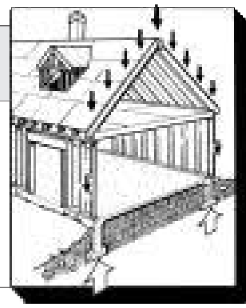
PRACTICAL ENGINEERING



Wood I-Joist Fundamentals

by John Siegenthaler, P.E.

COURTESY OF TRUS JOIST

Most contractors that frame residential and light-commercial buildings are now (or soon will be) using wood I-joists. For builders accustomed to the shape and heft of conventional sawn lumber joists, the weight and appearance of a typical wooden I-joist often raises an immediate concern about its ability to handle the load. How could such a thin, lightweight material carry as much as a sawn 2x10 or 2x12?

Situations like the one in the photo above seem to defy common sense. How can you possibly remove so much of the I-joist web in the middle of a span? Yet the hole chart for that particular I-joist allows you to. Can you imagine doing that with a sawn joist?

However, once you understand the kinds of loads present in a floor joist and how the shape of an I-joist accommodates these loads, you'll be able to use I-joists with confidence.

Stressed Out

There are two types of stresses that develop in a typical floor joist: shear stresses and bending stresses.

Shear. Horizontal shear is a tendency for the wood fibers in a loaded joist to slide past one another. Imagine a joist as a stack of individual wood strips, as shown in Figure 1. When a load is applied, the top of each strip in the imaginary beam shortens from compression while the bottom of each strip is lengthened by tension. Although the drawing greatly exaggerates the effect, the same thing happens to the wood fibers in a solid-sawn joist. The effect is greatest at the ends of a simply supported beam. Shear stress develops as the beam resists the sliding action. The maximum shear stress is at the ends of the joist, and decreases toward the center of joist, becoming (theoretically) zero at the exact center of the span. Thus, there is practically no tendency for the wood fibers to shear apart near the midspan of the beam.

When selecting sawn floor joists, building designers need to check that the maximum shear stresses at the ends of the joist will not exceed the allowable shear stresses for a given species and grade of wood. It's also important for builders to reject planks with long checks at the ends.

I-joist web strong in shear. Solid sawn lumber is somewhat prone to horizontal shearing because of the orientation of the wood grain. By contrast, the plywood or OSB web of an I-joist can handle much greater shear stresses. This allows a relatively thin web to safely transfer the shear forces developed in typical floor framing applications. However, when selecting an I-joist, always check that the maximum shear forces that will develop do not exceed the maximum values specified for a particular I-joist. In some cases web stiffener blocks must be nailed on both sides of the web, over the support walls, to help transfer large shear loads down through the web. This prevents bucking of the web, as well as the "knifing action" of the edge of the web against the lower flange.

Horizontal Shear in a Simply Supported Beam

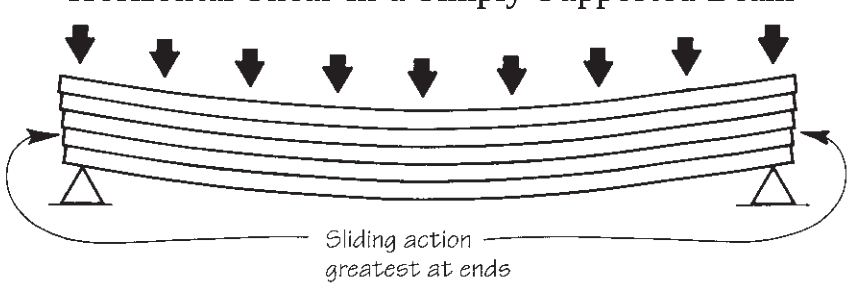


Figure 1. *To visualize horizontal shear, picture a beam as a stack of separate strips of wood. As the beam deflects under load, the strips slide in relation to one another as the top of each strip shortens in compression and the bottom lengthens from tension. The sliding action is greatest at the ends — the area of maximum shear stress.*

Bending Stress

In addition to shear stress, any simply supported beam under load (including the load from its own weight) also develops compressive stress in its upper fibers and tension stress in its lower fibers. Collectively, these tension and compression stresses are called bending stresses. They occur in any horizontal object that is supported only at its ends. Anyone who has ever tried to saw down through a log supported near its ends discovers this fact when the blade binds partway through the cut. Because the saw has removed material that was formerly transferring compressive stress, the saw kerf closes in on the top as the weakened log tries to reestablish this internal compression.

Bending stresses are greatest at the upper and lower edges of a simply supported beam halfway along its

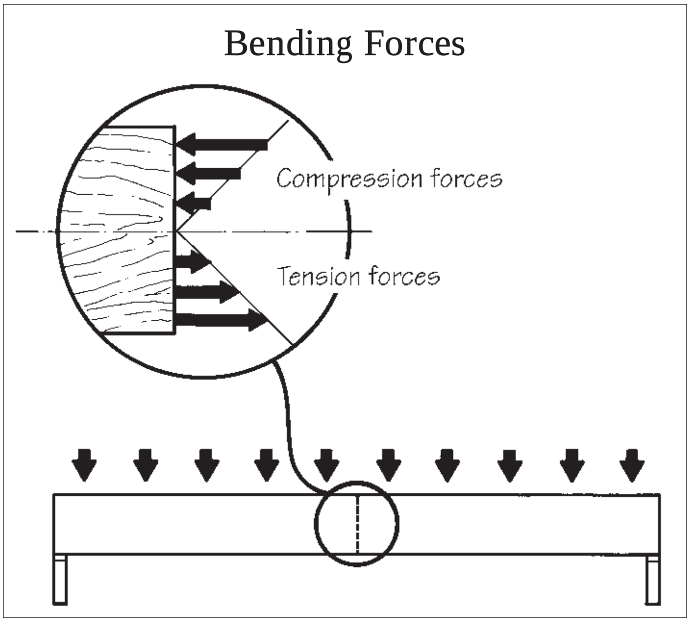


Figure 2. *Maximum bending stresses — tension and compression — occur at midspan in the top and bottom edges of a simply supported beam. They decrease to zero at the beam's centerline.*

span (Figure 2). They decrease to zero at the center fiber of the beam.

The spanning ability of a floor joist is, in part, limited by the bending stresses that the fibers at the edge of the beam can safely handle. These maximum safe stresses are called the *Fb* values. *Fb* values vary with different species and grade levels. A Select Structural Douglas fir 2x10 has an *Fb* of 1,667 pounds per square inch (psi) when used as part of a repetitive-member floor-framing system (value taken from 1991 *NDS Supplement*). A No. 2 spruce-pine-fir 2x10, in the same situation, has an *Fb* of 1,006 psi.

Optimization. By comparison, the laminated veneer lumber (LVL) flanges of a typical I-joist have *Fb* values in excess of 3,000 psi. This means that each square inch of LVL flange can handle 1.8 to 3 times as much stress as the same square inch of sawn lumber.

Simply put, I-joists are engineered to have the high-strength LVL material where the bending stresses are greatest and where it does the most good: in the flanges at the edges of the beam. If the same amount of LVL were placed near the center of the joist, where there is very low stress, it would add needless weight and cost to the joist without yielding any significant strength increase.

Likewise, the wood fiber near the centerline of a sawn floor joist also carries very little bending stress. It contributes to the weight and cost of the joist, but adds essentially nothing in strength. Its presence is simply a result of the rectangular sawn shape.

Cutting with Confidence

Once you understand how an I-joist works, it's easier to understand the manufacturers' rules for notching and hole-cutting. The high bending stresses in the I-joist flanges makes it imperative that no holes or saw cuts be made there. Even shallow kerfs in the lower (tension-carrying) flange can critically weaken the I-joist.

Likewise, the size and location of holes or slots in the I-joist web is tied directly to the magnitude of the shear stresses in the joist. That's why larger holes are generally allowed in the middle of a simple span, but not near the bearing points, where shear stresses are greatest. With that in mind, the photo of the duct chase that we started with should make a little more sense: The hole is at midspan, where shear force is minimal. Therefore, this particular manufacturer allows you to make a large opening in the web as long as you don't disturb the flanges, which are carrying the large bending stresses at that point.

As a final warning, don't make any holes until you refer to the manufacturer's hole charts. Also, no two manufacturers' charts are the same, so make sure you use the current literature that goes with the brand and series of I-joist you are using. ■

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