Curing Concrete

Keeping it warm and wet for a week will make concrete stronger and more watertight

by Bruce A. Suprenant

Some builders think that after the concrete is placed—whether in a wall or in a slab—the job is over. They don't understand that poorly cured concrete is weak and porous, and more likely to be damaged by cracks, wear, rebar corrosion, chemicals and freeze/thaw cycles. Improperly cured concrete may reach only half of its specified strength (see graph below). Smart builders, on the other hand, postpone Miller Time for a while and take steps to keep concrete moist—curing until it reaches its full strength. They also look for better, easier and cheaper methods of concrete curing.

A small portion of the water added to the concrete mix combines chemically with the cement in a process called hydration. Unfortunately, most of the water added to the concrete mix evaporates and leaves voids. These voids represent the difference between concrete that is properly cured and concrete, that is poorly cured or not cured at all. Good curing enables the hydrated cement to occupy most of these voids, and thereby increase the strength and durability of the concrete.

Curing compounds seal the surface of the concrete, preventing water from evaporating. In the photo above, a worker uses a garden-type sprayer to apply curing compound to a stamped concrete patio. *Photo courtesy of* Concrete Construction *magazine.*

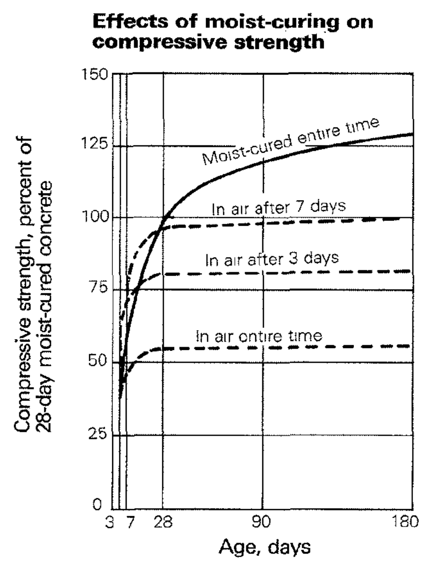
Temperature and time—Temperature affects the speed of hydration. The warmer the concrete, the faster cement hydrates and gains strength. At air temperatures between 50° F and 90° F, there's no need to control concrete temperatures. Fortunately, much concrete is placed within this temperature range, so a builder does not usually have to spend money on temperature control. Outside this range, though, a builder may have to take steps to heat or cool the concrete.

Concrete temperatures below 50° F make it hard to achieve early strength. Hydration is slow, so early strength is low. Below 40° F early-strength development is greatly retarded, and at 32° F little early strength develops.

Cement hydrates faster at temperatures above 90° F, and concrete gains strength rapidly. Its ultimate strength, however, isn't as high as that of concrete cured at a lower temperature (see graph, facing page). Also, later thermal cracking is more likely to occur in concrete placed on a hot day followed by a cool night. Thermal cracking looks like regularly spaced cracks running all the way through the concrete and is caused by changes in temperature.

According to the American Concrete Institute's "Specifications for Structural Concrete for Buildings" (see sidebar, p. 68) curing must continue for at least seven days for all concrete, except high-early-strength concrete (concrete made with Type III cement). At least three days of curing are required for high-early-strength concrete. You may be able to shorten the curing period, but only if you run strength tests on cylinders that have been kept adjacent to the pour and cured by the same methods. You can stop curing when the average compressive strength of these field-cured cylinders reaches 70% of the specified strength. The specified strength at 28 days is usually 3,000 lb. per square inch (psi), but check with your concrete supplier to verify the strength for your mix.

In addition to making efforts to retain moisture in the concrete, maintain the temperature of field concrete at a minimum of 50° F for as long as the laboratory-cured cylinders take to reach 85% of the specified strength. This temperature/time requirement should range from 7 to 12 days for all concrete, except for high-early-strength concrete, which ranges from 3 to 7 days. Once again, check with the supplier for a time estimate of curing for your concrete.



In all cases the rise in compressive strength is dramatic over the first seven days. Beyond that, the advantages of moist-curing are obvious, resulting in concrete where compressive strength is anywhere from 25% to 75% more than concrete that is simply air-dried.
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Cylinder testing—Don't let the idea of cylinder testing scare you. Most cities have two or three testing firms that will sell you plastic cylinder molds and will test the cylinders after you make them. Cylinders 6 in. in diameter and 12 in. long cost about $1 each (buy 6 to 8 for each job to be tested), and testing usually runs $10 to $15 per cylinder.

To make the cylinders, place the concrete with a scoop or trowel in three equal layers within each cylinder. After placing each layer, use a ⅝-in. dia. rod to mix the concrete by moving the rod up and down 25 times (called rodding). After the final layer has been rodded, screed off the top to form a level surface and lightly tap the sides of the cylinder with your hand to expel small air bubbles. Cure these cylinders using the same methods you use for the structure.

For most concrete, wait about five days and then take two cylinders into the testing lab. The test lab will break the cylinders and provide you with the strength results on the same day that you bring them in. If the strength results are not equal to 70% of the specified concrete strength, curing must continue, and another test will be required. Check with your concrete supplier for the approximate time when 70% strength will be achieved. This information can minimize the number of cylinders purchased and made, trips to the test lab, and overall cost. Testing with cylinders may cost up to $100, but may save two or three days in curing. This can be important on big jobs, but if time is not important, simply cure the concrete for seven days.

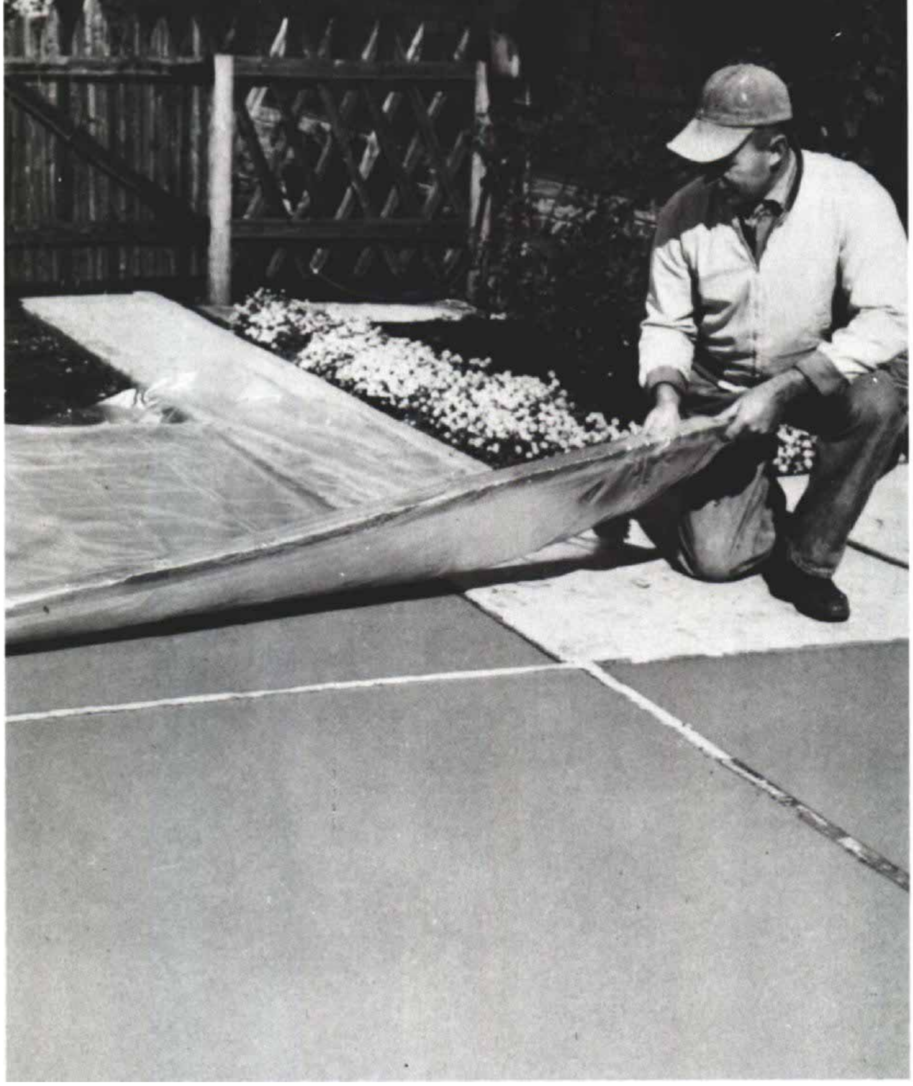
Curing methods and materials—The methods for maintaining the moisture content needed for curing fall into two categories. Applying water continuously calls for ponding water on slabs; sprinkling or fog-spraying; using soaker hoses and applying water-saturated cover materials such as burlap, straw, earth or sand. The second method calls for preventing excessive moisture loss, either with curing compounds or by covering the concrete with polyethylene sheets (photo right) or with reinforced waterproof paper. Most of these items are readily available at the local lumberyard and building-supply store. Additionally, most concrete suppliers either sell or know where to buy them.

Applying a curing compound to the concrete forms a membrane that seals the water into the concrete. This membrane is not completely waterproof, however, and a small amount of moisture is lost through evaporation. In this respect curing compounds aren't as effective as waterproof paper or polyethylene sheets, which retain all the moisture if they remain intact and in place during the entire curing period. But curing paper or plastic may be damaged on a site or dislodged by wind or workers.

Curing compounds are easy to apply on both horizontal and vertical surfaces, and for many concrete jobs, they are the most economical curing method. But if the concrete is to be coated, painted or covered with a flooring material, make sure that the curing compound won't interfere with the bonding of the final finish. Most curing compounds do interfere with bonding.

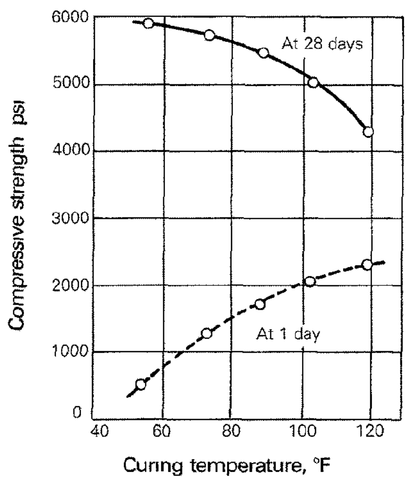
Generally, curing compounds are best applied right after finish-trowelling. They cost between $4 and $6 per gallon, and the typical coverage is 200 sq. ft. per gal. Spraying is the fastest method and typically, a farm or garden spray can is used (photo facing page). To ensure proper coverage, it's best to use two applications at right angles to each other. Brushes and rollers will work for small areas or small budgets. Pigmented compounds, colored white or grey, make it easier to see if the material has been applied uniformly. This helps eliminate missed spots and pinholes that can leak excessive moisture through the curing compound. The color fades away after a few days.

If you're dealing with colored concrete, use the curing methods recommended by the manufacturer of the dry-shake color or coloring admixture. Color-matched curing waxes are widely used for flatwork. Many curing methods may stain the concrete or cause efflorescence (white surface deposits). Plastic sheets and waterproof paper can cause a blotchy appearance because of uneven moisture distribution. Even curing compounds used for normal concrete are likely to be unsightly.



While curing compounds permit some evaporation, covering a slab with polyethylene sheeting will retain all of the moisture in the concrete. The disadvantage is that the poly can easily be damaged by wind or workers. *Photo courtesy of Portland Cement Association.*

Effects of curing temperature on compressive strength

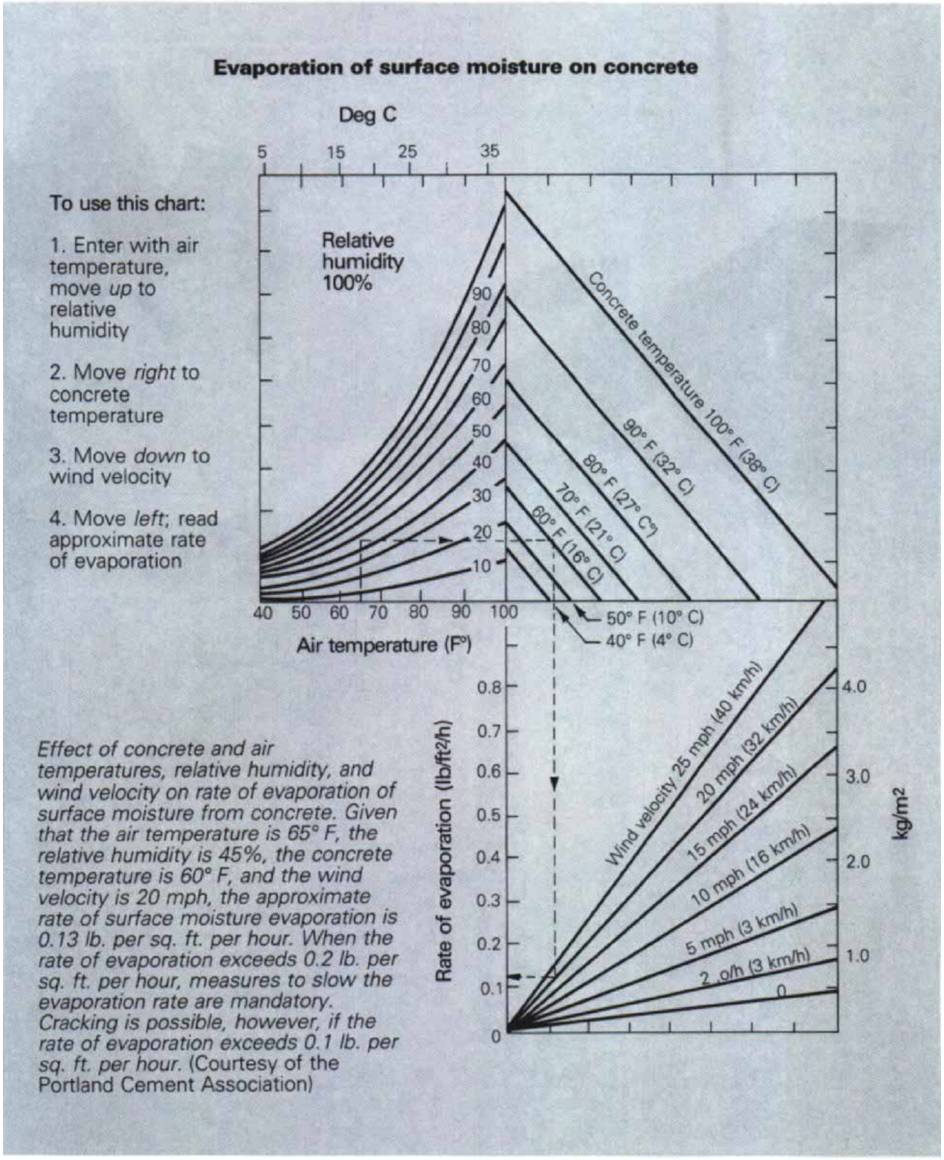


Increasing the curing temperature increases the early strength of concrete, but decreases final strength. For the material shown in the graph, 1-day strength increased from 800 psi to 2,000 psi when curing temperatures increased from 60° F to 100° F. But 28-day strength decreased from 5.900 psi to 5,200 psi. (Courtesy of the Portland Cement Association)

Curing in cold weather—Avoid curing with water during freezing weather. Water running out of heated enclosures freezes and may cause an icing hazard around the job site. Also, water-cured concrete is likely to be saturated when curing has ceased, which makes it vulnerable to damage from freezing.

In cold weather use curing compounds, polyethylene sheets, or waterproof paper to retain moisture. Then as hydration proceeds, internal water-filled voids will be partially emptied. When compressive strength reaches 500 psi (for most mixes this occurs at about 24 hours) water in the voids will be reduced enough to prevent damage from freezing.

For both temperature protection and moisture retention, you can cover the concrete with thermal curing blankets, available from the following companies: Acme Canvas Co., Inc. (171 Medford St., Malden, Mass. 02148); Ametek Microfoam Div. (Rtes. 1 and 202, Brandywine 4



Effect of concrete and air temperatures, relative humidity, and wind velocity on rate of evaporation of surface moisture from concrete. Given that the air temperature is 65° F, the relative humidity is 45%, the concrete temperature is 60° F, and the wind velocity is 20 mph, the approximate rate of surface moisture evaporation is 0.13 lb. per sq. ft. per hour. When the rate of evaporation exceeds 0.2 lb. per sq. ft. per hour, measures to slow the evaporation rate are mandatory. Cracking is possible, however, if the rate of evaporation exceeds 0.1 lb. per sq. ft. per hour. (Courtesy of the Portland Cement Association)

SEE ERRATA AT END OF ARTICLE

Bldg., Chadds Ford, Pa. 19317); Raven Industries, Inc. (Flexible Films Dept., P. O. Box 1007, Sioux Falls, S. D. 57117); Reef Industries (P. O. Box 750250, Houston, Tex. 77275-0250).

Curing in hot weather—During hot-weather concreting operations, water evaporates from the concrete, so water curing is preferred. Effective methods include placing wet burlap on the concrete and covering it with polyethylene or spraying it continuously with water. For large areas of flatwork, curing compounds are more practical. White-pigmented curing compounds help reduce concrete temperatures because they reflect sunlight and reduce heat absorption.

Rapid drying of flatwork in hot weather causes surface cracking. Workers have to apply water, curing compounds or coverings quickly after finishing to prevent plastic shrinkage cracking. If final curing is delayed, you can try fog-spraying as an intermediate curing method to prevent or reduce the chances of cracking.

Plastic shrinkage cracks are relatively short (2 ft. or 3 ft.), shallow (½ in. to 1 in.) parallel cracks that may occur before final finishing. They are the result of rapid moisture evaporation caused by high temperatures, low relative humidity and wind greater than 15 mph. The graph at left illustrates a method for evaluating the possibility of plastic shrinkage cracking. If the surface evaporation rate exceeds 0.2 lb. per sq. ft. per hour, plastic shrinkage cracking is likely to occur.

To minimize the possibility of plastic shrinkage cracking, take the following precautions: moisten subgrade and forms; erect temporary windbreaks and sunshades; place the concrete during the cool time of the day; reduce time between placing, finishing and start of curing. Immediate, continuous curing during hot weather also helps to prevent crazing (eggshell or chicken-wire patterns), cracks which are usually caused by early drying or intermittent wetting and drying.

Curing inexpensively—Under most conditions, leaving wall forms in place is an acceptable curing method. Keeping the forms wet helps to cool them, further reducing moisture loss. Builders should weigh the cost of leaving forms in place for up to seven days against stripping forms as soon as possible and curing by other methods.

Absorptive wooden forms left in place are not a satisfactory means for curing structures during hot, dry weather. Loosen the forms as soon as possible so curing water can be run down inside them. According to the American Concrete Institute, natural curing from rain, mist, high humidity, low temperature or moist backfill is sometimes sufficient. Its effect must be at least equivalent to keeping the concrete above 50° F and moist for the first 14 days with Type II cement, 7 days with Type I cement, or 3 days with Type III cement.

Curing properly—Unfortunately, no field test lets you know if the concrete was cured properly. Strength tests of field-cured cylinders can indicate curing effects, but these cylinders are also affected by vibration, their size and other factors. Also, poor curing has its most pronounced effect on the thin layer of surface concrete. The lower quality of this layer might affect the strength only marginally, but may reduce durability considerably.

Color differences give a clue to curing effectiveness. Well-cured concrete is typically darker in color than poorly cured concrete. But color differences are also caused by changes in cements and admixtures, so color comparison is a crude method at best.

The best way to guarantee proper curing is to choose the right method, initiate it promptly, follow recommended applications and continue curing for the required time period. With a little tender loving curing, your concrete will reward you with many years of good performance. □

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Publications on curing concrete

American Concrete Institute (P. O. Box 19150, Redford Station, Detroit, Mich. 48219)
"Standard Practice for Curing Concrete" (ACI-308-81, rev. 1986), $6.25
"Hot Weather Concreting" (ACI-305R, revised 1986), $10.50
"Cold Weather Concreting" (ACI-306R, revised 1986), $13.95

National Association of Home Builders (15th and M Streets, N. W., Washington, D. C. 20005-4099)
"Residential Concrete," $12.00

Portland Cement Association (5420 Old Orchard Rd., Skokie, Il. 60077-4321)
"Design and Control of Concrete Mixtures" (EB001T), $19.50 plus $2.00 postage
"Cement Mason's Guide" (PA122) $4.75 plus $2.00 postage

ERRATA

In our article on curing concrete *(FHB* #55, pp. 66-68), there are two mistakes in the graph on p. 68. In the lower portion, titled "Rate of Evaporation," 5 mph should be followed by "(8 km/h)," and the line immediately below should read "2 mph (3.2 km/h)."