Weather Considerations

### Key Points

- Preparations for hot- or cold-weather paving, as well as for a rain event, should be made well in advance.

- During hot-weather paving conditions, it is critical to reduce the evaporation rate from concrete to minimize plastic shrinkage cracking.

- During cold-weather paving conditions, primary concerns are to keep the concrete temperature above freezing so that hydration continues and to control cracking through joint placement.

- During a rain event, it is important to cover and protect the new concrete surface as well as to prepare for a possible cold front following the rain. A sudden, significant drop in temperature can increase the risk of uncontrolled cracking.

### Hot-Weather Concreting

The American Concrete Institute categorizes hot weather as a period when, for more than three consecutive days, the following conditions exist (ACI 1999):

- The average daily air temperature is greater than 25°C (77°F). The average daily temperature is the mean of the highest and the lowest temperatures occurring during the period from midnight to midnight.
- The air temperature for more than one-half of any 24-hour period is not less than 30°C (86°F).

Preparation for hot-weather paving should take place long before paving begins.

Whenever the construction team anticipates building a project in the summer, they should verify the concrete mixture for these conditions. Verification testing is conducted in the laboratory during the mix design phase. The testing laboratory mixes trial batches and casts specimens at temperatures representative of the site conditions to flag whether compatibility problems may arise.

During hot weather, problems that may occur include the following:

- Rapid slump loss.
- Reduced air contents.
- Premature stiffening.
- Plastic shrinkage cracking.
- Thermal cracking.

During hot weather, the construction team should take steps to reduce the evaporation rate from the concrete. The likelihood of plastic shrinkage cracking increases when the evaporation rate increases. Plastic shrinkage cracking results from the loss of moisture from the concrete before initial set. The evaporation rate is a function of the following:

- Air temperature.
- Concrete temperature.
- Relative humidity.
- Wind speed.

If the evaporation rate exceeds 1.0 kg/m²/hr (0.2 lb/ft²/hr), it is advisable to provide a more effective curing application, such as fog spraying, or to apply an approved evaporation reducer.

One or more of the following precautions can minimize the occurrence of plastic shrinkage cracking (Menzel 1954, as published in Kosmatka, Kerkhoff, and Panarese 2002). They should be considered while planning for hot-weather concrete construction or while dealing with the problem after construction has started. The precautions are listed in the order in which they should be done during construction:

- Moisten dry, absorptive aggregates.
- Keep the concrete temperature low by cooling aggregates and mixing water.
- Damper the subgrade and fog forms before placing the concrete.
- Erect temporary windbreaks to reduce wind velocity over the concrete surface.
- Erect temporary sunshades to reduce concrete surface temperatures.

If conditions of temperature, relative humidity, and wind are too severe (figure 8-16) to prevent plastic shrinkage cracking, or if corrective measures are not
effective, paving operations should be stopped until weather conditions improve (IPRF 2003).

The following are general recommendations/options/considerations for hot-weather concreting (IPRF 2003):

- Do not exceed the maximum allowable water/cementitious materials ratio or the manufacturer’s maximum recommended dosage of any admixture.
- Consider retarding admixtures if their performance has been verified during trial batches.
- Substitute ground, granulated blast-furnace slag or class F fly ash for part of the portland cement. These materials hydrate more slowly and generate lower heats of hydration than cement, reducing tendencies toward slump loss, premature stiffening, and thermal cracking. Certain class C fly ashes, with high calcium and aluminum contents, may cause premature stiffening.
- Low air contents can be corrected by increasing the dosage of air-entraining admixture. Better or longer mixing may allow maintenance of a constant air-void spacing factor without a greater air content. Using additional water reducer may also be helpful.
- Risk of early-age thermal cracking is reduced by ensuring that the temperature of the plastic concrete is as low as practical.
- Sprinkling with water may cool aggregates; be sure to correct for the aggregate moisture.

Figure 8-16. A monograph to estimate the rate of evaporation (PCA)
Aggregates need to be batched in a saturated surface-dry condition to avoid absorbing mixture water.

Chilling the mixing water or adding chipped ice in substitution for some of the water lowers the mix temperature. Be sure that all of the ice melts during mixing.

Consider painting the mixing and transporting equipment white or another light color to minimize the heat absorbed from the sun.

In extreme conditions, consider scheduling concrete placements for during the evening or night.

Moisten the base before the concrete is placed to keep the temperature down and to keep it from absorbing water from the concrete.

Place and finish the concrete as rapidly as possible to apply the curing compound at the earliest possible time. The use of a white curing compound will reflect the sun's heat. If there is any delay in applying the curing compound, use a fog spray or evaporation retardant to keep the surface from drying out.

Refer to ACI 305, Hot Weather Concreting, for additional information.

Cold-Weather Placement

Cold weather is defined by ACI as a period when, for more than three consecutive days, the following conditions exist (ACI 1988):

- The average daily air temperature is less than 4°C (40°F). The average daily temperature is the mean of the highest and lowest temperatures occurring during the period from midnight to midnight.
- The air temperature is not greater than 10°C (50°F) for more than one-half of any 24-hour period.

Cold-weather paving requires special considerations. The contractor and material supplier should address these considerations well before temperature forecasts predict temperatures to drop close to or below freezing. The primary concern is to keep the temperature of the concrete above freezing so that the hydration reaction continues and to control cracking through joint placement.

Trial batches are needed to verify that the proposed mixtures will achieve the desired strength at the potential temperatures. Mixtures with accelerating admixtures must be treated carefully to ensure that they accelerate the setting and/or early strength gain of concrete but do not lead to workability or constructibility challenges.

The following are recommendations/options/considerations for cold-weather concreting (IPRF 2003):

- Consider using a higher portland cement content in concrete mixture designs for placement at cooler temperatures.
- Reduce or eliminate ground, granulated blast-furnace slag, fly ash, and natural pozzolans from the mixture unless they are required for durability.
- The necessary air-entraining admixture dosage will likely be lower for cold-weather concrete than for concrete designed for normal temperatures.
- An accelerating admixture conforming to ASTM C 494 Type C or E may be used, provided its performance has been previously verified by trial batches.
- Do not use admixtures containing added chlorides. Also, do not use calcium chloride.
- Aggregates must be free of ice, snow, and frozen lumps before being placed in the mixer.
- Because the concrete will take longer to set, there is more risk for plastic shrinkage cracking, especially if the concrete is much warmer than the ambient air or the wind speed is significant.
- Consider heating the mix water (if practical for the size of the pour). The temperature of the mixed concrete should not be less than 10°C (50°F).
- The mixture water and/or aggregates may be heated to 66°C (150°F).
- The material must be heated evenly.
- Insulating blankets also are necessary for curing concrete pavement in cool weather. The blankets reduce heat loss and lessen the influence of both air temperature and solar radiation on the pavement temperature. The blankets are
not a substitute for curing compound, which is still needed to contain moisture for complete hydration.

- The concrete temperature should be maintained at 10°C (50°F) or above for at least 72 hours after placement and at a temperature above freezing for the remainder of the curing time (when the concrete attains a compressive strength of 20 MPa [3,000 lb/in²]). Corners and edges are the most vulnerable to freezing.
- Concrete should not be placed when the temperatures of the air at the site or the surfaces on which the concrete is to be placed are less than 4°C (40°F).
- Concrete placed in cold weather gains strength slowly. Concrete containing supplementary cementitious materials gains strength very slowly.
  - Sawing of joints and opening to traffic may be delayed.
  - Verify the in-place strength by a maturity method, temperature-matched curing, nondestructive testing, or tests of cores from the pavement before opening the pavement to traffic.
- Allow the slabs to cool before completely removing insulating blankets to avoid a thermal shock to the pavement that might induce contraction cracking. Insulating blankets may be temporarily rolled aside to saw contraction joints.
- Refer to ACI 306, Cold Weather Concreting, for additional information.

**Protection From Rain**

Plastic sheeting (figure 8-17) and steel side forms or wooden boards must be available at all times to protect the surface and edges of the newly placed concrete pavement when it rains. If rain is expected on newly placed concrete pavement that has not hardened, cover the surface with the plastic sheeting.

The sheets must be weighted down to prevent them from blowing in the wind. When it starts raining, a "rule of thumb" to determine how much of the pavement to cover is to go back to the point where the rain is not indenting the pavement surface. The covering does not need to be extended to areas where the rain is only washing away the curing membrane (ACPA 2003a).

Climatic conditions during a rain event can actually be conducive to good concrete curing. During rain, the humidity is at or near 100 percent and there is little chance for the evaporation of mix water. Temperatures are generally moderate during rain, which is also beneficial. In these situations, the rain essentially provides a beneficial moist curing environment, which assists with strength development and decreases the chance for uncontrolled cracking. This provides a natural cure.

Sometimes, particularly if the prevailing weather is hot and humid, rain precedes the passage of a cold front, which may drop the air temperature more than 11°C (20°F). Where this occurs, and when the pavement is under construction, the risk of uncontrolled cracking will increase (ACPA 2002). The drop in the dew point that usually occurs with a cold front may also lead to a lower relative humidity above the warm concrete and thus a greater susceptibility for plastic shrinkage cracking.

Some marring of the concrete surface may occur from the plastic sheeting used to protect the slabs from rain. Except for an undesirable appearance, there is nothing wrong with surfaces affected by plastic sheeting. A similar appearance can occur when using plastic sheeting to cure concrete.