Keeping concrete Cool in the heat of summer

By Ken Hover

Plan ahead for successful hot-weather concreting

The accelerating effects of hot weather not only cause concrete to lose workability and finishability faster, they also can reduce long-term strength. There are many simple and effective solutions for avoiding hot-weather concreting problems, such as breaking the job into smaller placements or using more vibrator operators and finishers. The key is to plan construction operations with hot weather in mind. This will help you avoid taking measures on the day of the pour that can make a bad situation worse, such as adding more water to the concrete mix.

The effects of temperature

The key to the performance of Portland cement concrete is a chemical reaction, called hydration, that occurs between the cement grains and water. The reaction products are microscopic crystals that grow on the surface of the cement grains and cause the grains to link together, like tiny Velcro fasteners. This linkage holds the hardened concrete together. As the reaction continues, more crystals develop, more linkages form, and porosity decreases, so the hardened cement paste and concrete become stronger and more durable.

Temperature is important because it dramatically influences the rate at which Portland cement and water combine. The reaction rate doubles when the temperature increases 20 degrees Fahrenheit, and is cut in half when the temperature...
drops by the same amount. At cold temperatures, the rate of cement hydration can slow to the point where the concrete doesn’t gain strength fast enough to safely remove forms and shores or to apply construction loads on schedule. The concrete can be damaged if the remaining mix water freezes.

It may seem that warmer concrete is better, since cement hydration accelerates as concrete temperature rises. Unfortunately, when hotter temperatures speed the reaction, the resulting bonding between the cement grains is weaker. For this reason, early-age strength increases with higher curing temperatures because the reaction rate is faster, but 28-day strength decreases because of the poor bond-

Problems and solutions

Strength loss and massive sections. Keeping concrete cool enough in hot weather so that long-term strength does not suffer is difficult because cement hydration releases heat. This can warm the concrete, accelerate hydration, and release even more heat. The thicker the concrete member being cast, the harder it is for the concrete to lose this extra heat to its surroundings and the hotter the concrete gets. That’s why massive concrete sections and hot weather can be a risky combination. The long-term strength of the warmer concrete near the center can be less than in cooler regions of the same placement. As a general guideline, concrete placements having least dimensions greater than 18 inches are susceptible to the effects of heat buildup. However, there is no exact rule and individual project conditions must be considered.

Not only is the loss of potential strength a problem, high temperatures near the center of massive placements cause that zone to ex-

Using cold mix water can help lower concrete temperatures. Liquid nitrogen is being injected into a ready mix truck to cool fresh concrete.

Substituting ice for part of the mix water lowers concrete temperatures dramatically. Use a crusher to finely crush the ice before adding to the truck.
pozzolans, produce less heat on a Btu-per-pound basis or produce heat at a slower rate than Portland cement.

It has been suggested that concrete can be kept cooler in transit when truck drums are painted a reflective color or spray bars are used to cool the drum. Once onsite it may be necessary to cool pump pipelines, shade conveyors, or shade the entire placing area. Windbreaks can reduce evapotranspiration. In some cases, it may be best to postpone concrete placement until cooler hours of the day or night.

Minimizing the difference in temperature between hot spots and cool surfaces can be done by attempting to cool the hot spot. In the building of major dams, this was done by complicated internal cooling systems. For building and bridge construction, it’s often more practical to warm the cool surfaces instead. Even in hot weather, it can be useful to put curing blankets or other insulation on the surfaces of massive placements to keep the surfaces from cooling too quickly. Insulating layers can be removed as the center cools.

**Loss of workability and faster setting time.** Most concretes lose slump and set faster in warmer weather. This is not necessarily a problem if construction operations are planned and organized for this shorter working time. Problems arise when concrete is inadequately consolidated or finished because the temperature accelerated mix “got away” from the crew. Problems also arise, with consequences appearing long after concrete has been finished, when workability and finishability are temporarily restored by adding water. Though the consequences of water addition can be debated, there is little question that the result is an increase in water-cement ratio with a corresponding decrease in strength and durability. The resulting concrete quality depends on the mix, the amount of water added, how well it is mixed, and the particular job conditions.

When there aren’t enough finishers to keep up with faster setting of concrete in hot weather, workers often try to save the surface by invoking the “ritual of the blessing of the slab.” They sprinkle water on the surface, trying to keep the paste “alive,” then work the water in with a finishing tool. The result is a more porous surface because the added water has been forced between the cement grains, forcing them apart and making it harder for the hydration products to connect. This time-honored practice is more a sacrifice than a ritual, as the long-term strength and durability of the slab surface are sacrificed to provide a desirable surface texture. Scaling and low abrasion resistance commonly result.

To help prevent rapid loss of workability or finishability, follow the steps discussed earlier to lower concrete temperature. To extend workability and setting time, consider using water-reducing or set-retarding admixtures. Many combination admixtures are available (ASTM C 494, Types D and G). Some retarders accelerate the rate of slump loss when used alone, but since setting is retarded the concrete can be brought back to life with a vibrator or finishing tool.

**Rapid evaporation and drying.** Another problem often associated with hot-weather concreting is rapid evaporation of water from the slab surface. The faster the evaporation rate, the faster the surface dries and the sooner effective curing measures have to be applied. A dry wind blowing over a freshly cast concrete surface warmed by sun makes for a hostile construction environment. As soon as the bleedwater evaporates, the slab surface begins to dry. This drying can reduce surface strength and durability, and lead to both plastic and drying shrinkage. Rapid evaporation also can be a problem in cold weather due to the combination of high winds, cold air, low humidity, and heated concrete.

To prevent water loss, keep the slab surface moist by techniques such as fog spraying, which mists the air above the slab. Fog spraying reduces the evaporation rate and replaces evaporating bleed water. The difference between fog spraying and slab blessing is critical: the fog spray is a light mist that hangs in the air and dampens but does not penetrate the slab surface. Because the fog droplets are not worked into the surface, no damage occurs. The faster the evaporation rate and the sooner the bleedwater disappears, the sooner fogging has to begin, and the more frequently it has to be reapplied. On dry, windy days, fogging becomes almost a continuous operation.

Since drying begins as soon as bleed water disappears, concern for drying is linked to the rate and quantity of bleed water. Mixes with low water-cement ratios, low water contents, fine cements, or mineral admixtures have sharply reduced tendencies for bleeding. These mixes may begin to dry at the surface almost immediately after placement. This is particularly true of mixes containing silica fume, where the need to prevent drying begins right after strike off. Immediate and continuous fog spraying may be essential for such mixes under rapid evaporation conditions.

For successful hot-weather construction, it is important to challenge traditional thinking that cur-
ing is a final step performed at the end of the day. The concrete surface loses moisture from the time the bleed water disappears or from the time fog spraying is stopped. Moreover, the rate of moisture loss is greatest in the early stages. A lot of damage can result by delaying curing.

Though wet curing is the most effective curing method, it may be impractical in some situations. Application of wet burlap or other curing materials may need to be delayed to avoid marring the surface of freshly cast concrete. When this is the case, moisture loss from the concrete can be minimized during the waiting period by applying a membrane-forming curing compound. This material can be spray-applied immediately after the last finishing pass, and well before wet curing. Once wet curing begins, make sure the concrete stays wet until the surface develops the desired properties.

**Hot-weather Concrete testing**

Take precautions when testing concrete in hot weather, whether performing tests to determine the strength of concrete as delivered or to estimate the strength of concrete in place. High concrete temperatures affect the strength of concrete in small test specimens and in pavements or structures.

In determining the strength of concrete as delivered, control cylinder temperatures from the time the cylinders are cast until they are placed in standard curing conditions back at the lab. ASTM C 31, “Making and Curing Concrete Test Specimens in the Field,” requires keeping cylinders to be tested later under laboratory conditions between 60°F and 80°F for the first 48 hours. In hot weather, this usually requires a temperature-controlled curing box onsite. Failure to cool the cylinders to within the specified temperature range will lower the 28-day strengths, providing an incorrect measure of the potential strength of concrete as delivered.

When evaluating the strength of concrete in a pavement or structure with field-cured cylinders, keep temperature records of both the cylinders and in-place concrete. The relatively small cylinders heat and cool faster than concrete in larger placements. After hours or days, the cylinders may have a much different temperature record, and a significantly different strength, than the concrete in place. Only when the temperatures and curing match is the field-cured cylinder strength a fair indicator of in-place concrete strength.

**References**

2. ACI 305R-91, “Hot-Weather Concreting,” American Concrete Institute (ACI), Detroit.
4. ACI 207.1 R-87, “Mass Concrete,” ACI.

Ken Hover was project engineer for concrete construction on the 1471 bridges over the Ohio River, where the Federal Highway Administration required nighttime deck placements to minimize hot-weather problems. He has since lectured on hot-weather concreting in Europe and Saudi Arabia.