

Concrete in Practice

What, why & how?



CIP 11 - Curing In-Place Concrete

WHAT is Curing

External curing is a step during construction that involves maintaining newly placed concrete at adequate **moisture** and **temperature** conditions so that it can develop properties, such as strength and durability, the mixture was designed to achieve. Curing begins immediately after placement and finishing and should be continued for a sufficient period of time, typically 3 to 7 days.

Hydration is the chemical reaction of cementitious materials with water that produces concrete's desired properties. The objective of curing is to prevent loss of moisture and maintain a favorable temperature to support continued hydration. Without an adequate supply of moisture, the cementitious materials in concrete cannot react to form a quality product.

Temperature is an important factor for curing. The rate of hydration, and therefore, strength development, is faster at higher temperatures. Temperature of placed concrete should be maintained above 50°F (10°C). Hydration generates heat that can be retained in cooler weather. In thicker sections curing procedures should minimize the temperature differential between the core and surface to avoid thermal cracking. Curing can also regulate the cooling rate to prevent thermal shock. See CIP 42.

When finishing, minimize the rate of moisture loss from the concrete surface to prevent plastic shrinkage cracking. See CIP 5.

Internal curing involves the use of absorptive materials, such as soaked lightweight sand and super-absorbent polymers, in the concrete mixture that release moisture with time. This is used in some applications. It does not negate the need for external curing.

WHY Cure Concrete

- a. **Predictable strength gain.** Concrete in a dry environment can lose as much as 50 percent of its potential strength compared that which is moist cured. At high temperature concrete gains early strength quickly but later strengths may be reduced. At cooler temperature concrete takes longer to gain strength, delaying form removal and subsequent construction.
- b. **Improved durability.** Well-cured concrete has better surface hardness to withstand surface wear and abrasion. Curing minimizes cracking and makes concrete more watertight, thereby reducing the intrusion of water and water-borne chemicals resulting in improved durability and service life.



Spray-on curing compound



Curing Blankets

- c. **Better serviceability and appearance.** Lack of curing will result in a less durable surface with poor resistance to wear and abrasion. Proper curing reduces the potential for crazing, dusting, and scaling.

HOW Should Concrete be Cured

Maintaining Moisture:

Concrete should be protected from losing moisture until final finishing using fogging or evaporation retarders. Subsequent to finishing, moist curing methods can involve application of additional water or retention of water in the concrete.

Methods using application of water:

- a. Continuous fogging or sprinkling is an excellent curing method. Soaker hoses can be used on vertical surfaces. Air temperatures should be above freezing and water should be readily available. Absorbent materials can be used to retain water. Alternate wetting and drying is not an acceptable curing practice.
- b. Ponding is the most thorough method of water curing

but is rare. A dike is created along the edge of the slab to pond water on the slab surface. It is sometimes used on smaller slabs and bridge decks. Temperatures should be above freezing for the curing duration.

- c. Use of absorbent materials like burlap or cotton mats can be used to hold water on horizontal or vertical surfaces applied by a soaker hose or sprinkler. The materials should be kept wet and weighted down to keep from blowing away. Materials should not stain the concrete surface.
- d. Damp earth, sand, or sawdust can be used to cure flatwork, especially floors. Materials should be clean and free of organic or iron-staining contaminants.
- e. Straw or hay sprinkled with water can be used on small areas. Straw can easily blow away and, if it dries is fire hazard. The layer of straw should be 6-in. (150 mm) thick and covered with a tarp.

Methods using retention of water:

Methods reduce evaporative water loss from the surface. They can be applied earlier than water-curing methods, do not need source of water, and are easier to handle.

- a. Plastic sheets - either clear, white (reflective), or black. Plastic film should conform to ASTM C171, be at least 4 mils (0.10 mm) thick. Film reinforced with fibers are more durable and less likely to tear. Clear and dark sheets absorb solar radiation and are recommended in cool weather or on shaded areas. Reflective sheets minimize heat gain when exposed to sunlight and should be used in warm weather. Plastic should be laid in direct contact with the concrete surface as soon as possible without marring the surface. Edges should overlap, be taped, and weighted down. Sheets should extend beyond the edge of slabs at least twice the slab thickness. Wrinkles will cause dark streaks or a mottled appearance due to variations of moisture and/or temperature. Plastic should not be used on concrete surfaces where appearance is important. Plastic is sometimes used over wet burlap to retain moisture.
- b. Liquid membrane-forming curing compounds must conform to ASTM C309 or C1315. These are wax or resin-based materials that form a surface film and minimize evaporation. Apply to the concrete surface, at the recommended rate, immediately after disappearance of water sheen on the surface after final finishing. Delayed application after surface has dried prevents the formation of the film. While a clear liquid may be used, a white pigment provides reflective properties and coverage is visible. Two coats, applied at right angles, is desirable for even coverage. Curing materials that are wax-free are recommended for concrete surfaces that will be painted, or if a surface covering has to be bonded to the concrete. Some curing compounds are formulated to self-dissipate with time and for compatibility with surface treatments.
- c. Waterproof paper - consists of two layers of kraft paper cemented together and reinforced with fiber. It is

more resistant to tearing and can be reused. Paper is used like plastic sheeting and is less likely to mar the surface or cause mottling. Curing paper should conform to ASTM C171.

Evaporation retardants are used to reduce evaporation from concrete surfaces before it sets to prevent plastic shrinkage cracking. These should not be used for final curing.

Control of temperature:

In cold weather do not allow concrete to cool faster than a rate of 5°F (3°C) per hour for the first 24 hours. Concrete should be protected from freezing until it reaches a compressive strength of at least 500 psi (3.5 MPa) using insulating materials. Curing methods that retain moisture, rather than wet curing, should be used when freezing temperatures are anticipated. Guard against rapid temperature changes after removing protective measures.

In hot weather, higher initial curing temperature will result in rapid strength gain and lower ultimate strengths. Water curing and sprinkling can be used to achieve lower curing temperatures in summer. Precautions should be used to protect against cooling faster than 5°F (3°C) per hour during the first 24 hours due to temperature extremes.

Termination of Curing:

Curing should be continued as required by the specification, or for at least 3 to 7 days. Termination of curing should allow for gradual drying of concrete and to prevent large temperature differentials in the concrete member. Cover materials should be allowed to dry before removal. Controlled drying procedures should be used to control the rate of drying with wet curing methods. Use of layers of insulation can be removed sequentially to reduce the development of large thermal differential. The use of embedded temperature and relative humidity monitoring devices can be useful in critical applications.

References

1. ASTM C171, C309 and C1315, Annual Book of ASTM Standards, Vol. 04.02, ASTM International West Conshohocken, PA. www.astm.org.
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3. *Guide to External Curing of Concrete*, ACI 308R, American Concrete Institute, Farmington Hills, MI., www.concrete.org
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6. *Guide to Cold Weather Concreting*, ACI 306R, American Concrete Institute, Farmington Hills, MI.
7. *Specification for Structural Concrete*, ACI 301, American Concrete Institute, Farmington Hills, MI.
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