3. CONCRETE

Concrete is a composite material composed mainly of water, aggregate, and cement. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses.

The aim is to mix these materials in measured amounts to make concrete that is easy to: Transport, place, compact, finish and which will set, and harden, to give a strong and durable product. The amount of each material (ie cement, water and aggregates) affects the properties of hardened concrete.

Production of concrete

A good quality concrete is essentially a homogeneous mixture of cement, coarse and fineaggregates and water which consolidates into a hard mass due to chemical action between the cement and water. Each of the four constituents has a specific function. The coarser aggregate acts as a filler. The fine aggregate fills up the voids between the paste and the coarse aggregate. The cement in conjunction with water acts as a binder. The mobility of the mixture is aided by the cement paste, fines and nowadays, increasingly by the use of admixtures.The stages of concrete productionare:Batching or measurement of materials, Mixing, Transporting, Placing, Compacting, Curing andFinishing.

Batching

It i s the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally batching is done by volume but most specifications require that batching be done by mass rather than volume.The proportions of various ingredients are determined by proper mix design.

A concrete mix is designed to produce concrete that can be easily placed at the lowest cost. The concrete must be workable and cohesive when plastic, then set and harden to give strong and durable concrete. The mix design must consider the environment that the concrete will be in; ie exposure to sea water, trucks, cars, forklifts, foot traffic or extremes of hot and cold. Proportioning concrete is a mixture of cement, water, coarse and fine aggregates and admixtures. The proportions of each material in the mixture affects the properties of the final hardened concrete. These proportions are best measured by weight. Measurement by volume is not as accurate, but is suitable for minor projects.

Cement content as the cement content increases, so does strength and durability. Therefore to increase the strength, increase the cement content of a mix. WaterContent adding more water to a mix gives a weaker hardened concrete. Always use as little water as possible, only enough to make the mix workable.Water to cement ratio as the water to cement ratio increases, the strength and durability of hardened concrete decreases. To increase the strength and durability of concrete, decrease the water-cement ratio.Aggregates too much fine aggregate gives a sticky mix. Too much coarse aggregate gives a harsh or boney mix.Mixing concrete must be mixed so the cement, water, aggregates and admixtures blend into an even mix. Concrete is normally mixed by machine. Machine mixing can be done on-site or be a pre-mixed concrete company. Pre-mixed concrete is batched (proportioned) at the plant to the job requirements. Truck mixing the materials are normally added to the trucks at batching plants and mixed for required time and speed at the plant. The trucks drum continues to rotate to agitate the concrete as it is delivered to the site. Site mixing when site mixing begin by loading a measured amount of coarse aggregate into the mixer drum. Add the sand before the cement, both in measured amounts.

Mixing

The mixing operation consists of rotation or stirring, the objective being to coat the surface the all aggregate particles with cement paste, and to blind all the ingredients of the concrete into a uniform mass; this uniformity must not be disturbed by the process of discharging from the mixer. The mixing may done by manually or by mechanical means like, Batch mixer, Tilting drum mixer, Non tilting drum mixer, Pan type mixer, Dual drum mixer or Continuous mixers.

There are no general rules on the order of feeding the ingredients into the mixer as this depend on the properties of the mixer and mix. Usually a small quantity of water is fed first, followed by all the solids materials. If possible greater part of the water should also be fed during the same time, the remainder being added after the solids. However, when using very dry mixes in drum mixers it is necessary to feed the coarse aggregate just after the small initial water feed in order to ensure that the aggregate surface is sufficiently wetted.

Compaction

The operation of placing and compaction are interdependent and are carried out simultaneously. They are most important for the purpose of ensuring the requirements of strength, impermeability and durability of hardened concrete in the actual structure. As for as placing is concerned, the main objective is to deposit the concrete as close as possible to its final position so that segregation is avoided and the concrete can be fully compacted. The aim of good concrete placing can be stated quite simply.

It is to get the concrete into position at a speed, and in a condition, that allow it to be compacted properly. To achieve proper placing following rules should be kept in mind:The concrete should be placed in uniform layers, not in large heaps or sloping layers.The thickness of the layer should be compatible with the method of vibration so that entrapped air can be removed from the bottom of each layer.The rate of placing and of compaction should be equal. If you proceed too slowly, the mix could stiffen so that it is no longer sufficiently workable. On no account should water ever be added to concrete that is setting. On the other hand, if you go too quickly, you might race ahead of the compacting gang, making it impossible for them to do their job properly. Each layer should be fully compacted before placing the next one, and each subsequent layer should be placed whilst the underlying layer is still plastic so that monolithic construction is achieved. Collision between concrete and formwork or reinforcement should be avoided.For deep sections, a long down pipe ensures accuracy of location of concrete and minimum segregation.You must be able to see that the placing is proceeding correctly, so lighting should be available for large, deep sections, and thin walls and columns.Once the concrete has been placed, it is ready to be compacted. The purpose of compaction is to get rid of the air voids that are trapped in loose concrete.

It is important to compact the concrete fully because:Air voids reduce the strength of the concrete. For every 1% of entrapped air, the strength falls by somewhere between 5 and 7%. This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength.Air voids increase concrete's permeability. That in turn reduces its durability. If the concrete is not dense and impermeable, it will not be watertight. It will be less able to withstand aggressive iquids and its exposed surfaces will weather badly.Moisture and air are more likely to penetrate to the reinforcement causing it to rust. Air voids impair contact between the mix and reinforcement (and, indeed, any other embedded metals). The required bond will not be achieved and the reinforced member will not be as strong as it should be.Air voids produce blemishes on struck surfaces. For instance, blowholes and honeycombing might occur. There are two methods for compaction which includes: vibration by vibrators or by tamping using tamping rods.

Curing

Curing is the process of making the concrete surfaces wet for a certain time period after placing the concrete so as to promote the hardening of cement. This process consists of controlling the temperature and the movement of moisture from and into the concrete.

Curing of concrete is done for the following purposes. Curing is the process of controlling the rate of moisture loss from concrete to ensure an uninterrupted hydration of Portland cement after concrete has been placed and finished in its final position.Curing also helps maintain an adequate temperature of concrete in its early stages, as this directly affects the rate of hydration of cement and eventually the strength gain of concrete or mortars.

Curing of concrete must be done as soon as possible after placement and finishing and must continue for a reasonable period of time, for the concrete to achieve its desired strength and durability.Uniform temperature should be maintained throughout the concrete depth to avoid thermal shrinkage cracks.

Material properties are directly related to micro-structure. Curing assists the cement hydration reaction to progress steadily and develops calcium silicate hydrate gel, which binds aggregates leading to a rock solid mass,makes concrete denser, decreases the porosity and enhances the physical and mechanical properties of concrete.

Some other purposes of curing can be summed up as: curing protects the concrete surfaces from sun and wind, the process of curing increase the strength of the structure, the presence of water is essential to cause the chemical action which accompanies the setting of concrete. Generally there is adequate quantity of water at the time of mixing to cause the hardening of concrete,but it is necessary to retain water until the concrete is fully hardened.

If curing is efficient, the strength of concrete gradually increases with age. This increase in strength is sudden and rapid in early stages and it continues slowly for an indefinite period.By proper curing, the durability and impermeability of concrete are increased and shrinkage is reduced.The resistance of concrete to abrasion is considerably increased by proper curing.

Curing period:

For ordinary Portland cement, the curing period is about 7 days to 14 days.If rapid hardening cement is used the curing period can be considerably reduced.

Disadvantages of improper curing:

Following are the disadvantages of improper curing of concrete:

The chances of ingress of chlorides and atmospheric chemicals are very high.The compressive and flexural strengths are lowered.The cracks are developed due to plastic shrinkage, drying shrinkage and thermal effects.The durability decreases due to higher permeability.The frost and weathering resistances are decreased.The rate of carbonation increases.The surfaces are coated with sand and dust and it leads to lower the abrasion resistance.The disadvantages are more prominent in those parts of surfaces which are directly exposed or which have large surfaces compared to depth such as roads, canal, bridges, cooling towers, chimneys etc.

Factors affecting evaporation of water from concrete:

The evaporation of water depends upon the following 4 factors: Air temperature, Fresh concrete temperature, Relative humidity and Wind velocity.

From the above mentioned factors it can be concluded environment directly influences the process of evaporation, hence only the fresh concrete temperature can be monitored or supervised by the concrete technologists.The evaporation of water in the first few hours can leave very low amount of water in the concrete hydration, this leads to various shrinkage cracks.Under normal condition the average loss of water varies from 2.5 to 10 N per m2 per hour.The major loss occurs in the top 50 mm layer over a period of 3 hours, the loss could be about 5% of the total volume of that layer.

Methods of curing:

While selecting any mode of curing the following two factors are considered:

- The loss of water should be prevented.
- The temperature should be kept minimum for dissipation of heat of hydration.

Methods of curing can be categorised into the following categories:

Water curing-preventing the moisture loss from the concrete surface by continuously wetting the exposed surface of concrete.

Membrane curing-minimizing moisture loss from concrete surface by covering it with an impermeable membrane.

Steam curing-keeping the surface moist and raising the temperature of concrete to accelerate the rate of strength gain.

Water curing is of the following types:

Ponding: most inexpensive and common method of curing flat slabs, roofs, pavements etc. A dike around the edge of the slab, is erected and water is filled to create a shallow pond. Care must be taken to ensure that the water in the pond does not dry up, as it may lead to an alternate drying and wetting condition.

Sprinkling: fogging and mist curing- using a fine spray or fog or moist of water to the concrete can be efficient method of supplying water to concrete during hot weather, which helps to reduce the temperature of concrete.

Wet coverings: water absorbent fabrics may be used to maintain water on concrete surfaces. They must be continuously kept moist so as to prevent the fabrics from absorbing water from the body of concrete,due to capillary action.

Impermeable membrane curing is of following types:-

Formwork: leaving the form work in place during the early age of concrete is an efficient method of curing.

Plastic sheeting: plastic sheets form an effective barrier to control the moisture losses from the surface of concrete, provided they are secured properly and protected from damage. The efficiency of this system can be enhanced by flooding the concrete surface with water, under the plastic sheet.

Membrane curing compounds: Curing compounds are wax, acrylic and water based liquids are spread over the freshly finished concrete to form an impermeable membrane that minimises the loss of moisture from the concrete surfaces.These are cost effective methods of curing where standard curing procedures are difficult to adopt.When applied to cure concrete the time of the application is critical for maximum effectiveness.Too early application dilutes the membrane, whereas too late application results in being absorbed into the concrete.They must be applied when the free water on the surface has evaporated.For concrete with low w/c ratio, this is not a suitable process.

Steam curing: Steam curing is the process of accelerating the early hardening of concrete and mortars by exposing it to steam and humidity. These types of curing systems are adopted for railway sleepers, concrete blocks, pipes, manhole covers, poles etc.Precast iron is cured by this method under pressure.Curing in hot and cold weather requires additional attention.

Hot weather: During hot weather, concrete must be protected from excessive drying and from direct wind and sun. Curing materials which reflect sunlight to reduce concrete temperature must be used.

Cold weather: Some problems associated with temperature below 40^0C are:

- Freezing of concrete before strength is developed.
- Slow development of concrete strength.
- Thermal stresses induced by the cooling of warm concrete to cooler ambient temperatures

Chemical curing: In this method water is sprinkled over the surface, after adding certain amount of some hygroscopic material (e.g. sodium chloride or calcium chloride). The hygroscopic materials absorb moisture from the atmosphere and thus keep the surface damp.

Alternating current curing: Concrete can be cured by passing alternating current through freshly laid concrete.

Water cement ratio and compressive strength

A cement of average composition requires about 25% of water by mass for chemical reaction. In addition, an amount of water is needed to fill the gel pores. Nearly 100 years ago, Duff Abrams discovered the direct relationship between water-to-cement ratio and strength, i.e.,lesser the water used higher the strength of the concrete,since too much water leaves lots of poresin the cement past. According toAbram's law, *the strength of fully compacted concrete at a given age and normal temperature is inversely proportional to the water – cement ratio.* Here the water-cement ratio is the relative weight of water to the cement in the mixture. For most applications, water-to-cement ratio should be between 0.4 and 0.5 lower for lower permeability and higher strength. In concrete, the trade off, of course,is with workability, since very low water content result in very stiff mixtures that are difficult to place. The water-to-cement ratio is a factor selected by the civil engineer.

* Under revision

Workability

Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e without bleeding or Segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs &/or pockets may also be visible in finished concrete.Definition of Workability "The property of fresh concrete which is indicated by the amount of useful internal work required to fully compact the concrete without bleeding or segregation in the finished product."

Factors affecting workability:

- Water content in the concrete mix
- Amount of cement & its Properties
- Aggregate Grading (Size Distribution)
- Nature of Aggregate Particles (Shape, Surface Texture, Porosity etc.)
- Temperature of the concrete mix
- Humidity of the environment
- Mode of compaction
- Method of placement of concrete
- Method of transmission of concrete

How to improve the workability of concrete

- Increase water/cement ratio
- Increase size of aggregate
- Use well-rounded and smooth aggregate instead of irregular shape
- Increase the mixing time
- Increase the mixing temperature
- Use non-porous and saturated aggregate
- With addition of air-entraining mixtures

Workability tests:

There are 4 types of tests for workability.They are slump test, compacting factor test, flow test, and vee bee test

Slump test

The slump test result is a slump of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete.Metal mould, in the shape of the frustum of a cone, open at both ends, and provided with the handle, top internal diameter 4 in (102 mm), and bottom internal diameter 8 in (203 mm) with a height of 1 ft (305 mm). A 2 ft (610 mm) long bullet nosed metal rod, (16 mm) in diameter.Apparatus Required: Compacting Factor apparatus, Trowels, Graduated cylinder, Balance and Tamping rod and iron bucket

The test is carried out using a mould known as a slump cone or Abrams **cone**. The cone is placed on a hard non-absorbent surface. This cone is filled with fresh concrete in three stages, each time it is tamped using a rod of standard dimensions. At the end of the third stage, concrete is struck off flush to the top of the mould. The mouldis carefully lifted vertically upwards, so as not to disturb the concrete cone. Concrete subsides. This subsidence is termed as slump, and is measured in to the nearest 5 mm if the slump is <100 mm and measured to the nearest 10 mm if the slump is >100 mm.

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump is an indication of too wet a mix. Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate. Very dry mixes; having slump 0 – 25 mm are used in road making, low workability mixes; having slump 10 – 40 mm are used for foundations with light reinforcement, medium workability mixes; 50 - 90 for normal reinforced concrete placed with vibration, high workability concrete; > 100 mm.

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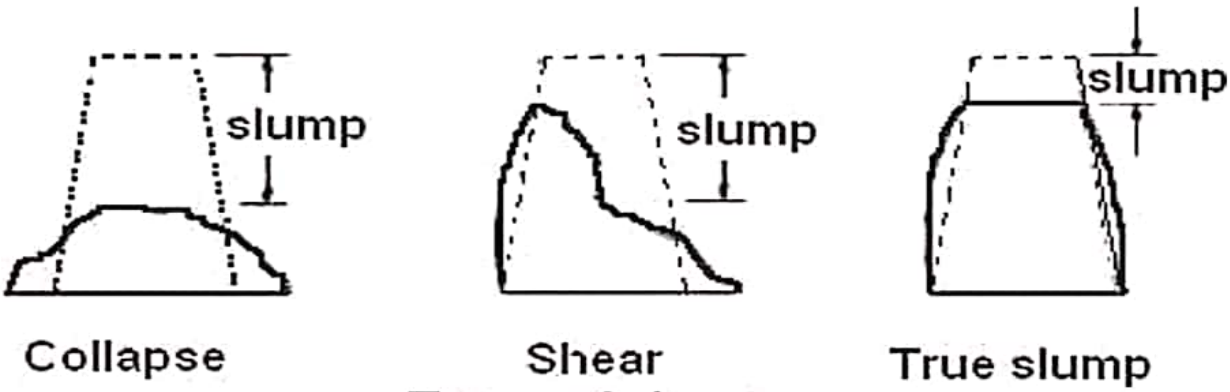
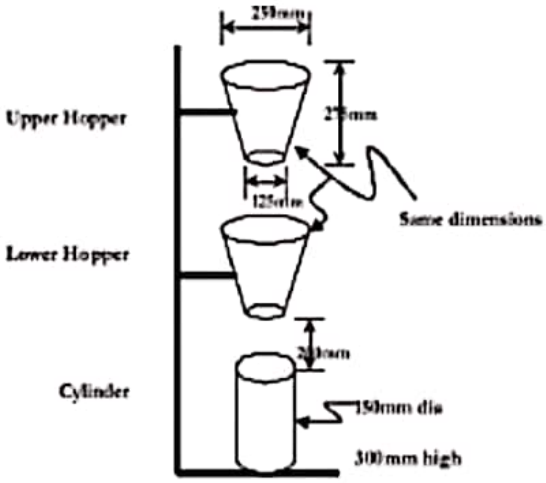


Types of slump

This test is usually used in laboratory and determines the workability of fresh concrete when size is about 40 mm maximum. The test is carried out as per specification of IS: 1199-1959.

Compacting factor test:



Steps for performing the experiment:

- keep the apparatus on the ground and apply grease on the inner surface of the cylinders.
- Measure the mass as w1 kg by weighing the cylinder accurately and fix the cylinder on the base in such a way that the central points of hoppers and cylinder lie on one vertical line and cover the cylinder with a plate.
- For each 5 kg of aggregate mixes are to be prepared with water-cement ratio by weight with 2.5 kg sand and 1.25 kg of cement and then add required amount of water thoroughly until and unless concrete appears to be homogeneous.

- With the help of hand scoop without compacting fill the freshly mixed concrete in upper hopper part gently and carefully and within two minutes release the trap door so that the concrete may fall into the lower hopper such that it bring the concrete into standard compaction.
- Fall the concrete to into the cylinder by bringing the concrete into standard Compaction immediately after the concrete has come to rest and open the trap door of lower hopper and then remove the excess concrete above the top of the cylinder by a pair of trowels, one in each hand wiX blades horizontal slide them from the opposite edges of the mould inward to the center with a sawing motion.
- Clean the cylinder from all sides properly. Find the mass of partially compacted concrete thus filled in the cylinder and say it W2 kg. After this refill the cylinder with the same sample of concrete in approximately 50 mm layers, by vibrating each layer heavily so as to expel all the air and obtain full compaction of the Concrete.
- Struck off level the concrete and weigh and cylinder filled with fully compacted concrete. Let the mass be W3 kg.
- Calculate compaction factor by using the formula: C.F = W2 – W1 / W3 – W1

Flow Table Test:

The flow table test or flow test is a method to determine the consistence of fresh concrete.

Flow table with a grip and a hinge, 70 centimetres (28 in) square.Abrams cone, open at the top and at the bottom - 30 centimetres (12 in) high, 17 centimetres (6.7 in) top diameter, 25 centimetres (9.8 in) base diameter.Water bucket and broom for wetting the flow table.Tamping rod, 60 centimetres (24 in) longConducting the testTheflowtable is wetted.The cone is placed in the center of the flowtable and filled with fresh concrete in two equal layers layers. Each layer is tamped 10 times with tamping rod.Wait 30 seconds before lifting the coneThe cone is lifted, allowing the concrete to flow.The flowtable is then lifted up 40mm and then dropped 15 times, causing the concrete to flowAfter this the diameter of the concrete is measured.

Vee-Bee Test:

This test is useful for concrete having low and very low workability. In this test the concrete is moulded into a cone in a cylinder container and the entire set up is mounted on a vibrating table. When vibrator starts, concrete placed on the cone starts to occupy the cylindrical container by the way of getting remoulded. Remoulding is complete when the concrete surface becomes horizontal. The time required for completion of remoulding since start of vibrator is measured and denoted as vee-bee seconds. This provides a measure for workability. Lesser is the vee-bee seconds more is the workability