CONCRETE Advice

Curing concrete

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Curing is the process of preventing the loss of moisture from the immature concrete whilst maintaining a satisfactory temperature regime. The purpose of minimising moisture loss is to achieve a high level of hydration of the cement in the *surface layer* of the concrete and thus improve durability. The purpose of maintaining a satisfactory temperature regime is to control strength development and reduce the risk of thermal cracking and damage from early age freezing.

The following considers the basic requirements for good curing.

1 General

Concrete has an inherent quantity of water within the mix from the time of batching, about 160 to 200 litres per cubic metre. The majority of this water is not required to hydrate the cement but is needed to improve the consistence. The water that is not chemically combined or held by capillary action within the concretes pore structure is free to evaporate i.e. dry.

Concrete must be protected whilst it is immature from the harmful effects of dry air, solar gain, drying winds and early age freezing, in order to achieve the maximum strength and durability. Normal curing relies for its effectiveness on the prevention of evaporation of water from a concrete surface; curing using applied insulation can also help to control large internal temperature differences in large masses of concrete, and to maintain an adequate temperature in the concrete during early age cold and freezing weather.

To ensure that the full benefits of curing will be achieved, all concerned in concrete production (engineers, supervisors, operatives) must clearly understand why and how the particular curing process is to be used

2 Influence of hydration on the properties of concrete

The development of strength and of durability of any concrete, regardless of the type of cement used, depends on maximum hydration of the cement to a dense matrix of low permeability that is resistant to the passage of water, carbon dioxide and oxygen.

Curing is essential to maintain the chemical reaction between the cement and water in the critical surface zone. The influence of curing is considered to be approximately 30mm from the surface.[1] If the surface is allowed to dry out, this reaction ceases and thus inhibits further hydration and strength development.

The durability characteristics developed by proper curing include;

- an increased wear resistance on slabs,
- a reduction of wall surface erosion on exposed conditions,
- an improved resistance to early age freezing,
- a decrease in permeability to fluids and gasses.

3 Horizontal surface

The materials used for curing horizontal surfaces such as roads, airfield pavements, external slabs and floor slabs are:

- proprietary spray-applied membrane-forming compounds,
- impervious sheeting laid in close contact with the concrete surface,
- impervious sheeting fixed to a frame providing a 50mm air gap with sealed edges to prevent a wind tunnel effect,
- damp materials such as continually watered hessian or similar,
- water in low bunds of sand.

Early curing of slabs is vital to minimize the risk of plastic shrinkage cracking especially in climatic conditions combining warmer temperatures with strong drying winds. The use of wind breaks is essential.

4 Vertical Surfaces

In temperate conditions, such as the United Kingdom, for most of the year formwork left in place for two or three days is sufficient to protect the immature concrete from loss of water by evaporation.

In dry, windy or arid conditions the formwork may need to be left in place for longer, depending on air temperature, wind speed and relative humidity.

Where formwork has to be stripped early, further curing may be required. The use of plastic sheeting or insulating panels can be effective; providing they are applied immediately the formwork is removed and held in close contact with the concrete surface.

Curing of formed vertical surfaces with water is usually impracticable.

The use of spray-applied curing compounds on formed vertical surfaces can be problematical and may be ineffective unless the selected grade of compound is applied immediately after the formwork is removed. Furthermore, coverage must be total, leaving no areas unprotected by the membrane.

Curing compounds are not recommended on surfaces that will subsequently receive an applied finish such as rendering, paints and other coatings, unless they can be subsequently removed.

The use of cold water can be hazardous, especially in hot climates, because of the risk of thermal shock leading to cracking and surface defects. A common method is to wrap columns in wet hessian and then polythene.

In arid regions water can rarely be used for curing in any case because of the lack of suitable water. Curing of reinforced concrete with seawater or brackish well water is normally prohibited due to the high risk of chloride attack on the reinforcement and of sulfate attack on the concrete.

Although expensive to apply, artificial fog spray can be a most effective curing medium since the creation of a high-humidity environment surrounding concrete surfaces virtually stops evaporation and the premature loss of water. Like any other curing process, however, it depends for its effectiveness on rapid application following formwork removal.

Other than its use for limited areas of high quality in-situ concrete, fog spray curing is more suited to factory production of precast concrete or perhaps in enclosed environments such as tunnels.

5 Duration and effectiveness of curing

Curing periods required by most specifications range from about three to seven days, irrespective of prevailing weather conditions, and are generally based on experience or on the published results of laboratory trials. The first 24 hours are the most critical as the rate of evaporation decreases rapidly after this and reaches an almost insignificant value within three or four days.

BS EN 13670[(2)] defines the level of curing by the duration of applied curing as a function of the development of the concrete properties in the surface zone. This development is described by curing classes 1 to 4 defined by curing period or percentage of the specified characteristic 28 day compressive strength (f_{ck}) as follows;

Class 1: 12 hours (provided set does not exceed 5 hours and the surface temperature is 5ºC or greater).
Class 2: 35% of the specified f_{ck}
Class 3: 50% of the specified f_{ck}
Class 4: 70% of the specified f_{ck}

To achieve the minimum curing duration in days Appendix F of BS EN 13670 provides tables for each class relating concrete surface temperature and the concrete strength development *r,* where *r* is the mean ratio of the strength at 2 days and 28 days. This is derived from initial tests or based on known performance of concrete of comparable composition; see BS EN 206-1[(3)]. Concrete strength gain is defined as rapid, medium or slow.

In this way the different strength developments associated with the different strength classes of Portland cement (CEM I) and cements containing additions at various percentages such as fly ash and ground granulated blastfurnace slag (ggbs) can be factored into the minimum curing time required.

Provided that all earlier stages of concrete production from batching to placing and compaction are well controlled, proper curing results in good durability, abrasion resistance and reduced thermal contraction. Furthermore, a reduction in plastic shrinkage cracking, particularly in concrete slabs or pavements, is a major advantage of early curing.

Similar advantages are normally gained by good curing of concrete walls, columns and beams, etc., although to obtain the full benefits, the open top surfaces must be protected as well as the vertical surfaces for the whole of the curing period. Do not use curing compounds at stop ends or on joint faces since this would seriously impair bond with subsequently placed concrete.

6 Extreme weather

Special precautions in hot weather
In the worst condition of hot dry weather with high winds, to cope with the fast drying conditions:

- provide wind shields to cut down air movement and minimize loss of water
- provide effective shading to minimize surface temperature variations
- be extra careful with the early application of a waterproof membrane. (Polythene or similar sheeting, laid in close contact with the fresh concrete, is extremely effective provided it is applied quickly.)

Special precautions in cold weather
In a cold but dry atmosphere, particularly during overnight frost or freezing conditions, immediate application of combined curing and protective measures is necessary. One of the most effective methods for slabs is to apply waterproof glass fibre or mineral wool blankets or other insulation matting directly on the freshly placed concrete.

Alternatively, a lightweight insulation material laid over polythene sheeting provides adequate protection provided the insulation material is kept dry. This is not only to minimize loss of water but to maintain an adequate temperature and, in the case of thick sections, to control the surface temperature so that the temperature gradient between the core and the surface does not become excessive.

Under no circumstances should water be used for curing in frosty or freezing conditions.

7 Curing specifications

Concrete may be placed in a wide variety of structures in a range of climatic conditions, so the production of a 'general' specification for curing concrete requires very careful consideration. It is particularly important that misrepresentation does not lead to inadequate curing.

To avoid ambiguity, curing should be specified for particular situations such as slip-formed road pavements, external slabs or large precast concrete units. Variability in the conditions under which the concrete will mature, and the type of cement used, can be taken into account by reference to the recommended curing periods in BS EN 13670[2].

The main categories to be considered are:

- horizontal exposed concrete such as pavements, slabs, beam, wall and column tops;
- vertical formed elements, such as columns, beams or walls.

Where concrete is to be placed in stages or which will receive further treatment, such as construction joints or floors to receive a cement/sand screed or columns to be rendered, should be considered separately in relation to specific curing needs, particularly since spray-applied curing compounds may not be suitable.

Precast concrete requires a specialized approach since the curing methods and the duration of curing periods will often be different from those for in-situ concrete. Most precast concrete work is carried out in a well-protected or enclosed environment using accelerated curing techniques which allow very early striking of the formwork. Curing by steam at atmospheric pressure or by autoclaving (steam at high pressure) are examples. Such techniques allow economic production levels to be achieved whilst producing units with satisfactory strength and maturity at an early age.

As a guide, requirements for curing the principal forms of in-situ concrete should be as shown in the Table overleaf.

8 Accelerated curing

Accelerated curing can be used for precast and in-situ concrete where, for example, programme requirements call for rapid turn-round of formwork or where high early strength or maturity is necessary. In such cases, an artificial environment is created around the concrete. This is relatively easy in precast factories and yards. For in-situ work the construction of a temporary environment, although more likely in colder locations such as Canada rather than the UK, by the provision of portable, sealed covers into which a controlled supply of warm, moist air is introduced can be undertaken.

Methods used include steam generators, propane gas space heaters or hot water pipes fed from a central boiler. Of these, propane gas space heaters are the most popular due to their portability.

All forms of accelerated curing require a high-energy input. It is advisable therefore to weigh carefully the advantage of rapid strength development to allow early formwork stripping against the additional cost of accelerated curing. It should also be remembered that concrete subjected to accelerated curing might require further protection at the end of the curing treatment to allow for gradual cooling. Accelerated curing will also reduce the ultimate strength compared to ambient curing.

Table: Guide to curing in-situ concrete in average conditions

Type of construction	Curing material	Application
1. Road and airfield pavements, open flat slabs, etc.	Pigmented resin-based curing compound with high efficiency rating Polythene or other impervious sheeting material	Immediately finishing process is complete Protect with shading for the first few hours especially in hot sunshine and high drying winds
2. Tops of beams, walls and columns	Polythene or other impervious sheeting material	Immediately finishing process is complete Protect with shading for the first few hours especially in hot sunshine and high drying winds
3. Concrete columns, beams, walls, etc., in hot dry conditions which are not to receive subsequent treatment	Resin-based curing compound Polythene or other impervious sheeting Formwork itself	Immediately formwork is removed* Apply in close contact with surface immediately formwork Is removed Ease from form surface but leave undisturbed for at least 4 days, preferably 6 days
4. Concrete columns, beams, walls, etc-, in temperate conditions and where subsequent treatment is envisaged	Polythene or other impervious sheeting material Formwork itself	Apply in close contact with surface immediately formwork is removed Ease from form surface but leave undisturbed for at least 4 days, preferably 6 days
5.Formed, permanently exposed concrete sections cast in cold weather	Insulation Delayed removal of formwork Top surface insulation	As soon as concrete is placed, and maintain for at least 6 days
6.Large concrete sections with a minimum thickness or depth exceeding, say, 1 m	Delayed removal of formwork or replacement of formwork by insulating material	Maintain for at least 6 days or until internal temperature gradient is minimized
** Some manufacturers of resin-based curing compounds recommend the re-wetting of formed concrete surfaces before application. To avoid thermal shock, water used for this purpose must be close to the temperature of the surface of the concrete.*		

References

1. Taylor, PC. *Curing Concrete,* Taylor and Francis, London, 2014
2. BSI. BS EN 13670: 2009, *Execution of concrete structures*, BSI, London
3. BSI. BS EN 206: 2013, *Concrete — Specification, performance, production and conformity,* BSI, London

Further reading

BSI. BS 7542: 1992, *Method of test for curing compounds for concrete*, BSI, London

CIRIA, *Curing concrete – an appraisal of attitudes, practices and knowledge*, Report 43, Construction Industry Research and Information Association, London, 1981

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