Concrete Tech Tip
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Curling of Concrete Slabs

1. WHAT is Curling?

Curling is the distortion of a slab into a curved shape by upward or downward bending of the edges. The occurrence is primarily due to differences in moisture and/or temperature between the top and bottom surfaces of the concrete slab. The distortion can lift the edges or the middle of the slab from the base leaving an unsupported portion. The slab section can crack when loads exceeding its capacity are applied. Slab edges might chip off or spall due to traffic when the slab section curls upward at its edges. In most cases, curling is evident at an early age. Slabs may, however, curl over an extended period.

2. WHY do Concrete Slabs Curl?

Changes in slab dimensions which lead to curling are most often related to moisture and temperature gradients in the slab. When one surface of the slab changes size more than the other, the slab will warp at its edges in the direction of relative shortening. This curling is most noticeable at the sides and corners. One primary characteristic of concrete which affects curling is drying shrinkage. Anything that increases drying shrinkage of concrete will tend to increase curling.

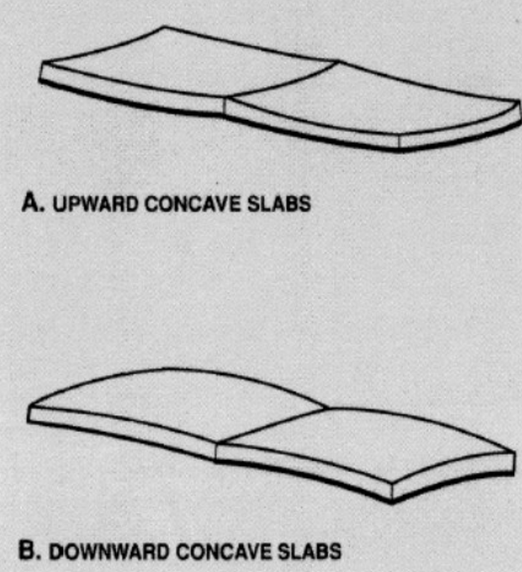

Figure 1. Curling of Concrete Slabs

The most common occurrence of curling is when the top surface of the slab dries and shrinks with respect to the bottom. This causes an upward curling of the edges of the slab (Figure 1 A). Curling of a slab soon after placement is most likely related to poor curing and rapid surface drying.

In slabs, excessive bleeding due to high water content in the concrete or water sprayed on the surface; or a lack of surface moisture due to poor or inadequate curing can create increased surface drying shrinkage relative to the bottom of the slab. Bleeding is accentuated in slabs placed directly on a vapour retarder (polyethylene sheet) or when topping mixtures are placed on concrete slabs. Shrinkage differences from top to bottom in these cases are larger than for slabs on an absorptive subgrade. Thin slabs and long joint spacing tend to increase curling. For this reason, thin unbonded toppings need to have a fairly close joint spacing.

In industrial floors, close joint spacing may be undesirable because of the increased number of joints and increased joint maintenance problems. However, this must be balanced against the probability of intermediate random cracks and increased curling at the joints.

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The other factor that can cause curling is temperature differences between the top and bottom of the slab. The top part of the slab exposed to the sun will expand relative to the cooler bottom causing a downward curling of the edges (Figure 1B). Alternatively, during a cold night when the top cools and contracts relative to the bottom surface in contact with a warmer subgrade, the curling due to this temperature differential will add to the upward curling caused by moisture differentials.

3. HOW to Minimize Slab Curling.

The primary factors controlling dimensional changes of concrete which lead to curling are drying shrinkage, construction practices, moist or wet subgrades, and day-night temperature cycles. The following practices will help to minimize the potential for curling:

1. Use the lowest practical water content in the concrete and avoid retempering with water, particularly in hot weather.
2. Use the largest practical maximum size aggregate and/or the highest practical coarse aggregate content to minimize drying shrinkage.
3. Take precautions to avoid excessive bleeding. In dry conditions, place concrete on a damp, but absorptive, subgrade so that all the bleed water is not forced to the top of the slab. This may not be appropriate for interior slabs on which a moisture sensitive floor covering will be applied.
4. Avoid using polyethylene vapor barriers unless covered with at least 100 mm of trimable, compactible granular fill (not sand). If a moisture-sensitive flooring will be placed on interior slabs, the concrete will generally be placed on a vapour retarder (see CTT#29) and other procedures may be necessary.
5. Avoid a higher than necessary cement content. Dense, impermeable concrete will produce larger top to bottom moisture differentials and curl more. Use of fly ash is preferable to very high cement content, and consideration should be given to specifying strength at 56 or 90 days.
6. Cure the concrete thoroughly, including joints and edges. If membrane curing compounds are used, apply at twice the recommended rate in two applications at right angles to each other.
7. When minimizing curling is critical, use a joint spacing not exceeding 24 times the thickness of the slab.
8. For thin toppings, clean the base slab to ensure bond and consider use of studs and wire around the edges and particularly in the slab corners.
9. Use a thicker slab.
10. The use of properly designed and placed slab reinforcement may help reduce curling. Load transfer devices that minimize vertical movement should be used across construction joints.
11. Certain types of breathable sealers or coatings on slabs can work to minimize moisture differentials and reduce curling.

When curling in a concrete slab application cannot be tolerated, alternate options include the use of shrinkage reducing admixtures, shrinkage compensating concrete, post tensioned slab construction or vacuum dewatering. These options should be considered before construction and may increase the initial cost of the project.

Some methods of remedying slab curling include ponding the slab to reduce curl followed by saw cutting additional contraction joints, grinding slab joints where curling has occurred to restore serviceability and injecting a grout to fill voids under the slab to restore support and prevent break-off of uplifted edges.

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