Position of Underlayment to Prevent Cracked Tile and Grout

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Introduction

The *2003–2004 Tile Council of America's (TCA) Handbook for Ceramic Tile Installation* contains numerous details for a double layer wood floor system supporting ceramic tile. The thicknesses of the subfloor and under- layment are given in each case. Specific guidance on where to butt the underlayment end joints is not given for any detail. For example, for F142-03, the *TCA Handbook* states, "offset end and edge joints of the underlayment panels by at least two inches from the joints of subfloor panels; they should not coincide with framing below." It further states, "underlayment fasteners should not penetrate joists below." In the case of F150-03, the offsetting is not mentioned, but it does

state, "underlayment fasteners should not penetrate joists below." The same holds true for F155; however, it also states, "face grain of plywood should run perpendicular to trusses, I-joists, or sawn lumber for maximum stiffness." 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.

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 depicted in **Figure 1**. 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?

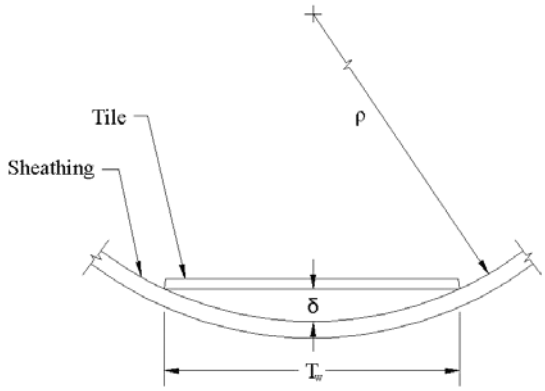

Figure 1.—Excessive curvature under a tile due to the bending of the floor sheathing from service loads can produce cracked tile and grout.

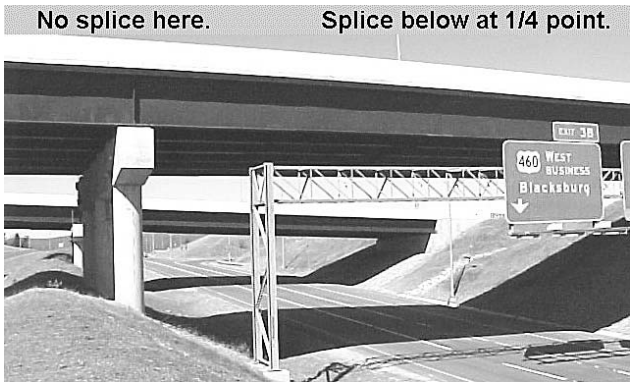

Figure 2.—A two-span highway bridge is shown. Note, though difficult to see in the photo, the splice in the steel beam is placed to the left of the Blacksburg sign, and not at the center concrete pier support. The dark line above concrete support is not a splice, but rather a web stiffener. Engineers splice their multi-span beams near the 1/4-points of spans where the bending stress is low. By analogy, it is logical to butt underlayment near the 1/4-points of the sheathing span between the floor joists.

Intuition Can Mislead

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 sub-floor 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.

How Beams (or Floor Sheathing) Bend

Figure 2 shows a two-span highway bridge near Blacksburg, Virginia. (This beam is analogous to a half sheet of plywood on joists at 24 in. on center.) Note that the beam is not spliced over the center support, but, rather, that it is spliced at the 1/4-point of the right span to the left of the Blacksburg sign (The dark line in **Fig. 2** above the pier support is a web stiffener, not a splice). If a two-span beam is spliced, it will generally be spliced near the 1/4 point of the span. Knowing that a splice is the weak point of a beam, why would highway engineers make the splice near the 1/4-point? The answer lies in the bending stress diagram under various loading conditions. As vehicles pass across the bridge, the stress diagram changes much like the stress that might be produced by a heavily loaded dolly in a house. In general, the stress at the center support is the highest where the curvature is maximum. At about the 1/4-point of the span, the stress is much lower relative to the center support location. Near the center of the right span, the stress and corresponding curvature increases again. The next time you drive past a 2-span or 3-span bridge, notice where the splices are: at the 1/4-points, not over the piers.

Underlayment End Joint Butt Rule

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 herein is to have two layers of sheathing at those points where the bending

stresses are greatest – over the joists. Thus, we propose the "1/4-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. on center joists, or 6 in. for 24 in. on center joists. Underlayment end joints should be placed as far away from subfloor end joints as possible. The end joint butt positioning is depicted in **Figure 3**.

Panel Edge Joint Offset Recommendation

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 1/2 the width of the subfloor panel, i.e., 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 the contractor, we have 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…" The closer nail spacing in **Table 1** will better guard against voids between the subfloor and underlayment sheathing layers, improve the composite action of the two layers of sheathing thus reducing sheathing curvature under service loads, and it will increase the buckling resistance of the underlayment thereby minimizing the potential for buckling of the underlayment due to seasonal moisture content changes.

Place underlayment panels (Exposure 1, plugged-face plywood of minimum 3/8-in. thickness) such that the following conditions are met:

1. Butt all underlayment end joints at 1/4-points between joists as depicted in **Figure 3**. Example: Butt underlayment panels on either side of the joist centerline at: 4 in. for 16 in. on center joists, 5 in. for 19.2 in. on center joists, or 6 in. for 24 in. on center joists. Underlayment end joints should be placed as far away from subfloor end joints as possible.
2. Underlayment to overlap edge joints of subfloor by 1/2 of the width of the subfloor panel (24 in.). At restraining surfaces, overlap may be less than the 24 in. when the subfloor panel is less than 48 in. wide.
3. Gap underlayment panels 1/8 in. on all ends and edges, and 1/4 in. at perimeter walls, cabinetry, or other restraining surfaces.

Description of the type of plywood underlayment and the recommended fastening schedule are given in **Table 1**. The following guidelines are recommended when fastening underlayment panels:

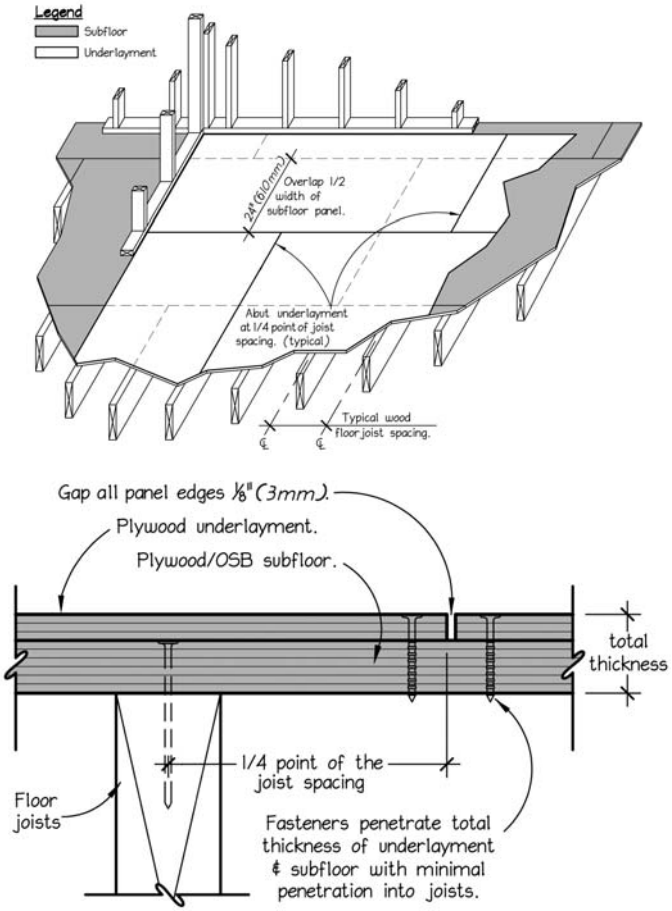

Figure 3.—This detail shows how underlayment butt joints should be placed relative to the subfloor butt joints in a tile installation. The underlayment butt joints are located at the 1/4-point of the span between joists, thus two layers of sheathing are present over the joists to take the "heat" from heavy floor loads.

Table 1.—Plywood underlayment grade, thickness, and fastener schedule guidelines. Minimum thickness of underlayment should be obtained from the *TCA Handbook*.

Plywood grades	Plywood thickness (in.)	Maximum On center fastener spacing (in.)	
		Panel edges	Field
Exposure 1, plugged-face plywood	3/8	4	6
	1/2	4	6
	Greater than 1/2	6	6

1. Use ring-shank nails or screws (no drywall screws).
2. Fasteners should pass through entire thickness of underlayment and sub-floor panels with minimal or no penetration into joists.

Summary

The recommendations for the placing of underlayment end joint butts at the 1/4-points of the sheathing span and as far away as possible from the subfloor end joints should

mitigate the detrimental effects that butted sections of underlayment have on the bending stiffness of the sheathing cross-section. The idea presented herein is to place end joint butts at the location where the integrity from the underlayment panel is least needed, and thus the full capacity of the underlayment panel is available over the joists. The procedures presented will not solve all of the problems that stem from the curvature or bending of double wood floor installations, but we believe it will greatly reduce the number of problems stemming from the wood sheathing.

The causative factors of tile and grout cracking on wood support systems are numerous and complicated. In this article, ideas were presented for consideration by architects, builders, and tile contractors that should increase the likelihood of excellent in-service performance of tile installations while not significantly increasing the labor or material costs of the installation.

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