CURING CONCRETE

A curing compound slows down the evaporation of moisture from freshly poured concrete. This is often the most practical way to control the curing process since, unlike wetting with a sprinkler, it has to be done only once.

BY DAVID CARNS

Most construction projects call for concrete in some form, whether as footings, walls, or flatwork. As a frequently used material, concrete is also a common source of problems. Foul-ups can occur at any stage, from batching, mixing, and transporting to placement, finishing, or even curing, the final step. Concrete that has been handled correctly all along can still be ruined if it's not properly cured.

Warm and Wet: Keys to Curing

Curing means taking steps to keep the concrete under the right temperature and moisture conditions during the first few days of hardening after placement. Proper curing is vital because the concrete will eventually be much harder and stronger if it is cured correctly.

Hydration. The hardening of concrete is not a drying process, but rather the result of a chemical reaction between the finely ground portland cement particles and the water in the mix. This reaction is known as *hydration*. Like most chemical reactions, hydration is greatly influenced by temperature. The basic idea behind proper curing is to allow this reaction to continue as long as practical by maintaining a suitable curing temperature, usually 50°F to 90°F, and by keeping the concrete wet. If the temperature of the concrete drops below 50°F, hydration begins to slow, and if the water in the mix freezes, the concrete will be ruined. Also, if too much water escapes from the concrete, hydration will stop altogether.

The longer favorable conditions are maintained, the longer the concrete will cure, resulting in a better product.

Benefits of Good Curing

Although it may require some extra effort on the average residential job site, maintaining proper curing conditions will result in superior concrete. Properly cured concrete has several desirable qualities:

- It is stronger in compression (see "Moist-Curing for Maximum Strength," next page).
- It resists abrasion much better. This is important for concrete floors and pavements.
- It is more durable; in particular, it is better able to withstand repeated freezing and thawing over the years.
- It is less permeable. This makes a big difference in concrete walls designed to keep out moisture, such as basements.

A note of caution. Keep in mind that proper curing will not compensate for poor quality concrete. Concrete that is poured too wet will be weak regardless of how it is cured. Not all of the water that is added to the concrete mix is necessary for the hydration process. In fact, the amount of water required to completely hydrate the cement is only about one half to two thirds of what is usually added at the batch plant or on the job site. The rest is added strictly to make the mix more workable. Adding too much water, however, might save work during placement, but it will also result in very weak, porous concrete, even with proper curing (see "Water in the Mix: Know When to Say When," next page).

How and When to Cure

Hydration begins as soon as the cement particles come in contact with the mix water. Curing begins immediately after placement, or in the case of flatwork, immediately after the final finishing is done. You should move quickly to create suitable curing conditions. Even when the temperature is within the 50°F to 90°F range, you need to prevent evap-

FOR A STRONG PRODUCT, KEEP FRESH CONCRETE MOIST AND WARM FOR AS LONG AS POSSIBLE oration from the concrete by sealing it or keeping it wet. If hot, dry, or windy weather is likely to cause excessive evaporation, or if cold temperatures threaten to freeze the concrete, the need to control temperature and moisture becomes even greater (see the sections on hot and cold weather curing, below.) For milder weather, here are some techniques that work well on residential job sites:

Slabs and flatwork. You can keep a slab wet with a continuous water spray, such as a lawn sprinkler. This provides the moisture necessary for the slab surface to properly cure, and cools the slab to slow evaporation during hot weather. However, you have to keep an eye on things, which isn't always practical. I remember one time when a homeowner came home and helpfully turned off the sprinkler, thinking that the contractor had forgotten about it. The slab dried out and curing stopped.

You can dam the edges of a slab with dirt or plastic and pond the surface with water. This works fine in theory, but it has the same drawback as the water spray: You have to keep watch.

You can also cover a slab with polyethylene sheets (see Figure 1). Use clear poly, 4 mil or heavier. Do not use black poly, especially in hot weather. The idea is to keep the moisture contained in the concrete from evaporating. If the plastic has even small holes or tears, or if a tight seal is not maintained around the edge of the slab, moisture will escape and curing will stop. Tape the plastic to any protruding rebar or plumbing, lap and weight any seams, and weight all the edges. This method is practical and inexpensive, and works well when the poly is completely sealed. There is one drawback: Where the plastic makes contact with the concrete, it can discolor the slab surface. If appearance is important, consider one of the other methods.

Curing compound. You can apply a curing compound. These commercially available compounds provide a thin sealing film that accomplishes the same thing as a plastic sheet, holding moisture in the concrete. These compounds may be either clear or pigmented; with the pigmented product, you can tell where you've sprayed. They are relatively inexpensive — a gallon sells for about $8 and covers 200 to 300 hundred square feet. A garden sprayer works well for applying the compounds. Usually two coats are recommended, the second at right angles to the first, to ensure complete coverage. Keep in mind that all surfaces should be coated, including slab edges.

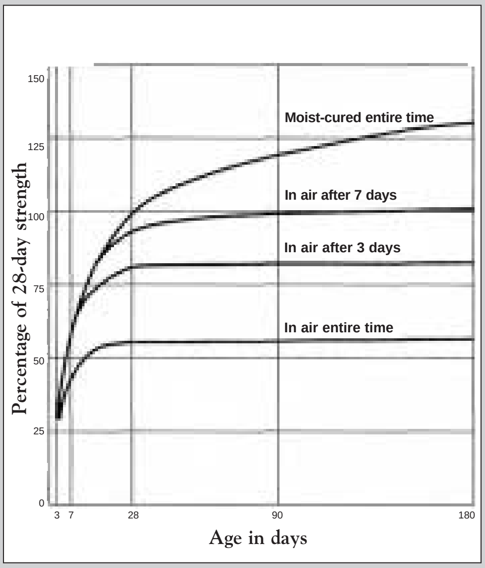
Although curing compounds will eventually wear off, some will prevent adhesion of paint, carpet, vinyl cements, or future concrete. Consult your supplier if this is a consideration. Curing compounds are widely used

Moist-Curing for Maximum Strength

Concrete continues to grow stronger as long as moisture is present and the temperature remains in a favorable range. Its ultimate strength, however, depends on how long it is moist-cured. The sooner moist-curing stops and the concrete is allowed to air-dry, the less the ultimate strength will be.

This graph shows strength gain as a percentage of 28-day compressive strength, an industry-wide standard used to rate the design strength of a concrete mix. After 28 days of moist-curing within an acceptable temperature range, normal concrete develops 100% of its design strength.

Of course, no one on the average residential job site cures concrete for two weeks, let alone for 28 days. But sometimes the job specs will require moist-curing for seven days because, as the graph shows, normal concrete kept wet for a week will eventually develop 100% of its design strength. Three days of moist-curing will get you into the 80% range — usually enough for residential loads, especially considering the safety margins built into concrete design. If you ignore moist-curing altogether, however, your concrete will only develop about half its design strength. *— JLC*



Bad Weather Curing

Weather Condition	Effect On Cure	Concrete Defect	Strategies
Moderately hot, dry and/or windy	Excessive evaporation from surface during initial curing	Crazing; loss of strength	Pour early in day; keep concrete wet with sprinkler or curing compound; or cover concrete
Extremely hot, dry, and/or windy	Excessive evaporation from concrete while in plastic state	Plastic shrinkage cracks; loss of strength	Pour early in day; use set retarder; add ice at plant; flood concrete surface; or cover concrete
Moderately cold (32°F to 45°F)	Hydration slowed	Slow strength gain	Use accelerators or insulating blankets/hay
Extremely cold (32°F and under)	Hydration slowed; freezing	Slow strength gain; weak, poor quality concrete; spalling	Use accelerators or Type III cement; add heated water/aggregate at plant; use insulating blankets, hay, or heated enclosure

Water in the Mix: Know When to Say When

Hardened concrete is a compound formed from the reaction between water and cement in the mix. The hydration reaction that forms this hard material will continue until all the cement hardens. Any surplus water not needed for this reaction will evaporate away, leaving microscopic voids in the hardened concrete. The voids prevent the cement from adhering to itself and to the aggregate in the mix. The more of these tiny bubbles your concrete has in it, the weaker and softer it will be.

The difference in strength is dramatic. The amount of water in a mix compared to the amount of cement (by weight) is called the water-cement ratio. A water-cement ratio of 0.28, meaning 28 pounds of water to 100 pounds of cement, contains enough water to hydrate all the cement. But a mix this stiff would never move off the truck or flow down the chute. In practice, concrete usually arrives on the job with a water-cement ratio of 0.45 to 0.5. A 0.4 ratio corresponds to a zero to 1-inch slump; a 0.5 ratio would give you about a 3-inch to 6-inch slump, fine for most residential uses. Adding enough water to give a ratio of 0.6, or about an 8-inch slump, will give you much weaker concrete.

How much weaker? Here at Central Washington University, we poured concrete samples of the same design strength but with varying amounts of water in the mix, then tested their strength after one week of curing. These were our results:

Water-cement ratio	Compressive strength (psi)
0.4	5,600
0.5	4,000
0.6	2,100

By pouring at a 1-inch slump instead of an 8-inch slump, we more than doubled the compressive strength of our concrete, increasing it by 3,500 psi after one week of curing. The weaker sample will never catch up, however long it cures. So if you don't mind soft concrete, go ahead and add water. If you want hard concrete, add some sweat. *— D.C.*

on both residential and commercial jobs, with good reason. They are easy to apply, inexpensive and effective, and they require little or no attention once applied. Best of all, you can use the slab as soon as it has cured enough that it won't be easily damaged.

Formed concrete. The best way to cure formed concrete walls is to leave the forms in place as long as practical — a minimum of three days is best. The formwork holds in moisture and, in cold weather, heat. In hot weather, keep the forms hosed down to control temperature and reduce moisture evaporation from the concrete. Any exposed concrete, such as the top of a concrete wall, should be covered with plastic or sprayed with curing compound.

If the forms are stripped earlier than three days, the concrete should be either covered with plastic for several days or sprayed with curing compound. There are some obvious practical considerations here. The idea is to allow the concrete to cure for a reasonable length of time, yet not delay the rest of the job.

How Long to Cure?

The answer to this question is the longer the better. Concrete will continue to hydrate and gain strength almost indefinitely as long as moisture is present and a suitable temperature is maintained. Try drilling or jackhammering 30-year-old concrete and you'll see what I mean. If concrete is cured in cool temperatures (32°F to 50°F), strength gain will be slow but the concrete will eventually reach a high strength as long as moisture is continuously present. However, concrete should not be allowed to get hotter than 90°F or to dry out during the curing period. If the concrete dries out too early in the hydration process (within the first three days), long-term strength will be compromised even if moist conditions return.

If your intention is to produce the highest quality concrete, keep freshly poured concrete moist at 50°F to 90°F for seven days for Types I or II portland cement ("regular" concrete) or for three days if Type III cement (*high-early*, or *rapid-hardening*) or accelerators are used.

As a practical matter, though, most concrete subs strip their wall forms after a few days, and few builders take the trouble to continue the curing process beyond that point. This is usually not a problem since, after curing for a few days behind the forms, 8-inch-thick concrete walls are plenty strong to carry residential loads (though you have to be careful about backfilling too soon). For slabs, though, with their increased surface area, you should pay more attention to curing, especially since conspicuous surface defects may be unacceptable.

Hot Weather Curing

The biggest problem in hot weather is excessive moisture loss from the concrete surface (see "Bad Weather Curing," facing page). This can be serious for thin concrete members, such as slabs, that have a large surface exposed to the weather. Surface evaporation is affected by a combination of four factors: concrete temperature, air temperature, relative humidity, and wind speed. Placing concrete in hot weather is complicated by the fact that the hydration reaction generates heat, adding to the problem of excessive evaporation.

Crazing. If you pour a slab on a hot, windy day without proper precautions, several defects can result. One defect, known as *crazing*, causes fine surface cracks in a chicken wire pattern that are especially visible if the slab is dampened (see Figure 2). Crazing results from too much surface evaporation during the initial curing period. It is a cosmetic problem, not a structural problem. Applying a curing compound or sealing the slab with plastic helps to prevent crazing; this should be done as quickly as possible after the slab is finished.

Plastic shrinkage cracks. A more serious problem, *plastic shrinkage cracks*, can happen when moisture evaporates from the slab while the concrete is still "plastic" — that is, wet and workable. This typically happens on a windy day, leaving short, parallel cracks (6 inches to 3 feet long) at right angles to the wind. Plastic shrinkage cracks can allow water to enter an outdoor slab, where it may freeze, causing further deterioration.

Under extremely hot, dry, and windy conditions, you may not be able to prevent crazing and plastic shrinkage cracks; it's best to pour early in the day or wait until conditions improve. You can also use set retarders to slow hydration, and some batch plants may offer ice as a replacement for part of the mix water.

Lower strength. Furthermore, excessive evaporation will lower the final strength of the slab, since hydration may not resume once moisture is again present. A slab that is not sealed with plastic or a curing compound must be kept continuously wet throughout the initial curing period if it is to achieve full strength.

Cold Weather Curing

Placing concrete in cold weather gives rise to two concerns: Strength gain is slowed because hydration slows, and the water in exposed concrete may freeze. Job specs often require concrete to attain a specified strength before use or form removal; in that case, slow strength gain may slow the job's progress. On the other hand, if moisture in curing concrete is allowed to freeze, the result can be weak, poor quality concrete or spalling (flaking) of the slab surface. The more freezing cycles the wet concrete endures, the worse the problem. Freezing becomes less of a concern after the first few days, as the hydra-

Figure 1. *Polyethylene film will prevent moisture from escaping from wet concrete in warm or windy weather, but it may discolor the concrete where it comes in contact.*

Figure 2. *A visual defect called crazing results when moisture evaporates too quickly from fresh concrete.*

Figure 3. *In moderately cold weather, insulating blankets can keep fresh concrete from freezing by retaining the heat of hydration.*

Figure 4. *In order to pour sidewalks in sub-freezing weather, these concrete subs erected a temporary plastic tent and supplied heat with a salamander heater.*

tion process continues to reduce the moisture in the concrete.

Heat of hydration. Often the "heat of hydration" will help speed cold-weather curing. Insulating blankets, straw-covered plastic, insulated forms, and windbreaks will all help retain this internal heat, speeding strength gain and preventing freezing (see Figure 3, previous page). Accelerators or Type III cement can also be added to the mix at the batch plant to speed curing. This won't cause more heat to be released overall, but it does result in more heat being released during the first few days when maintaining concrete temperature is most critical. If you use an accelerator, try to avoid the calcium-chloride type; the chloride tends to corrode reinforcing steel.

Enclosures. Heat can also be added to the concrete by building temporary enclosures of polyethylene or canvas and using a kerosene or propane "salamander" heater (see Figure 4, previous page). Combustion heaters should be vented outside the enclosure, however, because carbon dioxide in the exhaust will react with and soften the concrete surface. Also, in colder regions, ready-mix suppliers are often set up to heat either the mix water or the aggregate, or both, as is the case here in central Washington.

Common sense. Protecting concrete in cold weather becomes a function of the air temperature and common sense. If, for example, you pour a slab when it's 40°F outside and the weather forecast calls for temperatures to drop to the mid-twenties at night, covering the slab with an insulating blanket for the first night should keep the concrete warm enough until the next day, when the blanket can be removed as it warms up. If it's already below freezing when you pour, and the forecast calls for lower temperatures to come, keep the concrete covered or heated for at least several days. The major concern is to prevent the moisture in the concrete from freezing during the initial curing period.

Although concrete gains strength more slowly at lower temperatures, the strength of concrete cured at 40°F will eventually reach that of concrete cured at 70°F. Even if the concrete temperature drops to the mid teens, the hydration process will continue at a very slow rate. ■

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For More Information

For more on curing concrete, contact your local ready-mix supplier or the Portland Cement Association (5420 Old Orchard Road, Skokie, IL 60077; 708/966-6200).