Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials

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This guide contains materials, design, and construction recommendations for concrete slabs-on-ground and suspended slabs that are to receive moisture-sensitive flooring materials. These flooring materials include sheet rubber, epoxy coatings, vinyl composition tile, sheet vinyl, carpet, athletic flooring, laminates, and hardwood. Chapters 1 through 8 provide an understanding of concrete moisture behavior and drying, and show how recommended construction practices can contribute to successful performance of floor covering materials. This background provides a basis for the recommendations in Chapter 9 to improve performance of floor covering materials in contact with concrete moisture and alkalinity.

Because this guide is specific to floor moisture problems and solutions, refer to the most current editions of both ACI 302.1R, "Guide for Concrete Floor and Slab Construction," and ACI 360R, "Design of Slabs-on-Ground," for general information. These two documents contain guidance on floor design and construction that is needed to achieve successful floor covering performance.

Keywords: admixtures; cracking; curing; curling; drying; mixture proportioning; moisture movement; moisture test; relative humidity; slab-on-ground; specifications; vapor retarder/barrier.

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CHAPTER 1—INTRODUCTION AND BACKGROUND

1.1—Introduction

Delamination, blistering, staining, mold growth, and other problems related to the installation and performance of moisture-sensitive flooring materials on concrete slabs are common. The problems include claims for total failure of the flooring system, construction-schedule delays caused by slow concrete drying, and lawsuits involving indoor air quality. It is currently up to architects, engineers, floor covering installers, flooring and adhesive manufacturers, concrete contractors, and concrete producers to solve these problems.

The objective of this document is to reduce the potential for moisture-related problems in both slabs-on-ground and suspended slabs. It provides basic information on the concrete drying process, moisture behavior in concrete, testing for pH and moisture, and vapor retarders/barriers. Based on this information, recommendations for the design and construction of concrete slabs that will receive moisture-sensitive or pH-sensitive flooring materials or coatings are presented.

1.2—Flooring moisture issues

Figures 1.1 to 1.4 show typical problems that can occur in concrete slabs covered with flooring materials. These problems include debonding, adhesive bleed, blistering, mold growth, and adhesive degradation.

1.3—Concrete slabs that receive flooring materials

This document focuses on the behavior of moisture in concrete slabs, and the effect of the concrete moisture condition on the performance of applied flooring materials. Reaching a desired moisture state, however, should not be the only acceptance criterion for a concrete slab that will be coated or covered. Floor flatness, surface texture, cracking, curling, structural capacity, jointing requirements, and the potential for the slab to stay acceptably dry should also be considered. The goal is installation of a flooring system—subgrade, subbase, vapor retarder/barrier, concrete slab (and possibly reinforcement), coating or flooring adhesive, and floor covering—that satisfies performance requirements.

ACI 360R and 302.1R provide recommendations for designing and building concrete slab-on-ground substrates that are suitable for receiving flooring materials. This document supplements information contained in the ACI 360R and 302.1R guides and also applies to suspended slabs. When designing and building suspended slabs, this guide should be used in conjunction with ACI 318 and 302.1R.

1.4—Changes in construction methods and materials that affect floor systems

In the last 10 to 15 years, there has been an increase in the number of reported flooring problems—for example, blisters, debonding, staining, and mold growth—caused by moisture originating within or moving through concrete slabs. Some

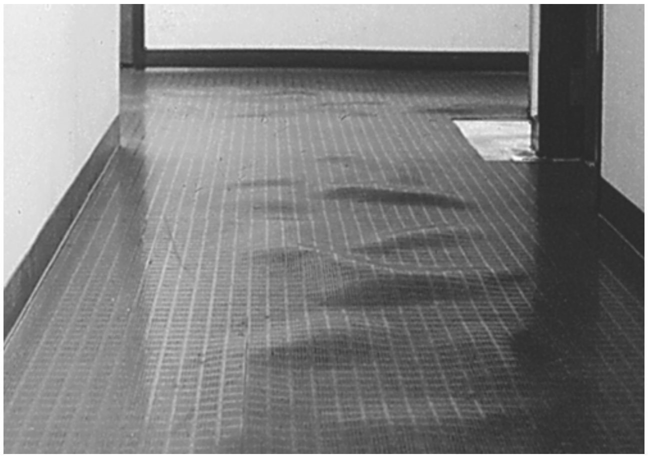


Fig. 1.1—Debonded sheet flooring due to moisture in the concrete slab. (Courtesy of Peter Craig and Herman Protze III.)

Fig. 1.2—Blisters due to moisture in concrete. (Courtesy of Peter Craig.)

problems may be related to fast-track construction methods that allow less time for concrete drying. Other problems may result from changes in the composition of floor covering adhesives related to restrictions on the use of volatile organic compounds (VOCs).

1.5—Floor flatness changes with time

Concrete shrinks when it loses moisture, and expands when it gains moisture. When the top of a slab loses more moisture than the bottom, the differential shrinkage causes edges and corners of the slab to deflect upward. This is called curling or warping. Because of this, concrete slabs that are built flat do not always stay flat.

The foreword of ACI 302.1R states that it is normal to expect some amount of curling on every project. Control of curling will be a design challenge if floor specifications are written to meet both CSI Division 3 and Division 9 flatness criteria (Construction Specifications Institute 2000; Craig 2004; Holland and Walker 1998; Suprenant 2002b,c). As shown in the examples by Suprenant (2003d), curling or warping can cause floor flatness and levelness, as measured by F-numbers, to decrease by 20 to 50% in a year.

Time-dependent changes in floor profiles occur on every project, but the magnitude of the profile change can vary. ACI 117-90 states: "Since neither deflection nor curling will

Fig. 1.3—Mold growth in carpet due to moisture in concrete. (Courtesy of Floor Seal Technology, Inc.)

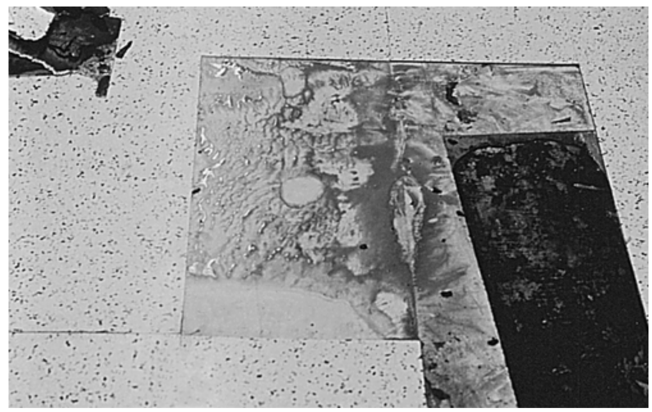


Fig. 1.4—Adhesive degradation leading to debonded solid vinyl tile installed over asbestos tile. (Courtesy of Peter Craig.)

significantly change a floor's F_F value, there is no time limit on the measurement of this characteristic." Flatness measurements on given floors at different ages, however, indicate that this statement is not true. Therefore, the design team should consider how changes in floor profiles with time might affect:

- The floor covering installers' ability to meet Division 9 specification requirements; and
- Long-term floor performance after the floor covering has been installed.

Figure 1.5 shows schematically how flatness of an unreinforced floor can vary over time. The F_F 50 required by a Division 3 specification—and produced by the contractor—decreases after 12 months. Because of curling, unreinforced jointed floors exhibit a similar flatness loss with time. This creates the gap between Division 3 and 9 requirements. Design professionals can use one of several approaches to provide a floor that meets the flatness needs of the floor covering installer.

Figures 1.6 (a) through (c) show three possible approaches:

- **Produce a higher initial F_F.** The engineer estimates the decrease in floor flatness with time, then specifies an initial F_F that later drops to the value needed by the floor covering installer. Making the estimate is difficult

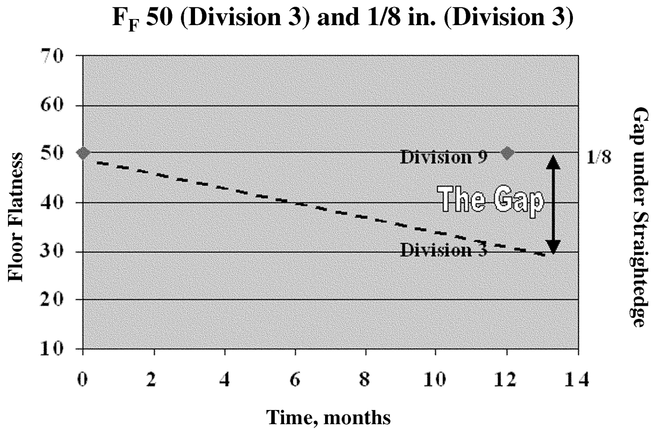


Fig. 1.5—When flatness of an unreinforced floor is measured initially, F-numbers may indicate a very flat floor. When flooring installers start their work, however, flatness may have changed, as indicated by the gap between Division 3 and Division 9 flatness (Suprenant 2003d).

because the amount of curling varies with the concrete properties and service environment. In addition, a floor with a high initial F_F experiences a greater percentage flatness loss for a given curling deflection;

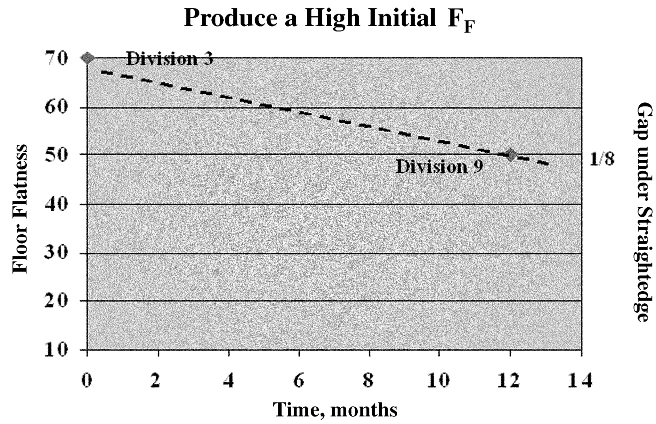
- **Use reinforcing steel.** The engineer selects a ratio of reinforcement area to gross concrete area—typically approximately 0.5% for Grade 60 steel—that minimizes curling. Refer to ACI 360R for more information; or
- **Correct flatness problems by grinding and patching.** The engineer designs a floor that is expected to curl, but requires the contractor or floor covering installer to include an allowance in the bid for repairing the curl (Suprenant and Malisch 1999b). Section 5.2.9 discusses various repair options.

1.6—Other considerations

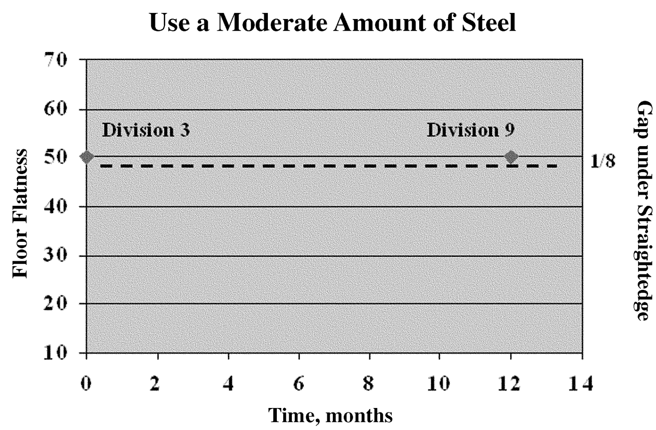
Wide random cracks in slabs create problems when floor materials are placed over them. Floor covering manufacturers all require some form of crack repair for wide cracks. To minimize crack width and crack repair, steel reinforcement should be considered for use in the slab (Fig. 1.7), as recommended by Holland and Walker (1998). Other methods for reducing the potential for excessive cracking include proper concrete mixture proportioning and joint spacing or other types of reinforcement such as post-tensioning.

Contraction, construction, and column blockout joints are almost always visible under thin flooring materials. Because of this problem, Holland and Walker (1998) recommend using reinforcing bars to minimize crack widths, and eliminating contraction joints and the traditional diamond-shaped isolation joints at columns when floors will receive a covering. Instead of using diamond-shaped isolation joints, steel columns in a floor system should be wrapped for the full floor depth with 1/4 to 3/8 in. (6.4 to 9.5 mm) thick compressible isolation joint material (Fig. 1.8). Refer to ACI 360R for more information.

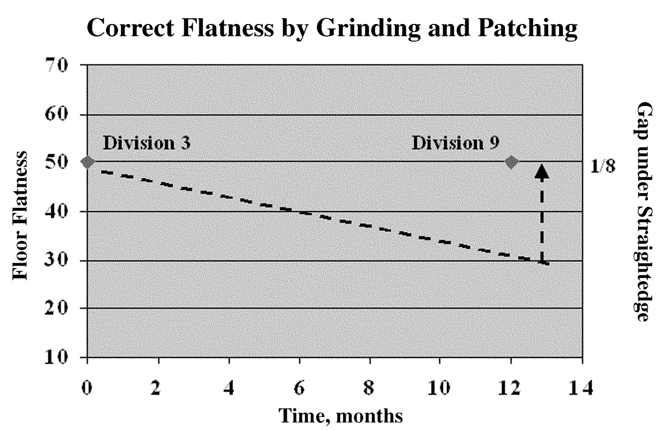
Carpeting and some other floor coverings can tolerate larger crack widths in the concrete floor without noticeable



(a)



(b)



(c)

Fig. 1.6—Approaches to providing a floor that meets the needs of the floor covering installer: (a) produce a higher initial F_F; (b) use reinforcing steel to reduce curling; and (c) correct flatness problems by grinding and patching (Suprenant 2003d).

projection of the crack through the surface opening. When these coverings are used, crack-control measures at columns may not be needed. The column-slab interfaces should simply be wrapped to isolate them from the slab. Refer to ACI 360R for more detailed information on the design of slabs-on-ground.

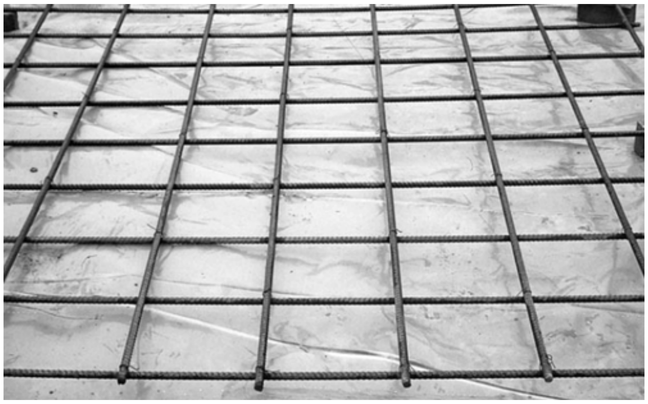


Fig. 1.7—Reinforcing bar in concrete slabs placed directly on vapor retarder help to control slab curling and cracking. Supported deformed bars no smaller than No. 4 (No. 13) should be used, and the bars spaced far enough apart so workers can step between them (Holland and Walker 1998).

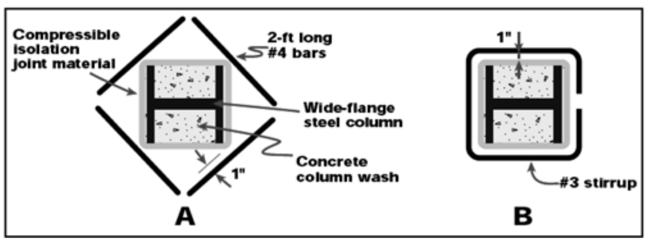


Fig. 1.8—Eliminate the normal isolation-joint boxouts at wide-flange steel columns by wrapping the column with compressible materials and using 2 ft (0.6 m) lengths of No. 4 bars (A) to control cracking at the re-entrant corners. To speed up steel placement at the columns, have the reinforcing bar supplier fabricate continuous No. 3 stirrups that workers can easily bend open to fit around the column (B). In either case, the steel should be positioned with a top-and-side clear cover of 1 in. (25 mm) (Holland and Walker 1998).

CHAPTER 2—CONCRETE MOISTURE BASICS

2.1—Introduction

Hardened concrete slabs contain water in either a liquid or vapor form. The amount and distribution of this water is of primary concern with regard to the installation and performance of floors and flooring materials. The amount of water in fresh concrete is determined by the concrete mixture proportions, the concrete batch weights, and any water added after batching. Initially, the distribution of water in a fresh concrete slab may be slightly affected by bleeding, placing and finishing practices, evaporation during finishing, and curing methods. It is the changes in moisture distribution after the concrete hardens, however, that have the greatest effect on the performance of flooring materials. Understanding how water moves through hardened concrete is important in determining:

- Consequences of the moisture movement;
- Effectiveness of moisture testing methods; and
- Validity of flooring manufacturers' warranty recommendations.

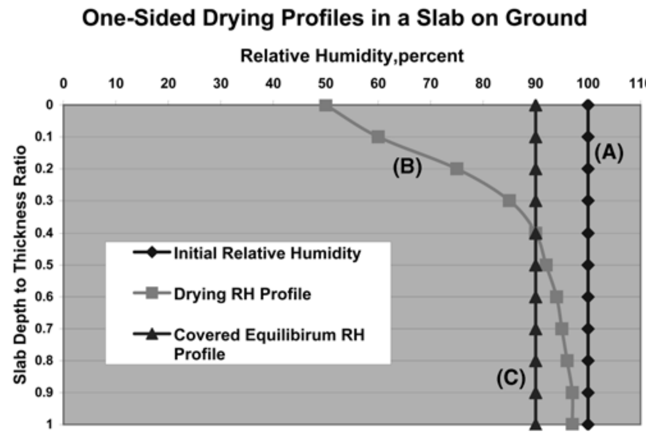


Fig. 2.1—One-sided drying profiles in a slab-on-ground showing initial, drying, and covered equilibrium relative humidity profiles (adapted from Hedenblad [1997]).

2.2—Moisture movement

After curing and before drying begins, the moisture distribution in a hardened concrete slab is reasonably uniform throughout the member thickness (Hanson 1968). As concrete dries, the amount and distribution of moisture changes (Hedenblad 1997).

2.2.1 *Drying of concrete slab-on-ground*—Figure 2.1, adapted from Hedenblad (1997), shows schematically the change in internal relative humidity (RH) of a concrete slab-on-ground as it dries from the top surface only. The vertical line at 100% relative humidity (Curve A) shows the initial distribution when drying begins. As the slab dries, the concrete loses more moisture from the top than from the middle or bottom. This results in a moisture differential within the slab, with the internal relative humidity lower at the top. The profile of the drying curve (Curve B) varies with the temperature and relative humidity at the concrete surface, the length of the drying period, and the concrete properties.

Drying ceases or slows when a floor covering is installed, depending on the permeability of the floor covering, and the internal moisture redistributes throughout the concrete before reaching an equilibrium level at which the RH is nearly uniform throughout the concrete. Figure 2.1 shows the new RH profile as a vertical line (uniform moisture) at 90% RH (Curve C). The absolute RH value at equilibrium varies depending on the initial moisture content, drying conditions, and length of the drying period (Hedenblad 1997).

2.2.2 *Drying of suspended concrete slab*—Figure 2.2 (adapted from Hedenblad) shows schematically the change in internal RH of a concrete slab drying from both the top and bottom. Similar to the concrete slab-on-ground, the vertical line at 100% RH (Curve A) shows the initial distribution when drying begins. As it dries, the concrete loses moisture from both the top and bottom of the slab. This results in a moisture differential within the slab, but now with the maximum RH at mid-depth of the slab (Curve B). The profile of the drying curve again varies with the temperature and RH at the concrete surfaces, the length of the drying period, and the concrete properties.