APPENDIX D

Preventing Cracked Tile and Grout

By Frank Woeste and Peter A. Nielsen

The 2003–2004 Tile Council of America's *Handbook for Ceramic Tile Installation* contains numerous details for a double-layer wood floor system supporting ceramic tile. The thicknesses of the subfloor and underlayment are given in each case.

Specific guidance on where to butt the underlayment end joints is not given for any detail. The purpose of this article is to propose specific guidelines for the orientation and placement of underlayment, including end and edge joints, beyond the rules given in the TCA *Handbook*, to improve the performance of double-layer wood systems. These guidelines are based on engineering science and field observations.

The Tile Council of America's standard formula for measuring maximum deflection under a tile floor is called L-360. Divide the total span of the floor joists by 360 for the maximum amount the floor can give in the middle. For example, if the floor joists span 15 ft.: 15x12 (in.) = 180 in. divided by 360 = 0.5. The maximum allowable deflection for a joist span of 15 ft. is ½ in. The l-360 standard applies to most ceramic, porcelain, and hard stone. But for certain soft stone tile such as limestone or light marble, the L-720 formula applies, cutting the maximum allowable deflection in half. Ways of reducing deflection include adding extra layers of plywood underlayment or installing additional support under the floor framing.

Background

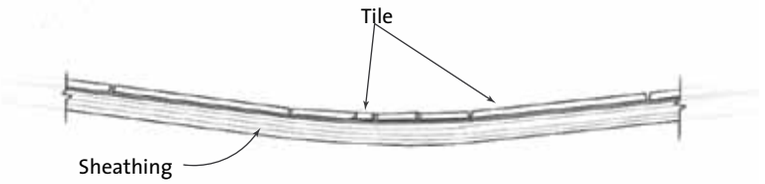
While many factors can contribute to an installation failure, we believe that the localized bending or curvature of the subfloor–underlayment assembly produced by vertical loads can lead to tile and grout cracks. When cracked tiles are observed, it is common for them to be above a joist and run (generally) parallel to the joist. This crack pattern is physical evidence that the subfloor and underlayment on top of the joists experienced enough curvature to break the brittle materials above.

The term "curvature" in this discussion relates to how much an originally flat surface is "bent." For example, the surface of the earth has only a slight curvature, whereas a basketball has extreme curvature relative to the earth. Excessive curvature under a tile is shown in the drawing below. When installing tile over double wood floor systems, we believe the two-layer wood substrate under service loads should have minimum curvature in order to prevent tile and grout cracking. How, then, can we position the underlayment relative to the subfloor to yield an area having the least curvature when loaded in service?

Intuition can be misleading

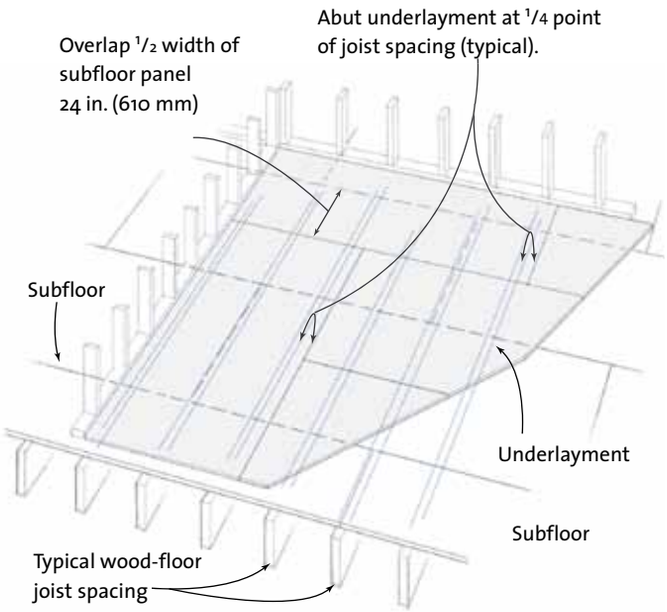
Aside from the instructions in the TCA *Handbook*, many contractors butt the underlayment end joints directly over the joists because their intuition leads them to believe it's the best way. The logic might be, after all, that since you always butt the subfloor end joints on a joist for the obvious support, why not butt the underlayment end joints on a joist as well? We believe that this logic is flawed for a brittle surface covering because the curvature of the subfloor is the greatest directly over the joist where there is no help from the butted underlayment. This non-intuitive fact stems from the bending stress diagram of continuous beams.

If you apply bridge design principles to underlayment placement, the goal is to place the underlayment end joint splice at a point where the bending stresses in the subfloor are relatively low. The idea presented here is to have two layers of sheathing at those points where the



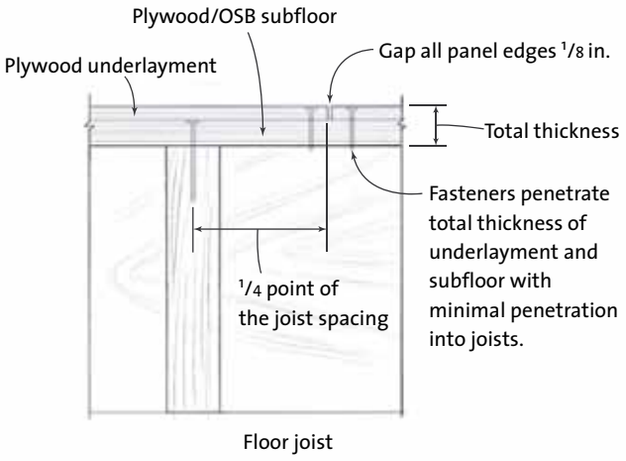
Excessive curvature under a tile duct, due to the bending of the floor sheathing from service loads, can produce cracked tile and grout.

bending stresses are greatest—over the joists. We thus propose the "¼-point rule" for the placement of underlayment end joint butts. For example, abut underlayment panels on either side of the joist centerline at 4 in. for 16-in. on-center joists, 5 in. for 19.2-in. o.c. joists, or 6 in. for 24-in. o.c. joists. Underlayment end joints should be placed as far away from subfloor end joints as possible. The end joint butt positioning is depicted in the drawing at right.



Edge joint offset

While the TCA *Handbook* and American Plywood Association (APA) literature permit the edge joints of the subfloor and underlayment panels to be as close as 2 in., we believe the underlayment should overlap the edge joints of the subfloor by one-half the width of the subfloor panel (that is, 24 in.) to prevent potential damaging curvature from occurring between the sides of adjoining panels. This practice simply requires that the first set of underlayment panels be ripped lengthwise (no extra materials should be required).



General recommendations for underlayment

To assist contractors and installers, we've summarized our ideas for underlayment placement and orientation; panel end, edge, and perimeter gaps; and nailing. The recommendations given for nailing are more conservative than specified in ANSI A108-1999, Section AN-3.4.1.3, which states, "locate nails at 6-inch centers along panel edges and 8-inch centers each way throughout the panel." Closer nail spacing as given in Table 1 on p. 198 will better guard against voids between

the subfloor and underlayment sheathing panels, improve the composite action of the two layers of sheathing, thus reducing sheathing curvature under service loads, and increase the buckling resistance of the underlayment, thereby minimizing the potential for buckling of the underlayment due to seasonal moisture-content changes. This closer fastener spacing also eliminates the need for panel adhesive between the underlayment panels and the subfloor. The potential value of this practice is important to note, as the use of panel adhesive can be problematic if not applied properly. Many panel adhesives are applied with a caulking gun and can skin over quickly. In this type of adhesive application, the underlayment panels may rest on top of skinned-over "beads" of adhesive, creating voids between the underlayment panels and the subfloor. Any gap between the two sheathing layers will reduce the shear stiffness of the nail or screw connections, and thus to some extent reduce the composite action of the sheathing layers. In this case, the adhesive can create more problems than it solves.

Place underlayment panels (Exposure 1, plugged-face plywood of minimum ⅜-in. thickness) such that the following conditions are met:

- Butt all underlayment end joints at the ¼-point between joists. Underlayment end joints should be placed as far away from subfloor end joints as possible.
- Underlayment should overlap edge joints of subfloor by one-half the width of the subfloor panel. At restraining surfaces, overlap may be less than 24 in. when the subfloor panel is less than 48 in. wide.
- Gap underlayment panels ⅛ in. on all ends and edges and ¼ in. at perimeter walls, cabinetry, or other restraining surfaces.

TABLE 1. Maximum on-center fastener spacings for installing underlayment panels. Minimum thickness of underlayment should be obtained from the latest edition of the TCA *Handbook*.

Plywood Grades	Plywood Thickness (in.)	Maximum On-Center Fastener Spacing (in.)	
		PANEL EDGES	FIELD
Exposure 1, plugged-face plywood	⅜	4	6
	½	4	6
	Greater than ½	6	6