BY FRANK WOESTE AND JOSEPH LOFERSKI

Ledger Strips and the Code

Before joist hangers became widely available, ledger strips were commonly used to help support toe-nailed joists, whether the joists were hung from an interior rim joist or flush beam or from an exterior deck ledger. But now builders commonly use joist hangers, and while ledger strips are still OK to use in interior applications, the 2018 edition of the IRC no longer permits their use on exterior decks (2018 IRC R507.6.1).

PRACTICAL ISSUES

As a practical matter, ledger strips used outdoors are required to be pressure treated, typically southern pine (SP) in the mid-Atlantic and Southeast. But according to information from three SP lumber inspection agencies—Southern Pine Inspection Bureau (spib.org), Timber Products (tpinspection.com), and RRA/Southeastern Lumber Manufacturer's Association (slma.org)—as well as our own observations at big-box lumber outlets, stress-rated nominal 2x2 pressure-treated (PT) lumber has not been available in the marketplace for a number of years. Thus, under the previous IRC editions, contractors were faced with a supply issue. One solution is to rip larger sizes of treated 2-by stress-rated material (such as PT No. 2 SP) to the correct 2x2 dimension, but ripping creates two technical problems.

The first problem is that the grade of a piece of lumber, such as a 2x6 No. 2, does not carry over to the individual pieces that result from ripping. For example, if three 2x2 pieces are made from a 2x6 and regraded by an experienced grader, one 2x2 might be graded as "cull," the next as No. 2, and the third as No. 1. Stress-grading is more than just the number and size of the knots; it also takes into consideration other factors, such as slope of grain. As anyone who has ever shattered a baseball bat can tell you, localized grain deviations are hard to detect and can greatly impact strength.

The second problem is that ripping treated lumber exposes at least one and in some cases two largely untreated surfaces. While the 2015 IRC and earlier editions require field-cut ends, notches, and drilled holes of preservative-treated wood to be treated in the field in accordance with AWPA M4 (2015 IRC R317.1.1), the language does not cite "edges" for field treatment. Nonetheless, these untreated surfaces along the ripped edges are a durability concern and still may require treatment per the manufacturer's product warranty.

In a nutshell, a code requirement for a product that is not (apparently) available in at least one region of the country is not a good situation for DIYers and contractors. But our testing has shown even more compelling reasons to not permit 2x2 ledger strips outdoors.

LOAD-TESTING 2X2 LEDGER STRIPS

Recently, we load-tested 2x2 ledger strips to see how they might perform in service. The design of the test specimens was guided by nailing requirements in the 2015 IRC and by the availability of PT 2x2s in a local big-box store. We wanted to test PT ledger-strip connections that were in the wet condition (not kiln-dried after treatment), as might be used by a DIYer or contractor.

We went to our local big-box lumberyard and purchased dimensional PT framing lumber and 2x2x8s for our testing **(1)**. When we measured the cross-section dimensions of the nominal 2x2s with a tape, they averaged 1 3/8 inches by 1 3/8 inches (1.375 by 1.375), while the treatment tags on the ends indicated that the 2x2s measured 1.3125 inches by 1.3125 inches. As such, neither the actual measured dimensions nor the dimensions on the

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Photos by Frank Woeste

Typical of commercially available stress-rated pressure-treated 2x2 southern pine, this nominal 2x2 purchased at a lumberyard measures 1 3/8 inches by 1 3/8 inches, while the treatment tag reads 1.3125 inches by 1.3125 inches. Neither the measured nor the tag dimensions conform to the nominal dimensions of a 2x2 specified in the 2015 IRC.

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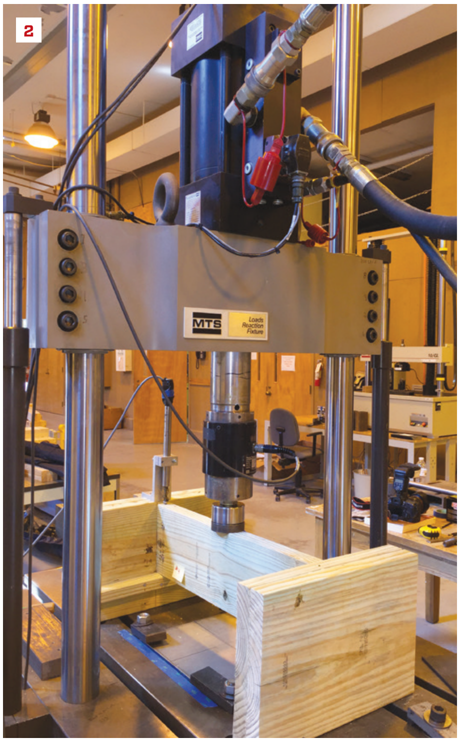

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To measure the load capacity and deflection of a 2x2 ledger connection per the 2015 IRC, the authors assembled this laboratory test. On one side of the assembly, a simulated 2x8 joist was supported by a 2x2 ledger strip nailed to a 2x12 with four 10D (3-in. x 0.148-in.) polymer-coated smooth-shank nails **(2)**. On the other end of the assembly, the joist was supported by a Simpson Strong-Tie 316 stainless steel LUS28SS joist hanger and ring-shank 316 stainless steel nails (SSA10DD 3-in. x 0.148-in.) **(3)**. Loads were applied by a hydraulic ram controlled by a uniform downward movement, allowing the load value to peak and then fall off to a much lower value.

treatment tag conformed to the requirements in the 2015 IRC, which specifies that a nominal 2x2 measure 51mm by 51mm, or $1\frac{1}{2}$ inches by $1\frac{1}{2}$ inches (2015 IRC R506.2).

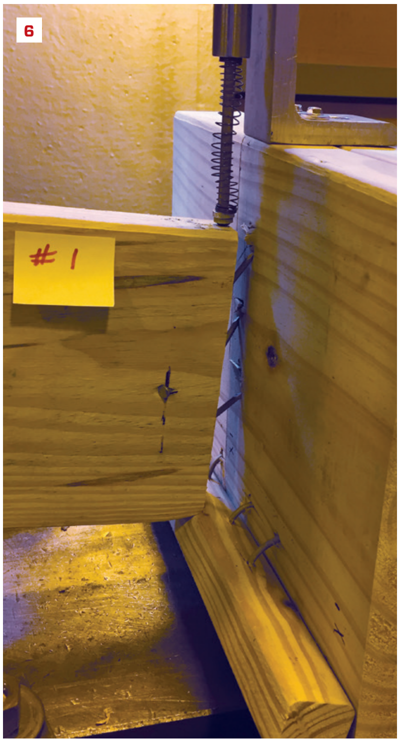
Our test assembly consisted of a 2x8 joist fastened to two 2x12s to create two joist-to-framing connections, each sharing 50% of the total applied load from a hydraulic ram. On one end, the joist was supported by a 2x2 ledger nailed to the 2x12. For lateral support, three 10D toenails were installed, with two on one side of the 2x8 joist and one on the other side, per the 2015 IRC. On the other end, the joist was supported by a stainless steel joist hanger. An electronic device—called an LVDT, or linear variable differential transformer—was used to measure the vertical deflection of the end of the simulated 2x8 joist relative to the top of the simulated deck ledger **(2, 3)**.

Our objective wasn't to test the capacity of the joist hanger connection. That said, it's important to note that within 300 feet of salt-water exposure, the 2018 IRC requires stainless steel connectors and fasteners (2018 IRC Table R507.2.3, footnote b: "Fasteners and connectors exposed to salt water or located within 300 feet of a salt water shoreline shall be stainless steel").

TESTING RESULTS AND OBSERVATIONS

As we applied a load to the test assembly **(4–6)**, we were particularly interested to see the counterclockwise rotation of the 2x2 ledger strip, which created a pronounced "V" between the 2x2 and deck ledger (or support beam). We anticipated that this would happen, due to the fact that the depth of the nailed 2x2 ledger strip was only $1\frac{3}{8}$ inches, allowing it to rotate because it wasn't laterally restrained by other rows of nails. A more effective approach would be to support the joists with a much deeper member, such as a 2x6, nailed along both the top and bottom edges.

As the ledger-strip connection was configured, the polymer-coated steel nails were stressed in bending and subject to withdrawal. It should be noted that nail withdrawal design strengths are relatively low, and when smooth-shank nails are installed in green lumber (MC >19%) that subsequently dries, the design value is reduced to only one-fourth of the tabulated design value. Between the loss of nail withdrawal strength due to moisture cycling, and the combined bending and withdrawal of the nails allowed by the shallow depth of the 2x2, even a full-size ($1\frac{1}{2}$ inches by $1\frac{1}{2}$ inches)



Before the vertical load was applied to the test assembly, the 2x2 ledger strip was snugly attached to the simulated 2x12 deck ledger **(4)**. As the load on the joist increased, substantial rotation of the ledger strip was evident, as indicated by the angle (bottom right in photo) between the 2x2 and the deck ledger **(5)**. As can be seen by the separation between the joist and the ledger after completion of the load test, a supported floor and ledger would have collapsed under a gravity-type loading, such as the load produced by deck occupants **(6)**.

2x2 ledger-strip connection may not be reliable in a typical outdoor deck application. Based on the issues discussed and our observations, the 2018 IRC code change that prohibits the use of 2x2 ledger strips to support deck joists was a valuable change for property owners and public safety.

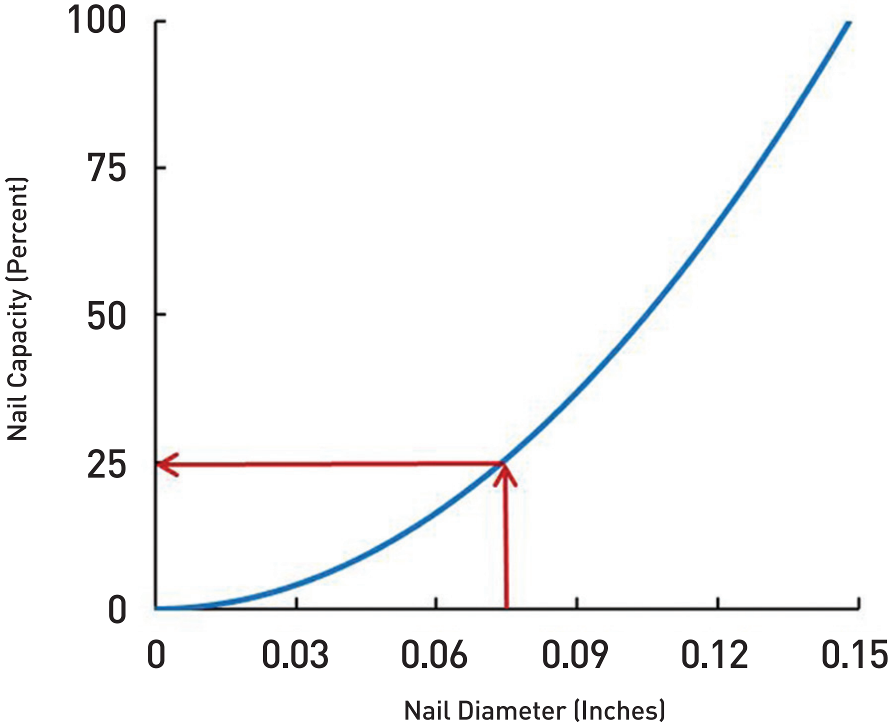
As an interesting aside, we did not observe any perceptible movement or deflection of the joist hanger used on the other end of the test assembly during and at the completion of each test. Clearly, the 10D ring-shank stainless steel nails (SSA10DD 3-in. x 0.148-in.) installed per manufacturer's instructions in an engineered hanger demonstrated a test safety factor well above the IRC-compliant connection. On the other hand, as photo 6 shows, when the hydraulic loading ram was lifted from the assembly, the ledger-strip connection had clearly failed.

COASTAL DECK CONSIDERATIONS

Because of the impact of salt corrosion on commonly used galvanized nails, a major safety concern has been the use of 2x2 ledger strips in a salt-water environment. In some cases where a deck collapsed, later investigations have shown that the shanks and heads of the nails had been totally consumed by oxidation. In many locations along a ledger strip, the nail shanks between the 2x2 ledger strips and the face of the beams or rim joists were totally red rust, indicating that the nail connections no longer provided load support for the joists bearing on them.

Even before a 2x2 ledger is loaded in-service, the connection creates a water-trapping joint between two pieces of PT lumber. This configuration alone creates an elevated risk of nail corrosion of a section of the nail shank at the face of the ledger/beam, which is the "business" section of a nail connection supporting a floor joist. In a coastal setting and under service loads, the water-trapping joint is transformed into a "V," creating a valley that traps both water and sea salts (in our example, of course, the width of the "V" is exaggerated due to our load testing; under more typical conditions, the rotation of the 2x2 is still present, but less pronounced). So it is not at all surprising that 2x2 ledger-strip nail connections to beams have a very limited useful lifetime in an exterior environment.

The practical question is, what is the useful lifetime of a 2x2



As red rust attacks the shank of a steel nail and effectively decreases its diameter, the design load capacity of the nail decreases accordingly. For example, if half the 0.148-inch diameter of a 10d common nail is lost due to red rust, the nail's design load capacity (90 pounds for wet use) would be reduced by 75%, with only 25% capacity remaining (22.5 pounds).

ledger-strip connection to a deck beam in a coastal environment? By not including the detrimental impact of 2x2 rotation on the nail connection load capacity, the residual strength of a nail connection can be calculated by assuming that the diameter of a steel nail shank at the 2x2-to-beam interface is reduced by a certain amount. For example, if the diameter of a 10D common nail is reduced by half due to red rust, the nail design load capacity is reduced to one quarter—or 25%—of the original value (see graph, above). Based on published nail design load values, a 10D (3-in. x 0.148-in.) nail load-rated for 90 pounds in southern pine in a deck application would be rated at 22.5 pounds when the nail shank diameter was reduced by half at the 2x2-to-beam interface.

Another way to view the impact of nail shank corrosion is by how it affects occupant design load. Since the typical total design load for a residential deck is 50 pounds per square foot (10-pound dead load plus 40-pound live load), the assumed 50% reduction in shank diameter reduces the total floor-design ledger-connection load to 12.5 pounds per square foot, meaning the weight of the dead floor plus occupant weight would be limited to 12.5 pounds per square foot. Clearly, when the shank diameters of the nails holding a ledger strip in place are reduced by 50% due to red rust, the ledger-strip-to-joist connection is well beyond its useful lifetime.

DRY LOCATIONS?

We are not aware of issues with 2x2 ledgers used inside residences in dry conditions; however, a word of caution is warranted for the possibility of high moisture exposure for the ledger connections, such as in an improperly maintained crawlspace. High moisture conditions open the door to wood decay, and that outcome alone would weaken ledger-strip nail connections, thus lowering load capacity for occupant live loads.

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