CONCRETE PAVEMENT
CPTP
TECHNOLOGY PROGRAM

Curing Practice for Slipformed Concrete Pavements

TechBrief

The Concrete Pavement Technology Program (CPTP) is an integrated, national effort to improve the long-term performance and cost-effectiveness of concrete pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, CPTP's primary goals are to reduce congestion, improve safety, lower costs, improve performance, and foster innovation. The program was designed to produce user-friendly software, procedures, methods, guidelines, and other tools for use in materials selection, mixture proportioning, and the design, construction, and rehabilitation of concrete pavements.

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U.S. Department of Transportation
Federal Highway Administration

This technical brief identifies best practices for curing portland cement concrete pavements. It provides important concepts in pavement curing, discusses the use of curing compounds and evaporation retarders, and describes how to estimate evaporation and bleeding rates and manage temperature.

INTRODUCTION

Curing has long been recognized as an important process in constructing durable concrete pavements. Curing of concrete is defined as the maintenance of adequate moisture and temperature conditions to allow the development of required physical properties. Curing can consist of both initial and final measures. Initial curing measures include fogging and evaporation retarders where critical drying is likely, and final curing measures typically include white pigmented curing compounds, as shown in Figure 1. Poor curing practices can result in excessive curling, early-age cracking, surface deterioration, low early strengths, and reduced durability. Most of the damage caused by poor curing is irreversible.

Figure 1. Properly applied curing compound.

- In practice, it is necessary to retain mixing water and protect the concrete from extreme temperature events in hot and cold weather. Following good practices (for example, American Concrete Institute [ACI] 2001) is always recommended, even though the weather may provide the moisture and temperature required for hydration.
- In hot weather, concrete is prone to rapid slump loss, reduced air contents, premature stiffening, plastic shrinkage cracking, and thermal cracking. Exposure to high temperatures early in the curing process can strengthen concrete initially but result in a lower ultimate strength than standard cured concretes.

- In cold weather, concrete is prone to delayed setting, loss of water, slow strength development, and cracking due to slowed hydration rates.

IMPORTANT CONCEPTS

In hot weather, the concrete needs to be cooled and protected from early drying for proper hydration and to minimize cracking (ACI 1999; National Cooperative Highway Research Program [NCHRP] 2004). In cold weather, the concrete should be kept warm to minimize cracking and allow proper hydration and acceptable setting times (ACI 1988; NCHRP 2004). The time until initial setting under field conditions can be estimated based on placing temperatures (see FHWA-RD-02-099 for the calculation [Federal Highway Administration 2005]). HIPERPAV™ software provides information on the effects of temperature as it relates to curing, strength development, and cracking potential.

Curing should be initiated as soon as possible after placing the concrete to prevent excessive water loss and drying of the surface. The meaning of "as soon as possible" depends on the particular situation. Where critical drying is likely, initial curing should be initiated immediately following placement. Where critical drying is not likely, final curing can be initiated after texturing has been completed. Curing compounds work by sealing the concrete surface and reducing the rate of moisture loss. Rising bleed water can become trapped under a prematurely finished surface layer (National Ready Mixed Concrete Association [NRMCA] 2005). Bleed water that rises after the application of a curing compound can disrupt the curing membrane and can form a lens that causes spalling or delaminations. Bleeding typically stops at about the time of initial setting (American Society for Testing and Materials [ASTM] 1999b), when solid particles interlock with cement hydration products. For slipformed concrete, finishing and texturing are completed well before the initial setting; therefore the concrete is still plastic, and bleeding may not have stopped when the curing compound is applied. Slipform paving concrete typically does not bleed until 20 minutes after concrete placement and may never bleed. For slipform paving concrete, the evaporation rate almost always exceeds the bleed rate of the concrete, which is approximately 0.025 kg/m^2/hr (0.05 lb/ft^2/hr) or less.

Plastic shrinkage occurs when the rate of evaporation exceeds the rate of bleeding. Under these conditions, the concrete surface may appear dry even under modest drying conditions. Moisture loss can be slowed before texturing by the use of evaporation retarders that provide a monomolecular film on the surface. Small to moderate amounts of bleeding help protect the concrete surface from early-age drying. The time it takes for bleeding to begin and the bleeding rate are determined by factors such as cementitious material and content, aggregate grading and fines content, water content, admixtures, and the concrete temperature (Kosmatka 1994). At low water to cementitious material ratio (w/cm), bleeding is slow to develop after placing the concrete, and may slow down significantly near the

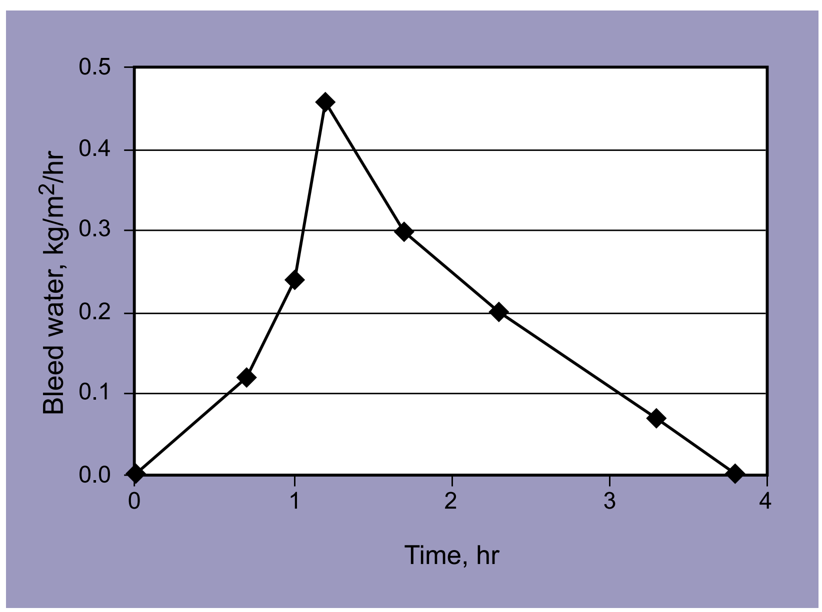

Figure 2. Typical bleeding pattern of low w/cm (0.40) paving mixture (1.0 kg/m^2/hr = 0.2 lb/ft^2/hr).

time of initial setting. A low w/cm (less than 0.45) contributes to low bleeding rates. Fine cements (Blaine >400) and some supplementary cementitious materials can also reduce bleeding rates.

The bleeding behavior of concrete affects texturing and when a curing compound can be applied. High bleeding rates will delay the application of the curing compound. Low bleeding rates can result in a loss of moisture and increased risk of plastic shrinkage cracking. The ASTM C 232 procedure (ASTM 1999a), using a covered container that simulates pavement thickness (a 15 x 30 cm [6 x 12 in.] cylinder mold is ideal for <30 cm [12 in.] pavements), can indicate the mixture's bleeding behavior. Figure 2 shows an example of the bleeding behavior of a paving concrete mixture and the crucial times (the first hour after placing, and the last hour before initial setting) at which cracking may occur unless loss of water is minimized.

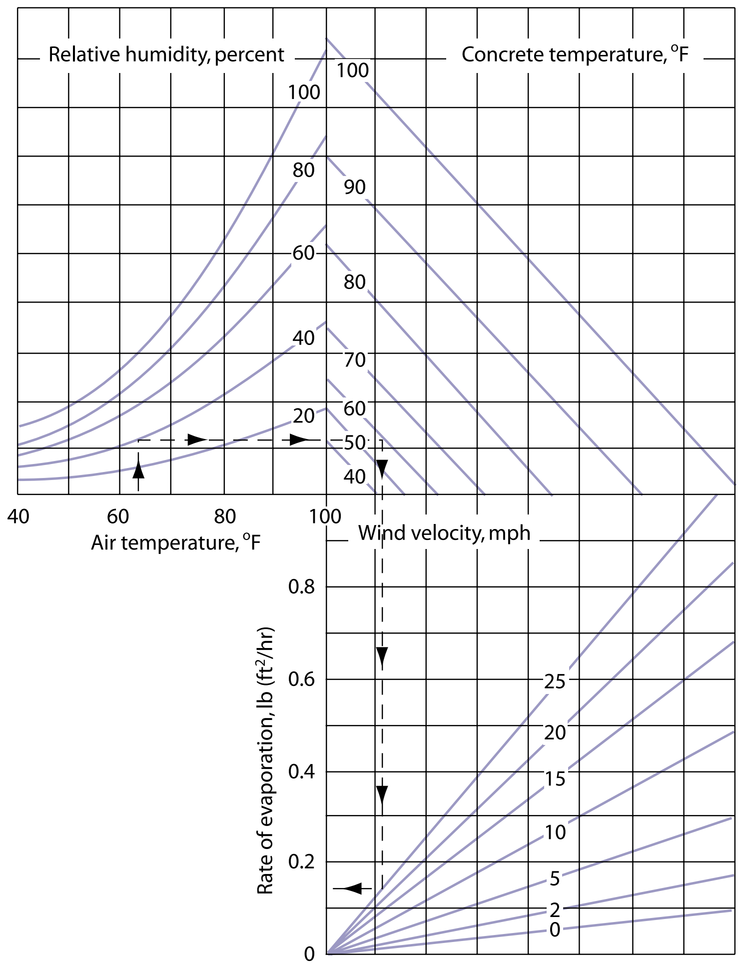

Figure 3. Chart to estimate evaporation rate (reprinted from ACI 2001; Kosmatka et al. 2002).

CURING METHODS

The most common method of curing in paving is the application of a curing compound right after texturing the fresh concrete. If, as demonstrated in Figure 3 (ACI 2001), a high rate of evaporation >1.0 kg/m^2/hr (0.2 lb/ft^2/hr) exists, then preventive measures (initial curing) such as fogging or the application of an evaporation retarder may be needed. These measures reduce the risk of plastic shrinkage cracking and maintain proper hydration of the surface. Similarly, delays in texturing will require preventive measures until curing is initiated.

A liquid-membrane-forming compound that meets ASTM C 309 (ASTM 2003) and American Association of State Highway and Transportation Officials (AASHTO) M 148 material requirements (<0.55 kg/m^2 [0.11 lb/ft^2] at 72 hours) is adequate for most situations. Different curing compounds provide different levels of protection from moisture loss and daylight reflectance. ACI 305R (ACI 1999) recommends <0.39 kg/m^2 (0.08 lb/ft^2) for concrete placed in hot weather. Some States have a more stringent maximum water retention limit; for instance, the Virginia Department of Transportation specifies 0.30 kg/m^2 (0.06 lb/ft^2).

- Due to environmental regulations, there has been a shift to water-based curing compounds that are also more tolerant of bleeding effects. White pigmentation in the compound is preferable to a clear compound because of the ability to see the coverage and reflect solar radiation that may otherwise heat the concrete surface excessively.
- The American Concrete Pavement Association

(ACPA 1994) recommends an application rate of between 2.5 and 5.0 m^2/L (100 and 200 ft^2/gal), depending on the pavement type.
- Curing compound should be applied by power-driven spray equipment. Hand-operated equipment should only be used for small areas. The concrete surface should be damp when the coating is applied. Normally, one smooth, even coat is applied. However, under some conditions, a second coat may be necessary.

Evaporation retarders may be applied immediately after placing and before texturing work to limit the risk of early drying in hot and high-evaporation conditions. ASTM is developing a specification for evaporation retarders.

Other available curing methods include water spray or fog, wet burlap sheets, plastic sheets, and insulating blankets in cold weather. When moist curing, maintain the moist condition over the entire concrete surface for the entire curing period (typically 7 days) or until a curing compound is applied.

BEFORE CONSTRUCTION

Estimate the expected bleeding rates. Compare bleed-rate estimates with drying-rate estimates to determine whether critical drying is probable. If critical drying is likely, or delays in texturing are expected, consider the following precautions:

- Use evaporation retarders.
- Manage temperatures by choosing low-heat hydration materials and by cooling stockpiles.
- Apply additional curing compound. For expected low to moderate evaporation rates (<1.0 $kg/m^2/hr$; 0.2 $lb/ft^2/hr$), apply the curing compound promptly after texturing.

PRECAUTIONS DURING CONSTRUCTION

It is important to monitor and compensate for the conditions on site. Specific steps include:

- Estimate the drying conditions (rate of evaporation) during concrete placement using the nomograph shown in Figure 3. In addition, FHWA-RD-02-099 (FHWA 2005) has an equation for evaporation rate that can be written into a spreadsheet, and HIPERPAV™ software also calculates the evaporation rate.
- Verify temperature and drying conditions at the job site—monitor temperature, wind, and relative humidity.
- Reduce evaporation if necessary.
- Apply curing measures at the correct time, in the correct amounts.
- Verify the time, amount, and uniform application of curing material.
- Ensure that curing compound covers the edges and ends, and does not wash off or become disrupted by bleeding water.
- If necessary, another coat of curing compound should be applied as the first coat becomes tacky and the bleed water has stopped.

When curing compounds and evaporation retarders are used as recommended and a proper temperature is managed, curing may be assumed to be adequate.

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HIPERPAV® Software—The software can be downloaded from the following Federal Highway Administration (FHWA) Web site: www.fhwa.dot.gov/pavement/pccp/hipemain.cfm.

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THE CONCRETE PAVEMENT TECHNOLOGY PROGRAM

The Concrete Pavement Technology Program (CPTP) is a national program of research, development, and technology transfer that operates within the Federal Highway Administration (FHWA) Office of Pavement Technology.

The CPTP includes some 30 research and demonstration projects, each of which is delivering products for improved design, construction, repair, and rehabilitation of concrete pavements.

The focus areas for the CPTP include advanced designs, optimized concrete materials, improved construction processes, rapid repair and rehabilitation, and user satisfaction. The CPTP continues to produce implementable products that result in safer, smoother, quieter, and longer lasting concrete pavements. Longer lasting pavements, in turn, contribute to FHWA's success in the areas of safety, congestion mitigation, and environmental stewardship and streamlining.

Technology transfer of products resulting from the CPTP is being accomplished under CPTP Task 65. This 5-year activity was initiated in September 2003 and is overseen by an Executive Expert Task Group (ETG) that includes State Department of Transportation (DOT) chief engineers and representatives from industry and academia.

An Engineering ETG, made up of pavement and materials engineers from State DOTs, FHWA field offices, plus representatives from industry and academia, reviews the technical aspects of CPTP products.

These products include:

- Guidelines / Technical briefs
- Test protocols / Draft specifications
- Software
- Workshops / Conferences
- Presentations / Videos
- Field demonstrations
- Equipment loans (available from FHWA's Mobile Concrete Laboratory)

The delivery of CPTP products, in workshops and other formats, is tailored to meet the needs of each State DOT and its related industry groups. For more information, please contact:

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