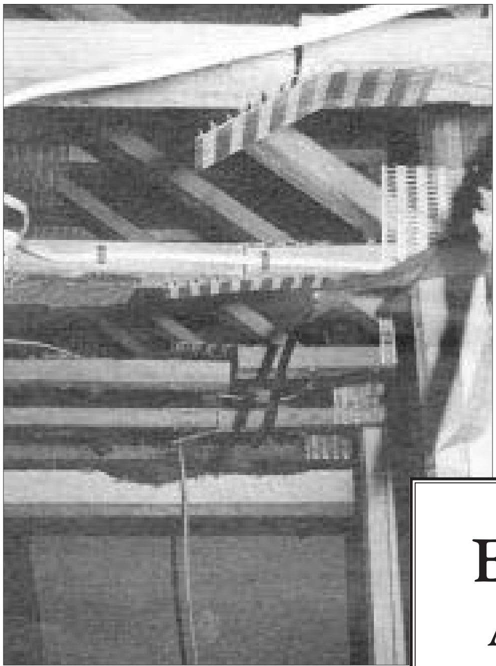
CASE STUDY:

FLAT TRUSS FAILURE

BY STEPHEN SMULSKI

Parallel chord floor trusses are becoming more common in residential construction (see "Framing With Floor Trusses," 4/93). One reason is that the open webs speed the installation of plumbing, heating, and wiring. Although building codes don't require that pipes passing through a truss space be insulated, there are cases where they probably should be. Though desirable from an energy conservation standpoint, pipe insulation may be unnecessary when the trusses are fully exposed, such as over a basement or a garage. But as this case study shows, problems can arise when uninsulated cold water supply and forced hot water heating lines run through a closed floor truss space.



A Sagging First Floor

Eight years after its construction in 1984, the owners of the house noticed that the first floor was sagging in several places. The floors had been framed with 26-foot-long, wood-webbed, top-chord-bearing trusses. Kraft-faced batt insulation had been stapled to the bottom chords.

When the insulation was removed, it was discovered that metal connector plates had partially or completely withdrawn from splices in the 4x2 bottom (tension) chords of many trusses ("4x2" is truss terminology for a horizontally-oriented 2x4). Plates were popped at random, with about half of the trusses affected. A few top (compression) chord splice plates were also partially backed out. Web-to-chord panel point connections were essentially unaffected. The trusses were temporarily shored (they were eventually repaired by screwing and gluing southern pine splints over the loosened splices) and an investigation begun.

Inspections made by myself and two professional engineers showed that the trusses were satisfactorily made using the proper grade of lumber (No. 2 Dense southern yellow pine KD15). Though some framing errors were found — a few trusses were incorrectly located, and others reversed end for end — they didn't necessarily involve the trusses with the withdrawn plates. After reviewing the trusses' design and calculating the stresses that had developed in them under the code-required floor loads, the engineers eliminated overloading of the trusses as a possible cause.

Heat and Moisture

All observations pointed to the presence of excessive heat and moisture in the closed truss space. Water at 160°F to 180°F circulated through the uninsulated copper pipes of the building's forced hot water heating system that ran through the space. Pipes passed within inches of many of the popped plates, raising the possibility of local overdrying and excessive shrinking. The domestic hot water lines, carrying water at about 110°F, were also uninsulated.

The uninsulated copper cold water pipes that ran through the cavity were coated with a heavy green surface patina, and were speckled with drip marks from water vapor that had condensed on their surfaces. The batt insulation located below these pipes was heavily stained and damp in places, as was the truss lumber.

Ungalvanized pipe hangers and fasteners in the space were caked with rust. The surface of the truss lumber had severe raised grain and was dappled with mildew, indicating exposure to at least the threshold 70% surface relative humidity required for its growth. A leaky first-floor shower drain worsened things.

Looking back, splice plate back-out was a blessing in disguise. Though favorable temperatures (fungi need temperatures between 40°F and 100°F) and water trapped in the insulation created an environment ripe for rot (see "Wood Fungi Causes and Cures," 5/93), I found no wood-destroying fungi. If plates hadn't popped, decay-conducive conditions within the space might not have been discovered. Eventually, the truss lumber's integrity might have been compromised by decay, forcing costly replacement instead of simple repair.

A Closed Space

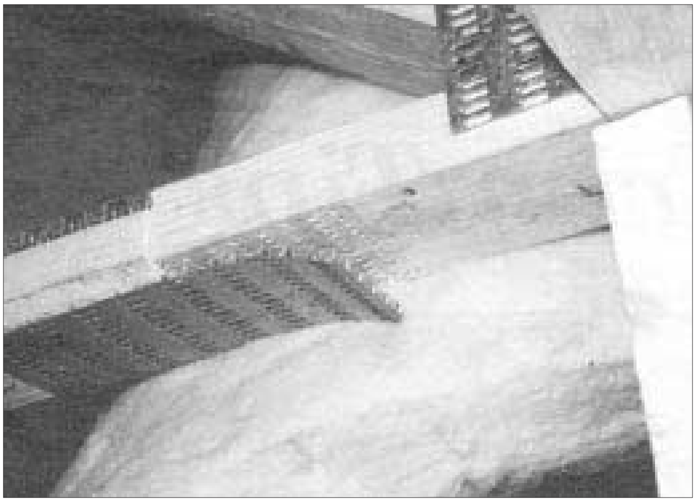
The kraft-faced insulation was a well-intentioned, but misdirected effort to reduce heat loss to the basement. The main problem was that it had been stapled vapor-retarder-out to the bottom chord, effectively closing off the truss space. The insulation acted together with tongue-and-groove plywood subflooring to impede the flow of heat and air into and out of the space. With no easy way to escape, water vapor condensed on the uninsulated cold water supply lines, driving up the relative humidity and wood moisture content during the cooling season. Heat radiating from uninsulated domestic and forced hot water lines drove relative humidity and moisture content down during the heating season.

After considering the most likely seasonal variations in temperature and relative humidity, I estimated that the moisture content of the lumber surfaces into which connector plate teeth were embedded could easily fluctuate from as low as 6% during the winter to 14% or higher during the summer. Since installed eight years before, the truss plates had endured eight cycles of across-the-grain shrinking and swelling of the wide face of the flat-sawn chords. This cyclic movement caused the chord faces to cup alternately concave and convex with respect to the plane of the plates, ratcheting the 3/8-inch-long teeth out of the lumber. This is the same reason that nails back out of siding, trim, and other exterior wood.

EXCESSIVE HEAT AND MOISTURE CAUSED THE METAL PLATES IN THESE EIGHT-YEAR-OLD FLOOR TRUSSES TO LOSE THEIR GRIP

Second-Floor Troubles

A similar situation was discovered with the second-floor trusses. Viewed through a ceiling scuttle, splice plates were also seen to have backed out from several trusses supporting the second floor, although



All of the withdrawn plates were embedded in the wide face of the chords, where shrinkage and swelling are greatest.

Drip-marked pipes and stained insulation indicated too much moisture in the truss floor cavity.

the number of plates and the extent of withdrawal was much less than with the first floor. The problem here appeared to be excessive wood shrinkage driven by heat, with moisture playing a minor role. As with the first-floor trusses, the uninsulated domestic and forced hot water lines radiated heat into the space. Moisture was supplied not by condensation on the cold water lines (they were stain-free), but by a leaky bath exhaust fan and water seepage where an unflashed exterior stair joined the sidewall. Lack of a ceiling vapor retarder meant that occupant-generated moisture had probably wended its way into the space as well. Seasonal swings in temperature, relative humidity, and wood moisture content apparently weren't as drastic here as in the first-floor trusses, however, so splice plates were affected to a lesser degree.

What About Roof Trusses?

Theoretically, the same thing could happen in sloped roof trusses. Limited back-out of plates, caused by the initial shrinkage of wet lumber (greater than 19% moisture content) after truss assembly, and by fluctuating relative humidity, has been documented in the laboratory. (Truss manufacturers, using recommendations supplied by the Truss Plate Institute and the Uniform Building Code, reduce connector plate withdrawal values by 20% to compensate for the initial shrinkage effect. They usually do this by using larger plates with more teeth.)

Realistically, however, moisture-caused plate back-out in a roof truss is very unlikely. One reason is that the lumber chords of roof trusses in properly insulated and ventilated attics are unlikely to experience the extreme seasonal swings in moisture content that fueled the plate withdrawal in this floor truss example. In fact, even though the underside of this building's plywood roof sheathing was cloaked with mildew where a bath fan vented into the attic, the roof truss plates were still firmly and fully seated.

More importantly, the chord and connector plate orientation in roof trusses make plate withdrawal even less likely. In a floor truss, the chord lumber is used as a plank, with its wide face oriented horizontally. The small bending forces that arise under load act perpendicular to both the wide face of the chords and the plane of the splice plates. The result is that connector plate teeth can be subjected to a small, direct withdrawal force. (It's the same force that sometimes causes plates to pop from roof trusses that are bent laterally by mishandling.) Sloped roof trusses, on the other hand, are assembled with the wide faces of the chords positioned vertically, much like a joist. So the small bending forces induced by roof loads act parallel to the plane of the connector plates, loading the teeth in shear, not in direct withdrawal.

Recommendations

Although this case is admittedly unusual, it should serve as a cautionary tale. It's unlikely that truss plates would have withdrawn in this case if (1) batt insulation had been properly located above the plumbing and heating lines with the vapor retarder against the underside of the subflooring, or (2) the cold water supply and forced hot water heating lines within the closed truss space had been insulated to prevent condensation and reduce heat loss. The best way to prevent similar problems is to insulate the cold water supply and forced hot water heating lines inside any closed floor truss space, especially when the trusses separate a building's conditioned and unconditioned zones. ■

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