"How Did You Do That?" Concrete Shrinkage

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In a previous issue, From Experience presented the subject of Concrete Slump. In this installment in the series, the effect of slump on shrinkage and cracking will be discussed.

To keep the discussion simple, we should first define some of the language that is used. Slump, of course, is controlled by the total water per cubic yard of concrete, while strength is governed by the thickness or consistency of the paste. This thickness is determined by the ratio of the weight of water to the weight of cement.

Shrinkage and cracking are not synonymous terms. It is possible to have a considerable amount of shrinkage with little or no cracking. Conversely, we may have a comparatively low shrinkage concrete that has a large number of cracks. Shrinkage is simply the reduction in volume that takes place when the concrete dries from its original wet condition down to a point where its moisture condition reaches equilibrium with the humidity in the air. When shrinkage movements are restrained, then concrete will crack. Unrestrained shrinkage within limits, however, does not develop cracks. Reinforcing steel does not prevent concrete from drying and will not stop cracking, although it does hold the cracks together. Whether it is due to structural causes or due to restrained shrinkage, **cracking is simply a failure in tension**.

In the previous discussion on slump, it was stated that for most mixes the addition of one gallon of water (8.33 pounds) to a cubic yard of concrete will add approximately one inch to its slump.

On the basis of a number of research investigations, it has been found that between 18 and 20 pounds of water will eventually become chemically united with every 100 pounds of cement. This equates to 2 to 2 ½ gallons per 94-pound sack of cement. Any mix water which is not used to chemically unite with, or hydrate, the cement is classified as evaporable water. This evaporable water is one of the principal sources of shrinkage in concrete.

To calculate the potential increase in shrinkage of a typical concrete mixture due to a one-inch greater slump, a specific example is used. In this example, a trial mix indicated that a specified strength of 3000 psi and a slump limitation of 3 inches could be achieved with a 6.0 sack mix using 36 gallons of water per cu yd. The water/cement ratio is 36 x 8.33 / 6.0 x 94 = 0.53. The water needed chemically to hydrate the cement at 2 ½ gallons per sack is simply 6.0 x 2.5 = 15 gallons. The remaining evaporable water now becomes 36-15 = 21 gallons. If this mix is changed to a 4-inch slump by the addition of 1 gallon of water, but no additional chemical water was needed, the evaporable water is now increased from 21 to 22 gallons.

Since the shrinkage under controlled conditions is roughly proportional to the evaporable water in all mixes, this 1-inch change of slump could result in one divided by 21, or less than 5 percent additional shrinkage. (Big Deal!) (1/32-inch in 100 feet)

Linear concrete shrinkage for the majority of most structural concrete typically falls between 0.0004 and 0.0006 inches/inch which is equivalent to ½ to ¾ inch per 100 feet. When a concrete slab-on-grade shrinks, it is restrained from movement by the subgrade, and internal tensile stresses are induced. By forming a groove extending part way through the slab with a tool or a saw, the slab is reduced in thickness and a straight contraction crack develops.

The American Concrete Institute and others suggest that the spacing of contraction joints, in feet, be two to three times the thickness of the slab in inches. This suggestion would indicate a contraction joint spacing of 12 to 18 feet for a 6-inch slab, and 8 to 12 feet for a 4-inch slab. Experience, however, reveals that for maximum performance and appearance on plain or reinforced slabs, the joint spacing on all slabs 6-inches or greater should be limited to 15 feet. For concrete mixtures using maximum aggregate size of ½-inch (pea gravel

pump mixes), the maximum joint spacing should be reduced to about half of the spacing suggested for larger size aggregates. This closer spacing that smaller aggregate mixes require is due to more initial mix water and, thus, will have much higher shrinkage. If reinforcing steel is used, every other bar or wire should be cut at the joint to provide a plane of weakness in the mat of steel with the intermediate steel extended through for load transfer.

Since concrete shrinks equally in both directions, the spacing of joints should result in an approximately square layout. Panel length to width ratios should not exceed 1.5 to 1. A greater number of "Wise Cracks", with particular attention to reentrant corners and continuous joints, is much more desirable than unwanted crooked cracks. For many reasons it is strongly suggested that the location of all floor joints should be detailed on the plans. It is much cheaper to put in an extra joint than to repair a crack.

Since the actual shrinkage movement between joints is less for more closely spaced joints, the actual width of the crack is significantly reduced. This results in much more efficient wheel load transfer across the joint through improved aggregate interlock.

A more closely spaced joint pattern also reduces the amount of potential slab curling and corner cracking. Mathematically it can be demonstrated that slab curling is directly proportional to the square of the distance between joints. Doubling the joint spacing produces four times the amount of curling. Curling is also inversely proportional to the depth or thickness of the slab. At the same joint spacing, a thicker slab will not curl as much as a thinner slab.

The most common method of producing a contraction joint is to use a concrete cutting saw. A newly developed "early entry" saw now permits cutting a groove immediately following trowelling. This saw cuts without the need for cooling water on the blade, which makes the cleanup operation easier. Shallower cuts of 15 to 20% of the slab thickness appears to be adequate compared to 25 to 33% depths formerly suggested. Reduced depth should also reduce costs.▪

The author, Bob Tobin, is a retired Structural Engineer in Los Angeles. He has been involved with concrete since graduation in 1938. This now adds up to 65 years of "experience."