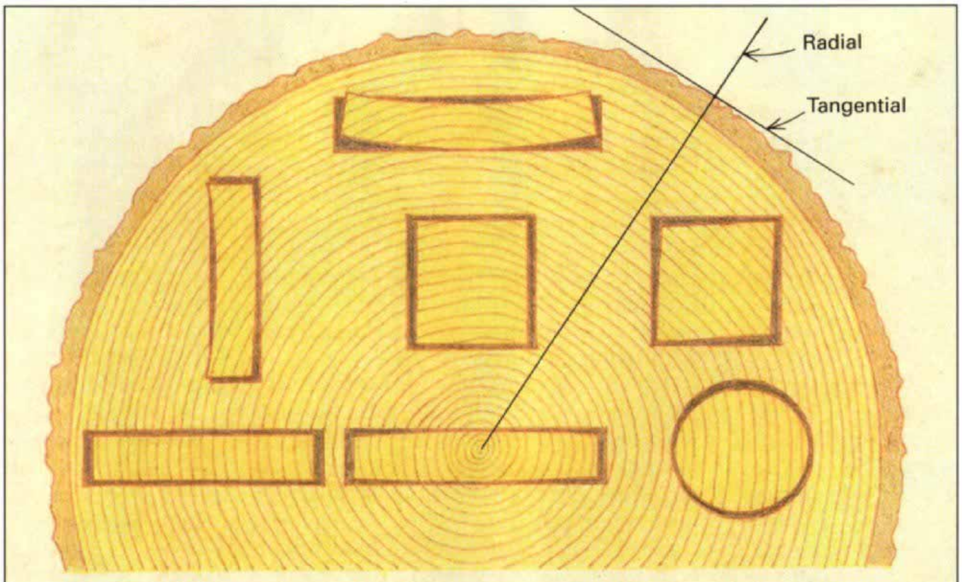


From log to lumber. *Lumber shrinks and changes shape as it dries. It shrinks about twice as much tangentially as it does radially. Those differences acting in concert produce cupping and warping, depending on where in the log the lumber was cut from.*

Detailing for Wood Shrinkage

If you think ahead, you can avoid nail pops, cracked drywall and sloping floors

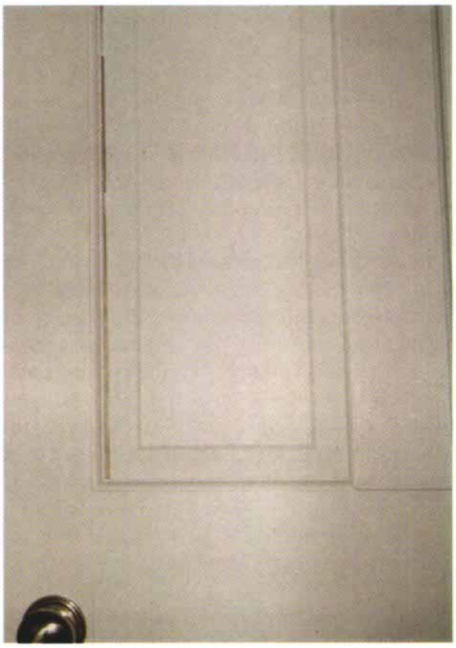
by Stephen Smulski

On a still night, people living in a new house often hear a loud creak or snap. They reassure themselves the house is just settling. But wood-frame houses don't really settle. They shrink.

A typical two-story, platform-framed house will shrink about ¾ in. in height after it is built (top drawing, facing page). Most of that shrinkage takes place in the first heating season as framing lumber gradually dries out. Builders are often called back to make minor repairs or adjustments that result from this first-year shrinkage.

Stairs might squeak. Nail heads pop through drywall. Doors no longer fit, or they show paint lines where panels have shrunk (photo right). Builders can disguise the movement, or build around it, but they can't stop it. By accommodating wood movement, in the design and during construction, most problems can be avoided.

Wood and water—In a tree, wood is saturated with water. Some of it fills the cavities of wood's hollow, strawlike cells; some of it swells the cell walls. To increase wood's stiffness, strength, dimensional stability and usefulness, the water must be removed. When wood is dried—either in a kiln or outside in a stickered pile—water evaporates first from cell cavities. But even when all that water is gone, the lumber is the same size.



Shrinking door panel. **This interior door panel was painted when its moisture content was relatively high. When lower relative humidity allowed the panel to shrink, the paint line was exposed.**

Only when water starts to leave swollen cell walls do dimensions start to diminish.

Moisture content (MC) is the amount of water in wood, described as a percentage of the wood's oven-dry weight. Minimum dimensions are reached when wood is oven-dry, or at 0% MC. For almost all kinds of unfinished wood, shrinkage begins when moisture content falls below about 30% (called the fiber-saturation point). Below this point, the amount of shrinkage is directly proportional to the moisture loss. (The converse is true when dry wood picks up water and swells.) Typically, the moisture content of wood in heated buildings ranges from about 4% to 16%, depending on the locale and the time of the year (see sidebar p. 56).

Because wood's strawlike cells are in concentric circles (the growth rings), with their length parallel to the tree trunk, green lumber shrinks by different percentages in length, width and thickness during drying. With the exception of some kinds of abnormal wood, shortening along the grain (longitudinal shrinkage) is only about 0.1% from green to oven-dry. It usually can be ignored. But shrinkage across the grain, whether around the growth rings (tangential shrinkage) or across them (radial shrinkage), is substantial (drawing above). Across-the-grain shrinkage must be accounted for in the design of just about anything made from wood. Though shrinkage values vary widely among wood species, tangential shrinkage averages about 8%, and radial shrinkage about 4%.

Unequal shrinkage (and swelling) in the longitudinal, tangential and radial directions gives rise to bowing, crooking, twisting, cupping and other forms of warpage commonly seen in lumber. Uneven shrinkage is also responsible for the wide checks and splits that open in large timbers used in post-and-beam construction.

Where problems begin—Framing lumber is usually sold with a moisture content of between 15% and 19%, and it is exposed to moisture before and during construction. Once a building is weather-tight and heated, the year-round average moisture content of studs, joists and rafters will fall to about 10%. That's where the ¾-in. loss in height for a year-old house comes from. Virtually all the shortening is due to across-the-grain shrinkage through the depth of the rim joists and the thickness of the wall plates.

Joist and plate shrinkage can buckle plywood siding panels outside or drywall inside, especially in stairwells and spaces with cathedral ceilings. The problem arises when a panel crosses the rim joist between floors so that it's fastened to studs above and below the joist. Vertical shrinkage of studs is virtually nil, but vertical shrinkage of joists and plates can be substantial. A 2x10 will shrink nearly ¼ in. across the grain as its moisture content drops from 19% to 10%. As joists and plates shrink, studs on the two floors are drawn together, crushing or buckling the panel fastened to them.

The solution is to break panels between floors. For drywall used in a stairwell, for example, this may mean using an expansion or control joint at the joist or applying the drywall to resilient metal channels installed on top of the wall studs. Both expansion joints and resilient metal channels provide a buffer between wooden framing members and drywall. The framing can move slightly without crushing or distorting (and thus cracking) drywall. For plywood siding, a gap (which should be flashed) of about ¼ in. at panel ends will provide the same kind of protection against buckling.

Diagonal cracks occasionally appear in drywall at corners over windows and interior doors. In some cases, too many fasteners in the wrong places are to blame; in others, the floor framing is at fault. If drywall is fastened to both the header and the studs around an opening, the header, which is usually wider dimensional lumber installed on edge over a window or a door, will pull on the drywall as it shrinks. Fasteners in the studs resist the downward pull, placing the panel in tension, and presto, a diagonal crack. The remedy is simple: Around door and window openings, fasten drywall to studs only.

Initial framing shrinkage also can lead to roof leaks when chimney flashing is rigidly (and thus incorrectly) connected to both the masonry and the wood frame. In one case history I read, the consequence of initial shrinkage was unhappy tenants. The casement windows on the top floor of a brick-clad, three-story apartment building wouldn't open after the first heating season. The platform-framed floors shrank below the openings in the masonry veneer, trapping the bottom edge of the windows behind the brick.

Why floors tilt—Floor framing plans commonly call for 2x10 joists to rest on top of a central girder made of 2x10s and supported by metal columns. From a shrinkage perspective, the design is flawed. While one end of each joist bears on the 9¼-in. deep girder, the other end rests on a mudsill that's only 1½ in. thick. The deck, though level when built, will slope slightly toward the center of the building after the framing shrinks because of the unequal depths of wood under opposite ends of the joists. Diagonal drywall cracks, racked interior door frames and, in severe cases, separation of interior partitions from floors are possible results.

You can avoid these problems by mounting joists on the face of the girder with metal hangers or by seating them on a ledger attached to a deeper girder. This way the entire deck area will be lowered more uniformly as joists shrink. But beware. There is one trap you can fall into when face-mounting joists to glulams, laminated-veneer lumber or other engineered structural wood beams. These products are typically somewhat drier (around 12% MC to 15% MC) than framing lumber when sold. If you install joists flush with the top of an engineered beam, the joists probably will shrink below the top of that beam later. That creates a ridge in the floor. Mount the joists slightly higher than the top of the girder, at least ⅛ in. but less than ¼ in. This is also a good practice when face mounting the ends of floor joists to built-up girders of deeper 2x material. When the joists shrink, their top edges will become flush with the top of the girder (drawing below left). To avoid a squeaky floor later, don't nail through the plywood subfloor into the girder. One drawback of butting joists into the face of a girder is that electricians and plumbers will find it harder to do their jobs. The bays between joists won't be continuous, so wiring and plumbing will have to be routed under girders.

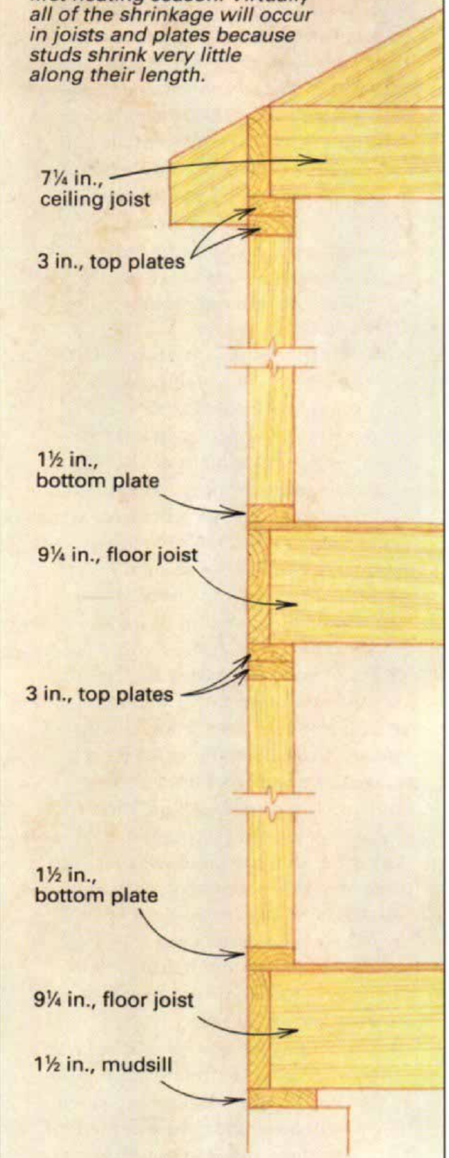
Using a steel carrying beam is another solution. When a 2x nailer is attached to the top of a steel beam, the shrinkage potential is the same as it is for a 2x mudsill sitting on a concrete foundation wall. Floors built this way will sink very slightly and uniformly.

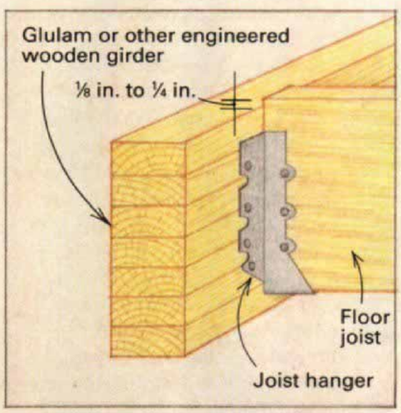
Framing floors with drier, engineered wood I-joists, which shrink minimally after installation, also is a good solution. I-joists are more expensive than 2x dimensional lumber but bridge greater spans for the same depth.

Stopping nail pops—The sight of a nail head or a screw head popping free of a wall or a ceiling is a familiar and annoying problem in drywall installations. It occurs because studs and joists shrink. When first fastened, drywall is driven tightly against framing. As the wood dries and shrinks, it pulls away from the back of the drywall, leaving a small gap between framing and panel. Pressure applied later to the panel closes the gap but may force the fastener head to lift

Potential for shrinkage

A typical two-story, platform-framed house may shrink ¾ in. in height as framing materials dry out in the first heating season. Virtually all of the shrinkage will occur in joists and plates because studs shrink very little along their length.





Keeping floors level

Raising the top edges of 2x floor joists 1/8 in. to 1/4 in. above the top of glulams or other engineered wood beams will help prevent sloping floors as floor joists dry.

Drawings: Vince Babak

taped seams or break through the thin veneer of joint compound that covers it.

Pops are fewer and less pronounced with screws than with nails. First, for the same holding power, screws are shorter than nails, so there is less wood between the screw tip and the framing face to shrink. Second, drywall is less likely to slide along the threaded shank of a drywall screw than it is along a smooth nail.

Pops that appear when outlet and switch covers are screwed down, or when interior trim is applied, may be the result of using too many fasteners or misplacing them. One solution is to avoid using nails and screws immediately around an outlet or a switch box—in other words, don't treat the area like an edge that must be generously fastened. In general, you can reduce the potential for pops by screwing *and* gluing drywall. The Gypsum Association (810 First St. N. E., Washington, D. C. 20002; 202-289-5440), for example, extends its recommended fastener spacing from 16 in. o. c. when only screws are used to 24 in. o. c. when both screws and drywall adhesive are used.

Prevent the nail pop that telegraphs through vinyl sheet flooring by using screws or ring-shank nails. It's also a good idea to recess nail or screw heads as is typically done with drywall. Floor squeaks result when subflooring or stair treads rub against the shanks of fasteners that have popped from joists and stringers or where wood rubs on wood. Happily, prevention is easy. Just lay down a bead of construction adhesive on the joists or stringers before installing subflooring and stair treads, and a gap will never form. Using ring-shank or coated nails seems to help, too.

Nail withdrawal outside—Nail pops occur inside buildings because of the initial shrinkage of wood framing members. But cyclical shrinkage, swelling and warping of exterior siding, trim and decking can completely withdraw nails from wood (top left photo, facing page). The holding power of nails driven into green wood that stays wet, or seasoned wood that stays dry, is essentially unchanged over time. But the withdrawal resistance of nails sunk into green wood that dries in place, or seasoned wood repeatedly wetted and dried, drops substantially over time. As exterior wood swells in thickness, it tries to pull nails straight out. The pulling action is amplified in flat-sawn lumber whose edges lift as the lumber cups. I recently looked at a house where this cyclical cupping of flat-sawn, beveled siding pulled nails out completely. A lack of back-priming (priming the backside of wooden siding), smooth nails that were too short and butt joints that didn't fall over framing members all contributed to this problem.

Decks made from pressure-treated lumber are particularly prone to shrinkage (bottom photo, facing page). Saturated during treatment and sold essentially green, deck boards always shrink in thickness after installation, so nails flush with the surface when driven will later protrude. And regardless of whether the boards are laid bark-side up or not, flat-sawn deck boards almost always cup up because the sun dries their exposed tops faster than their shaded bottoms. Cupping reverses itself when tops are wetted by rain, but this cycle can slowly pry nails from framing.

Reduce the potential for nail withdrawal in exterior wood by using ring-shank nails of proper size or, where appropriate, screws. Apply paint, stain or water repellent as soon as possible to reduce cyclical dimensional changes. When possible, choose quartersawn (vertical-grain) wood rather than flat-sawn wood, and narrow siding patterns rather than wide. Always back-prime siding and use fasteners that penetrate the sheathing and framing at least 1½ in.

You can also minimize moisture content and dimensional changes (top right photo, facing page) by buying siding, trim and treated lumber ahead of time and acclimating it to site conditions before you use it. Keep the wood off the ground under a loosely draped tarp. Or consider trying the newly available engineered wood-fiber and flake-based siding and trim products, which are touted as being more dimensionally stable and resistant to warping than is solid wood.

Solutions to truss rise—While solving old problems, new building technology can also bring new dilemmas with it. Such is the case with the two-decade-old truss-rise bugaboo that causes cracks to open at wall-ceiling junctions under roofs framed with trusses. This heating-season problem is not a structural flaw; however, it is unappealing.

Truss rise is usually associated with long-span trusses (more than 26 ft.) with roof slopes of less than 6-in-12 and where attic insulation is over 8 in. deep. Exposed to essentially the same air temperature and relative humidity, top and bottom truss chords have about the same moisture content for most of the year. But during the heating season, the moisture content of the bottom chords, smothered in insulation and surrounded by warmer air at lower relative humidity, will drop. Meanwhile, the moisture content of the top chords, enveloped in much colder air at higher relative humidity, may increase.

As a result, the bottom chord shortens slightly, and the top chord may grow a bit longer. The truss arches upward, and the bottom chord lifts the drywall with it. Gaps close once the heating season ends as the moisture content of the top and bottom chords equalize. Changes in moisture content don't affect the length of a board very much. But because these trusses span such large distances (26 ft. or more), the effect is very noticeable.

Truss rise can't be stopped, but you can mask truss movement in several ways. One option is to create a floating corner by holding fasteners in ceiling drywall back about 16 in. from partitions (top drawing, p. 58). Then use a drywall clip fastened only to the partition to make the ceiling-wall corner. Or omit the clip and hide the gap by fastening corner molding to the ceiling only. That will hide any movement in the corner by allowing the ceiling to rise slightly without disturbing the wall-ceiling connection.

Another way to mask truss movement is to make partition-truss connections using L-shaped brackets called roof-truss clips. They are attached to the bottom chord of a roof truss with a single

Moisture content changes with humidity levels

The relationship between relative humidity and wood moisture content alters the size of door panels and the width of strip flooring and countertops. That's because wood is a hygroscopic material and exchanges water vapor with air, picking up moisture when atmospheric relative humidity is high and giving it off when relative humidity is low. Because wood swells as it absorbs water and shrinks as it releases water, both its moisture content and dimensions are controlled by the relative humidity of the surrounding air.

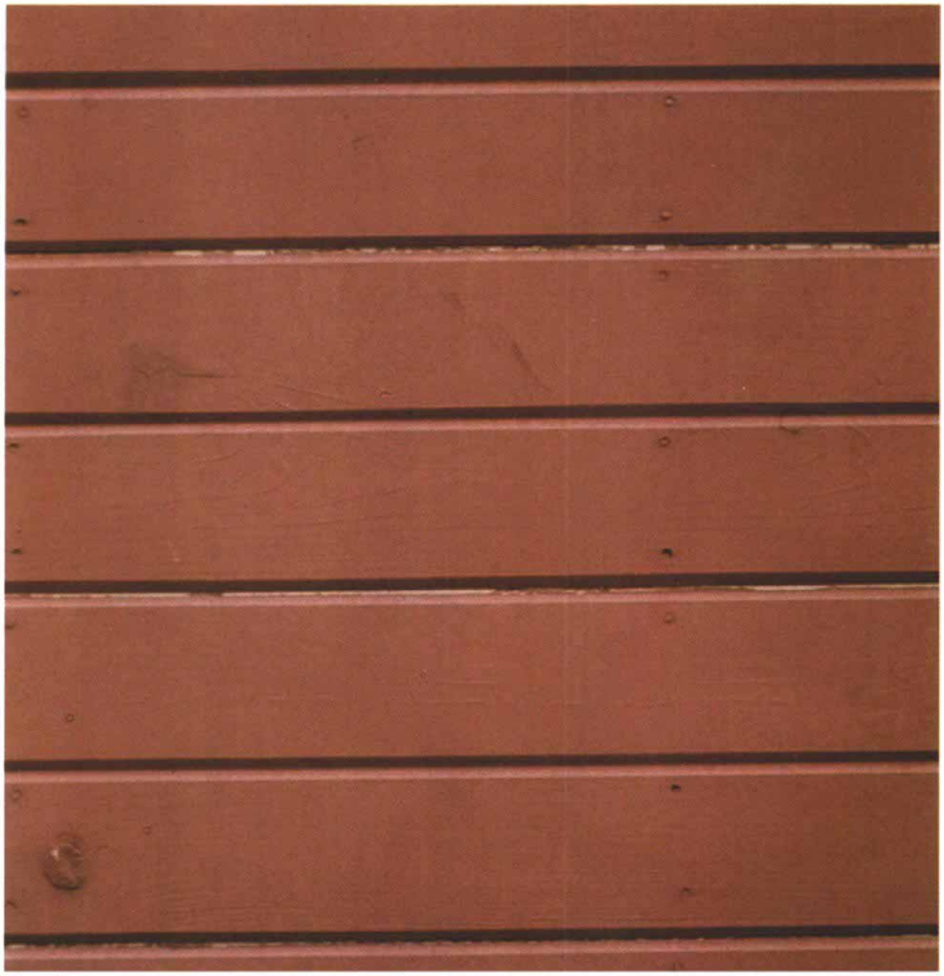
Water vapor is always present in the air. The amount of water vapor that air can hold depends on the air's temperature: Warm air can hold more moisture than cold air can. Except when it is rainy or foggy, air seldom contains the maximum amount of water vapor that it could. Relative humidity is simply the ratio of the amount of water vapor in air at a given temperature to the maximum amount of water vapor the air at that temperature could hold.

Despite wide day-to-day fluctuations, average outdoor relative humidity actually changes little from season to season. As a result, the moisture content of wood used or stored outdoors but protected from direct wetting varies little through the seasons. Inside homes, however, there are wide seasonal swings in relative humidity because air is heated and cooled without humidification or dehumidification. Changes in wood moisture content and dimensions will result.

For example, wood at equilibrium in a room at 70° F with a relative humidity of 40% (typical for whiter in a heated house) will have a moisture content of 7.7%. The same wood in equilibrium in a 70° room with a relative humidity of 70% in summer will have a moisture content of 13.1%. That difference can mean big changes in dimensions, especially in wide boards that might be used in such things as door panels or wooden countertops. Let's take an edge-glued sugar-maple countertop that's 25 in. wide at 13.1% MC. Its width will shrink nearly ⅜ in. when its moisture content falls from 13.1% to 7.7%.

Short of installing a humidifier or a dehumidifier to control relative humidity indoors, the best way to minimize changes in wood moisture content and dimensions is to build with wood that's been conditioned to the average equilibrium moisture content that it will see in service. Then finish the wood with low-permeability coatings. —*S. S.*

Nail pops. **This siding has cupped, pulling out the nails. Back-priming the siding and using longer nails would have helped.**



Exterior siding shrinks. **This T&G wood siding dried out after it was painted, exposing unpainted surfaces between some of the boards. The problem would have been avoided had the wood been allowed to acclimate on site before installation.**

fastener that slides in a slot as the truss arches upward. Here, too, ceiling fasteners are held back 16 in. from partitions.

Never rigidly attach trusses to partitions; this could induce bending forces that trusses weren't designed to carry, or it may cause partitions to be lifted off the floor.

Preventing buckled panels—When plywood, oriented strand board (OSB) and waferboard buckle, it's almost always because the edges were tightly (and thus improperly) butted during installation. Though considerably more stable than solid lumber, wood-based panels are typically much drier (6% MC to 10% MC) when sold and should be expected to increase in size when exposed to outdoor relative humidity during construction. Because panels whose edges are tightly butted can't expand laterally, they accommodate expansion by buckling outward. That's why it's important to space panels according to the recommendation stamped on each sheet, usually ⅛ in. on the ends and at the edges. The H-clips used between panels in roofs framed 24 in. o. c. keep the panels at their correct spacing.

Builders have rightfully complained that when 4x8 panels are spaced as recommended, their ends don't fall on the framing after five or so sheets have been laid end to end. The American Plywood Association listened, and members now produce 47⅞-in. by 95⅞-in. sized-for-spacing panels that do line up with framing.

Drying deck boards. **Pressure-treated lumber is often delivered with a high moisture content and is therefore susceptible to shrinkage after installation. These mitered corners on a deck bench have opened considerably since the wood was installed.**

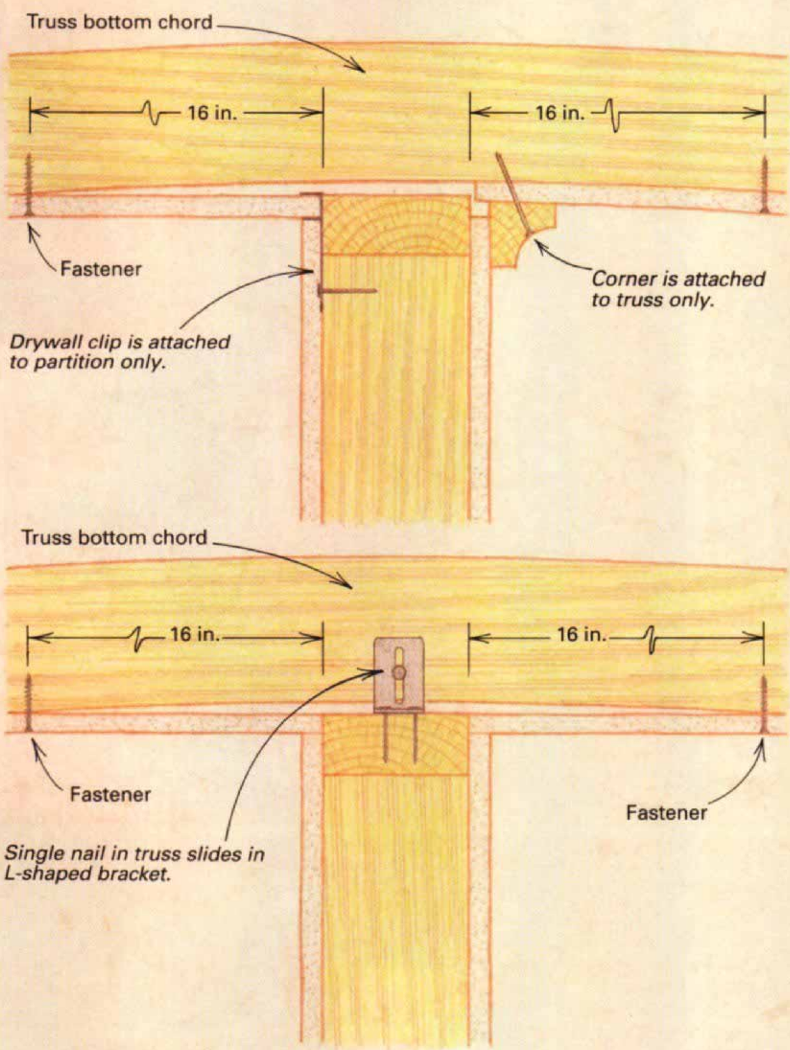
Even when properly spaced, panels soaked by rain during construction or moistened by high relative humidity or condensation in completed attics and crawl spaces can buckle. Buckling occurs more readily with thin panels and long spans and when fasteners miss framing. And because it absorbs water more readily than plywood made from Douglas fir, plywood made from southern yellow pine buckles much faster.

How you fix buckling depends on its cause. With tightly butted panels, create an expansion slot between panels by sawing a kerf along the unspaced edges. Swept free of ponded water, rain-buckled subflooring will usually flatten as it dries. Extra blocking below and a few additional fasteners may be needed to coax the subflooring flat. At least one waferboard maker notches the tongue in its T&G subflooring panels to encourage water to drain. The buckling of roof sheathing before shingles are applied is usually a result of rain. Buckling after roofing is in place often signals an interior moisture source and inadequate attic ventilation.

The best defense against buckling is proper spacing of panels, but using glue, screws and

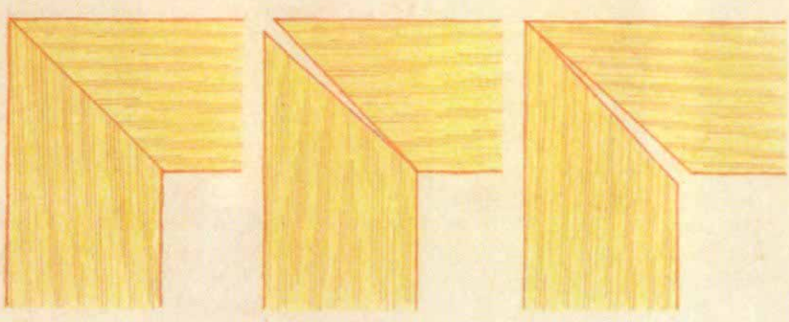
Coping with truss rise

The bottom chord of a roof truss can arch upward when the moisture content of top and bottom chords is different. There are several methods for preventing cracks at the ceiling-wall junction when roof trusses are used.



Moving miters

Miters assembled with wood that is allowed to reach equilibrium moisture content before installation can still move seasonally.



Joint is tight when assembled... but opens at the outside corner as moisture content of the wood rises... and opens at the inside corner as moisture content falls.

ring-shank or coated nails also helps. Buy panels ahead of time, and let them acclimate to site conditions—elevated off the ground under a loosely draped tarp.

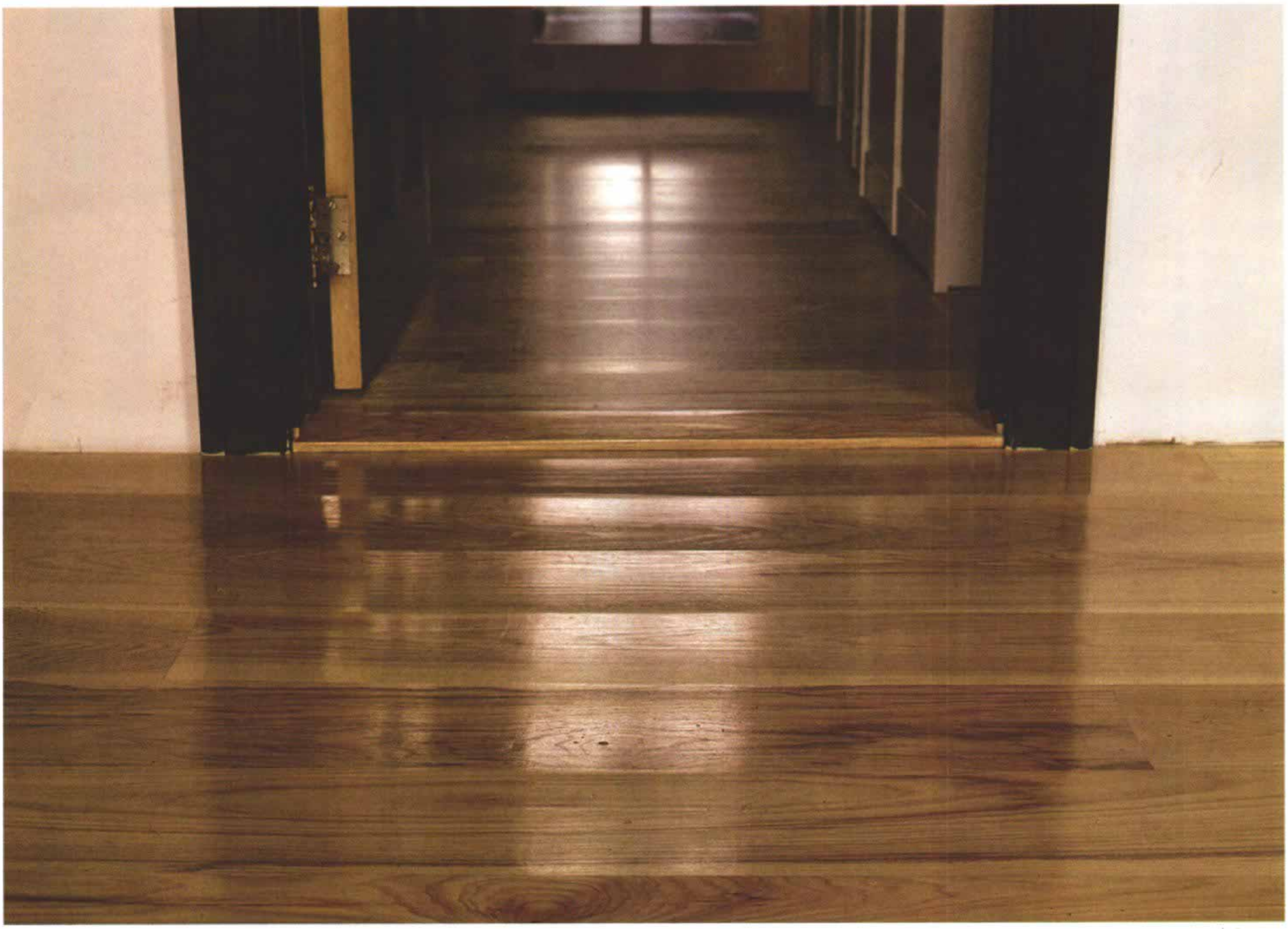
Edge swelling can also occur, especially in OSB and waferboard, because exposed end grain and voids on these panels' edges absorb water much faster than their faces do. Edges that swell after installation may telegraph through roof shingles or vinyl sheet flooring, making a faint outline of the panel permanently visible. Water-based flooring adhesives applied to underlayment can produce the same effect, but here the shadow usually disappears as the water disperses throughout the panel. Most OSB and waferboard makers now edge-seal panels with brightly colored, low-permeability coatings to minimize moisture gain during storage, shipment and construction. If practical, it's also a good idea to seal the edges with a water repellent when you cut the panels.

Coping with seasonal changes—Skillfully executed trim, stairs and floors are the source of a home's beauty, as well as a finish carpenter's pride. But swings in indoor relative humidity are typically wide and can cause perfectly mated joints to yawn and gape. During the dead of winter, indoor relative humidity may drop below 30%. During summer, with windows wide open, relative humidity may rise to the outdoor level of 70% to 80%. The result is that the moisture content of unfinished wood indoors, which averages about 8% year-round, may drop to as low as 4% during the heating season and then climb to as high as 16% in summer.

Rough lumber for millwork and flooring is initially kiln dried to 6% MC to 9% MC, but there's no guarantee that it's going to stay that way during shipment and storage. That's why it's critical that doors, trim, stair parts and flooring be acclimated on site for a few days with indoor temperature and relative humidity near occupancy levels before the wood becomes part of the building. There are many factors at work here—lumber thickness, wood species and even the shape of a piece of wood—so it is hard to be precise about how long it takes for wood to reach moisture equilibrium with its surroundings. In general, give wood that will be used in trim and floors at least four or five days before installing it.

On-site conditioning can minimize wood's seasonal movement, but it can't stop it. Take the case of a mitered corner joint in molding that is tightly closed most of the year (bottom drawing, left). As the width of the trim changes in response to seasonal relative humidity, the joint's outside corner opens in summer; its inside corner opens in winter. I'm skeptical that even a glued spline will keep this joint closed all the time.

Aware that wood movement couldn't be stopped, our woodworking forefathers allowed it to happen harmlessly through judicious design. Framed panel construction, in which a wide, bevel-edged wood panel floats in an oversized groove inside a wood frame, is a classic technique still used today for doors, cabinets and wall panels. Pinned to the frame only at midwidth, the panel is free to expand and contract without unduly pushing or pulling on the frame.



Floors that move. **This 6-in. wide hickory flooring, installed over a damp crawl space, swelled and cupped after installation as it absorbed water from below. The result is a rippled surface. Narrower flooring would have been less likely to cup. And even these wide boards might not have been a problem if they had been sealed on the backside and if steps had been taken to reduce moisture in the crawl space.**

When there isn't enough room inside to accommodate seasonal swelling of the panel, this outward push sometimes is enough to break the joint between rail and stile.

Solid-wood countertops, like the 36-in. wide sugar-maple slab in my kitchen, should have the same freedom to move. I use L-clips that are screwed to the bottom of the counter but are free to slide in a groove cut in the frame of the cabinet. These clips, which are usually available from cabinet-hardware suppliers, keep the counter flat and secure but allow seasonal changes in width.

Floor cracks and ripples—I know of no better advice about wood flooring than that given long ago by an anonymous author at the U. S. Department of Agriculture's Forest Products Laboratory: "The cure for cracks in a floor lies wholly in preventing them."

Except when indoor relative humidity is mechanically controlled, narrow cracks ($\frac{1}{32}$ in. to $\frac{1}{16}$ in. with $2\frac{1}{4}$-in. wide flat-sawn oak) should be expected to open between some courses in wood-strip floors during the heating season. But wide cracks can develop when flooring is allowed to absorb excess moisture before or after installation. Flooring acclimated on site before concrete, masonry, drywall or plaster is thoroughly dry, or before the heating plant is operating, will likely pick up moisture and swell. Edges butted at installation will shrink as the moisture content drops during the first few months of occupancy. By the middle of the first heating season, cracks can become chasms.

Even flooring installed at the proper moisture content can develop wide cracks later if it is allowed to pick up excess moisture before or after finishing in a meagerly heated, unoccupied home. The phenomenon is called compression set. As moisture is absorbed, tightly butted edges prevent strips from widening, so no apparent swelling occurs. In reality, swelling is accommodated by partial crushing of the strips along their edges. Though crushed, a compressed strip will still shrink by the same percentage as an uncompressed strip. Because its swollen width is narrower than that of an uncompressed strip, its shrunken width will be narrower, too, making cracks between compressed strips wider.

Subsequent swelling pressure during later periods of high relative humidity can increase the compression set and the width of cracks. Compression set explains why old wood floors that were mopped with water often have gaping cracks. It's also why wooden tool handles continue to loosen after soaking them in water to tighten them. The tightening is temporary; subsequent drying produces even greater looseness. The solution is to keep flooring (and tool handles) dry so that compression set can't develop.

The edges of plank flooring that picks up moisture on its underside from wet subflooring or humid basements and crawl spaces will cup up and produce a rippled floor (photo above). □

Stephen Smulski runs Wood Science Specialists, Inc., a consulting firm in Shutesbury, Mass., that specializes in solving performance problems with wood products. Photos by the author except where noted.

FOR MORE INFORMATION

Two good books are available that help explain relative humidity, wood moisture content and dimensional change in wood. They are *Understanding Wood* by R. Bruce Hoadley (Taunton Press, 1980) and the USDA Forest Service's Wood Handbook: *Wood As An Engineering Material* (USDA Forest Service Products Laboratory, Madison, Wis. 53705).

Photo this page: Kevin Ireton