Beyond Code: Preventing Floor Vibration

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Floor vibration, or bounce, is not a safety issue — it's a performance issue, and one that's likely to be important to homeowners. No one likes to hear the china rattling in the cabinet when they walk across the room. But at what point is the floor stiff enough, and how can a builder predict how the floor will perform?

Unfortunately, there's no clear-cut rule for a builder to follow, and the physics of vibration are so complicated that it's no easy matter to design a guaranteed bounce-free floor (see "Sizing Stiff Floor Girders," *Practical Engineering,* 8/97). Also, "acceptable" floor performance is highly subjective: What's good enough for one homeowner may not be good enough for another.

The building codes don't help much in this regard. They're primarily concerned with safety — in other words, the strength of the beam rather than its stiffness. The most stringent code limit for joist deflection is 1/360 of the span: For example, a joist with a clear span of 15 feet must not deflect more than 1/2 inch under live load (people and furniture). The dead load — the weight of the floor materials — is not typically included in calculating deflection.

And yet it has been known for decades that a span/360 live-load deflection limit will not necessarily yield floors that are acceptable to everyone when it comes to vibration.

The purpose of this article is to provide some simple rules of thumb for taking the annoying vibrations out of floor

Table 1. Maximum Clear Spans (Lmax) for Joists Longer than 15 Feet (deflection limited to 1/2 inch)

Lcode	Lmax	Lcode	Lmax	Lcode	Lmax	Lcode	Lmax	Lcode	Lmax
Less than 15-0	Same as Lcode	16-0	15-9	17-0	16-5	18-0	17-2	19-0	17-11
15-1	15-0	16-1	15-9	17-1	16-6	18-1	17-3	19-1	17-11
15-2	15-1	16-2	15-10	17-2	16-7	18-2	17-3	19-2	18-0
15-3	15-2	16-3	15-11	17-3	16-7	18-3	17-4	19-3	18-1
15-4	15-3	16-4	15-11	17-4	16-8	18-4	17-5	19-4	18-1
15-5	15-3	16-5	16-0	17-5	16-9	18-5	17-6	19-5	18-2
15-6	15-4	16-6	16-1	17-6	16-10	18-6	17-6	19-6	18-3
15-7	15-5	16-7	16-2	17-7	16-10	18-7	17-7	19-7	18-3
15-8	15-6	16-8	16-2	17-8	16-11	18-8	17-8	19-8	18-4
15-9	15-6	16-9	16-3	17-6	17-0	18-9	17-8	19-9	18-5
15-10	15-7	16-10	16-4	17-10	17-1	18-10	17-9	19-10	18-6
15-11	15-8	16-11	16-5	17-11	17-1	18-11	17-10	19-11	18-6

*For code spans 20-0 and greater, $L_{max}=(180\ L^3_{code})^{0.25}$, where Lcode is in inches.

Limiting joist deflection to 1/2 inch is an effective way to reduce annoying floor vibrations. For spans longer than 15 feet, the code L/360 maximum deflection limit results in actual deflections greater than 1/2 inch. In this chart, numbers in the red columns represent code-allowable joist spans (in feet-inches) assuming a deflection limit of L/360. In the blue columns, those spans have been reduced so that the actual deflection is limited to 1/2 inch. To use this chart, locate your required clear span in the blue columns. Then, using a span table designed for L/360 maximum deflection, 40 psf live load, and the appropriate dead load, find a joist size and species that will work for the corresponding number in the red column. Your joist will then be sized to limit live load deflection to 1/2 inch.

Table 2. Expected Vibrational Performance of Residential Floor Trusses (40 psf Live Load)

Live Load Deflection Limit	Strongback Installed	Truss Spacing (inches)	Vibration Rating
Span/360	No	24 or less	Code minimum; not rated
Span/360	Yes	24 or less	Good*
Span/480	No	24 or less	Good*
Span/480	Yes	24 or less	Very Good*

*Ratings require a minimum 23/32" APA-Rated sheathing, glued to truss chord and using nails or screws, and span-to-depth ratio of 20 or less. Ratings apply to maximum spans at the tabulated deflection limit. The ratings are based on specific input from experienced wood-truss design professionals, and our interpretation of opinions of experts and case studies.

systems, whether you're framing with solid-sawn joists, metal-plate-connected floor trusses, or wood I-joists. There's no guarantee that every customer will be satisfied if you follow these guidelines, but they should prevent the vast majority of complaints.

Some Quick Rules of Thumb

Before looking at specific types of joists, here are some general guidelines for controlling bounce.

✔***Shorten the span.*** In general, shorter spans make for stiffer floors. For example, if the L/360 span table tells you a joist of a given size, grade, and species will just barely work for your span, shorten the span by adding a girder near the center of the original span. The resulting floor will vibrate less.

✔***Increase the joist depth one size.*** If the code requires a 2x8 at 16 inches on-center, then use a 2x10 of the same grade and species. Or use a 14-inch-deep floor truss when a 12-inch deep truss would meet code requirements. This may not be the most cost-effective solution in every case, but it's easy to remember and will save time and worry.

Probably the least efficient way to improve floor performance is to reduce the on-center spacing — 16 inches to 12 inches, for instance. Occupants feel "bounce" as a result of a foot impacting an individual joist. But even at 12 inches on-center, the joists are not close enough for the shock of a foot to be carried by two joists.

✔***Glue and screw the sheathing.*** Floor sheathing should always be glued down. Screws work better than nails for long-term bounce control.

Design for Solid-Sawn Joists

Our recommendation for stiffening solid-sawn floors is a simple modification of a rule that was published in 1964 by the FHA: For floors up to 15 feet, limit live-load deflection to span/360; for spans over 15 feet, limit the live-load deflection to 1/2 inch (see Table 1, page 69). In adopting this rule, we encourage builders and designers to ignore the reduced live load of 30 psf for sleeping areas, and instead use the standard 40 psf live load for all rooms. After all, a bedroom can become a study or home office, and the traffic may be heavier than in a living room.

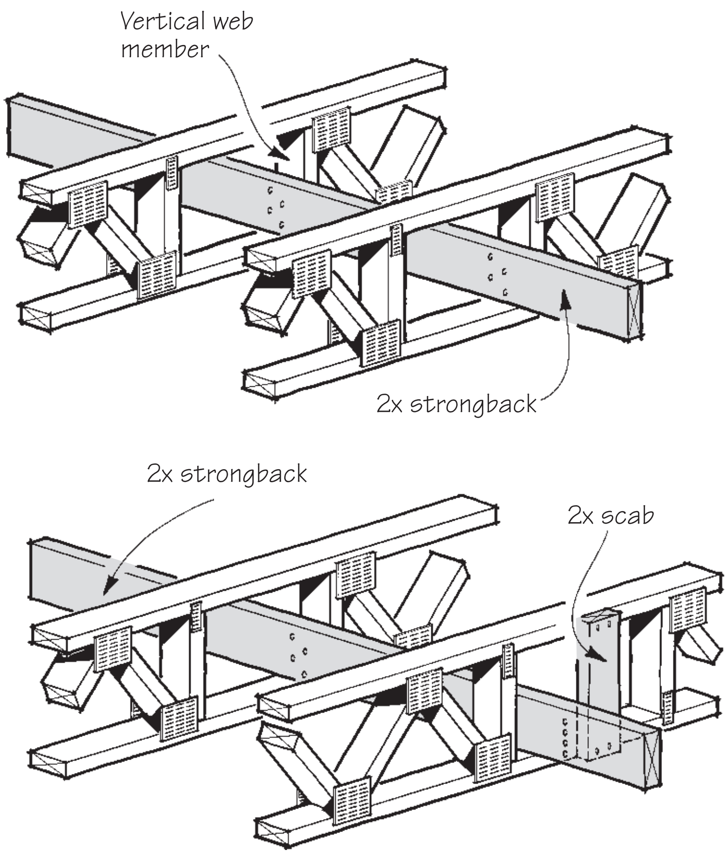
Metal-Plate-Connected Floor Trusses

Floor trusses are a unique product in that they accommodate effective strongback bracing (see *On the House,* 7/98, for more on strongbacks). The consensus among wood truss professionals is that strongbacks are effective in minimizing annoying vibrations, and that they are well worth the time and money it takes to install them.

Table 2 illustrates the expected performance of various floor truss designs, using a 40-psf live load. Table 3 gives guidelines for sizing and installing strongbacks. For best performance, strongbacks should be installed near the center of the span (versus two at the third points) in upright position and attached to a vertical web. The strongback should also be located at the bot-

Table 3. Sizing and Attaching Strongbacks

Clear span	Strongback size	Connection requirement at each truss web (minimum)
Greater than 15 feet, but less than or equal to 20 feet	2x6	4-16d Box (0.135"x3.5")
Greater than 20 feet	One 2x8 (or 2 2x6s)	8-16d Box (0.135"x3.5")



Strongbacks should be securely attached to a vertical web member at center span next to the bottom chord (top illo). If the vertical web members don't line up properly, you can attach a 2x4 or 2x6 scab from chord to chord and nail the strongback to the scab (above illo). To transfer the load, use as many nails to attach the scab as you use to attach the strongback (see chart).

tom of a vertical web. To be effective, the strongback must be snugly attached to each web, as indicated by the nailing recommendations in Table 3.

When, for whatever reason, the vertical webs don't line up, you can attach a 2x4 or 2x6 scab to the top and bottom chords for attaching the strongback to the truss (see illustration). The total number of nails used to attach the scabs to the truss chords should match the number used to attach the strongback to the vertical web.

Some of the truss professionals that we interviewed when developing Table 2 had more restrictive rules to offer, but none had less restrictive design advice. Again, no design criteria is guaranteed to totally eliminate vibrations, but we believe that following the recommendations in the table will minimize complaints.

Wood I-Joists

When using wood I-joists, a simple way to get good results is to always use the tables designed for span/480 deflection. Any I-joist stamped under the new APA standard for performance rated I-joists is automatically designed to meet the span/480 limit. The standard also uses 40 psf as the minimum live load for any floor. The APA standard is now being used by some I-joist manufacturers to make selection of I-joists easier. The allowable spans for various spacings are printed right on each joist.

Another design system for control vibration in wood I-joist floors is Trus Joist MacMillan's TJ-Beam software. Trus Joist has done extensive testing of floor performance and has developed its own rating system. Using the software, a user can select a number between 20 and 70, with 70 offering the greatest level of protection against potential floor problems as judged by an occupant. For example, a design that is rated at 55 is expected to be judged as "Good to Excellent" by 96% of the population, while 2% should judge such floors as "Marginal," and 2% should judge the floor to be "Unacceptable." This system allows the homeowners, through their contractors or architects, to select the level of floor performance to meet their expectations.

We tested the software for a 16-foot clear span supported by 2x4 walls (16 ft. 7 in. outside-to-outside), with I-joists 16 inches on-center and a residential load of 40/12 (live load/dead load). Using a 9.5-inch TJI Pro-250, the rating was 35. Increasing the depth to a 14-inch TJI Pro-250, the rating was a 53. Tightening up the spacing of the 9.5-inch I-joist to 12 inches on-center increased the rating only to 42 — illustrating that going to a deeper joist at the same spacing is a better solution.

The TJ-Beam software also provides a relative cost index that tells the user how much extra an improved floor will cost. Often an improved performance design can be obtained with the same or even lower cost than the original design.

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