Q. The standard specifications I’m modifying for a project require the contractor to take steps to prevent plastic shrinkage cracking when the rate of evaporation exceeds 0.2 lb/ft²/h (1 kg/m²/h). How is the contractor supposed to measure this?

A. Plastic shrinkage cracks occur when the surface of the concrete dries rapidly and shrinks before it can gain sufficient tensile strength to resist cracking. When ambient conditions and concrete temperatures combine to produce conditions that create a high evaporation rate, the chances of the surface drying prematurely and shrinkage cracks forming increases. Although most people associate high evaporation rates with hot, dry weather, it’s important to note that placing hot concrete on a cold, dry day can actually create a much worse condition.

The nomograph shown in Fig. 1 is a commonly used method to estimate evaporation rates. This nomograph was first published by the National Ready Mixed Concrete Association in 1960 and is included in References 2 and 3 as well as several other publications related to concrete construction. In this nomograph, the rate of evaporation is estimated by following the four steps listed on the left side of the chart. The arrows demonstrate an example for a day where the ambient air temperature is 80 °F (27 °C), the relative humidity is 50%, the concrete temperature is 87 °F (31 °C), and the wind velocity is 12 mph (19 km/h). The resulting rate of evaporation is about 0.25 lb/ft²/h (1.2 kg/m²/h).

The following equation from a 1998 *ACI Materials Journal* paper is also used to predict evaporation rates

\[ E = (T_c^{2.5} - rT_a^{2.5})(1 + 0.4V) \times 10^{-6} \] (in-lb units)

\[ E = 5[(T_c - 18)^{3.5} - r(T_a + 18)^{3.5}](V + 4) \times 10^{-6} \] (SI units)

where
- \( E \) = evaporation rate, lb/ft²/h (kg/m²/h);
- \( T_c \) = concrete temperature, °F (°C);
- \( T_a \) = air temperature, °F (°C);
- \( r \) = relative humidity in percent/100; and
- \( V \) = wind velocity, mph (km/h).

Readily solved using commonly available calculators, the equation provides results nearly identical to those found using the nomograph—for the previous example, this equation predicts an evaporation rate of 0.24 lb/ft²/h (1.15 kg/m²/h).

An additional tool, a free online computer program, not only calculates evaporation rates for given conditions, but can vary one parameter at a time to determine conditions for an evaporation rate of 0.1 lb/ft²/h. For the previous example, the program calculates an evaporation rate of 0.24 lb/ft²/h.

It’s important to obtain the data used to calculate evaporation rates properly. An average wind speed (not the maximum gust speed) should be used, and it should be measured at an elevation about 20 in. (0.5 m) above the surface of the concrete. Reported wind speeds from weather stations and airports are typically measured at an elevation of 33 ft (10 m) above grade. Wind speed increases with height above grade (the wind speed at 20 in. [0.5 m] above grade will only be about 2/3 of the wind speed at 33 ft [10 m] above grade). Because reported wind speeds also will not include the effects of local terrain and surrounding obstructions, these reported wind speeds should not be used in the chart. The relative humidity and air temperature should be measured in the shade, upwind of the placement, and 4 to 6 ft (1.2 to 1.8 m) above the concrete surface. Hand-held, electronic weather stations are now available and cost less than $250. These devices make it much easier to obtain site-specific air temperature, relative humidity, and wind velocity data.

One important variable—concrete bleeding rate—is not included in the nomograph but affects the probability of plastic shrinkage cracking. If the concrete has a lower bleeding rate, the evaporation rate needed to prematurely dry the concrete surface will be reduced. High amounts of fine material (such as cement, silica fume, or fly ash)
Fig. 1: Nomograph for estimating the rate of evaporation of water from a concrete surface. The arrows demonstrate an example for a day where the ambient air temperature is 80 °F (27 °C), the relative humidity is 50%, the concrete temperature is 87 °F (31 °C), and the wind velocity is 12 mph (19 km/h). The resulting rate of evaporation is about 0.25 lb/ft²/h (1.2 kg/m²/h) (Figure courtesy of Portland Cement Association)*
Concrete decrease bleeding rate and increase susceptibility to plastic shrinkage cracking. Although synthetic fibers also tend to reduce bleeding, they have become popular for use in concrete flatwork for control of plastic shrinkage cracking. Conditions that cause high evaporation rates can make it difficult to judge the proper time to start finishing high-fines concretes because the dry surface suggests that finishing can begin before all of the bleed water has come to the surface. When the surface is finished before all of the bleed water has evaporated, a plane of weakness can form near the surface and decrease durability. When high-fines concretes are exposed to conditions causing high evaporation rates, initial curing procedures discussed in ACI 308R-01, “Guideto Curing Concrete,” may be necessary before the start of finishing operations.

Because the nomograph produces an estimate of the evaporation rate, and the bleeding rate of various concrete mixtures can vary significantly, it’s best to view evaporation rates as an indicator of how quickly initial curing procedures will have to be started, rather than as a hard limit for the initiation of plastic shrinkage cracking.

References

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