building blocks

Stable, Strong and Green…

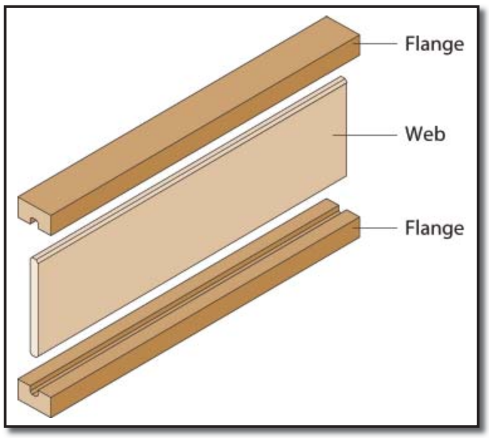
Engineered Wood I-joists

By Edward L. Keith, P.E.

Engineered wood I-joists are finally coming into their own. First developed and promoted in the 1960's by Trus-Joist Corporation® (a Weyerhaeuser company), there are now over a dozen domestic and foreign I-joist manufacturers. I-joists are supplanting lumber and other engineered wood products for flooring and roofing applications at an ever-increasing rate. With current industry production of over a billion lineal feet a year (2003 production) and a rate of increase of over 20% per year, engineered wood I-joists are here to stay!

So, what exactly is an engineered wood I-joist and what does it do?

An engineered wood I-Joist is an "I"-shaped structural member designed for use in residential and commercial applications. The product is prefabricated using sawn or structural composite lumber flanges and plywood or oriented strand board (OSB) webs, bonded together with exterior type adhesives.



Engineered wood I-Joist

The first universally recognized standard for wood I-joists was ASTM D5055, *Standard Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists*. This consensus standard provides guidelines for the evaluation of mechanical properties, physical properties and quality of wood I-joists and is the current common testing standard for I-joists. However, since ASTM D5055 does not specify required levels of performance, individual manufacturers of I-joists generally have their own proprietary standards that govern the every-day production practice for their products. The market dictates the common sizes and design properties for I-joists and the major I-joist manufacturers all have similar product offerings.

Since the merging of the three traditional model code agencies (ICBO, BOCA, and SBCCI) into the International Code Council (ICC). I-joist manufacturers gain code recognition through evaluation reports provided by the International Code Council–Evaluation Services (ICC-ES) agency. ICC Evaluation Services AC14, *Acceptance Criteria for Prefabricated Wood I-Joists*, provides guidelines on implementing performance features of the International Building Code, IBC.

Although ASTM D5055 and ICBO AC14 provide guidance for developing proprietary design values, no standard performance levels or grades are presented in the documents.

The building codes currently recognize these products for residential or commercial floor and roof applications. They have also been used for studs in super-insulated homes, although this is not specifically provided for in the building codes.

I-Joists used in roof-framing applications

Why use engineered wood I-joists?

What is the reason for this almost unparalleled success? Actually, there is more than one reason:

<u>They are environmentally friendly</u>

With the advent of forest farming as a primary source of wood fiber in the US, it is exceedingly difficult to find a resource that will permit the milling of larger pieces of framing lumber. As an example, a 16-foot 2x12 requires a log considerably larger than 11.25 inches in diameter for the entire 16-foot length. Wood I-joists, on the other hand, can be manufactured in depths exceeding 48 inches and lengths over 40 feet. To do this, trees no larger than those required for the 2 x 4 flanges are needed. As the flanges may be finger jointed, or manufactured from laminated veneer lumber, the logs for producing the flange material do not have to be of any great length. And, by the nature of their "I" cross-section, they use up to 60% less wood fiber than solid-sawn joists.

When OSB is used as the web material, the requirement for log diameter and length is even less restrictive. OSB can be manufactured out of species that have little or no other commercial value, such as Aspen.

The increased use of engineered wood products, such as wood I-joists in construction, has had a positive impact on the environment from the standpoint of reducing demand for products from older-growth forests. The use of engineered wood products, such as I-joists and rim board, led the way in the early green building movement.

The environmental benefits of using engineered wood I-joists do not stop at the manufacturing facility. On the job site there is little or no waste. (*See the paragraphs below on dimensional stability and waste.*)

<u>I-joists are dimensionally stable</u>

Fabricated from dry materials to very tight manufacturing standards, wood I-joists generally do not shrink, warp, cup, crown, or twist. They are symmetrical; thus, there is no need to place joists in a "crown-up" orientation.

I-joists have known strength characteristics

The tightly controlled manufacturing process and quality assurance programs that are required insure final products of uniform strength and stiffness. There is never a “soft spot” caused by variations in stiffness that can happen with visually graded lumber framing members. They are also manufactured in a wide range of depths and “capacities”, so a designer can order just what he needs for a specific application.

With respect to conventional framing (16-inches or 19.2-inches on center joist spacing), I-joists are 50% stiffer than solid sawn lumber. In terms of strength, for simple spans, an I-joist series with the lowest design values (PRI-20) can span to within inches of the strongest solid sawn lumber joist (S. Pine). Using stronger I-joist series or comparing with weaker species of lumber widens the gap even more. In multiple span situations, I-joists have no equal because solid sawn lumber in lengths greater than 20 feet is quite rare and expensive. Building dealers and I-joist manufacturers have substitution analysis software and are eager to provide this service free of charge in most cases.

There is less waste associated with the use of engineered wood I-joists

You need 20 joists, you buy 20 joists! I-joists’ dimensional stability, tight manufacturing and quality assurance programs mean 100% utilization in the field. They can even be ordered cut to exact length in many cases, resulting in little or no waste on the jobsite which helps reduce dump fees. In addition to environmental benefits, no waste also permits the contractor to more accurately control costs for that portion of the job.

I-Joist are light wieght and easy to handle on the job-site

Hangers designed specifically to accommodate I-Joists

I-joists come in a wide range of sizes

In addition to the common nominal 10- and 12-inch depths, wood I-joists are made in depths impossible with traditional framing lumber. Depths up to 48 inches and lengths limited only by ground transportation and handling are available to the designer. A tremendous advantage over lumber is that a deeper I-joist member is only incrementally more expensive than a shallower member, because it is made deeper by adding just a bit more web material. With lumber however, selecting a deeper joist means competing for a more scarce resource and the cost goes up accordingly. A lumber 2x12 is just a few pennies a foot more than a 2x10.

I-joists minimize the need for toe-nails

While not obvious at first glance, the geometry of the wood I-joist eliminates the need to use toe-nails in many applications. Wood design engineers are understandably uneasy about the use of toe-nails in structural applications. The flange of the I-joist offers the opportunity to face nail the joist to a supporting member, resulting in a stronger, more foolproof connection.

I-joists are easier to handle in the field

Because of their “I” cross sectional shape, they weigh up to 60% less than lumber joists. The flange permits a firm, comfortable, secure grip even when the joist is wet or covered with wood dust. A single worker can easily handle a joist 25- to 40-feet in length.

Common I-Joists range from 9-1/2” to 16” deep. Depths up to 48” can be special ordered

I-joist manufacturers provide simple prescriptive guides for proper residential applications

These guidelines negate the need for engineering common details for residential applications. For unconventional applications, or non-residential use, specific design properties are available for the engineer/architect.

I-joists are recognized by the International family of Codes

Because they are referenced in the Building and Residential codes (Sections 2303.1.2 and R502.1.4, respectively), they may theoretically be used in code conforming construction without requiring an ICC-ES report. (Note: All manufacturers have such reports to provide essential information to the designer/builder.)

Metal hardware is available for I-joist products

Most major hardware manufacturers have hanger/hardware lines manufactured specifically for I-joists used in engineered applications.

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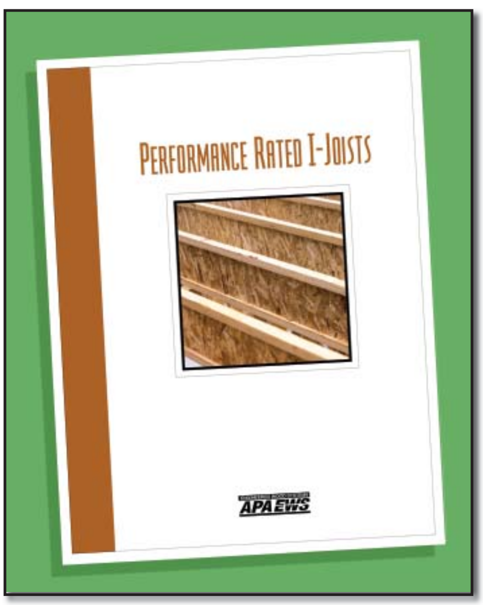
What Structural Engineers should know about designing with I-joists…

There are two separate avenues for the designer using I-joists. Prescriptive design aids for residential construction or published design values for engineered applications.

Residential Construction

If the designer wants to use I-joists in residential construction applications, he may use the prescriptive design aids that have been developed for conventional construction applications. These design aids are available from the joist manufacturers, from APA–the Engineered Wood Association, and from ICC-ES reports. These aids include construction details and fastening recom-mendations, as well as span tables, web hole tables, and cantilever tables. Similar to the conventional construction provisions of the IRC, applications outside of those covered by this information must be engineered.



APA Performance rated I-Joists

Engineered Applications

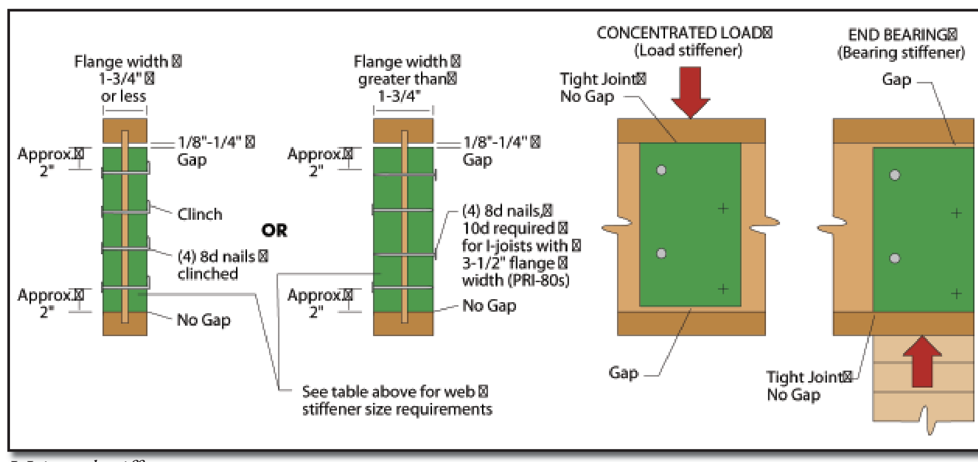
For applications and specific details outside of those covered by the prescriptive design aids, design information is provided by the manufacturer.

When designing with I-joists, the procedures used are similar to lumber design with one major exception. In the design of I-joists, the end and interior bearing capacities must be checked. This is similar to a bearing check in normal timber design, except that the I-joist interior and exterior bearing capacities are predicated on a specific bearing length and are related to the capacity of the I-joist web-to-flange joint. Exceeding this capacity can cause the web to crush through the flange like a blunt knife (understandably called a "knife-through" failure). At I-joist end-supports, the addition of "web stiffeners" can often be used to increase this capacity up to the full shear capacity of the I-joist. Always check with the manufacturer before proceeding in this direction. Some manufacturers opt to publish two sets of bearing values; one with web stiffeners and one without.

The geometry of a wood I-joist can cause some concerns for a designer new to the product. Attaching two or more joists together to make a header or trimmer (for a stairway opening in a floor, for example) can be problematic without the use of wood blocks to fill the space between the webs. Fortunately for the designer, this and similar details, such as cantilevers, have already been worked out by the manufacturer. Contact your supplier or download the manufacturer's ICC ES report from **www.iccsafe.org** for this and similar details.

2x12s, 2x14s, and 2x16s. There are many applications in roofing systems, and especially residential floors, where other elements are used in conjunction with the I-joists for the express purpose of transferring load through the floor system without overloading the floor joists. Examples of these other elements are blocking panels over an interior bearing wall, and rim or starter joists. In these cases, the vertical load from the structure above the plane of the floor is transferred through the floor into the structure/foundation below by way of direct bearing on the blocking panels, rim or starter joist.

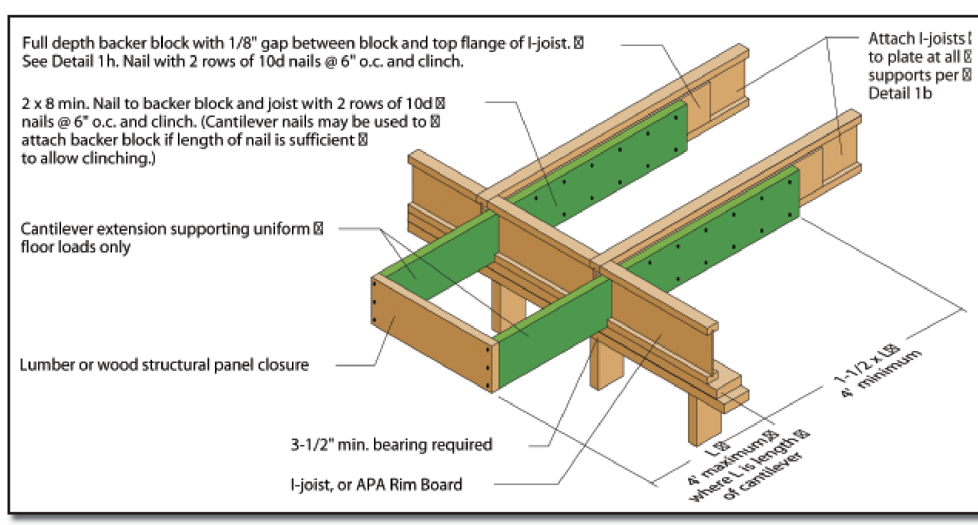
Because the load is transferred in direct bearing, it is essential that the blocking panels, rim or starter joist be the same height as the floor joist. Solid sawn lumber cannot be used in applications like these because of the very likely potential for shrinkage. Shrinkage by as little as 1/8-inch (3 mm) can be enough



I-Joist web stiffeners

Mixing I-joists with solid sawn lumber

Most wood common wood I-joists are manufactured in 9 ½-, 11 7/8-, 14-, and 16-inch net depths. It is no accident that these sizes are not compatible with, and are larger than, traditional lumber net depths for 2x10s, to transfer the vertical loads from the walls above directly to the floor joists, thus inducing possible bearing or reaction overload conditions at these locations. The solution to the problem is to use engineered wood products for these applications. They are manufactured in the correct depths and have the same dimensional stability properties.



Typical Cantilever details

Repair of I-joists

Damage to wood I-joists within a structural system is normally associated with notching of the flanges or misapplication of the manufacturer's web-hole information. Fixes for this kind of damage usually consist of one of or a combination of the following:

- Wood structural panels or engineered rim board (always the correct dimension) glue nailed to one or both sides of the damaged area.
- I-joist doubler rolled into place or scabbed on to the affected area of the damaged I-joist.
- I-joist replacement.

Designing a repair for a damaged I-joist can be very difficult and requires an understanding of I-joists, adhesives and fasteners that may be beyond the capability of many designers. Fortunately, most manufacturers are more than willing to provide fixes for most applications.

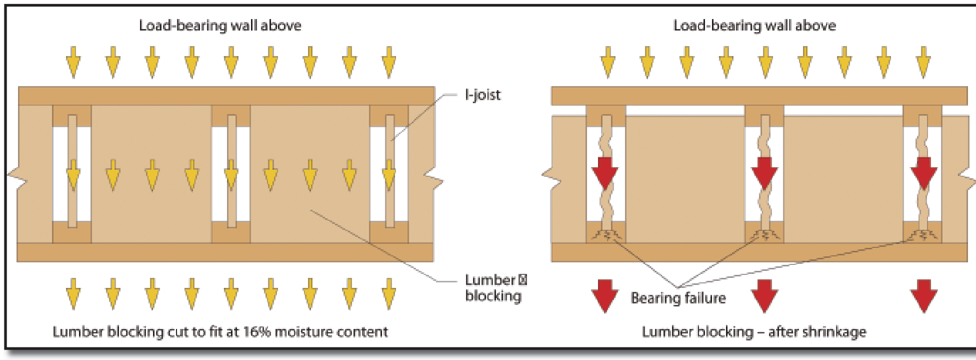
As mentioned previously, improperly sized or placed holes are a relatively common occurrence on the jobsite. There are a number of innovative products currently working through the code acceptance system that can be used in the field to restore the joist to its full capacity, without having to have the solution engineered.

Conclusion

By all accounts, the dramatic increase in the use of engineered wood I-joists that has been witnessed in the past can be expected to continue growing in the future. The ability of the wood I-joist to satisfy a wide range of social, economical, and resource needs, puts them in a uniquely favorable position for continued growth. The technology that they represent for making high quality, large-dimension structural products out of one of the most common and easily replaceable resources holds great hope for providing "green" housing solutions now and in the future.▪

Other Sources of Information

- **www.iccsafe.org is the website of the International Code Council and the publisher of the International family of codes including the International Building and Residential codes. From this location you can download ES reports from each manufacturer that contain technical information about specific proprietary products.**
- **Individual I-joist manufacturer's literature.**
- **APA–The Engineer Wood Association via their website at www.apawood.org for generic information and specific information about I-joists produced by member organizations.**



Effects of differential shrinkage between lumber and engineered wood I-Joists on load transfer

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