

Concrete in Practice

What, why & how?



CIP 19 - Curling of Concrete Slabs

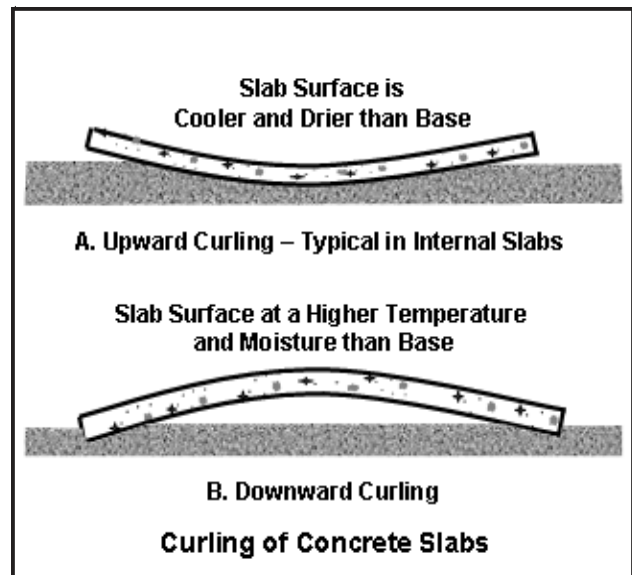
WHAT is Curling?

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 a 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 upwards at its edges. In most cases, curling is evident at an early age. Slabs may, however, curl over an extended period.

WHY do Concrete Slabs Curl?

Changes in slab dimensions that lead to curling are most often related to moisture and temperature gradients in the slab. When one surface of the slab changes size relative to 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 that affects curling is drying shrinkage. Anything that increases drying shrinkage of concrete will tend to increase curling.

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 a slab (Figure 1A). 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 vapor retarder (polyethylene sheeting) 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.

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). Alternately, during a cold night when the top surface 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.

HOW to Minimize Slab Curling?

The primary factors controlling dimensional changes of concrete that 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.
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 would be placed.
4. Avoid using polyethylene vapor retarders unless covered with at least four inches (100 mm) of a trimable, compactible granular fill (not sand). If a moisture-sensitive floor covering will be placed on interior slabs, the concrete will generally be placed directly on a vapor retarder (see CIP29) and other procedures may be necessary.
5. Avoid a higher than necessary cement content. Use of pozzolan or slag is preferable to very high cement content.
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, or increase the thickness of the slab at edges.

10. The use of properly designed and placed slab reinforcement may help reduce or eliminate 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 decided before the construction and could increase the initial cost of the project.

Some methods of remedying slab curling include ponding the slab to reduce curl followed by sawing 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.

References

1. *Guide for Concrete Floor and Slab Construction*, ACI 302.1R American Concrete Institute, Farmington Hills, MI www.concrete.org
2. *Slabs on Grade*, ACI Concrete Craftsman Series, CCS-1 American Concrete Institute, Farmington Hills, MI.
3. *Shrinkage and Curling of Slabs on Grade, Series in three parts*, R. F. Ytterberg, ACI Concrete International, April, May and June 1987, American Concrete Institute.
4. *Concrete Slab Surface Defects: Causes, Prevention, Repair*, IS177, Portland Cement Association, Skokie, IL, www.cement.org
5. *Pavement Design*, Transportation Research Record 1207, National Research Council, Washington, D.C., 1988, p. 44.
6. *Controlling Curling and Cracking in Floors to Receive Coverings*, J. Holland and W. Walker, Concrete Construction, July 1998, www.worldofconcrete.com.
7. *Where to Place the Vapor Retarder*, B. Suprenant and W. Malisch, Concrete Construction, May 1998.
8. *Repairing Curled Slabs*, B. Suprenant, Concrete Construction, May 1999.
9. *Residential Concrete*, National Association of Home Builders, Washington, DC, www.nahb.com.

1990, 2002, 2004



National Ready Mixed Concrete Association • 900 Spring Street, Silver Spring, MD 20910 • www.nrmca.org • 888-84NRMCA

© National Ready Mixed Concrete Association (NRMCA). Technical information prepared by NRMCA. All rights reserved.

No part of this publication may be reproduced in any form, including photocopying or other electronic means, without permission in writing from NRMCA.