Practical Considerations for Dealing with Concrete Cracks in Decks

By Craig E. Barnes, P.E., SECB

Ever since cement, aggregate, and water were combined to create concrete, engineers, architects, contractors and end users have recognized that the material is prone to cracking. The reason concrete cracks is that, when transforming from the constituent parts to the final product called concrete, there is a reduction in volume. Although cement and aggregate are solids, the volume of water changes. During the hydration process, which takes place when water and cement are combined and results in the creation of concrete, only a small amount of the water placed into the mixture is used for hydration of the cement. Water not used in the hydration process evaporates and, during that evaporation process, concrete volume reduces, resulting in the phenomenon known as shrinkage. When curing concrete is constrained, cracks result in the concrete of a width approximately equivalent to the water volume lost in evaporation.

For years, professionals, contractors, researchers, and product manufacturers have been trying to find ways to reduce the cracks that form in concrete. With the exception of the most exotic procedures, which in themselves are not foolproof, elimination of cracks in restrained concrete has not been possible. The majority of concrete cracks the industry contends with occur one of three ways.

Causes

- Shrinkage: The reduction in volume of concrete during the hydration process through water evaporation.
- Sloughing: As concrete volume changes through water loss and consolidation of the constituent parts of concrete, more rigid elements, such as normal reinforcement, provide a resistance to the consolidation and shrinkage, resulting in the formation of cracks. (*Figure 1*)
- Load-Induced Cracking: Loads passing through concrete that exceed the tensile capacity of the concrete will result in cracks.
- Lesser known phenomenon such as "curling restraint" and "thermal gradient" are not considered herein.

Techniques

Dealing with cracks in concrete is just one of many issues that engineers and contractors must consider when designing and constructing in concrete. Many of the techniques engineers and contractors use have been developed through years of practice, and by utilizing manufactured products developed specifically to make concrete a more user-friendly material.

Water Reducers

Manufacturers, knowing that changes in the volume of water often lead to cracking, have developed additives that are introduced during the mixing process to reduce the amount of water necessary for hydration. Water reducers have been developed that can decrease the amount of water needed by more than 30% and still result in a workable concrete mix. While beneficial, these products are not a panacea, and what results is a concrete mix that still has more water than necessary for the process of hydration. Water reducers have provided limited contribution in decreasing the degree of concrete shrinkage, and some of the chemical technologies used in water reducers have had no effect on shrinkage whatsoever.

Curing Slab Concrete

Curing, the process in which aggregate, cement, and water evolve from constituent parts into the product called concrete, is improved through the retention of as much of the mix water as practical to allow for thorough hydration of the cement. Immersing the concrete in water during the hydration process is the most desirable, although not usually practical. During the construction process, a practical way to undertake this task is by using sprinklers or wet mats to add water to the exposed concrete surface to counteract the process of evaporation. Because of concrete's amazing ability to redistribute and adjust to shrinkage related stresses if properly moistened, moist curing offers one of the best methods for reducing the effects of shrinkage. Material manufacturers have also responded to this challenge by creating curing compounds, which are applied to the surface of freshly placed concrete, and act as a membrane that reduces the amount of water evaporation from the surface.

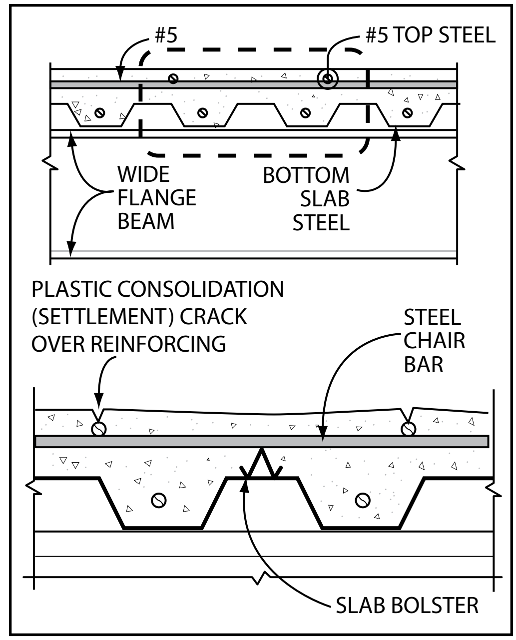

Figure 1.

Controlling the Location of Crack Formation

The process of hydration along with concrete restraint sets up tensile stresses in the concrete mass. Concentrating those stresses in specific locations by the use of stress risers, often called control joints, is one technique.

Distributing Cracks

Normal reinforcement, such as welded wire fabric, steel reinforcing bars, or fiber mesh consisting of small strands of plastic or metal, are often used. Polypropylene fibers, some no more than two or three inches long, and often little more than two to three times the diameter of human hair, are intended to function in a like manner. In the case of steel fibers, the diameter is about the same or is rectangular in section.

Shrinkage-Compensating Concrete

This concrete is created with manufactured additives intended to expand the concrete to counteract shrinkage caused by water loss.

Compression

Pre-stressed or post-tensioned reinforcement, which is intended to compress the concrete, will make up for volume losses by "squeezing" the concrete.

Metal Decking

When an engineer works with metal deck, a combination of practical experience and engineering comes into play. With a metal deck system typically used

Figure 2.

in a parking garage or office building, unless unusual construction care is exercised, welded wire fabric inevitably ends up directly on the metal deck and serves no practical purpose for shrink control. The problem with mesh, which is relatively flexible and very difficult to support, is that it is subject to abuse by the feet of workmen in the field and can be depressed by objects on the site such as pump hoses, wet concrete, etc. Photos from CBI archives illustrate where WWF commonly ends up in a system; on the bottom. Note in *Figure 2*, the care that was taken to force the crack to occur over the beam line (note the shear studs) by saw cutting the concrete. The concrete did not read the plans and cracked where it wanted, approximately 4 inches away from the saw cut. *Figure 3* is an attempt to deal with that phenomenon. Welded wire fabric (WWF) is used cautiously as flexural reinforcement by structural engineers for this reason. After years of bad experience, the author has shied away from the use of WWF except in unusual circumstances, and instead uses normal reinforcement for flexural reinforcement. The composite metal deck the author specifies in garage decks is not for structural purposes. Before deck coatings achieved wide use, cost conscious developers would use concrete without a deck coating and with the composite deck alone serving as reinforcement. Even with the use of galvanized deck, it would take only a few years for the deck to corrode to a point where the structural integrity was compromised.

The composite deck is used, but for a different purpose. A bit of background diversion is important here. Young engineers have not experienced the give and take of designers and contractors regarding the substrate on which concrete slabs on grade are placed. In short, and the author has been on both sides of the issue, one school of thought is to place a polyethylene sheet between the concrete and the supporting soil. Benefits include: a) providing a slip sheet to direct shrinkage to specific control joints, b) promoting curing by retaining water in the concrete, c) providing a membrane to prevent substrate moisture from migrating up through the concrete, possibly disrupting surface treatment on the concrete, and d) easier substrate for construction traffic to negotiate. The disadvantages include: a) increased slab curling, b) loss of friction interface with soil which can benefit shrinkage crack distribution, and c) the difficulty of maintaining the membrane intact during the construction process.

The property that causes metal deck to be composite with concrete is the small lugs that are impressed in the sides of the flutes of the metal deck. This creates a mechanical bond between the concrete and the deck similar to the friction created between soil and slab-on-grade concrete. Casting a slab directly on a soil substrate has an unusual benefit, more uniform distribution of shrinkage cracks due to the friction created at the interface between substrate aggregate and concrete. That same friction, which is effective for creating the composite structural action in metal decks, is the same type of action that promotes shrinkage control in the longitudinal direction. In the perpendicular direction the same effect is generated by the deck flutes, which act as lugs (keys) in the concrete system. From a practical standpoint, the combination of metal deck and concrete is an efficient crack mitigation medium. Flexural cracking and sloughing concrete cracking, which are not directly related to shrinkage, are tangential issues.

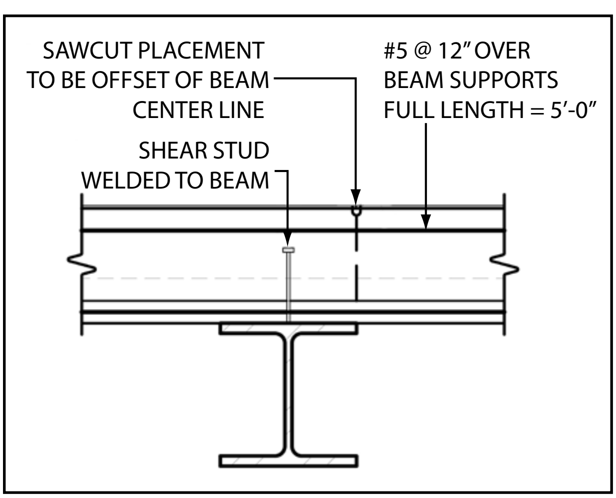

Figure 3.

Urethane Coating

The opaque urethane coating used on a parking garage deck addresses a variety of issues. One important purpose of the coating is to bridge cracks in the concrete, and prevent the intrusion of water and chlorides. With the use of aggregate in the coating; another benefit is skid resistance. Every coating manufacturer provides in their application manual details and or specifications for dealing with concrete cracks. When concrete has reached the end of the 28-day curing period, the bulk of the evaporative water has left the system leaving behind the bulk of shrinkage cracks that will occur. During the process of membrane installation and, before opaque coating, the cracks remaining are dealt with in a particular way. Unless the deck has been opened to traffic prematurely, cracks remaining at 28 days typically originate from either sloughing or shrinkage. Hairline cracks in concrete are often self healing as long as the cracks are not working cracks. It is a phenomenon on which one should not rely, however.

Manufacturers make a distinction between cracks, not classed specifically as expansion joints; $^1/_{16}$ inch is considered the break line for treatment. At $^1/_{16}$ inch or less, these cracks are "detailed." Detailing provides additional coating thickness over a crack. When a crack is greater than $^1/_{16}$ inch, the crack is routed and sealed with an elastomeric sealant before it is coated over, thereby providing for crack movement. The important note here is that manufacturers are not concerned with what creates the crack, but the size of the crack. It is extremely unlikely that additional shrinkage cracking would occur following a 28-day period or following the coating application. More likely, crack formation would result from the deck system being utilized to support the design load, which would not be present during the curing process. The flexible nature of the coating itself is designed to deal with cracks that form during the life cycle of the deck coating system.

Shrinkage cracks in the office building slab are not usually in locations where corrosion is an issue. As a result, routing and filling the cracks, is usually sufficient unless an architectural finish which will read through is proposed.▪

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