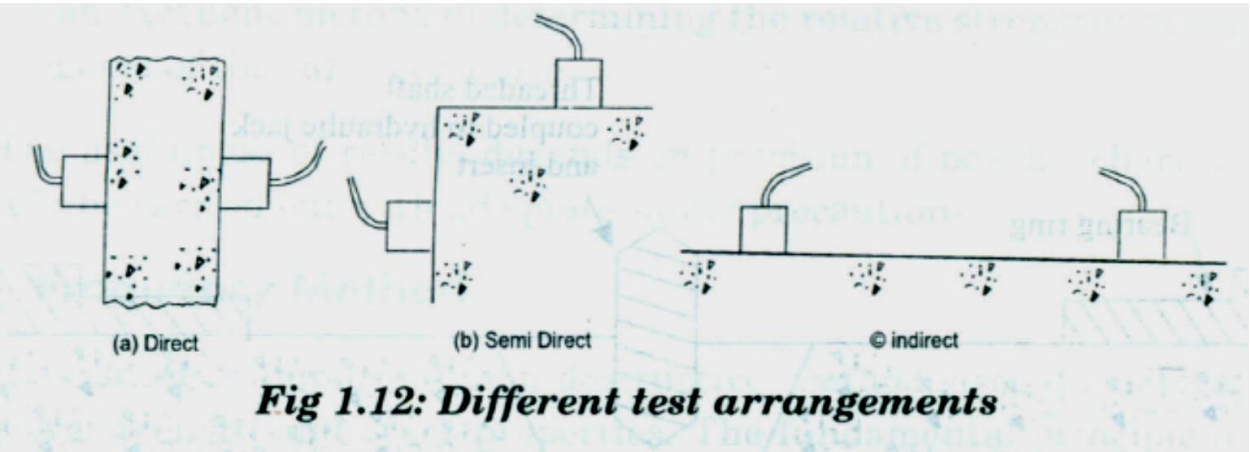


Fig 1.12: Different test arrangements

A calibration chart correlating the velocity of the pulse with strength of concrete serves as reference for assessment of in-situ concrete. High pulse velocity readings in concrete are indicative of concrete of good quality. Table 1.19 gives the pulse velocity range of quality of concrete (Shetty, 2006).

Table 1.19 Concrete quality and pulse velocity

Pulse velocity (m/s)	General consideration
4575	Excellent
3660 – 4575	Good
3050 – 3660	Questionable
2135 – 3050	Poor
2135	Very Poor

The method provides an excellent means of establishing uniformity of concrete and deserves a definite place in quality control operations. The equipment is relatively inexpensive, easy to operate and portable. The test can be carried out both on laboratory sized specimen and on large scale completed concrete structures. The test range is upto about 3 m thickness, which can be enhanced up to 10 mm with the help of boosters. Different test arrangements are shown in Fig 1.12

Certain parameters such as wetness of concrete affect the results. The assessment of strength will be with an accuracy of only ± 20%

Pull-out Test

The pull-out test consists of pulling out form concrete a specially shaped steel insert whose enlarged end has been cast into concrete (Fig l.13).

The pull-out force required is measured using a dynamometer. Because of its shape, the steel inset is pulled out along with a cone of concrete. The concrete in the pulled out region will be in shear/tension with generating lines of the cone running at approximately 45° to the direction of pull.

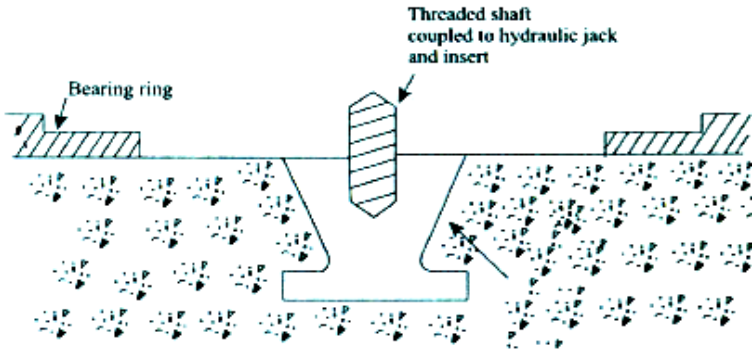


Fig 1.13: Pull - out test set-up

The equipment is simple to assemble and operate. It is safe and test can be carried out in the field in a matter of minutes. The tests are reproduce with an exceptional degree of accuracy and correlation with compressive stress of concrete is good.

The major drawback in this method is that the concrete surface gets dam and needs to be repaired after the tests. The test does not measure the stress in the interior of concrete because the pull out assembly has to be inserted concrete at the time of concreting itself.

Windsor Probe Test

The Windsor consists of a powder actuated gun, hardened alloy probes, lot cartridges and depth gauge for measuring penetration of probes. The probes have diameter of about 6 mm and length of 80 mm. The probe is driven into the concrete by the firing of precision powder charge that develops and energy of 79.5 m kg.

The method of testing relatively simple. When in-situ concrete is to be tested, three probes are fired into concrete, one at each corner of a 175 mm equilateral triangle. The exposed length of the individual probes are measured and averaged out.

For any given concrete, the relationship between the penetration resistance and the strength may be established and used to assess in-situ concrete strength

The method is simple enough. May be used to access uniformity of concrete and to delineate zones of poor quality or deteriorated concrete in structures. In brief, it is an excellent method of determining the relative strengths of concrete in various regions of the same structure.

The usefulness of results depends on precision of powder charge. And the test should be carried out with adequate safety precautions.

Frequency Method

It is another important non-destructive method used to determine the compressive strength and other properties. The fundamental principle on which the method based is velocity of material through a material. A mathematical relation could be made between the resonant frequency of the material to the modulus of elasticity of the material. Property of homogeneous material can be made use on heterogeneous material like concrete with judgment.

Nuclear Method

This is a new technique which is used to find the moisture content. This method employs the scattering of neutrons directed towards the concrete and the number of neutrons returned. With a standard relationship number of neutrons and water content/cement content the required water or cement content can be found.

Radioactive Method

Here X-rays and gamma rays are used. When X-rays and gamma rays are passed through concrete the electromagnetic spectrum penetrate concrete but undergo attenuation in the process. The degree of attenuation is a function of the kind of matter traversed its thickness and the wavelength of the radiation. Further the intensity of the incident gamma-rays and the emerging gamma-rays after passing through the specimens are measured. These two values are used to calculate the density of concrete.

Gamma-rays transmission method is particularly used to measure the thickness of concrete slabs of known density. This is achieved by passing gamma radiation of known intensity to penetrate through the concrete. The thickness of the concrete is measured based on the intensity of gamma ray measured on the other end.

Magnetic Method

Magnetic devices are developed to measure the depth of reinforcement cover in concrete and also to detect the position of reinforcement. This apparatus is known as cover meter.

Electrical Methods

Electrical methods are used for determining the moisture content of hardened concrete, tracing of moisture permeation through concrete and determining thickness of concrete pavements.

Determination of accurate value of moisture content of hardened concrete is required in connection with creep, shrinkage and thermal conductivity stud In this method the principle applied is that the dielectric properties of hardened concrete change with the change in moisture content

Mostly the electrical resistivity methods are used to find the thickness of concrete pavements. This is based on the principle that the material of resistance to the passage of an electric current. A concrete pavement has resistivity characteristic that is different from that of the underlying sub grade layers. The depth of concrete pavement is estimated from the change in the slope of the resistivity versus depth curve.

Break-off Method

This method has been developed by Johansen (1979) to determine the situ strength of concrete. This method has been used in Scandinavian count and has been standardized by ASTM

In this method, a plastic sleeve with annular seating ring is inserted in fresh concrete to form a cylindrical test specimen and a counter bore. After hardening the sleeve is removed. Alternatively, in the hardened concrete a concrete coring machine may be to drill similarly shaped test specimen.

A special loading mechanism is placed in the counter bore. A hand operated pump is used to generate a force at the uppermost section of the cylinder so as to break from the concrete mass. The test result is reported as a break-off number. It is the maximum pressure recorded by the gauge measuring the hydraulic pressure in the loading mechanism. The break-off number has been correlated to compressive and flexural strength of concrete.

Pull-off Test

This was developed in UK during 1970s. The pull-off test involves bonding a circular steel disc to the surface of the concrete under test by means of an epoxy resin. Prior to the bonding, sandpaper is used to abrade the surface of concrete to remove laitance, followed by degreasing the surface using a suitable solvent.

After the curing of the epoxy resin, a tensile force is then applied to the steel disc. Because of the tensile strength of bond is higher than that of the concrete, the latter fails in tension.

Knowing the area of disc and the force applied at failure, the tensile strength of concrete can be found. The pull-off test still is in the developing stage.

Maturity Method

The compressive strength of an adequately cured concrete increases with time. The increase in strength is function of curing time, the temperature and the moisture content. Several investigators have studied the combined effect of time and temperature on the concrete. Some researchers have published strength- maturity relationship. Maturity was defined as the product of time and temperature above a datum temperature of -10^0 c (14^0 F).