

Chapter Six: Fresh Concrete



6.1 Introduction

The potential strength and durability of concrete of a given mix proportion is very dependent on the degree of its compaction.

It is vital, therefore, that the consistency of the mix (consistency: ability to flow) be such that the concrete can be transported, placed, and finished sufficiently early and easily enough to attain the expected strength and durability without segregation or bleeding.

For fresh concrete to be acceptable, it should:

1. Be easily mixed and transported.
2. Be uniform throughout a given batch and between batches.
3. Be of a consistency so that it can fill completely the forms for which it was designed.
4. Have the ability to be compacted without excessive loss of energy.
5. Not segregate and bleeding during placing and consolidation.
6. Have good finishing characteristics.

Therefore, the main properties of fresh concrete during mixing, transporting, placing and compacting are:

1. **Fluidity or consistency**: capability of being handled and of flowing into formwork and around any reinforcement, with assistance of compacting equipment.
2. **Compact ability**: air entrapped during mixing and handling should be easily removed by compaction equipment, such as vibrators.
3. **Stability or cohesiveness**: fresh concrete should remain homogenous and uniform. No segregation of cement paste from aggregates (especially coarse ones).

Fluidity, compact-ability and stability is represented by the term "**workability**".

6.2 Definition of Workability

- 1- The amount of useful internal work necessary to produce full compaction without occurrence of the known concrete problems. The useful internal work is the work or energy required to overcome the internal friction between the individual particles in the concrete.

In practice, however, additional energy is required to overcome the surface friction between concrete and the framework or the reinforcement. Thus, in practice, it is difficult to measure the workability as defined above, and what we measure is workability which is applicable to particular method adopted.

- 2- This term is defined in ASTM C 125 as the property determining the effort required to **manipulate** a freshly mixed quantity of concrete with minimum loss of homogeneity. The term **manipulate** includes the operations of placing, compacting and finishing the concrete.

6.3 Factors Affecting Workability

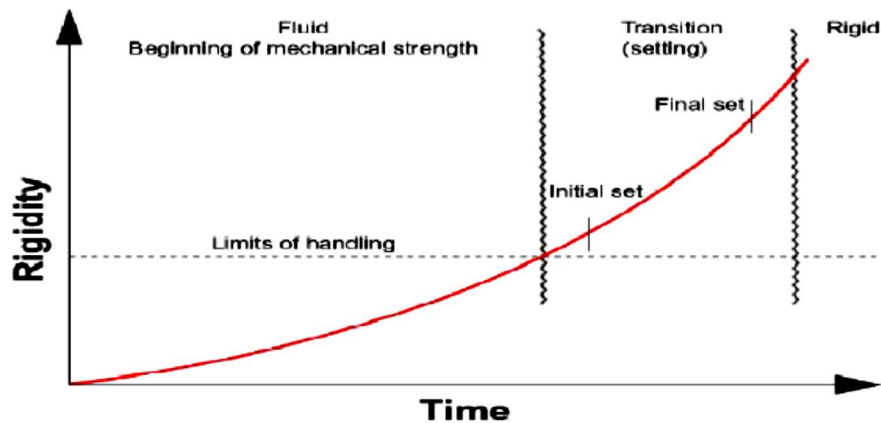
1. **Water Content of the Mix**. This is the most important fact for governing workability of concrete. A group of particles requires a certain amount of water. Water is **absorbed on the particle surface**, in the **volumes between particles**, and **provides "lubrication"** to help the particles move past one another more easily. Therefore, finer particles require more water. Side-effects of increased water are loss of strength and possible segregation.
2. **Influence of Aggregate Mix Proportions**. Increasing the proportion of aggregates relative to the cement will decrease the workability of the concrete. Also, any additional fines will require more cement in the mix. An **"over sanded"** mix will be permeable and less economical. A concrete deficient of fines will be difficult to finish and prone to segregation.
3. **Aggregate Properties**. The ratio of **coarse/fine aggregate** is not the only factor affecting workability. The gradation and particle size of sands are important. Shape and texture of aggregate will also affect workability.

Spherical shaped particles will not have the interaction problems associated with more angular particles. Also, spherical shapes have a low surface/volume ratio, therefore, less cement will be required to coat each particle and more will be available to contribute to the workability of the concrete.

Aggregate which is porous will absorb more water leaving less to provide workability. It is important to distinguish between total water content, which includes absorbed water, and free water which is available for improving workability.

Use of larger **maximum size of aggregate** gives less surface area to be wetted and more water in medium, and hence improvement in workability.

4. **Time and Temperature.** In general, increasing temperature will cause an increase in the rate of hydration and evaporation. Both of these effects lead to a loss of workability.
5. **Loss of Workability.** Workability will decrease with time due to several factors; continued slow hydration of C3S and C3A during dormant period, loss of water through evaporation and absorption, increased particle interaction due to the formation of hydration products on the particle surface. Loss of workability is measured as "**slump loss**" with time. Due to absorption of water by cement (and aggregates if absorbent) workability may decrease rapidly after mixing.



6. **Cement Characteristics.** Cement characteristics are less important than aggregate properties in determining workability. However, the increased fineness of rapid-hardening cements will result in rapid hydration and increased water requirements, both of which reduce workability.
7. **Admixtures.** In general, air-entraining, water-reducing, and set-retarding admixtures will all improve workability. However, some chemical admixtures will react differently with cements and aggregates and may result in reduced workability.

6.4 Measurement of Workability

Unfortunately, there is no accepted test, which measure directly the workability. There are numerous attempts to correlate workability with some easily determinable physical measurements, but none of these is fully satisfactory, although they may provide useful information within a range of variation in workability.

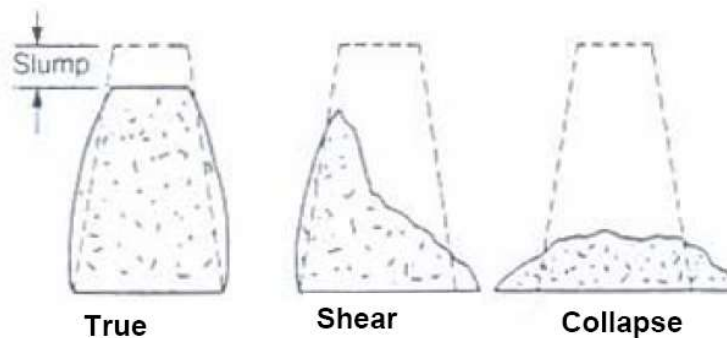
Different empirical measurements of workability have been developed over the years. None of these tests measure workability in terms of the fundamental properties of concrete.

However, the following tests have been developed:

6.4.1 Subjective Assessment. The oldest way of measuring workability based on the judgement and experience of the engineer. Unfortunately, different people see things, in this case concrete, differently.

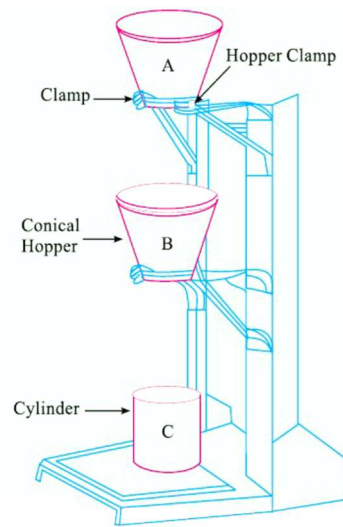
6.4.2 Slump Test. The oldest, most widely used test for determining workability. The device is a hollow cone-shaped mold. The mold is filled in three layers of each volume. Each layer is rodded with a 16mm steel rod 25 times. The mold is then lifted away and the change in the height of the concrete is measured against the mold. The slump test is a measure of the resistance of concrete to flow under its own weight. There are three classifications of slump; "true" slump, shear slump, and collapse slump. **Slump test gives good results for rich mixes.**

True slump is a general reduction in height of the mass without any breaking up. **Shear slump** indicates a lack of cohesion, tends to occur in harsh mixes. This type of result implies the concrete is not suitable for placement. **Collapse slump** generally indicates a very wet mix.



Consistency grade	Slump (mm)	Recommended method of compaction
Stiff, K1	0 - 60	Mechanical compaction like vibration
Plastic, K2	60 – 130	Mechanical or hand compaction (rodding, tampering)
Flowing, K3	130 – 200	Hand compaction or no compaction
Self compacting, K4	≥ 200	No compaction

6.4.3 Compacting Factor Test. Concrete strength is proportional to its relative density. A test to determine the compaction factor was developed in 1947. It involves dropping a volume of concrete from one hopper to another and measuring the volume of concrete in the final hopper to that of a fully compacted volume. This test is difficult to run in the field and is not practical for large aggregates (over 1 in.). **Compacting factor test is used for low workable concretes.**



Compacting Factor Apparatus

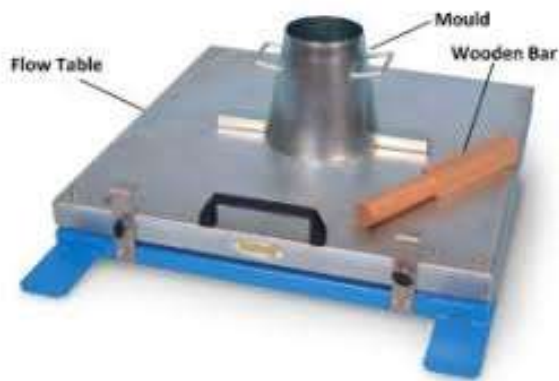
$$\text{Compacting factor} = \frac{\text{weight of partially compact concrete}}{\text{weight of fully compact concrete}}$$

Degree of workability	Slump (mm)	Compacting factor
Very low	0-25	0.78
Low	25-50	0.85
Medium	50-100	0.92
High	100-175	0.95

6.4.4 Flow Table Test. It measures a concrete's ability to flow under vibration and provides information on its tendency to segregate. There are a number of tests available but none are recognized by ASTM. However, the flow table test described for mortar flows is occasionally used. **It is usually used for high workable concretes.**

The table top is cleaned of all gritty material and is wetted. The mold is kept on the center of the table, firmly held and is filled in **two layers**.

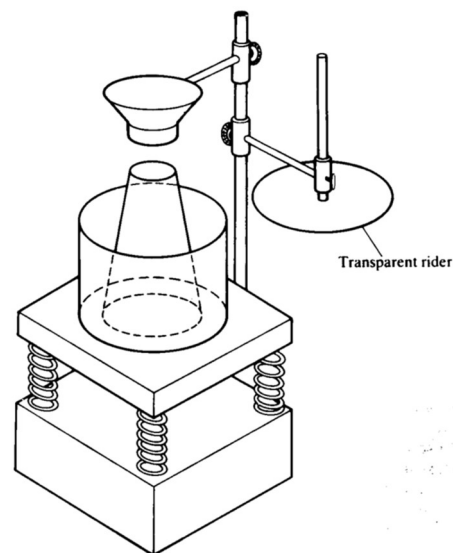
Each layer is rodded 25 times with a tamping rod 1.6 cm in diameter and 61 cm long rounded at the lower tamping end. The mold is lifted vertically upward and the concrete stands on its own without support. The table is then raised and dropped 12.5 mm 15 times in about 15 seconds. The diameter of the spread concrete is measured in about 6 directions to the nearest 5 mm and the average spread is noted. **The Flow is the average diameter of the concrete**



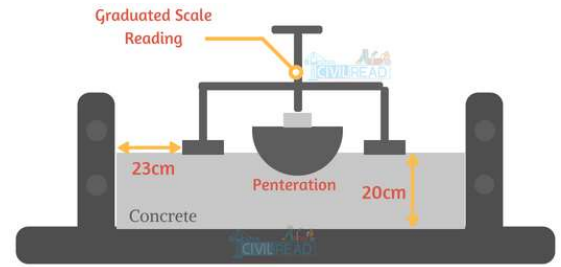
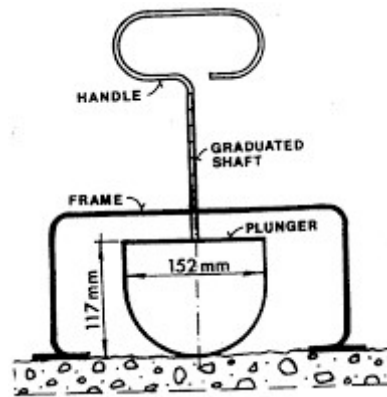
Flow Table Test

6.4.5 Remolding Tests. It developed to measure the work required to cause concrete not only to flow but also to conform to a new shape.

- 1- **Vebe Test** - A standard slump cone is cast, the mold removed, and a transparent disk placed on top of the cone. The sample is then vibrated till the disk is completely covered with mortar. The time required for this is called the **Vebe time**. It is used for low workable concretes (fiber reinforced concrete).



- 2- **Penetration Test** - A measure of the penetration of some indenter into concrete. It is a practical field test. Only the **Kelly ball penetration test** is included in the ASTM Standards. The **Kelly ball** penetration test measures the penetration of a 30 lb. hemisphere into fresh concrete. This test can be performed on concrete in a buggy, open truck, or in form if they are not too narrow.



It can be compared to the slump test for a measure of concrete consistency. For a given concrete mixture, the results of the Kelly ball test can be correlated to slump. Typically, the value of slump is 1.10 to 2.00 times the Kelly ball test reading

6.5 Segregation

Segregation can be defined as separation of the constituents of a heterogeneous mixture so that their distribution is no longer uniform. Also, **Segregation** refers to a separation of the components of fresh concrete, resulting in a non-uniform mix. This can be seen as a separation of coarse aggregate from the mortar, caused from either the settling of heavy aggregate to the bottom or the separation of the aggregate from the mix due to improper placement.

Some factors that increase segregation are:

1. Larger maximum particle size (25mm) and proportion of the larger particles.
2. High specific gravity of coarse aggregate.
3. Decrease in the amount of fine particles.
4. Particle shape and texture.
5. Water/cement ratio.

Good handling and placement techniques are most important in prevention of segregation.

There are two forms of segregation:

1. In the first form, the coarse particles tend to separate out since they tend to settle more than fine particles.
2. The second form of segregation occurs particularly in wet mixes; it is indicated by the separation of (cement+water) from the mix.

Causes of Segregation of Concrete

1. Use of high water-cement ratio in concrete. This general happens in case of concrete mixed at site by unskilled workers.
2. Excessive vibration of concrete with mechanical needle vibrators makes heavier particles settle at bottom and lighter cement sand paste comes on top. This prohibition includes the use of a vibrator to spread a heap of concrete over a large area. This is particularly so when vibration is allowed to continue too long; with many mixes.
3. When concreting is done from height in case of underground foundations and rafts, which causes concrete to segregate.
4. Dropping concrete from a considerable height, passing along a chute, particularly with changes of direction and discharging against an obstacle.
5. The use of coarse aggregate whose specific gravity differs appreciably from that of fine aggregate would lead to increased segregation.

Prevention of Concrete Segregation

1. Wherever depth of concreting is more than 1.5 meters, it should be placed through temporary inclined chutes. The angle of inclination may be kept between 1:3 and 1:2 so that concrete from top of chutes travels smoothly to bottom.
2. The delivery end of chute should be as close as possible to the point of deposit.
3. The concrete does not have to travel too far and to be transferred directly from the wheelbarrow to the position in the form, the danger of segregation is small.
4. Concrete should always be placed direct in the position in which it is to remain and must not be allowed to flow or be worked along the form.
5. The improvement of cohesive of concrete reduces the danger of segregation. For example, entrained air in concrete controls the danger of segregation.





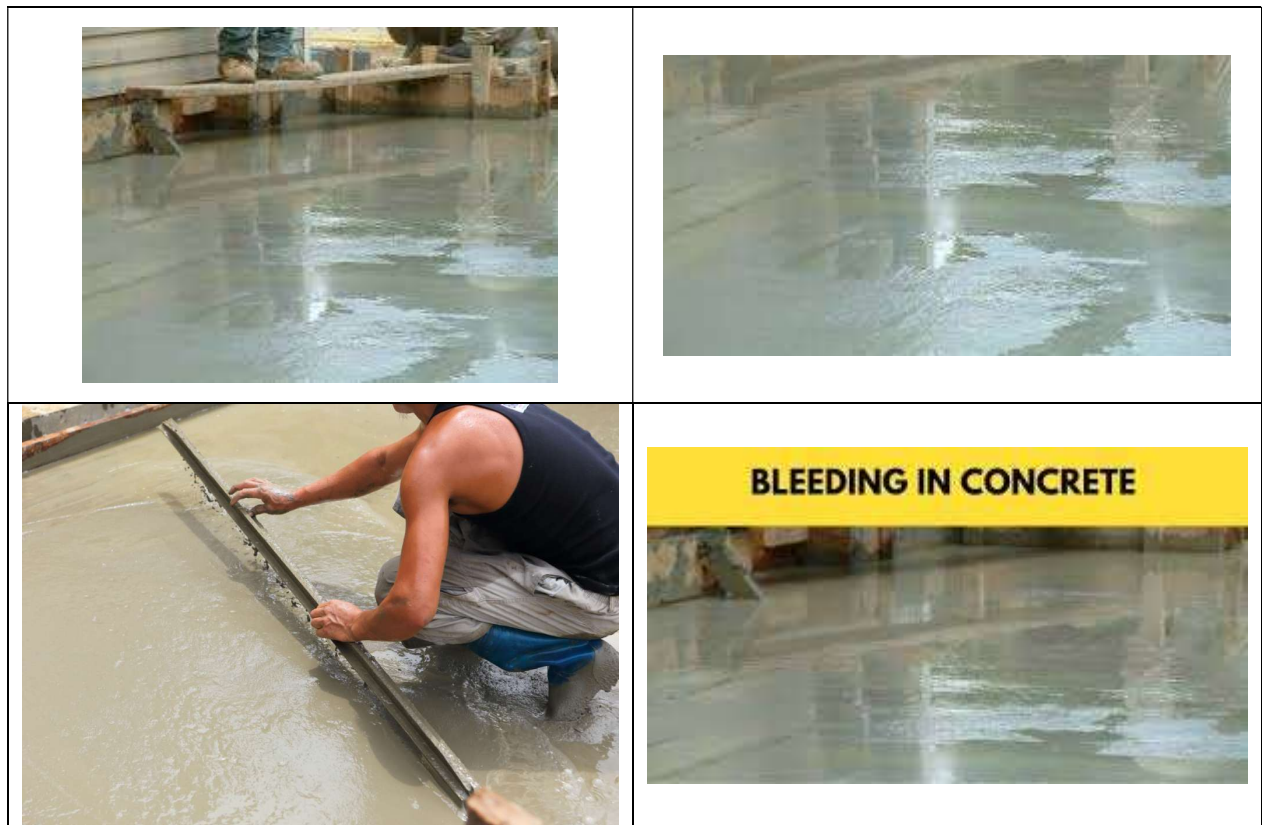
6.6 Bleeding of Concrete

Bleeding is defined as the appearance of water on the surface of concrete (water gain) after it has consolidated **but before it is set**. Since mixing water is the lightest component of the concrete, this is a special form of segregation. This is caused by the inability of the solid constituents of the mix to hold all of the mixing water when they settle downwards. Also, it can be said that bleeding is the result of aggregates settling into the mix and releasing their mixing water.

The upper layers will become too rich in cement with a high w/c ratio causing a weak, porous structure. On the other hand, if the rising water carries with it a considerable amount of the finer cement particles a layer of scum will be formed. At the top of a slab, a porous surface will form and result with a permanently dusty surface. At the top of a lift a plane of weakness would form and the bond with the next lift would be inadequate. For this reason, scum should always be removed by brushing and washing.

Bleeding may be reduced by:

1. delaying the finishing operations until the bleeding water has evaporated.
2. Increasing cement fineness.
3. Increasing the rate of hydration (adding of calcium chloride).
4. Using air-entraining admixtures.
5. Reducing the water content.



6.7 Mixing Time

On a site, there is often a tendency to mix concrete as rapidly as possible, and therefore, it is important to know what is the minimum mixing time necessary to produce a concrete uniform in composition and as result of satisfactory strength.

For a given mixer, there exists a relation between mixing time and uniformity of the mix. It is apparent that mixing for less than 1 to 1 ¼ minutes produces an appreciably more variably concrete, but prolonging the mixing time beyond these values results in no significant improvement in uniformity.

Recommended minimum mixing times

Capacity of mixer (m ³)	Mixing time (Minutes)
0.8	1
1.5	1 ¼
2.3	1 ½
3.1	1 ¾
3.8	2
4.6	2 ¼
7.6	3 ¼

ACI 304-73 (reaffirmed 1983) and ASTM Standard C 94-83.

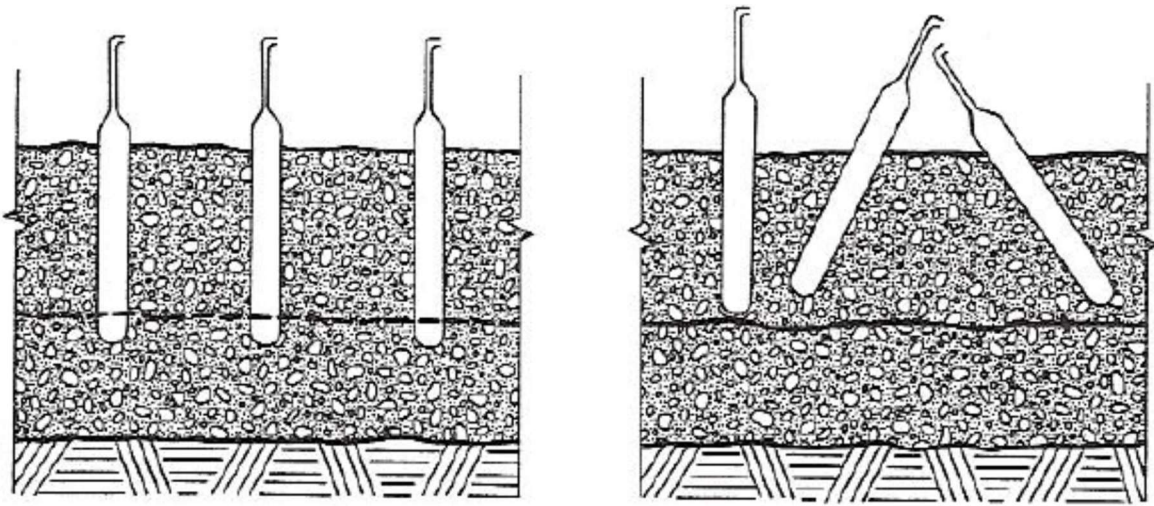
6.8 Compaction of Concrete

This is a very significant stage of concrete production. The process of compacting the concrete consists essentially of the elimination of entrapped air in concrete. It can be achieved either by ramming or by vibration. In any case, the particles are so separated that a compact mass is obtained.

The use of vibration as a mean of compaction makes it possible to use drier mixes that for a given strength concrete can be made with lower cement content. But, vibration must be applied uniformly to the entire concrete mass so that, for some parts of it will not be left without compaction while others are segregated owing to over-vibration.

The two basic methods of compaction require mixes of different workabilities: too dry mix cannot be sufficiently worked by hand; and, conversely, too wet mix should not be vibrated as segregation may result.





6.9 Curing of Concrete

Curing of Concrete is a method by which the concrete is protected against loss of moisture required for hydration and kept within the recommended temperature range. Curing will increase the strength and decrease the permeability of hardened concrete. **Curing** is also helps in mitigating (reduction) thermal and plastic cracks, which can severely impact durability of structures.

A curing practice involves keeping the concrete damp or moist until the hydration of concrete is complete and strength is attained. Curing of concrete should begin soon after final setting time of concrete or formwork/shuttering is removed and must continue for a reasonable period of time as per the specified standards, for the concrete to achieve its desired strength and durability.

Significance of Curing of Concrete

- Enhance Hydration of Concrete to achieve desired Strength
- Improved durability of concrete by reducing cracks.
- Higher serviceability performance by increasing abrasion resistance.
- Improved microstructure by developing better hydrate gels and solid mass.

Methods to Cure Concrete

Depending upon the site constraints, type of structure and other material parameters, different methods of curing are adopted at site. Methods of curing concrete fall into the following categories:

1. Water curing
2. Membrane Curing
3. Steam Curing
4. Internal Curing (**student activity!!**)

Water curing prevents the water loss from the concrete surface by uninterrupted wetting of the exposed surface of concrete. It's done by spraying or sprinkling water or curing agents over the concrete surface to ensure that the concrete surface is continuously moist. Moisture from the body of concrete is retained from evaporating and contributes to the strength-gain of concrete.

Water curing methods are:

1. **Ponding**
2. **Sprinkling, fogging & mist curing**
3. **Wet coverings**

Membrane curing lessens moisture loss from the concrete surface by wrapping it with an impermeable membrane. Curing compounds are wax, acrylic and water based liquids. These are sprayed over fresh concreting to create an impermeable membrane this will reduce the loss of wetness from the concrete.

Membrane curing methods are:

4. **Plastic sheeting**
5. **Formwork**





Steam curing keeps the surface moist and raises the temperature of concrete to quicken the rate of strength achievement. It is a process done to speed up the early hardening of concrete and mortars by subjecting it to steam and humidity. This method is most commonly used for precast concrete plants where products are mass-produced and the turnaround or striking time of the formwork is very quick.

Note:

It is witnessed that at construction sites, curing of concrete is left to the decision and comfort of the unskilled manual worker. Site engineers and supervisors should put additional effort to guarantee that curing is not overlooked at site. They should arrange for the essential resources to retain satisfactory levels of curing, by using best techniques available.

Student Activity

1. Study the various operation of concrete making (mixing, transportation, pumping, casting, etc).
2. What is internal Curing and how it works.
3. find other methods, techniques, tests or approaches for measuring or calculating the workability of concrete.