Misplaced Load Paths

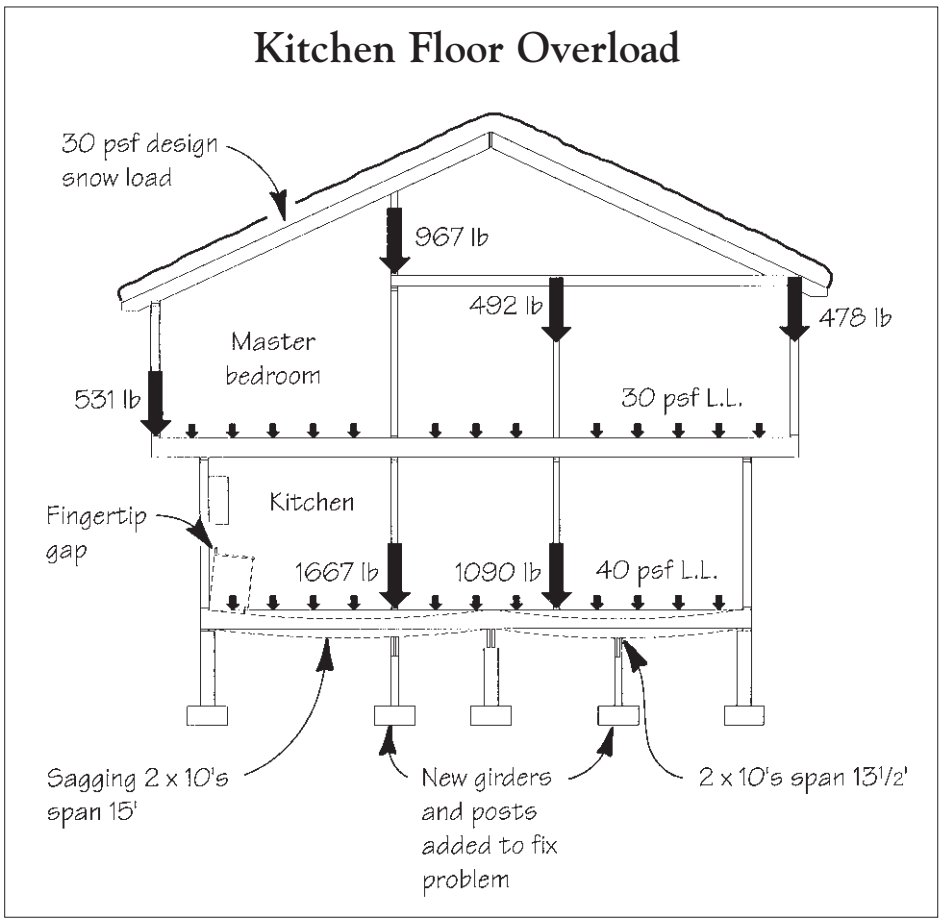
by Robert Randall, P.E.

Not long ago, Mr. & Mrs. P. called me in to help them figure out why their kitchen counter was pulling away from the wall. The problem was bad enough that you could fit your fingertips into the gap behind the backsplash. They also noticed cracked tiles, sloping floors, and on the second floor, doors that were sticking or not closing correctly.

A Classic Case

What I found was a classic case of misplaced load paths. The construction was inadequate, traced to a deficient design that had been followed in all innocence by the well-meaning contractor. It seems he bought some plans from a plan mill in a distant state and hired a local engineer to "stamp" them. Unfortunately, neither the designer nor the local engineer nor the building official spent much time reviewing the design. As a result, there were some seriously misaligned load paths carrying loads from the upper floors and roof down onto floor framing that wasn't strong enough.

The illustration shows a section through the middle of the house. Rafters, joists, and studs are all set at 16-inch centers, and the forces indicated are the loads at various points carried by each rafter, joist, or stud.



A fatal flaw of this house design was the upstairs cathedral ceiling, which interrupted the second-story ceiling joists and placed more than half of the roof load on the interior wall of the master bedroom. This load, along with floor loads from the second story and attic, greatly overstressed the 2x10 kitchen floor joists. The numbers represent the total concentrated loads in pounds carried by each individual stud onto the joists below.

Load design criteria for southern New York are 30 psf snow load, 30 psf live load on upper floors, and 40 psf live load on the main floor. I used 10 psf for the dead load of floor and roof assemblies, a common conservative value.

Significantly, the distress experienced by Mr. and Mrs. P. was primarily due to dead loads, as they had little furniture and a small family. The sagging took place in the first three years following construction.

The Biggest Mistake

The worst mistake by the designer was to overlook the fact that the cathedral ceiling in the master bedroom eliminated the truss effect that results from attic floor joists working with the rafters to form a triangle. This common roof-triangle "truss" normally transfers all the roof loads to the exterior walls. But with the addition of the cathedral ceiling, more than half of the roof loads were being carried by the interior wall of the master bedroom.

Additional loads from the attic floor, the dead loads of walls, and second-floor loads were all added in, creating a concentrated, or point, load on the first-floor framing. The 2x10 floor joists had probably been sized using a uniform load span table; the spans would have been pretty much maxed out even without this added point load.

Repairs

The calculated bending stress (fb = 3,370 psi) was more than three times the allowable bending stress in the kitchen floor framing, and almost as bad at the front of the house. While a structural collapse probably would not have occurred, the excessive sagging would have continued to cause problems with sticking doors and cracking tile and drywall, not to mention the gaping space behind the kitchen counter.

The builder, a man of integrity, agreed to jack the floors level, install additional girders and piers, and repair all the secondary damages at his own expense. He probably won't overlook the matter of proper load paths again. ■

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