Why do on-grade slabs curl?

The problem: uneven drying-shrinkage

The most common cause of curling in on-grade slabs is the difference in shrinkage rates between the top and bottom portions of the slab. The upper portion of a fresh slab is subject to heat, air movement, and low humidity, which causes water to evaporate rapidly, while evaporation from the underside is restricted by moist subgrades and sometimes a vapor barrier. The resulting difference in evaporation rates, or vapor transmission, causes the concrete to shrink more rapidly on the top than on the bottom, and the result is curling.

The solution: reduce drying-shrinkage

The more cement paste, the more shrinkage

The key to reducing curling lies in reducing the amount of drying-shrinkage in a slab. Many factors work to influence how much the concrete will shrink, but the greatest indicator is the amount of cement paste. A high volume of cement paste is created when water is added to a mix to make it workable, well beyond the amount needed to hydrate the cement. And when that extra water evaporates, the cement paste shrinks and the concrete with it.

A good solution for reducing the volume of cement paste is to use the maximum-sized aggregate practical for a job. Providing the aggregate is clean and noncompressible, its overall volume will diminish the volume of the paste and thereby limit the amount of drying- shrinkage.

The role of water reduction

Drying shrinkage can also be lessened by reducing the amount of water added to a mix. To reduce the amount of water used, try some of the following options.

1. Use a coarser sand
2. Use a coarser-grade cement
3. Use cement with a low C_4A content
4. Use the maximum-sized coarse aggregate that is practical
5. Use aggregates free of clay and other contaminants
6. Reduce the travel time between the ready mix plant and the jobsite
7. Reduce the agitating revolutions after mixing is completed
8. Lower the temperature

It's important to realize that the materials used in a particular mix have a tremendous, cumulative impact on the concrete's shrinkage. Mix designers would be wise to specify tests for a number of different mixes and select the one with the lowest shrinkage suitable for the job.

Using water reducers to lower the water content

Most people assume that using high range water reducers (HRWR) or superplasticizers will reduce shrinkage to the same degree they reduce water demands. This is typically not true. ASTM C 494, Standard Specification for Chemical Admixtures for Concrete, allows concrete with admixtures 35%more shrinkage than concrete without an admixture. Again, the only way of knowing if the water reducer will lower the shrinkage is to actually test it within a mix design.

The Role of Slump in Shrinkage

ACI and PCA literature suggests that a low slump is the key to minimizing shrinkage drying. Yet fairly large increases in slump often yield only small increases in shrinkage (going from a 3 - 4" slump to a 6 - 7" slump will only increase shrinkage by about 10%). As mentioned before, the shrinkage of the cement paste is the main determinant in the overall shrinkage of the concrete. It therefore makes more sense to focus on other factors, such as using larger noncompressible aggregates and selecting materials carefully as specified above in options 1 - 8.

Conclusion

The best ways to reduce or eliminate curling in on-grade slabs is to even out the evaporation rates from the top and bottom of the slab. This can often be accomplished by reducing the slab’s overall shrinkage. Use large, clean, noncompressible aggregate to reduce the volume of cement past that will shrink when the water evaporates, and follow measures 1 – 8 listed above to reduce the overall water content of the cement mix.