Concrete Technology
Lecture 7

Contents

- Curing
- Methods of Curing

Curing

- 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
- The rate of hydration is fast to start with, but 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
- 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.

Curing

- 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 the hydration is to continue unabated, extra water must be added to replenish the loss of water on account of absorption and evaporation. Alternatively, some measures must be taken by way of provision of impervious covering or application of curing compounds to prevent the loss of water from the surface of the concrete.
- Therefore, the curing can be considered as creation of a favourable environment during the early period for uninterrupted hydration

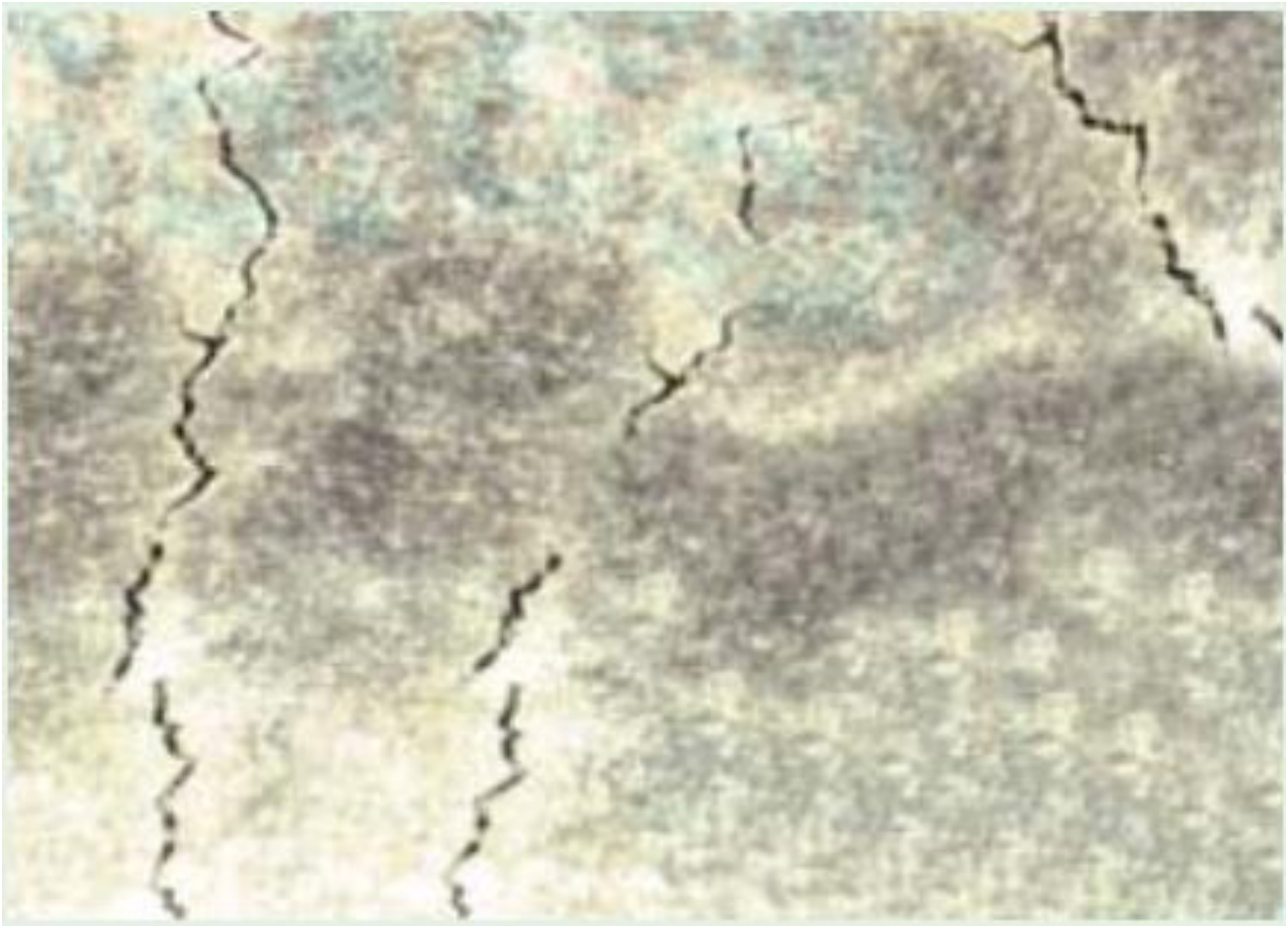
Curing

- Curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continue.
- More elaborately, it can be described as the process of maintaining a satisfactory moisture content and a favourable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service.
- If curing is neglected in the early period of hydration, the quality of concrete w ill experience a sort of irreparable loss

Curing

- A concrete laid in the afternoon of a hot summer day in a dry climatic region, is apt to dry out quickly.
- The surface layer of concrete exposed to acute drying condition, with the combined effect of hot sun and drying wind is likely to be made up of poorly hydrated cement with inferior gel structure which does not give the desirable bond and strength characteristics.
- In addition, the top surface, particularly that of road or floor pavement is also subjected to a large magnitude of plastic shrinkage stresses.
- The dried concrete naturally being weak, cannot withstand these stresses with the result that innumerable cracks develop at the surface

Shrinkage cracks on concrete surface due to inadequate curing



Effect of duration of water curing on strength

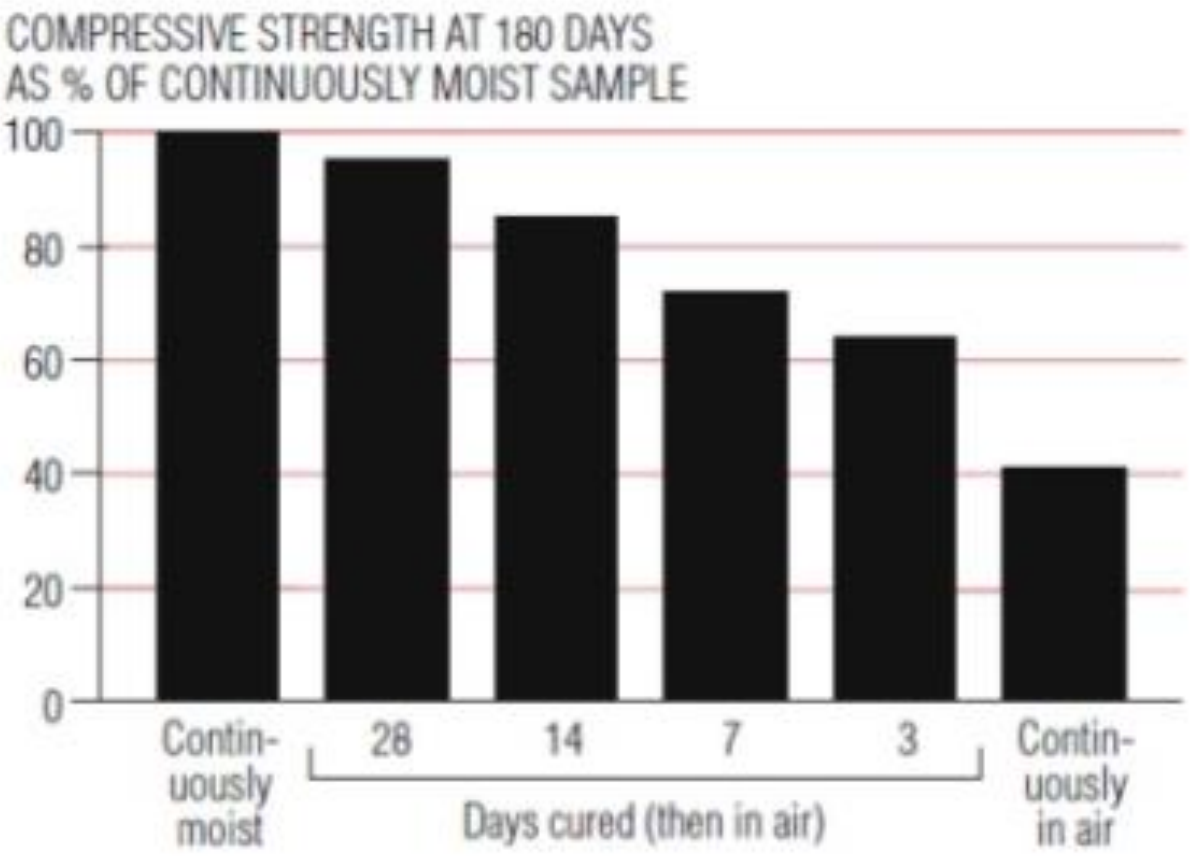


Figure 1: Effect of duration of water curing on strength of concrete.

Methods of Curing

- 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 (for pre-cast members, concrete cylinders etc.)
b) Ponding (pavements, roof slabs etc.)
c) Spraying or Fogging (vertical retaining walls, plastered surface etc.)
d) Wet covering (for vertical and horizontal members. Gunny bags, jute matting, saw dust, moist sand etc.)

Water Curing

Membrane Curing

- Concrete works are carried out in places where there is acute shortage of water.
- 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.
- It is found that the application of membrane or a sealing compound, after a short spell of water curing for one or two days is sometimes beneficial
- Membrane curing is 80% efficient as compared to water curing.
- Some of the materials, that can be used for this purpose are bituminous compounds, polyethylene or polyester film, waterproof paper, rubber compounds etc. In case of bituminous layer, and extra lime wash layer is added to prevent bitumen from absorbing heat from the moisture, which can be harmful for concrete.

Membrane curing

- Preferable for concrete in far off and inaccessible places, or where curing remains unsupervised.
- Sometimes membranes can be used at the interface of ground and concrete surface to prevent absorption of moisture from concrete.
- For best results, membrane curing should be used one or two days after actual wet curing.
- When water proofing paper or polyethylene paper are to be used for membrane curing, it must be made sure that the sheets are not punctured anywhere. Moreover, adequate lapping should be given at junctions and lapping should be effectively sealed.

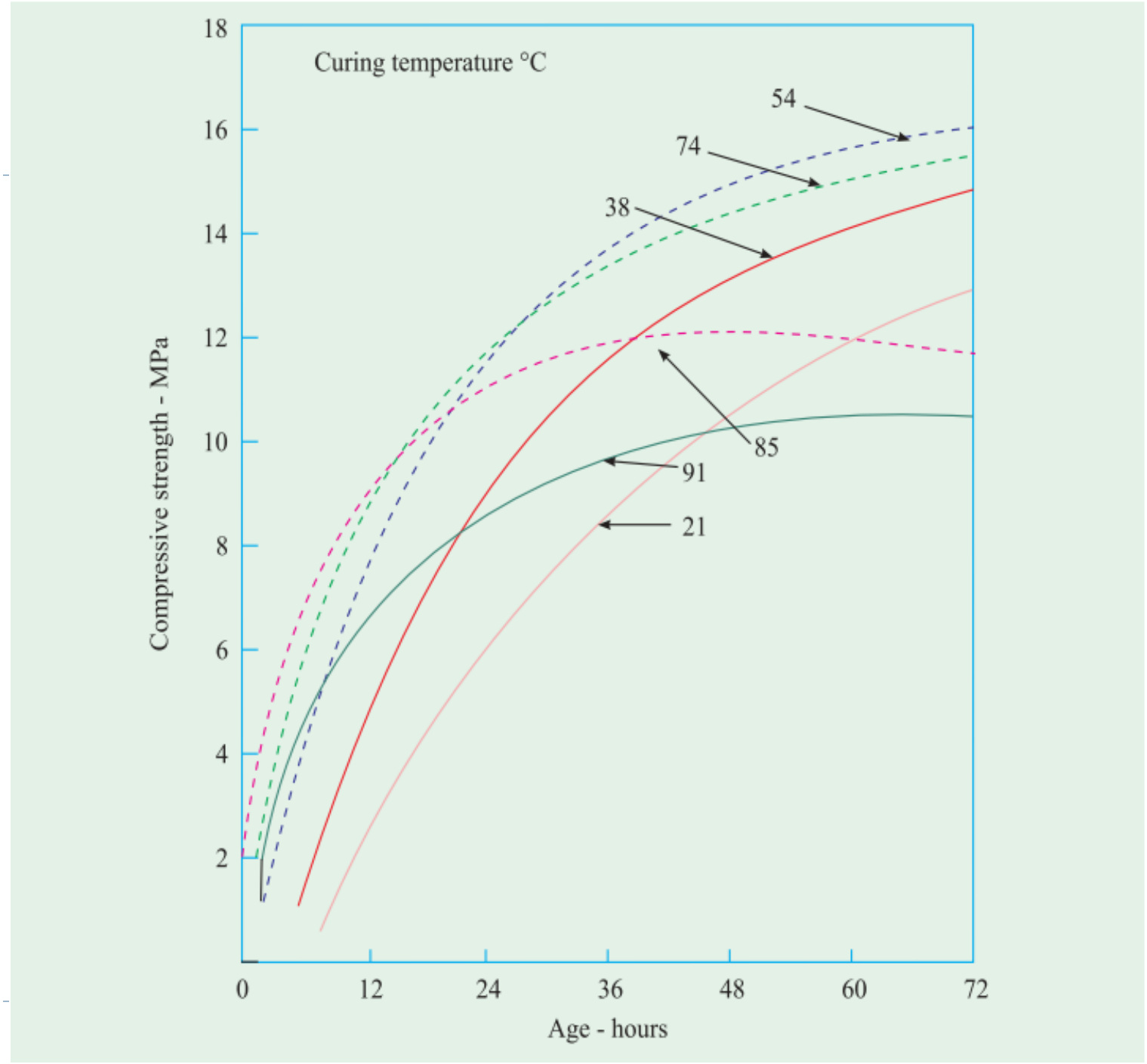
Membrane Curing

Application of heat

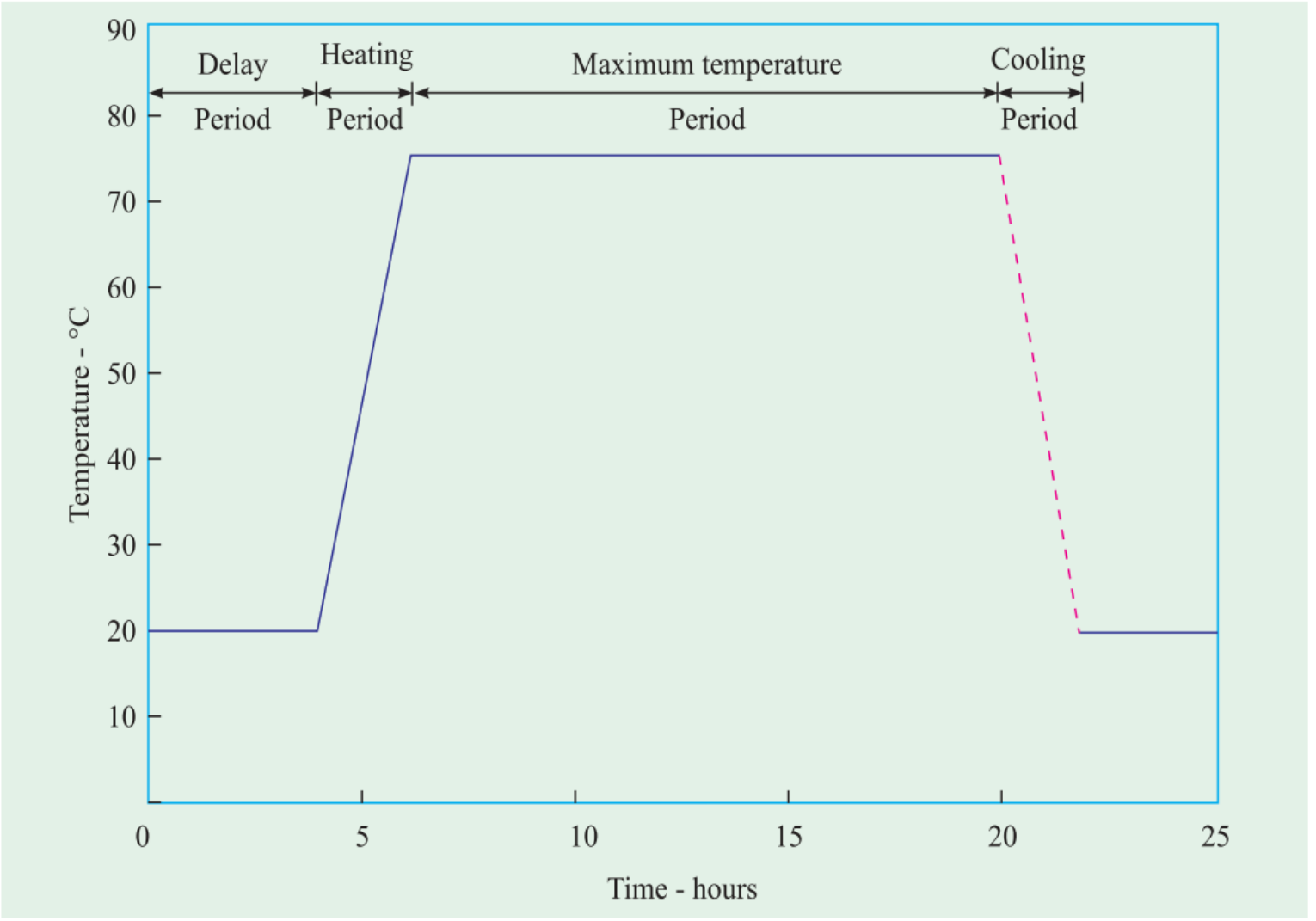
- When concrete is subjected to higher temperature it accelerates the hydration process resulting in faster development of strength.
- Concrete can not be dry heat to accelerate hydration process as moisture is a requisite for hydration.
- Therefore, subjecting the concrete to higher temperature and maintaining the required wetness can be achieved by subjecting the concrete to steam curing.
- The exposure of concrete to heat for curing can be achieved by following methods
  1. Steam curing at ordinary pressure 2. Steam curing at high pressure 3. Curing by infra red 4. Electrical curing

Application of heat

- Steam Curing at Ordinary Pressure:
- This method is often adopted for prefabricated elements stored in a chamber which should be big enough to store a days production. The chamber is closed and steam is applied either continuously, or at intervals. Sometimes large tunnels facilitated by trolleys can also be used.
- Concrete can attain 28days strength in 3 days by application of heat.
- Curing at high temperature can cause 'Retrogression in strength' which refers to high strength in early age due to heating but loss in strength at later age.
- Faster hydration on concrete due to high temperature can caused formation to poor quality gels with porous structure, as opposed to gels formed slowly and steadily at lowers temperature which are of good quality and dense in nature.
- It is recommended that certain delay period after casting of concrete should be allowed before heat is being applied.
  Concrete subjected to steam curing exhibits slightly higher drying shrinkage which is more prominent in rich mixes. Moreover, artificial aggregate also affected.


Curing temperature °C
54
74
38
85
91
21
Compressive strength - MPa
18
16
14
12
10
8
6
4
2
0
12
24
36
48
60
72
Age - hours

Steam Curing Cycle



Curing by heating

Application of heat

- High Pressure Steam Curing:
- A super heated steam at high temperature and high pressure is applied. This process is also called autoclaving usually performed on lightweight concrete products.
- The high pressure high steam cured concrete develops 28days equivalent strength in 1 days. Moreover, strength developed does not show retrogression.
- High resistance to sulphate attack and freezing and thawing. Less efflorescence.
- Lower drying shrinkage.
- Improvement in durability is more effective in concrete with high W/C ratio.
- Bond strength with reinforcement is reduced 30 to 50% as compared to wet curing.

Application of heat

- Curing by Infra-red radiation:
- Curing of concrete by Infra-red Radiation has been practised in very cold climatic regions in Russia.
- It is claimed that much more rapid gain of strength can be obtained than with steam curing
- The system is very often adopted for the curing of hollow concrete products.
- The normal operative temperature is kept at about 90°C.

Application of heat

- Electrical curing:
- Another method of curing concrete, which is applicable mostly to very cold climatic regions is the use of electricity.
- 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.

Electrical Curing

Miscellaneous method of curing

- Calcium chloride used either as a surface coating or an admixture. Calcium chloride being a salt shows affinity to moisture and absorbs moisture from atmosphere. This moist layer prevents evaporation of water from concrete, thus ensuring evaporation.
- Formwork, particularly in case of beam and columns prevents the evaporation of water.

When to start curing and how long to cure

- In case of hot weather concreting, concrete must not be allowed to set quickly. This ensure by covering the surface of concrete by wet gunny bags (to prevent evaporation) that are properly squeezed (so water does not drip into fresh concrete). This process should be maintained for 24 hours or at least till the setting time. Then, water curing should be commenced by ponding or spraying.
- Curing process should be continued till at least 70% of the design strength of concrete is achieved. Mass concrete, heavy footing, abutments, should be cured at least for 2 weeks.

Finishing

- Finishing is the last operation in making concrete. It is required in road pavement, air field pavement and domestic floors.
- One of the most widely used method is surface finishing. In case of road pavement, surface is made intentionally rough to offer better skid resistance. In case of domestic floors the surface is made smooth.
- In Surface finishing, the surface must be finished at the same rate as placement. Use of wooden float is better for start but at the end a steel float may be used.
- Extra rich mortar should be avoided for finishing purposed as it results inadequate bond and increased shrinkage. Moreover, strength and wear resistance is also reduced´.
- Use of extra mortar should be avoid for finishing purpose but it can be used if it is of same composition. It should be laid before the base layer of concrete has hardened.
- Sprinkling of dry cement should only be used in case to prevent bad effects of bleeding.
- A good concrete floor should be durable, no absorptive, free from cracks and other defects. It should be easy to clean and safe against slipping.

Assignment

- What is craziness of concrete floor finish? (short)
- What is whisper concrete? (Long)

THE END