Tiling Over Plywood Subfloors

For crack-free floors, limit joist deflection and install two layers of ¾-inch plywood and a thinset membrane

by Michael Byrne

A tile installation is a durable cladding, not a structural system. It depends on a sturdy and stable base for longevity. Because wood structures expand and contract with changes in humidity — and because they are inherently flexible — they are not ideal for tile. If they aren't carefully designed and built, flexing and deflection can cause tiles to crack or shear off the setting bed.

While a 2-inch mortar bed remains my first choice as a setting bed in wood-frame construction, the next best option is a double-plywood substrate (**see Figure 1, page 2**). The only problem is that plywood's rate of expansion and contraction far outstrips that of ceramic tile, which makes plywood a difficult bonding surface. Fortunately, the bonding problem is easily solved with the application of a load-bearing membrane system designed for use with tile. The combination of double-layer ¾-inch plywood and a membrane can be used for all ceramic tiles and many stone tiles. This installation method — which I'll demonstrate in this article — is a stronger version of Tile Council of North America Methods F149, F150, and F160, by virtue of the thicker sheets of plywood used and the addition of the membrane system.

Structural Requirements

Modern thinset tile installations using tiles smaller than 10 by 10 inches are generally designed to withstand a relatively small amount of deflection, referred to as L/360 (L designates the span of the floor joists in inches). This means that a 30-foot — or 360-inch — span can safely deflect 1 inch (360/360=1). But because the tile industry recognizes both uniform and concentrated loading, the L/360 standard also applies to the amount of deflection in the subfloor between two joists.

While many sawn or engineered floor systems claim to meet all the L/360 requirements necessary for tiling, their claims are based on uniform deflection only — not concentrated deflection of the subflooring between joists (see "Uniform vs. Concentrated Deflection," page 3). For example, deflection between joists installed at 24 inches on-center cannot exceed .067 inch, or a bit more than 1⁄16 inch. Many subfloors, even those made from 3⁄4-inch nominal exterior-grade plywood, cannot meet the L/360 deflection standard when installed over 24-inch joist spacing.

With some natural stone tiles — which do not have the same uniformity of strength as manufactured ceramic tiles — an even stiffer structure and subflooring are required. For most stone tiles the maximum allowable deflection is L/720 — or even less for some types of stone.

Laminated Plywood Setting Bed

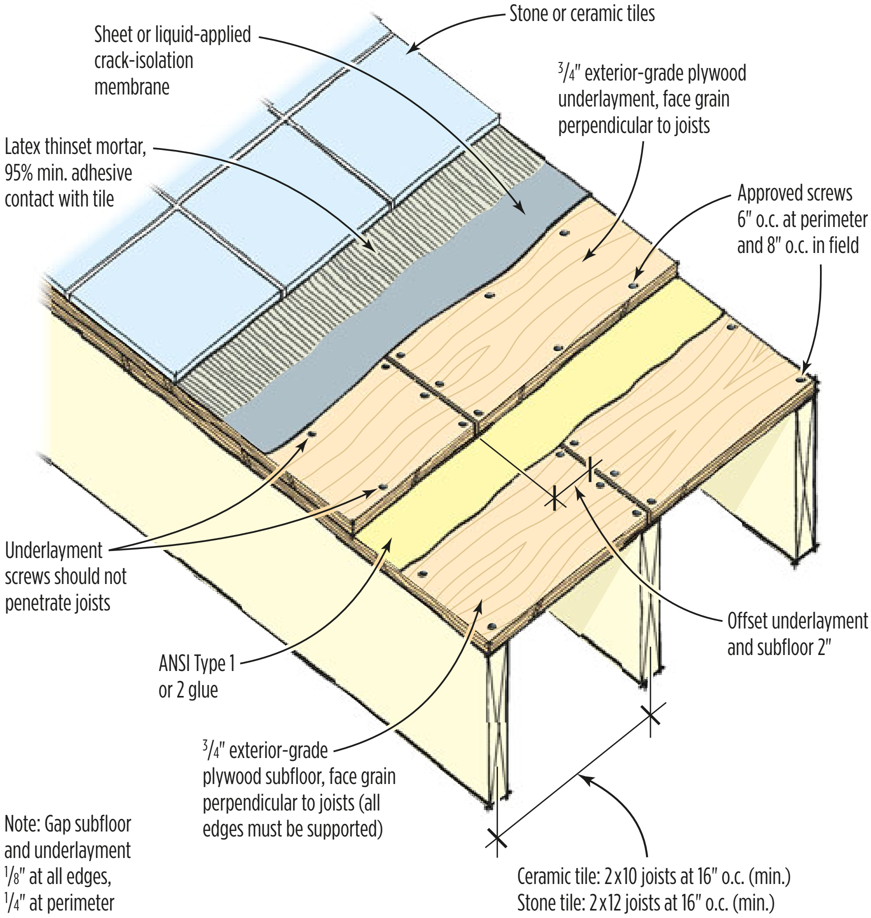


Figure 1. Because it is considerably stronger than the combination of plywood and backerboard, a double layer of 3⁄4-inch plywood covered with a membrane is the author's first choice for thin-bed tile floors. For extra strength on stone installations, or wherever deflection is an issue, the two plywood layers should be screwed and glued before the membrane is installed.

Joist sizing. Examining the joist size, spacing, and span is the first step in determining whether a structural surface can be tiled. For either ceramic or stone tiles, I generally recommend 2x12 joists in new construction, with unsupported spans no longer than 10 feet. I consider 2x10s the minimum joist size for ceramic tile. While I prefer 16-inch joist spacing for most tile installations, I usually specify 12-inch spacing for stone installations.

On some remodeling projects, it may be possible to sister new 2x10s or 2x12s to the existing joists to increase the strength and stiffness of the floor, or to add new joists centered between the existing ones. Sometimes structural deficiencies can be overcome through the use of a crack-isolation system. But without a strong floor structure, an isolation membrane alone cannot ensure a durable tile installation.

Joist blocking. Even though blocking and strapping have not been required for dimensional lumber or wood I-joist floor systems for some time, I still recommend the practice under floors receiving ceramic or stone tiles.

Subflooring. The subfloor needs to be flat and level, just as it should be for any tile installation. Tiles smaller than 10 inches on any edge need subsurfaces that are flat and level to within 1⁄4 inch in 10 feet, with no abrupt irregularities greater than 1⁄32 inch in 12 inches. Since larger tiles do not conform as easily to irregular surfaces, they require an even stricter standard, depending on the size of the tile.

For maximum strength, the face grain of the plywood used for both the subflooring and the underlayment should be oriented perpendicular to the joists. A detail often overlooked is a 1⁄8-inch minimum gap between subflooring sheets (T&G or square-edged) and a 1⁄4-inch gap around the perimeter.

I use plywood with an APA rating of

Uniform vs. Concentrated Deflection

For ceramic and stone tile installations, two different kinds of floor deflection must be measured: uniform and concentrated. Uniform deflection is the movement of the subflooring or setting bed as measured across the entire floor span when a load is spread evenly over the floor. Concentrated deflection is the movement of the subfloor or setting bed measured between two joists under a concentrated, or point, load.

In simple terms, deflection is the amount of sag or bounce that results from loading a particular floor with home furnishings, office equipment, people, and whatever else usually occupies the space. For ceramic tiles and some stone tiles, allowable deflection is usually limited to L/360; that is, the maximum deflection of the floor under tile cannot exceed 1/360th of the length (L) of the span.

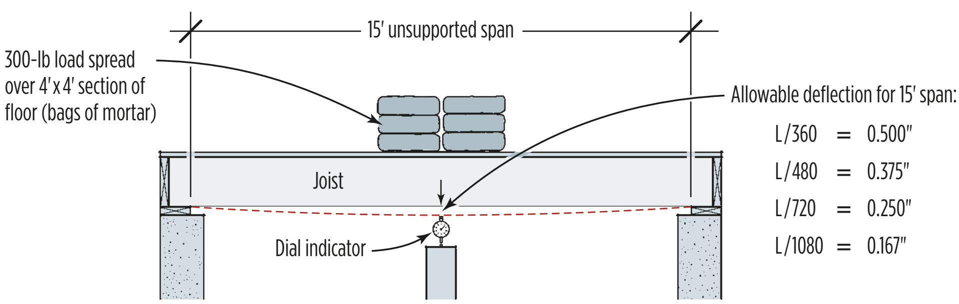
When measuring uniform deflection, the span is the overall length of the floor from one support to the other. When measuring concentrated deflection in a wood floor, the span is the clearance between two joists. So for a 30-foot (360-inch) span, L/360 deflection is 360 inches ÷ 360, or 1 inch. Allowable deflection between joists on 16-inch centers would be 14.5 inches ÷ 360 or .040 inch, just under 3/64 inch.

To test uniform deflection, I typically load a 4-square-foot area at the center of the span directly over two joists. Using tile, sacks of mortar, or water containers, I place at least 300 pounds on the floor and measure the movement with a dial indicator positioned below one of the joists. (You might also use a laser, but it would not be as accurate as my indicator, which has a .001-inch readout up to 1 inch.)

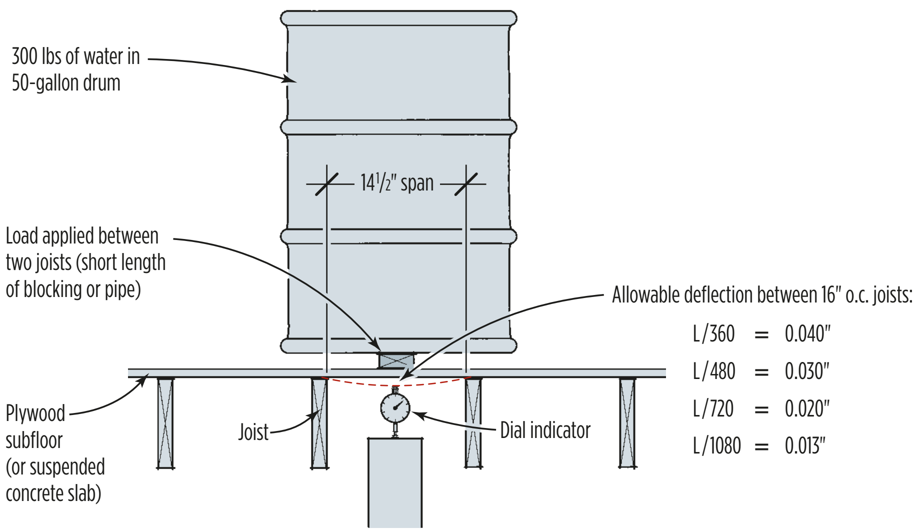
To measure concentrated deflection, the load must be positioned so that it bears midway between joists. Be aware that floor systems that meet ceramic tile's L/360 requirement for uniform loading may fail the concentrated loading test. Stone tiles may require L/480 to L/1080, depending on stone type and thickness.

Uniform and Concentrated Loads

Uniform Loading



Concentrated Loading



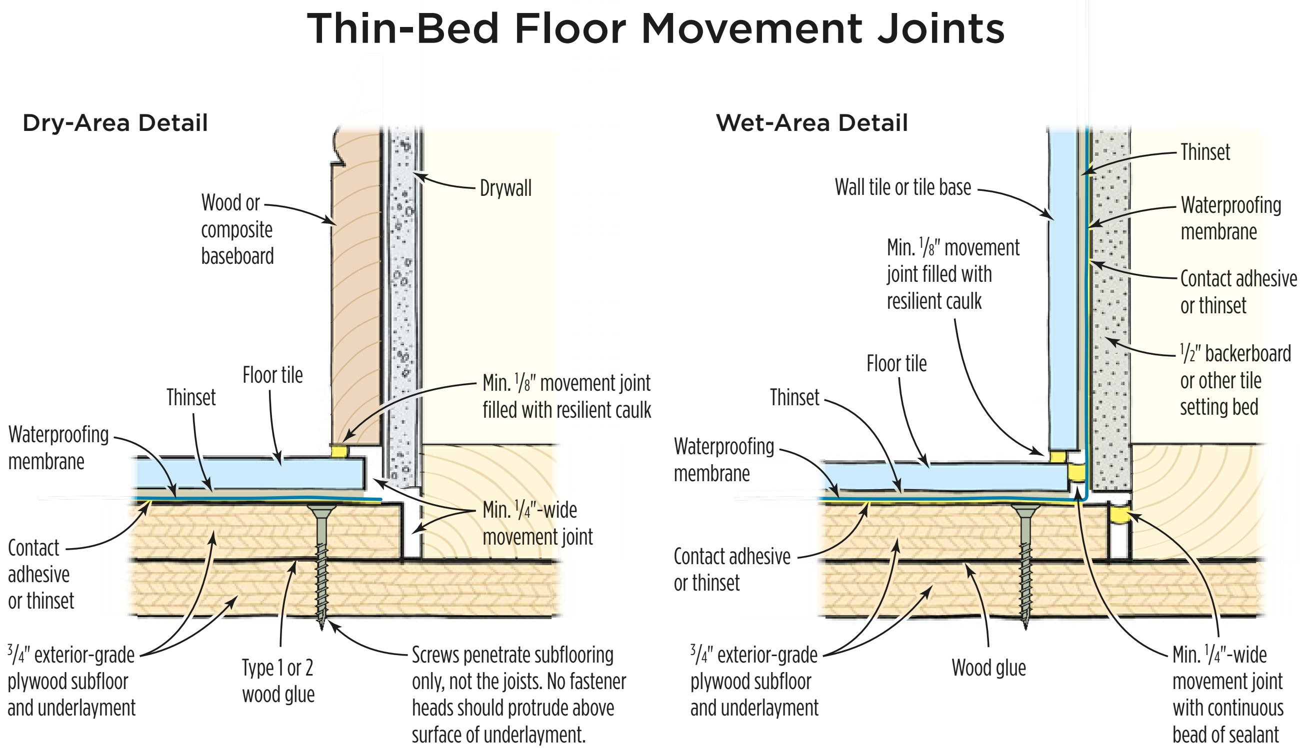


Figure 2. On wood construction, all movement joints must extend from the top of the subfloor to the top of the tile.

Figure 3. To achieve maximum strength and smoothness, 95 percent to 100 percent of the entire plywood surface must be covered with ANSI Type 1 or 2 water-resistant wood glue. At the perimeter of the floor, to avoid squeeze-over into the movement-joint slot, the author keeps the glue about 1/2 inch from the wall.

Exterior or Exposure 1, typically designated EGP (exterior glue plywood) by the tile industry.

Installing the 3/4-Inch Underlayment

For the best results, offset the underlayment joints so that they lie midway between the subflooring joints (a minimum 2-inch offset is required). To avoid problems down the road with cracked joints and loose tiles, don't fit the plywood too tightly around the perimeter or wherever there's a baseboard, tub, or other hard restraining surface. It's important to provide enough space at these locations for a movement joint (**Figure 2**).

For residential work, the minimum movement joint between the underlayment and tile layers and any restraining surfaces is 1/8 inch (1/4 inch is recommended). Movement-joint gaps are typically also required across thresholds between rooms, but the membrane used on this floor made those unnecessary.

Glue and screw. The underlayment should be fully laminated to the subflooring with a water-resistant (ANSI Type 1 or 2) wood glue spread uniformly over 100 percent of the subfloor surface with a $\frac{3}{32}$-inch U-notch trowel (**Figure 3, page 4**). For the project shown here, I used Titebond III, an ANSI Type 1 glue.

Always use a continuous layer of glue — not ribbons of adhesive squeezed from a tube. Ribbons of adhesive support only a portion of the plywood sheet and result in numerous air pockets between plywood panels that can severely reduce a floor's compressive strength.

Before spreading any glue, I do a quick layout and snap chalk lines on the subfloor (glue usually won't obliterate chalk lines). I spread only enough glue for one sheet of plywood, drop the plywood sheet into position, and secure it with $1\frac{5}{8}$-inch coated cement-board screws, spaced every 6 inches around the perimeter and every 8 inches within the field of each sheet. I start at one panel edge and work across to the other. (Working two ends toward the center of the panel can cause the underlayment to buckle in the middle.) It's critical that the screws penetrate the subflooring only, not the joists.

To ensure full coverage, I spread the glue a few inches beyond the perimeter of the first underlayment sheet (**Figure 4**). Once the first plywood sheet is properly aligned and secured with screws, the remaining whole and cut panels are glued and screwed. For greater efficiency, I install whole plywood sheets first and then, starting with the largest and working down to the smallest, fill in the remaining voids.

For this work — and all the other repetitive fastening tasks that are an essential part of a backerboard or plywood installation — I use a stand-up magazine-loading backerboard screw system called Quik Drive (800/999-5099, strongtie.com), which allows me to do in minutes what would take

Figure 4. The plywood underlayment is partially installed. Note that glue was spread a few inches beyond the footprint of the plywood sheets. As subsequent boards are secured, any exposed glue not covered within five minutes or so should be removed with a scraper and damp sponge.

Figure 5. Using a stand-up screw gun with quick-loading 22-screw clips is substantially faster than shooting individual screws. It's also much easier on the knees.

Figure 6. For maximum waterproofing protection, the author installs factory-made accessories like these corner pieces. He works the inside corner (left) and outside corner pieces (right) into the contact cement with his fingers.

Figure 7. To speed up sheet membrane installation, the author cuts, dry-fits, and folds all sections before applying adhesive. First, he positions the cut sheet (top), secures the back of the sheet with weighted buckets, and lifts it out of the way (above). He folds the loose end back, weighing it down with tiles (right) while he prepares to spread adhesive.

hours with an ordinary screw gun (**Figure 5, page 5**). In addition to being fast, a stand-up screw gun keeps me off my knees.

After a quick check to see that no fastener heads protrude above the surface of the underlayment — and after the floor has been vacuumed clean — I snap a few more layout lines to guide the placement of the sheet membrane.

Sheet Membrane

There are many types of membranes available for tiling, with varying levels of performance. Where strength is an issue and maximum protection is desired, I prefer a system I have used since the 1980s called NobleSeal TS (800/878-5788, noblecompany.com). NobleSeal TS offers both crack isolation and waterproofing, so it's perfect for the job shown here, which included a bathroom and small kitchen area.

Thinset vs. contact adhesive. This membrane can be installed with either a latex thinset mortar or a special contact-type adhesive supplied by the manufacturer. When you're working with a thinset mortar, repositioning the sheet is easy, because the thinset remains plastic for up to an hour, depending on the brand.

However, I prefer to use Noble's contact adhesive, because it's faster: I can begin installing tiles immediately after the membrane is laminated to the floor without having to wait for thinset mortar to cure. The problem with this cement is that it is almost impossible to reposition the sheet after initial adhesion without destroying it. That's why I use the following technique, which ensures that each sheet goes where I want it.

Surface prep. As with liquid membranes, no work should begin until the setting bed surface meets all the surface prep requirements for flatness and surface texture.

Installation. Before installation begins, the tiles and all installation materials should be on site and acclimated. I also verify that the setting bed is flat to within

¼ inch in 10 feet for tiles up to 8 inches on a side (larger tiles require a flatter setting bed).

When working with this sheet membrane, the first step is to plot enough layout lines to guide the membrane sections. (NobleSeal TS is available in 5-foot-wide by 100-foot-long rolls.) The next step is to install any accessory pieces that might be needed, such as inside or outside corner patches, using contact cement (**Figure 6, page 5**). To simplify this task, I use a small notched hand spreader to lay down the contact cement and press each piece into position.

To speed up the process, I cut, fold, dry-fit, and stage all the sheet sections needed to complete an installation before I spread any adhesive. With that done, I position the first sheet and weigh down the back of it with heavy buckets. Next, I drape the front part of the sheet out of the way, and use more weight to secure the loose end while I spread the contact cement (**Figure 7, page 6**), which I do with a ⅛-inch V-notch trowel to get even coverage.

After waiting 10 to 20 minutes for the cement to become tacky, I carefully unfurl the loose end of the sheet over the cement and laminate it to the floor with a short straightedge (**Figure 8**). A trowel or a heavy floor roller can also be used for this task. Once the front of the sheet has been

Figure 8. When the contact cement becomes tacky (which takes about 10 to 20 minutes), the author unfolds the loose end of the membrane (top) and laminates the sheet with a straightedge (above). With the front of the sheet laminated, he pulls the back portion forward and spreads contact cement for the rest of the sheet (left).

Figure 9. For a flat and leakproof seam in the sheet membrane, the author lays down two beads of manufacturer-supplied sealant (above) and flattens the seam with a straightedge (left). Sealant squeeze-out indicates the seam is closed.

Figure 10. Once the membrane has been installed with Noble's contact-type adhesive, tile layout and installation should follow as soon as possible to lessen the risk that the membrane surface will get dirty or damaged.

laminated, I pull the back portion forward and weigh it down while I spread cement on the rear portion of the floor. When this cement is tacky, I carefully ease the remainder of the sheet into position and laminate it to the floor.

When more than one course of the TS membrane is needed, I use Noble's sealant to join the two sheets. For both waterproofing and crack isolation, the seam must be leakproof and sit perfectly flat against the surface. The product shown here has 2-inch-wide seams. Following the manufacturer's instructions, I apply two $\frac{1}{8}$-inch beads of NobleSealant 150 at the lap (never use silicone, which releases from the sheet once it has cured). I then use a short straightedge to flatten the seam, looking for a small amount of squeeze-out to tell me the seam is closed (**Figure 9**).

Follow Immediately With Tile

With the membrane installation complete, the tiles now have a structurally sound, stable, and waterproof base. A double layer of $\frac{3}{4}$-inch exterior-grade plywood, glued and screwed, installed over 2x12 joists on 16-inch centers, and covered with this type of membrane should meet the demands of even an L/720 installation (stiff enough for most stone tile).

Keep in mind, though, that many careful membrane installations have been ruined when the surface of the freshly installed membrane was exposed to dust, overspray, and other contaminants or used as a walkway before it could be covered with tiles. It is imperative that the surface of any membrane or setting bed material be preserved in its virgin state to allow for the strongest possible adhesive bond. It's best to install the tile immediately (**Figure 10**).

*Contributing editor **Michael Byrne** is a tile setter, moderator of the tile forum at jlc online.com, and author of the recently released* Tiling for Contractors, *from which this article was adapted.*