

CONSTRUCTION

TIPS

PART 1 – SHRINKAGE CRACKING

A commonly known concern in concrete curing is maintaining the moisture level in fresh concrete. This article is organized in two parts. Part 1 provides information on common concrete curing problems. Part 2 provides information on concrete curing application.

Plastic Shrinkage Cracking

Two common problems found in concrete installation are plastic shrinkage cracking and dry shrinkage cracking.

Plastic shrinkage cracks occur when the evaporation of moisture at the surface of the concrete is greater than the availability of rising bleed water to replenish the surface moisture. If the concrete has not achieved enough tensile strength when this occurs, the volume change (shrinkage) at the surface will cause cracking.

Because most of today's concrete uses a low water-to-cement ratio and supplementary cementitious materials (SCMs), the amount of bleed water and the rate of bleeding are often lower than in the past. This places the concrete at greater risk of plastic shrinkage cracking. Proper curing can often, but not always, prevent plastic shrinkage cracking by delaying the evaporation of bleed water.

➔ Identifying Plastic Shrinkage Cracks

Plastic shrinkage cracking occurs when the concrete is in the plastic state, which is within the first 24 hours after the cement begins to hydrate. In addition, plastic shrinkage cracks are usually spaced 1 to 3 feet apart, are generally parallel to one another, do not generally extend to the free end of the concrete element, and can be of considerable depth¹. Figure 1 shows an example of plastic shrinkage cracks on the surface of a pavement. Figure 2 demonstrates the depth these types of cracks can reach.



Figure 1. Example of plastic shrinkage cracking. Note, the closely spaced, parallel cracking.



Published Quarterly
by the **Construction
and Bridge Divisions**

**Second Quarter
2006
Concrete Curing**

**PART 1 - SHRINKAGE
CRACKING**

1

Plastic Shrinkage Cracking
1

Drying Shrinkage Cracking
3

**Reduce Cracking Through
Curing**
3

PART 2 - APPLICATION
4

Curing Methods
4

**Timing the Application of
Curing Compounds**
4

**Application Rates for
Curing Compounds**
4

**Curing Material
Specifications**
5

References
6

Contact Information
6



Figure 2. Deep Plastic Shrinkage Crack (below mid-depth).

➔ Preventing Plastic Shrinkage Cracking

To prevent plastic shrinkage cracking, all concrete operations should be matched to the conditions in which the concrete is being placed. Use the following approaches to help minimize or control this cracking.

- Possible Concrete Changes (if allowed by specification and approved by the engineer)
 1. Reduce the SCM content.
 2. Accelerate the setting time and early tensile strength.
 3. Beware of admixture/cement interactions that could cause a delayed set (especially in sulfate-resistant concretes).
 4. Use synthetic fibers.
- Possible Construction Changes
 1. Do not place the concrete in adverse conditions.
 2. Erect wind screens or use a water fog mist. (NOTE: A water fog mist is NOT the same as adding finish water.)
 3. Provide additional personnel to accelerate the finishing and curing operations.
 4. Properly use evaporation retardants*, especially when finishing operations are lagging behind.
 5. After the curing compound application, provide a water cure.

**Use of Evaporation Retardants.* Evaporation retardants are a relatively new tool to properly cure concrete. Evaporation retardants are NOT substitutes for curing compounds! Their purpose is to prevent surface water evaporation until the curing compound can be applied.

Evaporation retardants are composed essentially of water, with a mono-molecular film to slow evaporation. Should the film be disturbed, for example by finishing operations, the effectiveness of the evaporation retardant has been erased, rendering it the same as if plain water had been sprayed on the surface.

Evaporation retardants, used properly, can “buy some time” during the period after finishing and before application of the curing membrane is applied (refer to Items 360 and 420 for time limits). They are not a substitute for curing compounds.

Curing compound requirements are described in [DMS-4650](#), Hydraulic Cement Concrete Curing Materials and Evaporation Retardants, with approved suppliers listed on the Material Producer List (MPL) for “[Concrete Evaporation Retardants](#).”



Figure 3. Drying Shrinkage Cracking.

Drying Shrinkage Cracking

➔ Identifying Drying Shrinkage Cracking

Concrete is usually mixed with more water than is needed to adequately hydrate the cement. The remaining water, known as water of convenience, evaporates, causing the concrete to shrink. Restraint to shrinkage, provided by the subgrade, reinforcement, or another part of the structure causes tensile stresses to develop in the hardened concrete. In many situations, drying shrinkage cracking is inevitable (see Figure 3). Therefore, contraction (control) joints are routinely placed in concrete to predetermine the location of drying shrinkage cracks.²

➔ Preventing Drying Shrinkage Cracking

It is often very difficult to completely eliminate drying shrinkage cracking, but the following approaches may help to minimize or control this cracking.

- Possible Concrete Changes (if allowed by specification and approved by the engineer)
 1. Reduce the total water in the mix, either through the use of chemical admixtures, better combined aggregate gradation, or SCMs such as Class F fly ash.
 2. Reduce the amount of paste (cement + water) in the mix.
 3. Minimize poorly graded fine aggregates.
- Possible Design and Construction Changes
 1. Design adequate and appropriate contraction and construction joints.
 2. Employ a design that minimizes restraint of the concrete, such as the use of a bond breaker.
 3. Saw contraction joints to the proper depth and as soon as possible.
 4. Provide good curing to allow the concrete to gain sufficient tensile strength before significant shrinking forces develop.

Reduce Cracking Through Curing

For more information on ways to reduce both types of shrinkage through concrete curing, read Part 2, Application.

PART 2 – APPLICATION

This part of the article provides information on the important elements related to the proper application of concrete curing. Proper concrete curing can minimize plastic shrinkage cracking and dry shrinkage cracking.

Curing Methods

There are three curing methods recognized in the *2004 TxDOT Standard Specifications*:

1. *form curing* - Form curing allows the concrete to cure by preventing mix water evaporation. Because the concrete is in direct contact with the forms, this direct contact acts as a moisture loss barrier.
2. *water curing* - Water curing, such as wet mats or using water spray or wet sand curing, is generally considered to be the best curing practice; it allows for the most complete hydration (reaction of mix water with the cement).
3. *membrane curing* - Membrane curing compound is used as a moisture-loss barrier for non-formed concrete in cases when water cure is not feasible due to time or other practical considerations.

Item 420, Concrete Structures, describes these methods. Either the governing specification or the plans will indicate which method to use for every concrete item.

Concrete curing is an essential stage of the concrete process. Curing compound, properly applied, can be effective in acting as a temporary (interim) curing method for a bridge deck until the concrete can support the weight of the personnel placing the mat and the weight of the wet mat itself. For concrete pavements, sidewalks and curbs, properly applied curing compound is the only protection to prevent the loss of moisture from the fresh concrete.

In either case, timing, application rate and material quality are important.

Timing the Application of Curing Compounds

In the *2004 TxDOT Standard Specifications*, Item 420, Concrete Structures, emphasizes the need to apply curing compound as quickly as possible. This item states:

“. . . apply interim cure . . . as soon as possible after application of the evaporation retardant and after the water sheen has disappeared, but no more than 45 min. after application of the evaporation retardant.”

Item 360, Concrete Pavements, describes similar time constraints:

“Apply the first coat within 10 min. after completing texturing operations. Apply the second coat within 30 min. after completing texturing operations.”

Do not allow the concrete surface to dry out! Keep in mind the use of supplementary cementitious materials (SCMs) and the low water-to-cement ratios in most of the concrete (used by TxDOT) usually produces very little bleed water. Allow the puddles of bleed water to dry or be absorbed with a towel before applying the curing compound. Then apply the curing compound as soon as possible.

Application Rates for Curing Compounds

The standard application rate is 180 sq. ft./gal./coat. It is not easy to determine if the application rate is being achieved unless there is extremely accurate accounting of the quantity of compound used and the surface area to which it is being applied. However, there is one commonly used guideline: *If any grey concrete can be seen through the fresh curing membrane, there is not enough curing compound!* The membrane works only if there is a solid barrier between the concrete and the environment; voids allow water to evaporate. Two evenly placed coats are more effective than one heavy coat.

Figure 4 shows typical benefits of curing compound application, measured by the Center for Transportation Research (CTR) researchers as part of Research Study (R.S.) 0-5106 – *Evaluation of Curing Membranes Effectiveness to Reduce Evaporation*.

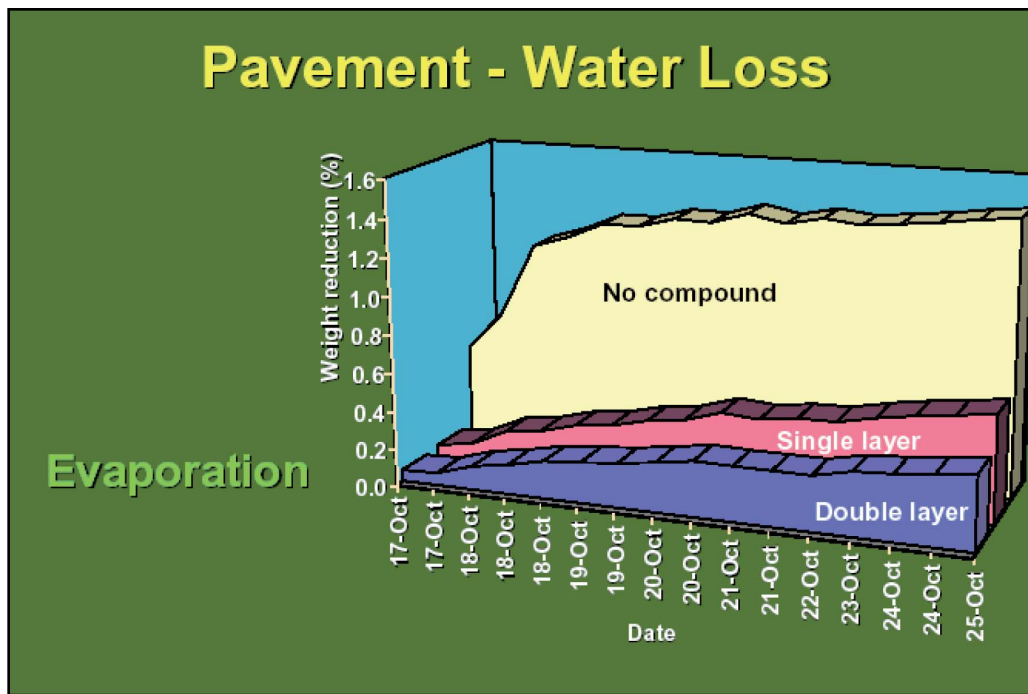


Figure 4. Concrete Moisture Loss vs. Curing Application (ref: CTR R.S. 0-5106).

Curing Material Specifications

Can the curing compound be thinned to keep the nozzles from clogging? No. **NEVER** use this method to prevent nozzle clogging.

➔ Approved Materials

The Construction Division - Materials and Pavements Section (CST-M&P) is responsible for assuring curing compound requirements, described in [DMS-4650 Hydraulic Cement Concrete Curing Materials and Evaporation Retardants](#), are met by the suppliers listed on the Material Producer List (MPL) for [Concrete Curing Compound \(Liquid Membrane-Forming\)](#).

To guarantee the material has been approved by CST-M&P:

- Inspectors should look for a TxDOT approval stamp, the laboratory number and the date for required retesting (found on the container and shipment papers).
- Verify that the product has been tested by matching the lab number on the container with the test report for the product issued by the CST-M&P. (NOTE: Check dates as well.)

Contact the Materials and Pavements Section, Traffic Materials Branch to address discrepancies or perform additional sampling.

➔ Materials Not Pre-tested

For materials that are not pre-tested (materials are not required to be from an MPL source), sample by project for each batch or shipment and send the sample to the Materials and Pavements Section, Traffic Materials Branch for testing. Materials should be tested and approved prior to use.

➔ Field Sampling of Questionable Materials

If you suspect the curing compound does not meet specifications, obtain a sample from the sprayer (a clean 4 × 8 cylinder mold, sealed, is a good sample container) and test for:

- gallon weight
- % solids and
- viscosity.

The Materials and Pavements Section, Traffic Materials Branch can perform these tests or any laboratory with a reliable scale (readable to 0.0001g) and an oven can perform the % solids tests.

Anecdotal observations indicate the chances of thinned curing compound are greater when the curing compound is sprayed by hand with a small compressor or when the curing compound is transferred from the manufacturer's tank to a secondary spray tank.

Preparing for Adverse Conditions

Some conditions are extremely adverse to concrete curing. Under these extreme conditions, even the best and most timely curing compound application will not prevent plastic shrinkage cracks. Factors that can contribute to this undesirable condition are:

- high wind
- low relative humidity
- slow tensile strength gain of the concrete (caused by low concrete and ambient temperatures, SCMs, admixture interactions and poor mixture design selection)
- high concrete temperature and
- high ambient temperature.

One concrete mix is not appropriate for every condition. Careful consideration should be given when weather conditions fluctuate, especially cold fronts during dry and/or windy periods seen in many parts of the state from late February through April.

There are tools to help determine if conditions exist for plastic shrinkage cracks to occur. For example, the nomograph in the Portland Cement Association's *Design and Control of Concrete Mixtures* and computer programs such as HIPERPAV™ can be used. Both tools along with documentation on how to use them are available upon request through the Concrete Laboratory. Contact names and numbers for the Concrete Laboratory are listed under "Contact Information."

An effective curing regimen can prevent plastic shrinkage cracks in most conditions and can minimize drying shrinkage cracks. Although curing is one of the last steps in concrete work TxDOT performs, obtaining proper curing is one of the most important tasks a TxDOT concrete inspector performs to ensure long-term concrete performance.

References

- ¹ Neville, A.M. *Properties of Concrete*. 4th Edition. Prentice Hall. 1995. Pgs. 423-424.
- ² Portland Cement Association, Frequently Asked Questions, http://www.cement.org/tech/faq_cracking.asp

Contact Information

If you have any questions regarding the content of this article, including how to find programs and information about concrete and concrete curing, please contact the Concrete Laboratory of the Construction Division – Materials and Pavements Section (CST-M&P):

- Lisa Lukefahr – 512/506-5858 elukefa@dot.state.tx.us
- Ryan Barborak – 512/506-5863 rbarbora@dot.state.tx.us

For questions regarding concrete curing compound approval or testing, please contact the Traffic Materials Laboratory of CST-M&P:

- Johnnie Miller – 512/506-5889 jmille3@dot.state.tx.us
- Jerry Howell – 512/506-5887 jhowell@dot.state.tx.us