Minimizing Early Age Concrete Bridge Deck Cracks

One of the primary factors affecting concrete durability is concrete shrinkage and the resultant cracking that serves as a pathway for corrosive materials like de-icing salts. The Standard Specifications (SS) place limits on shrinkage by requiring that the contractor-proposed concrete mix designs for bridge decks and approach slabs include AASHTO[1] T160, 28-day shrinkage test results as part of the mix design. Overall shrinkage in the forms of autogenous and drying shrinkage is collectively limited by specifications to 0.045 percent for bridge decks and 0.05 percent for approach slabs[2]. The review process does not end with the mix design check. The Structure Representative must verify that concrete delivered to the project is consistent with the approved mix, as variations in aggregate gradation, cleanliness value, sand equivalence, cementious material content, and water-cement ratio can significantly increase the amount of shrinkage that will occur after the concrete has hardened.

Cracking that occurs before concrete has set is referred to as plastic cracking. Concrete finishing and curing operations can directly affect the development of plastic cracks; this type of cracking occurs on concrete surfaces as the top layer dries and shrinks quicker than the moist inner concrete. Initially, bleed water rises within fresh concrete until it reaches the surface and evaporates, but as the internal water supply is depleted, the bleed water flow diminishes. Surface drying starts when the evaporation rate exceeds the bleed rate. Usually associated with warm weather concreting, plastic cracking can occur whenever the shrinkage strain exceeds the surface strength. Unless additional moisture is provided to the surface, plastic cracks can appear. Plastic cracks are shallow, usually less than 2 inches deep, irregular in pattern, and spaced about 1 to 3 feet apart. In any 500 sq ft portion of a new deck surface, if there are more than 50 feet of cracks having a width at any point of over 0.02 inch, a Contractor repair action is required per the Standard Specifications[3]. The standard repair for excessive cracking is methacrylate treatment. An example of plastic cracks on the bridge deck surface is shown in the Figure No. 1.

[1] AASHTO is the American Association of State Highway and Transportation Officials.
[2] SS 2010, Section 90-1.02A *General*.
[3] SS 2010, Section 51-1.01D(4)(d) *Crack Intensity*.

Figure No. 1: Example of Plastic Cracks on the Bridge Deck Surface

Chapter 5, Figure 5-22, of the *SC Concrete Technology Manual,* is an Evaporation Rate Nomograph[4], which relates the following environmental factors to determine the evaporation rate:

1. Air temperature.[5]
2. Relative humidity.
3. Concrete temperature.
4. Wind velocity.

When the nomograph originated approximately 50 years ago, bleed water typically replaced surface water until evaporation rates increased to about 0.2 pounds per square foot per hour where surface drying began to occur. The seven precautions listed below were developed to counteract plastic cracking and should be contemplated by the Contractor as part of the concrete placement plan.

1. Ensure aggregate stockpiles are maintained in the saturated surface dry condition.
2. Ensure surfaces coming into contact with fresh concrete, like forms and subgrade, are thoroughly moistened prior to placement.
3. Erect temporary windbreaks to reduce wind velocity over the concrete surface.
4. Erect temporary sunshades to reduce concrete surface temperatures.
5. Cool the mixing water and aggregates in extreme conditions to keep the fresh concrete temperature low.
6. Reduce time between placing and start of curing, by eliminating delays during construction.
7. Use water fogging sprays to maintain high humidity and surface moisture.

Because of advancements in concrete technology, the threshold for precautionary measures can occur at a much lower evaporation rate. For example, if a high range water reducing admixture is

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[4] American Concrete Institute (ACI) 308, *Standard Practice for Curing Concrete*
[5] http://dschq.dot.ca.gov/OSCHQDownloads/misc/CTM2013.pdf

used, the water/cement ratio will be reduced and the final set time could be extended; the result is that the amount of water that can bleed to the surface will be reduced, the time when fresh concrete is exposed to plastic cracking is extended, and the risk of plastic cracking is increased. Another example is the situation where an ultrafine supplementary cementitious material (SCM) like silica fume is included in the concrete mix. Ultrafine SCMs block the capillaries that bleed water would normally follow to reach the surface, so the amount of bleed water that reaches the surface is reduced and the risk of plastic cracking is increased.

The Standard Specifications[6] require two curing methods for bridge decks, the water cure and the curing compound method. The water cure specifications require the application of water as a fine mist to maintain bridge deck surface moisture until curing medium is applied. If the curing medium is not being applied, water misting must be used until concrete has set, then the deck must be continuously sprinkled until the end of cure.

For the best results, mist should be finely atomized water which gradually falls to the bridge deck. A good indication that the water spray is appropriately atomized is that the particles descend at approximately 1 foot per second. Misting should be sprayed from an upwind position over the bridge deck, not onto the deck, raising the humidity in the air above the deck. As the spray falls to the bridge deck, the objective is to maintain a surface sheen but avoid runoff, which would erode the surface.

Curing compound is applied to bridge deck concrete after finishing the surface, immediately before the moisture sheen disappears from the concrete surface but before drying shrinkage or craze cracks start to appear.[7] Curing compound is applied at a nominal rate of 150 square feet per gallon, such that there is uniform coverage without any thin areas or surface runs, by a power-operated spraying device. The curing compound is applied to facilitate concrete strength gain during the cure process; it does not preclude the possibility of plastic cracking, as shown in Figure No. 2.

If there is a delay in the placement of curing compound that may lead to surface dryness and cracking, surface fogging is required to keep the surface moist[8]. After applying curing compound, per the water method, the surface must be misted until covered with curing medium[9].

[6] 2010 SS, Section 51-1.03H or 2006 SS, Section 90-7 *Curing Concrete Structures*
[7] 2010 SS, Section 90-1.03B(3) or 2006 SS, Section 90-7.01B *Curing Compound Method*
[8] 2010 SS, Section 90-1.03B(2) or 2006 SS, Section 90-7.01A *Water Method*
[9] 2010 SS, Section 90-1.03B(2) or 2006 SS, Section 90-7.01A *Water Method*

Figure No. 2: Example of Plastic Cracking Occurring After Curing Compound Application.