CONCRETE *Advice*

Curing concrete

Mal Enoch, FICE,FCS

Concrete has an inherent quantity of water within the mix from the time of batching, about 200 litres per cubic metre. The majority of this water is not required to hydrate the cement but is needed to provide 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. Curing is the process of preventing the loss of moisture from the young 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 reduce the risk of thermal cracking and damage by frost.

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

1 General

Concrete must be protected whilst it is immature from the harmful effects of dry air, solar gain, internal temperature gradients, drying winds and frost, 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 cold and frosty weather.

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, salts and oxygen. Curing is essential to maintain the chemical reaction between the cement and water in the critical cover zone. If the surface is allowed to dry out, this reaction ceases and thus inhibits further hydration and hence strength development.

The durability characteristics developed by proper curing include:

- increased wear resistance
- reduction of surface erosion in exposed conditions
- improvement of frost resistance
- decrease in permeability to fluids and gasses.

3 Horizontal surfaces

The materials commonly 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 an insulating 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 flat slabs is vital to minimize the risk of plastic shrinkage cracking especially in climatic conditions combining high temperatures with strong drying winds.

Spray-applied curing compounds are rated according to the efficiency with which they provide a barrier to evaporation. This is measured as a percentage of total water retained in the concrete in accordance with BS 7542[1]. BS 8110[2] specifies the use of curing compounds with a minimum efficiency of 90%.

Tests[3,4] have shown the effects of delay in the application of curing compounds, by measuring the water loss from concrete specimens at various ages. The results of the tests on a trowelled slab, clearly shows the rapidity with which water can be lost if curing is delayed.

Although membranes formed by curing compounds normally degenerate after a period. Their use is not recommended on surfaces that are subsequently to receive an applied finish, such as a screed or coating, because of the likelihood of reduced bond.

Water is the most effective and cheapest curing medium but it is seldom used because of the practical problems associated with supply, containment and ultimate disposal. Materials such as wet hessian or wet sand are sometimes used but they must not be allowed to dry out.

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. Plastic sheeting or insulating panels can be effective, providing they are applied immediately the formwork is removed and are 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. One method that is commonly used in hot arid climates is to wrap columns with hessian overlayed with polythene.

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

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. In some 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.

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 8110 Table 6.1 recommends different curing periods depending on the type of cement used and the ambient conditions after casting. For average conditions four days is recommended for Portland cement (CEMI) and Sulfate resisting Portland cement (SRPC) concrete and six days for all other cements indicated in BS 8500-1[5] Table A.17 e.g. those containing ground granulated blastfurnace slag (ggbs) or pulverised fuel ash (pfa). In adverse conditions, i.e. hot or windy weather, full curing should continue for a minimum of six days for CEMI and SRPC and 10 days for all other cements.

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 early stage drying shrinkage. 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.

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 frosty conditions, immediate application of combined curing and protective measures is necessary. One of the most effective ways 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 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.

To avoid ambiguity, curing should be specified for particular situations such as slipformed road pavements, oversite 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 8110.

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.

Concrete to be placed in stages or which will receive further treatment, such as construction joints, 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.

Do not use curing compounds at stop ends or on joint faces since this would seriously impair bond with subsequently placed concrete.

8 Accelerated curing

Accelerated curing can be used for 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 by the provision of portable, sealed covers into which a controlled supply of warm, moist air is introduced.

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.

Table: Guide to curing In-situ concrete, average(2) 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 form from surface but then leave undisturbed for at least 4 days, preferably for 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 form from surface but then leave undisturbed for at least 4 days, preferably for 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, 1m	Delayed removal of formwork or replacement of formwork by insulating material against surface	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.*

FURTHER READING AND ADVICE

Further reading

1. BS 7542: *Method of test for curing compounds for concrete*

2. BS 8110: *Structural use of concrete, Part 1:Code of practice for design and construction, Part 2: Code of practice for special circustances*

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

4. CIRIA. *On-site curing of concrete microstructure and durability,* Report C530, Construction Industry Research and Information Assciation, London, 2001

5. BS 8500: *Concrete - Complementary British Standard to BS EN 206-1, Part 1: Method of specifying and guidance for the specifier*

Impartial advice can be sought from The Concrete Society. Members are entitled to substantial discounts on services and products including site visits and investigations, dependant on status. For publications and information, The Concrete Society Bookshop holds a wide range of books and pamphlets along with an extensive library stock. We provide many services such as literature searches and notification of new references to our extensive catalogue.

Contacts

Enquiries and advice

The Concrete Society 01276 607140
Bookshop 07004 607777
www.concrete.org.uk

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