Unit 4 module 1

Production of concrete and quality control

- Production of quality concrete requires at most care at every stage of manufacture of concrete.
- It is to be noted that the ingredients of good concrete and bad concrete are the same. If meticulous care is not exercised, and good rules are not observed, the resultant concrete is going to be of bad quality.
- With the same material if intense care is taken to exercise control at every stage, it will result in good concrete. *Therefore, it is necessary to know the rules to be followed in each stage of manufacture of concrete for producing good quality concrete*.
- The various stages of manufacture of concrete are:
- (a) Batching (b) Mixing (c) Transporting (d) Placing (e) Compacting (f) Curing (g) Finishing

(a) Batching

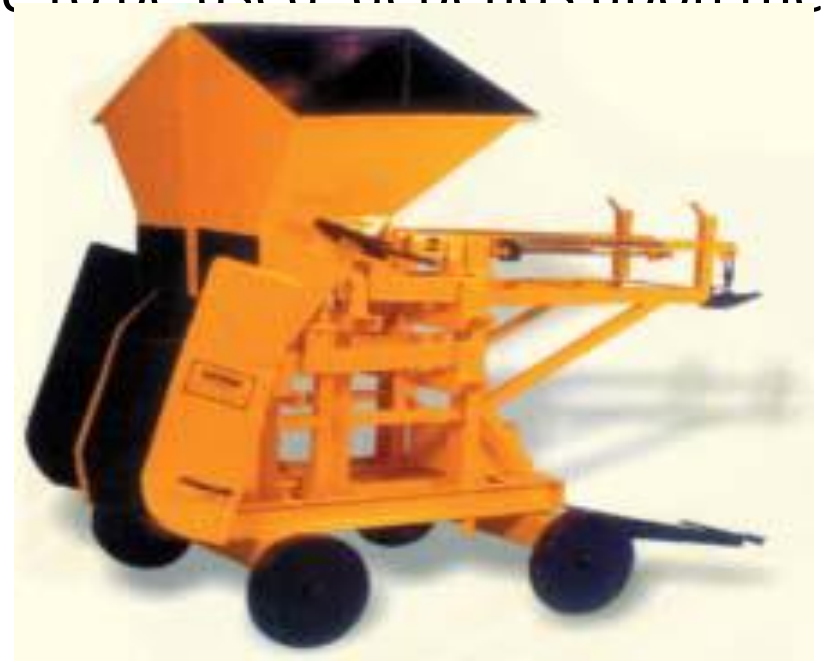
- The measurement of materials for making concrete is known as batching. There are two methods of batching:
- **(i) Volume batching** **(ii) Weigh batching**
- **(i) Volume batching:**
- Volume batching is not a good method for proportioning the material because of the difficulty it offers to measure granular material in terms of volume.
- Volume of moist sand in a loose condition weighs much less than the same volume of dry compacted sand.

- The amount of solid granular material in a cubic meter is an indefinite quantity.
- Because of this, for quality concrete, materials have to be measured by weight only.

- However, for unimportant concrete or for any small job, concrete may be batched by volume.
- Cement is always measured by weight.
- It is never measured in volume. **The volume of one bag of cement is taken as thirty five (35) litres.**
- Water can be measured either in kg or litres as may be convenient.

(ii) Weigh Batching:

- *Strictly speaking, weigh batching is the correct method of measuring the materials*. For important concrete, invariably, weigh batching system should be adopted.
- Use of weight system in batching, facilitates accuracy, flexibility and simplicity. Different types of weigh batchers are available, the particular type to be used depends upon the nature of the job.



- **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 color and consistency.
- There are two methods adopted for mixing concrete:
- (i) Hand mixing (ii) Machine mixing

Hand Mixing:

- Hand mixing is practised for small scale unimportant concrete works. As the mixing cannot be thorough and efficient, it is desirable to add 10 per cent more cement to cater for the inferior concrete produced by this method.
- Hand mixing should be done over an impervious concrete or brick floor of sufficiently large size to take one bag of cement. Spread out the measured quantity of coarse aggregate and fine aggregate in alternate layers.
- Pour the cement on the top of it, and mix them dry by shovel, turning the mixture over and over again until uniformity of colour is achieved.
- This uniform mixture is spread out in thickness of about 20 cm.
- Water is taken in a water-can fitted with a rose-head and sprinkled over the mixture and simultaneously turned over. This operation is continued till such time a good uniform, homogeneous concrete is obtained

- Water is taken in a water-can fitted with a rose-head and sprinkled over the mixture and simultaneously turned over. This operation is continued till such time a good uniform, homogeneous concrete is obtained. It is of particular importance to see that the **water is not poured but it is only sprinkled.**
- Water in small quantity should be added towards the end of the mixing to get the just required consistency.
- At that stage, even a small quantity of water makes difference.

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 and continuous mixers. 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.
- These types of mixers are 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.

- Mixers with a revolving star of blades are more efficient. They are especially suitable for stiff and lean mixes, which present difficulties with most other types of mixers, mainly due to sticking of mortar in the drum.
- The shape of the drum, the angle and size of blades, the angle at which the drum is held, affect the efficiency of mixer. It is seen that tilting drum to some extent is more efficient than non-tilting drum.
- As per I.S. 1791–1985, concrete mixers are designated by a number representing its nominal mixed batch capacity in litres.
- *The following are the standardized sizes of three types:*
- *a. Tilting: 85 T, 100 T, 140 T, 200 T*
- *b. Non-Tilting: 200 NT, 280 NT, 375 NT, 500 NT, 1000 NT*
- *c. Reversing: 200 R, 280 R, 375 R, 500 R and 1000 R*
- The letters T, NT, R denote tilting, non-tilting and reversing respectively.

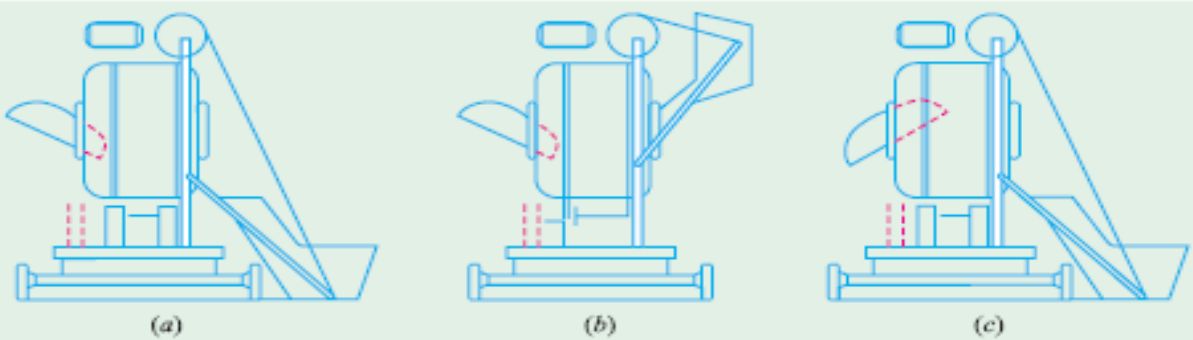
Pan / paddle mixer

Concrete mixer with hydraulic hopper 10/7

- Normally, a batch of concrete is made with ingredients corresponding
- to 50 kg cement.
- If one has a choice for indenting a mixer, one should ask for such a capacity mixer that should hold all the materials for one bag of
- cement.
- This of course, depends on the proportion of the mix. For
- *example, for 1 : 2 : 4 mix, the ideal mixer is of 200 litres capacity, whereas if the ratio is 1 : 3 : 6, the requirement will be of 280 litres capacity to facilitate one bag mix. Mixer of 200 litres capacity is insufficient for 1 : 3 : 6 mix and also mixer of 280 litres is too big, hence uneconomical for 1 : 2 : 4 concrete*

- To get better efficiency, the sequence of charging the loading skip is as under:
- Firstly, about half the quantity of coarse aggregate is placed in the skip over which about half the quantity of fine aggregate is poured. On that, the full quantity of cement i.e., one bag is poured over which the remaining portion of coarse aggregate and fine aggregate is deposited in sequence. This prevents spilling of cement, while discharging into the drum and also this prevents the blowing away of cement in windy weather.
- Before the loaded skip is discharged to the drum, about 25 per cent of the total quantity of water required for mixing, is introduced into the mixer drum to wet the drum and to prevent any cement sticking to the blades or at the bottom of the drum.
- Immediately, on discharging the dry material into the drum, the remaining 75 per cent of water is added to the drum.

- If the mixer has got an arrangement for independent feeding of water, it is desirable that the remaining 75 per cent of water is admitted simultaneously along with the other materials.
- The time is counted from the moment all the materials, particularly, the complete quantity of water is fed into the drum.



(*a*) Filling Material into Loading Skip
(*b*) Discharging Skip into Mixing Drum
(*c*) Concrete Discharged From Drum

Fig. 6.13. Illustrating Diagrammatically the Method of Operation of the Rotary and Tilting Type Concrete Mixer

Mixing Time:

- Concrete mixers are generally designed to run at a speed of 15 to 20 revolutions per minute. For proper mixing, it is seen that about 25 to 30 revolutions are required in a well-designed mixer. In the site, the normal tendency is to speed up the out turn of concrete by reducing the mixing time,this results in poor quality of concrete.
- On the other hand, if the concrete is mixed for a comparatively longer time, it is uneconomical from the point of view of rate of production of concrete and fuel consumption. Therefore, it is of importance to mix the concrete for such a duration which will accrue optimum benefit.
- The shape of drum, the number of blades, inclination of blades with respect to drum surface, the length of blades, the depth of blades, the space between the drum and the blades, the space between metal strips of blades and speed of rotation etc., are important to give uniform mixing quality and optimum time of mixing.
- Long-time mixing of concrete will generally result in increase of compressive strength of concrete within limits. Due to mixing over long periods, the effective water/cement ratio gets reduced, owing to the absorption of water by aggregate and evaporation

Transporting concrete:

- 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) Tansit Mixer*
- *(i) Pump andPipe Line*

Mortar Pan: Use of mortar pan for transporation of concrete is one of the common methods adopted in this country. It is labour intensive. In this case, concrete is carried in small quantities. While this method nullifies the segregation to some extent, particularly in thick members, it suffers from the disadvantage that this method exposes greater surface area of concrete for drying conditions. This results in greater loss of water, particularly, in hot weather concreting and under conditions of low humidity. It is to be noted that the mortar pans must be wetted to start with and it must be kept clean during the entire operation of concreting. Mortar pan method of conveyance of concrete can be adopted for concreting at the ground level, below or above the ground level without much difficulties.

Tough Rider for transporting concrete.

Truck mixer and dumper for transporting stiff concrete

Wheel Barrow: Wheel barrows are normally used for transporting concrete to be placed at ground level. This method is employed for hauling concrete for comparatively longer distance as in the case of concrete road construction. If concrete is conveyed by wheel barrow over a long distance, on rough ground, it is likely that the concrete gets segregated due to vibration. The coarse aggregates settle down to the bottom and matrix moves to the top surface. To avoid this situation, sometimes, wheel barrows are provided with pneumatic wheel to reduce vibration. A wooden plank road is also provided to reduce vibration and hence segregation.

Crane, Bucket and Rope Way: A crane and bucket is one of the right equipment for transporting concrete above ground level. Crane can handle concrete in high rise construction projects and are becoming a familiar sites in big cities. Cranes are fast and versatile to move concrete horizontally as well as vertically along the boom and allows the placement of concrete at the exact point. Cranes carry skips or buckets containing concrete. Skips have discharge door at the bottom, whereas buckets are tilted for emptying. For a medium scale job the bucket capacity may be 0.5 m^3.

Rope way and bucket of various sizes are used for transporting concrete to a place, where simple method of transporting concrete is found not feasible. For the concrete works in a valley or the construction work of a pier in the river or for dam construction, this method of transporting by rope way and bucket is adopted. The mixing of concrete is done on the bank or abutment at a convenient place and the bucket is brought by a pulley or some other arrangement. It is filled up and then taken away to any point that is required. The vertical movement of the bucket is also controlled by another set of pullies. Sometimes, cable and car arrangement is also made for controlling the movement of the bucket. This is one of the methods generally adopted for concreting dam work or bridge work. Since the size of the bucket is considerably large and concrete is not exposed to sun and wind there would not be much change in the state of concrete or workability.

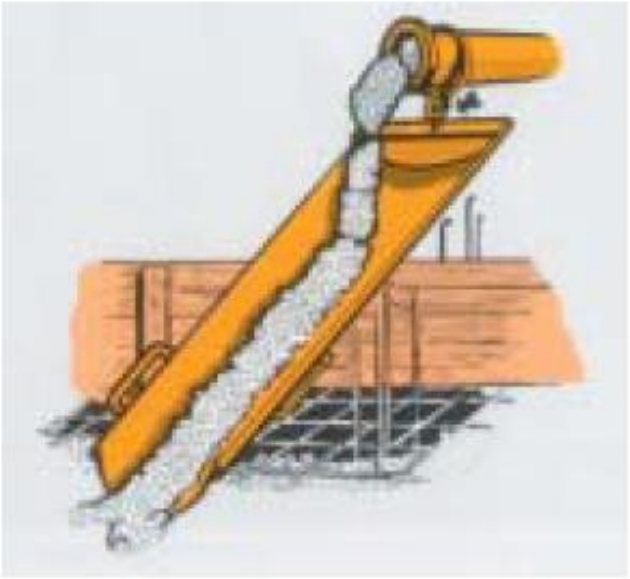
For discharging the concrete, the bucket may be tilted or sometimes, the concrete is made to discharge with the help of a hinged bottom. Discharge of concrete may also be through a gate system operated by compressed air. The operation of controlling the gate may be done manually or mechanically. It should be practised that concrete is discharged from the smallest height possible and should not be made to freely fall from great height.

- **Truck Mixer and Dumpers:**
- For large concrete works particularly for concrete to be placed at ground level, trucks and dumpers or ordinary open steel-body tipping lorries can be used.
- As they can travel to any part of the work, they have much advantage over the jubilee wagons, which require rail tracks. Dumpers are of usually 2 to 3 cubic metre capacity, whereas the capacity of truck may be 4 cubic metre or more.

Belt Conveyors: Belt conveyors have very limited applications in concrete construction. The principal objection is the tendency of the concrete to segregate on steep inclines, at transfer points or change of direction, and at the points where the belt passes over the rollers. Another disadvantage is that the concrete is exposed over long stretches which causes drying and stiffening particularly, in hot, dry and windy weather. Segregation also takes place due to the vibration of rubber belt. It is necessary that the concrete should be remixed at the end of delivery before placing on the final position.

Modern Belt Conveyors can have adjustable reach, travelling diverter and variable speed both forward and reverse. Conveyors can place large volumes of concrete quickly where access is limited. There are portable belt conveyors used for short distances or lifts. The end discharge arrangements must be such as to prevent segregation and remove all the mortar on the return of belt. In adverse weather conditions (hot and windy) long reaches of belt must be covered.

- **Chute:**
- Chutes are generally provided for transporting concrete from ground level to a lower level. Chute will be generally made of metal. The lay-out is made in such a way that the concrete will slide evenly in a compact mass without any separation or segregation. The required consistency of the concrete should not be changed in order to facilitate chuting. This is not a good method of transporting concrete.



Transporting and placing concrete by chute.

Skip and Hoist:

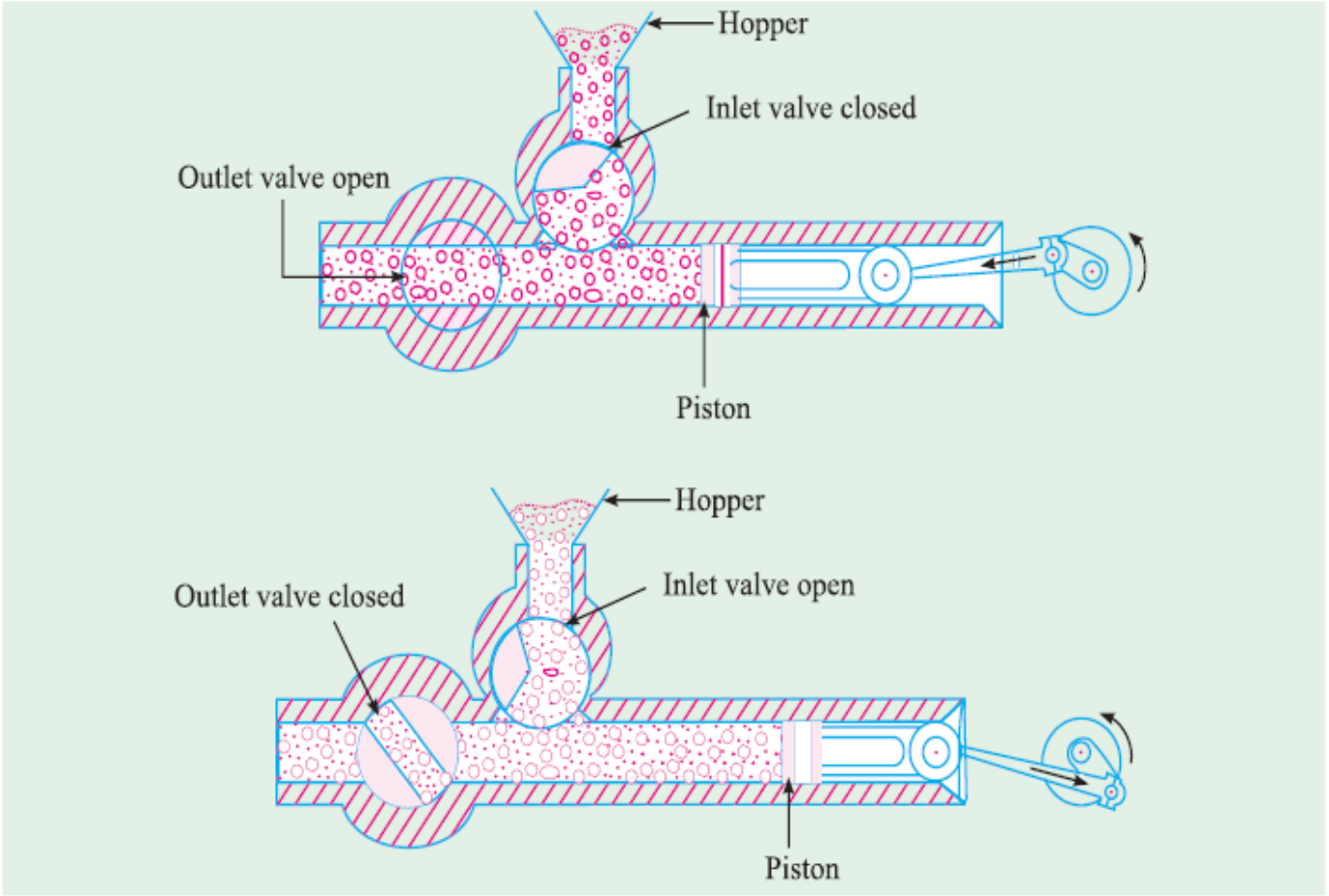
- This is one of the widely adopted methods for transporting concrete vertically up for multi-storey building construction.
- Transporting concrete by ladders is not normally possible for more than 3 or 4 storeyed building constructions.
- For laying concrete in taller structures, chain hoist or platform hoist or skip hoist is adopted. The quality of concrete i.e. the freedom from segregation will depend upon the extent of travel and rolling over the rails.

Tower Hoist and Winch, for lifting concrete to higher level.

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).
- They are truck mounted having a capacity of 4 to 7 m3. There are two variations. In one, mixed concrete is transported to the site by keeping it agitated all along at a speed varying between 2 to 6 revolutions per minute. In the other category, 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.

- **Pumps and Pipeline:**
- Pumping of concrete is universally accepted as one of the main methods of concrete transportation and placing. Adoption of pumping is increasing throughout the world as pumps become more reliable and also the concrete mixes that enable the concrete to be pumped are also better understood.
- **Pumpable Concrete:**
- A concrete which can be pushed through a pipeline is called a pumpable concrete. It is made in such a manner that its friction at the inner wall of the pipeline does not become very high and that it does not wedge while flowing through the pipeline.
- A clear understanding of what happens to concrete when it is pumped through pipeline is fundamental to any study of concrete pumping. Pumpable concrete emerging from a pipeline flows in the form of a plug which is separated from the pipe wall by a thin lubricating layer consisting of cement paste.


Hopper
Inlet valve closed
Outlet valve open
Piston
Hopper
Outlet valve closed
Inlet valve open
Piston

Pump and pipeline

Placing concrete:

- It is of utmost importance that the concrete must be placed in systematic manner to yield optimum results.
- Before placing concrete in the foundation, all the loose earth must be removed from the bed. Any root of trees passing through the foundation must be cut, charred or tarred effectively to prevent its further growth and piercing the concrete at a later date.
- The surface of the earth, if dry, must be just made damp so that the earth does not absorb water from concrete.
- On the other hand if the foundation bed is too wet and rain-soaked, the water and slush must be removed completely to expose firm bed before placing concrete.
- If there is any seepage of water taking place into the foundation trench, effective method for diverting the flow of water must be adopted before concrete is placed in the trench or pit.

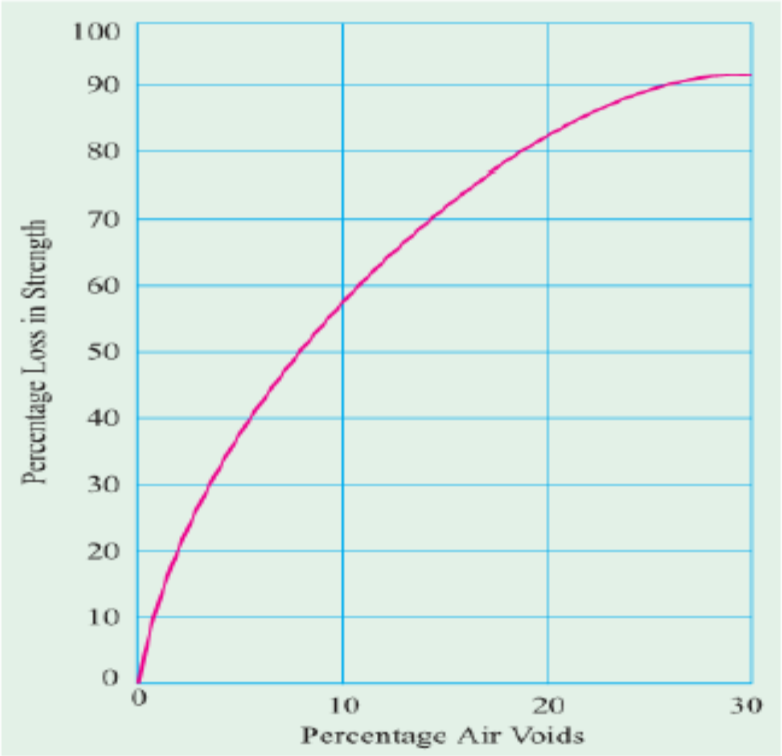
- For the construction of road slabs, airfield slabs and ground floor slabs in buildings, earth must be properly compacted and made sufficiently damp to prevent the absorption of water from concrete. If this is not done, the bottom portion of concrete is likely to become weak.
- The thickness of layers depends upon the mode of compaction. In reinforced concrete, it is a good practice to place concrete in layers of about 15 to 30 cm thick and in mass concrete, the thickness of layer may vary anything between 35 to 45 cm.
- Certain good rules should be observed while placing concrete within the formwork, as in the case of beams and columns. Firstly, it must be checked that the reinforcement is correctly tied, placed and is having appropriate cover.
- The joints between planks, plywoods or sheets must be properly and effectively plugged so that matrix will not escape when the concrete is vibrated.

- **Form work:**
- Form work shall be designed and constructed so as to remain sufficiently rigid during placing and compaction of concrete. The joints are plugged to prevent the loss of slurry from concrete.
- **Stripping Time:**
- Formwork should not be removed until the concrete has developed a strength of at least twice the stress to which concrete may be subjected at the time of removal of formwork.
- In normal circumstances, where ambient temperature does not fall below 15°C and where ordinary Portland cement is used and adequate curing is done, following striking period can be considered sufficient as per IS 456 of 2000.

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 figure below shows 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 Insufficient.



- 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 Jolting**
- **(d) Compaction by Spinning**.

Hand Compaction:

Hand compaction of concrete is adopted in case of unimportant concrete work of small magnitude. Sometimes, this method is also applied in such situation, where a large quantity of reinforcement is used, which cannot be normally compacted by mechanical means. Hand compaction consists of rodding, ramming or tamping. When hand compaction is adopted, the consistency of concrete is maintained at a higher level. The thickness of the layer of concrete is limited to about 15 to 20 cm. Rodding is nothing but poking the concrete with about 2 meter long, 16 mm diameter rod to pack the concrete between the reinforcement and sharp corners and edges. Rodding is done continuously over the complete area to effectively pack the concrete and drive away entrapped air. Sometimes, instead of iron rod, bamboos or cane is also used for rodding purpose.

Ramming should be done with care. Light ramming can be permitted in unreinforced foundation concrete or in ground floor construction. Ramming should not be permitted in case of reinforced concrete or in the upper floor construction, where concrete is placed in the formwork supported on struts. If ramming is adopted in the above case the position of the reinforcement may be disturbed or the formwork may fail, particularly, if steel rammer is used.

Tamping is one of the usual methods adopted in compacting roof or floor slab or road pavements where the thickness of concrete is comparatively less and the surface to be finished smooth and level. Tamping consists of beating the top surface by wooden cross beam of section about 10 x 10 cm. Since the tamping bar is sufficiently long it not only compacts, but also levels the top surface across the entire width.

Compaction by Vibration:

- It is pointed out that the compaction by hand, if properly carried out on concrete with sufficient workability, gives satisfactory results, but the strength of the hand compacted concrete will be necessarily low because of higher water cement ratio required .for full compaction.
- Where high strength is required, it is necessary that stiff concrete, with low water/cement ratio be used.
- To compact such concrete, mechanically operated vibratory equipment, must be used. The vibrated concrete with low water/cement ratio will have many advantages over the hand compacted concrete with higher water/cement ratio.
- **The action of vibration is to set the particles of fresh concrete in motion, reducing the friction between them and affecting a temporary liquefaction of concrete which enables easy settlement.**

Plate Vibrator

Screed Board Vibrator

Table Vibrator

Needle Vibrator
Electric

Needle Vibrator
Petrol

Curing of Concrete:

- Concrete derives its strength by the hydration of cement particles. The hydration of cement is not a momentary action but a process continuing for long time. But the rate of hydration is fast to start with, and continues over a very long time at a decreasing rate.
- The quantity of the product of hydration and consequently the amount of gel formed depends upon the extent of hydration.
- It has been mentioned earlier that cement requires a water/cement ratio about 0.23 for hydration and a water/cement ratio of 0.15 for filling the voids in the gel pores.
- In other words, a water/cement ratio of about 0.38 would be required to hydrate all the particles of cement and also to occupy the space in the gel pores.
- Theoretically, for a concrete made and contained in a sealed container a water cement ratio of 0.38 would satisfy the requirement of water for hydration and at the same time no capillary cavities would be left.

Fig.6.24. Cracks on concrete surface due to inadequate curing.

- However, it is seen that practically a water/cement ratio of 0.5 will be required for complete hydration in a sealed container form keeping up the desirable relative humidity level.
- *In the field and in actual work, it is a different story. Even though a higher water/cement ratio is used, since the concrete is open to atmosphere, the water used in the concrete evaporates and the water available in the concrete will not be sufficient for effective hydration to take place particularly in the top layer.*
- *If hydration is to be continued, then extra water must be added to replenish the loss of water on account of absorption and evaporation. The process of keeping the concrete moist and warm enough for the hydration of cement is called curing.*
- Curing is being given a place of increasing importance as the demand for high quality concrete is increasing.
- If curing is neglected in the early period of hydration, the quality of concrete will experience a sort of irreparable loss. An efficient curing in the early period of hydration can be compared to a good and wholesome feeding given to a new born baby

- The quick surface drying of concrete results in the movement of moisture from the interior to the surface. This steep moisture gradient cause high internal stresses which are also responsible for internal micro cracks in the semi-plastic concrete.
- Concrete, while hydrating, releases high heat of hydration. This heat is harmful from the point of view of volume stability. If the heat generated is removed by some means, the adverse effect due to the generation of heat can be reduced. This can be done by a thorough water curing.

Curing Methods:

- Curing methods may be divided broadly into four categories:
- (a) Water curing
- (b) Membrane curing
- (c) Application of heat
- (d) Miscellaneous.

- **Water Curing:**
- This is by far the best method of curing as it satisfies all the requirements of curing, namely, promotion of hydration, elimination of shrinkage and absorption of the heat of hydration.
- It is pointed out that even if the membrane method is adopted, it is desirable that a certain extent of water curing is done before the concrete is covered with membranes.
- Water curing can be done in the following ways:
- (a) Immersion (b) Ponding (c) Spraying or Fogging (d) Wet covering

Water ponding

- The precast concrete items are normally immersed in curing tanks for certain duration.
- Pavement slabs, roof slab etc. are covered under water by making small ponds. Vertical retaining wall or plastered surfaces or concrete columns etc. are cured by spraying water.
- In some cases, wet coverings such as wet gunny bags, hessian cloth, jute matting, straw etc., are wrapped to vertical surface for keeping the concrete wet.
- For horizontal surfaces saw dust, earth or sand are used as wet covering to keep the concrete in wet condition for a longer time so that the concrete is not unduly dried to prevent hydration.

Sprinkler curing

Membrane Curing:

- Sometimes, concrete works are carried out in places where there is acute shortage of water.
- The lavish application of water for water curing is not possible for reasons of economy. It has been pointed out earlier that curing does not mean only application of water, it means also creation of conditions for promotion of uninterrupted and progressive hydration.
- It is also pointed out that the quantity of water, normally mixed for making concrete is more than sufficient to hydrate the cement, provided this water is not allowed to go out from the body of concrete.
- For this reason, concrete could be covered with membrane which will effectively seal off the evaporation of water from concrete.

- Membrane curing is a good method of maintaining a satisfactory state of wetness in the body of concrete to promote continuous hydration when original water/cement ratio used is not less than 0.5.
- To achieve best results, membrane is applied after one or two days‟ of actual wet curing. Two or three coats may be required for effective sealing of the surface to prevent the evaporation of water.

Membrane curing by spraying.

Application of heat:

The development of strength of concrete is a function of not only time but also that of temperature. When concrete is subjected to higher temperature it accelerates the hydration process resulting in faster development of strength. Concrete cannot be subjected to dry heat to accelerate the hydration process as the presence of moisture is also an essential requisite. Therefore, subjecting the concrete to higher temperature and maintaining the required wetness can be achieved by subjecting the concrete to steam curing.

The exposure of concrete to higher temperature is done in the following manner:

(a) Steam curing at ordinary pressure.

(b) Steam curing at high pressure.

(c) Curing by Infra-red radiation.

(d) Electrical curing

Steam curing at ordinary pressure:

- This method of curing is often adopted for prefabricated concrete elements. Application of steam curing to in situ construction will be a little difficult task.
- However, at some places it has been tried for in situ construction by forming a steam jacket with the help of tarpaulin or thick polyethylene sheets.
- But this method of application of steam for in situ work is found to be wasteful and the intended rate of development of strength and benefit is not really achieved.
- *In India, steam curing is often adopted for precast elements, specially prestressed concrete sleepers. Concrete sleepers are being introduced on the entire Indian Railway. For rapid*
- *development of strength, they use special type of cement namely IRST 40 and also subject the sleepers to steam curing.*

Beam under steam curing.

High Pressure Steam Curing:

In the steam curing at atmospheric pressure, the temperature of the steam is naturally below 100°C. The steam will get converted into water, thus it can be called in a way, as hot water curing. This is done in an open atmosphere.

The high pressure steam curing is something different from ordinary steam curing, in that the curing is carried out in a closed chamber. The superheated steam at high pressure and high temperature is applied on the concrete. This process is also called "Autoclaving". The autoclaving process is practiced in curing precast concrete products in the factory, particularly, for the lightweight concrete products.

In high pressure steam curing, concrete is subjected to a maximum temperature of about 175°C which corresponds to a steam pressure of about 8.5 kg/sq.cm

High pressure steam curing exhibits higher strength and durability particularly in the case of cement containing a proportionately higher amount of C3S. A sample of cement containing higher proportion of C2S is not benefited to the same extent, as it produces lower amount of $Ca(OH)_2$.

Curing by Infra-red Radiation:

Curing of concrete by Infra-red Radiation has been practiced in very cold climatic regions in Russia. It is claimed that much more rapid gain of strength can be obtained than with steam curing and that rapid initial temperature does not cause a decrease in the ultimate strength as in the case of steam curing at ordinary pressure. The system is very often adopted for the curing of hollow concrete products. The normal operative temperature is kept at about 90°C.

- **Electrical Curing:**
- Another method of curing concrete, which is applicable mostly to very cold climatic regions is the use of electricity. This method is not likely to find much application in ordinary climate owing to economic reasons.
- Concrete can be cured electrically by passing an alternating current
- (Electrolysis trouble will be encountered if direct current is used) through the concrete itself between two electrodes either buried in or applied to the surface of the concrete.
- Care must be taken to prevent the moisture from going out leaving the concrete completely dry.
- As this method is not likely to be adopted in this country, for a long time to come, this aspect is not discussed in detail.

Miscellaneous Methods of Curing:

Calcium chloride is used either as a surface coating or as an admixture. It has been used satisfactorily as a curing medium. Both these methods are based on the fact that calcium chloride being a salt, shows affinity for moisture. The salt, not only absorbs moisture from atmosphere but also retains it at the surface. This moisture held at the surface prevents the mixing water from evaporation and thereby keeps the concrete wet for a long time to promote hydration.

Formwork prevents escaping of moisture from the concrete, particularly, in the case of beams and columns. Keeping the formwork intact and sealing the joint with wax or any other sealing compound prevents the evaporation of moisture from the concrete. This procedure of promoting hydration, can be considered as one of the miscellaneous methods of curing.

When to Start Curing and how Long to Cure:

- Concrete should not be allowed to dry fast in any situation. Concrete that are liable to quick drying is required to be covered with wet gunny bag or wet cloth properly squeezed, so that the water does not drip and at the same time, does not allow the concrete to dry.
- This condition should be maintained for 24 hours or at least till the final setting time of cement at which duration the concrete will have assumed the final volume.
- Water added after this time will not going to interfere with the water/cement ratio.
- Commencement of curing should be done only on the following day after concreting.
- Even on the next day they make arrangements and build bunds with mud or lean mortar to retain water. This further delays the curing

- Commencement of curing also depends on, prevailing temperature, humidity, wind velocity, type of cement, fineness of cement, w/c used and size of member etc.
- It is difficult to set a limit on how long to cure. For general guidance, concrete must be cured till it attains about 70% of specified strength. At lower temperature curing period must be increased.
- Curing period should be prolonged for concretes made with cements of slow strength gain characteristics. Pozzolanic cement or concrete admixed with pozzolanic material is required to be cured for longer duration. Mass concrete, heavy footings, large piers, abutments, should be cured for at least 2 weeks.
- To ascertain the period of curing or stripping of formwork, cubes or beams are cast and kept adjacent to the structure they represent and cured by the same method.
- The strength of these cubes or beams at different intervals of time would give better idea about the strength development of structures.
- The above method does not truly indicate the strength development of massive girder subjected to steam curing because of size difference of cubes and girders.