CALPORTLAND®

September 2021

concrete solutions®

www.calportland.com

DRYING SHRINKAGE CRACKING

A long-time concrete contractor we once knew liked to tell his customers that ready mix concrete came with four guarantees; it is grey, it gets hard, it will crack, and nobody will steal it. Of the four guarantees, the fact that concrete does crack is one factor that should always be considered and planned for in order to have the best job possible.

There are two types of cracks that represent the vast majority of cracks found in concrete. One type is Plastic Shrinkage Cracks. These cracks have been discussed in a previous issue (see *Concrete Solutions*, March 2021). The focus of our discussion here is Drying Shrinkage Cracks.

TENSILE STRENGTH VS. TENSILE STRESSES

When concrete will develop drying shrinkage cracks is a race between the tensile strength of the concrete and the tensile stresses that develop within the concrete as it hardens and matures. The race begins the moment water is combined with cement in the concrete matrix. A victory occurs only when the strength can always stay ahead of the stresses. If the stresses exceed the strength at any point, drying shrinkage cracking will occur. Concrete tensile strength depends on mix design, temperature and water retention. Concrete tensile stress depends on volume change due to water loss and temperature.

Drying shrinkage cracks are caused by the restraint of volume changes in the slab. As moisture leaves the slab surface, tension develops in the small pores within the cement/paste portion of the hardened concrete. When these pores lose moisture a meniscus forms at the air/water interface. Surface tension in this meniscus pulls the pore walls inward and the concrete responds to these internal forces by shrinking. If the concrete is not restrained, it can shrink freely and change volume without cracking. Since most concrete slabs face restraining factors such as subgrade friction and reinforcing tie bars into foundation walls and footings, these restraining forces generate tensile stress which can exceed the tensile strength that has built up within the concrete. This results in **cracking**. Since shrinkage originates in the hardened cement paste, the amount of shrinkage depends on:

- Shrinkage properties of the paste (water content plays a key role)
- Paste to aggregate ratio
- Aggregate stiffness
- Bond strength between the paste and the aggregate

PLAN FOR CRACKING

For slab construction, knowing that concrete will indeed shrink and thus create cracks provides us with the opportunity to plan so that <u>random</u> cracks can be reduced (or eliminated!) and the resultant cracks are acceptable by anticipating where they will occur. Among these include,

- A properly prepared subgrade to minimize restraint and moisture loss
- A properly planned and executed control joint pattern on the surface

- A concrete curing plan to protect against moisture loss

SUBGRADE PREPARATION

For slab on grade placements, proper subgrade preparation is an important part of crack prevention. The subgrade should have a solid, uniform bearing. It must be well compacted with no soft spots or pumping action. Ideally, concrete should be placed on a 3" to 4" sand base that has been thoroughly moistened. This will provide a smooth surface and the moisture conditioning of the base will provide for uniform water loss through the bottom of the slab. Slabs placed on plastic sheeting are highly susceptible to curling and cracking.

CONTROL JOINTS

A general rule of thumb states that control joint spacing works best when they are placed between 24 and 30 times the slab thickness in inches. Suggested joint spacing would be designed as follows:

4-inch-thick slab: Joint spacing would be between 8 and 10 feet apart

5-inch-thick slab: joint spacing would be between 10 and 12.5 feet apart

6-inch-thick slab: joint spacing would be between 12 and 15 feet apart

The depth of control joints placed into the concrete surface must be at least 25% of the slab thickness to provide a sufficient "weakening plane" to promote the concrete to crack at this point. Following these guidelines, the minimum joint depth should be as follows:

4-inch-thick slab: 1 inch deep (minimum)

5-inch-thick slab: 1 ¼ inch deep (minimum)

6-inch-thick slab : 1 ½ inch deep (minimum)

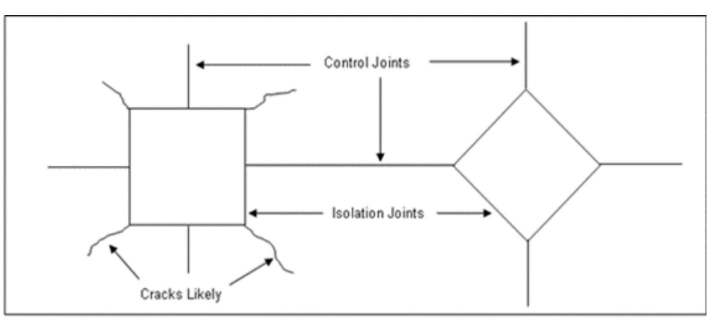
The ultimate owner should be included in the discussion as to what type of joint is chosen based on the planned utilization of the slab. Control joints created by a tool or imbedded plastic inserts to the 25% depth during the placing and finishing operation are ideal since they are in place prior to any drying shrinkage stresses. A dry-cut saw operation is usually timed to take place 1 to 3 hours after the slab is finished and can be effective. Wet saw cut joints should be placed when two criteria are met; the cut slab surface doesn't ravel away from the sawed edge and before the concrete cracks. Depending on the weather conditions, this could be at 2:00 am! If the concrete has already cracked near where the saw cut was planned, don't cut the slab at this location. The concrete has already relieved internal stresses near this location. If the concrete suddenly cracks ahead of the saw, stop sawing. No benefit will be gained by continuing the saw cut across the slab. The internal stresses have been relieved at this point.

Additionally, the joint pattern should be as square as possible. If they cannot be square, the length should never exceed 1.5 times the width. A 10' by 20' joint pattern has a very high likelihood of a random crack down the center leaving the slab in two approximately 10' x 10' sections. If the contractor doesn't put in the joint, the concrete will do it on its own. Keeping the maximum joint spacing to 15 feet or to the prescribed distance should allow for the majority of the control joints and construction joints to perform as intended.

A reentrant corner (think of it as an inside corner) is a generator of cracks. Try to incorporate this type of corner into the construction and control

joint pattern of the entire slab. If this is not possible, wet setting two or three pieces of deformed rebar about 24" long and spaced 8 to 12 inches apart into the concrete at an angle of 90 degrees to the diagonal coming from the corner can help tie together the concrete and prevent the crack from developing across the slab.

Control joints and construction joints should line up with column centers. Block outs for columns should be rotated 45 degrees (a diamond shape) so the corners line up with these joints and eliminate reentrant corners. See line diagram below:



Isolation joint material placed between the column concrete and the slab concrete will allow the slab to move vertically under load and not be tied to the column base. Slabs reinforced with welded wire fabric in the upper third of the slab will not prevent drying shrinkage cracking. The welded wire will only keep the crack from growing excessively wide. Polypropylene fibers have been successfully used as an alternative to welded wire fabric in many slab applications.

A control joint constructed into the slab surface that has reinforcing steel running across the slab

under the joint will render the control joint ineffective. In essence this creates a control joint as a weakening plane while reinforcing it with steel. A steel reinforced weakening plane is not a workable weakening plane. Dowels of deformed rebar placed into the concrete as a mechanism for load transfer across a construction joint will end up reinforcing the joint and cracks may appear parallel to the construction joint and the end of the rebar dowels. Proper dowel construction for load transfer must be constructed with either smooth dowels greased on one side or, if deformed rebar is used, the dowel on one side of the joint must be covered to allow for joint movement (see picture above). As always, the dowels should be placed 90 degrees to the slab edge and uniformly aligned vertically.

CONCRETE CURING

Proper curing plays a critical role in preventing drying shrinkage cracking by delaying water loss from the concrete. Curing allows the concrete to develop tensile strength before it is exposed to tensile stresses that are generated when drying eventually occurs. Protection from early water loss is very critical. The best early protection method available is fog misting. This proven crack reduction technique is achieved with the use of a pressure wash system equipped with fogging nozzles. The fog mist creates a high humidity zone over the concrete that slows down water evaporation. Spray on evaporation retardants used during the finishing operation are also very effective. When these methods are followed by a wet cure (soaking blankets, ponding or sprinklers) immediately after finishing operations, random crack reduction is dramatic. Application of a high solids content curing compound applied at the manufacturer's recommended rate can be used in scenarios where a wet cure is not practical. Remember that water loss drives tensile stress development. Restricting early water loss with these evaporation control methods will help prevent drying shrinkage cracking.

DRYING SHRINKAGE CRACKS

The fact that concrete does crack is one factor that should always be considered in order to have the best job possible. Planning exactly where to place crack control joints prior to the concrete placement is best. It is preferable to avoid a "by the seat of your pants" approach to control joint locations on the day concrete is being placed. The type of joint chosen should ideally include the owner and an understanding of how the slab will ultimately be utilized. Remember, concrete is the most resilient and durable building material produced today. Understanding and planning for eventual product shrinkage and cracks can go a long way to producing a functional, beautiful and long lasting finished product.

CALPORTLAND®

EXPECT MORE ... WE DELIVER!®

Please note information contained in this newsletter is for educational purposes only and should only be used as a guide.

If you know of others who would like to be added to our mailing list and receive this newsletter or to unsubscribe, please email tmason@calportland.com.

ENERGY STAR AWARD 2021

PARTNER OF THE YEAR

Sustained Excellence